

9. PALEOGENE PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY OF SITES 883 AND 884, DETROIT SEAMOUNT (SUBARCTIC PACIFIC)¹

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ABSTRACT

The first continuously cored Paleogene sequence in the subarctic Pacific containing planktonic foraminifer assemblages was drilled on Detroit Seamount during Ocean Drilling Program Leg 145. The stratigraphic distribution of about 40 species of planktonic foraminifers was analyzed. The low diversity of the foraminiferal assemblages, composed mostly of acarininids and globigerinids, and their generally poor to moderate preservation were evidently influenced both by their initially impoverished composition owing to the high-latitude position of Detroit Seamount in the Paleogene and strong dissolution. The most diverse and best preserved assemblages with notable share of thermophilic morozovellid species occur in the lower Eocene sediments corresponding to a Cenozoic warming maximum that has been recorded by paleontological and oxygen isotope data worldwide. The changes in foraminifer composition, diversity, and abundances through the Paleogene sequence reflect climatic deterioration from the middle Eocene to Oligocene.

On the whole, the Paleogene planktonic foraminifer assemblages from the Detroit Seamount sequence are similar in composition to those recorded in coeval sediments from the high latitudes of both the Northern and Southern hemispheres (Crimea, Ciscaucasia, northern Kamchatka, Maud Rise, and the Falkland, Kerguelen, and Campbell plateaus).

The taxonomic list and plates with photographs of the most common species are given in the paper.

INTRODUCTION

Despite a quarter-of-a-century-long history of deep-sea drilling in oceans that has resulted in thousands of holes drilled at almost a thousand sites, the high-latitude areas remained insufficiently studied until recently because the majority of the holes are located in the tropical-subtropical zone. Although the subpolar regions are remote and characterized by rough sea and weather conditions, these regions hold the key to understanding circulation patterns in the oceans because the oceanographic and climatic processes that develop in the subpolar regions affect the global ocean-atmosphere system. The late Mesozoic-early Cenozoic oceanographic and climatic history, as well as the history of the development of the surface and bottom biotas, were not well known because upper Mesozoic and Paleogene sequences were recovered previously in only a limited number of holes.

The high-latitude North Pacific drilled during Ocean Drilling Program (ODP) Leg 145 is one such region. One of the main objectives of the leg was to recover complete and continuously sampled Paleogene sequences with calcareous microfossils. The Paleogene sediments in the subarctic Pacific had been drilled at Site 192 during Leg 19 of the Deep Sea Drilling Project (DSDP) more than 20 years ago (Creager, Scholl, et al., 1973). Hole 192 was drilled with spot-coring atop Meiji Guyot in the Obruchev Swell northern extremity at a water depth of 3000 m. About 90-m section of Eocene-Oligocene sediments with rare poorly preserved planktonic foraminifers was recovered.

During Leg 145, Paleogene deposits were drilled at Sites 883 and 884 atop Detroit Seamount and on its lower eastern flank, respectively (Fig. 1). A new piston coring technique provided almost continuous sampling of the sequence at both sites. Planktonic foraminifers of Paleogene age occur in the sediments at both sites. They are more abundant, more diverse, and better preserved at shallower Site 883,

whereas only separate layers of the deeper Site 884 sediments contain rare planktonic foraminifers with generally poor preservation.

GEOLOGIC AND OCEANOGRAPHIC SETTING

Sites 883 and 884 are located in the northeastern part of Detroit Seamount on the Obruchev Swell. The latter is the direct continuation and the northern end of the Emperor Seamounts chain, the structure that stretches submeridionally southward as far as 30°N, where its direction changes to northwest-southeast.

Sites 883 and 884 were chosen in the western part of the Meiji Tongue, a large sedimentary body stretching along the eastern slope of the Emperor Seamounts (Ewing et al., 1968; Scholl et al., 1977; Mammerickx, 1985), where its thickness does not exceed 1 km, to allow penetration of basement at both sites. Site 883 was located at the top of Detroit Seamount at a water depth of 2385 m, whereas Site 884 was located at the foot of its eastern slope at a water depth of 3826 m. These two positions provide more extensive information on oceanographic changes in this region in the geological past.

The Obruchev Swell is now situated under a subarctic water mass with an average annual surface water temperature of about 6°C. In the upper 100 m the temperature decreases gradually to approximately 3°C and then increases again to 3.4°–3.6°C down to 300–500 m. From this depth the temperature very slowly decreases, reaching 1.5°C below 3000 m (Galerkin, 1982).

The surface water is characterized by very high zooplankton and phytoplankton productivity. Zooplankton biomass makes up more than 5 mg/m³ in the upper 100 m near the conjunction of the Kamchatka Peninsula and Aleutian Island arc. The average phytoplankton density reaches 4 × 10⁴ cells/L (Pasternak, 1982).

MATERIAL AND METHODS

Both Sites 883 and 884 were continuously cored with a recovery in the Paleogene portion of the sedimentary section varying from 1.4% to 104.7% at Site 883 and from 44% to 105.1% at Site 884 and

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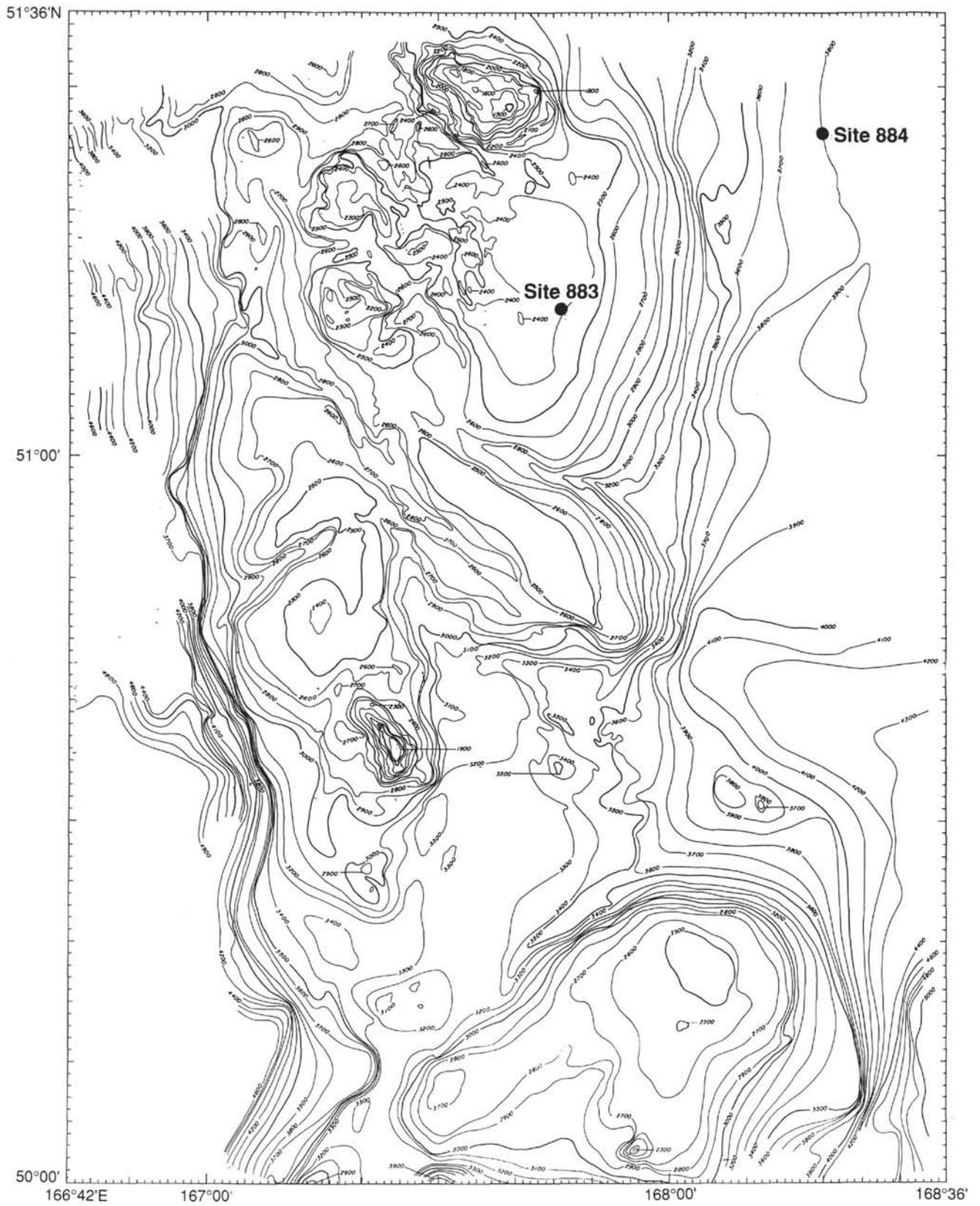


Figure 1. Location of Sites 883 and 884 on Detroit Seamount. Contours in meters.

with an average recovery of 64.3% and about 91%, respectively. The upper half of the section, composed mainly of pelagic sediments, was the most completely sampled segment at both sites. In the lower part, where slope slump and reworked deposits predominate, the recovery was, in general, significantly lower.

