

25. RADIOLARIANS FROM THE SOUTHERN MEXICO ACTIVE MARGIN, DEEP SEA DRILLING PROJECT LEG 66¹

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ABSTRACT

Radiolarians occur at all Leg 66 drill sites and permit biostratigraphic zonation of most sediments. Sedimentary and ecologic effects that create dating problems are (1) dilution by terrigenous sediments in trench and lower slope environments, (2) dissolution and recrystallization of radiolarian tests, (3) loss of most or all of the nassellarian radiolarian fauna in early Pleistocene and late Pliocene sediments, and (4) mixing and loss of faunas due to East Pacific upwelling and transportation by eastern boundary currents. Some or all of these problems may affect dating of older accretionary zone sequences. Coarse-grained trench sediments are best dated by sampling overlying lower slope sequences where reworking and dilution effects are reduced.

INTRODUCTION

Radiolarians occur at all Leg 66 drill sites (Table 1) on the southern Mexico margin. Most abundant faunas occur in upper and middle slope sediments; abundances are much reduced in lower slope and trench sediments because of terrigenous dilution. Reworked radiolarians occur everywhere but are especially prevalent on the middle slope. Pelagic brown clay sediments of the northern Cocos Plate have a poorly preserved fauna, but radiolarian abundance increases in hemipelagic sediments near the Middle America Trench.

Lower Miocene sediments cored at Sites 489 and 493 were the oldest recovered and contain an abundant radiolarian fauna. Middle Miocene sediments were absent at these sites owing to erosion or nondeposition. Upper Miocene sediments recovered at Sites 487, 490, 492, and 493 generally had a fair to good radiolarian fauna. Pliocene sediments present at Sites 487, 490, 491, 492, and 493 generally have a somewhat poorer fauna with some dissolution evident. The Quaternary sediments recovered at all sites had an excellently preserved fauna, and upper Quaternary radiolarians were especially well preserved and abundant.

RADIOLARIAN ZONATION

Previous workers have established a precise radiolarian zonation for Tertiary sediments of the Pacific Ocean (Riedel and Sanfilippo, 1971; Dinkelman, 1973). Quaternary sediments have been zoned separately in high latitudes (Hays, 1970) and in the equatorial regions (Nigrini, 1971). In this report, no attempt is made to modify the existing zonations, because sediments of the southern Mexico margin have many reworked radiolarians and the nearshore environment has an incomplete fauna (Table 2).

Radiolarian occurrences are recorded in Tables 3 through 9 from observations made on strewn slides.

Table 1. Site locations, Leg 66.

Hole	Latitude	Longitude	Location	Water Depth (m)	Drilling Penetration (m)
486	15°55.37'N	99°08.10'W	trench	5142	38.0
468A	15°54.83'N	99°08.28'W	trench	5138	22.0
487	15°51.21'N	99°10.52'W	outer slope	4764	181.7
488	15°57.10'N	99°01.66'W	lower inner slope	4254	429.0
489	16°16.19'N	99°01.13'N	mid inner slope	1240	34.5
489A	16°16.19'N	99°01.13'W	mid inner slope	1240	298.5
490	16°09.56'N	99°03.34'W	mid inner slope	1761	588.5
491	16°01.74'N	98°58.33'W	mid inner slope	2883	542.0
492	16°04.73'N	98°56.72'W	mid inner slope	1935	279.0
492A	16°04.73'N	98°56.72'W	mid inner slope	1935	70.8
492B	16°04.73'N	98°56.72'W	mid inner slope	1952	290.0
493	16°22.86'N	98°55.53'W	upper inner slope	645	670.5
493A	16°22.86'N	98°55.53'W	upper inner slope	645	12.0
493B	16°22.86'N	98°55.53'W	upper inner slope	645	126.0

Abundances of taxonomically useful species are noted, based on the scheme devised by Riedel and Sanfilippo (1971), as "abundant" (A), "common" (C), "few" (F), "rare" (R), and "very rare" (+). Reworked individuals are marked by an asterisk (*). Intervals in which a species was searched for but not found are marked with a dash (—).

Quaternary radiolarians occur at all sites. The generally abundant fauna is diluted by coarse terrigenous sediments at trench Site 486. Early Quaternary radiolarians are generally well preserved and fairly abundant except where diluted by lower slope and trench sediments at Site 488 or where partially dissolved at Cocos Plate Site 487 and upper slope Site 493.


Pacific Quaternary radiolarian zonations of Nigrini (1971) and Hays (1970) cannot be applied to Leg 66 sediments because of the absence of many index species. Collosphaerids used in the later Quaternary tropical zonation of Nigrini are very rare to absent. Most index species for Hays's Quaternary zonation are likewise very rare to absent; only *Axoprunum angelinum* (= *Stylatractus universus*) is common enough to be a useful index fossil. Rather than mix recognizable zones, I have used only the extinction levels of *A. angelinum* at 0.40

¹ Initial Reports of the Deep Sea Drilling Project, Volume 66.

Table 2. Neogene radiolarian zonations.

Epoch/Series	Radiolarian Zone	
	Epoch/Series	Radiolarian Zone
0	L	Pleistocene
	E	
5	L	Pliocene
	E	
10	L	
	M	Miocene
15	E	
20		

L.O. <i>A. angelinum</i>	
L.O. <i>A. angulare</i>	
L.O. (<i>P. prismatium</i>)	
L.O. <i>S. peregrina</i>	
F.O. (<i>P. prismatium</i>)	
F.O. <i>S. peregrina</i>	
F.O. <i>O. penultimus</i>	
F.O. (<i>O. antepenultimus</i>)	
F.O. (<i>C. petterssoni</i>)	
F.O. (<i>D. alata</i>)	
F.O. <i>C. costata</i>	
F.O. <i>C. virginis</i>	

Note:  = No radiolarians preserved.
L.O. = last occurrence,
F.O. = first occurrence.

m.y. (Hays, 1970) and of *Anthocyrtidium angulare* at 1.15 m.y. (Berggren and van Couvering, 1974) as datum levels. The *Axoprunum angelinum* datum occurs between Sections 8,CC and 9-4 in Hole 487, between Sections 18,CC and 19,CC in Hole 488, within Core 1 in Hole 490, between Sections 1,CC and 2-1 in Hole 491, and between Sections 2,CC and 3-1 in Hole 492. *A. angelinum* is absent in upper Quaternary sediments at Site 493, even though radiolarians are preserved down-section past the Brunhes/Matuyama boundary of 0.7 m.y. The *Anthocyrtidium angulare* extinction level occurs only within Core 18 in Hole 490 and within Core 3 in Hole 491. Erosion at Sites 489 and 492 removed early Quaternary sediments that included this datum level. Nonpreservation of most early Quaternary radiolarians at Sites 487 and 493 precludes recognition of this datum.

