21. PALEOCENE AND EARLY EOCENE MICROFACIES, BENTHONIC FORAMINIFERA, AND PALEOBATHYMETRY OF DEEP SEA DRILLING PROJECT SITES 236 AND 237, WESTERN INDIAN OCEAN

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ABSTRACT

A significant and abrupt change in the sedimentary regime at Site 237 provides evidence for an early Tertiary subsidence of the Mascarene Plateau area in the western Indian Ocean. Between approximately 62 and 57 m.y.B.P. pelagic sediments were deposited at Site 237 in upper bathyal (200-600 m) depths with admixtures of slumped material from nearby shoals at a rate of about 68 m/m.y. The sea floor began to sink in the late Paleocene (57-58 m.y.B.P.). Introduction of shallow-water material ceased and normal pelagic sedimentation proceeded, at a rate about six times slower, at lower bathyal (600-2500 m) depths. Deepening at Site 237 at this time permitted development of deep-water benthonic foraminiferal faunas similar to those at Site 236 to the north. A further decrease in the rate of sedimentation occurred near the end of the Paleocene and in early Eocene, from approximately 54 to 50 m.y.B.P. During that period of time an interval of nondeposition spanned the Paleocene/Eocene boundary at Site 236. The area at Site 237 has subsided approximately 2000 meters over the past 52 m.y.

This sequence of events on the Mascarene Plateau is similar to, and synchronous with, the subsidence history of the Chagos-Laccadive Ridge to the east.

INTRODUCTION

The Mascarene Plateau, a major structural element of the Indian Ocean, forms the foundation for a series of islands and shallow banks that extend in a gentle northwest to south crescent across the western tropical Indian Ocean (Fisher et al., 1967). During Leg 24 of the Deep Sea Drilling Project, *Glomar Challenger* drilled two holes in the Mascarene Plateau area. Site 236, in 4500 meters of water, is located in the outermost foothills southwest of the Carlsberg Ridge, 270 km northeast of the Seychelles Islands, the northern termination of the Mascarene Plateau. Site 237, in 1630 meters of water, was drilled in the saddle joining the granitic Seychelles Bank to the volcanic Saya de Malha Bank (Figure 1 and Table 1). The thickness of the Paleocene and lower Eocene section is 42 meters at Site 236 and about nine times greater (374 meters) at Site 237. Site 236 reached basement, whereas Site 237 was terminated before basement was reached for operational reasons.

The age of the foundation and the petrologic affinity of that part of the Mascarene Plateau located between Precambrian granitic Seychelles and volcanic Saya de Malha are a matter of controversy. Site 237 was drilled in this area to answer these questions and to establish the rate and continuity of subsidence of what was thought to be an extensive reef area on a massive igneous base. Drilling at Site 237 failed to determine the age and nature of the basement, but the thick early Tertiary sedimentary sequence recovered here provides clues to help elucidate the subsidence history of the area. No coralline section was penetrated and the area appears to have been a site of pelagic sedimentation since early Paleocene time. The purpose of this study was to gain information on the depositional environment and paleodepth on the Mascarene Plateau during the Paleocene and early Eocene. Thin sections from lithified oozes at Site 237 were examined for this purpose, as well as to complement the planktonic foraminiferal zonation established at this site based on the fauna extracted from the few soft horizons. Benthonic foraminiferal faunas extracted from these unlithified sediments at Sites 236 and 237 were also studied.

The Paleocene and lower Eocene sequence at Site 236, which underlies 263 meters of Quaternary to late Paleocene nannofossil chalk oozes, consists of nannofossil chalk with chert. It was continuously cored with a poor recovery. A good sediment/basement contact was obtained within Core 33 at 305 meters. The biostratigraphic age of the basal sediments is 56-58 m.y. old (*Discoaster mohleri* and P.4 zones) according to Berggren's (1972) scale; whereas the magnetic age of basement is 9 to 11 m.y. older (approximately magnetic anomaly 27, McKenzie and Sclater, 1971) according to the geomagnetic scale of Heirtzler et al. (1968). Two substantial stratigraphic gaps were found, one spanning the late Paleocene/early Eocene boundary and the other representing the entire middle Eocene.

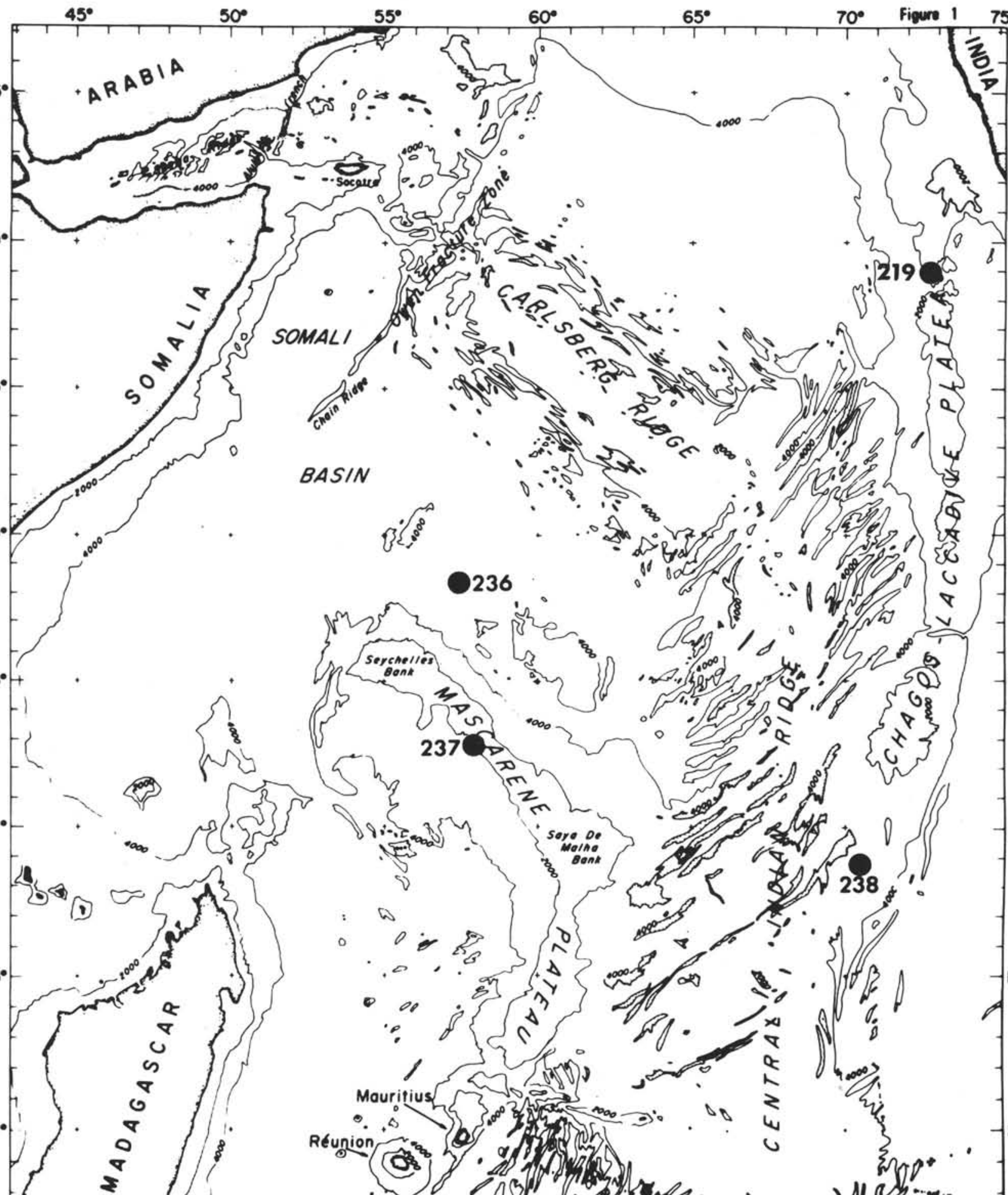


Figure 1. *Location of DSDP sites on the Mascarene Plateau/Central Indian Ridge/Chagos-Laccadive Plateau complex.*

TABLE 1
Location of Sites Containing Paleocene and Lower Eocene Deposits Drilled on Leg 24

Site	Latitude	Longitude	Water Depth (m)	Paleocene and Lower Eocene Section Thickness (m)	Cores
236	1°40.62'S	57°38.85'E	4504	42	29-33
237	7°04.99'S	58°07.48'E	1640	374	35-67

The Paleocene and lower Eocene section at Site 237, which underlies 320 meters of Quaternary to middle Eocene nannofossil ooze, consists of partly silicified nannofossil chalk with chert, with some glauconitic horizons in the upper Paleocene. Coring, with poor recovery, was continuous in the upper part of that section down to a depth of 585 meters, and from that depth to hole bottom alternate joints were cored.

A summary of the Paleocene and early Eocene lithology, fossil zonations, age assignment, and sedimentation rates at both Sites 236 and 237 is presented in Figure 2.

MICROFACIES

Folk's (1962) classification was used to describe the microscopic features of 42 thin sections from the Paleocene and lower Eocene silicified nannofossil chalks (lithologic Units 3, 4, and 5) of Site 237 (Table 2 and Figure 3). The bulk of the rocks consists of sparse to packed biomicrite, often modified by recrystallization and silicification, with planktonic foraminifera as the main skeletal grain in the Paleocene sequence and radiolarians in the lower Eocene. Recrystallization is very pronounced in the lower 54 meters (below Core 65). The high planktonic/benthonic foraminiferal ratio clearly reflects a pelagic environmnent, planktonic species usually comprising 90% or more of the foraminiferal population with an increasing trend up section. Among subordinate biogenic grain types, sponge spicules occur commonly while echinoderm spines and molluscan fragments are rare. Chambers of the skeletal components are infilled either by microspar, spar, micrite, or chert. Radiolarians are often calcified. The various biogenic components are regularly distributed throughout the sediment, and evidence of bioturbation is not common. Fecal pellets were found in a few horizons. Small quartz grains and glauconite, which occurs as grains or occasionally as infilling of foraminiferal chambers, are present in the lower part of the section from 410 to 670 meters, with an abundance of 1% and 1% to 5%, respectively.

The high degree of recrystallization precludes identification of the components of the matrix, which was probably composed of nannofossils as indicated by the smear-slide analyses. These show that nannofossils comprise 80% to 95% of the sediments above 516 meters; whereas below this level micarb, which may represent altered nannofossils, is the main contributor (80% to 95%) (Figure 3).

Interbedded in the Paleocene pelagic deposits are several horizons of coarse material. These consist of packed biomicrite or biosparite with larger foraminifera (*Discocyclina, Ranikothalia*), calcareous algae (*Archaeolithothamnium*), and fragments of molluscs, echinoderms, and bryozoans. These horizons represent slumped shallow-water deposits, and their contact with the fine-grained rock in which they occur is sharp (Thiede, this volume, Figure 30).

