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The distribution of Recent Radiolaria in surficial sediments of the continental margin off northern Namibia

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ABSTRACT—47 Species of radiolaria have been identified from 30 surface sediment samples collected along transects across the continental margin of northern Namibia between the Kunene River and Walvis Bay. From the distribution patterns of the 24 most abundant species, it was possible to identify a warm water, high salinity population and a cold water, low salinity population. The distribution patterns of each population shows a close correspondence with the known positions of the Angola Current (warm, high salinity water) and the Benguela Current (cold, low salinity water) respectively. Two other trends are apparent from the overall radiolaria distribution; dilution of the nearshore samples by terrigeneous input and a strong preference for open ocean conditions. There is no apparent correlation with upwelling.

REGIONAL SETTING

The continental margin of Namibia is a region of strong oceanic upwelling (Hart & Currie, 1960; Bremner, 1981 and others) and it is situated off an extremely arid coastline from which there is low terrigeneous input (Bremner, 1976). The northern margin of Namibia has been subdivided by Bremner (1981) into the Kunene Margin in the north and the Walvis Margin in the south separated by a transitional zone, the Walvis Ridge Abutment which lies between 18° 40′ S and 19° 30′ S.

The shelf on the Kunene Margin is narrow (24 n. miles), steep (0.31°) and shallow (shelf break depth 196 m) and is dominated by terrigeneous sediments. The Walvis Margin shelf is wider (100 n. miles) has a lower shelf gradient (0.16°) is deeper (outer shelf break 361 m) and has predominently biogenic sediments, Bremner (1981 b). Bremner (1981) gives the following figures for the mean percentage concentration of calcium carbonate, opal and organic matter respectively, for the Kunene Margin: 8.3%; 0.6%; 3.2% and for the Walvis Margin: 35.5%; 17.7%; 7.1%.

The surface water masses over the continental margin essentially comprise two contrasting ocean current systems. The northward flowing Benguela Current (an eastern boundary current) has been described by Stander (1964), Moroshkin *et al.*, (1970), Hart & Currie (1960), Bremner (1981) and others, as a slow moving (max. velocity 25 cm/sec.), cool (12–14°C), low salinity (34.9–35.1°/oo) and relatively well oxygenated and nutrient rich water mass. The main body of the Benguela Current moves offshore at the latitude of Walvis Bay (23° S) and it is actually three offshoots of the current that traverse the northern continental margin of Namibia, (Moroshkin *et al.*, 1970).

Entering the margin from the north is the warm water (16–18° C), high salinity (35.3°/oo), oxygen poor (3 ml/1) Angola Current. This current reaches a maximum velocity of more than 70cms/sec. off Angola although on the Kunene Margin its flow rate is reduced to 5–8 cms/sec. The maximum southward penetration of the Angola Current is to 23° S (Moroshkin *et al.*, 1970; Bremner pers. comm.).

METHODS

The samples were collected during joint University of Cape Town/Geological Survey Marine Geoscience Unit cruises on the R.V. Thomas B. Davie. A modified van Veen grab was used in shallow waters and a short gravity corer in deeper water.

The sample sites were chosen to cover the width of the continental margin from close inshore to the upper slope. Six transects of five sites each lie between the mouth of the Kunene river in the north (17° 20′ S) and a position (22° 15′ S) midway between Cape Cross and Walvis Bay in the south. The position and depth of the sample stations are listed in Table 1 and are shown in Fig. 1.

The samples were prepared and the radiolaria counted using the method developed by Goll & Bjorklund (1974). Species identification was carried out by scanning electron microscope and the taxonomy used was that of Nigrini & Moore (1979) in the first instance and Haeckel (1887) where the species is not listed by Nigrini & Moore.

RESULTS

Where radiolaria were present in the samples they were well preserved with little sign of dissolution.

Barren samples contained no recognisable radiolaria fragments suggesting that selective post mortem dissolution had not occurred.

