# RADIOLARIA FROM NEILL ISLAND, ANDAMAN SEA, AND THEIR DISTRIBUTIONAL CHARACTERISTICS

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#### ABSTRACT

This study reports 104 species of radiolaria from a Late Miocene to Early Pliocene sequence at Neill Island, Andaman Sea. The radiolarian assemblage, which belongs to the *Didymocyrtis penultima* Zone and *Stichocorys peregrina* Zone, also contains reworked species from older Miocene sediments.

A comparison of the fossil assemblage, with the modern radiolarian assemblage from the Indian Ocean, shows that the former is dominated by species belonging to the present day Tropical Assemblage of this region. The assemblage also contains a few species which mainly characterise the cold-water regions of modern oceans. Their relative increase in the *S. peregrina* Zone seems to be related to upwelling in this region during the deposition of sediments belonging to this Zone.

## INTRODUCTION

Neill Island, in the Andaman Sea, contains one of the deepest marine Neogene sedimentary facies in the Andaman-Nicobar region. As a result, the rocks are very rich in radiolaria in addition to other microfossils.

Studies of Cenozoic radiolaria from the Andaman-Nicobar region are very scanty and are mainly in the form of preliminary reports (Jacob and Srivastava, 1952; Jacob, 1954; Singh and Vimal, 1973; Jafri, 1986). The only work in some detail is by Srinivasan et al. (1983), who studied both radiolaria and foraminifera from the Early Miocene sediments of Colebrook Island, Andaman Sea, for the purpose of biostratigraphic zonation.

The Neogene planktonic foraminiferal biostratigraphy of Andaman-nicobar Islands is well established through the extensive work of Srinivasan and his co-workers. Srinivasan (1978) also proposed chronostratigraphic divisions of the Neogene sequences of these islands. The present status of biostratigraphy and chronostratigraphy can be found in Srinivasan (1988).

A detailed stratigraphy of Neill Island was presented by Srinivasan and Azmi (1976) and the same is adopted here (Table 1). They classified the lithologic sequences of this island into the Sawai Bay Formation and Neill West Coast Formation. The Sawai Bay Formation, represented by massive mudstone, is exposed in the eastern (at East Coast Section) and northeastern (at Nipple Hill Section) parts. The Neill West Coast Formation, consisting of siltstone overlain by limestone, occurs as discontinuous cliffs along

the coast, in the Western part. The mudstones (of the Sawai Bay Formation) are very rich in radiolaria. Between the two sections, exposing the Sawai Bay Formation, the sequence at East Coast Section is

Table 1. Stratigraphic succession at Neill Island (after Srinivasan and Azmi, 1976).

GROUP	FORMATION/ MEMBER	LITHOLOGY	AGE
		Shell limestone, coral rags and beach sand	Recent to Subrecent
	Unconformity		
i	Neill Limestone Member  Disconformity	Moderately hard, yellowish, medium grained, thinly- bedded limestone	Pleistocene
ARCHI- PELAGO GROUP	Disconformity		
	Neill Silty Mud- stone Member	Soft, greenish- grey, calcare- ous, silty mudstone	Late Pliocene
•	Hiatus (?)		
	Sawai Bay Formation	Soft, light-grey, massive, cal- careous mud- stone with occasional silty bands	Early Pliocene to Late Miocene

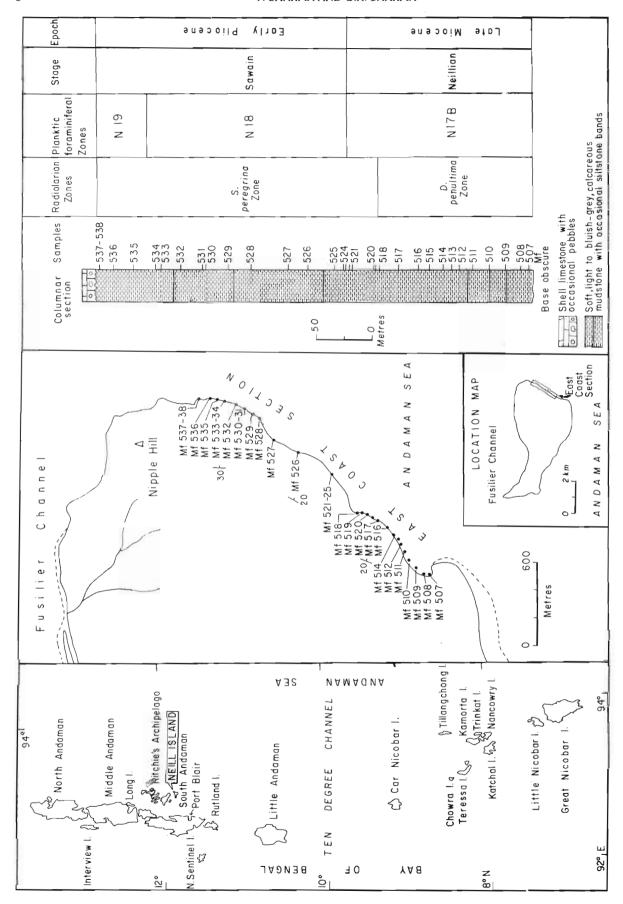


Fig. 1. Location of Neill Island, sample locations at East Coast Section, and stratigraphic position of samples. Foraminiferal zonal scheme is after Blow (1969; emended Srinivasan and Kennett, 1981a, 1981b). Stage names are after Srinivasan (1978, 1984).

better developed. The present study deals with the radiolaria from this section.