Planktonic foraminifera were identified and several foraminiferal zonal boundaries were defined. The *Morozovella pusilla-Morozovella angulata* (P.3)/*Morozovella uncinata-Turborotalia spiralis* (P.2) boundary, which separates the late and early Paleocene, was placed within Core 61, Section 1, at the lowest occurrence of *Morozovella angulata.* The *Planorotalites pseudomenardii* (P.4)/*Morozovella pusilla-Turborotalia spiralis* (P.3) boundary could not be defined between Cores 45, Section 2 and Core 54, Section 1, because of the co-occurrence in this interval of forms referable to *Morozovella velascoensis* and *Morozovella laevigata* (younger than P.3) and forms referable to *Planorotalites compressa* and *Subbotina triloculinoides* (older than P.4).

The position of the P.3/P.2 boundary at 574 meters in the section and of the *Discoaster mohleri* Zone/*Heliolithus kleinpella* Zone boundary at 403.5 meters, at 60 and 57.5 m.y.B.P., respectively (Berggren, 1972), permits the calculation of an average accumulation rate of 68.2 m/m.y. for the sediments deposited between these two points in time (Figure 2). If it is assumed that approximately 100 meters of additional sediments are present between the bottom of Hole 237 and the igneous basement below them (this volume, Chapter 8) and that the accumulation rate of 68.2 m/m.y. remained constant, then the age of the sediment/basement contact is approximately 63 m.y.B.P. (early Paleocene).

BENTHONIC FORAMINIFERA

Benthonic foraminifera are very rare at both Sites 236 and 237, with the bulk of the coarse fraction ($>61\mu$) consisting of planktonic foraminifera or siliceous components (radiolarians, sponge spicules) or both. Preservation is generally fair, but, the lower part of the section at Site 237 (corresponding roughly to the P.1 to P.3 interval) is dominantly recrystallized.

We identified 134 species of benthonic foraminifera. Many of these were described and illustrated in classical works on the faunas of the Midway Group of the U. S. Gulf Coastal Plain (Plummer, 1926; Cushman, 1951; Kellough, 1959, 1965) and the Velasco Formation of the Tampico Embayment in Mexico (Cushman, 1925, 1926; White, 1928, 1929; Cushman and Renz, 1946). The distribution of species at Sites 236 and 237 is shown in Tables 3 and 4. Species diversity, which may reflect bathymetry (Gibson and Buzas, 1973), was not investigated because the small volume of available samples and the low number of benthonic specimens precluded a statistically valid study.

PALEOBATHYMETRY

Basis for Paleobathymetric Interpretations

A number of faunal relationships provide good evidence of depositional environment (Bandy, 1960; Bandy and Arnal, 1960). The relative abundance of planktonic foraminifera in bottom sediments increases offshore (Grimsdale and Morkhoven, 1955; Bandy and Arnal, 1960). Planktonic

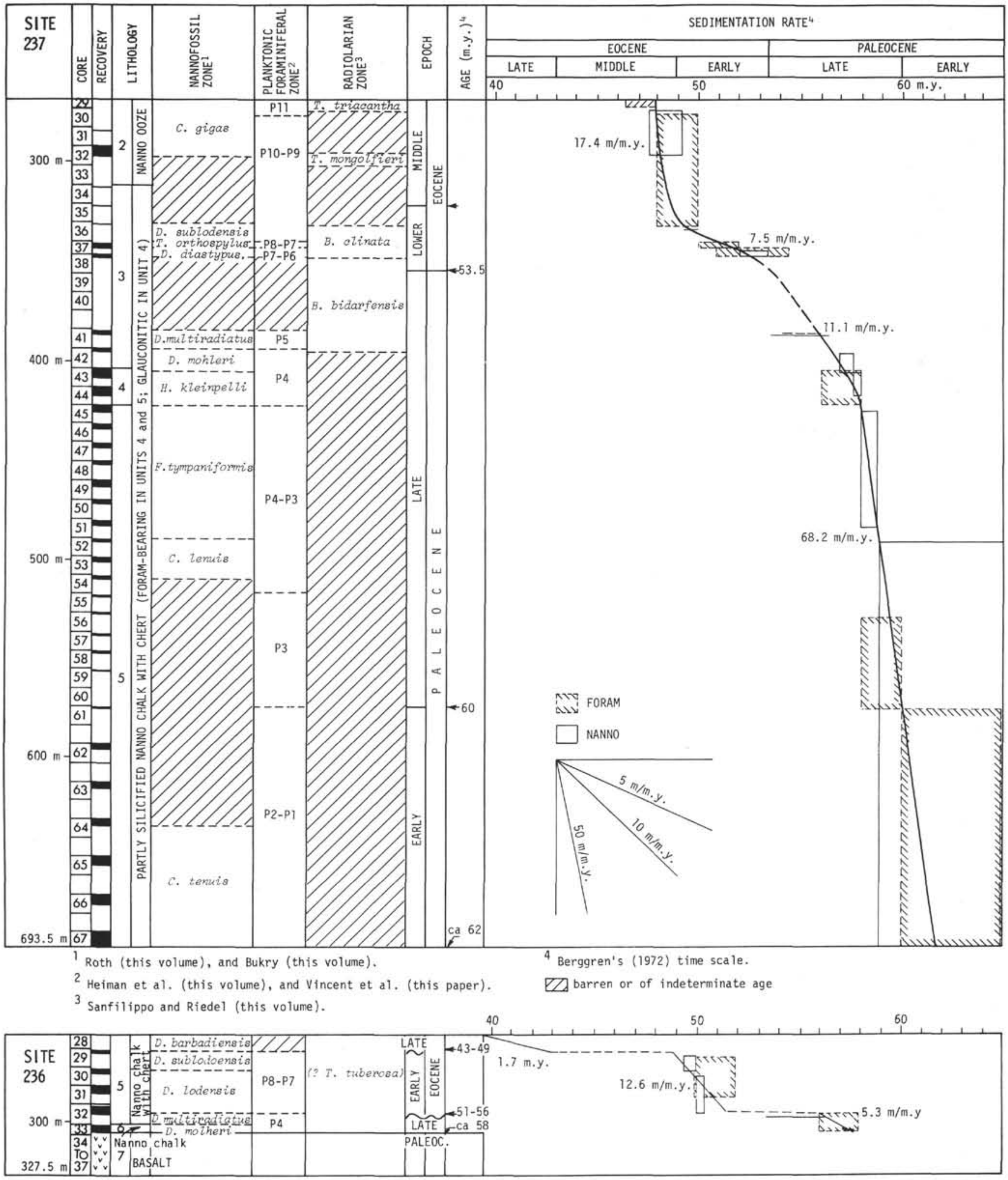


Figure 2. *Summary of lithology, biostratigraphy, and sedimentation rates of Paleocene and lower Eocene sections at Sites 236 and 237.*

TABLE 2
Microfacies of Lithified Calcareous Sediments at Site 237

Core	Section	Thin Section Number	Planktonic Foraminiferal Zone	Rock Type	Skeletal Grains (Whole or Fragments)	Identifiable Planktonic Foraminifera	Identifiable Benthonic Foraminifera	Planktonic Species vs Total Foram (%)	Infilling of Fossil Chambers	Authigenic and Terrigenous Grains
34	1	13	P10-P9	Sparse biomicrite	Radiolarians (C) Foraminifera (R)	*Acarinina bullbrooki* *Morozovella aragonensis* group		>99%	Chert	
37	2	15	P7-P6	Sparse biomicrite	Radiolarians (C) Foraminifera (R)	*Acarinina broedermanni* *A. bullbrooki* *Morozovella aragonensis* group *M. quetra* *Pseudohastigerina* sp.		>99%	Chert	
38	1	13	P7-P6	Sparse biomicrite	Radiolarians (C) Foraminifera (R)	*Acarinina broedermanni* *A. wilcoxensis* *Morozovella aequa* *M. formosa-gracilis* group subbotinids		>99%	Chert	
41	2	13	P5	Packed biomicrite	Foraminifera (A)	*Morozovella aequa* *M. velascoensis*		>99%	Chert	Glauconite (VR)
43	2	1	P4	Packed biomicrite, partially recrystallized	Foraminifera (A) Radiolarians (VR)	*Morozovella aequa* *M. laevigata* *M.* cf. *velascoensis* *Planorotalites pseudomenardii*		>99%	Micrite	Glauconite (VR) Quartz (VR)
44	1	12	P4	Sparse biomicrite	Radiolarians (R) Foraminifera (C) Sponge spicules (R)	*Chilogumbelina* sp. *Morozovella aequa* *M. laevigata*		>99%	Chert	Glauconite (C) Quartz (R) Feldspar (R)
44	2	2	P4	Sparse biomicrite	Foraminifera (R) Radiolarians (R)	*Morozovella aequa* *M. velascoensis* subbotinids		>99%	Calcite	Glauconite (C) Quartz (R)
45	2	6	P4-P3	Packed biomicrite	Foraminifera (A) Sponge spicules (R)	*Chilogumbelina* sp. *Morozovella angulata* *M. laevigata* *M. velascoensis* *Planorotalites ehrenbergi* group *Subbotina triloculinoides*	Rotaliids	ca 99%	Calcite	Glauconite (C) Quartz (R) Pyrite (R)
46	2	6	P4-P3	Packed biomicrite	Foraminifera (A) Radiolarians (R) Echinoderms (R)	*Morozovella angulata* *M. pusilla* *M. velascoensis* *Planorotalites compressa* *P. ehrenbergi-pseudomenardii* group *Subbotina triloculinoides*		ca 99%	Calcite	Glauconite (C) Quartz (R)
47	2	2	P4-P3	Packed biomicrite	Foraminifera (A)	*Morozovella angulata* *M. laevigata* *M.* cf. *velascoensis* *Planorotalites compressa*	Lageniids Textulariids	ca 98%	Calcite	Glauconite Quartz (R)
48	1	4	P4-P3	Packed biomicrite	Foraminifera (A) Radiolarians (R) Sponge spicules (R)	*Morozovella* cf. *acuta* *M. angulata* *M. laevigata* *M. velascoensis* *Planorotalites* cf. *compressa* *Subbotina* cf. *triloculinoides*		>99%	Micrite and chert	Glauconite Quartz (R)
48	2	120	P4-P3	Packed biomicrite	Larger foraminifera Bryzoans Echinoderms Calcareous algae	*Chilogumbelina* sp. *Morozovella acuta* *M. angulata* *M. velascoensis* subbotinids	*Discocyclina seunesi* *Miscellanea* sp. *Ranikothalia bermudezi* *Rotalia* sp.	ca 30%		
49	2	2	P4-P3	Packed biomicrite	Foraminifera (A)	*Chilogumbelina* sp. *Morozovella angulata* *M.* cf. *laevigata* *M.* cf. *velascoensis* *Planorotalites* cf. *compressa* *Subbotina* cf. *triloculinoides*	*Robulus* sp.	Ca 98%	Micrite	Glauconite (R)
50	1	13	P4-P3	Packed biomicrite	Foraminifera (C) Radiolarians (C) Sponge spicules (C)	*Chilogumbelina* sp. *Morozovella angulata* *M.* cf. *velascoensis* *Planorotalites* cf. *compressa* *Subbotina* cf. *triloculinoides*		>99%	Calcite and chert	Glauconite (R) Quartz (R)
51	2	10	P4-P3	Sparse biomicrite, pellets	Foraminifera (R) Radiolarians (C) Ostracodes (VR) Sponge spicules (R)	*Chilogumbelina* sp. *Morozovella* cf. *acuta* *M.* cf. *angulata* *M.* cf. *velascoensis* *Planorotalites* cf. *compressa* *Subbotina triloculinoides*	*Robulus* sp.	>99%	Calcite	Glauconite (R) Phosphate (VR)
52	1	13	P4-P3	Sparse biomicrite	Foraminifera (C) Radiolarians (R) Echinoderms (VR)	*Morozovella* cf. *abundocamerata* *M.* cf. *angulata* *M.* cf. *laevigata* *M.* cf. *velascoensis* *Planorotalites* cf. *compressa* *Subbotina* cf. *triloculinoides*		>99%	Micrite and calcite	Glauconite (R)
53	2	9	P4-P3	Recrystallized sparse biomicrite, pellets (R)	Foraminifera (C) Radiolarians (R)	*Morozovella acuta* *M.* cf. *angulata* *M.* cf. *laevigata* *M. velascoensis*	Anomalinids	ca 98%	Calcite	Glauconite

