

## 9. CENOZOIC FORAMINIFERA FROM THE SOUTH ATLANTIC, DSDP LEG 36<sup>1</sup>

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### ABSTRACT

Cenozoic foraminifera occur in four sites drilled during Leg 36, one in the Drake Passage (Site 326), one in the Falkland Outer Basin (Site 328), and two on the eastern end of the Falkland Plateau (Sites 327 and 329).

A calcareous section containing a well-preserved fauna was cored at Site 329. Planktonic foraminifera show that four Tertiary intervals were recovered, upper Paleocene-lower Eocene, Oligocene, lower Miocene, and upper Miocene. Some calcareous planktonics and benthonics are found in the Paleocene-lower Eocene of Site 327. The carbonate-free sediments of Site 328 only yielded an upper Cretaceous-lower Eocene arenaceous benthonic fauna.

Planktonic species diversity and faunal composition at Site 329 indicate a progressive warming during the latest Paleocene culminating with the invasion of mid-latitude angular acarininids and keeled morozovellids. Species diversity of Oligocene assemblages is high relative to the latitudinal position of the site. Intense cooling is inferred from extreme low-diversity assemblages in the late Miocene with predominance of *Globigerina bulloides*.

Four distinct benthonic assemblages occur in the Paleocene, lower Eocene, Oligocene, and upper Miocene. Comparison with low and mid-latitude assemblages from the South Atlantic suggests bathyal depth during the Paleocene. The remarkable stability of benthonic assemblages all through the Cenozoic with great similarities (on generic level) in faunal composition is a further indication for the absence of any substantial subsidence of the Falkland Plateau during the Cenozoic.

### INTRODUCTION

Leg 36 started from Ushuaia, southern Argentina on 4 April 1974, and terminated in Rio de Janeiro on 22 May. It was scheduled as the fourth Antarctic cruise of the Deep Sea Drilling Project with the objective to investigate the Scotia Sea and southernmost Atlantic. Adverse weather conditions necessitated a mid-cruise revision of itinerary which included a cancelling of virtually all Scotia Sea drill sites. Further drilling was then concentrated on more northern locations.

Tertiary sediments were penetrated at three sites of which 329 and 327 are situated on the eastern part of the Falkland Plateau (Figure 1) at the water depths of 1500 and 2400 meters, respectively, and Site 328 to the east in the Falkland Outer Basin at a depth of 5100 meters.

A calcareous section containing an exceptionally well preserved fauna was drilled at Site 329, some planktonics and calcareous benthonics were also found in Hole 327A. Only arenaceous benthonics were

recovered at Site 328. Planktonic foraminifera show that four Tertiary intervals were recovered from the Falkland Plateau, respectively, upper Paleocene-lower Eocene, Oligocene, lower Miocene, and upper Miocene (Table 1).

The early history of the Falkland Plateau is recorded in cores from Hole 327A and Site 330 where a pelagic sequence goes down to the Albian; a mostly sapropelic claystone sequence down to the Middle Jurassic and shallow water deposits overlying gneissic and granitic, continental basement of Precambrian age.

### SITE 326

This site is located in the Drake Passage, about 150 km southeast of Cape Horn in a water depth of 3812 meters. Only one surface core was obtained before a combination of high winds and strong currents resulted in loss of the drill string.

The 50 cm recovered consists of an alternation of detrital sandy silt with clayey silt. Gravels occur at the top and bottom of the core and consist of ice-rafted material of various ages. These were interpreted as lag deposits due to the winnowing action of bottom currents.

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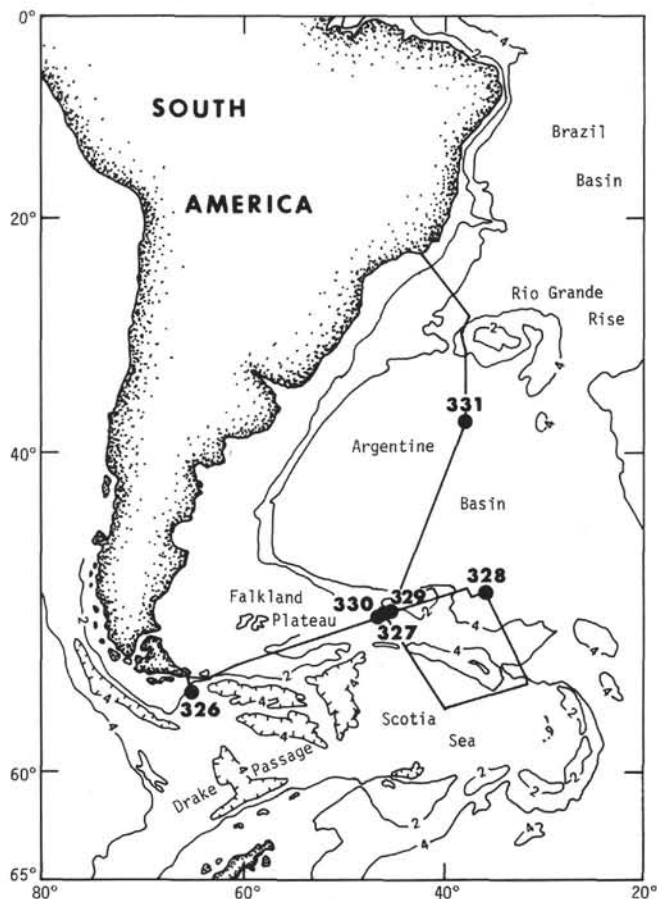


Figure 1. Location of Leg 36 drill sites.

Planktonic foraminifera recovered at two levels show moderate dissolution and sorting as a result of winnowing. The assemblages are assigned to the late Pleistocene to Recent *Globorotalia truncatulinoides* Zone (sensu Kennett, 1970) based on the presence of the zonal marker which, according to Kennett, invaded the Southern Ocean south of 50°S late in the Brunhes Normal Epoch or about 0.2 m.y. ago.

The poor assemblage which also contains *Globorotalia inflata*, *Neogloboquadrina pachyderma* (s), *Globigerina bulloides*, and *G. cf. bulloides* (sensu Keany and Kennett, 1972) is essentially similar to that reported from this area by Herb (1968).

TABLE 1  
Data of Sites Drilled, Leg 36

Hole	Latitude	Longitude	Water Depth (m)	Penetration (m)	No. of Cores
326	56° 35.00'S	65° 18.20'S	3812	9.5	1
327	50° 52.28'S	46° 47.02'W	2401	5.5	1
327A	50° 52.38'S	46° 47.02'W	2401	469.5	27
328	49° 48.67'S	36° 39.53'W	5013	397.0	12
328A	49° 48.67'S	36° 39.53'W	5013	17.0	2
328B	49° 48.67'S	36° 39.53'W	5013	471.0	8
329	50° 39.31'S	46° 05.73'W	1519	464.5	33
330	50° 55.19'S	46° 53.00'W	2626	575.5	17
330A	50° 55.19'S	46° 53.00'W	2626	53.0	5
331	37° 53.00'S	38° 06.92'W	5067	18.0	2

### SITE 327

Site 327 is situated on the elevated eastern part of the Falkland Plateau in a water depth of 2401 meters. One of the main objectives of the site was to obtain a relatively shallow water biostratigraphy. The section consists of a thin veneer of Quaternary sands and gravels (with an occasional diatom-rich clay) overlying a succession of lower Eocene zeolitic clay, siliceous ooze, and zeolitic clay before reaching Upper Cretaceous calcareous oozes at a depth of 90 meters. Two holes were drilled at the location, the first one (Hole 327) resulting in one core only. The surface cores of both holes yielded a well-preserved late Pleistocene to Recent assemblage (*Globorotalia truncatulinoides* Zone sensu Kennett, 1970) which in addition to the zonal marker, contains *Globorotalia inflata*, *G. scitula*, *Neogloboquadrina pachyderma* (s), *Globigerina bulloides*, *G. cf. bulloides*, *G. quinqueloba*, *Globigerinita glutinata*, and *G. uvula*.

At Hole 327A, Section 1 of Core 2 yielded poorly preserved planktonics and clayey casts of planktonics. Among the species identified are: *Acarinina mckannai*-group, *A. primitiva*, *Morozovella caucasica*, and *Planorotalites australiformis*, indicating a late early Eocene age.

Planktonic foraminifera are absent from the remaining part of Core 2 through Core 10, but at several levels in the siliceous ooze of Cores 5 and 6 dissolution-resistant benthonics are found such as *Gavelinella beccariformis*, *Pullenia coryelli*, *Tritaxia globulifera*, *Nuttallides truempyi*, *Oridorsalis umbonatus*, *Spiroplectamina spectabilis*, *Bolivinoidea delicatulus*, and *Coryphostoma limonense*. Although incomplete, this assemblage is essentially similar to that found in the Paleocene of the shallower Site 329. This assemblage is also dominant in a number of DSDP sites in the South Atlantic and is characteristic of bathyal depth during the late Paleocene.

### SITE 328

Site 328 was drilled in the Falkland (Malvinas) Outer Basin east of the Falkland Plateau and south of the Falkland Fracture zone in a water depth of 5103 meters. Operational difficulties resulted in three holes with a maximum penetration of 471 meters into strata of a probable late Cretaceous age. The lithology consists of carbonate-free sediments, including siliceous oozes, zeolitic clays, and claystones. These contain siliceous microfossils from which a relatively complete biostratigraphic record as far down as the Oligocene could be obtained.

In the lower part of Hole 328, mainly in Cores 8-10 and 12, rare arenaceous benthonic foraminifera are present. Most levels yielded only fragments of primitive, tubular species. Relatively well preserved, but species-poor faunas, including uniserial and triserial species, were recovered from Core 10. They represent yet another benthonic assemblage, very different from those at Hole 327A and Site 329 which are predominantly calcareous and lack simply constructed agglutinants.

The following species have been identified: *Amodiscus cretaceus*, *Glomospira charoides*, *G. gordialis*, *Rzehakina epigona*, *Haplophragmoides* sp., *H. excavata*, *Nodellum velascoense*, *Bathysiphon* sp., *Saccamina complanata*, *Hormosina ovulum*, *Uvigerinammina* sp., and *Paratrochamminoides* sp.