Planktonic foraminifera of East Coast Section were studied by Srinivasan and Azmi (1976) and the same samples are used in the present study. In the sequence at this section, Srinivasan and Azmi (1976) identified three planktonic foraminiferal zones, which, based on the work of Srinivasan and Kennett (1981 a,b) were slightly modified. The (modified) zones, in ascending order, are, *Pulleniatina primalis* Zone, *Globorotalia tumida tumida* Zone and *Sphaeroidinella dehiscens* Zone. (See Srinivasan, 1988), and the sequence, in part or whole, is equivalent to zones N17 B to N 19 of Blow (1969, emended Srinivasan and Kennett, 1981a, b) (Table 2).

Table 2. Radiolarian and planktonic foraminiferal biostratigraphic zones identified at East Coast Section. The planktonic foraminiferal zones are after Srinivasan and Azmi (1976; modified Srinivasan, 1984) and Blow (1969; emended Srinivasan and Kennett, 1981a, 1981b).

Rodiolarian Zones	Planktonic foraminiteral	Zones
	Sphaerodinella dehiscens Zone	N 19
Slichocorys peragrinn Zone	Gioborotalio tumida tumida Zone	N 18
Didymocyflis penullima Zone	Pullenratina primalis Zone	N 17

## METHODS OF STUDY

Thirty-two samples were analysed for the study. Samples were first soaked in  $H_2O_2$  and washed over a 63  $\mu m$  sieve. They were then treated for a brief period (15-20 seconds) in an ultrasonic bath to remove clay from inside the radiolarian tests and washed again. To dissolve calcareous material, washed samples were soaked in dilute HC1 solution, washed again and dried.

A fraction of the washed residue was used for the preparation of slides using canada balsam as the mounting medium. For each sample, 4-8 slides were prepared.

Distribution of radiolarian species was recorded according to their relative abundances. Slides of each sample, except those of samples Mf 507 to Mf 509,

contain 8,000 to 12,000 specimens of radiolaria. The distribution of radiolaria is recorded according to the following scheme: extremely rare (+, 1 or 2 specimens on the slides of a sample), rare (R, 3-50 specimens), few (F, 50-1000 specimens), common (C, 1000-5000 specimens), abundant (A, above 5000 specimens) and absent (-). Preservation of assemblage in a particular sample was observed according to the preservation of individual specimens. All the samples show good preservation of radiolarian species and this has been denoted by the letter 'G' in the distribution chart (Table 3). Stratigraphically important species like Didymocyrtis tetrathalamus, Spongaster pentas and S. tetras were especially searched for, but were found absent. However, their occurrences (as absent) are shown in the distribution chart. Classification is mainly based on the works of Nigrini and Moore (1979), Nigrini and Lombari (1984) and Bjørklund and Goll (1979).

## DISTRIBUTION OF RADIOLARIA IN THE SEQUENCE

In the assemblage, a numer of species are found to show consistent presence throughout the sequence (Table 4). However, none of the species is repres-

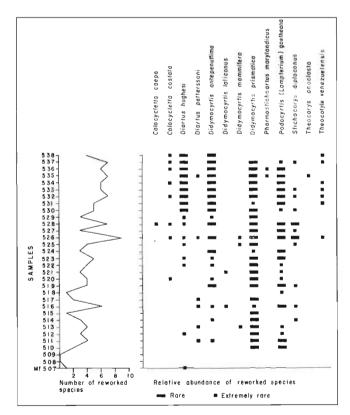


Fig. 2. Graph showing number of reworked species in each sample and visual estimate of their relative abundance.

ented by 'common' (C) or 'abundant' (A) specimens in a total of 104 species recorded from the studied material.

The assemblage is referable to the zonal scheme proposed by Riedel and Sanfilippo (1978) for the low latitude regions. Two zones, viz., *Didymocyrtis penultima* Zone and *Stichocorys peregrina* Zone have been recognised. Details of these zones are being described elsewhere.

The assemblage shows presence of some reworked species. The reworking has resulted in bringing radiolarian species from older sediments into the present assemblage, especially from the older Miocene sediments. A few forms viz., Podocyrtis (Lampterium) goetheana (Haeckel), Theocorys anaclasta Riedel and Sanfilippo and Theocotyle venezuelensis Riedel and Sanfilippo are from as old as Eocene sediments. These species occur extremely rarely. Towards the upper part of the sequence, particularly sample Mf 524 upwards, relative abundance and number of reworked species increase (Fig. 2). Species like Diartus hughesi (Campbell and Clark), Didymocyrtis antepenultima (Riedel and Sanfilippo) and Stichocorys delmontensis Campbell and Clark, persistently occur in larger number in the Stichocorys peregrina Zone. The last occurrences of these species are in the Late Miocene in the DSDP cores of low latitude areas of Pacific and Indian Oceans. The first two are restricted in their stratigraphic range within the Late Miocene, while S. delmontensis ranges from Early to Late Miocene (Sanfilippo et al., 1985), and all the three became extinct before the deposition of the sediments of the Stichocorys peregrina Zone. As such, their presence in large numbers in the younger sediments of the sequence indicates a pronounced reworking of radiolaria from the Early to Late Miocene sediments during the deposition of Early Pliocene sediments belonging to S. peregrina Zone. This part of the sequence is also characterized by a larger concentration of sponge spicules.

