

32. CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY AND PALEOCLIMATIC INDICES FOR THE LATE QUATERNARY, DEEP SEA DRILLING PROJECT LEG 96, GULF OF MEXICO¹

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ABSTRACT

Sediments from holes drilled at 11 sites in the northern Gulf of Mexico during Deep Sea Drilling Project Leg 96 were analyzed for calcareous nannofossil content. All sediments recovered are Holocene and late Pleistocene in age and are within the *Emiliania huxleyi* Zone. The datum level represented by the lowest stratigraphic occurrence of dominant *E. huxleyi* occurs at two sites (Sites 615 and 619) and can be dated at approximately 84,000 yr. ago at Site 619.

Reworked Cretaceous nannofossils are generally common or abundant and dominate the floral assemblages of the late Wisconsin glacial sediments. When present, indigenous late Quaternary species are rare or few in abundance. Slight increases in the contemporaneous Quaternary component of the floral assemblages can be documented by the use of a calculated *in situ*/reworked ratio. This ratio, based on the relative abundances of the indigenous Quaternary taxa and reworked taxa, shows potential both for local correlations between drill sites and for correlation with glacio-eustatic fluctuations during the late Pleistocene.

INTRODUCTION

Leg 96 of the Deep Sea Drilling Project (DSDP) was the third cruise of the *Glomar Challenger* into the Gulf of Mexico, but was the first cruise dedicated to a region of rapid late Pleistocene deposition south of the Mississippi River distributary system. A total of 308 hydraulic piston and rotary cores containing 1302 m of sediment were taken at 11 sites, 9 on the Mississippi Fan and 2 to the northwest in intraslope basins (Fig. 1).

The majority of the sediment is late Pleistocene in age; only a thin veneer (<50 cm) of overlying Holocene sediment was recovered at most sites. The horizon marked by the first evolutionary occurrence of *Emiliania huxleyi* was not penetrated at any of the sites.

As will be demonstrated in this chapter, the typical floral sequence observed in the Mississippi Fan sediments can be characterized by four units. The Holocene (Ericson Zone Z; Ericson and Wollin, 1968) is represented by less than 1 m of a marly foraminiferal ooze or calcareous clay containing abundant, fair to moderately preserved calcareous nannofossils. Few reworked Cretaceous nannofossils are present in this zone. The underlying terrigenous sand and mud sequences deposited during the late Wisconsin glacial (Ericson Zone Y) are dominated by common to abundant, solution-resistant Late Cretaceous nannofossils. Few indigenous Pleistocene nannofossils are present in this interval. The middle Wisconsin interstadial (Ericson Zone X) contains abundant, moderately preserved Pleistocene species and exhibits a significant reduction in reworked Cretaceous forms. The cool, early Wisconsin glacial stage (Ericson Zone W)

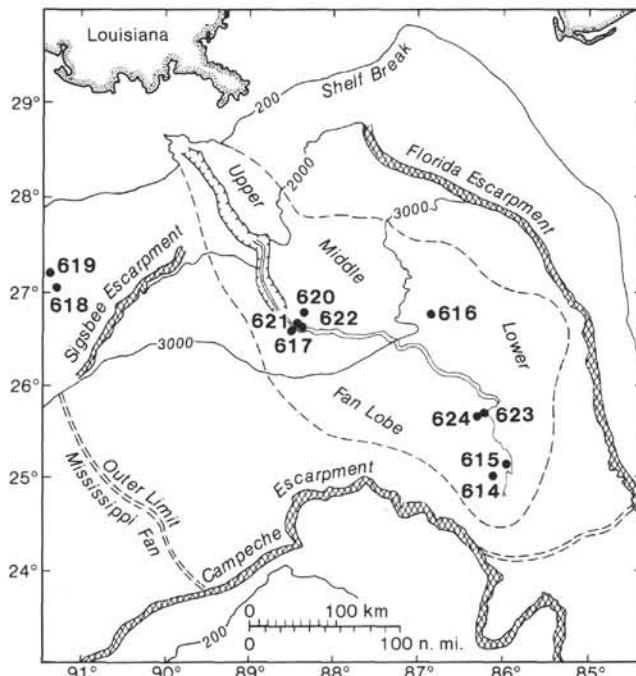


Figure 1. Location map of sites drilled on DSDP Leg 96.

consists of terrigenous clastic sediments dominated by reworked Cretaceous nannofossils. Rare, reworked early Pleistocene, Pliocene, and Miocene species are found throughout all units but are most prevalent in the warmer water intervals.

A similar four-unit floral sequence is encountered in the intraslope basin sites. Greater abundances of indigenous Pleistocene species, however, are present in the Wisconsin glacial intervals.

A number of previous studies have been made of the calcareous nannofossils from Gulf of Mexico sediments.

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Among these are the studies by Bukry and Bramlette (1969) and Hay (1969), which give a preliminary survey of the species recovered from sites drilled during DSDP Leg 1. Although not detailed, the thick Pleistocene section recovered in Hole 1 of DSDP Leg 1 shows a striking resemblance to the sediments recovered on DSDP Leg 96. Ellis et al. (1972) presented a detailed study of the calcareous nannofossils recovered from Site 3 of DSDP Leg 1 in the western Gulf of Mexico. Studies of the nannofossils encountered in DSDP Leg 10 sediments have been made by Hay (1973), Bukry (1973) and by Smith (in Smith and Beard, 1973). The same biostratigraphic framework for the Pleistocene of the Gulf of Mexico used by Smith and Beard in 1973 is presented again in Beard et al. (1982). A calcareous nannofossil biostratigraphy based on a more conventional framework of late Neogene earth history is given by Chen (1978) and Gartner et al. (1983) in their studies of two holes (E67-134 and E67-135) drilled by Shell Oil Company in the De Soto Canyon region of the northeast Gulf of Mexico. The nannofossil floral assemblages from Gulf of Mexico bottom-sediment samples and cores are well documented by Sachs (1970), Sachs and Skinner (1973), and Pierce and Hart (1979).

Paleontologic interpretations of Leg 96 sediments are complicated by extensive dilution from terrigenous detritus resulting from the high sedimentation rates of up to 12 m/1,000 yr. that are characteristic of the Mississippi Fan (site chapters, this volume; Wetzel and Kohl, this volume). A majority of the section is dominated by reworked Cretaceous taxa. Bukry (1974) showed that the abundance and type of reworked assemblages can be used to interpret the geologic history of somewhat similar sediment sequences in the Black Sea. Everett (1982) demonstrated that estimated counts of indigenous and reworked nannofossil species can be used as an aid in the subsurface interpretation of both ancient and recent Mississippi River deltas. A possible correlation between high sedimentation rates and high amounts of reworked nannofossil species was reported by Ellis and Lohman (1979) in the eastern Mediterranean DSDP Sites 375 and 376.

The main purpose of this chapter is to document the abundance and biostratigraphic distribution of the calcareous nannofossils. No attempt is made to present a complete taxonomic study.

METHODS AND PROCEDURES

Smear slides of 780 processed samples were examined for the calcareous nannofossil content with a light microscope in both cross-polarized and partial-polarized light. In order to maintain a semiquantitative control for the abundance of nannofossils recorded, the samples were processed in the following manner: 500 mg of unprocessed sample were placed in a 2-fluid-dram bottle and 70 ml of water were added. The sample was ground with a metal stirring rod, shaken, and allowed to settle for 1.5 min. Nannofossil solution was then extracted with a capillary tube placed approximately 1.5 cm below the surface of the solution. Slides were mounted employing commonly accepted techniques using 22-mm square cover slips.

Relative abundance estimates were based on the method introduced by Hay for DSDP Leg 4 (1970). Letters on the range charts (Tables 1-11) denote nannofossil abundances and are keyed to the $^{10}\log$ of the number of specimens of a particular taxon likely to be observed in any one field of view of the microscope at a magnification of $\times 1250$. These and the corresponding logs are designated as follows:

H = Highly abundant, +2 (more than 100 specimens per field of view)

V = Very abundant, +1 (more than 10 specimens per field of view)

A = Abundant, O (1 to 10 specimens per field of view)

C = Common, -1 (1 specimen per 2 to 10 fields of view)

F = Few, -2 (1 specimen per 11 to 100 fields of view)

R = Rare, -3 (1 specimen per 101 to 1000 fields of view)

Tabulations of reworked Cenozoic species and reworked Mesozoic species recorded on the range charts are also included employing the abundance criteria shown above. No attempt was made to subdivide the reworked Mesozoic taxa into a biozonational scheme.

The *in situ*/reworked ratio was calculated by dividing the relative abundance of indigenous taxa by the relative abundance of the reworked taxa. This ratio has theoretical limits from zero (all reworked taxa) to infinity (all indigenous taxa). One advantage of the *in situ*/reworked ratio is that it normalizes for differences in the density of the nannofossil solution dispersed on the cover slip. Although the relative abundances of the species will vary, the *in situ*/reworked ratio remains constant for both thick and thin nannofossil density dispersions. A control test made on 20 slides of varying densities processed from the same sample confirms this relationship. The total abundances observed in these slides ranged from less than 1 specimen per field of view to over 100 specimens per field of view. Calculations of the *in situ*/reworked ratio, however, consistently yielded values of approximately 100.

In calculating the *in situ*/reworked ratio, the relative abundance estimates of very rare indigenous Pleistocene taxa were made on the average number of specimens likely to be observed in one traverse across a 22-mm cover slip. For more abundant samples, relative abundances based on the number of specimens likely to be observed in any one field of view were converted to abundance per one traverse by multiplying by a factor of 150 (the approximate number of fields of view per traverse at a magnification of $\times 1250$). Although the precision of the ratios would be greatly improved by using data based on direct counts, the method outlined above is adequate to document the variations of the relative abundances of indigenous and reworked taxa observed during routine microscope examinations.

Selected samples near the datum level thought to represent deepest stratigraphic occurrence of dominant *Emiliania huxleyi* and the total depths of the holes were studied by scanning electron microscopy (SEM) to confirm the abundance and presence of *E. huxleyi*. Samples processed for SEM photography were concentrated and cleaned with a centrifuge settling technique.

The overall preservation of all samples examined is considered to be moderate. A majority of the specimens are slightly etched with the fine structures missing. No diagnostic morphological changes are visible under light microscopy.

CALCAREOUS NANNOFOSSIL ZONATION

The Gulf Coast and Caribbean-Antillean Zonation for the latest Pliocene through Recent of Boudreux and Hay (1967) was used to make zonal age assignments. Modifications made to this zonation by Gartner and Emiliani (1976) were employed in the sites in which the datum marked by the lowest dominant occurrence of *Emiliania huxleyi* could be identified. Gartner and Emiliani subdivided the *E. huxleyi* Zone of Boudreux and Hay into two zones: (1) the *E. huxleyi* Zone defined from the lowest occurrence of *E. huxleyi* to the lowest level of dominant *E. huxleyi* and (2) the *E. huxleyi* Acme Zone defined as the interval of dominant *E. huxleyi* (Fig. 2).

The identification of *E. huxleyi* specimens under the light microscope is provisional because of their small size and the difficulty in distinguishing between them and a similar species, *Gephyrocapsa protohuxleyi*. These factors, in conjunction with the rarity of indigenous Pleistocene species in most of the late Wisconsin glacial sediments, necessitates the use of the broader zonation of Boudreux and Hay at most sites.

Age	Paleo-magnetism	Glacial stages	Oxygen-isotope stages	Ericson zones	Tephro-chronology (ash beds)	Microfossil datums	Nannofossil zones	
							Gartner and Emiliani (1976)	Boudreux and Hay (1967)
Holocene	Brunhes normal	Postglacial	1	Z		<i>Globorotalia inflata</i> (12,000)		
Pleistocene			2					
		Late glacial	3	Y	Y6 (75,000)	<i>Emiliana huxleyi</i> acme zone		
			4		Y8 (84,000)	<i>Emiliana huxleyi</i> dominance (85,000)		
			a			<i>Globorotalia flexuosa</i> (85,000)		
			b					
			c					
		Wisconsin	d	X	X2 (110,000)			
			e					
		Inter-stadial						
		Early glacial	6	W	W1 (140,000)	<i>Emiliana huxleyi</i> zone		
		Sangamon	7	V				
			8			<i>Emiliana huxleyi</i> (270,000)		

Figure 2. Late Quaternary zonation for the Gulf of Mexico. (From Emiliani, 1966, 1971; Boudreux and Hay, 1967; Ericson and Wollin, 1968; Blow, 1969; Kennett and Huddleston, 1972; Rögl and Bolli, 1973; Gartner and Emiliani, 1976; Thierstein et al., 1977; Ledbetter, 1984; Williams, 1984.) The dates shown in tephrochronology and microfossil datums columns are in years ago.

In tropical and subtropical waters, the event marked by the reversal in dominance of *G. caribbeanica* and *E. huxleyi* has been associated with oxygen-isotope Substages 5b-5a at approximately 85,000 yr. ago by Thierstein et al. (1977). Williams (1984) also correlated the top of the Ericson Zone X, marked by the last occurrence of the planktonic foraminifer *Globorotalia flexuosa*, with isotope Substage 5b. The Y8 ash of Kennett and Huddleston (1972) occurs just above this event and has been dated at 84,000 yr. ago in association with Substage 5b in Gulf of Mexico sediments (Ledbetter, 1984). These correlations are shown in Figure 2.

SITE SUMMARIES

Leg 96 investigated the Mississippi Fan and two inslope basinal depressions between diapirically intruded salt masses. The Mississippi Fan is a broad, thick arcuate deposit of displaced Pleistocene sediments on the abyssal floor of the Gulf of Mexico. The youngest fan lobe has a large sinuous central channel that decreases in width and depth in the lower fan regions (introductory chapter, this volume). Although the site discussions are grouped by depositional province, each site is considered separately. Distribution charts are presented for all sites (Tables 1-11).

Middle Fan Sites

The middle fan region of the present Mississippi Fan is generally located between water depths of 2100 and 3100 m. The four sites cored in this area (Sites 617, 620, 621, and 622) provide a transit from the western levee, across the channel, and onto an overbank region (Fig. 1). In this region, located approximately 300 km from the present Mississippi River Delta, the channel is 1.5 to 2.5 km wide and bounded by prominent ridges or levees (Middle Fan Introduction and Summary, this volume).

Site 621

Site 621 ($26^{\circ}43.86'N$, $88^{\circ}29.76'W$; water depth, 2485 m) was hydraulic piston cored to a sub-bottom depth of 214.8 m to investigate an outer convex meander bend (thalweg) of the present channel. The recovered channel-fill sediments show a fining-upward trend from a basal gravel through sand, silt-mud laminates, into thick-bedded muds. The upper 50 m consist primarily of homogeneous muds (Site 621 chapter, this volume).