Pliocene sediments have the most poorly preserved radiolarian fauna. Absence of *Pterocanium prismatium* makes the *P. prismatium* Zone difficult to impossible to recognize. On the other hand, the presence of the *Stichocorys peregrina* extinction allows recognition of the top of the *Spongaster pentas* Zone at Sites 490, 491, 492, and 493. The absence of *P. prismatium* complicates recognition of the top of the *Stichocorys peregrina* Zone (Table 1), but the evolution of *Spongaster pentas*, which occurs near this boundary in the East Pacific (Dinkelman, 1973), permits a reasonable extrapolation of the zone boundary at Sites 490, 492, and 493.

Upper Miocene sediments contain a well-preserved and abundant radiolarian fauna that often contrasts with poorly preserved to nearly barren assemblages in Pliocene sediments. The first occurrence of *Stichocorys peregrina* allows recognition of the top of the *Ommatartus penultimus* zone at Sites 492 and 493. The *O. penultimus* zone is inferred at Site 487 from the presence of *S. delmontensis* and the absence of *O. hughesi* (Riedel and Sanfilippo, 1971). The top of the *O. antepenultimus* Zone is recognized by the evolutionary appearance of *O. penultimus* at Sites 492 and 493; but at Site 487 this zone is recognized by the presence of *O. hughesi*, whose extinction level occurs near or at the top of the *O.*

Table 3. Radiolarians at Site 487.

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Stichocorys delmontensis</i>	<i>Ommatartus hughesi</i>	<i>Theocorythium vetulum</i>	<i>Ommatartus avitus</i>	<i>Axoprunum angelinum</i>	<i>Lithopora bacca</i>	<i>Amphirophalum ypsilon</i>	<i>Ommatartus tetrathalamus</i>	<i>Spongaster tetras</i>	<i>Collosphaera tuberosa</i>
	1,CC	A G											
	2-1, 48-50	A G											
	2-4, 33-35	A G											
	2,CC	C G											
	3,CC	A G											
	4,CC	C M											
	5-1, 30-32	R M											
	5-2, 36-38	A G											
	5,CC	C G											
	6,CC	A G											
	7-2, 37-40	A G											
	7,CC	R G											
	8-2, 124-126	F M											
	8,CC	R G											
	9-4, 100-103	C G											
	9,CC	F M											
	10-3, 80-83	R M											
	10,CC	R G											
	11-2, 50-52	C G											
	11,CC	R G											
	12-3	R G											
	12,CC	F G											
	13,CC												
	14-3, 99-101												
	14,CC	R M											
<i>Ommatartus penultimus</i>	15-3, 59-61	F G											
	15,CC												
	16-1, 93-95	F G											
	16-3, 94-96	R G											
	16,CC	F G											
<i>Ommatartus antepenultimus</i>	17-2, 40-42	F G											
	17,CC	R P											
	18-3, 56-58												
	18,CC	R P											
	19-3, 100-102	R P											
	19,CC												

antepenultimus Zone (Dinkelman, 1973; Riedel and Sanfilippo, 1971, 1978). The base of the *O. antepenultimus* Zone was not penetrated at Sites 487 and 492, and at Site 493 it occurs within an unconformity.

Middle Miocene sediments are absent from Leg 66 cores. At Sites 489 and 493, the middle Miocene is represented by an unconformity; at other sites there was insufficient penetration. Reworked middle Miocene radiolarians are very scarce or possibly even absent. No reworked radiolarians with ranges restricted to the middle Miocene have been found, and only a few middle to upper Miocene reworked forms occur such as *Cannaratus laticonus*, *C. petterssoni*, and *S. delmontensis*.

Lower Miocene sediments in Sites 489 and 493 contain abundant well-preserved radiolarians in the upper portion of the section. Recrystallization of radiolarians

Table 4. Radiolarians at Site 488.

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Spongaster pentas</i>	<i>Ommatartus hughesi</i>	<i>Ommatartus penulimus</i>	<i>Eucyrtidium matuyami</i>	<i>Axoprunum angelinum</i>	<i>Collosphaera tuberosa</i>	<i>Drupptractus acquiloni</i>	<i>Spongaster tetras</i>	<i>Amphirhopalum ypsilon</i>	<i>Ommatartus tetrathalamus</i>
	1,CC	C	G								F	F	
	2,CC	C	G									F	
	3,CC	C	G								R	C	
	4,CC	C	G								R	C	
	5,CC	A	G	*					+	F	R	C	
	6,CC	C	G								R	C	
	7,CC	C	G								R	R	F
	8,CC	C	G								R	R	C
	9,CC	C	G		*						F	F	
	10,CC	C	G								R	F	
	11,CC	C	G								R	R	F
	13,CC	C	G								+	F	F
	14,CC	F	G								+	R	R
	15,CC	F	G								+	R	R
	16,CC	C	G									R	
	17-1, 41-43			Barren									
	17,CC	F	G								+		
	18,CC	R	G	*								+	
	19,CC	C	G								R	R	R
	20,CC	C	G							+	R		
	21,CC	F	G								R		
	22,CC	C	G								F	+	+
	23-1, 114-116	F	G								+	+	R
	23,CC	F	G		*						+	+	
	24-1, 26-28	F	G								+		
	24,CC			Barren									
	25-1	F	M						+				
	25,CC			Barren									
	26,CC			Barren									
	27,CC			Barren									
	28,CC			Barren									
	29,CC			Barren									
	30,CC	C	G						R		F	F	
	31,CC	C	G						R		+	F	F
	32,CC	C	G						+		F	F	
	33,CC	C	G						R		R	F	
	34,CC	F	G									+	+
	35,CC	F	M										
	36,CC	R	M								+		
	37,CC	R	G						+				
	38,CC	R	M									+	
	39,CC			Barren									
	40,CC	R	P										
	41,CC	R	P						+				
	42-2, 70-72	R	M										
	43,CC	F	P						+				
	44,CC	R	P						+				
	45,CC	R	P										
	46,CC	R	P										

toward the Oligocene/Miocene boundary makes taxonomic identification impossible. The early Miocene *Calocycletta costata* and *C. virginis* zones are recognized at Site 489 by the evolutionary appearance of *C. costata* in Core 2 (Riedel and Sanfilippo, 1971). Only the *C. costata* Zone is recognized at Site 493 before

Table 5. Radiolarians at Site 489.

