

## 28. BENTHIC FORAMINIFERS IN MESOZOIC AND CENOZOIC SEDIMENTS OF THE SOUTHWESTERN ATLANTIC AS AN INDICATOR OF PALEOENVIRONMENT, DEEP SEA DRILLING PROJECT LEG 71<sup>1</sup>

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### ABSTRACT

Benthic foraminiferal assemblages in Mesozoic and Cenozoic sediments were studied at Sites 511, 512, 513, and 514 drilled during Leg 71 in the southwestern Atlantic on the Maurice Ewing Bank and in the Argentine Basin. Benthic foraminifera in almost all stratigraphic subdivisions of Sites 511 and 512 reflect the gradual subsidence of the Falkland Plateau from shelf depths in the Barremian-Albian, when a semiclosed basin with restricted circulation of water masses and anaerobic conditions existed, to lower bathyal depths in the Late Cretaceous and Cenozoic, with an abrupt acceleration at the boundary of Lower and Upper Cretaceous.

The composition, distribution, and preservation of Late Cretaceous assemblages of benthic foraminifera suggest considerable fluctuations of the foraminiferal lysocline and the CCD. This is evidenced by dissolution facies and foraminiferal assemblages in which agglutinated and resistant calcareous forms predominated during high stands of the CCD and by calcareous facies in which rich assemblages of calcareous species predominated during low stands. The highest position of the CCD on the Plateau (less than 1500–2000 m) was in the late Cenomanian, Turonian, and Coniacian. In the Santonian and Campanian the CCD was at depths below 1500–2000 meters. At the end of the Campanian the CCD shifted again to depths comparable with those of Cenomanian and Turonian time. In the latest Campanian and the Maestrichtian the CCD was low and nanno-foraminiferal oozes with a rich assemblage of benthic foraminifera accumulated. Foraminiferal assemblages at Sites 513 and 514 in the Argentine Basin also testify to oceanic subsidence from lower bathyal depths in the Oligocene to abyssal ones at present. This process was complicated by the influence of geographical migrations of the Polar Front caused by extensions of the ice sheet in the Antarctic after the opening of the Drake Passage during the Oligocene.

In Mesozoic and Cenozoic deposits of the Falkland Plateau and the Argentine Basin seven assemblages of benthic foraminifera were distinguished by age: early-middle Albian, middle-late Albian, Late Cretaceous (including four groups), middle Eocene, late Eocene-early Miocene, middle-late Miocene, and Pliocene-Quaternary. The Albian assemblages contain many species common to the foraminiferal fauna of the Austral Biogeographical Province. The Late Cretaceous assemblage contains, along with Austral species, species common to foraminifera of North America, Western Europe, the Russian platform, and the south of the U.S.S.R. Deep-sea cosmopolitan species prevail in Cenozoic assemblages.

### INTRODUCTION

Leg 71 was the first of five DSDP legs of *Glomar Challenger* that aimed to study the geological history of the South Atlantic from its opening during the Mesozoic until the present. The study of Mesozoic and Cenozoic sediments and the distribution of their microfauna using DSDP materials in the South Atlantic is of great importance, because a significant part of the southern high latitudes is occupied by the ocean, and those few Mesozoic and Cenozoic sections that have been studied in Australia, New Zealand, South Africa, and South America are represented mostly by shallow-water facies. Foraminifera incorporated in oceanic sediments of the Southern Hemisphere have been studied in only a few DSDP sites—in the South Atlantic and the southern part of the Indian Ocean. Thus Leg 71 provided significant supplementary material for the solution of many

problems in the geological history of the South Atlantic region.

Four sites were drilled during the leg. Two of them are situated on the Maurice Ewing Bank of the Falkland Plateau and two are in the Argentine Basin on the western flank of the Mid-Atlantic Ridge (Fig. 1). The holes penetrated Cretaceous-Paleogene (Site 511), Paleogene-Neogene (Sites 512 and 513), and Pliocene-Quaternary sediments (Site 514). Most stratigraphic subdivisions, beginning with the Lower Cretaceous, contain foraminifera. This enables one to trace in detail changes of their assemblages over time and to restore the history of the oceanic subsidence of the Falkland Plateau, sediment accumulation, and oceanic circulation in the South Atlantic. Stratigraphic subdivision of oceanic sediments was carried out by means of planktonic microorganisms. Benthic foraminifera, for which detailed stratigraphic subdivision is not possible, are, however, a reliable indicator of paleoenvironments that reflect oceanic subsidence. In addition, they provide a means to determine paleogeographical conditions and paleobiogeographical bonds throughout the history of the development of this region.

<sup>1</sup> Ludwig, W. J., Krashennnikov, V. A., et al., *Init. Repts. DSDP, 71*: Washington (U.S. Govt. Printing Office).

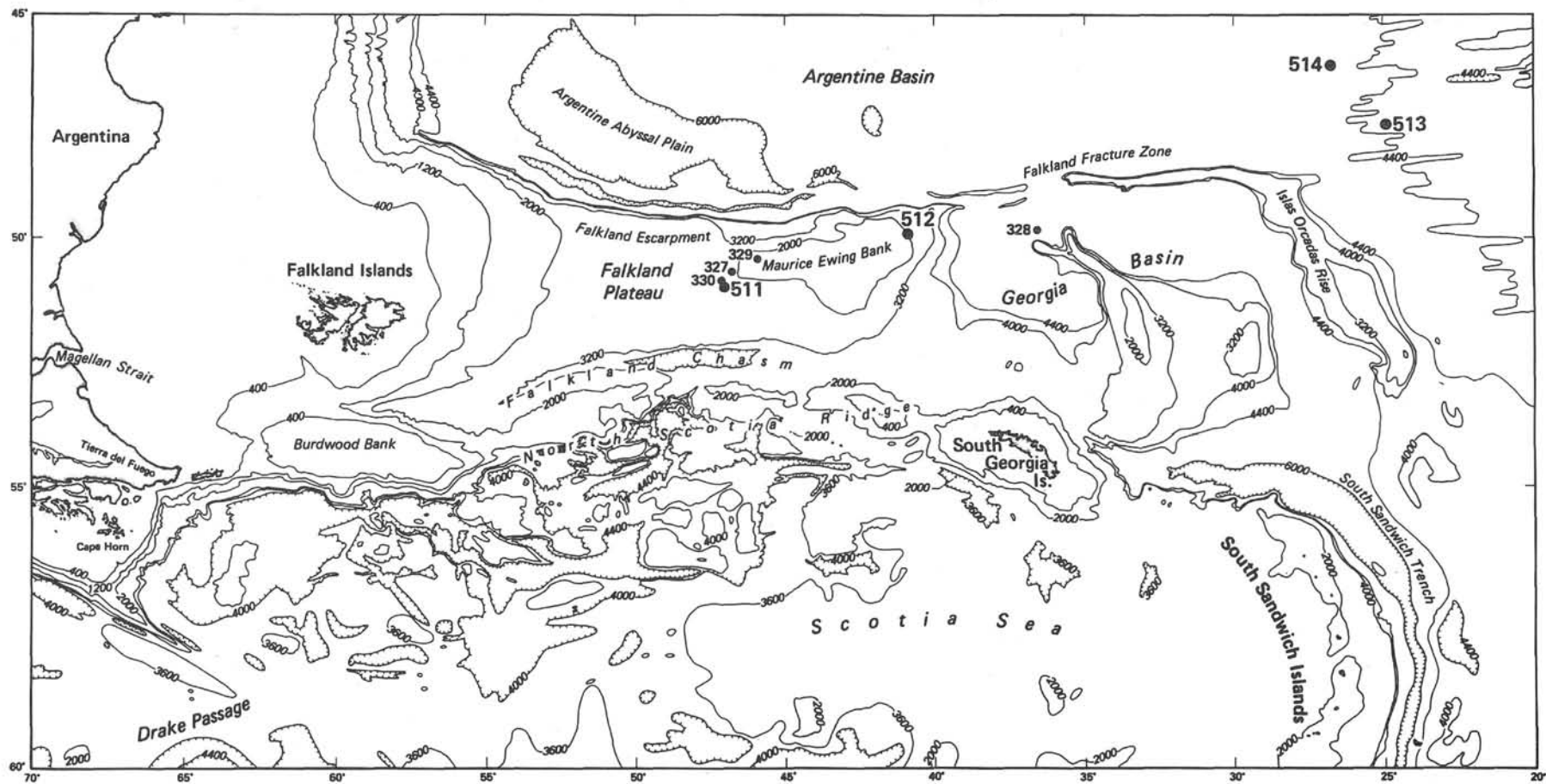


Figure 1. Site location map for Leg 71.

## DISTRIBUTION OF BENTHIC FORAMINIFERS IN MESOZOIC AND CENOZOIC SEDIMENTS

### Site 511

The earliest history of the geological development of the South Atlantic is reflected in the section of Site 511 that was terminated in Upper Jurassic deposits. The site was drilled on the western flank of the Maurice Ewing Bank (51°00.28'S; 46°58.30'W; water depth 2589 m; penetration 632 m). The drilling aimed to restore the history of the sediment accumulation, erosional events, and oceanic subsidence on the Falkland Plateau. The geographical location of the Plateau provided an opportunity to obtain data on significant paleoceanic events related to the establishment of ocean circulation systems after the breakup of Gondwanaland, the opening and gradual expansion of the South Atlantic, the opening of the Drake Passage, and the formation of an ice shield on Antarctica.

Seventy cores were obtained, with an average recovery of 61%. The Mesozoic and Cenozoic sediments penetrated incorporated benthic foraminifers in all stratigraphic subdivisions.

The lowermost part of the section (Cores 63–70) is composed of black shales devoid of benthic foraminifers (Fig. 2). These sediments accumulated under anaerobic conditions, which prevented the development of bottom life. Poorly preserved fragments of pelecypods (*Inoceramus*, *Meleagrinnella*, *Malayomaorica*, and *Ostrea*) were observed in some layers. Rather frequent are ammonites and belemnite rostra of Late Jurassic age (Jeletzky, this volume) which testify to intrashelf conditions.

### Barremian–Aptian

Benthic foraminifers of Cores 57–62 occurred only as very rare, stunted specimens. They are represented by lagenids not identified by species (*Guttulina*, *Astacolus*, *Frondicularia*, and *Marginulina*) and by rotaliids (*Gyrogoninoides* and *Gavelinella*) (Fig. 3).

### Albian

Albian deposits were penetrated in the sample interval from 511-49-5, 120–122 cm to 511-57-6, 11–13 cm, and were composed mostly of clay limestones and nannoplanktonic chalk 78 meters thick. In calcareous interbeds there are numerous pelecypods (*Aucellina* cf. *radiostrata* and *A.* cf. *andina*), gastropods, and rare rostra of belemnites (Jeletzky, this volume).

Benthic foraminifers in Albian sediments are rather diverse, yielding two assemblages. The first was recognized in the lower part of the Albian section (Cores 55–57) and consists mostly of shallow-water species: *Gaudryina dividens*, *Gavelinella intermedia*, *Gyrogoninoides primitiva*, *Osangularia utaturiensis*, *Anomalinoides indica*, and rare *Dorothia trochoides*, *Glomospira gordialis*, *Dentalina deflexa*, *Lenticulina turgidula*, *Saracenia* sp., *Astacolus* sp., *Pyrolinoides* sp., and *Frondicularia* sp.

The second assemblage of benthic foraminifers was found in the upper part of the Albian (Cores 49–55). Along with *Gavelinella intermedia*, *Osangularia utaturiensis*, *Gyrogoninoides primitiva*, and other species repre-

sentative of underlying deposits, the section abounds in *Clavulina gabonica*, *Dorothia trochoides*, *Glomospira corona*, *G. gordialis*, *Uvigerinamina jankoi*, *Conorboides minutissima*, *Spirillina minima*, *S. elongata*, *Patellinella australis*, *Patellina subcretacea*, *Anomalinoides indica*, *Tribrachia australiana*, and *Pleurostomella obtusa*. *Lingulina nodosaria*, *L. loryi*, *Stensioina* sp., and *Spirobolevina australis* are also common. A similar assemblage was described from middle–upper Albian deposits in the southern Indian and Atlantic oceans (Scheibnerová, 1974, 1978; Sliter, 1977a).

### Upper Cenomanian

Upper Cenomanian sediments were penetrated in the sample interval from 511-49-5, 102–104 cm to 511-48-1, 70–72 cm; they are insignificant in thickness and characterized by a quite different assemblage of benthic foraminifers that consists exclusively of the agglutinated *Glomospira corona*, *G. gordialis*, *Ammodiscus cretaceus*, *Rhabdammina* sp., and the like. The assemblage is represented by species with a wide stratigraphic range, but is ecologically distinctive (Fig. 4). Similar assemblages characterized abyssal conditions below the CCD during different geological epochs and in different regions of the World Ocean (Krashennikov and Pflaummann, 1978; Rögl, 1976).

### Turonian

The Turonian interval from Sample 511-48-1, 35–37 cm to Sample 511-47-1, 44–46 cm is very narrow and, like the upper Cenomanian sediments, is represented by a dissolution facies. The zeolitic clays contain an assemblage of mostly agglutinated benthic species that inhabited levels much lower than the CCD.

### Coniacian–Santonian

The sediments of this age (Cores 44–46) are represented by zeolitic clays with foraminiferal assemblages consisting mostly of resistant and some calcareous species (probably displaced): *Ramulina aculeata*, *R. pseudoaculeata*, *Dentalina cylindroides*, *Lenticulina muensteri*, *L. navarroensis*, *Valvulineria allomorphinoides*, *Conorbina marginata*, *Gavelinella stephensoni*, *Globorotalites* sp., *Pleurostomella obtusa*, *P. subnodosa*, and *Bandyella* aff. *greatvalleyensis*. There are also numerous agglutinated species: *Hyperammia elongata*, *H. friabilis*, *Glomospira corona*, *G. gordialis*, *Haplophragmoides bulloides*, *H. calcula*, *Ammobaculites echinatus*, *Ammodiscus cretaceus*, and *A. glabratus*. Horizons with contrasting faunas alternated in the section: (1) resistant calcareous foraminifers peculiar to the bathyal depths with a mixed calcareous and agglutinated microfauna and (2) assemblages of exclusively agglutinated species, the present-day analogs of which inhabit abyssal depths (Saidova, 1975). Such changes in assemblages testify to sediment accumulation near a fluctuating CCD rather than to variations in basin depth.

### Santonian

Santonian deposits (Cores 41–43) are composed of zeolitic clays and calcareous oozes and contain an assemblage of benthic species analogous to that observed in

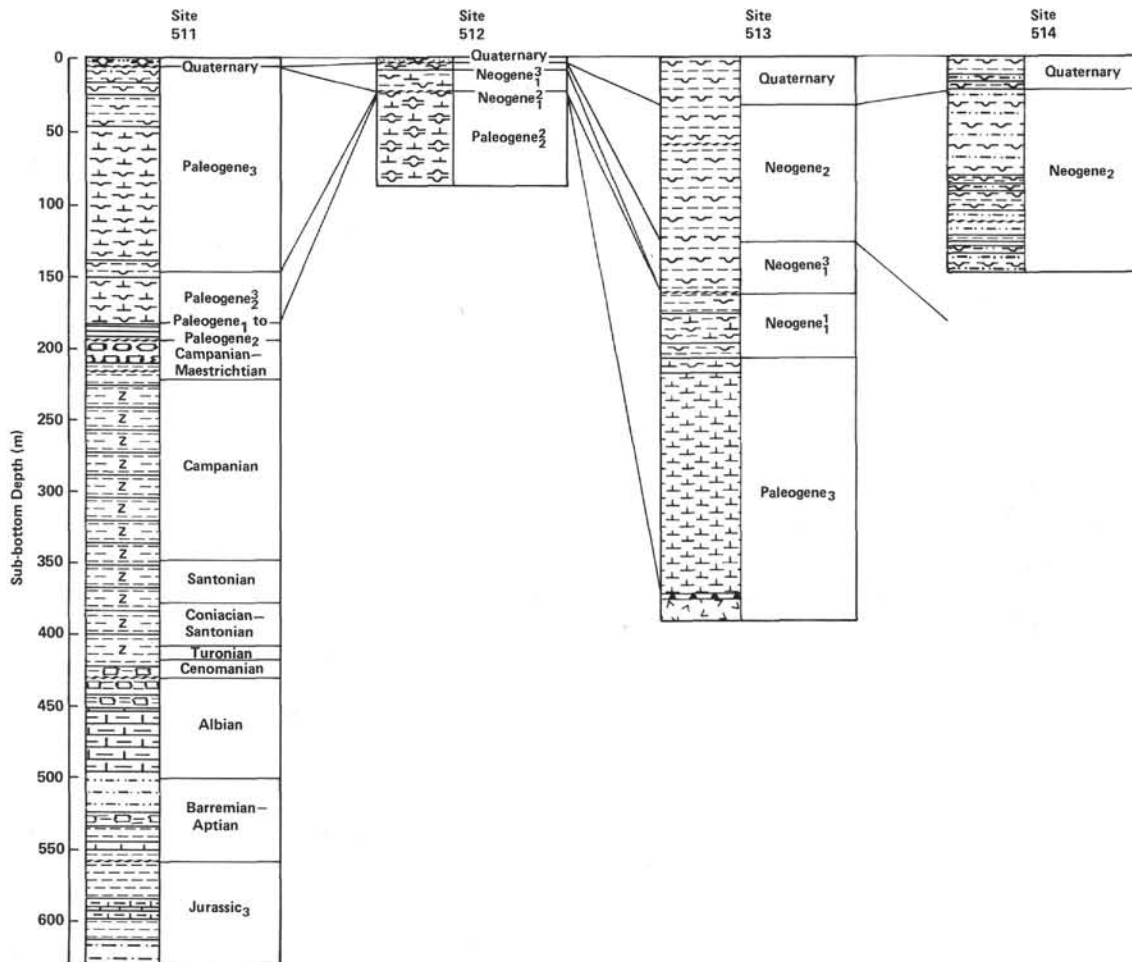


Figure 2. Stratigraphic correlation of Mesozoic and Cenozoic sediments at Leg 71 sites, Falkland Plateau and Argentine Basin. (For an explanation of the lithological symbols, see the Introduction to this volume.)

the underlying sediments. Agglutinated species are in smaller number, however, suggesting subsidence and stabilization of the CCD.

### Campanian

A thick section (137 m) of zeolitic clays and calcareous sediments (interval from Sample 511-27-1, 32–34 cm to Sample 511-41-3, 55–57 cm) contains diverse benthic foraminifers. The total number of species is over 150; their distribution in the section, however, is quite uneven. *Dorothia trochoides*, *Dentalina catenula*, *D. basiplanata*, *D. legumen*, *Marginulinopsis texaensis*, *Marginulina bullata*, *Lingulina pygmaea*, *Valvulineria brotzeni*, *Gyroidinoides nitidus*, *Conorbina marginata*, *Gavelinella stephensoni*, *Nuttallinella florealis*, *Globorotalites michelinianus*, *Charltonina* sp., and *Pleurostomella obtusa* are observed quite frequently throughout the section. Species such as *Glomospira corona*, *G. gordialis*, *Hyperammina elongata*, *Valvulineria camerata*, *V. gracilis*, *Pullenia jarvisi*, and *Praeulimina reussi* are associated with the lower part of the Campanian. Most of them are distributed irregularly and as very rare or single specimens, as a rule.

In the lower part of the Campanian Stage, zeolitic clays (dissolution facies) contain an impoverished, dissolution-resistant calcareous microfauna (*Gyroidinoides*, *Globorotalites*, *Osangularia*, *Bandyella*, and *Ellipsodimorphina*) and the agglutinated *H. elongata*, *H. gaultina*, *Glomospira corona*, *G. gordialis*, *Ammodiscus cretaceus*, and *Rzehakina epigona*. Presence of these species indicates sediment accumulation below the CCD. In the upper part of the Campanian, the foraminiferal assemblage is heavily impoverished as a result of dissolution. Nevertheless, it consists entirely of calcareous species, testifying to a lower position of the lysocline. On the whole, the Campanian assemblage of benthic foraminifers is representative of the lower bathyal depths (1500–2500 m) of open oceanic basins.

### Upper Campanian–Maestrichtian

Upper Campanian–Maestrichtian sediments (Cores 23–26) are represented by nanno-foraminiferal chalk and characterized by benthic foraminifers of a high species diversity (25–28 species in a sample; 60 species altogether). The microfauna in the section is, however, monotonous. The assemblage incorporates some species





Species	Core/Section (interval in cm)	Age	Paleogene	late Campanian-Maestrichtian	Campanian
<i>Giomospira corona</i>		21-1, 34-36 to 23-1, 3-4			
<i>Ammodiacis cretaceus</i>					
<i>Spiroplectammina</i> sp.					
<i>Giomospira gordialis</i>					
<i>Valvulinera allomorphinoides</i>					
<i>Bandyella greavesi</i>					
<i>Asiacolus larvisi</i>					
<i>Pleurotomella obtusa</i>					
<i>Hyperammima elongata</i>					
<i>Pseudoplectambonella</i> aff. <i>cretacea</i>					
<i>Pleurotomella subnodosa</i>					
<i>Dentalina legumen</i>					
<i>Rumulina pseudoculicaria</i>					
<i>Valvulinera camerata</i>					
<i>Hyperammima</i> sp.					
<i>Reussella</i> aff. <i>cushmani</i>					
<i>Dentalina gracilis</i>					
<i>Conorbina marginata</i>					
<i>Nodosaria affinis</i>					
<i>Tritaxia capiosa</i>					
<i>Dentalina basiplaneta</i>					
<i>Globorotalites</i> sp.					
<i>Marginalina stephensoni</i>					
<i>Lingulina pygmaea</i>					
<i>Præbulimina</i> sp.					
<i>Nuttallinella florealis</i>					
<i>Valvulinera brotzeni</i>					
<i>Dentalina crenulata</i>					
<i>Hyperammima</i> <i>frabilis</i>					
<i>Cavelinella stephensoni</i>					
<i>Haplophragmoides</i> sp.					
<i>Ellipsoidea robusta</i>					
<i>Marginalinopsis texensis</i>					
<i>Ammobaculites</i> sp.					
<i>Haplophragmoides bulloides</i>					
<i>Haplophragmoides calcata</i>					
<i>Recurvoides</i> sp.					
<i>Lenticulina muensteri</i>					
<i>Charitonina</i> sp.					
<i>Argonia oustzarenensis</i>					
<i>Gaudryina healyi</i>					
<i>Nodosaria aspera</i>					
<i>Frondecularia lomaeusis</i>					
<i>Gyrodina girardiana</i>					
<i>Gyrodinoides nitidus</i>					
<i>Pullenia americana</i>					
<i>Globorotalites michelinianus</i>					
<i>Argonia velaukensis</i>					
<i>Hyperammima gaultina</i>					
<i>Ellipsoidea gracilis</i>					
<i>Bolivina watersi</i>					
<i>Allomorphina trochoides</i>					
<i>Marginalina bullaria</i>					
<i>Præbulimina reussi</i>					
<i>Fissurina arbigayana</i>					
<i>Frondecularia macronata</i>					
<i>Osungularia incisa</i>					
<i>Rzehakina epigona</i>					
<i>Gavelinella beccariformis</i>					
<i>Rumulina aculeata</i>					
<i>R. globotubulosa</i>					
<i>Globulina lacrima</i>					
<i>Spiroplectammina semicomplanata</i>					
<i>Pleurotomella tortia</i>					
<i>Pullenia jervisi</i>					
<i>Gaudryina pyramidalis</i>					
<i>Ellipsoidea tomella curta</i>					
<i>Gavelinella whiteri</i>					
<i>Conorbina haldingeri</i>					
<i>Osungularia conderana</i>					
<i>Globulina subspheerica</i>					
<i>Pullenia coryelli</i>					
<i>Gyrodinoides quadratus</i>					
<i>Reussella szynochae</i>					
<i>Globorotalites spinosus</i>					
<i>Plectinella</i> sp.					
<i>Bolivina incompressa</i>					
<i>Guttulina adhaerens</i>					

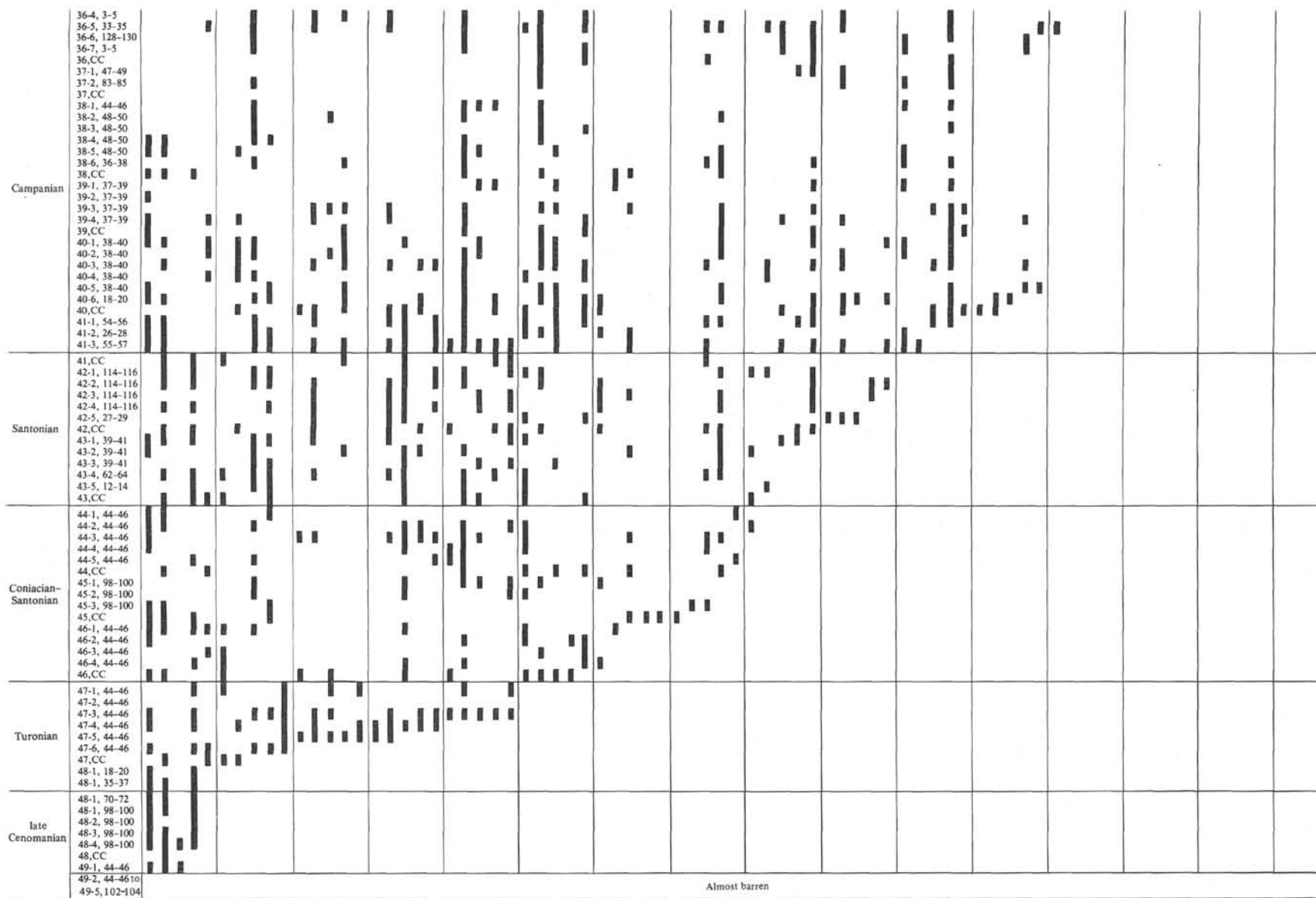


Figure 4. Distribution of benthic foraminifers in the Upper Cretaceous, Hole 511.

found in underlying deposits: *Gaudryina dividens*, *G. heyeli*, *Globulina subsphaerica*, *Dentalina gracilis*, *D. legumen*, *Ramulina aculeata*, *Marginulinopsis texaensis*, *Lenticulina muensteri*, *Pullenia americana*, *Valvulineria allomorphinoides*, and *V. brotzeni*. Those appearing for the first time in the section are *Pullenia coryelli*, *Globorotalites spineus*, *Gyroidinoides quadratus*, *Bolivina incrassata*, and *Reussella szajnochae*. This assemblage characterizes low bathyal conditions.

#### Paleogene

Campanian–Maestrichtian sediments are overlain by a sequence of zeolitic clays (Cores 21–23) that accumulated when the CCD was high and contain no benthic foraminifers. Very rare radiolarians favor a Paleocene–Eocene age for the clays.

Higher up the section are calcareous–siliceous sediments of the upper Eocene (Cores 17–20) and predominantly siliceous radiolarian and diatom oozes of the Oligocene (Cores 1–16).

