18. EOCENE CALCAREOUS NANNOFOSSILS, DEEP SEA DRILLING PROJECT SITE 605, UPPER CONTINENTAL RISE OFF NEW JERSEY, U.S.A.[1]

Joseph L. Applegate and Sherwood W. Wise, Jr., Department of Geology, Florida State University[2]

ABSTRACT

Deep Sea Drilling Project Site 605 recovered a nearly continuous and thick (366 m) lower to middle Eocene carbonate sequence. The diversity of nannofossils is quite high and coccoliths are generally abundant to very abundant. Preservation is moderate in the upper part of the sequence and poor in the lower part, corresponding to a marked decrease in the biogenic silica content. Unrestricted open marine conditions are indicated by the high pelagic content of the section. The proximity to the continent is suggested by the early representatives of *Tribrachiatus* in CP9a and the occurrence of braarudosphaerids where preservation is moderate. Strict application of the low latitude zonation of Bukry is hindered somewhat in two instances by (1) the apparent absence of the zonal marker *Coccolithus crassus* in this section, and (2) the unanticipated overlap of the subzonal markers *Chiasmolithus gigas* and *Reticulofenestra umbilica* over 53.1 m of section.

INTRODUCTION

Deep Sea Drilling Project Hole 605, Leg 93, drilled 97 n. mi. southeast of Atlantic City, New Jersey (Fig. 1), penetrated a thick (366 m) lower to middle Eocene carbonate sequence. We discuss here the calcareous nannofossil biostratigraphy of these strata. The coccolith stratigraphy of the underlying Paleocene–Maestrichtian section in this hole is presented elsewhere by Lang and Wise (this volume).

The Eocene units cored at Site 605 are part of an extensive carbonate sequence along the Atlantic margin which, in the immediate study area, extends upsection to the lowermost Oligocene (Poag, 1985). Just landward of Site 605, the Eocene units crop out along the contour of the lower continental slope in a broad belt which has been mapped in the area of our drill sites by Robb et al. (1981, 1982; see Fig. 2). During DSDP Leg 11, the previous *Glomar Challenger* cruise to this area, the Eocene outcrop belt was drilled at Site 108 some 8.5 km northwest of Site 605 using an experimental turbocorer (Hollister et al., 1972). By this method, two wash cores were recovered over a 36 m interval and yielded middle Eocene microfossils (Luterbacher, 1972; Wilcoxon, 1972). The Eocene outcrop in this area appears to have been exposed since at least late Miocene times, and Lang and Wise (this volume) report on the coccolith compositions of displaced middle and upper Eocene chalk or ooze incorporated in upper Neogene sediments from Hole 604, which lies 7 km downslope from Site 605 (Fig. 2).

The Eocene units dealt with in this report also extend shoreward beneath the New Jersey coastal plain. Jiang and Wise (this volume) describe Eocene nannofossil assemblages from four cored coastal plain wells and discuss their relationships with those reported here. Subsequent to Leg 93, DSDP Leg 95 drilled two sites, DSDP 612 and 613, which penetrated the Eocene carbonate in our study area (Fig. 2). Hole 612 on the middle slope yielded 187 m of middle Eocene to lower Oligocene sediment, and 303.5 m of lower to middle Eocene sediment were recovered from Hole 613 on the upper rise. The coccolith biostratigraphy of these Leg 95 holes is described by Valentine (in press).

METHODS, ZONATIONS, AND SPECIES CONSIDERED

The abundances of coccolith species on standard smear slides observed at a magnification of X1000 are tabulated on a range chart using the method of Hay (1970). Letters used to denote abundances are keyed to the ^{10}log of the number of specimens of a taxon likely to be observed in any one field of view of the microscope. These and the corresponding logs are determined as follows:

A = Abundant, 0 (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)

The abundances of reworked taxa and of downhole contaminants are denoted in lower-case letters.

The zonation applied in this study is that given by Okada and Bukry (1980; see Fig. 3). For comparison, the zones of Martini (1971) are also indicated. Taxa considered in this report are listed in the Appendix, where they are arranged alphabetically by specific epithets. Bibliographic references for these species are given in Leoblich and Tappan (1966, 1968, 1969, 1970a, b, 1971, 1973) or van Heck (1979a, b, 1980a, b, 1981a, b, 1982a, b, 1983).

EOCENE SECTION, SITE 605

Site 605 (38°44.53'N; 72°36.55'W; water depth, 2194 m) was drilled some 3 km seaward of the margin of the New Jersey continental rise sedimentary wedge. The Eocene carbonates lay disconformably beneath 198 m of gray Pleistocene silt-rich clay (Fig. 4) and were divided into two lithostratigraphic units, as follows:

Unit II: 153 m of lower middle Eocene biosiliceous nannofossil chalk rich in foraminifers, radiolarians, and well preserved diatoms. The biogenic silica content averages 12 to 15% and exceptionally is as high as 30%. The clay content is negligible except in the upper 67 m where

[1] van Hinte, J. E., Wise, S. W., Jr., et al., *Init. Repts. DSDP*, 93: Washington (U.S. Govt. Printing Office).
[2] Address: Department of Geology, Florida State University, Tallahassee, FL 32306-3026.

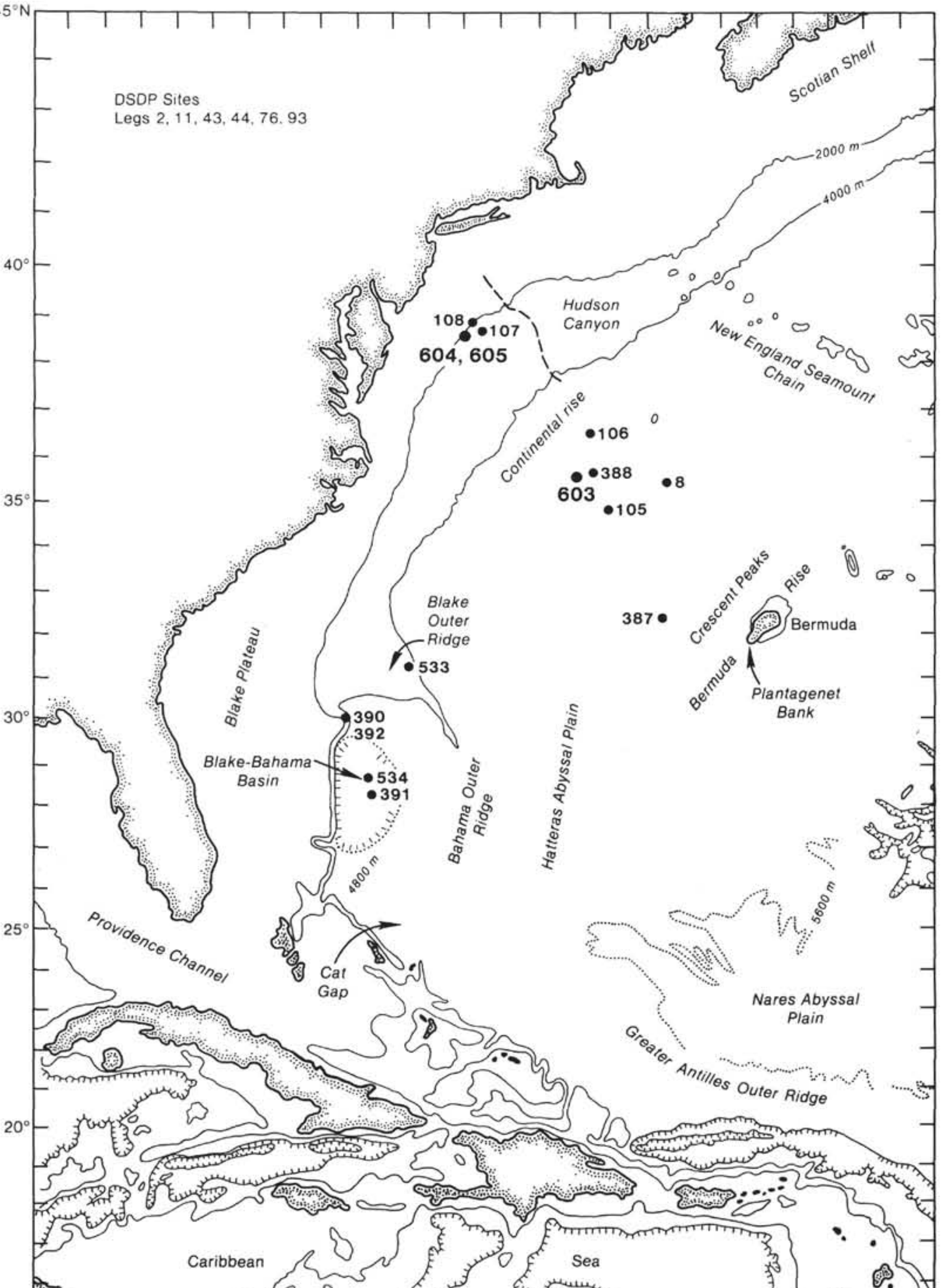

Figure 1. General location of Site 605.

it averages 6 to 8%. The sedimentation rate is high (56 m/m.y.), and bioturbation is heavy.

Unit III: 214 m of lower Eocene greenish gray nannofossil limestone with varying amounts of foraminifers and calcified radiolarians. The boundary with Unit II is not a visually apparent lithologic break, but is defined by a dramatic downward decrease in biogenic silica. The sedimentation rate and degree of bioturbation are the same as in Unit II. The clay content is variable, reaching 15-20% toward the base of the unit.

