

7. EOCENE BENTHIC FORAMINIFERAL BIOFACIES OF THE NEW JERSEY TRANSECT¹

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ABSTRACT

Benthic foraminiferal biofacies may vary independently of water depth and water mass; however, calibration of biofacies and stratigraphic ranges with independent paleodepth estimates allows reconstruction of age-depth patterns applicable throughout the deep Atlantic (Tjalsma and Lohmann, 1983). We have attempted to test these faunal calibrations in a continental margin setting, reconstructing Eocene benthic foraminiferal distributions along a dip section afforded by the New Jersey Transect (DSDP Sites 612, 108, 613). The following independent estimates of Eocene depths for the transect were obtained by "backtracking," "backstripping," and by assuming increasing depth downdip ("paleoslope"): Site 612, near the middle/lower bathyal boundary (about 1000 m); Site 108, in the middle bathyal zone (about 1600 m); and Site 613, near the lower bathyal/upper abyssal boundary (about 2000 m). Within uncertainties of backtracking (hundreds of meters), these estimates agree with estimates of paleodepth based on comparison of the New Jersey margin biofacies with other backtracked faunas. The stratigraphic ranges of many benthic taxa correspond to those found at other Atlantic DSDP sites.

The major biofacies patterns show: (1) a depth dichotomy between an early to middle Eocene *Nuttallides truempyi*-dominated biofacies (greater than 2000 m) and a *Lenticulina*-*Osangularia*-*Alabama* cf. *dissonata* biofacies (1000–2000 m); and (2) a difference between a middle and a late Eocene biofacies at Site 612. The faunal boundary at about 2000 m, between bathyal and abyssal zones, occurs not only on the margin, but also throughout the deep Atlantic. The faunal change between the middle and late Eocene at Site 612 was due to a decrease of *Lenticulina* spp., the local disappearance of *N. truempyi*, and establishment of a *Bulimina alazanensis*-*Gyroidinoides* spp. biofacies. Although this change could be attributed to local paleoceanographic or water-depth changes, we argue that it is the bathyal expression of a global deep-sea benthic foraminiferal change which occurred across the middle/late Eocene boundary.

INTRODUCTION

Drilling by DSDP Legs 11, 93, and 95 constitute the seaward end of a transect of the passive U.S. continental margin off New Jersey (Fig. 1). Leg 95 drilled two sites—612 (1404 m present depth; 38°49.21'N, 72°46.43'W) and 613 (2323 m present depth; 38°46.26'N, 72°30.43'W)—and recovered thick Eocene and upper Miocene to Recent sections. These sections are interrupted by numerous unconformities caused by downslope erosion (Miller, Curry, et al., 1985; Miller, Mountain, et al., 1985; Mountain, this volume; Poag and Mountain, this volume); little Oligocene to middle Miocene sediments were recovered. Nevertheless, the thick middle Eocene sections recovered (Site 612: 176 m Site 613: 161 m) contain well-preserved deep-sea benthic foraminiferal assemblages. Samples from Sites 108 (1815 m present depth; 38°48.27'N, 72°39.21'W) and 390 (2665 m present depth; 30°08.54'N, 76°06.74'W) also were used in mapping biofacies. We reconstruct the Eocene distribution of benthic foraminifera along a dip section on this margin from about 1000 m to nearly 3000 m.

Benthic foraminifera have been used widely to infer paleodepths and other paleoenvironmental information. Early distributional studies noted correlations between depth and modern benthic foraminiferal biofacies (Phleger and Parker, 1951; Bandy, 1953a; among others), and these correlations were applied to extant taxa in the fossil re-

cord to infer paleodepths (e.g., Bandy, 1953b). Despite this emphasis on depth, early studies recognized that factors other than depth controlled the distribution of biofacies, and noted correlations with other environmental parameters, particularly temperature (e.g., Phleger and Parker, 1951; Bandy, 1953a).

Subsequent studies established not only that depth limits of deep-sea taxa varied interregionally, but also that some benthic foraminiferal biofacies varied independently of paleodepth, migrating over 2000 m from glacial to interglacial periods (Lohmann, 1978a). Deep-sea benthic foraminiferal distributions were shown to be correlated instead with water masses (Streeter, 1973; Schnitker, 1974, 1979; Lohmann, 1978b; Corliss, 1979). Deep-sea water masses have very small temperature and salinity variations, and benthic foraminifera presumably are not sensitive to these slight differences. Associations of benthic foraminifera with water masses exist because water masses are strongly correlated with certain physiochemical parameters (carbonate availability, organic carbon content of sediment, dissolved oxygen content, etc.) (Bremer and Lohmann, 1982; Miller and Lohmann, 1982). These physiochemical controls can be isolated, and in conjunction with carbon isotopic data, certain benthic foraminifera can provide means for interpreting paleoceanographic changes.

Independent paleoenvironmental indicators must be used to evaluate benthic foraminiferal changes in order to avoid equivocal results. We particularly are limited in the Paleogene by the paucity of extant species, and are required to adopt a different approach to paleodepth estimates. This tool is provided by "backtracking" using empirical age-versus-subsidence curves (Sclater et al.,

¹ Poag, C. W., Watts, A. B., et al., *Init. Repts. DSDP*, 95: Washington (U.S. Govt. Printing Office).

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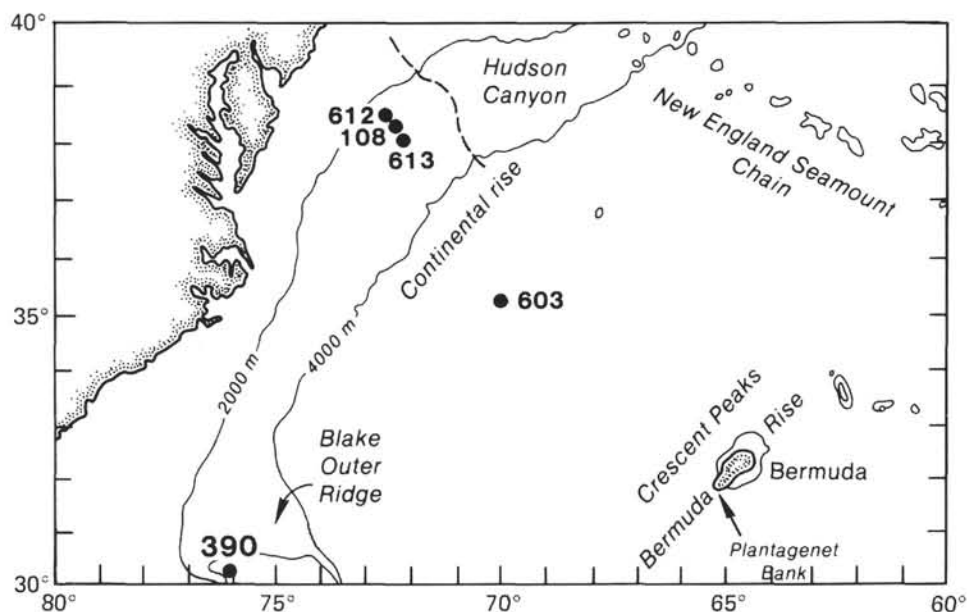


Figure 1. Location map.

1971; Berger and Winterer, 1974; Tucholke and Vogt, 1979). In addition, other geological and geophysical means can be used to place constraints upon paleodepth. For example, evidence of subaerial or shallow-water sediments can be used to constrain subsidence history of aseismic ridges (e.g., Barker, 1983), and seismic stratigraphy can be used to constrain amount of uplift in more complex regions (Miller, 1983). Changes in the distribution of benthic foraminiferal biofacies can be calibrated against these independent estimates of paleodepths (Tjalsma and Lohmann, 1983). Once the distributions are known, benthic foraminifers may be used to estimate paleodepths in other sections (e.g., Wood et al., 1985).

Tjalsma and Lohmann's (1983) calibrations of age-depth relationships of Paleocene to Eocene taxa provide a standard for comparison with the New Jersey Transect. Two factors, however, may complicate our interpretations of paleodepth based on their study: (1) Tjalsma and Lohmann lacked coverage of Eocene depths shallower than about 1400 m, so independent evidence of the paleodepths of sites shallower than this is limited; (2) their material was derived primarily from DSDP sites away from continental margins, and there may be significant faunal differences in a margin setting. Nevertheless, comparisons between their material and ours proved valuable, especially in estimating paleodepths of the deeper Sites 108 and 613.

Examination of benthic foraminiferal distributions in a dip section such as that provided by the New Jersey Transect provides another constraint upon paleodepth, albeit a relative one. Assuming simple thermal subsidence without major Eocene faulting, paleodepths can be assumed to have increased monotonically downdip (i.e., updip wells always penetrate shallower facies). The assumption of simple thermal subsidence is reasonable for the New Jersey margin (Watts and Steckler, 1979). Assuming reasonable depth gradients appropriate for the paleogeographic setting (shelf, slope, or rise), a slope

profile may be constructed for the Eocene margin, as has been done for the Campanian to Maestrichtian of the New Jersey margin (Olsson and Nyong, 1984; Nyong and Olsson, 1984). Using this approach, downdip trends may be calibrated to relative increasing paleodepth, although the precise paleodepth is still uncertain.

We map Eocene biofacies and evaluate bathymetric trends along the New Jersey transect (Fig. 1). Our strategy in evaluating bathymetric trends is based primarily upon faunal comparisons with "backtracked" biofacies (Tjalsma and Lohmann, 1983; Miller, 1983; Miller, Curry, et al., 1985) and geophysical estimates of subsidence of the margin. Bathymetric constraints also are imposed by the assumption of increasing depth downdip and other micropaleontological evidence.

METHODS

Benthic foraminifers were studied from samples taken from the lower Eocene to lowermost Oligocene sections recovered at Site 612 (29 samples), the lower to middle Eocene section at Site 613 (11 samples), and the middle Eocene section of Site 108 (2 samples) off the New Jersey coast (Fig. 1). The samples were soaked in a 3% hydrogen peroxide solution and washed through a 63- μ m sieve with a sodium hexametaphosphate solution. Aliquots from the >149- μ m size fraction were picked and mounted on a reference slide. Three hundred specimens were picked when possible, but several samples contained as few as 100 specimens (Tables 1, 2). Although benthic foraminiferal preservation was good in the middle Eocene at Sites 612 and 613, it was poor to moderate below the diagenetic front, which lies near the lower/middle Eocene boundary at those sites (Figs. 2, 4). Therefore, interpretations of the lower Eocene faunas at these sites are less certain.

The benthic foraminifers were identified using the taxonomy outlined by Tjalsma and Lohmann (1983), Miller (1983), and the Taxonomic Notes in this chapter. The census data are presented as percentages of the total benthic foraminifers counted (Tables 1, 2). We used computer programs provided by Lohmann (1980 and personal communication, 1982) to conduct Q-mode principal component and factor analyses of the census data. Our census contained 63 categories (Tables 1, 2). Our multivariate analyses are based upon 48 of these census categories that also were used by Tjalsma and Lohmann (1983) and Miller (1983). We did a factor analysis of the combined data from Sites 108, 390 (data after Tjalsma and Lohmann, 1983), 612, and 613.

In addition, we projected our samples from Sites 108, 612, and 613 onto Tjalsma and Lohmann's Eocene Principal Components. Only samples with more than 100 specimens were used in these comparisons.

Estimates of paleodepth for sites on the New Jersey Transect were obtained using "backtracking" (Sclater et al., 1971; Berger and Winterer, 1974) and "backstripping" techniques (Watts and Steckler, 1979). Backstripping estimates (accounting for flexure and decompaction) for the middle Eocene, provided by M. Steckler (personal communication, 1985), were as follows: Site 612, approximately 1050 m; Site 613, approximately 2000 m. Since Sites 612 and 108 were on continental or transitional crust, they cannot be rigorously "backtracked" using oceanic empirical age-subsidence curves. However, continental crust can be assumed to follow an exponential subsidence curve (Thorne and Watts, 1984) of the form

$$Pd = Id - A + A \cdot e^{(t/\tau)} - S \quad (1)$$

where Pd is paleodepth, Id is initial depth, t is (age basement - age of level considered), S is a sediment correction of $0.66 \cdot (\text{basement sub-bottom depth} - \text{sub-bottom depth of level considered})$, τ is a decay constant, and A is an empirical constant. We used a τ of 62.5, and an A of about -3650 (empirically derived from Pacific Ocean crustal subsidence using data of Parsons and Sclater, 1977, their table 2, solving equation for A assuming $Id = 2700$ m). Assuming crustal ages of 180 Ma, Eocene depths were estimated as follows: (1) Site 612, 1200 to 1400 m (assuming 13 km of sediments); (2) Site 108, 1600 to 1700 m (assuming 11 km of sediments); (3) Site 613, 2200 to 2300 m (assuming 10 km of sediments) (sediment thicknesses after Poag, 1985). Since the depth of the Eocene sediments is only a small portion of total sediments, these estimates are relatively insensitive to the total thickness of sediments. Also, since the Atlantic margin was already an old margin in the Eocene and most of the thermal subsidence had already taken place, these estimates are relatively insensitive to the value of A used (A can vary for Atlantic Ocean crust, from about -3300 to greater than -4100 [computed using empirical data of Tucholke and Vogt, 1979]) and to the exact time of rifting (viz. whether 180 or 165 Ma). The resulting paleodepth section (Fig. 6) has a gradient of about 1:20, which is similar to the modern slope gradient in this region (e.g., average modern gradients on the slope are 1:15; Heezen et al., 1959).

Site 390 is on the Blake Nose off the southeastern U.S.; the Eocene benthic biofacies reported from this site (Tjalsma and Lohmann, 1983) are remarkably similar to that at Site 613. Tjalsma and Lohmann (1983) estimated backtracked paleodepth for this site of 2700 m; using Eq. 1 (sediment = 0.38 km), we estimate slightly shallower depths of 2300 to 2500 m. Site 390 benthic foraminifers were compared with the New Jersey Transect by plotting biofacies at an assumed Eocene depth of 2700 m (Fig. 6).

We emphasize that the absolute paleodepths obtained by backtracking or backstripping are only broad estimates. Although Steckler's "backstripping" estimates probably are more reliable, we plotted paleodepth (e.g., Fig. 6) using the slightly deeper depths afforded by assuming subsidence along the oceanic curve. Uncertainties in the thermal subsidence estimates may be up to a few hundred meters; such uncertainties reflect, however, only a small part of the 1000- to 3000-m water depth estimates. Similarly, we assume that global changes in water depth were small relative to the total water depth (Kominz, 1984). Despite such uncertainties, we consider the following to be reasonable estimates of Eocene depths (Fig. 6): Site 612 was near the middle/lower bathyal boundary (about 1000 m), Site 108 was in the lower bathyal zone (1000-2000 m), Site 613 was near the bathyal/abyssal boundary (about 2000 m), and Site 390 was in the upper abyssal (>2000 m) zone (depth zones after Berggren, 1978).

RESULTS AND DISCUSSION

Biostratigraphic Ranges and Chronostratigraphic Control

Planktonic Foraminifers

We used planktonic foraminiferal biostratigraphy (site chapters; Miller and Hart, this volume) to correlate be-

tween sites (Figs. 1, 3, 5). Numerical age assignments used in biofacies comparison (Figs. 6, 8-17) were made by interpolating between first and last appearance levels (Figs. 2, 4, 7; Table 3) at Sites 612 and 613 (datum-level ages and time scale of Berggren et al., 1985). Biostratigraphic control is good at Site 613, with primary and secondary zonal criteria of Stainforth et al. (1975) and Blow (1979) in reasonable agreement.

Planktonic foraminiferal biostratigraphic interpretations of much of the Eocene section at Site 612 are uncertain, with inversions of expected ranges. For example, *in situ* *Morozovella aragonensis* last occurs in Samples 612-35, CC, while reworked specimens extend into Sample 612-24, CC (Fig. 7). This last occurrence is the primary zonal criterion for the base of the *M. lehneri* Zone (Stainforth et al., 1975), and should correlate with the base of Zone P12 (Berggren et al., 1985). However, the first occurrence of *Globigerinatheka kugleri* is in Sample 612-31, CC, suggesting that this is the base of Zone P11 (Blow, 1979) and that the last occurrence of *M. aragonensis* in Sample 612-35, CC is local. To complicate matters further, *Acarinina broedermanni* last occurs in Sample 612-34, CC, suggesting that this is the top of Zone P11 (alternative criterion; Blow, 1979). Cores 612-34 to 612-24 therefore may be equivalent to either Zone P11 or Zone P12, and age models are correspondingly uncertain.

At Sites 612 and 613 the biostratigraphic zonal assignment of the upper part of the middle Eocene is debatable. We did not observe *Orbulinoides beckmanni* at either site; thus, Zone P13 (= *O. beckmanni* total range zone) is not identifiable. Luterbacher (1972) reported this taxon from the upper middle Eocene strata at Site 108. Our examination of material from Site 108 failed, however, to confirm the presence of *O. beckmanni*, probably owing to our smaller-sized samples. Still, stratigraphic position suggests that the strata recovered at Site 612 are younger than this.

Jones (1983) and Berggren and Aubry (1984) reported planktonic foraminiferal fauna from the Castle Hayne Formation, North Carolina, which is quite similar to that of the upper middle Eocene at Sites 612 and 613 (with *Hantkenina longispina*, *Subbotina frontosa*, *Globorotalia cerroazulensis pomeroli*, *Acarinina bullbrooki*, *Truncorotaloides rohri*, *T. topilensis*, *Morozovella lehneri*, and *Globigerinatheka mexicana*). Although Jones (1982) originally favored assignment of this fauna to Zones P11 to P12, later (1983) he and Berggren and Aubry (1984) favored assignment to Zones P12 to P13. The primary zonal criterion for Zone P13, *O. beckmanni*, is also absent from the Castle Hayne Formation. The Castle Hayne Formation (*partim*) has been assigned to nanofossil Zone NP16 (Berggren and Aubry, 1984), and the upper middle Eocene strata at Sites 612 and 613 have been assigned to Zone CP14a (= upper NP16) (Valentine, this volume). This suggests that (1) the Castle Hayne Formation (*partim*) correlates with the uppermost middle Eocene strata at Sites 612 and 613; (2) both are older than 42 Ma, correlating with upper Zone P12 to lower Zone P14 (Berggren et al., 1985); and (3) this upper middle Eocene interval represents widespread deposition on

Table 1. Benthic foraminiferal census data (as percentages of total benthic foraminifers counted), Site 612.