## NATURE OF THE RADIOLARIAN ASSEMBLAGE

In the past few years, sufficient data have been gathered on the distribution of modern radiolaria in the Indian Ocean to permit a meaningful comparison of the radiolarian assemblages from Neill Island with modern assemblages, particularly from the northern Indian Ocean.

# MODERN ASSEMBLAGE IN THE INDIAN OCEAN

In the Indian Ocean, modern radiolaria from the surface sediments have been studied by Nigrini (1967), Petrushevskaya (1967, 1971), Lozano and

Hays (1976), Dow (1978) and Johnson and Nigrini (1980, 1082).

The most comprehensive work on the nature of radiolarian assemblages, in the Indian Ocean, is by Johnson and Nigrini (1980–1982). They used quantitative techniques to identify various assemblages. Their study (Johnson and Nigrini, 1982) of the radiolaria from the surface sediments of the eastern Indian Ocean, between latitudes 10°N and 50°S, is of great value in interpreting the composition of the Neill Island assemblages.

Johnson and Nigrini (1980) subjected radiolarian species from the western Indian Ocean to recurrent group analysis. Later, while analyzing the radiolaria from the eastern Indian Ocean by the same methods, they (1982) modified the recurrent groups of western Indian Ocean assemblage and identified six groups (A' to F') for both eastern and western Indian Ocean. All those samples which showed the presence of recurrent groups were then determined. Based on the presence and/or absence of one or more recurrent groups in a sample, they recognized nine radiolarian assemblages in the Indian Ocean.

# FOSSIL RADIOLARIA: A COMPARISON

In the radiolarian assemblage from Neill Island, a number of species occur extremely rarely. Others (76 in number) are represented by 'rare' (R) species that show nearly consistent occurrences with abundance 'F' in any one of the samples. These are here referred to as the 'dominant species' (Table 3). Ten of the 'dominant' species occur with abundance 'F' in at least 30% samples.

Table 3. List of dominant radiolarian species

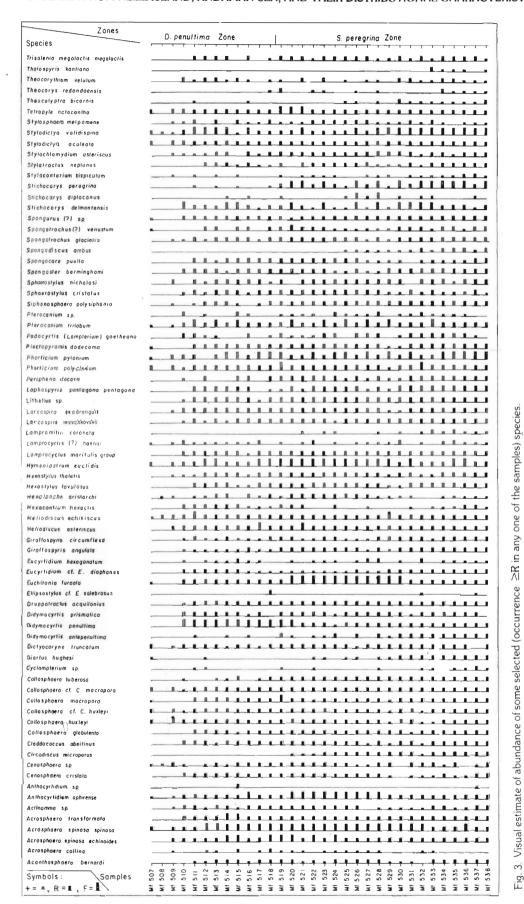
Category I: Species with abundance 'F' in at least 30% samples
Acrosphaera spinosa spinosa (Haeckel)
Anthocyrtidium ophirense (Ehrenberg)
Didymocyrtis penultima (Riedel)
Euchitonia furcata Ehrenberg

Hymeniastrum euclidis
Haeckel
Phorticium pylonium Haeckel
Pterocanium trilobum
(Haeckel)
Stylodictya validispina
Jorgensen
Stichocorys delmontensis
Campbell and Clark
Stichocorys peregrina (Riedel)

Category II: Species with abundance 'F' in less than 30% samples
Acrosphaera spinosa echinoides (Haeckel)
Acrosphaera transformata
Hilmers
Collosphaera huxleyi
Müller
Collosphaera macropora
Popofsky
Heliodiscus asteriscus
Haeckel
Heliodiscus echiniscus Haeckel
Phorticium polycladum

Tetrapyle octacantha Müller

Tan and Chang



of the samples) species one any 2 some selected (occurrence Visual estimate of abundance of ω.

W

The present assemblage when compared with the assemblage of Johnson and Nigrini (1982) from the . Indian Ocean shows that all the dominant species except Collosphaera huxlevi belong to Recurrent Group A' (Tropical latitudes). The species Collosphaera huxleyi, however, belongs to Recurrent Group C' (Subtropical latitudes). Other wellrepresented species belonging to Recurrent Group A' in the assemblage from Neill Island are Dictyocoryne truncatum (Ehrenberg), Larcospira quadrangula Haeckel, Siphonosphaera polysiphonia Haeckel and Collosphaera tuberosa Haeckel. Dominance and the consistent presence of species of Group 'A', and poorer representation of species of other recurrent groups in the sequence, shows that the radiolarian assemblage of Neill Island is dominated by the species of the Tropical Assemblage as defined by Johnson and Nigrini (1982).