TABLE 2 – *Continued*

Core	Section	Thin Section Number	Planktonic Foraminiferal Zone	Rock Type	Skeletal Grains (Whole or Fragments)	Identifiable Planktonic Foraminifera	Identifiable Benthonic Foraminifera	Planktonic Species vs Total Foram (%)	Infilling of Fossil Chambers	Authigenic and Terrigenous Grains
54	1	6	P4-P3	Packed biomicrite	Foraminifera (A)	*Morozovella angulata* *M.* cf. *pusilla* *M.* cf. *velascoensis* *Planorotalites* cf. *ehrenbergi* *Subbotina* cf. *triloculinoides*	Anomalinids *Bolivina* sp. *Dentalina* sp. *Nodosaria* sp. *Robulus* sp.	ca 98%	Micrite	Glauconite (R) Phosphate (VR)
56	1	5	P3	Recrystallized packed biomicrite, pellets (R)	Foraminifera (C) Sponge spicules (R) Ostracodes (VR)	*Morozovella angulata* *Subbotina* cf. *triloculinoides*	*Cibicides* sp. *Dentalina* sp. *Valvulinids*	ca 95%	Calcite	Glauconite
58	1	6	P3	Sparse biomicrite, pellets (C)	Foraminifera (C) Radiolarians (C)	*Morozovella angulata* *M.* cf. *pusilla*	*Cibicides* sp. small rotaliids	ca 95%	Calcite	
58	1	20	P3	Argillaceous sparse biomicrite	Foraminifera (C) Radiolarians (R) Sponge spicules (R)	*Chilogumbelina* sp. *Morozovella angulata* *M. pusilla*	*Bolivina* sp. *Cibicides* sp. *Dentalina* sp.	ca 95%		Glauconite (C)
58	1	95	P3	Biosparite	*Archeolithothamnium* (A) Foraminifera (R) Ostracodes (VR) Bryzoans (R)	Subbotinids		<30%		
61	1	5	P3	Sparse biomicrite	Foraminifera (R) Radiolarians (R) Sponge spicules (R) Ostracodes (R)	*Chilogumbelina* sp. *Morozovella angulata* *M.* cf. *pusilla* *M.* cf. *uncinata* Subbotinids	Anomalinids Urigerinids	ca 95%	Chalcedony	Glauconite (R) Quartz (R)
61	1	13	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (C) Bryzoans (R)	*Morozovella* cf. *pusilla* *M. uncinata* *Planorotalites* cf. *ehrenbergi* *P. trinidadensis*		ca 98%	Calcite	Quartz (R)
62	1	1	P2-P1	Fossiliferous micrite, partially recrystallized	Foraminifera (R) Sponge spicules (C) Echinoderms (VR)	Globogerinids *Morozovella uncinata*		ca 98%	Chalcedony	Glauconite (C)
62	1	6	P2-P1	Sparse biomicrite	Foraminifera (C) Sponge spicules (C) Echinoderms (R) Molluscs (R)	*Chilogumbelina* sp. *Morozovella uncinata*	*Cibicides* sp. *Discorbis* sp.	ca 90%	Calcite and micrite	Glauconite (C) Pyrite (C) Quartz (R) Phosphate (R)
62	2	5	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (R) Bryzoans (R) Echinoderms (C) Molluscs (R)	Globigerinids *Morozovella uncinata*	*Bolivina* sp. *Cibicides* sp. *Discorbis* sp. Small rotaliids	ca 90%	Calcite	Glauconite (C to A)
63	2	7	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (R) Echinoderms (C) Molluscs (C)	*Planorotalites trinidadensis* *Subbotina* cf. *pseudobulloides*	Small rotaliids	ca 90%	Micrite and calcite	Glauconite (C to A)
64	2	7	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (C) Sponge spicules (C) Ostracodes (R) Echinoderms (C) Lithothamnium, small fragments (R)	"globigerinids" *Morozovella uncinata* *Planorotalites trinidadensis*	Small rotaliids	ca 90%	Calcite	Glauconite (C) Quartz (R)
65	1	8	P2-P1	Sparse biomicrite largely recrystallized	Foraminifera (R) Sponge spicules (C) Molluscs (R) Echinoderms (R)	*Chilogumbelina* sp. *Morozovella uncinata* *Subbotina* cf. *pseudobulloides*	Small rotaliids *Robulus* sp.	ca 90%		Glauconite (C) Pyrite (C)
65	2	1	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (R) Sponge spicules (A) Echinoderms (R)	Small globogerinid *Morozovella uncinata*	Anomalinids Small rotaliids	ca 90%	Chalcedony	Glauconite (R)
65	2	12	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (R) Echinoderms (C)	*Morozovella uncinata* *Planorotalites trinidadensis*	Small rotaliids	ca 90%	Micrite	Glauconite (R) Pyrite (C)
65	3	5	P2-P1	Sparse biomicrite partially recrystallized	Foraminifera (R) Sponge spicules (R) Echinoderms (R)	*Morozovella uncinata*	Small rotaliids *Dentalina* sp.	ca 90%	Calcite	Glauconite (R)
66	1	11	P2-P1	Fossiliferous micrite	Foraminifera (R) Sponge spicules (R) Ostracodes (VR) Echinoderms, small Fragments (R)	*Chilogumbelina* sp. *Planorotalites trinidadensis* *Subbotina* cf. *triloculinoides*		(90%)	Chalcedony	Glauconite (R) Quartz (R)
66	2	14	P2-P1	Fossiliferous micrite, partially recrystallized	Foraminifera (R) Sponge spicules (R) Ostracodes (R) Molluscs (R)	Small "globigerinids"		(95%)	Chert and calcite	
66	3	17	P2-P1	Fossiliferous micrite	Foraminifera (R) Sponge spicules (C) Echinoderms (R) Molluscs (R)	*Planorotalites trinidadensis*		(95%)	Chert	

TABLE 2 – *Continued*

Core	Section	Thin Section Number	Planktonic Foraminiferal Zone	Rock Type	Skeletal Grains (Whole or Fragments)	Identifiable Planktonic Foraminifera	Identifiable Benthonic Foraminifera	Planktonic Species vs Total Foram (%)	Infilling of Fossil Chambers	Authigenic and Terrigenous Grains
66	3	21	P2-P1	Fossiliferous micrite, largely recrystallized	Foraminifera (R) Sponge spicules (R) Ostracodes (R) Echinoderms (R)	*Chilogumbelina* sp. Small "globigerinids"	*Robulus* sp. *Rotalia* sp.	ca 95%	Calcite	
67	1	2	P2-P1	Sparse biomicrite	Foraminifera (R) Sponge spicules (R) Ostracodes (R) Echinoderms (R)	Small "globigerinids" *Morozovella* aff. *uncinata*	*Rotalia* sp.	ca 95%	Calcite	

Note: (A) = abundant; (C) = common; (R) = rare; (VR) = very rare; (95%) = foraminifera too rare for a valid estimate of %.

species comprise less than 50% of the foraminiferal fauna on the continental shelf; their frequency increases to about 50% at the shelf edge and to very high values (> 99%) at bathyal depths. However, in an open-ocean environment near banks or shoals, or in areas near narrow shelves, a high planktonic/benthonic ratio may occur closer to shore. Another important faunal relationship providing evidence as to depth of deposition is that of the relative frequency of planktonic foraminifera and radiolarians. Today, radiolarian ooze is found primarily at great depths. With increasing depths, at depths approaching the lysocline (the depth at which the preservation of foraminiferal assemblages deteriorates rapidly), the relative frequency of calcareous foraminifera decreases while siliceous radiolarians increase in abundance and eventually become dominant below the CCD. Morphological trends in various benthonic species also appear to be correlated with water depth. For example, some species of the bathyal zone show a striking increase in size with increasing water depths (Bandy, 1963; Theyer, 1971).

Many modern foraminiferal species show the same upper depth limit in widely distributed geographic areas. Some of these depth indicators have isomorphs that occur in the Paleogene (Bandy, 1960; 1970). Bandy and Chierici (1966) have shown that the upper depth limits of isobathyal species are similar in various water masses of the world's oceans and suggested that variations of water depth in the bathyal realm have probably not served to alter the upper depth of this group of species. Douglas (1973b), however, has provided evidence to suggest that an interpretative error may result from estimates of paleodepth of fossil assemblages derived by analogy with modern benthonic assemblages, because of the migrational displacement of benthonic species throughout the Tertiary in response to fluctuations in the temperature and circulation of bottom water. Caution is especially needed for interpretation of populations older than middle Miocene, the time when modern deep-sea benthonic assemblages began to emerge.