The distribution of calcareous nannofossils in Eocene Units II and III is given in Table 1. Coccoliths are generally abundant to very abundant. The preservation of coccoliths is generally moderate in lithologic Unit II, where siliceous microfossils are also abundant and well preserved. There is an abrupt decrease in the percentage

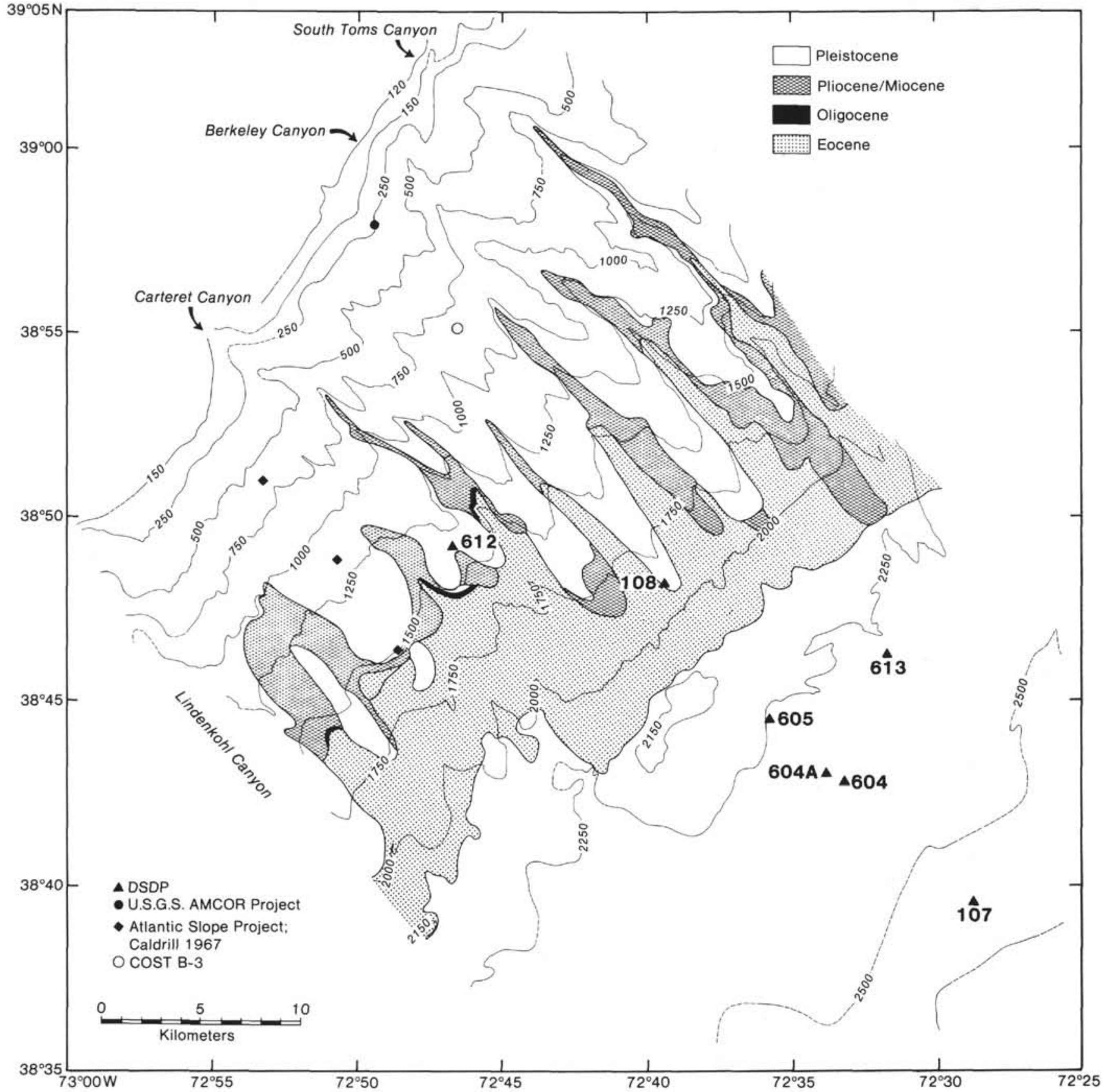

Figure 2. Location of DSDP Site 605 and neighboring sites on the New Jersey continental rise and slope (after Robb et al., 1981). Contours in meters below sea level.

of biogenic silica below Section 605-22-1, however, and the preservation of coccoliths drops off markedly in the lower Eocene. In Unit III it is generally poor, though it improves toward the base. Placoliths are characteristically etched and the discoasters strongly overgrown with secondary calcite.

Middle Eocene nannofossils were first sampled at 605-6-4, 150 cm. There coccoliths are abundant and belong to the *Chiasmolithus gigas* Subzone (CP13b) of the *Nannotetrina quadrata* Zone based on the presence of *C. gigas*. The assemblage includes common to abundant *C. solitus, Coccolithus formosus, C. pelagicus, Discoaster barbadiensis,* and *Reticulofenestra samodurovii. Sphenolithus furcatolithoides* and *S. spiniger* are few to common but rather consistently present below Cores 605-7 and 605-9, respectively. Also present in the top 53 m of this subzone are few to common *R. umbilica*, a point which will be discussed later (see "Discussion"). The *Chiasmolithus gigas* Subzone extends down to Sample 605-17-1, 50–52 cm. Rare specimens of the zonal marker below that point are considered to be downhole contaminants. Preservation in this interval is generally moderate; many of the placoliths are etched, whereas many of the discoasters have secondary calcite overgrowths.

Age	Zone		Subzone		Datum levels
					FAD *Reticulofenestra umbilica*
early middle Eocene	CP13	*Nannotetrina quadrata*	CP13c	*Coccolithus staurion*	LAD *Chiasmolithus gigas*
			CP13b	*Chiasmolithus gigas*	FAD *Chiasmolithus gigas*
			CP13a	*Discoaster strictus*	LAD *Rhabdosphaera inflata*
early Eocene	CP12	*Discoaster sublodoensis*	CP12b	*Rhabdosphaera inflata*	FAD *Rhabdosphaera inflata*
			CP12a	*Discoaster kuepperi*	FAD *Discoaster sublodoensis*
	CP11	*Discoaster lodoensis*			FAD *Coccolithus crassus*
	CP10	*Tribrachiatus orthostylus*			FAD *Discoaster lodoensis*
	CP9	*Discoaster diastypus*	CP9b	*Discoaster binodosus*	LAD *Tribrachiatus contortus*
			CP9a	*Tribrachiatus contortus*	FAD *Discoaster diastypus*

Figure 3. Calcareous nannofossil zonation used in this study, from Okada and Bukry (1980).

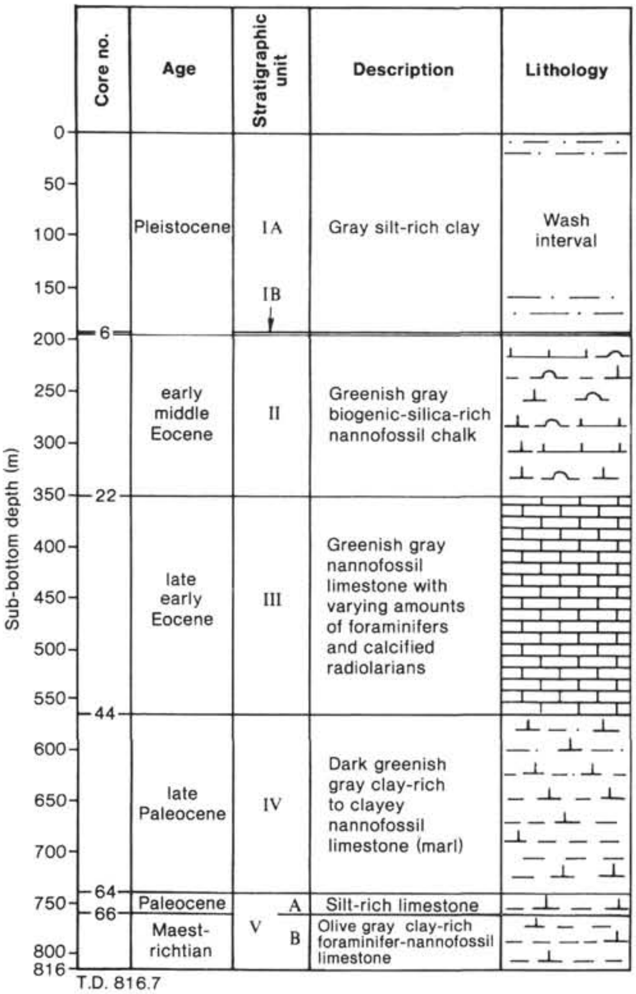

Figure 4. Lithostratigraphic column at DSDP Site 605.

A short interval from Sample 605-17-2, 50–52 cm to Sample 605-22-3, 110–111 cm is assigned to the *D. strictus* Subzone (CP13a). This assemblage of nannofossils is similar to CP13b but lacks *C. gigas*. The first appearance datum (FAD) of *S. furcatolithoides* is in the top of this subzone, and the last appearance datum (LAD) of *D. sublodoensis* occurs near the base. Few to rare *Nannotetrina quadrata* are consistently present only from Sections 605-14-1 to 605-19-1.

The *Rhabdosphaera inflata* Subzone (CP12b) of the *D. sublodeonsis Zone* encompasses the interval from Sample 605-22-4, 20–21 cm to Sample 605-26-2, 50–54 cm and is delineated here on the total range of the nominative species, which is consistently present throughout. One sample (605-22-3, 110–112 cm) separates the conspicuous LAD of *R. inflata* from the FAD of *N. quadrata*, the comarker for the boundary between CP12b and PC13a. The first *N. quadrata* are rare and not consistently present, however; therefore the *R. inflata* datum is used to mark the boundary. Preservation in CP 12b varies from poor to good and coccoliths are common to very abundant. The following species are generally common to abundant: *Chiasmolithus grandis, C. expansus, C. solitus, Coccolithus pelagicus, D. barbadiensis, D. sublodoensis, Reticulofenestra dictyoda,* and *S. radians. Braarudosphaera bigelowii* is common in the top of the subzone but temporarily disappears from the middle of the section. *Chiphragmalithus acanthodes* is common toward the bottom and ranges into the next subzone below.

The *D. kuepperi* Subzone (CP12a) extends from Sample 605-27-1, 50–52 cm down to Sample 605-31-4, 50–52 cm, which marks the lowest consistent occurrence of *D. sublodoensis*. Preservation in this interval is poor because there are secondary calcite overgrowths on many of the discoasters. This assemblage is similar to that of CP13b. The FAD of the form we identify as *S. spiniger* occurs near the base of this zone, somewhat lower than usually reported.