The absence of morphologically complex agglutinants and the abundance of tubular species like *Bathysiphon* sp. is typical of the so-called *Rhabdammina*-faunas (Brouwer, 1965) which characterize water depths well below the CCD. According to Brouwer they are confined to the abyssal environment even in the high latitudes. Their stratigraphic range is from Cretaceous to Recent, but the presence of *Rzehakina epigona* at Site 328 restricts this assemblage to the Late Cretaceous-early Eocene interval (Hiltermann, 1974). Similar, but more diversified faunas in association with complex agglutinants, have recently been reported from some southern high-latitude DSDP sites at water depths of 5000 meters. Of particular interest are those from the Late Cretaceous and early Paleocene of Site 323 in the Bellingshausen Abyssal Plain (Rögl, in press) and from the Paleocene-early Eocene of Site 283 in the Tasman Basin (Webb, 1975).

#### SITE 329

Site 329 is situated about 55 km northeast and upslope from Site 327, on the southwestern flank of the elongate rise forming the eastern end of the Falkland Plateau. Water depth is 1519 meters.

The objectives at this site were to obtain a comparatively shallow water biostratigraphic record from the Cenozoic to complement the record at Hole 327A (where the Paleocene was the only interval recovered adequately) and to compare this record with that of deep water Site 328. The co-occurrence of well-preserved siliceous microfossils (diatoms, Radiolaria, silicoflagellates) and calcareous microfossils (nanofossils and foraminifera) throughout most of the section makes Site 329 extremely important for high (southern) latitude biostratigraphy.

In total, 465.5 meters of sediment were penetrated, ranging in age from Quaternary to late Paleocene with an apparent hiatus between Quaternary and late Miocene, and probably between early Miocene and Oligocene and between Oligocene and early Eocene.

From reflection profiles the thickness of the sedimentary section above the Cretaceous was estimated to be 530 meters. Drilling ended at 465.5 meters when a stratigraphic overlap with the Paleocene of Hole 327A was obtained. Coring was continuous to 179.5 meters (Core 19), then intermittent to 388.5 meters (Core 28), and again continuously (Cores 28-31) down to 426.5 meters. Finally, two consecutive Cores (32-33) were taken from 445.5 to 464.5 meters. In total 215.1 meters (69%) were recovered with lowest recovery in the deeper part of the section where coring was discontinuous.

Two major lithologies are recognized. The upper one consists of a nanno-diatom ooze (Cores 1-27) most of which seems to be of late Miocene age. In its lower part

it grades into nanno-chalk (Cores 28-33) of Oligocene-late Paleocene age. Ice-rafted material mixed with diatom ooze is found in the upper part of Core 1.

In general, the preservation of the foraminifera is excellent, but below Core 26 dissolution has affected the planktonics as a result of the lithification process. This is evidenced by nanofloras which show calcite overgrowth at the same levels.

### PLANKTONIC FORAMINIFERA

#### Paleocene/Eocene

*Subbotina* and *Acarinina* are the dominant genera in the lowest Cores 32 and 33, with *Planorotalites* only second in importance to these.

Biostratigraphy in Core 33 had to be based solely on acarininids as they represent the most rapidly evolving group in this otherwise low-diversity assemblage.

The presence of *Acarinina mckannai* at the base of the core suggests a stratigraphic level of at least the *Planorotalites pseudomenardii* Zone. Higher up, in Section 4, the appearance of *Acarinina soldadoensis*, *A. primitiva*, and *A. esnaensis* indicates a somewhat higher level, most probably equivalent to that of the *Morozovella velascoensis* Zone.

Most conspicuous at these levels is the complex group of conical acarininids which center round the species *A. tadjikistanensis djanensis*, *A. cf. praepentacamerata*, and *A. nicoli*. The latter two persist in the basal part of Core 32.

*A. tadjikistanensis djanensis* is reported from the USSR from the *A. tadjikistanensis djanensis* Zone (Stratigraphic Commission, 1963). Luterbacher (1964) tentatively correlated this zone with the upper part of the *Morozovella pusilla pusilla* Zone and the lower part of the *Planorotalites pseudomenardii* Zone. If that is correct, then its range in Site 329 is unexpectedly long (Table 2).

The appearance of *Planorotalites australiformis* at the top of Section 3 is significant as this species has been reported to replace *P. pseudomenardii* during the late Paleocene in New Zealand (Jenkins, 1965). At Site 329 it intergrades with *P. planoconica* throughout its range.

The base of Core 32 shows an abrupt faunal change, possibly accentuated by the approximately 1-meter stratigraphic gap between Cores 33 and 32. Most notable is the influx of angular acarininids and keeled morozovellids, like *Acarinina wilcoxensis*, *A. apanthesma*, *A. aequa*, and rare *Morozovella subbotinae*. Among the acarininids there is the disappearance of the *Acarinina tadjikistanensis* group and *A. convexa*, while typical *A. mckannai* is replaced by more evolved forms like *A. pentacamerata camerata* and *A. pentacamerata acceleratoria*. Forms close to *A. gravelli* are seen in the upper part of the core.

Section 1 contains essentially the same assemblage, but the presence of *Acarinina pseudotopilensis* and *Pseudohastigerina wilcoxensis* places this part of the core definitely in the early Eocene, probably the *Morozovella subbotinae* Zone. In spite of the fact that the first occurrence of *Planorotalites wilcoxensis* has become a point of uncertainty recently (Premoli-Silva

TABLE 2  
Distribution of Selected Paleocene-Eocene Planktonic Foraminifera, Site 329

Sample Interval (cm)	Depth Below Sea Floor of Core-Top (m)	Recovery (m)	Diagnostic Planktonic Foraminifera	Preservation	Benthonic Assemblage	Planktonic Zone	Age
32-1, 69-71 32-1, 107-109 32-1, 139-143 32-4, 5-7 32-4, 33-35 32-4, 67-69 32-4, 107-109 32-4, 127-129 32, CC	445.5-455.0	2.2	As below but with addition of <i>P. wilcoxensis</i> <i>A. pseudotopilensis</i> , <i>Catapsydrax</i> sp.	G G E G G E F F E E	II	<i>M. subbotinae</i>	Early Eocene
33-1, 94-95 33-1, 125-127 33-1, 139-141 33-2, 70-71 33-2, 145-146 33-3, 10-12 33-3, 70-72 33-3, 118-120 33-4, 77-80 33-4, 100-102 33-4, 138-140 33, CC	455.0-464.5	4.8	As below but with addition of <i>P. australiformis</i> and <i>P. planoconica</i>	E E E G G F G G G F P G			
			As below but with addition of <i>A. soldadoensis</i> , <i>A. primitiva</i> , <i>A. aquiensis</i> , <i>A. esnaensis</i> , <i>S. varianta</i> , <i>T. reissi</i>				
			<i>S. triangularis/patagonica</i> , <i>S. velascoensis</i> , <i>A. mckannai</i> , <i>A. cf. tadjikistanensis</i> , <i>A. nicoli</i> , <i>A. convexa</i> , <i>Chiloguembelina</i> spp.			<i>P. pseudomenardii</i>	

Note: Preservation: E = excellent, G = good, F = fair, P = poor.

and Bolli, 1973; McGowran, 1974), its first appearance in lower Eocene sediments in mid latitudes (Beckmann et al., 1969; Berggren, 1969) seems to be well established.

### Oligocene

Relatively diverse assemblages are encountered in the Oligocene of Cores 28-31. Dominant genera are *Subbotina*, replaced by *Globigerina* in Core 28; less abundant are *Globorotaloides*, *Turborotalia*, *Catapsydrax*, and *Chiloguembelina*.

In Cores 29-31 *Subbotina angiporoides* dominates the assemblages, which consist of *Globorotaloides* cf. *suteri*, *Turborotalia munda*, *Catapsydrax unicavus*, *C. dissimilis*, and *Chiloguembelina cubensis*. *Turborotalia nana* and *Subbotina linaperta* occur sporadically throughout this interval. Forms with bullae such as *S. angiporoides*, *Catapsydrax unicavus*, *C. dissimilis*, *Globorotaloides* cf. *suteri*, and *Subbotina linaperta* occur frequently.

Based on the co-occurrence of *S. angiporoides* and *Turborotalia munda* Cores 29-31 can be correlated with the *Subbotina angiporoides* Zone of New Zealand, which according to the biostratigraphic scheme of Jenkins (1974, 1975) belongs to the early Oligocene.

Moderate dissolution in Core 28 and to some degree in Core 29 has affected the species diversity, resulting in the sporadic presence of some of the more delicate species like *Turborotalia munda* and *Chiloguembelina cubensis* (Table 3).

The rather uncharacteristic assemblage of Core 28 is dominated by *Globigerina brazieri* and contains in less abundance *Catapsydrax unicavus*, *C. dissimilis*, and *G. cf. suteri*. *Subbotina angiporoides* appears to be a dissolution-resistant species (Jenkins, 1975), and its absence in Core 28 indicates a stratigraphic level above the *S. angiporoides* Zone. In New Zealand both *Tur-*

*borotalia munda* and *Chiloguembelina cubensis* survive *Subbotina angiporoides* for a short time (Jenkins, 1971, 1974), as do both of these species in northern Europe (Berggren, 1969) and the South Atlantic (Berggren and Amdurer, 1973). The latter authors made an attempt to compare their South Atlantic DSDP Leg 3 sections with both Jenkins' New Zealand biostratigraphic scheme for the Oligocene and Blow's (1969) low latitude zonation. They correlate the *Subbotina angiporoides* Zone with Zones P18-P19/20 of Blow, while the overlying interval before the extinction of *Chiloguembelina* is considered to be equivalent with the lower part of Zone P21.

### Miocene

In Core 27 only the lower 40 cm were examined. The assemblages here are dominated by primitive members of the *Globorotalia miozea* lineage, generally covered by heavy crusts of secondary calcite. Following Walters (1965) bulk of the population is considered as transitional between *G. praescitula* and *G. miozea miozea*, as recorded from the lower Altonian Stage of New Zealand (sensu Scott, 1972b) which according to Berggren and Van Couvering (1974) is equivalent to the early Miocene Zones N6-7.