The radiolaria distribution pattern on the northern continental margin of Namibia reveals a distinctly higher abundance where open ocean conditions prevail. Seaward of the shelf break the mean concentration of radiolaria is 40,339 specimens/gm of dry sediment (calcium carbonate free) with a range from 4,572 to 153,670; samples from the shelf break to the coast have a mean radiolaria concentration of 607 with a range from 0 to 2435.

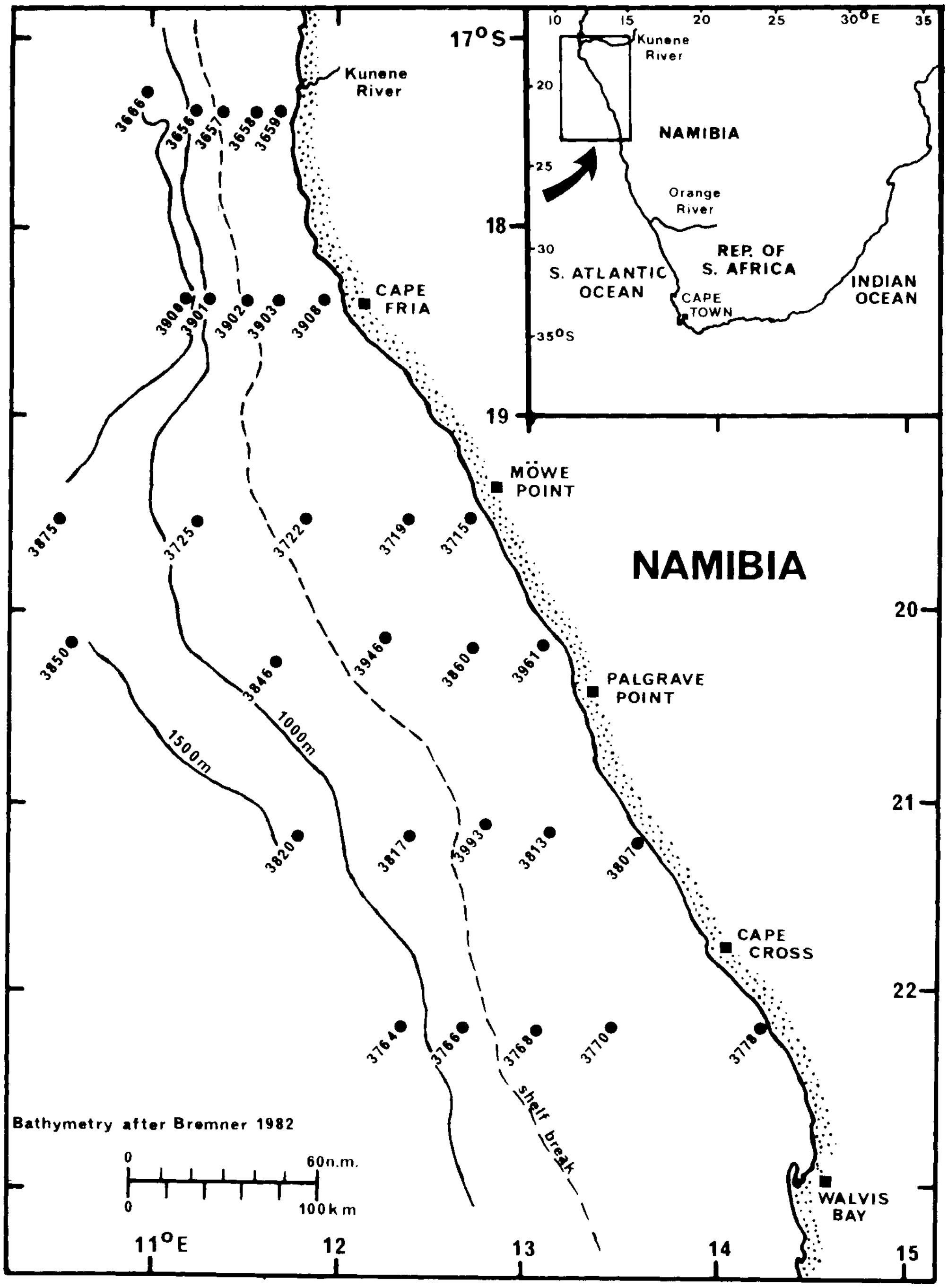


Fig. 1. Regional setting indicating the position of sample points, shelf break (dashed line), 1000 m and 1500 m isobaths (solid lines).

Table 1.

Sample No.	Position	Depth (m)	Sample No.	Position	Depth (m)
3778	22° 15′/14° 18′	20	3715	19° 34′/12° 41°	88
3770	22° 15′/13° 27′	169	3719	19° 34′/12° 23′	140
3768	22° 15′/13° 03′	280	3722	19° 34′/11° 48′	340
3766	22° 16′/12° 41′	698	3725	19° 33′/11° 14′	802
3764	22° 15′/12° 20′	1462	3875	19° 34′/10° 30′	1328
3807	21° 15′/13° 57′	29	3908	18° 24′/11° 52′	98
3813	21° 15′/13° 07′	139	3903	18° 24′/11° 39′	250
3993	21° 07′/12° 50′	320	3902	18° 23′/11° 30′	249
3817	21° 15′/12° 24′	683	3901	18° 23′/11° 20′	620
3820	21° 16′/11° 48′	1502	3900	18° 23′/11° 10°	1520
3961	20° 15′/13° 02′	90	3659	17° 24′/11° 38′	91
3860	20° 16′/12° 42′	130	3658	17° 24′/11° 34′	138
3946	20° 07′/12° 12′	283	3657	17° 24′/11° 24′	325
3846	20° 35′/11° 52′	810	3656	17° 24′/11° 52′	810
3850	20° 15′/10° 34′	1433	3666	17° 16′/11° 04′	1450

The taxonomy of the radiolaria identified in the samples is given in Table 2, the percentage of the total fauna (all 47 taxa observed) represented by a species and the number of samples in which it is found are shown in parenthesis after each entry. Where the percentage presence of the species is less than 1% it is indicated by an asterisk (*). The species frequency in individual samples is listed in Table 3.

