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Recent Calcareous Nannoplankton in the Southernmost Atlantic

By Joost W. Verbeek*

Summary: Between March and April of 1986 a series of water samples were taken in the South Atlantic to study the Recent calcareous nannoplankton assemblages in that part of the world. South of Africa, in the transitional floral zone, most of the coccolithophorid flora elements characteristic of this zone were recognized but in addition influences from the floras of the Indian Ocean were distinguished as well as floral elements belonging to the tropical and subtropical floral zones. It is concluded that the transitional floral zone should be redefined on the basis of seasonal changes of the assemblages. In the cold waters between the Subtropic and the Antarctic Convergences near the Antarctic continent, calcareous nannoplankton is scarce. Only a monospecific assemblage of malformed *Emiliania huxleyi* was found. Probably the combination of cold water and high hydro energy levels prevents the development of a diverse coccolith-bearing nannoplankton assemblage. South of the Antarctic Convergence no calcareous nannoplankton was found.

Zusammenfassung: Zwischen März und April 1986 wurde eine Reihe von Wasserproben im südlichen Atlantik gesammelt. Ziel war das Studium des rezenten kalkigen Nannoplanktons. Südlich von Afrika wurden in der floristischen Übergangszone die meisten Elemente dieser Zone wiedergefunden. Daneben wurden aber auch Einflüsse aus dem Indischen Ozean festgestellt sowie Arten des tropischen und subtropischen Bereichs. Deshalb muß die Definition der Übergangsflora berichtigt werden mit Rücksicht auf die jahreszeitlichen Änderungen der floristischen Assoziationen. In den kalten Gewässern zwischen der subtropischen und antarktischen Konvergenz ist kalkiges Nannoplankton selten. Nur eine monospezifische Vergesellschaftung mißgestalteter Exemplare der Art *Emiliania huxleyi* wurde gefunden. Wahrscheinlich behindert das Zusammentreffen von kaltem Wasser und hoher hydrodynamischer Energie die Bildung einer reichhaltigen Coccolithophoridenflora. Südlich der Antarktischen Konvergenz wurde kein kalkiges Nannoplankton gefunden.

1. INTRODUCTION

Between March 18th and April 27th in 1986, the German research vessel "Polarstern" made a cruise from Cape Town in South Africa to Punta Arenas in southern Chili (Fig. 1). This cruise, indicated by the code ANT-IV/4, was the fourth in a series undertaken to investigate the waters and sea bottoms around Antarctica as well as to study some coastal and interior areas of this continent (KOLTERMANN 1987). A small team of the Geological Survey of The Netherlands participated in this cruise, one of the objectives being to take water samples for a study on the Recent calcareous nannoplankton flora in the remote southern areas of the Atlantic.

The nannoflora in the southern and southeastern Atlantic is influenced by three separate water masses (Fig. 1). The first part of the cruise went directly southward from Cape Town through the area where the relatively cool subtropical waters of the southern Atlantic Ocean and the relatively warm Agulhas Current meet. The currents in the southern Atlantic flow in a direction parallel to the Circum Antarctic Current from west to east and turn northward near southern Africa. The Agulhas Current follows a route along the east coast of Africa originating from the tropical parts of the Indian Ocean. South of southern Africa the current turns eastward sharply and than part of it continues parallel to the Circum Antarctic Current, which flows around the Antarctic continent and the other part enters the Atlantic Ocean.

This resulted in water temperatures on the sampling sites of 20 to 22°C (samples 1-6, Table 1). At 41°' 32.75' S and 16°' 45.69' E, where the ship entered the cold Antarctic Circumpolar Current passing through the Subtropic Covergence, water temperatures dropped to 11°C and these decreased further to 3.0°C. The ship reached the Antarctic Convergence at about 51°30' S and 14°59' E, where the water temperatures again dropped sharply now below 1.5°C. Samples 7-18 were taken between the Subtropic and the Antarctic Convergences. From the position of sample 19 to about 60° S, the water temperatures of the sampling sides varied between 0.0 and 1.5° C. Further south and going westward water temperature was always slightly below zero. At a position of 59° 49.74' S and 49° 08.38' W, when the ship was sailing northwest toward Punta Arenas, the water temperature again rose above zero and increased to slightly more than 3° C.

Most of the studies on Recent calcareous nannoplankton in the Atlantic Ocean concern northern regions and are predominantly taxonomic (e.g. GAARDER 1954, 1970; GAARDER & MARKALI 1956; HALLDAL &

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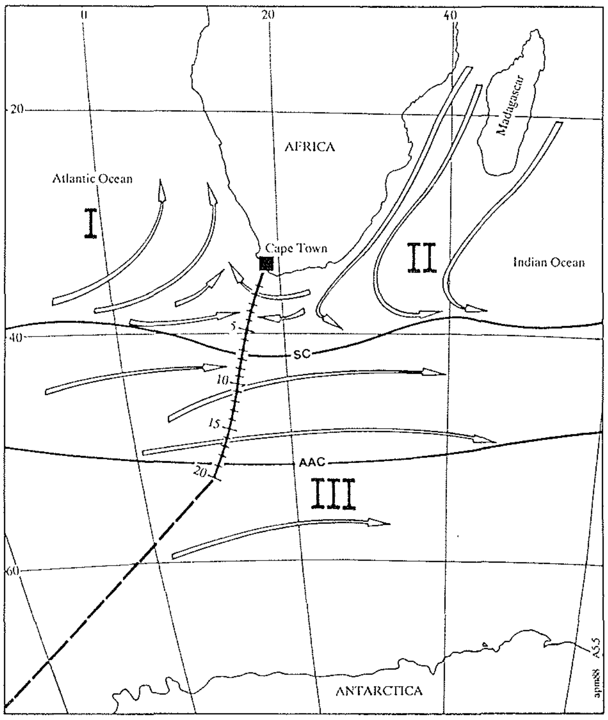

Fig. 1: Schematic overview of the hydrography between southern Africa and Antarctica with the transect of the first twenty samples (continuation of the cruise schematically indicated). I = relatively cool subtropical water current in the southern Atlantic Ocean. II = Agulhas Current. III = Circum Antarctic Current. SB = Subtropical Convergence. AAC = Antarctic Convergence.

Abb. 1: Schematische Übersicht der Hydrographie zwischen südlichem Afrika und Antarktika mit Positionen, an denen Proben 1—20 entnommen wurden (Fortsetzung der Fahrt schematisch angedeutet). I = relativ kalter subtropischer Wassserstrom im südlichen Atlantik, II = Agulhas Strom, III = Cirkumantarktischer Strom, SB = Subtropische Konvergenz, AAC = Antarktische Konvergenz.

MARKALI 1955; HEIMDAL 1973; HEIMDAL & GAARDER 1980). The number of publications concerning the ecology and distribution of calcareous nannoplankton communities of the Atlantic Ocean is much smaller. MCINTYRE & BÉ (1967) and OKADA & MCINTYRE (1977) combined these two topics with their discussion of the taxonomy. OKADA & MCINTYRE (1979) and VERBEEK (1985) have discussed the ecology and the distribution of the Recent coccolithophorid floras, respectively. Except for the above mentioned paper by MCINTYRE & BÉ (1969), which deals with both the North and the South Atlantic, all these papers are restricted to the North Atlantic.