Sample number ^a	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Depth (m sub-bottom)	136.0 ^b	136.0	137.6	139.1	140.6	141.3	143.6	145.1	149.3	154.7	158.8	164.5	168.3	174.0
Age (Ma)	36.6	36.6	36.6	36.7	36.7	36.7	36.8	36.8	36.9	37.1	37.2	37.4	37.5	37.6
Total number counted	335.0	393.0	369.0	196.0	148.0	173.0	292.0	129.0	321.0	329.0	181.0	421.0	162.0	242.0

Species included in censuses of Tjalsma and Lohmann (1983), Miller (1983), and Miller et al. (1985)

<i>Prim. agglutinans</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>S. spectabilis</i>	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.4
<i>G. cf. laevigata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
<i>G. pyramidata</i>	0.6	0.0	0.0	0.0	1.4	0.6	0.0	1.6	1.6	0.0	0.0	0.0	0.0	0.0
<i>G. cf. pyramidata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Vulvulina spinosa</i>	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>K. subglabra</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Pleurostomella</i> spp.	0.3	0.5	0.0	1.0	4.1	3.5	2.4	0.0	0.6	0.9	0.6	1.7	0.0	0.8
<i>Lenticulina</i> spp.	3.6	2.3	2.2	3.1	4.1	7.5	4.8	14.0	4.4	5.8	6.6	5.7	7.4	9.1
<i>S. aculeata</i>	2.7	1.8	0.0	0.0	0.0	5.8	1.0	0.8	1.2	0.0	1.1	0.2	0.0	0.8
<i>S. gracillima</i>	0.0	0.0	0.0	0.0	4.1	2.9	0.7	19.4	6.5	2.4	11.6	8.6	0.0	0.0
<i>S. subspinosa</i>	1.2	5.9	0.0	4.1	14.9	0.6	0.7	3.1	0.0	1.2	0.0	0.7	0.0	0.0
<i>Aragonia</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. alazanensis</i>	5.4	34.6	42.5	38.3	2.0	1.7	0.0	0.0	30.8	29.2	18.2	21.6	35.8	2.9
<i>B. tuxpamensis</i>	0.0	0.0	10.3	7.7	8.8	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Buliminella grata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
<i>B. jarvisi</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. macilenta</i>	7.2	2.5	2.2	0.0	4.1	4.0	1.4	8.5	0.9	0.6	0.6	1.2	0.0	0.0
<i>B. callahani</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. semicostata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. glomarchallengeri</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. trinitatis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.1	0.0	0.0	0.4
<i>T. robertsi</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>U. rippensis</i>	0.3	0.3	0.0	0.0	0.0	4.6	0.3	4.7	0.0	0.0	0.0	0.0	0.0	8.7
<i>Q. profunda</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Abyssamina</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Clinapertina</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Nonion</i> spp.	0.9	6.9	0.0	1.0	2.0	0.0	2.7	0.0	7.5	5.8	0.6	6.7	3.1	0.0
<i>P. eocenica</i>	1.5	7.4	0.3	9.2	6.1	13.9	12.7	0.0	12.5	10.3	15.5	9.7	11.7	14.5
<i>P. quinqueloba</i>	1.5	0.5	5.4	1.0	3.4	4.6	2.1	0.0	1.6	2.4	1.7	2.1	4.3	3.7
<i>Gyroidinoides</i> spp.	5.7	4.3	3.3	4.6	4.7	9.2	7.2	0.0	2.8	2.4	4.4	5.7	11.7	4.1
<i>Anomalinoidea</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.5	0.6	1.7
<i>G. capitata-semicribrata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.4
<i>G. micra</i>	0.9	0.0	0.5	0.0	0.0	1.7	1.0	0.0	1.2	1.5	1.7	0.0	3.7	1.7
<i>N. truempyi</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>O. umbonatus</i>	0.6	0.0	0.0	0.5	0.0	2.9	0.3	0.0	5.9	4.3	1.1	1.7	3.7	5.8
<i>Osangulana</i> spp.	31.0	15.8	1.1	5.6	0.0	4.6	25.3	0.0	4.7	21.0	15.5	20.4	0.6	7.9
<i>A. cf. dissonata</i>	3.0	0.3	4.9	10.7	22.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>H. ammophila</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
<i>G. subglobosa</i>	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.5	0.0	0.4
<i>C. grimsdalei</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. bradyi</i>	6.9	1.8	0.8	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	3.7
<i>C. havanensis</i>	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. mundulus</i>	3.0	1.0	4.3	4.6	2.7	5.8	4.1	0.0	7.8	1.5	3.9	1.9	1.2	3.7
<i>C. tuxpamensis</i>	0.6	0.0	3.0	1.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>C. cf. pseudoperlucida</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. subspiratus</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. laurissae</i>	1.5	0.3	0.3	0.0	0.0	0.6	8.2	0.0	0.0	0.0	3.9	3.8	0.0	0.8

Species not included in censuses of Tjalsma and Lohmann (1983), Miller (1983), and Miller et al. (1985)

<i>Trifarina</i> sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
<i>P. renzi</i>	0.0	1.0	2.4	1.5	1.4	2.3	0.0	0.0	0.0	0.0	0.0	0.7	0.0	3.7
<i>P. compressa</i>	0.3	0.3	1.9	0.5	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.2	1.2	11.2
<i>Cassidulina havanensis</i>	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.3	3.3	0.0	0.6	0.0
<i>Nonionella</i> spp.	0.3	0.3	0.0	0.5	0.7	2.3	0.7	0.0	0.9	0.6	0.6	1.0	1.2	0.0
<i>Siphonina</i> sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Sigmoilopsis</i> sp.	0.9	0.5	0.3	1.0	1.4	4.0	2.1	3.9	0.6	0.3	0.6	0.5	0.6	3.3
<i>Tritaxia</i> sp.	0.0	0.0	0.0	0.0	2.0	0.0	0.3	4.7	0.6	0.0	0.0	0.0	0.0	0.0
<i>K. chapapottensis</i>	0.3	0.0	0.8	0.5	0.7	0.0	0.7	3.1	0.0	1.2	0.0	0.0	1.2	0.0
" <i>Eggerella</i> " sp.	0.3	0.3	0.0	0.5	0.0	0.0	0.7	0.8	2.2	0.9	0.6	1.0	2.5	0.0
<i>B. antegressa</i>	1.5	0.3	3.8	1.5	0.7	0.6	1.0	4.7	0.6	0.6	0.0	0.2	0.0	0.8
<i>Dentalina/Vaginulina</i>	0.0	0.3	0.0	1.0	0.0	1.2	1.4	2.3	1.6	0.6	0.0	1.2	3.1	2.5
<i>U. hispida</i>	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.3	0.9	0.0	1.2	4.9	4.1
<i>U. basicordata</i>	16.7	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>T. danvilensis</i>	0.0	0.0	9.8	0.0	0.0	9.2	9.2	28.7	0.3	0.3	3.9	1.0	0.0	1.7

^a 1 = 16-7, 26-30 cm; 2 = 16,CC; 3 = 17-1, 140-144 cm; 4 = 17-2, 140-144 cm; 5 = 17-3, 140-144 cm; 6 = 17-4, 60-64 cm; 7 = 17-5, 140-144 cm; 8 = 17-6, 140-144 cm; 9 = 18-3, 60-64 cm; 10 = 18,CC; 11 = 19-3, 60-64 cm; 12 = 19,CC; 13 = 20-3, 60-64 cm; 14 = 20,CC; 15 = 21-1, 60-64 cm; 16 = 21-3, 60-64 cm; 17 = 22,CC; 18 = 24,CC; 19 = 26,CC; 20 = 28-6, 146-150; 21 = 30,CC; 22 = 32,CC; 23 = 33,CC; 24 = 35,CC; 25 = 37-3, 60-64 cm; 26 = 39-3, 60-64 cm; 27 = 41-3, 60-64 cm; 28 = 45-3, 60-64 cm; 29 = 49,CC; 30 = 55,CC; 31 = 59,CC.

^b Actual depth sub-bottom is 135.96 m — because of rounding error it appears as 136.0 m.

Table 1 (continued).

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
174.8	177.8	193.1	212.0	231.4	250.4	269.8	289.0	298.7	318.0	331.7	350.9	370.3	408.8	453.2	511.3	549.5
37.6	37.7	43.6	44.6	45.6	46.6	47.7	48.7	49.2	50.3	51.0	52.2	52.5	53.2	53.9	54.9	55.5
237.0	244.0	370.0	277.0	513.0	541.0	328.0	273.0	186.0	502.0	695.0	163.0	280.0	89.0	135.0	89.0	205.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.5	3.0	0.6	3.7	1.4	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.7	0.0	5.2	1.8	2.6	2.2	0.2	0.4	8.0	7.1	3.4	2.2	0.0	4.4
0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.5
0.8	0.8	0.5	1.4	0.6	0.9	0.9	0.4	0.0	1.8	0.1	0.0	0.0	4.5	3.0	14.6	2.0
14.3	8.6	18.6	15.9	12.3	9.2	13.1	19.8	32.3	19.1	14.0	23.3	23.9	19.1	17.8	29.2	18.0
4.6	2.0	0.0	0.7	4.9	9.4	0.0	0.0	0.5	3.4	7.2	0.0	0.0	2.2	0.0	5.6	0.0
0.0	1.6	8.1	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.1	16.9	0.0	0.0	0.0
0.0	4.1	1.1	0.0	3.3	3.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2	1.9	0.0	3.6	0.0	0.0	0.0	0.0
2.1	11.5	0.3	0.0	0.0	0.6	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0	1.1	0.0
0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.7	0.0	0.0	0.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	2.7	1.8	0.0	2.8	11.6	0.0	0.0	0.8	0.3	8.0	3.9	0.0	5.2	1.1	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.0	4.1	1.8	0.0	0.7	12.5	0.0	0.0	3.4	0.7	0.6	3.6	4.5	0.7	1.1	0.0
0.4	0.8	4.1	0.0	0.6	1.1	0.3	0.0	0.0	0.2	1.0	0.0	0.4	0.0	3.0	0.0	0.0
0.0	0.0	0.0	11.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.4	0.3	5.4	0.4	1.8	3.0	0.0	0.0	3.4	0.3	0.0	0.0	0.0	0.7	0.0	2.4
21.1	11.9	3.8	1.4	3.7	1.5	8.2	4.0	0.0	9.0	5.9	0.0	0.0	1.1	0.7	0.0	0.5
3.8	6.6	1.9	0.7	1.2	1.7	2.7	1.8	0.0	2.8	1.4	0.0	0.0	1.1	0.7	1.1	1.5
13.9	13.1	8.6	4.3	2.1	3.1	3.0	2.9	0.0	3.2	6.5	0.0	3.6	0.0	0.0	0.0	1.0
1.7	3.3	0.0	0.4	0.2	3.5	17.1	13.9	0.0	5.6	4.9	0.0	0.0	4.5	5.2	0.0	1.0
0.0	0.0	0.0	0.4	1.6	3.0	0.0	1.1	0.0	3.2	3.7	0.0	0.0	0.0	0.0	2.2	11.7
4.2	3.3	0.0	8.7	2.3	0.4	4.9	0.0	0.0	6.8	0.7	1.8	0.4	1.1	8.1	0.0	0.0
0.0	0.0	0.0	4.3	2.5	5.7	0.9	0.4	0.0	2.6	4.3	3.7	2.9	0.0	2.2	11.2	18.0
2.5	6.1	6.2	2.9	0.0	1.8	0.9	13.2	0.0	11.8	5.2	0.0	10.4	11.2	6.7	0.0	2.4
2.5	2.9	4.3	0.0	23.0	3.9	0.0	9.5	0.0	0.6	11.8	19.0	23.2	6.7	22.2	0.0	2.0
0.0	0.0	3.0	22.0	30.0	12.8	0.0	20.9	0.0	0.0	0.0	17.2	2.5	0.0	12.6	0.0	2.4
0.0	0.0	1.4	4.7	0.0	13.3	0.0	0.0	0.0	0.0	2.4	0.0	0.4	11.2	0.7	23.6	0.0
0.0	0.0	0.0	0.0	1.9	0.6	3.0	0.0	0.0	0.0	2.0	0.0	0.7	0.0	0.0	3.4	0.0
0.0	0.0	0.0	0.4	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.0	3.8	0.0	0.0	0.7	5.5	1.1	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	7.8	1.4	0.2	0.0	1.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0	4.4	3.4	6.3
11.4	6.1	2.4	0.0	6.0	0.0	3.0	1.1	0.0	0.0	14.2	2.5	4.6	0.0	1.5	0.0	25.4
0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	0.0	1.4	7.3	0.0	0.0	0.0	0.0	2.2	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	0.8	1.6	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	0.0	0.0	2.2	0.0	7.2	0.0	1.1	0.0	6.4	0.1	0.0	0.7	0.0	0.0	0.0	0.0
0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	0.4	0.5	0.0	0.0	1.1	0.3	2.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	10.4	3.2	10.1	0.0	0.0	0.0
2.1	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0	1.2	1.8	0.7	0.0	0.0	0.0	0.0
0.0	0.8	1.4	1.1	0.0	1.1	0.0	0.7	8.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.7	0.4	0.0	0.4	0.0	0.0	0.9	0.0	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
0.8	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	2.5	2.4	4.3	1.8	2.2	1.5	1.5	0.0	0.4	0.4	0.0	0.0	2.2	0.7	0.0	0.0
0.0	0.0	0.3	0.4	0.0	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. Benthic foraminiferal census data (as percentages of the total benthic foraminifera counted), Sites 613 and 108.

Sample ^a	Site 613						Site 108	
	1	2	3	4	5	6	1	2
Depth (m sub-bottom)	269.0	315.1	334.7	364.7	410.8	439.4	39.8	58.2
Age (Ma)	43.0	45.1	45.9	47.3	49.3	52.2	43.0	44.0
Total number counted	209.0	252.0	153.0	175.0	75.0	138.0	95.0	321.0

Species included in censuses of Tjalsma and Lohmann (1983), Miller (1983), and Miller et al. (1985)

<i>Prim. agglutinans</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>S. spectabilis</i>	3.3	10.3	0.0	0.0	1.3	0.7	0.0	0.0
<i>G. cf. laevigata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>G. pyramidata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>G. cf. pyramidata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Vulvulina spinosa</i>	2.9	3.2	2.6	2.3	4.0	2.2	0.0	2.2
<i>K. subglabra</i>	2.4	0.8	0.0	0.0	2.7	0.7	0.0	0.6
<i>Pleurostomella</i> spp.	1.0	0.4	2.6	1.7	0.0	0.7	0.0	0.3
<i>Lenticulina</i> spp.	14.4	13.1	11.1	9.7	6.7	36.2	13.7	21.2
<i>S. aculeata</i>	0.5	0.0	0.0	0.0	0.0	5.8	0.0	9.3
<i>S. gracillima</i>	5.7	6.0	17.0	2.9	0.0	2.2	0.0	0.0
<i>S. subspinosa</i>	1.4	8.3	5.2	6.3	0.0	1.4	0.0	0.0
<i>Aragonia</i> spp.	0.0	2.0	2.6	0.0	0.0	0.0	0.0	0.0
<i>B. alazanensis</i>	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.9
<i>B. tuxpamensis</i>	0.5	0.0	0.7	0.0	0.0	0.0	1.1	0.0
<i>Bullimina</i> spp.	0.0	0.0	0.0	0.0	0.0	5.8	0.0	2.5
<i>B. jarvisi</i>	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. macilenta</i>	1.4	0.0	2.6	1.1	0.0	2.9	2.1	0.9
<i>B. callahani</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. semicostata</i>	0.0	6.3	0.0	7.4	12.0	0.0	0.0	0.0
<i>B. glomarchallengeri</i>	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
<i>B. trinitatis</i>	4.8	0.8	0.7	2.9	13.3	2.2	3.2	0.0
<i>T. robertsi</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
<i>U. rippensis</i>	0.5	0.0	0.0	0.0	0.0	0.0	3.2	0.0
<i>Q. profunda</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Abyssamina</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Clinapertina</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>N. havanense</i>	1.4	0.0	1.3	0.6	0.0	0.0	5.3	2.8
<i>P. eocenica</i>	1.9	2.0	0.7	4.0	0.0	0.0	4.2	4.0
<i>P. quinqueloba</i>	1.0	2.0	0.0	0.6	0.0	0.0	0.0	1.2
<i>Gyroidinoides</i> spp.	8.6	6.3	7.2	5.7	2.7	0.0	14.7	0.9
<i>Anomalina</i> spp.	1.9	2.4	0.0	9.7	1.3	0.0	0.0	1.2
<i>G. capitata-semicibrata</i>	0.0	0.0	0.0	0.0	4.0	5.1	0.0	1.9
<i>G. micra</i>	1.9	1.6	4.6	0.0	6.7	0.0	2.1	0.9
<i>N. truempyi</i>	7.7	0.8	3.3	9.7	25.3	2.2	6.3	9.0
<i>O. umbonatus</i>	11.0	9.5	19.0	0.0	9.3	5.1	0.0	2.8
<i>Osangularia</i> spp.	0.0	0.8	0.7	0.0	0.0	8.0	2.1	5.0
<i>A. cf. dissonata</i>	11.0	0.0	0.0	0.0	0.0	0.7	6.3	13.1
<i>H. ammophila</i>	5.3	0.0	0.0	0.6	0.0	0.0	11.6	7.5
<i>G. subglobosa</i>	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0
<i>C. grimsdalei</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. bradyi</i>	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
<i>C. havanensis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
<i>C. mundulus</i>	0.0	1.6	3.3	0.6	0.0	0.7	17.9	0.6
<i>C. tuxpamensis</i>	7.7	0.0	2.0	24.6	0.0	12.3	0.0	5.6
<i>C. cf. pseudoperlucida</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>C. subspiratus</i>	0.0	14.3	0.0	3.4	2.7	0.0	0.0	0.0
<i>C. laurisae</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6

Species not included in censuses of Tjalsma and Lohmann (1983), Miller (1983), and Miller et al. (1985)

<i>Trifarina</i> sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>P. renzi</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>P. compressa</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Cassidulina havanensis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Nonionellina</i> spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Siphonina</i> sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Sigmoilopsis</i> sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Tritaxia</i> sp.	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.6
<i>K. chapapottensis</i>	1.4	0.0	9.2	1.7	0.0	0.0	0.0	0.9
" <i>Eggerella</i> " sp.	0.0	1.6	1.3	1.7	0.0	0.0	2.1	0.0
<i>B. antegressa</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Dentalina/Vaginulina</i>	0.0	4.4	2.0	0.6	6.7	5.1	1.1	0.9
<i>U. hispida</i>	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
<i>U. basicordata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>T. danvilensis</i>	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0

^a Site 613: 1 = 20, CC; 2 = 24, CC; 3 = 26-6, 60-64 cm; 4 = 30, CC; 5 = 34, CC; 6 = 37, CC.
Site 108: 1 = 1-1, 77-80 cm; 2 = 2-1, 118-122 cm.

the margin from New Jersey (Charletta, 1980; this study) to North Carolina (Jones, 1982, 1983; Berggren and Aubry, 1984).

Despite uncertainties in zonations, planktonic foraminifera suggest a major break (about 5 m.y.) across the disconformity separating the middle Eocene and upper Eocene at Site 612 (Fig. 7). The unconformity separating lower Eocene from middle Eocene strata appears to have little paleontological break, for Zones P10/P11 (un-

differentiated) lie atop Zone P9. Estimates of sedimentation rate suggest, however, that some time is missing across the lower/middle Eocene disconformity. At least three age (sedimentation rate) models are applicable to the middle Eocene of Site 612 (Fig. 7): one suggests as much as a 5-m.y. break at the early/middle Eocene boundary, whereas the minimum break suggested is about 1 m.y. (see Miller and Hart, this volume, for discussion). Owing to hiatuses and problems in correlation, our reconstruction of Eocene biofacies along the transect are somewhat incomplete. Nevertheless, our sample coverage (Fig. 6) is sufficient to resolve changes in Eocene biofacies.

Benthic Foraminifera

Our compilation of benthic foraminiferal ranges from Sites 612 and 613 (Figs. 3, 5) shows that, within the sample resolution and considering hiatuses, first occurrences are relatively constant in the Eocene to lowermost Oligocene. At these sites, the first and last occurrences of many taxa correlate with first and last occurrences noted at other Atlantic DSDP sites (Table 4). There are problems in using benthic foraminifera for stratigraphic control. Local first and last occurrences caused by ecological changes are more common in benthic foraminifera than in planktonic organisms. For example, at Site 612, *Nuttallides truempyi* is absent from the upper Eocene (Fig. 3), although it is known to range elsewhere to the top of the Eocene (see e.g., Tjalsma and Lohmann, 1983; Wood et al., 1985). Despite such potential problems, many benthic foraminiferal ranges are consistent (Table 4) between sites. This consistency indicates that benthic foraminifera can be biostratigraphically useful, allowing recognition of major stratigraphic subdivisions (e.g., upper versus middle Eocene, etc.).

Comparisons with Tjalsma and Lohmann (1983)

The benthic biofacies at Sites 613 and 108 are similar to Tjalsma and Lohmann's "shallow" (<2000 m) assemblage. This similarity is shown by moderate to high loadings on their Principal Component I (Fig. 6), which constitutes an average of their Atlantic Eocene deep-sea data. The biofacies at Sites 613, 108, and 390 are equivalent to their *Lenticulina-Bulimina-Osangularia* assemblage, as exemplified by high percentages of these taxa at these sites (Figs. 12B, 12C) and by moderate to high negative loadings on their Principal Components II and III. Tjalsma and Lohmann (1983) found that this assemblage predominated at lower bathyal depths (1-2 km) in their Eocene samples, consistent with our assignment of Sites 108 and 613 to this depth zone.

The lower and middle Eocene biofacies at Site 612 also shows moderate affinities with Tjalsma and Lohmann's (1983) *Lenticulina-Bulimina-Osangularia* assemblage (Fig. 6). The upper Eocene biofacies at Site 612 is, however, quite different from their assemblages. This, in part, reflects the very high abundances of *Bulimina alazanensis* in the upper Eocene at Site 612 (Fig. 9) and lower abundances in their data. Still, removing this taxon from the Q-mode principal component analysis shows that the difference is not due entirely to *B. alazanensis*, but part-

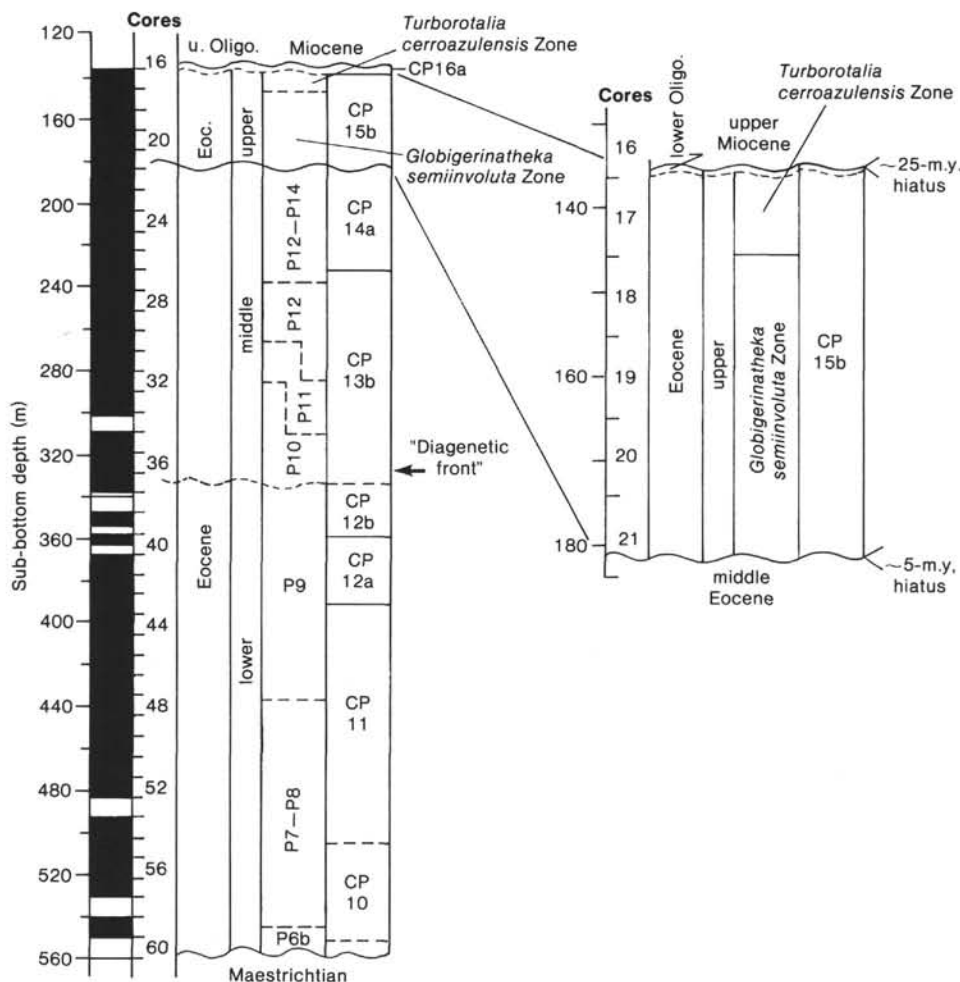


Figure 2. Paleogene section recovered at Site 612. Recovered intervals are shaded, and intervals of no recovery are open. Nannofossil zones after site chapter. Wavy lines indicate unconformities. Section on right shows upper Eocene section on a larger scale.

ly to higher abundances of *Pullenia eocenica* and lower abundances of *Lenticulina* spp. and *Nuttallides truempyi*. The distinct nature of the upper Eocene biofacies may be attributed to (1) a local paleoceanographic change or shallowing of the site; (2) a global benthic change in the early late Eocene; (3) Tjalsma and Lohmann's lack of late Eocene samples shallower than 1900 m (see discussion following).

