

Calcareous Nannofossils in Surface Sediments of the Central and Northern Parts of the South China Sea

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ABSTRACT

Taxonomic composition and quantitative distribution of calcareous nannofossils in the northern and central parts of the South China Sea were studied in 146 samples of surface sediments taken from estuary, continental shelf, continental slope and deep-water basin. This paper reports distribution patterns of nannofossils in the area, including nannofossil abundance, species, assemblages and specimen size. Abundance increases from shelf to slope, with a decrease from the lower part of the slope towards the abyssal plain. The assemblages are dominated by *Emiliania huxleyi*, *Gephyrocapsa oceanica* and *Florisphaera profunda*. Ecologically the effects of water temperature, and nutrient inputs can be detected in the distribution of nannofossils, while dilution by terrigenous materials and deep sea carbonate dissolution influence the sedimentological aspect of the samples. The composition of the South China Sea nannofossil assemblage enables it to be grouped with the central zone of the North Pacific in biogeographic zonations of nannoplankton. *J. Micropalaeontol.*, 11 (2): 167-176, December 1992.

INTRODUCTION

In the Chinese sea area, systematic research on calcareous nannofossils from surface sediments has been concentrated in the East China Sea (Wang and Min, 1981; Wang and Samtleben, 1983; Wang and Cheng, 1985; Zhang and Siesser, 1986). In the South China Sea, Okada and Honjo (1975) analysed calcareous nannoplankton in 61 water samples collected south of 11°N, also Chen and Shieh (1982), Okada (1983) analysed calcareous nannofossils in surface sediment samples from the southern part of the Sea. Okada (1983) studied samples from the Gulf of Thailand, Chen and Shieh (1982) mainly worked on the Sunda Shelf and Southern Basin of the Sea. Varol (1985) studied calcareous nannofossils from nearshore localities in Jason Bay. There have been no previous studies of the calcareous nannofossils in the surface sediments of the northern part of the South China, which are the subject of this study.

STUDY AREA

The samples were collected from the northern part of the South China Sea (12°-23°N, 108°-118°E) (Fig.1), including the eastern part of Beibu Gulf, continental shelf, continental slope, and abyssal plain. Two major rivers flow into the area — the Zhujiang (Pearl) River and the Hanjiang River. The bottom topography of the area is high in the northwest and low in the southeast, the maximum water depth in the area is over 4000m. The shelf / slope boundary is at a depth of approximately 150m. The abyssal plain starts at approximately 3600m (*Physical Geography of China* Compilation Committee, 1979). From continental shelf to abyssal plain, the clastic sediments fine gradually, the 30% sand contour is at about 200m (Fig.2a); and CaCO₃ content gradually declines, it is less than 10% below a water depth of 3500m (Fig.2b).

MATERIALS AND METHODS

146 samples were studied; 100 of these were collected during 1983-84 by the Second Institute of Oceanography, State Oceanic Administration, 46 were collected during 1974-78 by South China Sea Headquarters of Geological Survey, MGMR (Fig.1).

Light microscope slides were prepared by diluting 0.1 grams of sediment in 40 millilitres of distilled water and spreading a drop of the slurry on a cover glass (24 X 32 mm²). All samples were studied under polarised light microscope (Leitz ORTHOLUX 2 POL BK). The number of nannofossils per 10 randomly selected fields of view at X630 magnification was used as the nannofossil abundance of the sample. If this abundance was under 300, a further 10 fields were examined, and the results averaged. In addition, these abundances are converted to specimens per gram of sediment (Tab.1) (specimens per gram of sediment = specimens per 10 fields of view X (24x32mm² / 10 fields of view area) X (40ml / drop volume) X (1g / 0.1g) = specimens per 10 fields of view X 1300 X 880 X 10 = specimens per 10 fields of view X 11.44 million). If the difference between specimens per 10 fields of view counted in different times is 1, the difference between specimens per gram of sediment estimated in different times will be 11.44 million. The estimate of specimens per gram of sediment is accurate to at most 10⁷. Seventy-one samples with more abundant nannofossils were examined with a scanning electron microscope (Hitachi H-8010 SEM part of Hitachi H-800 transmission electron microscope) at X5000 magnification. In forty-eight of them, with the most abundant nannofossils, the assemblages were counted (counts of more than 300 specimens) to assess the relative abundance of taxa and specimen size.

