

### 43. RADIOLARIANS IN THE GULF OF CALIFORNIA: DEEP SEA DRILLING PROJECT LEG 64<sup>1</sup>

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#### INTRODUCTION

Radiolarians from the Gulf of California have been the subject of micropaleontological studies for at least two decades (Bandy, 1961). Though Benson (1966) did carry out extensive taxonomic research on such radiolarians, however, there have been neither biostratigraphic nor paleoceanographic studies of the Gulf based on these organisms. DSDP Leg 64 provides a first opportunity for such work.

A large contribution of terrigenous debris, associated with the tectonic formation of the Gulf as well as with major climatic changes, has greatly diluted radiolarian remains in some parts of the sedimentary column. This, plus the particular oceanographic conditions prevailing in the Gulf, such as incursions of the California Current (Roden, 1964, 1972), prevented our recognizing any of the radiolarian zonations established in the subtropical Pacific (Riedel and Sanfilippo, 1970, 1971; Moore, 1971; Nigrini, 1971). For these reasons, among others, the micropaleontologists on Leg 64 agreed that rather than defining biozones, we would identify "datum surfaces" calibrated to such geochronostratigraphies as paleomagnetostratigraphy and oxygen-isotope stratigraphy ( $\delta^{18}\text{O}$ ).

The stratigraphy established in this study for sites at the mouth of the Gulf (Sites 474, 475, and 476) shows a down-core sequence of radiolarian events similar to that in the biostratigraphy defined by Kling (1973) at Site 173, which is under the clear influence of the California Current.

This chapter considers only those sites at the mouth of the Gulf (Fig. 1; Sites 474, 475, and 476) because those processes reflected in the sedimentary column at the Guaymas Basin (Sites 477, 478, 479, and 481) precluded recording of any evident radiolarian stratigraphy. The sedimentary column at Sites 477, 478, and 481 is composed largely of turbidites (Kelts, this volume, Pt. 2). Further, the apparent age of the deepest sediment drilled at these sites is less than 0.4 m.y., too young to permit a radiolarian stratigraphy since during the Quaternary the elapsed time between radiolarian events (of morphotypical type; Riedel and Sanfilippo, 1971) was generally no fewer than 0.4 m.y. (e.g., Hays and Opdyke, 1967; Hays, 1970). The radiolarians from Site 479

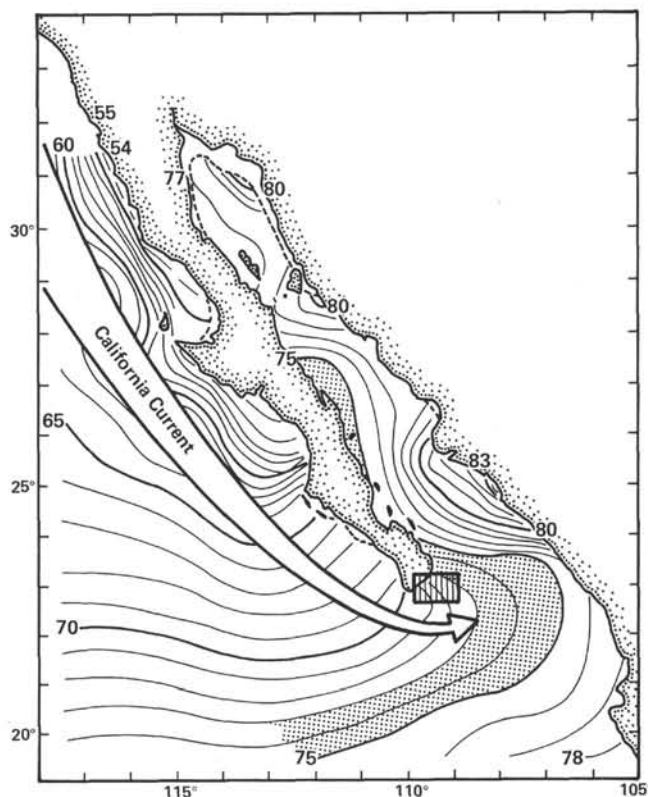


Figure 1. Distribution of July temperature ( $^{\circ}\text{F}$ ) at 30 meters of depth, according to Robinson (1973). Notice how the isotherms are deflected by the California Current, which forms an oceanographic front (dotted area) when it meets warmer waters at the mouth of the Gulf of California. The shaded square shows the region in which Sites 474 to 476 were drilled.

are too diluted by diatom remains, except in the uppermost part (Holocene?) of the sedimentary column.

Because of restrictions in sampling the core, we did not analyze the laminated sediments from Site 480, collected with the hydraulic piston corer (Schrader et al., 1980).

#### PROCEDURE

About 700 slides for micropaleontological analysis were prepared using the settling technique developed by Moore (1973) and refined by Molina-Cruz (1978; 1980). Since this technique provides slides with evenly and randomly distributed grains, it was possible to determine the relative abundance of radiolarian remains down core (Fig. 2), expressed as numbers of radiolarians per cubic centimeter. In our calculations, we used a constant volume of subsampled sediment ( $2\text{ cm}^3$ ) and constant areas for both the cover slide ( $8.8\text{ cm}^2$ ) and the "settling container" ( $78.5\text{ cm}^2$ ). Estimates were obtained by counting the number of radiolarians in the area under the cover slide and then making the following computations:

<sup>1</sup> Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP, 64*: Washington (U.S. Govt. Printing Office).

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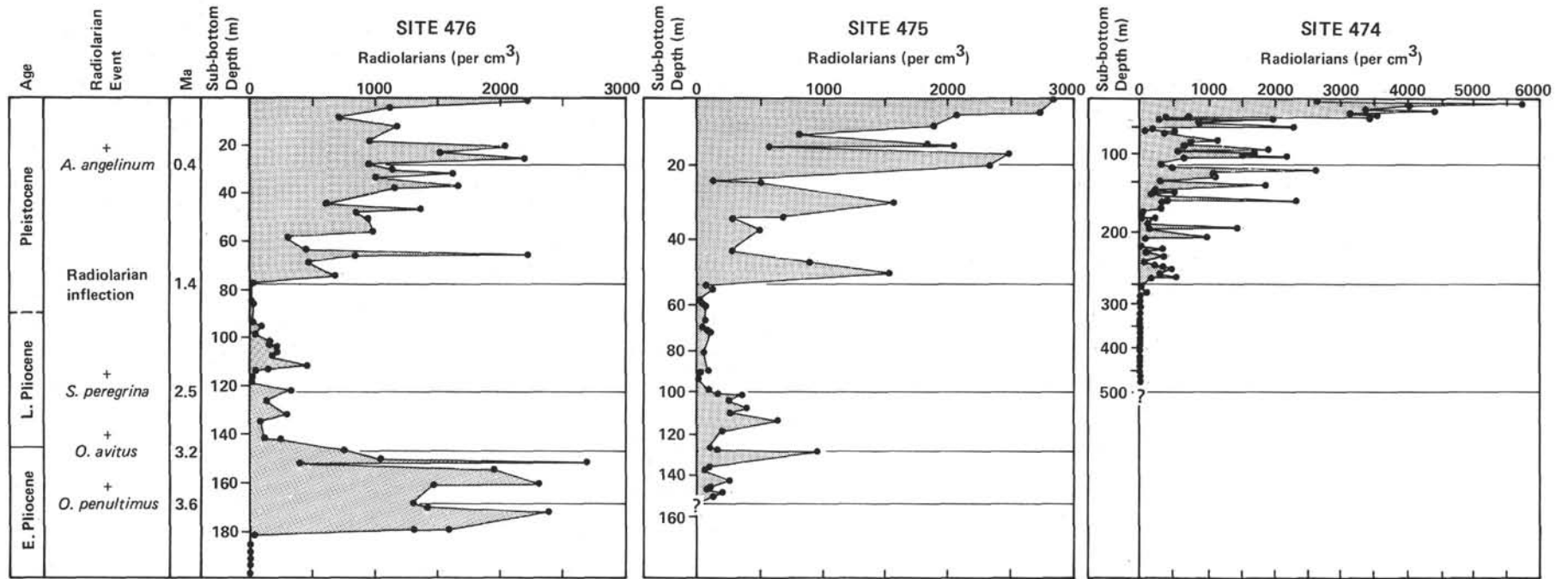


Figure 2. Down-core records of the relative abundance of radiolarian remains in the sediments. The sample values were plotted down core in accordance with the radiolarian based stratigraphy shown to the left of the figure. In a profile across the continental margin, Site 476 is the closest to the coast.

$$\begin{aligned} \text{no. rads. cm}^3 &= \frac{\text{no. rads}}{\text{area: cover slide}} \times \frac{\text{area: settling}}{\text{container}} \\ &= \frac{\text{no. rads. under cover slide}}{\text{area: cover slide}} \times \frac{\text{area: settling}}{\text{subsample vol.}} \\ &= \text{no. rads. under cover slide} \times 4.46. \end{aligned}$$

This formula is similar to that employed by Lozano and Hays (1976) to estimate the number of radiolarians per gram in the Antarctic sediments.

Counting the radiolarians in the area under the cover slide was not terribly difficult because they were diluted by diatoms or by "marginal debris" in the sediments.

Because the number of species in the radiolarian populations has generally been large, it has been customary to build up a taxonomic framework before making counts of taxa (Kling, 1973; Molina-Cruz, 1977). The framework utilized in this study (Systematics; Tables 1-3) considers both traditional index species and the species I observed frequently in an earlier analysis conducted on board the *Glomar Challenger* during Leg 64. I at first included the species *Stichocorys delmontensis*, *Ommatartus antepenultimus*, *Acrobotrys tributus*, *Solenosphaera omnitubus*, *Spongaster berminghami*, *S. pentas*, and *Pterocanium prismatium*. These did not occur in any of the samples, however, so I omitted them from the biostratigraphy tables (Tables 1-3).

In order to make inferences related to biostratigraphy and paleoceanography, I analyzed the distribution down core of each of the radiolarian species in the taxonomic framework. Such distributions, expressed in terms of relative abundance (percentages of each species in a radiolarian population sample of more than 80 individuals), are shown in Tables 1-3. When it was not possible to estimate percentages, because a slide contained fewer than 80 individuals, the presence of species was signified in the tables by an *x*; a method of tabulating data followed by Ingle (1973a) and Keller (1978). Table 4 shows a list of barren samples in the lower part of the sedimentary column from Hole 474A.

According to micropaleontological data from Leg 64, the oldest drilled sediments in the Gulf of California are from Site 476. Thus, I selected the down-core record from this site as a reference axis on which to build a stratigraphic section (Fig. 2) which includes the sites drilled during Leg 64. In this section, biostratigraphic correlation is shown, as well as fluctuations in radiolarian abundance in sediments through time.

The paleoceanographic inferences have been supported by studies of the down-core records of some environmental index species (Figs. 3 and 4).

## RESULTS AND DISCUSSION

Theyer and coworkers (1978) have discussed the convenience of developing a frame of reference in which biostratigraphic events of the morphotypical type (that is, each taxon's first and last occurrence) are calibrated to some geochronologic stratigraphy, based on, for example, paleomagnetism or oxygen-isotope stratigraphy ( $\delta^{18}\text{O}$ ). This approach lessens traditional problems, such as those related to time-transgressiveness of events or to correlating events from different climatic regions.

As mentioned, we decided to use this approach. Thus, the radiolarian events or "datum levels" detected in this study (Table 5) have been geochronostratigraphically calibrated in the Pacific Ocean, either paleomagnetostratigraphically (Theyer et al., 1978) or through oxygen-isotope stratigraphy (Hays and Shackleton, 1976).

For the Gulf of California, we have added two new datums to the framework (Table 5). These are the extinction of *Ommatartus avitus* and, informally, the marked inflection in the abundance of radiolarians during early Pleistocene (Fig. 2).

The last occurrence of *O. avitus* corresponds with the extinction of the nannoplankton index species *Reticulofenestra pseudumbilica* (Aubry, this volume, Pt. 2). Therefore, this event can be tentatively calibrated as having an age of 3.2 Ma. This agrees with the observation that the last occurrence of *O. avitus*, which has a short stratigraphic range, is confined to the "a" event of the paleomagnetostratigraphic Gilbert epoch (Theyer et al., 1978).

A linear interpolation of the histogram of sedimentation rate, from either Site 476 or Site 475, gives an age of approximately 1.4 Ma for the marked inflection in numbers of radiolarians during the early Pleistocene. This age is consistent with the biochronostratigraphy (Aubry et al., this volume, Pt. 2) established for the sites from Leg 64.

Sites 474, 475, and 476, located at the mouth of the Gulf, at the southern end of the California Current (Fig. 1), show a stratigraphic sequence of radiolarian events somewhat similar to the upper part of the sequence observed in sites farther north, which are under the clear influence of the California Current (Site 173, Kling, 1973; Sites 467, 468, and 470, Wolfort, 1980). The difference is that the suggested events related to the extinction of *Lamprocyrtis heteroporos* and the first occurrence of *Eucyrtidium matuyamai* have not been defined in Leg 64 sites for the following reasons: (1) *L. heteroporos* has been observed in only two samples from Site 476 (Table 1; Sample 18-6, 81-83 cm and Sample 18,CC), and (2) *E. matuyamai* was not considered in this study because a satisfactory basis for distinguishing it from *E. calvertense* has not been achieved (Kling, 1973). The *L. heteroporos* and *E. matuyamai* events have been thought to occur at the base of the Olduvai paleomagnetic event (Hays, 1970) at about 1.8 Ma (Opdyke, 1972). Thus, if these events occurred at Leg 64 sites, they were within a section of the sedimentary column which is scarce in radiolarian remains (Fig. 2).