Species diversity patterns (using all 47 species identified) show high values where intermixing of the two current systems takes place indicating that contrasting radiolaria populations are being brought together. These areas of intermixing and the consequent high species diversity (more than 11 species/100 specimens) are found in two regions. In the south centred around sample 3768 and in the two northernmost transects where samples 3666, 3657, 3901, 3902 and 3908 have species diversity values in excess of 20 species/100 specimens.

Five radiolaria species common on the Namibian continental margin have been recorded as abundant in the Peru and Chile current systems by Molina-Cruz (1977). The summed distribution patterns of these five species (*T. octacantha*, *A. stauraxonium*, *L. maritalis*, *S. validispina* and *C. davisiana*) show some correlation with the position of the offshore components of the Benguela Current, underlining the similarities of temperature and salinity of the Benguela, Peru and Chile Currents.

The zones of upwelling described by Hart & Currie (1960) show no correlation with radiolaria abundance, similarly there is no correlation with the position of the diatomaceous mud belts or the distribution of organic matter in the surficial sediments described by Bremner (1981).

CONCLUSIONS

The low radiolaria abundance on the shelf is not due to dilution in high porosity sand dominated sediments (there is no correlation between radiolaria lows and high concentrations of sand sized sediments). Neither is there evidence to show that it is due to the mechanical destruction of the radiolaria skeletons by their interaction with medium to coarse grained sediments. Polychete worms are abundant on the shelf but an examination of their feacal pellets revealed no recognisable traces of radiolaria skeletons eliminating their activities as a possible cause for the low abundances on the shelf.