Benthic foraminifers are mostly rare because of biogenic dilution, are unevenly distributed in the section, and form a single assemblage that abounds in *Nonion havanense*, *Anomalinoidea spissiformis*, *Oridorsalis umbonatus*, *Pullenia bulloides*, *P. quinqueloba*, *Gyroidina zealandica*, *G. planulata*, *Cibicidoides* sp., *Bulimina* sp., *Stilostomella basicarinata*, *S. bradyi*, *S. curvatura* (Fig. 5). The assemblage is poor compared to those of the Late Cretaceous, consisting mostly of cosmopolitan species indicative of the lower bathyal conditions of sediment accumulation (2000–2500 m).

#### Quaternary

The uppermost bed of sediments of Core 1 is characterized by a poor assemblage of benthic foraminifers consisting of deep-water species (*Pyrgo murrhina*, *Hoe-glundina elegans*, *Oridorsalis tenerus*, *Gyroidina soldanii*, *Laticarinina pauperata*, and *Cibicidoides wuellerstorfi*). All are typical of Recent sediments of the lower bathyal zone north of the Antarctic convergence (Herb, 1971; Basov, 1975).

#### Site 512

This site was drilled on the eastern margin of the Maurice Ewing Bank (49°52.194' S, 40°50.713' W; water depth 1846 m) in order to elucidate the Tertiary history of sedimentation and oceanic circulation in the South Atlantic. It was supposed to obtain for the first time in high latitudes a complete section of relatively shallow water Cenozoic calcareous sediments, to trace the CCD variations during the Paleogene, and to reveal paleoceanic and erosional events related to the opening of the Drake Passage and formation of the circum-Antarctic current. The site was continuously cored by hydraulic piston corer down to 77.9 meters and then cored conventionally to 87.3 meters. The hole reached middle Eocene sediments before drilling ceased because of strong currents, swells, and deteriorating weather conditions. Benthic foraminifers are evenly distributed throughout the section.

#### Middle Eocene

The lower part of the section (Core 512A-2 and 512-6 to 512-19) is composed of nannoplanktonic ooze containing a rather rich foraminiferal assemblage (over 60 species). The species diversity is on average 15 species per sample, sometimes increasing up to 20–25 and decreasing to 5–10. The assemblage abounds in *Karreriella subglabra*, *Pullenia riveroi*, *P. quinqueloba*, *Anomalinoidea semicribrata*, *A. spissiformis*, *Heterolepa* sp., *Nonion havanense*, *Oridorsalis ecuadorensis*, *Gyroidina girardana*, *Cibicidoides perlucidus*, *Bulimina inflata*, *B. jarvisi*, *Stilostomella caribea*, *S. gracillima*, and *Orthomorphina rohri* (Fig. 6). Common also are *Gyroidina planulata*, *G. soldanii*, *Alabamina dissonata*, *Osangularia pteromphalia*, *Pleurostomella torta*, *Ellipsoidella robusta*, *Nodosarella subnodosa*, and *Bradynella subglobosa*. This assemblage has many species common to benthic foraminifers from the Oceanic Formation of Barbados (Beckmann, 1953) and is also extremely similar to the foraminiferal assemblage from Eocene sediments of the southeastern Atlantic (Beckmann, 1978). The species composition of the assemblage, dominated by representatives of the order Rotaliida and subordinate numbers of lagenids and agglutinated forms, suggests bathyal conditions in its habitat. Good and moderate preservation of calcareous tests indicates sediment accumulation above the foraminiferal lysocline.

#### Middle Miocene

Middle Eocene oozes are overlain unconformably by middle Miocene siliceous sediments (Cores 2–5). The species diversity of foraminifers is lower than in the middle Eocene. Thirty-five species were identified, the most representative of which are deep-water *Karreriella bradyi*, *Eggerella bradyi*, *Pyrgo murrhina*, *Pullenia bulloides*, *P. quinqueloba*, *Melonis affinis*, *Cibicidoides kulenbergi*, *Oridorsalis umbonatus*, *Gyroidina soldanii*, *Sphaeroidina bulloides*, *Bulimina inflata*, *Angulogerina esuriens*, and *Bradynella subglobosa*. A similar assemblage described from the Miocene of the Indian Ocean (Boltovskoy, 1978) testifies to lower bathyal depths (1500–2000 m) and a low foraminiferal lysocline.

#### Upper Miocene

Upper Miocene sediments (Core 1) contain a similar but greatly impoverished assemblage of benthic foraminifers compared to the middle Miocene. Most frequent are *Eggerella bradyi*, *Karreriella bradyi*, *Pyrgo murrhina*, *Pullenia bulloides*, *P. quinqueloba*, *Melonis affinis*, *Cibicidoides kulenbergi*, *Oridorsalis umbonatus*, and *Bradynella subglobosa*. They inhabit Recent sediments of the bathyal zone near the Antarctic convergence (Herb, 1971; Basov, 1975).

#### Site 513

This site is located in the Argentine Basin on the western flank of the Mid-Atlantic Ridge (47°34.99' S, 24°38.40' W; water depth 4373 m; Magnetic Anomaly 15).



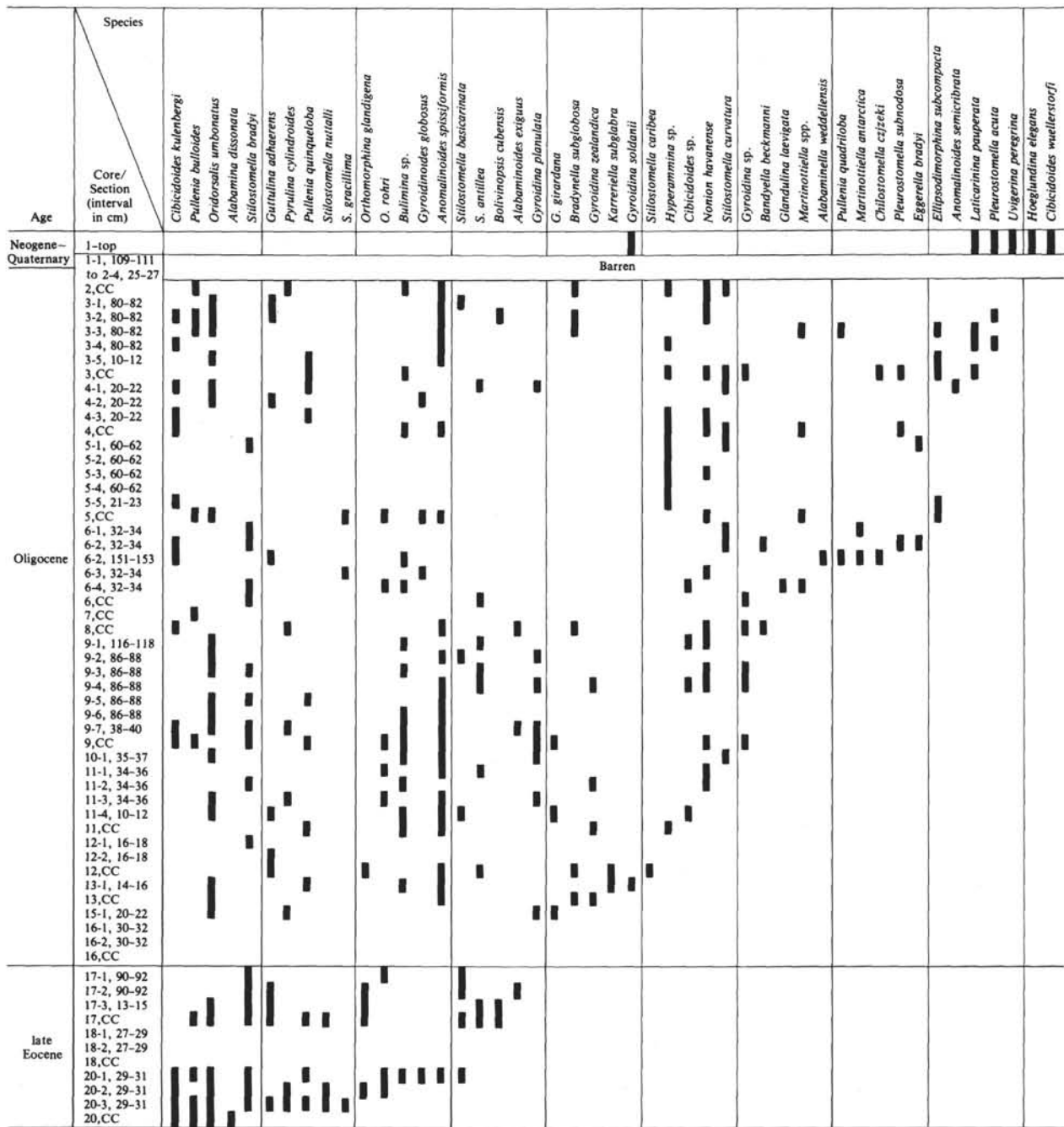


Figure 5. Distribution of benthic foraminifers in the upper Eocene, Oligocene, and Quaternary, Hole 511.

This site was chosen slightly north of the present position of the Polar Front, which approximately corresponds to the northern boundary of the siliceous ooze belt in the South Atlantic, in order to study the Cenozoic history of the geographic migrations of the Polar Front caused by pulsations of the Antarctic ice sheet. The history of biogenic siliceous sedimentation in the region recorded in the Cenozoic section reflects the climatic and oceanic evolution of the Southern Hemisphere. Study of it can elucidate the history of the formation of the Antarctic ice cover and the establishment of the Circumpolar Current which helps determine the climate not only of the Southern Hemisphere but of the whole plan-

et. Oligocene, lower and upper Miocene, Pliocene, and Quaternary sediments (total thickness 379.5 m) overlying basalts of the oceanic basement were rotary drilled and continuously cored.

Benthic foraminifers are present throughout almost the whole section except its uppermost part, but their distribution is very irregular (Fig. 7).

### Oligocene

Oligocene sediments are composed of calcareous and siliceous oozes in the lower part of the section (Cores 513A-25 to 513A-33) and of siliceous diatom and radiolarian oozes in the upper part (Cores 513A-16 to

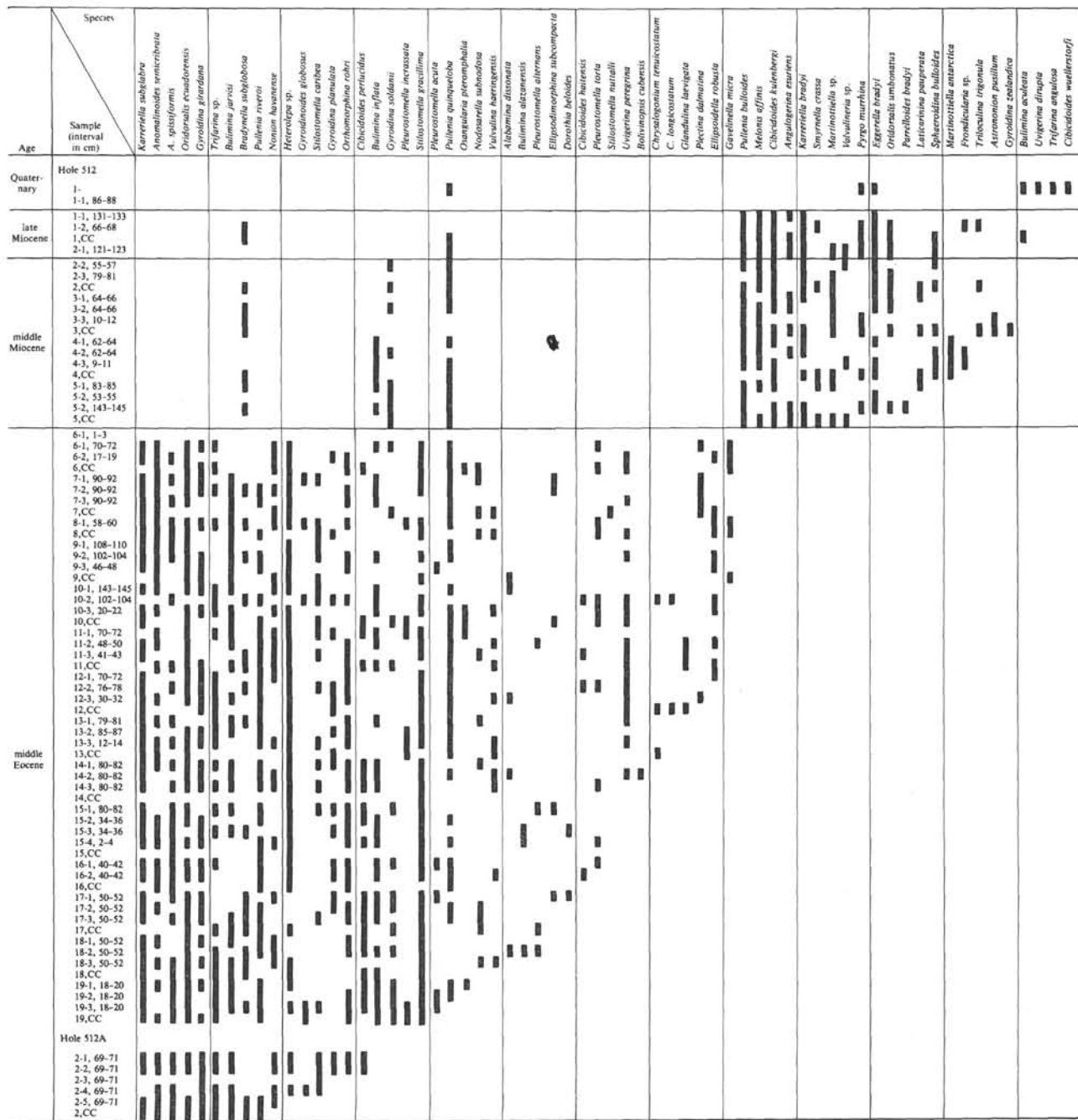


Figure 6. Distribution of benthic foraminifers in the middle-upper Miocene and Quaternary, Site 512.

513A-24). Benthic foraminifers are encountered in all samples, in greater numbers in the calcareous portion of the section. The foraminiferal assemblage amounts to 60 species and is dominated by *Bolivianopsis cubensis*, *Oridorsalis umbonatus*, *Gyroidina soldanii*, *G. planulata*, *G. girardina*, *Nonion havanense*, *Anomalinoidea spissiformis*, *Cibicides kulenbergi*, *Bradyella subglobosa*, *Stilostomella curvatura*, and *S. nuttalli*. *Astrononion pusillum*, *Stilostomella bradyi*, *Chrysalogonium tenuicostatum*, and *Orthomorphina rohri* are often present as well.

This assemblage has many species in common with foraminiferal fauna from the upper Eocene-Oligocene

sediments of Site 511. It is typical of the lower bathyal zone, confirming depths exceeding 4 km for the Oligocene CCD level in the South Atlantic (van Andel et al., 1977).

**Lower Miocene**

Lower Miocene siliceous radiolarian-diatom oozes occur in Cores 513A-12 to 513A-15 and contain an assemblage of benthic foraminifers that is impoverished compared to the Oligocene one. The quantity of specimens is not large because of significant biogenic dilution. Forty species were found. *Bolivianopsis cubensis*, *Oridorsalis umbonatus*, *O. tenerus*, *Laticarinina pauper-*



*ata*, *Anomalinoidea spissiformis*, *Pullenia subcarinata*, *Gyroidina soldanii*, *Cibicoides floridanus*, and *Brady-nella subglobosa* occur most frequently. They are accompanied by *Eggerella bradyi*, *Pullenia bulloides*, *Gyroidina girardana*, *Astronion pusillum*, and *Stilostomella nuttalli*. This assemblage is indicative of lower bathyal-upper abyssal depths, above the foraminiferal lysocline.

### Upper Miocene

The Upper Miocene diatom oozes (Cores 513A-7 to 513A-11) are almost barren of benthic foraminifers. Only two species, *Martinottiella antarctica* and *Spirolocammina exigua*, occur rarely here, testifying to the accumulation of siliceous deposits in the abyssal zone below the CCD level.

### Pliocene-Quaternary

Biogenic siliceous sediments of this age (Cores 513-1 to 513-6 and Cores 513A-1 to 513-9) contain an impoverished fauna of benthic foraminifers, consisting mainly of agglutinated species, such as *Martinottiella antarctica*, *Eggerella bradyi*, and *Spirolocammina exigua*, usually represented by very rare specimens or by test fragments. These species characterize abyssal depths well below the CCD (4000-5000 m). Traced throughout almost the whole section of Site 513, they do not possess any stratigraphic value. *S. exigua*, which is the only exception and which was never found in the Quaternary, was described by Burmistrova (1978) from Neogene sediments in deep-sea piston cores taken in the Indian Ocean (Station 4599, water depth 4888 m; Station 5315, water depth 5162 m; *Vitjaz*, U.S.S.R.). This species disappears in the middle of the Pliocene interval at Site 513.

Pleistocene sediments (Cores 513-1 to 513-3) contain very rare specimens of *M. antarctica* in separate layers. The benthic foraminiferal assemblage suddenly becomes rich in Samples 513-3-1, 133-135 cm and 513-3-2, 38-40 cm, where it is represented by *M. antarctica*, *Karrerella bradyi*, *Pyrgo murrhina*, *Quinqueloculina pygmaea*, *Melonis affinis*, *M. pompilioides*, *Oridorsalis umbonatus*, *Pullenia quinqueloba*, *Alabaminoides exiguus*, and other forms (17 species in total). This assemblage is indicative of abyssal depths and at the same time some subsidence of the foraminiferal lysocline. This was possibly connected with an increase in the productivity of calcareous microfossils in surface water as a result of migration of the Polar Front to the south. Moderately warm water planktonic species (*Globorotalia puncticulata*, *G. inflata*, *Globigerina pachyderma*, and *G. bulloides*) in the same samples support this conclusion. Recent sediments (from Sample 513-1-1, 132-134 cm to Sample 513-1-3, 64-66 cm) are characterized by two species, *Martinottiella antarctica* and *Cyclammina pusilla*, which are typical of present abyssal depths.

### Site 514

Site 514 is situated on the western flank of the Mid-Atlantic Ridge in the eastern Argentine Basin (46° 02.77'S; 26° 51.30'W; water depth 4318 m) approximately 150 km to the northwest of Site 513 and about

250 km north of the present-day position of the Polar Front. Like Site 513 it was drilled to reconstruct the Cenozoic history of the Polar Front, to determine its influence on zoo- and phytoplankton productivity in surface waters, and to correlate late Cenozoic sediments of DSDP sites drilled in the South Atlantic.

The site was drilled and HPC cored through 150.8 meters of Pliocene-Quaternary sediments, consisting of greenish gray and gray diatom oozes and diatom clays with separate layers of clayey nannofossil ooze.

Benthic foraminifers are found throughout almost the whole section of Pliocene-Quaternary sediments but are distributed quite irregularly, reflecting instability of the sedimentation rate (Fig. 8).

### Pliocene

The benthic foraminiferal assemblage in Pliocene sediments (from Core 514-6 to Core 514-35) includes more than 40 species, with never more than 15 species per sample. An impoverished fauna of agglutinated foraminifers (Cores 23-27 and 8-14) consisting of *Martinottiella antarctica* and *Eggerella bradyi* alternates with layers containing relatively rich assemblages dominated by *M. antarctica*, *E. bradyi*, *Pullenia bulloides*, *P. quinqueloba*, *Melonis affinis*, *Oridorsalis umbonatus*, *Alabaminoides exiguus*, *Alabaminella weddellensis*, and *Brady-nella subglobosa* (Cores 28-35, 15-22, and 6-7). They in their turn show strongly variable species diversity in different samples. Benthic species in these layers are usually accompanied by rare planktonic forms.

Pliocene benthic foraminiferal assemblages reflect sedimentation at abyssal depths, evidently near the CCD, influenced by variable productivity of calcareous plankton in surface water.

### Quaternary

Quaternary sediments in Core 514-1 are almost barren of benthic foraminifers. Only a few samples contain rare specimens of the agglutinated *Martinottiella antarctica*. The only exception is Sample 514-1, CC, where benthic foraminifers are represented by *M. antarctica*, *Psammosphaera fusca*, *Reophax nodulosus*, *Cyclammina pusilla*, and *Uvigerina aff. dirupta*. These are characteristic of Recent abyssal sediments in the South Atlantic. Rare tests of planktonic forms such as *Globorotalia inflata* and *Globigerina pachyderma*, which live at present near the Polar Front, are also found.

### BIOSTRATIGRAPHY

Benthic foraminifers recognized at Leg 71 sites do not guarantee a detailed stratigraphic subdivision of Mesozoic and Cenozoic sediments. Nevertheless, one can distinguish natural associations, replacing one another upward in the section, that correspond to certain stratigraphic intervals. These associations contain some index species with wide geographic distribution and rather narrow stratigraphic range. But rapid and frequent changes of paleoenvironmental conditions on the Falkland Plateau strongly influenced species composition. The limited materials at Site 511 for Cretaceous stratigraphy do not allow one to differentiate entirely



between the influence of evolutionary and of ecologic factors.

Albian sediments at Site 511 are characterized by two assemblages of benthic foraminifers. The oldest was observed in Cores 55–57 and is represented mostly by *Gavelinella intermedia*, *Osangularia utaturiensis*, and *Gyroidinoides primitivus*. *Dorothia trochooides*, *Glomospira gordialis*, *Anomalinoidea indica*, and various lagenids (genera *Dentalina*, *Lenticulina*, *Pyrolinoidea*, *Fron-dicularia*, and *Saracenaria*) are rare. Only some of these species are stratigraphically significant. *Gavelinella intermedia* was described from the Aptian–Albian (Scheibnerová, 1974, 1978; Sliter, 1980), Albian (Lambert and Scheibnerová, 1974) and lower–middle Albian deposits of the Austral province. *O. utaturiensis*, described for the first time from upper Albian deposits of the Utatur Formation, Trichinopoly district, Madras, Indian (Sastri and Sastri, 1966), was also identified in middle Albian sediments of Leg 27 in the Indian Ocean (Scheibnerová, 1974), Aptian–Albian of Sites 363 and 364 of the South Atlantic (Scheibnerová, 1978), Albian of the East Atlantic (Sigal, 1979), and lower–middle Albian of the Falkland Plateau, Site 330 (Sliter, 1977a). *Gyroidinoides primitiva* was described by Hofker (1957) from the upper Albian–Cenomanian of Holland and Northwestern Germany. In the Southern Hemisphere the species was found in middle–upper Albian clays of the Indian Ocean, Sites 259 and 260 (Scheibnerová, 1974), in lower and middle Albian sediments of the Falkland Plateau, Site 327 (Sliter, 1977a), and in the upper Albian of the Southeastern Atlantic, Site 364 (Scheibnerová, 1974). The occurrence of these species jointly with the planktonic *Ticinella roberti* on the Falkland Plateau testifies to the early Albian age of sediments.

The second assemblage of benthic foraminifers was distinguished in the upper part of the Albian (Cores 49–55). It is characterized by a greater diversity of species. Along with the species from the lower assemblage, it contains numerous *Clavulina gabonica*, *D. trochooides*, *Glomospira corona*, *G. gordialis*, *Uvigerinamina jankoi*, *Spirillina elongata*, *S. minima*, *Patellinella australis*, *Patellina subcretacea*, *Orithostella australiana*, *A. indica*, *Tribrachia australiana*, and *Pleurostomella obtusa*. *Lingulina nodosaria* and *L. loryi* are also common. Some species have limited stratigraphic distribution and are useful for age determination. *A. indica*, described for the first time from the upper Albian beds of the Utatur Formation, India (Sastri and Sastri, 1966), is also representative of the upper Albian of the southeastern Atlantic (Scheibnerová, 1978) and the Indian Ocean (Scheibnerová, 1974). *Patellinella australis*, frequently occurring in the upper part of the Albian section of Hole 327A (Sliter, 1977a) and Hole 511, was identified in the Albian sediments of Zululand, South Africa (Scheibnerová, 1974). *O. australiana* was described from the early Albian of South Africa (Scheibnerová, 1972) and the southeastern Atlantic (Scheibnerová, 1978). *T. australiana* is also a species peculiar to Albian sediments of the Austral province (Ludbrook, 1966; Scheibnerová, 1974, 1978). *Spirobolevina australis*, which was recognized in the middle–upper Albian of

Holes 327A and 330A on the Falkland Plateau (Sliter, 1977a), is also present in the upper Albian sediments of Site 364 in the southeastern Atlantic (Scheibnerová, 1978) and Site 259 in the Indian Ocean (Scheibnerová, 1974). At Site 511 this species is also peculiar to the upper half of the Albian section. The middle–late Albian age of the sediments is evidenced by *C. gabonica*, *D. trochooides*, *U. jankoi*, and *Conorboides minutissima* (Scheibnerová, 1974, 1978; Sliter, 1977a).

Upper Cretaceous sediments (Site 511) are characterized by an assemblage of benthic foraminifers consisting of more than 200 species. The assemblage contains four groups, replacing one another upward in the section. They reflect both changes of sedimentation conditions during the Late Cretaceous development of the South Atlantic and the evolution of microfauna.

The first group of species was distributed in upper Cenomanian–Santonian deposits. It frequently contains, along with calcareous *Valvulinera allomorphinoides*, *V. brotzeni*, *V. camerata*, *Conorbina marginata*, *Nuttallinella florealis*, *Pleurostomella obtusa*, *P. subnodosa*, *Bandyella greatvalleyensis* agglutinated to *Hyperammia elongata*, *H. friabilis*, *H. gaultina*, *Haplophragmoides calcula*, *H. bulloides*, *Ammobaculites* sp., *Cribrostomoides* sp., *Recurvoides* sp., *Ammodiscus cretaceus*, *Glomospira corona*, and *G. gordialis*. They testify to the accumulation of sediments during the late Cenomanian–Santonian under conditions below or near the CCD. Numerous lagenids in this part of the section are either displaced from shallower depths or correspond to periods of relatively low CCD levels. Almost all these species are long-ranging and have no stratigraphic significance, being only a useful index of ecological conditions.

The second group of species, which is characteristic of most of the Campanian section (Cores 31–41), displays considerable diversity, with many species which appear both in underlying and overlying Cretaceous deposits. Most frequent are representatives of the genera *Dentalina*, *Marginulina*, *Lingulina*, *Marginulinopsis*, *Lenticulina*, *Gyroidina*, *Gyroidinoides*, *Pullenia*, *Charltonina*, *Globorotalites*, *Valvulinera*, *Gavelinella*, *Praebulimina*, and *Pleurostomella*. The agglutinated *Glomospira corona*, *G. gordialis*, and *A. cretaceus* are present in small number in the lowermost Campanian. Taking into account the dominance of calcareous species, sediment accumulation during the Campanian occurred above the CCD.

The third group of species is peculiar to the upper part of the Campanian, the age of which has been determined by the presence of double-keeled *Globotruncana*. The assemblage is of low diversity and consists mainly of long-ranging species: *Dentalina catenula*, *D. gracilis*, *D. legumen*, *N. florealis*, *Valvulinera allomorphinoides*, *V. brotzeni*, *Gyroidinoides nitidus*, *Globorotalites michelinianus*, *Gavelinella beccariiformis*, *G. whitei*, *Osangularia cordieriana*, and *Bolivina watersi*. Scarce foraminifers of low species diversity, bad preservation of tests, and the presence of noncalcareous clays in the section testify to sediment accumulation near a fluctuating CCD.