Earlier studies on the Recent calcareous nannoflora in this region are scarce. MCINTYRE & BÉ (1967) divided the southern Atlantic into four floral zones, the two southernmost of which cover the present study area. These authors recognize their transitional floral zone North of about 41° S and the subantarctic floral zone south of this latitude.

In a study of the nannoflora in the upwelling zone northwest of Cape Town in march 1983 MITCHELL-INNES & WINTER (1987) found an assemblage strongly dominated by *E. huxleyi* and including *G. oceanica* and *Syracosphaera epigrosa* as two other frequently occurring species. Core tops from the southwestern Atlantic have been studied by MOSTAJO (1985), who reported the presence of *E. huxleyi* and *Coccolithus pelagicus* near southern Argentina.

In the southwest part of the Indian Ocean, near the Natal Valley, WINTER et al. (1985) studied the flora in the Agulhas Current. They reported floras dominated by *E. huxleyi*, *Umbilicosphaera hulburtiana*, *Umbellosphaera tenuis* and *G. oceanica*. According to these authors core tops from the same area revealed a flora with *E. huxleyi*, *G. oceanica*, *U. sibogae* and *C. leptopora*.

2. METHODS

At regular intervals (Table 1) ten liter samples of surface water were collected. All samples were treated according

SAMPLE NR.	LATITUDE	LONGITUDE	WATER-TEMP.
1	35 23.27' S	17 53.05' E	20.5
2	36 45.88' S	17 30.77' E	21.8
3	37 51.21' S	17 22.49' E	22.1
4	38 55.24' S	17 09.26' E	20.5
5	40 08.95' S	16 59.23' E	20.4
6	41 22.29' S	16 46.20' E	21.6
7	42 46.85' S	16 22.12' E	11.0
8	43 24.83' S	16 13.52' E	13.7
9	44 04.48' S	16 09.00' E	9.0
10	44 29.42' S	16 03.64' E	9.6
11	45 20.31' S	15 51.04' E	7.7
12	46 15.92' S	15 40.73' E	6.4
13	47 01.72' S	15 26.06' E	6.2
14	47 31.50' S	15 20.85' E	6.1
15	48 25.28' S	15 08.66' E	5.6
16	49 09.56' S	15 01.54' E	5.1
17	50 02.54' S	15 00.23' E	4.1
18	51 00.11' S	14 59.94' E	3.0
19	51 58.82' S	14 59.69' E	1.6
20	52 02.04 S	14 51.43' E	1.3

Tab. 1: Sample positions and water temperatures.

Tab. 1: Positionen der Entnahmestellen und Wassertemperaturen.

to MCINTYRE & BÉ (1967) and HONJO & OKADA (1974). The sample was led through an 0.8 micron cellulose nitrate filter with the help of a vacuum pump. Residual salt was removed from the filter by rinsing with fresh water. The filter was than taken from the vacuum system, placed in a petri dish, dried, and stored for shore based studies.

Eightyone samples were collected in this way. Not all of these samples have been studied. The samples from one through twenty have all been studied, whereas from the other samples only one third has been randomly selected for examination and none of these samples contained calcareous nannoplankton, although diatoms and many other organisms occur abundantly.

Parts of the filter were mounted on a scanning electron microscope (SEM) stub, covered with gold and examined in an ISI SS40 SEM for calcareous nannoplankton. Attempts to remove the nannoplankton from the filters or to dissolve the filters without damaging the nannoflora failed, which made light-microscopical studies impossible.

3. RESULTS

The findings concerning the nannoplankton distribution are given in Table 2. It is clear, that two distinct flora assemblages can be distinguished, one occurring north of the Subtropical Convergence (samples 1 to 6) and the other south of the Convergence (samples 7 to 16). The floras present between southern Africa and the Subtropical Convergence are generally diverse, with a total of 22 species, the only exceptions being the samples 1 and 5 with low diversity. This problem of barren or almost barren samples in a transect with a rich flora has been discussed by various authors (e.g. OKADA & MCINTYRE 1977), but has never been explained satisfactorily. The present study has not yielded an explanation either. The flora assemblage is dominated by *Emiliania huxleyi* and *Gephyrocapsa ericsonii*. Other frequently occurring species are *Gephyrocapsa oceanica*, *Rhabdosphaera clavigera*, *Umbilicosphaera hulburtiana*, *Umbilicosphaera sibogae* and *Discosphaera tubifera*. Scarce specimens of *Cyclococcolithina leptopora*, *Syracosphaera pulchra* and *Umbellosphaera tenuis* occur in samples 2, 3 and 5. *Umbellosphaera irregularis* was only found in the northern part of the transect, not in the southern part. With the exception of *Coccolithus pelagicus*, coccospheres of all species mentioned were found and thus only the observation of the latter species is not completely reliable. Of the holococcoliths, only one specimen of *Helladosphaera aurisinae* was found; all other species are heterococcoliths.

Three of the twelve samples between the Subtropic and the Antarctic Convergence in the Circum Antarctic Current contained calcareous nannoplankton, sample 11 containing only some poorly preserved isolated coccoliths. It is

LEGEND:
1 = 5%
2 = 5—10%
3 = 10—15%
4 = 15%

CURRENT	FLORAL ZONE	SAMPLE NUMBER	*Emiliana huxleyi*	*Gephyrocapsa oceanica*	*Neosphaera coccolithomorpha*	*Cyclococcolithina leptopora*	*Discosphaera tubifera*	*Gephyrocapsa ericsonii*	*Gephyrocapsa protohuxleyi*	*Rhabdosphaera clavigera*	*Syracosphaera halldali*	*Syracosphaera pulchra*	*Syracosphaera variabilis*	*Umbilicosphaera hulburtiana*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*	*Umbellosphaera tenuis*	*Anoplosolenia brasiliensis*	*Coccolithus pelagicus*	*Helladosphaera aurisinae*	*Helicosphaera hyalina*	*Oolithus fragilis*	*Syracosphaera elatensis*	*Florisphaera profunda*	*Percentage interminable*
COOL SUB-TROPICAL/ AGULHAS	TRANSI-TIONAL	1	4	2	1																				0
		2	4	1		1	1	1	1	2	1	1	1	1	2	1	1								5
		3	4	3		1	1	3		1		1		1	2	2	1	1	1	1	1	1	1		7
		4	4	1			1	3		1	1			1	1	1									6
		5	4																						0
		6	4	1		1	1	3		1		1		1		1	1							1	11
CIRCUM ANTARCTIC CURRENT	SUB-ANTARCTIC	7																							—
		8																							—
		9																							—
		10																							—
		11		4				4																	33
		12																							—
		13																							—
		14																							—
		15	4																						0
		16	4																						0
		17																							—
		18																							—
		19																							—
		20																							—

Tab. 2: Distribution chart of nannoplankton species recorde.

Tab. 2: Verbreitungstabelle der gefundenen Coccolithophoridenarten.