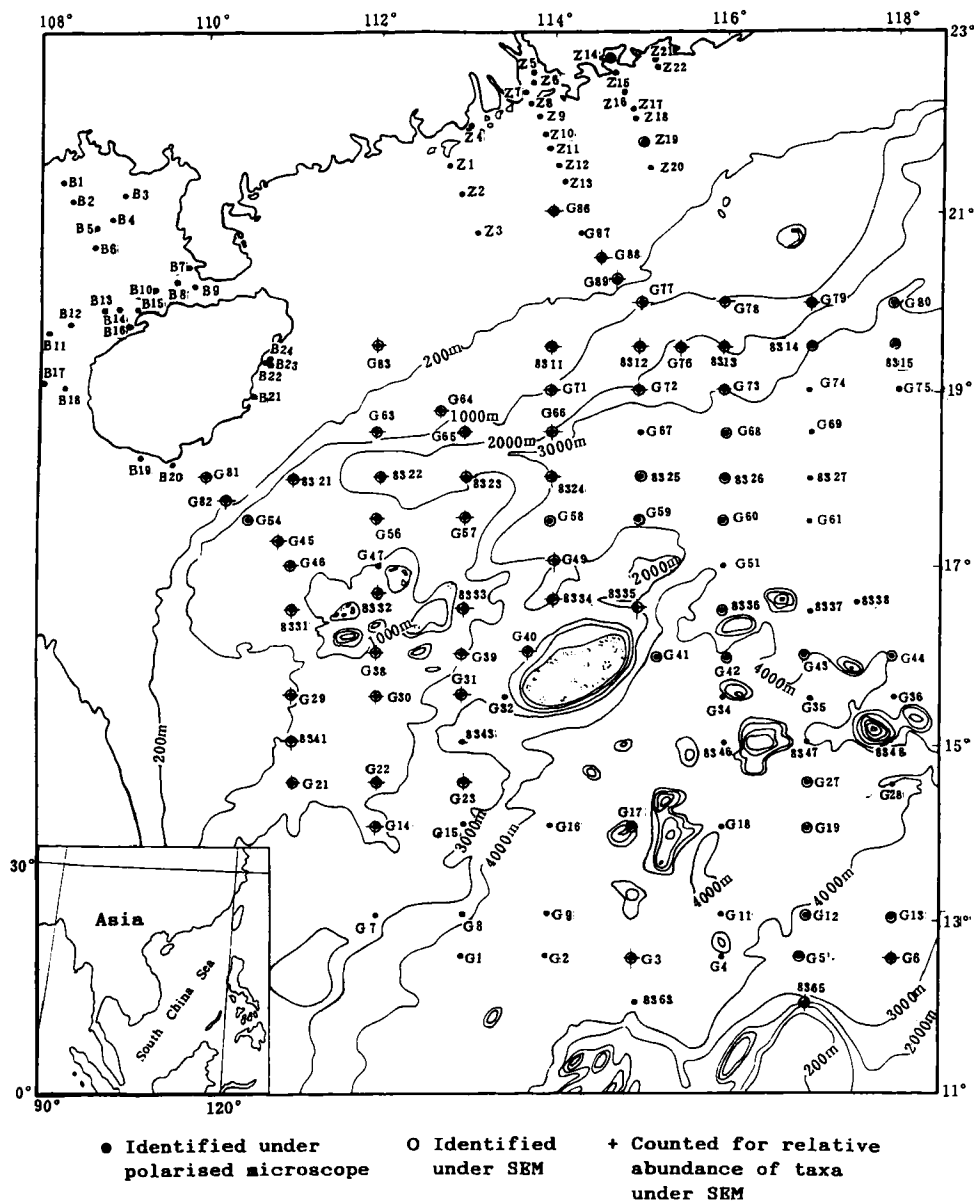


Fig. 1. Localities of sample stations: identified under polarised microscope, ○ identified under electron microscope, counted for relative abundance of taxa under electron microscope (Topographic map reduced from South China Sea Institute of Oceanology, Academia Sinica, 1981).

RESULTS

Nannofossil Abundance

The abundance distribution of calcareous nannofossils (Fig. 2c) is closely related to water depth. Specimens are widely distributed in the samples, from nearshore at a water depth of few metres to the deep basin at a water depth of more than 4000 metres. However, the abundances range from 0 to 1664. Abundances over 300 are limited mainly to water depths of 200m to 3500m (Tabs. 1 and 2, Fig. 2c). Calcareous nannofossils form less of the sediments in the shelf area (<200m) and much less of the sediments in the abyssal plain (>3500m), where almost no nannofossils could be found in most samples.

Sediment grain size and carbonate content are closely related to nannofossil abundance. Nannofossil content is low in coarse sediments and high in fine sediments. For example, at stations on the northern shelf, sediments are coarse and the sand content is high, and most nannofossil abundances are less than 300 (Figs. 2a and 2c). Generally speaking, high nannofossil contents correlates with high carbonate content (Figs. 2b and 2c).

Species Distribution

Twenty-nine calcareous nannofossil species or groups of species, and two species of calcareous dinoflagellates