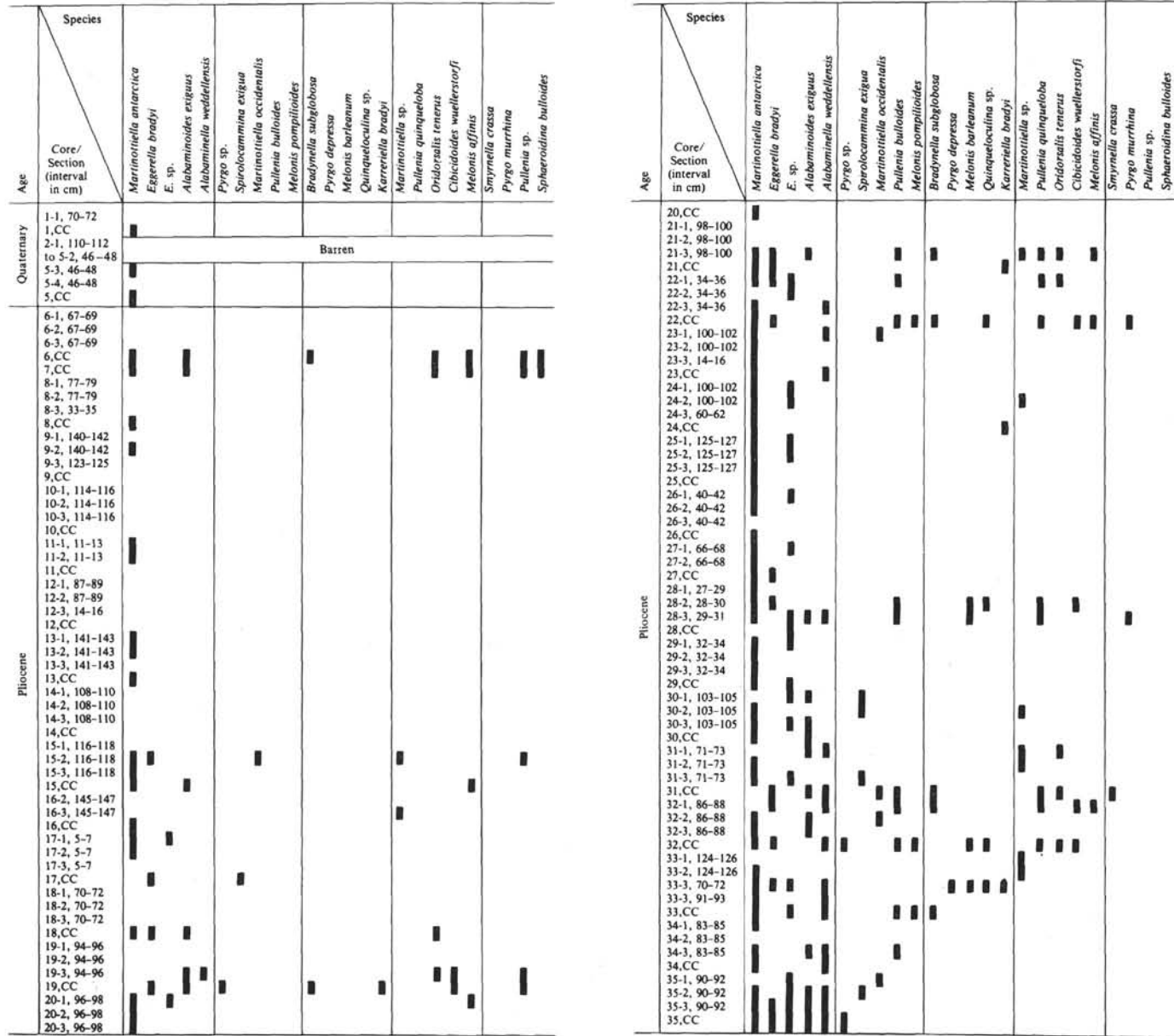


Figure 8. Distribution of benthic foraminifers in the Pliocene-Quaternary, Hole 514. *Psammospira fusca*, *Reophax nodulosus* and *Cyclammina pusilla* were present only in Sample 514-1,CC.

The fourth group of species is incorporated in upper Campanian–Maestrichtian sediments (Cores 23–26); species composition is very monotonous, indicating stable conditions of sediment accumulation above the CCD. Most frequent are *Spiroplectammina complanta*, *Gaudryina healyi*, *G. pyramidata*, *D. catenula*, *D. gracilis*, *D. legumen*, *Lenticulina muensteri*, *Astacolus jarvisi*, *Ramulina aculeata*, *Globulina subsphaerica*, *Guttulina adhaerens*, *V. allomorphinoides*, *V. brotzeni*, *Gavelinella beccariiiformis*, *G. whitei*, *Pullenia americana*, *P. coryelli*, *Gyroidinoides nitidus*, *G. quadratus*, *Conorbina haidingeri*, *V. camerata*, *Globorotalites spineus*, *B. incrassata*, *Reussella szajnochae*, and *Ellipsoidella robusta*.

Most of the Late Cretaceous species are long-ranging; some of them, however, are associated with relatively short stratigraphic intervals. *Tritaxia capitosa*, identified at Site 511 in Coniacian–Santonian and lower Campanian sediments, has also been observed in the Coniacian–Santonian of the southeast Atlantic (Beckmann, 1978). *Gavelinella whitei* (Campanian–Maestrichtian at Site 511) is usually identified in Santonian–Maestrichtian sediments (Sliter, 1968, 1977b). *Globorotalites michelinianus* (Campanian of Site 511) has been described from the Campanian–Maestrichtian of North America (Sliter, 1968), the uppermost Coniacian, Santonian, Campanian, and part of the lower Maestrichtian of the Russian platform and other areas of the U.S.S.R. (Vassilenko, 1961), and the Campanian of Western Europe (Hofker, 1957). At Site 356, drilled in the Southwest Atlantic on the São Paulo Plateau, rare specimens of this species were found in the middle Maestrichtian (Sliter, 1977b). The Campanian–Maestrichtian interval at Site 511 is very distinctive and is characterized by a number of key benthic species (*Pullenia coryelli*, *Gyroidinoides quadratus*, *Gavelinella beccariiiformis*, *Globorotalites spineus*, *Osangularia cordieriana*, *Reussella szajnochae*, and *Bolivina incrassata*). These species are identified in Campanian–Maestrichtian sediments of most regions (Sliter, 1968, 1977a, b; Beckmann, 1978; Hofker, 1957; Sigal, 1979).

Cenozoic benthic foraminifers include middle Eocene, late Eocene–Oligocene (and partly early Miocene), middle–late Miocene, and Pliocene–Quaternary assemblages.

A middle Eocene assemblage of benthic foraminifers was observed in Hole 512 (Cores 6–12) and Hole 512A. Representative species are *Karriella subglabra*, *Anomalinoidea semicribrata*, *A. spissiformis*, *Alabamina dissonata*, *Gyroidina girardana*, *Nonion havanense*, *Oridorsalis ecuadorensis*, *Pullenia riveroi*, *P. quinqueloba*, *Cibicidoides perlucidus*, *Bulimina inflata*, *B. jarvisi*, *Stilostomella caribaea*, *S. gracillima*, and *Orthomorphina rohri*. Frequent also are *Gyroidina planulata*, *G. soldanii*, *Osangularia pteromphalia*, *Uvigerina* aff. *peregrina*, *Pleurostomella torta*, *Ellipsoidella robusta*, and *Nodosarella subnodosa*.

Many species of this assemblage are long-ranging; some of them, however, can serve as good stratigraphic datum markers for Eocene deposits. Thus, *A. dissonata*, *Oridorsalis ecuadorensis*, *Osangularia pteromphalia*, *B. alazanensis*, and *B. jarvisi* have been observed in the Atlantic and Pacific oceans in Eocene sediments only (Berg-

gren, 1972; Douglas, 1973; Proto Decima and Bolli, 1978). *Plectina dalmatina*, *Nonion havanense*, *C. perlucidus*, *S. gracillima*, and *N. subnodosa* are typical of the Eocene (Beckmann, 1953; Douglas, 1973; Proto Decima and Bolli, 1978), though they can sometimes be observed in the Oligocene as well.

The late Eocene–Oligocene to early Miocene assemblages were identified in the upper Eocene and Oligocene sediments of Site 511 (Cores 1–23) and the Oligocene–lower Miocene oozes of Hole 513A (Cores 12–33). Predominant species are *Bolivinoopsis cubensis*, *Anomalinoidea spissiformis*, *Oridorsalis umbonatus*, *Gyroidina girardana*, *G. planulata*, *G. soldanii*, *Pullenia bulloides*, *P. quinqueloba*, *Bradynella subglobosa*, *S. curvatura*, *S. bradyi*, and *S. nuttalli*. Frequent are *Astrononion pusillum*, *Chrysalogonium tenuicostatum*, and *Orthomorphina rohri*. *Eggerella bradyi*, *Cibicidoides floridanus*, and *Uvigerina holicki* appear in lower Miocene sediments. This assemblage contains species common to the middle Eocene assemblage, on the one hand, and to foraminiferal assemblages from younger sediments, on the other hand. *Bolivinoopsis cubensis*, *Alabamina dissonata*, *N. havanense*, *G. planulata*, *Anomalinoidea spissiformis*, and *Chrysalogonium tenuicostatum*, which appear and become common in the middle Eocene oozes of Site 512, disappear at various levels of the upper Eocene, Oligocene, and lower Miocene. *Martinottiella antarctica*, *P. bulloides*, *Oridorsalis tenerus*, *O. umbonatus*, *Astrononion pusillum*, and *Laticarinina pauperata* appear in the Oligocene; most of these are still living today.

The middle Eocene and late Eocene–Oligocene to early Miocene assemblages have many species in common with the assemblages from synchronous deposits of the Caribbean Basin (Beckmann, 1953), Atlantic Ocean (Berggren, 1972; Proto Decima and Bolli, 1978), and the Pacific Ocean (Douglas, 1973). Their characteristic feature is the subordinate role of lagenids, which occur in great numbers in deposits of the Late Cretaceous and older.

The middle–late Miocene assemblage of foraminifers (Site 512) is more ecologically than stratigraphically determined, for all dominant species are widely distributed in Recent sediments (Saidova, 1975) (*M. antarctica*, *E. bradyi*, *Karriella bradyi*, *Pyrgo murrhina*, *Triloculina trigonula*, *O. umbonatus*, *L. pauperata*, *Melonis affinis*, *P. bulloides*, *A. pusillum*, and *Sphaeroidina bulloides*). Species such as *P. murrhina*, *T. trigonula*, *S. bulloides*, *Smyrnelia crassa*, and *Angulogerina esuriens* appear for the first time in middle Miocene sediments of Site 512. The hiatus between the middle Eocene and middle Miocene does not allow determination of the lower stratigraphic limits of these species at that site. In lower Miocene oozes of Hole 513A, most of these species are missing. This, however, may be related to the various depths inhabited by the early Miocene and middle–late Miocene assemblages. The absence of these species, nevertheless, in the Oligocene sediments at Site 511 that formed at the same depth as sediments at Site 512 reliably shows that they appeared no earlier than the early Miocene. A similar assemblage was described by



Boltovskoy (1978) from the Miocene of the Indian Ocean, which, as on the Falkland Plateau, is characteristic of lower bathyal depths (1500–2000 m).

The Pliocene–Quaternary assemblage at Sites 513 and 514 and observed as fragments in the uppermost sections of Sites 511 and 512 is characterized by low diversity. Most frequent are *Martinottiella antarctica*, *E. bradyi*, *K. bradyi*, *P. murrhina*, *Spirolocammina exigua*, *Pullenia bulloides*, *P. quinqueloba*, *Melonis affinis*, *M. pompilioides*, *Oridorsalis umbonatus*, *Alabaminoides exiguus*, *Alabaminella weddellensis*, *Sphaeroidina bulloides*, and *Bradynella subglobosa*. The ecological restriction of this assemblage is quite possible.

In the uppermost Quaternary sediments of all these sites are *Psammospaera fusca*, *Reophax nodulosa*, *Martinottiella antarctica*, *Cyclammina pusilla*, *E. bradyi*, *Pyrgo murrhina*, *Pullenia quinqueloba*, *Gyroidina orbicularis*, *O. tenerus*, *Hoeglundina elegans*, *Cibicidoides wuellerstorfi*, *Laticarinina pauperata*, and *Bulimina aculeata*, most of which have been described from Recent deep-water sediments of the South Atlantic (Earland, 1934; Heron-Allen and Earland, 1932; Herb, 1971; Basov, 1975).

### BIOGEOGRAPHY

Benthic foraminifers are not only an important subsidiary means of stratigraphic correlation of oceanic sediments, but they also have great significance for the elucidation of biogeographical connections between the oceanic basins of the past, the migration pathways of organisms that inhabited them, and paleoenvironmental changes.

Leg 71 data enable us to trace the changes in benthic foraminiferal assemblages from shallow water (shelf-upper slope) in the Albian to deep water (lower bathyal-upper abyssal) in the Cenozoic and to determine their resemblances to synchronous assemblages from various regions of the world.

Scheibnerová (1972, 1974, 1978), who has done much for studies of the Southern Hemisphere Lower Cretaceous benthic foraminifers, distinguishes an Austral Biogeographical Province and includes in it the Great Artesian Basin in Australia, the southern part of the Hindustan peninsula, the southern extremities of Africa and South America from among the continents as well as the southern parts of the Indian and Atlantic oceans. The benthic foraminiferal fauna that populated this Province during the Early Cretaceous is characterized by the large-scale development of representatives of the genera *Anomalinoides*, *Gavelinella*, *Tribranchia*, *Patellinella*, and some others which are found exclusively in sediments of high latitudes in the Southern Hemisphere. *A. indica*, *Orithostella australiana*, *P. australis*, *Spirobovina australis*, and *T. australiana* from Site 511 Albian sediments are typical elements of the Austral Province microfauna.

At the same time Albian benthic foraminifers of the Falkland Plateau are similar to a synchronous, pelagic, but relatively shallow water foraminiferal assemblage populating the western tropical part of the North Atlantic in the Blake Plateau area (Gradstein, 1978). Many species such as *G. intermedia*, *Osangularia utaturiensis*,

*Gyroidinoides primitiva*, *Valvulineria gracillima*, *Pleurostomella obtusa*, *Dorothia trochooides*, *D. gradata*, *Gaudryina dividens*, and *Astacolus crepidularis*, which are widely distributed in the Barremian–Albian deposits of the Blake Plateau, also often occur in synchronous sediments of the Falkland Plateau and other areas within the Austral Province. This likeness, which is yet to be properly analyzed, testifies to the existence of connections between the incipient South Atlantic and the already well developed North Atlantic. Some affinity of the Albian benthic foraminifers of the area under study and the Lower Cretaceous fauna of Site 416, Morocco Basin (Sliter, 1980), confirms this supposition.

Some problems of the biogeographical distribution and ecologic features of benthic foraminiferal assemblages in the Mesozoic deposits of the North Atlantic were analyzed by Basov (1980). Among other ecologic types, he singled out the anomalinid–buliminid ecologic type of microfauna containing species of *Anomalinoides*, *Osangularia*, *Globorotalites*, *Gyroidinoides*, *Pleurostomella*, *Valvulineria*, *Praebulimina*, *Gaudryina*, *Clavulina*, *Glomospirella*, and *Hyperammina*. Evidently, the Albian benthic foraminifers of the Falkland Plateau stand close to this ecologic type.

Well-known shallow-water Albian benthic foraminifers of the Southern Hemisphere assist in making firm biogeographical divisions and in eliciting the biogeographical links of various regions.

The deep-water Upper Cretaceous foraminiferal fauna, together with Austral species, also contains forms common to the Upper Cretaceous assemblages from the tropical and subtropical Atlantic Ocean (Beckmann, 1978; Sliter, 1977b) and the northern subtropical part of the Pacific (Douglas, 1971). There is also a similarity with foraminiferal assemblages from synchronous deposits in North America (Cushman, 1946; Sliter, 1968), Western Europe (Brotzen, 1936; Hofker, 1957), and the Soviet Union (Vassilenko, 1961; Podobina, 1975). The increase in widely distributed benthic foraminiferal species in the Upper Cretaceous of the Falkland Plateau, when compared to the Lower Cretaceous, suggests the final opening of the South Atlantic and the establishment of its wider connections with other oceans and the Tethys Sea.

Considered as a whole, Cenozoic benthic foraminifers in Leg 71 are deep-water cosmopolitan species widely distributed in synchronous sediments of the oceans and continents.

### PALEOGEOGRAPHY AND PALEOCEANOLOGY OF THE SOUTHWEST ATLANTIC BASED ON BENTHIC FORAMINIFERS

Analysis of foraminiferal assemblages at Sites 511 and 512, together with other groups of macro- and microfossils and the character of sediments, show a long and complicated development of the Falkland Plateau during Mesozoic and Cenozoic time.

#### The Cretaceous

Before the separation of South America from Africa in the Early Cretaceous (125–127 Ma; Larson and Ladd, 1973; Sclater et al., 1977), there existed within the Falk-



land Plateau a shallow-water semiclosed basin with a restricted water mass circulation, in which mostly black shales enriched in organic matter accumulated. Anaerobic conditions unfavorable to the development of bottom life were predominant in the basin because of the poor water exchange. The presence of pelecypod tests (*Malayomaorica*, *Meleagrinea*, and *Ostrea*), belemnite rostra (*Hybolites*), and ammonites (*Virgatosphinctes*) in some layers testifies to neritic conditions during Late Jurassic time. The depth of this basin did not exceed 100–150 meters and in some periods conditions became intrashelf to littoral.

The bivalve fauna identified in synchronous deposits at Site 330, Leg 36, is exclusive to the Indo-Pacific Biogeographical Province (Jones and Plafker, 1977). This fact prompted these authors to adopt the paleogeographical scheme suggested by Veevers et al. (1971). According to that reconstruction, the Maurice Ewing Bank, which was possibly the termination of the Falkland Plateau, is a microplate that broke off the Pacific margin of Gondwanaland but did not directly join Africa. However, Barker, Dalziel, et al. (1977), using the data from Leg 36, prefer the reconstruction in which the Falkland Plateau and the Maurice Ewing Bank were both attached directly to the southern termination of Africa. The absence of Tethyan elements in the Late Jurassic–Early Cretaceous fauna of the Plateau in this case, they believe, is due to the fact that the Plateau itself played the role of a barrier to the southward transgression of Tethyan water.

Anaerobic conditions persisted in the basin during the Neocomian after the beginning of seafloor spreading in the South Atlantic. However, during certain periods it had a restricted opening to the ocean, and at those times the bottom was briefly inhabited by heavily impoverished fauna of benthic foraminifers. Tests of the genera living there (*Guttulina*, *Marginulina*, *Astacolus*, *Fronicularia*) are, as a rule, small, transparent, and thin-walled, testifying to oxygen deficiency in the bottom water of the basin. Benthic foraminifers with a similarly stunted appearance can be observed in Recent sediments of the hydrogen-sulfide-rich zones on the shelf of Southwest Africa and of South America (Basov, 1979; Khusid, 1977).

The beginning of spreading corresponded to or was preceded by a rise in the basin floor and a decrease of its depth. As a result, sediment accumulation ceased, previously accumulated sediments were denuded, and there developed the stratigraphic hiatus (Site 511) at the Jurassic/Cretaceous boundary that covers the time interval from the late Tithonian to the early Barremian. Despite the considerable duration of the hiatus (about 15 to 20 m.y.), neither a denudation surface, nor an appreciable change in sediment composition, nor an oxidation surface were observed in the section. This hiatus, probably regional in character, was observed at Site 330 by the participants in Leg 36, who also emphasized the absence of any evident physical features.

Oceanic conditions in the basin were established in the early Albian after final separation of the Falkland Plateau from South Africa and the initiation of a con-

stant water exchange with the Indian Ocean. At the beginning, this relation could occasionally be interrupted or limited, a situation manifested in a periodic impoverishment of benthic foraminifers.

The Albian basin in which calcareous sediments with thin interbeds of black shales at the base accumulated was shallow. The presence of *Uvigerinamina jankoi*, *Dorothia trochoides*, *D. gradata*, *Clavulina gabonica*, *Spirillina elongata*, *S. minima*, *Osangularia utaturiensis*, *Gavelinella intermedia*, *Orithostella australiana*, *O. indica*, *Conorboides minima*, *Patellinella australis*, *Patellina subcretacea*, *Pseudopatellinella* sp., *Anomalinoidea indica*, and *Gyroidinoides primitiva* together with numerous representatives of lagenids suggests, according to the bathymetrical model of benthic foraminifer distribution by Sliter and Baker (1972), conditions of the outer shelf, and probably the upper part of the continental slope. Sliter (1977a) who studied the Cretaceous benthic foraminifers of Leg 36, concluded that the Albian assemblages of the Falkland Plateau characterize depths of 100–400 meters (shelf-break fauna). Study of the Leg 71 benthic foraminifers convincingly confirms this conclusion. The mollusks (*Aucellina* cf. *radiatostriata*, *A.* cf. *andina*) are also peculiar to outer neritic–upper bathyal conditions of sediment accumulation (Jeletzky, this volume).

During the late Albian–early Cenomanian, the depth of the basin increased sharply as a result of a dramatic acceleration of subsidence. By the late Cenomanian the Falkland Plateau was part of an open oceanic basin inhabited only by agglutinated foraminifers (*Rhabdammina* sp., *Glomospira gordialis*, *G. corona*, *Ammodiscus cretaceus*, *A. incertus*, etc.). The absence of calcareous benthic species testifies to the accumulation of sediments below the CCD (Fig. 9). Though the benthic foraminifers are representative of abyssal depths, the depth of the basin in the late Cenomanian hardly exceeded 1000–1500 meters. The high CCD could have been caused by cold bottom currents encroaching periodically from the south (Barker, Dalziel, et al., 1977), possibly from the Pacific Ocean, either through a strait between eastern and western Antarctica or through a strait that may have existed in the Drake Passage area.

Throughout the Turonian undersaturation of bottom water allowed some calcium carbonate to be preserved and resulted in a thin sequence (about 10 m) of zeolitic clays with an impoverished assemblage of agglutinated and resistant calcareous benthic foraminifers. The assemblage consists of *Hyperammia elongata*, *Glomospira corona*, *G. gordialis*, *Ammodiscus cretaceus*, *Valvulineria allomorphinoides*, *Bandyella greatvalleyensis*, and *Pleurostomella obtusa*, which, as in the underlying deposits, lived below or near the CCD.

During the Coniacian–Santonian a gradual lowering of the CCD took place. This is evidenced by the foraminifer assemblages. Units with agglutinated foraminifers (*Hyperammia*, *Glomospira*, *Ammodiscus*, *Haplophragmoides*, *Ammobaculites*), the analogs of which in Recent oceans inhabit lower bathyal and abyssal depths (Saidova, 1976) below the CCD, alternated with units containing resistant *Globorotalites*, *Pleurostomella*, *Val-*

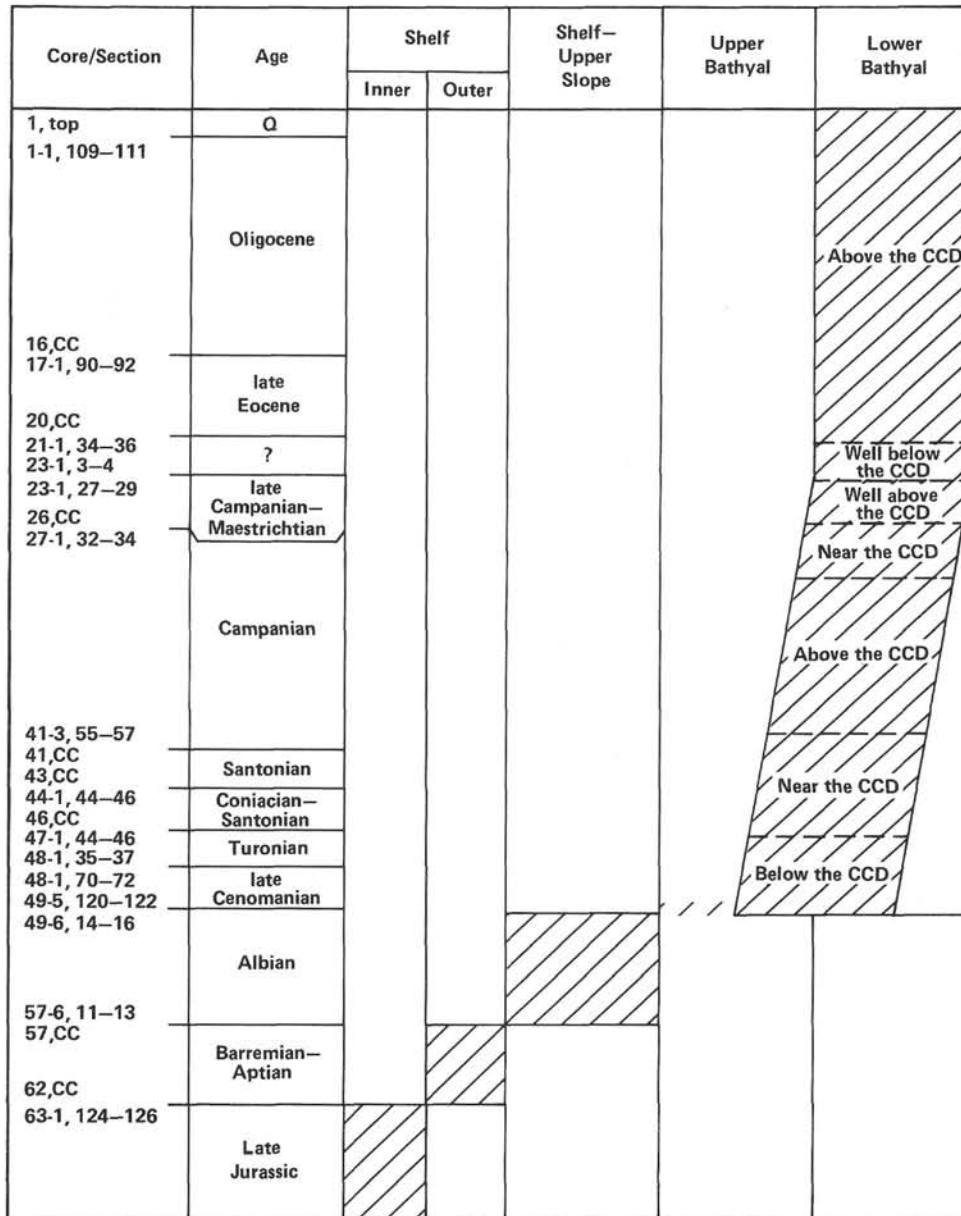


Figure 9. Reconstruction of the process of oceanic subsidence on the Falkland Plateau during Late Jurassic–Cenozoic time, based on benthic foraminifers from Hole 511.

*vulineria*, *Allomorphina*, *Bandyella*, and *Praebulimina*, all peculiar to low bathyal depths (1500–2000 m). The frequent presence of nodosariids (*Dentalina*, *Lenticulina*, *Marginulina*) probably indicates shallower depths, although the possibility of their redeposition from shallower portions of the basin cannot be disregarded. The macrofauna (*Inoceramus* and other pelecypods, solitary corals) also testifies to bathyal conditions of sedimentation and to the probable displacement of sediments and fossils from the shallower depths (Jeletzky, this volume).

A relatively small section of upper Cenomanian, Turonian, Coniacian, and Santonian deposits and their predominantly noncarbonate composition reflect a mid-Cretaceous hiatus in sedimentation, of the global character shown in sections at many DSDP sites by dissolution facies. The nature of this hiatus was discussed in

detail by Sliter (1977a). Sliter considers changes in water mass circulation caused by a general tectonic reconstruction of the Indian and Atlantic ocean basins to be one of the possible reasons for its global extent. This is the period when, as a result of the northward drift of India and Africa, the precursor of the circum-Antarctic current may have originated. This event could have led to a general lowering of temperature in the South Atlantic and a decrease in the productivity of calcareous plankton in surface water. Decreased productivity could result in a rise in the CCD, followed by the accumulation of carbonate-free clays with agglutinated and resistant calcareous species of benthic foraminifers. Thus the alternation in a section of horizons of pelagic sediments containing assemblages of agglutinated or calcareous foraminiferal species, respectively, may be explained in

one of two ways. It is caused either by variation in the productivity of calcareous zoo- and phytoplankton in surface water or by changes in the extent to which bottom water is likely to affect calcium carbonate dissolution—changes connected to patterns of circulation of deep water masses. It is hardly possible, although very tempting, to explain these variations by tectonic movements, as it is difficult to imagine such frequent changes in the direction and amplitude of movement in a relatively short geological time.

The CCD curve in the South Atlantic during the Mesozoic and Cenozoic shows that the CCD in the mid-Cretaceous (95–80 Ma) was at a depth of about 3 km (van Andel et al., 1977). In the high latitudes of the South Atlantic Ocean the CCD was likely to be at lesser depths. In addition, van Andel et al. (1977) note that the calcareous sediments at Site 361 that enabled them to determine the position of the CCD 100 Ma could have been shifted from shallower depths. In this case their figure of 2.9 km for the CCD at the Early/Late Cretaceous boundary is overstated.

Sediment accumulation below or near the CCD level on the Falkland Plateau continued until the end of the Santonian or even the beginning of the Campanian. Indeed, in the lowermost parts of the latter there is a dissolution facies with a peculiar fauna of agglutinated *Hyperammina elongata*, *H. gaultina*, *Glomospira corona*, *G. gordialis*, *Ammodiscus cretaceus*, and *Rzehakina epigona* and an impoverished assemblage of the calcareous resistant species *Gyroidinoides nitidus*, *Globorotalites michelinianus*, *Osangularia* aff. *compressa*, *Bandyella* sp., and *Ellipsodimorphina subnodosa*.

By the late Campanian the position of the CCD became more or less stable, and sedimentation on the plateau proceeded above this level. In the mid-Campanian the sediments accumulated above but not very far from the CCD, as is evidenced by an impoverished assemblage of carbonate resistant species of foraminifers. In the Maestrichtian the CCD occupied a somewhat lower position, and a nanno-foraminiferal chalk with a rich but monotonous fauna of benthic foraminifers accumulated. At the very top of the Campanian there was a small decline in the CCD and a dissolution facies with agglutinated foraminifers appeared.

Many species of foraminifers are observed throughout almost the entire section. Thus, despite the variations of the CCD level during the Late Cretaceous, the depth of the basin appeared to change only slightly—from 1000–1500 meters in the Cenomanian to 1500–2000 meters in the Campanian–Maestrichtian.