The 0.25 m of a marly foraminiferal ooze recovered at the top of Core 621-1 was the only interval containing abundant, moderately well-preserved Quaternary nannofossils (Table 1). Most common of these are *Emiliana huxleyi*, *Crenalithus doronicoides*, and *Gephyrocapsa* spp. (small). Reworked Cretaceous nannofossils are very rare.

In the sediments below this upper Holocene ooze, the nannofossil assemblages are dominated by common reworked Cretaceous species. Pleistocene taxa, when present, are rare. SEM identification of small coccoliths in Core 621-33 as *E. huxleyi* dictates that all cores recovered at this site be placed in the *E. huxleyi* Zone.

The values of the *in situ*/reworked ratio generally increase uphole from low values of 0.01 to a high of 100 in the Holocene veneer (Fig. 3). This suggests that sedimentation rates at this site were decreasing throughout the late Wisconsin glacial stage.

Site 622

Site 622 ($26^{\circ}41.41'N$, $88^{\circ}28.82'W$; water depth, 2495 m) was hydraulic piston cored in the inner concave meander bend ("point bar") of the present channel. The total depth of penetration was 208.0 m sub-bottom. The lithologic sequence recovered, with the exception of a thicker, sandy basal section, is similar to that at Site 621 (Site 622 chapter, this volume).

Table 1. Distribution of calcareous nannofossils, Site 621.

Table 1 (continued).

Core-Section (interval in cm)	Sub- bottom depth (m)	Braarudosphaera bigelowii	Ceratolithus cristatus	Crenalithus doronicoides s. ampl.	Coccolithus pelagicus	Cricolithus jonesii	Cyclococcolithus leptoporus	Discosphaera tubifera	Emiliania huxleyi	Gephyrocapsa caribbeana	Gephyrocapsa oceanica	Gephyrocapsa spp. (small)	Helicosphaera carteri	Helicosphaera wallichi	Pontosphaera discopora	Pontosphaera multipora	Pontosphaera spp.	Rhabdosphaera clavigera	Scapholithus fossilis	Syracosphaera histrica	Syracosphaera lamina s. ampl.	Syracosphaera nodosa	Syracosphaera pulchra	Syracosphaera spp.	Thoracosphaera heimii	Thoracosphaera saxea	Umbellosphaera irregularis	Umbellosphaera tenuis	Umbilicosphaera mirabilis	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
20-1, 40-41	128. 11	R	R		F	R	R	R									R	R						C	.15								
20-2, 40-41	129. 61		F R		F	R	R	R R								R R	R R		R	R			R C	.2									
21-1, 40-41	131. 31	R	R		F	R	R	R	R							R							C	.1									
21-2, 40-41	132. 81		F		F	R	R	R															C	.1									
22-1, 40-41	134. 11	R		F	R	R	R																F	.15									
22-2, 40-41	135. 61		F		F	R	R	R R														F	.15										
23-1, 15-16	137. 66	R		R		R		R														F	.05										
23-2, 15-16	139. 16			R R	R																	F	.1										
24-1, 40-41	147. 51	R		R		R										R						F	.1										
24-2, 40-41	149. 01		R		F F	R																C	.1										
25-1, 16-17	156. 87			R		R										R						F	.15										
25-2, 16-17	158. 37	R	R	R R																		C	.05										
26-1, 11-12	166. 42	R		R R	R R	R R	R R															C	.05										
26-2, 16-17	167. 97		R		R R R	R R	R R	R														C	.075										
27-1, 16-17	176. 05	R	R		R R	R R	R R	R R	R								R		R			C	.05										
27-2, 18-19	177. 54	R	R	R	R R R R R R	R R R R R R	R R R R R R	R R R R R R	R								R		R			C	.05										
28-1, 30-31	185. 81		F R		R R	R R	R R	R R	R R	R R	R R	R R				R R	R R	R R	R R	R F		.2											
30-1, 47-48	199. 68		F		R R R R R R	R R R R R R	R R R R R R	R R R R R R	R R R R R R							R R	R R	R R	R R	A		.05											
31-1, 80-81	201. 01	R	R	R	R	R	R	R													A	.05											
32-1, 40-41	201. 71	R	R	R R	R R	R R	R R	R R								R		R		R	A	.03											
33-1, 100-101	212. 31			R R	R R	R R	R R	R R								R					A	.01											

Note: For abundance, A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$).

Nannofossils common in the marly foraminiferal ooze in the top few centimeters of Section 622-1-1 include most taxa that are typical of Holocene assemblages in the Gulf of Mexico (Pierce and Hart, 1979) (Table 2). Below this ooze, the floral assemblage is dominated by reworked Cretaceous species. *Gephyrocapsa oceanica*, *G. caribbeana*, and *Emiliania huxleyi* are the most frequently occurring Pleistocene nannofossils.

The *in situ*/reworked ratio curve for this site is very similar to Site 621 (Fig. 3). Slight increases in the ratio to values of 0.3 to 0.4 in Cores 622-12 through 16 (105–135 m sub-bottom) suggest a minor temporary decrease in the sedimentation rate for this interval. The mud and clay sediments above this zone probably represent deposition during the waning phase of the late Wisconsin glacial.

Site 617

Site 617 ($26^{\circ}41.93'N$, $88^{\circ}31.67'W$; water depth 2478 m) was hydraulic piston cored in a ridge and swale topography immediately adjacent to the channel and penetrated 191.2 m of overbank deposits. The vertical sequence of muds with silt laminations initially increases

in grain size, then exhibits a fining-upward trend into homogeneous mud (Site 617 chapter, this volume).

The surficial foraminiferal ooze was not recovered in Hole 617. Hole 617A, however, did contain a well-developed ooze, containing abundant, well-preserved calcareous nannofossils (Table 3). Reworked Cretaceous nannofossils are the major floral constituent in the remainder of Holes 617 and 617A.

Values of the *in situ*/reworked ratio remain low throughout the samples examined, suggesting a rapid sedimentation rate for all the fine-grained sediments deposited at this site. Calculations of the sedimentation rate based on seismic projections to seismic Horizon "30" (introductory chapter, this volume) indicate a rate in excess of 10 m/1000 yr. for the late Wisconsin glacial period. Only one very slight increase in the abundance of Pleistocene nannofossils could be identified. This was found in the muddy interval sampled by Core 617-15 (132.5–135.5 m sub-bottom).

Site 620

Site 620 ($26^{\circ}50.12'N$, $88^{\circ}22.25'W$; water depth, 2612 m), located in overbank deposits about 18 km from

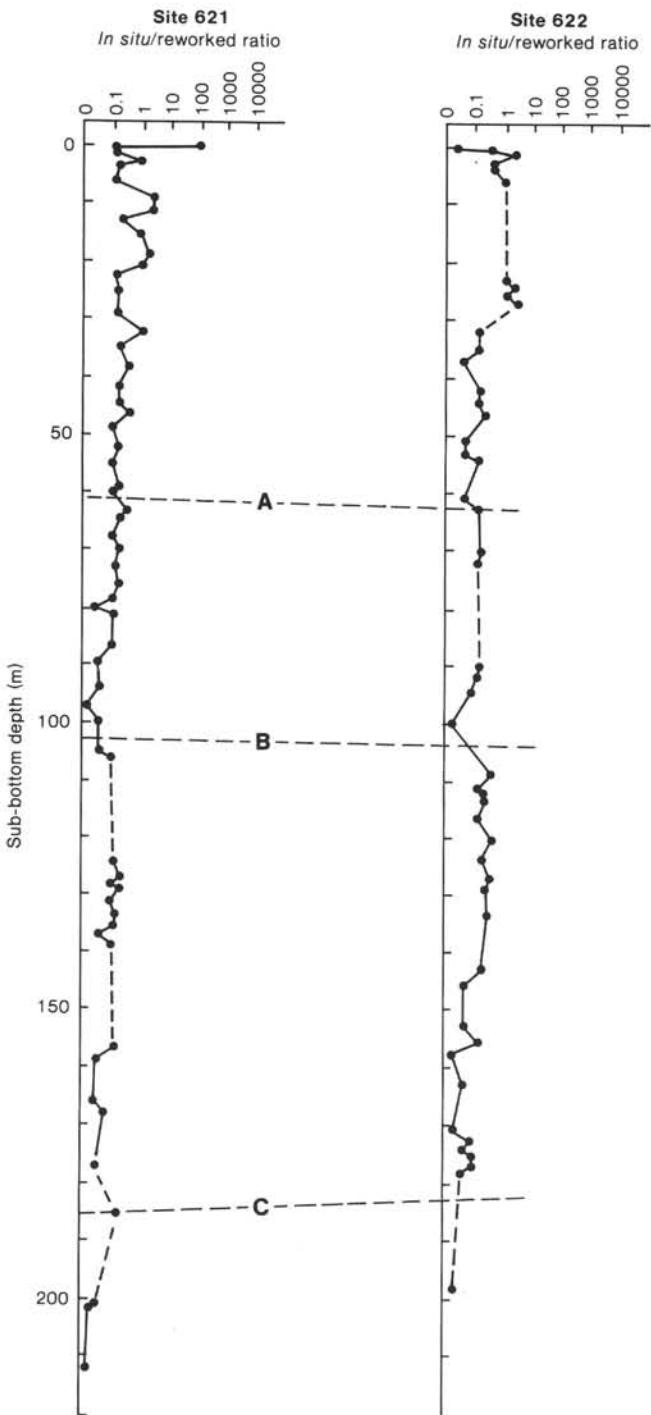


Figure 3. Correlation of the *in situ*/reworked ratio curves for Sites 621 and 622. Lines A, B, and C indicate probable correlations between sites.

the channel-levee complex, was rotary cored with relatively poor recovery to a depth of 422.7 m. These overbank deposits consist primarily of fine grained clay and silty clay arranged in alternating coarsening-upward sequences (Site 620 chapter, this volume). The overall clay percentage at this site is estimated at approximately 73%.

All cores recovered from this site are interpreted to be in the *Emiliania huxleyi* Zone (Table 4). Well-preserved Quaternary nannofossils are abundant only in the thin

Holocene marly calcareous ooze. Below this ooze, the nannofossil assemblages are dominated by reworked Cretaceous species. Pleistocene nannofossils are rare, resulting in low *in situ*/reworked ratios.

Slight increases in the abundance of indigenous Pleistocene taxa are present. The most significant increase occurs near the bottom of the hole, between Cores 620-40 and 620-45 (365–410 m sub-bottom). This increase coincides with the projection of seismic Reflector “20” at a sub-bottom depth of 371 m (introductory chapter, this volume). This interval, in which the *in situ*/reworked ratios may reach 10, could represent a reduction of the sedimentation rate in response to a warmer pulse during oxygen-isotope Stage 3.

Lower Fan Sites

On the lower fan, the wide single channel-levee complex narrows to less than 500 m and changes to a less sinuous and channel-switching mode. Two sites (623 and 624) were drilled on the margins of this lower fan channel and two sites (615 and 614) were positioned near the distal end of the channel terminations (introductory chapter, this volume; Fig. 1).

Site 623

Site 623 ($25^{\circ}46.09'N$, $86^{\circ}13.84'W$; water depth, 3188 m) was hydraulic piston cored to a total penetration of 202.2 m to evaluate the switching nature of the channel in the lower fan region. The recovered sediments consist of both fining-upward channel fill sequences and coarsening-upward overbank intervals consisting of thin sands, silts, and muds (Site 623 chapter, this volume).

The warm-water Holocene planktonic ooze unit is absent. Core 623-1 probably did not sample the sediment/water interface. Pleistocene calcareous nannofossils are generally few in number (Table 5). The floral assemblages are dominated by moderately preserved reworked Cretaceous nannofossils. Increases in the abundance of indigenous Pleistocene taxa occur sporadically. One slight increase is noted in the muddy interval of Cores 621-13 through 621-14 (112–125 m sub-bottom). The *in situ*/reworked ratio values are generally low throughout all recovered sediments.

Site 624

Site 624 ($25^{\circ}45.24'N$, $86^{\circ}16.63'W$; water depth, 3198 m), located 4.8 km from the channel, was cored with the advanced piston corer/extended core barrel (APC/XCB) (Explanatory Notes, this volume) to a depth of 199.9 m (Hole 624A). All cores recovered at this hole are assigned to the *Emiliania huxleyi* Zone (Table 6). Except for the presence of a thin (6 cm) Holocene marly foraminiferal ooze, the nature of the sediment recovered is very similar to Site 623 (Site 624 chapter, this volume). The marly ooze in the top of Core 624-1 contains a moderately well-preserved nannofossil assemblage dominated by *E. huxleyi*; *in situ*/reworked ratios can reach 6,000 (Table 6).

As at Site 623, the interval below the Holocene ooze is dominated by reworked Cretaceous species. The generally low *in situ*/reworked ratios are a function of the

Table 2. Distribution of calcareous nannofossils, Site 622.

Note: For abundance, V = very abundant, 10–100 specimens/field; A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of x1250).

Table 3. Distribution of calcareous nannofossils, Site 617.

Note: For abundance, A = abundant, 1–10 specimens/field, C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of x1250).

Table 4. Distribution of calcareous nannofossils, Site 620.