In the stratigraphic section shown in Fig. 2, it is apparent that the sediments above the "basement" are older at Site 476 than are those at Site 474. This is a part of the evidence for the model of tectonic history of opening of the mouth of the Gulf, as outlined by Curray et al., (this volume, Pt. 2), and Moore and Curray, (this volume, Pt. 2).

Pleistocene fluctuations of sea level have caused erosion of sediments from the continental shelf and upper continental slope, including a debris flow unit in Site 474 (Moore et al., this volume, Pt. 2). This is further confirmed by the erratic occurrence of some index species within the biochronostratigraphic sequence (Aubry et al., this volume, Pt. 2). The occurrence of *Axoprunum angelinum* at Site 474 from Sample 3-1, 140-142 cm to Sample 8-6, 30-32 cm (Table 3) has also been considered evidence of reworking, as has its occurrence in Sample 475B-1,CC from Site 475.

The sedimentation rate at Site 474 (average ~200 m/m.y.) is approximately five times higher than that at Sites 475 and 476 (~40 m/m.y.), because Site 474 is

Table 1. Percent abundance and stratigraphic distribution of radiolarian species, Site 476.

Event	Age	Ma	Sample				<i>A. medianum</i>	<i>A. ypsilon</i>	<i>H. laevigatum</i>	<i>D. truncatum</i>	<i>D. irregularis</i>	<i>D. cf. pyriformis</i>	<i>E. delicatulum</i>	<i>Euchitonia</i> spp.	<i>E. furcata</i>	<i>H. euclidis</i>	<i>L. minor</i>	<i>O. stenozona</i>	<i>O. penulitimus</i>	<i>O. avitus</i>	<i>O. tetrathalamus</i>	<i>Ommatodiscus</i> sp.	<i>S. tetras</i>	<i>S. puella</i>		
			Slide	Core	Section	Interval																				
+ <i>A. angelinum</i>	Pleistocene	0.4	225	1	2	73-75	0.0	0.4	1.2	0.0	0.0	2.0	0.0	1.0	0.2	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.4		
			226	1	4	69-71	0.4	0.0	0.4	0.4	0.0	3.6	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.4	
			227	1		c.c.	0.0	0.0	0.6	0.0	1.3	3.2	0.0	1.9	0.6	0.0	1.9	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.6	
			228	2	3	44-46	0.0	0.4	1.5	0.0	0.0	4.1	1.1	1.1	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			229	2		c.c.	0.0	0.0	1.9	0.0	0.0	2.4	0.5	0.5	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	
			230	3	2	46-48	0.2	1.5	0.6	0.0	0.0	0.0	0.9	0.6	0.2	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
			231	3	4	46-48	0.3	0.9	0.6	0.0	0.0	0.0	0.0	1.2	0.3	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.3	0.0	1.2	
			232	3	6	62-64	0.0	0.4	0.0	0.0	0.4	4.6	1.0	1.2	0.2	0.2	0.8	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.2	
			233	3		c.c.	0.0	0.5	0.0	0.5	0.0	1.0	0.5	0.0	2.4	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.9
			234	4	2	47-49	0.0	1.5	0.8	0.4	0.0	2.3	1.5	0.4	0.4	0.4	0.4	1.9	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4
			235	4	3	64-66	0.0	1.1	0.0	0.0	0.3	3.5	0.8	0.0	0.8	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
			236	4	5	17-19	0.4	0.5	0.0	0.0	3.2	3.2	2.3	0.0	0.5	0.9	1.8	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
			237	4		c.c.	0.0	0.0	0.3	0.2	1.1	5.0	0.5	0.8	0.3	0.0	0.8	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0
			238	5	1	43-45	0.4	0.0	0.4	0.8	0.8	3.4	0.4	1.1	0.4	0.0	0.8	0.0	0.0	0.0	0.0	1.1	0.4	0.0	0.0	0.0
		239	5	4	38-40	0.0	0.0	0.9	1.9	1.4	6.1	0.9	0.5	0.9	0.5	0.9	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	
		240	5	6	25-27	0.0	0.7	0.0	0.0	0.7	4.4	1.5	0.7	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.7	0.0	
		241	5		c.c.	0.3	0.0	0.0	0.0	3.2	4.2	1.0	0.6	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	
		242	6	1	58-60	0.0	1.1	0.0	0.0	2.1	3.2	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	
		243	6	3	56-58	0.0	0.0	0.0	0.0	0.5	1.4	0.9	0.0	0.0	0.0	2.3	0.0	2.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	
		244	6		c.c.	0.0	0.0	0.0	0.4	0.4	2.2	0.9	0.0	0.9	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		245	7	2	99-101						x					x										
		246	7	6	94-96	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		247	7		c.c.	0.0	0.2	0.0	0.2	0.8	2.4	0.6	0.6	0.2	0.2	1.8	0.0	0.0	0.0	0.0	0.2	0.4	0.0	0.8	0.0	
248	8	1	58-60	0.0	0.0	0.0	0.0	0.5	2.1	0.5	1.0	1.1	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
249	8	3	26-28	0.0	0.0	0.0	0.0	3.9	1.9	0.0	1.0	2.9	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0			
250	8		c.c.	0.0	0.0	0.0	0.6	1.2	1.2	4.4	0.6	1.2	0.6	2.5	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0			
Radiolarian inflection	Pleistocene	1.4	251	9	2	131-133					x						x									
			252	9		c.c.																				
			253	10	2	18-20								x					x							
			254	10	7	13-15																				
			255	11	2	57-59									x	x										
			256	11	4	49-51							x													
			257	11	6	37-39					x									x						
			258	11		c.c.					x			x	x	x				x						
			259	12	2	45-47				x				x	x	x				x						
			260	12	3	53-55				x																
			261	12	4	46-48				x			x		x											
			262	12	6	32-34	0.0	0.9	0.0	0.0	3.7	0.0	0.0	0.0	0.0	2.8	0.0	1.8	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
			263	12		c.c.						x										x				
			264	13	1	93-95										x										
265	13	3	92-94																							
266	13	4	93-95																							
+ <i>S. peregrina</i>	I. Pliocene	2.5	267	13		c.c.	0.0	0.0	0.0	0.0	1.2	1.2	1.2	3.7	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			268	14	3	72-74						x			x											
			269	14		c.c.							x													
			270	15	2	87-89																				
			271	15		c.c.																				
			272	16	1	71-73							x			x										
			273	16	3	40-42	0.0	0.0	0.0	0.6	1.2	1.7	2.9	1.7	1.2	0.6	1.7	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	
274	16		c.c.	0.4	0.0	0.4	0.4	1.3	0.4	0.4	2.1	1.2	0.8	0.8	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0				
275	17	1	63-65	0.0	0.0	0.8	0.1	0.0	3.3	1.1	2.4	1.1	1.1	1.1	0.0	0.0	1.8	1.1	0.0	0.0	0.1	0.0				
276	17	1	126-130	0.0	0.0	0.0	0.0	1.1	2.2	2.2	6.7	3.4	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0				
277	17	3	61-63	0.4	0.0	0.2	0.0	1.1	5.7	1.6	1.8	0.7	0.7	1.1	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0				
278	17		c.c.	0.4	0.0	0.6	0.8	0.4	2.8	0.9	1.3	0.2	0.0	2.1	0.0	0.0	3.6	2.1	0.0	0.0	0.0	0.0				
279	18	1	78-80	0.4	0.0	0.0	0.6	1.9	3.4	1.1	1.5	1.5	0.6	2.0	0.0	0.0	1.1	0.2	0.0	0.0	0.0	0.4				
+ <i>O. avitus</i>	Pleistocene	3.2	280	18	6	81-83	0.0	0.0	0.0	0.3	0.9	3.9	0.3	2.7	2.7	0.0	0.3	0.0	0.6	3.3	0.3	0.0	0.0	0.3		
			281	18		c.c.	0.3	0.0	0.0	0.7	0.3	3.8	0.3	2.8	4.1	0.3	1.0	0.0	1.0	0.7	0.0	0.0	0.0	0.0		
			282	19	2	44-46	0.0	0.0	0.3	0.3	1.2	5.8	0.0	1.2	1.5	0.0	2.1	0.0	0.0	0.9	0.3	0.6	0.0	0.6		
			283	19	7	45-47	0.0	0.0	0.4	0.2	0.2	5.2	0.6	1.8	1.5	0.2	0.7	0.0	0.7	0.2	0.2	0.0	0.0	0.4		
			284	19		c.c.	0.0	0.0	0.0	0.0	1.2	2.0	0.3	1.7	1.7	0.0	1.1	0.0	0.6	0.8	0.0	0.0	0.0	0.0		
			285	20	2	99-101	0.0	0.0	0.0	0.0	1.5	3.7	0.0	2.6	1.9	0.0	1.5	0.0	0.3	1.7	0.0	0.0	0.0	0.0		
			286	20	5	100-102																				
			287	20		c.c.																				



Table 2. Percent abundance and stratigraphic distribution of radiolarian species, Site 475.

Event	Age	Ma	Sample				<i>A. medianum</i>	<i>A. ypsilon</i>	<i>H. laevigatum</i>	<i>D. truncatum</i>	<i>D. irregularis</i>	<i>D. cf. pyriformis</i>	<i>E. delicatulum</i>	<i>Euchitonia</i> spp.	<i>E. furcata</i>	<i>H. euclidis</i>	<i>L. minor</i>	<i>O. stenozona</i>	<i>O. penultimus</i>	<i>O. avitus</i>	<i>O. tetrathalamus</i>	<i>Ommatodiscus</i> sp.	<i>S. tetras</i>	<i>S. puella</i>	
			Slide	Core	Section	Interval																			
<i>A. angelinum</i>	Pleistocene	0.4	173	1	2	44-46	0.6	0.6	0.8	0.0	7.1	3.3	0.9	1.2	0.5	0.0	1.7	0.5	0.0	0.0	2.8	0.3	0.0	0.3	
			174	1		c.c	0.3	0.2	1.1	0.1	0.5	3.4	1.6	2.8	0.8	0.7	1.5	0.3	0.0	0.0	1.3	0.0	0.0	1.1	
			223	1B	5	25-27	0.0	1.0	1.3	0.0	0.0	1.3	0.2	2.1	0.4	0.0	0.9	0.2	0.0	0.0	0.0	1.3	0.0	0.0	0.4
			224	1B		c.c	0.5	0.2	0.2	0.2	1.0	1.9	0.5	3.3	0.0	0.2	1.2	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.9
			175	2	5	24-26	0.6	2.8	1.7	0.0	2.8	2.2	0.5	1.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.1	0.0	0.0	1.1
			176	2	6	98-100	0.2	0.7	0.5	0.7	0.7	2.4	0.9	1.4	0.0	0.2	1.4	0.2	0.0	0.0	0.0	2.6	0.0	0.0	0.5
			177	2	7	5-7	0.4	1.5	1.3	0.0	0.0	1.0	0.9	1.3	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
			178	2		c.c	0.5	1.4	1.4	0.0	0.0	3.2	0.7	0.9	0.0	0.0	3.0	0.2	0.0	0.0	0.0	0.4	0.0	0.2	1.0
			179	3	2	20-22	0.0	3.9	0.0	1.6	0.0	3.9	0.0	2.4	0.0	0.0	0.0	1.6	0.0	0.0	0.0	2.4	0.0	0.0	0.8
			180	3	4	20-22	0.0	1.0	0.6	0.4	0.2	1.7	0.2	0.6	0.2	0.6	0.6	1.1	0.0	0.0	0.0	0.4	0.0	0.0	0.6
			181	3	7	22-24											x								
			182	3		c.c	0.0	0.0	0.9	0.9	0.0	2.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
			183	4	4	93-95	0.0	0.0	1.4	0.0	0.0	3.0	1.1	2.2	0.0	0.6	0.6	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.3
			184	4		c.c	0.0	0.0	0.0	0.7	0.0	3.9	0.0	1.3	0.0	1.3	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.7
			185	5	1	7-9						x													
			186	5	3	50-52	0.0	0.0	0.9	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	5.2	0.0	0.0	0.9
			187	5		c.c						x													
			188	6	2	135-137	0.0	0.0	0.0	0.0	0.0	2.4	1.0	5.4	0.0	0.5	1.5	0.0	0.0	0.0	0.0	2.9	0.0	0.0	1.5
			189	6	5	21-23	0.0	0.0	6.9	0.0	1.1	3.5	0.9	0.9	0.0	0.9	0.9	1.4	0.0	0.0	0.0	1.7	0.0	0.0	0.9
Radiolarian inflection	1.4		190	6		c.c					x														
			191	7	2	49-51						x	x												
			192	7	4	82-84																x			
			193	7	6	19-21							x												
			194	7		c.c								x											
			195	8	5	23-25										x									
			196	8		c.c																			
			197	9	1	122-124					x	x						x							
			198	9	2	5-7						x						x							
			199	9		c.c						x			x			x							
+ <i>S. peregrina</i>	I. Pliocene	2.5	200	10	1	11-13						x													
			201	10		c.c																			
			202	11	1	67-69																			
			203	11	3	69-71																			
			204	11	6	41-43																			
			205	11		c.c																			
			206	12	1	57-59	0.0	0.0	1.2	0.0	0.0	0.0	0.0	6.0	0.0	1.2	2.4	0.0	0.0	0.0	0.0	2.4	0.0	0.0	1.2
			207	12	3	57-59			x			x	x										x		
208	12	5	122-124	0.0	0.0	0.0	0.0	2.2	9.0	0.0	7.9	0.0	1.1	5.6	0.0	0.0	0.0	0.0	3.4	0.0	1.1	0.0			
209	12		c.c						x	x										x					
+ <i>O. avitus</i>	e. Pliocene	3.2	210	13	3	127-129	0.0	0.0	0.7	0.0	0.0	7.4	0.0	6.1	0.7	1.3	4.7	0.0	0.0	0.0	0.7	0.0	0.7	0.0	
			211	13		c.c							x												
			212	14	6	137-139																			
			213	14		c.c						x	x												
			214	15	1	107-109	0.0	0.0	1.8	0.5	1.4	5.1	0.0	2.8	0.0	0.0	1.4	0.0	0.0	0.0	0.5	0.9	0.0	0.0	0.0
215	15	6	94-96			x			x																
216	15		c.c			x			x																
217	16	4	49-51			x			x											x					
218	16	6	36-38			x			x											x					
219	16		c.c			x			x																
220	17	1	58-60			x	x	x																	
221	17	2	30-32			x																			
222	17	5	2-4			x				x															