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Calocycletta virginis</i>	<i>Cannartus prismaticus</i>	<i>Lychnocanium bipes</i>	<i>Cyrtocapsella cornuta</i>	<i>Cannartus tubarius</i>	<i>Cannartus violina</i>	<i>Sichocorys delmontensis</i>	<i>Cannartus mamiferus</i>	<i>Calocycletta costata</i>	<i>Amphirhopalum ypsilon</i>	<i>Ommatartus tetrathalamus</i>
	Hole 489													
	1-1, 10-12	A	G	*										
<i>Calocycletta costata</i>	1,CC	A	G	A										
	2-3, 64-66	A	G	A										
<i>Calocycletta virginis</i>	2,CC	A	G	C				R	C					
	3,CC	C	G	C										
	4,CC	F	G	F										
	5,CC	A	G	C	+									
	Hole 489A													
	1-1, 10-12	A	G											
<i>Calocycletta costata</i>	1,CC	A	G	C										
	wash module			F										
	2-2, 88-90	R	M											
	2,CC	R	F	F										
	3,CC	R	G											
	4,CC			Barren										
	5,CC	F	P											
	6,CC			Barren										
	7,CC	F	M	F										
	8-3, 138-140	C	M	F										
<i>Calocycletta virginis</i>	8,CC	C	M	R										
	9,CC	C	G	F										
	10,CC	C	G	C	R	R		R						
	11,CC	F	M	R										
	12,CC	C	G	F										
	13,CC	C	G	R										
	14,CC	R	M	R										
	15,CC	C	G	F	+									
	16,CC	C	G	F										
	17,CC	C	G	F	+									
	18-2, 22-24	C	G	R	+	+								
	Core Catchers			Barren										
	18,CC through													
	31,CC													

radiolarian recrystallization precludes identification below Core 493-35. The *C. costata*/*C. virginis* boundary occurs within the NN4 Zone at Site 489, yet Berggren and van Couvering (1974) correlate this boundary with the NN3 Zone. Whether the data from calcareous nanoplankton or radiolarians are erroneous or the boundary is really different could not be determined.

DISCUSSION

Micropaleontological study of the Leg 66 active margin drill sites illustrates the potential problems and complexity in dating older accretionary zone sequences exposed in orogenic belts. Some of the problems complicating radiolarian biostratigraphic determinations are the following: (1) poor faunal preservation, (2) reworking of older microfossils, (3) an incomplete fauna lacking some critical index species, and (4) mixing of faunas due to oceanographic effects associated with the eastern boundary current.

Radiolarian preservation is good in upper Quaternary and Miocene sediments and poor in Pliocene and lower Quaternary intervals. Locally barren intervals

Table 6. Radiolarians at Site 490.