The remaining part of assemblages consist of long-ranging species such as *Globigerina bulloides* s.l. and *Globigerinita glutinata*. Globigerinids of the *G. bulloides* group are frequently covered with a thick crust of secondary calcite concealing most of the specific characters. This encrustation phenomenon is present in varying degree from Core 27 upwards. Core catcher 27 also contains *G. cf. suteri* and *G. zealandica incognita*. The latter species also occurs in the lower Altonian of New Zealand.

The presence of late Miocene is suggested by the occurrence of *Neogloboquadrina acostaensis* in Section 1

TABLE 3  
Distribution of Oligocene Planktonic Foraminifera, Site 329

Sample (Interval in cm)	Depth Below Sea Floor of Core-Top (m)	Recovery (m)	<i>Subbotina angiporoides</i>	<i>Chiloguembelina cubensis</i>	<i>Turborotalia munda</i>	<i>Catapsydrax unicavus</i>	<i>Globorotaloides cf. suteri</i>	<i>Turborotalia nana</i>	<i>Catapsydrax dissimilis</i>	<i>Globigerina praebulloides</i>	<i>Subbotina linaperta</i>	<i>Globigerina woodi</i>	<i>Globigerina brazieri</i>	Disso- lution	Benthonic Assemblage	Planktonic Zone	Age
28-1, 15-17	388.5-398.0	1.5					T	T	R				A	M	III	P21	Oligo- cene
28-1, 97-99					T	T	T	T	T	T				A			
28, CC			R	C	C	C	R	T	T			R	C	L			
29-1, 123-125	398.0-407.5	1.0	A		C	C			F					M			
29, CC			C	R	C	F				F	T	A		L-M			
30-3, 119-121	407.5-417.0	4.3	A	C	C	C		R						L		P18-19/20	
30, CC			A	C	C	C	C	T	R	C				L			
31, CC	417.0-426.5	0.1	A	T	R	F	C						L				

Note: Frequency: A = abundant, C = common, F = frequent, R = rare, T = traces. Dissolution: L = slightly affected, M = moderately affected.

of Core 26. This is the only sample examined from this core in which *N. acostaensis* occurs together with its ancestor *Turborotalia continuosa*, and thus the lower boundary of Zone N16 may fall between this level and Section 1 of Core 27 or be absent altogether. *Neogloboquadrina acostaensis* is most frequent in Cores 26 and 25. It is defined as a five-chambered form with an umbilical-extraumbilical aperture with a broad lip often protruding over the narrow umbilicus, the wall-surface is cancellate (Table 4). In higher cores its morphology is less distinct, and it seems to grade into more compact, four-chambered forms with a more or less umbilical aperture with or without protruding lip. This form, close in morphology to *Neogloboquadrina pachyderma* (surface form), is present in Core 26 and replaces *N. acostaensis* above Core 8. More frequent in the cores than the latter group is *Turborotalia continuosa* which gradually develops into a form with a more umbilical, high-arched aperture (Plate 7, Figure 6).

Compared to the lower biostratigraphic units, the assemblages are extremely low in diversity, with *Globigerina bulloides* and *Globorotalia scitula* as main constituents. Other species occur at irregular intervals: *Globigerinita glutinata*, *G. uvula*, *Globorotalia anfracta*, and keeled *G. panda*. The latter two are reported from low latitude Pacific/Indian Ocean faunas and the New Zealand region.

#### Pleistocene

In the upper half of Core 1, two of Kennett's (1970) Pleistocene zones could be recognized, based on the successive occurrence of *Globorotalia puncticulata* with *G. inflata* (*G. inflata* Zone) in Sections 3 and 2, and *G. inflata* with *G. truncatulinoides* (*G. truncatulinoides* Zone) in Section 1. The varying abundance of planktonics and mixing at some levels in the lower half of Core 1 make zone assignment impossible.

#### BENTHONIC FORAMINIFERA

Benthonics are well preserved and comparatively common throughout the stratigraphic section of Site 329. Their abundance relative to that of the planktonic foraminifera varies between an estimated 5% (in the >149  $\mu\text{m}$  fraction) down in the Paleocene to over 90% in some cores of the Miocene. Four distinct pre-Quaternary assemblages are present at Site 329, which are dated as Paleocene, early Eocene, Oligocene, and late Miocene. They are partly separated by uncored intervals and partly by probable stratigraphic hiatuses, with the exception of the first two which are found at short distance of each other at the bottom of Core 32 with no evidence of a stratigraphic break of any magnitude. The assemblages at Site 329 are more or less analogous to the stratigraphic groups distinguished by Douglas (1973) in the Central North Pacific and which include the upper Cretaceous-Paleocene, Paleocene-middle Eocene, middle Eocene-lower Oligocene, upper Oligocene-middle Miocene, and middle Miocene-Recent.

#### Assemblage I

This assemblage is present in Core 33 and the core catcher of Core 32. It is dominated by *Gavelinella beccariiiformis*, *G. danica*, and *Pullenia coryelli* while at two distinct levels (33-4, 77-102 cm and 33-1, 125 cm to 33-2, 71 cm) arenaceous species like *Tritaxia globulifera* and also *Gaudryina pyramidata* occur abundantly.

The assemblage is also characterized by the presence of: *Spiroplectammina spectabilis*, *S. cretosa*, *Gaudryina laevigata*, *Lenticulina* sp., *Nodosaria limbata*, *N. monile*, *N. velascoensis*, *Fronicularia jarvisi*, *Neoflabellina jarvisi*, *Tappanina selmensis*, *Bolivinoidea delicatulus*, *Coryphostoma limonense*, *Quadriformina allomorphinoides*, *Pullenia* sp., *Gyroidinoides globosus*, *G. girardanus*, *G. cf. quadratus*, *Gavelinella hyphalus*,

TABLE 4  
Distribution of Neogene Planktonic Foraminifera, Site 329

Sample (Interval in cm)	Depth Below Sea Floor of Core-Top (m)	Recovery (m)	<i>Globorotaloides</i> cf. <i>suteri</i>	<i>Globorotalia</i> <i>zealandica</i> -group	<i>Globigerina</i> sp.	<i>Globorotalia</i> <i>mitozoa</i> -Group	<i>Globigerina</i> <i>bulloides</i> s.l.	<i>Globigerina</i> <i>woodi</i>	<i>Globigerinita</i> <i>glutinata</i>	<i>Turborotalia</i> <i>continua</i>	<i>Neogloboquadrina</i> <i>acostaensis</i>	<i>Globorotalia</i> <i>scitula</i> s.l.	<i>Globigerinita</i> <i>uvula</i>	<i>Globorotalia</i> <i>anfracta</i>	<i>Globorotalia</i> <i>panda</i>	<i>Neogloboquadrina</i> <i>pachyderma</i>	<i>Globorotalia</i> <i>inflata</i>	<i>Globorotalia</i> <i>puncticulata</i> (sensu Kennett)	<i>Globigerina</i> <i>quinqueloba</i>	<i>Globorotalia</i> <i>truncatulinoides</i>	Relative Abundance of Planktonic Foraminifera	Benthonic Assemblage	Planktonic Zone	Age
1-1, 38-40	0.0-9.5	9.1		A	R	T	C		A	C	R	F									A	IVa	<i>Globorotalia</i> <i>truncatulinoides</i> <i>Globorotalia</i> <i>inflata</i>	Pleistocene
1-3, 104-106				A	F									A	C	R					R			
1-4, 106-108				A	T	F	T							T							R			Pleistocene
1-5, 100-102				A	R		R	T						A	C	C	R				R			L. Miocene
2-3, 100-102	9.5-19.0	8.0		R		A	R		T												T			
6-3, 100-102	46.5-56.0	9.2		A		R	R														F			
8-4, 100-104	65.5-75.0	8.5		A		F	R														C			
12-4, 100-104	103.5-113.0	9.5		C		C	R														F			
13-4, 100-104	113.0-122.5	9.5		A		R								R							R	IV	N16	Late Miocene
17-6, 99-103	151.0-160.5	9.5		C		R	C	R													C			
20, CC	189.0-198.5	9.5		A							C		A								C			
25, CC	303.0-312.0	0.1		C		F	R	R	A	R											C			
26-1, 106-107	331.5-341.0	3.9		C		R	R	C	A	R											C			
27-1, 120-124	360.0-369.5	1.5		F	A	C	T	F													A	III- IV	N6-7	Early Miocene
27, CC				F	R	R	A	C													R			

Note: Frequency: A = abundant, C = common, F = frequent, R = rare, T = traces.

*Oridorsalis* cf. *umbonatus*, *Alabamina* sp., and *Cibicidoides* sp.

The environmental distribution of Paleocene deep water benthonics from DSDP sites in the Atlantic has recently been studied by Lohmann and Tjalsma (in preparation). Five different assemblages were distinguished with R-mode factor analysis, based on a census of 28 of the most common species. Assemblage I characterized by *P. coryelli*/*G. danica*/*T. globulifera* also occurs during the late Paleocene in South Atlantic Sites 21 and 144A at paleodepths between 1300 and 2400 meters. A point of difference is the exceptionally low abundance of buliminids (less than 4% in the >149 μm fraction) and the absence of *Aragonia* at Site 329.

**Assemblage II**

This assemblage starts just above the base of Core 32, it is rich in specimens and species compared to assemblages in the same time interval in other parts of the Atlantic.

It is dominated almost completely by Paleocene relict species such as *Cibicidoides* sp., *Oridorsalis umbonatus*, *Nonion* sp., *Nuttallides truempyi*, *Anomalinoidea affinis*, and *Pullenia* cf. *jarvisi*. Less frequent are *Gavelinella danica*/*aragonensis*, *Bulimina trinitatensis*, *Tappanina selmensis*, *Aragonia aragonensis*, *Nodosaria velascoensis*, and *N. monile*. Among the very few new species are *Tritaxia* sp., *Bulimina* cf. *semicostata*, *Bulimina* spp., and *Boldia cushmani*.

The transition from Assemblage I into II represents the most drastic change among deep-water benthonics

since the Campanian-Maestrichtian. The event, although present in other oceans as well (Site 245, Indian Ocean, Sigal, 1974) has not been well documented. This is partly due to sedimentary hiatuses in this particular period of time in many parts of the world (Rona, 1973).