Core-Section (interval in cm)	Sub-bottom depth (m)	<i>Braarudosphaera bigelovii</i>	<i>Ceratolithus cristatus</i>	<i>Crenolithus doronicoides</i> s. ampl.	<i>Cricolithus jonesii</i>	<i>Cyclococcolithus leptoporus</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa caribbeanica</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa</i> spp. (small)	<i>Heilocapsaera carteri</i>	<i>Pontosphaera multipora</i>	<i>Rhabdosphaera clavigera</i>	<i>Scapholithus fossilis</i>	<i>Syracosphaera lamina</i> s. ampl.	<i>Syracosphaera pulchra</i>	<i>Syracosphaera</i> spp.	<i>Thoracosphaera heimii</i>	<i>Thoracosphaera saxea</i>	<i>Umbellosphaera tenuis</i>	<i>Umbellosphaera mirabilis</i>	<i>Umbellosphaera irregularis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
1-1, 21-22	.22	R	F	F	F	C	F	F	R	F	F	R	R	F	R				R	F	F			8.		
1-2, 43-44	1. 94	F	R	F	F								R	R											C	1
2-1, 39-40	3. 40	R		F	F			R					R	R											A	.05
2-3, 39-40	6. 40			R		R	R																		A	.01
2-5, 39-40	9. 40	F		F	F			R																	A	.05
3-1, 40-41	13. 01	R		R	R																				A	.01
3-3, 40-41	16. 01	R	R		R														R	C					C	.01
4-2, 40-41	24. 11	R	R		R	R	R											R	R	C					C	.05
4-3, 40-41	25. 61				R	R	R											R	C						C	.01
5-1, 110-111	32. 91	R		R																					A	.025
5-3, 40-41	33. 71	R			R								R												A	.025
6-1, 40-41	41. 81			R	R																				A	.01
6-3, 40-41	44. 81	R		R		R	R																		C	.02
7-1, 40-41	51. 41	R	R		F	R	R												R	C					C	.03
7-3, 40-41	54. 41	F		F	R	R	R																		C	.05
8-1, 40-41	61. 01			R	R																				A	.01
9-2, 40-41	72. 11	R		R																					A	.01
9-5, 40-41	76. 61	F		R	R	R																			C	.05
9-6, 40-41	78. 11			R	R	R																			A	.025
10-1, 40-41	80. 21	R		R	R	R																			C	.025
10-3, 40-41	83. 21	R		R	R																				A	.025
11-1, 40-41	89. 81	R		R	R	R												R	A						A	.025
12-1, 110-111	99. 71	F		R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	A	A				C	.01	
12-4, 40-41	103. 51	F	R	R	F	R	R	R					R												C	1
12-6, 40-41	106. 51	R		F	R	R																			A	.05
13-1, 40-41	108. 21	R		R																					A	.01
13-3, 40-41	111. 21	R		R	R												R	R						A	.02	
14-1, 40-41	117. 41	R		F	R	R	R																	A	.025	
14-3, 40-41	120. 41	F		F	R	R	R																	A	.05	
15-2, 40-41	128. 51			R	R																			A	.025	
15-4, 40-41	131. 51	R			R	R							R											A	.02	
15-5, 40-41	133. 01	R		R	R	R							R											A	.02	
16-1, 40-41	136. 61			F	R	R																		C	.05	
16-2, 40-41	138. 11			R	R	R											R							A	.025	
16-4, 40-41	141. 11	R			R	R																		A	.02	
17-1, 40-41	146. 21			R		R																		C	.075	
17-3, 40-41	149. 21	R	F	R	F	R	R	R				R					R	C						C	.1	
17-6, 40-41	153. 71	R		R	R	R																		A	.02	
18-1, 40-41	156. 51	R		R	R								R											C	.05	
18-2, 40-41	157. 31	R			R																			A	.02	
18-5, 40-41	161. 81	R		R	R	R																		A	.02	
19-1, 40-41	165. 41			R		R																		A	.02	
20-1, 40-41	175. 01	R		F	R	R																		C	.05	
20-4, 40-41	179. 51				R	R																		A	.02	
20-5, 40-41	181. 01	F		F	R	R											R		C					C	.05	
21-1, 40-41	184. 41	R		F	R	R							R							C				C	1	
21-2, 40-41	185. 91	F		F	R	R	R																	C	.15	
22-1, 40-41	193. 81	F		F	R	R																		A	.05	
22-2, 40-41	195. 31	R		F	R	R							R											A	.05	
22-2, 40-41	204. 71	R		R																				A	.02	
22-3, 40-41	206. 21		R		R	R																		C	.02	

Table 4 (continued).

Core-Section (interval in cm)	Sub- bottom depth (m)	<i>Braarudosphaera bigelowii</i>	<i>Ceratolithus cristatus</i>	<i>Crientalithus doronicoides s. ampli</i>	<i>Coccolithus pelagicus</i>	<i>Cricolithus jonesii</i>	<i>Cyclococcolithus leptoporus</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa caribbeonica</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa spp. (small)</i>	<i>Helicosphaera carteri</i>	<i>Helicosphaera wallichi</i>	<i>Pontosphaera multipora</i>	<i>Rhabdosphaera spp.</i>	<i>Scapholithus fossilis</i>	<i>Syracospheara lamina s. ampli</i>	<i>Syracospheara pulchra</i>	<i>Thoracosphaera hemimili</i>	<i>Thoracosphaera sarev</i>	<i>Umbellosphaera irregularis</i>	<i>Umbellosphaera tenuis</i>	<i>Umbilicosphaera mirabilis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone		
24-1, 40-41	212.71							R	R																				
24-6, 40-41	220.21	R	R																									.02	
25-1, 40-41	222.21	R	R	R					R																			.02	
26-2, 40-41	233.21	R			R																							.01	
26-4, 40-41	236.21	R	R																									.01	
27-1, 12-13	241.03	R	R																	R								.01	
28-1, 33-34	250.84			R	R	R																					.01		
28-2, 40-41	252.41	R	R																									C	
28-6, 40-41	258.41	F	F	R	R	R																						.025	
29-1, 40-41	260.51	R	F	R	R																R	F						.075	
30-1, 42-43	270.13	R	R																			A						.02	
30-3, 42-43	273.13			R	R	R														R		C						.02	
30-6, 42-43	277.63	R	R	R																		C						.02	
31-1, 41-42	279.72		R	R	R	R																C						.025	
31-2, 41-42	281.22	R	R	R															R			C						.025	
31-3, 41-42	282.72	R	F	R	R	R																A						.05	
32-1, 46-47	289.37	R	R																			F						.05	
32-2, 40-41	290.87	F	F	R	R														R			C						.05	
32-3, 40-41	292.37		R	R	R	R																C						.02	
32-5, 40-41	295.37	R	R	R	R																	C						.025	
33-1, 44-47	298.97		R	R	R																	A						.02	
33-2, 46-47	300.47	R	F	R																		C						.05	
33-3, 46-47	301.97	F	F	R	R	R																A						.025	
33-5, 46-47	304.97	R	R	R	R	R													R		A						.05		
33-6, 46-47	306.47	F	F	R	R														R	R	A						.05		
34-1, 46-47	308.56	F	F	R	R	R															C						.05		
35-1, 46-47	318.17		R	R	R																C						.025		
35-2, 46-47	319.67	R	R	R	R	R															A						.02		
35-5, 46-47	324.17	R	R	R	R	R															A						.025		
36-1, 46-47	327.77	F	F	R	R	R															A						.05		
36-2, 46-47	329.27	F	F	R	R	R															A						.025		
37-2, 46-47	338.87	F	F	R	R	R															A						.05		
37-5, 46-47	343.37	R	R	R	R																A						.025		
37-6, 46-47	344.87	F	F	R	R																A						.04		
38-3, 46-47	349.97	R	R	R	R	R															C						.025		
38-5, 46-47	352.97	R	R	F	R	R	R											R			C						.075		
40-1, 46-47	365.97	F	F	R	R	R	R														F						2		
40-2, 46-47	367.47	F	F	F	R	R	R											R	R		F						1.		
40-4, 46-47	370.47	R	F	R	F																F						.15		
40-5, 46-47	371.97	F	F	F	R	R	R											R	R		F						2		
41-1, 46-47	375.47	R	F	C	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F						2.5		
41-6, 46-47	382.97	R	F	R	R	R															F						5		
42-1, 46-47	384.97	F	R	C	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F						3.		
42-2, 46-47	386.47	F	R	R	C	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F						5.	
43-1, 12-13	394.14	R	R	F	R	R	C	F	F	R	R	R	R	R	R	R	R	R	R	R	F	R	F				10.		
44-1, 15-16	403.66	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F				2.		
44-5, 46-47	409.97	F	R	C	F	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F						3.	
45-1, 44-45	413.55	F	R	F	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F						1.	
45-2, 44-45	415.05	R	R	R	R	R															F						25		

Note: For abundance, A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$).

Table 5. Distribution of calcareous nannofossils, Site 623.

Core-Section (interval in cm)	Sub- bottom depth (m)	Ceratolithus cristatus Crenalithus dononicoides s. ampl. Coccolithus pelagicus Cricolithus jonesii Cyclococcolithus leptoporus Discosphaera tubifera Emiliania huxleyi Gephyrocapsa caribbeonica Gephyrocapsa oceanica Gephyrocapsa spp. (small) Helicosphaera carteri Helicosphaera wallichi Pontiosphaera multipora Pontiosphaera japonica Pontiosphaera spp. Rhabdosphaera clavigera Scapholithus fossilis Syracospaera histrica Syracospaera lamina s. ampl. Syracospaera nodosa Syracospaera pulchra Syracospaera spp. Thoracosphaera helmi Thoracosphaera saxes Umbellosphaera irregularis Umbellosphaera tenuis Umbilicosphaera mirabilis Reworked Cenozoic spp. Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
1-1, 40-41	.41	R	R R R R R R	
1-1, 110-111	1.11	R	F R R R R R	
1-2, 40-41	1.91	R	R R R R R R	
1-3, 40-41	3.41	R	R R R R R R	
1-4, 40-41	4.91	R	R R R R R R	
2-1, 40-41	7.01	R	F R R R R R	
2-3, 40-41	10.01		R R R R R R	
2-4, 40-41	11.51	F	F R R R R R	
2-6, 40-41	14.51	R R	F R R R R R	
3-1, 40-41	16.61	R R	R R R R R R	
3-3, 40-41	19.61	R	R R R R R R	
3-5, 40-41	22.61	R	F R R R R R	
4-1, 40-41	26.21	R R	R R R R R R	
4-3, 40-41	29.21	R F R	F F R R R R	
4-5, 40-41	32.21	F	R R R R R R	
5-1, 40-41	35.81	F	F R R R R R	
5-3, 40-41	38.81	R	R R R R R R	
5-5, 40-41	41.81		R R R R R R	
6-1, 40-41	45.81	R	R R R R R R	
6-3, 40-41	48.41	R	F R R R R R	
6-5, 40-41	51.41	F	R R R R R R	
7-1, 40-41	55.01		F R R R R R	
7-2, 40-41	56.51	R R	F R R R R R	
7-3, 40-41	58.01	R R R	F R R R R R	
8-1, 52-53	64.73		F R R R R R	
8-2, 78-79	66.49		R R R R R R	
8-3, 50-51	67.71	R	R R R R R R	
9-2, 49-50	75.80	R	R R R R R R	
9-3, 49-50	77.30		R R R R R R	
9-4, 49-50	78.80	R	R R R R R R	
10-1, 55-56	83.96		R R R R R R	
10-3, 60-61	87.01	R	R R R R R R	
10-4, 10-11	88.01	R	R R R R R R	
11-1, 26-27	93.26		F R R R R R R	
11-3, 40-41	96.41		R R R R R R	
11-4, 28-29	97.79	R	R R R R R R	
12-1, 45-46	103.06	R R R R R C R F R R R R R R R R	R R R R R R	1.
12-3, 29-30	105.89	R F	F R R R R R R R R R R R R	R R R R R R
12-4, 21-22	107.31	F	R R R R R R R R R R R R	R R R R R R
13-1, 26-27	112.26	F	C R R R R R R R R R R R R	R R R R R R
14-1, 41-42	121.82	C R	C F R R R R R R R R R R R R	R R R R A
14-2, 41-42	123.32	F	C R R R R R R R R R R R R	R R C
14-3, 48-49	124.89	F	C R R R R R R R R R R R R	R R A
15-1, 26-27	131.06	R	F R R R R R R R R R R R R	A
16-1, 40-41	140.51	R	R R R R R R R R R R R R	C
16-2, 40-41	142.01	R	F R R R R R R R R R R R R	C
16-3, 40-41	143.51	R	R R R R R R R R R R R R	C
17-1, 40-41	149.81	F	F R R R R R R R R R R R R	A
17-2, 40-41	151.31	R	F R R R R R R R R R R R R	C

Note: For abundance, A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$).

Table 6. Distribution of calcareous nannofossils, Site 624.

Note: For abundance, V = very abundant, 10–100 specimens/field; A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$).

high deposition rates in this region. A sedimentation rate of 2.1 cm/1000 yr. is calculated for the Holocene; a rate of nearly 7.5 m/1000 yr. for the late Wisconsin glacial is based on projections to seismic Horizon "30" (introductory chapter, this volume).

Site 615

Site 615 ($25^{\circ}13.34'N$, $85^{\circ}59.53'W$; water depth, 3284 m) is located approximately 40 km south of Sites 623 and 624. It is positioned adjacent to the channel on

the distal part of the lower fan. This site, the deepest drilled on Leg 96, was cored to a depth of 523.2 m sub-bottom. Thick sands and silt-mud sequences as old as the early Wisconsin glacial (Ericson Zone W) were recovered (Site 615 chapter, this volume). The Wisconsin interstadial (Ericson Zone X) is represented by a 29-m-thick carbonate sequence, thought to have originated on the West Florida platform (Brooks et al., this volume).

The upper 17 cm of sediment recovered in Section 615-1-1 consists of a marly foraminiferal ooze containing abundant, moderately well-preserved calcareous nannofossils typical of pelagic Holocene sediments in the Gulf of Mexico (Table 7). *Emiliana huxleyi* is the dominant taxon.

The interval below this ooze, from Samples 615-1-1, 32 cm through 615-48,CC, is a late Wisconsin glacial interbedded sand-mud sequence in which reworked Cretaceous nannofossils are the major component. Only very slight to slight increases in the indigenous Pleistocene flora are encountered in this interval. The increase found in Core 615-18 (153 m sub-bottom) may be correlative with the increase in the bottom sample of Hole 614A (shown in Fig. 4 as line B). Although rare, *E. huxleyi* is clearly the dominant Quaternary taxon, placing the entire upper interval from sea bottom through Sample 615-48,CC in the *E. huxleyi* Acme Zone of Gartner and Emiliani. SEM examinations of Samples 615-47,CC, 615-46,CC, 615-42-1, 3-4 cm, and other samples near the bottom of this interval confirm that within the indigenous component, *E. huxleyi* is dominant over *Gephyrocapsa* spp.

A calcareous nannofossil-foraminiferal ooze deposited during the middle Wisconsin interstadial occurs in Samples 615-48,CC through 615-51,CC. This interval appears to grade from a nannofossil ooze in Core 615-49 into a foraminiferal ooze in Core 615-51 and is terminated by a gravelly conglomerate in Sample 615-51,CC. Reworked Eocene to early Pleistocene taxa are common in the flora in this interval, including important biostratigraphic marker species such as *Pseudoemiliania lacunosa*, *Cyclococcolithus macintyreai*, *Discoaster brouweri*, *D. pentaradiatus*, *Sphenolithus abies*, *Reticulofenestra pseudoumbilica*, *D. quinqueramus*, and *D. barbadiensis*. Within the highly abundant late Pleistocene flora in this interval, *Gephyrocapsa* spp. appears dominant over *E. huxleyi*, placing these and remaining sediments in the *E. huxleyi* Zone of Gartner and Emiliani. Although *E. huxleyi* is abundant, SEM studies of samples from this carbonate ooze show that *E. huxleyi* is a relatively minor component of the Pleistocene assemblage. *Gephyrocapsa* spp. is clearly the dominant taxa. The last occurrence of the planktonic foraminifer *Globorotalia flexuosa* also occurs in this interval (Site 615 chapter, this volume). This gives secondary support for the placement of the boundary between the *E. huxleyi* Zone and the *E. huxleyi* Acme Zone in Sample 615-48,CC. The lowest dominant occurrence of *E. huxleyi* has been shown to occur at 85,000 yr. ago in tropical and subtropical waters (Thierstein et al., 1977). At Site 619, this event has been dated at approximately 84,000 yr. ago (see Site 619, this chapter).