### The Paleogene

The Cretaceous/Paleogene boundary within the Plateau is marked by a sequence of zeolitic clays (dissolution facies) that corresponds to a global hiatus in sediment accumulation seen in most of the DSDP sites that penetrated this boundary. Accumulation of zeolitic clays proceeded at levels much lower than the CCD, and these clays are completely devoid of foraminifers. This hiatus has a different duration even at adjacent sites (Fig. 10). At Site 511 (water depth 2589 m) it continued until the

late Eocene. During that time a thin (18 m) unit of zeolitic clays almost devoid of any fauna accumulated. At Site 330 (water depth 2626 m), situated 10 km from Site 511, Eocene diatom ooze and upper Albian–Cenomanian nannofossil clay are separated by a 20-meter uncored interval. At Site 327 (water depth 2400 m), situated 10 km from Site 330, higher up along the western slope of the Maurice Ewing Bank, the hiatus embraces lower Paleocene sediments. In the late Paleocene and early Eocene an 80-meter sequence of zeolitic clays (dissolution facies) accumulated with minimal amounts of biogenic siliceous and calcareous material, resistant benthic foraminifers, and no planktonic species (Tjalsma, 1977). At Site 329 (water depth 1519 m) drilled higher up the slope (55 km from Site 327), this hiatus probably occupies a still shorter interval. Upper Paleocene and lower Eocene nanno-foraminiferal chalk with rich planktonic and benthic foraminifers accumulated under stable conditions well above the CCD level. An increase in the duration of the hiatus (or in the time the dissolution facies accumulated) at various sites down the slope appears to result from the gradual diminution of an intense bottom current impinging at that time on the Maurice Ewing Bank from the west or from the confinement of the current to greater depths.

During the middle Eocene (Site 512) nannoplanktonic oozes rich in radiolarians and diatoms accumulated on the Plateau. The quantity of siliceous microorganisms gradually increased upsection, illustrating the global cooling tendency during this time and the evolution of currents in the South Atlantic. Barker and Burrell (1977) believe that the opening of the Drake Passage considerably affected the formation of the circum-Antarctic current, one consequence of which was the irreversible deterioration of climate in the Southern Hemisphere which took place about 29 Ma. This coincides with the ages for the existence of the Antarctic ice sheet (25 m.y.) (Hayes, Frakes, et al., 1973). However, there are convincing data showing that the circum-Antarctic current could have existed much earlier than the opening of the Passage. Presence of a large hiatus in sediment accumulation on the western slope of the Maurice Ewing Bank (Sites 327, 329, 330, and 511) in pre-Oligocene time is one such piece of evidence.

Barker and Burrell (1977) note that before the opening of the Drake Passage a narrow shallow-water passage could have existed between South America and Antarctica (less than 50 km wide and 1000 m deep), through which Pacific Ocean water could have penetrated into the South Atlantic, ending sedimentation or causing erosion of sediments. The almost complete absence of Paleogene deposits at Site 323 in the Bellingshausen Sea to the west of the Drake Passage may also be related to the existence of this passage (Weaver et al., 1976). If so, the enrichment of Eocene and Oligocene sediments with radiolarians and diatoms on the Maurice Ewing Bank is due to the intensification of currents and increase in productivity of siliceous plankton as a result of cooling that began in the Southern Hemisphere. The species diversity of benthic foraminifers in Eocene sediments (10–15 species per sample) is much lower than in



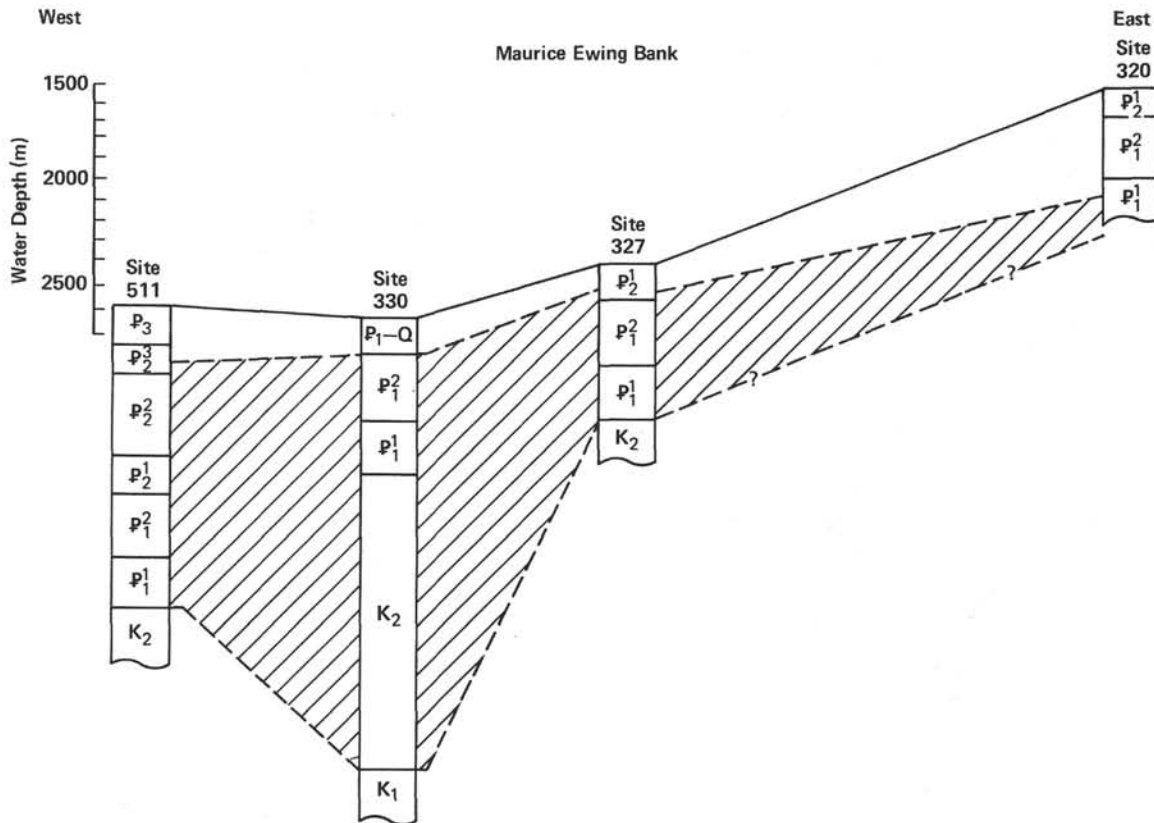


Figure 10. Durations of hiatuses or periods of dissolution facies accumulation on the Falkland Plateau at the Cretaceous/Paleogene boundary. (Duration scale, 5 m.y. = 1 cm. K<sub>2</sub>, Upper Cretaceous; K<sub>1</sub>, Lower Cretaceous; P<sub>1</sub>, Paleocene; P<sub>2</sub>, Eocene; P<sub>3</sub>, Oligocene; P<sub>2</sub><sup>2</sup>, middle Eocene, etc.; Q, Quaternary.)

the Maestrichtian (25 species). Boersma and Shackleton (1977) note that species diversity can be one of the indicators of the bottom water temperature. Proceeding from this, we can assume that in the Eocene the temperature was lower than during the Cretaceous. This agrees well with the presence in the Upper Cretaceous—though in small amounts—of relatively warm water, double-keeled *Globotruncana* and, correspondingly, with the absence of keeled forms of *Globorotalia* in the upper Paleocene and Eocene oozes.

Beginning in the late Eocene, the siliceous radiolarian-diatomaceous oozes drilled by Sites 511 and 512 accumulated on the Falkland Plateau. At the same time the carbonate plankton contributed significant amounts to upper Eocene sediment accumulation, testifying to the formation of the Antarctic ice cover and the possible establishment of a Circumpolar Current. Benthic foraminifers in the middle-upper Eocene sediments of the Falkland Plateau abound in rotaliids—the genera *Pullenia*, *Anomalinoides*, *Heterolepa*, *Nonion*, *Gyroidina*, and *Cibicidoides*. Buliminids are an essential component of this assemblage as well. This microfauna, together with the high carbonate content of the sediments and the well-preserved planktonic and benthic species, indicates sediment accumulation at lower bathyal depths and a low position of the CCD.

Lower Oligocene sediments of the Plateau (Site 511) are characterized by a foraminiferal assemblage that differs considerably from the Eocene association, de-

spite many common species. Some species on the Plateau were identified in Eocene deposits only, and are missing in the Oligocene: *Vulvulina haeringensis*, *Alabamina dissonata*, *Pullenia riveroi*, *Gyroidina globosa*, *Planulina ammophila*, *Osangularia pteromphalia*, *Gavelinella micra*, *Oridorsalis ecuadorensis*, *Bulimina jarvisi*, *B. alazanensis*, and *Pleurostomella torta*. Many species, on the contrary, appear for the first time in the Oligocene at Site 511 (*Bolivinoidea cubensis*, *Laticarinina pauperata*, *Pullenia bulloides*, *P. osloensis*, *Chilostomella czjzeki*, *Alabaminoides exiguus*, and others).

The species diversity of benthic foraminifers in the lower Oligocene oozes (5–10 species per sample, on the average) decreases compared to the Eocene ones, evidently reflecting a further deterioration of climate in the South Atlantic that was responsible for the rise in productivity of siliceous plankton.

#### The Neogene-Quaternary

During the late Oligocene the western portion of the Maurice Ewing Bank probably began to be affected by a strongly flowing branch of the Circumpolar Current; from then until the present, sediment accumulation there has ceased. The gap in sedimentation embraces almost the whole Cenozoic; sedimentation began again in the latest Pliocene and Quaternary only. On the eastern Maurice Ewing Bank at Site 512 nondeposition is recorded even earlier, at the end of the middle Eocene or at the beginning of the late Eocene. During the middle-



late Miocene, however, a sequence of radiolarian–diatomaceous oozes accumulated in the Site 512 area. These deposits contain a benthic foraminiferal assemblage of about 30 species. Most representative are *Karreriella bradyi*, *Eggerella bradyi*, *Pyrgo murrhina*, *Pullenia bulloides*, *P. quinqueloba*, *Melonis affinis*, *Cibicidoides kulenbergi*, *Oridorsalis umbonatus*, *Gyroidina soldanii*, *Sphaeroidina bulloides*, *Bulimina inflata*, *Angulogerina esuriens*, and *Bradynella subglobosa*. They almost all occur in Recent sediments and have been described from the Neogene of the Indian (Boltovskoy, 1978), Atlantic (Berggren, 1972), and Pacific (Douglas, 1973) oceans. Most of these species are resistant; they characterize the lower bathyal–upper abyssal depths (Saidova, 1976).

The depth of the ocean over the Plateau during Miocene time apparently did not exceed 2 km. Therefore, the presence of deep-water resistant species in a foraminiferal assemblage testifies to a relatively high level of the CCD in the middle–late Miocene, an assumption that is in accordance with Berger's (1972) data from the South Atlantic.

The oldest sediments drilled in the Argentine Basin are the Oligocene radiolarian–diatomaceous oozes recovered by Site 513. Though benthic foraminifera in Cenozoic sediments of the Argentine Basin (Sites 513 and 514) consist of deep-water species throughout the section, their presence, in conjunction with the composition of the sediments, demonstrates the process of oceanic subsidence. In Oligocene–lower Miocene siliceous oozes enriched with CaCO<sub>3</sub> (Site 513) species composition of benthic foraminifera is relatively rich. Predominant among these species are *Karreriella* sp., *Bolivinoidea cubensis*, *Oridorsalis umbonatus*, *Anomalinoidea spissiformis*, *Gyroidina girardana*, *G. soldanii*, *Astrononion pusillum*, *Laticarinina pauperata*, *Pullenia subcarinata*, *Cibicidoides floridanus*, *Stilostomella bradyi*, and *S. nuttalli*, which indicate lower bathyal conditions of sediment accumulation (2000–3000 m). Higher up the section in Neogene–Quaternary oozes at Site 513 the composition of benthic foraminifera becomes considerably impoverished; agglutinated foraminifera such as *Martinottiella antarctica*, *Eggerella bradyi*, and *Spirolocamina exigua* are most widely distributed. All are peculiar to lower bathyal–upper abyssal depths (3000–4000 m).

In Pliocene–Quaternary sediments at Site 514 the foraminiferal assemblage is richer and contains calcareous forms along with the agglutinated species mentioned. Nevertheless, it has the appearance of a deep-water assemblage, compared to the Oligocene–early Miocene assemblage at Site 513. First, here as in the Neogene of Site 513 agglutinated forms prevail; second, the available calcareous foraminifera (*Pyrgo*, *Pullenia*, *Melonis*, *Alabaminella*, *Alabaminoides*, *Sphaeroidina*, and *Smyrnelia*) are deep-water, resistant, and indicative of lower bathyal and upper abyssal depths.

The influence of oceanic subsidence on the composition of benthic foraminifera in this study area is complicated by parallel effects induced by the geographical northward migration of the Polar Front and its fluctuations during the late Cenozoic as a result of expansion of the Antarctic ice sheet. This effect is especially obvi-

ous in the Pliocene–Pleistocene sediments of Sites 513 and 514, where among monotonous siliceous oozes with a poor fauna of agglutinated foraminifera there occur horizons of the same oozes, somewhat enriched with CaCO<sub>3</sub> and with a relatively diverse assemblage of benthic foraminifera that consists mostly of calcareous species. These horizons correspond with the most southerly positions of the Polar Front. At such times the productivity of calcareous plankton in the surface water of the regions around Sites 513 and 514 increased and the carbonate lysocline level dropped.

On the whole, the distribution of foraminifera in Cenozoic sediments reflects both the gradual cooling in the South Atlantic that is linked to the formation of the circum-Antarctic current and the Antarctic ice sheet and the migrations of the Antarctic convergence zone.

#### SYSTEMATIC PALEONTOLOGY

This section contains comments on selected species of Cretaceous and Cenozoic benthic foraminifera; it includes data on their morphology, frequency, preservation, stratigraphic range, and paleobiogeographic distribution, among other aspects.

More than 400 species of benthic foraminifera were found in the Mesozoic and Cenozoic deposits drilled by Leg 71 sites. Nearly 100 of them are encountered in Albian, about 200 in Upper Cretaceous, and more than 100 in Cenozoic sediments.

Brief descriptions of the characteristics of many benthic foraminifera widely distributed in the Mesozoic and Cenozoic sediments of Leg 71 Sites are given hereafter. For some well-known species only stratigraphic ranges are noted. Some of the mainly Mesozoic species, though met in separate samples, are very important stratigraphically and ecologically and are described here as well. Finally, several species are mentioned under open nomenclature; they are interesting for stratigraphy but their exact determination needs further study.

Despite many investigations of benthic foraminifera, their systematics and diagnostics are not well clarified, and the reports of DSDP sites have sometimes lacked proper descriptions and illustrations. Despite the need for them, detailed studies carried out with modern knowledge and techniques of foraminiferal research and with complete descriptions and SEM illustrations are comparatively rare. This makes the species determination difficult and a comparison of assemblages from synchronous deposits of various regions often impossible.

Limitations of space and time made impossible a detailed analysis of all benthic foraminifera found in Leg 71 samples, as well as a revision of their taxonomic position, which should be carefully investigated in the future.

Descriptions of taxa follow in taxonomic order, but illustrations are given in stratigraphic order (Lower Cretaceous, Upper Cretaceous, Paleogene, Neogene–Quaternary).

#### Family HYPERAMMINIDAE

##### Genus *HYPERAMMINA* Brady, 1878

##### *Hyperammina elongata* Brady (Plate 4, Fig. 9)

*Hyperammina elongata* Brady, 1878, p. 433, pl. 20, fig. 2.

Very variable, long-ranging species, characteristic of dissolution facies of Upper Cretaceous (Turonian–lowermost Campanian) at Site 511.

#### Family AMMODISCIDAE

##### Genus *GLOMOSPIRA* Rzehak, 1888

##### *Glomospira corona* Cushman and Jarvis (Plate 4, Fig. 10; Plate 5, Fig. 1)

*Glomospira charoides* var. *corona* Cushman, 1946, p. 19, pl. 2, figs. 1–3.

Easily recognized by tight regularly coiled initial part of test and irregularly coiled later part. Widely distributed throughout the world. Very typical of the dissolution facies in the Cretaceous (Albian–Campanian), Site 511.

*Glomospira gordialis* (Jones and Parker)  
(Plate 5, Fig. 2)

*Glomospira gordialis* Cushman, 1946, p. 18, pl. 1, figs. 38–40.

May be recognized by an irregularly coiled test with an almost planispiral plane of coiling. Cosmopolitan, long-ranging species typical of the dissolution facies of the Upper Cretaceous at Site 511.

**Genus AMMODISCUS Reuss, 1861**  
*Ammodiscus glabratus* Cushman and Jarvis  
(Plate 5, Fig. 4)

*Ammodiscus glabratus* Cushman and Jarvis, 1928, p. 86, pl. 12, fig. 6.

Specimens here are close to those described and illustrated by Cushman and Jarvis from the Upper Cretaceous of Trinidad but differ slightly in more involute coiling of the whorls. Found in the Coniacian–Santonian at Site 511.

*Ammodiscus cretaceus* (Reuss)  
(Plate 5, Fig. 3)

*Ammodiscus cretaceus* Cushman, 1946, p. 17, pl. 1, fig. 35.

Specimens here correspond well to Cushman's description. Recorded from the Cretaceous in Europe, the Upper Cretaceous in North America, and the Cretaceous of the southwestern Atlantic. Common in Upper Cretaceous at Site 511.

**Family LITUOLIDAE**  
**Genus HAPLOPHRAGMOIDES Cushman, 1910**

*Haplophragmoides bulloides* (Beissel)  
(Plate 5, Fig. 5)

*Haplophragmium bulloides* Beissel, 1891, p. 17, pl. 2, figs. 1–3; pl. 4, figs. 24–30.

Specimens here are close to those described and illustrated by Krasheninnikov (1974) from the Upper Cretaceous deep-water sediments at DSDP Sites 260 and 261, Argo and Gascoyne Abyssal Plains, Indian Ocean. Encountered in the dissolution facies of the Coniacian–Santonian at Site 511.

*Haplophragmoides calcula* Cushman and Waters  
(Plate 5, Fig. 7)

*Haplophragmoides calcula* Cushman, 1946, p. 19, pl. 2, fig. 11, 12.

May be distinguished by a very coarsely arenaceous test, closely coiled and strongly compressed, with slightly lobulate periphery and indistinct chambers and sutures. Common in Upper Cretaceous sediments of western North America. Rare specimens are present in dissolution facies of the Upper Cretaceous at Site 511.

*Haplophragmoides* sp.  
(Plate 5, Fig. 6)

Test planispiral, involute, strongly compressed, and biumbilical, with subacute periphery. Has 5 chambers in last whorl, enlarging gradually. Sutures distinctly depressed, gently curved. Aperture a low interiomarginal arch. Maximum diameter 0.25 mm, thickness 0.07 mm. Present specimens appear to be similar to those described by Sliter (1968) as *Haplophragmoides* sp. cf. *H. famosus* Takayanagi from the Campanian–Maestrichtian of California, but they differ in being completely involute. Very typical of dissolution facies of Upper Cretaceous at Site 511.

**Genus RECURVOIDES Earland, 1934**

*Recurvoides* sp.  
(Plate 5, Fig. 8)

Test free, small, agglutinated, oval in shape with rounded periphery and depressed sides. Has 5–6 chambers in last whorl, low, enlarging gradually as added, every succeeding chamber located at an angle to the preceding one, forming a streptospiral coiling. Wall is composed of relatively large mineral grains protruding above the test surface. Sutures indistinct, flat. Aperture areal, broad, and short, slit on slightly convex apertural face. Diameter 0.5 mm, thickness 0.3 mm. Rare specimens are characteristic of the Site 511 Coniacian–Santonian dissolution facies.

**Genus AMMOBACULITES Cushman, 1910**

*Ammobaculites* sp.  
(Plate 5, Fig. 9)

Test free, small, agglutinated, elongated, with planispiral, depressed initial part; it is uncoiled, uniserial, cylindrical in adult stage. In coiled part has 4–5 chambers, triangular in shape, enlarging very gradually, and in uniserial part has 2–3 uniform, spherical ones. Wall composed of middle-sized mineral grains forming rough, uneven surface. Sutures distinct, slightly and widely depressed. Aperture terminal, rounded. Diameter of coiled part 0.2 mm, diameter of uniserial part 0.15 mm, length 0.35 mm. Rare specimens characteristic of the Site 511 Coniacian–Santonian dissolution facies.

**Family RZEHAKINIDAE**  
**Genus SPIROLOCAMMINA Earland, 1934**

*Spirolocammina exigua* Burmistrova  
(Plate 12, Fig. 1)

*Spirolocammina exigua* Burmistrova, 1978, p. 169, pl. 28, fig. 5.

This species with small, elongated, fragile, siliceous test is described from Pliocene sediments of Stations 4599 and 5315 *Vitjaz*, Indian Ocean. Specimens here identical to those from the Indian Ocean. Present rarely but constantly in Oligocene–Pliocene sediments at Sites 513 and 514.

**Family TEXTULARIIDAE**  
**Genus SPIROPLECTAMMINA Cushman, 1927**

*Spiroplectammina semicomplanata* (Carsey)  
(Plate 5, Fig. 10)

*Textularia semicomplanata* Carsey, 1926, p. 28, pl. 3, fig. 4.

Specimens encountered in the Campanian–Maestrichtian at Site 511 are similar to those originally described from the Navarro and Taylor formations, the Cretaceous of North America.

**Genus VULVULINA d'Orbigny, 1826**

*Vulvulina haeringensis* (Guembel)  
(Plate 12, Fig. 3)

*Venilina haeringensis* Guembel, 1868, p. 649, pl. 2, fig. 84.

Recorded in the middle Eocene–Oligocene sediments of Sites 360, 362, and 363, southeast Atlantic. In Leg 71 material found only in the middle Eocene at Site 512.

**Genus BOLIVINOPSIS Yakovlev, 1890**

*Bolivinopsis cubensis* (Cushman and Bermudez)  
(Plate 12, Fig. 2)

*Spiroplectoides cubensis* Cushman and Bermudez, 1937, p. 13, pl. 1, figs. 44–46.

Test elongate, with tightly coiled initial portion, later rectilinear and biserial. Chambers low, distinct, enlarging gradually. Sutures distinct, oblique in initial part and horizontal, parallel, depressed in rectilinear part. Length 0.65 mm, width 0.15 mm, thickness 0.1 mm. Described from the Eocene of Cuba. Rather common in the Oligocene–middle Miocene deep-water sediments at Site 513, rare in the Oligocene at Site 511.

**Family ATAXOPHRAGMIIDAE**  
**Genus GAUDRYINA d'Orbigny, 1839**

*Gaudryina dividens* Grabert  
(Plate 1, Fig. 3)

*Gaudryina dividens* Grabert, 1959, p. 9–11, pl. 1, fig. 35; pl. 2, figs. 16–30.

Encountered in the lower part of the Site 511 Albian section.

**Genus UVIGERINAMMINA Majzon, 1943**

*Uvigerinamina jankoi* Majzon  
(Plate 1, Fig. 8)

*Uvigerinamina jankoi* Majzon, 1943, p. 158, pl. 11, fig. 15.

Test trochoid, fusiformed, slightly compressed with three chambers in whorl rapidly enlarging in size. Aperture terminal, simple and

rounded in shape, and located on short thick neck. Length 1.0 mm, thickness 0.5 mm, width 0.6 mm. Described from the Upper Cretaceous of Western Europe and DSDP Sites 327 and 330, Falkland Plateau (Sliter, 1976), 367 and 368, Cape Verde Basin (Krasheninnikov and Pflaumann, 1978). Encountered in the upper part of the Albian at Site 511.

**Genus CLAVULINA d'Orbigny, 1826**

*Clavulina gabonica* Le Calvez, de Klasz, and Brun  
(Plate 1, Figs. 1-2)

*Clavulina gabonica* Le Calvez, de Klasz, and Brun, 1971, p. 308, pl. 1, figs. 7, 9.

Rather common species in the Albian sediments at Site 511.

**Genus EGGERELLA Cushman, 1933**

*Eggerella* sp.  
(Plate 16, Figs. 1-2)

Test arenaceous, small, conical, and triserial with distinct, inflated, closely arranged chambers. Sutures distinct, flush. Aperture a small, interiomarginal, archlike slit at the base of final chamber. Height 0.4 mm, diameter 0.4 mm. This deep-water species is recorded from Oligocene to Recent sediments at Sites 513 and 514.

**Genus DOROTHIA Plummer, 1931**

*Dorothia trochoides* (Marsson)  
(Plate 1, Fig. 7)

*Gaudryina crassa* Marsson var. *trochoides* Marsson, 1878, p. 158, pl. 3, fig. 27.

Holotype illustration of this species shows 3 chambers in the last whorl—a feature which differs slightly from our specimens. It is quite possible that a specimen illustrated by Marsson represents the initial portion of a test. Rather common in the Albian at Site 511.

*Dorothia gradata* (Berthelin)  
(Plate 1, Figs. 4-6)

*Gaudryina gradata* Berthelin, 1880, p. 24, pl. 1, fig. 6.

Agglutinated test, rapidly widening as it grows, with distinct chambers trochoidally arranged in initial part, later ones biserially arranged, rapidly enlarging as added. Sutures distinct, broadly depressed. Aperture archlike, at the base of the last chamber. Length 0.5 mm, width 0.4 mm, thickness 0.3 mm. Originally described from the Albian of France. Encountered in the Albian at Site 511.

**Genus KARRERIELLA Cushman, 1933**

*Karrerella bradyi* (Cushman)  
(Plate 16, Fig. 3)

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

This cosmopolitan, deep-water species can be recognized by its arenaceous test, initially triserial, later biserial. As many authors have noted, however, immature specimens might be confused with *Eggerella bradyi*. Common in the lower-middle Miocene at Site 512 and rare in the Pliocene at Sites 513 and 514.

*Karrerella subglabra* (Guembel)  
(Plate 12, Fig. 4)

*Gaudryina subglabra* Guembel, 1868, p. 602, pl. 1, fig. 4.

This species differs from *Karrerella bradyi* (Cushman) by having a smaller test, with chambers arranged more compactly and a smoother surface. Commonly present in the middle Eocene at Site 512 and rare in the Oligocene at Site 511 and Oligocene-lower Miocene at Site 513.

**Genus MARTINOTTIELLA Cushman, 1933**

*Martinottiella antarctica* (Parr)  
(Plate 16, Figs. 4-5)

*Schenckiella antarctica* Parr, 1950, p. 284, pl. 5, fig. 27.

Well-known and widely distributed Neogene-Quaternary species of the high latitudes. Constantly present in Oligocene to Recent deep-water sediments at Leg 71 sites.

*Martinottiella occidentalis* Cushman  
(Plate 16, Fig. 6)

*Martinottiella occidentalis* Cushman, 1922, p. 87, pl. 17, figs. 1-2.

Tests are characterized by a small triserial section and very long uniserial one. Present in the Pliocene at Sites 513 and 514.

*Martinottiella* sp.  
(Plate 16, Fig. 7)

Distinguished by a large triserial section and a very short uniserial one. Rather common throughout the Pliocene at Sites 513 and 514.

**Family MILIOLIDAE**  
**Genus PYRGO Defrance, 1824**

*Pyrgo murrhina* (Schwager)  
(Plate 16, Fig. 8)

*Biloculina murrhina* Schwager, 1866, p. 203, pl. 4, fig. 15.

Typical of Recent deep-water sediments. Rarely present in the Pliocene at Sites 513 and 514.

**Family LAGENIDAE**  
**Genus NODOSARIA Lamarck, 1812**

*Nodosaria aspera* Reuss  
(Plate 6, Fig. 1)

*Nodosaria aspera* Reuss, 1845, p. 26, pl. 13, figs. 14-15.

Test elongate, with distinct, inflated, subglobular chambers enlarging uniformly and with distinct, horizontal, depressed sutures. Aperture terminal, at the end of slender, elongate, cylindrical neck. Length 0.7 mm, diameter 0.25 mm. Reported from the Cretaceous in Europe and North America. Rare specimens present throughout the middle part of the Upper Cretaceous at Site 511.

*Nodosaria obscura* Reuss  
(Plate 1, Fig. 9)

*Nodosaria obscura* Reuss, 1845, p. 26, pl. 13, figs. 7-9.

Test free, elongate, rectilinear, polygonal in cross section. Chambers inflated, each overlapping the preceding one. Sutures distinct, horizontal, depressed. Test smooth, with six transparent ribs extending from the aperture to the initial chamber. Aperture terminal, radiate. Length 1.2 mm, diameter 0.3 mm. Described throughout the world in Cretaceous sediments. Rare specimens found in Site 511 Albian sediments.

**Genus LINGULINA d'Orbigny, 1826**

*Lingulina loryi* (Berthelin)  
(Plate 1, Fig. 10)

*Frondicularia loryi* Berthelin, 1880, p. 60, pl. 4, fig. 5.

Test free, elongate, widely tapering, uniserial, wedgelike. Succeeding chambers strongly overlap preceding ones. Sutures slightly depressed, archlike, curved. Aperture a terminal slit extending along compression line. Length 0.25 mm, width 0.1 mm. Very rare specimens found in the lower Albian at Site 511.

*Lingulina nodosaria* Reuss  
(Plate 1, Figs. 11-12)

*Lingulina nodosaria* Reuss, 1863, p. 59, pl. 5, fig. 12.