Fine grain sediments are brought onto the shelf by the Kunene River in the north and by windblown material from the arid coastline. It is thought that the low concentration of radiolaria in the shelf samples is due partly to their dilution by these terrigeneous sediments especially on the Kunene Margin, whilst on the Walvis Margin the dilution is mostly caused by the high concentrations of diatoms and carbonate microfossils. The most important factor in radiolaria distribution in this area seems to be their predilection for open ocean conditions.

Comparisons between the plotted distributions of the 24 most numerous species and the current systems active on the continental margin of Namibia frequently show excellent correlations with their known temperature and salinity preference (taken from the literature). In this way it is possible to characterise the Angola and Benguela Currents by the species composition of their radiolaria assemblages as found in the surficial sediments (Fig. 2). Samples dominated by warm water species lay beneath the Angola Current and cold water species dominated the sediments beneath the Benguela Current.

Eight radiolaria species predominate in the sediments beneath the Angola Current and can therefore be associated with warm, high salinity, oxygen poor water. These are *Ommatartus tetrathalamus*, *Spongocore puella*, *Hexacontium enthacanthum*, *Carpocanarium papillosum*, *Axoprunum stauraxonium*, *Eucyrtidium hexagonatum*, *Cenosphaera* spp. and *Phormospyris stabilis scaphipes*. This population is best typified by the distribution pattern of *Ommatartus tetrathalamus* and is given that title in Fig. 2. These species are illustrated on Plate 1.