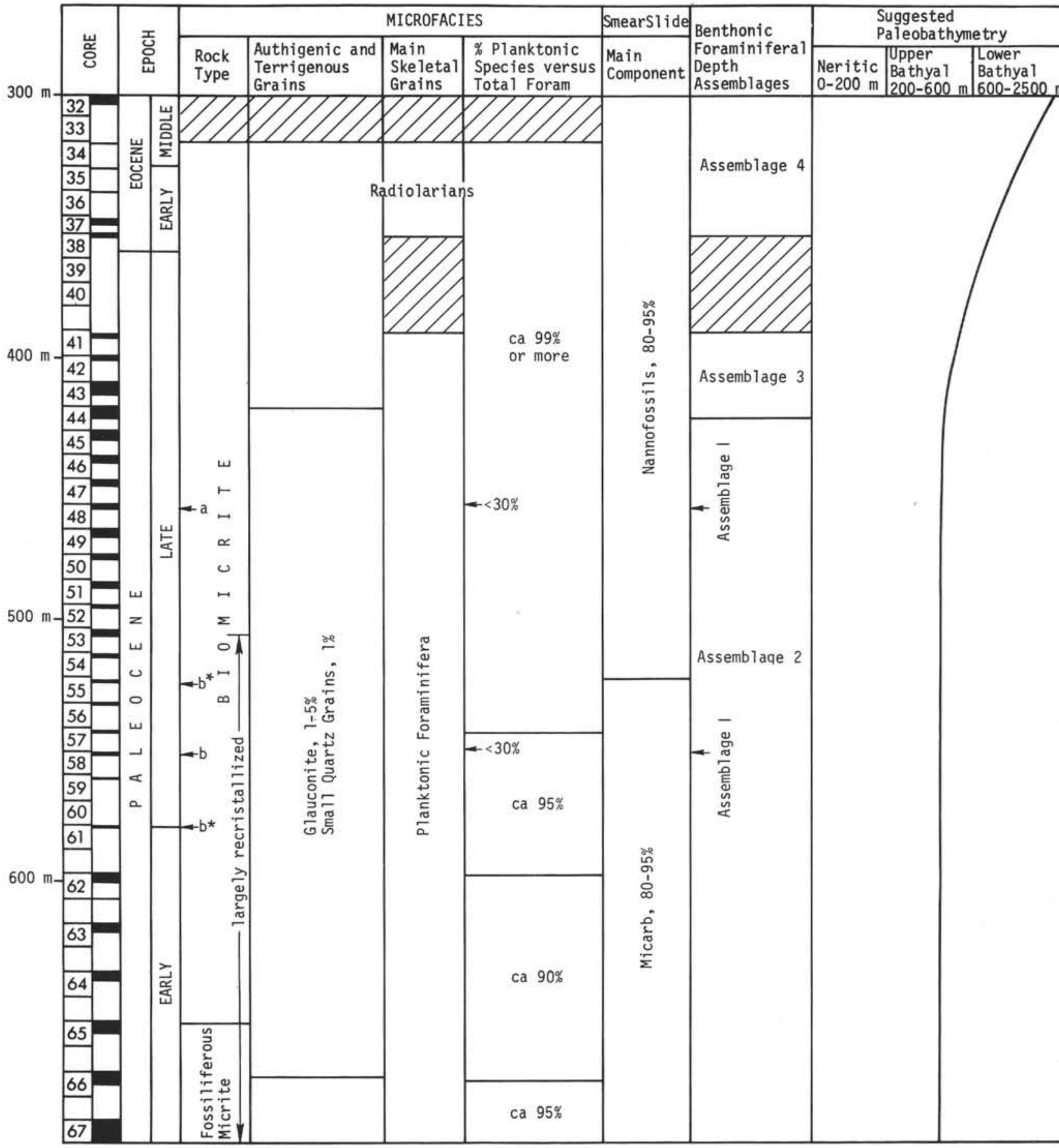
Although the number of Paleocene and Eocene paleobathymetric studies of benthonic foraminifera is limited, especially with respect to bathyal and abyssal populations, these studies are of great value for comparison between geographic regions. A cosmopolitan distribution of benthonic assemblages is expected during early Tertiary time because of the more uniform thermal structure of the oceans and the more equitable climatic conditions.

Bandy (1970) considered the association of a "*Pleurostomella-Nuttalides* fauna" with a rich radiolarian assemblage to be indicative of "abyssal" water depths (> 2000 m) during the late Paleocene and early Eocene of the Central America area. In this study we assign a paleodepth of 2000 to 2500 meters to a similar fauna, characterized by *Nuttallides truempyi*; and robust pleurostomellids. Tjalsma (personal communication) investigated Paleocene faunas from the western Atlantic (Gulf of Mexico and Carribbean) and South Atlantic (Rio Grande Rise) from DSDP sites and recognized deep-water (>1000 m) assemblages ("Velasco-type fauna") characterized by, among other species, robust anomalinids (*Gavelinella danica, G. velascoensis), Nuttalides truempyi,* and various gyroidinids and buliminids. He has examined material from our study, which he compared to his material, and found deep-water species common to both Atlantic and Indian ocean assemblages.

The bathymetric distribution of Paleocene benthonic assemblages from the Tethyan and circum-Atlantic regions was studied by Berggren (in press, a, b) and Berggren and Phillips (1971) who assigned upper neritic to upper bathyal water depths to a "Midway-type fauna." For example, faunas including larger foraminifera such as those of a few Paleocene horizons at Site 237 were interpreted as upper neritic assemblages; whereas faunas composed, as in most of the Paleocene section at Site 237, of buliminids, *Cibicides Gaudryina, Gavelinella, Osangularia, Oridorsalis,* and *Vaginulina* were interpreted as representative of lower neritic to upper bathyal water depths. Douglas (1973a) considered assemblages composed of *Aragonia, Gaudryina, Osangularia,* and *Spiroplectammina* to be indicative of "deep-sea assemblages" for the Paleocene in the northwest Pacific Ocean. Gibson (1973) arrived at a similar paleobathymetric interpretation (approximately 600 m) for "Midway-type assemblages" of the California coastal area. Early Eocene assemblages in the California basins appear to be shoaler than that at Sites 236 and 237. *Nuttalides truempyi* was not found in the Californian faunas and furthermore, the amphimorphinids, lagenids, and plectofrondiculariids characteristic of the California sequences are lacking or poorly developed at the Indian Ocean sites.

Attribution of Depth Assemblages

Four depth assemblages were recognized in the Paleocene and early Eocene faunas at Sites 236 and 237. The



a: Larger foraminifera limestone (packed biomicrite)
b: Calcareous algal limestone (biosparite); b*: no thin section available

Figure 3. *Summary of variations of microtextural components, benthonic foraminiferal assemblages, and bathymetry of Paleocene and lower Eocene sediments of Site 237.*

distribution of these assemblages at the sites is indicated on Tables 3 and 4 and Figure 3.

Assemblage 1 (Paleocene): Upper neritic (< 50m). Characterized by larger foraminifera (*Discocyclina, Ranikhotalia*) various rotaliids, and the calcareous algae *Archaeolithothamnium.*

Assemblage 2 (Paleocene): Lower neritic to upper bathyal (50-600 m). "Midway-type fauna" characterized by *Anomalina midwayensis, Cibicides alleni, Gavelinella danica, Gyroidina girardana, G. globosa, G. nitida, Loxostomum applinae, Marssonella oxycona, Pleurostomella paleocenica, Pullenia coryelli, Stilostomella* spp., and *Vaginulina longiforma* among numerous others.

Assemblage 3 (Paleocene): Lower bathyal (600-2500 m). Dominated by *Nuttalides truempyi* in co-occurrence with *Pseudovalvulineria beccariformis* and *Gavelinella* aff. *G. danica* among others.

Assemblage 4 (Eocene): Lower bathyal (600-2500 m). Dominated by *Nuttalides truempyi. Anomalina dorri aragonensis* replaces the Paleocene morphotypes (*P. beccariformis* and *G.* aff. *G. danica*). Forms such as *Gyroidina planata* and *Stilostomella kressenbergensis* also appear.

The change in morphology of forms assignable to *Pleurostomella paleocenica* to those referred as *Pleurostomella* aff. *P. paleocenica* suggests a trend of increasing size and robustness with increasing water depth, because this morphological trend parallels the increase in abundance of the deep-water species *Nuttalides truempyi.*

DISCUSSION

The Paleocene and early Eocene benthonic assemblages (assemblages 3 and 4) at Site 236 are characteristic of deep water, as shown by the dominance throughout the section of *Nuttalides truempyi* and the presence of robust pleurostomellids. Reconstruction of former water depths at the site derived from the age/depth constancy of basaltic oceanic basement (Sclater et al., 1971) shows that the paleodepth at Site 236 was approximately 2000 meters for the upper Paleocene sediments just above basement, deepening to approximately 2500 meters for lower Eocene sediments approximately 50 m.y. old (Figure 4). A deep-water environment interpreted from the foraminiferal assemblages is therefore in good agreement with these lower bathyal paleodepths.

The benthonic fauna in the lower part of the section at Site 237 between Cores 67 and 49 is poorly preserved and nondiverse, and consists of very few individuals. However the presence of such elements as *Anomalina midwayensis, A. welleri, Pleurostomella paleocenica, Pullenia quinqueloba angusta, Stilostomella paleocenica,* and *Vaginulina longiforma* suggests a lower neritic to upper bathyal environment. In the interval between Cores 49 and 44 the preservation is good and the fauna is substantially more common and diverse. It contains such typical Midway faunal elements as: *Anomalina midwayensis, A. welleri, Bulimina arkadelphiana midwayensis, Clavulina aspera whitei, C. midwayensis, Eponides* aff. *E. bollii,* frondiculariids, *Gavelinella danica, Gyroidina globosa, G. nitida, Palmula reticulata, Pleurostomella paleocenica, Pseudovalvulineria beccariformis, Pullenia coryelli, Stilostomella paleocenica, Trifarina herberti, Vaginulina longiforma.* This assemblage (assemblage 2) represents lower neritic to upper bathyal depths, and includes no lower bathyal or abyssal indicators. The deep-water species *Nuttallides truempyi* which characterizes assemblage 3, first appears in Sample 44, 2, 116-118 cm; it occurs rarely in the first samples above this level and increases in abundance upwards until it dominates the Eocene faunas. A transition zone from the shallower assemblage 2 to the deeper assemblage 3 occurs in the interval between Cores 44 and 42, where the two assemblages overlap. The early Eocene assemblage (assemblage 4) is very similar to the early Eocene assemblage at Site 236, differences in preservation account for the minor discrepancies.

It thus appears that during late Paleocene (later than 57-58 m.y.) and early Eocene time a lower bathyal (600-2500 m) environment prevailed at both Sites 236 and 237. The sediments contain deep-water benthonic assemblages (assemblages 3 and 4). The foraminiferal fauna shows a very high planktonic/benthonic ratio, with planktonic species comprising more than 99% of the fauna. Depth of deposition at Site 236 was on the order of 2000 to 2500 meters and may have been of the same order of magnitude at Site 237. However, as the upper depth limit of Paleogene benthonic species is not well known, the assemblages at Site 237 may reflect a shallower depth as well. It is probable that the depth at Site 237 during late P.4 and *Discoaster molheri* Zone time (Core 42) was shallower than the contemporaneous depth at Site 236, as shown by the greater abundance of *Nuttallides truempyi* at the latter site. Site 237, however, may have reached a depth as great as that at Site 236 in Eocene time, when *N. truempyi* become dominant. The presence of the deep-water ostracode *Abyssocythere* in middle Eocene sediments of Site 237 (Benson, this volume) support this bathymetric attribution. Populations of *Abyssocythere* are well developed in Eocene deep-water sediments of Atlantic DSDP sites. The depth range of modern representatives of this form is from 2000 to 4500 meters, with a peak in abundance at 3000 meters (Richard H. Benson, personal communication). An increase in the radiolarian/planktonic foraminifera ratio in middle and late Eocene sediments of both Site 236 and 237 may indicate that during that time, a time of shallowing of the CCD (Berger, 1972), the depth at these sites was close to the lysocline level.

The average accumulation rate for upper Paleocene sediments younger than 57-58 m.y. is approximately 11 m/m.y. at Site 237 and 5 m/m.y. at Site 236. Sedimentation slowed significantly near the end of the Paleocene. A period of nondeposition of about 5 m.y. spanned the Paleocene/Eocene boundary at Site 236, whereas at Site 237 sediments accumulated at a reduced rate of 7.5 m/m.y. In late early Eocene time, sedimentation resumed at Site 236 with a rate of about 13 m/m.y., and at Site 237 the accumulation rate increased again at the beginning of the middle Eocene to a value of approximately 17 m/m.y. (Figure 2). The average sedimentation rate for sediments laid down at Site 237 between about 57 and 49 m.y.B.P. (latest Paleocene and early Eocene) is approximately 13 m/m.y.