The benthonic event was originally recorded from the Paleocene-Eocene Lizard Springs Formation in Trinidad, where according to Beckmann (1960) only 53% of the Paleocene benthonic species continue into the lower Eocene. Recently Braga et al. (1975) described deep water benthonics from a continuous Paleocene-Eocene section at Possagno, northern Italy. Here too the lower Eocene is characterized by an impoverished fauna in which new elements appear just below the middle Eocene.

Biostratigraphic data on the benthonic event in mid-latitude Site 21 (South Atlantic) and low-latitude Site 152 (Caribbean) indicate that the benthonic faunal event occurs within the range of *Morozovella subbotinae* in the upper part of the *Morozovella velascoensis* Zone (Tjalsma and Lohmann, in preparation), which supports the presumed isochronous character of the event.

**Assemblage III**

This assemblage is confined to Cores 28-31, although some species are found in Core 27 occurring together with species of Assemblage IV. Moderate dissolution in Cores 28 and 29 has concentrated the benthonics.

Dominant genera are *Uvigerina*, *Pullenia*, and *Neoeponides*. *Cibicidoides*, *Gyroidinoides*, and *Anomalinoides* are also common. Some of the characteristic species included in the assemblages are: *Pullenia bulloides*, *P. cf. quinqueloba*, *Neoeponides cf. waltonensis*, *Gyroidinoides girardanus*, *Cibicidoides trincherasensis*, *Anomalinoides alazanensis*, *A. aragonensis*, *Nonion havanense*, *Laticarinina bulbrooki*, *Vulvulina jarvisi*, *V. spinosa*, and *Bulimina macilenta*. In general the faunal relationship between Assemblage III and the Oceanic Formation in Barbados (Beckmann, 1953) appears to be tenuous.

#### Assemblage IV

This assemblage is present in Cores 2-26 with *Pullenia bulloides* as the most dominant species. At some levels it is replaced by *Gyroidinoides neosoldanii* or *Eggerella bradyi*. In a number of samples *Oridorsalis umbonatus* or *Fursenkoina earlandi* occur in abundance.

Also common are *Cibicidoides grossepunctatus*, *Pullenia quinqueloba*, *Melonis barleeanum*, *Pyrgo murrhina*, and in the upper part of the section *Planulina wuellerstorfi*. Characteristic, but less common, are *Karreriella bradyi*, *K. novangliae*, *Martinotiella communis*, *M. nodulosa*, *Sphaeroidina bulloides*, *Valvulinaria laevigata*, and *Laticarinina pauperata*. Species occurring sporadically are: *Bulimina aff. subacuminata*, *Melonis pompiloides*, *Oridorsalis cf. sidebottomi*, *Trifarina earlandi*, *Globocassidulina subglobosa*, *Pyrgo depressa*, *Plectofrondicularia advena*, *Lagena elongata*, and *Orthomorphina ambigua*.

The larger part of this assemblage is recorded from Recent occurrences in the Drake Passage area (Herb, 1971). Most of the species mentioned display a rather wide bathymetrical distribution, some of which reach the shelf at their upper depth limit. Based on the rather scarce data from lower bathyal stations, the occurrence of *Eggerella bradyi*, *Karreriella bradyi*, *Martinotiella communis*, and *M. nodulosa* is of particular importance as their present-day upper depth limit lies around the 1800 meter depth.

The great accumulation of diatoms and calcareous nanofossils during the late Miocene indicates a period of high phytoplankton productivity in the vicinity of the site related with an area of upwelling, similar to present-day upwelling of nutrient-rich bottom water at the Antarctic Divergence and/or transport of these light particles by bottom currents. Relative abundance of the planktonic foraminifera is generally low in this part of the stratigraphic section due to dilution by large numbers of diatom frustules. Benthonic foraminifera, on the other hand, are relatively abundant in the same interval, supporting the suggestion of high phytoplankton productivity in the surface waters.

#### Assemblage IVa

In the upper half of Core 1 a low-diversity fauna is dominated by *Bulimina aculeata* and *Trifarina angulosa*, with additional species such as *Uvigerina peregrina*, *Hoeglandina elegans*, and *Pyrgo* sp. Species of Assemblage IVa include *Globocassidulina crassa*, *Karreriella bradyi*, *Oridorsalis umbonatus*, and *Planulina wuellerstorfi*.

## DISCUSSION

The geological history of the Falkland Plateau, as it has been inferred from the sediments cored at Sites 330 and 327, starts with the gneissic and granitic, continental basement of Precambrian age. Subsidence was initiated most probably during the middle Jurassic by the deposition of shallow water sediments. Euxinic conditions prevailed during a long period from Middle/Late Jurassic to Aptian with the formation of dark sapropelic claystones. Open marine conditions were established in the Aptian/Albian during which time the plateau underwent rapid subsidence with pelagic sedimentation from the Albian upwards.

Evaluation of the Paleocene benthonic assemblages is crucial in determining whether additional subsidence occurred during the Cenozoic. In three sites early Paleogene benthonics are recovered and the difference in faunal composition as well as the state of preservation reflects the difference in water depth of these sites during that time.

The presently deepest site, Site 328 east of the Falkland Plateau (water depth 5100 m) contains a so called *Rhabdammina*-fauna (Brouwer, 1965) with primitive arenaceous species with *Rzehakina epigona*, indicative of a Late Cretaceous-early Eocene age and sedimentation below the CCD.

The much shallower Site 327 (present water depth, 2400 m) on the plateau itself yielded a late Paleocene (based on nannoplankton data) calcareous residue assemblage in which primitive agglutinants are virtually lacking. The same assemblage, unaffected by dissolution, is found in the upper Paleocene of the nearby Site 329 (water depth, 1500 m). It is characterized by the dominant species *Pullenia coryelli*/*Gavelinella danica*/*Tritaxia globulifera*.

The distribution of Paleocene deep water assemblages has recently been studied by Lohmann and Tjalsma (in preparation). The *P. coryelli*/*G. danica*/*T. globulifera* assemblage has a wide geographical distribution, and during the late Paleocene it seems to prefer intermediate depths in the low to mid latitudes of the South Atlantic, where it was found in DSDP Sites 21 and 144A at paleodepths of 1300 and 2400 meters, respectively.

In spite of the difference in latitude, which might account for differences in depth preferences of an assemblage, the pelagic character of the foraminiferal fauna in Site 329 (P/B ratio near 20:1) supports the assumption of similar water depth during the Paleocene.

The remarkable stability of benthonic assemblages all through the Cenozoic is a further indication for the lack of Cenozoic subsidence. Notwithstanding the specific differences, there are remarkable similarities at the generic level, as for instance the recurring dominance of *Pullenia* (from *P. coryelli* in the Paleocene to *P. bulloides* in the Late Miocene) and the important role that genera such as *Gyroidinoides*, *Oridorsalis*, and *Cibicidoides* play in the successive assemblages.

Late Miocene species are virtually the same as those which live today in the area and the bathyal character

of the fauna is further illustrated by the common occurrence of *eggerella bradyi*, *Karrerella bradyi*, *Martiniella communis*, and *M. nodulosa*. The present upper depth limit of these species is around the 1800 meters (Herb, 1971).

Planktonic foraminiferal diversity has been used by several workers as a tool for estimating relative Cenozoic paleotemperatures (Jenkins, 1968; Margolis and Kennett, 1971). Although our data are not quantitative and we made only a rough inventory of the early Paleogene faunas, some of the gross trends can readily be observed.

The upper Paleocene at the bottom of the section of Site 329 contains a low-diversity assemblage consisting of the genera *Subbotina*, *Chiloguembelina*, and *Acarinina*, all three of which have a preference for mid to high latitudes. The subsequent rapid increase in number of species as well as the appearance of new genera (*Turborotalia*, *Planorotalites*) suggests a progressive warming during the late Paleocene, culminating with the invasion by mid-latitude angular acarininids and keeled morozovellids during the latest Paleocene. The even higher species diversity together with the appearance of two more genera (*Pseudohastigerina*, *Catapsydrax*) in the basal Eocene indicate a continuation of this trend. The presence of morozovellids in the upper lower Eocene of Hole 327A suggests that this warming included most of the early Eocene.

The Oligocene assemblages are more or less as diversified as the oldest Paleocene but contain more genera. Compared to low-latitude faunas (Bolli, 1957), species diversity is high relative to the latitudinal position of the site. An analogous situation has been reported from New Zealand where above the low-diversity fauna at the base of the Oligocene a large influx of immigrant species appears in the upper *Subbotina angiporoides* Zone, interpreted by Jenkins (1973) as a warming trend.

The species-poor fauna in the lower Miocene seems to be unreliable, merely the result of selective dissolution resulting in the high dominance of members of the *Globorotalia miozea* lineage.

Intense cooling is inferred from extreme low-diversity assemblages in the upper Miocene, with a high dominance of *Globigerina bulloides*. However, this analogy may not be applicable to Recent assemblages of this area. The higher diversity of Recent assemblages may be the result of better adaptation of the species since the late Miocene to the generally cool conditions of these latitudes (Kennett and Vella, 1975). This may especially be the case with the globorotaliids; analogs of Plio/Pleistocene *G. inflata* and *G. truncatulinoides* appear to be nonexistent during the Miocene.

## TAXONOMIC NOTES

### *Acarinina nicoli* (Martin?) (Plate 1, Figures 1-3)

*Globorotalia nicoli* Martin, 1943. Stanford Univ., Calif., Univ. Ser., Geol. Sci., v. 3, p. 117, pl. 7, fig. 3a-c.

The species is characterized by the low conical umbilical side, the narrow umbilicus and the tangential sutures on the spiral side. There

is quite a variation in the degree of the conical angle, in some variants being less sharp than figured in the holotype.

Throughout its range it grades into five-chambered forms which are close to *Acarinina praepentacamerata* (Plate 1, Figures 4-6).

The peak abundance of *A. nicoli* occurs somewhat above that of *A. tadjikistanensis djanensis*, notably in the top of Core 33. Moreover, it outranges the latter species in the base of Core 32 where it occurs in low frequencies.

### *Acarinina cf. tadjikistanensis* (Bykova) (Plate 1, Figures 9-12)

cf. *Globorotalia tadjikistanensis* Bykova, 1953. Microfauna USSR, Trudy n.s., v. 6, p. 86, pl. 3, fig. 5a-c.