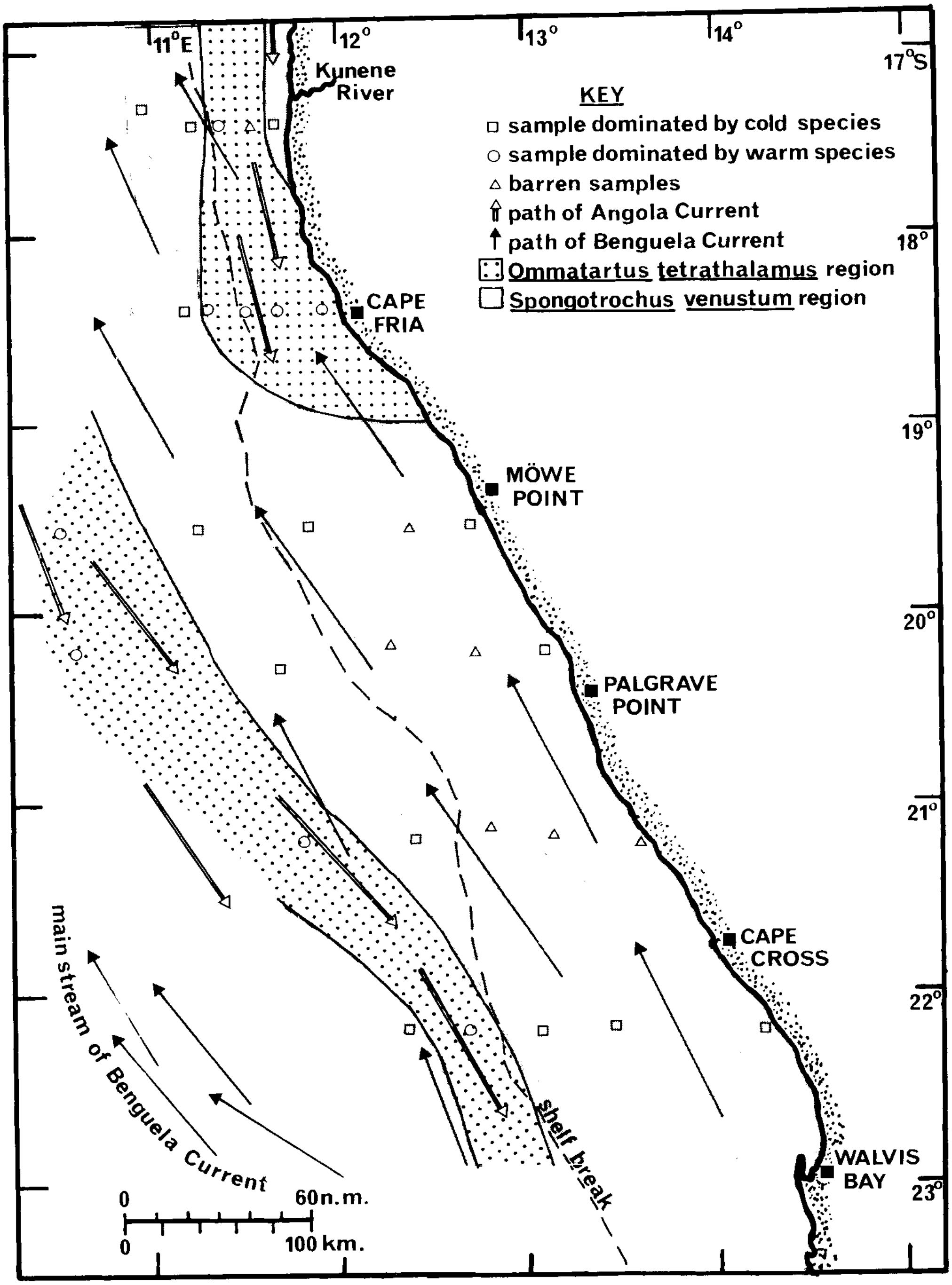
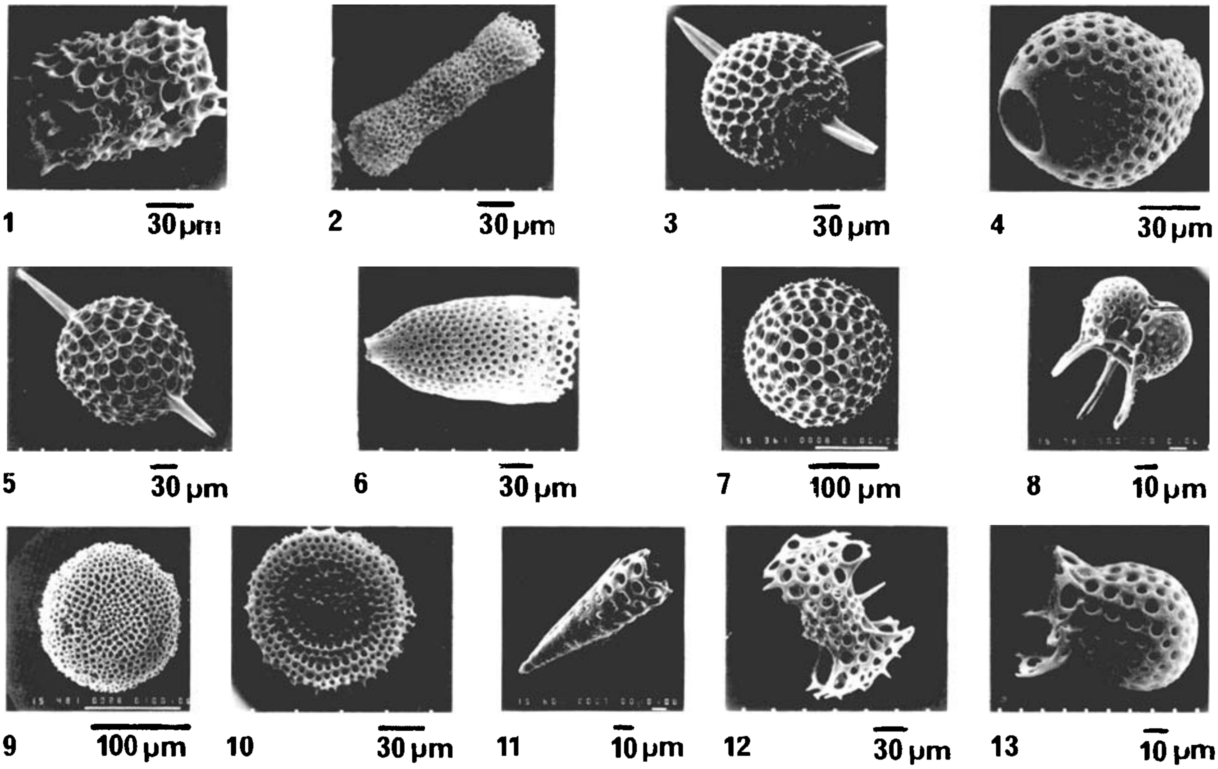