Samples for foraminiferal studies were collected from each 1.5-m core section as well as from most of the core catchers. A total of 69 and 145 samples were taken from Sites 883 and 884, respectively. Sampling took sediment composition into consideration, where possible, with a preference for layers with no or slight disturbance and a high calcium carbonate content. At Site 884 in the interval of Cores 145-884B-81X through -85X, where sediments were extensively disturbed by drilling, samples were taken from pieces of lithified rocks inside the drilling breccia. The samples taken at Site 883 had a volume of 10 cm³, whereas 20-cm³ samples were collected from Site 884 sediments, which have a lower CaCO₃ content.

All the samples were disintegrated and washed with tap water through a 63- μ m sieve. Strongly lithified samples that were difficult to disintegrate were pretreated with a 3% hydrogen peroxide solution. Dried residues were then examined with a light microscope to determine the abundance, preservation, and composition of foraminifers. Overall assemblage abundances in samples were defined in terms rare (R = <10 specimens), few (F = 10–100 specimens), common (C = 100–500 specimens), and abundant (A = >500 specimens). Four semiquantitative categories were used to estimate individual species abundances: rare (<1%), few (1%–5%), common (5%–25%), and abundant (>25%). For the samples with overall abundances less than 100 specimens the percentage of individual species was not estimated. Preservation of planktonic foraminifers is considered good (G) when they show minor dissolution, no recrystallization, and minimal test fragmentation. The moderate (M) preservation rating is assigned to the assemblages with moderate test etching and fragmentation. The assemblages with severe dissolution and test breakage are considered poorly (P) preserved.

SITE 883

Site Description

Site 883 is located atop Detroit Seamount in the northern part of the Obruchev Swell (51°11.908'N, 167°46.128'E) at a water depth of 2396 m (Fig. 1). Recovery at the six holes (883A–883E) drilled was a 830-m-thick sequence of uppermost Cretaceous through Quaternary sediments overlying basaltic basement. The most complete sedimentary sequence was obtained at Hole 883B, which was cored using the advanced piston corer (APC) and extended core barrel (XCB) with an average recovery of 97%. Paleogene sediments occur in Hole 883B in the interval from 652.2 to 818.5 m below seafloor (mbsf) and are composed mostly of nannofossil chalk with a subordinate admixture of volcanic ash, the amount of which increases downsection. Accordingly, calcium carbonate content decreases from a range of 38.8%–96% in the upper portion of the section (652.2–774 mbsf) to a range of 2.8%–86.9% in its lower portion (774–818.5 mbsf). The lower unit shows the structures such as diamictite, small-scale cross and convolute lamination, load clasts, scoured surfaces, burrowed hardgrounds, microfaulting, and syngenetic deformations; all these indicate the downslope transportation of sedimentary material and its reworking.

The Paleogene section is unconformably overlain by a lower Miocene chalk with a notable amount of biogenic siliceous material (Gladenkov and Barron, this volume) and underlain by an ash altered to clays of latest Cretaceous (late Maastrichtian?) age (Beaufort and Olafsson, this volume). At least three unconformities occur inside the Paleogene sequence, which are confined to the Paleocene/Eocene, lower/middle Eocene, and possibly middle/upper Eocene boundaries.

Biostratigraphy

Planktonic foraminifers in Hole 883 occur throughout the Paleogene sequence, but vary in abundances from very rare occurrences, where single specimens are present in a sample residue, to abundant, where foraminiferal shells are the main constituent of a residue. Foraminifers are very rare to few in the upper portion of the middle Eocene interval and in most of the Oligocene sediments. A number of samples collected from these sediments are completely barren of planktonic foraminifers. They are also rare in the basal layers of sedimentary sequence (Table 1).

The abundance of foraminifers increases noticeably in the lower and upper parts of the middle Eocene sequence, where they are few to common. Their maximum abundance is confined to the lower Eocene interval, where planktonic foraminifer shells constitute the major part of the residue. Very low abundances are recorded in upper Paleocene sediments.

The preservation of foraminifers varies from poor to good. Generally, it correlates well with their diversity and abundance. As a rule, relatively diverse and abundant assemblages are characterized by moderate to good preservation, whereas impoverished assemblages with low abundance are poorly preserved.

Poor to moderate preservation is characteristic of the relatively impoverished assemblages in the upper Eocene(?)–Oligocene interval. Basal layers of the Paleogene section also show very poorly preserved rare foraminifers. More diverse and abundant assemblages in the lower Eocene and in the lower and upper parts of the middle Eocene have a moderate to good preservation.

Single specimens of probably reworked Cretaceous (Maastrichtian) planktonic foraminifers occur in the lowermost layers of the Hole 883B sedimentary sequence (Core 145-883B-86X).

Paleocene

Sediments from the lower part of Core 145-883B-85X are assigned, on the basis of nannofossils, to Zones NP7 and NP8 (upper Paleocene). Lower Cores 145-883B-86X and -87X are referred to the Upper Cretaceous (upper Maastrichtian?) based on the occurrence of *Micula decussata*, *M. concava*, *Watznaueria barnesae*, *Ceratolithus aculeus*, and *Lithraphidites cf. quadrata* (Beaufort and Olafsson, this volume).

Only samples from Core 145-883B-86X were available for this study. They contain very rare specimens of *Acarinina mckannai*, *A. aff. primitiva*, *Subbotina velascoensis*, *S. sp.*, and *Morozovella quetra*. The assemblage correlates the sediments to the upper Paleocene (interval of *Planorotalites pusilla*–*Morozovella velascoensis* Zones), which contradicts the age determination by nannofossils. The cause of this discrepancy is not clear. In Sample 145-883B-86X-4, 120–122 cm, two specimens of the uppermost Maastrichtian foraminiferal species *Abathomphalus mayaroensis*, together with the rare upper Paleocene *Morozovella quetra*, were observed. The occurrence of upper Paleocene species below and directly above this sample suggests reworking. However, because of scarceness and poor preservation of foraminifers downhole, contamination cannot be ruled out.

Lower Eocene

On the basis of nannofossil evidence, the Paleocene/Eocene boundary is placed within the Core 145-883B-85X. No samples for foraminiferal studies were available from this core. Basal sediments from Sample 145-883B-85X-CC contain a nannofossil assemblage that correlates them with Zones NP7–NP8 of the upper Paleocene. In Sample 145-883B-85X-3, 100 cm, the first occurrence of *Discoaster lodoensis* marks the base of Zone NP12. Thus, the nannofossil data indicates the absence of the uppermost Paleocene and the lower part of the lower Eocene (Beaufort and Olafsson, this volume).

Table 1. Occurrence of planktonic foraminifers in Paleogene sediments recovered from Hole 883B.

AGE	HOLE 883B		ABUNDANCE PRESERVATION	<i>Acarinina nitida</i> <i>Morozovella quetza</i> <i>Acarinina mckarrat-subspheerica</i> <i>Subbotina velascoensis</i> <i>Acarinina primitiva</i> <i>Acarinina soldadensis</i> <i>Acarinina triplex</i> <i>Morozovella aragonensis</i> <i>Acarinina pentacamerata</i> <i>Muricoglobigerina sami</i> <i>Acarinina vilcoensis</i> <i>Morozovella formosa graciles</i> <i>Morozovella caucasica</i> <i>Morozovella lenstformis</i> <i>Acarinina mattheusae</i> <i>Subbotina eocaeni</i> <i>Subbotina tinaperta</i> <i>Globigerina losanoi</i> <i>Acarinina rugosoculeata</i> <i>Catapsydrax martini</i> <i>Globorotaloides aff. carcosellensis</i> <i>Globorotaloides suteri</i> <i>Truncarotaloides rohri</i> <i>Acarinina bullbrooki</i> <i>Catapsydrax unicus</i> <i>Subbotina nagri</i> <i>Turbotalia cerrosulensis frontosa</i> <i>Subbotina angiporoides minima</i> <i>Subbotina eocaeni</i> <i>Turbotalia griffinae</i> <i>Globigerinatheka index</i> <i>Pseudoglobigerina micra</i> <i>Globorotaloides testarugosa</i> <i>Denticuloglobigerina galavist</i> <i>Globigerina praebulloidis</i> <i>Globigerina angustimbricata</i> <i>Tenuitella gemma</i>
	SAMPLE (core, section, interval in cm)			
late Eocene(?) - early Oligocene	71X-1, 132-134	R P		
	2, 132-134	R P		
	3, 132-134	R P		
	4, 132-134	R P		
	5, 132-134	R P		
	6, 132-134	R P		
	73X-1, 120-122	R P		
	2, 120-122	R P		
	3, 132-134	R P		
	4, 120-122	R P		
	5, 120-122	R P		
	6, 120-122	F M		
	7, 44-46	F M		
	74X-1, 120-122	R P		
2, 120-122	R P			
middle Eocene	75X-1, 120-122	C M		
	2, 45-47	C M		
	3, 25-27	R P		
	4, 25-27	R P		
	4, 120-122	R P	R	
	5, 25-27	R P		
	CC,			
	76X-1, 120-122	R P	R	
	2, 120-122	R P		
	3, 120-122	R P		
	4, 120-122	R P		
	5, 120-122	R P		
	6, 50-52	R P		
	77X-1, 120-122	R P		
	2, 120-122	R P		
	3, 120-122	R P		
	4, 120-122	R P		
	5, 80-82	R P		
	CC,			
	78X-1, 121-123	R P		
	2, 120-122	R P		
	3, 120-122	R P		
	4, 121-123	R P		
	5, 123-125	R P	R	
6, 121-123	R P			
79X-1, 120-122	R P			
2, 120-122	R P			
3, 120-122	F M			
CC, 29-31	R P			
80X-CC, 7-9	R P			
81X-CC, 13-15	R P			
early Eocene	82X-1, 120-122	C M	C F F F	
	2, 120-122	A G	A F F F F C	
	3, 118-120	A G	C C C C F	
	4, 120-122	A G	C C C C C	
	5, 120-122	A G	R R F C C C	
	6, 120-122	G M	C F F C C	
	CC, 50-52	C M	C C C C	
	83X-1, 120-122	C M	R C C C R F	
	2, 120-122	R P	R	
	3, 120-122	C M	F C F R C F R R	
	4, 122-124	C M	C R C R R C F	
	CC, 34-36	A G	C F C F C C F	
	84X-1, 60-62	A G	F R C F C	
	CC, 12-14	C M	C C F C F R	
late Paleocene	86X-1, 120-122	R P	F F	
	2, 120-122	R P		
	3, 120-122	R P		
	4, 120-122	R P	R	
	5, 60-62	R P	R	
CC, 28-30	R P	R		

Note: The abundance and preservation codes are given in the "Material and Methods" section (this chapter).

