30. CRETACEOUS BENTHIC FORAMINIFERS FROM THE WESTERN SOUTH ATLANTIC LEG 39, DEEP SEA DRILLING PROJECT

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ABSTRACT

Cretaceous benthic foraminifers from DSDP Leg 39, Sites 355-358, in the western South Atlantic, range in age from Albian to Maestrichtian, and indicate middle bathyal to abyssal depositional environments. Foraminifers of Maestrichtian and possibly Campanian age from Site 355 in the Brazil Basin, and of Maestrichtian age from Site 358 in the Argentine Basin, indicate abyssal water depths of 3000 to 4000 meters. The Albian assemblage of Site 356 on the São Paulo Plateau is from middle bathyal depths of 500 to 1500 meters, whereas Santonian to Maestrichtian assemblages are lower bathyal (1500-2500 m). Foraminiferal assemblages at Site 357 on the Rio Grande Rise range from middle to lower bathyal in the Santonian to lower bathyal in the Campanian and Maestrichtian.

The distribution and preservation of the late Cretaceous foraminifers suggest the lysocline and the carbonate compensation surface in the South Atlantic ranged between 3000 and 4000 meters. Dissolution of most agglutinated and calcareous benthic species occurred at the CCD, resulting in an assemblage composed of corroded specimens of the Cassidulinacea, with rare resistant agglutinated species. Faunal variations in the Campanian sample of Site 356, and similar variations—together with dissolution of planktonic and selected benthic species—in the Campanian of Site 357, may suggest an influx of corrosive bottom waters, or alternatively, an oxygen-minimum layer between 1000 and 1500 meters.

A mid-Cretaceous hiatus detected at Sites 356 and 357 correlates with the hiatus at Hole 327A of Leg 36 on the Falkland Plateau. Thus the mid-Cretaceous hiatus, recognized at many DSDP sites in the Southern Hemisphere, extends well into the South Atlantic.

INTRODUCTION

Most Cretaceous sediments recovered from the western South Atlantic during Leg 39 proved to be fossiliferous. This study describes the Cretaceous benthic foraminifers from Sites 355 to 358 (Figure 1). These sites flank the Rio Grande Rise, and range from about 15° to 37°S latitude. The foraminifer faunas add considerably to our knowledge of Cretaceous lower bathyal and abyssal species and paleo-oceanographic conditions in the South Atlantic. A total of 180 species, ranging in age from Albian to Maestrichtian, was identified from a size fraction greater than 150 μm taken from samples of approximately uniform volume. These species form the basis of the biostratigraphic and environmental reconstructions that follow. The cosmopolitan nature of many Leg 39 species is apparent in the geographic distribution of assemblages with faunal affinities, such as those from the U.S. Gulf Coast (Tappan, 1940, 1943; Cushman, 1946), California (Sliter, 1968), Trinidad (Bartenstein et al., 1957), Sweden (Brotzen, 1936), Poland (Stejn, 1957; Gawor-Biedowa, 1972), Czechoslovakia (Hanzlíková, 1972); Rumania (Neagu, 1965, 1968, 1970), and Australia (Belford, 1960). Within the South Atlantic and Indian Ocean areas, foraminiferal assemblages showing similarities have been described by Ferreira and Rocha (1957), Scheibnerová (1974), Lambert (1971), Natland et al. (1974), Malumian (1968), and Sliter (in press).

BIOSTRATIGRAPHY

Site 355

Site 355, in the Brazil Basin, lies at a water depth of 4901 meters. Coring here recovered 44 meters of upper Cretaceous clay-rich nannofossil ooze and chalk. Foraminiferal faunas consist primarily of corroded and fragmented benthic species, with planktonic species rare or absent. Samples from Cores 17 to 20 contain a benthic fauna suggestive of a Maestrichtian age, based on the presence of *Aragonia ouezzaensis*, *Gaudryina pyramidata*, *Gavelinella cayeuxi mangshlakensis*, and *Spiroplectammina dentata* (Figures 2, 3; see Plates 1-13 and Appendix for species identifications). The Maestrichtian age assumed for Cores 19 and 20 conflicts with a Campanian age based on calcareous nannofossils from these same cores (Bukry, this volume). Although a Campanian age for these species is possible, such an extension at Site 355 would be