Fig. 2. Correspondence between the position of the Angola and Benguela Currents and the radiolaria assemblages found in the surficial sediments.



Explanation of Plate 1

Figs. 1–8. The Angola Current, "*Ommatartus tetrathalamus* population".
Fig. 1. *Ommatartus tetrathalamus* (Haeckel), sample 3875, 1460 m.
Fig. 2. *Spongocore puella* (Haeckel), sample 3901, 1120 m.
Fig. 3. *Hexacontium enthacanthum* Jorgensen, sample 3766, 698 m.
Fig. 4. *Carpocanarium papillosum* (Ehrenberg), sample 3900. 1506 m.
Fig. 5. *Axoprunum stauraxonium* Haeckel, sample 3817, 683 m.
Fig. 6. *Eucyrtidium hexagonatum* Haeckel, sample 3850, 1433 m.
Fig. 7. *Cenosphaera* spp., sample 3875, 1460 m.
Fig. 8. *Phormospyris stabilis* (Goll) *stabilus* (Haeckel), sample 3766, 698 m.

Figs. 9–13. The Benguela Current, "*Spongotrochus venustum* population".
Fig. 9. *Spongotrochus venustum* (Bailey), sample 3722, 300 m.
Fig. 10. *Stylodictya validispina* Jorgensen, sample 3722, 300 m.
Fig. 11. *Cornutella profunda* Ehrenberg, sample 3722, 300 m.
Fig. 12. *Tetrapyle octacantha* Muller, sample 3900, 1506 m.
Fig. 13. *Lithomelissa setosa* Jorgensen, sample 3900, 1506 m.

Five radiolaria species preferentially occupy the Benguela Current and are therefore associated with cool, low salinity, oxygen rich water. These five species are *Spongotrochus venustum*, *Stylodictya validispina*, *Cornutella profunda*, *Tetrapyle octacantha* and *Lithomelissa setosa*. *Spongotrochus venustum* best defines this population and it is so identified in Fig. 2. The thirteen species characterising these two populations are illustrated in Plate 1.

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Table 2. Taxonomy of identified radiolaria.

Subclass Radiolaria Muller
Order Polycystina Ehrenberg, 1838, emend. Riedel, 1967
Suborder Spumellaria Ehrenberg, 1875
Family Actinommidae Haeckel, 1862
emend. Riedel, 1967
Cenosphaera spp. [6%, 19]
Ommatartus tetrathalamus (Haeckel) [4%, 20]
Actinomma haysi Bjorklund [7%, 20]
Actinomma Leptodermum (Jorgensen) [*, 5]
Actinomma antarcticum (Haeckel) [*, 1]
Anomalocantha dentata (Mast) [*, 8]
Axoprunum stauraxonium Haeckel [1%, 11]
Hexacontium enthacanthum Jorgensen [4%, 15]

Family Sponguridae (Haeckel, 1862)
emend. Petrushevskaya, 1975
Spongocore puella (Haeckel) [1%, 13]

Family Phacodiscidae Haeckel, 1881
Heliodiscus astericus Haeckel [2%, 4]