Planktonic foraminifers in the lower Eocene sediments are relatively diverse and of moderate to good preservation, thus allowing age determination. Their association of about 20 species in total is the richest in the entire Paleogene section recovered at this site. However, the absence of the most index species or their discrete distribution through the sequence permits only a tentative subdivision of this interval.

The lower Eocene assemblage of planktonic foraminifers occurs in the interval from Samples 145-883B-82X-CC through 145-883B-84X-CC. The basal lower Eocene layers contain six species, including *Morozovella subbotinae*, *Acarinina primitiva*, *A. nitida*, *A. soldadoensis*, and *Subbotina velascoensis*. Acarininids referred to the *Acarinina mckannai-subsphearica* group are also rather common here.

Sediments from Cores 145-883B-82X through -83X contain a more diverse assemblage of planktonic foraminifers. *Morozovella aragonensis*, *Acarinina triplex*, and *Muricoglobigerina senni* are rare to common in the lower layers of this interval. *Morozovella subbotinae*, *Acarinina mckannai-subsphearica*, *A. nitida*, *Acarinina primitiva*, and *A. soldadoensis* continue to occur here, though in subordinate quantities. Very rare and sporadically distributed are *A. pentacamerata*, *A. matthewsae*, *A. esnaensis*, *A. wilcoxensis*, and *Morozovella caucasica*. In the uppermost part of this interval single specimens of *Subbotina linaperta* and *Globigerina lozanoi* are present.

This association undoubtedly dates the sediments as early Eocene. At the same time their correlation with zonal units is rather uncertain. The impoverished planktonic foraminifers prevents use of the standard tropical-subtropical scale (Bolli, 1957a, 1957b, 1957c, 1966; Blow, 1969, and its later modifications) for subdivision of the sediments. The most acceptable scale is the Crimean-Caucasian zonal scale (Subbotina, 1953; Shutskaia, 1970; Krasheninnikov, 1980), which had been applied to the subdivision of high-latitude Paleogene sequences of the Pacific (Krasheninnikov et al., 1988). The correlation of the zonations is shown in Table 2.

The lower Eocene sediments in the interval of Cores 145-883B-82X through -85X are referred from nanofossils (Beaufort and Olafsson, this volume) to the NP12 Zone, which correlates to the *Morozovella aragonensis* Zone and to the uppermost *Morozovella formosa formosa* Zone of the foraminiferal scheme of Bolli (1957a, 1957b, 1957c; Premoli Silva and Bolli, 1973). The planktonic foraminifers confirm this age. The basal layers of the lower Eocene sediments (Core 145-883B-84X), where *Morozovella subbotinae*, *Subbotina velascoensis*, *Acarinina mckannai-subsphearica*, *A. primitiva*, *A. soldadoensis*, and *A. nitida* co-occur, correlate most likely to the *Morozovella subbotinae* s.l. Zone defined for the Paleogene of the Pacific high-latitude areas (Krasheninnikov et al., 1988). This zone includes the *Morozovella edgari*, *Morozovella subbotinae* s. str. and *Morozovella formosa formosa* Zones of the Premoli Silva and Bolli (1973) zonal scale and corresponds to the interval of the *Morozovella subbotinae* s. str. and *Morozovella marginodentata* Zones of the Crimean-Caucasian scheme. The sediments of the upper, larger part of the lower Eocene interval are referred to the *Morozovella aragonensis* s.l. Zone, correlative to the interval of the *Morozovella aragonensis* s. str. and *Morozovella palmerae* (or *Acarinina pentacamerata*; Toumarkine and Luterbacher, 1985) Zones. The boundary between the *Morozovella subbotinae* s.l. and *Morozovella aragonensis* s.l. Zones is defined by the first occurrence of the index species of the latter in Sample 145-883B-83X-CC. The presence of numerous *Morozovella subbotinae* in the top layers of the lower Eocene section indicates that the sediments of the lower Eocene terminal zone are missing from the Hole 883B sequence. According to Toumarkine and Luterbacher (1985) this species became extinct at the end of the *Morozovella aragonensis* s. str. Zone.

Middle Eocene

The middle Eocene sediments in the interval of Cores 145-883B-75X through -81X are characterized by an impoverished assemblage

of planktonic foraminifers with a low diversity and poor preservation. The lower part of the middle Eocene sequence incorporates few to common *Muricoglobigerina senni*, *Subbotina linaperta*, *Acarinina rugosoaculeata*, *A. triplex*, *Catapsydrax martini*, and *Globorotaloides suteri*. The middle part of this interval contains only rare specimens of *S. linaperta* and *G. suteri*. *A. bullbrookii* was also found in two samples. A more diverse assemblage occurs in the upper one-third of the middle Eocene section. Here it is mostly represented by *Catapsydrax martini*, *Globorotaloides suteri*, *Subbotina linaperta*, and rarer *S. hagni*. In the top layers *S. eoecena*, *S. angiporoides minima*, *Turborotalia cerroazulensis frontosa*, *T. griffinae*, *Globigerinatheka index*, and *Pseudohastigerina micra* occur. This assemblage dates the sediments of this interval as middle Eocene. It is evident that the lower and middle Eocene sediments are divided by a hiatus; however, its duration is not clear. The occurrence of *S. linaperta*, *G. suteri*, *C. martini*, and *A. rugosoaculeata* in the lower part of the middle Eocene interval most likely indicates that only upper middle Eocene sediments are present here. Nevertheless, taking into consideration the poor preservation of the foraminifers and their specific characteristics (small dimensions, compact arrangement of chambers, less open aperture, and others) that makes identification difficult, one cannot elude the presence of the lower middle Eocene in this section.

Upper Eocene–Oligocene

The sediments of late Eocene–Oligocene age (about 30 m thick) are identified based on the planktonic foraminifers in Cores 145-883B-71X through -74X. Their impoverished and poorly preserved assemblage consists of six species occurring irregularly and in low quantity. The most common are *Globorotaloides suteri*, *G. testarugosa*, and *Catapsydrax unicavus*. In some samples *Globigerina praebuloides*, *G. angustumbilicata*, *Denticuloglobigerina galavisi*, and *Tenuitella gemma* are recorded. The presence of the latter species dates the sediments most likely as early Oligocene. At the same time the composition of the whole assemblage assumes that upper Eocene sediments are present in Hole 883B. On the basis of diatoms (Gladenkov and Barron, this volume) and nanofossils (Beaufort and Olafsson, this volume), the lower Oligocene is conformably overlain by upper Oligocene sediments (Cores 145-883B-69X through -70X), which in turn are overlain with a hiatus and lower Miocene layers. The impoverished lower Miocene planktonic foraminifer assemblage available for this study in Cores 145-883B-67X through -68X consists of dominant *Catapsydrax dissimilis*, *C. unicavus*, and *Globigerina venezuelana* accompanied by rare *Globorotaloides testarugosa*, *G. suteri*, *Globigerina euapertura*, and *G. praebuloides*. The samples from Core 145-883B-68X, which is placed by diatoms in the lower Miocene *Thalassiosira spinosa* Zone (Gladenkov and Barron, this volume), contain single specimens of late Oligocene foraminiferal species *Globigerina ciperoensis* and *Globoquadrina tripartita*, that probably represent reworking.

SITE 884

Site Description

Site 884 is located on the eastern lower flank of the Detroit Seamount (51°27.026'N; 168°20.228'E) at a water depth of 3827 m (Fig. 1). Five holes (884A–884E) were drilled at this site, and the 854-m-thick Paleogene–Quaternary sedimentary sequence was cored with the APC and XCB. In Hole 884B, 214-m-thick section of Paleogene sediments was recovered in the interval of Cores 145-884B-69X through -91X (640–854 mbsf) with average recoveries of 87.5% in the upper one-third of the sequence and 8.2% in the lower part. The sediments rest on basaltic basement and are conformably overlain by lower Miocene claystone with an admixture of diatoms and nanofossils.

Table 2. Correlation of low- and high-latitude zonal scales with the results of this study.