Assemblage 3, of late Paleocene age, lies directly upon basalt at Site 236, while at Site 237 it overlies 280 meters

TABLE 3
Distribution of Benthonic Foraminifera in Paleocene and Lower Eocene Sediments at Site 236

Epoch	Eocene				Paleocene							
	Early				Late							
Planktonic Foraminiferal Zone	P8-P7				P4							
Depth Assemblage	Assemblage 4				Assemblage 3							
Taxa / Sample (Interval in cm)	29-1, 80-82	30-2, 130-132	31-2, 70-72	32-2, 70-72	32-3, 50-52	32, CC	33-1, 107-109	33-1, 178-180	33-2, 90-92	33-2, 20-22	33-3, 37-39	33-3, 105-107
Ammopalmula sp.		X										
Anomalina dorri aragonensis Nuttall		X	X									
Anomalina midwayensis (Plummer)							X					
Anomalina praespissiformis Cushman and Bermudez		X										
Anomalina welleri (Plummer)						X	X					X
Anomalina sp.			X									
Aragonina aragonensis (Nuttall)	X		X									
Aragonina velascoensis (Cushman)								X				X
Astacolus sp.						X	X	X				
Asterigerina crassaformis (Cushman and Siegfus)?												
Bathysiphon eocenicus Cushman and Hanna?					X							
Bolivina cf. *B. anglica* Cushman												
Bolivinoides delicatula Cushman												X
Bulimina beaumonti Cushman and Renz										X		
Bulimina cf. *B. bradburyi* Martin		X							X			
Bulimina cf. *B. eccentrica*		X										
Bulimina excavata Cushman and Parker						X			X	X		
Bulimina impendens Parker and Bermudez						X						
Bulimina microcostata Cushman and Parker		X					X					
Bulimina cf. *B. microcostata* Cushman and Parker												
Bulimina semicostata	X	X	X									
Bulimina aff. *B. versa*		X	X									
Bulimina spp.						X			X		X	
Cibicides spiropunctatus Galloway and Morrey		X	X			X	X	X		X		
Cibicides cf. *C. spiropunctatus* Galloway and Morrey	X											X
Cibicides spp.	X											
Clavulina cf. *C. aspera whitei* Cushman and Jarvis							X					X
Clavulina cf. *C. petrosa* (Cushman and Bermudez)							X					
Clavulina cf. *C. tricarinata* (Reuss)											X	
Clavulina spp.						X						
Dentalina colei Cushman and Dusenbury	X						X		X			
Dentalina dusenburyi Beck												
Dentalina cf. *D. eocenica* Cushman									X			
Dentalina cf. *D. pseudo-obliquistriata* (Plummer)												
Dentalina soluta Reuss												
Dentalina spp.	X		X			X		X		X		X
Eponides aff. *E. bolli* Cushman and Renz												
Eponides spp.		X	X					X	X			
Fissurina orbignyana Seguenza												X
Gaudryina laevigata Franke	X	X					X	X				X
Gaudryina aff. *G. laevigata* Franke										X		
Gavelinella aff. *G. danica* (Brotzen)								X				X

TABLE 3 – *Continued*

Epoch	Eocene				Paleocene							
	Early				Late							
Planktonic Foraminiferal Zone	P8-P7				P4							
Depth Assemblage	Assemblage 4				Assemblage 3							
Taxa / Sample (Interval in cm)	29-1, 80-82	30-2, 130-132	31-2, 70-72	32-2, 70-72	32-3, 50-52	32, CC	33-1, 107-109	33-1, 178-180	33-2, 90-92	33-2, 20-22	33-3, 37-39	33-3, 105-107
Gavelinella hyphalus (Fisher)						X	X					
Globolina sp.												X
Gyroidina girardana (Reuss)	X							X				
Gyroidina globosa (Hagerow)						X	X	X	X			X
Gyroidina nitida (Reuss)										X		
Gyroidina planata Cushman			X									
Lagena acuticosta Reuss						X						
Lagena cf. *L. laevis* (Montagu)							X					X
Lagena spp.	X					X	X					
Lenticulina cf. *L. rosetta* (Gimbel)												X
Lenticulina velascoensis White						X	X	X		X		X
Lenticulina aff. *L. vortex* (Fichtel and Moll)												X
Loxostomum trinitatensis Cushman and Renz						X	X					
Marginulina cf. *M. subrecta* Franke						X						
Marginulina spp.												
Marssonella oxycona (Reuss)						X	X	X	X	X		X
Marssonella cf. *M. oxycona* (Reuss)	X											
Melonis aff. *M. planatus* (Cushman and Thomas)	X					X	X			X		X
Neoeponides hildebrandti Fisher												X
Nodosarella advena Cushman and Siegfus		X	X									
Nodosarella aff. *N. attenuata* (Plummer)	X											
Nodosarella spp.		X					X					
Nodosaria latejugata Gümbel			X						X			
Nodosaria sp.							X	X				
Nuttallides truempyi (Nuttall)	X	X	X	X		X	X	X	X	X		X
Oridorsalis umbonatus Reuss?	X		X									X
Osangularia culter (Parker and Jones)	X	X	X									
Osangularia aff. *O. culter* (Parker and Jones)				X								
Palmula aff. *P. delicatissima* (Plummer)							X					
Pleurostomella aff. *P. paleocenica* Cushman	X	X				X	X		X	X		X
Pseudogloborotalia florealis (White)						X	X					X
Pseudonodosaria manifesta (Reuss)							X		X			
Pseudonodosaria spp.			X				X					X
Pseudovalvulineria beccariformis (White)						X		X	X	X		
Pullenia coryelli White						X	X	X	X	X		
Pullenia quinqueloba angusta Cushman and Todd	X											
Pullenia sp.	X											
Spiroplectammina excolata (Cushman)							X	X				X
Spiroplectammina mexiaensis Lalicker							X					
Spiroplectammina cf. *S. spectabilis* (Grzybowskii)												X
Spiroplectammina sp.									X	X		
Stilostomella cf. *S. bradyi* (Cushman)	X											

TABLE 3 – *Continued*

Epoch	Eocene				Paleocene							
	Early				Late							
Planktonic Foraminiferal Zone	P8-P7				P4							
Depth Assemblage	Assemblage 4				Assemblage 3							
Taxa / Sample (Interval in cm)	29-1, 80-82	30-2, 130-132	31-2, 70-72	32-2, 70-72	32-3, 50-52	32, CC	33-1, 107-109	33-1, 178-180	33-2, 90-92	33-2, 20-22	33-3, 37-39	33-3, 105-107
Stilostomella hispidula Cushman		X										
Stilostomella kressenbergensis (Gümbel)		X	X									
Stilostomella paleocenica (Cushman and Todd)	X											X
Stilostomella plummerae (Cushman)							X			X		X
Stilostomella spp.												X
Trifarina advena Cushman	X											
Vaginulina cf. *V. longiforma* (Plummer)										X		
Vaginulinopsis sp.		X	X									

of older sediments. At the latter site the hole was terminated in sediments approximately 62 m.y. old (P.1 and *Cruciplacolithus tenuis* zones) and basement was not reached. The lower 280 meters of section at Site 237 shows a sedimentary history different from that of the overlying sequence. Sediments include a characteristic Midway benthonic assemblage (assemblage 2), which reflects lower neritic to upper bathyal water depths with admixtures in several thin horizons of displaced upper neritic fauna (assemblage 1). The environment, however is clearly pelagic, well below shelf depth as planktonic foraminifera constitute 95% or more of the foraminiferal population throughout the section, except in the few horizons with displaced neritic material in which their frequency is much lower (< 30%). An upper bathyal environment of several hundred meters (600 m or less) thus appears to have persisted from approximately 62 to 57-58 m.y.B.P. This water depth is in the range at which glauconite is most commonly formed (Porrenga, 1967). The presence of glauconite (1% to 5%) in the rocks throughout this part of the section, as pellets and in some instances as fillings of foraminiferal tests, would thus support the water depth inferred from benthonic assemblages. The presence of fine quartz grains (1%) throughout this part of the sequence is also consistent with this bathymetric interpretation. It is possible, however, that these components were transported downslope and cannot be used as bathymetric indicators.

The very high sedimentation rate which average 68.2 m/m.y. for the lower 290 meters of sediments (a rate of accumulation about five times higher than for the succeeding upper Paleocene and lower Eocene sequence) and the admixture of slumped shallow-water sediments indicate that the location of Site 237 functioned as a sediment trap during the early Paleocene and early late Paleocene. In addition to slumping of coarse material from nearby banks or shoals on a few occasions, it is probable that a continuous influx of fine-grained material was taking place. The bulk of the rock is very fine-grained calcite, but the degree of recrystallization prevents identification of its origin. Much shallow-water fine-grained carbonate debris was probably carried downslope into the area, where it accumulated together with the tests of pelagic organisms.

CONCLUSIONS

The rather abrupt change in sedimentary regime, reflected in the sediments at Site 237 at about 400 meters from a higher sedimentation rate below to a lower rate above and from a shallower environment below to a deeper environment above indicates a change in the topographic situation of the site. This change occurred at approximately 57-58 m.y. B.P., a time which may mark the onset of rupture between the Chagos and Saya de Malha regions. Fisher et al. (1971) suggested that the Mascarene and Chagos-Laccadive plateaus were adjacent in pre-Miocene time prior to the start of the present episode of spreading from the median Central Indian Ridge (Figure 5). Results from Site 238, located in the Central Indian Ridge area near the southern end of the Chagos-Laccadive Ridge (Figure 1), show that sundering of the Chagos region from the Saya de Malha region took place as early as late early Oligocene (Chapter 9, this volume). It may have started even earlier, however, perhaps in late Paleocene time.