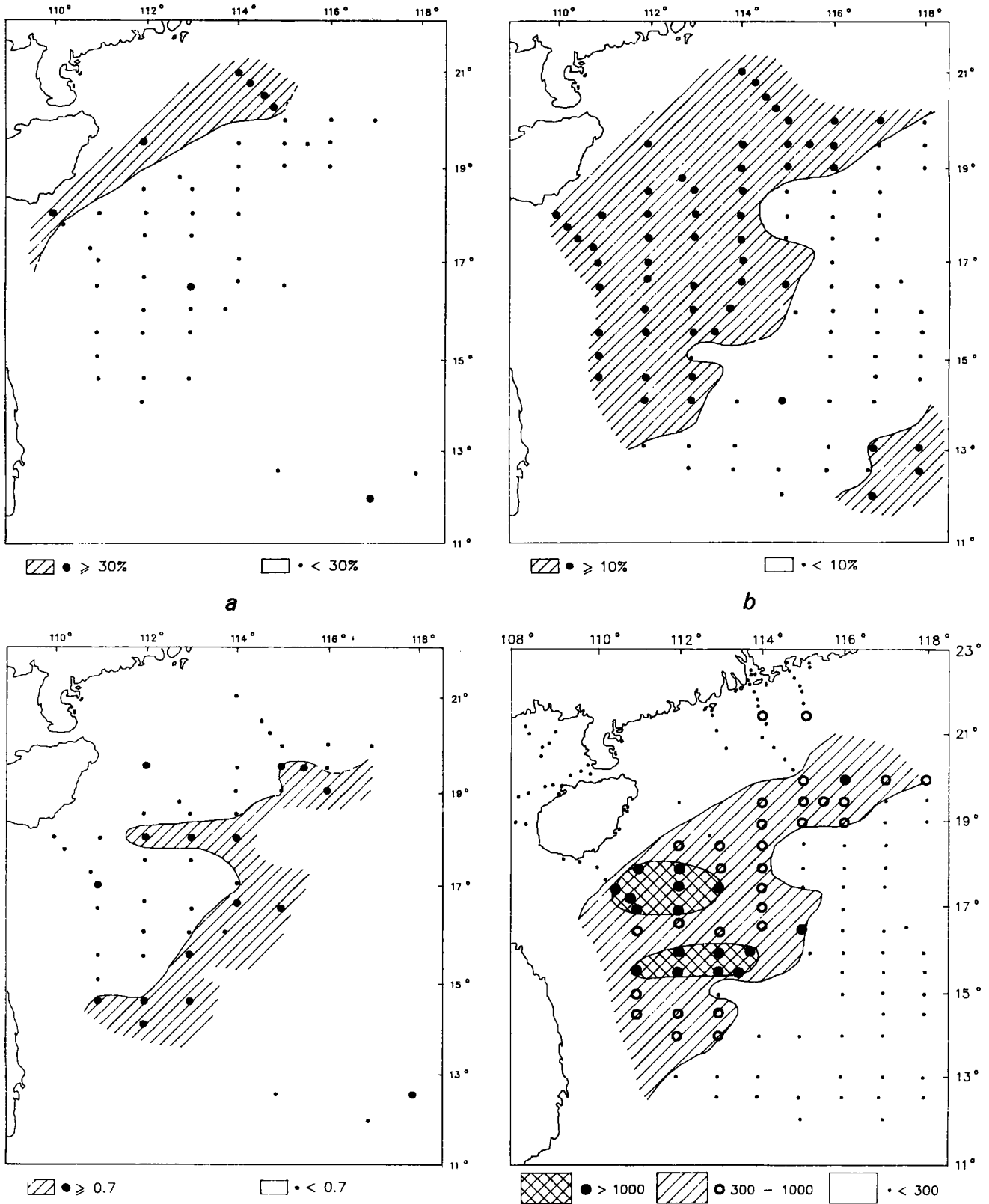


Fig. 2. (a) Sand distribution in the central and northern parts of the South China Sea; (b) CaCO_3 distribution in the central and northern parts of the South China Sea; (c) Distribution of calcareous nannofossil abundance; (d) Relative abundance of broken specimens to all specimens of *Emiliana huxleyi*.

(*Thoracosphaera heimii* and *T. tuberosa*), were identified (Tab.3). For each species, the percentage of samples it occurred in "frequency", and the average percentage of the total counted assemblages in "average relative abundance", are given in Table 3. In addition, some reworked nannofossils, such as *Discoaster deflandrei*, *D. brouweri*, *Pseudoemiliania lacunosa*, *Gephyrocapsa protohuxleyi*, *G. aperta* and *Sphenolithus abies*, occurred sporadically in samples from the slope (Tab.5). Distributional aspects are described below for major species.

***Emiliania huxleyi* (Lohmann) Hay & Mohler.** *E. huxleyi* (Fig.3a) is widely distributed and an abundant species in the area, it occurred in all 48 samples counted. The relative abundance per sample varies from 15.83% to 86.13%, it is highest between about 150m and 2000m depth (>55%). This species has the greatest biogeographic range in modern oceans (McIntyre and Bé, 1967), and is often found in nearshore seas, for example, in marginal seas of the western Pacific (Okada and Honjo, 1975; Chen and Shieh, 1982; Wang and Cheng, 1985). McIntyre and Bé (1967) described a "warm water form" and a "cold water form". The "warm water form" has T-shaped elements in both shields and a delicate plate of interconnected rods forming a grill covers the proximal side of the central opening. The "cold water form" has T-shaped elements only in the distal shield and the solid proximal shield has a central plate of thin interlocked elements completely closing the pore. These forms were identified and counted separately in the study, but there was no indication that their occurrence varied with temperature. The relative abundance of the species (Fig.3a) and the relative abundance of broken specimens (Fig.2d) have a close relation to water depth.

***Gephyrocapsa oceanica* Kamptner.** This is an important species in coccolith assemblages in modern oceans and abundant in marginal seas around the western Pacific Ocean, it is a major component of coccolith assemblages in the East and South China Seas (Okada and Honjo, 1975; Chen and Shieh, 1982; Okada, 1983; Wang and Samtleben, 1983; Wang and Cheng, 1985). *G. oceanica* (Fig.3b) is also abundant and widespread in this area, and found in all samples counted for relative abundance. The relative abundance varies from 0.6% to 70%. The high values (>25%) are in the northern continental shelf at water depths of less than 150m and in the lower continental slope at water depths of more than 2000m.