Radiolarian Zone	Sample (interval in cm)	Abundance	Preservation	<i>Calocyclus costata</i>	<i>Calocyclus virginis</i>	<i>Canartius violina</i>	<i>Cyrtocapsella japonica</i>	<i>Cyrtocapsella tetrapera</i>	<i>Ommatartus hughesi</i>	<i>Stichocorys delmontensis</i>	<i>Ommatartus antepenultimus</i>	<i>Ommatartus penultimus</i>	<i>Stichocorys peregrina</i>	<i>Spongaster pentas</i>	<i>Theocorythium vetulum</i>	<i>Anthocyrtidium angulare</i>	<i>Asophranum angulatum</i>	<i>Amphiropholium ypsilon</i>	<i>Ommatartus tetrahalmus</i>	<i>Spongaster tetras</i>
Pterocanium prismatium	1-1, 49-51	F	G				*			*						—	+	—		
	1-2, 49-51	C	G							*						—	+	—		
	1-3, 49-51	C	G							*						R	—	—		
	1-4, 49-51	C	G							*						F	F	C		
	1, CC	C	G							*						+	+	—		
	2-1, 78-80	C	G							*	*	*				C	+	R		
	2-3, 78-80	A	G							*	*	*				F	—	R		
	2-6, 78-80	C	G							*	*	*				+	+	+		
	2, CC	C	G							*	*	*				F	R	R		
	3-3, 90-92	C	G							*	*	*				C	—	—		
	3, CC	A	G							*	*	*				C	R	R		
	4, CC	F	G				*			*	*	*				+	—	—		
	5, CC	A	G							*	*	*				C	—	R	R	
	6, CC	F	G							*	*	*				+	—	—		
	7, CC	A	G							*	*	*				C	—	R	C	
	8, CC	C	G				*			*	*	*				R	—	R	F	
	9, CC	C	G							*	*	*				F	R	R	F	
	10, CC	C	G							*	*	*				R	—	F	—	
	11, CC	C	G							*	*	*				—	—	—	—	
	12, CC	A	G							*	*	*				F	R	F	F	
	13, CC	C	G							*	*	*				R	—	R	R	
	15, CC	C	G							*	*	*				F	F	R	F	
	16-3, 94-96	C	G							*	*	*				C	—	+	+	
	16, CC	C	G							*	*	*				F	—	+	+	
	17-4, 50-52	C	G							*	*	*				—	—	—	—	
Pterocanium prismatium	17, CC	C	G							*	*	*				F	—	+	F	
	18-1, 30-32	C	G							*	*	*				—	—	—	—	
	18-3, 30-32	R	G							*	*	*				—	—	—	—	
	18, CC	A	G							*	*	*				+	+	R	R	F
	19, CC	C	G							*	*	*				+	+	R	R	F
	20, CC	C	G							*	*	*				F	—	R	R	
	21, CC	C	G							*	*	*				R	+	—	R	
	22, CC	C	G							*	*	*				—	+	—	—	
	23-2, 34-36	A	G							*	*	*				R	—	+	R	
	23, CC	F	G							*	*	*				R	—	R		
	24-3, 56-58	R	G							*	*	*				+	—	—	—	
	24, CC	R	G							*	*	*				+	—	—	—	
	25, CC	C	G							*	*	*				R	+	+	F	
	26, CC	F	M							*	*	*				+	—	—	—	
	27, CC	F	M							*	*	*				+	—	—	—	
	28-3, 30-32	R	G							*	*	*				R	+	+	—	
	28, CC	F	M							*	*	*				+	—	—	—	
	29, CC	R	M							*	*	*				+	—	—	—	
	30-3, 30-32	R	M							*	*	*				+	—	—	—	
	30, CC	R	G							*	*	*				+	—	—	—	
Spongaster pentas	31-1, 84-86	R	G							*	*	*				+	—	—	—	
	31-2, 9-11	R	G							*	*	*				+	—	—	—	
	31, CC	F	G							*	*	*				+	—	—	—	
	32, CC	R	M							*	*	*				+	—	—	—	
	33, CC	R	M							*	*	*				+	—	—	—	
	34, CC	F	M							*	*	*				+	—	—	—	
	35, CC	F	M							*	*	*				+	—	—	—	
	36, CC	F	M							*	*	*				+	—	—	—	
	37, CC	R	G							*	*	*				+	—	—	—	
	38, CC	R	G							*	*	*				+	—	—	—	
	39, CC	F	G							*	*	*				+	—	—	—	
	40, CC	F	G							*	*	*				+	—	—	—	
	41, CC	F	M							*	*	*				+	—	—	—	
	42, CC	F	M							*	*	*				+	—	—	—	
	43, CC	F	M							*	*	*				+	—	—	—	
	44, CC	R	M							*	*	*				+	—	—	—	
	45, CC	R	M							*	*	*				+	—	—	—	
	46, CC	R	M							*	*	*				+	—	—	—	
	47, CC	R	M							*	*	*				+	—	—	—	
Stichocorys peregrina	48, CC	R	M							*	*	*				+	—	—	—	
	49, CC	R	M							*	*	*				+	—	—	—	
	50, CC	R	M							*	*	*				+	—	—	—	
	51, CC	R	M							*	*	*				+	—	—	—	
	52-1, 53-55	F	G							*	*	*				+	—	—	—	
	52, CC	R	M							*	*	*				+	—	—	—	
	53-1, 66-68	F	G							*	*	*				+	—	—	—	
	53, CC	F	M							*	*	*				+	—	—	—	
	54-3, 2-3	R	M							*	*	*				+	—	—	—	
	54, CC	R	M							*	*	*				+	—	—	—	
	55-3, 54-56	R	M							*	*	*				+	—	—	—	
	55, CC	R	M							*	*	*				+	—	—	—	
	56, CC	R	M							*	*	*				+	—	—	—	
	57, CC	R	M							*	*	*				+	—	—	—	
	58-4, 108-110	R	M							*	*	*				+	—	—	—	
	58, CC	R	M							*	*	*				+	—	—	—	
	59-3, 52-54	R	M							*	*	*				+	—	—	—	
	59, CC	R	M							*	*	*				+	—	—	—	
	60, CC	F	G							*	*	*				+	—	—	—	
	61-2, 2-3	R	G							*	*	*				+	—	—	—	
	61, CC	C	G							*	*	*				+	—	—	—	
Stichocorys peregrina	62-3, 32-34	C	G							*	*	*				R	—	—	—	
	62, CC	C	G							*	*	*				R	—	—	—	
	63, CC	C	G							*	*	*				R	—	—	—	
	64, CC	C	G							*	*	*				R	—	—	—	

Table 7. Radiolarians at Site 491.