Test free, elongate, slightly compressed, uniserial, tapering down, with short spine. Test consists of 6 chambers slowly increasing in size. Sutures widely depressed, horizontal. Aperture a terminal slit. Length 0.3 mm, width 0.1 mm. Rare in Albian sediments at Site 511.

**Genus FRONDICULARIA Defrance, 1826**

*Frondicularia mucronata* Reuss  
(Plate 6, Fig. 2)

*Frondicularia mucronata* Reuss, 1845, p. 31, pl. 13, figs. 43-44.

Characteristic features are an elongate, flattened test with a long proloculum bearing a central ridge, basal spine, deeply embracing chambers, and distinct sutures. Length 0.9 mm, width 0.35 mm. De-



scribed from the Turonian to the Maestrichtian in Europe, North America, and Australia (Cushman, 1946; Belford, 1960; Sliter, 1968). Rare specimens present sporadically in Site 511 Campanian sediments.

**Genus TRIBRACHIA Schubert, 1912**

*Tribrachia australiana* Ludbrook  
(Plate 2, Fig. 1)

*Tribrachia australiana* Ludbrook, 1966, p. 128, pl. 10, fig. 6.

Test free, medium in size, elongated, tapering downward, triangular in cross-section, uniserial. Chambers trilobate, low, each overlapping preceding one, with ends hanging down. Sutures distinct, depressed, archlike. Aperture terminal, radiate. Length 0.6 mm, diameter 0.3 mm. This rare species was described from the upper Albian sediments of DSDP Site 259, the Indian Ocean (Scheibnerová, 1974), the lower-middle Albian of the South Atlantic (Sliter, 1977a), and Albian sediments of the southeastern Atlantic (Scheibnerová, 1978). Middle part of the Site 511 Albian section.

**Genus CHRYSALOGONIUM Schubert, 1907**

*Chrysalogonium longicostatum* Cushman and Jarvis  
(Plate 12, Fig. 5)

*Chrysalogonium longicostatum* Cushman and Jarvis, 1934, p. 74, pl. 10, fig. 12.

Distinguished from the similar *Chrysalogonium tenuicostatum* by fewer ribs on the test surface. Found in the middle Eocene at Site 512 and upper Eocene at Site 511.

*Chrysalogonium tenuicostatum* Cushman and Bermudez  
(Plate 12, Figs. 6-8)

*Chrysalogonium tenuicostatum* Cushman and Bermudez, 1936, pl. 5, figs. 3-5.

Characterized by elongate test covered with fine ribs extending along the whole surface and also by terminal sievelike aperture. Ranges from the middle Eocene at Site 512 to the Oligocene-lower Miocene at Sites 511 and 513.

**Genus ORTHOMORPHINA Stainforth, 1956**

*Orthomorphina rohri* (Cushman and Stainforth)  
(Plate 12, Fig. 9)

*Nodogenerina rohri* Cushman and Stainforth, 1945, p. 39, pl. 1, fig. 26.

Test elongate, uniserial with distinct inflated chambers, deeply depressed sutures, and terminal, rounded aperture encircled by low rim. Length 0.6 mm, diameter 0.15 mm. This cosmopolitan species was originally described from the Ciperó Marl Formation (Oligocene) of Trinidad. Encountered frequently in the middle Eocene at Site 512 and rarely in the Oligocene at Sites 511 and 513.

**Genus ASTACOLUS Montfort, 1808**

*Astacolus crepidularis* (Roemer)  
(Plate 2, Fig. 2)

*Planularia crepidularis* Roemer, 1842, p. 273, pl. 7B, fig. 4.

Test free, elongate, flat with parallel sides. Chambers low, broad, situated in a fanlike arrangement. Sutures widely depressed, curved. Aperture terminal, radiate. Length 0.5 mm, width 0.2 mm, thickness 0.1 mm. Our specimens are almost identical to those illustrated by Sliter (1980) from the Neocomian of the eastern North Atlantic, Site 416, Leg 50, but have fewer chambers. Rare specimens were encountered in the middle part of the Site 511 Albian section.

*Astacolus jarvisi* (Cushman)  
(Plate 6, Fig. 3)

*Marginulina jarvisi* Cushman, 1946, p. 63, pl. 22, figs. 18-20.

Test elongate, arcuate, compressed, initial portion coiled, later one uncoiling. Chambers increasing rapidly in size as added. Sutures distinct, oblique, slightly curved. Aperture terminal, radiate. Length 0.65 mm, width 0.15 mm, thickness 0.1 mm. Very typical of the Upper Cretaceous and lower Tertiary of Trinidad and California. Common in the Upper Cretaceous at Site 511.

**Genus MARGINULINOPSIS Silvestri, 1904**

*Marginulinopsis juncea* (Cushman)  
(Plate 6, Fig. 4)

*Marginulina juncea* Cushman, 1946, p. 59, pl. 20, fig. 24.

Test very elongate, slender, with coiled relatively small initial portion, later rectilinear, curved. Chambers distinct, elongate, inflated in rectilinear part, small and compressed in coiled part. Sutures widely depressed only between last 4-5 chambers of uncoiled part. Aperture terminal, radiate. Length 0.9 mm, diameter 0.1 mm. Characteristic of Upper Cretaceous sediments of western and northern parts of the U.S.A. Rare specimens found in the middle part of the Upper Cretaceous at Site 511.

*Marginulinopsis stephensoni* (Cushman)  
(Plate 6, Fig. 5)

*Marginulina stephensoni* Cushman, 1946, p. 59, pl. 20, figs. 25-26.

Test elongate, with coiled initial part, later uncoiled, rectilinear. Chambers compressed in coiled part and inflated in rectilinear portion, enlarging slowly as added. Sutures distinct, widely depressed only in rectilinear part. Aperture terminal, radiate. Length 0.6 mm, diameter of initial coiled part 0.15 mm, width 0.1 mm. Originally described from the Upper Cretaceous of North America. Rather common in the Upper Cretaceous (Cenomanian-Santonian) sediments of Site 511.

*Marginulinopsis texaensis* (Cushman)  
(Plate 6, Fig. 6)

*Marginulina texaensis* Cushman, 1946, p. 61, pl. 21, figs. 21-29, 38, 40.

Present specimens are close to those described by Cushman (1946) from the Upper Cretaceous of the Gulf Coast region, North America, and found throughout the Coniacian-Maestrichtian part of Site 511.

**Genus MARGINULINA d'Orbigny, 1826**

*Marginulina bullata* Reuss  
(Plate 6, Fig. 7)

*Marginulina bullata* Reuss, 1845, p. 29, pl. 13, figs. 34-38.

Recognized by its slightly arcuate test with semicoiled initial part, by strongly inflated chambers, and by aperture with protuberant, cylindrical neck. Described from the Cretaceous of Europe and the Upper Cretaceous of North America. Found in the Campanian-Maestrichtian at Site 511.

**Genus DENTALINA d'Orbigny, 1839**

*Dentalina catenula* Reuss  
(Plate 6, Fig. 8)

*Dentalina catenula* Reuss, 1860, p. 185, pl. 3, fig. 6.

Test elongate, tapering, usually two-chambered, initial end with spine. Chambers uniform in size and shape. Suture distinct, strongly depressed. Aperture terminal, radiate. Length 0.7 mm, diameter 0.3 mm. Described from the Upper Cretaceous of Western Europe and North America. Found in the Coniacian-Maestrichtian at Site 511.

*Dentalina cylindroides* Reuss  
(Plate 6, Fig. 9)

*Dentalina cylindroides* Reuss, 1860, p. 185, pl. 1, fig. 8.

Test elongate, usually two-chambered. Chambers fusiform, the last a little overlapping the first one. Sutures distinct, horizontal, strongly depressed. Aperture terminal, radiate. Length 0.5 mm, width 0.15 mm. Described from Upper Cretaceous sediments of Europe, Australia, and many DSDP sites. Rare specimens found throughout the Upper Cretaceous at Site 511.

*Dentalina legumen* Reuss  
(Plate 6, Fig. 10)

*Dentalina legumen* Cushman, 1946, p. 65, pl. 23, figs. 1-2.

Specimens are similar to those described from the Upper Cretaceous of western North America by Cushman (1946), who stressed the variability of this cosmopolitan species. Common throughout the Upper Cretaceous at Site 511.

*Dentalina debilis* (Berthelin)

(Plate 2, Fig. 3)

*Marginulina debilis* Berthelin, 1880, p. 35, pl. 3, fig. 28.

Test free, elongate, medium-sized, uniserial. Chambers arranged along slightly arched axes, each strongly overlapping preceding one; sutures strongly oblique, widely depressed. Aperture terminal, radiate. Length 0.6 mm, width 0.3 mm. Specimens from Leg 71 material are similar to those encountered by Sliter (1980) in the Morocco Basin (Valanginian). Rare specimens in the middle Albian of Site 511.

## Family POLYMORPHINIDAE

## Genus GLOBULINA d'Orbigny, 1839

*Globulina lacrima* Reuss

(Plate 6, Fig. 11)

*Globulina lacrima* Reuss, 1851, p. 27, pl. 4, fig. 9.

Test subglobular, droplike in shape, semitransparent, with a few chambers and indistinct flush sutures. Surface covered by small spines, resembling *G. lacrima* var. *horrida* (Cushman, 1946). This cosmopolitan species is widely recorded from the Upper Cretaceous of Europe and North America and from Campanian sediments at DSDP Site 357, Atlantic Ocean. Common in the Campanian sediments at Site 511.

## Genus PYRULINA d'Orbigny, 1839

*Pyrulina cylindroides* (Roemer)

(Plate 7, Fig. 1)

*Pyrulina cylindroides* Cushman, 1946, p. 97, pl. 40, figs. 18-19.

Test elongate, tapering toward both ends, fusiform, biserial. Chambers elongate, much embracing. Sutures strongly oblique, flush, sometimes depressed. Aperture terminal, radiate. Length 0.85 mm, diameter 0.25 mm. Recorded from Europe and North America. Rare specimens in the Campanian at Site 511.

## Genus RAMULINA Jones, 1875

*Ramulina aculeata* (d'Orbigny)

(Plate 7, Fig. 2)

*Dentalina aculeata* (d'Orbigny) Cushman, 1946, p. 67, pl. 26, figs. 17-18.

Closely related to *Ramulina pseudoaculeata* but differs from it by more elongate, fusiform chambers, connected by tubes of larger diameter. Originally described from the Upper Cretaceous of France. Encountered from Campanian to Maestrichtian sediments at Site 511 and more characteristic of the upper part of this interval.

*Ramulina pseudoaculeata* (Olsson)

(Plate 7, Fig. 3)

*Dentalina pseudoaculeata* Olsson, 1960, p. 14, pl. 3, figs. 1-2.

Test consisting of globular chambers with two rounded apertures at open ends of short tubes situated opposite each other, giving chambers an inflated fusiform shape. Surface covered by distinct short spines. Diameter 0.4 mm, length with tubes 0.5 mm. Specimen illustrated is similar to that described by Sliter (1968) from Rosario Formation (Campanian-Maestrichtian), California, but differs slightly in that tubes between chambers are a little shorter. Rare specimens present throughout the Upper Cretaceous of Site 511.

## Genus GLANDULINA d'Orbigny, 1839

*Glandulina laevigata* (d'Orbigny)

(Plate 12, Fig. 10)

*Nodosaria* (*Glandulina*) *laevigata* d'Orbigny, 1826, p. 252, pl. 10, figs. 1-3.

Specimens of this cosmopolitan, widely distributed, Cenozoic species are present in the middle Eocene sediments at Site 512.

## Family DISCORBIDAE

## Genus CONORBINA Brotzen, 1936

*Conorbina marginata* Brotzen

(Plate 7, Figs. 4-5)

*Conorbina marginata* Brotzen, 1936, p. 142, pl. 10, fig. 5, text-figure 50.

Specimens differ slightly from those described by Brotzen (1936) from the lower Senonian of Sweden by more conical test and more rounded periphery. Common from the upper Turonian to the lower Campanian of Site 511.

## Genus VALVULINERIA Cushman, 1926

*Valvulineria allomorphinoides* (Reuss)

(Plate 7, Figs. 6-8)

*Valvulina allomorphinoides* Reuss, 1860, p. 223, pl. 11, fig. 6.

Test free, trochospiral, biconvex with involute umbilical side. Periphery broadly rounded. Has 4 chambers in last whorl; last chamber with wide umbilical flap occupies almost half of test. Sutures indistinct, slightly curved. Aperture a broad arc, partially covered by flap. Length 0.6 mm, width 0.4 mm, thickness 0.25 mm. Common in Upper Cretaceous sediments of Europe and North America and at DSDP sites in the South Atlantic. Rare in the Lower Cretaceous and common in the Campanian-Maestrichtian at Site 511.

*Valvulineria brotzeni* Nakkady and Talaat

(Plate 7, Fig. 9; Plate 8, Fig. 1)

*Valvulineria brotzeni* Nakkady and Talaat, 1959, p. 460, pl. 7, fig. 2.

Rather typical of Coniacian-Maestrichtian sediments at Site 511.

*Valvulineria camerata* Brotzen

(Plate 8, Figs. 2-4)

*Valvulineria camerata* Brotzen, 1936, p. 155, pl. 10, figs. 1-2.

Test small, trochospiral, biconvex, oval in shape with evolute spiral side and involute umbilical side. Has 4-5 chambers in last whorl, enlarging rapidly as added. Sutures distinct, slightly curved on spiral side, depressed radial on umbilical side. Aperture an interiomarginal arch extending to umbilicus, partially covered by triangular flap. Length 0.35 mm, width 0.29 mm, thickness 0.1 mm. Originally described from the Senonian of Sweden, later found in the Campanian of North America (Sliter, 1968). Ranges from Turonian to Campanian at Site 511 and is most characteristic of the Campanian.

## Genus GYROIDINA d'Orbigny, 1826

*Gyroidina girardana* (Reuss)

(Plate 12, Figs. 11-13; Plate 13, Fig. 1)

*Rotalina girardana* Reuss, 1851, p. 73, pl. 5, fig. 34.

Test large, trochospiral, with flat spiral side and strongly convex umbilical side, truncated conelike. Has 8-9 chambers in last whorl, narrow. Periphery widely rounded, but with sharp bend at the edge of spiral side. Sutures almost indistinct, flush. Aperture an interiomarginal slit extending nearly from the spiral side to the deep, wide umbilicus. Diameter 0.6 mm, height 0.46 mm. Common in the Eocene at Site 512, in the Oligocene at Site 511, and in the Oligocene-lower Miocene at Site 513.

*Gyroidina planulata* Cushman and Renz

(Plate 13, Fig. 2)

*Gyroidina planulata* Cushman and Renz, 1941, p. 23, pl. 4, fig. 1.

Distinguished from other *Gyroidina* species in having flattened test with sharply rounded periphery and with narrow umbilicus. Originally described from the Paleogene of the Caribbean. Typical of the middle Eocene at Site 512 and the Oligocene at Sites 511 and 513.

## Genus GLOBOROTALITES Brotzen, 1942

*Globorotalites conicus* (Carsey)

(Plate 8, Figs. 5-6)

*Truncatulina refulgens* Montfort var. *conica* Carsey, 1926, p. 46, pl. 4, fig. 15.

Test free, trochospiral, planoconvex, with spiral side slightly convex and umbilical side strongly convex, conelike in shape. Periphery carinate with poreless keel. Chambers enlarge gradually. Sutures oblique, indistinct on spiral side, slightly curved on umbilical side. Aperture an interiomarginal slit on umbilical side extending to pseudoumbilicus. Diameter 0.5 mm, height 0.35 mm. Encountered in the Santonian of Australia (Belford, 1960), the Campanian-Maestrichtian of the western South Atlantic (Sliter, 1977b), and the Coniacian-early Maestrichtian of the eastern Atlantic (Beckmann, 1978). Rare speci-



mens were found in the very top layer of Albian sediments and in the Santonian-Campanian at Site 511.

*Globorotalites michelinianus* (d'Orbigny)  
(Plate 8, Figs. 7-9)

*Globorotalia micheliniana* Cushman, 1946, p. 152, pl. 63, figs. 2-3.  
*Globorotalites michelinianus* Sliter, 1968, p. 119, pl. 22, fig. 1.

Test planoconvex, with flattened or slightly concave spiral side and high, conical, umbilical side. Umbilicus distinct, wide, deep. Periphery acute with keel, lobulate. Chambers low, 6-7 in last whorl, enlarging gradually as added. Sutures distinct, straight on umbilical side and oblique on spiral side. Aperture an elongate interiomarginal slit. Diameter 0.5 mm, height 0.3 mm. Species described from Upper Cretaceous of Europe and North America. Common throughout the Upper Cretaceous (Santonian-Maestrichtian) at Site 511.

*Globorotalites spineus* (Cushman)  
(Plate 9, Fig. 1)

*Truncatulina spinea* Cushman, 1926, p. 22, pl. 2, fig. 10.

Test free, trochospiral, planoconvex, with spiral side slightly concave and umbilical side strongly convex, semispheric in shape. Periphery acute with series of spines, one or two on each chamber. Chambers indistinct, 6-7 in last whorl. Sutures indistinct on both sides, slightly depressed on umbilical side. Aperture an interiomarginal slit extending from periphery to umbilicus. Diameter 0.35 mm, thickness 0.2 mm. Described from the Cretaceous of North America (Cushman, 1946; Sliter, 1968) and the Campanian-Maestrichtian of the South Atlantic (Sliter, 1977a, b; Beckmann, 1978). Our specimens differ from the holotype by having a few spines per chamber instead of one and may possibly be referred to a new subspecies. Common in Campanian-Maestrichtian sediments at Site 511.

**Genus GYROIDINOIDES Brotzen, 1942**

*Gyroidinoides globosa* (Hagenow)  
(Plate 13, Fig. 3)

*Nonionina globosa* Hagenow, 1842, p. 574.

Our specimens are similar to those illustrated under this name by Proto Decima and Bolli (1978) from the Paleocene at southwest Atlantic sites, Leg 40. Common in the middle Eocene sediments at Site 512.

*Gyroidinoides nitidus* (Reuss)  
(Plate 9, Figs. 2-3)

*Rotalina nitida* Reuss, 1846, p. 34, pl. 34, pl. 8, fig. 52; pl. 13, figs. 8, 20.

Test subspherical, trochospiral, planoconvex, with flat or slightly convex spiral side and strongly convex umbilical side. Has 5 chambers in final whorl, enlarging as added. Sutures indistinct on spiral side, distinct and slightly depressed between last chambers on umbilical side. Aperture an interiomarginal slit extending from the middle of apertural surface to umbilicus. Originally described from the Cretaceous of Western Europe; found in the Upper Cretaceous of the U.S.S.R., North America, and the Atlantic Ocean. Common in the Upper Cretaceous (Santonian-Maestrichtian) sediments at Site 511.

*Gyroidinoides primitiva* Hofker  
(Plate 2, Figs. 4-6)

*Gyroidinoides primitiva* Hofker, 1957, p. 393, fig. 436.

Present specimens are close to those described by Hofker (1957) from the upper Albian-upper Cenomanian of Holland and northwest Germany. Widely distributed in Albian sediments at Site 511.

*Gyroidinoides quadratus* (Cushman and Church)  
(Plate 2, Figs. 4-6)

*Gyroidina quadrata* Cushman and Church, 1929, p. 516, pl. 41, figs. 7-9.

Test trochospiral, spiral side concave, umbilical side strongly convex, umbilicate. Periphery acute. Has 6-7 chambers in last whorl enlarging gradually as added. Sutures distinct, radial. Aperture a low interiomarginal slit extending from umbilicus nearly to periphery. Diameter 0.5 mm, height 0.4 mm. Recorded from the Santonian-

Maestrichtian in California (Sliter, 1968), the Santonian-Maestrichtian in the southwestern Atlantic (Sliter, 1977a, b) and the Coniacian in the southeastern Atlantic (Beckmann, 1978). Common in the Campanian-Maestrichtian at Site 511.

**Genus STENSIOINA Brotzen, 1936**

*Stensioina* sp.  
(Plate 2, Figs. 7-8)

Test free, trochospiral, unequally biconvex, with strongly convex spiral side and elevated umbilical side; periphery rounded, with indistinct keel. Has 5 chambers in last whorl, enlarging gradually. Sutures strongly depressed on umbilical side and strongly curved with elevated granular ridges on spiral side. Umbilicus depressed. Aperture a low interiomarginal opening. Diameter 0.4 mm, thickness 0.2 mm. Found in the upper part of the Albian at Site 511.

**Family LINGULOGAVELINELLIDAE**

**Genus ORITHOSTELLA Eicher and Worstell, 1970**

*Orithostella australiana* Scheibnerová  
(Plate 2, Figs. 9-10)

*Orithostella australiana* Scheibnerová, 1972, p. 214, pl. 1, fig. 3, text-figure 7a-c.

Present specimens almost identical to the holotype but have 7-9 chambers instead of 6 in the last whorl. Rarely encountered in the lower part of the Albian at Site 511.

**Family PSEUDOPARRELLIDAE**

**Genus OSANGULARIA Brotzen, 1940**

*Osangularia cordieriana* (d'Orbigny)  
(Plate 9, Figs. 7-8)

*Rosalina cordieriana* d'Orbigny, 1840, p. 33, pl. 3, figs. 9-11.

Test trochospiral, biconvex, biumbonate, with carinate, gently waved periphery. Has 7-8 chambers in last whorl, enlarging gradually as added. Sutures distinct, gently curved, oblique on spiral side, radial on umbilical side. Aperture is a V-shaped opening, may be divided into two interiomarginal and areal slits. Diameter 0.62 mm, thickness 0.1 mm. At Site 511, range limited to Campanian-Maestrichtian.

*Osangularia utaturiensis* (Sastry and Sastry)  
(Plate 3, Figs. 1-2)

*Eponides utaturiensis* Sastry and Sastry, 1966, p. 292, pl. 13, figs. 3-4.

This species with lenslike or planoconvex test, sharp periphery, and strongly curved sutures was originally described from the Utatur Formation, India, as *Eponides utaturiensis*. Very typical of Albian sediments of the Indian (Scheibnerová, 1974) and Atlantic (Scheibnerová, 1978; Sliter, 1977b) oceans. Constantly present in Albian sediments at Site 511.

**Genus ALABAMINA Toulmin, 1941**

*Alabamina dissonata* (Cushman and Renz)  
(Plate 13, Figs. 4-5)

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

Test trochospiral, lenticular with subangular periphery. Chambers distinct, 5 in the last whorl, enlarging gradually. Sutures distinct, oblique on spiral side and radial on umbilical side. Aperture an interiomarginal slit at the base of a triangular, slightly concave apertural surface. Diameter 0.28 mm, thickness 0.1 mm. Characteristic of the Eocene of the Caribbean and Pacific. Constantly present in the middle Eocene sediments at Site 512 and very rare in the upper Eocene at Site 511.

**Genus ALABAMINOIDES Gudina and Saidova, 1967**

*Alabaminoides exiguus* (Brady)  
(Plate 16, Fig. 9)

*Pulvinulina exigua* Brady, 1884, p. 696, p. 103, figs. 13-14.

Test small, transparent, with 5-6 chambers in the last whorl. Sutures distinct, oblique on spiral side and radiate on umbilical side. Aperture an interiomarginal slit at the base of a triangular, slightly

concave apertural face. Maximum diameter 0.25 mm, thickness 0.1 mm. Originally described from Recent sediments, later recorded from the Neogene of the Mediterranean (Wright, 1978). Encountered throughout the Pliocene section at Site 514 and in the very top of the Pliocene at Site 513.

**Genus ORIDORSALIS Andersen, 1961**

***Oridorsalis ecuadorensis* (Galloway and Morrey)  
(Plate 13, Figs. 6-7)**

*Rotalia ecuadorensis* Galloway and Morrey, 1929, p. 26.

This species, with a strongly biconvex test and more or less rounded periphery, is closely related to *Oridorsalis umbonatus* (Reuss) and may be an ancestor of the latter. It is distributed only in the middle Eocene sediments at Site 512.

***Oridorsalis tenerus* (Brady)  
(Plate 16, Fig. 10)**

*Truncatulina tenera* Brady, 1884, p. 665, pl. 95, fig. 11.

This cosmopolitan, well-known, long-ranging, deep-water species was recorded from Oligocene to Recent sediments at Sites 513 and 514.

**Family CERATOBULIMINIDAE**

**Genus CONORBOIDES Hofker, 1952**

***Conorboides minutissima* (Tappan)  
(Plate 3, Figs. 3-4)**

*Discorbis minutissima* Tappan, 1943, p. 511, pl. 82, figs. 5-6.

Test free, low, trochospiral, and umbilicate, with rounded periphery. Has 4 chambers in the last whorl. Sutures curved, strongly depressed on umbilical side. Aperture a low interiomarginal slit extending to umbilicus and covered by broad flap. Diameter 0.45 mm, thickness 0.15 mm. Described from the Lower Cretaceous sediments of Washita Group, North America. Rare in the upper part of the Albian at Site 511.

**Family EPISTOMARIIDAE**

**Genus NUTTALLINELLA Belford, 1959**

***Nuttallinella florealis* (White)  
(Plate 9, Fig. 9)**

*Gyroidina florealis* White, 1928, p. 293, pl. 40, fig. 3.

Rather common species throughout the Coniacian-Campanian at Site 511.

**Family ANOMALINIDAE**

**Genus ANOMALINOIDES Brotzen, 1942**

***Anomalinoides indica* Sastry and Sastri  
(Plate 3, Figs. 5-7)**

*Anomalina indica* Sastry and Sastri, 1966, p. 293, pl. 19, fig. 10.

Initially described from the Utatur Formation (upper Albian), India. Characteristic of upper Albian sediments of the Atlantic and Indian oceans (Scheibnerová, 1974; Sliter, 1977a). Widely encountered in Albian deposits at Site 511.

***Anomalinoides semicibrata* (Beckmann)  
(Plate 13, Figs. 8-11)**

*Anomalinoides semicibrata* Douglas, 1973, p. 648, pl. 14, figs. 1-2.

Recognized by its thick, compact test with widely rounded periphery, distinctly perforated surface of spiral side, and smooth surface of umbilical side. Recorded from the middle Eocene to middle Miocene in the central Pacific (Douglas, 1973) and the Eocene to Oligocene in the southeastern Atlantic (Proto Decima and Bolli, 1978). Very characteristic of middle Eocene sediments at Site 512.

***Anomalinoides spissiformis* (Cushman and Stainforth)  
(Plate 14, Figs. 1-3)**

*Anomalina alazanensis* var. *spissiformis* Cushman and Stainforth, 1945, p. 71, pl. 14, fig. 5.

Described from the Cipero Marl Formation of Trinidad. Common in the middle Eocene to lower Miocene sediments of Sites 511, 512, and 513.

**Genus CIBICIDOIDES Talman, 1939**

***Cibicidoides perlucidus* (Nuttall)  
(Plate 14, Figs. 4-5)**

*Cibicides perlucidus* Nuttall, 1932, p. 33, pl. 8, fig. 10-12.

Originally described from the lower Oligocene of Mexico. Later found in Eocene-Oligocene sediments in Caribbean, Atlantic, Pacific, and Mediterranean areas. Present in middle Eocene sediments at Site 512.

**Genus GAVELINELLA Brotzen, 1942**

***Gavelinella compressa* Sliter  
(Plate 10, Figs. 2-4)**

*Gavelinella compressa* Sliter, 1968, p. 122, pl. 24, fig. 2.

Our specimens differ slightly from those described by Sliter (1968) from the Campanian of California and Mexico in being a little biconvex. They were encountered throughout the Coniacian-Campanian sediments of Site 511.

***Gavelinella stephensoni* (Cushman)  
(Plate 10, Figs. 5-6)**

*Cibicides stephensoni* Cushman, 1946, p. 159, pl. 65, fig. 4.

Our specimens differ somewhat from those described by Cushman (1946) from the Upper Cretaceous of western North America in having 9 instead of 10-11 chambers in the last whorl. Encountered in the Coniacian-Campanian at Site 511.

***Gavelinella whitei* (Martin)  
(Plate 10, Figs. 7-9)**

*Anomalina whitei* Martin, 1964, p. 106, pl. 16, fig. 4.

*Gavelinella whitei* (Martin) Sliter, 1968, p. 126, pl. 24, fig. 1.

Leg 71 specimens are similar to those described by Sliter (1968) from the upper Santonian-Maestrichtian of California. Common in the Campanian-Maestrichtian at Site 511.

**Genus HETEROLEPA Franzenau, 1884**

***Heterolepa* sp.  
(Plate 14, Figs. 6-7)**

Test is trochospiral, slightly biconvex, with acute nonperforated keel. Has 8 chambers in the last whorl, gradually enlarging. Sutures distinct, curved, widely depressed on the ventral side, indistinct and strongly oblique on the dorsal one. Aperture slitlike, interiomarginal, slightly extending to umbilicus. Diameter 0.6 mm, thickness 0.25 mm. Common in the middle Eocene sediments at Site 512.