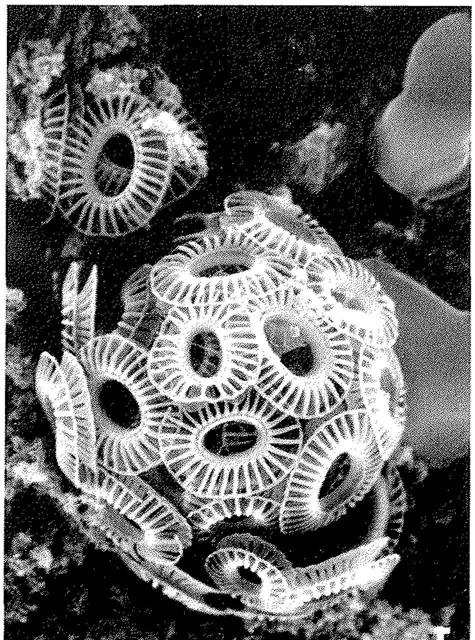

Fig. 2: *Emiliania huxleyi*, sample 2: cold water form.

Abb. 2: *Emiliania huxleyi*, Probe 2: Kaltwasserexemplar.

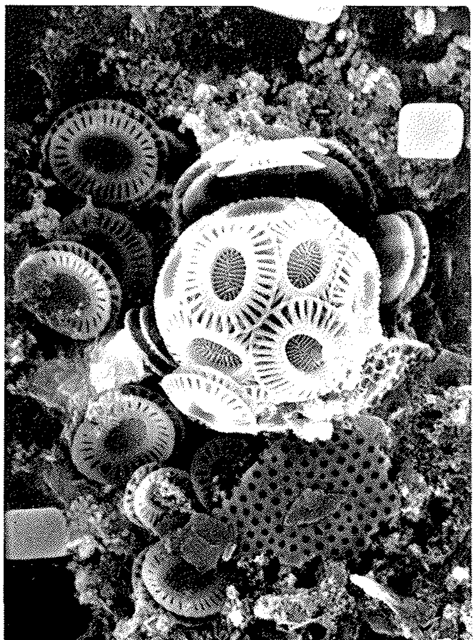

Fig. 3: *Emiliania huxleyi*, sample 2: warm water form.

Abb. 3: *Emiliania huxleyi*, Probe 2: Warmwasserexemplar.

assumed that these coccoliths are not representative of the floras present in the southernmost part of the Atlantic. The other two samples contained only some specimens of *E. huxleyi* with malformed coccoliths. South of the Antarctic Convergence no calcareous nonnaplankton was observed.

4. DISCUSSION

The transect from Cape Town to the Subtropic Convergence falls in the transitional floral zone of MCINTYRE & BÉ (1976). These authors reported a dominance in descending order of *E. huxleyi*, *C. leptopora* and *G. ericsonii* in their floral zone. Other important species are *R. stylifera* (= *R. clavigera* in the present study), *G. oceanica* and *U. tenuis*. They also reported the presence of *C. pelagicus* in the transitional floral zone, but that record applies to the North Atlantic equivalent of this floral zone. *E. huxleyi* and *G. ericsonii* are indeedly prominent present in the recorded floras. However, *C. leptopora* is only present in very low percentages in three samples. This last observation is more in accordance with HENTSCHEL (1933), who also found a more restricted distribution for *C. leptopora*. The other important species of MCINTYRE & BÉ (1967) have also been recorded. Thus, the greater part of the nannoflora of the transitional zone have been recognized in the floras recorded south of Africa. The dominant floral component in the study of MITCHELL-INNES & WINTER (1987) is again *E. huxleyi*. *G. oceanica* and *S. epigrosa* are two other important flora elements recorded by these authors, of which the first was seen less frequently in the present study and the latter was even absent.

WINTER et al. (1985) redorded in the Agulhas Current floras dominated by *E. huxleyi*, *Umbilicopsphaera hulburtiana*, *U. tenuis* and *G. oceanica*, among which *U. hulburtiana* has not been reported from the transitional floral zone, but this species was not described until 1970 by GAARDER and therefore it was not recognized as

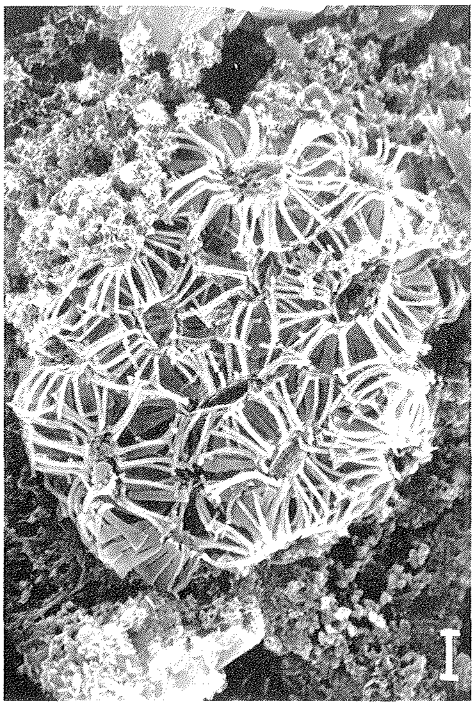

Fig. 4: *Emiliania huxleyi*, sample 2, malformed specimen from warm subtropical water.

Abb. 4: *Emiliania huxleyi*. Probe 2: mißgestaltetes Exemplar aus warmem subtropischem Wasser.

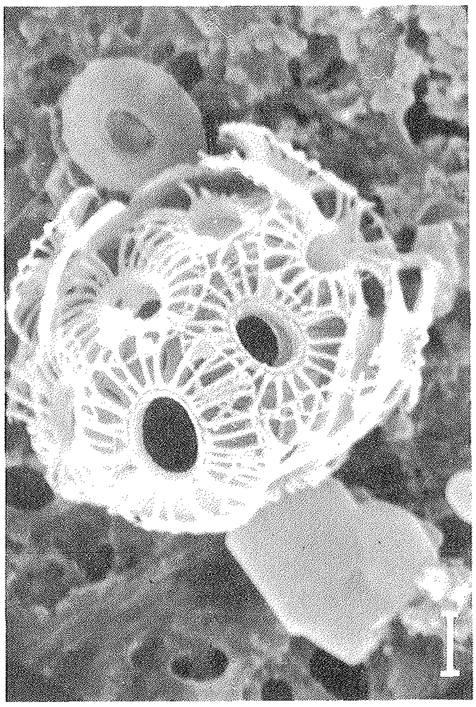

Fig. 5: *Emiliania huxleyi*, sample 15, malformed specimen from polar waters.

Abb. 5: *Emiliania huxleyi*. Probe 15: mißgestaltetes Exemplar aus polarem Gewässer.

a species by MCINTYRE & BÉ in 1967. However, it is difficult to detect a species in which the *U. hulburtiana* specimens could have been included. Apparently, *C. leptopora*, *G. ericsonii* and *R. clavigera* are less prominent in this current in the Indian Ocean. In the present study *U. hulburtiana* was found in the four samples with a diverse flora.