***Florisphaera profunda* Okada & Honjo.** *F. profunda* (Fig.3c), in terms of its dominance, is third only to *E. huxleyi* and *G. oceanica*. It is found in all assemblages counted. It is abundant (>10%) in sediments from water depths of 1000 to 2000m. It has been widely neglected due to its unusual shape, so few references to the species can be found. According to Okada and Honjo (1973), living *F. profunda* is abundant in the deeper surface waters (100-150m) over a wide temperature range (10-28°C). Okada (1983) suggested that its relative abundance in surface sediments shows a positive correlation with water depth from the lower continental shelf to abyssal depths and that *F. profunda* dominates the associations in deep basins. This study found a different distribution. The relative

abundance of *F. profunda* increases with water depth to 2000m but decreases below this depth.

***Calcidiscus leptoporus* (Murray & Blackman) Loeblich & Tappan.** *C. leptoporus* (Fig.3d) is distributed in water depth from 1000 to 3500m. Its average relative abundance is 0.79%, with values greater than 0.8% mainly found in water depths from 2000 to 3500m. The different varieties of *C. leptoporus* proposed by McIntyre et al. (1967, 1970) were not distinguished because total numbers counted were low.

***Umbilicosphaera sibogae* (Weber-van Bosse) Gaarder.** *U. sibogae* (Fig.3e) is not abundant (average relative abundance is 2.86%), but it is present in most samples (frequency is 89.58%). There is little regularity of relative abundance variation although most of the stations in which the value is over 4% come from water depths between 1000 and 3000m. McIntyre and Bé (1967) distinguished cold water and warm water forms of *U. sibogae*. They were not distinguished in this study because of their low relative abundance. The species was also found in the East China Sea (Wang and Cheng, 1985), but with lower relative abundances than those found here.

***Syracosphaera pulchra* Lohmann.** This species is rare (average relative abundance is 0.84%) and there is no obvious pattern to the relative abundance variation (Fig.3f).

***Umbellosphaera tenuis* (Kamptner) Paasche.** Although *U. tenuis* is rare (average relative abundance is 0.43%) (Fig.3g), it is present in most samples (frequency 87.50%).

***Helicosphaera carteri* (Wallich) Kamptner.** The relative abundance of *H. carteri* (Fig.3h) is very low (average is only 0.32%), however, it is widely distributed in the area (frequency 93.75%).

Assemblage Zones

Based on the distribution of species and their relative abundance in the surface sediments, three assemblage zones (Fig.4a) can be established:

Zone 1. Zone 1 approximately corresponds to the northern continental shelf (<150m). *G. oceanica* and *E. huxleyi* are abundant in the zone. *F. profunda*, *Umbellosphaera irregularis*, *U. sibogae* and *Umbilicosphaera hulburtiana* can be found.

Zone 2. Zone 2 is situated in the upper continental slope at depths of 150 to 2000m. *E. huxleyi* is predominant, *G. oceanica* and *F. profunda* are common in the zone. *U. irregularis*, *U. sibogae*, *U. tenuis*, *Thoracosphaera heimii*, *Cricosphaera calvata* and *Discosphaera tubifer* can be found. The zone can be subdivided into two subzones based on relative abundance variation of *F. profunda*. *F. profunda* is more abundant in subzone 2b than in 2a.

Zone 3. Zone 3 is in the lower continental slope (>2000m). *G. oceanica* is abundant, *E. huxleyi* is still common, but much less abundant than in zone 2. *C. leptoporus*, *F. profunda*, *U. sibogae*, *U. irregularis*, *U. tenuis*, *H. carteri* and *H. hyalina* can be found.