Characteristic of this species is the low conical umbilical side and the convex spiral side. Specimens generally show a broadly rounded periphery in axial view with exception of the last chamber which may be subacute. They resemble best *Acarinina tadjikistanensis djanensis* (Shutzkaya, manuscript) as referred to by Luterbacher (1964). However, as far as the writer is aware, no formal description of this subspecies was ever published. They are accompanied and sometimes difficult to separate from more tightly coiled forms with tangential dorsal sutures which resemble *A. praepentacamerata* Shutzkaya (1956), except for their generally subacute axial periphery (Plate 1, Figures 4-6).

Both *A. tadjikistanensis djanensis* and *A. praepentacamerata* are reported from the USSR, from the *A. tadjikistanensis djanensis* Zone which was tentatively correlated by Luterbacher (1964) with the upper part of the *Planorotalites pusilla pusilla* Zone and the lower part of the *P. pseudomenardii* Zone. At Site 329 they occur frequent to common all through Core 33, in assemblages for the larger part definitely younger than the *P. pseudomenardii* Zone.

### *Subbotina varianta* (Subbotina) (Plate 3, Figures 1-3)

*Globigerina varianta* Subbotina, 1953. Fossil Foram. USSR, VNIGRI, Trudy n.s., no. 76, p. 63, pl. 3, fig. 5a-12c; pl. 4, fig. 10a-11b.

*Globorotalia (G.) varianta* (Subbotina) von Hillebrandt, 1962. Bayer. Akad. Wiss., Math.-Naturw. Kl., Abh., n.f., 108, p. 125, pl. 12, fig. 10a-11b.

Our specimens are characterized by a low trochospiral coiling, 5 chambers in the penultimate whorl and 3½ to 4 in the final one. The aperture which tends to be extraumbilical, is usually bordered by a lip which may extend over the umbilical region.

The species was reported from the Paleocene-lower Eocene of the USSR and is found from the lower part of Core 33 all through Core 32.

### *Planorotalites australiformis* (Jenkins) (Plate 2, Figures 7-10)

*Globorotalia australiformis* Jenkins, 1965. N.Z.J. Geol. Geophys., v. 8, p. 112, fig. 11, no. 92-96.

Our specimens match Jenkins' species except for the last chamber which lacks the incipient keel. Throughout its range at Site 329 it shows a morphologic intergradation into *Planorotalites planoconica* (Subbotina) to which it may be related (see Plate 2, Figures 5, 6). Typical specimens though have less chambers in the last whorl (4 instead of 5-5½), the chambers are more inflated than *P. planoconica* and the axial periphery is less acute (compare Plate 2, Figures 7-10 with Figures 1-3).

*P. australiformis* was reported from New Zealand to replace *P. pseudomenardii* in the upper Paleocene and to range well into the lower Eocene. At Site 329 it occurs frequently from the top of Section 3, Core 33 to the top of Core 32.

### *Subbotina angiporoides* (Hornibrook) (Plate 5, Figures 1)

*Globigerina angiporoides* Hornibrook, 1965. N.Z. J. Geol. Geophys., v. 8, p. 835, 838, fig. 1, 2.

*Globigerina (Subbotina) angiporoides angiporoides* Hornibrook, Jenkins, 1971. N.Z. Geol. Surv. Paleont. Bull., v. 42, p. 160, pl. 20, fig. 588-594.

The wide variation of this species in Cores 31-29 is consistent with the variation of the species at Sites 267 and 274 as figured by Kaneps



(1975). Forms with arched apertures were only found in Sample 29, CC.

*Subbotina angiporoides* has also been reported from middle and high latitudes in the northern hemisphere, from northwest Europe (Berggren, 1969), and Sites 116-117A, Rockall Bank (Berggren, 1972a).

**Turboroelia munda (Jenkins)**  
(Plate 4, Figures 7-11)

*Globorotalia munda* Jenkins, 1965. N.Z. J. Geol. Geophys., v. 8, p. 1121, fig. 14, no. 126-133.

The smooth wall and the inflation of the chambers are the most typical features of this small species. Variation mainly concerns the number of chambers in the final whorl (4 to 5).

It occurs at most levels in Cores 31-28. Reported from middle to high northern latitudes, from northwest Europe (Berggren, 1969) where it persists above the highest occurrence of *Subbotina angiporoides* (as at Site 329) and from Site 112, Labrador Sea (Berggren, 1972a).

**Globorotaloides cf. suteri Bolli**  
(Plate 5, Figures 5-10)

cf. *Globorotaloides suteri* Bolli, 1957. U.S. Nat. Mus., Bull. 215, p. 117, pl. 27, fig. 9a-13b.

Specimens differ from *Globorotaloides suteri* mainly for their coarse cancellated wall surface. Adult specimen typically have 3½ chambers in the final whorl and 5, occasionally 6 in the previous one. The low umbilical aperture is bordered by a lip. The aperture of pre-adult specimens tend to be extraumbilical in position.

A bulla as is common in *G. suteri* is present only in a minor part of the population. *G. cf. suteri* may be a high latitude variant of *G. suteri*, similarly to *G. testarugosa* (Jenkins) from New Zealand from which it differs mainly by the *Globigerina* character of the adult. At Site 329 it is common in Cores 31-28 (Oligocene) and the core catcher of Core 27 (early Miocene).

**Globorotalia miozea-group**  
(Plate 6, Figures 6-12)

Members of this group are dominant in Core 27. There is a wide variation in respect to the height of the umbilical side, number of chambers in the final whorl (4-5), and height of the aperture. Part of this variation is due to the development of the secondary crust, which tends to fill up the sutures and to add to the height of the specimens (Scott, 1972a). It also tends to conceal the aperture as particular high pustules develop in the umbilical region. Small specimens tend to become almost circular in equatorial outline during the process.

Rare nonencrusted specimens are here referred to *Globorotalia praescitula* while the major part of the population is closest in morphology to the forms considered by Walters (1965) as transitional between *G. praescitula* and *G. miozea miozea*.

**Globorotalia zealandica group**  
(Plate 6, Figures 1-3)

Some rare specimens referable to *G. zealandica incognita* Walters, oldest member of the *G. zealandica* lineage, were found in the core catcher of Core 27. The species has also been reported from the lower Miocene of DSDP Site 18 in the southern Atlantic by Berggren and Amdur (1973).

**Globorotalia panda**

*Globorotalia menardii panda* Jenkins, 1960. Micropaleontology, v. 6, p. 364, pl. 4, fig. 10a-c.

*Globorotalia panda* Jenkins, 1971. N.Z. Geol. Surv. Paleont. Bull., v. 42, p. 96, pl. 6, fig. 152-154.

*Globorotalia panda* Jenkins, Kennett, 1973. In Burns, R. E., Andrews, J. E., et al., Initial Reports of the Deep Sea Drilling Project, v. 21, pl. 11, fig. 6-9.

Rare specimens appear at two levels in the upper part of Site 329. The most distinctive feature of these thin-keeled forms is the reniform shape of the chambers on the spiral side although less pronounced than the somewhat similar *G. hirsuta* and the flat umbilical side. The species was reported from the upper Miocene and Pliocene of New Zealand by Jenkins (1971).

**Globigerina bulloides**  
(Plate 7, Figures 9-14)

A broad species concept has been applied due to the wide variation. In the Miocene, specimens are frequently overcrusted with secondary calcite thus obtaining a very coarse surface texture. In typical specimens calcite growth on the apertural face has lowered the originally arched aperture to almost a slit (see Plate 7, Figures 10, 14). A similar phenomenon is seen in *G. cf. bulloides* described by Keany and Kennett (1972) from the upper Pliocene of a northern Antarctic core near Australia.

**Globorotalia anfracta Parker**  
(Plate 7, Figures 1-4)

*Globorotalia anfracta* Parker, 1967. Am. Paleontol. Bull., v. 52, p. 175, pl. 28, fig. 3a-8.

*Tenuitella anfracta* Parker, Fleisher, 1974. In Whitmarsh, R. B., Weser, O. E., Ross, D. A., et al., Initial Reports of the Deep Sea Drilling Project, v. 23, p. 1033, pl. 17, fig. 9, 10.

This species occurs in abundance in the core catcher of Core 20 only. *Globorotalia anfracta* has been described up till now exclusively from low latitude regions, including the Central Pacific (Parker), the Red Sea (Berggren and Boersma), and the Arabian Sea (Fleisher). The oldest recorded occurrence has been early Pliocene from the last-mentioned location (Site 219).

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PLATE 1

- Figure 1 *Acarinina nicoli* (Martin).  
Sample 329-33-2, 145-146 cm; late Paleocene.  
Spiral view,  $\times 120$ .
- Figure 2, 3 *Acarinina nicoli* (Martin).  
Sample 329-33-1, 125-127 cm; late Paleocene.  
2. Umbilical view,  $\times 205$ .  
3. Side view,  $\times 180$ .
- Figure 7, 8 Specimens intermediate between *Acarinina* cf. *praepentacamerata* (Schutzkaya) and *Acarinina tadjikistanensis djanensis* Shutzkaya.  
Sample 329-33-2, 145-147 cm; late Paleocene.  
7. Spiral view,  $\times 150$ .  
8. Umbilical view,  $\times 180$ .
- Figures 9-12 *Acarinina tadjikistanensis djanensis* Shutzkaya.  
Sample 329-33-2, 145-146 cm; late Paleocene.  
9. Spiral view,  $\times 150$ .  
10. Spiral view,  $\times 150$ .  
11. Umbilical view,  $\times 150$ .  
12. Side view,  $\times 180$ .