The lower Eocene section is first encountered in Sample 605-31-5, 50–52 cm. The *D. lodoensis* Zone (CP11) extends from this level down close to Core 605-36. Because *Coccolithus crassus*, the basal marker for the zone, is absent in this section, the boundary between CP11 and the underlying CP10 can only be approximated (see "Discussion"). The species common to Zone CP11 are *C. formosus, C. pelagicus, D. barbadiensis, D. kuepperi, D. lodoensis, S. radians,* and *Zygrhablithus bijugatus*. An abrupt LAD for *Tribrachiatus orthostylus* is noted in Section 605-33-1, and the highest occurrence of *S. editus* is recorded in Section 605-34-1.

The *T. orthostylus* Zone (CP10) spans the interval from approximately Core 605-37 to Sample 605-42-1, 50–52 cm. Preservation in this zone is poor because placoliths are etched, particularly those of the genus *Chiasmolithus*. The abundance of this species decreases downhole, and the lowest occurrences of *C. expansus* and *C. solitus* are near the top of CP10, close to the LAD of *Chiphragmalithus calathus*. *D. binodosus* and a form we identify as *S. anarrhopus* have their highest occurrence in this interval. The FAD of *Neoccoccolithes dubius* and the LAD of *Ellipsolithus macellus* occur in Section 605-39-1. In the next lower core, the FAD of *D. kuepperi* provides a consistent marker some 20 m from the bottom of the zone. This marker can be recognized by its interference figure in cross-polarized light, despite overgrowths on the specimens. Interestingly, this important datum coincides in our section with the FAD of *Chiphragmalithus calathus*, and lies just above that of *Toweius gammation*.

Below the FAD of *D. lodoensis*, a short interval from Sample 605-42-2, 50–52 cm to Sample 605-43-2, 110–111 cm is assigned to the *D. binodosus* Subzone (CP9b) of the *D. diastypus Zone*. The LAD of *D. diastypus* is near the top of this interval. *Chiasmolithus eograndis* has its lowest occurrence within this interval at the same depth (Section 605-43-1) as the apparent LADs of *C. bidens* and *C. californicus*. We term these LADs "apparent" because at this point, preservation improves downsection from poor to moderate and braarudosphaerids are once again present. Thus, our ability to trace *C. bidens* and *C. californicus* through their upper ranges may have been affected by diagenesis.

The top of the *Tribrachiatus contortus* Subzone (CP9a) is marked by the highest occurrence of the nominative species. This subzone extends from Sample 605-43-3, 50–52 cm to the FAD of *D. diastypus* in Sample 605-44-1, 50–52 cm. Within this subzone the evolutionary steps from *T. bramlettei* to *T. orthostylus* can be seen, a phenomenon seldom observed in DSDP sections. Note that we decreased our sample spacing through this interval, which spans only 6.6 m of section. Mobile mounts were prepared to distinguish the lowest occurrence of *D. diastypus*, which marks the base of the Eocene. Other species which have their first occurrence in CP9a are *D. barbadiensis*, *D. binodosus*, *Sphenolithus anarrhopus*, *T. contortus*, and, near the top, *T. orthostylus*.

DISCUSSION

The Eocene section at Site 605 is considerably expanded because of its relatively shallow depth on the continental margin. This provides an opportunity to compare stratigraphic ranges among the rather diverse coccolith assemblages with those reported elsewhere, even though nannofossil preservation in lithostratigraphic Unit III is poor. Combined with other sections drilled in this area during DSDP Leg 95, this section could become an important reference area for mid-latitude Eocene nannofossil stratigraphy.

In applying the Bukry (1973) zonation to our Eocene section, two problems are immediately apparent. The first derives from the overlapping ranges of *Chiasmolithus gigas* and *Reticulofenestra umbilica* in the middle Eocene at the top of this section. Because the strata above our Eocene carbonate is a coccolith-poor Pleistocene clay, we assume that the *R. umbilica* in the Eocene cannot represent downhole contamination. The second problem stems from the absence in the lower Eocene of the index species *Coccolithus crassus*.

According to the low-latitude zonation of Bukry (1973), the total range of *Chiasmolithus gigas* lies within the *Nannotetrina quadrata* Zone, and its LAD is separated from the subsequent FAD of *R. umbilica* by a gap which is referred to as the *Coccolithus staurion* Subzone of the *N. quadrata* Zone. At Site 605, the range of *C. gigas* is either somewhat expanded or the FAD of *R. umbilica* is somewhat lower than generally recorded elsewhere. The latter case may be partly a matter of species concept and identification, because *R. umbilica* appears to evolve from a smaller antecedent, *R. samodurovii*, and the point at which *R. umbilica* first occurs is not well agreed upon among nannofossil specialists (Perch-Nielsen, 1985). We rather arbitrarily consider forms in that lineage over 14 μm in length to be *R. umbilica* (Wise and Mostajo, 1983).

Bukry (personal communication, 1985) examined selected samples from our section and noted in Sample 605-12-1, 50–52 cm "a large small-centered *Reticulofenestra* sp. which resembles *R. umbilica* in external size." He further noted, however, the presence of *C. gigas* and sparse forms which he identified positively as *R. umbilica*. In view of the presence of *C. gigas* and the absence of *Discoaster bifax* (the co-markers for the base of the *R. umbilica* Zone), he concurred with our assignment of the top of our section to the *C. gigas* Subzone.

The Martini (1971) zonation for this interval does not address the overlap problem in that Martini does not use *C. gigas*, *R. umbilica*, or *D. bifax* as Eocene zonal markers. We did not observe at Site 605 the rather restricted species *Rhabdosphaera gladius*, which is Martini's zonal marker for this part of the section. Perch-Nielsen (1985) suggested that the LAD of *Nannotetrina quadrata*, which is characteristically sparse at Site 605, could be used to approximate the *R. gladius* datum, particularly where *R. umbilica* seems to appear too low in the section. Because our section has been truncated by erosion, we cannot say whether we observed the actual LAD of *N. quadrata* at our site.

In summary, we observe an overlap between *C. gigas* and *R. umbilica* which shows that at Site 605, the former taxon either ranges higher or the latter taxon ranges lower than would be indicated by the Bukry (1973) zonation. It is understood, however, that the subzones in the Bukry low-latitude zonation may be to some extent provincial and not strictly applicable beyond the tropics. This may well be true in the present case, as is suggested by the fact that Gartner (1971, fig. 4) also records an overlap in the ranges of the two species in JOIDES Hole J3 on the Blake Plateau to the south. There, how-

Table 1. Distribution of lower to middle Eocene calcareous nannofossils, Hole 605.