As indicated in the introduction, the water samples come from an area where the Agulhas Current meets the relatively cool waters of the subtropical southern Atlantic Ocean. The floras in these two water masses have some elements in common. *E. huxleyi* is dominant in both, but also *U. tenuis* and *G. oceanica* are relatively common in both currents. These flora elements were also recorded in the present study. Of the other species, *G. ericsonii* and *R. clavigera* are typical for the transitional floral zone of the cool subtropical waters in the southern Atlantic Ocean, and *U. hulburtiana* can be called characteristic for the Agulhas Current. Thus, as could expected, a mixture of the floras of both water masses was observed.

Nevertheless, there are three regularly recorded species that are not mentioned by MCINTYRE & BÉ (1967) or WINTER et al. (1985) as occurring south of Africa recently. First there is *U. sibogae*, which has been reported from the subtropical floral zone (MCINTYRE & BÉ, 1967, as *U. mirabilis*) and was found in core tops from the sediments below the Agulhas Current by WINTER et al. (1985). *D. tubifera* was reported by MCINTYRE & BÉ (1976) from their subtropical floral zone, whereas they described *U. irregularis* as the most important species from the tropical floral zone. It is obvious that or flora contains elements which are more characteristic for the relatively warm waters of the Atlantic, than for the cooler parts of that ocean. This cannot be explained in terms of the rather high water temperatures of more than 20° C, after warming up of the cool waters of the southern Atlantic Ocean when streaming to the north, giving some tropical and subtropical flora elements the opportunity to migrate to the south in summer. The absence of these three species in the study of MITCHELL-INNES & WINTER (1987) is explained by the relatively cold water in the upwelling area northwest of Cape Town.

Fig. 6: *Emiliania huxleyi*, sample 15: malformed specimen from polar waters.

Abb. 6: *Emiliania huxleyi*, Probe 15: mißgestaltetes Exemplar aus polarem Gewässer.

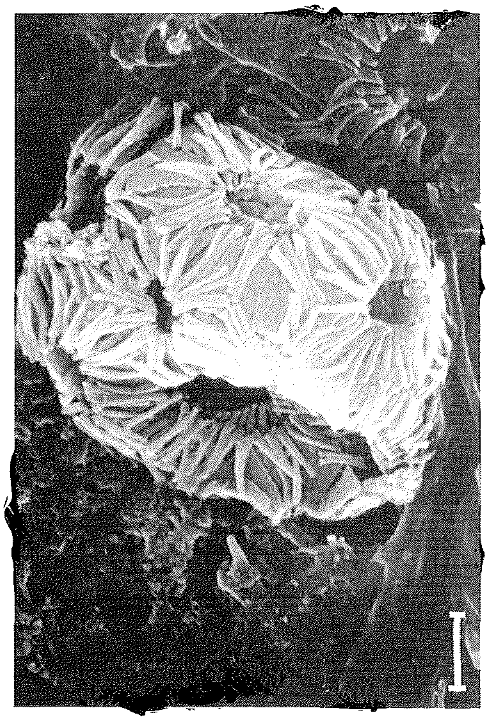

Fig. 7: *Emiliania huxleyi*, sample 15: malformed specimen from polar waters.

Abb. 7: *Emiliania huxleyi*, Probe 15: mißgestaltetes Exemplar aus polarem Gewässer.

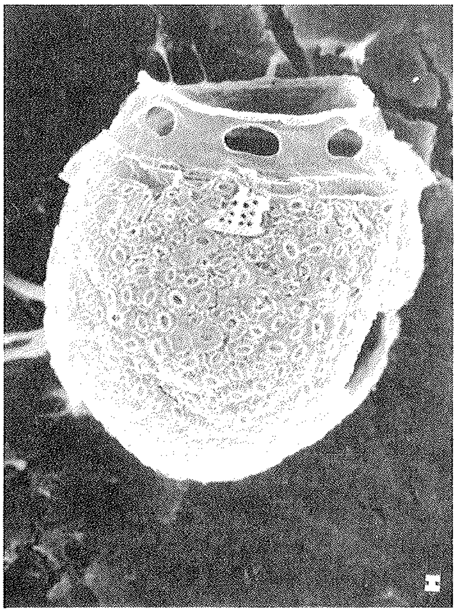

Fig. 8: *Stenosomella ventricosa*, sample 15:

Abb. 8: *Stenosomella ventricosa*, Probe 15:

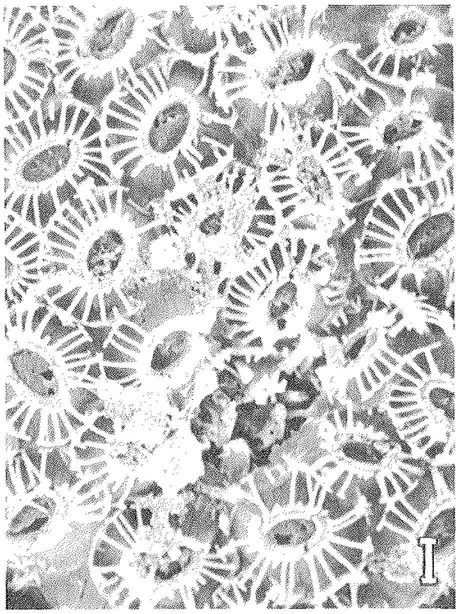

Fig. 9: detail of fig. 8.

Abb. 9: Detail der Fig. 8.

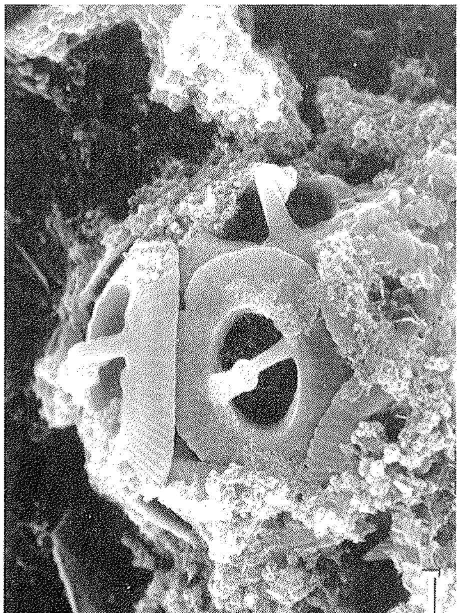

Fig. 10: *Gephyrocapsa oceanica*, sample 3.

Abb. 10: *Gephyrocapsa oceanica*, Probe 3.

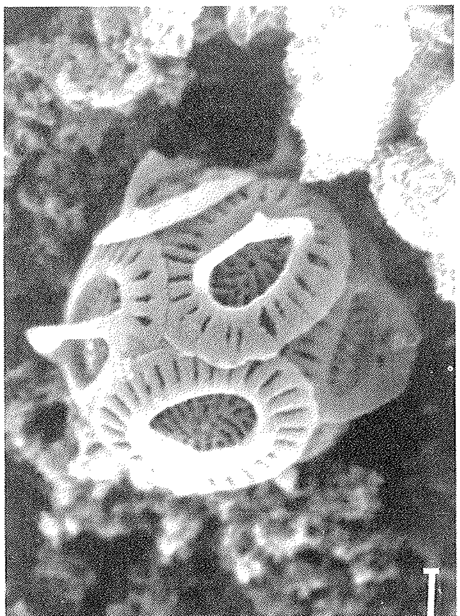

Fig. 11: *Gephyrocapsa ericsonii*, sample 3.