Fisher et al. (1971) suggested that the volcanic foundation of the Chagos-Laccadive Ridge and the segment of the Mascarene Plateau extending south-southwest from Saya de Malha was probably formed along the trace of the Chagos Fracture Zone, a Cretaceous and early Tertiary transform fault of major proportion, during a long pause in spreading (Figure 5). The age of the foundation and the petrologic affinity of that part of the Mascarene Plateau located between the granitic Seychelles Bank and the volcanic Saya de Malha Bank is still controversial, as the drilling at Site 237 failed to determine the age and nature of the basement. The configuration of the sea floor in this

TABLE 4
Distribution of Benthonic Foraminifera in Paleocene and Lower Eocene Sediments at Site 237

Epoch	Eocene			Paleocene									
	Mid.	Early		Late							Early		
Planktonic Foraminiferal Zone	P.10-P.9		P7-P6	P5-P4				P3			P2-P1		
Depth Assemblage	Assemblage 4			Ass. 3		Assemblage 2							
Taxa / Sample (Interval in cm)	32-3, 115-117	36-1, 132-134	38-1, 90-92	41-2, 48-50	44-2, 116-118	48-1, 100-102	49-1, 143-145	49-2, 97-99	56-1, 145-147	58-1, 70-72	58-1, 145-147	67-2, 80-82	67-5, 65-67
Ammodiscus incertus (d'Orbigny)									X		X		
Angulogerina virginiana Cushman						X	X						
Anomalina cubana Cushman and Bermudez							X						
Anomalina dorri aragonensis Nuttall		X											
Anomalina midwayensis (Plummer)				X		X	X	X	X	X	X	X	
Anomalina welleri Plummer						X			X	X		X	
Anomalina sp.													X
Aragonina aragonensis (Nuttall)	X	X											
Astacolus sp.	X												
Bathysiphon eocenicus Cushman and Hanna		X					X		X		X		
Bolivina aff. *B. anglica* Cushman			X										
Bolivina crenulata Loetterle				X									
Bolivina midwayensis Cushman				X	X		X		X	X			X
Bolivina cf. *B. nacheolensis* (Cushman)							X		X				
Bolivina spp.								X			X		
Bulimina arkadelphiana midwayensis Cushman & Parker					X					X	X		
Bulimina aff. *B. arkadelphiana midwayensis* Cushman and Parker				X									
Bulimina cf. *B. bradburyi* Martin	X			X									
Bulimina impendens Parker and Bermudez	X												
Bulimina cf. *B. impendens* Parker and Bermudez				X									
Bulimina spp.					X		X					X	X
Cibicides alleni Plummer												X	X
Cibicides blanpiedi Toulmin													
Cibicides cf. *C. blanpiedi* Toulmin						X	X						
Cibicides constrictus (Cushman)				X				X					
Cibicides cf. *C. spiropunctatus* Galloway and Morey			X										
Citharina sp.				X					X	X	X		
Clavulina aspera whitei Cushman and Jarvis				X	X		X						
Clavulina midwayensis (Cushman)					X	X	X						
Dentalina aculeata (d'Orbigny)					X								
Dentalina basiplanata Cushman							X						
Dentalina colei Cushman and Dusenbury		X		X	X	X	X	X					
Dentalina cf. *D. colei* Cushman and Dusenbury													X
Dentalina cf. *D. communis* (d'Orbigny)		X	X						X	X			
Dentalina dusenburyi	X												
Dentalina eocenica Cushman						X	X		X	X	X		X
Dentalina pseudo-obliquistriata (Plummer)							X		X				
Dentalina soluta Reuss			X				X	X					
Dorothia cf. *D. bulletta* Carsey							X						
Dorothia principensis Cushman and Bermudez				X									
Eponides aff. *E. bollii* Cushman and Renz				X			X						
Eponides sp.		X	X										

TABLE 4 – *Continued*

Epoch	Eocene			Paleocene									
	Mid.	Early		Late							Early		
Planktonic Foraminiferal Zone	P.10-P.9		P7-P6	P5-P4				P3			P2-P1		
Depth Assemblage	Assemblage 4			Ass. 3		Assemblage 2							
Taxa / Sample (Interval in cm)	32-3, 115-117	36-1, 132-134	38-1, 90-92	41-2, 48-50	44-2, 116-118	48-1, 100-102	49-1, 143-145	49-2, 97-99	56-1, 145-147	58-1, 70-72	58-1, 145-147	67-2, 80-82	67-5, 65-67
Fissurina orbignyana Sequenza							X						
Frondicularia aff. *F. archiacana* d'Orbigny							X						
Frondicularia midwayensis Cushman													X
Frondicularia nacheolensis Cushman and Todd							X						X
Gaudryina laevigata Franke		X		X	X								
Gavelinella danica (Brotzen)				X	X	X	X	X					X
Glandulina laevigata (d'Orbigny)					X	X							
Gyroidina globosa (Hagerow)				X	X	X	X	X	X	X			
Gyroidina nitida (Reuss)					X								
Gyroidina cf. *G. nitida* (Reuss)													
Lagena acuticosta Reuss						X							
Lagena laevis (Montagu)						X							
Lagena cf. *L. vulgaris* Williamson					X								
Lenticulina arcuatostriata caroliniana Cushman				X	X		X						X
Lenticulina cf. *L. arcuatostriata caroliniana* Cushman						X			X				
Lenticulina degolyeri Plummer							X			X			
Lenticulina insulsa Cushman							X			X	X		
Lenticulina midwayensis (Plummer)											X		
Lenticulina velascoensis White					X						X		
Lenticulina spp.	X												
Loxostomum applinae (Plummer)							X						
Marginulina dubia Neugeboren												X	
Marginulina cf. *M. exima* Terquem					X								
Marginulina glabra d'Orbigny					X								
Marginulina cf. *M. glabra* d'Orbigny							X						
Marginulina scitula Bornemann							X	X					
Marginulina cf. *M. scitula* Bornemann					X				X				
Marginulina spp.			X										
Marssonella oxycona (Reuss)					X	X	X						X
Marssonella cf. *M. oxycona* (Reuss)			X										
Melonis aff. *M. planatus* (Cushman and Thomas)										X			
Nodosaria affinis Reuss				X			X			X	X		X
Nodosaria arundinea Schwager													X
Nodosaria cf. *N. ewaldi* Reuss									X				
Nodosaria granti Plummer											X		
Nodosaria latejugata Gümbel	X						X						
Nodosaria cf. *N. latejugata* Gümbel					X	X		X					
Nodosaria velascoensis Cushman								X					
Nuttallides truempyi (Nuttall)	X	X		X	X								
Oridorsalis umbonatus Reuss?				X					X	X			
Osangularia culter (Parker and Jones)		X			X		X	X					
Palmula reticulata Reuss				X			X						

TABLE 4 – *Continued*

Epoch	Eocene			Paleocene									
	Mid.	Early		Late							Early		
Planktonic Foraminiferal Zone	P.10-P.9		P7-P6	P5-P4				P3			P2-P1		
Depth Assemblage	Assemblage 4			Ass. 3		Assemblage 2							
Taxa / Sample (Interval in cm)	32-3, 115-117	36-1, 132-134	38-1, 90-92	41-2, 48-50	44-2, 116-118	48-1, 100-102	49-1, 143-145	49-2, 97-99	56-1, 145-147	58-1, 70-72	58-1, 145-147	67-2, 80-82	67-5, 65-67
Palmula sp.						X							
Pleurostemella paleocenica Cushman					X	X	X	X	X	X	X		X
Pleurostemella aff. *P. paleocenica* Cushman		X		X									
Pseudonodosaria manifesta (Reuss)					X	X							
Pseudovalvulineria beccariformis (White)					X								
Pullenia coryelli White				X	X	X					X		
Pullenia quinqueloba angusta Cushman and Todd	X											X	X
Quadromorphina allomorphinoides (Reuss)							X						
Ramulina navarroana Cushman					X								
Saracenaria cf. *S. trigonata* (Plummer)							X						
Spiroplectammina mexiaensis Lalicker					X								
Spiroplectammina spectabilis Grzybowski				X									X
Spiroplectammina sp.		X											
Stilostomella hispidula Cushman			X										
Stilostomella kressenbergensis (Gümbel)	X	X											
Stilostomella midwayensis (Cushman and Todd)					X								
Stilosteomella paleocenica (Cushman and Todd)		X		X	X	X	X	X	X	X	X		
Stilostomella spp.	X		X										
Textularia plummerae Lalicker							X						
Trifarina adrena Cushman	X		X										
Trifarina berberti Cushman and Renz				X				X			X		X
Vaginulina longiforma (Plummer)				X		X	X		X				X
Vaginulina sp.				X									
Vaginulinopsis cf. *V. mexicana*		X											

area during early Tertiary time is not fully known. It is clear, however, that at this time the area of Site 237 was not a reef-capped bank, as was expected prior to drilling, although there were nearby shoals from which slumped material was transported and redeposited in the pelagic sediments at Site 237. Between approximately 62 and 57 m.y. B.P. this site was probably not deeper than several hundred meters (perhaps 600 m or less) and was located at the base of a steep slope where slumped sediments could accumulate rapidly. It may therefore have been adjacent to some shallow-water structure which was probably in existence west of the Chagos Fracture Zone during this time. In late Paleocene time (ca 57 m.y. B.P.) a sudden sinking of the sea floor took place. The shoal portion of the Mascarene Plateau probably subsided below shelf depth, and slumping of shallow-water material into the area at Site 237 ceased. This deepening of Site 237 permitted lower bathyal benthonic faunas, similar to contemporaneous benthonic assemblages at Site 236 to the north, to develop in this area of the Mascarene Plateau. Pelagic sedimentation proceeded here during latest Paleocene and early Eocene at a reduced rate averaging 13 m/m.y. During this time interval, however, it slowed near the end of the Paleocene and in early Eocene during a time of nondeposition at Site 236. Sedimentation increased to approximately 17 m/m.y. at the beginning of the middle Eocene.

The basal sediments at Site 237 are presently found at 2334 meters below the sea floor. If they were deposited in water depths of a few hundred meters, then the area has subsided about 2000 meters over the past 62 m.y. indicating a mean subsidence rate of 32 m/m.y. This value is similar to the mean subsidence rate (36 m/m.y.) obtained at Site 219 located at the northern end of the Chagos-Laccadive Ridge (Figure 1). At the latter site, shallow-water sediments were deposited in a water depth of approximately 100 meters during late Paleocene at a rate of 70 m/m.y. The seabed began to sink probably toward the end of the Paleocene and after a period of nondeposition of

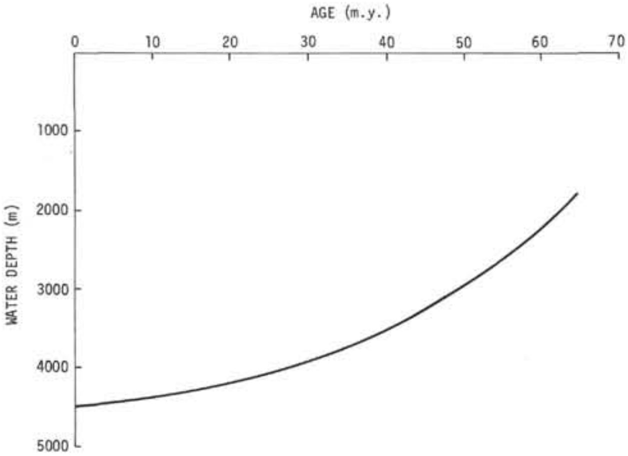


Figure 4. *Depth as a function of age at Site 236 (derived from Sclater et al., 1971; and Berger, 1973).*

about 5 m.y. spanning the Paleocene/Eocene boundary (as at Site 236), pelagic sediments were deposited at bathyal depths with a slower rate of 18 m/m.y. Total subsidence was of the order of 2100 meters (Whitmarsh, Weser, et al., 1974, Chapter 3). There is, therefore, a remarkable synchroneity and similarity in the subsidence history of the Mascarene Plateau and the Chagos-Laccadive Ridge.