**Genus LATICARININA Galloway and Wissler, 1927**

***Laticarinina pauperata* (Parker and Jones)  
(Plate 16, Fig. 11)**

*Laticarinina pauperata* Loeblich and Tappan, 1964, p. 580, fig. 457, 2-3.

Easily distinguished by its broad peripheral keel. Our specimens are identical to those illustrated by Loeblich and Tappan (1964) from Recent sediments of the Caribbean. Rather common in the Oligocene-middle Miocene deep-water sediments at Sites 511 and 513 and in the lower-middle Miocene at Site 512.

**Family NONIONIDAE**

**Genus PULLENIA Parker and Jones, 1862**

***Pullenia bulloides* d'Orbigny  
(Plate 14, Figs. 8-9)**

*Pullenia bulloides* Loeblich and Tappan, 1964, p. 748, fig. 613, 6.

Test large, planispiral, spherical, involute. Has 5-6 chambers in the last whorl, low, increasing gradually in size. Sutures indistinct, flush, radial. Aperture an archlike slit extending from one umbilicus

to another. This cosmopolitan species was encountered in the Oligocene at Site 511, the Oligocene-middle Miocene at Site 513, and the Pliocene at Site 514.

***Pullenia coryelli* White**  
(Plate 11, Figs. 1-2)

*Pullenia coryelli* White, 1929, p. 56, pl. 5, fig. 22.

Test planispiral, involute, inflated, with broadly rounded periphery. Has 4-5 chambers in the last whorl, low, inflated, enlarging gradually, embracing final chamber. Sutures slightly distinct, depressed, direct. Surface smooth. Aperture a low interiomarginal arch at the base of the final chamber connecting both umbilical areas of a test. Diameter 0.45 mm, thickness 0.39 mm. Very characteristic of Campanian-Maestrichtian sediments at Site 511.

***Pullenia jarvisi* Cushman**  
(Plate 10, Fig. 10)

*Pullenia jarvisi* Cushman, 1936, p. 77, pl. 13, fig. 6.

Present specimens are completely identical to those described by Cushman from the Upper Cretaceous of the Lizard Springs Formation, southeastern Trinidad, and the Tampico Embayment region of Mexico. Easily recognized by its planispiral, biumbilical test, with 5-6 chambers in last whorl, distinct, depressed, slightly curved sutures and low, interiomarginal, archlike aperture. Encountered in Campanian sediments at Site 511.

***Pullenia quinqueloba* (Reuss)**  
(Plate 14, Figs. 10-11)

*Nonionina quinqueloba* Reuss, 1851, p. 71, pl. 5, fig. 31.

This cosmopolitan species is easily distinguished by its planispiral, biumbilical, compressed, 5-chambered test, with radial depressed sutures and an interiomarginal archlike aperture. Common in the middle Eocene and lower-middle Miocene at Site 512 and rare in the Oligocene-middle Miocene at Sites 511 and 513 and in the Pliocene at Site 514.

***Pullenia riveroi* Bermudez**  
(Plate 15, Figs. 1-2)

*Pullenia riveroi* Bermudez, 1939, p. 11, pl. 2, figs. 1-6.  
Common in the middle Eocene at Site 512.

**Genus *NONION* Montfort, 1808**

***Nonion havanense* Cushman and Bermudez**  
(Plate 15, Figs. 3-4)

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

Test planispiral, involute, slightly compressed, lenticular, oval from the peripheral view. Periphery rounded. Sutures indistinct, flush, radial. Aperture interiomarginal, arch-shaped. Diameter 0.5 mm, thickness 0.3 mm. Encountered throughout the middle Eocene at Site 512 and the Oligocene at Sites 511 and 513.

**Genus *MELONIS* Montfort, 1808**

***Melonis affinis* (Reuss)**  
(Plate 17, Figs. 1-3)

*Nonionina affinis* Reuss, 1851, p. 43, pl. 5, fig. 32.

This well-known species with planispiral, symmetrical, compressed, perforated test is widely distributed in Neogene-Quaternary sediments at Sites 512 and 514.

***Melonis pompilioides* (Fichtel and Moll)**  
(Plate 16, Figs. 12-13)

*Nautilus pompilioides* Fichtel and Moll, 1798, p. 31, pl. 2, figs. a-c.

This well-known species was encountered in Pliocene sediments at Site 514.

**Family SPIRILLINIDAE**  
**Genus *SPIRILLINA* Ehrenberg, 1843**

***Spirillina minima* Schacko**  
(Plate 3, Figs. 8-9)

*Spirillina minima* Schacko, 1892, p. 159, fig. 4.

This species with a small, thin, depressed, symmetrical, evolute test was originally described from the Cenomanian of Germany. Frequently present throughout the Albian section at Site 511.

***Spirillina elongata* Bielecka and Pozaryska**  
(Plate 4, Fig. 1)

*Spirillina elongata* Bielecka and Pozaryska, 1954, p. 196, pl. 10, fig. 53.

Clearly distinguished representatives of this species, originally described from the Upper Jurassic (Kimmeridgian), were encountered in the Albian at Site 511.

**Genus *PATELLINA* Williamson, 1858**

***Patellina subcretacea* Cushman and Alexander**  
(Plate 4, Fig. 2)

*Patellina subcretacea* Cushman and Alexander, 1930, p. 12, pl. 3, fig. 1.

Our specimens are close to those described and illustrated by Cushman and Alexander, slightly differ in the higher spiral arrangement of chambers on the dorsal side. Found in Albian sediments at Site 511.

***Patellina* sp.**  
(Plate 4, Figs. 3-4)

Test trochospiral, high conical, and planoconvex; all whorls visible on dorsal side and only last 2 chambers visible on ventral side. Sutures distinct, forming spiral rim protruding above the test surface. Aperture a broad arch opening into umbilicus. Encountered in the upper part of the Albian at Site 511.

**Genus *PATELLINELLA* Cushman, 1928**

***Patellinella australis* Lambert and Scheibnerová**  
(Plate 4, Fig. 6)

*Patellinella australis* Lambert and Scheibnerová, 1974, p. 82, pl. 3, fig. 5, text-figure 12.

Test free, trochospiral, high conical, and planoconvex. All whorls are visible on dorsal side; only 2 chambers, comprising the last whorl, are visible on ventral side. Aperture a wide, archlike opening in umbilical area. Height 0.3 mm, diameter 0.3 mm. Described from the middle-upper Albian of South Africa (Lambert and Scheibnerová, 1974) and the Albian of the South Atlantic (Sliter, 1977a; Scheibnerová, 1978). Common in the upper part of the Albian at Site 511.

**Genus *PSEUDOPATELLINELLA* Takayanagi, 1960**

***Pseudopatellinella* sp.**  
(Plate 4, Fig. 5)

Test free, small, low, trochospiral, oval, with slightly convex spiral side and flattened umbilical side. Chambers rapidly increasing in size, twisting while growing; only two of them are visible in the last whorl. Aperture a narrow slit on umbilical side extending along a long axis up to center of chamber. Length 0.35 mm, width 0.2 mm, thickness 0.1 mm. Found in the uppermost part of the Albian at Site 511.

**Family CHILOSTOMELLIDAE**  
**Genus *ALLOMORPHINA* Czjzek, 1848**

***Allomorphina minuta* Cushman**  
(Plate 11, Figs. 3-4)

*Allomorphina minuta* Cushman, 1946, p. 145, pl. 60, fig. 6.

Test small, trochoid, slightly biconvex, triangular-rounded in shape. The last whorl contains 3 chambers, increasing rapidly in size as added. Sutures indistinct on spiral side and widely depressed on umbilical side. Aperture a narrow slit under a distinct triangular-shaped flap attached to the final chamber. Length 0.2 mm, width 0.2 mm, thickness 0.1 mm. Described from the Upper Cretaceous of North America (Cushman, 1946). Rare specimens are present throughout the Upper Cretaceous at Site 511.

**Genus *CHILOSTOMELLA* Czjzek, 1848**

***Chilostomella* Czjzeki Reuss**  
(Plate 15, Fig. 5)

*Chilostomella szjzeki* Reuss, 1850, p. 380, pl. 48, fig. 13.

Small, thin, and transparent test. Rarely encountered in the Oligocene sediments at Site 511.



**Genus SPHAEROIDINA d'Orbigny, 1826*****Sphaeroidina bulloides* d'Orbigny**

(Plate 17, Figs. 4–5)

*Sphaeroidina bulloides* d'Orbigny, 1826, p. 267, mod. 65.

This long-ranging cosmopolitan species, distinguished by a sub-globular test with chambers strongly embracing, occurs in Neogene sediments at Sites 512 and 514.

**Family BULIMINIDAE****Genus BULIMINA d'Orbigny, 1826*****Bulimina inflata* Seguenza**

(Plate 15, Fig. 6)

*Bulimina inflata* Seguenza, 1862, p. 109, pl. 1, fig. 10.

This cosmopolitan, long-ranging species is encountered throughout the middle Eocene at Site 512.

***Bulimina jarvisi* Cushman and Parker**

(Plate 15, Fig. 7)

*Bulimina jarvisi* Cushman and Parker, 1936, p. 39, pl. 7, fig. 1.

Test small, elongate, tapering, with slightly inflated chambers and surface characteristically etched as a result of porosity. The species is reported from the Eocene-early Miocene of the central Pacific (Douglas, 1973) and the Oligocene-middle Miocene of the Ninteyeast Ridge in the Indian Ocean (Boltovskoy, 1978). Rather common in Site 512 middle Eocene sediments.

**Genus REUSSELLA Galloway, 1933*****Reussella szajnochae* (Grzybowski)**

(Plate 11, Figs. 5–7)

*Verneuilina szajnochae* Grzybowski, 1896, p. 27, pl. 9, fig. 19.*Reussella szajnochae* (Grzybowski) Hofker, 1957, p. 214, fig. 262.

Test free, large, with low subtriangular chambers and short spine on initial end surface. Sutures distinct, deeply depressed. Aperture terminal and loop-shaped to the rear, extending from the margin of the last chamber along its surface. Length 0.8 mm, width 0.5 mm. Specimens of this species are similar to those illustrated by Hofker (1957) from Campanian sediments in Holland and Germany. Common in Campanian-Maestrichtian sediments at Site 511.

**Genus UVIGERINA d'Orbigny, 1826*****Uvigerina* aff. *peregrina* Cushman**

(Plate 15, Fig. 8)

Common in deep-water sediments of the middle Eocene at Site 512. Very similar to the recent representatives of *Uvigerina peregrina*.**Genus ANGULOGERINA Cushman, 1927*****Angulogerina esuriens* Hornibrook**

(Plate 17, Fig. 7)

*Angulogerina esuriens* Hornibrook, 1961, p. 69, pl. 9, figs. 154–155.

Leg 71 specimens differ slightly from the holotype described from the Oligocene-lower Miocene of New Zealand; sometimes there are more ribs on the surface of the test. The species is present in the middle-upper Miocene of Site 512.

**Genus TRIFARINA Cushman, 1923*****Trifarina angulosa* (Williamson)**

(Plate 17, Fig. 6)

*Uvigerina angulosa* Williamson, 1858, p. 67, pl. 5, fig. 140.

Specimens from the Quaternary sediments of Site 512 are very close to those illustrated by Loeblich and Tappan (1964) as a paratype of this species. Some Leg 71 specimens often have distinct ribs extending along a test.

**Family PLEUROSTOMELLIDAE****Genus PLEUROSTOMELLA Reuss, 1860*****Pleurostomella obtusa* Berthelin**

(Plate 4, Fig. 8)

*Pleurostomella obtusa* Berthelin, 1880, p. 29, pl. 1, fig. 9.

Widely distributed in Cretaceous sediments at many DSDP sites in the Atlantic and Indian oceans. Encountered in Albian to Campanian sediments at Site 511.

***Pleurostomella subnodosa* Reuss**

(Plate 11, Fig. 8)

*Pleurostomella subnodosa* Reuss, 1860, p. 204, pl. 8, fig. 2.

Our specimens completely correspond to the description of this species by Cushman (1946) from the Upper Cretaceous sediments of the western coastal region of North America. Originally described from the Cretaceous of Europe. Rare specimens constantly present in the upper part of the Upper Cretaceous at Site 511.

***Pleurostomella torta* Cushman**

(Plate 11, Figs. 9–10)

*Pleurostomella torta* Cushman, 1946, p. 133, pl. 55, fig. 11.

Specimens identical to those described and illustrated by Cushman (1946) from the Upper Cretaceous of the Gulf Coast region, North America, were encountered in the Campanian sediments at Site 511.

**Genus ELLIPSOIDEA Heron-Allen and Earland, 1910*****Ellipsoidella primitiva* (Cushman)**

(Plate 11, Fig. 11)

*Nodosarella primitiva* Cushman, 1946, p. 134, pl. 55, fig. 17.

Test elongate, tapering to the ends, with slightly flattened biserial initial part; later part uniserial. Chambers increasing gradually in size as added. Sutures distinct, strongly oblique in the initial portion, slightly oblique to subhorizontal between final chambers, depressed. Aperture terminal, one side raised above another one. Length 0.75 mm, diameter 0.15 mm. Originally described from the Upper Cretaceous of North America; differs from related species by a most distinct, biserial, initial part to its a test. Rare specimens in the middle part of the Upper Cretaceous at Site 511.

***Ellipsoidella robusta* (Cushman)**

(Plate 11, Fig. 12)

*Nodosarella robusta* Cushman, 1943, p. 92, pl. 16, fig. 8.

Rarely present throughout the Coniacian-Campanian and common in the Maestrichtian at Site 511.

**Genus BANDYELLA Loeblich and Tappan, 1962*****Bandyella greatvalleyensis* (Trujillo)**

(Plate 11, Fig. 13)

*Bandyella greatvalleyensis* (Trujillo) Loeblich and Tappan, 1964, p. C 730, fig. 598, 2.

Recognized by short, inflated, initially triserial, later biserial test with distinct chambers, depressed sutures, and subterminal, hooded, T-like aperture. Originally described from the Santonian of California and ranged from Coniacian to Maestrichtian. Encountered in Coniacian to Maestrichtian of Site 511.

**Genus STILOSTOMELLA Guppy, 1894*****Stilostomella caribaea* (Palmer and Bermudez)**

(Plate 15, Fig. 9)

*Ellipsoidella caribaea* Palmer and Bermudez, 1936, p. 297, pl. 18, figs. 10, 11.

Originally described from the Oligocene of Cuba. Encountered throughout the middle Eocene at Site 512 and in Oligocene sediments at Sites 511 and 513.

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

(Plate 15, Fig. 10)

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

Elongated, slightly curved test, tapering to the initial end. Present in the middle Eocene at Site 512 and in the Oligocene at Sites 511 and 513.

*Stilostomella nuttalli* (Cushman and Jarvis)  
(Plate 15, Fig. 11)

*Ellipsonodosaria nuttalli* Cushman and Jarvis, 1934, p. 72, pl. 10, fig. 6.

Easily distinguished from other species of this genus by its large test with distinct inflated chambers and spines at the base of the initial chamber. This cosmopolitan species is common in the Oligocene-middle Miocene of Site 513, rare in the middle Eocene of Site 512 and in the Oligocene of Site 511.

Family CASSIDULINIDAE  
Genus CASSIDULINA d'Orbigny, 1826

*Cassidulina laevigata* d'Orbigny  
(Plate 17, Fig. 8)

*Cassidulina laevigata* Brady, 1884, p. 428, pl. 54, figs. 1-5.

This widely distributed deep-water species is recorded from the Quaternary sediments at Site 512.

Genus BRADYNELLA Saidova, 1975

*Bradynella subglobosa* (Brady)  
(Plate 17, Fig. 9)

*Cassidulina subglobosa* Brady, 1884, p. 430, pl. 54, fig. 17.

*Bradynella subglobosa* (Brady) Saidova, 1975, p. 344, pl. 91, fig. 10, pl. 92, figs. 1-3.

This well-known species, originally described by Brady (1884) in Recent sediments from the *Challenger* expedition's material as *Cassidulina subglobosa* was assigned by Saidova (1975) to the new genus *Bradynella*. Rather frequent throughout Eocene-Recent sediments at Sites 511, 512, 513, and 514.

Family BOLIVINITIDAE  
Genus SPIROBOLIVINA Hofker, 1956

*Spirobolivina australis* Scheibnerová  
(Plate 4, Fig. 7)

*Spirobolivina australis* Scheibnerová, 1974, p. 713, pl. 4, fig. 4; pl. 10, fig. 14.

Leg 71 specimens are identical to those described by Scheibnerová (1974) from the upper Albian at Site 259, Leg 27, Indian Ocean. Present in the upper part of the Albian, Site 511.

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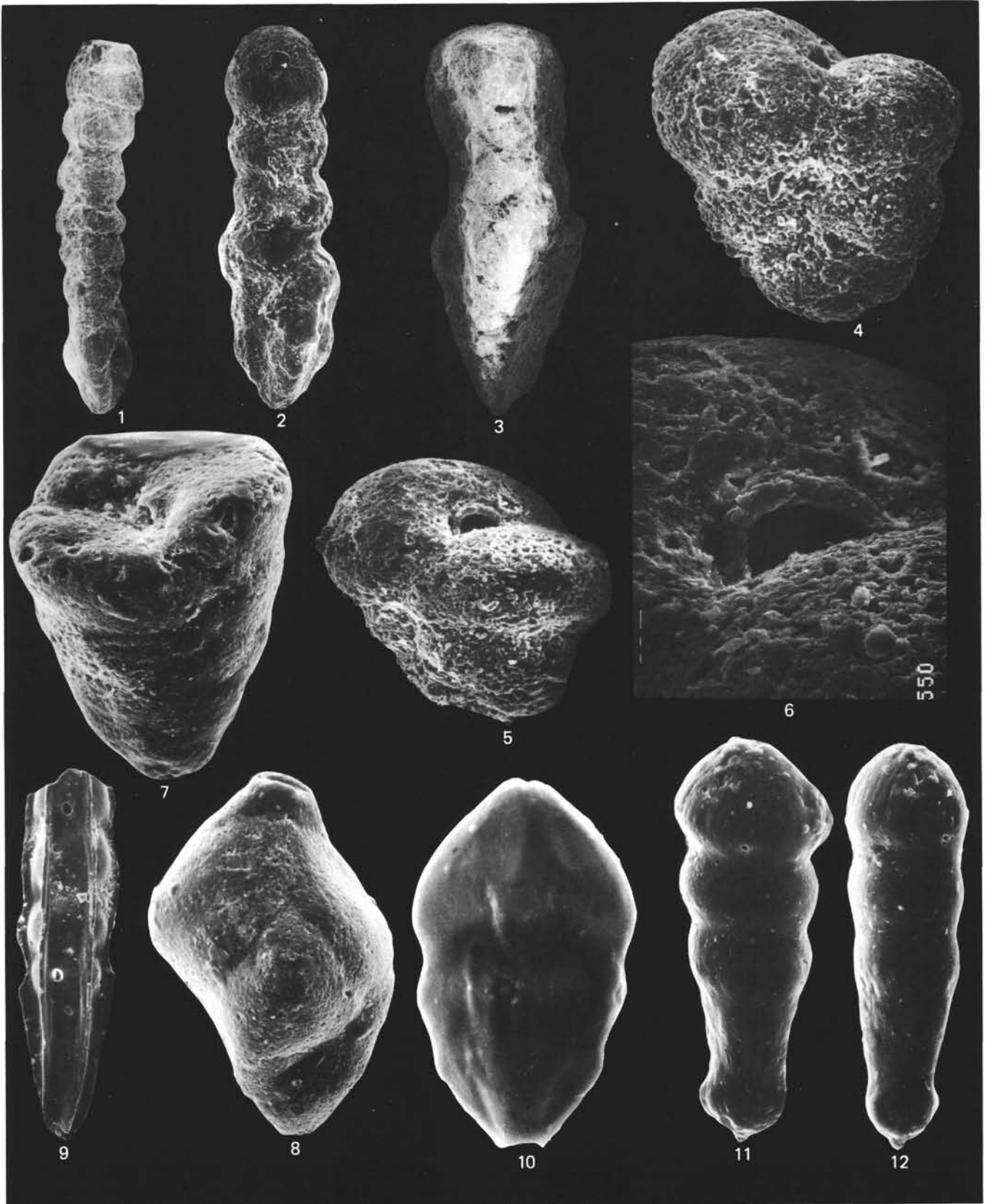


Plate 1. Lower Cretaceous foraminifera. 1-2. *Clavulina gabonica* Le Calvez, de Klasz, and Brun. Sample 511-56-1, 119-121 cm (1)  $\times 60$  (2)  $\times 80$ . 3. *Gaudryina dividens* Grabert,  $\times 90$ . Sample 511-50-1, 18-20 cm. 4-6. *Dorothis gradata* Berthelin. Sample 511-50, CC. (4-5)  $\times 120$  (6)  $\times 375$ ; detail showing the aperture. 7. *Dorothis trochoides* (Marsson),  $\times 140$ . Sample 511-52, CC. 8. *Uvigerinamina jankoi* Majzon,  $\times 140$ . Sample 511-51-1, 60-62 cm. 9. *Nodosaria obscura* Reuss,  $\times 55$ . Sample 511-52-3, 60-62 cm. 10. *Lingulina loryi* Berthelin,  $\times 270$ . Sample 511-54, CC. 11-12. *Lingulina nodosaria* Reuss. Sample 511-52-7, 14-16 cm (11)  $\times 220$  (12)  $\times 225$ .

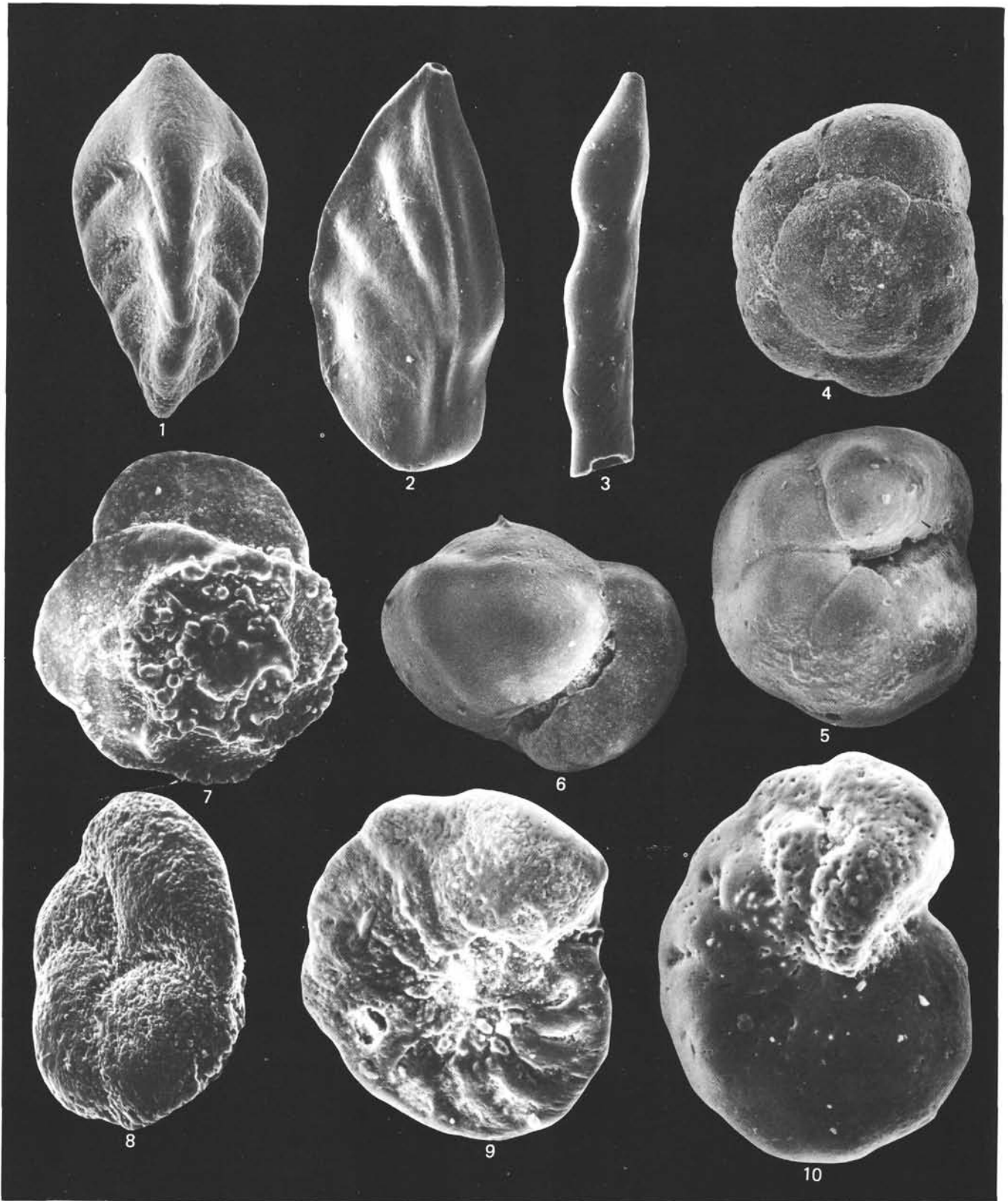


Plate 2. Lower Cretaceous foraminifers. 1. *Tibrachia australiana* Ludbrook,  $\times 110$ . Sample 511-54-4, 34-36 cm. 2. *Astacolus crepidularis* (Roemer),  $\times 140$ . Sample 511-52-3, 60-62 cm. 3. *Dentalina debilis* Berthelin,  $\times 110$ . Sample 511-51-3, 60-62 cm. 4-6. *Gyroidinoides primitivus* Hofker. Sample 511-54, CC (4)  $\times 140$ , dorsal view (5)  $\times 150$ , ventral view (6)  $\times 140$ , apertural view. 7-8. *Stensioina* sp.,  $\times 150$ . Sample 511-50-1, 18-20 cm (7) dorsal view (8) ventral view. 9-10. *Orithostella australiana* Scheibnerová. Sample 511-52-3, 60-62 cm (9)  $\times 140$ , dorsal view (10)  $\times 200$ , dorsal view.



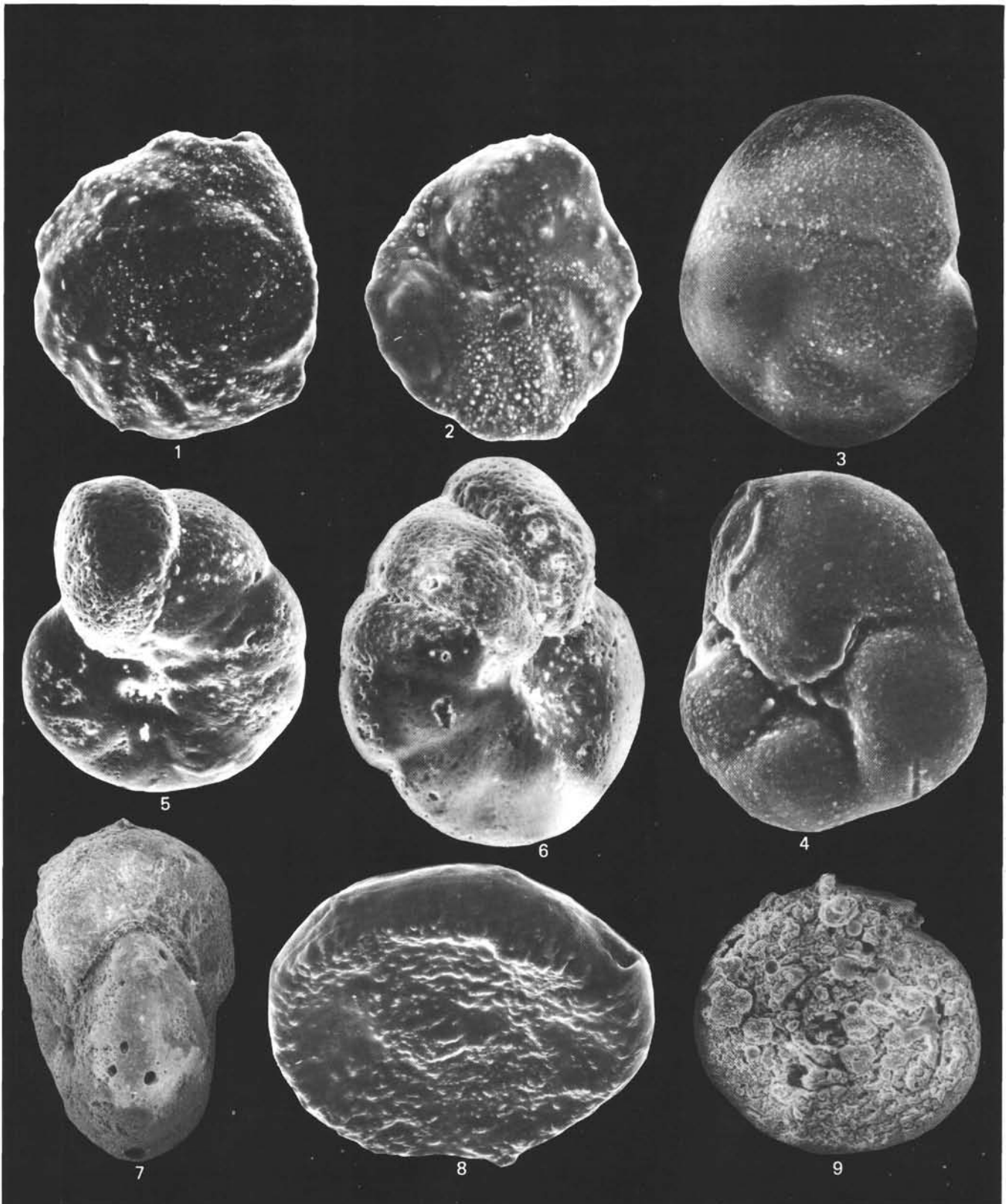


Plate 3. Lower Cretaceous foraminifers. 1-2. *Osangularia utaturiensis* Sastry and Sastri,  $\times 180$ . Sample 511-51, CC (1) dorsal view (2) ventral view. 3-4. *Conorboides minutissima* (Tappan). Sample 511-51-6, 60-62 cm (3)  $\times 140$ , dorsal view (4)  $\times 230$ , ventral view. 5-7. *Anomalinoides indica* Sastry and Sastri (5-6) Sample 511-52-3, 60-62 cm (5,  $\times 140$ , dorsal view; 6,  $\times 150$ , ventral view) (7)  $\times 150$ , apertural view. Sample 511-53-5, 74-76 cm. 8-9. *Spirillina minima* Shacko. Sample 511-51, CC (8)  $\times 160$  (9)  $\times 150$ .