Age	Okada and Bukry (1980) zonation: Zone	Subzone	Martini (1971) zone	Lithostratigraphic units	Sub-bottom depth (m)	Core/Section (interval in cm)	x	x	*Braarudosphaera bigelowii*	*B. discula*	*Blackites spinosus*	*B. tenuis*	*Calcidiscus? kingii*	*Campylosphaera dela*	*Cepekiella lumina*	*Chiasmolithus bidens*	*C. californicus*	*C. consuetus*	*C. eograndis*	*C. expansus*	*C. gigas*	*C. grandis*	*C. solitus*	*C. litus*	*Chiphragmalithus acanthodes*	*C. calathus*	*Coccolithus cribellum*	*C. formosus*	*C. pelagicus*	*C. staurion*	*Discoaster barbadiensis*
middle Eocene	CP13 *Nannotetrina quadrata*	CP13b *Chiasmolithus gigas*	NP15	II	197.7	6-4, 150	A	P E, O	F											F	R	A	C	C				C	A	R	A
					202.8	7-1, 50-54	VA	M E, O	F	F			F		F					F	F	F	A	C			F	C	A		A
					222.5	9-1, 83-85	VA	M O	F	F	C	C		F						C	F	F	A	F				A	A		C
					231.6	10-1, 50-54	VA	M O	F		F	C	F	F	F					F	R	F	A	C				C	A	R	C
					241.2	11-1, 50-54	A	M O	R		F	C	F	F						C	R	C	C	F				C	A	F	C
					250.8	12-1, 50-54	VA	M E, O	F	F	C	C	F	F	C					A	F	C	A	C			F	C	A		C
					261.1	13-1, 110-112	VA	M E, O	R		F	C	C		C					F	F	C	C	F				C	A	F	A
					270.0	14-1, 50-54	VA	P E, O			F	C	F		F					C	C	C	A	C				C	A	C	C
					279.6	15-1, 50-54	VA	M E, O	F			F			C					C	F	C	C	F				A	A		C
					290.7	16-2, 50-52	A	M O	F			F			C					C	C	C	C	F				A	A	F	C
					298.8	17-1, 50-52	VA	M O	F			C			C					C	F	C	C	F			F	A	A		C
		CP13a *Discoaster strictus*			300.3	17-2, 50-52	VA	M O	F			C			C					C		C	C	F				A	A		C
					309.9	18-2, 50-54	VA	M O	F			C		R	F					C	r	C	C	F			F	C	A	R	C
					318.0	19-1, 50-52	VA	M O	F			C	F		F					F	r	C	C	F				C	A	C	C
					328.2	20-1, 110-111	VA	M O	F			C								C		C	A					C	A	R	C
					337.2	21-1, 50-52	A	P E, O	C			F		F	C					C		C	C	F				C	A	R	C
					346.8	22-1, 50-52	VA	M O	C	F		C		F	F					C		C	A	C				C	A		C
					350.4	22-3, 110-111	A	M O	C	C		C		F	R					C		C	A	C				C	A		C
	CP12 *D. sublodoensis*	CP12b *Rhabdosphaera inflata*	NP14	III	351.0	22-4, 20-21	A	G	C	F		C		F	F					C		C	A	C				C	A	R	C
					351.3	22-4, 50-52	A	G	C	F		C			F					C		C	A	F				C	A		C
					352.8	22-5, 50-52	VA	M O	F			C			F					C		C	A	F	F			C	A		C
					354.9	22-6, 110-111	A	M O	F			C		F	F					C		C	A	F				C	A	R	C
					356.4	23-1, 50-54	C	E O	R			C			F					F		F	F	F	C			F	C		C
					370.0	24-1, 50-54	VA	P E, O				F		F	R					C		C	C		F			C	A	R	C
					375.6	25-1, 50-54	VA	M O						F	F					F		F	C		C			C	A		C
					386.7	26-2, 50-54	A	M E, O							F					F		F	C		F			C	A		C
early Eocene		CP12a *D. kuepperi*			394.8	27-1, 50-52	A	P E, O						R	F					F		C	C		C			C	A		C
					404.4	28-1, 50-54	A	P E, O							F					F		F	C		F			F	A		A
					425.1	30-2, 50-54	A	P O						R	R					F		F	C					C	A		C
					434.7	31-2, 50-52	A	P E, O												F		F	C				R	C	A		C
					437.7	31-4, 50-52	A	P E, O												F		F	C					C	A		C
	CP11 *D. lodoensis*		NP13		439.2	31-5, 50-52	A	P E, O												F		F	C					C	A		C
					442.8	32-1, 50-52	A	M O						R	R					F		F	C					C	A		C
					452.4	33-1, 50-52	A	P E, O											F	R		F	F					F	A		C
			NP12		462.0	34-1, 50-54	VA	M O						C	F			C	F	F		F	C					A	A		A
					470.6	35-3, 50-52	VA	P E, O						R	F			C	C	F		F	C					C	A		C
					481.2	36-1, 50-52	A	P E, O						R				F	C	F		C	F					F	C		C
	CP10 *Tribrachiatus orthostylus*				482.7	36-2, 50-52	A	P E, O							F			F	C	F		F	F						C		C
					490.8	37-1, 50-52	VA	P E, O							F			C	F	F		F				R			A		C
					500.4	38-1, 50-52	A	P E, O										F	F			F				C			C		C
					510.4	39-1, 50-52	A	P E, O	R					F				F	F			F				F		R	C		C
					519.6	40-1, 50-54	A	M E, O						C	C			C	F							F			C		C
					529.2	41-1, 50-52	A	P E, O						F	R			C	C										C		C
					536.7	41-6, 50-52	A	P E, O						F				C	F										C		C
					538.8	42-1, 50-52	VA	P O						R				C	F										A		C
	CP9 *D. diastypus*	CP9b *D. binodosus*	NP11		540.3	42-2, 50-52	A	P O										C	F										A		C
					548.4	43-1, 50-52	A	M E, O	C	C				F		cf	R	C	F										A		C
					550.5	43-2, 110-111	A	M E	F	C					R	C	F	F											C		C
		CP9a *Tribrachiatus contortus*	NP10		551.4	43-3, 50-52	A	M E, O	F	F						F	F	C											C		C
					552.9	43-4, 50-52	A	M E, O	C	C				F	F	C	F	C											C		C
					555.0	43-5, 110-111	A	M O	C	C				R		C	R	C											C		C
					556.5	43-6, 110-111	A	M O	C	C					F	C	F	C											C		C
					558.0	44-1, 50-52	A	P O	F	F				R		C		C											C		C
Paleocene	*D. multiradiatus*	CP8	NP9	IV	559.5	44-2, 50-52	A	M O	F	C				F		C	F	C											C		
					565.5	44-6, 50-52	VA	M O	C	C				F		C	F	C											A		

Note: For abundance, VA = very abundant, A = abundant, C = common, F = few, R = rare; for preservation, B = barren, E = etched, O = overgrown, G = good, M = moderate, P = poor.

ever, the overlap is only one foot (vs. 53.1 m in Hole 605), a slight amount even taking into account the lower sedimentation rate at Site J3. Thus the overlap may decrease and eventually disappear toward the tropics.

The second problem is posed by the absence of *Coccolithus crassus* in the section. We should note at the outset that this would not be a problem if the Martini (1971) zonation could be applied at Site 605, because most of the interval in question (CP10 and CP11) would fall within Martini's *Tribrachiatus orthostylus* Zone (which is bounded at the top by the LAD of *T. orthostylus*). Bukry (1973) questioned the reliability of that datum, however, noting that it may occur higher in the section in some areas. This may be the case at Site 605 because, if Martini's zonation were used, there would be little section (13 m or less) assigned to his superjacent *Discoaster lodoensis Zone*. On the other hand, Martini's Zone NP13 may be truncated in this section by a hiatus (see discussion, later).

A number of datums on the range chart in Table 1 might be of value for approximating or constraining the boundary between CP10 and CP11 at Site 605. The two zones combined span 100 m of section, the midpoint of which would fall between Cores 605-36 and -37 at about 490 m. If sedimentation rates were reasonably uniform throughout this interval, a datum near that midpoint would be a convenient place to approximate a boundary between the zones (see Fig. 5).

The FADs of *Chiasmolithus expansus* and *C. solitus* along with the LADs of *Chiphragmalithus calathus* and

Table 1 (continued).

D. binodosus	*D. diastypus*	*D. distinctus*	*C. falcatus*	*D. gemmifer*	*D. kuepperi*	*D. lodoensis*	*D. mediosus*	*D. mirus*	*D. multiradiatus*	*D. saipanensis*	*D. septemradiatus*	*D. strictus*	*D. sublodoensis*	*D. woodringii*	*D. nobilis*	*Discolithina rimosa*	*Ellipsolithus macellus*	*E. distichus*	*Fasciculithus schaubii*	*F. tympaniformis*	*Helicosphaera lophota*	*H. seminulum*	*Helicosphaera* sp.	*Markalius inversus*	*Nannotetrina cristata*	*N. quadrata*	*Neococcolithes dubius*	*N. protenus*	*Pontosphaera pulchra*	*P. multipora*	*P. plana*	*Reticulofenestra dictyoda*	*R. samodurovii*	*R. umbilica*	*R.* sp.	*Rhabdosphaera inflata*	*R. morionum*	*Sphenolithus anarrhopus*	*S. conspicuus*	*S. editus*	*S. furcatolithoides*	*S. moriformis*	*S. primus*	*S. radians*	*S. spiniger*	*Toweius callosus*	*T. eminens*	*T. gammation*	*T. pertusus*	*Tribrachiatus bramlettei*	*T. contortus*	*T. orthostylus*	*Zygolithus chiastus*	*Zygrhabdolithus bijugatus*
		C								C		C												F	R		R			R		C	A	F								F		F										
		C								C		F										F		C			C		C	C		C	A	C								C		C										C
		F								C		F										F		F	R	F	C		C	C		C	A	F							F	C		C										C
		C								C		F		F								C		F			C		C	C		C	C	F							C	C		C	C									C
		C								C												C		F	R		C		F	F		C	C	F							C	C		C	F									C
		C								C												C					C		C	F	F	C	C	C	C						C	C		C	F									C
		C								C												F					C		C	C		C	C		C						F	C		C	C									C
		C								C		C		C								C		F	F	R	C		C			A	A		C						C	C		C	C									C
		C								C		C		C								C			F	F	C		C			A	A		C						C	C		C	C									C
		C								C				C								C			F	R	C		C			C	C		C							C		C	C									C
		C								C		F										C				F	C		F	C		C	A		C						F	C		C	C									C
		C								F		F						R				C				F	C		F	F		A	C		C						F	C		C	C									C
		C								F		F		C								F				F	C		F	F		A	C		C						R	C		C	C									C
		C								C		F		C		R		R				C			R	R	C		C	F		A	C		C							C		C	C									C
		C								C		F						R			R				C	R	C	F				A	C		C							C		C	F									C
		C								C		C		C		R								F	C		C	C			F	A	C		C							C		C	C									C
		C		F						C		F	F	F		R					F			F	C	R	C	C		F		A	C		C							C		C	C									C
		C		F						F		C	F	F							F			F	C		C	F			F	A	C		C							C		C	C									C
		C		F						F		C	C	C							C	C		F	F		C	F			F	A	F		C	C						F		F	C									C
		C		F						F		C	C	F							C			R	F		C	C			F	A	C		F	C						C		C	C									C
		C		F						C		F	C	C							C			F	F		C	C		C		C	F		F	C						F		F	C									C
		C		F						C		F	C	C							C	F		F	F		C	C				A	F		C	C						F		F	C									C
		F								C		F	C	C							F	F		F	C		F	F			C	C	F		C	C						C		C	F									C
		C				cf		F		F		F	C								F			C	C		C	C			F	A	C		C	R						C		C	F									A
		C				cf		F		F		F	C	C							C	R		C	F		C	F			F	A	C		C	R	R					C		C	F									A
		C		R		F		R		C			C								F			C	R		C	C			R	C			C	R						C		C	F			F						C
		C		F	R	C		C		C			C											R	R		F	F			F	C			C							F		F	F			F						C
		C		F	R	C		C		F			C								F						F	F				A			C							C		C	C			F						C
		C			C	C		C		F			F								F			F			F	C				C			C							C		C	F			F						C
		C			C	C		C					F														R	C				C			C							C		C	F			R						C
		C			C	C		C					F											F			F	C				C			C							C		C										C
		C			C	C		F																F			F	C				C			F							C		C				R						C
		C			C	C		F			F													F			C	C				C			F							C		A				F						A
		C			C	C		C			F													F			C	C							F							C		C								C		C
		C			C	A		C								R											F	C												F		C		C								C		A
		C			C	C															R						F	C			F									C		C		C				F				C		C
		C			C	F																		R			C	F			F									C		C		A				R				C		C
		C			C	C										F								R			C	F			F									C		C		A				R				C		C
		C			C	C										F											F	R	R		R									C		C		A				R				C		C
		C			C	F			R															F			F	F										C		C		C		A				F				C		A
F		C			C	F			R							R	F				F		R	C			F	F	F									C		C		C		C				C				C		C
C		F			F	F			F							F	F							F				F	F									F		F		C		F				C				C		C
F		C				F											R							F				F	F									C	F	C		C		F				C				C		C
F	cf	C				R											F							F				F										C	F	C		C		C								C		C
C	F	C				F										R	F	R			C			F				C	F									C	F	F		C		C								C		A
C	C	C															C											C										C	F	F		C		F								C		A
C	C	F							F								C	F										C			F							F		C		C		F								C		A
F	C	C							F								F	F		C				R				C										F		C		C		F								C		A
F	C	F					F		F							F	F	F		C								C										C		F		C		R							F	C	F	A
C	C						F		C								F	F		C				F			R	C										C		F		C									C		F	C
C	C						F		C								F	F		C								C	R													C								F	F			C
F	C		F				R		C								F	F		C								F														C	C							F	F		C	C
F	F		F				F		C						C	F		F		C			C															R					C			C	C		C	F			C	C
			F				F		C						C	F		F		C			C																				C			C	C		F				C	
			F				F		C						C	F		C	C	C			C																				C			C	A		C				C	