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Calocyclus costata</i>	<i>Calocyclus virginis</i>	<i>Ommatartus antepenultimus</i>	<i>Cannarius laeiconus</i>	<i>Stichocorys delmontensis</i>	<i>Ommatartus hughesi</i>	<i>Ommatartus penultimus</i>	<i>Ommatartus avitus</i>	<i>Stichocorys peregrina</i>	<i>Spongaster pentas</i>	<i>Eucyrtidium matuyami</i>	<i>Theocorythium vetulum</i>	<i>Lamprocyclus heteroporos</i>	<i>Druppactractus acquilinus</i>	<i>Anthocyrtidium angulare</i>	<i>Asophranum angulatum</i>	<i>Amphirotopolum ypsilon</i>	<i>Ommatartus tetrahalmus</i>	<i>Spongaster tetras</i>	<i>Collosphaera tuberosa</i>
<i>Pterocanium prismatium</i>	1-3, 42-44	A	G						*	*									*	F	R	R	+
	1-7, 42-44	A	G						*	*									—	F	R	R	+
	1, CC	A	M						*	*									—	F	R	R	+
	2-1, 104-106	A	G						*	*									+	F	F	F	—
	2-2, 104-106	A	G						*	*									+	F	F	F	—
	2-3, 104-106	A	G						*	*									+	F	F	F	—
	2-4, 104-106	A	G						*	*									+	F	F	F	—
	2, CC	A	G						*	*									+	F	F	F	—
	3-1, 40-42	C	G					*	*										—	+	+	+	—
	3-3, 40-42	C	G					*	*										—	+	+	+	—
	3-5, 40-42	C	G					*	*										—	+	+	+	—
	3, CC	A	G					*	*										—	+	+	+	—
	4-2, 70-72	C	G					*	*										—	+	+	+	—
	4-3, 70-72	C	G					*	*										—	+	+	+	—
	4, CC	A	G					*	*										—	+	+	+	—
	5-2, 70-72	C	G					*	*										—	+	+	+	—
	5, CC	A	G					*	*										—	+	+	+	—
	6-3, 62-64	C	M					*	*										—	+	+	+	—
	6, CC	C	M					*	*										—	+	+	+	—
	7-3, 66-68	C	G					*	*										—	+	+	+	—
	7, CC	A	G					*	*										—	+	+	+	—
	8-3, 100-102	A	F	G						+	+								—	+	+	+	—
	8-6, 100-102	R	F	G						+	+								—	+	+	+	—
	8, CC	R	F	G	*					—	—								—	+	+	+	—
	9-1, 112-114	R	F	G				*											—	+	+	+	—
	9-3, 112-114	C	G	G						—	—	*	—		—				F	R		—	R
	9, CC	C	G	G						—	—	*	—		—				—	—		—	—
	10-3, 31-33	R	G	G						+	+	—	—		+				—	—		—	—
	10, CC	C	G	G	*					+	+	—	—		+				—	—		—	—
	11-3, 80-82	C	G	G						+	+	—	—		—				—	—		—	—
11, CC	F	G	G						+	+	+	—		—				—	—		—	—	
12, CC	F	G	G	*					+	+	+	—		—				—	—		—	—	
13-1, 140-142	C	G	G			*			+	+	—	—		—				—	—		—	—	
13, CC	R	G	G						+	+	—	—		—				—	—		—	—	
14-3, 30-32	C	G	G			*			R	+	—	—		+				—	—		—	—	
14, CC	F	G	G						—	—	—	—		—				+	—		—	—	
15-3, 30-52	C	G	G			*			—	—	—	—		—				—	—		—	—	
15, CC	F	G	G						+	—	—	—		—				—	—		—	—	
16, CC	F	G	G															—	—		—	—	
17, CC	F	G	G			*												—	—		—	—	
18, CC	R	M	M																				
19, CC	R	G	G																				
20-1, 61-63	R	G	G			*	*													+		+	
20, CC	R	G	G			*	*																
21, CC	F	M	M																	+			
22, CC	R	M	M																				
23, CC	R	M	M																	+			
24, CC	R	M	M																				
25-3, 50-52	R	M	M			*																	
25, CC	F	G	G									+											
26, CC	F	G	G						+											+			
27, CC	R	G	G																	+			
28, CC	R	M	M																	+			
29, CC	F	M	M																	+			
30, CC	F	M	M																	+		+	
32, CC	R	M	M																				
33, CC	R	M	M																				
34, CC	R	M	M																	+			
35-3, 90-92	R	M	M																				
35, CC	R	M	M																	+			
36, CC	R	M	M																				
37, CC	R	P	P																	+			
38, CC	R	P	P																	+			
39, CC	R	P	P																	+			
40-3, 80-84	R	M	M																	+			
40, CC	F	M	M								+									+		+	
41, CC	F	M	M			*														+		+	
42-1, 77-79	R	P	P	Barren																			
42-3, 77-79	R	P	P		*			*										+					
42, CC	F	M	M																				
43, CC	R	M	M																				
44, CC	R	M	M																				
45-3, 59-61	R	M	M																	+			
45, CC	F	M	M															+					
46, CC	F	M	M															+	F				
47, CC	R	M	M	Barren																+			
48, CC	R	M	M																				
49, CC	R	M	M																				
50-4, 62-64	R	M	M																				
50, CC	R	M	M																				
51, CC	R	M	M													+				+			
52, CC	R	M	M																				
53, CC	F	M	M	Barren																			
54, CC	R	P	P																				
55-1, 47-49	R	P	P																				
55-3, 47-49	R	M	M																				
55, CC	R	M	M																				
56-1, 45-47	F	M	M																	+			
56, CC	R	M	M																	+			
57, CC	R	M	M																				

Table 8. Radiolarians at Site 492.

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Cannartus tubarius</i>	<i>Cyrtocapsella tetrapera</i>	<i>Lithopera bacca</i>	<i>Eucyrtidium calvertense</i>	<i>Calocyclus costata</i>	<i>Calocyclus virginis</i>	<i>Cannartus petterssoni</i>	<i>Cannartus laticonus</i>	<i>Stichocorys delmontensis</i>	<i>Ommatartus hughesi</i>	<i>Ommatartus antepenultimus</i>	<i>Ommatartus avitus</i>	<i>Ommatartus penultimus</i>	<i>Stichocorys peregrina</i>	<i>Theocorythium vetulum</i>	<i>Spongaster pentas</i>	<i>Anthocyrtidium angulare</i>	<i>Axoprunum angelinum</i>	<i>Amphirhopalum ypsilon</i>	<i>Ommatartus tetrathalamus</i>	<i>Spongaster tetras</i>
	Hole 492																							
	1-1, 30-32	R	G																		—	+	+	+
	1-3, 30-32	R	G																		—	+	F	—
	1,CC	C	G																		—	R	F	—
	2-1, 40-42	C	G																	*	—	F	F	F
	2-2, 40-42	A	G																		—	—	F	F
	2-3, 40-42	C	G																		—	C	F	F
	2,CC	A	G																		—	C	F	F
	3-1, 60-62	C	M													—	—					F	—	—
	3-3, 60-62	R	G													—	—					—	—	—
3,CC	C	G													+	+		+	F	—	—	R		
<i>Spongaster pentas</i>	4-3, 45-47	R	G												—	—	+			—	+	—	—	
	4,CC	C	G												—	—	—			—	R	—	—	
	5-3, 70-72	C	G												R	—	+			—	+	—	—	
	5,CC	C	G												—	+	+				F	—	—	
	6-3, 60-62	C	G									*	*	R	+	+				+	+	+	+	
	6,CC	C	G						*						R				R	F	—	—	—	
	7-1, 60-62	R	G																—	R	—	—	—	
	7-2, 60-62	R	G												+	+	+			+				
	7,CC	F	G		*	+		*							+	+	+			—	+			
	8-1, 84-86	R	G												—	—	—			—	—			
<i>Stichocorys peregrina</i>	8-3, 84-86	R	G						*								+		—	F				
	8,CC	C	G						*								F	—		F				
	9-2, 84-86	C	G			+			*								C	—		F				
	9,CC	C	G						*		*			+			—	F		—				
	10-3, 84-86	C	G				*			*		*		+		+				F				
	10,CC	C	G																	R				
	11-3, 68-70	F	G							—										+				
	11-4, 68-70	F	G				*		*		*			+			+	R		—				
	11,CC	C	G		*				*											+				
	12-1, 70-72	R	G							—						+	+			R				
<i>Ommatartus penultimus</i>	12-3, 70-72	R	G						*		+		+			—				+				
	12,CC	F	G		*					R						—				R				
	13-3, 60-62	R	G														—			F				
	13,CC	C	G		*				*		R		+	F		F				F				
	14,CC	C	G											R		F				R				
	15,CC	C	G								C			F		—				R				
	16,CC	F	M						*		F					R				—				
	17,CC	C	G								C			F		F				R				
	18,CC	F	G									+		R		R				R				
	19-3, 98-100	C	G								+			+		C				R				
	19,CC	C	G						*		R			F						R				
	20-3, 40-42	R	G								R	+		+		C				+				
	20,CC	C	G																	—				
	21-1, 120-122	R	G						*		R	+		C		+				R				
	21-3, 64-66	C	G																	F				
		21,CC	C	G											C		—				—			
22-4, 30-32		C	G								+			C		—				+				
22,CC		F	G								—	F								—				
23,CC		C	G								—	F		C						—				
24,CC		C	G							—	R	F		C						—				