A number of species occurring in the material are found to have a wide latitudinal range in modern oceans. Species like Spongotrochus glacialis Popofsky, Stylodictya validispina Jorgensen, Phorticium pylonium Haeckel, Theocalyptra bicornis (Popofsky) and Lampromitra coronata Haeckel prefer cold-water areas, though they are also found in warmer regions (Petrushevskaya, 1971; Casey, 1971; Sachs, 1973; Lozano, 1974; Robertson, 1975; Morley, 1977; Keany, 1979). Increase in the relative numbers of some of these species (Table 4) in the S. peregrina Zone is possibly indicative of upwelling in this region during the period from Latest Miocene to Early Pliocene.

Table 4A. Distribution of radiolarian species in the samples. Details of symbols are given in the text. Reworked species are marked with asterisks.

		Demyltima	Denultima   S16	Moseme Early Pilocene	Radiolarian Zones Srichocorys Perestina Zone	538 537 536 535 534 531 532 532 528 527 526 525 525 524 523 522 522 523 522 521 520 531 532 532 532 532 533 533 533 534 534 535 534 535 536 537 536 537 537 538 538 538 538 538 538 538 538 538 538	A A A A A A A A A A A A A A A A A A A	oonnoonnoonnoonnoonnoonnoonnoonnoonnoo	Busharabaraberaberandi		20 + + + + + + + + + + + + + + + + + + +	A. murrayana	A. Spinosa echinoides	изитичичичичичичичи A.spinosa spinosa	P. CERRETAR S S S S S S S S S S S S S S S S S S S	Actinomma sp.	N N T T T T T T T T T T T T T T T T T T	+ 1 1	A. sp.	*Calocycletta caepa		. + + · · · · · · · · · · · · · · · · ·	R R R R R R R R + + + + + A + + R R Cenosphaera cristata	'dn'3 R + - R + R R R - R R + + R R R R R R R	Ceratocyreis histricosa	Ceratospyris sp.	Circodiscus microporus	REBERRETHE	Clathrocanium diadema	BEBERRER BEBERRER Slebulents	C. huxleyi	BEBBBBBBHBBHBBBBBB C. cf. C. huxleyi	HANDA PERMANANTER BEBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB	
3 Zone   S15   A G   R - R - F F F + R - R R R R - + R R R	Zone 515 A G R - R - F F F + R - R R R R - + R R R R 514 A G R F F F R R R R R - R	Zone	Zone	100		51.7	A	G		-	R +	ě	R	F	R		R	-	-		-	-			-	-	-	R			R	B.	R	
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Table 4B. Distribution of radiolarian species in the samples. Details of symbols are given in the text. Reworked species are marked with asterisks.

Aga	Radiolarian Zones	Sample	Abundance	Preservation Species	C. cuberosa	Cyclampterlum sp.	*Diarrus hughesi	*o. percerssoni	Dictyocoryne truncatum	*Didymocyrtis antepenultima	D. avita	*D, laticonus	D. mammifera	D. penultina	D. prismatica	Druppatractus acquilonius	Ellipsostylus of. E.salebrosus	Euchitonia furcata	Sucyrtidium acuminatum	E. cf. E. diaphanes	E. hexagonatum	Ciraffospyris angulata	G, circumflexa	Heliodiscus asteriscus	H, schiniscus	Hexacontium hexactis	Hexalonche aristarchi	Hexastylus favulosus	H. chaletis	Symenlastrum, euclidis	Lamprocyclas maritalis grams
		538	A	G	R		R		R	R	+		-	H	-	R	-	R		R	4	R	R	R	R	+	+	R	R	R	R
		537	A.	G	R	R	R	-	-	R	+	-	-	R	R	R	+	R	-	R	+	R	R	R	R	R	+	R	R	R	R
		536	Α	G	R	+	R	-	R	3	-	-	-	R	R	R	-	R	-	R	+	R	R	R	R	R		R	R	F	R
1		535	A	G	R		R	+	R	*	+	-	-	R	R	R	-	R		R	+	R	R	R	R	+	+	-R	R	F	R
		534	A	G	技	-	R		R	R	ł-	-		R	R	R		R	-	R	+	R	R	R	R	+	+	R	R	R	R
- 11		533	A	C	R		R	-	R	R	+	-	-	R	R	R	*	R		R	-	t	+	R	R	+	-	R	+	R	R
		532	A	G	R		R	-	R	R		-	-	R	R	R	+	R	-	R	R	R	R	R	8	-	-	8		R	R
		530	A	G	R	-	R	-	B	R	+	-	-	R	*	R	-	R	~	R		R	R	R	R	+	*	K	R	ř	R
4		529	A	G	R		*		K	K	-	•	-	K	R.	R	-	8	-	R	*	R	R	R	R		+	+	R	R	R
Early Pliocene		528	A	G	R	î	I		D		-			R		R	-	F		K		-	R	R		-	*	1	*	F	R
10	Stichocorys	527	A	G	R			÷	9						0						D	14		R.	P.		T D	n.	D.		N.
De l	peregrina	526	A	G	R		+	+	+	R		Ċ			2	P		6	0	0		9	1	p.	2	*					0
17	Zone	525	A	C	R	2	+		R		_		+	R	8	R		P		-		B		0	9		0	0		-	R
100		524	A	G	R	-			R	R				+	+	R		F		+		2	R	R	2			2	2		8
		523	A	C	R		+		R	+		-		R	R	R		F		+	+	8	R	R	R		18	2	R	9	R
		522	A	G	R	+	٠	-	R	+	-	-		R	R	R		F		+	+	R	+	R	R		R	R	R	F	R
		521	A	G	R	-	-		H			+		R	R	R		F		+		R	+	F	R	R	R	R	R	F	R
		520	A	G	R	-	-		H	+	-	-		2	R	R	-	F		+	+	R	R	R	R	R	R	R	R	F	R
		519	A	G	R	+	-	-	8	R	-	-		F	R	R	-	R	-	+	-	R	R	R	R	R	+	R	R	F	R
60	Didymocyrits	518	A	G	R	-	-	-	R	-	-	-	-	F	-	R	R	R		+		+	R	R	R	+	R	R	R	F	R
9	perulting	517	A	G	+	-	-	+	41	-	-	-	-	F	R	R	-	R	-	+	+	+	+	F	R	+	+	R	R	F	R
-	Zona	51.6	Α	G	1	-	-	+	R	+	-	+		F	+	3	-	R	-	+	+	R	+	R	75	+	R	*	+	R	+
Late Mocene	cored :	515	A	G	R	-	-	-	8	-	-	-	-	F	R	R	-	R	-	R	R	+	+	R	R	R	-	+	R	R	R
		513	A	G	+	-	-	-	+	٠	-	-	-	F	R	R	-	R	-	R	f	+	R	R	R	R	R	R	R	R	R
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Table 4C. Distribution of radiolarian species in the samples. Details of symbols are given in the text. Reworked species are marked with asterisks.