the form we identify as *Sphenolithus anarrhopus* occur closest to this midpoint. The first three taxa are in general sparsely represented in this interval, however, and the ranges of all of these may be affected by the poor preservation in this part of the section. Also somewhat questionable is the first consistent occurrence of *Coccolithus formosus* at 481 m. Bukry (personal communication, 1985) has reported this species much further down in Eocene strata. Perhaps more promising but farther from the midpoint are the FAD of *Neococcolithes dubius* and the LAD of *Ellipsolithus macellus* at 510 m. However, this level is only 9 m above the more widely reported and easily distinguished FAD of *D. kuepperi*, which lies closer to the basal boundary than to the midpoint of the two zones.

A closer sample spacing in this section and a comparison with the other sequences drilled in the New Jersey area will be necessary to determine which, if any, of the above datums would serve as a satisfactory substitute for the *Coccolithus crassus* datum. We provide this preliminary description as a point of departure for such a study.

Despite poor preservation from about 394 to 540 m, the diversity of the coccoliths deposited in this bathyal continental margin environment is reasonably high. Unrestricted open marine conditions are indicated by the high pelagic content of the section. The proximity to the continent is suggested by the early representatives of *Tribrachiatus* in CP9a and the consistent occurrence of braarudosphaerids where preservation is moderate.

Because there is no absolute correlation between the occurrence of braarudosphaerids and coccolith preservation, their absence in CP10 and CP11 might indicate a diminution of nearshore influences through transgres-

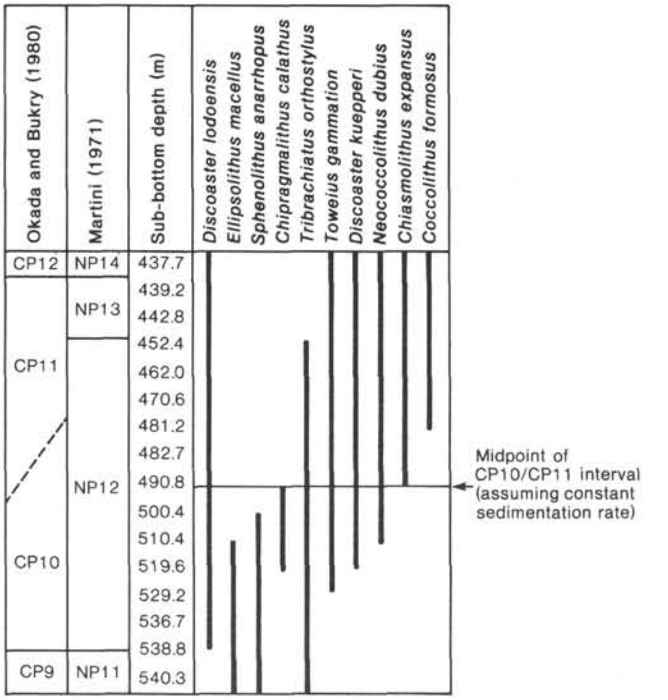

Figure 5. First and last appearance datums of species within the CP10–CP11 interval.

sion and high sea levels as indicated by the Vail et al. (1977) coastal onlap curve. CP10 and CP11 coincide closely with Vail et al.'s Cycle TE1.2, which marks the high point of early Eocene onlap. Such a high stand would also help explain the poor preservation of coccoliths in this part of the section, because less detrital clay reached Site 605, and the diagenetic dissolution–diffusion–reprecipitation reaction that degrades coccolith preservation was able to work more efficiently in the high-carbonate sediment (see Wise, 1977). That in turn compounded the biostratigraphic problems relative to these zones which we have already discussed.

Interestingly, the major "Type I" sea level drop which, according to Vail et al. (1977), occurred at the CP11/CP12 boundary (NP13/NP14 of Martini, 1971), is not manifested at Site 605 either by an increase in clay content or by a return of braarudosphaerids. Instead, braarudosphaerids are encountered again upsection only at the top of Core 605-23, and become common only in Section 605-22-4, close to the point at which biogenic silica becomes an important sedimentary component. The effect of biogenic silica on coccolith preservation is much the same as that of clay; it would account for the consistent occurrence of the relatively dissolution prone braarudosphaerids in the upper part of the section.

The Vail "Type I" sea-level drop (base cycle TE2.1) near the early/middle Eocene boundary (previously mentioned) might, however, be expressed in this section by the relatively short interval occupied by Martini's Zone NP13. This suggests an undetected hiatus in this section, within or at the boundary of Zone NP13.

ACKNOWLEDGMENTS

We are pleased to acknowledge reviews of this paper by Laurel M. Bybell (U.S. Geological Survey, Reston) and Stefan Gartner (Texas A&M University). David Bukry (U.S. Minerals Management Service, La Jolla) kindly examined selected samples and provided us his opinions on identifications and occurrences of certain taxa. Shipboard notes made on core-catcher samples by J. M. Covington and J. Muza were helpful. Micrographs for Plate 1, Figures 7–9 and Plate 5, Figures 5–6 were taken by Sandee Weiterman (FSU) as part of a nannofossil class project; all prints were made by Gabrielle Li (FSU). Laboratory facilities were supported in part by NSF Grant DPP 84-14268 and an equipment grant from the Amoco Foundation.

REFERENCES

Bukry, D., 1973. Low-latitude coccolith biostratigraphic zonation. *In* Edgar, N. T., Saunders, J. B., et al., *Init. Repts. DSDP,* 15: Washington (U.S. Govt. Printing Office), 685–703.

Gartner, S., Jr., 1971. Calcareous nannofossils from the *Joides* Blake Plateau cores, and revision of Paleogene nannofossil zonation. *Tulane Stud. Geol. Paleontol.*, 8(no. 3):101–121.

Hay, W. W., 1970. Calcareous nannofossils from cores recovered on Leg 4. *In* Bader, R. G., Gerard, R. D., et al., *Init. Repts. DSDP,* 4: Washington (U.S. Govt. Printing Office), 455–501.

Heck, S. E., van, 1979a. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 1:AB1-5, A1-12, B1-27.

________, 1979b. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 1:ABVI, A13-28, B28-42.

________, 1980a. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 2:5–34.

________, 1980b. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 2:43–81.

________, 1981a. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 3:4–41.

________, 1981b. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 3:51–86.

________, 1982a. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 4:7–50.

________, 1982b. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 4:65–96.

________, 1983. Bibliography and taxa of calcareous nannoplankton. *Int. Nannoplankton Assoc. Newsl.*, 5:4–13.

Hollister, C. D., Ewing, J. I., et al., 1972. Site 108: Continental slope. *In* Hollister, C. D., Ewing, J. I., et al., *Init. Repts. DSDP*, 11: Washington (U.S. Govt. Printing Office), 357–364.

Loeblich, A. R., Jr., and Tappan, H., 1966. Annotated index and bibliography of the calcareous nannoplankton. *Phycologia*, 5:81–216.

________, 1968. Annotated index and bibliography of the calcareous nannoplankton III. *J. Paleontol.*, 42:584–598.

________, 1969. Annotated index and bibliography of the calcareous nannoplankton III. *J. Paleontol.*, 43:568–588.

________, 1970a. Annotated index and bibliography of the calcareous nannoplankton IV. *J. Paleontol.*, 44:558–574.

________, 1970b. Annotated index and bibliography of the calcareous nannoplankton VI. *Phycologia*, 9:157–174.

________, 1971. Annotated index and bibliography of the calcareous nannoplankton VI. *Phycologia*, 10:315–339.

________, 1973. Annotated index and bibliography of the calcareous nannoplankton VII. *J. Paleontol.*, 47:715–759.

Luterbacher, H., 1982. Paleocene and Eocene planktonic foraminifera, Leg 11, Deep Sea Drilling Project. *In* Hollister, C. D., Ewing, J. I., et al., *Init. Repts. DSDP*, 11: Washington (U.S. Govt. Printing Office), 951–973.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In* Farinacci, A. (Ed.), *Proc. II Planktonic Conf., Roma:* Rome (Edizioni Tecnoscienza), 2:739–785.

Okada, H., and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the "Low-latitude coccolith biostratigraphic zonation" (Bukry, 1973; 1975). *Mar. Micropaleontol.*, 5:321–325.

Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils. *In* Bolli, H. M., et al. (Eds.), *Plankton Stratigraphy:* Cambridge, England (Cambridge University Press), pp. 427-554.

Poag, C. W., 1985. Cenozoic and Upper Cretaceous sedimentary facies and depositional systems of the New Jersey slope and rise. *In* Poag, C. W. (Ed.), *Geologic Evolution of the United States Atlantic Margin:* New York (Van Nostrand-Reinhold, Inc.), pp. 343-365.

Robb, J. M., Hampson, J. C., Jr., Kirby, J. R., and Twichell, D. C., 1981. Geology and potential hazards of the Continental Slope between Lindenkohl and South Toms Canyons offshore Mid-Atlantic United States. *U.S. Geological Survey Open-File Rept.*, 81-600.

Robb, J. M., Hampson, J. C., Jr., and Kirby, J. R., 1982. Surficial geologic studies of the continental slope in the Northern Baltimore Canyon Trough area—techniques and findings. *Proc. 14th Ann. Offshore Tech. Conf.*, Houston, Texas, Paper OTC 4170, pp. 39-43.