Table 8. (Continued).

Radiolarian Zones	Sample (interval in cm)	Abundance	Preservation	<i>Cannartus tubarius</i>	<i>Cyrtocapsella tetrapera</i>	<i>Lithopora bacca</i>	<i>Eucyrtidium calvertense</i>	<i>Calocyclus costata</i>	<i>Calocyclus virginis</i>	<i>Cannartus petterssoni</i>	<i>Cannartus laticonus</i>	<i>Stichocorys delmontensis</i>	<i>Ommatartus hughesi</i>	<i>Ommatartus antepenultimus</i>	<i>Ommatartus avitus</i>	<i>Ommatartus penultimus</i>	<i>Stichocorys peregrina</i>	<i>Theocorythium vetulum</i>	<i>Spongaster pentas</i>	<i>Anthocyrtidium angulare</i>	<i>Axoprunum angelinum</i>	<i>Amphirophalum ypsilon</i>	<i>Ommatartus tetrathalamus</i>	<i>Spongaster tetras</i>
<i>Ommatartus antepenultimus</i>	25,CC	C	G							—	F	—												
	26,CC	C	G							—	—	R	C	—										
	27,CC	C	G							—	F	—	R	F										
	28,CC	—	G							—	—	—	—	—										
	29,CC	C	G							+	R	R	—	F										
	30,CC	C	G							C	R	R	—	F										
	31,CC	A	G							R	F	R	C	R										
Hole 492A	1,CC	A	G																					
	2,CC	C	G																					
	3,CC	C	G																					
	4,CC	R	G																					
	5-2, 88-90	C	G																					
	6-1, 124-126	C	G																					
	6-2, 124-126	C	G																					
	6,CC	C	G																					
	7-1, 78-80	C	G																					
	7-2, 58-60	C	G																					
	7,CC	C	G									*		R	F	R	F							
	8-1, 105-107	C	G											—		F								
	8,CC	C	G											—		F	R							
	9-1, 90-92	C	G											F	F	F	R							
	9,CC	C	G										*	—		F	—							
	10,CC	A	G							*	*	*		C	C	F								
	11,CC	C	G									+		F	C	—								

within Sites 490 and 493 might be due to silica dissolution, because sedimentation rates in these intervals are not high enough for the absence of radiolarians to be caused by sediment dilution only. Radiolarian recrystallization occurs in the lower Miocene sediments of Sites 489 and 493.

Reworking of older forms is a biostratigraphic problem at trench slope Sites 488, 490, 491, and 492 and is especially serious because reworking often occurred so soon after deposition that radiolarians from one zone were reworked into the next succeeding zone. This type of reworking, a result of the youthful age and tectonic instability of this margin, sometimes makes it virtually impossible to recognize the extinction level of index species.

Loss of a portion of the radiolarian fauna is another problem for biostratigraphic determinations. The abundance of nassellarian radiolarians fluctuates greatly throughout the Neogene section recovered in Leg 66 sediments. This variation is expressed as the ratio of nassellarian to spumellarian radiolarians in Leg 66 cores in Figure 1. Upper Quaternary sediments contain abundant nassellarians, but their number decreases downhole until they are nearly absent in some Pliocene samples. Nassellarian abundances fluctuate throughout the

late Miocene but are generally low. Lower Miocene sediments have a high ratio with about equal numbers of nassellarians and spumellarians. This low of nassellarians in Pliocene and lower Pleistocene sediments has some serious consequences for biostratigraphy. The nassellarian radiolarian *Pterocanium prismatum* is totally absent from the Leg 66 area, and other nassellarians such as *Anthocyrtidium angulare* and *Stichocorys peregrina* are not very abundant.

Definite explanations for the loss of nassellarian radiolarians have not been found; however, there are a few possible causes. Nassellarian abundance decreases inshore in modern radiolarian assemblages collected from offshore Texas (Casey and Bauer, 1976). Apparently, nassellarians prefer more "open ocean" conditions, whereas spumellarians can survive nearshore. A decrease in the ratio of nassellarians to spumellarians to a minimum value offshore Guatemala was correlated with the late Pleistocene lowering in sea level which moved nearshore environments with fewer nassellarians offshore (McMillen, 1979). This same effect could have contributed to the loss of nassellarians in Pliocene and lower Pleistocene sediments offshore southern Mexico, as this has been established to be a period of generally lowered sea level (Vail and Mitchum, 1979). However,

Table 9. Radiolarians at Site 493.