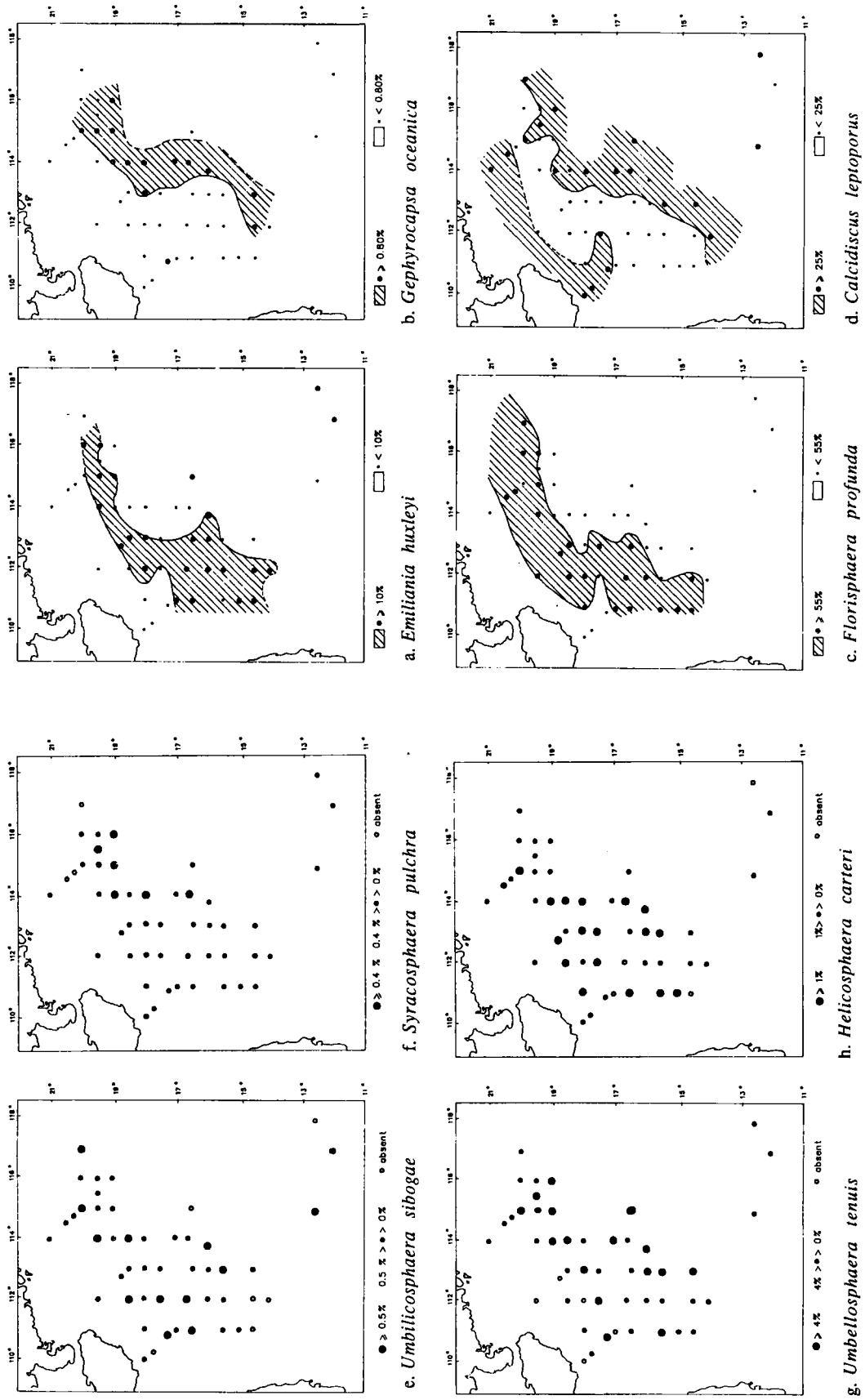


Fig. 3. (a) Relative abundance of *Umbilicosphaera sibogae*; (b) Relative abundance of *Gephyrocapsa oceanica*; (c) Relative abundance of *Florisphaera profunda*; (d) Relative abundance of *Calcidiscus leptoporus*; (e) Relative abundance of *Umbilicosphaera sibogae*; (f) Relative abundance of *Syracosphaera pulchra*; (g) Relative abundance of *Umbilicosphaera tenuis*; (h) Relative abundance of *Helicosphaera carteri*.