located down the continental slope, in the lowermost part (water depth 3023 m), and thus in a province with better conditions for deposition than Sites 476 and 475.

The California Current, which presently influences the region in which Sites 474 to 476 were drilled, has flowed southward along the Pacific coast of North America (Fig. 1) since at least the Cretaceous (Sliter, 1972). But in the Gulf of California, even though a "marine environment" did develop about 4.4 Ma (Schrader, this volume), clear evidence of the California Current was not recorded in the sediments until the Pleistocene. This is suggested by the fact that at Sites 475 and 476 some differences in faunal composition are

observed between the radiolarian assemblages from early Pliocene and from Pleistocene (Tables 1, 2).

At the mouth of the Gulf of California an oceanographic front forms, where the "cool" California Current meets and mixes with water masses from the subtropical Pacific and from the Gulf itself (Fig. 1, Roden, 1964; 1972). This front apparently provides favorable environmental conditions for the development of *Theocalyptra davisiana* (Molina-Cruz, in press). Having analyzed the down-core record of *T. davisiana* at Sites 475 and 476 (Fig. 3), I believe that this oceanographic front began to develop at the mouth of the Gulf during the early Pleistocene. Since its development is presumably

Table 2. (Continued).

<i>S. osculosa</i>	<i>A. angelinum</i>	<i>T. octacantha</i>	<i>P. murrayana</i>	<i>Spongotrochus</i> (?) spp.	<i>A. ophirensis</i>	<i>A. zanguebaricum</i>	<i>B. auritus/australis</i> group	<i>B. aquilonaris</i>	<i>C. profunda</i>	<i>E. calvertense</i>	<i>L. heteroporos</i>	<i>L. neoheteroporos</i>	<i>L. nigriinae</i>	<i>L. hystrix</i>	<i>P. corbula</i>	<i>P. stabilis scaphipes</i>	<i>P. praetextum</i>	<i>P. zancleus</i>	<i>S. peregrina</i>	<i>T. davisiana</i>	<i>T. vetulum</i>	<i>T. trachelium</i>	<i>Carpocanistrum</i> spp.	<i>L. thoracites</i>	Spumellaria	Nassellaria	No. of specimens counted	
1.4	0.0	0.6	0.3	2.5	0.6	0.8	4.5	4.9	0.0	0.1	0.0	0.0	0.8	0.2	0.5	1.0	0.3	4.5	0.0	6.8	0.0	0.0	1.1	0.5	58	42	645	
0.2	0.0	1.3	0.0	3.3	0.3	1.3	5.9	0.2	0.7	0.1	0.0	0.0	0.8	0.7	1.3	2.1	0.5	3.9	0.0	9.1	0.0	0.0	1.3	0.2	53	47	614	
0.6	0.0	1.9	0.9	2.8	0.2	0.6	1.5	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.7	3.4	0.9	3.4	0.0	7.3	0.0	0.0	0.6	1.0	49	51	466	
0.9	0.5	1.2	0.3	3.3	0.2	0.5	2.8	2.2	0.2	0.0	0.0	0.0	0.9	0.5	1.9	1.1	5.4	0.0	12.	0.0	0.0	0.5	0.7	49	51	424		
1.7	0.0	1.1	0.5	1.7	1.1	0.6	7.7	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.7	0.6	5.0	0.0	10.	0.0	0.0	2.2	0.6	52	48	181		
0.7	0.0	0.0	0.5	3.4	0.0	0.5	5.3	0.7	0.2	0.2	0.0	0.0	0.5	0.2	0.9	1.3	1.2	3.4	0.0	12.	0.0	0.7	1.2	0.2	53	47	415	
0.4	0.0	1.0	0.0	3.0	0.4	0.0	4.5	0.6	0.2	0.6	0.0	0.0	0.4	0.0	0.4	2.4	0.4	3.7	0.0	11.	0.0	0.0	1.7	0.9	46	54	462	
1.9	0.0	1.2	0.2	2.8	0.0	0.0	3.7	0.2	0.0	0.0	0.0	0.0	0.4	0.2	0.5	2.1	0.2	3.9	0.0	15.	0.0	0.0	0.5	0.0	52	48	561	
0.8	0.0	2.4	0.8	3.9	0.0	1.6	3.9	0.0	0.0	0.0	0.0	0.0	0.8	0.0	2.4	0.0	1.6	1.6	0.0	3.1	0.0	0.0	3.1	0.0	54	47	127	
0.0	0.4	1.0	0.6	3.4	0.2	0.0	5.5	0.9	0.2	0.0	0.0	0.0	0.8	0.6	1.3	5.1	0.9	5.9	0.0	9.0	0.0	0.0	1.1		42	58	527	
x				x														x					x			48	52	27
0.0	0.9	0.9	0.9	2.6	1.7	0.0	0.9	0.0	0.9	1.7	0.0	0.0	0.0	0.0	0.0	x	0.0	3.4	0.0	6.1	0.0	0.0	0.9	0.2	48	52	115	
0.0	0.3	0.0	0.0	1.9	1.4	0.0	2.5	0.0	0.9	0.3	0.0	0.0	0.0	0.3	0.9	2.2	1.4	5.0	0.0	6.7	0.0	0.0	0.6	0.0	46	54	357	
0.0	0.6	1.3	0.0	4.6	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.	0.0	0.0	0.0	0.0	0.0	59	41	154	
		x		x			x									x		x		x			x			42	58	57
0.0	0.0	0.9	1.7	1.7	0.0	1.7	2.6	0.9	0.9	1.7	0.0	0.0	0.9	0.0	0.9	2.6	0.9	0.0	0.0	10.	0.0	0.0	0.0	0.0	57	43	116	
		x		x			x									x				x						70	30	56
3.4	1.0	1.0	0.0	5.9	0.0	0.5	1.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0	1.9	0.0	0.5	1.5	0.0	4.0	0.0	0.5	1.5	0.0	61	39	204	
0.9	0.9	0.3	0.0	2.9	1.1	0.9	4.6	1.1	1.1	0.3	0.0	0.0	0.9	0.0	0.0	2.0	0.6	4.3	0.0	11.	0.0	0.0	0.6	0.3	48	52	347	
	x						x											x		x						92	8	13
																										75	25	28
				x																						99	1	4
																										99	1	12
																					x				75	25	16	
			x																				x			93	7	15
																										62	38	8
	x				x				x																	84	16	19
								x																		84	16	25
																										85	15	13
		x		x																						90	10	10
		x		x																						81	19	21
								x																		86	14	7
																										100		1
																										83	17	18
x		x																								82	18	38
0.0	0.0	0.0	0.0	3.6	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	1.2	0.0	0.0	0.0	0.0	75	25	83	
		x		x																x						79	21	52
2.2	1.0	5.6	1.1	7.9	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	1.1	0.0	0.0	0.0	0.0	1.1	0.0	0.0	81	19	99	
		x		x																x						83	17	53
0.0	0.7	4.8	0.0	2.7	0.7	0.7	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	1.4	0.0	0.0	0.0	0.7	0.7	0.7	80	20	138	
		x		x																						87	13	45
		x		x																						95	5	21
																										97	3	35
0.0	0.5	1.4	0.0	4.2	0.5	0.4	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	2.3	5.5	0.9	0.0	0.0	0.0	0.0	72	28	216	
		x																		x						53	47	19
																										70	30	10
			x																							75	25	61
																										64	36	25
																										75	25	16
			x																							68	32	47
								x																		73	27	33
																												8

linked to the "intensification" of the California Current, this suggestion does not conflict with Ingle's observation (1973b). Ingle, in building up a stratigraphic section along the California Current (using Site 173, the Mohole cores, and locations with Neogene sequences on the California coast), showed that in the interval between the Pliocene and the Holocene the subarctic planktonic biofacies of the California Current migrated southward to the latitudes of the mouth of the Gulf only during the Pleistocene and Holocene. This conclusion is also supported by the down-core record (Fig. 4) of *Botryostrobus aquilonaris* (= *Artostrobium miralestense*; Kling, 1973; Wolfort, in press). This species has shown

ecological preference for subarctic waters, including those from the California Current (Moore, 1973b; Wenkan, 1976; Wolfort, 1980).

Ingle has also suggested (1973b) that during the early Pliocene subtropical biofacies migrated north as far as 47°N. Thus, it is possible to explain why in the lower Pliocene of Sites 475 and 476 a biostratigraphic sequence with traditional index species from the subtropical Pacific was recorded (Fig. 2; Riedel and Sanfilippo, 1971; Moore, 1971).

As shown in Tables 1 and 2, the early Pliocene is dominated by spumellarians, whereas the Pleistocene is dominated by nassellarians. However, the scarcity of





Table 3. (Continued).