Abb. 11: *Gephyrocapsa ericsonii*, Probe 3.

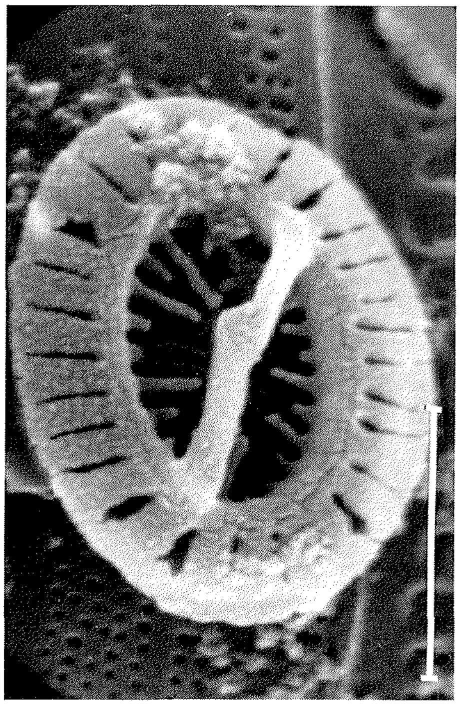

Fig. 12: *Gephyrocapsa protohuxleyi*, sample 2.

Abb. 12: *Gephyrocapsa protohuxleyi*, Probe 2.

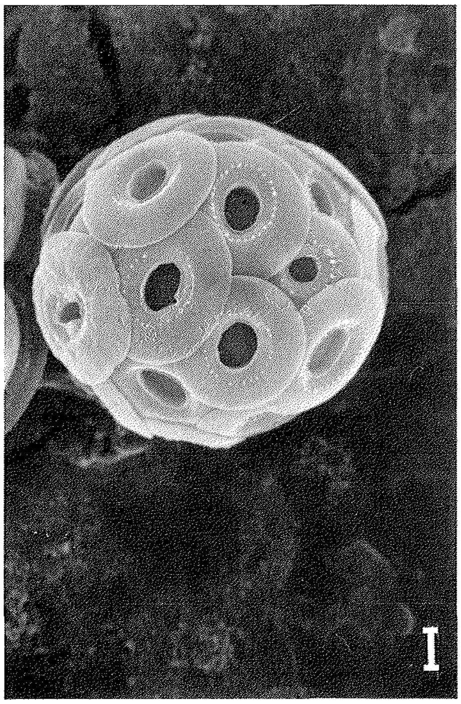

Fig. 13: *Umbilicosphaera hulburtiana*, sample 2.

Abb. 13: *Umbilicosphaera hulburtiana*, Probe 2.

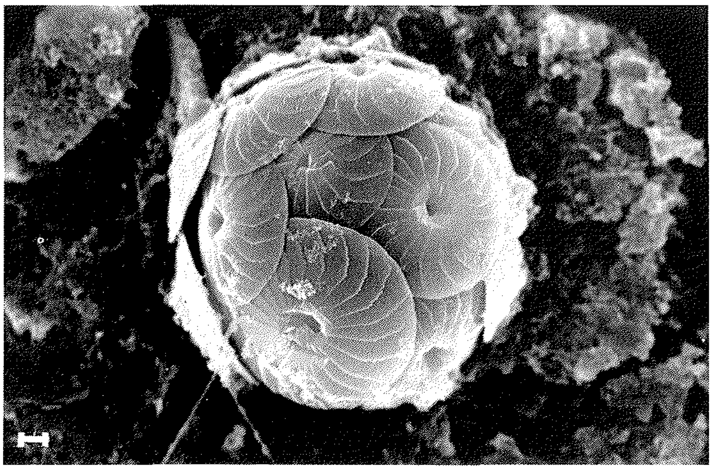

Fig. 14: *Cyclocoocolithina leptopora*, sample 3.

Abb. 14: *Cyclocoocolithina leptopora*, Probe 3.

Fig. 15: *Umbilicosphaera sibogae*, sample 2.

Abb. 15: *Umbilicosphaera sibogae*, Probe 2.

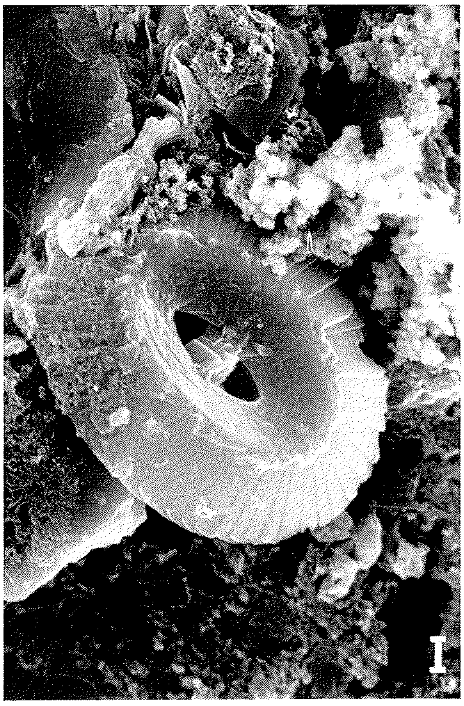

Fig. 16: *Coccolithus pelagicus*, sample 3.

Abb. 16: *Coccolithus pelagicus*, Probe 3.

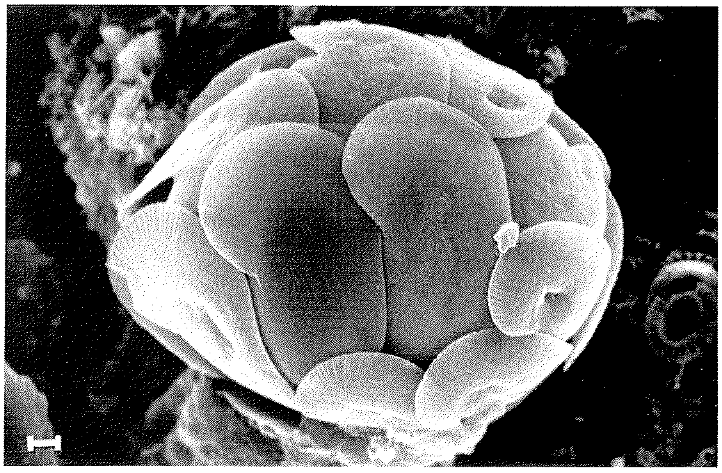

Fig. 17: *Helicosphaera hyalina*, sample 3.

Abb. 17: *Helicosphaera hyalina*, Probe 3.

Fig. 18: *Neosphaera coccolithomorpha*, sample 1.

Abb. 18: *Neosphaera coccolithomorpha*, Probe 1.