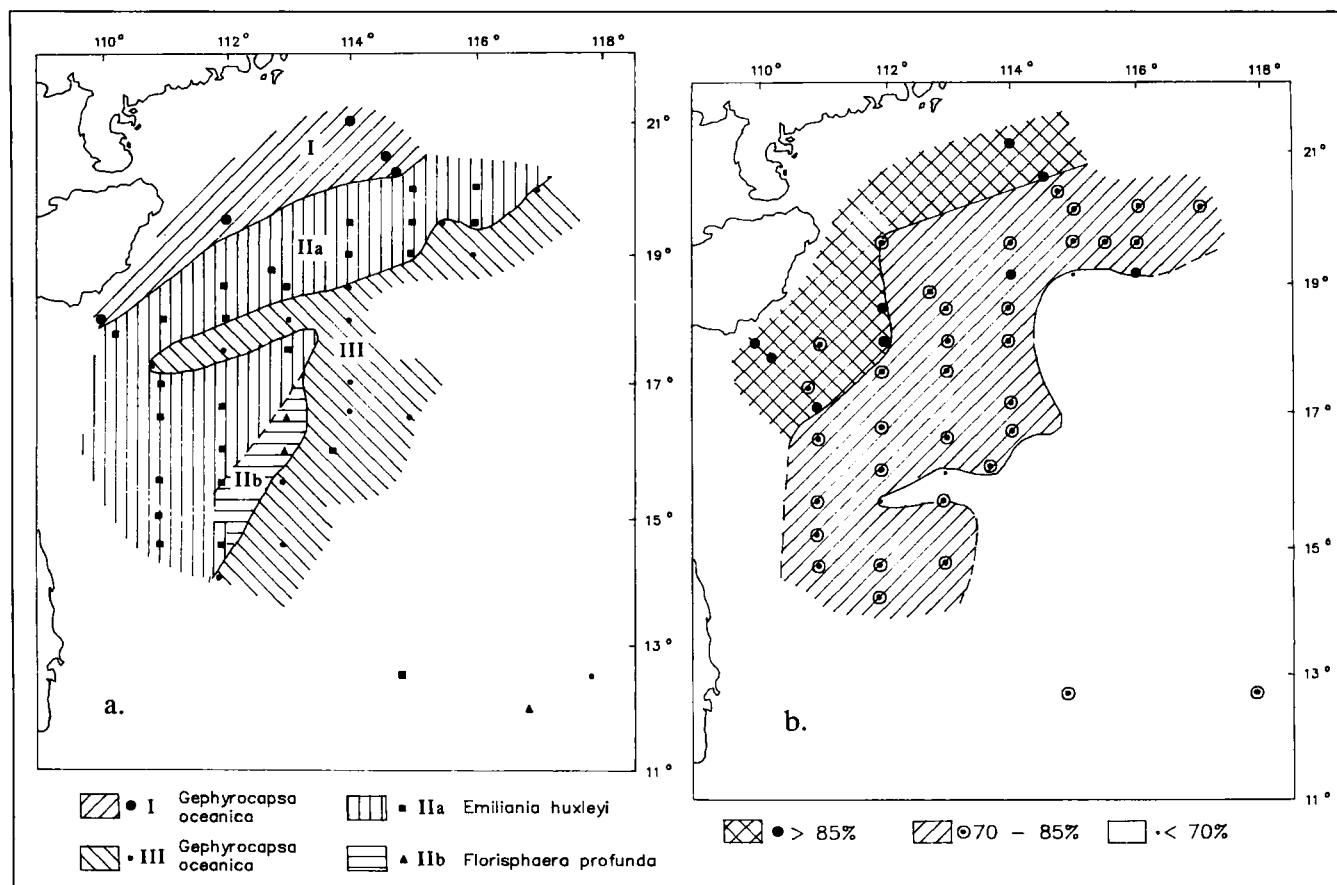


Fig. 4. (a) Calcareous nannofossil zones; (b) Distribution of small calcareous nannofossils (*E. huxleyi* *G. oceanica*)

Specimen Size

E. huxleyi and *G. oceanica* are smaller than 6 microns and can be designated "small nannofossils". The percentage of the small nannofossils is higher (over 85%) nearshore and lower seawards (Fig.4b).

DISCUSSION

Comparison

The nannofossil assemblages in the central and northern parts of the South China Sea can be compared with those in the southern part of the Sea (Chen & Shieh, 1982). The dominant species are the same, *E. huxleyi* and *G. oceanica*. There is a similar relative abundance variation trend of dominant species. *G. oceanica* prevails in nearshore environments, increasing in number towards the shoreline, while *E. huxleyi* increases in relative abundance towards continental slope and open ocean environments, decreasing again in the deep sea basin. But *E. huxleyi* predominates in the central and northern parts, and *G. oceanica* predominates in the southern part. What caused this difference remains to be studied.

Tab.4 compares assemblages for the East China Sea (Wang and Cheng, 1985) and the study area. They are generally similar, however, the dominance of *E. huxleyi* and *G. oceanica* is higher in the East China Sea. The relative abundances of other species, especially warm water species, *U. irregularis*, *U.*

sibogae and *O. fragilis* are higher in the South China Sea. These differences may result from the difference in latitudes. The South China Sea is situated in the tropics, the variation of surface water temperature there is less than that in the East China Sea.

Roth and Coulbourn (1982) recognized four coccolith assemblages (equatorial, central, transitional and subarctic) (Tab.4) in surface sediments of the North Pacific. They found that the coccolith assemblages followed the distribution of surface water masses. The central assemblage is dominated by *E. huxleyi* and *G. oceanica*. Although not a dominant species, *U. tenuis* was considered an important water-mass discriminator because it is restricted to the central water-mass. Comparing the average nannofossil assemblage in the central and northern South China Sea with the Pacific assemblages, that of the South China Sea is most closely equivalent to the central assemblage of the North Pacific, as shown by the dominance of *E. huxleyi* and *G. oceanica*, and the presence of *U. tenuis* (Tab.4).

Controlling Factors

E. huxleyi and *G. oceanica* are adapted to different environments. The former is the most ubiquitous species in today's seas, and can be found from tropical to subpolar waters; the latter is a warm water species, occurring in tropical, subtropical and temperate zones. The high water temperature in the

South China Sea is responsible for the dominance of *G. oceanica* and *E. huxleyi* in the area. *E. huxleyi* is found in low to highly fertile waters throughout the world's oceans, but *G. oceanica* dominated in highly fertile and productive waters. Nutrients (e.g. phosphate) have an effect on *G. oceanica*. In the Gulf of Aqaba (Elat), Red Sea, Winter (1982) found that the distribution of *G. oceanica* was closely related to the distribution of phosphate. While *G. oceanica* in surface sediments was decreasing with phosphate from south to north, *E. huxleyi* was increasing. So it is likely that the riverine nutrient input cause the higher productivity of *G. oceanica* in the coastal area. However, the predominance of *G. oceanica* over *E. huxleyi* in the deep water area might be due to dissolution of delicate *E. huxleyi*. Evidence for this is provided by the increase in broken specimens of *E. huxleyi* in samples from below 2000m (Fig.2d). Also the increase in *C. leptoporus* in deep water (Zone 3) are presumably dissolution effects.

The distribution of nannofossils in surface sediments is also influenced by sedimentological factors. Gartner (1981) found that on the continental shelf of the northern Gulf of Mexico coccoliths were relatively rare in the predominantly detrital sediments, even though they were produced in abundance in the water column. He thought this was due to the dilution by detrital materials. The continental shelf of the studied area receives a high input of terrigenous materials from the Zhujiang and Hanjiang Rivers, so it is likely that the low abundance of nannofossils nearshore is a result of dilution by terrigenous materials. As noted above, the distribution of calcareous nannofossils is closely related to the sediment carbonate content. A low value of abundance often corresponds to a low value of carbonate content. Although there is a close relationship between distributions of nannofossil and carbonate, carbonate content depends not only on nannofossils but also on other factors. Distribution of sediment carbonate in the South China Sea is mainly controlled by three factors: dilution by non-carbonate components, supply of calcareous skeletons of organisms, and carbonate dissolution. Carbonate content is lower near shore (e.g. 12.30%, 11.80%, 18.80% and 16.60% in stations G81, G82, G83 and G86) (Tab.5) due to dilution by terrigenous materials. It is also controlled by the supply of biogenic carbonate. Its distribution is closely related to these fossils, for example, foraminifers and nannofossils. It decreases towards abyssal plain as foraminifers (Zheng, 1987) and nannofossils (Figs.2b and 2c) do. Another important controlling factor of the distribution and content of carbonate is preservation. Carbonate dissolution increases with depth as bottom water becomes more undersaturated in calcium carbonate (Kennett, 1982). So low value of carbonate content including foraminifers and nannofossils (<10%) could be attributed to the carbonate dissolution in deep sea. The relation between nannofossil abundance and sediment grain size reflects, to a certain extent, the effect of sorting on grain size, which results in more abundant nannofossils in fine sediments than in coarse ones.