Аде	%adiolarian Zones	Samples	Abundance	Preservation Species	Lamprocyrtis (?) bancai	Lampromitte coronata	Lampronitors sp.	Larcospira moschiovikii.	L. quardrangula	Liriospyris reciculata	Lithelius Sp.	Lophophama sp.	Laphospyris pentagona pentagona	Lychnodictym audax	Pertiphene decora	* Promostichoratus mary landicus	Prorrictum polycladum	P. pylonium	Plectopyramis dodecona	* Podocyrcis(Lampcorium)goedhama	Prerogenium trilobum	Pterocanius ci. P. trilopus	Р. ир.	Serhophornun sp.	Siphonosphaera polysiphonia	Siphostichartus corocu	Spinagrostylus cristanus	S. ntcholasi	Spongaster bermingham
		538	A	G:		+	+0	R	R		R	-	8.	+	R	-	R	F	R	-	R		-	+	R	-	+.	R	K
		537	A	G	.0	+	-0	2	14	-	R	-	R		A		3	F	R	4	R			+	R	-	2	2	18
		536.	A	C	+	+	+	R	24		3	-	R	-	R	+	Ľ	F	R	R	R		+	+	R	+	R	R	R
		535	A	0	R	2	+	R	8	-	8	-	R	-	R	+	R	F	2	R	R	-	+	+	R				2
		534	A	G	+	+	+	7.	R	-	R	-	R	+	R	-	R	F	R	R	R		+	+	R		+	2	R
		533	A	G	54	R	-	R	R	-	R	+	R	+	Ř	+	R	8	R	R	F	-	+	+	R.	-	R	R	R
		512	A	G.	+	+	+	2	R	-	2	*	R	+	R	-	F	R	R	R	R	-	R		R	*		R	H.
		531	A	G	-	-	+	R	R	-	R	-	R	-	R		R	F	R	8	R		+		R	-	R		R
2		53C	A	0	R	+	-	8	+	-	R		R		+		R	R	+	+	R	-	+	-	R	-	+	R	R
20		529	A	G.	. +	-		R		•	3	-	+		+	**	+	2	+	-	F	-	м	-	R	-	+	17	R
=	Stichocotys	328	A	G	+	+	-	2	R	-	R		R	*	R	-	R	R	R	R	R		R	+	R		8	R	+
Early Plincene	peregrina	527	A	G.	+	-	-	R	R		R	-	+		+	-	R	F	8	R	F	-	+	-	R	-	R	R	+
1	Zone	526	A	0:	+			R	R	-	3	-	3	•	2	•	R	R	3	R	R		+	+	R	-	R	2	R
12		525	A	G	-	-		8	R	-	8	-	R		3	-	R	F	8.	-	9		+	+	R	-	R	8	+
*		524	A	G:	+	+	-	*	R	-	3	-	R		2	-	R	F	R	R	R	-	R	+	R	-	R	R	+
		523	A	G		+		R	R	*	8	-	R		8	-	R	R	R	R	F	-			R	-	R	R	R
		322	A	C	2			R	H	-	R	-	R		R		R	F	R	+	R	-	+	-	R	-	R	R	7.
		521/	A	G	+	+	-	R	K	+	R	-	+	*	R		R	R	3	+	R	*			8	-	R	R	R.
		520	A	G.	-	-		R	3	•	K		R		R	-	R	R	8	+	F	-	$\bar{\tau}$	-	R		R		3
		519	A	G		-	-	R	R	-	R	-	+		2	-	F.	F	3	R	R	+	+		R	-	R	R	A.
2		513	A	G	-	-	-	R	3	-	8		+	-	8	-	R	F	8		8	*	-	*	R		R	*	R
Late Missens	Didymocyrtis	517	1	G	K		-	2	R	-	+	-	-	-	-	-	8	F	3	-	R		-	-	+	-	A	3	H
==	penultima	516	A	G.		-	-	R	R	-	3	-	R		8	-	K	R	R	3	R	0	+	+	-		+	8	8
12.0	Zone	515	A	G:	*	-	-	R	R		R	-	R	-	8	-	8	E	4		E	3	8		+	4	R	8	34
7		514	A	G	*		-	+	K	-	K	-	R			-	8	F	4		×	4	-	-	R		N.	R	+
		513	A	G	+		-	A.	R	-	3		18			-	R	R	3		F	-	-		K	-	R.	R	A
		312	A	9	+	-	-		R	-	3	3	16		R	-	4	-	4		14	-	+		K	-	*	*	· ·
		311	A	G			7	K	K	-	4	+	×		-	-	at.	K	1		F	-	-		R		×	R.	-34
		510	A	G	16	-	-	*	K		+	-	•	-		-	+	×		1	K	-	R	-	-	-		-	it
			C	G			-	-	-	-	-	-	-	-	-	-	35	IC.	-		+	-	-		+	•		X	-
		508	R	C	-	-	-		-	-	-		-		-	-		-	-		-	-		-	-	-		-	-
		Mf 507	F	Q:		-	-	-			-		-		-	-	R	. *	+		+				-	-	*	-	-