Radiolarian Zones	Samples (interval in cm)	Abundance	Preservation	<i>Cannartus tubarius</i>	<i>Cannartus laticonus</i>	<i>Cyrtosapella tetrapera</i>	<i>Cyrtosapella cornuta</i>	<i>Cyrtosapella woffii</i>	<i>Cannartus mammiferus</i>	<i>Cannartus violina</i>	<i>Stichocorys armata</i>	<i>Calocycletta virginis</i>	<i>Calocycletta costata</i>	<i>Ommatartus hughesi</i>	<i>Stichocorys dolomontensis</i>	<i>Ommatartus unispinus</i>	<i>Ommatartus penulimus</i>	<i>Spongaster pentas</i>	<i>Stichocorys peregrina</i>	<i>Spongaster tetras</i>	<i>Amphirhopalum ypsilon</i>	<i>Ommatartus teratulum</i>
Spongaster pentas	Hole 493																					
	1-1, 8-10	A	G																			
	1-2, 115-117	C	G																			
	1-2, 126-128	A	G																			
	1-4, 122-124	C	G																			
	1, CC	C	G																			
	2-1, 90-92	R	M																			
	2, CC																					
	3, CC																					
	4, CC																					
Stichocorys peregrina	5, CC	F	M																			
	6, CC																					
	7, CC	C	G																			
	8, CC	C	G																			
	9, CC	C	G																			
Ommatartus penulimus	10, CC	C	G																			
	11, CC	C	G																			
	12, CC	C	G																			
	13, CC	C	G																			
	14, CC	C	G																			
	15, CC	C	G																			
	16, CC	G	G																			
	17, CC	A	G																			
	18, CC	C	G																			
	19, CC	C	G																			
Ommatartus ante-penulimus	20, CC																					
	21, CC	F	G																			
	22, CC	F	G																			
	23, CC	F	G																			
	24, CC	F	G																			
	25, CC	F	G																			
	26, CC	C	G																			
	27, CC	F	M																			
	28, CC	A	G																			
	29, CC	A	G																			
Calocycletta costata	30, CC	C	G																			
	31, CC	F	G																			
	32, CC	A	G																			
	33, CC	C	M																			
	34, CC	C	M																			
	35, CC	C	M																			
	36, CC	R	P																			
	37, CC	C	M																			
	38, CC	C	P																			
	39, CC	R	P																			
Hole 493A	40, CC																					
	41, CC	C	P																			
	42, CC	F	P																			
	43, CC	C	P																			
	44, CC	C	P																			
	45, CC	C	P																			
	46, CC	C	P																			
	47, CC	C	P																			
	48, CC	F	M																			
	49, CC	C	P																			
Hole 493B	50, CC	C	P																			
	54, CC																					
	1, CC	C	G																			
	2, CC	R	G																			
	3, CC	F	G																			
	4, CC	C	G																			
	5, CC	F	M																			
	6, CC																					
	7-3, 130-135	R	M																			
	7, CC	F	M																			
Hole 493C	8, CC	R	M																			
	9, CC																					
	10, CC																					
Hole 493D	11, CC	C	G																			
	12, CC																					

this ratio could also be the result of general oceanographic changes in the East Pacific. The loss of nassellarian radiolarians does seem to be a special aspect of nearshore environments and might be a recurrent problem in continental margin studies.

The eastern boundary currents of the Eastern Pacific seem to have some influence on the Quaternary radio-

larian assemblages at this latitude. The Quaternary equatorial zonation of Nigrini (1971), which has been successfully used in the central equatorial Pacific (Johnson, 1976) and eastern equatorial Pacific (Dinkelman, 1973), could not be used offshore southern Mexico owing to the absence of the collosphaerid *Buccinosphaera invaginata* and virtual absence of *Collosphaera tuberosa*, which are used to define the upper two zones, although other species of Nigrini's zones such as *Amphirhopalum ypsilon*, *Anthocyrtidium angulare*, and *Theocorythium vetulum* are present. Both collosphaerid species are also absent south of the equator near the South America coast (Sachs, 1976). Apparently, Nigrini's late Quaternary zones are restricted in latitudinal distribution, especially in the East Pacific. Both of these collosphaerids have been shown to inhabit surface waters (Casey et al., 1979; McMillen and Casey, 1978) and upwelling associated with eastern Pacific boundary currents might exclude these species.

Several of the species used by Hays (1970) in his North Pacific Quaternary zonation occur in varying abundances; *Axoprunum angelinum* (= *Stylatractus universus*) is commonly present in Miocene through upper Pleistocene sediments, and its extinction level of 0.40 m.y. can be recognized in all Leg 66 sites except in coarse clastics at Site 486 and at Site 493. Other species used in Hays's scheme—*Eucyrtidium matuyami*, *E. calvertense*, *Druppitractus acquilonius*, and *Lamprocyclus heteroporos*—are either absent or very rare so that the zonation cannot be applied. The radiolarian fauna offshore southern Mexico seems in part to be intermediate between those in the equatorial and North Pacific.

The combined effects of collosphaerid removal by oceanographic effects and the loss of nassellarians in lower Pleistocene and in Pliocene sediments make zonation difficult enough without the additional problems of extensive reworking and dilution by clastic sediments. Trench sediments are especially difficult to zone because of problems of dilution and dissolution. Ages of inferred trench sequences in Sites 488, 491, and 492 were determined from dates of the overlying lower slope deposits. Dating trench deposits in ancient accretionary zones would have to proceed on similar lines to arrive at accurate ages. This means slope deposits overlying the accretionary zone will have to be identified in these older sequences, which could be a problem in sequences composed mostly of deformed trench deposits with a small volume of slope deposits in stratigraphic contact with the wedge.

LIST OF SPECIES

- Amphirhopalum ypsilon* Haeckel, 1887, p. 522 Nigrini, 1967, p. 35, pl. 3, fig. 32d.
Anthocyrtidium angulare Nigrini, 1971, p. 445, pl. 34.1, fig. 32b.
Axoprunum angelinum (Campbell and Clark), Kling, 1973, p. 634, pl. 1, figs. 13-16; pl. 6, figs. 14-18.
Calocycletta costata (Riedel), Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 12.
Calocycletta virginis (Haeckel), Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 10.
Cannartus laticonus Riedel, 1959, p. 291, pl. 1, fig. 5.
Cannartus mammiferus (Haeckel), Riedel, 1959, p. 291, pl. 1, fig. 4.