Biofacies Distribution on the New Jersey Transect

Factor analysis and percentage data both show distinct paleodepth patterns. Factor II (Fig. 8) represents shallower taxa which were abundant only in the late Eocene at Site 612. *Bulimina alazanensis* (Fig. 9), *Pullenia eocenica* (Fig. 10), and *Gyroidinoides* spp. (Fig. 11) were more abundant in the late Eocene at Site 612, whereas *Lenticulina* spp. and *Nuttallides truempyi* were less abundant (Figs. 12B, 13B).

High loadings (greater than 0.4) on Factor I occurred only at middle and lower bathyal Sites 612, 108, and 613 (Fig. 12A). *Lenticulina* spp. dominated this biofacies (Fig. 12B). In addition, both *Osangularia* spp. (Fig. 12C) and *Alabamina* cf. *dissonata* (Fig. 12D) were important in

the Factor I biofacies, although they were most abundant at middle bathyal Site 612.

Sites 613 and 390 had a distinct middle Eocene biofacies represented by Factor III (Fig. 13A). *Nuttallides truempyi* dominated this lowermost bathyal to abyssal biofacies (Fig. 13B). *Bulimina trinitatensis* occurred in higher abundances in this biofacies (Fig. 13C), and *B. semicostata* was restricted to it (Fig. 14).

The most important middle Eocene downdip faunal change occurred close to the bathyal/abyssal boundary near Site 613 (Figs. 12–14). This faunal break represents the transition from the *Lenticulina* spp. biofacies (Factor I) to the *Nuttallides truempyi* biofacies (Factor III). The transition was noted by Tjalsma and Lohmann (1983) to have occurred near 2000 m throughout the Atlantic, indicating that this change was not restricted to the New Jersey margin.

Biofacies changes with time can be evaluated in the most complete section at Site 612. Here, the major faunal abundance change occurred during the middle/late Eocene hiatus (Figs. 6, 8–11). One of the most important faunal abundance changes of the Tertiary occurred across the middle/late Eocene boundary throughout the

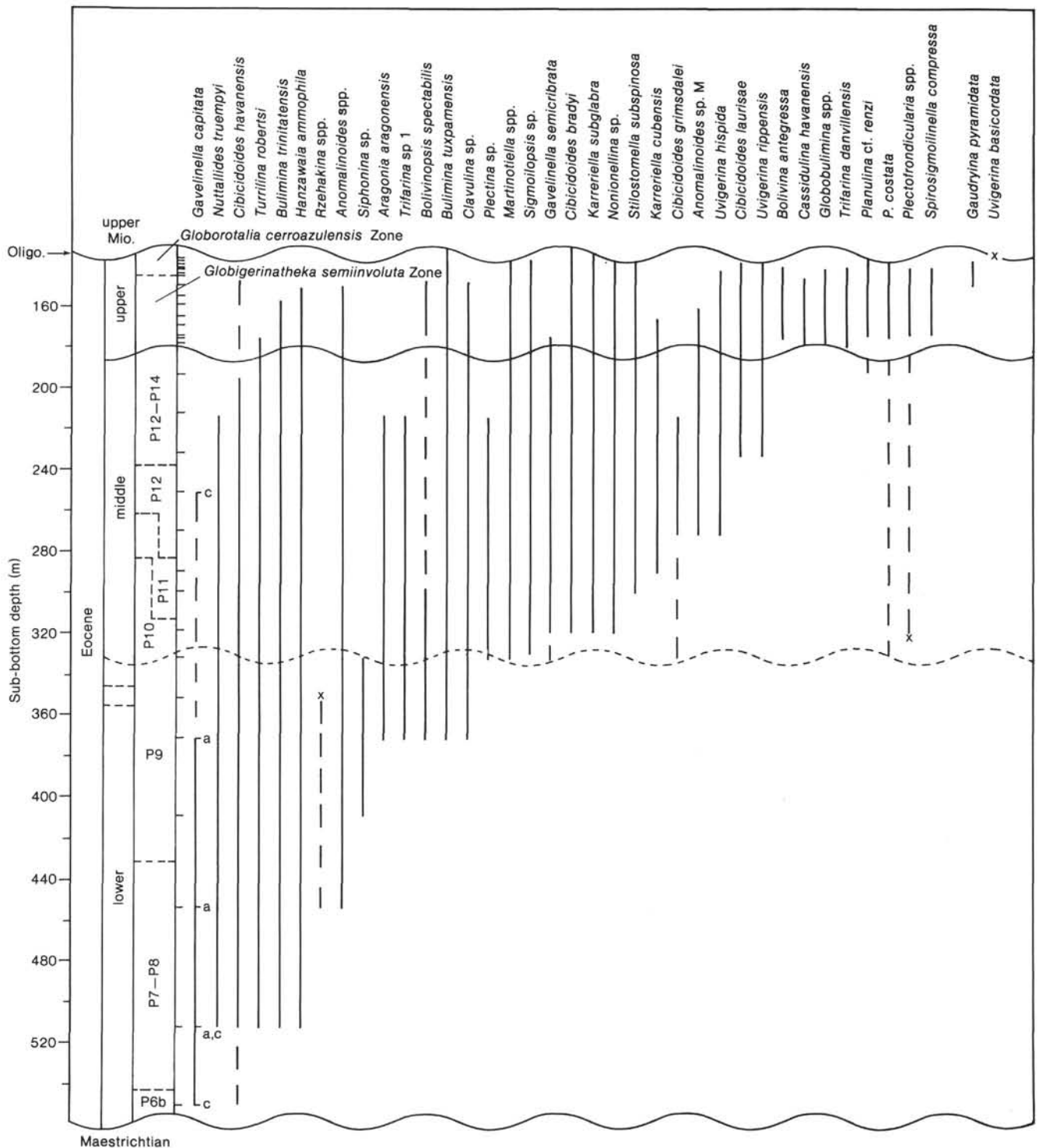


Figure 3. Range charts of benthic foraminifers, Paleogene of Site 612. Inner tick marks indicate level examined for benthic foraminifers. Dashed lines mean uncertain range; x = isolated occurrence; a = *Gavelinella capitata* var. *aragonensis*; c = *Gavelinella capitata* s.s. Planktonic foraminiferal zones as in Figure 2.

deep sea (Tjalsma and Lohmann, 1983; Miller, 1983; Miller, Curry, et al., 1985; Wood et al., 1985; Corliss and Keigwin, in press); *Nuttallides truempyi*, which dominated the deep-sea fauna throughout the earlier Eocene, dramatically decreased in abundance at this time. Within the afforded resolution, this event correlates with the change at Site 612.

Miller, Curry, et al., (1985) discussed the middle/late Eocene faunal abundance change at upper abyssal (estimated depth 2–2.5 km) Site 549 and lower bathyal (estimated depth 1.0–1.5 km) Site 548 on the Goban Spur. The assemblages noted at Site 548 are quite similar to those at Site 612. This is shown by projection of the Site 612 samples onto the vector defined by Principal Com-

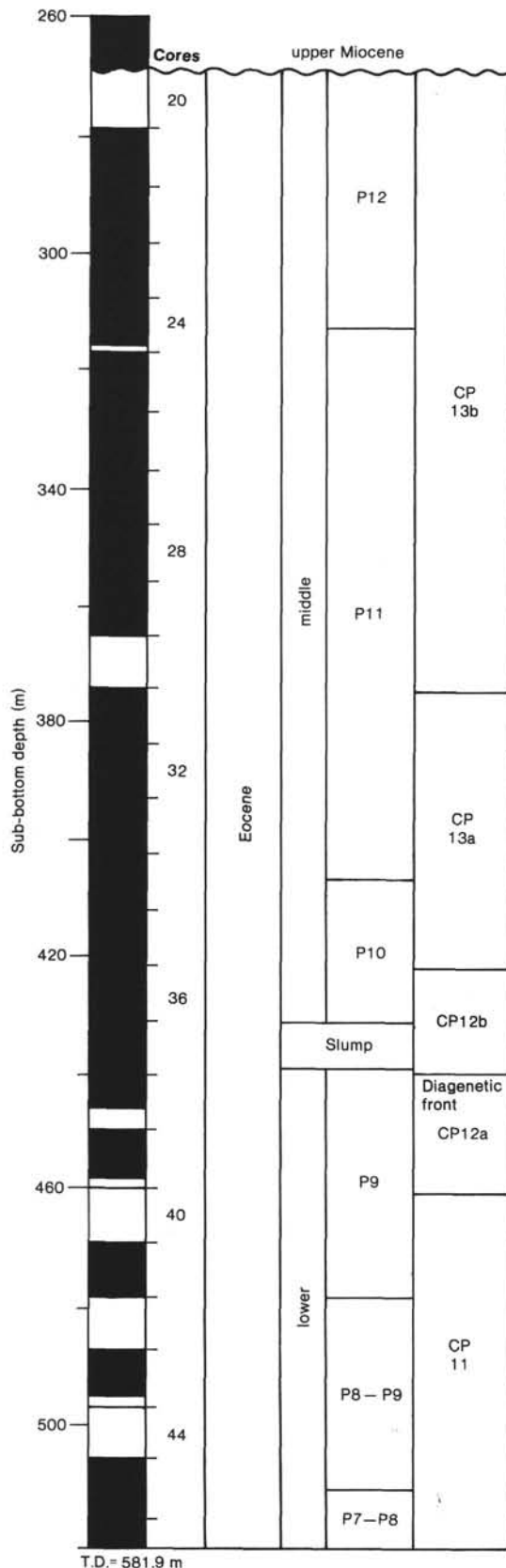


Figure 4. Portion of Eocene section studied for benthic foraminifers at Site 613. Recovered intervals are shaded, and intervals of no recovery are open. Nannofossil zones after site chapter. T.D. = total depth of hole, which bottomed in lowered Eocene.

ponent II of Site 548 (Fig. 15) (Miller, Curry, et al., 1985). The faunal change noted at Site 612 is similar to that at Site 548 (Fig. 15), with a *Lenticulina* spp. biofacies in the middle Eocene and a *Gyroidinoides* spp.-*Bulimina alazanensis* biofacies in the late Eocene. The similarity in faunal abundances and patterns between Sites 612 and 548 further supports our estimate of an Eocene depth of about 1 km for Site 612.

Although many taxa show useful, consistent paleo-depth distributions, some do not. *Oridorsalis* spp., for example, shows no particular age-depth distribution in the Eocene (Fig. 16; fig. 15 in Tjalsma and Lohmann, 1983). We have shown elsewhere that the relative percentage of this taxon varies independently of its absolute abundance. Variations in percentage of this common taxon therefore reflect changes in absolute abundances of other taxa, and are not directly related to paleoenvironmental controls (Katz and Miller, 1985).

Paleodepth, Unconformities, and Margin Erosion

The faunal change between the middle and late Eocene at Site 612 may be attributed either to a local change (shallowing or oceanographic change) or to a global change in benthic foraminifers. There is limited evidence to indicate a shallowing between the middle and late Eocene at Site 612. The percentage of planktonic foraminifers is positively correlated with depth on margins (Grimsdale and van Morkhoven, 1955). At Site 612, there is no distinct change in percentage of planktonic foraminifers during the Eocene (Fig. 17); the ratios suggest depth of deposition in excess of 700–900 m (Grimsdale and van Morkhoven, 1955). *Nuttallides truempyi* is common to abundant in the lower to middle Eocene section at Site 612, but absent from the upper Eocene section. Since this taxon has an upper depth limit of 500 to 600 m (Berggren and Aubert, 1983), its disappearance could be attributed to a decrease in water depth at Site 612 from middle to upper bathyal depths. However, it dramatically decreased in abundance near the middle/late Eocene boundary (Tjalsma and Lohmann, 1983; Miller, Curry, et al., 1985; Wood et al., 1985), and its absence from the upper Eocene at Site 612 could be attributed to this global change.

We believe that the faunal change between the middle and late Eocene can be explained by oceanographic causes. As already mentioned, the faunal change upsection at Site 612 was also noted at Site 548, and may be related to the global benthic foraminiferal abundance change near the middle/late Eocene boundary. This change has been related to bottom-water changes associated with initial cooling of the deep sea near the middle/late Eocene boundary (Tjalsma and Lohmann, 1983; Miller, Curry, et al., 1985; Wood et al., 1985; Corliss and Keigwin, in press).

Following this interpretation, the difference between the upper Eocene of Site 612 and Tjalsma and Lohmann's (1983) samples may best be explained by the faunal abundance change that occurred near the middle/late Eocene boundary. Tjalsma and Lohmann's lack of upper Eocene samples from depths less than 1900 m prevented their delineating the effects of this change on bathyal

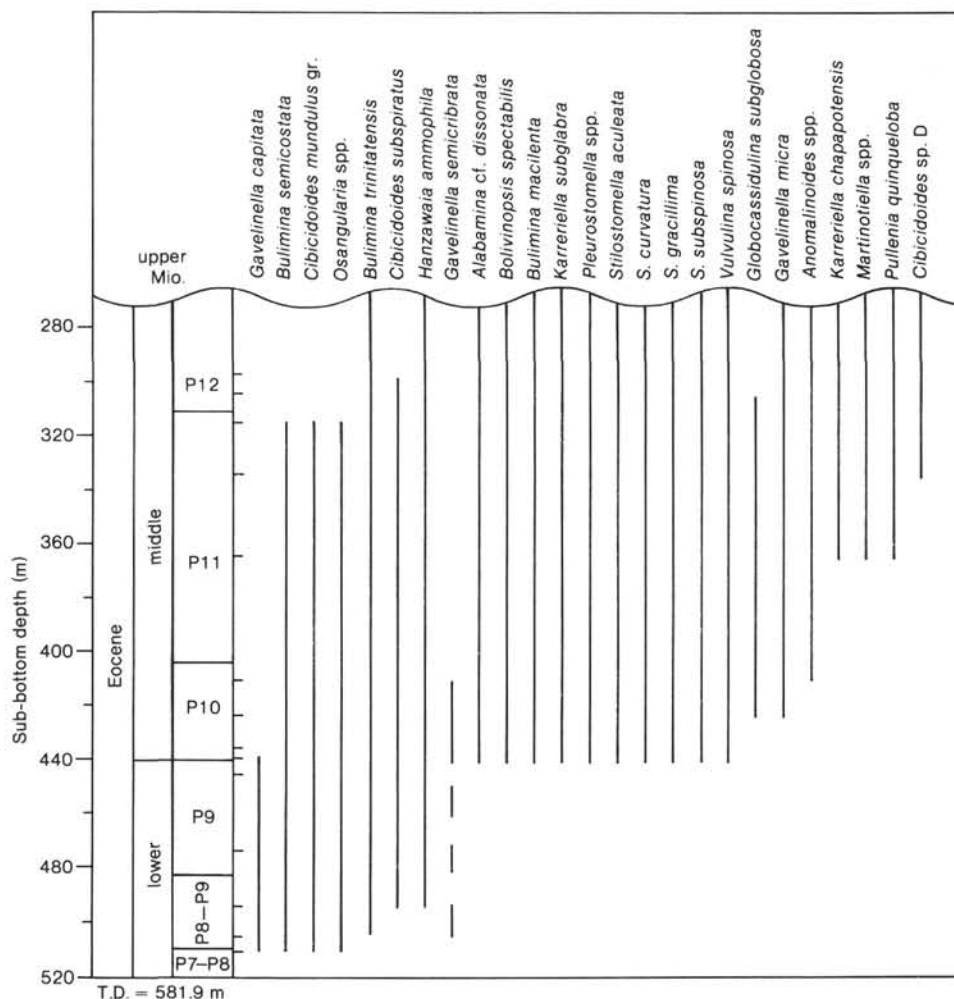


Figure 5. Range chart of benthic foraminifers, Paleogene of Site 613. Inner tick marks indicate level examined for benthic foraminifers. Dashed lines mean uncertain range. T.D. = total depth of hole.

benthic foraminifers. But the record at Site 548 (Fig. 15) allowed us to decipher the impact of the middle/late Eocene boundary faunal change at a bathyal location and to dispute an interpretation which would require a shallowing of several hundred meters across this boundary at Site 612.

Coeval unconformities have been noted across the lower/middle and middle/upper Eocene boundaries on both the New Jersey (Figs. 2, 6) and Irish (Goban Spur) margins (New Jersey margin: Poag, this volume; Miller and Hart, this volume; this study; (Irish margin: Poag et al., 1985; Miller, Curry, et al., 1985; Miller, Mountain, et al., 1985). An unconformity in the "middle" Oligocene has also been noted on both margins (Poag et al., 1985; Miller, Curry, et al., 1985; Miller, Mountain, et al., 1985). The similarity in stratigraphic position of these unconformities, also noted in northwest Europe (Aubry, 1985), suggests a global cause. The erosion associated with these unconformities correlates with coastal offlap events of Vail et al. (1977). Erosion apparently occurred during the greatest rate of sea-level fall (Pitman, 1978; Miller, Mountain, et al., 1985). Erosion occurred on the slope and rise as a result of downslope

processes (Miller, Mountain, et al., 1985); Mountain, this volume; Poag and Mountain, this volume).

Paleodepth changes based upon benthic foraminifers at Sites 612, 108, and 613 do not reflect these inferred sea-level changes. This may be because magnitudes of the sea-level changes are small (30–100 m; Kominz, 1984; Miller, Mountain et al., 1985) relative to the total paleodepths at these sites, and deep-sea faunas are not sensitive to such small fluctuations in water depth. Vail et al. (1977) maintained, however, that sea-level changes were much larger (hundreds of meters). If that is true, some effect upon benthic foraminifers might have been expected at Site 612. In any case, the best locations to observe sea-level changes as benthic foraminiferal changes would be in the upper bathyal zone (e.g., near COST B-3 and B-2 wells; Charletta, 1980; Poag, 1980). We believe that future drilling is needed in upper bathyal environments not only to delineate benthic changes but also to date downslope erosional events and inferred sea-level history.