Age		Caribbean (Bolli, 1957a, 1957b, 1957c, 1966; Blow, 1969; Premoli Silva, Bolli, 1973)	Crimean-Caucasian (Subbotina, 1953; Shutskaya, 1970; Krasheninnikov, 1980)	New-Zealand (Jenkins, 1971)	Northern Kamchatka (Krasheninnikov et al., 1988)	This study	
Oligocene	late	<i>Globorotalia kugleri</i>	Rare planktonic foraminifers	<i>Globigerina woodi woodi</i>	Single planktonic foraminifers	No data	
		<i>Globigerina ciperoensis</i>		<i>Globigerina euapertura</i>			
		<i>Paragloborotalia opima</i>					
	early	<i>Globigerina ampliapertura</i>		<i>Subbotina angiporoides</i>			
		<i>C. chipolensis</i> - <i>Globigerina sellii</i>					
		<i>P. micra</i> <i>Globigerina tapuriensis</i>		<i>G. tapuriensis</i>			
Eocene	late	<i>Turborotalia cerroazulensis</i>	<i>Turborotalia cunialensis</i>	<i>Subbotina brevis</i>	Rare planktonic foraminifers	late Eocene-early Oligocene assemblage	
		<i>S. gortanii</i> - <i>T. centralis</i>	<i>T. cocoaensis</i>				
		<i>Turborotalia cocoaensis</i>	<i>G. semiinvoluta</i>	<i>Subbotina linaperta</i>			
	middle	<i>Globigerinatheka semiinvoluta</i>					
		<i>Truncorotaloides rohri</i>	<i>Globigerina turkmenica</i>	<i>Acarinina rugosoaculeata</i>	Beds with <i>T. frontosa</i>	middle Eocene assemblage	
		<i>Orbulinoides beckmanni</i>	<i>Hantkenina alabamensis</i>	<i>Globigerinatheka index</i>			
		<i>Morozovella lehneri</i>	<i>Acarinina rotundimarginata</i>	<i>Pseudogloboquadrina primitiva</i>	Beds with <i>T. boweri</i>		
		<i>Globigerinatheka kugleri</i>	<i>Acarinina bullbrooki</i>				
	<i>Hantkenina aragonensis</i>						
	early	<i>Morozovella palmerae</i>	<i>Morozovella aragonensis</i> s.l.	<i>Morozovella crater</i>	<i>Morozovella aragonensis</i> s.l.	Hiatus	
		<i>Morozovella aragonensis</i>				<i>M. aragonensis</i> s.l.	
		<i>Morozovella formosa</i>	<i>M. subbotinae</i> s.l.	<i>Morozovella dentata</i>	<i>Morozovella wilcoxensis</i>	<i>Morozovella subbotinae</i> s.l.	
<i>Morozovella subbotinae</i>		<i>Morozovella subbotinae</i>					
<i>Morozovella edgari</i>							
Paleocene	late	<i>Morozovella velascoensis</i>	<i>A. acarinata</i>		<i>A. acarinata</i>	late Paleocene assemblage	
		<i>Planorotalites pseudomenardii</i>	<i>A. mckarnai</i>	<i>Subbotina triloculinoides</i>	Rare planktonic foraminifers		
		<i>Planorotalites pusilla</i>	<i>A. tadjikistanensis</i>				
		<i>Morozovella angulata</i>	<i>M. conicotruncata</i>				
			<i>M. angulata</i>				<i>Globorotalia angulata</i>

The Paleogene section is composed of claystone with some chalk and an admixture of biogenic siliceous material in the interval of Cores 145-884B-69X through -75X (640-695 mbsf), irregular alternation of chalk, claystone with a high smectite content (most likely altered ash) and, to a lesser extent, fresh ash in the interval of Cores 145-884B-75X through -83X (695-771 mbsf), and interlayered claystone and altered ash with some chalk layers in the interval of Cores 145-884B-83X through -91X (771-854 mbsf).

The sediments display strong evidence for displacement and reworking in the form of turbidite, debris-flow and diamictite layers, and soft-sediment deformations including recumbent folding and microfaults.

Biostratigraphy

Planktonic foraminifers in the Paleogene sediments at Site 884 are characterized by a generally low diversity and abundance. Of the 145 samples, collected from the Hole 884B Paleogene section, only about 20 samples, mainly from the lower portion, contained planktonic foraminifers. The upper Eocene and Oligocene sediments are completely barren of foraminifers except for single unidentifiable specimens found in two samples from the upper Eocene interval.

Planktonic foraminifers in the upper portion of the undivided lower-middle Eocene interval (dating by nannofossils) occur in most of the samples although seldom in large numbers. In the lower part of this interval planktonic foraminifers disappear again. Their preservation at this site varies from poor to moderate and is in general poorer in comparison to that at the shallower Site 883 owing to deeper location and, accordingly, to more intense dissolution at Site 884 (Table 3).

The assemblage of planktonic foraminifers, recorded in the interval of Core 145-884B-82X through Sample 145-884B-86X-4, 25-30 cm, shows a mixed composition that testifies to sediment reworking and displacement. Most common are *Acarinina primitiva*, *A. bullbrooki*, *Subbotina linaperta*, *S. eocaena*, *Muricoglobigerina senni*, and *Turborotalia cerroazulensis frontosa*. *Acarinina pentacamerala*, *A. triplex*, *Turborotalia boweri*, *Subbotina eocaenica*, and *Pseudohastigerina micra* occur in subordinate quantities. This association correlates the sediments to the middle Eocene. Reworked foraminifers of a very poor preservation are represented by lower Eocene *Morozovella* aff. *subbotinae* and *Acarinina* aff. *nitida*. Poorly preserved lower-middle Eocene *Morozovella* aff. *aragonensis* is probably also redeposited.

DISCUSSION

Drilling at Sites 883 and 884 on the Detroit Seamount recovered the first Paleogene sequence with relatively diverse planktonic foraminifers in the subarctic Pacific. The richer, better preserved assemblage of planktonic foraminifers that occurs at the shallower Site 883 allows the identification of the upper Paleocene, Eocene, and Oligocene whereas at the deeper Site 884, only the middle Eocene sediments contain planktonic foraminifers, which are impoverished and poorly preserved. On the whole, the planktonic foraminifer assemblage in the Paleogene of Hole 883B numbers less than 40 species, which are characterized by rare to common abundance and by poor to good preservation. Their general morphology is characteristic of assemblages at high latitudes, as evidenced by the smaller test dimensions of most the species, compact arrangement of chambers in the last whorl, muted surface sculpture, and restricted apertures or weak development of the apertural lip. These peculiarities make species identification difficult in many cases. The taxonomic composition also displays features peculiar to cold-water associations of high-latitude areas. The assemblages are composed mostly of subbotinids and acarininids with a subordinate share of keeled morozovellids in the lower Eocene interval. Species of *Hantkenina*, *Globigerinatheka*, and *Orbulinoides*, as well as many representatives of the keeled

Table 3. Occurrence of planktonic foraminifers in Paleogene sediments recovered from Hole 884B.

AGE	HOLE 884B		ABUNDANCE PRESERVATION	<i>Acarinina primitiva</i> <i>Subbotina linaperta</i> <i>Acarinina bullbrooki</i> <i>Acarinina triplex</i> <i>Turborotalia boweri</i> <i>T. cerroazulensis frontosa</i> <i>Pseudohastigerina micra</i> <i>Muricoglobigerina senni</i> <i>Subbotina eocaenica</i> <i>Acarinina</i> aff. <i>pentacamerala</i> <i>A. aff. nitida</i> <i>Morozovella</i> aff. <i>subbotinae</i> <i>Subbotina eocaena</i> <i>Morozovella</i> aff. <i>aragonensis</i>
	SAMPLE (core, section, interval in cm)			
	70X-1, 30-35 to		No planktonic foraminifers	
middle Eocene	81X-5, 20-25		No planktonic foraminifers	
	82X-1, 31-34	R P	R	R
	2, 30-33			
	3, 30-34			
	4, 37-39	R P	R R	R R R
	5, 16-21	R P		R R
	6, 60-63	R P	R R	R R
	CC, 28-32	F M	F F F R	R R
	83X-1, 28-31			
	2, 32-35	R P	R	R
	3, 53-56	R P		
	4, 27-31			
	5, 69-72			
	6, 44-47	R P	R	
	7, 71-74			
	CC, 36-40	R P	R R	R R R
	84X-1, 48-52			
	2, 22-26	R P	R R	R R
	3, 24-28	R P	R R	R R
	4, 27-31	F P	R F R F	R R
5, 29-33	R P	R	R	
6, 37-41				
7, 15-19				
CC,			No planktonic foraminifers	
85X-1, 31-36			No planktonic foraminifers	
2, 21-26				
3, 35-40				
4, 30-35	F M	F	F F R R	
5, 37-42				
6, 31-36	R P		R	
7, 34-39	R P	R R	R R	
CC, 17-22	R P	R R R R R		
86X-1, 35-40				
2, 20-25				
3, 28-33	R P	R		
4, 25-30	R P	R R		
5, 21-26				
to			No planktonic foraminifers	
91X-3, 30-35			No planktonic foraminifers	

Note: The abundance and preservation codes are given in the "Material and Methods" section (this chapter).

morozovellids that dominate at lower latitudes are missing from the Paleogene sequence at Detroit Seamount. However, on the Hess and Shatsky rises (32°-37°N), in the geographically close Paleogene sections of the North Pacific, they occur in notable amounts (Krasheninnikov and Hoskins, 1973; Krasheninnikov, 1982).