Vail, P. R., Mitchum, R. M., Jr., Todd, R. G., Widmier, J. M., Thompson, S., III, Sangree, J. B., Bubb, J. N., and Hatlelid, W. G., 1977. Seismic stratigraphy and global changes in sea level. *In* Payton, C. E. (Ed.), *Seismic Stratigraphy—Applications to Hydrocarbon Explorations*. Am. Assoc. Pet. Geol. Mem., 26:49-212.

Valentine, P. C., in press. Lower Eocene calcareous nannofossil biostratigraphy beneath the Atlantic Slope and upper rise of New Jersey—new zonation based on Deep Sea Drilling Project Sites 612 and 613. *In* Poag, W. C., Watts, A. B., et al., *Init. Repts. DSDP*, 95: Washington (U.S. Govt. Printing Office).

Wilcoxon, J. A., 1972. Upper Jurassic-Lower Cretaceous calcareous nannoplankton from the western North Atlantic Basin. *In* Hollister, C. D., Ewing, J. I., et al., *Init. Repts. DSDP*, 11: Washington (U.S. Govt. Printing Office), 427-458.

Wise, S. W., 1977. Chalk formation; early diagenesis. *In* Andersen, N. R., and Malahoff, A. (Eds.), *The Fate of Fossil Fuel Co_2 in the Oceans:* New York (Plenum), pp. 717-739.

Wise, S. W., and Mostajo, E. L., 1983. Correlation of Eocene-Oligocene calcareous nannofossil assemblages from piston cores taken in the vicinity of Deep Sea Drilling Sites 511 and 512, Southwest Atlantic Ocean. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 1171-1180.

Date of Initial Receipt: 3 June 1985
Date of Acceptance: 18 February 1986

APPENDIX

Calcareous Nannofossils Considered in This Chapter (in alphabetical order of species epithets)

Chiphragmalithus acanthodes Bramlette and Sullivan, 1961
Sphenolithus anarrhopus Bukry and Bramlette, 1969
Discoaster barbadiensis Tan, 1927
Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, 1967
Discoaster bifax Bukry, 1971
Braarudosphaera bigelowii (Gran and Braarud) Deflandre, 1947
Zygrhablithus bijugatus (Deflandre) Deflandre, 1959
Discoaster binodosus Martini, 1958
Tribrachiatus bramlettei (Brönnimann and Stradner) Proto Decima et al., 1975
Chiphragmalithus calathus Bramlette and Sullivan, 1961
Chiasmolithus californicus (Sullivan) Hay and Mohler, 1967
Toweius callosus Perch-Nielsen, 1971
Zygolithus chiastus Bramlette and Sullivan, 1961
Sphenolithus conspicuus Martini, 1976
Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Mohler, 1967
Tribrachiatus contortus (Stradner) Bukry, 1972
Coccolithus crassus Bramlette and Sullivan, 1961
Coccolithus cribellum (Bramlette and Sullivan) Stradner, 1962
Nannotetrina cristatus (Martini) Perch-Nielsen, 1971
Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler, 1967
Discoaster diastypus Bramlette and Sullivan, 1961
Reticulofenestra dictyoda (Deflandre and Fert) Stradner, 1968
Braarudosphaera discula Bramlette and Riedel, 1954
Ellipsolithus distichus (Bramlette and Sullivan) Sullivan, 1964
Discoaster distinctus Martini, 1958
Neococcolithes dubius (Deflandre) Black, 1967
Sphenolithus editus Perch-Nielsen, 1978
Toweius eminens (Bramlette and Sullivan) Gartner, 1971
Chiasmolithus eograndis Perch-Nielsen, 1971
Chiasmolithus expansus (Bramlette and Sullivan) Gartner, 1970
Discoaster falcatus Bramlette and Sullivan, 1961
Coccolithus formosus (Kamptner) Wise, 1973
Sphenolithus furcatolithoides Locker, 1967
Toweius gammation (Bramlette and Sullivan) Romein, 1979
Discoaster gemmifer Stradner, 1961
Chiasmolithus gigas (Bramlette and Sullivan) Radomski, 1968
Rhabdosphaera gladius Locker, 1967
Chaismolithus grandis (Bramlette and Riedel) Radomski, 1968
Rhabdosphaera inflata Bramlette and Sullivan, 1961
Markalius inversus (Deflandre) Bramlette and Martini, 1964
Calcidiscus kingii (Roth) Loeblich and Tappan, 1978
Discoaster kuepperi Stradner, 1959
Discoaster lodoensis Bramlette and Riedel, 1954
Helicosphaera lophota Bramlette and Sullivan, 1961
Cepekiella lumina (Sullivan) Bybell, 1975
Ellipsolithus macellus (Bramlette and Sullivan) Sullivan, 1964
Discoaster mediosus Bramlette and Sullivan, 1961
Discoaster mirus Deflandre *in* Deflandre and Fert, 1954
Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, 1967
Rhabdosphaera morionum (Deflandre) Bramlette and Sullivan, 1961
Pontosphaera multipora (Kamptner) Roth, 1970
Discoaster multiradiatus Bramlette and Riedel, 1954
Discoaster nobilis Martini, 1961
Tribrachiatus orthostylus Shamrai, 1963
Coccolithus pelagicus (Wallich) Schiller, 1930
Toweius pertusus (Sullivan) Romein, 1979
Pontosphaera plana (Bramlette and Sullivan) Haq, 1971
Sphenolithus primus Perch-Nielsen, 1971
Neococcolithus protenus (Bramlette and Sullivan) Black, 1967
Pontosphaera pulchra (Deflandre) Romein, 1979
Nannotetrina quadrata (Bramlette and Sullivan) Bukry, 1973
Sphenolithus radians Deflandre in Grassé, 1952
Discolithina rimosa (Bramlette and Sullivan) Levin and Joerger, 1967
Discoaster saipanensis Bramlette and Reidel, 1954
Reticulofenestra samodurovii (Hay, Mohler, and Wade) Roth, 1970
Fasciculithus schaubi Hay and Mohler, 1967
Helicosphaera seminulum Bramlette and Sullivan, 1961
Discoaster septemradiatus Klumpp, 1953
Chiasmolithus solitus (Bramlette and Sullivan) Locker, 1968
Sphenolithus spiniger Bukry, 1971
Blackites spinosus (Deflandre and Fert) Hay and Towe, 1962
Coccolithus staurion Bramlette and Sullivan, 1961
Discoaster strictus Stradner, 1961
Discoaster sublodoensis Bramlette and Sullivan, 1961
Blackites tenuis (Bramlette and Sullivan) Bybell, 1975
Chaismolithus titus Gartner, 1970
Fasciculithus tympaniformis Hay and Mohler, 1967
Reticulofenestra umbilica (Levin) Martini and Ritzkowski, 1968
Discoaster woodringii Bramlette and Riedel, 1954

NOTE ON PLATES

All illustrations on the following plates are light micrographs. The abbreviations Pol, Ph, and Tr denote polarized, phase contrast, and transmitted light, respectively.

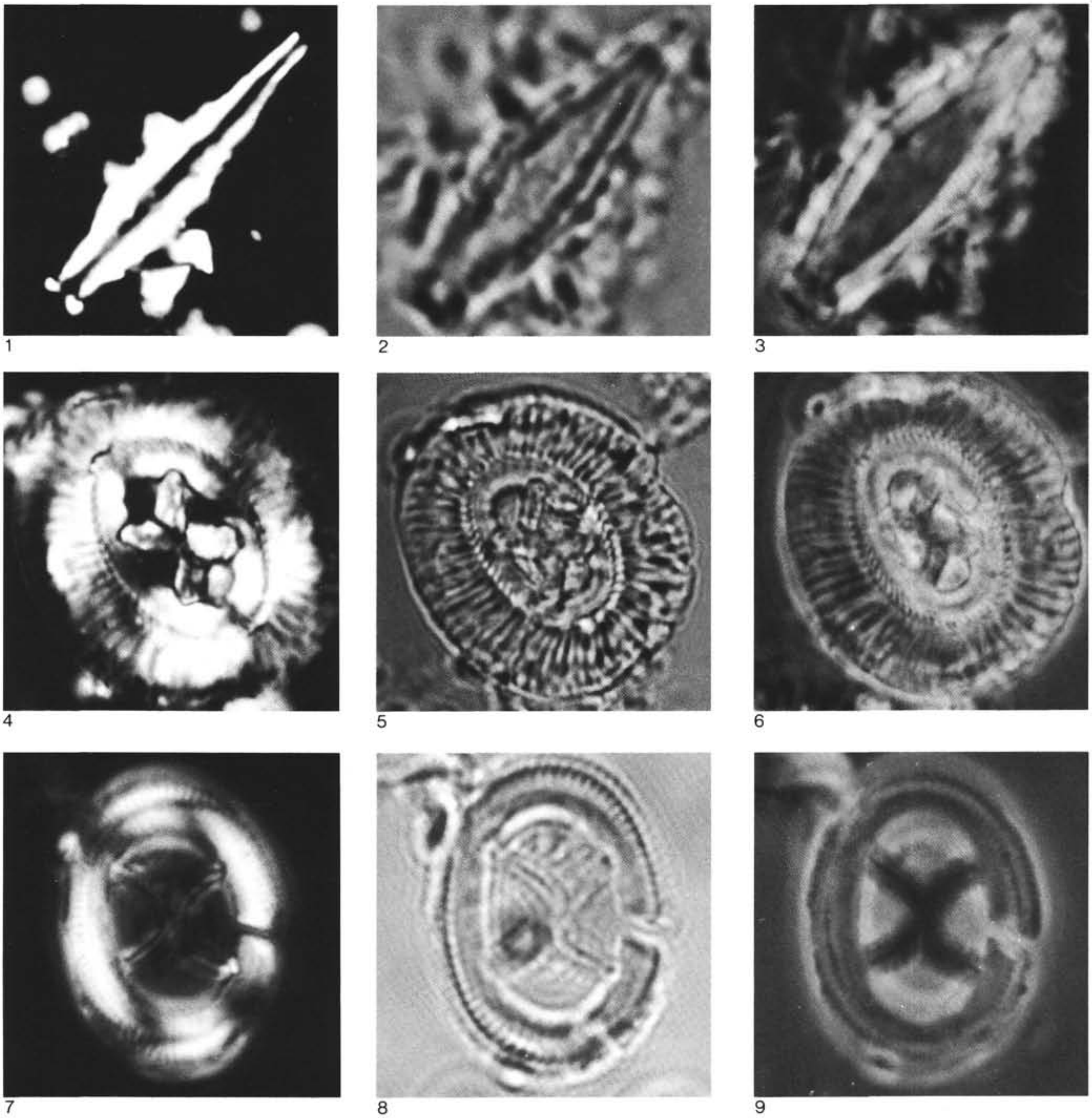

Plate 1. **1–3.** *Rhabdosphaera inflata* Bramlette and Sullivan, ×4000, Sample 605-22-5, 50–52 cm (1, Pol; 2, Tr; 3, Ph). **4–6.** *Chiasmolithus gigas* (Bramlette and Sullivan), ×3000, Sample 605-7-1, 50–54 cm (4, Pol; 5, Tr; 6, Ph). **7–9.** *Chiasmolithus expansus* (Bramlette and Sullivan), ×3200, Sample 605-6,CC (7, Pol; 8, Tr; 9, Ph).