CONCLUSIONS

1. There was a distinct early to middle Eocene benthic foraminiferal biofacies boundary near 2000 m water

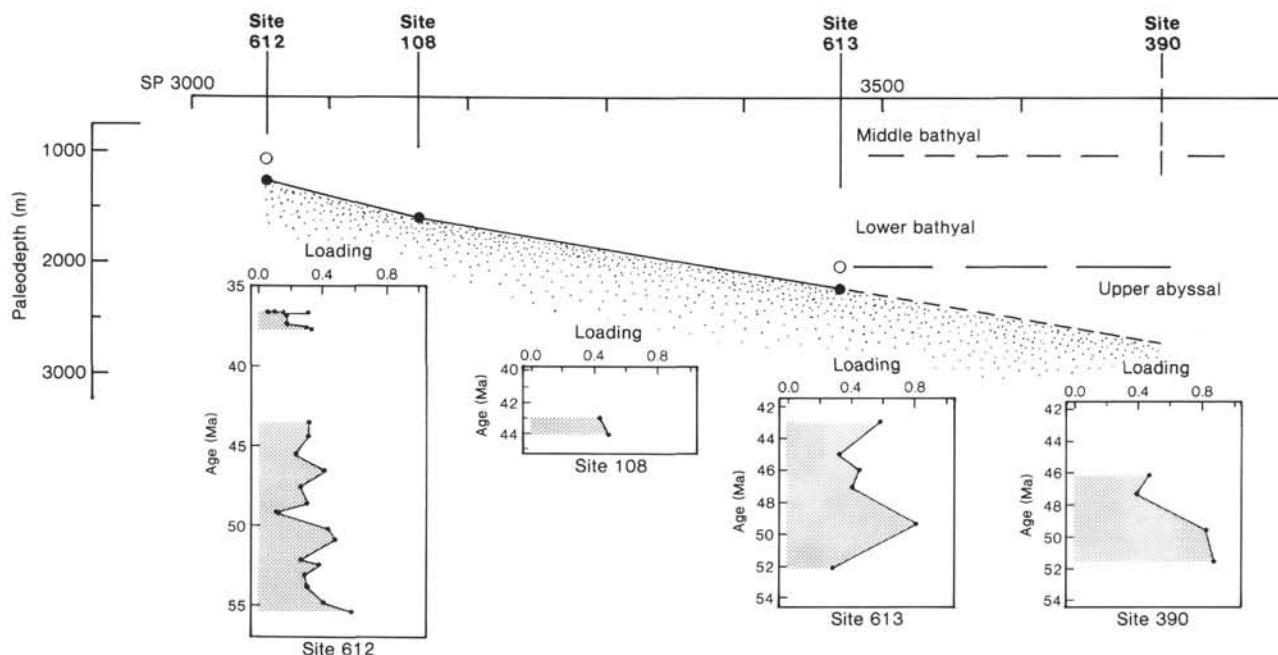


Figure 6. Projected loadings of New Jersey Transect samples onto Tjalsma and Lohmann's (1983) Principal Component I. Horizontal scale across top represents shotpoints (SP) along USGS Line 25 (50 m/shot). Site 613 has been projected from about 6 km away. Position of Site 390 is drawn at 2700 m (backtracked depth), assuming a gradient of 1:25 extrapolated from Site 613. Other paleodepth estimates (closed circles) used to derive paleoslope profile have been derived by "backtracking," assuming subsidence along an empirical age-subsidence curve; open circles represent "backstripping" estimates provided by M. Steckler (personal communication, 1985).

depth on the New Jersey margin. *Nuttallides truempyi* dominated the abyssal (>2000 m) biofacies, whereas *Lenticulina* spp., *Osangularia* spp., and *Alabamina* cf. *dissonata* constituted a middle and lower bathyal biofacies. The early to middle Eocene margin biofacies distributions are similar to those mapped in other Atlantic locations. Therefore, even though benthic biofacies may change depth through time, consistent age-depth relationships can be determined. Once these relationships are known, synoptic comparisons may be used to estimate paleodepths.

2. Stratigraphic ranges of benthic foraminifers are similar between the New Jersey margin and other Atlantic locations.

3. The only site on the New Jersey Transect where upper Eocene sediments were recovered was middle bathyal Site 612. There, a faunal change occurred between the middle and late Eocene, with a decrease of *Lenticulina* spp., the local disappearance of *N. truempyi*, and the development of a *Bulimina alazanensis*-*Gyroidinoides* spp. biofacies. We interpret this change as the bathyal expression of a global deep-sea benthic foraminiferal change which occurred across the middle/late Eocene boundary.

Our study of benthic foraminifers along a dip section of the New Jersey margin documents the value of such margin transects in reconstructing paleoenvironments. Although controls on benthic foraminiferal distributions remain elusive, mapping biofacies along a depth transect provides useful age-depth information, which can be applied to interpreting environments in sections of unknown depth. Mapping biofacies versus "paleoslope" has proven useful in mapping biofacies in neritic to up-

per bathyal environments (Charletta, 1980; Olsson and Nyong, 1984) and middle bathyal to abyssal environments (Nyong and Olsson, 1984; this study). Perhaps the greatest gap in our knowledge of late Paleogene faunas is in the upper to middle bathyal zones (about 300–900 m). Further drilling of sections along the New Jersey margin (i.e., near the COST B-3 well) and other margins is needed to elucidate the benthic foraminiferal biofacies in these depths, which are critical to our understanding of sea-level change.

TAXONOMIC NOTES

Species are listed here alphabetically. The taxonomic base is that of Tjalsma and Lohmann (1983) as modified by Miller (1983). In addition, we include taxonomic changes that were required after comparison of material at the U.S. National Museum (Miller and Berggren, unpublished data) and various European collections (Berggren, personal communications, 1984, 1985). We include descriptions of the most abundant taxa; in addition, we include taxa which may have been rare but which are stratigraphically useful. No attempt has been made to subdivide various species of *Fissurina*, *Gyroidinoides*, *Lagena*, *Lenticulina*, *Loxostomum*, *Marginulinopsis*/*Vaginulinopsis*, *Nonionella*, *Osangularia*, *Oridorsalis*, *Plectofrondicularia*, pleurostomellids, primitive agglutinants, and *Textularia*.

Alabamina cf. *dissonata* (Cushman and Renz) (Plate 3, Figs. 4–6)

Pulvinulinella atlantisae Cushman var. *dissonata* Cushman and Renz, 1948, p. 35, pl. 7, figs. 11–12.

Alabamina dissonata (Cushman and Renz). Miller, 1983, p. 431, pl. 1, fig. 8.

Alabamina dissonata (Cushman and Renz). Tjalsma and Lohmann, 1983, p. 22, pl. 17, figs. 3a, b; pl. 20, fig. 5.

The specimens noted here differ from typical *A. dissonata* by having only a faintly developed keel and by lacking raised sutures on the spiral side. We noted that this species was most common (up to 30%) at the middle bathyal Site 612 (Fig. 12D). Tjalsma and Lohmann (1983)

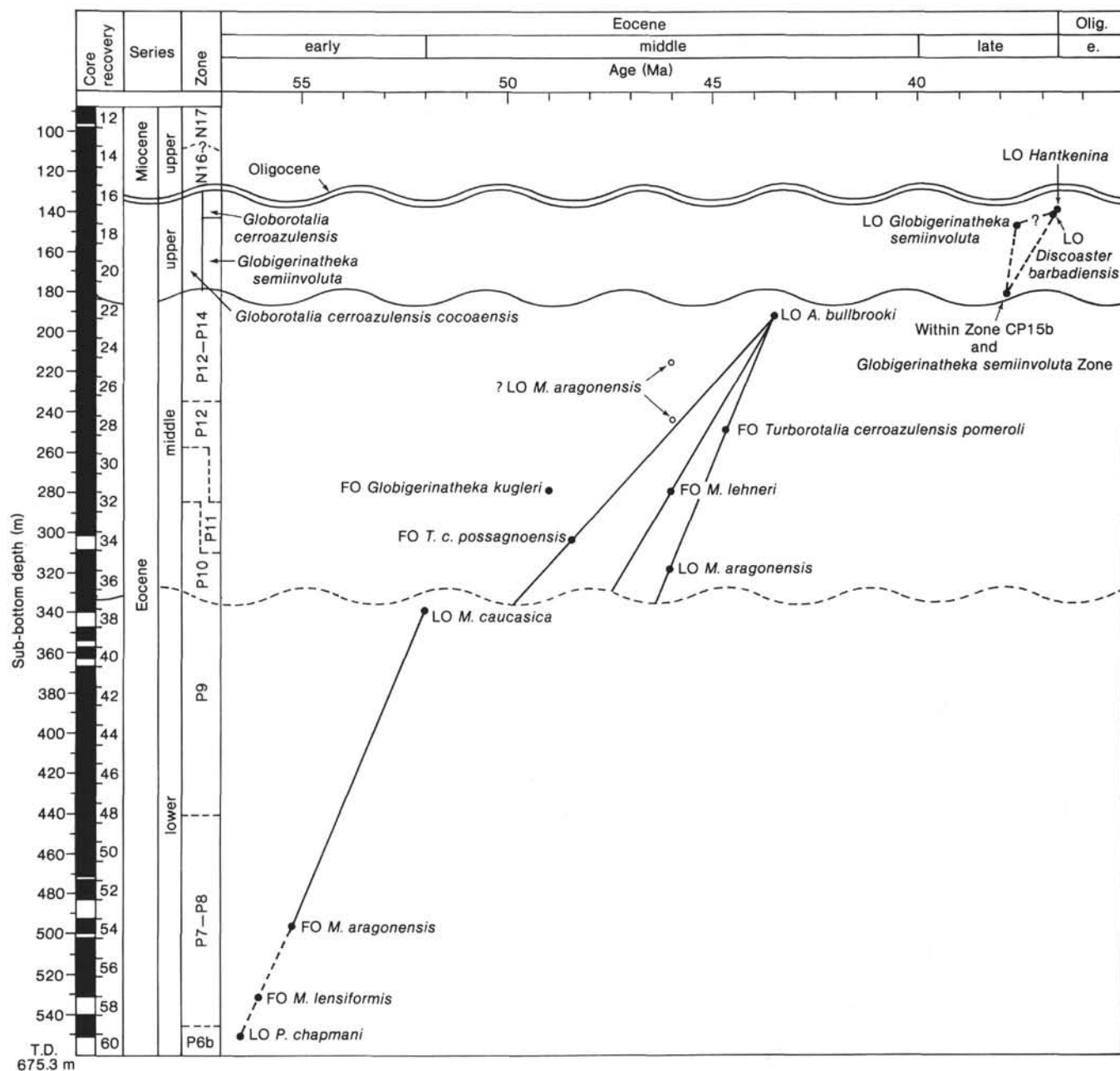


Figure 7. Age-depth plot for the Paleogene of Site 612, showing levels of planktonic foraminiferal datum levels. Datum-level ages and chronostratigraphic subdivisions drawn after Berggren et al. (1985) FO = first occurrence; LO = last occurrence. Wavy lines indicate unconformities and associated hiatuses. Open circles indicate two isolated occurrences of *M. aragonensis*, interpreted as reworked.

did not report this taxon from upper abyssal Site 390. Typical *A. dissonata* s.s. are usually found at abyssal (mostly lower abyssal) depths (Tjalsma and Lohmann, 1983; Miller 1983). We regard *A. cf. dissonata* as a bathyal variant of the abyssal species *A. dissonata*. *A. wilcoxensis* Brotzen, noted in the middle neritic New Jersey coastal plain by Charletta (1980), is smaller and lacks a keel.

***Anomalinoides* sp. M**
(Plate 2, Figs. 11, 12)

This form is very similar to *Melonis pompilioides*, except that it is slightly trochospiral. It may be the ancestor to that taxon, which has been noted first in the lower Oligocene of Cuba and Trinidad (Miller, personal observation). Found only in the upper middle to upper Eocene at Site 612.

***Anomalinoides spissiformis* (Cushman and Stainforth)**

Anomalina alazanensis Nuttall var. *spissiformis* Cushman and Stainforth, 1945, p. 71, pl. 14, figs. 5a-c.

Anomalina spissiformis Cushman and Stainforth. Tjalsma and Lohmann, 1983, p. 23, pl. 20, figs. 4a-c.

Abundant at Site 612. Absent in the lower Eocene at Site 613. Common at Site 108.

***Aragonia aragonensis* (Nuttall)**

Textularia aragonensis Nuttall, 1930, p. 280, pl. 23, fig. 6.

Aragonia aragonensis (Nuttall). Tjalsma and Lohmann, 1983, p. 23, pl. 11, figs. 2a, b.

Aragonia capdevilensis (Cushman and Bermudez). Tjalsma and Lohmann, 1983, p. 23, pl. 11, figs. 3a, b.

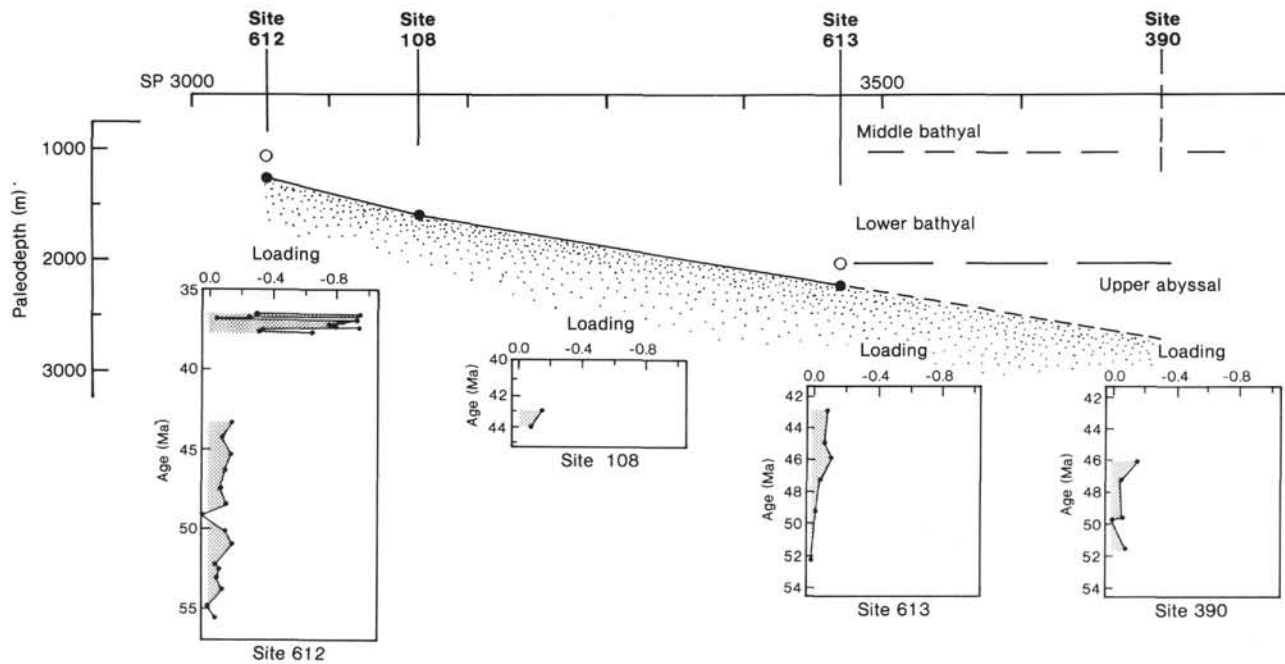


Figure 8. Loadings on Factor II computed by analysis of New Jersey Transect (Sites 612, 108, 613) and Site 390 (Tjalsma and Lohmann, 1983) census data of 48 taxa. Layout as in Figure 6.

Table 3. Interpolation points for age models (age models were derived for sites by linearly interpolating sedimentation rates between the levels shown).

	Sub-bottom depth (m)	Age (Ma)
Site 612 — age model I (used in constructing Figs. 6, 8–17)		
LO <i>Hantkenina</i> spp.	136.2	36.6
Level within upper Eocene, within Zone CP15b, and <i>G. cerroazulensis</i> Zone	181.2	37.8
Hiatus		
Within range of <i>A. bullbrooki</i> (see text)	183.0	43.0
Arbitrary level within Zone P10	331.7	51.0
Hiatus		
LO <i>M. caucasica</i>	337.5	52.0
FO <i>M. aragonensis</i>	530.6	55.2
Hiatus		
Site 613		
Within range of <i>A. bullbrooki</i> (see text)	269.0	43.0
LO <i>M. aragonensis</i>	336.0	46.0
FO <i>T. rohrri</i>	430.0	50.2
Possible hiatus — slow sedimentation rates (5 m/m.y.)		
LO <i>M. caucasica</i>	440.0	52.0
FO <i>M. caucasica</i>	578.0	55.2

Note: LO = last occurrence; FO = first occurrence.

Aragonia aragonensis (Nuttall). Charletta, 1980, p. 68, pl. 5, fig. 11.

This taxon is rare in our material. We have not attempted to differentiate the aragoniids here, although our specimens fall into the *A. aragonensis*–*A. capdevilensis* group. Therefore, we have adopted the senior synonym. Occurs in the lower to middle Eocene of Site 612 (Zones P9–P12) and in Zone P12 at Site 613. Absent at Site 108.

Table 4. Comparison of ranges of benthic taxa.

Taxon	Reference	Site 612
LO <i>Spiroplectammina spectabilis</i>	Top Eocene (ref. 1)	Top Eocene
FO <i>Hanzawaia ammophila</i>	P6a (ref. 1)	P7
FO <i>Gavelinella capitata</i>	P6b (ref. 1)	P6b (base of section)
FO <i>G. semicribrata</i>	P12 (ref. 1)	P11/P12
FO <i>Cibicoides laurissae</i>	P10 (ref. 1)	P12
FO <i>Uvigerina rippensis</i>	P10, P14 (abundant) (ref. 1)	P12
FO <i>Cibicoides havanensis</i>	P8 (ref. 1)	P7
FO <i>Planulina costata</i>	P15 (ref. 2)	P15
FO <i>Uvigerina basicordata</i>	upper Eocene (ref. 2)	Basal Oligocene
FO <i>Planulina renzi</i>	P15–P16 (ref. 3)	Cf. in P15
FO <i>Cassidulina havanensis</i>	P18 (ref. 4)	P15
FO <i>Bolivina antegressa</i>	P15 (ref. 4)	P15
	P18 (ref. 3)	
LO <i>Rzehakina epigona</i>	P12 (ref. 2)	P9
	lower Eocene (ref. 5)	
Site 613		
TR <i>Cibicoides subspiratus</i>	P9–P13 (ref. 1)	P8/9–P12
FO <i>Gavelinella micra</i>	P10 (ref. 1)	P10
FO <i>Semicribrata</i>	P12 (refs. 1, 4)	P10

Note: FO = first occurrence, LO = last occurrence, TR = total range. Ref. 1 = Tjalsma and Lohmann (1983); ref. 2 = van Morkhoven et al., unpublished MS.; ref. 3 = Tjalsma, 1983; ref. 4 = Miller et al. (1985); ref. 5 = Miller et al. (1982).

Bolivina antegressa Subbotina (Plate 2, Figs. 1, 2)

Bolivina antegressa Subbotina, 1953, p. 226, pl. 10, figs. 11–16.

Bolivina antegressa Subbotina. Miller, Curry, et al., 1985, pl. 4, fig. 11.

Common to abundant in the upper Eocene at Site 612. Absent at Sites 108 and 613. We included forms both with and without a medial ridge (cf. figs. 12 and 14–16 of Subbotina). Although Cushman (1926a) illustrated faint striae on his *B. tectiformis*, examination of his type specimen shows a faint medial ridge, but no striae. Therefore we adopted Subbotina's taxon for this striate bolivinid.

Bulimina alazanensis Cushman (Plate 3, Figs. 12, 13)

Bulimina alazanensis Cushman, 1927b, p. 161, pl. 25, fig. 4.

Bulimina alazanensis Cushman, Tjalsma and Lohmann, 1983, p. 24, pl. 14, fig. 4.

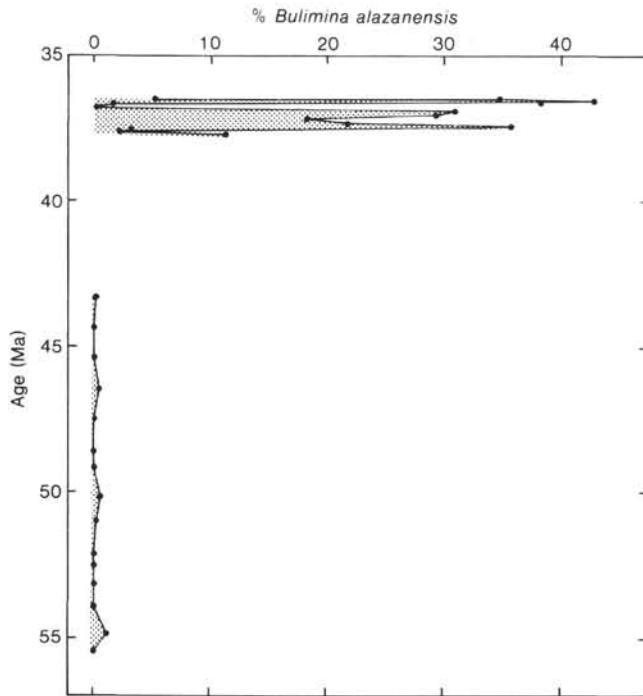


Figure 9. Percent abundance of *Bulimina alazanensis* at Site 612. This taxon is absent from Sites 108, 613, and 390.

Bulimina alazanensis Cushman, Miller, Curry, et al., 1985, pl. 4, fig. 6.

Abundant in the upper Eocene at Site 612 and present throughout; single occurrence at Site 613. Rare at Site 108.

***Bulimina glomarchallengeri* Tjalsma and Lohmann**

Bulimina glomarchallengeri Tjalsma and Lohmann, 1983, p. 25, pl. 13, figs. 8–12c.

Bulimina glomarchallengeri Tjalsma and Lohmann. Miller, 1983, p. 431, pl. 3, fig. 11.

Bulimina glomarchallengeri Tjalsma and Lohmann. Miller, Curry, et al., 1985, pl. 4, fig. 1.

B. semicostata is distinguished from *B. glomarchallengeri* by its triangular, tapered test. Single occurrence at Site 613 in the middle Eocene. Absent at Sites 108 and 612.

***Bulimina jacksonensis* Cushman**

Bulimina jacksonensis Cushman, 1925, pl. 1, figs. 6, 7.

Rare at Site 612. Absent at Sites 108 and 613.

***Bulimina macilenta* Cushman and Parker**

Bulimina denticulata Cushman and Parker, 1936, p. 42, pl. 7, figs. 7a–8c.

Bulimina macilenta Cushman and Parker, 1939 (new name), p. 93.