Table 4D. Distribution of radiolarian species in the samples. Details of symbols are given in the text. Reworked species are marked with asterisks.

\de	Rodio Lariaa Zonesi	Samples	Abundance	Preservation Species	Spongoore puells	Spongodiscus aubus	Spongocrochus glacialis	S. (?) venuetum	Spongurus (?) sp.	Sciencorys delboncensis	S. diplocerus	S. peregrina	Stylacontarium bispiculum	Stylatractus neptunus	Stylochlundlim asteriscus	Stylodictys aculeata	S. validispina	Stylosphaera melponene	Tecrapyle occasions	Theocalyptra bicorrula	T, devisions devisions	* Theocorys anaclasta	T. redoublensis	Theocorychism veculus	Theocotyle venezuelensis	Tholospyris kantlana	T. memadllaris	Trisolenta megalaccia megalaccia	Sygnetreus products capulasus	2. products cricurinatus
		538	A	G	R	R	R	R	R	R	0	F	+	R	R	R	F	+	R	R	*	-	+	+	+	+	6-	+	+	+
	8	537	A	G	R	+	R	R	R	+	+	R	R	R	R	R	F	+	R	+	-	-	+	+	+		+	R	+	+
		536	A	G	+	R	R	+	R	R	-	F	8	R	R	R	F	+	R	+	+	-	+	+	-	+	-	R	+	+
		535	A	G	+	R	R	R	R	8	-	F	+	R	+	R	F		R	+	*		+	R	-	+	-	2	+	+
		5.14	Α	G	+	R	R	R	R	R		P	+	R	R	R	F	+	R	+	+	•	R	R	+	+	-	R	+	+
		533	A	G	+	+	R	+	R	F	+	F	+	R	R	R	F	R	٩	+	-	-	-	+	+	R	-	R	+	÷
		532	A	G		R	R	R	R	F	+	F	+	+	+	R	F	+	9	٠	+	-	-	5	+	-	+	٠	+	٠
		531	A	G	-	+	R	R	R	F	-	R	2	R	R	R	P	R	R	+	+	-	-	8.	+	-	+	R	-	-
9		530	A	G	+	+	R	R	R	F	+	P		+	R	R	F	+	R	R	-	-	+	7	•	-	-	9	-	+
		529	A	G	+	+	+	*	R	+	-	+	+	+	R	R	F	+	Ŗ	-	-	-	-	-	*	-	-	٠	-	-
	St Lehneneys	528	A	G	+	*	R	+	R	F	R	۶	+	+	R	R	F	+	R	+	-	-	+	+	•		-	+	•	-
	peregrina	527	A	G	+	+	*	+	R	+	+	R	+	R	R	R	R	R	3	-	-	-	-	+	-	-	•	3	-	-
1	Time	526	A	G	R	*	R	*	R	F	R	F		R	R	R	F	K	Я	٠	-		+	-	+	-	•	R	-	-
		525	A	G	R	+	R	*	R	+	+	+		R	R	8	R	R	А	*	-	-	-	4-	•	-	-	R	*	-
		524	A	G	R		R	+	R	+	-	R	+	R	R	R	R	R	3	•	-	-	-			•	-	R	•	•
		523	A	G	1	*	R	R	R	F		F	+	R	R	R	R	R	4	•	-	-	+	K	•	-		3		-
		522	A	G	R		R	R	R	+	-	R	*	R	R	R	R	R	3	-	-	-	+		-	-	-	*		-
		521	A	C	1	-	R	R	R	R	-	F		R	R	R	F	+	R	-	-	-	•	R	•	-	•	8	-	-
		520	A	G	R	R	R	F	+	F	-	1			8	R	K	+	F	•		-			•	•	•	ĸ	•	-
		519	A	G	R		R	R	R	R	+	R	+	R	R	R	R	*	1	-	-	•	7.	*	-	-			-	•
4	200 200	513	A	G	R		R	R	R	R	-	+		*	R	R	R	R	8	-	-	-	*	٠	-	-		+	-	-
3	Didymocyrtis	517	A	G	R		*		2	*			-	+	+	K	R		R.	-	-	-	-		-			- D	-	-
2	nenultima	51.6	A	G	R	-	15	×	R	R				R.	K	K			1	٠	-	-	•	,	•			3	1	-
3	Zone	515	A	G	R		R	15	R	1		•	*	-		N.	-	K	Χ.	-	-	-	-	,	-	•	•		-	-
Late Hancolle		514	A	G	R		K		N D		+			-	K	N.	E.	9	κ,		-	-		,			-	2	-	-
		513	Λ	G	2		16	K	K	K	-	+	*		K	2	E.	N.		-	-	-	•	a.		-	-	,	-	-
		512	A	G	R	-	*	K	K	K	-	-	-	8.	+	×	2	0	×		1		-	K	-			ì	-	-
		510	A		1		IK.	-	K	K	-	+			+	71	0	1	7,	-	-	-		9	-		-			-
			A C	G	1			-	*	1			+		-	N	K		rs D	-	-		-			-			-	-
		509	3	G G			*	-	9	-	-				*	*	-		К		-		-				-			-
										-		-					n		R	•		-	•		Ċ	Ċ			•	·
		Mf 507	7	10			-		+	-		-	-	-		14	R	-	100	-		-	-		70	-		-	-	-