Below the conglomerate in Sample 615-51,CC, a pelagic foraminiferal ooze containing an abundant late Pleistocene assemblage was recovered in Section 615-52-1. This ooze contains relatively few reworked Pliocene taxa and appears to have been deposited by hemipelagic sedimentation. Seismic Horizon "30" (introductory chapter, this volume) is thought to be associated with this carbonate unit. The regional distribution of Horizon "30" may be the result of widespread hemipelagic sedimentation in response to the rise of sea level during the middle Wisconsin interstadial.

A dark brown mud containing a sparse nannofossil assemblage is encountered in Sample 615-52,CC. This interval is again dominated by reworked Cretaceous taxa indicating a return to terrigenous sedimentation.

Site 614

Site 614 ($25^{\circ}04.08'N$, $86^{\circ}08.21'W$; water depth, 3314 m) was drilled 23 km southwest of Site 615 in an area near the termination of the lower fan channel. Holes 614 and 614A together penetrated to a total depth of 150.3 m sub-bottom. The sand, silt, and mud recovered are similar to the sediments recovered in the upper portions of Site 615 (Site 614 chapter, this volume) and are interpreted to be in the *Emiliana huxleyi* Acme Zone of Gartner and Emiliani.

The marly foraminiferal ooze recovered in Section 614-1-1 is the only interval that contains abundant Quaternary nannofossils (Table 8). The dominant taxon in this assemblage is *E. huxleyi*.

Reworked Cretaceous nannofossils are the major constituent of the remainder of Holes 614 and 614A. Because of the rapid sedimentation rate (calculated at 6.4 m/1000 yr. based on correlations with seismic Horizon "30"), only rare Pleistocene nannofossils are present in the samples. A slight increase in the indigenous Pleistocene taxa is observed in Sample 614A-13,CC (Fig. 4).

Fan Margin Site

One site was selected on the fan margin to core the feature identified as a slump by Walker and Massingill (1970; Fan Margin Introduction and Summary, this volume).

Site 616

Site 616 ($26^{\circ}48.67'N$, $86^{\circ}52.83'W$; water depth 2999 m) was cored to a total sub-bottom depth of 371 m. This site is located 55 km northeast of the midfan channel (Fig. 1). Muds, sands, and fining-upward sand-silt-mud sequences were recovered. The upper 96 m consist of a mud and silt unit displaying dips of up to 65° that is interpreted to be a series of discrete slides (Site 616 chapter, this volume). Excluding this interval, sedimentation rates of the late Wisconsin glacial sediments based on correlations with seismic Horizon "30" are as high as 5.6 m/1000 yr.

This rapid deposition rate extensively diluted the indigenous Quaternary nannofossil assemblage with reworked Cretaceous taxa (Table 9). The rarity of indigenous taxa makes the determination of the presence of an *Emiliana huxleyi*/*Gephyrocapsa* dominance reversal dif-

Table 7. Distribution of calcareous nannofossils, Site 615.

Table 7 (continued).

Core-Section (interval in cm)	Sub- bottom depth (m)	Acanthoica quattrospina Braarudosphaera bigelowii Ceratolithus cristatus Ceratolithus doronicoides s. ampl. Coccolithus pelagicus Cricolithus jonesii Cyclococcolithus leptoporus Discosphaera tubifera Emiliania huxleyi Gephyrocapsa caribeanica Gephyrocapsa oceanica Gephyrocapsa protohuxleyi Gephyrocapsa spp. (small) Hayaster perplexus Helicosphaera carteri Helicosphaera hyalina Helicosphaera wallacii Homozygosphera schilleri Homozygosphera wettsteinii Oolithus fragilis Pontosphaera discopora Pontosphaera multipora Pontosphaera scutellum Pontosphaera spp. Rhombosphaera clavigera Scapholithus fossilis Scyphosphaera abstenei Scyphosphaera pulcherrima Syracosphaera japonica Syracosphaera istrica Syracosphaera lamina s. ampl. Syrosphaera nodosa Syrosphaera pulchra Syrosphaera spp. Thracosphaera heimii Thracosphaera savea Umbilicosphaera irregularis Umbilicosphaera tenuis Umbilicosphaera mirabilis Reworked Cenozoic spp. Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
27-2, 42-43	240.13			F
28-1, 22-23	247.93	R	R	C
29-1, 39-40	257.60	R	R	A
29-3, 39-40	260.60	R	R	C
29-5, 39-40	263.60	R	R	.05
30-1, 18-19	266.89	R	R	F
32-1, 41-42	286.12	R	R	.01
32-2, 7-8	287.28	R	R	C
33-2, 9-10	306.30	R	R	.05
34-1, 44-45	314.65	R	R	.01
34-3, 49-50	317.70	R	R	A
35, CC	323.80	R	R	.05
36-1, 46-47	333.67	R	R	A
38-1, 59-60	352.80	R	R	A
38-2, 53-54	354.24	F	R	C
40-1, 82-83	372.03	F	R	C
42-1, 3-4	399.72	F	R	.05
43-1, 6-7	409.27	R	R	F
43-4, 70-71	414.41	R	R	F
43-6, 75-76	417.46	R	R	.05
44-1, 8-9	418.79	R	R	C
44, CC	419.00	R	R	.05
45, CC	420.72			R
46, CC	438.05	F	R	R
47-1, 86-88	457.57	F	R	F
47-2, 9-10	458.30	F	R	.15
47, CC	466.20	F	R	10.
48, CC	485.20	R	A	3,600.
49-1, 42-43	485.63	R	A	5,400.
49-2, 42-43	487.13	R	A	2,900.
49-3, 42-43	488.63	R	V	3,600.
49-4, 42-43	490.13	R	V	6,000.
49-5, 42-43	491.63	R	A	3,000.
49-6, 42-43	493.13	R	A	4,000.
50-1, 42-43	495.13	R	A	3,600.
50-2, 42-43	496.63	R	A	5,400.
50-3, 42-43	498.13	R	A	4,800.
50-4, 42-43	499.63	R	A	6,000.
50-5, 42-43	501.13	R	A	6,000.
50-6, 42-43	502.63	R	A	6,000.
51-1, 41-42	504.62	A	C	6,000.
51-2, 41-42	506.12	R	A	6,000.
51-3, 41-42	507.62	R	A	6,000.
51-4, 41-42	509.12	A	C	6,000.
51-6, 41-42	510.62	R	A	6,000.
51, CC	513.20	R	A	10,000.
52-1, 40-41	514.11	R	F	10,000.
52-1, 105-106	514.76	F	A	9,000.
52-1, 117-118	514.88	R	A	10,000.
52, CC	515.24	R	R	.5

Note: For abundance, V = very abundant, 10–100 specimens/field; A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$). The depth of Sample, 48,CC has been adjusted to the bottom of the cored interval, as the shipboard scientists think that it came from that depth (Site 615 chapter, this volume); standard DSDP convention would place it at 475.7 m (Explanatory Notes, this volume).

ficult. Therefore, all samples are placed in the *E. huxleyi* Zone of Boudreault and Hay.

A slight increase in Pleistocene species is found in Cores 616-9 through 616-10. This increase corresponds to an increase in planktonic and benthic foraminifers and may represent a period of slower sedimentation.

Intraslope Basin Sites

Salt diapirism on the Louisiana continental slope is responsible for the formation of a hummocky bottom topography. The depressions between the salt diapirs are often filled with thick sequences of sediments. Two types

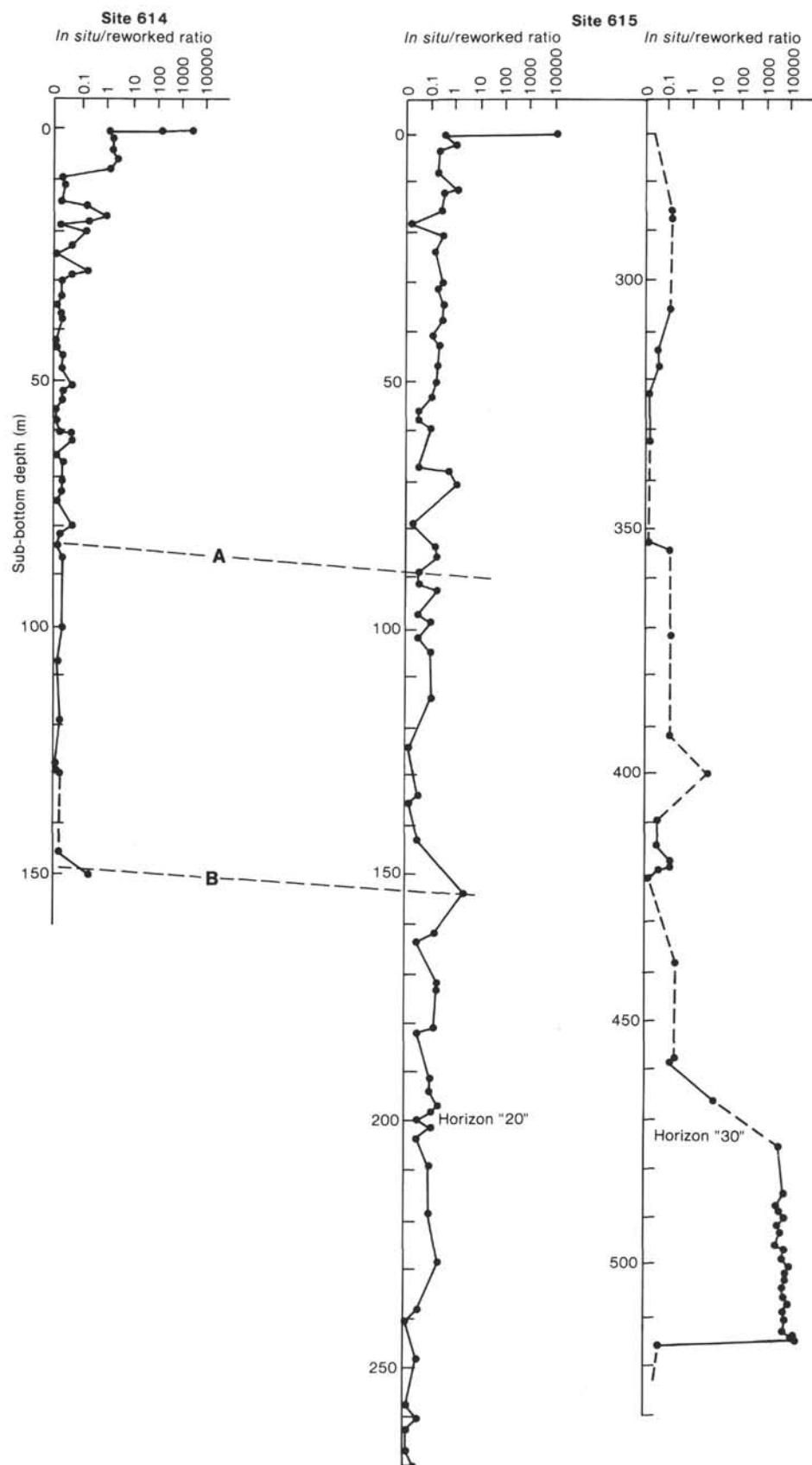


Figure 4. Correlation of the *in situ*/reworked ratio curves for Sites 614 and 615. Lines A and B indicate probable correlations between sites. The placements of regional seismic Horizons "20" and "30" (introductory chapter, this volume) are shown for Site 615.

Table 8. Distribution of calcareous nannofossils, Site 614.