Bulimina macilenta Cushman and Parker. Tjalsma and Lohmann, 1983, p. 25, pl. 14, fig. 3.

Bulimina aff. *striata mexicana* Cushman-subacuminata Cushman and Stewart. Charletta, 1980, p. 66, pl. 5, fig. 14.

Common at all sites.

***Bulimina semicostata* Nuttall**

Bulimina semicostata Nuttall, 1930, p. 285, pl. 23, figs. 15, 16.

Bulimina semicostata Nuttall. Tjalsma and Lohmann, 1983, p. 25, pl. 13, figs. 1–3.

Bulimina semicostata Nuttall. Miller, 1983, p. 433, pl. 3, fig. 12.

Among our sites, present at Site 613 only. Noted by Tjalsma and Lohmann (1983) from Site 390. This taxon is therefore restricted to paleodepths >2000 m on the New Jersey Transect.

***Bulimina trinitatensis* Cushman and Jarvis**

(Plate 3, Figs. 10, 11)

Bulimina trinitatensis Cushman and Jarvis, 1928, p. 102, pl. 14, figs. 12a, b.

Bulimina trinitatensis Cushman and Jarvis. Tjalsma and Lohmann, 1983, p. 7, pl. 3, figs. 3, 4; pl. 14, fig. 1.

Bulimina trinitatensis Cushman and Jarvis. Miller, 1983, p. 433, pl. 3, fig. 7.

Common at all three sites. We included *B. impendens* Parker and Bermudez in both the census (following Tjalsma and Lohmann, 1983) and the range charts.

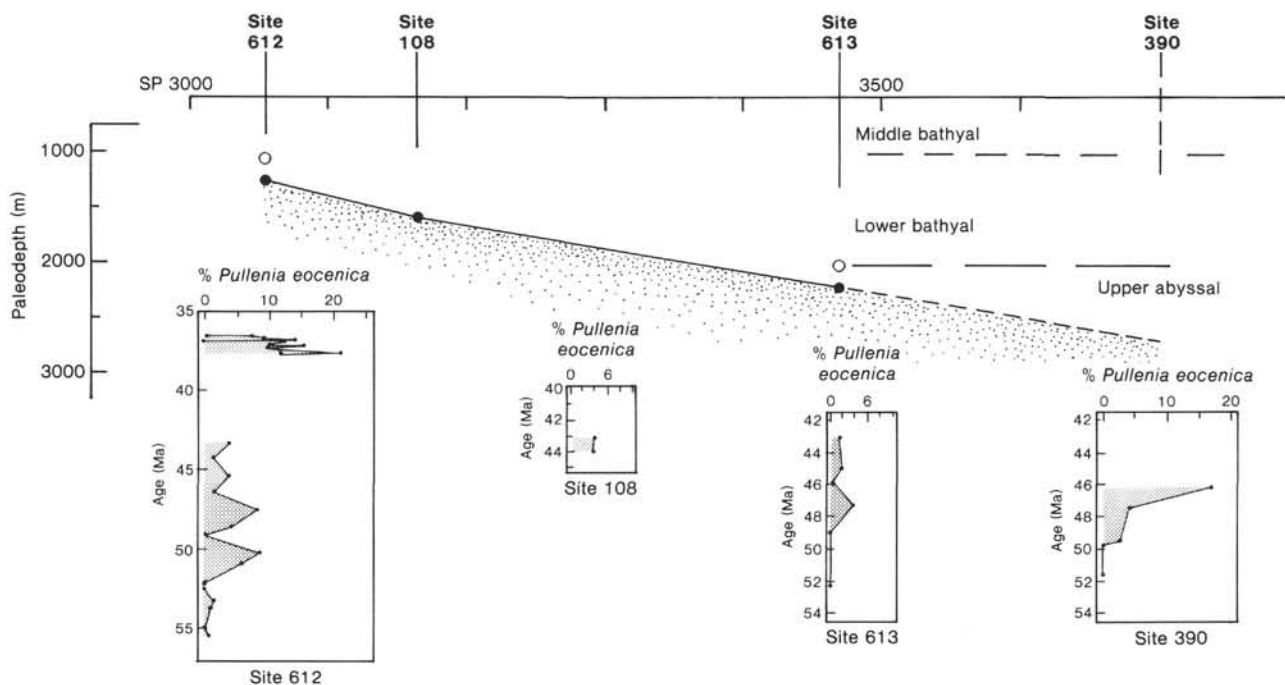


Figure 10. Percent abundance of *Pullenia eocenica* along paleoslope. Layout as in Figure 6.

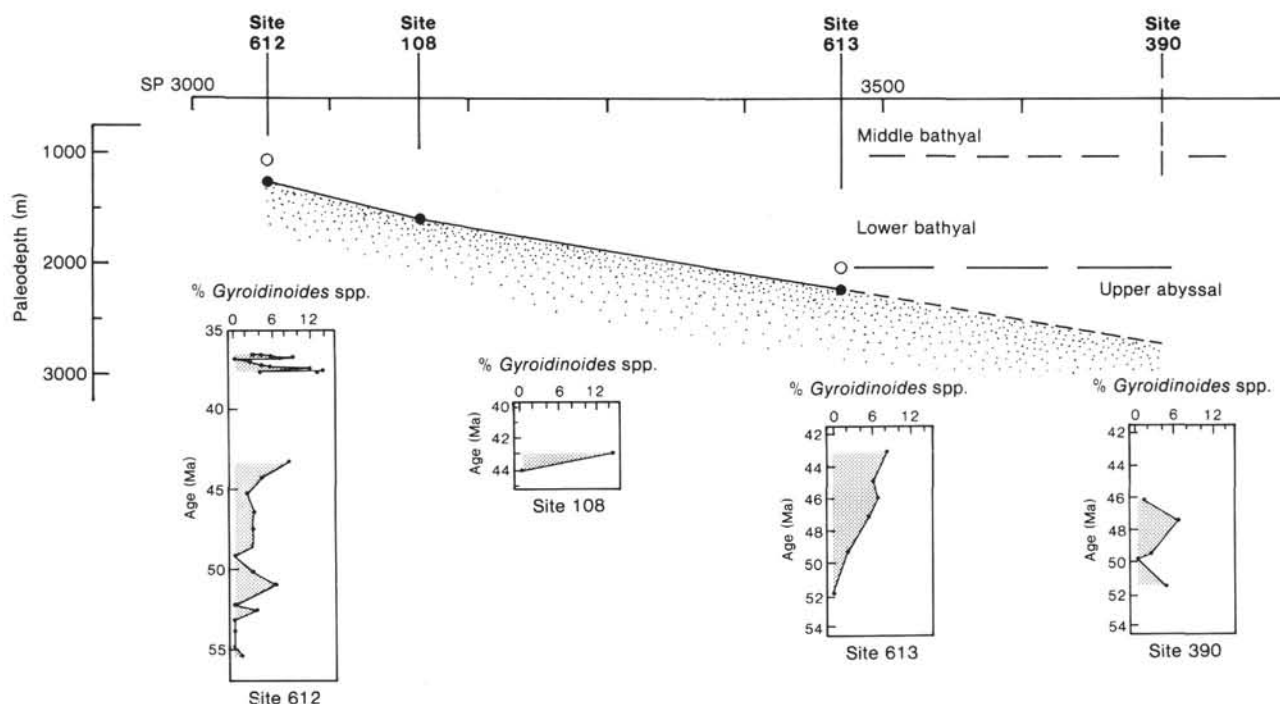


Figure 11. Percent abundance of *Gyroidinoides* spp. along paleoslope. Layout as in Figure 6.

***Bulimina tuxpamensis* Cole**
(Plate 3, Figs. 14, 15)

Bulimina tuxpamensis Cole, 1928, p. 212, pl. 32, fig. 23.

Bulimina tuxpamensis Cole. Tjalsma and Lohmann, 1983, p. 26, pl. 12, figs. 3a-4.

Bulimina tuxpamensis Cole. Miller, Curry, et al., 1985, pl. 4, fig. 7.

Most common in the upper Eocene of Site 612. Rare at Site 613. Rare at Site 108. We included forms assignable to *Bulimina bradburyi* Martin (1943) in both the census (following Tjalsma and Lohmann, 1983) and the range charts.

***Buliminella grata* Parker and Bermudez**

Buliminella grata Parker and Bermudez, 1937, p. 515, pl. 59, figs. 6a-c.

Buliminella grata Parker and Bermudez. Tjalsma and Lohmann, 1983, p. 26, pl. 12, figs. 7a, b.

Rare at both Site 612 and Site 613. Common at Site 108.

***Cassidulina crassa* d'Orbigny**

Cassidulina crassa d'Orbigny, 1839, p. 56, pl. 7, figs. 18-20.

Possible occurrences in the upper Eocene at Site 612. Absent at Sites 108 and 613.

***Cassidulina havanensis* Cushman and Bermudez**
(Plate 3, Figs. 1-3)

Cassidulina havanensis Cushman and Bermudez, 1936, p. 36, fig. 11.

Cassidulina havanensis Cushman and Bermudez. Miller, 1983, p. 433.

Cassidulina havanensis Cushman and Bermudez. Miller, Curry, et al., 1985, pl. 4, figs. 12, 13.

Restricted to the upper Eocene at Site 612. Absent at Sites 613 and 108.

***Cibicidoides* sp. D**
(Plate 6, Figs. 4-6)

Cibicidoides ungerianus s.l. Miller, 1983, p. 435.

This species is reminiscent of both *C. mundulus/ungerianus* group and *C. tuxpamensis*, but differs from the former in being more biconvex in axial view. Abundant in the upper middle Eocene at Site 613. Present in one sample only from Site 612. Absent at Site 108.

***Cibicidoides bradyi* (Trauth)**

Truncatulina dutemplei Brady (not d'Orbigny), 1884, p. 665, pl. 95, fig. 5 (type figure).

Truncatulina bradyi Trauth, 1918, p. 235 (type reference).

Cibicidoides haitiensis (Coryell and Rivero). Tjalsma and Lohmann, 1983, p. 26, pl. 17, figs. 6a, b.

Cibicidoides haitiensis (Coryell and Rivero). Miller, 1983, p. 433, pl. 2, fig. 5.

Tjalsma and Lohmann (1983) used Coryell and Rivero's (1940) species name for Eocene-Oligocene forms, although Coryell and Rivero had illustrated an upper middle Miocene form. We find that the form illustrated by Brady and named *T. bradyi* by Trauth is difficult to distinguish from Eocene-Oligocene forms, although Eocene forms may have a flatter spiral side. Tjalsma and Lohmann (1983) placed *Gyroidina jarvisi* of Cushman and Stainforth (1945, p. 62, pl. 11, figs. 3a-c.) in synonymy with *Cibicidoides robertsonianus* var. *haitiensis* Coryell and Rivero. We agree that these are conspecific, but would place them as junior synonyms of the closely related *Cibicidoides robertsonianus* (Brady) and retain *C. bradyi* (Trauth) as the senior synonym of *C. haitiensis* of Tjalsma and Lohmann (not Coryell and Rivero). Abundant in the middle to upper Eocene at Site 612. Single occurrence in the middle Eocene at Site 613. Absent at Site 108.

***Cibicidoides grimsdalei* (Nuttall)**

Cibicides grimsdalei Nuttall, 1930, p. 291, pl. 25, figs. 7, 8, 11.

Cibicidoides grimsdalei (Nuttall). Schnitker, 1979, pl. 11, figs. 1-3.

Cibicidoides grimsdalei (Nuttall). Tjalsma and Lohmann, 1983, p. 26, pl. 18, figs. 2a-c; pl. 22, figs. 6, 7.

Cibicidoides grimsdalei (Nuttall). Miller, 1983, p. 433, pl. 2, fig. 8.

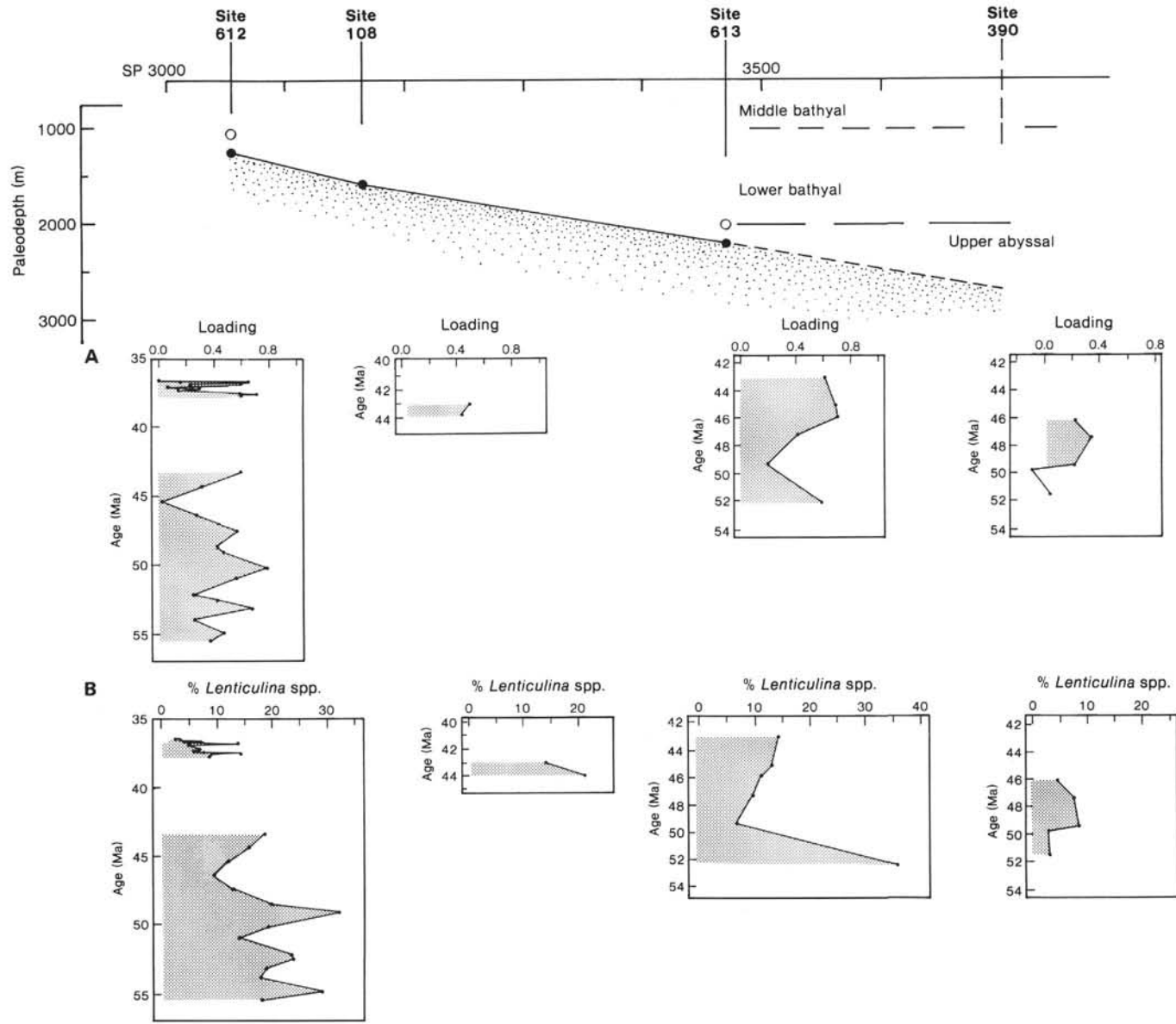
Cibicidoides grimsdalei (Nuttall). Miller, Curry, et al., 1985, pl. 1, figs. 7-9.

Present in the middle Eocene at Site 612. Absent at Sites 108 and 613.

***Cibicidoides havanensis* (Cushman and Bermudez)**

Cibicides havanensis Cushman and Bermudez, 1937, p. 28, pl. 3, figs. 1-3.

Cibicidoides havanensis (Cushman and Bermudez). Tjalsma and Lohmann, 1983, p. 27, pl. 22, figs. 4a-c.



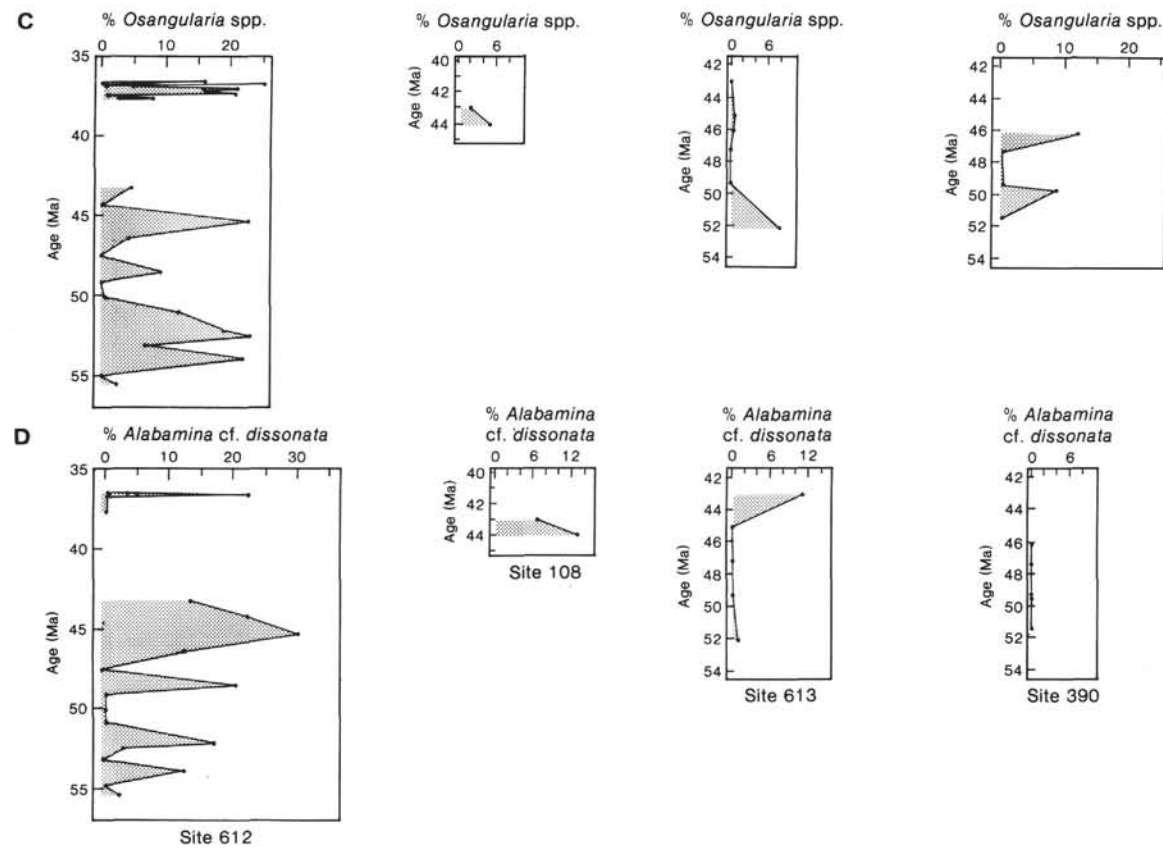


Figure 12. Layout as in Figure 6. A. Loadings on Factor I computed by analysis of New Jersey Transect (Sites 612, 108, 613) and Site 390 (Tjalsma and Lohmann, 1983) census data of 48 taxa. B. Percent abundance of *Lenticulina* spp. along paleoslope. C. Percent abundance of *Osangularia* spp. along paleoslope. D. Percent abundance of *Alabamina* cf. *dissonata* along paleoslope.