	<i>A. angelinum</i>	<i>T. octacantha</i>	<i>P. murrayana</i>	<i>Spongotrochus</i> (?) spp.	<i>A. ophirese</i>	<i>A. zanguebaricum</i>	<i>B. auritus/</i> <i>australis</i> group	<i>B. aquilonaris</i>	<i>C. profunda</i>	<i>E. calvertense</i>	<i>L. heteroporos</i>	<i>L. neoheteroporos</i>	<i>L. nigriinae</i>	<i>L. hystrix</i>	<i>P. corbula</i>	<i>P. stabilis/</i> <i>scaphipes</i>	<i>P. praetextum</i>	<i>P. zancleus</i>	<i>S. peregrina</i>	<i>T. davisiana</i>	<i>T. vetulum</i>	<i>T. trachelium</i>	<i>Carpocanistrum</i> spp.	<i>L. thoracites</i>	<i>Spumellaria</i>	<i>Nassellaria</i>	No. of specimens counted
0.0	1.8	0.2	3.0	0.0	0.3	4.0	12.0	0.3	0.0	0.0	0.0	0.6	0.1	0.3	0.8	0.4	2.6	0.0	5.9	0.0	0.3	2.1	0.1	56	44	1118	
0.0	5.9	0.0	3.9	0.0	0.5	2.0	5.4	1.0	0.0	0.0	0.0	0.0	0.8	0.3	0.8	0.5	3.3	1.5	7.9	0.0	0.1	0.8	0.3	63	37	589	
0.0	4.8	0.2	3.4	0.4	0.0	5.0	2.5	0.4	0.1	0.0	0.0	0.4	0.2	1.8	1.4	0.9	2.3	0.0	11.0	0.0	0.1	1.5	0.1	58	42	893	
0.0	2.6	0.1	1.7	0.4	0.0	7.4	0.9	0.8	0.3	0.0	0.0	1.6	1.0	1.0	3.7	0.6	4.6	0.0	10.0	0.0	0.1	1.0	0.6	41	59	749	
0.0	3.1	1.0	0.0	0.0	0.0	3.6	0.1	1.5	0.3	0.0	0.0	0.8	1.9	0.2	4.4	0.4	5.4	0.0	7.7	0.0	0.0	0.7	1.7	40	60	1153	
0.0	1.5	0.0	2.1	0.3	0.0	4.6	1.5	0.2	0.8	0.0	0.0	1.0	0.8	1.0	2.1	0.8	4.6	0.0	9.8	0.2	0.2	0.4	0.3	52	48	1280	
0.0	2.4	0.3	1.9	0.2	0.0	10.1	1.4	0.3	0.3	0.0	0.0	1.1	0.5	0.4	2.6	1.2	6.4	0.0	7.8	0.2	0.1	0.2	0.5	47	53	1140	
0.1	2.5	0.0	3.0	0.0	0.0	9.3	0.5	0.0	0.3	0.0	0.0	0.2	1.5	0.7	4.2	1.0	3.8	0.0	3.8	0.0	0.5	0.4	1.5	46	54	895	
0.2	1.9	0.4	2.6	0.1	0.5	6.2	0.6	0.0	0.1	0.0	0.0	0.8	0.7	0.5	2.4	0.4	5.3	0.0	8.6	0.0	0.0	0.2	0.7	51	49	1167	
0.0	3.2	0.0	1.6	0.0	0.0	1.6	3.2	0.0	0.5	0.0	0.0	1.6	0.0	0.0	0.5	0.0	1.0	0.0	13.0	0.0	0.0	0.5	0.0	66	34	187	
0.2	1.5	1.1	3.1	0.4	0.0	14.1	0.8	0.6	0.1	0.0	0.0	0.2	1.5	1.7	3.5	1.0	5.9	0.0	5.8	0.0	0.2	0.4	1.7	45	55	880	
0.0	1.3	0.2	3.2	0.5	0.4	3.2	1.4	0.8	0.7	0.0	0.0	0.2	0.2	0.8	2.8	0.4	5.1	0.0	7.0	0.0	0.1	0.9	0.4	53	47	741	
0.3	2.7	0.4	3.1	0.1	0.1	6.7	0.9	0.2	0.4	0.0	0.0	0.4	1.0	0.7	2.1	0.1	6.0	0.0	11.0	0.1	0.1	0.6	0.6	51	49	1028	
0.0	3.3	0.5	1.6	0.6	0.0	10.1	0.4	0.6	0.1	0.2	0.0	1.5	0.8	0.7	3.4	0.3	9.4	0.0	11.0	0.1	0.1	1.1	0.5	39	61	996	
0.4	5.9	0.0	4.7	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.7	1.5	1.1	7.1	0.0	4.3	0.0	0.0	1.5	1.1	60	40	253	
0.0	0.7	0.1	1.8	0.5	0.2	5.1	0.0	0.7	0.0	0.0	0.0	0.1	2.8	0.7	3.8	0.2	2.5	0.0	28.0	0.0	0.5	3.0	2.0	24	76	697	
0.5	1.6	0.0	3.1	0.5	1.2	9.8	0.2	1.3	0.0	0.0	0.0	0.0	1.0	0.5	4.6	0.1	2.3	0.0	21.0	0.0	0.1	1.6	37	63	802		
0.2	2.5	0.0	2.4	0.1	0.7	7.1	0.6	0.5	0.8	0.0	0.0	0.7	0.7	1.1	3.7	0.9	7.0	0.0	10.0	0.0	0.0	0.7	0.2	44	56	771	
0.0	2.3	0.0	12.0	0.0	0.0	0.0	2.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	1.1	0.0	36	4	85	
0.0	2.4	0.0	6.7	0.0	0.0	0.6	2.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	3.7	0.0	85	15	162	
0.0	1.5	0.0	3.8	0.6	0.0	5.3	1.7	0.2	0.0	0.0	0.0	1.1	0.0	0.9	2.2	0.4	5.3	0.0	8.7	0.0	0.0	1.1	0.2	55	45	446	
0.4	1.6	0.0	4.9	0.0	0.0	2.4	2.8	1.2	0.4	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.4	0.0	14.0	0.0	0.0	1.6	0.0	63	37	243	
0.0	2.7	1.1	5.0	0.0	0.0	1.1	0.0	0.0	1.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0	6.6	0.0	13.0	0.0	0.0	1.1	0.0	65	35	182	
0.8	0.8	0.0	4.8	0.0	0.4	3.6	1.2	0.4	1.2	0.0	0.0	2.0	0.0	0.4	0.8	0.4	11.0	0.0	9.7	0.0	0.0	2.4	0.4	50	50	247	
0.0	0.7	0.2	4.8	0.4	0.7	3.0	0.7	0.0	0.7	0.0	0.0	0.7	0.0	0.7	1.6	0.2	3.2	0.0	12.0	0.0	0.0	2.5	0.0	56	44	430	
0.9	1.8	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.9	0.0	0.0	0.9	0.0	5.4	0.0	6.3	0.0	0.0	7.2	0.0	66	34	111	
0.7	0.7	0.0	6.3	0.7	0.0	2.2	3.7	1.1	0.7	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.1	0.0	12.0	0.0	0.0	1.4	0.3	69	31	269	
0.5	0.7	0.0	5.5	0.1	0.0	2.8	2.8	0.5	0.7	0.0	0.0	0.7	0.3	0.0	0.5	0.0	0.9	0.0	14.0	0.0	0.0	2.1	0.0	60	40	521	
0.0	1.9	0.0	6.1	0.0	0.9	3.3	3.7	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.4	0.0	9.0	0.0	0.0	1.9	0.0	74	26	211		
	x		x			x			x			x			x				x			x			77	23	40
1.8	1.8	0.0	11.0	0.0	0.0	0.9	3.6	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	1.8	0.0	84	16	111	
0.0	0.0	0.0	5.8	0.0	0.0	2.3	3.4	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	4.6	0.0	0.0	1.1	0.0	69	31	86	
0.0	0.4	0.0	1.4	0.0	0.0	14.1	8.3	2.9	1.0	0.0	0.0	0.0	0.9	0.9	2.4	0.0	3.4	0.0	13.0	0.0	0.0	2.4	1.4	42	58	263	
0.0	0.5	0.0	2.8	0.0	0.5	4.0	4.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	1.7	0.0	1.1	0.0	19.0	0.0	0.0	2.3	0.0	55	45	174	
0.0	2.1	0.0	5.0	0.0	0.0	12.1	1.4	1.4	0.7	0.0	0.0	0.7	0.0	0.7	2.8	0.0	1.4	0.0	8.6	0.0	0.0	2.8	0.0	56	44	139	
0.0	1.0	0.0	0.7	0.0	0.0	8.7	0.0	0.7	1.4	0.0	0.0	0.7	0.0	0.7	5.4	0.0	9.4	0.0	17.0	0.0	0.0	1.4	0.3	35	65	276	
0.0	1.6	0.9	2.2	0.0	0.2	14.1	2.0	0.9	0.2	0.0	0.0	0.2	0.0	0.2	1.3	0.2	7.0	0.0	12.0	0.0	0.0	2.2	0.4	42	58	438	
0.0	5.3	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	1.7	0.0	8.0	0.0	0.0	1.7	1.7	70	30	112	
0.0	2.0	0.0	3.6	0.0	0.2	2.8	1.3	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.5	0.0	3.1	0.0	9.5	0.0	0.0	2.6	0.0	73	27	368	
0.0	0.8	0.0	4.7	0.0	0.0	3.8	2.3	0.5	0.0	0.0	0.0	0.5	0.3	0.8	2.9	0.0	2.0	0.0	11.0	0.0	0.0	1.1	0.8	61	39	337	
0.0	1.0	0.0	1.4	0.0	0.2	7.6	0.2	0.0	0.0	0.0	0.0	1.6	1.0	2.2	3.2	0.2	4.6	0.0	9.3	0.0	0.6	0.8	1.0	42	58	494	
0.0	6.3	1.9	8.9	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	3.8	0.6	5.0	0.0	4.4	0.0	0.0	3.1	0.6	65	35	207	
0.0	3.4	2.7	10.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	4.1	0.0	0.6	0.0	0.0	2.7	0.6	71	29	146	
0.0	4.9	1.4	3.5	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	2.1	2.1	3.5	0.0	3.5	0.0	0.0	6.9	0.7	62	38	143	
0.0	5.5	2.3	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.5	0.0	1.5	0.0	2.3	0.0	0.0	0.7	0.7	72	28	127		
			x			x									x				x			x			52	48	60
1.0	2.0	0.0	8.0	0.0	0.0	3.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	0.0	2.0	0.0	9.0	0.0	0.0	2.0	0.0	65	35	100	
0.0	0.5	0.1	3.5	0.5	0.6	4.0	0.3	0.1	0.0	0.0	0.0	0.5	0.6	0.5	2.0	0.1	2.5	0.0	14.0	0.0	1.1	0.3	0.6	39	61	591	
0.4	0.8	0.0	5.0	0.4	1.2	2.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	9.3	0.0	0.0	0.8	0.0	69	31	237	
0.4	2.7	0.0	3.5	0.4	0.0	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.0	5.9	0.0	4.7	0.0	0.4	0.4	0.0	68	32	251	
0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	5.9	0.0	0.0	1.9	0.0	63	37	54	
0.5	0.0	1.0	4.3	0.5	0.0	6.9	1.0	1.0	0.0	0.0	0.0	0.5	0.0	0.0	5.3	0.0	0.5	0.0	4.3	0.0	0.0	2.6	0.0	82	18	101	
0.0	2.5	0.0	3.5	0.2	0.2	3.5	1.6	2.1	0.2	0.0	0.0	0.9	0.0	0.0	0.9	0.4	0.7	0.0	14.0	0.0	0.0	1.6	0.2	57	43	186	
0.8	0.0	0.0	9.6	0.0	0.0	7.0	5.2	1.7	0.8	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.8	0.0	1.7	0.0	68	32	38	
			x			x									x				x			x			42	58	114
1.2	2.4	2.4</																									

Table 4. List of barren samples in Hole 474A.

Slide	Sample (interval in cm)
145	12A,CC
146	13A-1, 41-43
147	13A-3, 49-51
148	13A-5, 50-52
149	13A,CC
150	14A-1, 21-23
151	14A-3, 37-39
152	14A-5, 52-54
153	14A,CC
154	16A-1, 31-33
155	16A-3, 35-37
156	16A-5, 57-59
817	16A,CC
157	17A-1, 24-26
158	17A-3, 137-139
159	17A-5, 24-26
818	17A,CC
160	18A-1, 3-5
161	18A,CC
162	19A-2, 76-78
163	19A,CC
164	20A,CC
165	21A-1, 46-48
166	21A-3, 37-39
167	21A-5, 83-85
168	21A-6, 22-24
169	22A-1, 109-111
170	22A-3, 47-49
171	22A,CC
100	23A-3, 54-56
819	23A,CC
101	24A-2, 90-92
102	24A-3, 94-96
820	24A,CC
98	25A-2, 6-8
97	25A-5, 40-42
99	26A-1, 103-105
103	26A-2, 101-103
104	26A,CC
105	27A-1, 18-20
106	27A-4, 64-66
107	27A,CC
36	28A-1, 8-10
87	28A-3, 78-80
88	28A,CC
89	28A,CC
90	29A-1, 18-20
91	29A-5, 41-43
92	29A-5, 111-113
93	29A,CC
94	30A-2, 93-95
95	30A-4, 43-45
96	30A,CC
74	31A-1, 69-71
75	31A-3, 70-72
76	31A-5, 63-65
77	31A,CC
78	32A-2, 34-36
79	32A-4, 4-6
80	32A-6, 73-75
821	32A,CC
81	33A-2, 49-51
82	33A-3, 8-10
83	33A-6, 24-26
822	33A,CC

Table 4. (Continued).

Slide	Sample (interval in cm)
84	34A-2, 21-23
85	34A-4, 115-117
63	35A-1, 33-35
64	35A-3, 66-68
65	35A,CC
66	36A-3, 89-91
67	36A,CC
68	37A-2, 49-51
69	37A-3, 117-119
70	37A,CC
71	38A-2, 75-76
72	38A-3, 54-56
73	38A,CC
172	40A,CC

radiolarians in the sediments from the late Pliocene and the earliest Pleistocene (Fig. 2) prevents us from determining whether this difference stems from ecological factors or differential preservation of specimens.

## CONCLUSIONS

At least five radiolarian datum levels can be defined in the sedimentary column from the mouth of the Gulf of California. Calibrated geochronostratigraphically, the oldest datum corresponds to the extinction of *Ommatartus penultimus*, which occurred 3.6 Ma, and the youngest to the extinction of *Axoprunum angelinum*, which occurred 0.4 Ma.

A stratigraphic section across the outer continental slope of the peninsula of Baja California (Sites 474 to 476) shows that the radiolarians in the oldest marine sediments above basement rocks are older in Sites 475 and 476 than in Site 474. This is compatible with the explanation of geological history of the Gulf and subsidence of the Baja California margin presented elsewhere by Curry et al. (this volume, Pt. 2).

An oceanographic front at the mouth of the Gulf, originating from mixing of the California Current and water masses from the subtropical Pacific and from the Gulf itself, began to form during the early Pleistocene. The onset of this feature prevented the continued development during the Pleistocene of the subtropical biostratigraphic sequence that was recorded during early Pliocene time.

## SYSTEMATICS

Though the number of radiolarian species in the sediments from the Gulf of California is very large (Benson, 1966), many are scarce. The taxonomic framework built up for this study includes only species which are found frequently though not always abundantly; it also contains "traditional" biostratigraphic species.