Core-Section (interval in cm)	Sub-bottom depth (m)																					<i>In situ/reworked ratio</i>		Zone or subzone				
		<i>Braarudosphaera bigelovii</i>	<i>Ceratolithus cristatus</i>	<i>Coccolithus pelagicus</i>	<i>Cricocollithus jonesii</i>	<i>Cyclococcolithus leptoporus</i>	<i>Discosphaera tubifera</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa caribbeana</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa</i> spp. (small)	<i>Helicosphaera carteri</i>	<i>Helicosphaera wallachii</i>	<i>Oolithus fragilis</i>	<i>Pontosphaera discopora</i>	<i>Pontosphaera multipora</i>	<i>Rhabdosphaera clavigera</i>	<i>Scapholithus fossilis</i>	<i>Scyphosphaera apsteinii</i>	<i>Syracosphaera nodosa</i>	<i>Syracosphaera pulchra</i>	<i>Syracosphaera</i> spp.	<i>Thaumasphaera lamina</i> s. ampl.	<i>Umbellosphaera irregularis</i>	<i>Umbellosphaera tenuis</i>	<i>Umbilicosphaera mirabilis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.
Hole 614																												
1-1, 8-9	.09	F	C	F	C	R	V	C	F	A	C	F	R	R	R	R	C	R	F	F	R	R	R	R	R	4100.		
1-1, 27-28	.28	R	F	R	R	C		F		R							R		R		R	R	R	R	R	300.		
1-1, 47-48	.48	R						R		R							R		R		R	R	R	R	R	1.		
1-2, 47-48	1. 98	R	R					R	R	R							R	R	R	R	R	R	R	R	R	2.		
1-4, 47-48	4. 98	F		R	F	R	R	R									R	R	R	R	R	R	R	R	R	2.		
1-5, 47-48	6. 48	R	F	R	R	C	R	R	F	R	R					R	F	R	R	R	R	R	R	R	R	4.		
1-6, 47-48	7. 98	F	R		C	R	R	F	R	R						R	R	R	R	R	R	R	R	R	2.			
2-1, 47-48	9. 88	R						R																			A	
2-2, 39-40	11. 30							R	R	R																	C	
2-4, 47-48	14. 38	R						R	R	R																	C	
2-5, 4-5	15. 45	R	R		F	R	R	R																			F	
2-6, 47-48	17. 38	R		R	F	R	R	R									R	R	R	R	R	R	R	R	R	1.		
2-7, 24-25	18. 65	F			R	R	R	R										R		R	R	R	R	R	R	C		
3-1, 47-48	19. 17	R			R	R	R	R									R				R	R	R	R	R	0.01		
3-2, 47-48	20. 67	F	R		R	R	R	R									R	R	R	R	R	R	R	R	R	0.02		
3-4, 47-48	23. 67	R			R	R	R	R																			F	
3-5, 47-48	25. 17				R	R	R	R																			0.05	
3-6, 47-48	26. 67	R	R		R	R	R	R									R	R	R	R	R	R	R	R	R	0.06		
4-2, 20-21	28. 70	F	R		F	R	R	R													R	R	R	R	R	R	0.02	
5-1, 76-79	29. 34	R			R	R	R	R																			F	
5-2, 47-48	30. 98				R	R	R	R																			R	
5-4, 47-48	33. 98	R			R	R	R	R																			R	
5-5, 47-48	35. 48																											0
Hole 614A																												
1-1, 17-18	37. 18	R	R		R	R	R	R																			F	
1-2, 47-48	38. 98	R			R	R	R	R																			R	
1-4, 47-48	41. 98																											R
1-6, 47-48	44. 98																											R
2-1, 47-48	45. 48	R																										R
2-3, 47-48	48. 48	R			R	R	R	R																			F	
2-5, 47-48	51. 48	R			R	R	R	R																			F	
2-6, 47-48	52. 98	R			R	R	R	R									R										C	
3-1, 47-51	54. 79	R			R	R	R	R																			F	
3-2, 47-51	56. 29																											R
3-4, 47-51	59. 29																											R
3-5, 27-31	60. 59	R			R	R	R	R																			F	
4-1, 47-48	61. 28																R											R
4-2, 47-48	62. 78	R			R	R	R	R										R		R	R	R	R	R	R	R	0.05	
4-4, 47-48	65. 78																											R
4-5, 26-27	67. 06	R																										F
5-1, 47-48	70. 68	R			R	R	R	R										R		R	R	R	R	R	R	C		
5-3, 47-48	73. 68	R	R		R	R	R	R										R		R	R	R	R	R	R	F		
5-4, 47-48	75. 18																											R
6-1, 47-48	80. 07	R			R	R	R	R									R										C	
6-2, 47-48	81. 57	R			R	R	R	R										R									C	
6-4, 47-48	84. 57																											R
6-5, 47-48	86. 07																R	R	R	R	R	R	R	R	R	R	0.05	
7-1, 75-76	89. 76	F			R	R	R	R									R										R	
8-1, 22-23	98. 72	F			R	R	R	R										R									A	
8-2, 45-46	100. 46	R			F	R	F	R																			A	
9-1, 58-59	108. 59																											A
10-1, 39-40	118. 20	R			R	R	R	R																			A	
11-1, 39-40	127. 39				R	R	R	R									R										0	
11-2, 43-45	128. 94	R			R	R	R	R									R										A	
13, CC	150. 30	F	R		F	R	R	R									R	R	R	R	R	R	R	R	R	2		

Note: For abundance, V = very abundant, 10-100 specimens/field; A = abundant, 1-10 specimens/field; C = common, 1 specimen/2-10 fields; F = few, 1 specimen/11-100 fields; R = rare, 1 specimen/101-1000 fields (when viewed at a magnification of x 1250).

Emiliania huxleyi
acme

Table 9. Distribution of calcareous nannofossils, Site 616.

Core-Section (interval in cm)	Sub- bottom depth (m)	<i>Braarudosphaera bigelovii</i>	<i>Ceratolithus cristatus</i>	<i>Coccolithus pelagicus</i>	<i>Cricolithus jonesii</i>	<i>Cyclococcolithus leptoporus</i>	<i>Discosphaera tubifera</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa caribbeana</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa spp. (small)</i>	<i>Helicosphaera carteri</i>	<i>Helicosphaera wallichi</i>	<i>Oolithus fragilis</i>	<i>Pontosphaera discopora</i>	<i>Pontosphaera multipora</i>	<i>Pontosphaera japonica</i>	<i>Rhabdosphaera clavigera</i>	<i>Scapholithus fossilis</i>	<i>Scyphosphaera spp.</i>	<i>Syracosphaera lamina s. ampl.</i>	<i>Syracosphaera histrica</i>	<i>Syracosphaera nodosa</i>	<i>Syracosphaera pulchra</i>	<i>Syracosphaera spp.</i>	<i>Thoracosphaera heimii</i>	<i>Thoracosphaera saxesenii</i>	<i>Umbellospahaera irregularis</i>	<i>Umbellospahaera tenuis</i>	<i>Umbilicosphaera mirabilis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone				
1-1, 0-2	.02	R	C	R	R	F	R	A	R	R	F	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	500.						
1-1, 15-17	.17																																	Barren				
1-1, 20-22	.22																																	Barren				
1-1, 41-42	.42	R	F		R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
1-2, 41-42	1.92	F	R	R	F	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	2.						
1-3, 41-42	3.42	F	R	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
1-4, 41-42	4.92	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.2						
2-1, 42-43	6.53	R	R	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
2-3, 42-43	9.53	R	R	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.6						
2-5, 42-43	12.53	R			R		R																														.05	
3-1, 42-43	16.03	R			R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
3-2, 42-43	17.53	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
3-4, 42-43	20.53	F			F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.1						
3-6, 42-43	23.53	R			F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
4-1, 42-43	25.53	F			C	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
4-3, 27-28	28.38	F	R	R	R	C	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	5.						
4-5, 42-43	31.53	F			F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	3.						
4-6, 42-43	33.03	R	F	R	R	C		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	5.						
5-1, 33-34	34.93	F		R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
5-3, 33-34	37.93	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.1						
5-5, 33-34	40.93	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
5-6, 33-34	42.44	F			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
6-1, 69-70	44.90	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
6-3, 69-70	47.90	R			F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
6-5, 69-70	50.90	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
6, CC	52.32	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
7-1, 65-66	54.46	F			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
7-3, 65-66	57.46				R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
7-5, 65-66	60.46	R	R		F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
8-1, 81-82	64.22	R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
8-3, 81-82	67.22	R	R	R	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
9-1, 36-37	73.37	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
9-3, 36-37	76.37	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
9, CC	78.20	F	R	R	C	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	5.						
10-1, 47-48	83.07	F			F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	2.						
10-3, 47-48	86.07	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	1.						
11-1, 63-64	92.84	R	F		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
11-3, 63-64	95.84	R	R	R	F	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
13-1, 47-48	114.07	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
13, CC	115.02	F			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
14, CC	123.22	F			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
15, CC	132.82	R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.075						
16-1, 81-82	143.22	R			R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
16-3, 81-82	146.22	F			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
16, CC	149.02	R	R		F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
17-1, 69-70	152.70	F	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.05						
17-3, 69-70	155.70	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						
18-1, 98-99	162.59	R			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	.01						

Table 9 (continued).

Core-Section (interval in cm)	Sub- bottom depth (m)	<i>Braarudosphaera bigelovii</i>	<i>Ceratolithus cristatus</i>	<i>Crenalithus doronicoides</i> s. ampl.	<i>Coccolithus pelagicus</i>	<i>Cyclococcolithus leptoporus</i>	<i>Discosphaera tubifera</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa</i> spp. (small)	<i>Helicosphaera carteri</i>	<i>Helicosphaera wallichii</i>	<i>Oolithus fragilis</i>	<i>Pontosphaera discopora</i>	<i>Pontosphaera multipora</i>	<i>Pontosphaera japonica</i>	<i>Rhabdosphaera clavigera</i>	<i>Scapholithus fossilis</i>	<i>Scyphosphaera</i> spp.	<i>Syracosphaera histrica</i>	<i>Syracosphaera lamina</i> s. ampl.	<i>Syracosphaera nodosa</i>	<i>Syracosphaera pulchra</i>	<i>Syracosphaera</i> spp.	<i>Thoracosphaera hemisphaera</i>	<i>Umbelliosphaera saeva</i>	<i>Umbelliosphaera irregularis</i>	<i>Umbilicosphaera lenius</i>	<i>Umbilicosphaera mirabilis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
18-2, 72-73	163.82		R			R R R R																									.05		
19,CC	171.22	F				C R F R R																									.25		
20-1, 6-7	180.77	R				R R R	R										R														.1		
20,CC	181.02	R					R R																									.1	
21-1, 36-37	190.42	R R				R R R R R																									.15		
21-3, 36-37	191.92	R				R R R	R										R		R	R R	C									.01			
22,CC	209.25	R				R R	R																								.01		
23-1, 36-37	228.92	R				R R R	R																								.01		
23,CC	230.10	R				R R R											R														.01		
24-1, 37-38	247.87	R R R				R R R R R										R			R R R R C											.05			
24,CC	249.80					R R																									R	.1	
25,CC	267.02	F				R R R R R R																								C	.1		
26-1, 48-49	286.59	R				R R R R	R																							C	.05		
26,CC	287.22	R				R R	R																							A	.01		
27,CC	295.50	R				R	R																							C	.01		
28-1, 55-56	305.85	R				R	R																							A	.01		
28,CC	308.50	R				R R R	R												R		R	C								.05			
29,CC	314.98	R R				R R R	R									R			R R R	C									.08				
30-1, 81-82	325.12	F				R R R	R												R		A									.01			
30-3, 81-82	328.12	R				R	R R																							C	.05		
30-5, 81-82	331.12	R				R R R	R																							A	.01		
30,CC	333.70	R				R R R	R											R		C									.01				
32-1, 71-73	343.82	R				R R R	R R																						C	.01			
32-3, 71-73	346.82	R				R	R																						C	.01			
32-5, 71-73	349.82	F				R R R	R R									R		R	R R C									.05					
32,CC	352.38	R				R R R	R R									R													C	.01			
33-1, 30-31	352.71	R				R R R	R											R		C									.01				
33-3, 30-31	355.71	R				R										R			A										.01				
33,CC	356.90	R				R R R	R R R									R			R C									C	.01				
34-1, 66-67	362.37	R				R R R R R	R																						C	.01			
34-4, 66-67	366.87	R				R R R R R	R												R A										.01				
34-5, 66-67	368.37	R				R R R R R	R									R			A										.01				
34,CC	368.50	R				R R R R R	R												R A										.01				

Note: For abundance, A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of $\times 1250$).

of these intraslope basins were drilled during Leg 96 at Sites 618 and 619 (Intraslope Basin Introduction and Summary, this volume).

Site 618

Site 618 ($27^{\circ}00.68'N$, $91^{\circ}15.73'W$; water depth 2422 m), located in the Orca Basin, was hydraulic piston cored to a depth of 92.5 m sub-bottom. The diapiric walls of this interdomal basin rise up to 700 m above the basin floor, which is covered by a 200-m-thick layer of anoxic, hypersaline brine. Anoxic, dark-black clays alternate with gray clays to a depth of 41 m sub-bottom.

Reworked Pliocene nannofossils are common in most samples (Table 10). *Discoaster pentaradiatus*, *D. brouweri*, and *Sphenolithus abies* occur most often. Miocene and Eocene species show sporadic occurrences and include *D. quinqueramus*, *D. bollii*, and *D. barbadiensis*. The presence of *Emiliania huxleyi* in all samples, however, places all the sediments recovered at this site in the *E. huxleyi* Zone of Boudreux and Hay.

Carbonate clasts averaging 0.5 mm in size are found in washed foraminifer Samples 618-4-4, 120–126 cm, 618-7,CC, and 618A-3,CC (Plate 4, Fig. 1). These clasts contain common to abundant, moderately preserved nan-

Table 10. Distribution of calcareous nannofossils, Site 618.