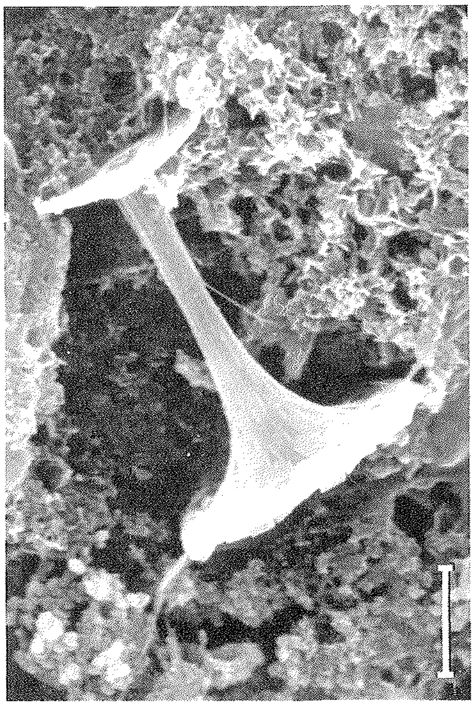

Fig. 19: *Discosphaera tubifera*, sample 2.

Abb. 19: *Discosphaera tubifera*, Probe 2.

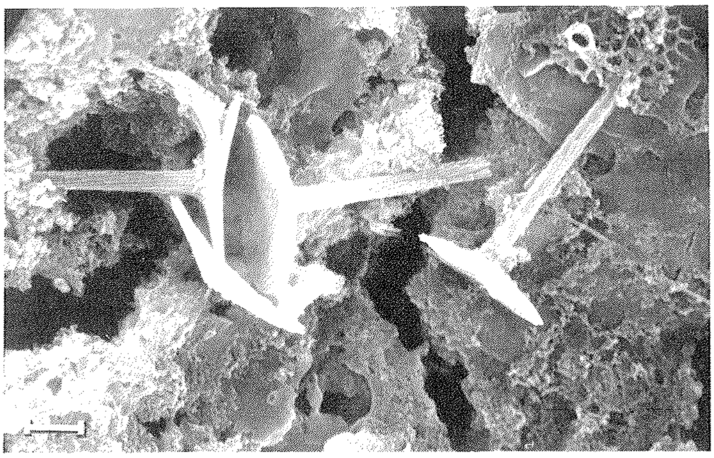

Fig. 20: *Rhabdosphaera clavigera*, sample 2.

Abb. 20: *Rhabdosphaera clavigera*, Probe 2.

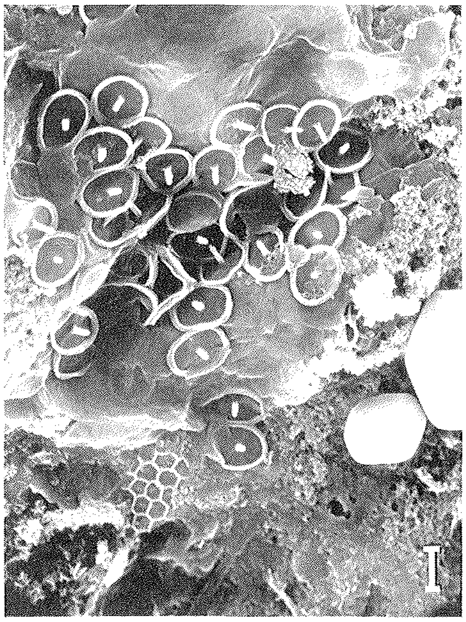

Fig. 21: *Syracosphaera haldali*, sample 2.

Abb. 21: *Syracosphaera haldali*, Probe 2.

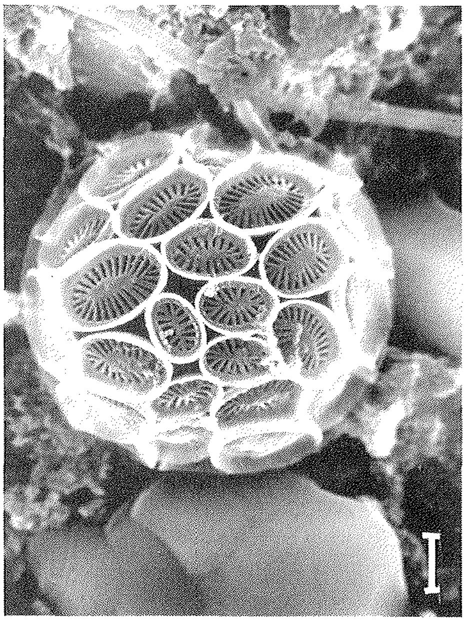

Fig. 23: *Syracosphaera variabilis*, sample 2.

Abb. 23: *Syracosphaera variabilis*, Probe 2.

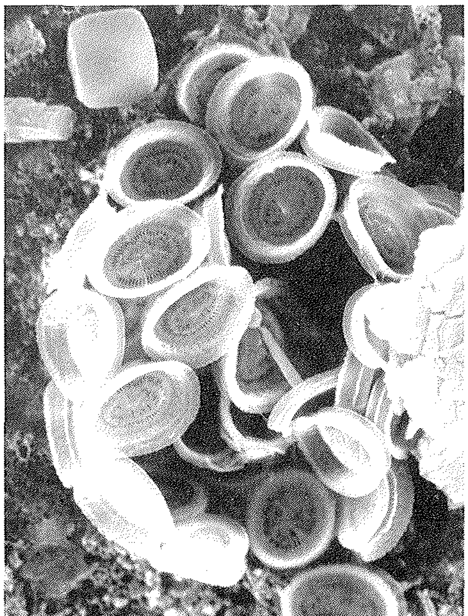

Fig. 22: *Syracosphaera pulchra*, sample 2.

Abb. 22: *Syracosphaera pulchra*, Probe 2.

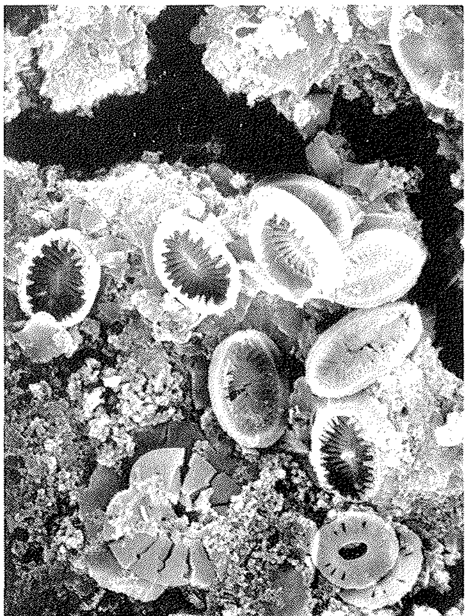

Fig. 24: *Syracosphaera elatensis*, sample 3.

Abb. 24: *Syracosphaera elatensis*, Probe 3.