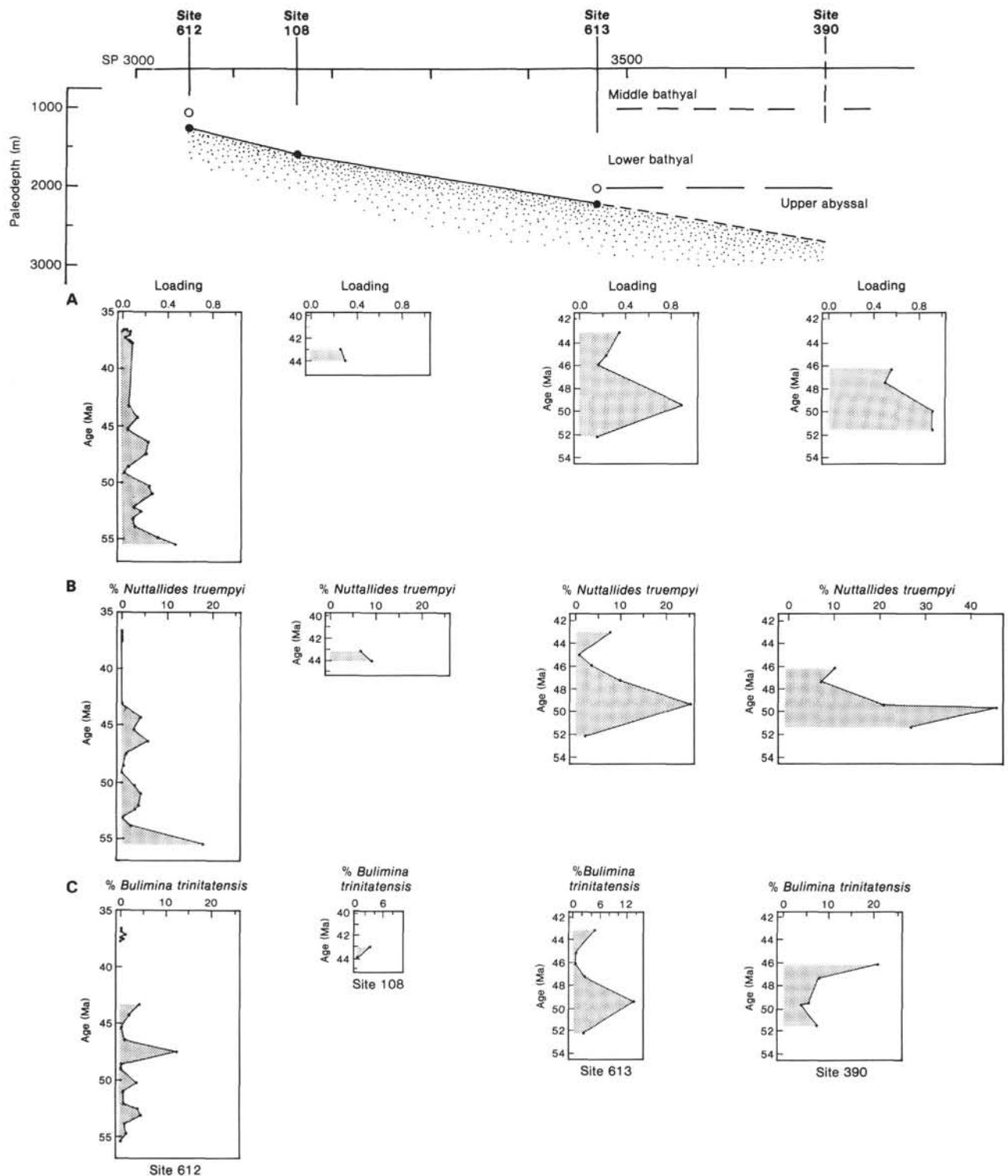


Figure 13. Layout as in Figure 6. A. Loadings on Factor III computed by analysis of New Jersey Transect (Sites 612, 108, 613) and Site 390 (Tjalsma and Lohmann, 1983) census data of 48 taxa. B. Percent abundance of *Nuttallides truempyi* along paleoslope. C. Percent abundance of *Bulimina trinitatensis* along paleoslope.

Cibicoides havanensis (Cushman and Bermudez). Miller, 1983, p. 433, pl. 2, figs. 9, 10.

Cibicoides havanensis (Cushman and Bermudez). Miller, Curry, et al., 1985, p. 2, figs. 7-9.

Present at Site 612. Restricted to the lower Eocene at Site 613. Absent at Site 108.

Cibicoides laurissae (Mallory)
(Plate 7, Figs. 4-6)

Cibicides laurissae Mallory, 1959, p. 267, pl. 24, figs. 8a-c.

Cibicoides aff. *laurissae* (Mallory). Tjalsma and Lohmann, 1983, p. 27, pl. 17, figs. 2a-c.

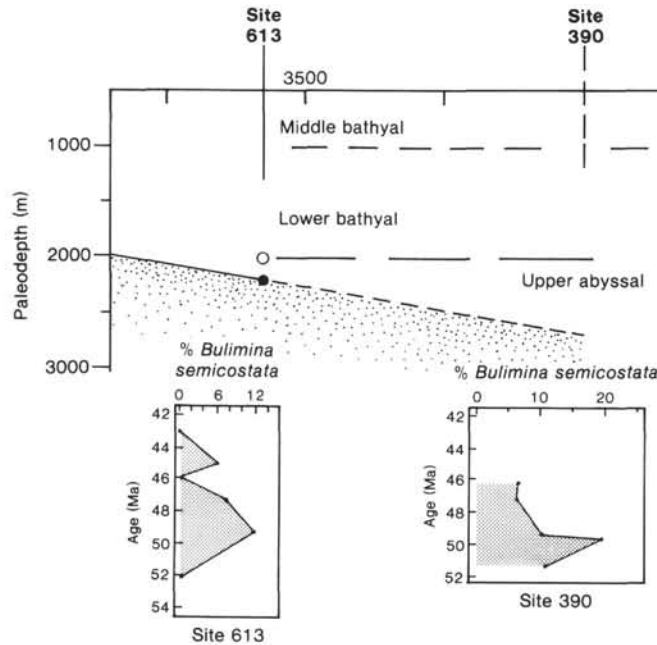


Figure 14. Percent abundance of *Bulimina semicostata* along paleoslope. This taxon was absent from Sites 612 and 108. Layout for Sites 613 and 390 as in Figure 6.

Cibicidoides aff. *laurisae* (Mallory). Miller, 1983, p. 433, pl. 2, figs. 3, 4.
Cibicidoides laurisae (Mallory). Miller, Curry, et al., 1985, pl. 2, figs. 4–6.

Cibicidoides aff. *laurisae* (Mallory). Tjalsma, 1983, p. 742, pl. 8, figs. 2a–c.

We used a broad concept for this species, including both more convex specimens noted by Tjalsma and Lohmann (1983) and specimens with flatter umbilical sides. We include forms with and without umbilical infilling. Restricted to the upper middle to upper Eocene at Site 612. Common at Site 108. Absent at Site 613.

***Cibicidoides mundulus* group**
 (Plate 6, Figs. 1–3.)

Truncatulina mundula Brady, Parker, Jones, 1888, p. 228, pl. 45, figs. 25a–c.

Cibicides kullenbergi Parker, in Phleger, F. B., Parker F. L., and Peirson, J. F., 1953, p. 49, pl. 11, figs. 7, 8.

Cibicidoides ungerianus (d'Orbigny). Tjalsma and Lohmann, 1983, p. 28, pl. 18, figs. 1a–c; pl. 21, figs. 5, 6.

Cibicidoides ungerianus (d'Orbigny). Miller, 1983, p. 435, pl. 2, figs. 6, 7.

Cibicidoides ungerianus (d'Orbigny). Miller, Curry, et al., 1985, pl. 1, figs. 4–6.

Considerable confusion has surrounded the taxonomy of this group of abundant cibicidids. The genotype of *Cibicidoides* is *C. mundulus*, which is identical to and the senior synonym of Parker's species. Tjalsma (1983) noted the evolution of *C. mundulus* from a taxon he termed *C. ungerianus*. However, *C. ungerianus* (d'Orbigny) is a shallow-water Neogene form which is not related to the deep-sea taxon illustrated by many authors, including Tjalsma (1983), Tjalsma and Lohmann (1983), and Miller (1983). Therefore, another name for the Paleogene forms antecedent to *C. mundulus* is needed. Until a proper name is identified or designated, we assign both the antecedents and descendants to the *C. mundulus* group. Abundant at Site 612. Common at Site 613. Rare at Site 108.

***Cibicidoides* sp. P**
 (Plate 7, Figs. 1–3)

Rare at Site 612. Absent at Sites 108 and 613.

***Cibicidoides subspiratus* (Nuttall)**
 (Plate 7, Figs. 7–9)

Cibicides subspiratus Nuttall, 1930, p. 292, pl. 25, figs. 9, 10, 14.

Cibicidoides subspiratus (Nuttall). Tjalsma and Lohmann, 1983, p. 28, pl. 18, figs. 5a–c; pl. 22, figs. 5a, b.

This distinctive taxon is restricted in our material to Site 613. It has a stratigraphically useful range of Zones P10 to P12, in agreement with that of Tjalsma and Lohmann (1983), who noted a range of Zones P9 to P13.

***Cibicidoides tuxpamensis* (Cole)**
 (Plate 6, Figs. 7–9)

Cibicides tuxpamensis Cole, 1928, p. 219, pl. 1, figs. 2, 3; pl. 3, figs. 5, 6.

Cibicidoides tuxpamensis (Cole). Tjalsma and Lohmann, 1983, p. 28, pl. 18, figs. 3a–4c; pl. 22, figs. 1a–3c.

Cibicidoides tuxpamensis (Cole). Miller, Curry, et al., 1985, pl. 1, figs. 1–3.

Common at Site 612. Abundant at Sites 108 and 613.

***"Eggerella"* sp.**

"Eggerella" sp. Miller, 1983, p. 435.

This agglutinated form is triserial in the later stages, with earlier portions indeterminate. It has a loop-shaped aperture. Miller (1983) noted this taxon in the Eocene to Oligocene Bay of Biscay. Restricted to and common in the middle to upper Eocene at Site 612. Common in the middle Eocene at Site 613, with a single isolated occurrence in the lowermost Eocene. Present at Site 108.

***Gaudryina pyramidata* Cushman**
 (Plate 1, Figs. 9, 10)

Gaudryina laevigata Franke var. *pyramidata* Cushman, 1926b, p. 587, pl. 16, figs. 8a, b.

Gaudryina cf. *pyramidata* Cushman. Tjalsma and Lohmann, 1983, p. 31, pl. 8, figs. 2a, b.

Restricted to the upper Eocene at Site 612. Absent at Sites 108 and 613.

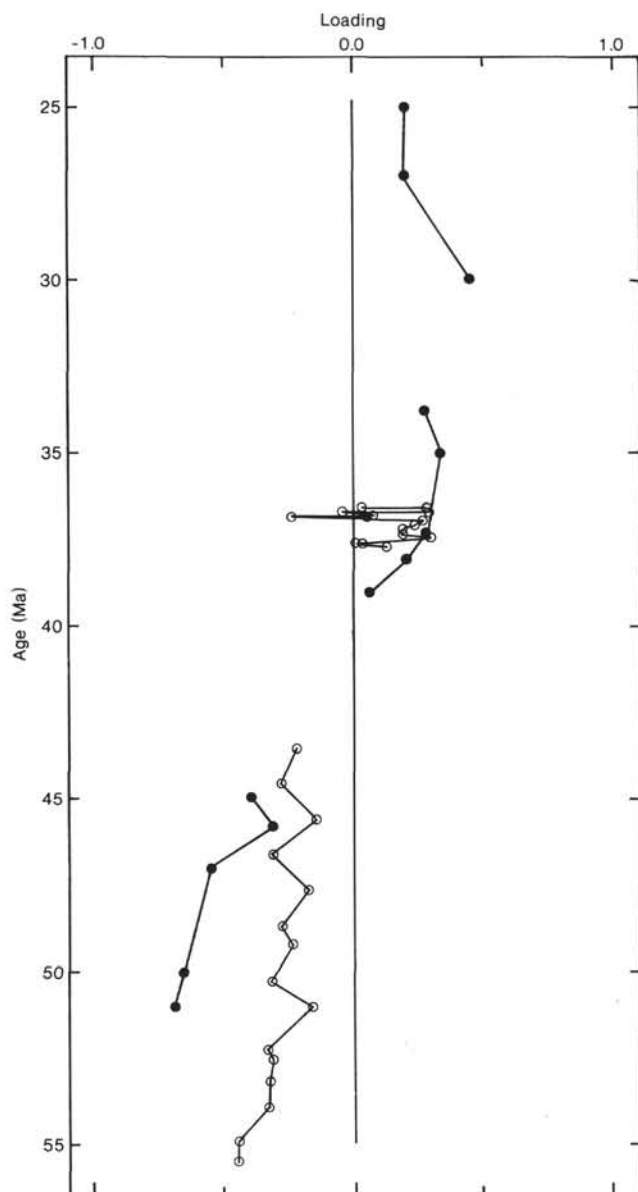


Figure 15. Loadings on Principal Component II, Site 548, Goban Spur. Closed circles are from Site 548; open circles are projections of Site 612 samples onto this vector. Vertical line drawn through 0.0 loadings.

***Gavelinella capitata* (Guembel)**
(Plate 4, Figs. 4, 5, 6, 10, 11)

Rotalia capitata Guembel, 1868, p. 653, pl. 2, figs. 92a-c.
Anomalinoidea capitatus (Guembel). Hagn, 1956, p. 176, pl. 16, figs. 15, 16.

Gavelinella capitata (Guembel). Tjalsma and Lohmann, 1983, p. 31, pl. 16, figs. 4a-5b.

Restricted to the lowermost Eocene at Site 612 and the lower Eocene at Site 613. Absent at Site 108. Combined with *G. semicribrata* in census (following Tjalsma and Lohmann, 1983).

We recognized a distinctive morphology, originally described by Nuttall (1930) as *A. dorri* var. *aragonensis*, which is restricted to the lower Eocene at Site 612 but absent from Site 613. Tjalsma and Lohmann (1983) included *A. dorri* and *A. aragonensis* as junior synonyms of *G. capitata*; we followed this and placed the highly ornamented specimens in *G. capitata* var. *aragonensis* (Plate 4, Figs. 4-6).

***Gavelinella micra* (Bermudez)**
(Plate 4, Figs. 7-9)

Cibicides micrus Bermudez, 1949, p. 302, pl. 24, figs. 34-36.

Gavelinella micra (Bermudez). Tjalsma and Lohmann, 1983, p. 31, pl. 16, figs. 7a, b; pl. 20, fig. 7.

Gavelinella micra (Bermudez). Miller, 1983, p. 437, pl. 3, figs. 15-16.
Anomalinoidea acuta (Plummer). Charletta, 1980, p. 64, pl. 4, figs. 16-18.

Abundant at Site 612. Common in the middle Eocene at Site 613; absent in the lower Eocene. Common at Site 108. Charletta (1980) noted *A. acuta* throughout the Eocene of the New Jersey coastal plain.

***Gavelinella semicribrata* (Beckmann)**

Anomalina pompilioides Galloway and Heminway var. *semicribrata* Beckmann, 1953, p. 400, pl. 27, fig. 3; text-figs. 24, 25.

Gavelinella semicribrata (Beckmann). Tjalsma and Lohmann, 1983, p. 31, pl. 16, figs. 6a, b.

Gavelinella semicribrata (Beckmann). Miller, 1983, p. 437, pl. 3, figs. 2, 5.

Combined with *G. capitata* in census (following Tjalsma and Lohmann, 1983). Restricted to the middle and lowermost Eocene at Site 612. Present in middle Eocene Zones P10 to P11 at Site 613. Common at Site 108.

***Globocassidulina subglobosa* (Brady)**

Cassidulina subglobosa Brady, 1881, p. 60 (type reference).

Cassidulina subglobosa (Brady) Brady, 1884, p. 430, pl. 54, figs. 17a-c (type figure).

Globocassidulina subglobosa (Brady). Tjalsma and Lohmann, 1983, p. 31, pl. 16, fig. 9.

Present throughout the Site 612 section. Restricted to the middle Eocene at Site 613. Absent at Site 108.

***Hanzawaia amorphila* (Guembel)**
(Plate 5, Figs. 7-9)

Rotalia amorphila Guembel, 1868, p. 652, pl. 2, figs. 90a, b.

Cibicides cushmani Nuttall, 1930, p. 291, pl. 25, figs. 3, 5, 6.

Hanzawaia cushmani (Nuttall). Tjalsma and Lohmann, 1983, p. 32, pl. 17, figs. 1a-c.

Hanzawaia cushmani (Nuttall). Miller, 1983, p. 437, pl. 1, fig. 12.

Planulina? amorphila (Guembel). Charletta, 1980, p. 66, pl. 5, figs. 7-9.

Hagn (1956) placed *H. cushmani* and *H. amorphila* into synonymy. Tjalsma and Lohmann (1983) examined one paratype, provided by Hagn to the U.S. National Museum, and suggested that the latter was more rapidly uncoiling. Berggren (personal communication, 1985) examined type material provided by Hagn and concluded that *H. amorphila* was the senior synonym. Charletta (1980) reported this taxon from the middle to upper Eocene of the COST B-2 well. Abundant at Site 612 (sporadically). Restricted to Zones P11 to P12 at Site 613. Abundant at Site 108.

***Karreriella chapapottensis* (Cole)**
(Plate 1, Figs. 3, 4)

Textularia chapapottensis Cole, 1928, p. 206, pl. 33, fig. 9.

Karreriella chapapottensis (Cole). Tjalsma and Lohmann, 1983, p. 32, pl. 9, figs. 2a, b.

Common in the middle to upper Eocene at Site 612 and in the middle Eocene at Sites 108 and 613. We noted *K. chapapottensis* var. *monumentensis* Mallory in these sections.

***Karreriella cubensis* Cushman and Bermudez**

Karreriella cubensis Cushman and Bermudez, 1937, p. 4, pl. 1, figs. 18, 19.

Karreriella cf. *cubensis* Cushman and Bermudez. Tjalsma and Lohmann, 1983, p. 33, pl. 9, figs. 4a, b.

We did not see an initial triserial portion; but we retained Tjalsma and Lohmann's (1983) taxonomy. This form actually may be assignable to *Siphotextularia* sp. Rare in the middle to upper Eocene at Site 612. Possible occurrences at Site 613. Absent at Site 108.

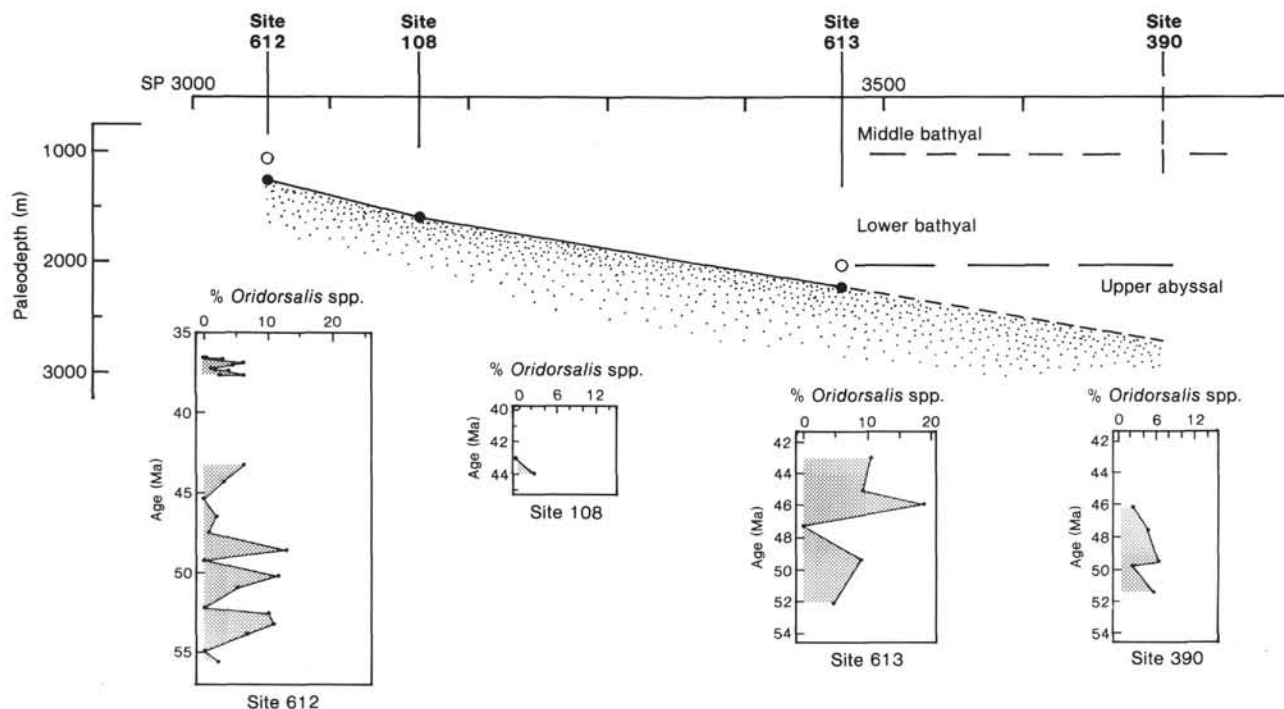


Figure 16. Percent abundance of *Oridorsalis* spp. along paleoslope. Layout as in Figure 6.

***Karreriella subglabra* (Guembel)**

(Plate 1, Figs. 1, 2)

Gaudryina subglabra Guembel, 1868, p. 602, pl. 1, figs. 4a, b.

Gaudryina bradyi Cushman, 1911, p. 67, fig. 107.

Karreriella bradyi (Cushman). Cushman, 1937, p. 135, pl. 16, figs. 6–11.

Karreriella bradyi (Cushman). Barker, 1960, pl. 46, figs. 1–4.

Karreriella subglabra (Guembel). Tjalsma and Lohmann, 1983, p. 34, pl. 9, figs. 1a, b.

Miller (1983) suggested that *K. subglabra* might be conspecific with *K. bradyi*. If so, then the senior synonym is *K. subglabra*. Rare at Sites 108 and 612. Common at Site 613.

***Nonion havanense* Cushman and Bermudez**

(Plate 2, Figs. 13, 14)

Nonion havanense Cushman and Bermudez, 1937, p. 19, pl. 2, figs. 13, 14.

Nonion havanense Cushman and Bermudez. Tjalsma and Lohmann, 1983, p. 17, pl. 7, figs. 6a, b.

Common to abundant at all three sites.

***Nonionellina* sp.**

(Plate 2, Figs. 15, 16)

Common in the middle and upper Eocene at Site 612. Absent from Sites 108 and 613. Differs from *Nonionella* in lacking a chamber extension over the umbilicus and from *Pseudononion* in being almost planispiral in the final stage.