The classification of species is based largely on *A Guide to Modern Radiolaria* by Nigrini and Moore (1979), but some synonymies are considered and other references noted. Species are arranged alphabetically with suborders and families.

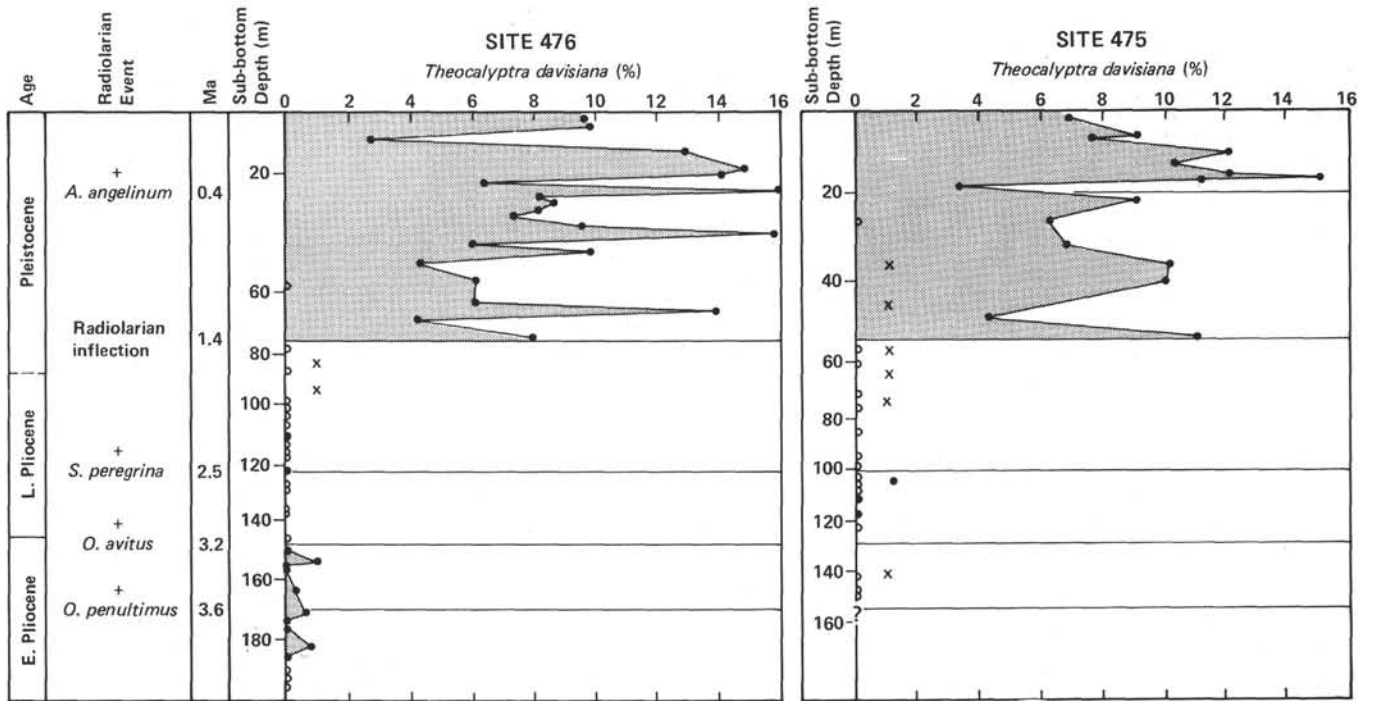


Figure 3. Down-core record of the relative abundance of *Theocalyptra davisiana*. The sample values were plotted down core in accordance with the radiolarian based stratigraphy shown to the left of the figure. Open circles in the records denote samples barren of radiolarians, and x denotes presence of scarce species (fewer than 80 specimens in samples) for which the percentage was not calculated.

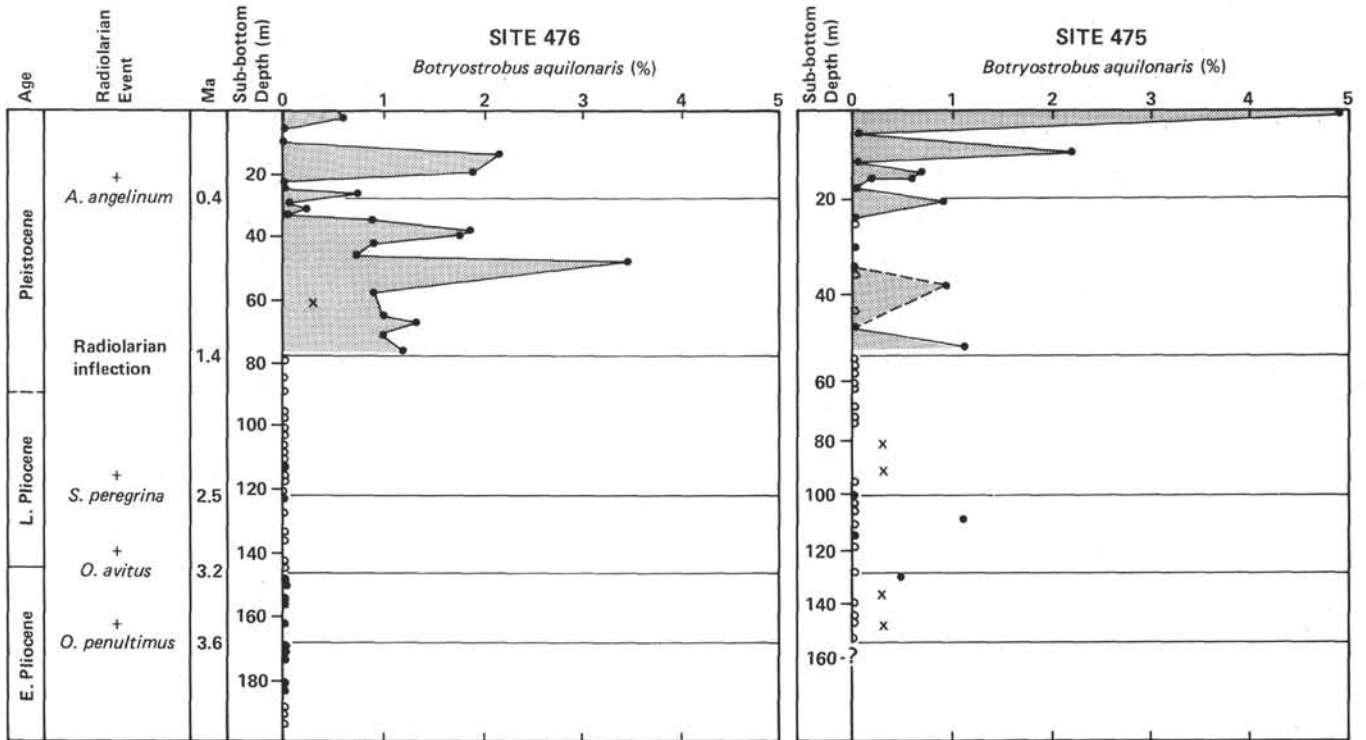


Figure 4. Down-core record of the relative abundance of *Botryostrobus aquilonaris*. (See caption, Fig. 3.)

Table 5. Geochronologic calibration of radiolarian events.

Radiolarian Event	Age (Ma)	Calibrated to:	Reference
extinction of <i>Axoprunum angelinum</i> (Campbell and Clark) (= <i>Stylatractus universus</i> Hays).	0.4	$\delta^{18}\text{O}$ stratigraphy	Hays and Opdyke, 1976
extinction of <i>Stichocorys peregrina</i> (Riedel)	2.5	paleomagnetostatigraphy	Theyer, et al., 1978
extinction of <i>Ommatartus penultimus</i> (Riedel)	3.6	paleomagnetostatigraphy	Theyer, et al., 1978

**Subclass RADIOLARIA Müller, 1858****Order POLYCYSTINA Ehrenberg, 1838; emend. Riedel, 1967****Suborder SPUMELLARIA Ehrenberg, 1875****Family COLLOSPHAERIDAE Müller, 1858****Genus POLYSOLENIA Ehrenberg, 1872; emend. Nigrini, 1967***Polysolenia murrayana* (Haeckel)

(Plate 2, Fig. 2)

*Choenicosphaera murrayana* (Haeckel), Benson, 1966, p. 120, pl. 2, fig. 3.*Polysolenia murrayana* (Haeckel), Nigrini and Moore, 1979, p. S17, pl. 2, figs. 4a, b.**Family ACTINOMMIDAE Haeckel, 1862; emend. Riedel, 1967****Genus ACTINOMMA Haeckel, 1860; emend. Nigrini, 1967***Actinomma medianum* Nigrini, 1967

(Plate 2, Fig. 8)

*Actinomma medianum* Nigrini, 1967, p. 27, pl. 2, figs. 2a, b; Nigrini and Moore, 1979, p. S31, pl. 3, figs. 5, 6.**Genus AXOPRUNUM Haeckel, 1887***Axoprunum angelinum* (Campbell and Clark)

(Plate 1, Figs. 5, 6)

*Stylosphaera angelina* Campbell and Clark, 1944, p. 12, pl. 1, figs. 14–20.*Stylatractus universus* Hays, 1970, p. 215, pl. 1, figs. 1, 2.*Axoprunum angelinum* (Campbell and Clark), Kling, 1973, p. 634, pl. 1, figs. 13–16; pl. 6, figs. 14–18.**Genus DRUPPATRACTUS Haeckel, 1887***Drupptractus irregularis* Popofsky

(Plate 2, Fig. 5)

*Drupptractus irregularis* Popofsky, Benson, 1966, p. 180, pl. 7, figs. 7–11.*Drupptractus cf. pyriformis* (Bailey)

(Plate 2, Figs. 6, 7)

*Drupptractus cf. pyriformis* (Bailey), Benson, 1966, p. 177, pl. 7, figs. 2–6.**Genus ECHINOMMA Haeckel, 1881***Echinomma delicatum* Dogiel, 1952

(Plate 2, Fig. 3)

*Echinomma delicatum* Dogiel, Petrushevskaya, 1968, p. 18, fig. 11.*Echinomma delicatum* Dogiel, Molina-Cruz, 1977, p. 333, pl. 1, fig. 5.**Genus HEXACONTIUM Haeckel***Hexacantium laevigatum* Haeckel, 1887

(Plate 2, Fig. 13)

*Hexacantium laevigatum* Haeckel, 1887, p. 193, pl. 24, fig. 6; Nigrini and Moore, 1979, p. S47, pl. 5, figs. 2a, b.**Subfamily ARTISCINAE Haeckel, 1881, emend. Riedel, 1967****Genus OMMATARTUS Haeckel, 1881, emend. Riedel, 1971***Ommatartus avitus* Riedel

(Plate 1, Figs. 9–11)

*Ommatartus avitus* Riedel, Riedel and Sanfilippo, 1971, p. 1588, pl. 4, fig. 6; Zachariasse et al., 1978, p. 105, pl. 2, fig. 9.**Remarks.** The polar caps of this species frequently are broken, so it is sometimes difficult to distinguish this species from *O. penultimus*. *O. avitus* is, however, characterized by its tuberculate (knobby) cortical shell. In this study, the extinction of *O. avitus* (about 3.2 Ma) is considered a chronostratigraphic datum level (see text).*Ommatartus penultimus* Riedel

(Plate 1, Figs. 7, 8)

*Ommatartus penultimus* Riedel, Riedel and Sanfilippo, 1971 (*sensu stricto*), p. 1588, pl. 1C, fig. 10 only; Moore, 1971, pl. 12, fig. 11.*Ommatartus tetrathalamus tetrathalamus* (Haeckel)

(Plate 2, Fig. 4)

*Ommatartus tetrathalamus tetrathalamus* (Haeckel), Nigrini and Moore, 1979, p. S49, pl. 6, figs. 1 a–d.**Remarks.** Some specimens of *O. tetrathalamus coronatus* (Nigrini and Moore, 1979) were probably included within this species.**Family SPONGORIDAE Haeckel, 1862;****emend. Petrushevskaya, 1975****Genus SPONGOCORE Haeckel, 1887***Spongocore puella* Haeckel, 1887

(Plate 3, Fig. 2)

*Spongocore puella* Haeckel, Benson, 1966, p. 187, pl. 8, figs. 1–3; Nigrini and Moore, 1979, p. S69, pl. 8, figs. 5a–c.**Family SPONGODISCIDAE Haeckel 1862, emend. Riedel, 1967****Genus AMPHIRHOPALUM Haeckel, 1881, emend. Riedel, 1967***Amphirhopalum ypsilon* Haeckel, 1887

(Plate 3, Fig. 3)

*Amphirhopalum ypsilon* Haeckel, Nigrini and Moore, 1979, p. S75, pl. 10, figs. 1a–e.**Genus DICTYOCORYNE Ehrenberg, 1860***Dictyocoryne truncatum* (Ehrenberg)

(Plate 3, Fig. 4)

*Dictyocoryne cf. truncatum* (Ehrenberg), Benson, 1966, p. 235, pl. 15, fig. 1; Nigrini and Moore, 1979, p. S89, pl. 12, figs. 2a, b.**Genus EUCHITONIA Ehrenberg, 1872***Euchitonia furcata* Ehrenberg, 1872

(Plate 3, Fig. 5)

*Euchitonia furcata* Ehrenberg, Nigrini and Moore, 1979, p. S85, pl. 11, figs. 2a, b.**Remarks.** Some specimens of *E. elegans* (Ehrenberg) (Nigrini and Moore, 1979) were probably counted, too.*Euchitonia* spp.