Core-Section (Interval in cm)	Sub-bottom depth (m)	<i>Braarudosphaera bigelovii</i>	<i>Ceratolithus cristatus</i>	<i>Coccolithus pelagicus</i>	<i>Cricolithus jonesii</i>	<i>Cyclococcocolithus leptoporus</i>	<i>Discosphaera tubifera</i>	<i>Emiliana huxleyi</i>	<i>Gephyrocapsa caribbeonica</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa spp. (small)</i>	<i>Helicosphaera cartieri</i>	<i>Helicosphaera wallachii</i>	<i>Oolithus fragilis</i>	<i>Pontosphaera discopora</i>	<i>Pontosphaera multipora</i>	<i>Pontosphaera scutellum</i>	<i>Pontosphaera laponica</i>	<i>Rhabdosphaera clavigera</i>	<i>Scapholithus fossili</i>	<i>Scyphosphaera apsteinii</i>	<i>Scyphosphaera pulcherrima</i>	<i>Syracosphaera histrica</i>	<i>Syracosphaera lamina s. ampli.</i>	<i>Syracosphaera nodosa</i>	<i>Syracosphaera pulchra</i>	<i>Syracosphaera spp.</i>	<i>Thoracosphaera heimii</i>	<i>Thoracosphaera saxea</i>	<i>Umbellosphaera irregularis</i>	<i>Umbellosphaera tenuis</i>	<i>Umbilicosphaera mirabilis</i>	Reworked Cenozoic spp.	Reworked Mesozoic spp.	In situ/reworked ratio	Zone or subzone
1-1. 0-1	.01	R C R F F F R	A A C A F F											R F R																		72.				
1-2. 120-121	2.71	R R C R F F F	A A C A F F R											R C F																		80.				
1-3. 115-116	4.16	R R C R F F F R	A A C A F F											R C F																	40.					
1-4. 105-106	5.56	R C R F F F	A C C C C F											R C F																	35.					
1-5. 40-41	6.41	R R C R F F F R	V C C C A F F											R C R																	167.					
1,CC	6.50	R R C F F F R	V C C C A F F R											R R C F																	96.					
2-1. 119-120	7.70	R C R F F F	A C C C A F R											R F R C																	84.					
2-2. 45-46	8.45	R C R F F F	A C C C A F R											R R F R C																	80.					
2-3. 119-120	10.70	R C C F F	A C C C A F R											R F R C																	140.					
2-4. 45-46	11.45	R R C R C F F	A C C C A F R											R C R C																	72.					
2-5. 45-46	12.95	R R F R F F	A C F A C F											F F																	70.					
2-6. 45-46	14.45	R F F F	A F F A F F R											F F																	96.					
2,CC	16.10	R R C R F F F	A C C C A F R											R C F																	72.					
3-1. 39-40	16.50	R C F R F C R	V V F F C C F											R R	R C C																200.					
3-2. 39-40	18.00	F F R F C	V F F C C C R R											R R C F R																	467.					
3-3. 39-40	19.50	R F F R F C	V C F C C C F R											R R C C R																	300.					
3-4. 39-40	21.00	R F R F F F	A C C C A F F R											C F																	120.					
3-5. 39-40	22.50	F F R F F F	A C C C C F R											C F																	70.					
3-6. 39-40	24.00	R F F R F F R	A C C C A C F											R F F																	33.					
3,CC	25.70	C F R F C F	V C C A C F F R											R R R C C																	533.					
4-1. 18-19	25.89	R F C R F F F	V A A A F F R											F F																	100.					
4-2. 18-19	27.39	R F F F F	A A C A F R											C F																	50.					
4-3. 18-19	28.89	R R F R F F R	V C C A C R											C F																	200.					
4-4. 18-19	30.39	R C F F	A A A A A C R											R F F																	24.					
4-6. 125-126	34.45	R C R F F F	A A A A A F R											R C F																	35.					
4,CC	35.30	R R C R F F F	A A A A A F F											R R	R C F																20.					
5-1. 9-10	35.40	R R C F F F	A A A C A F R											R C F																	62.5					
5-2. 9-10	36.90	F F F C F R	V C F A F R											R C C																	250.					
5-3. 9-10	38.40	R F F C F R	V C F A F R											R C C																	600.					
5-4. 9-10	39.96	R F F F F	A C F A F F											R C F																	36.					
5-6. 9-10	42.90	R R F F F F	A C F C F R											R F F																	28.					
5,CC	44.90	R R F F F R	A C F C R R R											F F																	20.					
6-1. 9-10	45.00	F R F F	A C F A F R											F F																	32.					
6-2. 9-10	46.50	R R F R F R	A A A A R											C F																	20.					
6-3. 9-10	48.00	C R F R	C A C A F R											R F F																	27.					
6-4. 9-10	49.50	R R F F F R	A C F A C F R											R F F	R																32.					
6,CC	50.90	R F F F	C C C C F											F F																	24.					
7-1. 9-10	51.00	F F R F C	C C F C R R											F F																	18.					
7-2. 9-10	52.50	R C F F R	A C C A F R											F F																	24.					
7-3. 9-10	54.00	R R C R F F	A C F A F R											R F F																	27.					
7-4. 9-10	55.50	R R F R F F R	A C F C F											R F F																	27.					
8-1. 30-31	57.21	F F R F R	R A C F C F											F R																	30.					
8-2. 30-31	58.71	R R R F F R	A C F C F											F F																	21.					
8-3. 30-31	60.21	R F R F F	A C F A F R											R R F F																	27.					
8-5. 30-31	63.21	R F C R R A	C F C F R											F F																	36.					
8,CC	63.50	R F R F F	F R R F											R																	04.					
9-1. 29-30	70.20	R F R C F	A C F A F R											F F																	48.					
9-2. 29-30	71.70	R R F R F F	A C F A F R											F F																	20.					
9,CC	74.40	R F R F F	A C C A F R											F F																	40.					
10-1. 66-67	75.07	F F F	C C F C F											R F F																	40.					
10-2. 48-49	76.40	R F R F F	A C F A F R											F F																	40.					
10-4. 66-67	79.57	R F F F R	C C F C F											R F F																	30.					
10,CC	81.00	R F F F	A A F A F R											F C																	40.					
11-1. 3-4	89.14	R F F F	C A F A F R											F F																	36.					
11-2. 3-4	90.60	R C F F	A A F V F											R F F																	30.					
11,CC	92.50	R R F F	A C F C F R											F F																	24.					

Note: For abundance, V = very abundant, 10–100 specimens/field; A = abundant, 1–10 specimens/field; C = common, 1 specimen/2–10 fields; F = few, 1 specimen/11–100 fields; R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of x1250).

nannofoils of early Pliocene age. The fairly diverse nannofoil flora includes *D. pentaradiatus*, *D. brouweri*, *S. abies*, *Reticulofenestra pseudoumbilica*, and *D. tamalis* and is assignable to Okada and Bukry's (1980) *R. pseudoumbilica* Zone (CN11), equivalent to NN15 of Martini (1971). The common co-occurrence of *Pseudomelania lacunosa*, *Gephyrocapsa oceanica*, and other gephyrocapsids in these clasts suggest that they may be early Pleistocene in age, with a common reworked Pliocene constituent.

The calculated values of the *in situ*/reworked ratio are considerably higher than in the Mississippi Fan (Fig. 5). The sawtooth pattern above 41 m is a result of the abundance of indigenous calcareous nannofoils in the black clay layers. The ratio in the remainder of the hole is relatively constant resulting from the overall large amount of reworking and mixing of sediments. Active diapirism and instability of the basin slope sediments

may be responsible for the considerable amount of reworking at this site.

Site 619

Site 619 ($27^{\circ}11.61'N$, $91^{\circ}24.54'W$; water depth, 2274 m) is located near the axis of Pigmy Basin, a blocked-canyon intraslope basin on the Louisiana middle continental slope. An almost complete clay sequence of Holocene and Wisconsin (Ericson Zones, Z, Y, and X) sediments was recovered to the total penetration depth of 208.7 m sub-bottom. Early Wisconsin glacial (Ericson Zone W) sediments may have been encountered in Section 619-18-2 through Sample 619-25,CC, but the biostratigraphic placement of this interval is still interpretive at the time of this writing (Kohl, this volume; Williams and Kohl, this volume).

Moderately well-preserved nannofoils are generally abundant throughout all samples at this site (Table 11). They are particularly abundant in the intervals from Sections 619-1-1 through 619-1-3 and from Cores 619-15 through 619-18. Reworked Cretaceous taxa are relatively rare, especially in comparison with their almost total domination of the assemblages in the Mississippi Fan sites. Samples from 619-1-1, 0-1 cm through 619-16-4, 24-25 cm are placed in the *E. huxleyi* Acme Zone of Gartner and Emiliani, while the interval from Samples 619-16,CC through 619-25,CC is placed in the *E. huxleyi* Zone. The boundary between these zones, marked by the reversal in dominance of *E. huxleyi* and *Gephyrocapsa* spp., is placed in Sample 619-16,CC. While *Gephyrocapsa* spp. is only marginally dominant in this sample, it is clearly dominant in Sample 619-17-1, 30-31 cm. In Sample 619-16-4, 24-25 cm, *E. huxleyi* is dominant.

In tropical and subtropical waters, the reversal in dominance of *E. huxleyi* and *Gephyrocapsa* spp. is associated with oxygen-isotope Substage 5b-5a, approximately 85,000 yr. ago (Thierstein et al., 1977). Anderson and Steinmetz (1983) reconfirm this relationship in the late Quaternary Caribbean Core P6304-4. Williams and Kohl (this volume) also place the deepest occurrence of dominant *E. huxleyi* in oxygen-isotope Substages 5b-5a.

A volcanic ash layer, also found in Sample 619-16,CC, has been identified as the Y8 ash of Kennett and Huddleston (1972) and is dated at 84,000 yr. ago (Ledbetter, this volume). The deepest dominant occurrence of *E. huxleyi* in Site 619 can therefore be most accurately dated by both stable isotope and tephrochronology as occurring in isotope Stage 5b-5a at 84,000 yr. ago.

DISCUSSION

The amount of terrigenous detrital material available for deposition in the deep water sites of Leg 96 is controlled by glacio-eustatic fluctuations. During interglacial high stands of sea level, much of the sediment is trapped on the broad continental shelf. The lowering of sea level during glacial periods is responsible for an increase in the amount of detritus because of increased stream gradients, sediment instability, and an overall narrowing of the continental shelf. A detailed discussion of the factors controlling this relationship can be found in

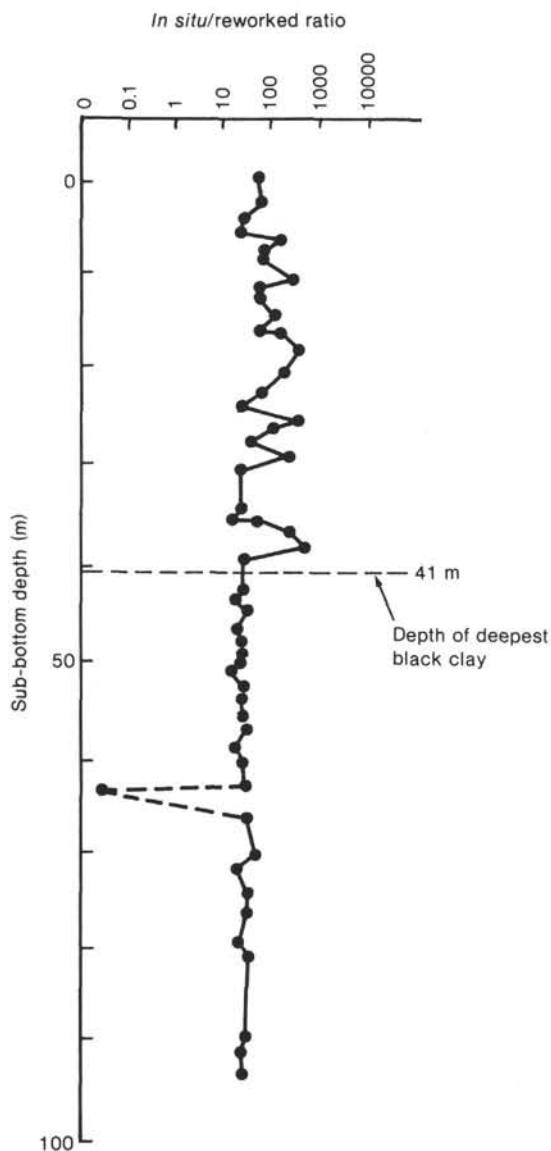


Figure 5. *In situ*/reworked ratio curve for Site 618.

Table 11. Distribution of calcareous nannofossils, Site 619.

Table 11 (continued).

Note: For abundance, H = highly abundant, more than 100 specimens/field, V = very abundant, 10–100 specimens/field. A = abundant, 1–10 specimens/field. C = common, 1 specimen/2–10 fields, F = few, 1 specimen/11–100 fields, R = rare, 1 specimen/101–1000 fields (when viewed at a magnification of x1250).

the study of Holes E67-134 and E67-135 on the northwest Florida shelf by Chen (1978) and Gartner et al. (1983). These authors correlated the amount of detrital sedimentation (by means of percent carbonate) with global oxygen-isotope curves. They also noted an increase in the abundance of reworked nannofossils during the glacial intervals.

A similar correlation can be made between the *in situ*/reworked ratio curve of Site 619 and the stable isotope curves of Emiliani (1972) and Anderson and Steinmetz (1981, 1983) (Fig. 6). The high peaks of this curve found in Core 619-1 (0–9 m sub-bottom) and Cores 619-15 through 619-18 (127–158 m sub-bottom) generally correlate with isotope Stages 1 and 5, respectively. The low values immediately below and above these peaks represent the cool Stages 2 and 4.

The *in situ*/reworked ratio curve of Site 619 can be related to the percentage curves of planktonic and benthic foraminifers (Kohl, this volume). In general, the higher percentages of warm planktonic foraminifers coincide with the higher values of the *in situ*/reworked ratio, indicating a relative decrease in the terrigenous component in the sediment during interglacial times.

The patterns of occurrences of reworked Cretaceous nannofossils differ from those of the reworked Cretaceous foraminifers. Whereas the Cretaceous foraminifers are restricted primarily to zones of coarser clastic deposition, the small reworked nannofossils can be abundant in any depositional facies with a fine textural component.

CONCLUSIONS

This preliminary study shows that the relative abundance of indigenous versus reworked taxa in transitional marine environments is a potential tool for both local and global correlations. More detailed quantitative investigation is needed to substantiate and refine these initial results.

1. The horizon marked by the first evolutionary occurrence of *Emiliania huxleyi* was not encountered at any of the Leg 96 sites.
 2. The datum level represented by the lowest stratigraphic occurrence of dominant *E. huxleyi* at Site 619 is dated by tephrochronology at 84,000 yr. ago.
 3. The relative abundances of indigenous Quaternary taxa and reworked taxa is controlled by glacio-eustatic fluctuations during the late Pleistocene. This relationship can be documented by use of calculated *in situ*/reworked ratios.
 4. Glacial coolings and interstadial warmings are responsible for the four-unit floral sequence observed in Leg 96 sediments. During cool glacial periods, large influxes of detrital, reworked Cretaceous nannofossils result in low *in situ*/reworked ratios. Reduced sedimentation rates during the warmer intervals yield a relative increase in the abundance of indigenous Quaternary taxa and higher *in situ*/reworked ratios.
 5. The depositional facies has no significant effect on the pattern of occurrences of reworked Cretaceous

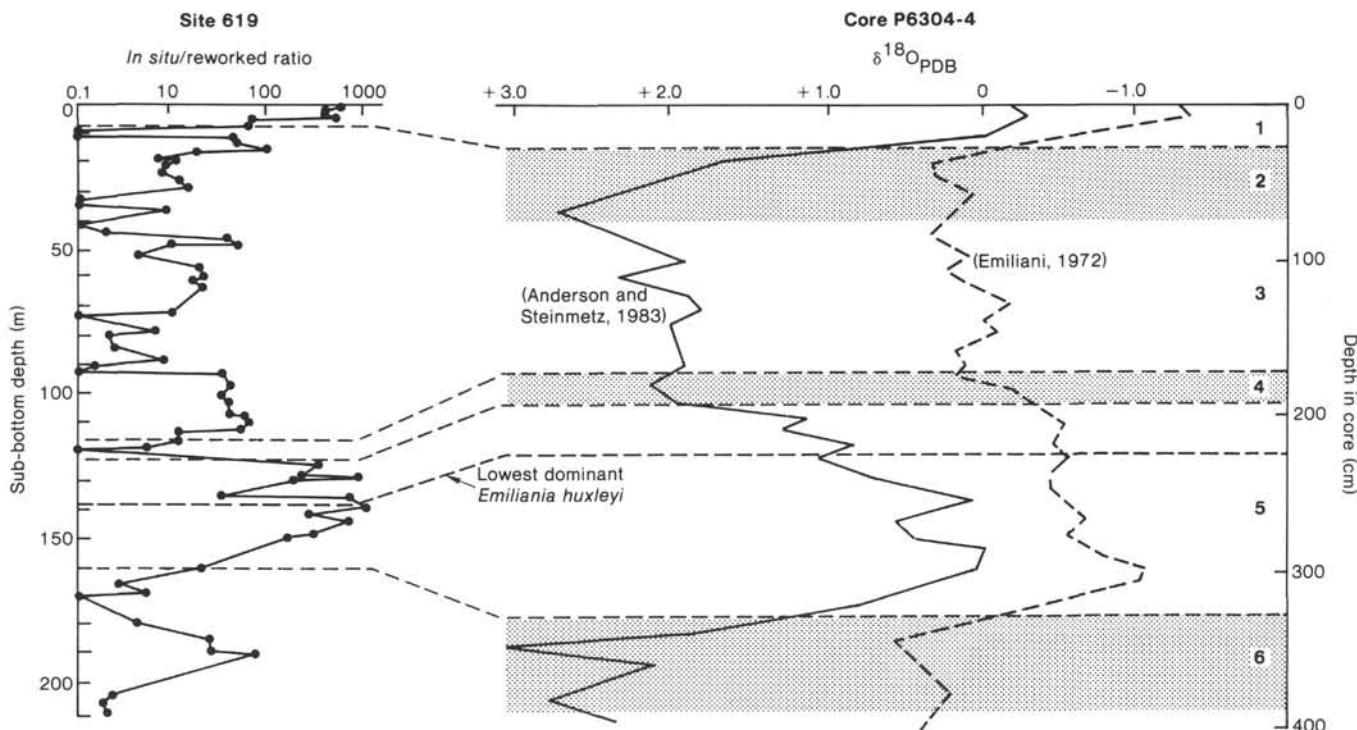


Figure 6. Comparison of the *in situ/reworked* ratio curve of Site 619 with stable isotope curves from the Caribbean Core P6304-4 (from Emiliani, 1972; Anderson and Steinmetz, 1983). Shaded areas represent the cool, even-numbered isotopic stages (shown on right-hand side of figure).

nannofossils. Reworked nannofossils can be abundant in any sediment with a fine textural component.