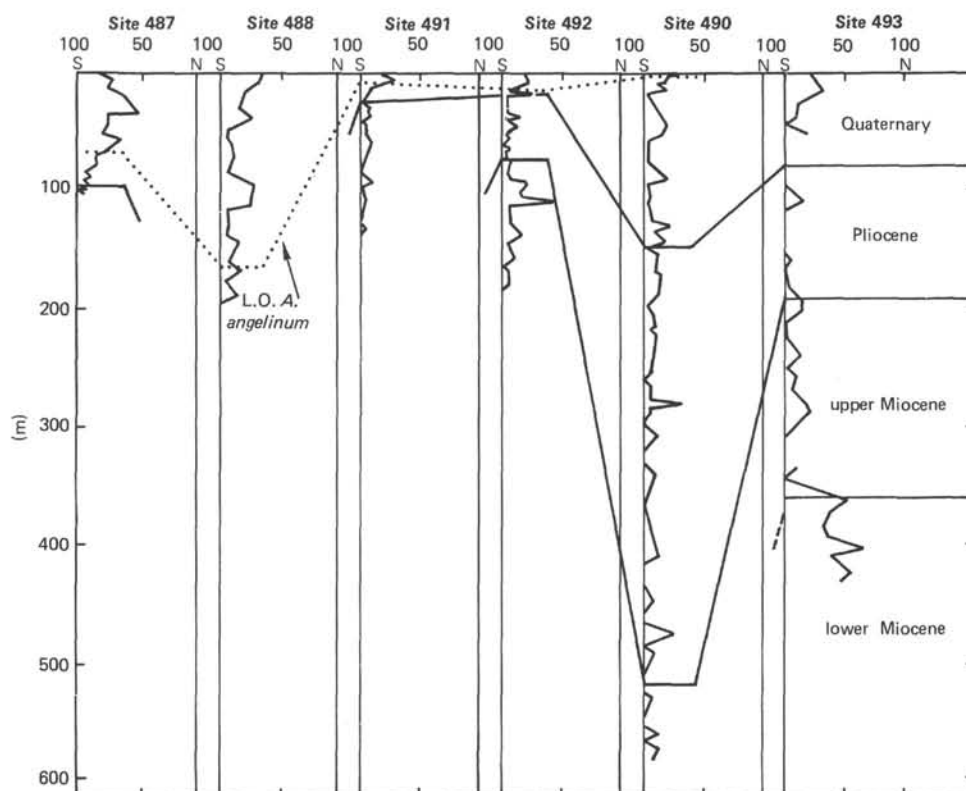


Figure 1. The ratio of nassellarian to spumellarian radiolarians at some Leg 66 sites. The loss of nassellarians in early Quaternary, Pliocene, and upper Miocene sediments might be related to lowered sea level at this time or to different oceanographic conditions. Early Miocene ratios are more nearly like those at present. Most faunas are generally well preserved, so dissolution probably has not been a significant factor in the loss of nassellarians. Age designations in Site 493 column apply to other sites as indicated by solid lines.

- Cannartus petterssoni* Riedel and Sanfilippo, 1970, p. 520, pl. 14, fig. 3.
Cannartus prismaticus (Haeckel), Riedel and Sanfilippo, 1970, p. 520, pl. 15, fig. 1.
Cannartus tubarius (Haeckel), Riedel and Sanfilippo, 1970, p. 520, pl. 15, fig. 2.
Cannartus violina Haeckel, 1887, p. 358, Riedel, 1959, p. 290, pl. 1, fig. 3.
Collosphaera tuberosa Haeckel, 1887, p. 97; Nigrini 1971, p. 445, pl. 34.1, fig. 1.
Cyrtocapsella cornuta (Haeckel), Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19, 20.
Cyrtocapsella japonica (Nakaseko), Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 13-15.
Cyrtocapsella tetrapera (Haeckel), Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 16-18.
Drupptractus acquilonius Hays, 1970, p. 214, pl. 1, figs. 4, 5.
Eucyrtidium calvertense Martin, 1904, p. 450, pl. 130, fig. 5.
Eucyrtidium matuyami Hays, 1970, p. 213, pl. 1, figs. 7-9.
Lamprocyclus heteroporos Hays, 1965, pp. 179-180, fig. 1.
Lithopera bacca Ehrenberg, 1872, p. 314; Nigrini, 1967, p. 54, pl. 6, fig. 2.
Lychnocanium bipes Riedel, 1959, p. 294, figs. 5, 6; Dinkelman, 1973, p. 780, pl. 6, fig. 1.
Ommatartus antepenultimus Riedel and Sanfilippo, 1970, p. 521, pl. 14.
Ommatartus avitus (Riedel), Riedel and Sanfilippo, 1971, p. 1588, pl. 4, fig. 6.
Ommatartus hughesi (Campbell and Clark), Riedel and Sanfilippo, 1970, p. 521.
Ommatartus penultimus (Riedel), Riedel and Sanfilippo, 1970, p. 521, 1971, pl. 1C, figs. 5-7.
Ommatartus tetrathalamus (Haeckel), Riedel and Sanfilippo, 1971, p. 1588, pl. 1C, figs. 5-7.

- Spongaster pentas* Riedel and Sanfilippo, 1970, p. 523, pl. 15, fig. 3.
Spongaster tetras Ehrenberg, 1860, p. 833; Nigrini, 1967, p. 41, pl. 5, figs. 1a, 1b, 2.
Stichocorys armata (Haeckel), Riedel and Sanfilippo, 1971, p. 1595, pl. 2E, figs. 13-15.
Stichocorys delmontensis (Campbell and Clark), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9.
Stichocorys peregrina (Riedel), Riedel and Sanfilippo, 1970, p. 530; 1971, pl. 8, fig. 5.
Stichocorys wolfii Haeckel, 1887, p. 1479; Riedel, 1954, p. 173, pl. 1, fig. 4; Riedel and Sanfilippo, 1971, pl. 2E, figs. 8, 9.
Theocorythium vetulum Nigrini, 1971, p. 447, pl. 34.1, figs. 6a, 6b.

ACKNOWLEDGMENTS

I am grateful to Richard Casey and Jean Westberg for reviewing the manuscript.

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