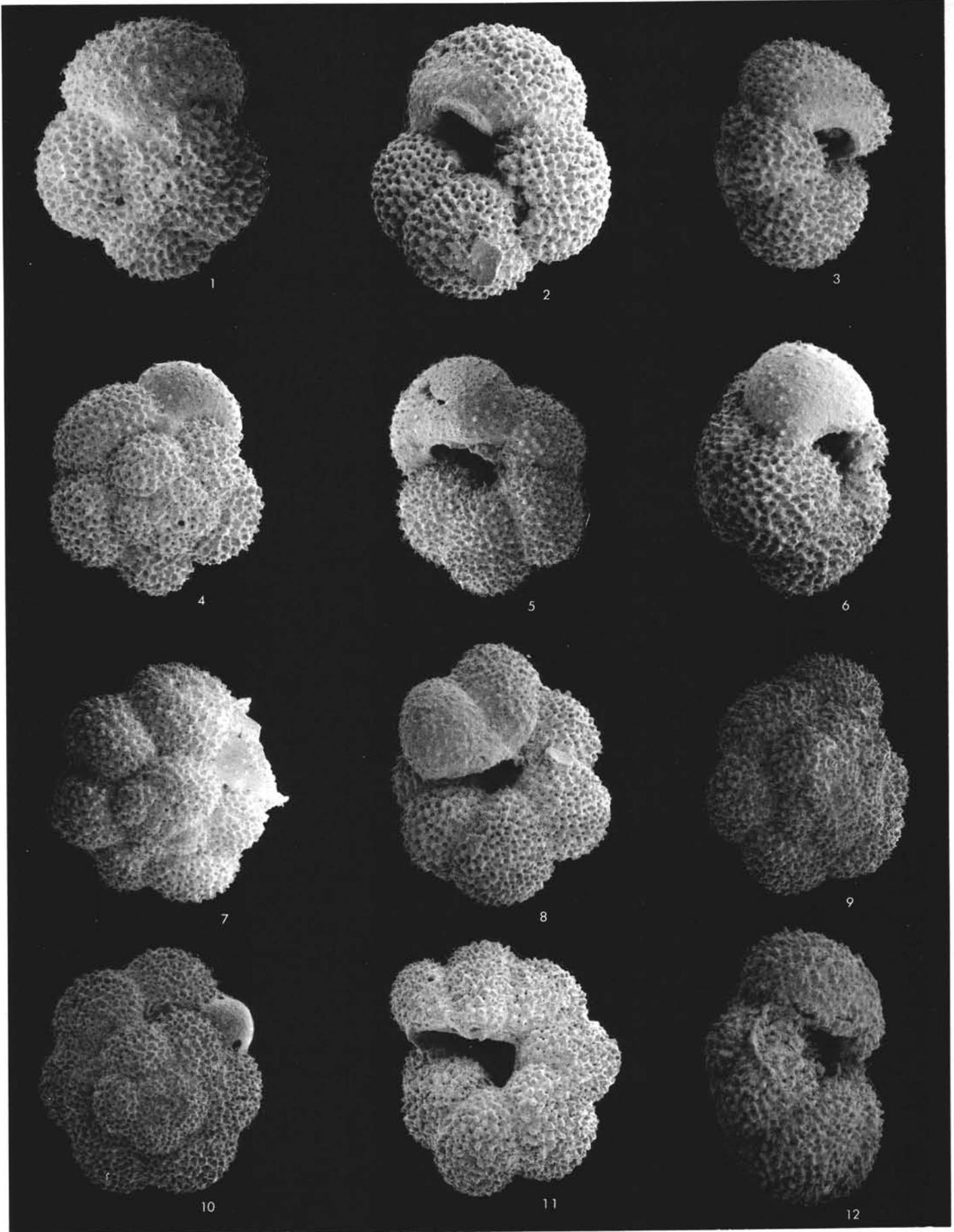
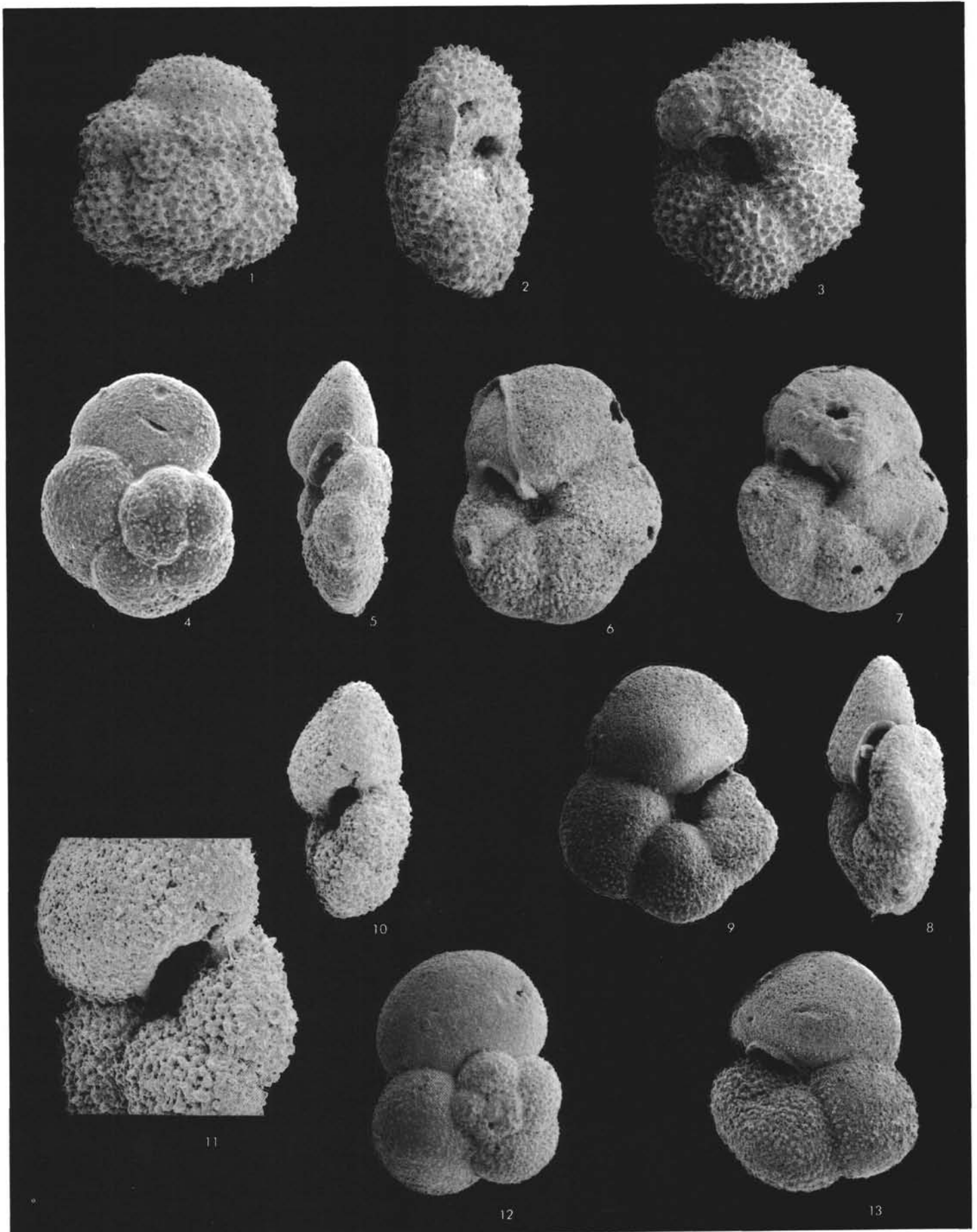


PLATE 2

- Figures 1-3 *Acarinina convexa* (Subbotina). Sample 329-33-3, 119-120 cm; late Paleocene.  
1. Spiral view,  $\times 240$ .  
2. Side view,  $\times 240$ .  
3. Umbilical view,  $\times 205$ .
- Figures 4-6 *Planorotalites planoconica* (Subbotina). Sample 329-33-1, 125-127 cm; late Paleocene.  
4. Spiral view,  $\times 210$ .  
5. Side view,  $\times 240$ .  
6. Umbilical view,  $\times 240$ .
- Figure 7 *Planorotalites planoconica* (Subbotina). Sample 329-32-4, 67-69 cm; latest Paleocene. Umbilical view,  $\times 180$ .
- Figures 8, 9 Specimens intermediate between *Planorotalites planoconica* (Subbotina) and *Planorotalites australiformis* (Jenkins). Sample 329-33-1, 125-127 cm; late Paleocene.  
8. Side view,  $\times 210$ .  
9. Umbilical view,  $\times 180$ .
- Figures 10-12 *Planorotalites australiformis* (Jenkins). Sample 329-32-1, 141-143 cm; early Eocene.  
10. Side view,  $\times 190$ .  
11. Oblique view of same specimen,  $\times 360$ .  
12. Spiral view,  $\times 180$ .
- Figure 13 *Planorotalites australiformis* (Jenkins). Sample 329-33-1, 125-127 cm; late Paleocene. Umbilical view,  $\times 210$ .



## PLATE 3

- Figures 1-3     *Subbotina varianta* (Subbotina). Sample 329-33-1, 125-127 cm; late Paleocene.  
 1. Umbilical view,  $\times 150$ .  
 2. Side view,  $\times 180$ .  
 3. Umbilical view,  $\times 150$ .
- Figures 4, 5     *Turborotalia reissi* (Loeblich and Tappan). Sample 329-32-4, 67-69 cm; latest Paleocene.  
 4. Four-chambered variant, umbilical view,  $\times 150$ .  
 5. Five-chambered variant, umbilical view,  $\times 210$ .
- Figures 6, 8, 9     *Turborotalia reissi* (Loeblich and Tappan). Sample 329-32-1, 141-143 cm; early Eocene.  
 6. Side view,  $\times 150$ .  
 8. Umbilical view,  $\times 150$ .  
 9. Same specimen as 6, oblique view,  $\times 150$ .
- Figure 7     *Turborotalia reissi* (Loeblich and Tappan). Sample 329-32-4, 107-109 cm; latest Paleocene. Spiral view,  $\times 150$ .
- Figure 10     *Pseudohastigerina wilcoxensis* (Cushman and Ponton). Sample 329-32-1, 141-143 cm; early Eocene. Oblique side view showing the somewhat asymmetrical mode of coiling in this particular specimen,  $\times 180$ .
- Figure 11     *Acarinina apantesma* (Loeblich and Tappan). Sample 329-32-4, 107-109 cm; latest Paleocene. Oblique side-view, showing the acute and spinose periphery,  $\times 120$ .
- Figure 12     *Acarinina wilcoxensis* (Cushman and Ponton). Sample 329-32-4, 107-109 cm; latest Paleocene. Oblique side view,  $\times 180$ .
- Figure 13     *Acarinina aequa* (Cushman and Renz). Sample 329-32-4, 107-109 cm; latest Paleocene. Umbilical view,  $\times 180$ .