REMARKS ON SELECTED CALCAREOUS NANNOFOSSIL TAXA

Bibliographic references for these taxa are presented by Loeblich and Tappan (1966, 1968, 1969, 1970a, b, 1971, 1973), Heck (1979a, b, 1980a, b, 1981a, b, 1982a, b) or by Steinmetz (1983a, b, 1984). Most of the calcareous nannofossil species considered in this study are documented elsewhere and need no further discussion. A broad, utilitarian species concept, however, is used for some of the taxa listed below.

Acanthoica quattrospina Lohmann, 1903. This taxon may be related to *Rhabdosphaera stylifera* Lohmann, 1902, which is classified with *R. clavigera* Murray and Blackman in this study.

Braarudosphaera bigelovii (Gran and Braarud) Deflandre, 1947.

Calyptrosphaera oblonga Lohmann, 1902, s. ampl., This taxon includes *Calyptrosphaera catillifera* (Kamptner) Gaarder, 1962 and may include poorly preserved specimens of *Anthosphaera quadricornu* (Schiller) Halldal and Markali, 1955. *C. catillifera* is known only as a living species.

Ceratolithus cristatus Kamptner, 1950. Includes *Ceratolithus telesmus* Norris, 1965.

Crenalithus doronicoides (Black and Barnes) Roth, 1973, s. ampl. This taxon is used broadly and includes *Coccolithus productus* (Kamptner) Sachs and Skinner, 1973 and *Crenalithus productellus* Bukry, 1975. Many small coccoliths with no discernible bridge are included in *C. doronicoides*.

Coccolithus pelagicus (Wallich) Schiller, 1930.

Corisphaera gracilis Kamptner, 1937.

Cricolithus jonesii Cohen, 1965.

Cyclococcolithus leptoporus (Murray and Blackman) Kamptner, 1954.

Discosphaera tubifera (Murray and Blackman) Ostenfeld, 1900.

Emiliania huxleyi (Lohmann) Hay and Mohler, 1967.

Gephyrocapsa caribbeanica Boudreaux and Hay, 1967.

Gephyrocapsa oceanica Kamptner, 1943. *G. omega* Bukry, 1973 and *G. lumina* Bukry, 1973 were included in this taxon.

Gephyrocapsa protohuxleyi McIntyre, 1970. This taxon can only be identified with the scanning electron microscope.

Gephyrocapsa spp. (small). Among others, this grouping includes: *G. aperta* Kamptner, 1963; *G. ericsonii* McIntyre and Bé, 1967; *G. kamptneri* Deflandre and Fert, 1954; *G. sinuosa* Hay and Beaudry, 1973; and *G. protohuxleyi* McIntyre, 1970. With the light microscope *G. protohuxleyi* cannot be separated and is included with *Gephyrocapsa* spp. (small).

Hayaster perplexus (Bramlette and Riedel) Bukry, 1973.

Helicosphaera carteri (Wallich) Kamptner, 1954. Includes *Helicopontosphaera kamptneri* Hay and Mohler, 1967.

Helicosphaera hyalina Gaarder, 1970.

Helicosphaera wallichii (Lohmann) Okada and McIntyre, 1977.

Homozygospaera schilleri (Kamptner) Okada and McIntyre, 1977. Same as *Holodiscolithus macroporus* (Deflandre) Roth, 1970.

Homozygospaera wettsteinii (Kamptner) Halldal and Markali, 1955. *Neosphaera coccolithomorpha* Lecal-Schlauder, 1950, s. ampl. This taxon includes *Craspedolithus declivus* (Kamptner) Nishida, 1970 and *Cyclolithella annula* McIntyre and Bé, 1967.

Oolithus fragilis (Lohmann) Okada and McIntyre, 1977.

Pontosphaera discopora Schiller, 1925 emed. Burns, 1973. This taxon includes forms with three rows of perforations.

Pontosphaera multipora (Kamptner), Roth, 1970. This taxon includes forms with two rows of perforations.

Pontosphaera scutulata Kamptner, 1952.

Pontosphaera japonica (Takayama) Nishida, 1971.

Pontosphaera spp. Any species that cannot readily be placed in one of the four *Pontosphaera* species listed above is included in *Pontosphaera* spp.

Rhabdosphaera clavigera Murray and Blackman, 1898. Includes *Rhabdosphaera stylifera* Lohmann, 1902.

Scapholithus fossilis Deflandre, 1954.

Scyphosphaera apsteinii Lohmann, 1902.

Scyphosphaera pulcherrima Deflandre, 1942. Occurrences of this taxon may be reworked.

Scyphosphaera spp. Various forms of *Scyphosphaera* that do not fit the descriptions of *S. apsteinii* and *S. pulcherrima* are placed in this category. Many species of *Scyphosphaera* are described in the literature (Deflandre, 1942; Kamptner 1955).

Syracospaera histrica Kamptner, 1941.

Syracospaera lamina Lecal-Schlauder, 1951, s. ampl. This taxon includes species with longitudinal central bar: *S. ribosa* (Kamptner)

- Borsetti and Cati, 1972; *S. lactaria* (Lecal) Loeblich and Tappan, 1968; *S. nana* (Kamptner) Okada and McIntyre, 1977; *S. ossa* (Lecal) Loeblich and Tappan, 1968; *S. tuberculata* Kamptner, 1937; *S. variabilis* (Halldal and Markali) Okada and McIntyre, 1977.
- Syracospaera nodosa* Kamptner, 1941.
- Syracospaera pulchra* Lohmann, 1902.
- Syracospaera* spp. Taxa not readily placed in the four *Syracospaera* species listed above are placed in *Syracospaera* spp.
- Thoracosphaera heimii* (Lohmann) Kamptner, 1941.
- Thoracosphaera saxeana* Stradner, 1961.
- Umbellosphaera irregularis* Paasche, 1955.
- Umbellosphaera tenuis* (Kamptner), Paasche, 1955.
- Umbilicosphaera mirabilis* Lohmann, 1902. This taxon is not considered to be a junior synonym of *Umbilicosphaera sibogae* (Weber-van Bosse) Gartner, 1970. The original description and illustration of two concentric circles by Weber-van Bosse (1901) is not adequate to determine that *U. mirabilis* is equivalent to *U. sibogae*.

Reworked Cenozoic Species

Reworked Cenozoic calcareous nannofossils occur sporadically throughout the Leg 96 sites and include the following significant biostratigraphic taxa.

- Cyclococcolithus tropicus* (Kamptner) Gartner, Chen and Stanton, 1983. This may not be the same as *C. macintyrei* Bukry and Bramlette, 1969. Since the classification of these taxa is still questionable, we tabulated them together.
- Discoaster asymmetricus* Gartner, 1969.
- Discoaster barbadiensis* Tan, 1927.
- Discoaster bollii* Martini and Bramlette, 1963.
- Discoaster berggrenii* Bukry, 1971.
- Discoaster brouweri* Tan, 1927.
- Discoaster deflandrei* Bramlette and Riedel, 1954.
- Discoaster pentaradiatus* Tan, 1927.
- Discoaster quinqueramus* Gartner, 1969.
- Discoaster surculus* Martini and Bramlette, 1963.
- Discoaster variabilis* Martini and Bramlette, 1963.
- Helicosphaera sellii* (Bukry and Bramlette) Jafar and Martini, 1975.
- Lithostromation perdurum* Deflandre, 1942.
- Pseudoemiliania lacunosa* (Kamptner) Gartner, 1969.
- Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969.
- Sphenolithus abies* Deflandre, 1954, s. ampl. This taxon also includes *S. neobabies* Bukry and Bramlette, 1969.
- Sphenolithus heteromorphus* Deflandre, 1953.

Reworked Mesozoic Species

Although Jurassic and Early Cretaceous species can be found, this assemblage is dominated by solution-resistant Late Cretaceous species. The most common of these are listed below.

- Arkhangelskiella cymbiformis* Vekshina, 1959.
- Brownia parca* (Stradner) Bukry, 1969.
- Eiffellithus turrisifeli* (Deflandre and Fert) Reinhardt, 1965.
- Lithastrinus floralis* Stradner, 1962.
- Micula decussata* Vekshina, 1959.
- Prediscosphaera cretacea* (Arkhangelsky) Gartner, 1969.
- Prediscosphaera spinosa* (Bramlette and Martini) Gartner, 1968.
- Watznaueria barnesae* (Black) Perch-Nielsen, 1968.

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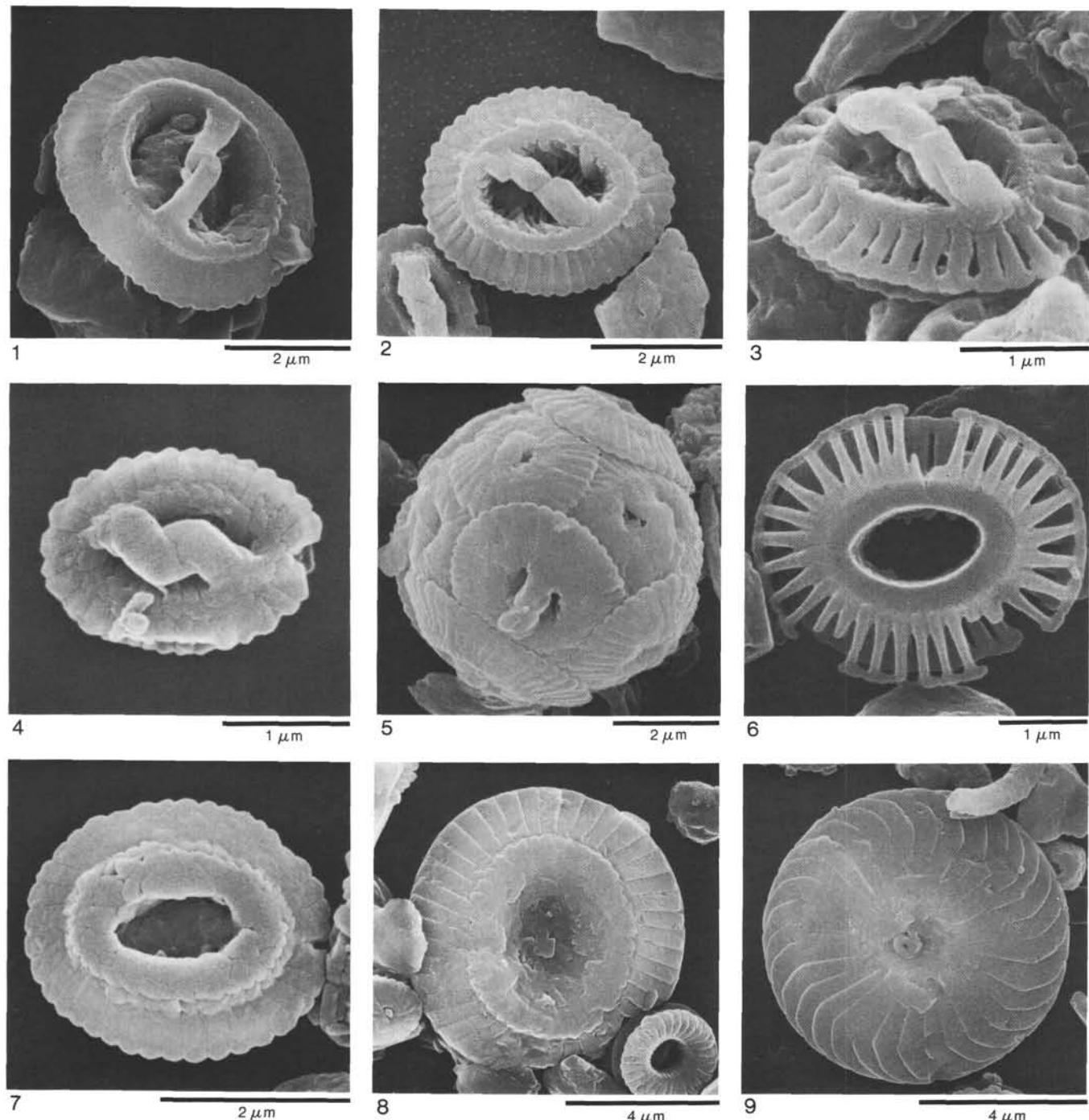


Plate 1. 1. *Gephyrocapsa oceanica* Kamptner, D, Sample 619-16,CC. 2. *Gephyrocapsa caribbeanica* Boudreux and Hay, D, Sample 615-48,CC. 3. *Gephyrocapsa protohuxleyi* McIntyre, D, Sample 615-51,CC. 4. *Gephyrocapsa sinuosa* Hay and Beaudry, D, Sample 615-48,CC. 5. *Gephyrocapsa* spp. (small), coccospHERE, Sample 615-48,CC. 6. *Emiliana huxleyi* (Lohmann) Hay and Mohler, D, Sample 615-51,CC. 7. *Crenalithus doronicoides* (Black and Barnes) Roth, D, Sample 615-48,CC. 8. *Coccolithus pelagicus* (Wallich) Schiller, D, Sample 615-51,CC. 9. *Cyclococcolithus leptoporus* (Murray and Blackman) Kamptner, D, Sample 615-51,CC. All figures are scanning electron micrographs. P = proximal view, D = distal view, L = lateral view.