The prevalence of acarininids and subbotinids in planktonic foraminifer assemblages from the Detroit Seamount sequence makes them similar to the assemblages observed in coeval sediments of

Southern Hemisphere high latitudes: from New Zealand (Jenkins, 1971) and Campbell Plateau (Jenkins, 1975; Jenkins and Srinivasan, 1986; Krasheninnikov et al., 1988), Falkland Plateau (Tjalsma, 1977; Krasheninnikov and Basov, 1983, 1986), Maud Rise (Stott and Kennett, 1990), and Kerguelen Plateau (Huber, 1991; Berggren, 1992). Similar assemblages were also described from the southern areas of the former Soviet Union (Crimea, Ciscaucasia, and Middle Asia) (Subbotina, 1953; Shutskaia, 1970) and the northern Kamchatka region (Krasheninnikov et al., 1988). Most of these sequences were located at higher latitudes during the Paleogene in comparison to the Detroit Seamount area, which suggests that the planktonic foraminifer impoverishment at the latter site could be caused by both relatively cold-water environments and selective dissolution.

Such a composition of planktonic foraminifers in the subarctic Pacific prevents the use of the usual tropical-subtropical zonal scales (Bolli, 1957a, 1957b, 1957c, 1966; Bolli and Premoli Silva, 1973; Premoli Silva and Bolli, 1973; Blow, 1969; Berggren et al., 1985; Toumarkine and Luterbacher, 1985; Berggren and Miller, 1988) for detailed subdivision of the Paleogene sequence at Detroit Seamount. Only the lower Eocene assemblages in Hole 883B provide the possibility of defining intervals correlative to the zonal units of the Crimean-Caucasian scheme (Subbotina, 1953; Shutskaia, 1970; Krasheninnikov, 1980). Application of the biostratigraphic zonation suggested by Stott and Kennett (1990) for the Antarctic region and correlated with available low-latitude zonations also meets with large difficulties because of the absence or discrete distribution in Detroit Seamount sequence of zonal markers such as *Planorotalites australiformis*, *Chiloguembelina cubensis*, *Pseudohastigerina micra*, *Globigerinatheka index*, *Acarinina pentacamerata*, and others. The comparison of Paleogene planktonic foraminifers from these two high-latitude regions is a subject of future studies that require more detailed sampling and a larger sample volume.

Despite the general impoverishment of the planktonic foraminifer assemblages of the subarctic Pacific, the changes in their diversity and composition reflect climatic fluctuations through the Paleogene established by a number of oxygen isotope studies and paleontological data in different low- and high-latitude areas (Shackleton and Kennett, 1975; Boersma and Shackleton, 1977; Vergnaud-Grazzini et al., 1978; Haq, 1981; Hsü et al., 1984; Keller, 1983; Oberhänsli and Toumarkine, 1985; Oberhänsli, 1986; Oberhänsli and Hsü, 1986; Oberhänsli et al., 1991; Boersma et al., 1987; Stott et al., 1990; Barrera and Huber, 1991; and others). At the same time local preservational environments appear to affect some assemblages significantly by reducing their original diversity and changing the composition, which prevents reliable paleoceanographic interpretation. This is evidenced primarily by a correlation of diversity, abundances, and the state of preservation of the foraminiferal assemblages through the Hole 883B section. As a rule, the more diverse and abundant assemblages are characterized by better preservation. The upper Paleocene assemblage that consists of five poorly preserved species is an example of reduction by dissolution.

The most diverse and best preserved assemblages in the lower Eocene reflect the warm-water environments. This is also confirmed by an occurrence along with various acarininids and subbotinids of keeled *Morozovella* species (*M. subbotinae*, *M. aragonensis*, *M. formosa gracilis*, and *M. caucasica*). The excursion of keeled morozovellids into higher latitudes during a recognized early Eocene worldwide warming maximum has been recorded in both the Northern and Southern hemispheres: in the northern Kamchatka region (Krasheninnikov et al., 1988), Australia–New Zealand region (Jenkins, 1971, 1975; Jenkins and Srinivasan, 1986; Krasheninnikov and Basov, 1986; Krasheninnikov et al., 1988), Kerguelen Plateau (Huber, 1991; Berggren, 1992), and Falkland Plateau (Tjalsma, 1977). It is noteworthy that no keeled morozovellids or any other thermophilic species were observed in the lower Eocene sediments from the Maud Rise (Stott and Kennett, 1990).

The diversity of planktonic foraminifers in the middle Eocene remained as high as in the early Eocene; however, their composition

displays more cold-water character. The resistant cosmopolitan species of *Subbotina*, *Globorotaloides*, and *Catapsydrax* dominated in the assemblages whereas rare acarininids occurred only at separate levels. No warm-water forms characteristic of tropical-subtropical planktonic foraminifer assemblages (keeled morozovellids, species of *Hantkenina*, *Orbulinoidea*, and others) were observed in the middle Eocene at the Detroit Seamount sites. The upper Eocene(?)–lower Oligocene assemblage numbers seven species in total, which belong to the *Globigerina*, *Denticuloglobigerina*, *Globorotaloides*, and *Turborotalia* genera. This reduction in planktonic foraminifer diversity is in accordance with a climatic cooling trend recorded worldwide by oxygen isotope data.

A similar trend in changes in planktonic foraminifer composition and diversity has been observed in the northern Kamchatka Paleogene sequences (Krasheninnikov et al., 1988). Here, the most diverse assemblages are dominated by acarininids and subbotinids with an insignificant admixture of keeled morozovellids in the lower Eocene, where the *Morozovella subbotinae* s.l. and *Morozovella aragonensis* s.l. Zones are identified. The middle Eocene sediments reveal an assemblage comparable in diversity to that from the *Morozovella aragonensis* s.l. Zone and, as at Site 883, devoid of any warm-water species. Only rare planktonic foraminifers of no stratigraphic significance are present in the upper Eocene and Oligocene.

The comparison of Detroit Seamount Paleogene assemblages of planktonic foraminifers with those from the nearest North Pacific sequences shows that they are very similar in composition and diversity patterns to the northern Kamchatka associations, which are thought to belong to the temperate-boreal province (Krasheninnikov et al., 1988). In the area of the Shatsky and Hess rises (32°–37°N), planktonic foraminifers are much more diverse and include, along with *Acarinina*, *Subbotina*, *Catapsydrax*, and *Pseudohastigerina* species, the various thermophilic forms of *Morozovella*, *Globigerinatheka*, *Truncorotaloides*, and *Hantkenina* genera. The latter, according to Krasheninnikov (1982), are characteristic of the southernmost part of the subtropical belt. Reef-associated bryozoans from the lower Eocene of DSDP Site 308 drilled on the Koko Seamount in the southern Emperor Seamounts chain at 35°N also indicate a tropical climate for the early Eocene (Cheetham, 1975).

Northward, the upper Paleocene–lower Eocene assemblages of planktonic foraminifers as well as reefal bryozoan-algal assemblages at DSDP Site 433 on Suiko Seamount (about 45°N) show subtropical features (Butt, 1980). On the whole, the composition of planktonic foraminifers in the lower Eocene sediments from this area is indicative of somewhat warmer conditions as compared to those at Detroit Seamount. The paleolatitude of the Suiko Seamount area for that time is estimated to be 26.9° ± 3.5°N (Kono, 1980). This and paleolatitude estimations (Rea, Basov, Janecek, Palmer-Julson, et al., 1993) place the Paleogene planktonic foraminifer assemblages at Detroit Seamount in the northern subtropical province, which is supported by the temperate-warm character of nannofossils in the lower Eocene sediments at Meiji Seamount Site 192 (Worsley, 1973).

SPECIES LIST AND TAXONOMIC NOTES

Planktonic foraminifer species from the Paleogene sediments of Sites 883 and 884 (Holes 883B and 884B) on Detroit Seamount in the subarctic Pacific are listed in alphabetical order (Pls. 1–4). Comments are added for several species concerning taxonomy, morphology, and distribution. The generic classification of the Paleogene planktonic foraminifer faunas remains under debate (see analyses by Toumarkine and Luterbacher, 1985; Corfield, 1987). The classification scheme adapted in this study is based mainly on these works.

Acarinina broedermanni (Cushman and Bermudez) 1949; Pl. 1, Fig. 4

Acarinina bullbrooki (Bolli) 1957; Pl. 1, Figs. 1–3

Acarinina esnaensis (LeRoy) 1953

Acarinina matthewsae Blow, 1979; Pl. 1, Figs. 5, 6

Acarinina mckannai (White) 1952; Pl. 1, Figs. 9, 10

The two independent species *A. mckannai* and *A. subsphaerica* are de-

scribed in the literature; however, their morphology as well as stratigraphic distribution are rather similar. Both of them are characteristic of the upper Paleocene–lower Eocene of oceanic and continental sediments. Only one morphological feature differentiates these forms: *A. mckannai* is characterized by a higher conical test in comparison with that of *A. subsphaerica*. However, this difference may be the result of intraspecific variability, which is confirmed by the presence of transitional forms. Most likely, the latter is a junior synonym of the former, as it is considered by Toumarkine and Luterbacher (1985). Both low and high conical forms are present in Hole 883B upper Paleocene–lower Eocene sediments and they are considered here as the *A. mckannai*-*subsphaerica* group. Generally they have six chambers in the last whorl.