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## **REFERENCES**

- BJORKLUND, K.R. & GOLL, R.M., 1979. Internal skeletal structures of *Collosphaera* and *Trisolenia*: A case of repetitive evolution in the Collosphaeridae (Radiolaria). *Jour. Paleont.* **53**(6): 1293-1326.
- BLOW, W.H., 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: P. Bronnimann and H. Renz (Editors). Proc. First Int. Conf. Planktonic Microfossils, Geneva (1967). E.J. Brill, Leiden. 199-421.
- CASEY, R.E., 1971. Radiolarians as indicators of past and present water-masses. In: B.M. Funnell and W.R. Riedel (Editors). The Micropaleont. of Oceans. Cambridge Univ. Press, Cambridge, 331-341.
- DOW, R.L., 1978. Radiolarian distribution and the Late Pleistocene history of the southern Indian Ocean. Mar. Micropal. 3: 203-227.
- JACOB, K., 1954. The occurrence of radiolarian cherts in association with ultra-mafic instrusives in the Andaman Islands, and its significance in sedimentary tectonics. *Records Geol. Surv. India.* 83(2): 397-422.

- JACOB, K., & SRIVASTAVA, R.N., 1952. Fossil radiolaria and silicoflagellata from the Tertiary clays of Colebrook Island and the Ritchie's Archipelago, Andaman Island. Sci. and Cult. 17(8): 346-348.
- JAFRI, S.H., 1986. Occurrence of Hagiastrids in chert associated with Port Blair Series, South Andaman, India. Jour. Geol. Soc. India. 28(1) 41-43.
- JOHNSON, D.A. & NIGRINI, C., 1980. Radiolarian biogeography in surface sediments of the western Indian Ocean. Mar. Micropal. 5: 111-152.
- JOHNSON, D.A. & NIGRINI, C., 1982. Radiolarian biogeography in surface sediments of the eastern Indian Ocean. Mar. Micropal. 7: 237-281.
- KEANY, J., 1979. Early Pliocene radiolarian taxonomy and biostratigraphy in the Antarctic region. Micropaleont. 25(1): 50-74.
- LOZANO, J.A., 1974. Antarctic sedimentary, faunal and sea surface temperature responses during the last 230,000 years with emphasis on comparison between 18,000 years ago and today. *Ph.D. dissertation, Columbia Univ., New York*, 400 p. (reference from Nigrini and Moore, 1979).
- LOZANO, J.A., & HAYS, J.D., 1976. Relationship of radiolarian assemblages to sediment types and physical oceanography in the Atlantic and western Indian Ocean sectors of the Antarctic Ocean. Geol. Soc. Am. Mem. 145: 303-336.
- MORLEY, J., 1977. Upper Pleistocene climatic variations in the South Atlantic derived from a quantitative radiolarian analysis: accent on the last 18,000 years. *Ph.D. dissertation, Columbia University, New York.* 282 p. (reference from Nigrini and Moore, 1979).
- NIGRINI, C. 1967. Radiolaria in pelagic sediments from the Indian and Atlantic Oceans. Bull. Scripps Inst. Oceanogr., Univ. California, La Jolla. 11: 1-125.
- NIGRINI, C. & LOMBARI, G., 1984. A guide to Miocene Radiolaria. Cush. Found. Foram. Res., Spec. Publ. 22: S1-S102; N1-N206.