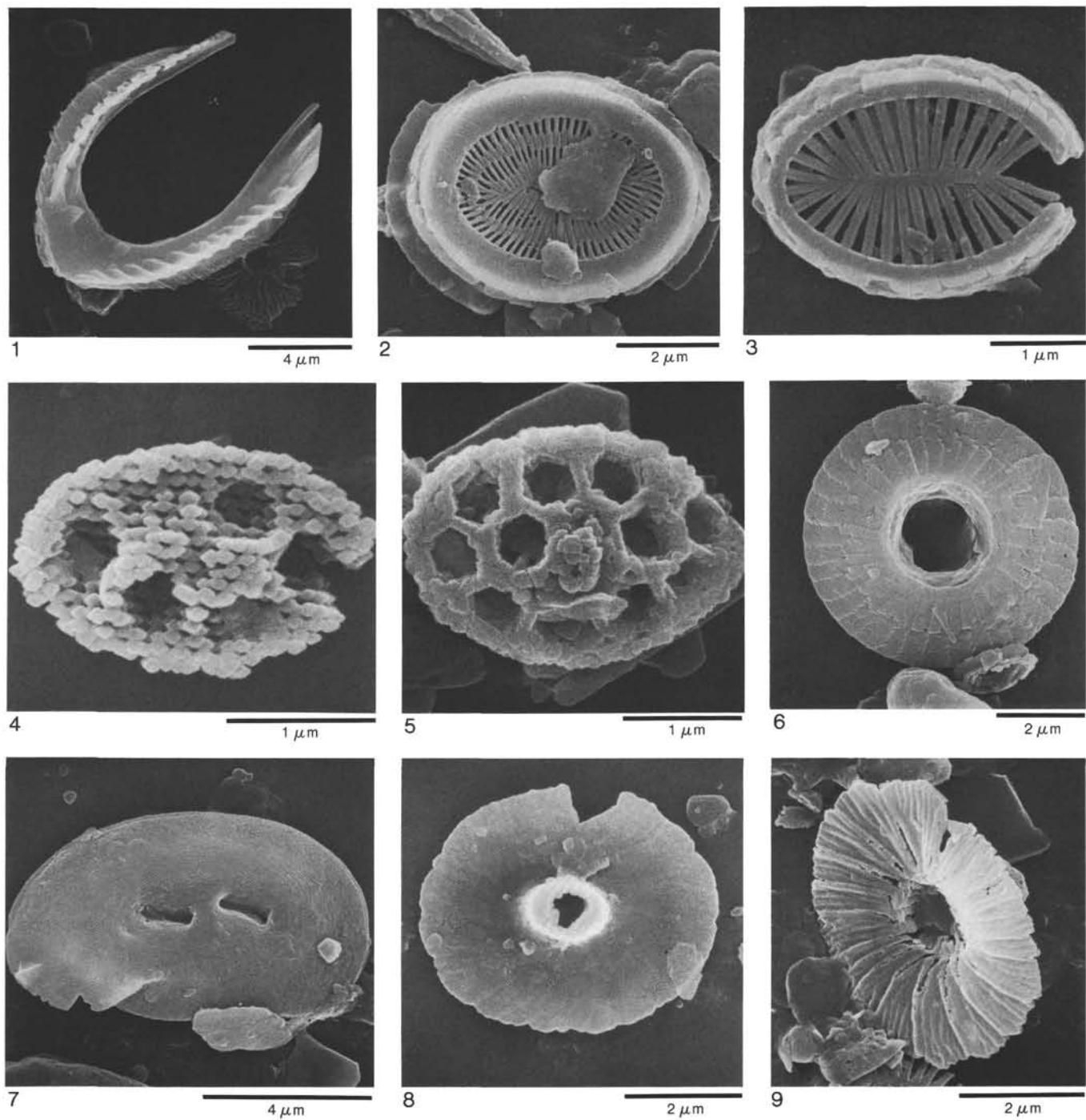


Plate 2. 1. *Ceratolithus cristatus* Kamptner, L, Sample 617A-1-1, 0-2 cm. 2. *Syracosphaera pulchra* Lohmann, P, Sample 619-16,CC. 3. *Syracosphaera lamina* Lecal-Schlauder s. ampl., P, Sample 619-16,CC. 4. *Homozygospaera wettsteinii* (Kamptner) Halldal and Markali, P, Sample 619-16,CC. 5. *Homozygospaera schilleri* (Kamptner) Okada and McIntyre, D, Sample 615-51-1, 41-42 cm. 6. *Umbilicosphaera mirabilis* Lohmann, D, Sample 619-16,CC. 7. *Helicosphaera wallichii* (Lohmann) Okada and McIntyre, D, Sample 619-16,CC. 8. *Umbellospheara* sp. distal plate, P, Sample 619-16,CC. 9. *Umbellospheara tenuis* (Kamptner) Paasche, D, Sample 617A-1-1, 0-2 cm. All figures are scanning electron micrographs. P = proximal view D = distal view, L = lateral view.

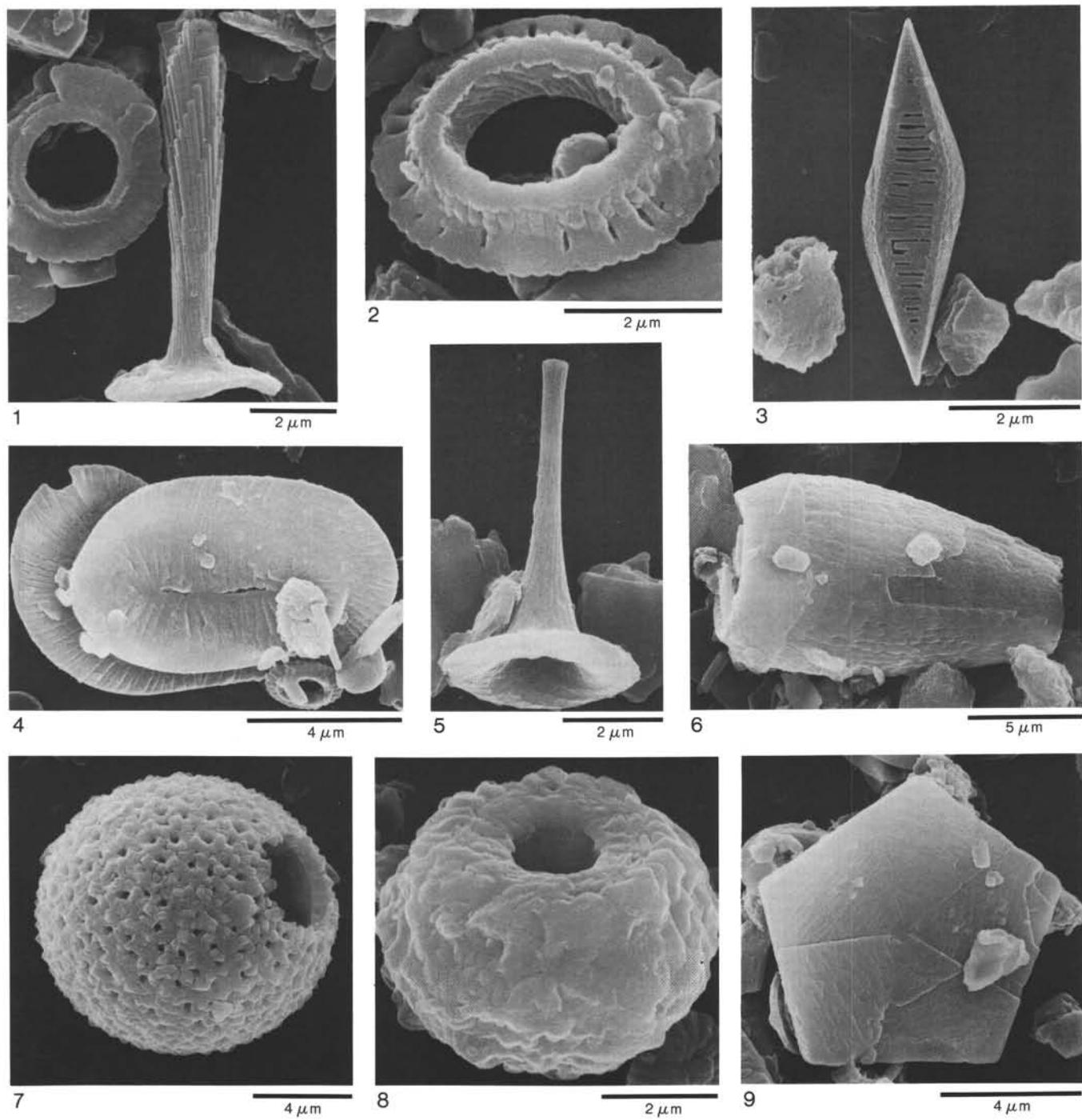


Plate 3. 1. *Rhabdosphaera clavigera* Murray and Blackman, L, Sample 615-48,CC. 2. *Pseudoemiliania lacunosa* (Kamptner) Gartner, D, Sample 615-48,CC. 3. *Scapholithus fossilis* Deflandre, P, Sample 619-16,CC. 4. *Helicosphaera carteri* (Wallich) Kamptner, P, Sample 615-48,CC. 5. *Discosphaera tubifera* (Murray and Blackman) Kamptner, L, Sample 619-16,CC. 6. *Scyphosphaera* sp., L, Sample 615-49-4, 117-118 cm. 7. *Thoracosphaera heimii* (Lohmann) Kamptner, L, Sample 619-16,CC. 8. *Thoracosphaera* sp., L, Sample 615-48,CC. 9. *Braarudosphaera bigelowii* (Gran and Braarud) Deflandre, P, Sample 615-48,CC. All figures are scanning electron micrographs. P = proximal view, D = distal view, L = lateral view.

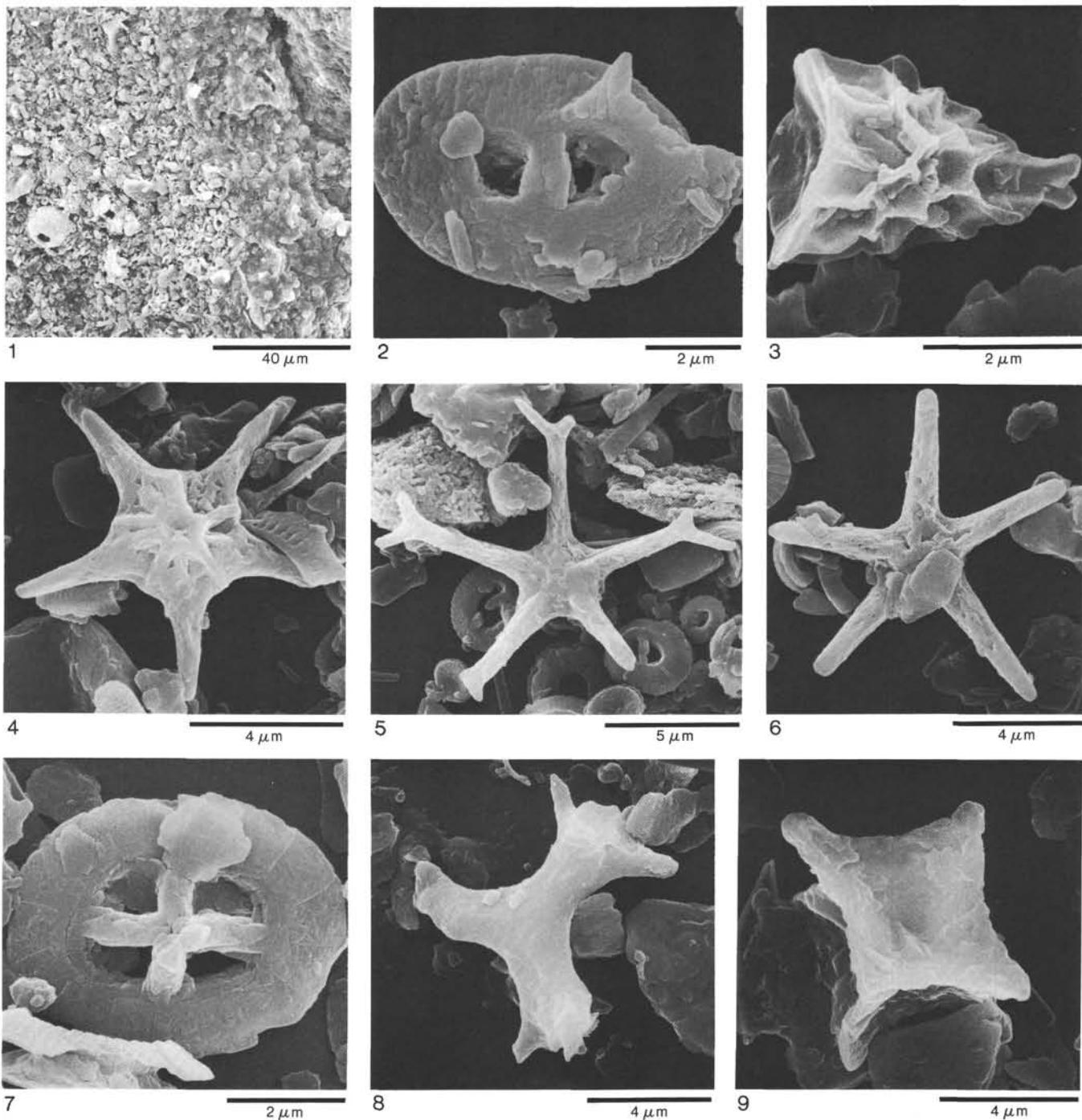


Plate 4. 1. Boundary between reworked calcareous clast with abundant calcareous nannofossils (left side) and mud matrix (right side), Sample 618-4-4, 120–126 cm. 2. *Helicosphaera sellii* (Bukry and Bramlette) Jafar and Martini, D, Sample 615-48,CC. 3. *Sphenolithus abies* Deflandre, L, Sample 615-51,CC. 4. *Discoaster berggrenii* Bukry, D, Sample 615-48,CC. 5. *Discoaster pentaladiatus* Tan, P, Sample 615-48,CC. 6. *Discoaster asymmetricus* Gartner, P, Sample 615-48,CC. 7. *Prediscosphaera spinosa* (Bramlette and Martini) Gartner, D, Sample 619-16,CC. 8. *Marthasterites furcatus* (Deflandre and Fert) Deflandre, L, Sample 619-16,CC. 9. *Micula decussata concava* (Stradner) Bukry, L, Sample 619-16,CC. All figures are scanning electron micrographs. P = proximal view, D = distal view, L = lateral view.