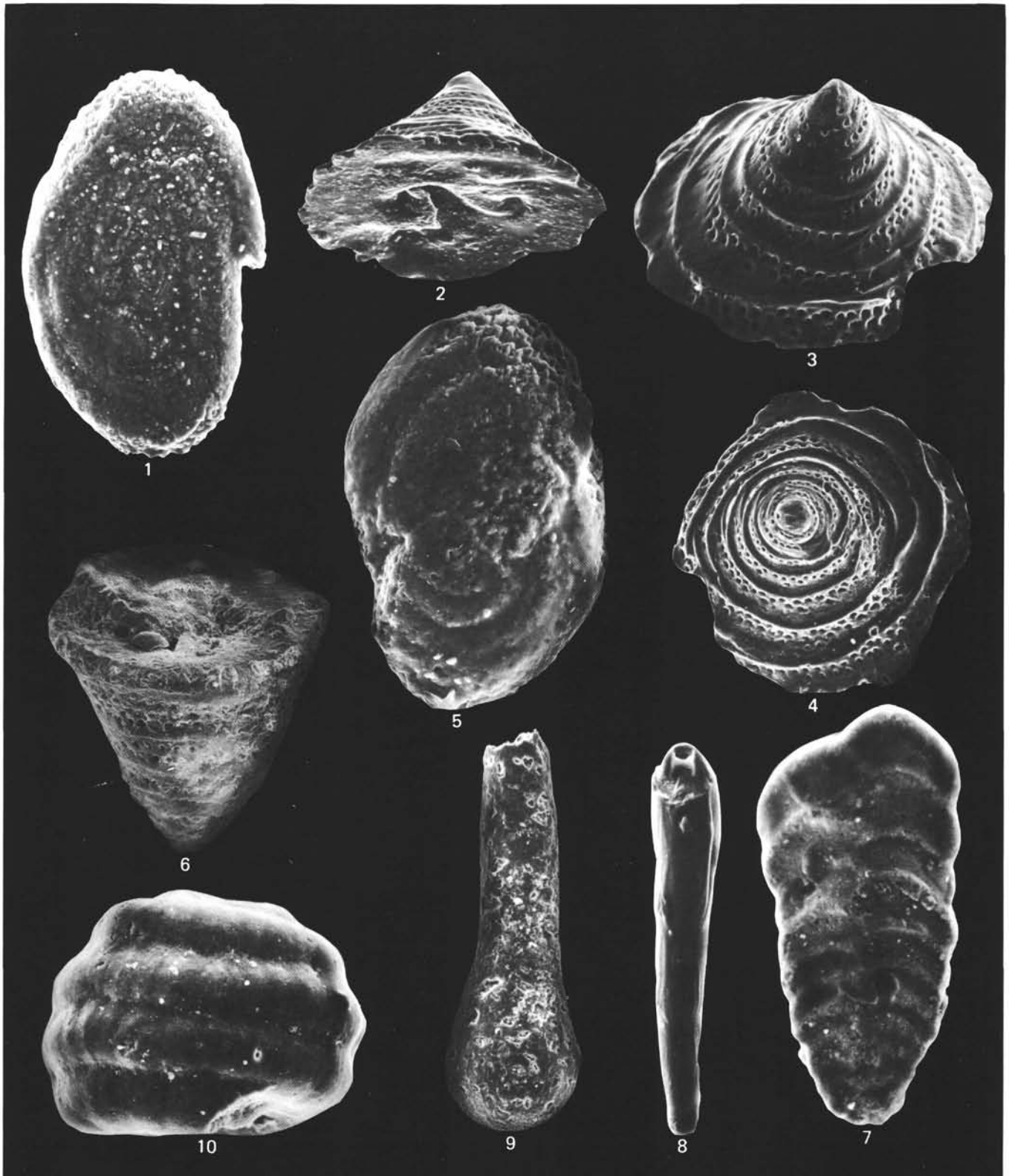


Plate 4. Lower Cretaceous foraminifers. 1. *Spirillina elongata* Bielecka and Pozaryska,  $\times 170$ . Sample 511-50,CC. 2. *Patellina subcretacea* Cushman and Alexander,  $\times 130$ , ventral view. Sample 511-51,CC. 3-4. *Patellina* sp.,  $\times 130$ . Sample 511-50,CC (3) side view (4) dorsal view. 5. *Pseudopatellinella* sp.,  $\times 200$ , dorsal view. Sample 511-50-1, 18-20 cm. 6. *Patellinella australis* Lambert and Scheibnerová,  $\times 140$ . Sample 511-51,CC. 7. *Spirobolivina australis* Scheibnerová,  $\times 120$ . Sample 511-51-3, 60-62 cm. 8. *Pleurostomella obtusa* Berthelin,  $\times 100$ . Sample 511-52-3, 60-62 cm. 9. *Hyperammina elongata* Brady,  $\times 90$ . Sample 511-47-6, 44-46 cm. 10. *Glomospira corona* Cushman and Jarvis,  $\times 140$ , side view. Sample 511-41-2, 26-28 cm.

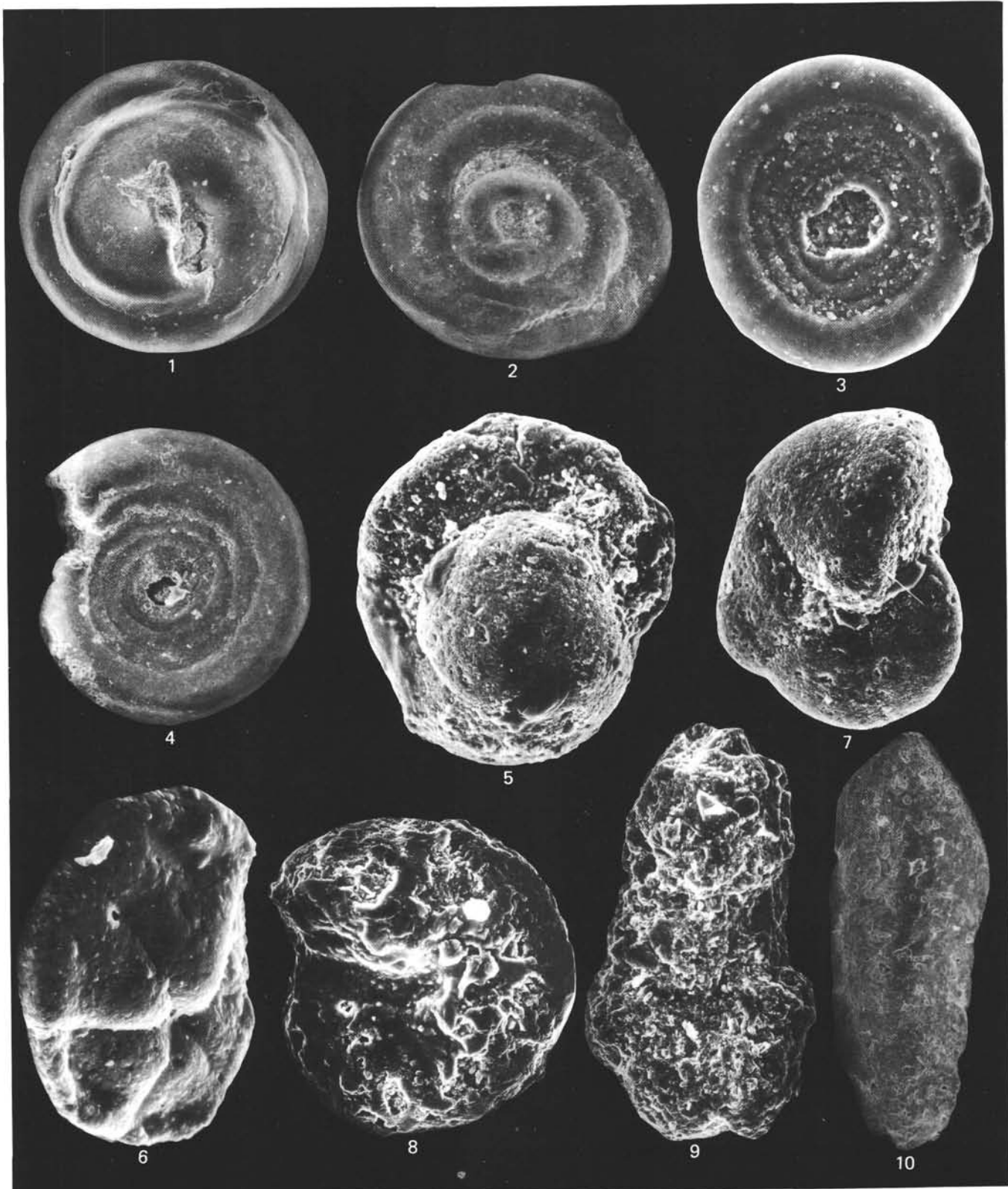


Plate 5. Upper Cretaceous foraminifera. 1. *Glomospira corona* Cushman and Jarvis,  $\times 140$ , view from above. Sample 511-41-2, 26-28 cm. 2. *Glomospira gordialis* (Jones and Parker),  $\times 120$ . Sample 511-48-4, 98-100 cm. 3. *Ammodiscus cretaceus* (Reuss),  $\times 270$ . Sample 511-49-1, 44-46 cm. 4. *Ammodiscus glabratus* Cushman and Jarvis,  $\times 210$ . Sample 511-45, CC. 5. *Haplophragmoides bulloides* (Beissel),  $\times 160$ , apertural view. Sample 511-45, CC. 6. *Haplophragmoides* sp.,  $\times 260$ . Sample 511-41-2, 26-26 cm. 7. *Haplophragmoides calcula* Cushman and Waters,  $\times 190$ . Sample 511-45, CC. 8. *Recurvoides* sp.,  $\times 190$ . Sample 511-45-3, 98-100 cm. 9. *Ammobaculites* sp.,  $\times 200$ . Sample 511-45, CC. 10. *Spiroplectammina semicomplanata* (Carsey),  $\times 120$ . Sample 511-23, CC.

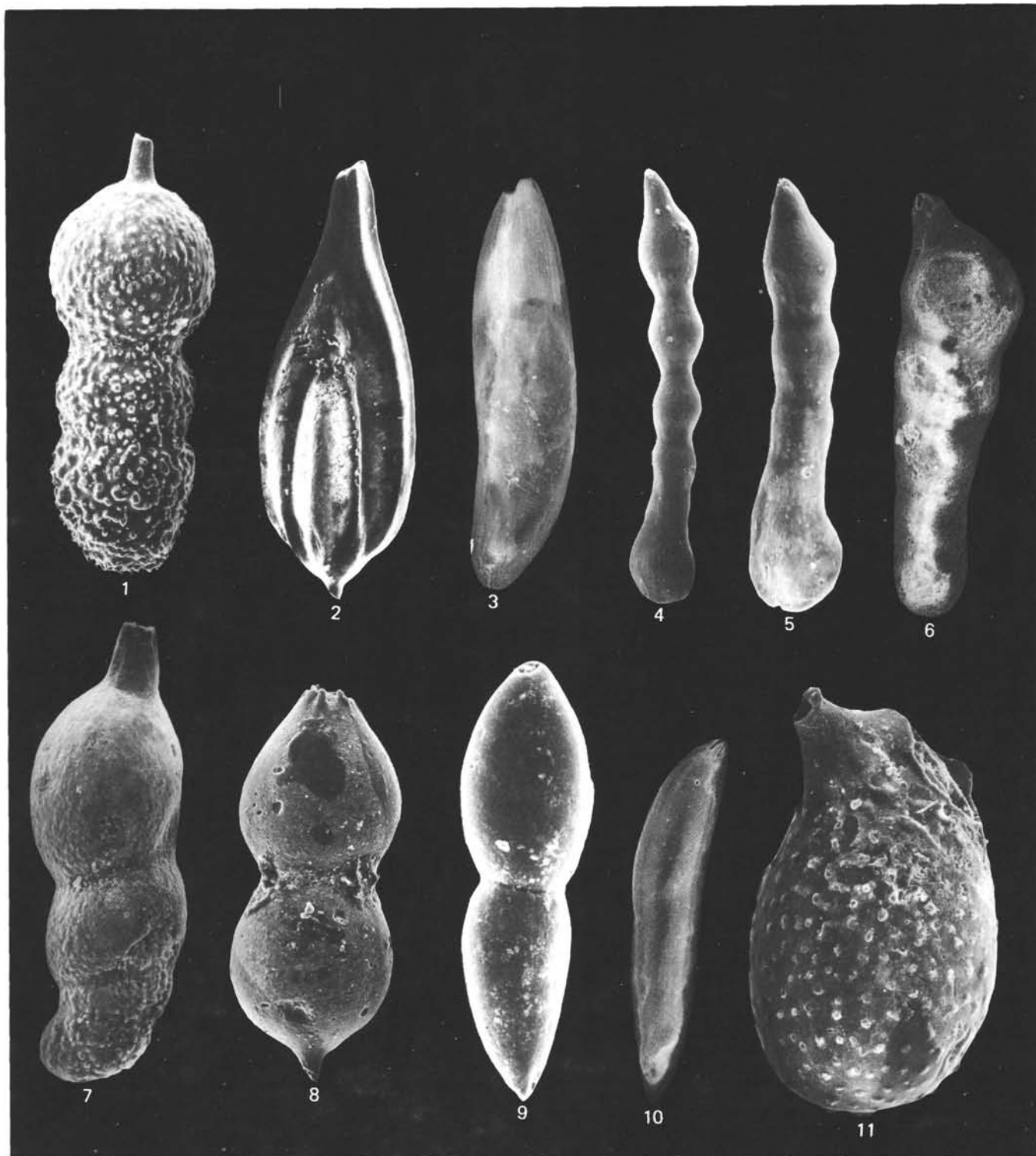


Plate 6. Upper Cretaceous foraminifers. 1. *Nodosaria aspera* Reuss,  $\times 110$ . Sample 511-42-2, 114-116 cm. 2. *Frondicularia mucronata* Reuss,  $\times 80$ . Sample 511-28-6, 90-92 cm. 3. *Astacolus jarvisi* (Cushman),  $\times 110$ . Sample 511-33-3, 74-76 cm. 4. *Marginulinopsis juncea* (Cushman),  $\times 125$ . Sample 511-31-6, 0-4 cm. 5. *Marginulinopsis stephensoni* (Cushman),  $\times 125$ . Sample 511-31-6, 0-4 cm. 6. *Marginulinopsis texaensis* (Cushman),  $\times 110$ . Sample 511-28-7, 25-28 cm. 7. *Marginulina bullata* Reuss,  $\times 135$ . Sample 511-24-7, 15-17 cm. 8. *Dentalina catenula* Reuss,  $\times 100$ . Sample 511-23-1, 3-4 cm. 9. *Dentalina cylindroides* Reuss,  $\times 150$ . Sample 511-47-3, 44-46 cm. 10. *Dentalina legumen* Reuss,  $\times 75$ . Sample 511-41-3, 55-57 cm. 11. *Globulina lacrima* Reuss,  $\times 140$ . Sample 511-32, CC.



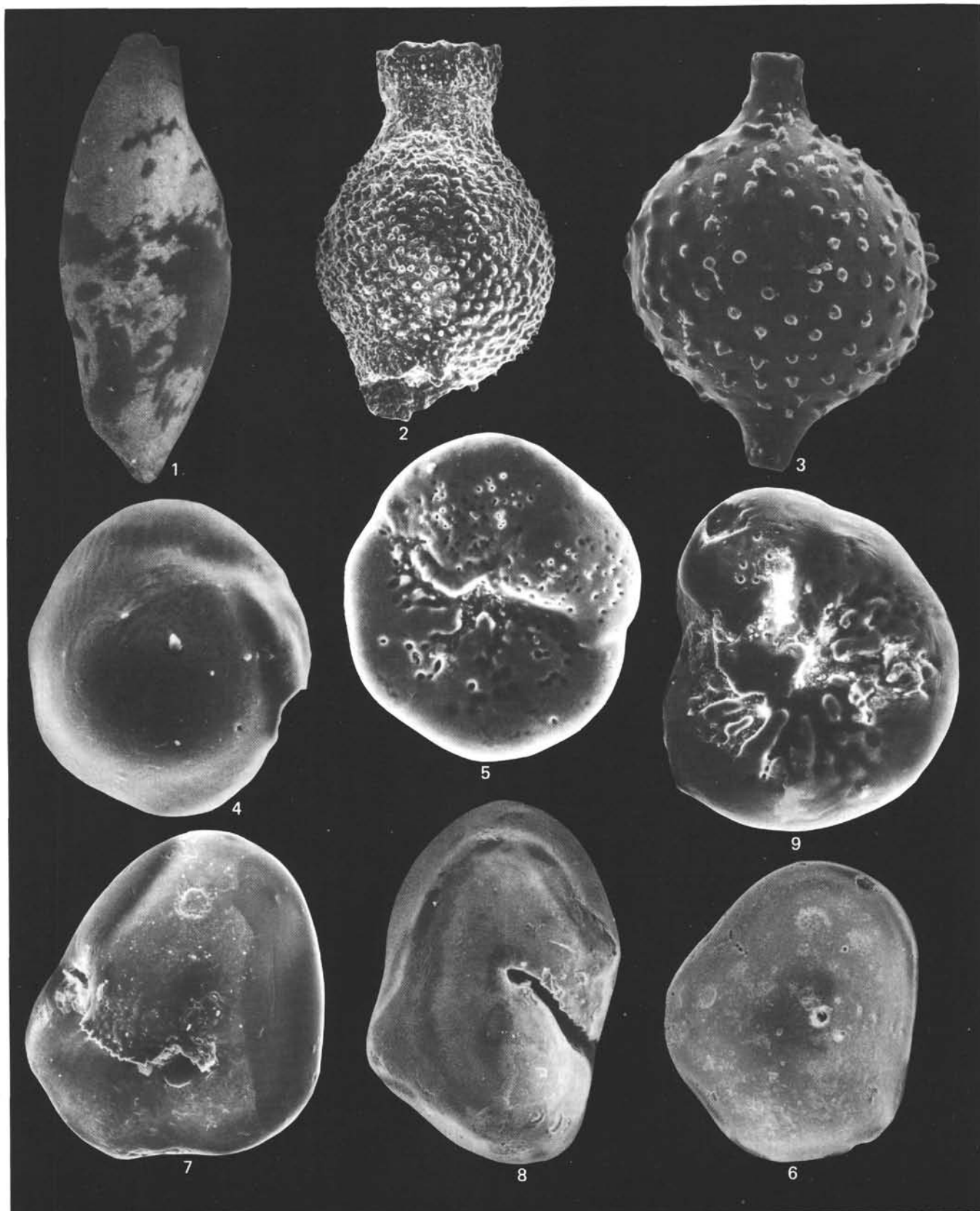


Plate 7. Upper Cretaceous foraminifera. 1. *Pyrulina cylindroides* (Roemer),  $\times 100$ . Sample 511-24, CC. 2. *Ramulina aculeata* (d'Orbigny),  $\times 75$ . Sample 511-23, CC. 3. *Ramulina pseudoaculeata* (Olsson),  $\times 150$ . Sample 511-31-4, 45-48 cm. 4-5. *Conorbina marginata* Brotzen,  $\times 140$ . Sample 511-41-3, 55-57 cm (4) dorsal view (5) ventral view. 6-8. *Valvulineria allomorphinoides* (Reuss). Sample 511-24, CC (6)  $\times 90$ , dorsal view (7)  $\times 100$ , ventral view (8)  $\times 120$ , apertural view. 9. *Valvulineria brotzeni* Nakkady and Talaat,  $\times 160$ , ventral view. Sample 511-23, CC.

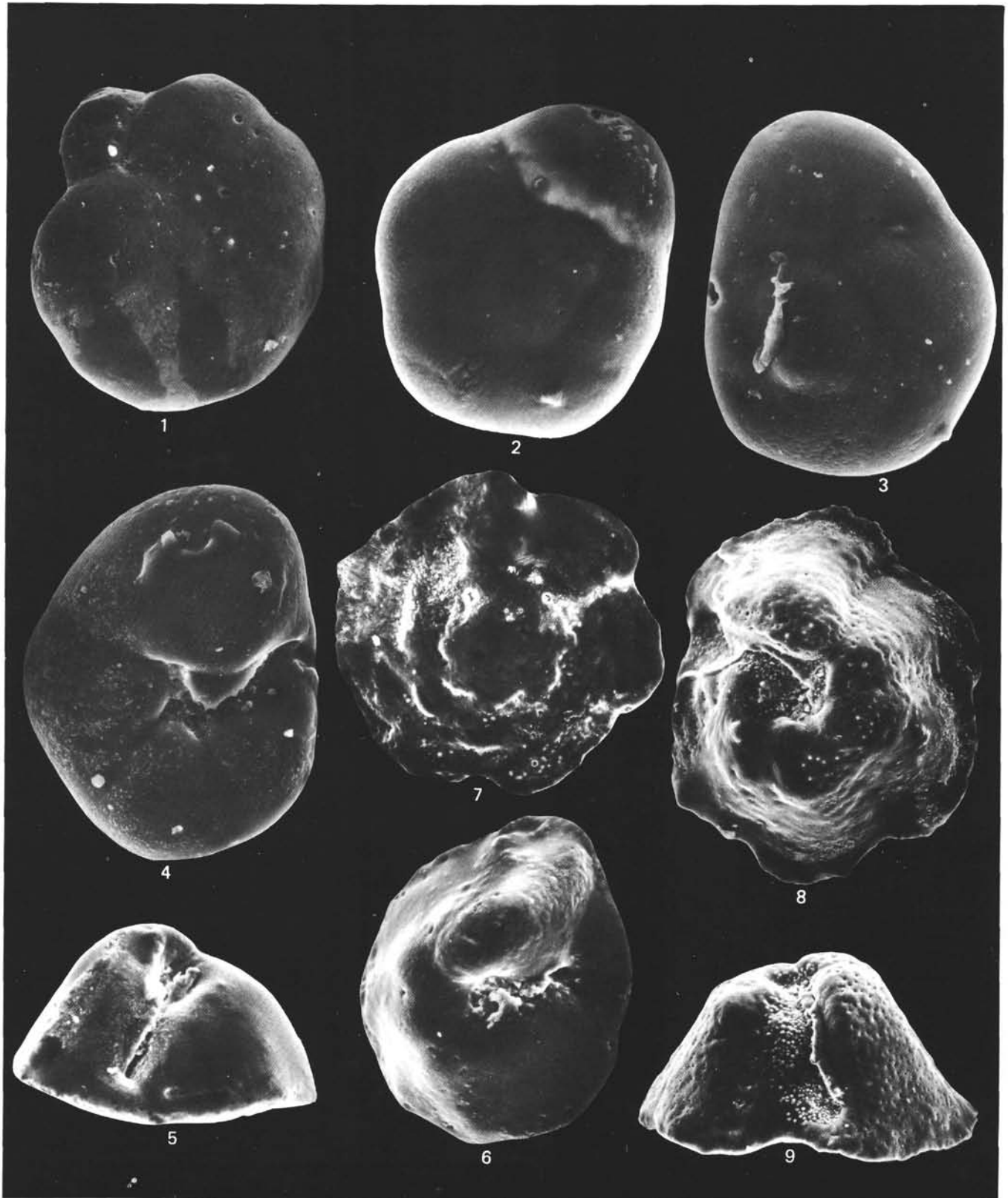


Plate 8. Upper Cretaceous foraminifers. 1. *Valvulineria brotzeni* Nakkady and Talaat,  $\times 160$ , dorsal view. Sample 511-23, CC. 2-4. *Valvulineria camerata* Brotzen (2)  $\times 180$ , dorsal view. Sample 511-24-6, 78-80 cm (3-4)  $\times 300$ . Sample 511-33-6, 74-76 cm (3, dorsal view; 4, ventral view). 5-6. *Globorotalites conicus* (Carsey). Sample 511-47-1, 44-46 cm (5)  $\times 110$ , apertural view (6)  $\times 200$ , ventral view. 7-9. *Globorotalites michelinianus* (d'Orbigny) (7)  $\times 130$ , dorsal view. Sample 511-42, CC (8)  $\times 160$ , ventral view. Sample 511-42-3, 114-114 cm (9)  $\times 150$  apertural view. Sample 511-42, CC.

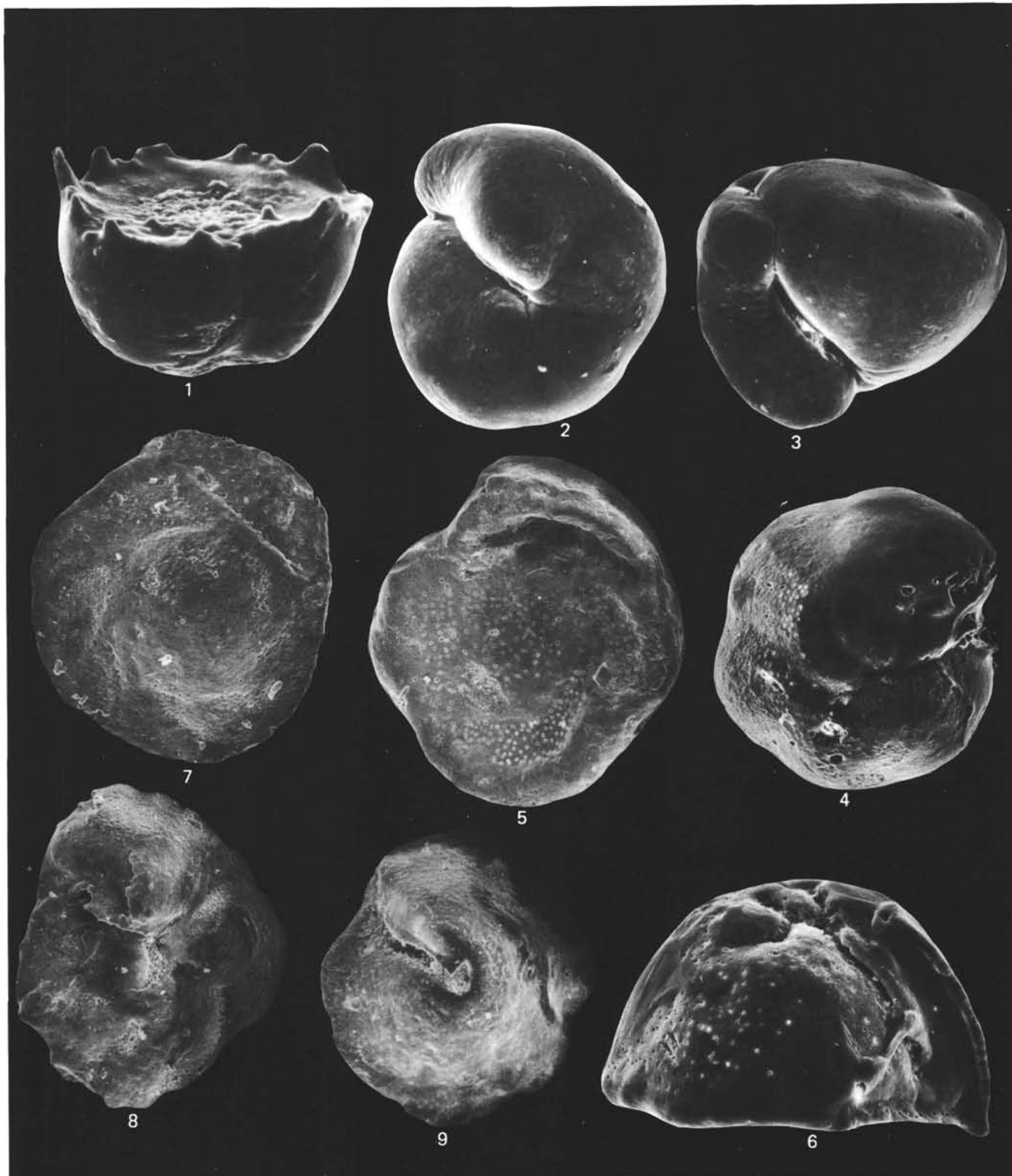


Plate 9. Upper Cretaceous foraminifera. 1. *Globorotalites spineus* (Cushman),  $\times 160$ , apertural view. Sample 511-23, CC. 2-3. *Gyroidinoides nitidus* (Reuss),  $\times 150$ . Sample 511-41-3, 55-57 cm (2) ventral view (3) apertural view. 4-6. *Gyroidinoides quadratus* (Cushman and Church). Sample 511-24-6, 78-80 cm (4)  $\times 100$ , ventral view (5)  $\times 200$ , dorsal view (6)  $\times 280$ , apertural view. 7-8. *Osangularia corderiana* (d'Orbigny) (7)  $\times 90$ , dorsal view. Sample 511-28-6, 90-92 cm (8)  $\times 170$ , ventral view, Sample 511-31-1, 113-116 cm. 9. *Nuttallinella florealis* (White)  $\times 130$ , ventral view, Sample 511-40, CC.