Acarinina nitida (Martin) 1943; Pl. 1, Figs. 7, 8

Acarinina pentacamerata Subbotina, 1936; Pl. 1, Figs. 14, 15

Acarinina primitiva (Finlay) 1947; Pl. 1, Figs. 11–13

Acarinina rugosoaculeata Subbotina, 1953

This species with a characteristic small, spinose, low conical five-chamber test with flattened spiral side is a senior synonym of *Globorotalia aculeata* Jenkins, which is typical of the upper middle Eocene deposits of New Zealand. At Detroit Seamount Site 883 it also occurs in the middle Eocene sediments.

Acarinina soldadoensis (Brönnimann) 1952; Pl. 1, Figs. 18–20

Both *A. soldadoensis soldadoensis* and *A. soldadoensis angulosa* are present in the Site 883 lower Eocene sediments.

Acarinina triplex Subbotina, 1953; Pl. 1, Figs. 16, 17

Acarinina wilcoxensis (Cushman and Ponton), 1932, s.l.; Pl. 2, Fig. 1

Specimens from lower Eocene sediments of Site 883 probably should be referred to the subspecies *A. wilcoxensis bergreni*; however, the limited number found prevents their reliable definition.

Catapsydrax dissimilis (Cushman and Bermudez) 1937; Pl. 4, Fig. 1

Catapsydrax martini (Blow and Banner), 1962; Pl. 4, Figs. 6, 7

Catapsydrax unicavus Bolli, Loeblich, and Tappan, 1957; Pl. 4, Figs. 8, 9

Denticuloglobigerina galavisi (Bermudez) 1961; Pl. 4, Fig. 16

Globigerina angustiumbilocata Bolli, 1957; Pl. 4, Fig. 14

Globigerina ciperoensis Bolli, 1957; Pl. 4, Fig. 15. Single specimens of this typical late Oligocene species that occur in the lower Miocene sediments of Hole 883B most likely represent reworking.

Globigerina euapertura Jenkins, 1960

Globigerina lozanoi Colom, 1954; Pl. 3, Figs. 5, 6

Globigerina praebuloides Blow, 1959; Pl. 4, Fig. 17

Globigerina venezuelana Hedberg, 1937; Pl. 4, Figs. 18, 19

Globigerinatheka index (Finlay) 1939; Pl. 2, Fig. 13

Globoquadrina tripartita Koch, 1926

Single specimens of this upper Oligocene species were reworked into lower Miocene sediments of Site 883.

Globorotaloides aff. *carcosellensis* Toumarkine and Bolli, 1975; Pl. 4, Figs. 11, 12

Specimens with five and a half chambers in the last whorl and with the last chamber partly covering the umbilicus are referred to this species. They differ from typical representatives by their gradual increase of chamber size in spiral view instead of the last chamber appearing smaller than the penultimate one.

Globorotaloides suteri Bolli, 1957

Globorotaloides testarugosa (Jenkins) 1960; Pl. 4, Fig. 13

Muricoglobigerina senni (Beckmann), 1953; Pl. 2, Fig. 14

Morozovella aragonensis (Nuttall) 1930; Pl. 2, Figs. 2, 3

Morozovella caucasica (Glaessner) 1937; Pl. 2, Fig. 4

Morozovella lensiformis (Subbotina) 1953; Pl. 2, Figs. 6, 7

Morozovella quetra (Bolli) 1957

Morozovella subbotinae (Morozova) 1929; Pl. 2, Figs. 8–10

Subbotina angiporoides minima (Jenkins) 1966; Pl. 3, Figs. 12, 13

Subbotina eocaena (Guembel) 1868; Pl. 3, Figs. 2–4

The characteristic feature of this species is smaller size of the last chamber as compared with that of preceding ones. Some specimens from the Hole 883B middle Eocene sediments show a gradual increase of chamber dimensions in the last whorl.

Subbotina eocaenica (Terquem) 1882; Pl. 2, Figs. 18, 19; Pl. 3, Fig. 1

Subbotina hagni (Gohrbandt) 1967; Pl. 3, Figs. 7, 8

Subbotina linaperta (Finlay) 1939; Pl. 3, Figs. 9–11

Specimens from the Detroit Seamount sediments have a less expressed apertural lip than typical representatives of this species.

Subbotina velascoensis Cushman, 1925; Pl. 2, Figs. 15–17

Pseudohastigerina micra (Cole) 1927; Pl. 2, Fig. 11

Tenuitella gemma (Jenkins) 1966; Pl. 4, Fig. 20

Truncorotaloides rohri Brönnimann and Bermudez, 1953; Pl. 2, Fig. 12

Turborotalia bowyeri (Bolli). Pl. 4, Figs. 1, 2

Toumarkine and Luterbacher (1985) considered this species a synonym of *Turborotalia cerroazulensis frontosa* (Subbotina). However, the subquadrate shape of the test of the former species, more compact arrangement of chambers in the last whorl, and their perpendicular position to each other make it quite distinctive from the latter. Here *T. bowyeri* is considered an independent species.

Turborotalia cerroazulensis frontosa (Subbotina) 1953; Pl. 3, Figs. 14–16

Turborotalia griffinae Blow, 1979; Pl. 4, Figs. 3–5

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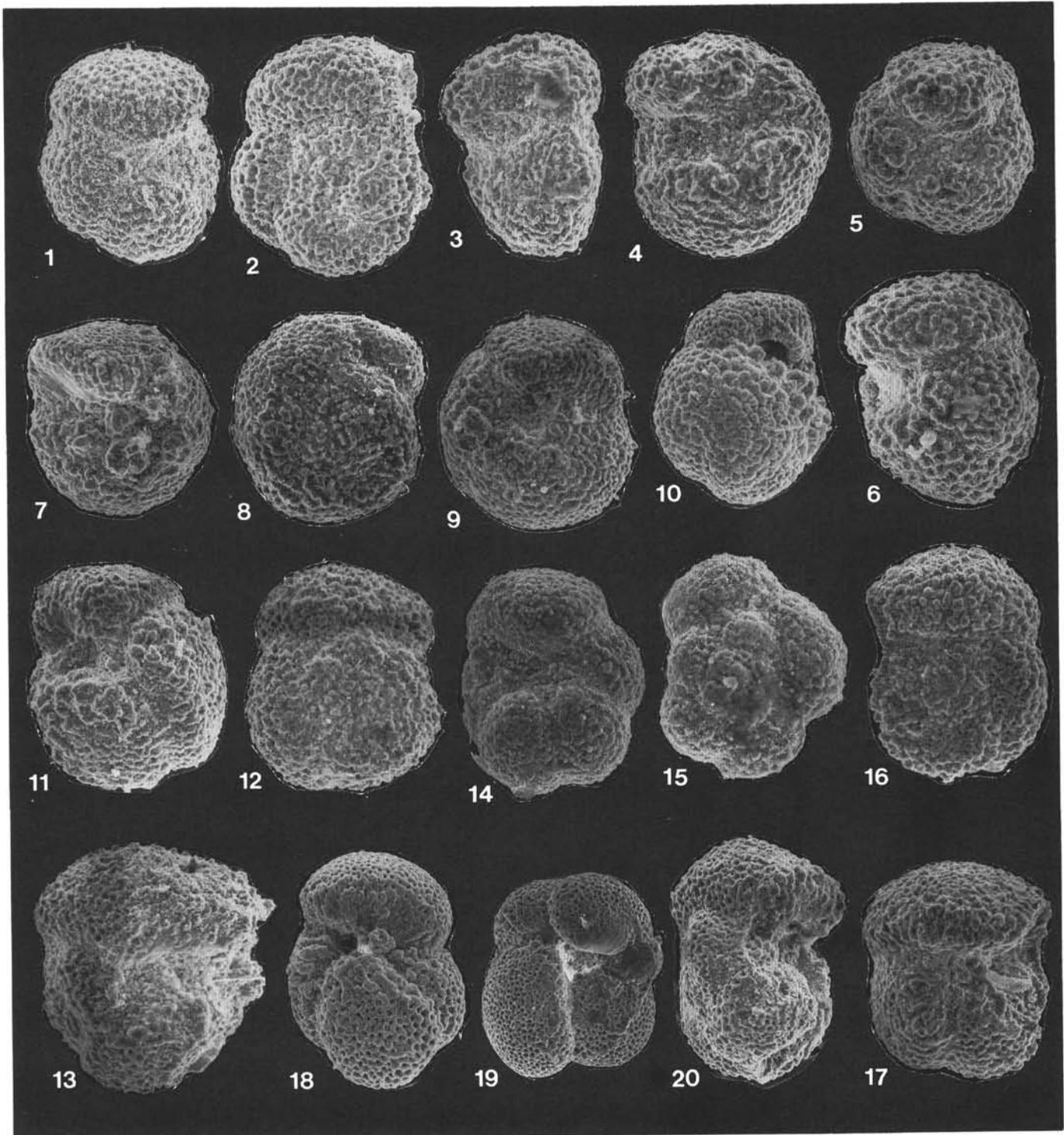