CONCLUSIONS

1. Calcareous nannofossil abundance in surface sediments increases from continental shelf to slope, with a decrease from lower continental slope to abyssal basin.

2. *E. huxleyi* and *G. oceanica* are dominant species. The high relative abundance zones of the latter are situated in northern continental shelf and lower continental slope. Highest value of the former is in the area between water depths about 150 to 2000 metres.

3. The nannofossil assemblages in the northern and central parts of the South China Sea are similar to those in the East China Sea and in the central zone of the North Pacific Ocean.

4. There are two main groups of controlling factors: a) ecological factors including water temperature and supply of nutrients, b) sedimentological factors including dilution by terrigenous materials, deep water carbonate dissolution and the sorting effect.

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N	D(m)	a/10f	A	N	D(m)	a/10f	A	N	D(m)	a/10f	A
Z4	2	1	0.1	G88	104	78	8.9	8324	3242	413	47.2
Z5	5	0	0.0	G83	114	119	13.6	G13	3280	116	13.3
Z6	6	0	0.0	G82	160	131	15.0	G6	3327	150	17.2
Z7	6	1	0.1	G89	181	91	10.4	G17	3417	88	10.1
Z14	7	35	4.0	G63	480	412	47.1	8315	3427	82	9.4
B22	7	0	0.0	8311	560	552	63.1	G7	3430	0	0.0
Z8	8	2	0.2	G64	600	254	29.1	G58	3500	690	78.9
B16	12	100	11.4	8365	600	110	12.6	8343	3550	29	3.3
B23	13	23	2.6	G77	895	830	95.0	G59	3652	285	32.6
B24	13	1	0.1	G29	900	1200	137.3	8325	3677	49	5.6
Z21	15	18	2.1	8332	910	792	90.6	G67	3686	3	0.3
B7	15	32	3.7	G47	981	1250	143.0	G68	3773	75	8.6
B3	19	137	15.7	G71	1040	543	62.1	G74	3800	1	0.1
B8	19	9	1.0	G38	1115	1012	115.8	G75	3825	1	0.1
B10	19	15	1.7	8331	1163	888	101.6	G60	3868	18	2.1
Z15	20	31	3.5	8321	1200	1410	161.3	G69	3870	1	0.1
Z22	20	5	0.6	G54	1230	1282	146.7	8326	3940	1	0.1
B1	20	46	5.3	8341	1240	622	71.2	G35	3942	2	0.2
B19	20	25	2.9	8333	1244	598	68.4	8327	3967	1	0.1
Z9	21	31	3.5	G78	1257	1112	127.2	G51	3975	10	1.1
B15	22	15	1.7	G46	1300	1488	170.2	G61	3977	4	0.5
B21	22	37	4.2	G56	1347	1064	121.7	8338	3980	2	0.2
B2	25	81	9.3	G21	1370	770	88.1	G28	3990	1	0.1
Z10	29	110	12.6	G57	1432	1062	121.5	G5	4000	15	1.7
Z16	29	83	9.5	G30	1579	1480	169.3	8337	4018	3	0.3
B4	29	160	18.3	G45	1600	1190	136.1	G36	4022	6	0.7
Z1	30	9	1.0	G79	1600	776	88.8	G43	4072	3	0.3
B14	30	98	11.2	8312	1640	490	56.1	G44	4080	1	0.1
B9	32	12	1.4	G65	1659	382	43.7	G12	4100	212	24.3
B18	34	25	2.9	G22	1699	864	98.8	8348	4106	1	0.1
B5	36	197	22.5	G39	1747	1346	154.0	G9	4114	2	0.2
Z17	41	55	6.3	8313	1937	590	67.5	8336	4120	1	0.1
B20	41	22	2.5	8323	2050	660	75.5	G42	4127	4	0.5
Z11	42	143	16.4	G14	2050	500	57.2	G2	4140	0	0.0
B6	42	82	9.4	G66	2172	632	72.3	G41	4162	5	0.6
Z18	47	31	3.5	G72	2234	872	99.8	G27	4170	80	9.2
B12	49	25	2.9	G23	2398	940	107.5	8346	4172	1	0.1
Z2	50	182	20.8	G76	2400	970	111.0	8347	4184	2	0.2
Z12	53	352	40.3	8322	2412	1156	132.2	G18	4200	0	0.0
B11	55	45	5.1	G40	2420	1664	190.4	G34	4207	4	0.5
B13	55	31	3.5	G32	2600	1070	122.4	G1	4265	0	0.0
B17	62	167	19.1	G15	2710	483	55.3	G19	4274	91	10.4
Z13	71	11	1.3	G31	2800	1034	118.3	G8	4280	0	0.0
Z19	72	275	31.5	G49	2850	866	99.1	G11	4300	1	0.1
Z3	73	92	10.5	G73	2970	646	73.9	G4	4367	0	0.0
G86	82	213	24.4	G80	2980	312	35.7	G16	4400	0	0.0
G87	84	83	9.5	8335	3050	1172	134.1	G3	4400	196	22.4
Z20	95	510	58.3	8314	3060	109	12.5	8363	4420	4	0.5
G81	95	66	7.6	8334	3200	668	76.4				