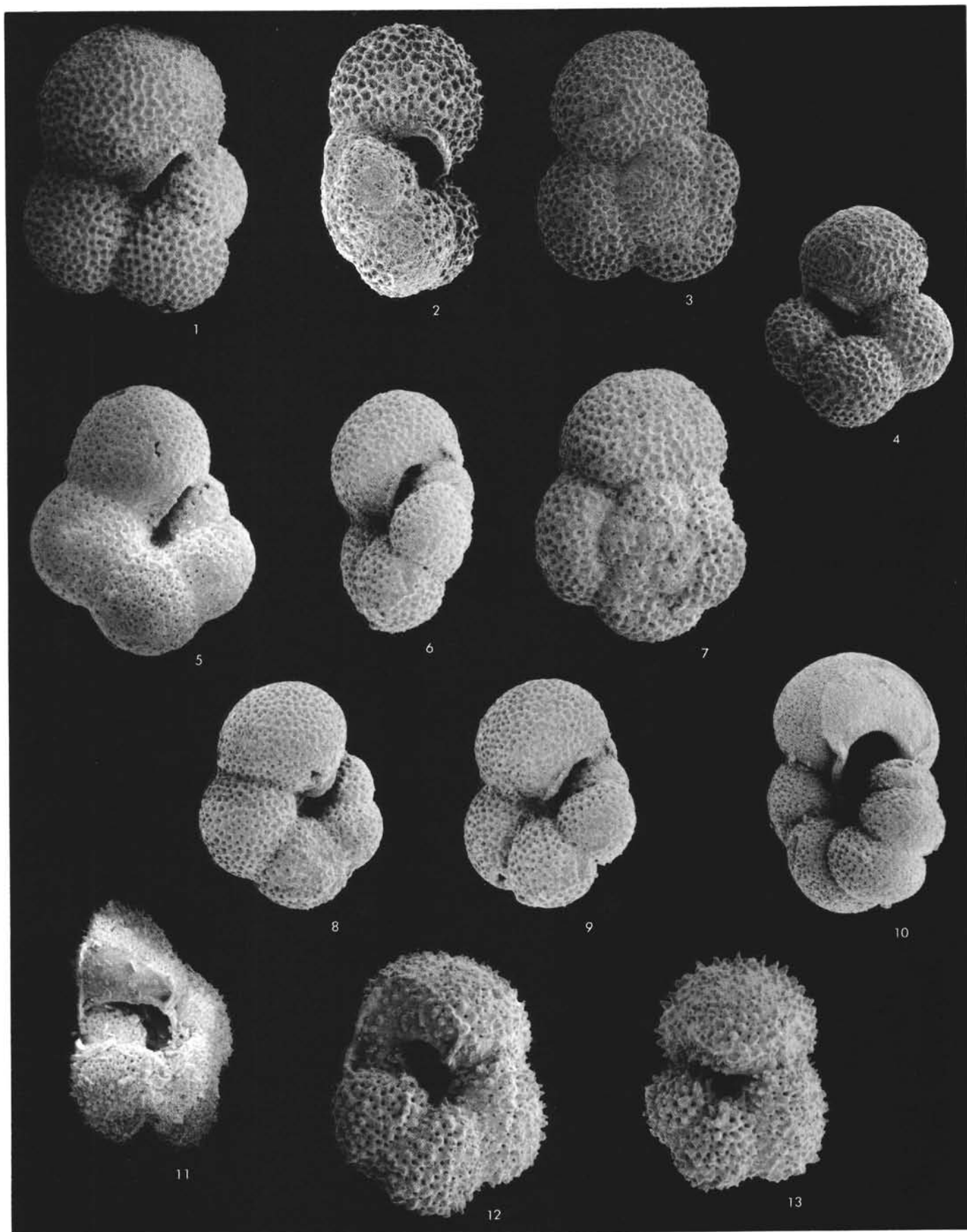


PLATE 4

- Figure 1 *Subbotina velascoensis* (Cushman). Sample 329-33-3, 118-120 cm; late Paleocene. Umbilical view,  $\times$  150.
- Figure 2 *Subbotina patagonica/triangularis* group. Sample 329-32-4, 67-69 cm; latest Paleocene. Umbilical view,  $\times$  150.
- Figures 3-6 *Subbotina patagonica/triangularis* group. Sample 329-32-1; 139-141 cm; early Eocene. All umbilical views.  
3.  $\times$  145.  
4.  $\times$  150.  
5.  $\times$  180.  
6.  $\times$  130.
- Figures 7, 9 *Turborotalia munda* (Jenkins). Sample 329-28, CC, Oligocene.  
7. Side view,  $\times$  240.  
9. Umbilical view,  $\times$  240.
- Figures 8, 10, 11 *Turborotalia munda* (Jenkins). Sample 329-30, CC, Oligocene.  
8. Spiral view,  $\times$  240.  
10. Umbilical view,  $\times$  205.  
11. Umbilical view,  $\times$  180.

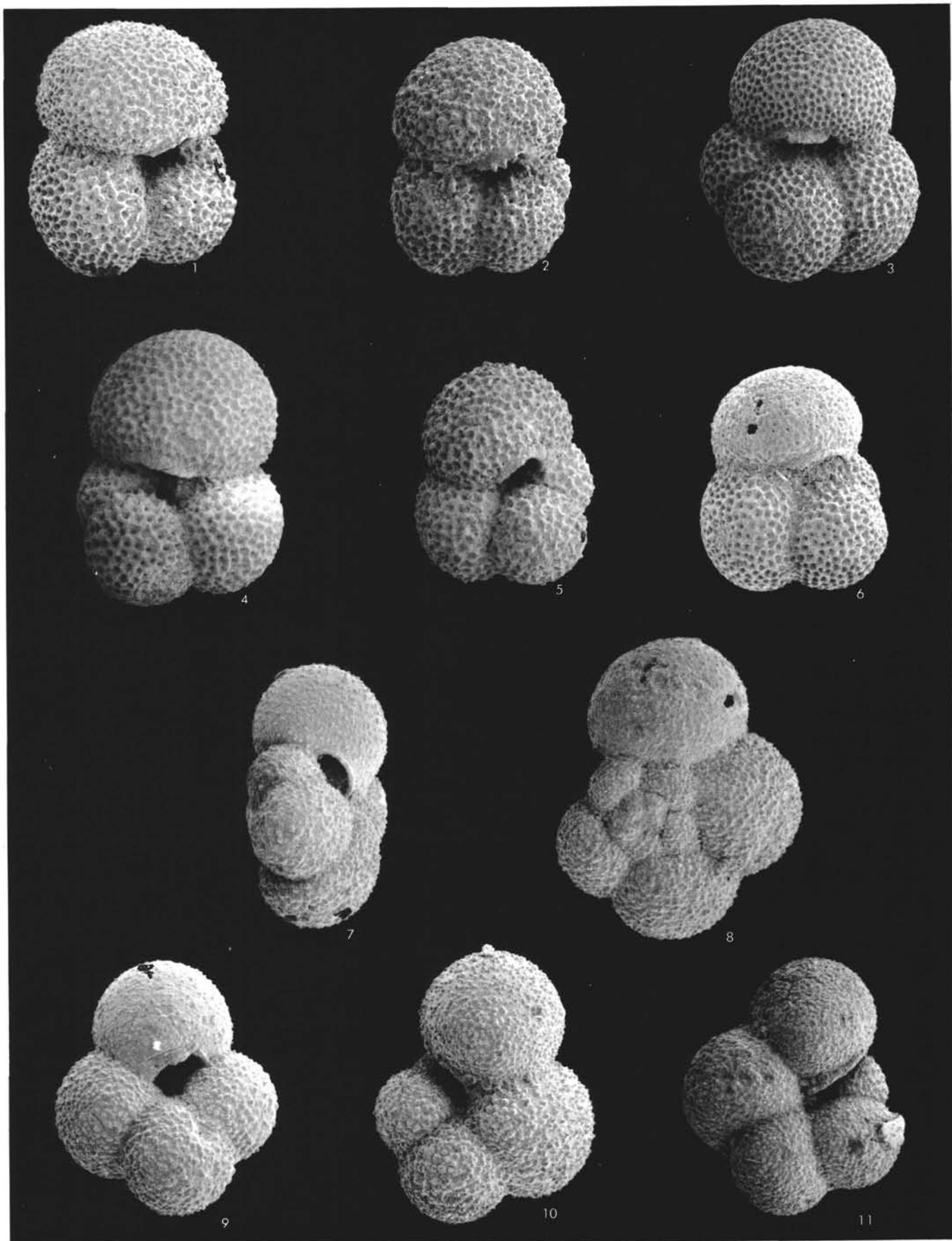


PLATE 5

- Figure 1 *Subbotina angiporoides* (Hornibrook). Sample 329-30-3, 119-121 cm; Oligocene. Umbilical view through broken bulla,  $\times 105$ .
- Figure 2 *Globigerina brazieri* Jenkins. Sample 329-28, CC; Oligocene. Umbilical view,  $\times 130$ .
- Figure 3 *Catapsydrax dissimilis* (Cushman and Bermudez). Sample 329-30, CC; Oligocene. Umbilical view of specimen without bulla,  $\times 110$ .
- Figure 4 *Subbotina linaperta* (Finlay). Sample 329-29, CC; Oligocene. Umbilical view,  $\times 180$ .
- Figures 5-10 *Globorotaloides* cf. *suteri* Bolli. Sample 329-28, CC; Oligocene.  
5. Spiral view,  $\times 120$ .  
6. Detail last chamber,  $\times 600$ .  
7. Umbilical view,  $\times 130$ .  
8. Umbilical view,  $\times 120$ .  
9. Umbilical view,  $\times 150$ .  
10. Umbilical view,  $\times 165$ .
- Figure 11 *Globigerina* sp. Sample 329-27-1, 120-124 cm; early Miocene. Umbilical view,  $\times 150$ .