Plate 1. **1–3.** *Acarinina bullbrooki*, Sample 145-883B-75X-1, 120–122 cm: (1) umbilical view, $\times 100$; (2) spiral view, $\times 120$; (3) side view, $\times 130$. **4.** *Acarinina broedermanni*, Sample 145-883B-82X-5, 120–122 cm, umbilical view, $\times 130$. **5, 6.** *Acarinina matthewsae*, Sample 145-883B-79X-1, 120–122 cm: (5) umbilical view, $\times 120$; (6) side view, $\times 150$. **7, 8.** *Acarinina nitida*, Sample 145-883B-82X-6, 120–122 cm: (7) umbilical view, $\times 110$; (8) spiral view, $\times 120$. **9, 10.** *Acarinina mckannai*, Sample 145-883B-84X-1, 60–62 cm: (9) umbilical view, $\times 120$; (10) side view, $\times 120$. **11–13.** *Acarinina primitiva*, Sample 145-883B-86X-4, 120–122 cm: (11) umbilical view, $\times 110$; (12) spiral view, $\times 110$; (13) side view, $\times 120$. **14, 15.** *Acarinina pentacamerata*, Sample 145-884B-82X-4, 34–39 cm: (14) umbilical view, $\times 130$; (15) spiral view, $\times 140$. **16, 17.** *Acarinina triplex*, Sample 145-883B-82X-5, 120–122 cm: (16) spiral view, $\times 110$; (17) umbilical view, $\times 100$. **18–20.** *Acarinina soldadoensis*, Sample 145-883B-84X-1, 60–62 cm: (18) umbilical view, $\times 120$; (19) umbilical view, $\times 110$; (20) side view, $\times 120$.

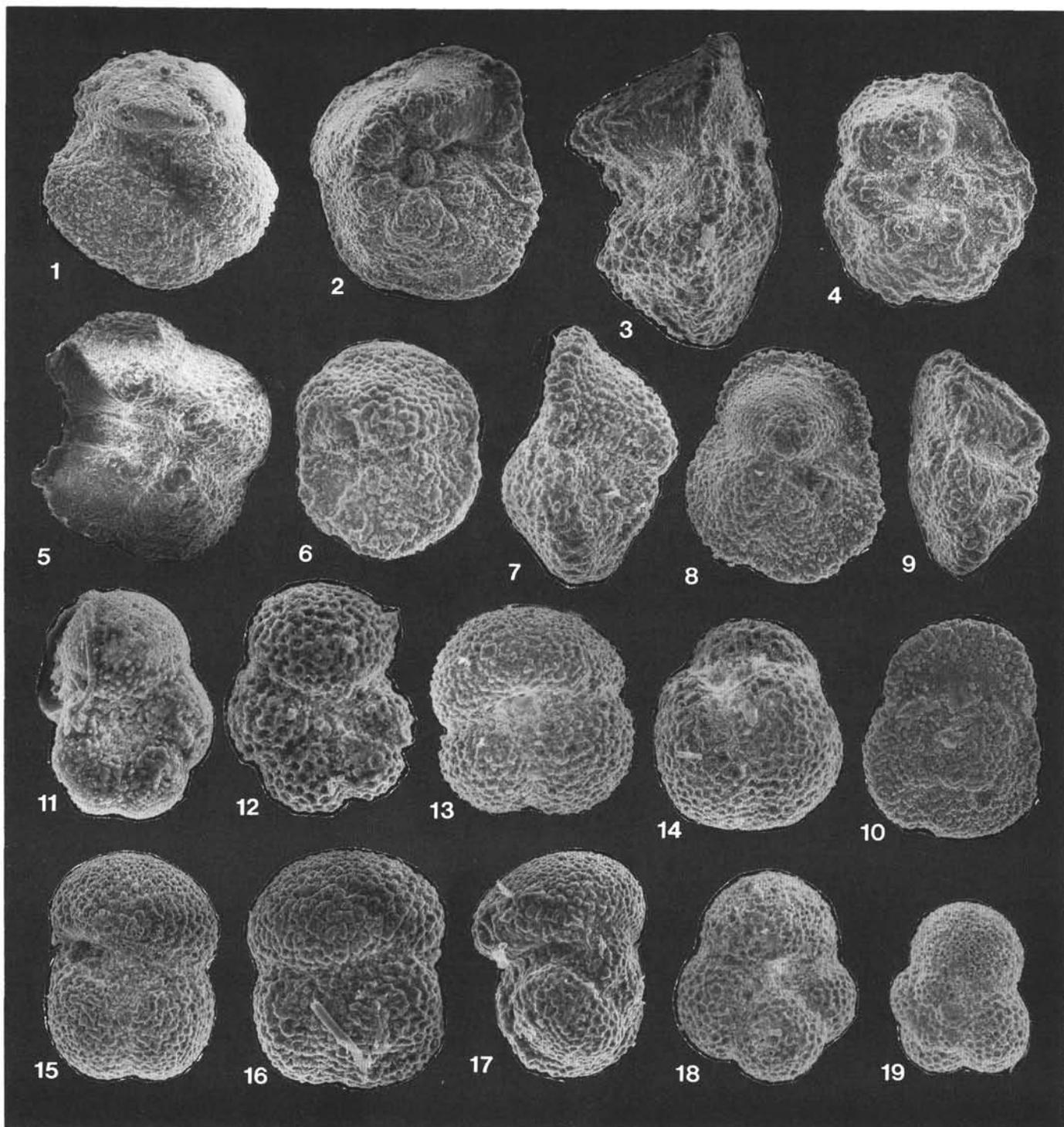


Plate 2. **1.** *Acarinina wilcoxensis*, Sample 145-883B-82X-3, 118–120 cm, umbilical view, $\times 80$. **2, 3.** *Morozovella aragonensis*, Sample 145-883B-82X-5, 120–122 cm: (2) umbilical view, $\times 90$; (3) side view, $\times 140$. **4.** *Morozovella caucasica*, Sample 145-883B-82X-5, 120–122 cm, umbilical view, $\times 90$. **5.** *Morozovella formosa gracilis*, Sample 145-883B-82X-5, 120–122 cm, $\times 80$. **6, 7.** *Morozovella lensiformis*, Sample 145-883B-84X-1, 60–62 cm: (6) umbilical view, $\times 120$; (7) side view, $\times 120$. **8–10.** *Morozovella subbotinae*, Sample 145-883B-82X-5, 120–122 cm: (8) umbilical view, $\times 90$; (9) side view, $\times 110$; (10) spiral view, $\times 100$. **11.** *Pseudohastigerina micra*, Sample 145-883B-75X-1, 120–122 cm, side view, $\times 260$. **12.** *Truncorotaloides rohri*, Sample 145-883B-79X-1, 120–122 cm, $\times 160$. **13.** *Globigerinatheka index*, Sample 145-883B-75X-1, 120–122 cm, umbilical view, $\times 130$. **14.** *Muricoglobigerina senni*, Sample 145-883B-75X-4, 120–122 cm, umbilical view, $\times 130$. **15–17.** *Subbotina velascoensis*, Sample 145-883B-84X-1, 60–62 cm: (15) umbilical view, $\times 100$; (16) spiral view, $\times 130$; (17) side view, $\times 110$. **18, 19.** *Subbotina eocaenica*, Sample 145-883B-75X-1, 120–122 cm: (18) umbilical view, $\times 120$; (19) spiral view, $\times 120$.