Table 1. Nannofossil abundance and water depth (bathymetric data provided by Second Institute of Oceanography, SOA and South China Sea Headquarters of Geological Survey, MGMR). N - Sample number

water depth, metres	number of samples	nannofossil abundance				
		minimum	maximum	average		
< 200	53	0	510	78	Beibu Gulf	58
					Zhujiang Estuary	90
					northern shelf	112
200-500	1	412	412	412		
500-1000	7	110	1250	713		
1000-2000	20	382	1488	948		
2000-3000	14	312	1664	843		
3000-3500	10	0	1172	349		
3500-4000	16	1	285	30		
> 4000	25	0	212	25		

Table 2. Calcareous nannofossil abundancies with water depth

Taxa	average % abundance	frequency %
<i>Anoplosolenia brasiliensis</i> (Lohmann) Deflandre	0.56	64.58
<i>Calcidiscus leptoporus</i> (Murray & Blackman) Loeblich & Tappan	0.79	89.58
<i>Calciopappus caudatus</i> Gaarder & Ramsfjell	0.03	8.33
<i>Ceratolithus cristatus</i> Kamptner	0.04	10.42
<i>Ceratolithus</i> spp.	0.04	10.42
<i>Coccolithus pelagicus</i> (Wallich) Schiller	0.04	8.33
<i>Crenalithus sessilis</i> (Lohmann) Okada & MacIntyre	0.05	6.25
<i>Crenalithus</i> spp.	0.10	16.67
<i>Cricosphaera calvata</i> Steinmetz	0.12	25.00
<i>Discosphaera tubifer</i> (Murray & Blackman) Ostenfeld	0.12	29.17
<i>Emiliania huxleyi</i> (Lohmann) Hay & Mohler	54.82	100.00
<i>Florisphaera profunda</i> Okada & Honjo	11.13	100.00
<i>Gephyrocapsa ericsonii</i> McIntyre & Bé	0.67	64.58
<i>Gephyrocapsa oceanica</i> Kamptner	23.98	100.00
<i>Gephyrocapsa</i> spp.	0.02	6.25
<i>Hayaster perplexus</i> (Bramlette & Riedel) Bukry	0.10	27.08
<i>Helicosphaera carteri</i> (Wallich) Kamptner	0.32	93.75
<i>Helicosphaera hyalina</i> Gaarder	0.26	29.17
<i>Neosphaera coccolithomorpha</i> Lecal-Schlauder	0.21	47.92
<i>Oolithotus fragilis</i> (Lohmann) Okada & McIntyre	0.41	77.08
<i>Pontosphaera japonica</i> (Takayama) Nishida	0.01	4.17
<i>Rhabdosphaera claviger</i> Murray & Blackman	0.38	64.58
<i>Syracosphaera lamina</i> Lecal-Schlauder	0.14	27.08
<i>Syracosphaera pulchra</i> Lohmann	0.84	91.67
<i>Syracosphaera</i> spp.	0.76	81.25
<i>Umbellosphaera irregularis</i> Paasche	0.50	64.58
<i>Umbellosphaera tenuis</i> (Kamptner) Paasche	0.43	87.50
<i>Umbilicosphaera hulburtiana</i> Gaarder	0.09	20.83
<i>Umbilicosphaera sibogae</i> (Weber-van Bosse) Gaarder	2.86	89.58
<i>Thoracosphaera heimii</i> (Lohmann) Kamptner	0.12	33.33
<i>Thoracosphaera tuberosa</i> Kamptner	0.01	2.08

Table 3. Average relative abundancies and frequencies of nannofossils.

Species	North Pacific Roth & Colbourn, 1982				East China Sea Wang & Cheng, 1985	South China Sea	
	Equat- orial	Central	Trans- itional	Sub arctic		This study	
<i>C. pelagicus</i>		0.1	4.9	57.8			
<i>G. caribbeanica</i>	3.3	2.7	42.8	21.3			
<i>C. leptoporus</i>	6.8	2.9	12.9	6.0	0.2	0.9	0.8*
<i>F. profunda</i>							11.1*
<i>E. huxleyi</i>	24.9	42.6	30.0	10.8	57.1	62.1	54.8*
<i>U. sibogae</i>	12.9	3.6	1.9		1.3	3.2	2.9*
<i>H. carteri</i>	3.6	3.0	1.0		0.2	0.4	0.3*
<i>G. oceanica</i>	38.9	28.7	3.2	3.0	36.5	26.6	24.0*
<i>O. fragilis</i>	1.2	0.6			0.1	0.5	0.4*
<i>U. tenuis</i>		1.9			2.6	0.5	0.4*
<i>U. irregularis</i>	2.2	1.5	0.1	0.1		0.6	0.5*

Table 4. Comparison of nannofossil assemblages in surface sediments of the South China Sea, the East China Sea (after Wang & Cheng, 1985) with those of the North Pacific (after Roth & Colbourn, 1982) (figures given in percent, *nannofossils counted with *Florisphaera profunda*)