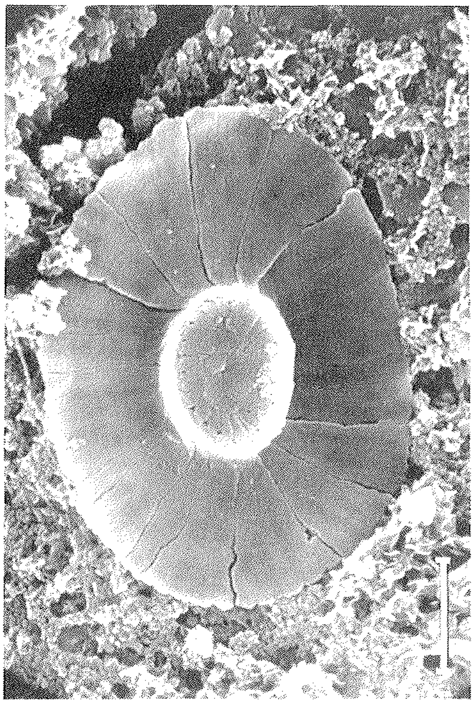

Fig. 25: *Umbellosphaera irregularis*, sample 2.

Abb. 25: *Umbellosphaera irregularis*, Probe 2.

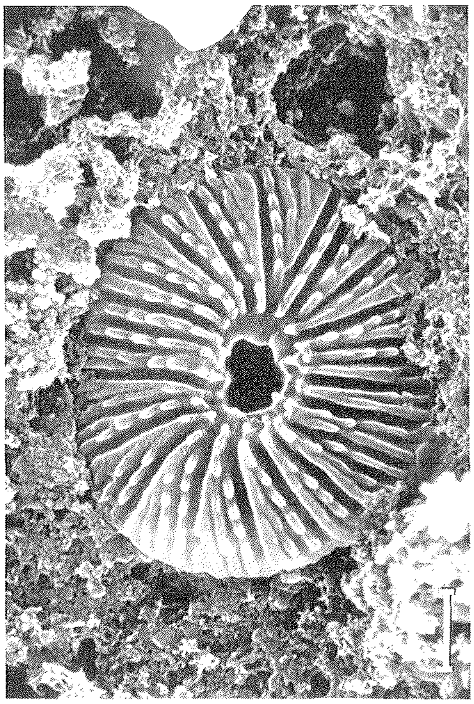

Fig. 26: *Umbellosphaera tenuis*, sample 2.

Abb. 26: *Umbellosphaera tenuis*, Probe 2.

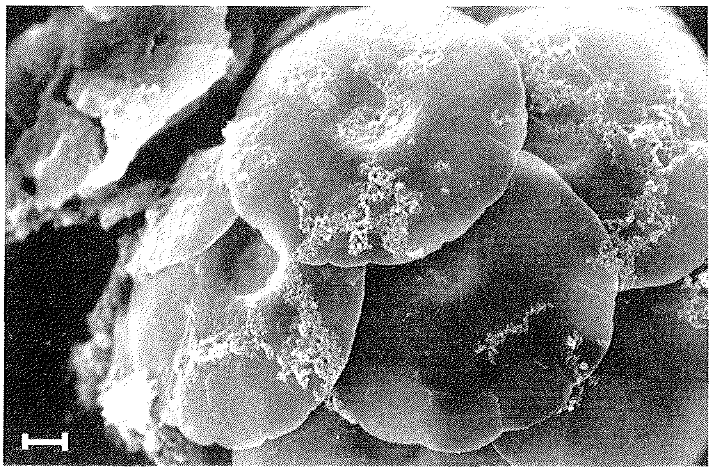

Fig. 27: *Oolithus fragilis*, sample 3.

Abb. 27: *Oolithus fragilis*, Probe 3.

Fig. 28: *Anoplosolenia brasiliensis*, sample 3.

Abb. 28: *Anoplosolenia brasiliensis*, Probe 3.

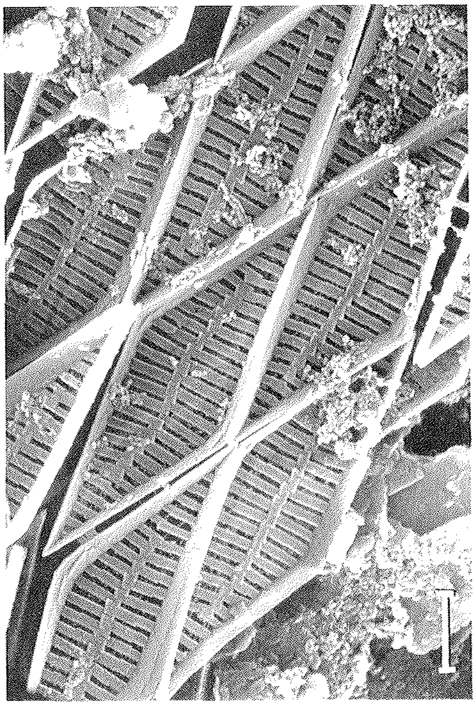

Fig. 29: detail of fig. 28.

Abb. 29: Detail der Fig. 28.

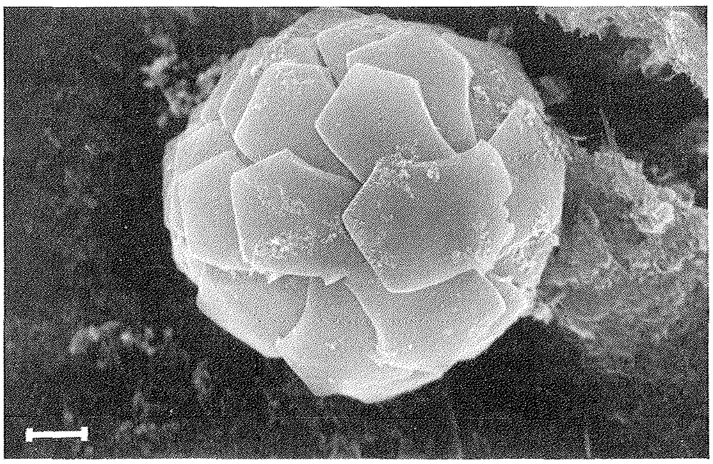

Fig. 30: *Florisphaera profunda*, sample 6.

Abb. 30: *Florisphaera profunda*, Probe 6.

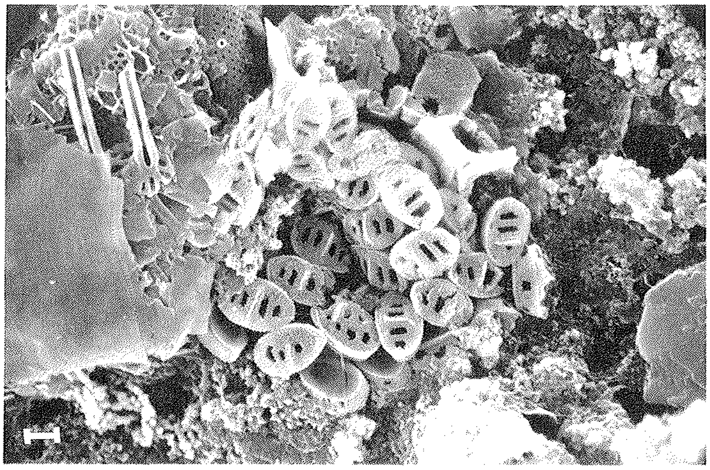

Fig. 31: *Helladosphaera aurisinae*, sample 3.

Abb. 31: *Helladosphaera aurisinae*, Probe 3.