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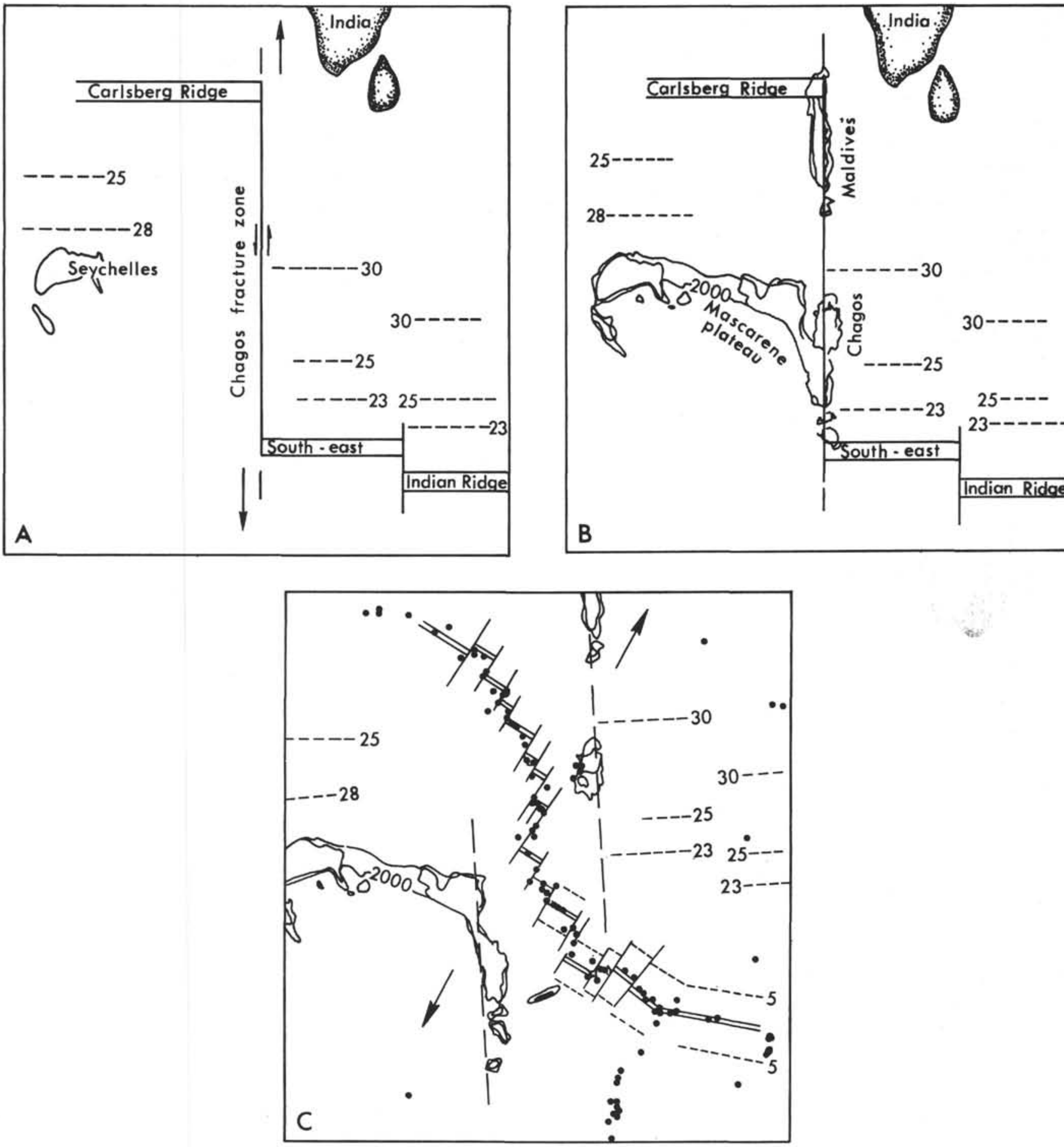

Figure 5. *Schematic diagram of the Central Indian Ocean.*

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PLATE 1

Figure 1	Sparse biomicrite with radiolarians. Sample 237-37-2 (15), ×130.
Figure 2	Sparse biomicrite with planktonic foraminifera and radiolarians. *Morozorella* cf. *subbotinae* (Morozova). Sample 237-38-1 (13), ×63.
Figure 3	Sparse biomicrite with planktonic foraminifera and radiolarians. *Morozorella* gr. *velascoensis* (Cushman). Sample 237-41-2 (13), ×63.
Figure 4	*Morozorella aequa* (Cushman and Senz). Sample 237-44-1 (12), ×130.
Figure 5	Packed biomicrite with planktonic foraminifera. *Planorotalites ehrenberghi* (Bolli). *Morozorella* gr. *pusilla* (Bolli). Sample 237-45-2 (6). ×44.
Figure 6	*Planorotalites* gr. *ehrenberghi* (Bolli). Sample 237-46-2 (6), ×130.
Figure 7	Packed biomicrite. Valrulinid. Sample 237-47-2 (2), ×44.
Figure 8	*Morozorella* gr. *velascoensis* (Cushman). Sample 237-47-2 (2), ×130.
Figure 9	*Morozorella angulata* (White). Sample 237-47-2 (2), ×130.
Figure 10	*Morozorella* gr. *velascoensis* (Cushman). Sample 237-48-1 (4), ×130.
Figure 11, 12	Packed biomicrite with larger foraminifera, bryozoan, mollusc, and echinoderm debris. *Discocyclina seunesi* Douvillé, *Ranikothalia bermudezi* (Palmer). Sample 237-48-2 (120), ×39.

PLATE 1

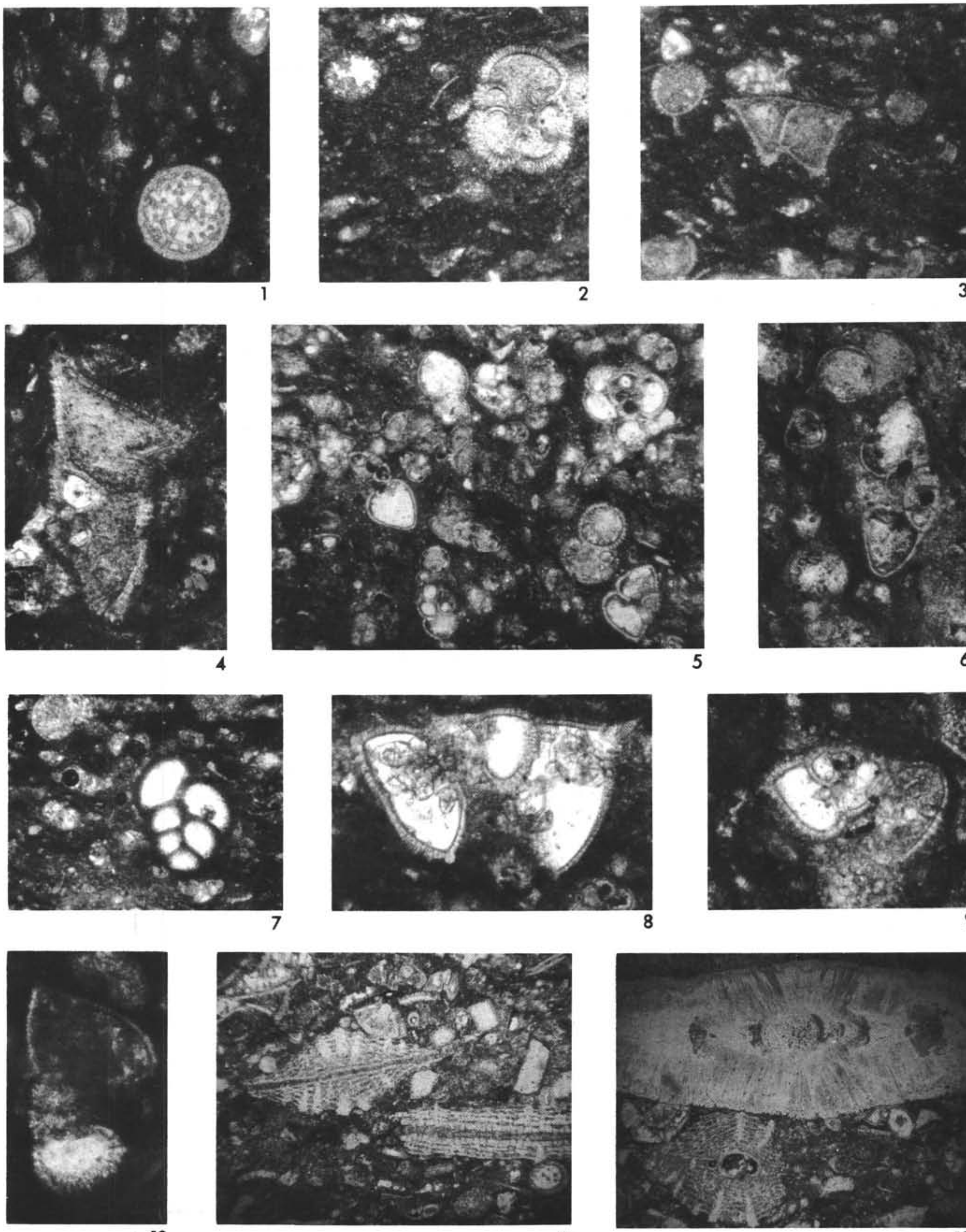

PLATE 2

Figure 1	*Morozorella angulata* (White). Sponge spicule. Sample 237-50-1 (13), ×130.
Figure 2	Sparse biomicrite with radiolarians and planktonic foraminifera. Sample 237-51-2 (10), ×44.
Figure 3	Sparse biomicrite. Pellets. Sample 237-51-2 (10), ×44.
Figure 4	*Morozorella* gr. *velascoensis* (Cushman). Sample 237-51 2 (10), ×130.
Figure 5	*Morozorella* cf. *angulata* (White). Sample 237-52-1 (13), ×130.
Figure 6	*Planorotalites* cf. *compressa* (Plummer). Sample 237-54-1 (6), ×130.
Figure 7	Packed biomicrite with planktonic foraminifera. *Lenticulina* sp. Sample 237-54-1 (6), ×44.
Figure 8	*Archaeolithothamnium*. Mollusc and echinoderm debris. Sample 237-58-1 (95), ×44.
Figure 9	*Planorotalites* cf. *compressa* (Plummer). Sample 237-61-1 (13), ×130.
Figure 10	*Morozorella inconstans* (Subbotina). Glauconite grains. Sample 237-64-2 (7), ×130.
Figure 11	Sparse biomicrite. *Morozorella inconstans* (Subbotina). Sample 237-61-1 (13), ×130.
Figure 12	Fossiliferous micrite. "Globigerinid." Sample 237-67-3 (7), ×130.