***Nuttallides truempyi* (Nuttall)**

(Plate 4, Figs. 1–3)

Eponides truempyi Nuttall, 1930, p. 287, pl. 24, figs. 9, 13, 14.

Nuttallides truempyi (Nuttall). Tjalsma and Lohmann, 1983, p. 17, pl. 6, figs. 4a, b; pl. 17, figs. 4a–5b, pl. 21, figs. 1a–4c.

Nuttallides truempyi (Nuttall). Miller, 1983, p. 439, pl. 1, figs. 4–6.

Abundant in the lower to middle Eocene at Sites 612, 108, and 613; absent in the upper Eocene at Site 612. Charletta (1980) reported that this taxon is restricted to lower Eocene deposits on the New Jersey shelf (COST B-2 well).

***Planulina costata* (Hantken)**

(Plate 5, Figs. 1–3)

Truncatulina costata Hantken, 1875, p. 73, pl. 9, figs. 2a–c.

Planulina cocoaensis Cushman. Charletta, 1980, p. 58, pl. 2, figs. 10–12.

This distinct, flattened, planulinid is restricted to the upper Eocene of Site 612, with an isolated possible occurrence in the middle Eocene of that site. Absent at Sites 108 and 613. In the New Jersey coastal plain, Charletta reported sporadic occurrences of this taxon in middle and upper Eocene deposits, including the COST B-2 well.

***Planulina* cf. *renzi* Cushman and Stainforth**

(Plate 5, Figs. 4–6)

Planulina renzi Cushman and Stainforth, 1945, p. 72, pl. 15, figs. 1a–c. *Planulina renzi* Cushman and Stainforth. Tjalsma, 1983, p. 743, pl. 3, fig. 4; pl. 6, figs. 6, 7.

Restricted to the upper Eocene at Site 612, with an isolated occurrence in the uppermost middle Eocene. Absent from Sites 108 and 613. Elsewhere, the first occurrence of this species is generally in the Oligocene. In general, our specimens are not typical, but have an enlarged umbonal boss with rapidly increasing chambers. The specimen illustrated here is closer in morphology to typical *P. renzi*.

***Plectofrondicularia* spp.**

Restricted to the upper Eocene at Site 612, except for a single isolated occurrence in the middle Eocene. Absent from Site 613.

***Pullenia eocenica* Cushman and Siegfus**

(Plate 3, Fig. 7)

Pullenia eocenica Cushman and Siegfus, 1939, p. 31, pl. 7, figs. 1a, b.

Pullenia eocenica Cushman and Siegfus. Tjalsma and Lohmann, 1983, p. 36, pl. 16, fig. 1.

Pullenia eocenica Cushman and Siegfus. Miller, 1983, p. 439, pl. 4, fig. 11.

We included forms assignable to *P. bulloides* (d'Orbigny). Abundant at all sites, particularly in the upper Eocene of Site 612. Tjalsma and Lohmann (1983) reported a first appearance in Zone P9, with a questionable appearance in Zone P6a. At Site 612, this taxon occurs

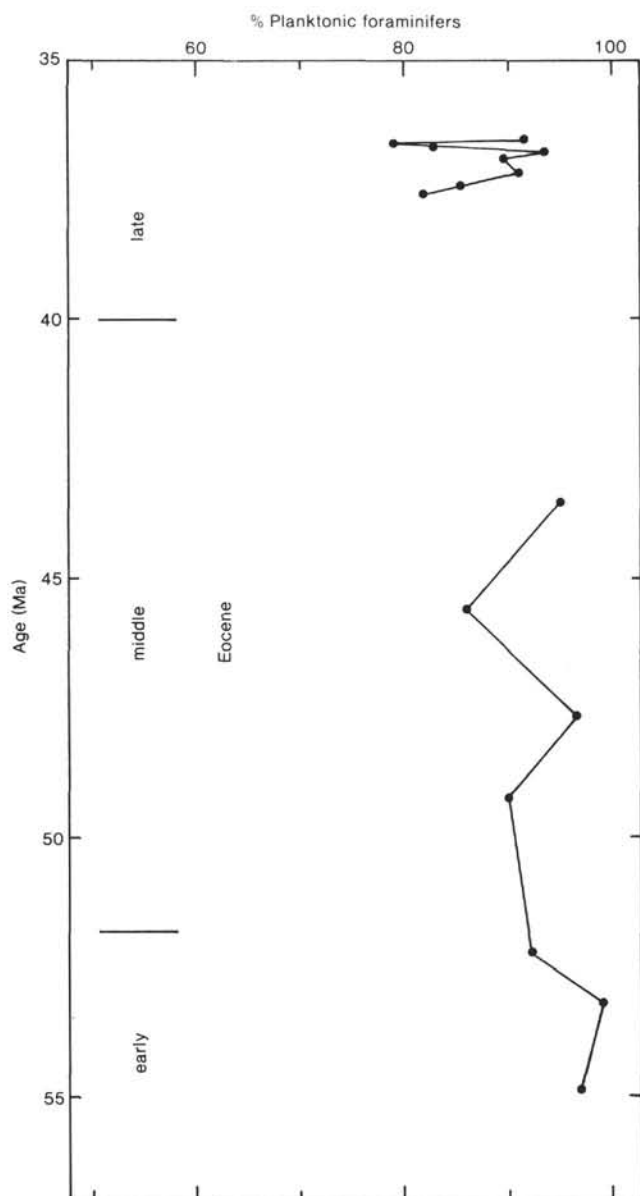


Figure 17. Planktonic foraminifers as percentage of total foraminifers counted, Site 612.

in the next to lowest sample examined (Zone P7). At Site 613 it occurs throughout the section studied.

***Pullenia quinqueloba* (Reuss)**

(Plate 3, Figs. 8, 9)

Nonionina quinqueloba Reuss, 1851, p. 71, pl. 5, figs. 31a, b.

Pullenia quinqueloba (Reuss). Tjalsma and Lohmann, 1983, p. 36, pl. 16, fig. 2.

Pullenia quinqueloba (Reuss). Miller, 1983, pl. 4, figs. 9, 10.

Abundant at Site 612. Common in the middle Eocene at Sites 108 and 613.

***Rzehakina epigona* (Rzehak)**

(Plate 1, Figs. 15, 16)

Silicina epigona Rzehak, 1895, p. 214, pl. 6, figs. 1a-c.

Rzehakina epigona (Rzehak), Gradstein and Berggren, 1981, p. 248, pl. 5, fig. 1.

Miller et al. (1982) noted a range into lower Eocene of the Labrador Shelf. Restricted to the lower Eocene of Site 612. Present in the lowermost middle Eocene at Site 613. Absent at Site 108.

***Sigmoilopsis* sp.**

(Plate 1, Figs. 11, 12)

Similar to *S. schlumbergeri*, but more compressed. Present in every sample from the uppermost middle to upper Eocene at Site 612, with a single isolated occurrence in the lowermost middle Eocene. Absent at Sites 108 and 613.

***Siphonina* sp.**

(Plate 5, Figs. 10-12)

In our material, this unusual siphoninid has no pronounced siphon. This may be an artifact of preservation, or else this species may be assignable to *Pulsisiphonina*. Abundant and restricted to the upper lower Eocene (Zone P9) and the sample immediately above the middle/lower Eocene unconformity at Site 612. Absent at Sites 108 and 613.

***Spiroplectammina spectabilis* Grzybowski**

(Plate 1, Figs. 5, 6)

Spiroplecta spectabilis Grzybowski, 1898, p. 293, pl. 12, fig. 12.

Spiroplectoides clotho (Grzybowski). Cushman and Jarvis, 1928, p. 101, pl. 14, figs. 13, 14.

Spiroplectammina grzybowskii Frizzell, 1943, p. 339, pl. 55, figs. 12a, b, 13.

Spiroplectammina grzybowskii Frizzell. Cushman and Renz, 1946, p. 20, pl. 5, figs. 34-38.

Spiroplectammina spectabilis (Grzybowski). Tjalsma and Lohmann, 1983, p. 20, pl. 1, fig. 11, pl. 9, figs. 8-10.

Spiroplectammina spectabilis (Grzybowski). Miller et al., 1982, p. 22, pl. 2, figs. 2, 3.

Found in the upper lower Eocene to upper Eocene at Site 612 and middle Eocene of Site 613. Does not occur in Oligocene samples at Site 612. Absent at Site 108.

***Spirosgmoilinella compressa* Matsunaga**

(Plate 1, Figs. 13, 14)

Spirosgmoilinella compressa Matsunaga, 1955, p. 50, figs. 1, 2.

Spirosgmoilinella compressa Matsunaga. Miller et al., 1982, p. 20, pl. 2, fig. 5.

Miller et al. (1982) reported this taxon from the upper middle to upper Eocene of the southern Labrador Sea and the middle to upper Eocene of the North Sea. The forms noted here are acid-soluble, however, unlike the acid-insoluble specimens noted by Miller et al. (1982). Restricted to the upper Eocene at Site 612 and the middle Eocene at Site 613. Absent at Site 108.

***Stilostomella aculeata* (Cushman and Renz)**

Ellipsonodosaria nuttalli Cushman and Jarvis var. *aculeata* Cushman, and Renz, 1948, p. 32, pl. 6, fig. 10.

Stilostomella aculeata (Cushman and Renz). Tjalsma and Lohmann, 1983, p. 36, pl. 14, fig. 12.

Stilostomella aculeata (Cushman and Renz). Miller, 1983, p. 439, pl. 4, fig. 1.

We included in this taxon rare specimens with basal spines which lacked the ring of spines on the lower part of the chamber and which may actually belong in *E. nuttalli*. Common to abundant at Sites 108 and 612. Rare at Site 613.

***Stilostomella curvatura* (Cushman)**

(Plate 2, Fig. 3)

Ellipsonodosaria curvatura Cushman, 1939, p. 71, pl. 12, fig. 6.

Stilostomella curvatura (Cushman). Tjalsma, 1983, p. 743, pl. 1, figs. 7-11.

Common at Sites 108 and 612. Rare at Site 613.

***Stilostomella gracillima* (Cushman and Jarvis)**

Ellipsonodosaria nuttalli var. *gracillima* Cushman and Jarvis, 1934, p. 72, pl. 10, fig. 7.

Stilostomella gracillima (Cushman and Jarvis). Tjalsma and Lohmann, 1983, p. 36, pl. 14, figs. 13-15.

Stilostomella gracillima (Cushman and Jarvis). Miller, 1983, p. 439, pl. 4, fig. 3.

Abundant from the upper lower to upper Eocene at Site 612. Abundant in the middle Eocene at Site 613. Absent at Site 108.

***Stilostomella subspinos* (Cushman)**

Ellipsonodosaria subspinos Cushman, 1943, p. 92, pl. 16, figs. 6–7b. *Stilostomella subspinos* (Cushman). Tjalsma and Lohmann, 1983, p. 36, pl. 14, figs. 16, 17.

Stilostomella subspinos (Cushman). Miller, 1983, p. 440, pl. 4, fig. 2. Abundant in the middle and upper Eocene at Site 612 and in the middle Eocene at Site 613. Absent at Site 108.

***Trifarina danvillensis* (Howe and Wallace)**

Uvigerina danvillensis Howe and Wallace, 1932, p. 62, pl. 12, fig. 5. *Trifarina danvillensis* (Howe and Wallace). Tjalsma, 1983, pl. 2, figs. 6, 7.

Restricted to the upper Eocene and the Oligocene at Site 612. Single occurrence in the middle Eocene at Site 613. Absent at Site 108. Tjalsma (1983) found it restricted to the Oligocene of Site 516.

***Trifarina wilcoxensis* (Cushman and Ponton)**

(Plate 2, Fig. 5, 6)

Pseudouvigerina wilcoxensis Cushman and Ponton, 1932, p. 66, pl. 8, fig. 18.

Trifarina wilcoxensis (Cushman and Ponton). Charletta, 1980, p. 62, pl. 4, fig. 5.

Rare to abundant in the upper lower to middle Eocene at Site 612. Absent at Sites 108 and 613.

***Turrilina robertsi* (Howe and Ellis)**

Bulimina robertsi Howe and Ellis, 1939, p. 63, pl. 8, figs. 32, 33.

Turrilina robertsi (Howe and Ellis). Tjalsma and Lohmann, 1983, p. 37, pl. 14, fig. 5.

Turrilina robertsi (Howe and Ellis). Miller, 1983, p. 440, pl. 3, fig. 9. *Turrilina* sp. (sic), Charletta, 1980, p. 62, pl. 3, figs. 11–13.

Restricted to the lower and middle Eocene at Site 612. Common at Site 108. Absent from Site 613.

***Uvigerina basicordata* Cushman and Renz**

Uvigerina gallowayi Cushman var. *basicordata* Cushman and Renz, 1941, p. 21, pl. 3, figs. 18a, b.

Occurs in high abundance in the two uppermost (Oligocene) samples at Site 612. Absent at Sites 108 and 613. The first occurrence of this taxa at the base of the Oligocene may be stratigraphically useful.

***Uvigerina hispida* Schwager**

(Plate 2, Fig. 4)

Uvigerina hispida Schwager, 1866, p. 249, pl. 7, fig. 95.

Uvigerina chirana Cushman and Stone, 1947, p. 17, pl. 2, fig. 25.

Uvigerina chirana Cushman and Stone. Tjalsma, 1983, pl. 2, fig. 11.

Common in the upper middle to upper Eocene at Site 612. Isolated occurrence in the middle Eocene at Site 613. Absent at Site 108.

***Uvigerina rippensis* Cole**

Uvigerina rippensis Cole, 1927, p. 11, pl. 2, fig. 16.

Uvigerina rippensis Cole. Tjalsma and Lohmann, 1983, p. 38, pl. 14, figs. 6, 7.

Restricted to the upper middle to upper Eocene at Site 612; single occurrence at Site 613. Common at Site 108.

***Vaginulina decorata* Reuss**

(Plate 2, figs. 7, 8)

Cristellaria decorata Reuss, 1855, p. 269, pl. 8, fig. 16; pl. 9, figs. 1, 2.

Rare at Site 612. Absent at Sites 108 and 613.

***Vulvulina spinosa* Cushman**

(Plate 1, Figs. 7, 8)

Vulvulina spinosa Cushman, 1927b, p. 111, pl. 23, fig. 1.

Vulvulina spinosa Cushman. Tjalsma and Lohmann, 1983, p. 38, pl. 10, figs. 4a–5b.

Common to abundant in the lower to middle Eocene at Site 612; several occurrences into the Oligocene. Common to abundant in the middle Eocene at Sites 108 and 613.

Other taxa not discussed: *Clavulina* sp., *Dentalina/Vaginulina* spp., *Globobulimina* spp., *Martinotiella* sp., *Melonis* spp., *Plectina* spp., *Tritaxia* sp.

ACKNOWLEDGMENTS

We thank W. A. Berggren, G. S. Mountain, R. K. Olsson, A. Palmer, C. W. Poag, and R. C. Tjalsma for reviewing the manuscript; R. C. Tjalsma for discussions and for providing samples from Site 390; the shipboard party for discussions; M. Hart and C. W. Poag for providing planktonic biostratigraphic data; S. Hambos for technical assistance; A. C. Charletta for providing comparative material; and A. D. Chave for software. We especially thank M. Steckler for providing unpublished backstripped estimates and D. Grieg of Chevron for producing the scanning electron microscope micrographs. Samples were provided by DSDP. This research was funded by NSF Grant OCE 83 10086 and OCE 85 00859, a grant from the Arco foundation, and a consortium of oil companies (Arco, BP, Chevron, Elf, Exxon, Gulf, Mobil, Phillips, Shell, Shell International, Phillips, Texaco, and Union). This is Lamont-Doherty Geological Observatory Contribution number 4021.

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Date of Initial Receipt: 7 July 1985

Date of Acceptance: 8 January 1986

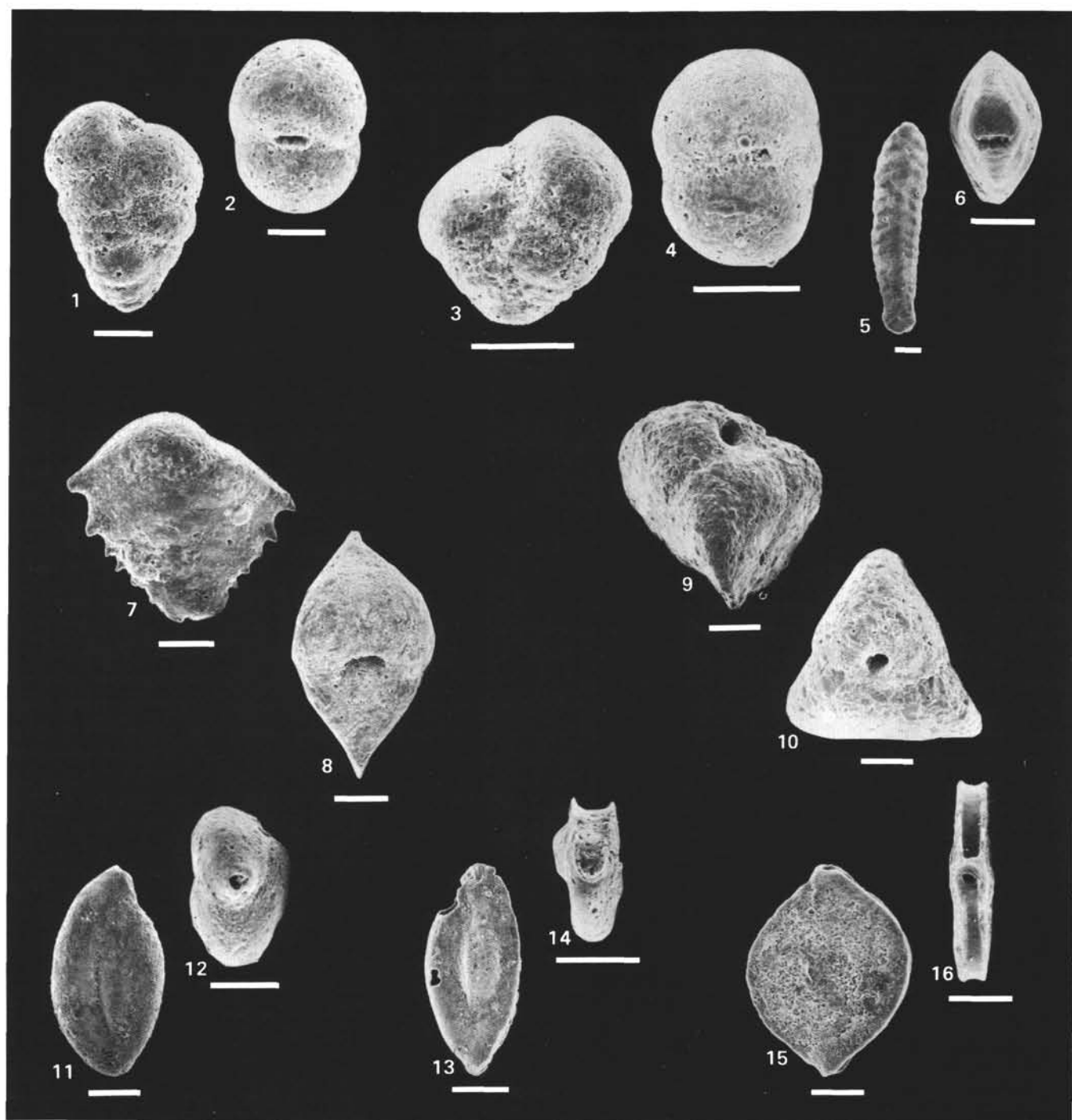


Plate 1. (Scale bar = 100 μ m.) 1, 2. *Karreriella subglabra* (Guembel), Sample 612-21-3, 60-64 cm. 3, 4. *K. chapapotensis* var. *monumentensis* Mallory, Sample 612-21-3, 60-64 cm. 5, 6. *Spiroplectamina spectabilis* (Grzybowski), Sample 612 33, CC. 7, 8. *Vulvulina spinosa* Cushman, Section 612-28-6, base. 9, 10. *Gaudryina pyramidata* Cushman, Sample 612-17-6, 140-144 cm. 11, 12. *Sigmoilopsis* sp., Sample 612-17-5, 140-144 cm. 13, 14. *Spirosigmoilinella compressa* Matsunaga, Sample 612-20, CC. 15, 16. *Rezehakina epigona* (Rzehak), Sample 612-45-3, 60-64 cm.



Plate 2. (Scale bar = 100 μ m.) 1, 2 *Bolivina antegressa* Subbotina, Sample 612-16, CC. 3. *Stilostomella curvatura* (Cushman), Sample 612-17-2, 140–144 cm. 4. *Uvigerina hispida* Schwager, Sample 612-18, CC. 5, 6. *Trifarina wilcoxensis* (Cushman and Ponton), Sample 612-17-6, 140–144 cm. 7, 8. *Vaginulina* cf. *decorata* (Reuss), Sample 612-45-3, 60–64 cm. 9, 10. *Osangulara mexicana* (Cole), Sample 612-17-5, 140–144 cm. 11, 12. *Anomalinoidea* sp. M, Sample 612-30, CC. 13, 14. *Nonion havanense* Cushman and Bermudez, Sample 612-18-3, 60–64 cm. 15, 16. *Nonionellina* sp., Sample 612-18-3, 60–64 cm.