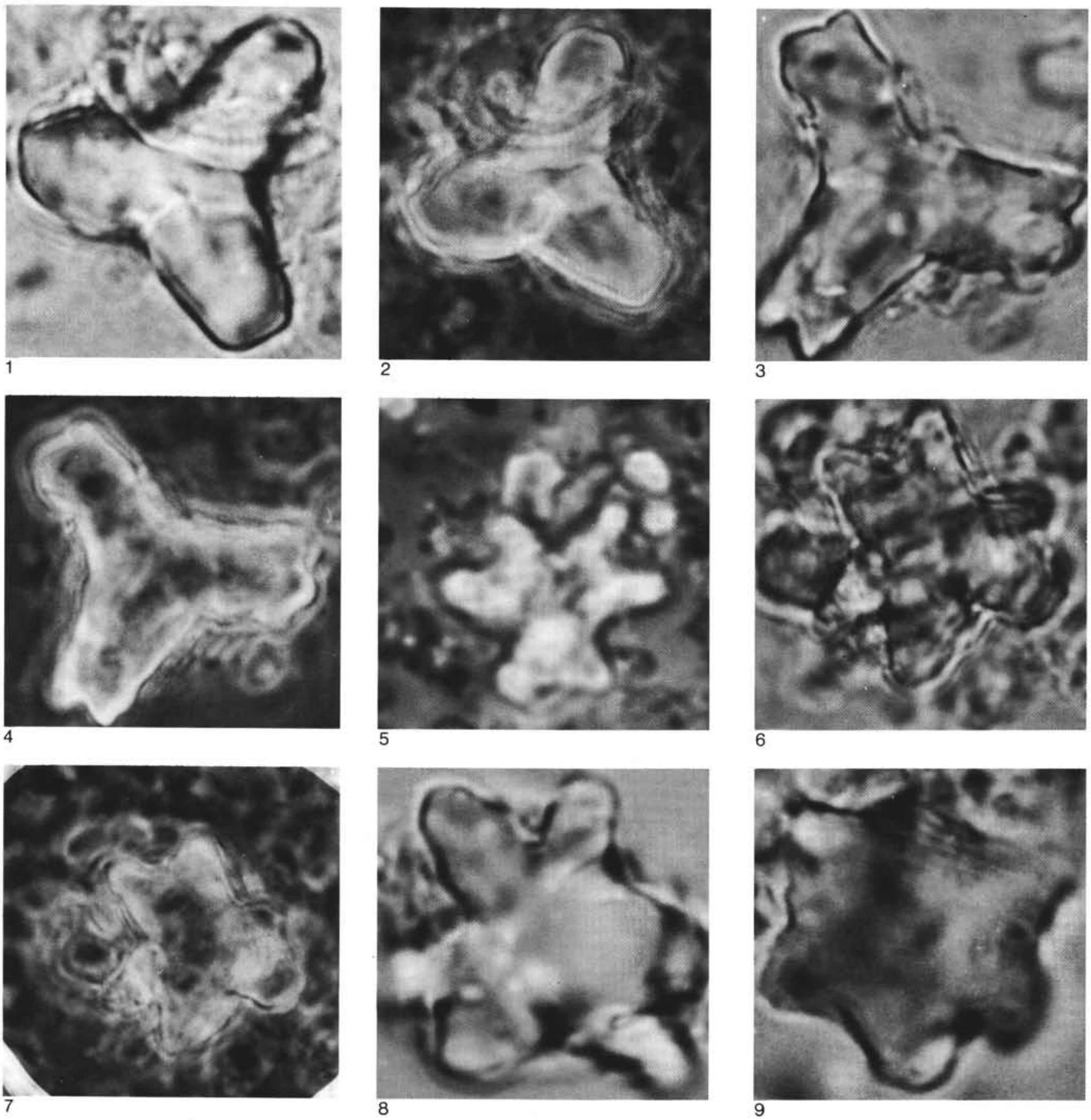

Plate 2. **1–4.** *Tribrachiatus orthostylus* Shamrai, (1) ×3100, Sample 605-34-1, 50–54 cm, Tr; (2) same specimen, ×2700, Ph; (3) ×3100, Sample 605-43-4, 50–52 cm, Tr; (4) same specimen, Ph. **5–7.** *Tribrachiatus contortus* (Stradner), (5) Sample 605-43-6, 110–111 cm, ×2100, Ph; (6) ×2400, Sample 605-43-6, 110–111 cm, Ph; (7) same specimen as 6, Tr. **8–9.** *Tribrachiatus bramlettei* (Brönnimann and Stradner), (8) ×3900, Sample 605-43-5, 50–52 cm, Tr; (9) ×3900, Sample 605-43-6, 110–111 cm.

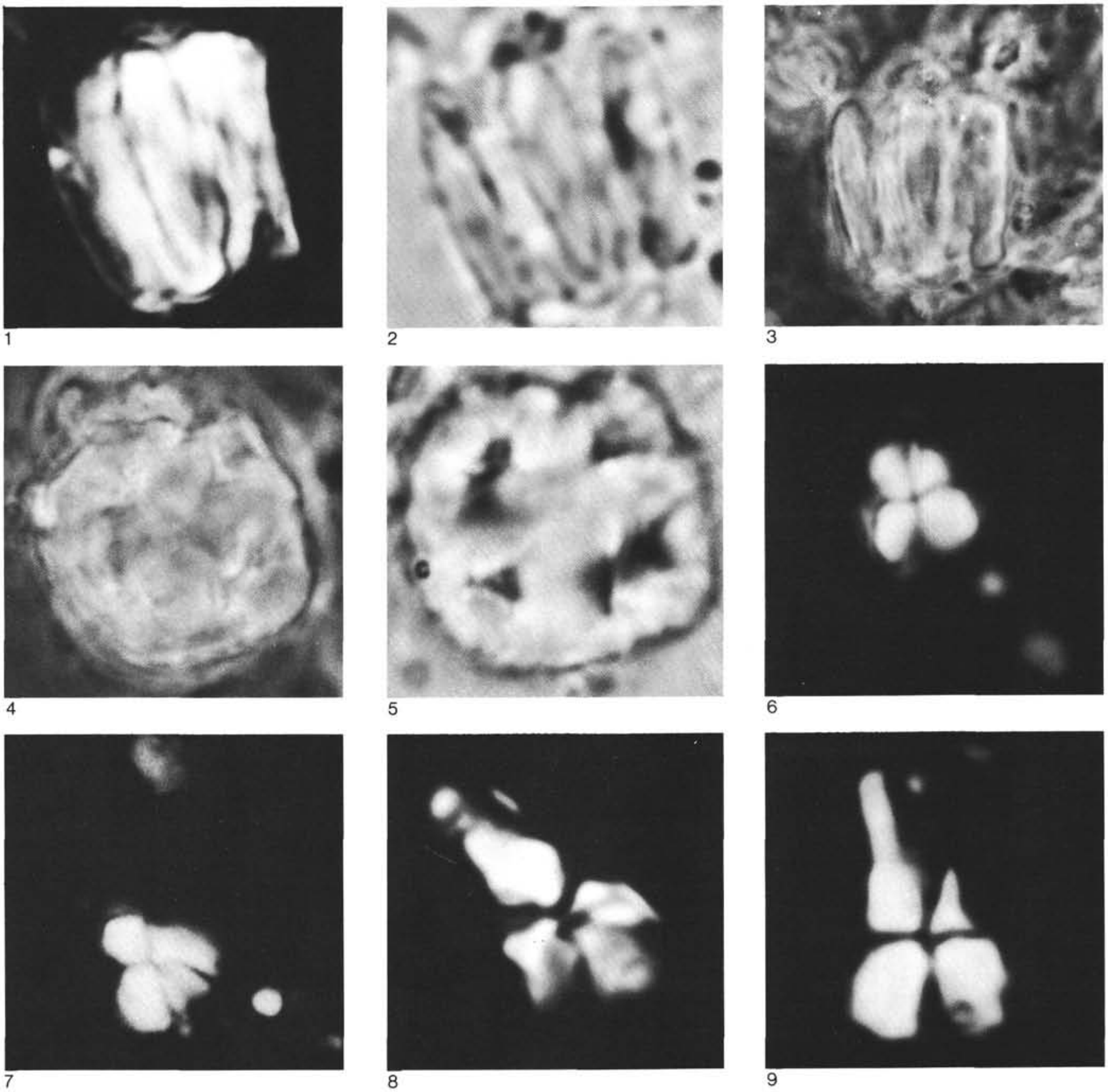

Plate 3. **1–5.** *Chipragmalithus calathus* Bramlette and Sullivan, ×3900, Sample 605-38-1, 50–52 cm, (1–3) side view (1, Pol; 2, Tr; 3, Ph); (4, 5) end view (4, Ph; 5, Tr). **6, 7.** *Sphenolithus spiniger* Bukry, ×4100, Sample 605-7-1, 50–54 cm, (6) Pol, long axis 0° to crossed nicols; (7) Pol, long axis 45° to crossed nicols). **8, 9.** *Sphenolithus anarrhopus* Bukry and Bramlette, ×4600, Sample 605-43-3, 50–52 cm, (8) Pol, long axis 45° to crossed nicols; (9) Pol, long axis 10° to crossed nicols.