Family Spongidiscidae Haeckel, 1862
emend. Riedel, 1967
Spongotrochus venustum (Bailey) [7%, 19]
Stylodictya validispina Jorgensen [5%, 14]
Hymeniastrum euclides Haeckel [6%, 22]

Family Cubosphaeridae Haeckel, 1881
Hexacontida pachyderma Jorgensen [*, 4]

Family Pyloniidae Haeckel, 1881
Tetrapyle octacantha Muller [4%, 20]

Family Litheliidae Haeckel, 1862
Lithelius minor Jorgensen [6%, 17]

Family Astrosphaeridae Haeckel, 1881
Rhizoplegma boreala (Cleve) [*, 2]

Family Larcoidea Haeckel, 1883
?*Larnacalpis lentellipsis* Haeckel [*, 3]

Suborder Nassellaria Ehrenberg, 1875
Family Phaenocalpidae Haeckel, 1887
Litharachnium tentorium Haeckel [*, 2]

Family Tricyrtidae Haeckel, 1881
Corocalyptra elisabetha Haeckel [*, 14]

Family Trissocyclidae (Haeckel, 1881)
emend. Goll, 1968
Phormospyris stabilis (Goll) *stabilus* (Haeckel) [*, 11]
Phormospyris stabilis (Goll) *antarctica* (Haeckel) [*, 8]
Phormospyris stabilis (Goll) *scaphipes* (Haeckel) [*, 11]
Lophospyris pentagona pentagona (Ehrenberg) [*, 4]
Giraffospyris angulata (Haeckel) [*, 8]

Family Carpocaniidae (Haeckel, 1881)
emend. Riedel, 1967
Carpocanarium papillosum (Ehrenberg) [2%, 18]

Family Theoperidae Haeckel, 1881
emend. Riedel, 1967
Cycladophora davisiana (Ehrenberg) [5%, 17]
Dictyophimus hirundo (Haeckel) [*, 7]
Eucyrtidium hexagonatum Haeckel [*, 11]
Peripyramis circumtexta Haeckel [*, , 7]
Pterocanium praetextum praetextum (Ehrenberg) [*, 2]
Pterocanium trilobum (Haeckel) [1%, 16]
Pterocanium longispinum Jorgensen [4%, 17]

Family Pterocoryidae Haeckel, 1881
emend. Riedel, 1967
Androcyclas gymphonycha (Jorgensen) [*, 5]
Anthocyrtidium ophirense (Ehrenberg) [*, 4]
Anthocyrtidium zanguebaricum (Ehrenberg) [*, 6]
Theocorythium trachelium (Ehrenberg) [*, 2]
Lamprocyclas maritalis Haeckel *polypora* Nigrini [3%, 16]
Lamprocyrtis (?) *hannai* (Campbell & Clark) [*, 9]
Pterocorys hertwigi (Haeckel) [*, 2]
Pterocorys minythorax (Nigrini) [*, 5]

Family Cyrtocalpidae Haeckel, 1881
Cornutella profunda Ehrenberg [1%, 14]

Family Artostrobiidae Riedel, 1967
emend. Foreman, 1973
Botryostrobus auritas/australis (Ehrenberg) [13%, 21]
Siphocampe lineata (Ehrenberg) [*, 6]

Family Dicyrtidae Haeckel, 1862
Lithomelissa thoracite Haeckel [2%, 10]
Lithomelissa setosa Jorgensen [5%, 17]