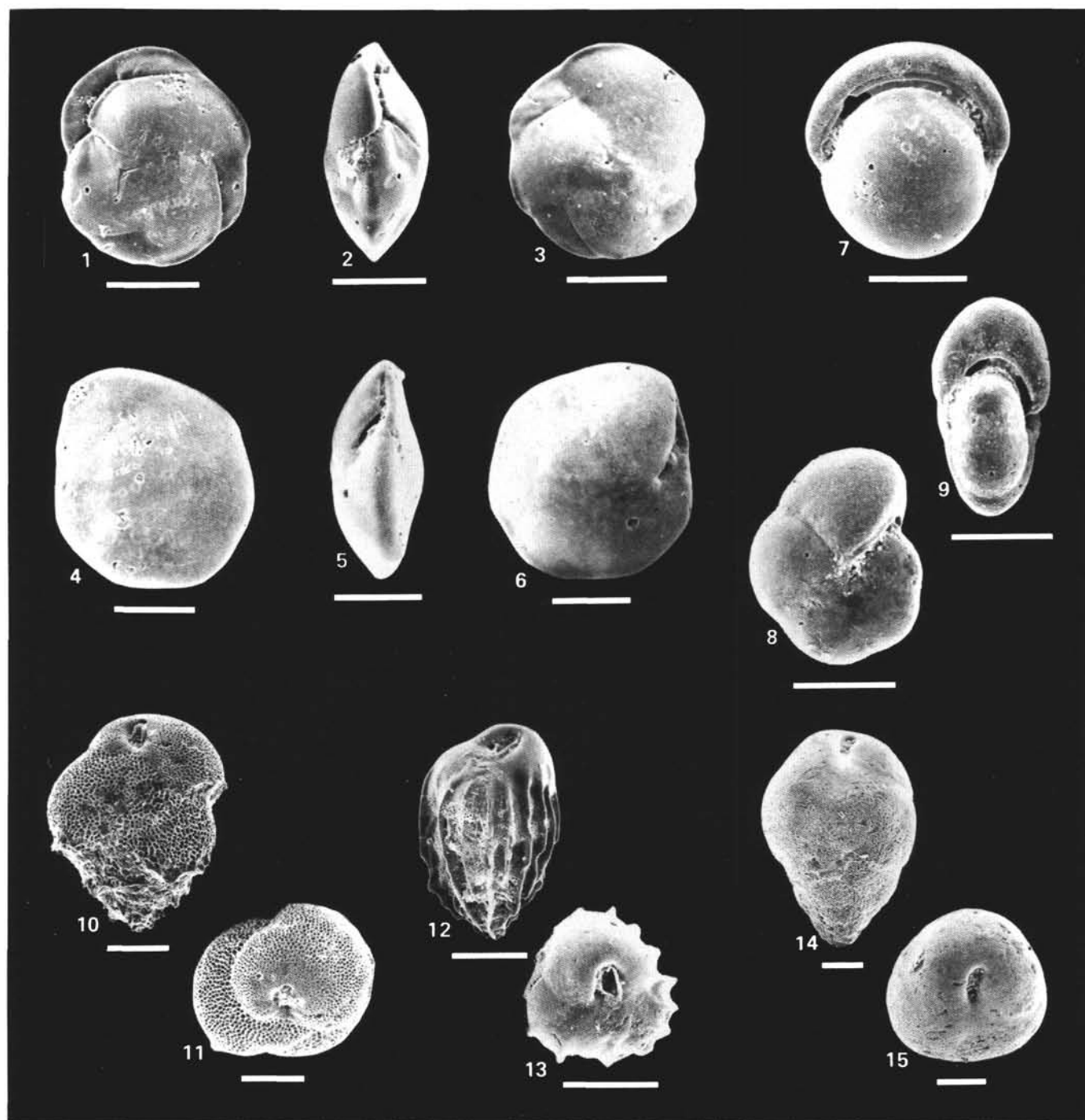


Plate 3. (Scale bar = 100 μ m.) 1-3. *Cassidulina havanensis* Cushman and Bermudez, Sample 612-19-3, 60-64 cm. 4-6. *Alabamina cf. dissonata* (Cushman and Renz), Sample 612-17-3, 140-143 cm. 7. *Pullenia eocenica* Cushman and Siegfus, Sample 612-17-4, 60-64 cm. 8, 9. *P. uniuqueloba* (Reuss), Sample 612-17-6, 140-144 cm. 10, 11. *Bulimina trinitatensis* Cushman and Jarvis, Sample 612-18, CC. 12, 13. *B. alazanensis* Cushman, Sample 612-16, CC. 14, 15. *B. tuxpamensis* Cole, Sample 612-17-3, 140-143 cm.

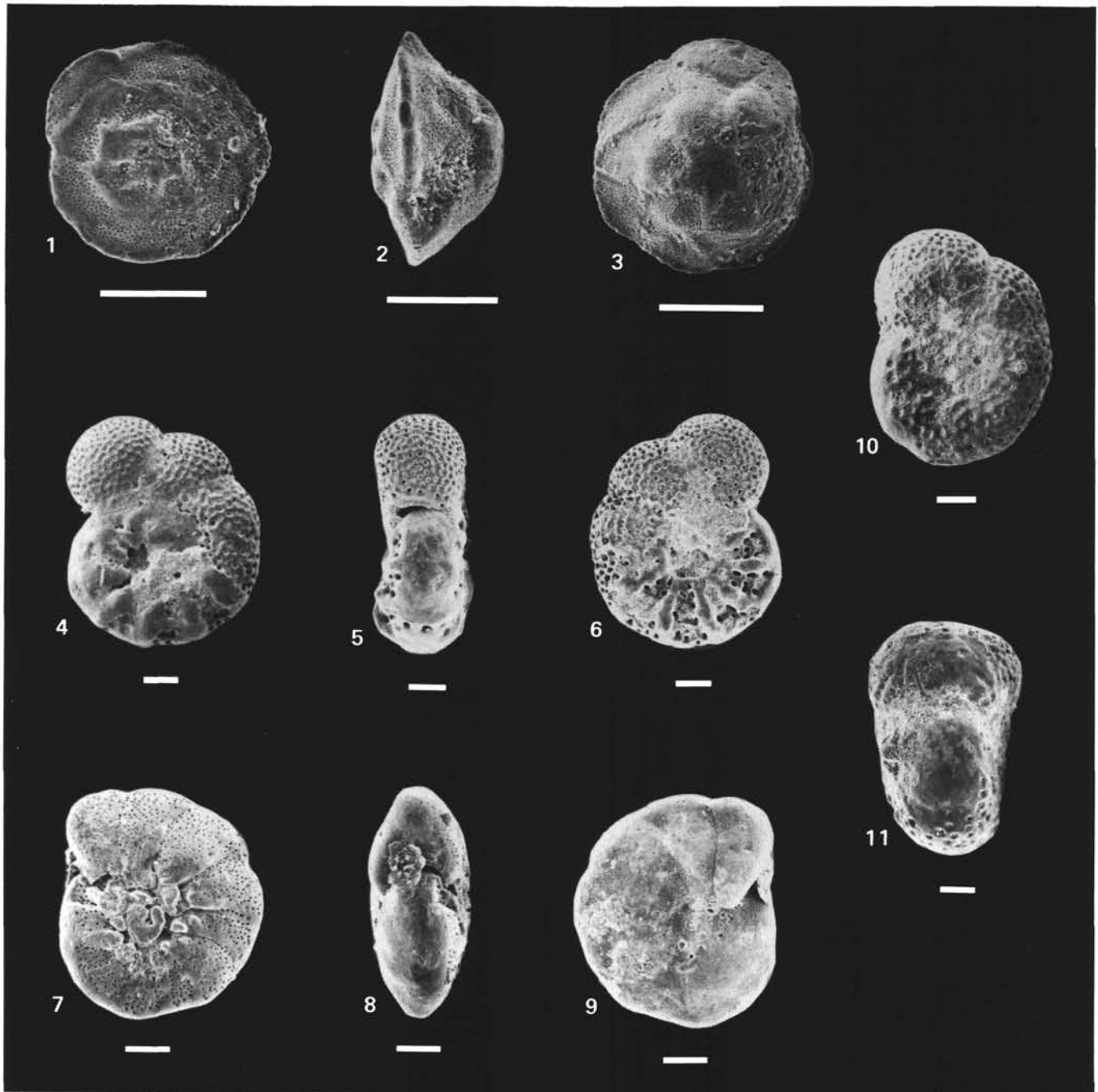


Plate 4. (Scale bar = 100 μ m.) 1-3. *Nuttallides truempyi* (Nuttall), Sample 612-24, CC. 4-6. *Gavelinella capitata* (Guembel) var. *aragonensis* (Nuttall), Sample 612-41-3, 60-64 cm. 7-9. *G. micra* (Bermudez), Sample 612-26, CC. 10, 11. *G. capitata* (Guembel), Section 612-28-6, base.

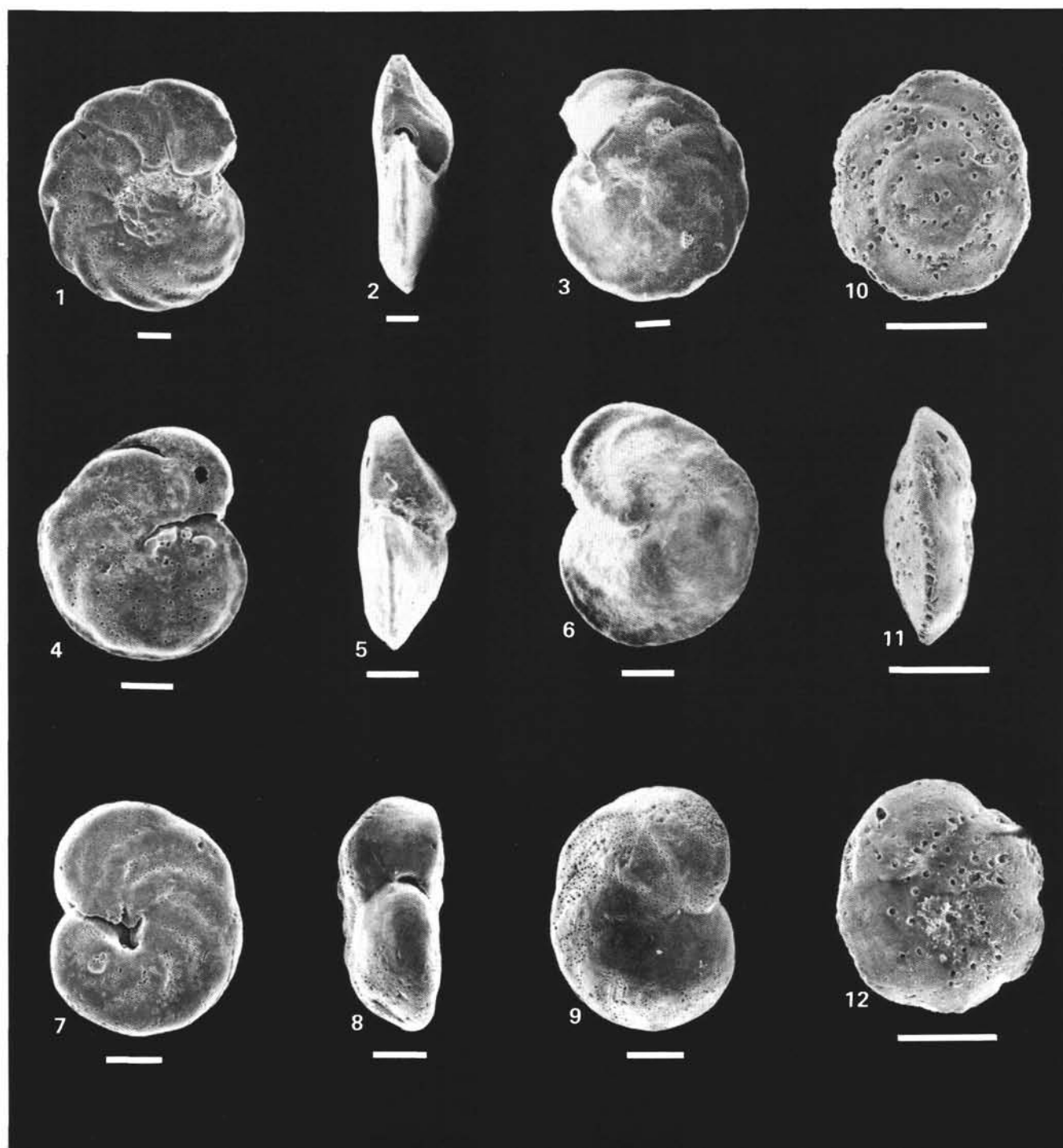


Plate 5. (Scale bar = 100 μ m.) 1-3. *Planulina costata* (Hantken), Sample 612-20, CC. 4-6. *P. cf. renzi* Cushman and Stainforth, Sample 612-16, CC. 7-9. *Hanzawaia ammophila* (Guembel), Sample 612-18-3, 60-64 cm. 10-12. *Siphonina* sp., Sample 612-39-3, 60-64 cm.

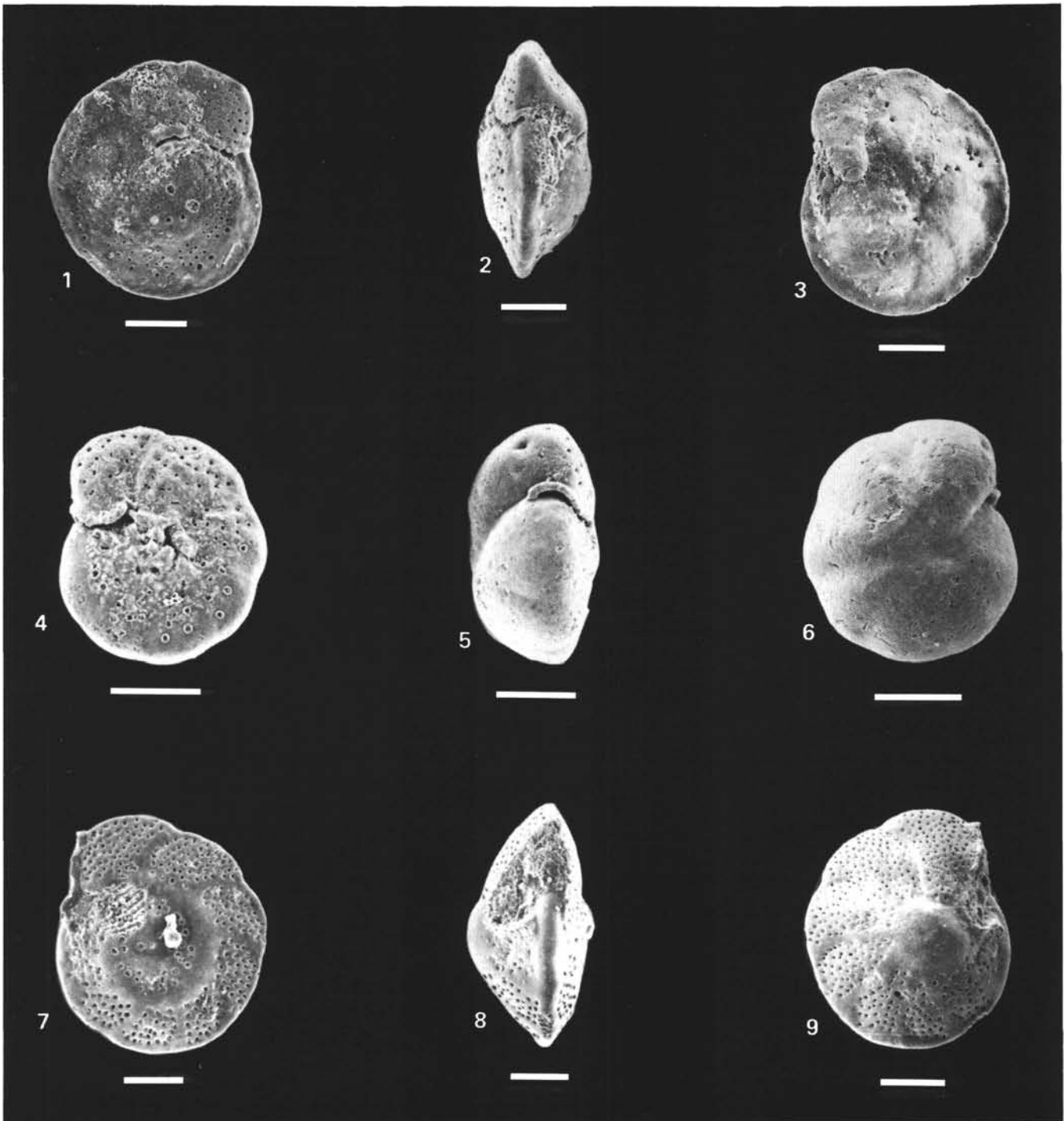


Plate 6. (Scale bar = 100 μm .) 1-3. *Cibicidoides mundulus* group, Sample 612-22, CC. 4-6. *Cibicidoides* sp. D. Sample 613-20, CC. 7-9. *Cibicidoides tuxpamensis* (Cole), Sample 612-41-3, 60-64 cm.

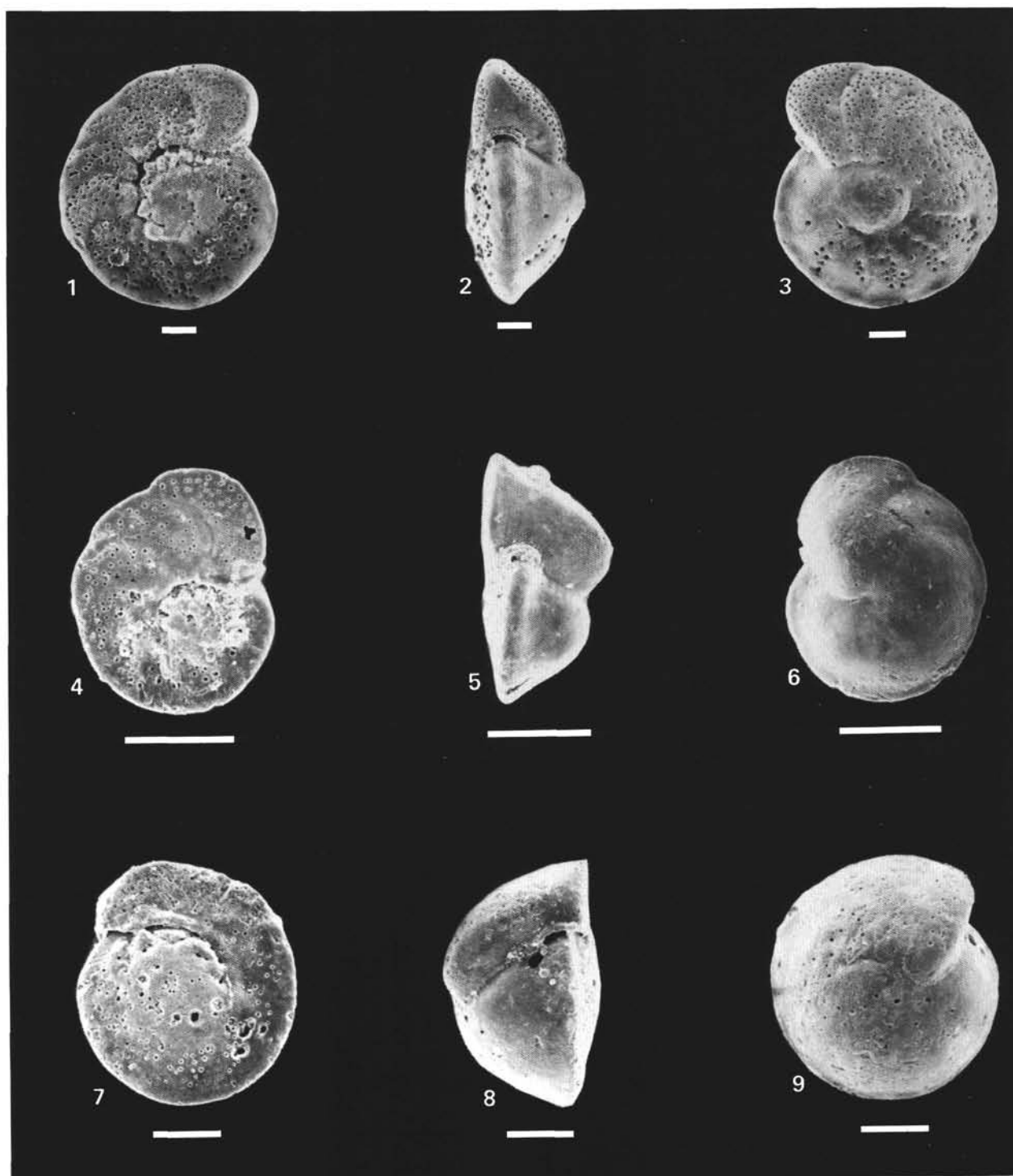


Plate 7. (Scale bar = 100 μ m.) 1-3. *Cibicidoides* sp. P, Sample 612-17-4, 60-64 cm. 4-6. *C. laurissae* (Mallory), Sample 612-20, CC. 7-9. *C. subspiratus* (Nuttall), Sample 613-30, CC.