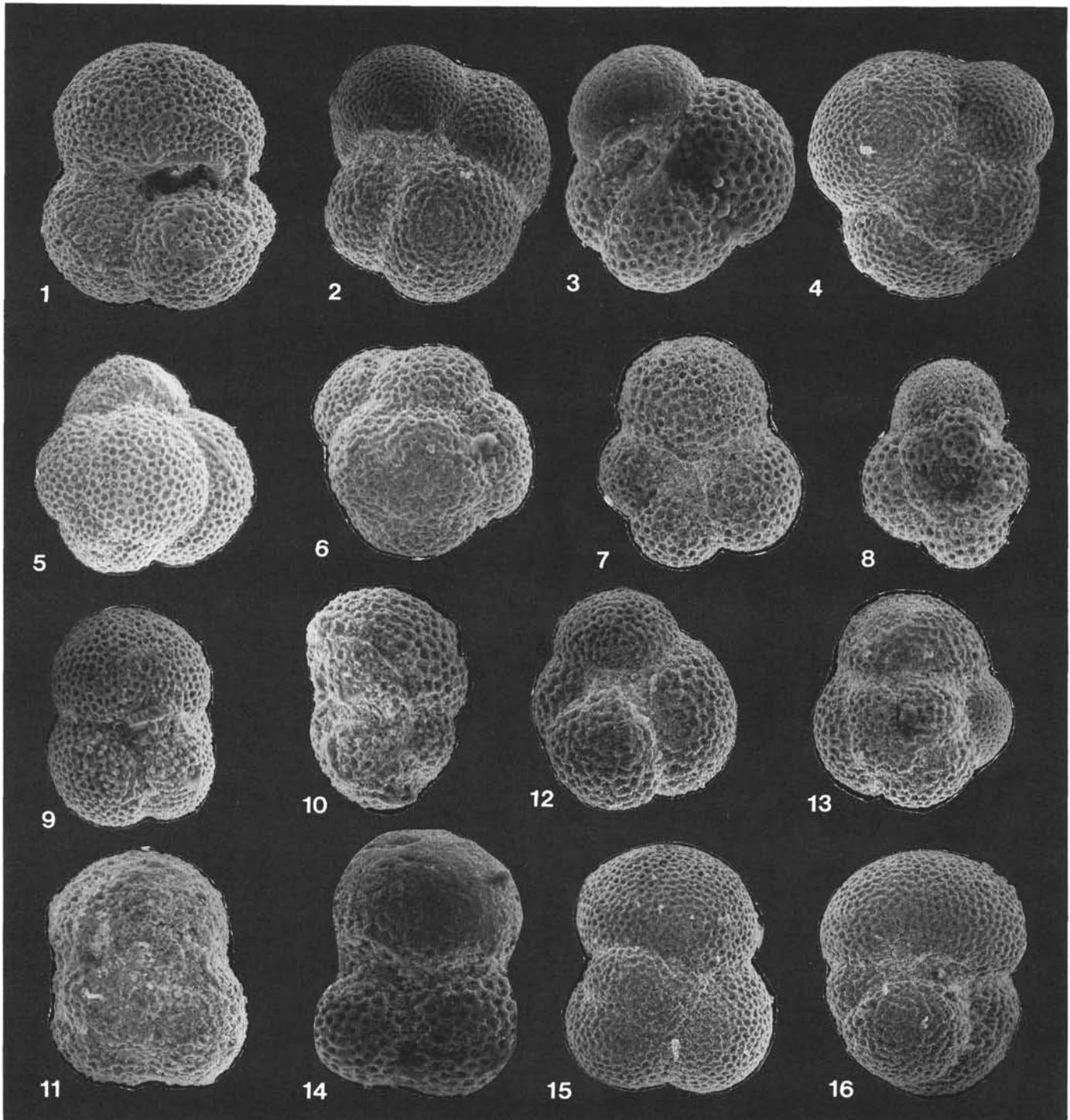


Plate 3. **1.** *Subbotina eoacnica*, Sample 145-883B-82X-2, 120–122 cm, $\times 110$. **2–4.** *Subbotina eoacna*, Sample 145-883B-75X-1, 120–122 cm: (2, 3) umbilical view, $\times 110$; (4) spiral view, $\times 110$. **5, 6.** *Globigerina lozanoi*, Sample 145-883B-82X-2, 120–122 cm: (5) umbilical view, $\times 100$; (6) spiral view, $\times 100$. **7, 8.** *Subbotina hagni*, Sample 145-883B-75X-1, 120–122 cm: (7) umbilical view, $\times 110$; (8) spiral view, $\times 140$. **9–11.** *Subbotina linaperta*, Sample 145-883B-79X-1, 120–122 cm: (9) umbilical view, $\times 140$; (10) side view, $\times 140$; (11) spiral view, $\times 150$. **12, 13.** *Subbotina angiporoides minima*, Sample 145-883B-75X-1, 120–122 cm: (12) umbilical view, $\times 140$; (13) spiral view, $\times 120$. **14–16.** *Turborotalia cerroazulensis frontosa*, Sample 145-883B-75X-1, 120–122 cm: (14) umbilical view, $\times 130$; (15) spiral view, $\times 110$; (16) side view, $\times 110$.

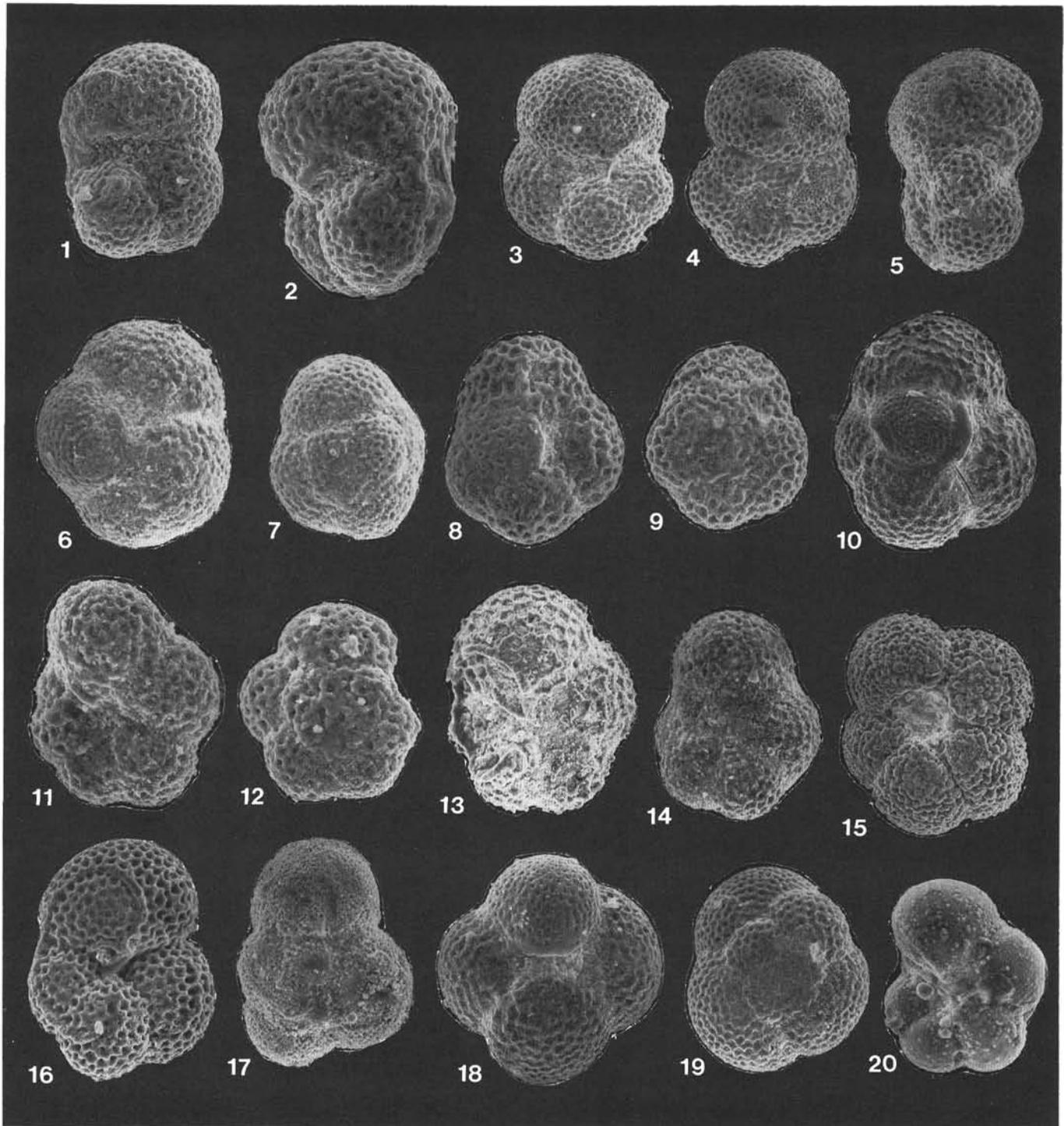


Plate 4. **1, 2.** *Turborotalia boweri*, Sample 145-884B-85X-CC: (1) umbilical view, $\times 120$; (2) side view, $\times 200$. **3–5.** *Turborotalia griffinae*, Sample 145-883B-75X-1, 120–122 cm: (3) umbilical view, $\times 130$; (4) spiral view, $\times 140$; (5) side view, $\times 150$. **6, 7.** *Catapsydrax martini*, Sample 145-883B-81X-CC: (6) umbilical view, $\times 130$; (7) spiral view, $\times 120$. **8, 9.** *Catapsydrax unicavus*, Sample 145-883B-73X-7, 44–46 cm: (8) umbilical view, $\times 170$; (9) spiral view, $\times 180$. **10.** *Catapsydrax dissimilis*, Sample 145-883B-68X-3, 120–122 cm, umbilical view, $\times 90$. **11, 12.** *Globorotaloides* aff. *carcosellensis*, Sample 145-883B-79X-3, 120–122 cm: (11) umbilical view, $\times 260$; (12) spiral view, $\times 250$. **13.** *Globorotaloides testarugosa*, Sample 145-883B-75X-1, 120–122 cm, umbilical view, $\times 140$. **14.** *Globigerina angustiumblicata*, Sample 145-883B-73X-5, 120–122 cm, umbilical view, $\times 140$. **15.** *Globigerina ciperoensis*, Sample 145-883B-68X-3, 120–122 cm, umbilical view, $\times 100$. **16.** *Denticuloglobigerina galavisi*, Sample 145-883B-73X-6, 120–122 cm, umbilical view, $\times 160$. **17.** *Globigerina praebulloides*, Sample 145-883B-67X-4, 120–122 cm, spiral view, $\times 150$. **18, 19.** *Globigerina venezuelana*, Sample 145-883B-68X-3, 120–122 cm: (18) umbilical view, $\times 100$; (19) spiral view, $\times 100$. **20.** *Tenuitella gemma*, Sample 145-883B-77X-5, 80–82 cm, umbilical view, $\times 220$.