(Plate 3, Fig. 7)

**Remarks.** Within *Euchitonia* spp. I included Spongodiscidae with three chambered "arms" (excluding *E. furcata*) which exhibit bilateral symmetry; i.e., individuals in which one of the angles between the "arms" is clearly smaller than the other two. Also, one of the "arms" is generally longer than the other two.**Genus HYMENIASTRUM Ehrenberg, 1847***Hymeniasstrum euclidis* Haeckel, 1887

(Plate 3, Fig. 1)

*Hymeniasstrum euclidis* Haeckel, Benson 1966, p. 222, pl. 12, figs. 1–3; Nigrini and Moore, 1979, p. S91, pl. 12, fig. 3.

**Genus OMMATODISCUS**

*Ommatodiscus* sp. (Benson, 1966)  
(Plate 2, Fig. 1)

*Ommatodiscus* sp. (Benson), Benson, 1966, p. 210, pl. 10, fig. 2 only, text, fig. 13.

**Genus SPONGASTER Ehrenberg, 1860**

*Spongaster tetras tetras* Ehrenberg, 1860  
(Plate 3, Fig. 6)

*Spongaster tetras tetras* Ehrenberg, Nigrini and Moore, 1979, p. S93, pl. 13, fig. 1.

**Remarks.** I did not distinguish between *S. tetras tetras* and *S. tetras irregularis* (Nigrini, 1967) in this study.

**Genus SPONGOPYLE Dreyer, 1889**

*Spongopyle osculosa* Dreyer, 1889  
(Plate 3, Fig. 8)

*Spongodiscus(?) osculosa* Dreyer, Petrushevskaya, 1967, p. 42, figs. 20-22.

*Spongopyle osculosa* Dreyer, Nigrini and Moore, 1979, p. S115, pl. 15, fig. 1.

**Genus SPONGOTROCHUS Haeckel, 1860**

*Spongotrochus* spp.

**Remarks.** *Spongotrochus* spp. includes individuals of the *S. glacialis* Popofsky group and *S. (?) venustum* Bailey (Nigrini and Moore, 1979). Since most the specimens are broken around the periphery, it is difficult to distinguish one from the other. Also, it is possible that some damaged individuals of *Spongopyle osculosa* Dreyer were included within this genus. These Spongodiscidae were abundant in the mouth of the Gulf of California, principally during the Pliocene.

**Family PYLONIIDAE Haeckel, 1881****Genus OCTOPYLE Haeckel, 1881**

*Octopyle stenozona* Haeckel, 1887  
(Plate 2, Fig. 9)

*Octopyle stenozona* Haeckel, Benson, 1966, p. 251, pl. 16, figs. 3-4; Nigrini and Moore, 1979, p. S123, pl. 16, figs. 2a, b.

**Genus TETRAPYLE Müller, 1858**

*Tetrapyle octacantha* Müller, 1858  
(Plate 2, Figs. 10, 11)

*Tetrapyle octacantha* Müller, Benson, 1966, p. 245, pl. 15, figs. 3-10, pl. 16, fig. 1, fig. 18; Nigrini and Moore 1979, p. S125, pl. 16, figs. 3a, b.

**Family LITHELIIDAE Haeckel, 1862****Genus LITHELIUS, Haeckel, 1862**

*Lithelius minor*, Jorgensen, 1889  
(Plate 2, Fig. 12)

*Lithelius minor* Jorgensen, Benson, 1966, p. 262, pl. 17, figs. 9-10; Nigrini and Moore, 1979, p. S135, pl. 17, figs. 3, 4a, b.

**Suborder NASSELLARIA Ehrenberg 1875****Family PLAGONIIDAE Haeckel, 1881, emend. Riedel, 1967****Genus LITHOMELISSA Ehrenberg, 1847**

*Lithomelissa hystrix* Jorgensen  
(Plate 4, Fig. 11)

*Lithomelissa hystrix* Jorgensen, Benson, 1966, p. 363, pl. 24, figs. 6-9.

*Lithomelissa thoracites* Haeckel  
(Plate 4, Figs. 12, 13)

*Lithomelissa thoracites* Haeckel, Benson, 1966, p. 366, pl. 24, figs. 10-13.

**Family TRISSOCYCLIDAE Haeckel, 1881, emend. Goll, 1968****Genus PHORMOSPYRIS Haeckel, 1881, emend. Goll, 1977**

*Phormospyris stabilis* (Goll) *scaphipes* (Haeckel)  
(Plate 4, Fig. 10)

*Tristylospyris scaphipes* Haeckel, Benson, 1966, p. 316, pl. 22, figs. 7, 9-10.

*Phormospyris stabilis* (Goll) *scaphipes* (Haeckel), Nigrini and Moore, 1979, p. N19, pl. 20, figs. 2a-d.

**Family CARPOCANIIDAE Haeckel, 1881, emend. Riedel, 1967****Genus CARPOCANISTRUM Haeckel, 1887**

*Carpocanistrum* spp.  
(Plate 5, Fig. 8)

*Carpocanium petalospyris*, Benson, 1966, p. 434, pl. 29, figs. 9, 10; text fig. 25.

*Carpocanistrum* spp., Riedel and Sanfilippo, 1971, p. 1596, pl. 1G, figs. 1-6, 8-13; pl. 2F, figs. 5-6, pl. 3D, figs. 1, 2, 6, 7, 9; Nigrini and Moore 1979, p. N23, pl. 21, figs. 1a-c.

**Family THEOPERIDAE Haeckel, 1881, emend. Riedel, 1967****Genus CORNUTELLA Ehrenberg**

*Cornutella profunda* Ehrenberg  
(Plate 4, Fig. 7)

*Cornutella profunda* Ehrenberg, Kling, 1973, p. 635, pl. 3, figs. 1-4; pl. 9, figs. 8-17.

**Genus EUCYRTIDIUM Ehrenberg, 1847, emend. Nigrini, 1967**

*Eucyrtidium calvertense* Martin, 1904  
(Plate 5, Fig. 4)

*Eucyrtidium calvertense* Martin, Hays, 1970, p. 213, pl. 1, fig. 6; Kling, 1973, p. 636, pl. 4, figs. 16, 18, 19; pl. 11, figs. 1-5.

**Remarks.** As Kling (1973) pointed out, it is difficult to distinguish between *E. calvertense* Martini and *E. matuyamai* Hays (1970). Thus, it is possible that some specimens of *E. matuyamai* Hays have been recorded as *E. calvertense* Martin. Comments regarding *E. matuyamai* Hays appear in the text.

**Genus PTEROCANIUM Ehrenberg, 1847**

*Pterocanium praetextum praetextum* (Ehrenberg), 1872  
(Plate 5, Fig. 7)

*Pterocanium praetextum praetextum* (Ehrenberg), Nigrini and Moore (1979), p. N41, pl. 23, fig. 2.

**Genus STICHOCORYS Haeckel, 1881**

*Sstichocorys peregrina* (Riedel)  
(Plate 1, Figs. 1-4)

*Stichocorys peregrina* (Riedel), Riedel and Sanfilippo, 1978, p. 118, pl. 5, figs. 5-7; Kling, 1973, p. 638, pl. 13, figs. 9, 10.

**Genus THEOCALYPTRA Haeckel, 1887**

*Theocalyptra davisiana* (Ehrenberg), 1861  
(Plate 5, Figs. 9, 11)

*Cycladophora davisiana* (Ehrenberg), Petrushevskaya, 1967, p. 122, pl. 69, figs. I-VII.

*Theocalyptra davisiana* (Ehrenberg), Kling, 1973, p. 638, pl. 3, figs. 9-12, 28; Nigrini and Moore, 1979, p. N57, pl. 24, figs. 2a, b.

**Remarks.** Following Kling's suggestion (1973), specimens with a smoothly conical shape (pl. 6, fig. 10) were not included in counts of *T. davisiana*. It appears that *T. davisiana* began to inhabit the Gulf of California in the earliest Pleistocene.

**Family PTEROCORYIDAE Haeckel, 1881, emend. Riedel, 1967****Genus ANTHOCYRTIDIUM Haeckel, 1881**

*Anthocyrtidium ophirensis* (Ehrenberg), 1872  
(Plate 4, Fig. 1)

*Anthocyrtidium ophirensis* Ehrenberg, Haeckel, 1887, p. 1270.

*Anthocyrtidium ophirensis* (Ehrenberg), Nigrini, 1967, p. 56, pl. 6, fig. 3; Nigrini and Moore, 1979, p. N67, pl. 25, fig. 1.

*Anthocyrtidium zanguebaricum* (Ehrenberg)  
(Plate 4, Fig. 2)*Anthocyrtidium zanguebaricum* (Ehrenberg), Nigrini, 1967, p. 58, pl. 6, fig. 4; Nigrini and Moore, 1979, p. N69, pl. 25, fig. 2.Genus *LAMPROCYRTIS* Kling, 1973*Lamprocyrtis heteroporos* (Hays)*Lamprocyrtis heteroporos*? Hays, 1970, p. 214, pl. 1, fig. 3.*Lamprocyrtis heteroporos* (Hays), Kling, 1973, p. 639, pl. 5, figs. 19-21; pl. 15, fig. 6.**Remarks.** This species was rarely found in this study.*Lamprocyrtis neoheteroporos* Kling, 1973  
(Plate 4, Fig. 3)*Lamprocyrtis neoheteroporos* Kling, 1973, p. 639, pl. 5, figs. 17, 18; pl. 15, figs. 4, 5.**Remarks.** This species was seldom found in this study.*Lamprocyrtis nigrinae* (Caulet), 1971  
(Plate 4, Fig. 4)*Lamprocyrtis haysi* Kling, 1973, p. 639, pl. 5, figs. 15, 16; pl. 15, figs. 1-3.*Lamprocyrtis nigrinae* (Caulet), Nigrini and Moore, 1979, p. N81, pl. 25, fig. 7.Genus *PTEROCORYS* Haeckel, 1881*Pterocorys zancleus* (Müller), 1858  
(Plate 5, Figs. 2, 3)*Theoconus zancleus* (Müller), Benson, 1966, p. 482, pl. 33, fig. 4 (not fig. 5).*Pterocorys zancleus* (Müller), Nigrini and Moore, 1979, p. N 89, pl. 25, figs. 11a, b.**Remarks.** It is possible that some specimens of *P. minythorax* (Nigrini, 1968, p. 57, pl. 1, fig. 8) which did not show clear morphological characteristics have been classified as *P. zancleus*.Genus *THEOCORYTHIUM* Haeckel, 1887*Theocorythium trachelium* (Ehrenberg)  
(Plate 5, Fig. 6)*Theocorythium trachelium trachelium* (Ehrenberg), Nigrini 1967, p. 79, pl. 8, fig. 2; pl. 9, fig. 2; Nigrini and Moore, 1979, p. N93, pl. 26, fig. 2.**Remarks.** I did not distinguish between *T. trachelium trachelium* and *T. trachelium* (Ehrenberg) *dianae* (Haeckel) (Nigrini and Moore, 1979, p. N97, pl. 26, figs. 3a, b) in this study.*Theocorythium vetulum*  
(Plate 5, Fig. 5)*Theocorythium vetulum* Nigrini, 1971, p. 447, pl. 34.1, figs. 6a, 6b.Family *ARTOSTROBIIDAE* Riedel, 1856, emend. Foreman, 1973Genus *BOTRYOSTROBUS* Haeckel, 1887, emend. Nigrini, 1977*Botryostrobus auritus/australis* (Ehrenberg) group  
(Plate 4, Fig. 5)*Lithostrobus seriatus* Haeckel, Petrushevskaya, 1968, p. 145, pl. 82, figs. I-IV.*Botryostrobus auritus/australis* (Ehrenberg) group, Nigrini 1977, p. 246, pl. 1, figs. 2-5; Nigrini and Moore, 1979, p. N101, pl. 27, figs. 2a-d.*Botryostrobus aquilonaris* (Bailey)  
(Plate 4, Fig. 6)*Eucyrtidium aquilonaris* Bailey, 1856, p. 4, pl. 1, fig. 9.*Eucyrtidium tumidulum* Bailey(?), Kling, 1971, pl. 1, fig. 2.*Artostrobium miralestense* (Campbell and Clark), Riedel and Sanfilippo, 1971, pl. 1H, figs. 9-17; pl. 21, figs. 9, 10; pl. 3E, fig. 12; Kling, 1973, p. 639, pl. 5, figs. 31-35; pl. 12, figs. 28-31.*Siphocampium erucosum* (Haeckel), Benson, 1966, p. 527, pl. 35, figs. 18-20.*Siphocampe aquilonaris* (Bailey), Molina-Cruz, 1977, p. 338, pl. VIII, figs. 10, 11; Wenkam, 1976, p. 39, p. 101.*Botryostrobus aquilonaris* (Bailey), Nigrini, 1977, p. 246, pl. 1, fig. 1; Nigrini and Moore, 1979, p. N99, pl. 27, fig. 1.**Remarks.** It appears that *B. aquilonaris* began to inhabit in the Gulf of California in the Pleistocene.Genus *PHORMOSTICHOARTUS* Campbell, 1954,  
emend. Nigrini, 1977*Phormostichoartus corbula* (Harting), 1863  
(Plate 4, Figs. 8, 9)*Siphocampe corbula* (Harting), Nigrini, 1967, p. 85, pl. 8, fig. 5; pl. 9, fig. 3; Molina-Cruz, 1977, p. 338, pl. VIII, fig. 6.*Phormostichoartus corbula* (Harting), Nigrini, 1977, p. 252, pl. 1, fig. 10; Nigrini and Moore, 1979, p. N103, pl. 27, fig. 3.