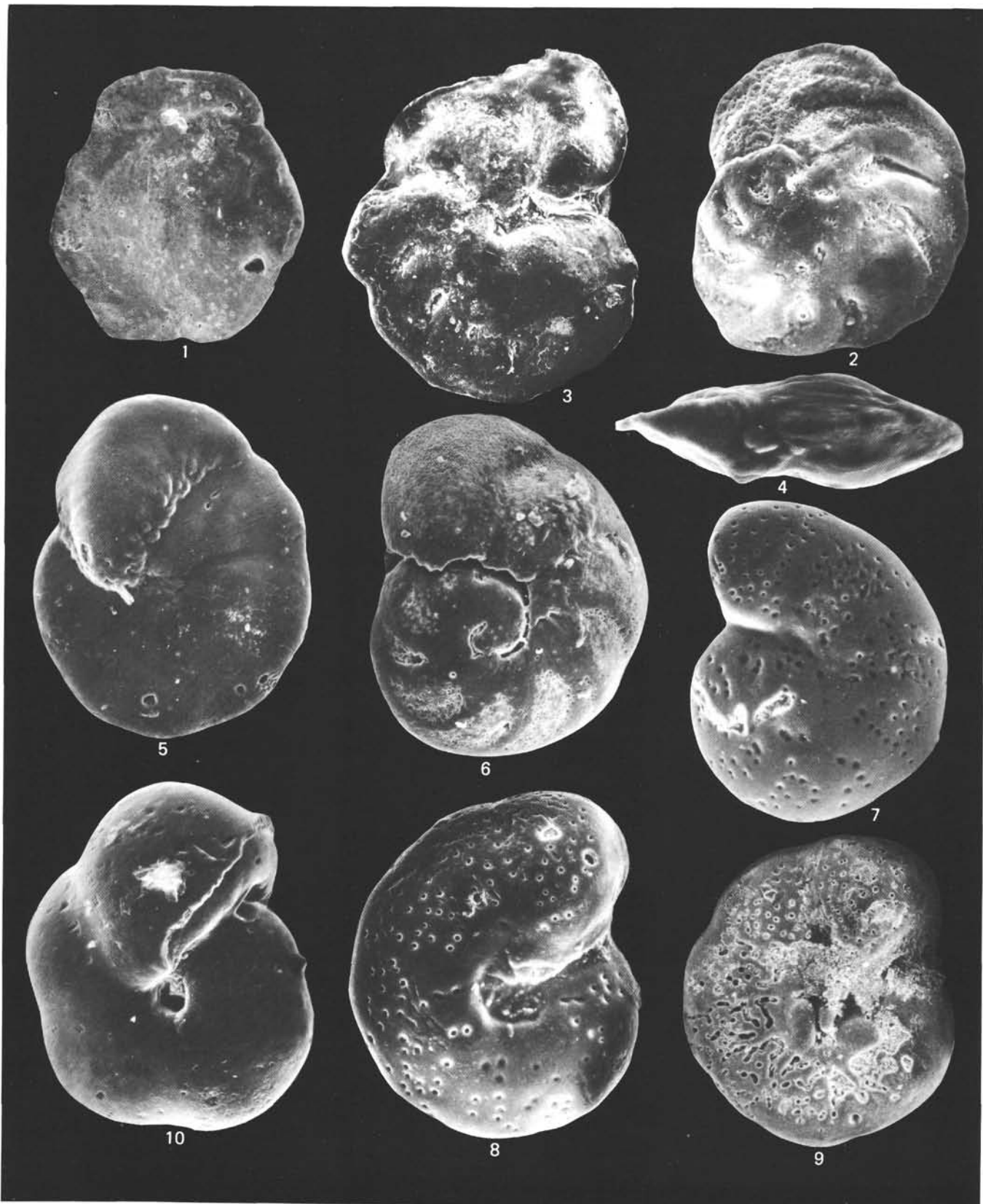


Plate 10. Upper Cretaceous foraminifers. 1. *Nuttallinella florealis* (White),  $\times 130$ , dorsal view. Sample 511-40, CC. 2-4. *Gavelinella compressa* Sliter,  $\times 130$  (2) dorsal view. Sample 511-46-3, 44-46 cm (3) ventral view. Sample 511-46-2, 44-46 cm (4) apertural view. Sample 511-46-3, 44-46 cm. 5-6. *Gavelinella stephensoni* (Cushman),  $\times 140$ . Sample 511-34, CC (5) dorsal view (6) ventral view. 7-9. *Gavelinella whitei* (Martin),  $\times 200$  (7-8) Sample 511-23, CC (7, dorsal view; 8, ventral view) (9) ventral view, Sample 511-25, CC. 10. *Pullenia jarvisi* Cushman,  $\times 135$ , side view. Sample 511-44-3, 44-46 cm.





Plate 11. Upper Cretaceous foraminifera. 1-2. *Pullenia coryelli* White,  $\times 130$ . Sample 511-23, CC (1) side view (2) apertural view. 3-4. *Alломorphina minuta* Cushman,  $\times 300$ . Sample 511-24, CC (3) ventral view (4) dorsal view. 5-7. *Reussella szajnochae* (Grzybowski). Sample 511-23, CC (5)  $\times 80$  (6)  $\times 90$  (7)  $\times 80$ . 8. *Pleurostomella subnodosa* Reuss,  $\times 100$ . Sample 511-28-6, 90-92 cm. 9-10. *Pleurostomella torta* Cushman,  $\times 75$ . Sample 511-31-3, 50-53 cm (9) apertural view (10) side view. 11. *Ellipsoidella primitiva* (Cushman),  $\times 100$ . Sample 511-41-3, 55-57 cm. 12. *Ellipsoidella robusta* (Cushman),  $\times 115$ , side view. Sample 512-23, CC. 13. *Bandyella greatvalleyensis* (Trujillo),  $\times 90$ . Sample 511-46-3, 44-46 cm.

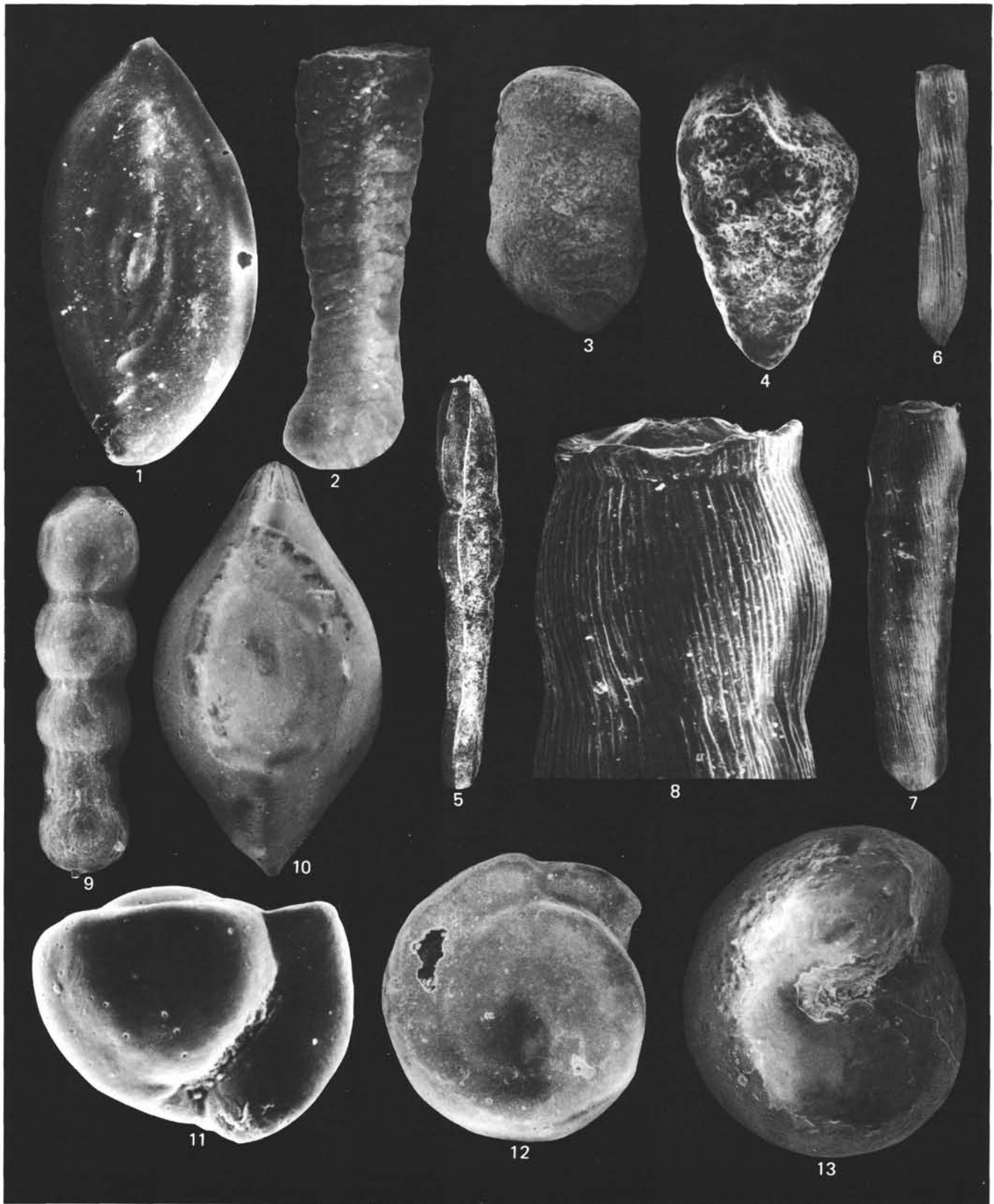


Plate 12. Paleogene foraminifers. 1. *Spirolocamina exigua* Burmistrova,  $\times 120$ . Sample 512-12, CC. 2. *Bolivinopsis cubensis* (Cushman and Bermudez),  $\times 120$ . Sample 513A-17-5, 80-82 cm. 3. *Valvulina haeringensis* (Guembel),  $\times 55$ . Sample 512-8, CC. 4. *Karriella subglabra* (Guembel),  $\times 100$ . Sample 512-19, CC. 5. *Chrysalogonium longicostatum* Cushman and Jarvis,  $\times 75$ . Sample 512-12, CC. 6-8. *Chrysalogonium tenuicostatum* Cushman and Bermudez (6)  $\times 35$ . Sample 512-13, CC (7-8) Sample 513A-18-5, 64-66 cm (7,  $\times 70$ ; 8,  $\times 200$ , detail showing the aperture). 9. *Orthomorphina rohri* (Cushman and Stainforth),  $\times 140$ . Sample 512-19, CC. 10. *Glandulina laevigata* d'Orbigny,  $\times 150$ . Sample 512-11, CC. 11-13. *Gyroidina girardana* (Reuss) (11)  $\times 95$ , apertural view. Sample 514-43-12, 83-85 cm (12-13) Sample 512-19-1, 18-20 cm (12,  $\times 100$ , dorsal view; 13,  $\times 110$ , ventral view).

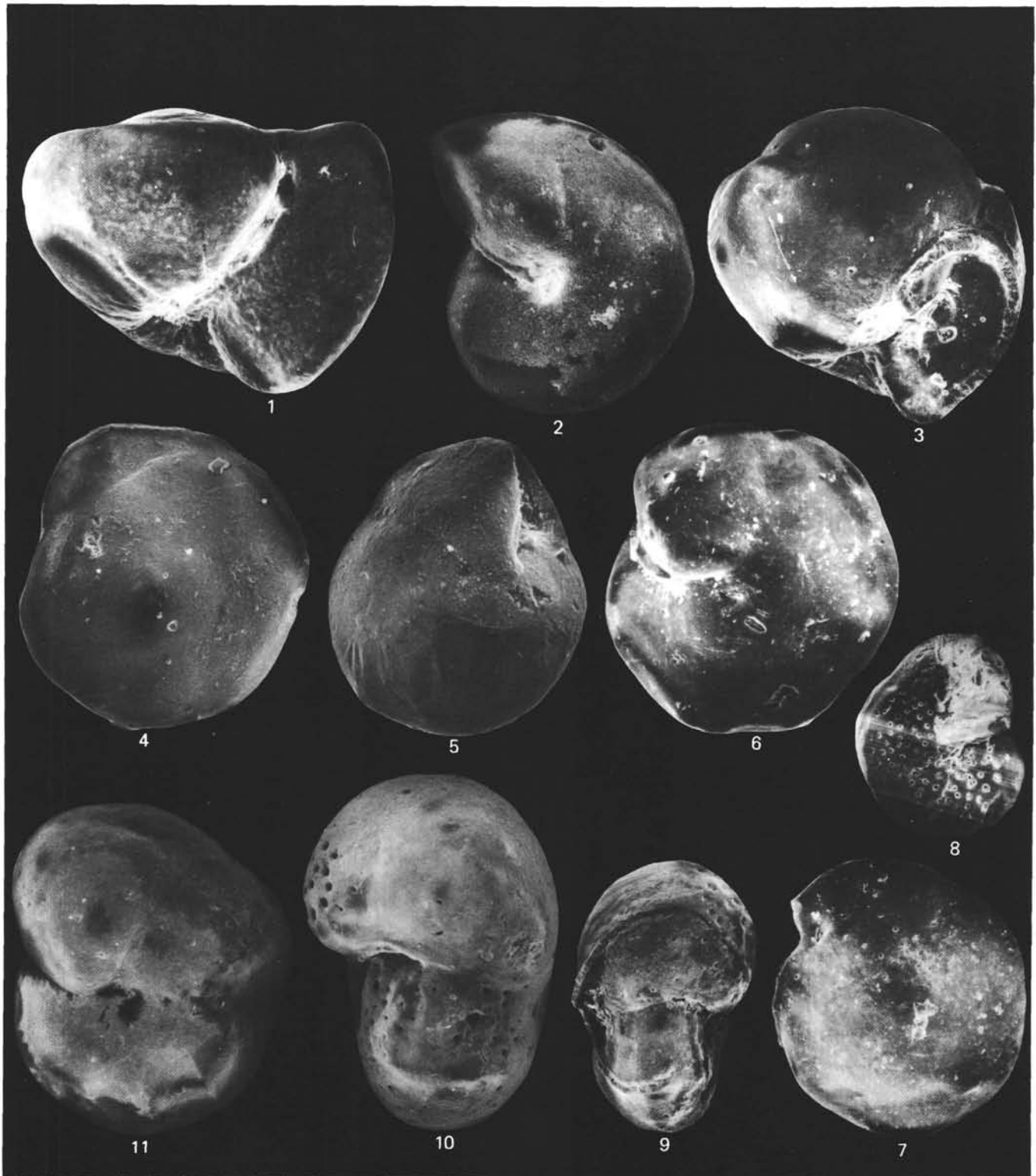


Plate 13. Paleogene foraminifera. 1. *Gyroidina girardana* (Reuss),  $\times 130$ , apertural view. Sample 512-14-3, 80-82 cm. 2. *Gyroidina planulata* Cushman and Renz,  $\times 135$ , ventral view. Sample 512-15-1, 80-82 cm. 3. *Gyroidinoides globosa* (Hagenow),  $\times 120$ , apertural view. Sample 512-19-3, 18-20 cm. 4-5. *Alabamina dissonata* (Cushman and Renz),  $\times 200$  (4) dorsal view. Sample 512-10-20, 102-104 cm (5) ventral view. Sample 512-10-2, 102-104 cm. 6-7. *Oridorsalis ecuadorensis* (Galloway and Morrey). Sample 512-19, CC (6)  $\times 130$ , ventral view (7)  $\times 120$ , dorsal view. 8-11. *Anomalinoides semicibrata* (Beckmann) (8)  $\times 90$ , dorsal view, Sample 512-11, CC (9)  $\times 100$ , apertural view, Sample 512-17-2, 50-52 cm (10-11) Sample 512-10, CC (10,  $\times 200$ , apertural view; 11,  $\times 130$ , ventral view).

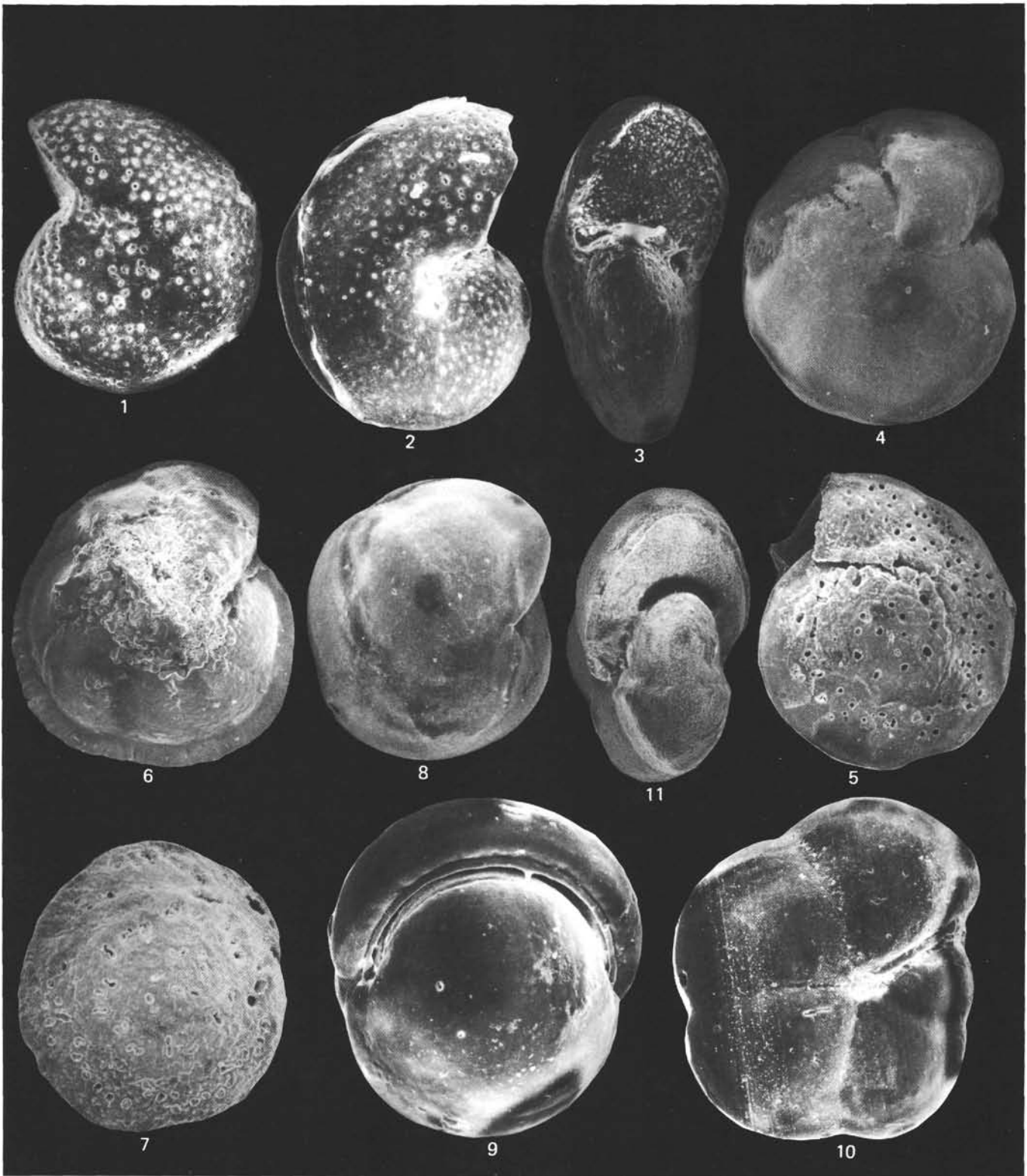


Plate 14. Paleogene foraminifers. 1-3. *Anomalinoidea spissiformis* (Cushman),  $\times 150$ . (1-2) Sample 512-19-2, 18-20 cm (1, dorsal view; 2, ventral view) (3) apertural view. Sample 512-13-2, 85-87 cm. 4-5. *Cibicoides perlucidus* (Nuttall). Sample 512-17-2, 50-52 cm (4)  $\times 120$ , ventral view (5)  $\times 160$ , dorsal view. 6-7. *Heterolepa* sp.,  $\times 100$ . Sample 512-7, CC (6) ventral view (7) dorsal view. 8-9. *Pullenia bulloides* d'Orbigny. Sample 511-5, CC (8)  $\times 125$ , side view (9)  $\times 140$ , apertural view. 10-11. *Pullenia quinqueloba* (Reuss) (10)  $\times 130$ , side view. Sample 512-8, CC (11)  $\times 100$ , apertural view. Sample 512-12, CC.





Plate 15. Paleogene foraminifera. 1-2. *Pullenia riveroi* Bermudez,  $\times 140$ . Sample 512-19-1, 18-20 cm (1) side view (2)  $\times 140$ , apertural view. 3-4. *Nonion havanense* Cushman and Bermudez,  $\times 130$ . Sample 512-11, CC (3) side view (4) apertural view. 5. *Chilostomella czjzeki* Reuss,  $\times 110$ . Sample 511-6-2, 32-34 cm. 6. *Bulimina inflata* Seguenza,  $\times 350$ . Sample 512-15-3, 34-36 cm. 7. *Bulimina jarvisi* Cushman and Parker,  $\times 100$ . Sample 512-15-3, 34-36 cm. 8. *Uvigerina* aff. *peregrina* Cushman,  $\times 115$ . Sample 512-11, CC. 9. *Stilostomella caribaea* (Palmer and Bermudez),  $\times 100$ . Sample 512-18-3, 50-52 cm. 10. *Stilostomella gracillima* (Cushman and Jarvis),  $\times 30$ . Sample 513A-18-1, 64-66 cm. 11. *Stilostomella nuttalli* (Cushman and Jarvis),  $\times 65$ . Sample 513A-15-5, 24-26 cm.

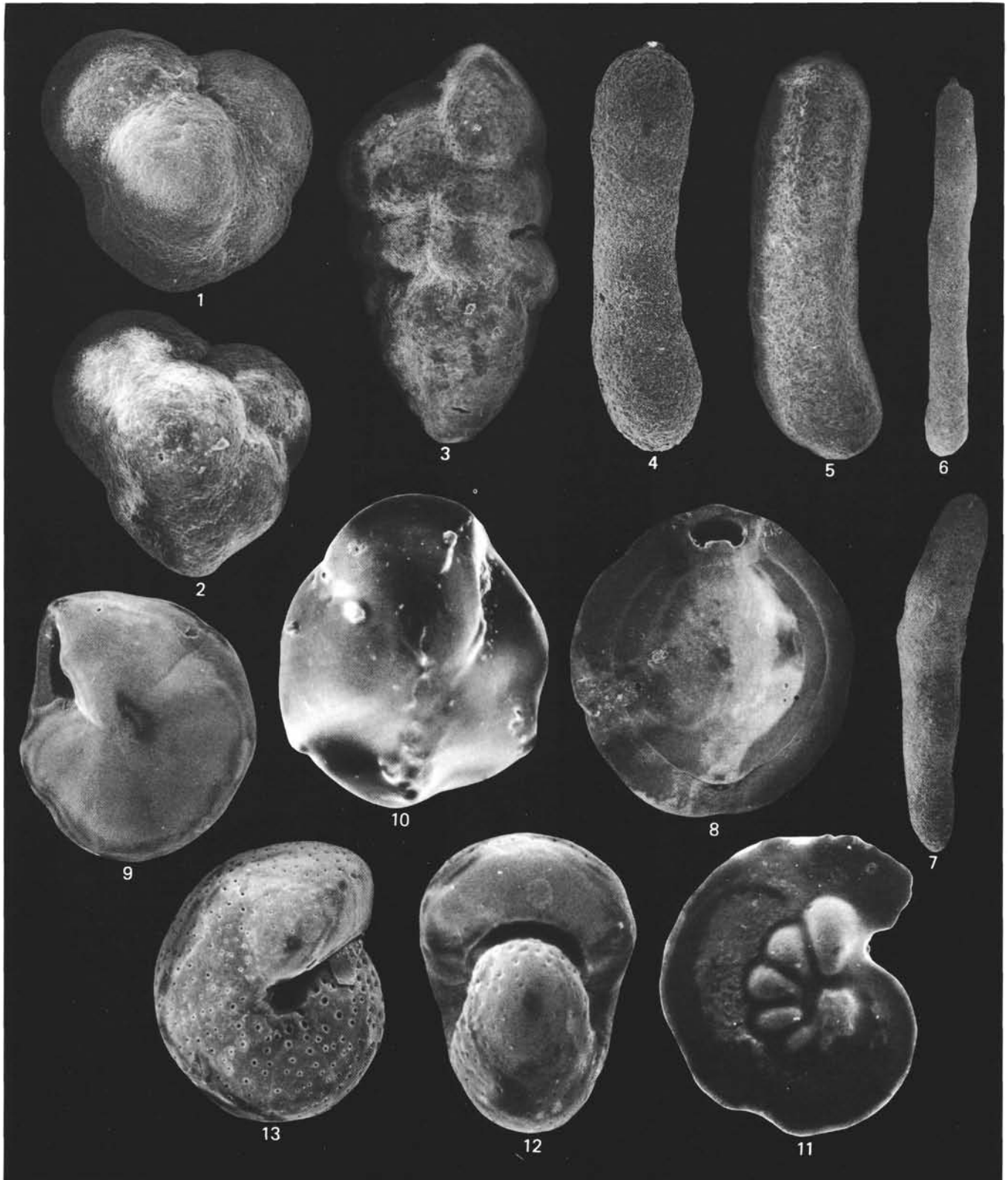


Plate 16. Neogene-Quaternary foraminifers. 1-2. *Eggerella* sp.,  $\times 120$ . Sample 513-6-6, 34-36 cm. 3. *Karriella bradyi* (Cushman),  $\times 120$ . Sample 512-1, top. 4-5. *Martinottiella antarctica* (Parr) (4)  $\times 65$ . Sample 514-23, CC (5)  $\times 70$ . Sample 514-25, CC. 6. *Martinottiella occidentalis* Cushman,  $\times 30$ . Sample 514-15, CC. 7. *Martinottiella* sp.,  $\times 25$ . Sample 514-20, CC. 8. *Pyrgo murrhina* (Schwager),  $\times 110$ , apertural view. Sample 511-5-2, 60-62 cm. 9. *Alabaminoides exiguus* (Brady),  $\times 200$ , ventral view. Sample 514-3-3, 56-58 cm. 10. *Oridorsalis tenerus* (Brady),  $\times 170$ , ventral view. Sample 513A-15-5, 24-26 cm. 11. *Laticarinina pauperata* (Parker and Jones),  $\times 65$ , ventral view. Sample 513A-15-5, 24-26 cm. 12-13. *Melonis pompilioides* (Fichtel and Moll) (12)  $\times 160$ , apertural view. Sample 514-22, CC (13)  $\times 110$ , side view. Sample 513-3-2, 38-40 cm.



Plate 17. Neogene-Quaternary foraminifera. 1-3. *Melonis affinis* (Reuss). Sample 512-3,CC (1-2)  $\times 160$  (1, side view; 2, apertural view) (3)  $\times 150$ , side view. 4-5. *Sphaeroidina bulloides* d'Orbigny (4)  $\times 125$ , apertural view. Sample 513-3-2, 38-40 cm (5)  $\times 150$ , side view. Sample 512-5-1, 83-85 cm. 6. *Trifarina angulosa* (Williamson),  $\times 120$ . Sample 512-1, top. 7. *Angulogerina esuriens* Hornibrook,  $\times 220$ . Sample 512-3,CC. 8. *Cassidulina laevigata* d'Orbigny,  $\times 200$ , apertural view. Sample 512-1, top. 9. *Bradynella subglobosa* (Brady),  $\times 110$ , apertural view. Sample 512-5-2, 53-55.