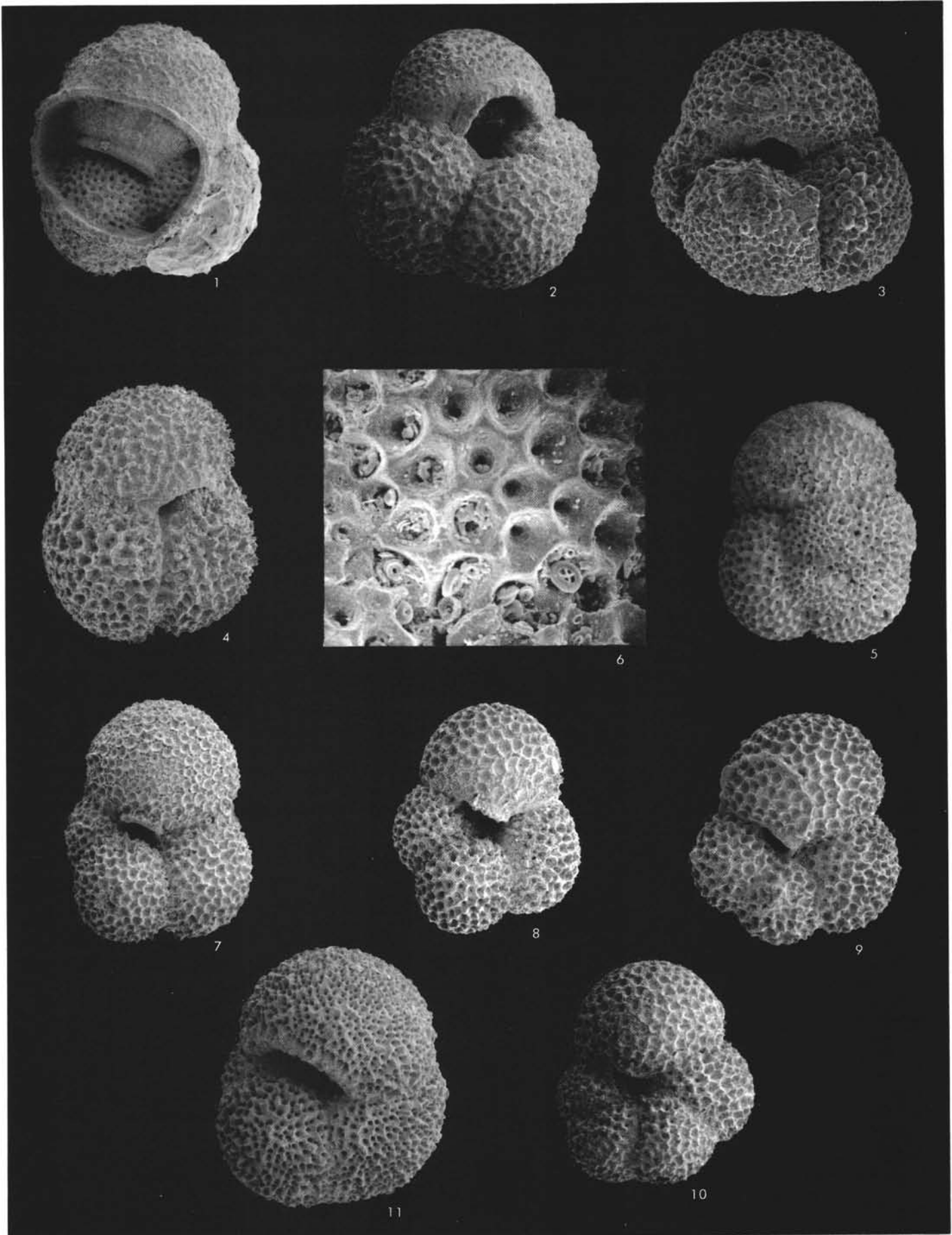
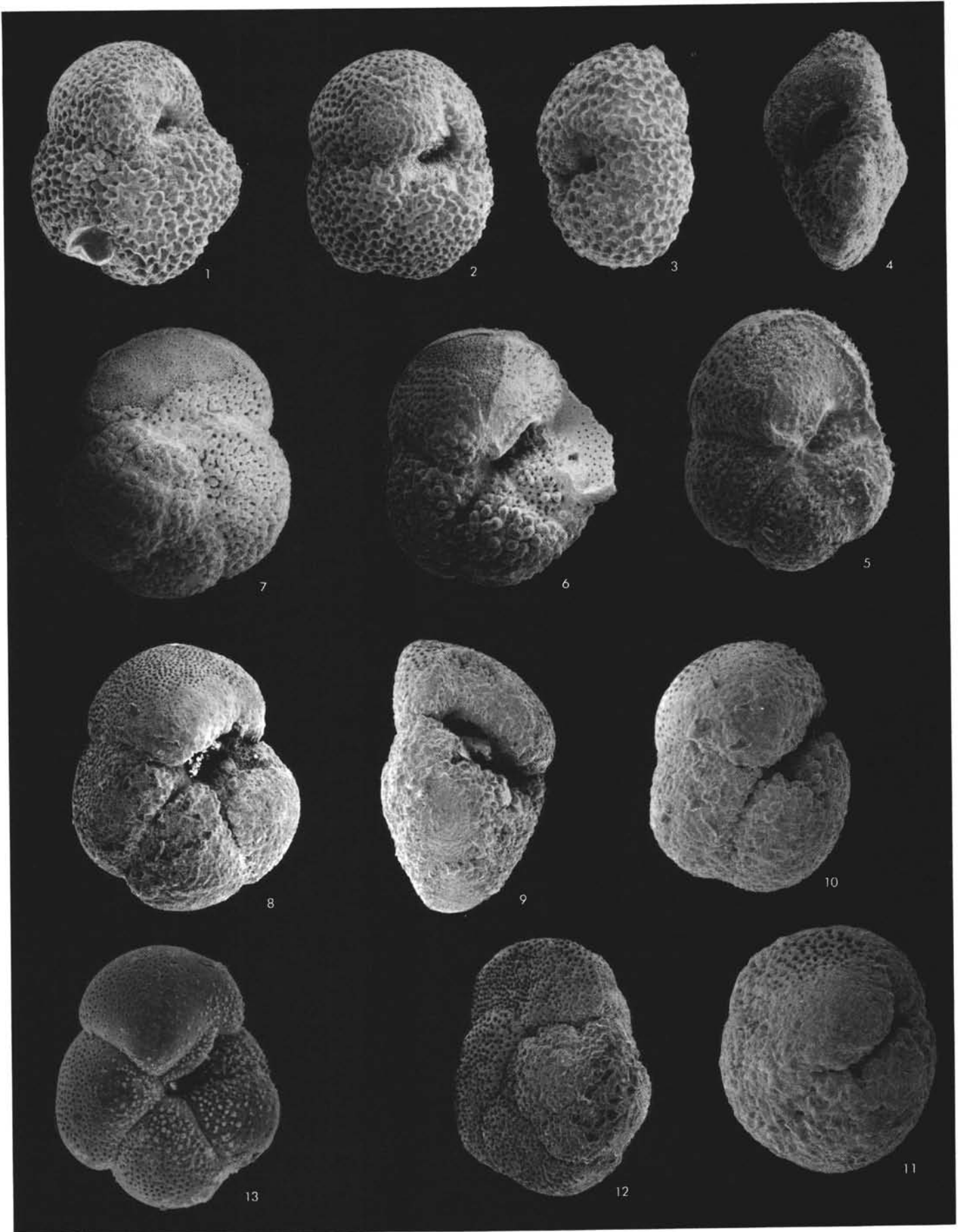


PLATE 6

- Figures 1-3 *Globorotalia zealandica incognita* Walters. Sample 329-27, CC; early Miocene.  
1. Umbilical view,  $\times 180$ .  
2. Umbilical view,  $\times 150$ .  
3. Side view,  $\times 180$ .
- Figures 4, 5 *Globorotalia praescitula* Blow. Samples 329-27-1, 120-124 cm; early Miocene.  
4. Side view,  $\times 150$ .  
5. Umbilical view,  $\times 180$ .
- Figures 6-12 *Globorotalia miozea*-group, specimens transitional between *G. praescitula* Blow and *G. miozea miozea* Finlay. Sample 329-27-1, 120-124 cm; early Miocene.  
6. Specimen with the various layers of secondary crust peeled off the last chamber. Note the surface texture on the aperture face and on top of the last chamber, similar to that of *G. praescitula*,  $\times 120$ .  
7. Spiral view, peeled off crust on the final chambers shows the original wall surface,  $\times 120$ .  
8. Umbilical view,  $\times 90$ .  
9. Side view,  $\times 95$ .  
10, 11. Umbilical views of thickly encrusted specimens, resulting in circular outline in Figure 11.  
10.  $\times 120$ .  
11.  $\times 150$ .  
12. Spiral view,  $\times 90$ .
- Figure 13 *Globorotalia scitula* (Brady). Sample 329-20, CC; late Miocene. Umbilical view,  $\times 120$ .



## PLATE 7

- Figures 1-4 *Globorotalia anfracta* Parker. Sample 329-20, CC; late Miocene.  
 1. Umbilical view,  $\times 210$ .  
 2. Side view,  $\times 180$ .  
 3. Spiral view,  $\times 180$ .  
 4. Bullate specimen, umbilical view,  $\times 210$ .
- Figure 5 *Neogloboquadrina acostaensis* (Blow). Sample 329-8-4, 100-104 cm; late Miocene. Umbilical view,  $\times 180$ .
- Figure 6 *Turborotalia cf. continuosa* Blow. Sample 329-12-4, 100-104 cm; late Miocene. Specimen characteristic for the interval above Core 20, with high-arched aperture,  $\times 240$ .
- Figure 7 *Globorotalia scitula* (Brady). Sample 329-17-6, 99-103 cm; late Miocene. Umbilical view,  $\times 180$ .
- Figure 8 *Globorotalia scitula* (Brady). Sample 329-17-2, 100-104 cm; late Miocene. Side view,  $\times 120$ .
- Figures 9-14 *Globigerina bulloides* d'Orbigny, morphology altered due to intense secondary calcification process. Sample 329-17-6, 99-103 cm; late Miocene.  
 9. Oblique side view,  $\times 150$ .  
 10. Detail of apertural region showing smooth apertural face of previous chamber with high-arched aperture as contrasted to the low-arched aperture of the last chamber heavily covered with secondary calcite,  $\times 420$ .  
 11. Umbilical view of specimen with a relative arched aperture,  $\times 180$ .  
 12. Side view,  $\times 150$ .  
 13. Spiral view,  $\times 150$ .  
 14. Umbilical view of specimen with aperture reduced to slit,  $\times 150$ .