## ACKNOWLEDGMENTS

I express my gratitude to William R. Riedel and Annika Sanfilippo for their critical review of this manuscript. This gratitude is also extended to Lupita Vargas-Cardenas for her assistance in the laboratory work and to Elena Corona, who typed this work. This study was partially supported by the Consejo Nacional de Ciencia y Tecnología de México through the project PROMAR No. PCMANSF 790321: Paleocyanografía del Golfo de California.

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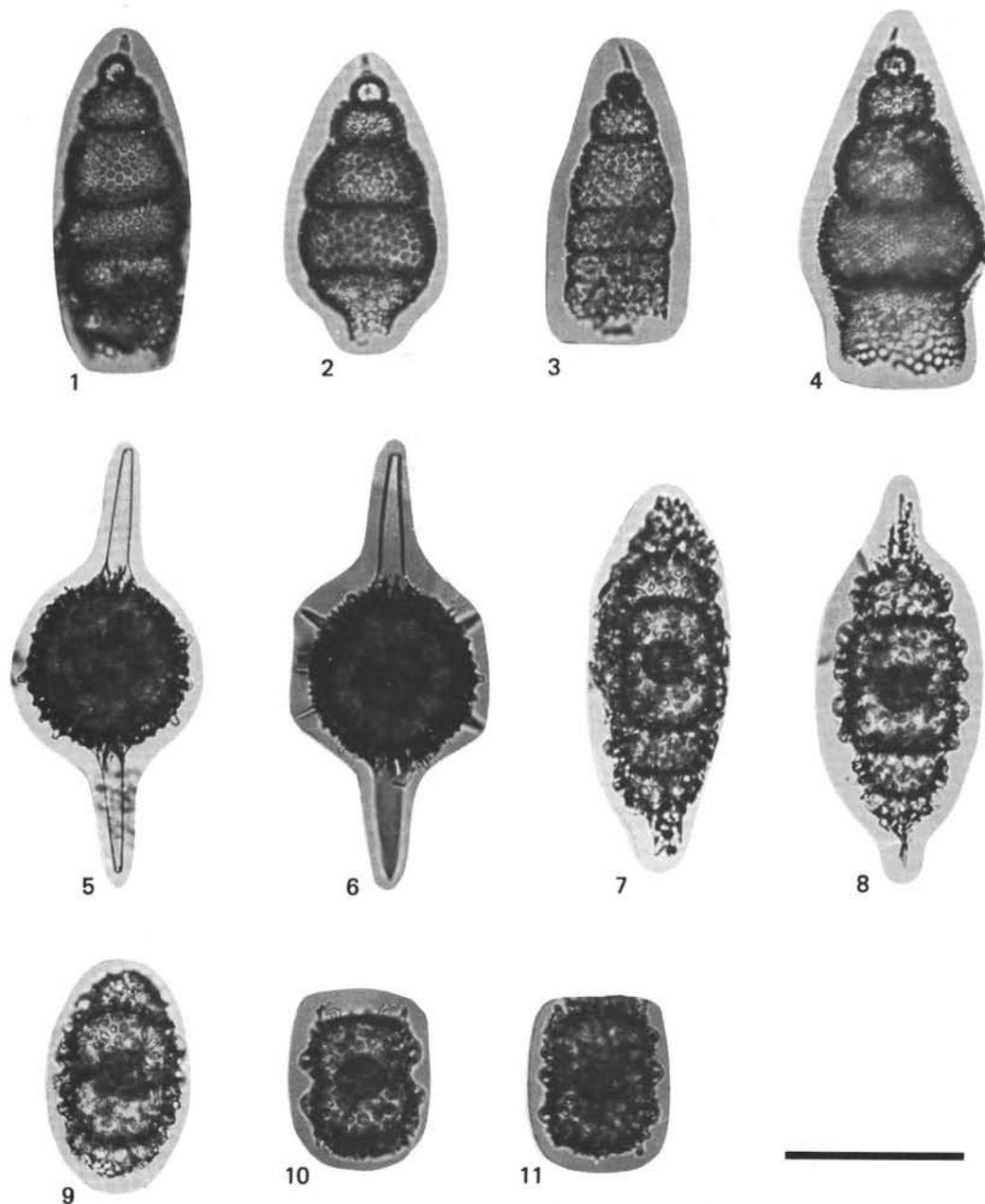


Plate 1. Radiolarians. (Scale bar equals 100  $\mu$ m.) 1. *Stichocorys peregrina* (Riedel), Sample 476-16-4, CC. 2. *Stichocorys peregrina* (Riedel), Sample 476-16-4, CC. 3. *Stichocorys peregrina* (Riedel), Sample 476-18-6, 81-83 cm. 4. *Stichocorys peregrina* (Riedel), Sample 476-18-6, 81-83 cm. 5. *Axoprunum angelinum* (Campbell and Clark), Sample 474-8-6, 30-32 cm. 6. *Axoprunum angelinum* (Campbell and Clark), Sample 475-3, CC. 7. *Ommatartus penultimus* Riedel, Sample 476-18-6, 81-83 cm. 8. *Ommatartus penultimus* Riedel, Sample 476-18, CC. 9. *Ommatartus avitus* Riedel, Sample 476-18, CC. 10. *Ommatartus avitus* Riedel, Sample 476-18-6, 81-83 cm. 11. *Ommatartus avitus* Riedel, Sample 476-18-6, 81-83 cm.



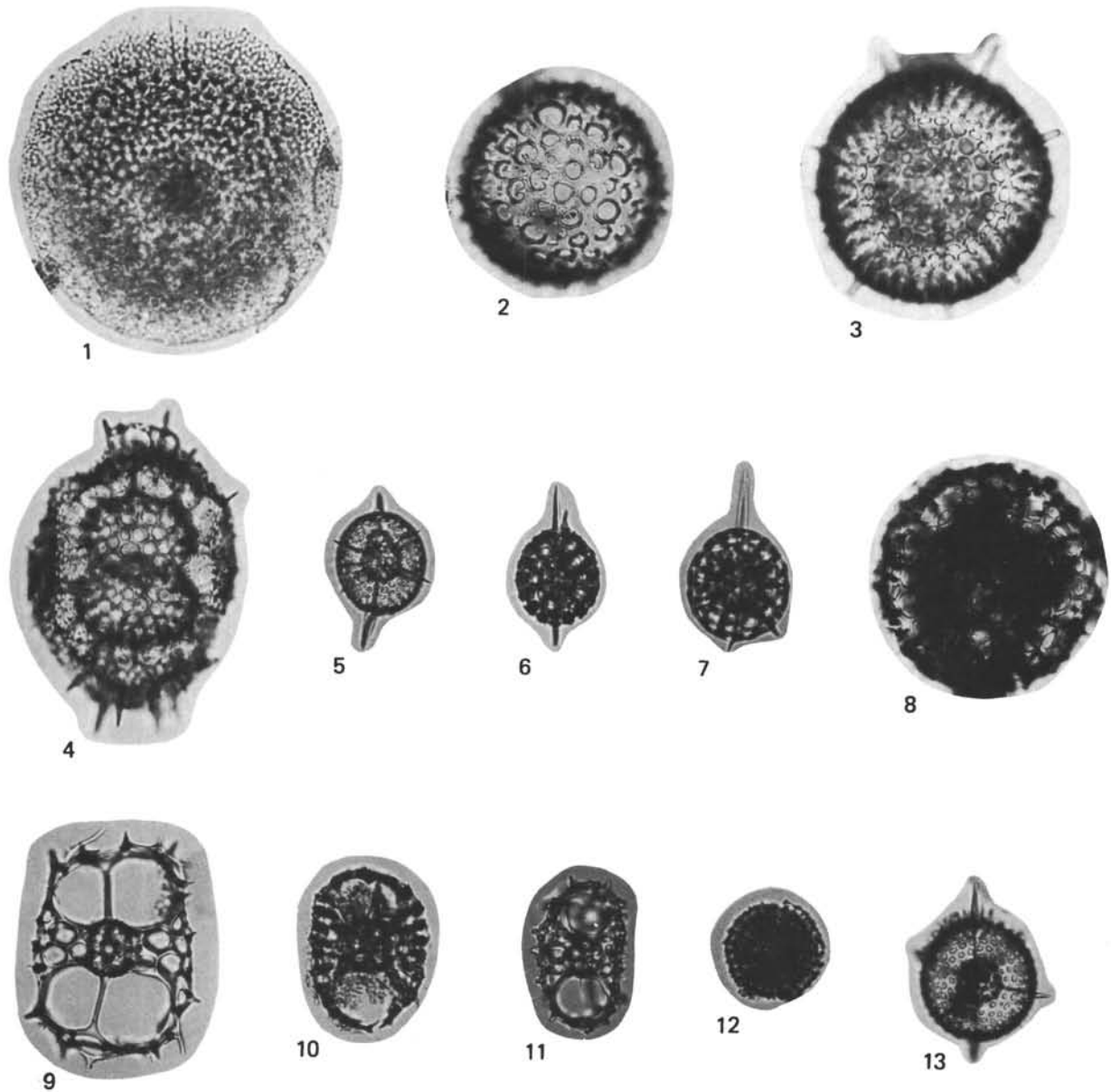


Plate 2. Radiolarians. (Scale bar equals 100  $\mu\text{m}$ .) 1. *Ommatodiscus* sp. (Benson), Sample 475-1-2, 44-46 cm. 2. *Polysolenia murrayan* (Haeckel), Sample 474-2-1, 89-91 cm. 3. *Echinomma delicatulum* Dogiel, Sample 475-1-2, 44-46 cm. 4. *Ommatartus tetrathalamus tetrathalamus* (Haeckel), Sample 475-1-2, 44-46 cm. 5. *Druppattractus irregularis* Popofsky, Sample 475-1-2, 44-46 cm. 6. *Druppattractus* cf. *pyriformis* (Bailey), Sample 476-3-4, 46-48 cm. 7. *Druppattractus* cf. *pyriformis* (Bailey), Sample 476-4, CC. 8. *Actinomma medianum* Nigrini, Sample 476-4, CC. 9. *Octopyle stenozona* Haeckel, Sample 474-2-3, 7-9 cm. 10. *Tetrapyle octacantha* Müller, Sample 476-7, CC. 11. *Tetrapyle octacantha* Müller, Sample 474-2-1, 89-91 cm. 12. *Lithelius minor* Jorgensen, 474-2-1, 89-91 cm. 13. *Hexacantium laevigatum* (Haeckel), 474-2-3, 7-9 cm.