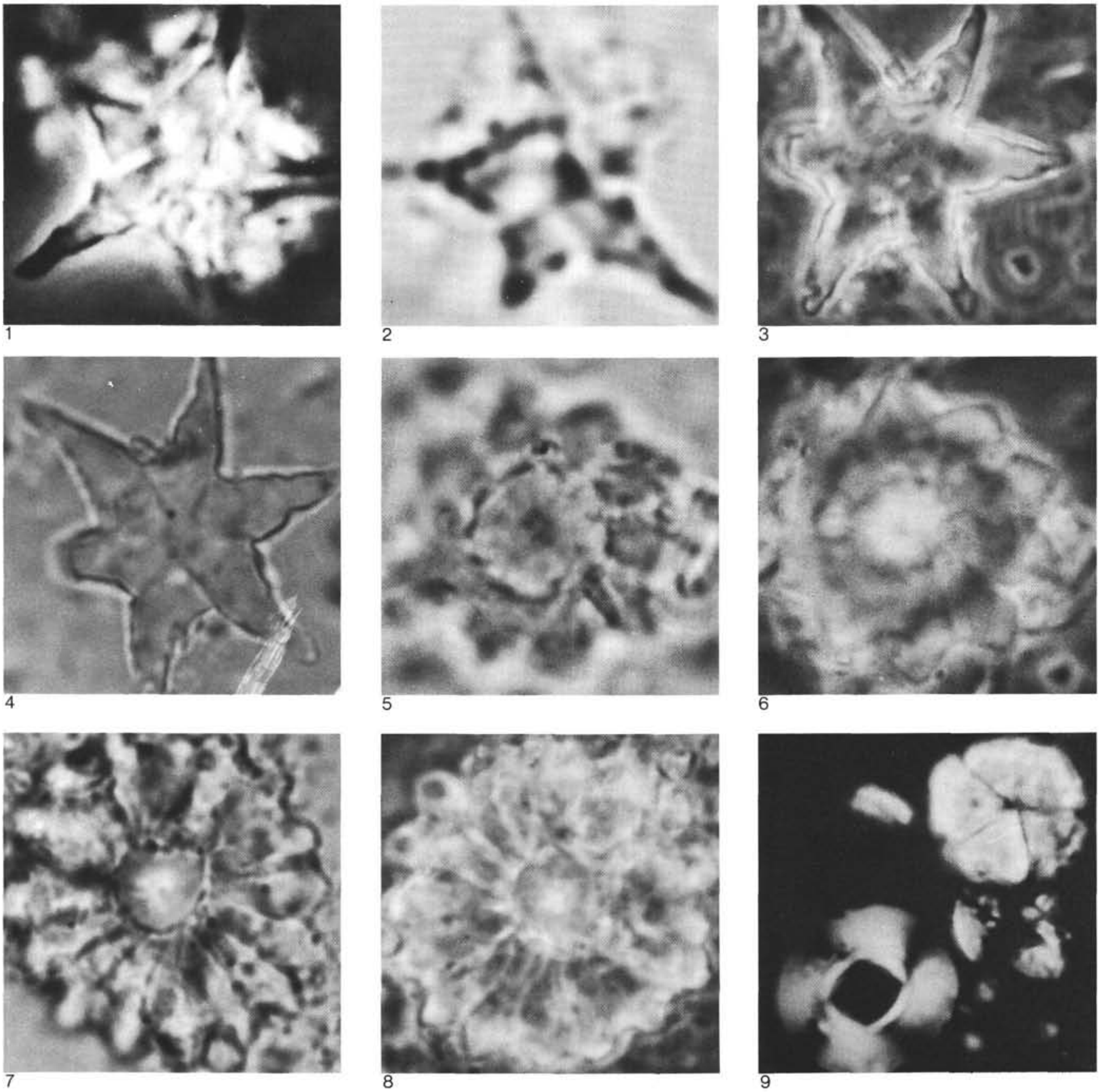

Plate 4. **1-2.** *Discoaster sublodoensis* Bramlette and Sullivan, ×5000, Sample 605-22-5, 50–52 cm, (1) Ph; (2) Tr, same specimen, right–left reversed. **3-4.** *Discoaster lodoensis* Bramlette and Riedel, ×2600, Sample 605-34-1, 50–54 cm (3, Ph; 4, Tr). **5-6.** *Discoaster kuepperi* Stradner, ×4000, Sample 605-34-1, 50–54 cm, (5) Tr, high focus; (6) Ph, low focus. **7-8.** *Discoaster diastypus* Bramlette and Sullivan, ×2500, Sample 605-43-3, 50–52 cm, (7, Tr; 8, Ph). **9.** *Reticulofenestra samodurovi* (Hay, Mohler, and Wade) and *Braarudosphaera discula* Bramlette and Riedel, ×2800, Sample 605-7-2, 50–54 cm, Pol.

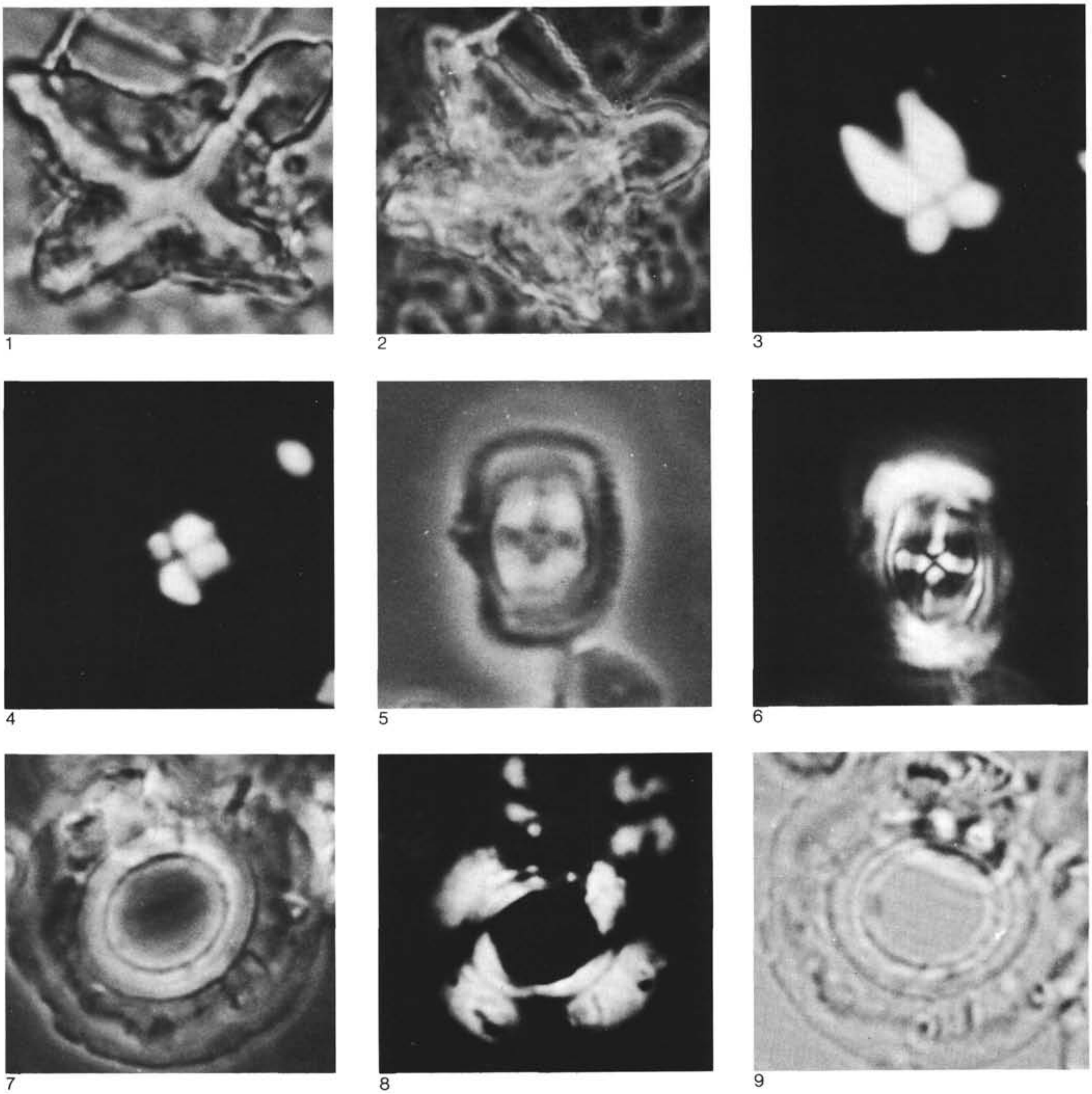

Plate 5. **1, 2.** *Nannotetrina quadrata* (Bramlette and Sullivan), ×3000, Sample 605-17-1, 50–52 cm (1, Tr; 2, Ph). **3, 4.** *Sphenolithus furcatolithoides* Locker, ×5000, Sample 605-10-1, 50–54 cm, (3) Pol, long axis 0° to crossed nicols; (4) Pol, long axis 45° to crossed nicols. **5, 6.** *Campylosphaera dela* Bramlette and Sullivan, ×3800, Sample 605-6,CC (5, Ph; 6, Pol). **7–9.** *Reticulofenestra umbilica* (Levin), ×3500, Sample 605-7-1, 50–54 cm, (7) Pol; (8) Ph; (9) Tr, rotated 30°.