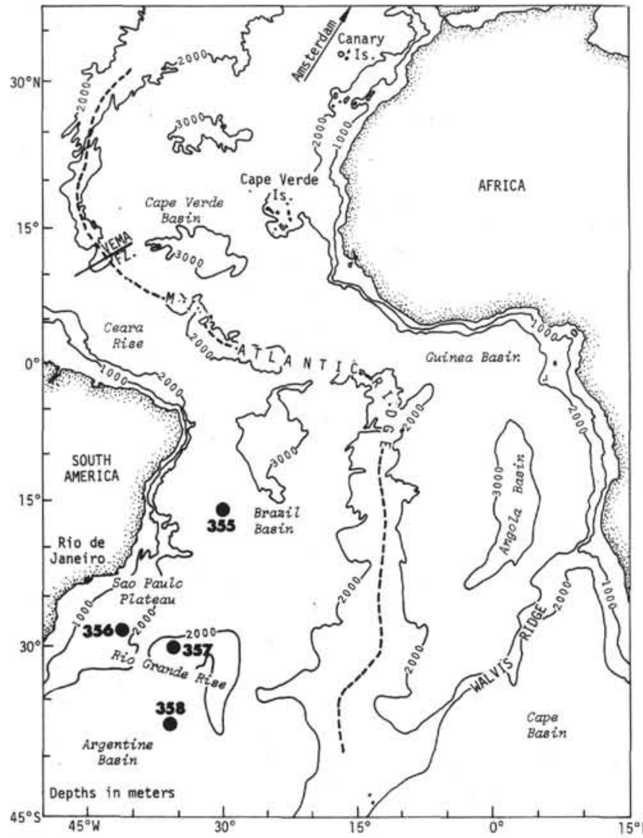

Figure 1. *Location of DSDP Leg 39 Sites 355 to 358.*

surprising, in light of their Maestrichtian range at the adjacent sites of Leg 39 (see below).

Site 356

Site 356 is on the southeastern edge of the São Paulo Plateau, at a water depth of 3175 meters. The nine samples examined from Hole 356 range in age from Albian to Maestrichtian (Figures 4, 5). Core 42 is primarily calcareous mudstone, with a characteristic Albian benthic foraminiferal assemblage that includes such species as *Gavelinella intermedia*, *Lenticulina gaultina*, *Pleurostomella obtusa*, *Saracenaria bononiensis*, and *Tritaxia gaultina*. Section 39-5, from an interval of clay-pebble conglomerate, contains no benthic foraminifers and only rare fragments of planktonic foraminifers.

Cores 35 and 37, dolomitic marly calcareous chalk, contain a Santonian assemblage characterized by *Globorotalites multiseptus*, *Gyroidinoides praeglobosus*, *Osangularia whitei*, and *Pleurostomella austinana*. No assemblage of unequivocally Coniacian age was recovered. The marly calcareous chalk of Core 34 is Campanian in age, based on the occurrence of species such as *Gavelinella nacatochensis*, *Globorotalites spineus*, *Gyroidinoides globosus*, and *Osangularia cordieriana*. Cores 29 to 32, consisting of nannofossil chalk ranging downward to marly calcareous chalk, are Maestrichtian in age, as evidenced by *Gaudryina pyramidata*, *Gavelinella velascoensis*, *Pullenia coryelli*, and *P. minuta*, among others.

Site 357

Site 357, on the northern flank of the Rio Grande Rise, lies at a water depth of 2086 meters. The nine samples examined range in age from Santonian to Maestrichtian. Section 50-4, from dark greenish-gray marly limestone, contains no foraminifers. In contrast, the medium-grained gray marly chalk and marly limestone of Cores 47 and 48 contain a poorly preserved and fragmented benthic foraminiferal fauna of at least Santonian age, based on *Gavelinella whitei*, *Globorotalites multiseptus*, *Gyroidinoides praeglobosus*, *Osangularia whitei*, *Pseudospiroplectinata compressiuscula*, and *Valvulineria lenticula*, among others (Figures 6, 7). *Pseudospiroplectinata compressiuscula*, described from Santonian strata of Australia (Chapman, 1917; Belford, 1960), and characteristic of a Santonian to Campanian age range in Germany (Klasz, 1953) and Czechoslovakia (Salaj and Samuel, 1966; Hanzlíková, 1972), ranges into the Coniacian of the Manin Group of Czechoslovakia (Salaj and Samuel, 1966) and older strata in the Donets Basin of the USSR (Gorbenko, 1960). Also contributing to the Santonian affinities of these cores is the common occurrence of *Gavelinella whitei*, which ranges from the Santonian to the Maestrichtian in North America (White, 1928; Martin, 1964; Sliter, 1968), and from the Campanian to the Maestrichtian of Czechoslovakia (Hanzlíková, 1972).