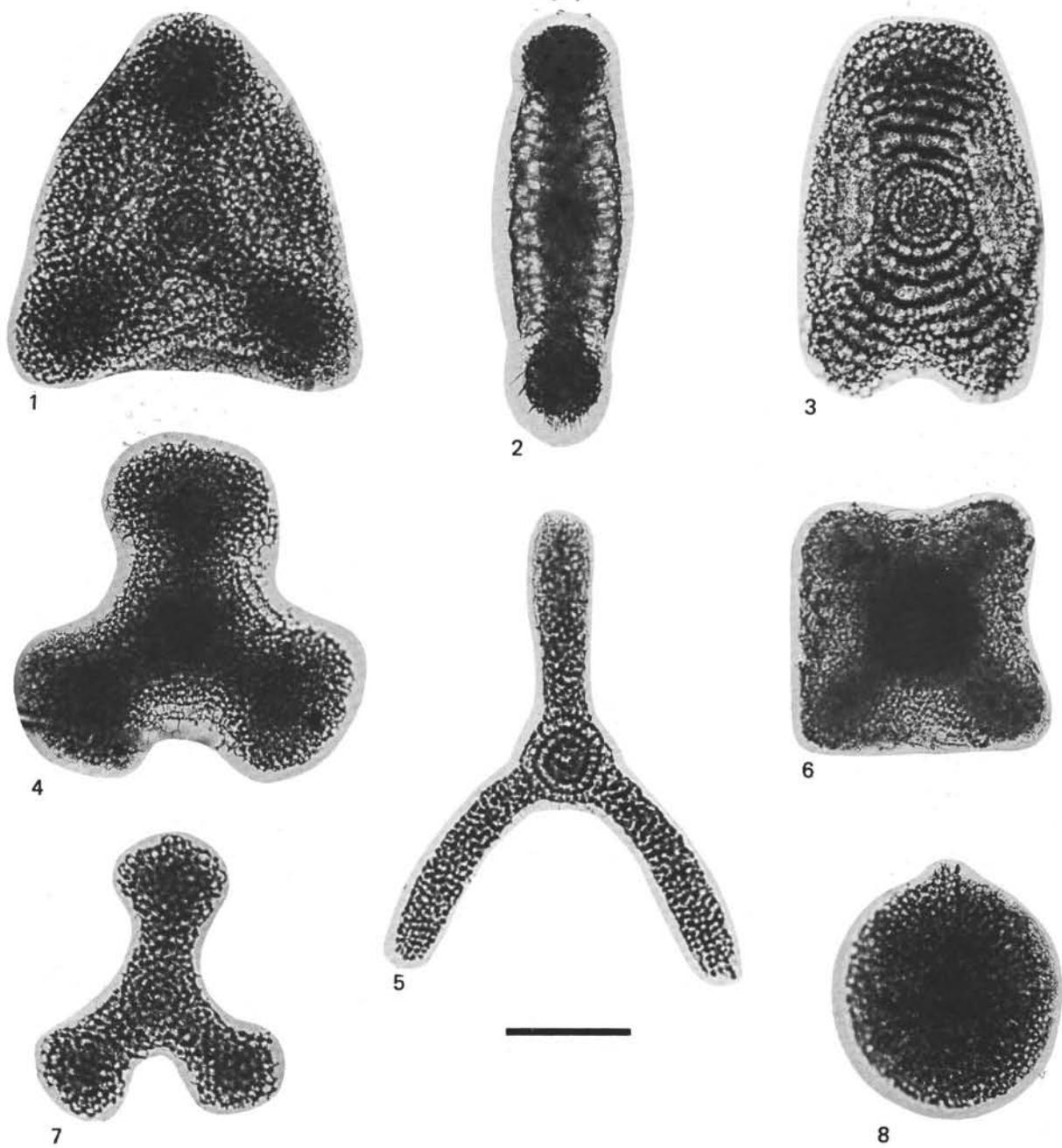


Plate 3. Radiolarians. (Scale bar equals 100  $\mu\text{m}$ .) 1. *Hymeniastrum euclidis* Haeckel, Sample 475-1, CC. 2. *Spongocore puella* Haeckel, Sample 475-1-2, 44-46 cm. 3. *Amphirhopalum ypsilon* Haeckel, Sample 474-2-3, 7-9 cm. 4. *Dictyocoryne truncatum* (Ehrenberg), Sample 474-3-2, 40-42 cm. 5. *Euchitonia furcata* Ehrenberg, Sample 475-1-2, 44-46 cm. 6. *Spongaster tetras* Ehrenberg, Sample 476-18-6, 81-83 cm. 7. *Euchitonia* sp., Sample 474-2-1, 89-91 cm. 8. *Spongopyle osculosa* Dreyer, Sample 475-1-2, 44-46 cm.

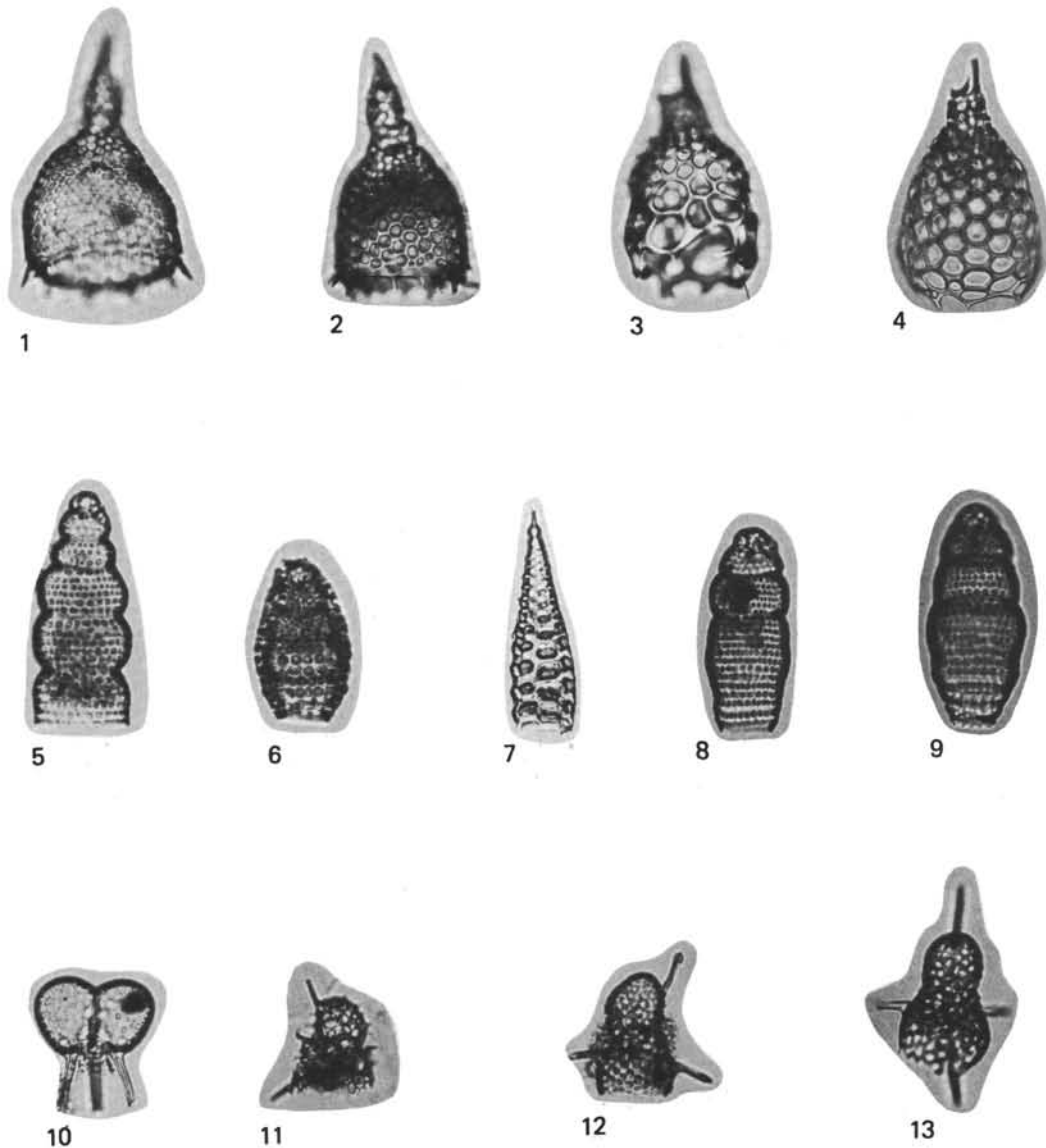


Plate 4. Radiolarians. 1. *Anthocyrtidium ophirens* (Ehrenberg), Sample 474-2-3, 7-9 cm. 2. *Anthocyrtidium zanguebaricum* (Ehrenberg), Sample 475-1, CC. 3. *Lamprocyrtis neoheteroporos* Kling, Sample 476-7, CC. 4. *Lamprocyrtis nigrinia* (Caulet), Sample 474-2-3, 7-9 cm. 5. *Botryostrobus auritus/australis* (Ehrenberg), Sample 475-1-2, 44-46 cm. 6. *Botryostrobus aquilonaris* (Bailey), Sample 475-1-2, 44-46 cm. 7. *Cornutella profunda* Ehrenberg, Sample 476-19-7, 45-47 cm. 8. *Phormostichoartus corbula* (Harting), Sample 476-3-4, 46-48 cm. 9. *Phormostichoartus corbula* (Harting), Sample 474-2-1, 89-91 cm. 10. *Phormospyris stabilis* (Goll) scaphipes (Haeckel), Sample 475-1-2, 44-46 cm. 11. *Lithomelissa hystrix* Jorgensen, Sample 474-2-2, 58-60 cm. 12. *Lithomelissa thoracites* Haeckel, Sample 476-4, CC. 13. *Lithomelissa thoracites* Haeckel, Sample 476-3-4, 46-48 cm.

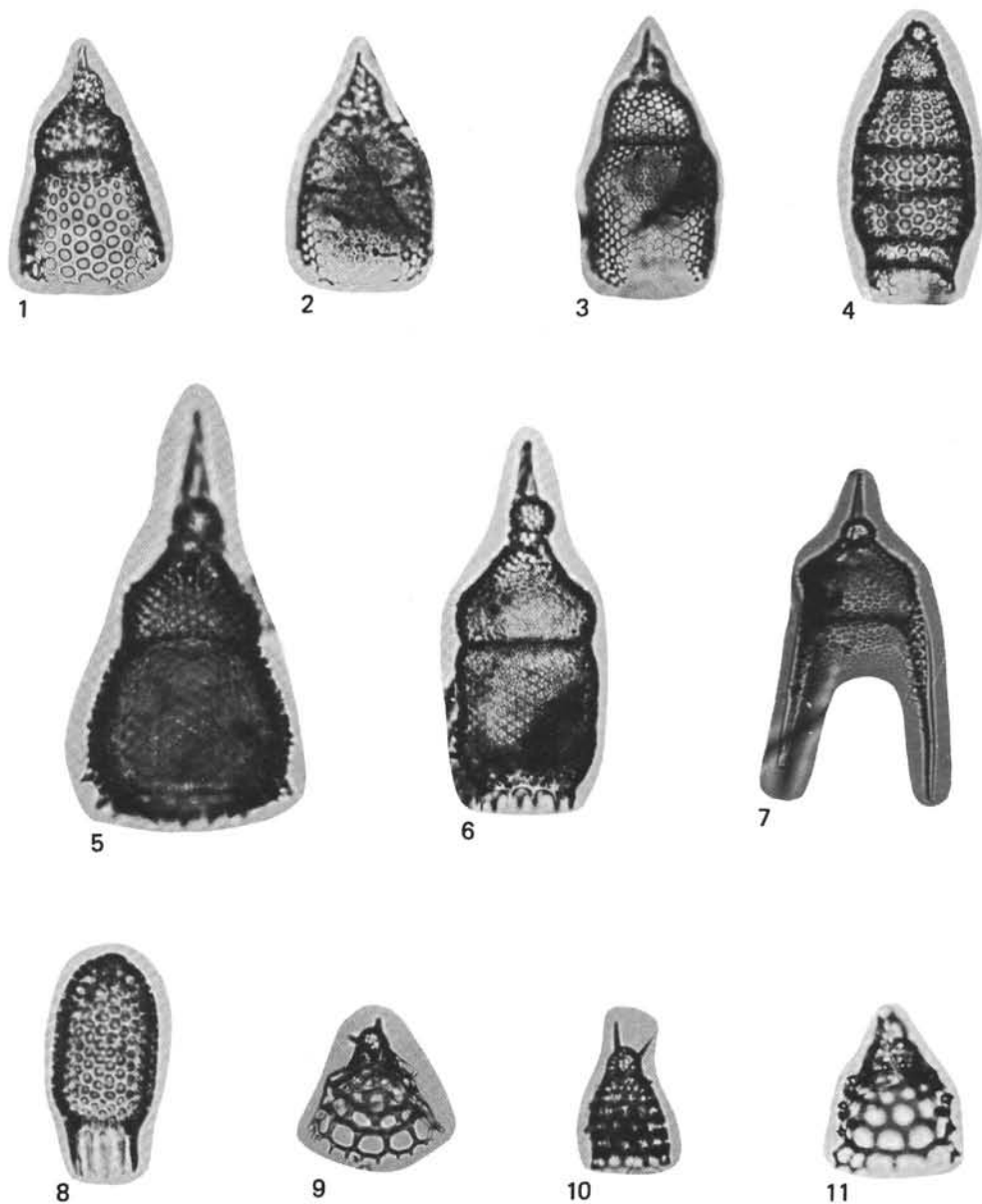


Plate 5. Radiolarians. (Scale bar equals 100  $\mu$ m.) 1. *Pterocorys minythorax* (Nigrini), Sample 474-2-1, 89-91 cm. 2. *Pterocorys zancleus* (Müller), Sample 475-3-4, 20-22 cm. 3. *Pterocorys zancleus* (Müller), Sample 474-2-3, 7-9 cm. 4. *Eucyrtidium calvertense* Martin, Sample 474-2-3, 7-9 cm. 5. *Theocorythium vetulum* Nigrini, Sample 476-7, CC. 6. *Theocorythium trachelium* (Ehrenberg), Sample 475-1, CC. 7. *Pterocanium praetextum* (Ehrenberg), Sample 474-2-3, 7-9 cm. 8. *Carpocanistrum* sp., Sample 475-1-2, 44-46 cm. 9. *Theocalyptra davisiana* (Ehrenberg), Sample 474-2-4, 7-9 cm. 10. *Theocalyptra davisiana* (Ehrenberg)(?), Sample 476-3-3, 46-48 cm. 11. *Theocalyptra davisiana* (Ehrenberg), Sample 474-2-3, 7-9 cm.