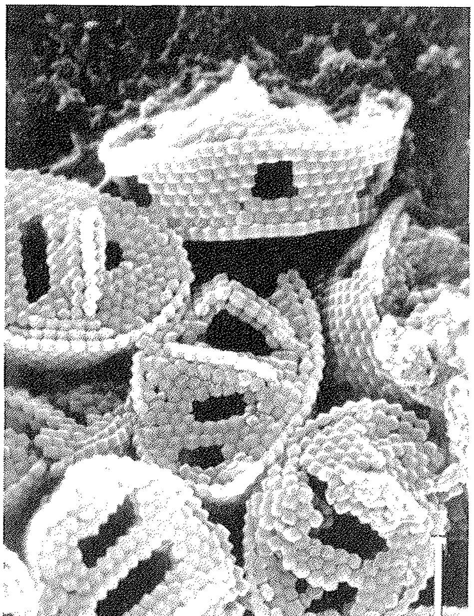

Fig. 32: detail of fig. 31.

Abb. 32: Detail der Fig. 31.

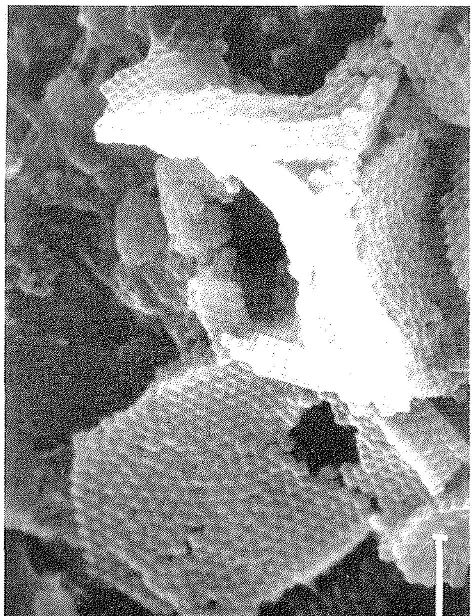

Fig. 33: detail fig. 31.

Abb. 33: Detail der Fig. 31.

It is possible, however, that at least some of these tropical flora elements come from the Indian Ocean but were not represented in numbers large enough to be mentioned by WINTER et al. (1985). The presence of large numbers of *U. irrigularis* was not reported for the core tops from the area studied by WINTER et al. (1985) either, which makes this posibility less likely.

VERBEEK (1985) reported, that the transitional floral zone is difficult to recognize in the North Atlantic in the winter. But even the authors who proposed this floral zone themselves expressed doubts about the reliability of this zone as they wrote: "this flora is not a distinct unit and deserves the appellation "transitional". Although MCINTYRE & BÉ (1967) and OKADA & MCINTYRE (1979) reported, that many species are eurythermal, it must be kept in mind that seasonal changes in water temperature can influence the nannoflora dramatically, especially when other factors as nutrient levels and light penetration also change with the seasons. The transitional floral zone is situated in those parts of the Atlantic, where water temperatures fluctuate strongly with the seasons (TCHERNIA, 1980), and probably often exceed the thermal tolerances of individual species.

Further study will be needed for a redefinition of the transitional flora zone and this redefinition should be based on the seasonal changes in the boundaries between the assemblages and in the composition of these assemblages. To obtain the best comparisons between coming studies in the future, it is recommended to include the sampling datum in publications on calcareous nannoplankton ecology.

The monospecific assemblages of *E. huxleyi* observed south of the Subtropic Convergence correspond partially with those described by MCINTYRE & BÉ (1967), who reported that this species is the most important flora element in this region, which constitutes their subantarctic floral zone. The other flora element in this floral zone is, according to these authors, *C. leptopora*. This observation was not confirmed by the present findings. Furthermore, there is another difference in that MCINTYRE & BÉ (1967) report finding *E. huxleyi* and *C. leptopora* in waters with temperatures down to 2 °C, whereas in the present study these species are not found in waters colder than 5 and 20 °C respectively. Special attention was paid to the species *E. huxleyi*. This species has two morphotypes whose occurrence depends according to MCINTYRE & BÉ (1967) on the temperatures of the water. The "cold-water" morphotype has thin elements in the distal shield, that are only connected near the tube between the proximal and distal shields and an open central area (Fig. 2), whereas the "warm-water" morphotype has a distal shield in which the thicker elements are connected over a distinctly longer distance and the central area is closed by a grill (Fig. 3). WINTER (1985) found both morphotypes in the California current in warm waters. Our samples 1 to 6 also contained both morphotypes and seriously malformed specimens (Fig. 4), which supports WINTER's (1985) conclusion, that temperature is not the only factor controlling the occurrence of the morphotypes. He also concluded that a combination of nutrient levels, degree of light penetration, temperature, and salinity controls the occurrence of the morphotypes. However, only malformed *E. huxleyi* specimes were observed in the cold waters of the Circum Antarctic Current (Fig. 5—7). The "cold-water" morphotype without malformation was observed by MCINTYRE & BÉ (1967) in this region and in the present study we found a specimen of the nannoplankton predator *Stenosemella ventricosa* with a scale composed of coccoliths of this "cold-water" morphotype (Fig. 8—9). The "warm-water" morphotype has never been reported from cold waters, which indicate that temperature determines the distribution of the "warm-water" morphotype and that the distribution of the "cold-water" morphotype is influenced by a combination of ecological factors.

All of the samples, both with and without calcareous nannoplankton, of water from the Circum Antarctic Current even from places with a temperature slightly below 0 °C showed many other algae such as diatoms, silicoflagellates and dinoflagellates, which means that the waters near Antarctica are favourable for unicelullar algae. Nutrients, light and the like do not seem to have been strongly limiting factors for these organisms at the time of sampling. Nevertheless only three samples containted some calcareous nannoplankton.

In the waters of the Circum Antarctic Current there is another factor, that might influence the forming of coccoliths: the high hydro energy induced by high wind velocities. Coccoliths are formed by the calcification of an organic mould (WILBUR & WATABE, 1963; KLAVENESS, 1972), and it seems to us likely that hydro energy influences either the formation or the calcification of the mould. This hypothesis is supported by observations made by the author during studies in the North Atlantic (VERBEEK, 1985), where he found only malformed specimens of *G. oceanica* in a sample taken under very bad weather conditions. For other species and generally also *E. huxleyi*, the combination of cold water, high hydro energy and possibly some of the other factors mentioned by WINTER (1985), the environment is too unfavourable to survive or, if present, to produce coccoliths.

5. CONCLUSIONS

1. In the waters south of Africa down to the Circum Antarctic Current a flora occurs in summer, which contains flora elements not representative for the transitional floral zone of MCINTYRE & BÉ (1967).

2. The transitional floral zone must be redifined, but further study is required to define this zone on basis of seasonal changes in the assemblages.

3. Calcareous nannoplankton is extremely scarce in the Circum Antarctic Current representing the Antarctic floral zone of MCINTYRE & BÉ (1967); even most of the eurythermal species are absent, and calcareous nannoplankton does not occur in water colder than 5 °C, although calcareous nannoplankton has been reported from waters with a temperature of 1 °C in other regions of the world.

4. It is suggested that bad weather conditions (storm) play an important role with respect to the presence of coccolith bearing nannoplankton near the Antarctic.

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