- NIGRINI, C. & MOORE, T.C., JR. 1979. A guide to Modern Radiolaria. Cush. Found. Foram. Res., Spec. Publ. 16: S1-S142; N1-N106.
- PETRUSHEVSKAYA, M.G., 1967. Radiolarii Otryadov Spumellaria i Nassellaria Antarcticheskoi Oblasti (po materialam Sovetskoi Antarcticheskoi Ekspeditsii). Issledovanya fauny morei, t. IV (XII), Resultaty biologicheskikh issledovanity Sovets-koi Antarctich, Eksped. 1955-1958. 3: 5-186.
- PETRUSHEVSKAYA, M.G., 1967. Radiolaria in plankton and Recent sediments from the Indian Ocean and Antarctic. In: B.M. Funnell and W.R. Riedel (Editors). The Micropaleontology of Oceans. Cambridge Univ. Press, Cambridge. 319-329.
- RIEDEL, W.R. & SANFILIPPO, A., 1978. Stratigraphy and evolution of Tropical Cenozoic radiolarians. *Micropal.* **24**(1): 61-96.
- ROBERTSON, J., 1975. Glacial to interglacial oceanographic changes in the north-west Pacific, including a continuous record of the last 400,000 years. *Ph.D. dissertation, Columbia Univ., New York.* 355 p. (reference from Nigrini and Moore, 1979).
- SACHS, H.M., 1973. Quantitative radiolarian-based paleoceanography in Late Pleistocene subarctic Pacific sediments. Ph.D. dissertation, Brown Univ. Providence. 280 p. (reference from Nigrini and Moore, 1979).
- SANFILIPPO, A., WESTBERG-SMITH, M.J., & RIEDEL, W.R., 1985. Cenozoic Radiolaria. In: H.M. Bolli, J.B. Saunders and K. Perch-Nielsen (Editors). Plankton Stratigraphy. Cambridge University Press Cambridge, 631-712.
- SINGH, P. & VIMAL, K.P., 1973. A note on the geology and

- micropaleontology of Neill Island, South Andaman. Curr. Sci. 42(7): 239-241.
- SRINIVASAN, M.S., 1978. New Chronostratigraphic divisions of the Andaman-Nicobar Late Cenozoic. In: Recent Researches in Geology, HIndustan Publ. Corp., Delhi. 4: 22-36.
- SRINIVASAN, M.S., 1984. The Neogene of Andaman-Nicobar. In: N. Ikebe and R. Tsuchi (Editors). Contributions to Biostratigraphy and Chronology. University of Tokyo Press, Japan. 203-207.
- SRINIVASAN, M.S., 1988. Late Cenozoic sequences of Andaman-Nicobar Islands; their regional significance and correlation. Ind. Jour. Geol. 60(1): 11-34.
- SRINIVASAN, M.S. & AZMI, R.J., 1976. Contribution to the Stratigraphy of Neill Island, Ritchie's Archipelago, Andaman Sea. Proc. VI Indian Colloquium Micropaleont. and Strat. 283-301.
- SRINIVASAN, M.S. & KENNETT, J.P., 1981 a. A review of Neogene planktonic foraminiferal biostratigraphy: applications in the equatorial and South Pacific. In: J.E. Warme, R.G. Douglas and E.L. Winterer (Editors), The Deep Sea Drilling Project: A Decade of Progress. SEPM Spec. Publ. 32: 395-432.
- SRINIVASAN, M.S. & KENNETT, J.P., 1981 b. Neogene planktonic foraminiferal biostratigraphy: Equatorial to Subantarctic, South Pacific. Mar. Micropaleont. 6: 499-534.
- SRINIVASAN, M.S., LOMBARI, G. & DAVE, A., 1983. Early Miocene planktonic foraminiferal and radiolarian zonation, Colebrook Island, Andaman Sea. Jour. Geol. Soc. India. 24(1): 1-8.

## **EXPLANATION OF PLATES**

# PLATE I

- Acrosphaera spinosa spinosa (Haeckel)
   Sample no. Mf 510, X 220; focussed on perimeter.
- 2. Euchitonia furcata Ehrenberg Sample no. Mf 507, X 200
- Acrosphaera transformata Hilmers Sample no. Mf 524, X 285; focussed on perimeter
- Stichocorys delmontensis Campbell and Clark Sample no. Mf 511, X 370
- 5. Hymeniastrum euclidis Haeckel Sample no. Mf 532, X 170
- Stylodictya validispina Jörgensen Sample no. Mf 510, X 245
- Stichocorys peregrina (Riedel) Sample no. Mf 522, X 190
- Acrosphaera spinosa echinoides (Haeckel) Sample no. Mf 520, X 335
- Didymocyrtis penultima (Riedel)
   Sample no. Mf 510. X 345

# PLATE II

- Pterocanium trilobum (Haeckel) Sample no. Mf 510, X 230
- Tetrapyle octacantha Müller Sample no. Mf 538, X 420
- Spongaster berminghami (Campbell and Clark) Sample no. Mf 524, X 425
- Collosphaera huxleyi Müller Sample no. Mf 510, X 230

- Spongaster berminghami (Campbell and Clark) S. pentas Riedel and Sanfilippo, transitional form, Sample no. Mf 532, X 380
- Anthocyrtidium ophirense (Ehrenberg) Sample no. Mf 530, X 240
- Heliodiscus echiniscus Haeckel Sample no. Mf 507, X 225; focussed on perimeter
- Collosphaera macropora Popofsky Sample no. Mf 538, X 165
- Phorticium polycladum Tan and Chang Sample no. Mf 510, X 230

## PLATE III

- Phorticium pylonium Haeckel Sample no. Mf 510, X 460
- 2. Didymocyrtis antepenultima (Riedel and Sanfilippo) Sample no. Mf 528, X 305
- 3,4.Stichocorys delmontensis (Campbell and Clark) S. peregrina (Riedel), transitional form, Sample no. Mf 522; fig. 3, X 140, fig. 4, X 270
- 5. Heliodiscus asteriscus Haeckel Sample no. Mf 507, X 320
- Didymocyrtis avita (Riedel)
   Sample no. Mf 531, X 490, focussed on perimeter