PLATE 2

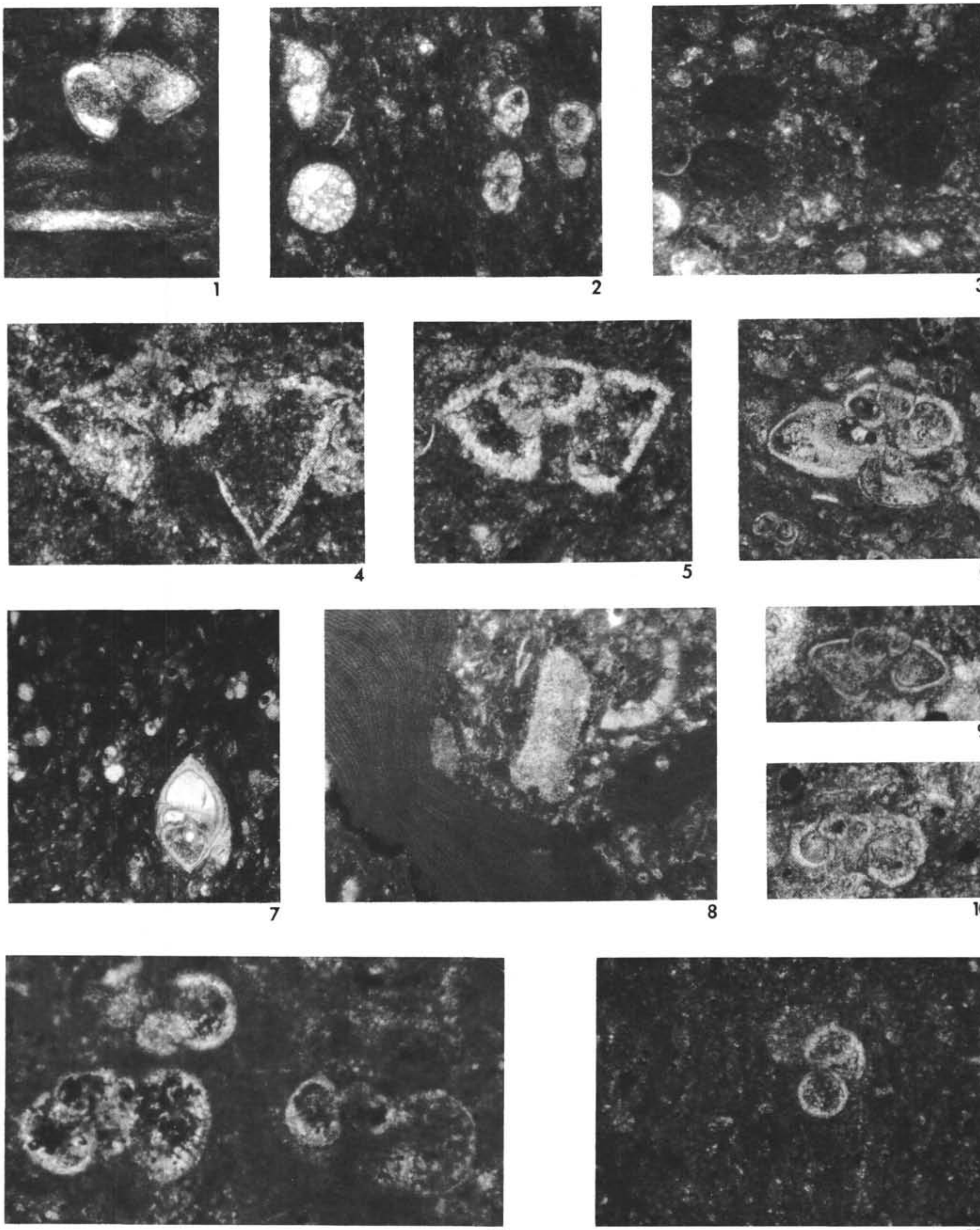

PLATE 3

Paleocene, Site 236

Figure 1	*Marssonella oxycona* (Reuss, 1860). Sample 33-3, 105-107 cm. X 50.
Figure 2	*Gaudryina laerigata* Franke, 1914. Sample 33-3, 105-107 cm. X50.
Figure 3	*Spiroplectammina excolata* (Cushman, 1926). Sample 33-3, 105-107 cm X100.
Figure 4	*Spiroplectammina spectabilis* Gryzbowski, 1898. Sample 33-1, 107-109 cm X100.
Figure 5	*Aragonia valascoensis* (Cushman, 1926). Sample 33-3, 105-107 cm X55.
Figure 6	*Bolivinoides delicatula* Cushman, 1927. Sample 33-3, 105-107 cm X100.
Figure 7	*Melonis planatus* (Cushman and Thomas, 1930). Sample 33-3, 105-107 cm X110.
Figure 8	*Palmula delicatissima* (Plummer, 1926). Sample 33-1, 107-109 cm X100.
Figure 9	*Pseudogloboro florealis* (White, 1928). Sample 33-1, 107-109 cm X50.
Figure 10	*Gyroidina depressa* (Alth, 1850). Sample 33-3, 105-107 cm. a. Umbilical view X100 b. Apertural view X100.
Figure 11	*Osangularia* aff. *O. culter* (Parker and Jones, 1865). Sample 33-3, 105-107 cm X50.
Figure 12	*Loxostomum trinitatensis* Cushman and Renz, 1946. Sample 33-1, 107-109 cm X100.
Figure 13	*Nuttallides truempyi* (Nuttall, 1930). Sample 33-3, 105-107 cm. a. Umbilical view X100. b. Dorsal view X100.
Figure 14	*Pullenia coryelli* White, 1929. Sample 33-1, 107-109 cm X100.
Figure 15	*Bulimina velascoensis* (Cushman, 1925). Sample 33-1, 107-109 cm X50.
Figure 16	*Gyroidina girardana* (Reuss, 1851). Sample 33-1, 107-109 cm. X100.
Figure 17	*Lenticulina velascoensis* White, 1928. Sample 33-3, 105-107 cm. X100.
Figure 18	*Gavelinella* aff. *G. danica* (Brotzen, 1940). Sample 33-3, 105-107 cm. X100.
Figure 19	*Pseudovalvulineria beccariiformis* (White, 1928). Sample 33-3, 105-107 cm X100.
Figure 20	*Gyroidina globosa* (Hagenow, 1842). Sample 33-1, 107-109 cm X100.

PLATE 3

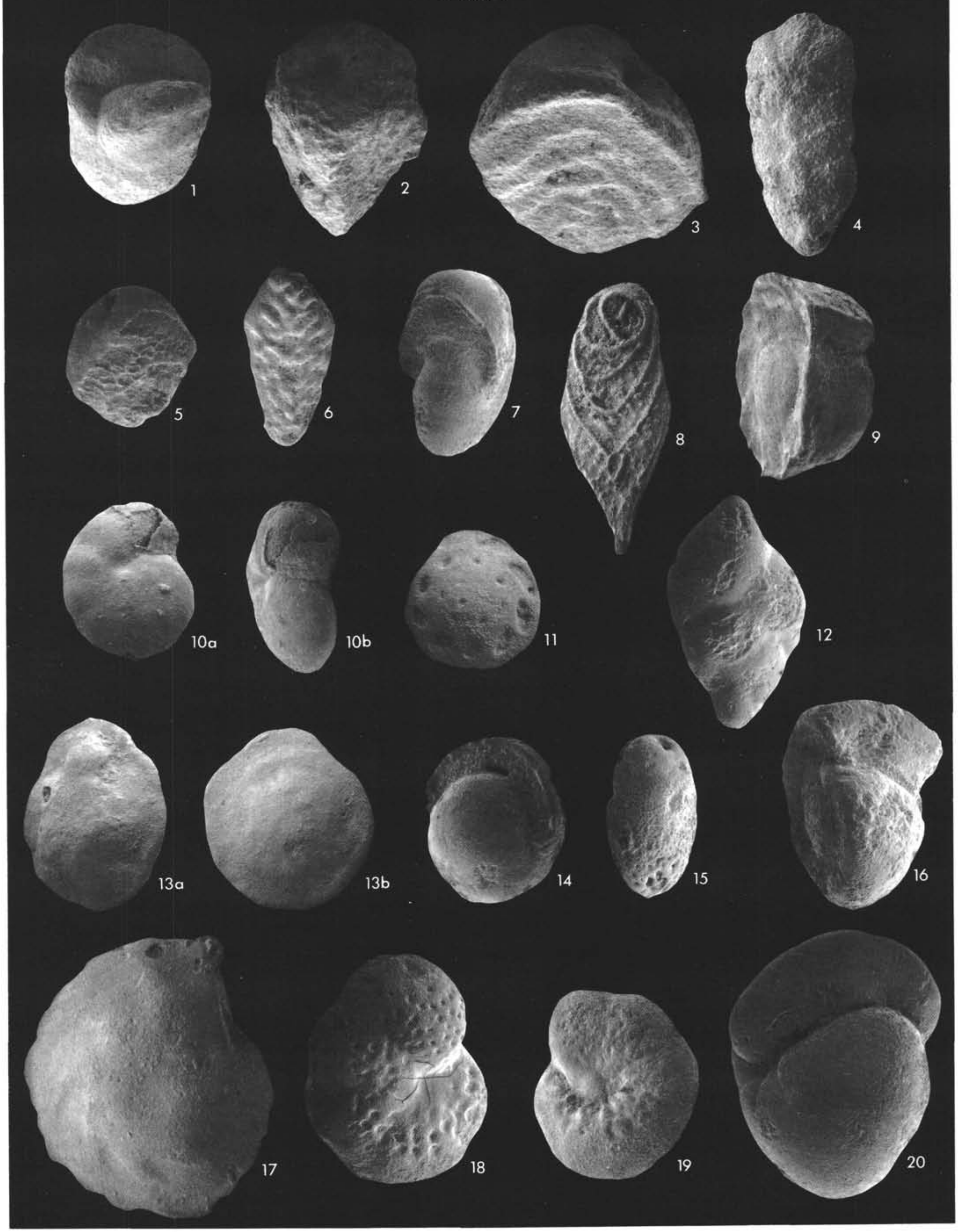

PLATE 4

Paleocene and Early Eocene, Sites 236 and 237

Figure 1	*Anomalina uelleri* (Plummer, 1926). Sample 236-33-1, 107-109 cm. a. Umbilical view ×100. b. Apertural view ×100.
Figure 2	*Clavulina aspera* Cushman, 1926. Sample 237-49-1, 143-145 cm. ×50.
Figure 3	*Pleurostemella paleocenica* Cushman, 1947. Sample 237-67-5, 65-67 cm. ×100.
Figure 4	*Bolivina midwayensis* Cushman, 1937. Sample 237-56-1, 145-147 cm ×100.
Figure 5	*Bulimina arkadelphiana midwayensis* Cushman and Parker, 1936. Sample 237-49-1, 143-144 cm ×100.
Figure 6	*Vaginulina longiforma* (Plummer, 1926). Sample 237-67-5, 65-67 cm ×50.
Figure 7	*Palmula reticulata* (Reuss, 1851). Sample 237-44-2, 116-118 cm ×100.
Figure 8	*Aragonia aragonensis* (Nuttall, 1930). Sample 236-31-2, 70-72 cm ×100.
Figure 9	*Anomalina dorri aragonensis* Nuttall, 1930. Sample 236-31-2, 70-72 cm ×50.
Figure 10	*Pleurostomella* aff. *P. paleocenica* Cushman, 1947 (robust form). Sample 236-29-1, 80-82 cm. ×100.
Figure 11	*Bulimina* sp. Sample 236-29-1, 80-82 cm. ×100.
Figure 12	*Nuttallides truempyi* (Nuttall, 1930). Sample 236-29-1, 80-82 cm. ×100.

PLATE 4