Species. Sample numbers :	3659	3657	3656	3666	3908	3903	3902	3901	3900	3715	3722	3725	3875	3961	3846	3850	3817	3820	3778	3770	3768	3766	3764
Ommatartus tetrathalamus	7	R	R		22	13	6	3	R	3	R	R	R		3	4	2	R		19	R	4	3
Actinomma haysi	R	13	8	R	3	6	5	3	9	4	5	5		11	11	8	6			8	9	11	17
Actinomma leptodermum	2			R		R																	4
Anomalocantha dentata									R	R	R	R	R				2	R				R	
Axoprunum stauraxonium		R	R	R				R			R	R	R			R	R	2					3
Hexacontium enthacanthum	R		4	R				8	2		R	4	6			10	4	5		8	8	11	4
Actinomma antarcticum								R															
Spongocore puella	R		R	R				R	R		R	R	R			2	R	3				3	R
Heliodiscus astericus												2	5										
Spongotrochus venustum	8	4	6	10	5			7	5	R	9	5	3		18	10	8	10		4	9	8	5
Stylodictya validispina			5	4	5						10	3	2		3	6	8	2		22	19	6	12
Hymeniastrum euclides	10	11	7	6	11	5	9	9	4	13	13	3	5	R	7	7	6	4		18	10	5	R
Hexacontida pachyderma									3		R	5			11								
Tetrapyle octacantha	7	R	R	7		12	12	3	8	7	4	R	R	7	4	4	3			7	5	4	9
Lithelius minor	10	11	R	15	5	12	24	12	10	3	8	5			11	9	5	8					8
Unknown Spumellarian		5	R					3			R	R	R					2			R		
?Larnacalpsis lentellipsis	3							2	5														
Rhizoplegma boreala								R	3														
Litharachnium tentorium													R										R
Corocalyptra elisabetha		R	R			R	3	R	R	R	R	R	R			R	R			R		2	
Phormospyris stabilis stabilus	R	R	R				6	2	R	R	R	R	R					R					
Phormospyris stabilis antarctica		R	R	R					R		R		R				R				R		
Giraffospyris angulata		R		R	3			R	R	3		R	2										
Phormospyris stabilis scaphipes	R		R	R	10	3	3	R	R	3		R	2										R
Lophospyris pentagona pentagona	R			R					R								R						
Carpocanarium papillosum	R	R			5	4		R	3	R	R	2	R	4	3	5	3	3		R	R	2	2
Cycladophora davisiana	8	5	4	2	5	3	4	6	18	2	R	4	7			4	3	6					3
Dictyophimus hirundo		R		2				R				R	R			R		R					
Eucyrtidium hexagonatum			3			R	3	R	R		R	R	R			R	R					R	
Peripyramis circumtexta			R					R	R							R		R				R	R
Pterocanium praetextum praetextum					3												R						
Pterocanium trilobum	R		R			R	3		R	R	2	R	R			R	4	R		6	3	2	2
Pterocanium longispinum	6		2		14			5	3	16	R	4	4	24		R	3	R	33		R	3	2
Androcyclas gymphonycha	R		R								R	R	R										
Anthocyrtidium ophirense		11				R						R						R					
Anthocyrtidium zanquebarica			R			R					R		2					R					R
Lamprocyclas maritalis polypora			3		3	6	3	3	R		4	R	R		7	4	3	3			R	4	3
Pterocorys hertwigi												R				R							
Pterocorys minythorax				R							R	R					R	R					
Theocorythium trachelium	R							2															
Lamprocyrtis hannai		5	R		3			R	R								R			3	5	R	
Botryostrobus auritas/australis	9	11	15	15	5	10	9	12	8	4	19	18	17		18	8	18	10		R	14	15	9
Siphocampe lineata		R	2	2				R	R			R											
Lithomelissa thoracite			5	6	3						R	5	10	3			R	R				R	
Lithomelissa setosa	20	R	12	4		R		R	11	25	R	3	3	64			R		67		R	R	R
Cornutella profunda	R		R	4		R		R	R		R	R	4			R	R	R			R	R	
Cenosphaera spp.	R	9	3	7		16	12	3	2	2	3	2	6	R		10	3	14			6	8	11
Number of radiolaria in sample:	123	57	315	81	38	171	34	129	282	118	323	394	338	33	28	335	350	366	60	72	77	183	202

Table 3. Percentage of each species per sample. (R = rare i.e. less than 2%).

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