The greenish-gray marly limestone of Cores 42 and 44, unlike that of the lower cores, is definitely of Santonian age, based on *Bolivinoides strigillatus* associated with *Gaudryina austinana*, *Globorotalites spineus*, and *Pleurostomella austinana*.

Core 40 is olive-gray calcareous chalk with a Campanian benthic fauna characterized by the first appearances of several indicator species, such as *Coryphostoma plaitum*, *Gyroidinoides quadratus*, *Nuttallinella florealis*, *Osangularia cordieriana*, and *Reussella szajnochae*, among others. The brown foraminiferal nannofossil chalk of Core 36 also belongs in the Campanian, as the continued occurrence of many indicator species from Core 40 and the first appearances of *Gavelinella velascoensis* and *Pullenia coryelli* indicate. This sample contains only very rare and fragmented planktonic foraminifers and a benthic assemblage of reduced diversity and fewer individuals.

Maestrichtian sediments in Cores 32 and 33 are light brown nannofossil chalks. The benthic assemblage includes the first occurrences of several Maestrichtian species, such as *Aragonia ouezzaensis*, *A. velascoensis*, *Bolivinoides australis*, *B. sidestrandensis*, and *Pullenia minuta*; several Campanian-to-Maestrichtian species common to the underlying samples persist.

Site 358

Coring at Site 358 in the Argentine Basin (water depth 4962 m) recovered 5.2 meters of Cretaceous sediments. In the two samples examined, from dark reddish-brown ferruginous mudstone and from blue-gray mudstone and marly chalk, no planktonic foraminifers occur. Benthic foraminifers are only moderately well preserved, and specimens are corroded

Age		Sample (Interval in cm)	*Dorothia bulletta*	*Gavelinella cayeuxi mangshlakensis*	*G. whitei*	*Globorotalites conicus*	*Gyroidinoides beisseli*	*Osangularia cordieriana*	*Rhabdammina discreta*	*Spiroplectammina dentata*	*Tritaxia aspera*	*Aragonia ouezzaensis*	*Ellipsoglandulina obesa*	*Glomospira corona*	*G. gordialis*	*Gyroidinoides nitidus*	*Paratrochamminoides ? intricatus*	*Reussella szajnochae*	*Spiroplectammina sigmoidina*	*Dorothia oxycona*	*Gyroidinoides lunata*	*Gavelinella* sp.	*Praebulimina reussi*	*Pullenia cretacea*	*Ammodiscus glabratus*	*Gaudryina pyramidata*
Cretaceous	Maestrichtian	17-5, 58-60	2	5	3	14	11	13	1	18	14		2		1	3			4				3	1		
Cretaceous	Maestrichtian	18-3, 120-122	6	7	3	11	27	14	9	17	12	80	2	11			11	3	2							
Cretaceous	Maestrichtian or Camp.?	19-3, 120-122	12	17	3	8	6	26	3	14	4	41		2	2	2	1	5		1	11	4				
Cretaceous	Maestrichtian or Camp.?	20-2, 100-102	10	17	4	14	11	44	9	14	13	35	4	1	1	8	2	11	3	1	6	3	3	1	1	1

Sample (Interval in cm)	*Lituotuba lituoformis*	*Marginulina bullata*	*M. curvatura*	*Oolina apiculata*	*Reusella* cf. *R. pseudospinulosa*	*Lenticulina muensteri*	*Saccammina complanata*	*Spiroplectammina semicomplanata*	*Ellipsoidella kugleri*	*Globorotalites spineus*	*Gyroidinoides globosus*	*Praebulimina cushmani*	*Ammodiscus cretaceus*	*Cribrostomoides cretaceus*	*Fissurina orbignyana*	*Alabamina dorsoplana*	*Arenobulimina preslii*	*Gyroidinoides depressus*	*Lagena apiculata*	*Pleurostomella subnodosa*	*Pullenia coryelli*	*Oolina delicata*	*Recurvoides globulosus*
17-5, 58-60						2			2	4	1	1				1	2	1	1	1	1	1	2
18-3, 120-122						5			1	1	10	1	4	1	2								
19-3, 120-122						4	1	1															
20-2, 100-102	2	1	2	2	1																		

Figure 2. *Distribution of Cretaceous benthic foraminifers at Site 355. Numbers represent specimens counted.*

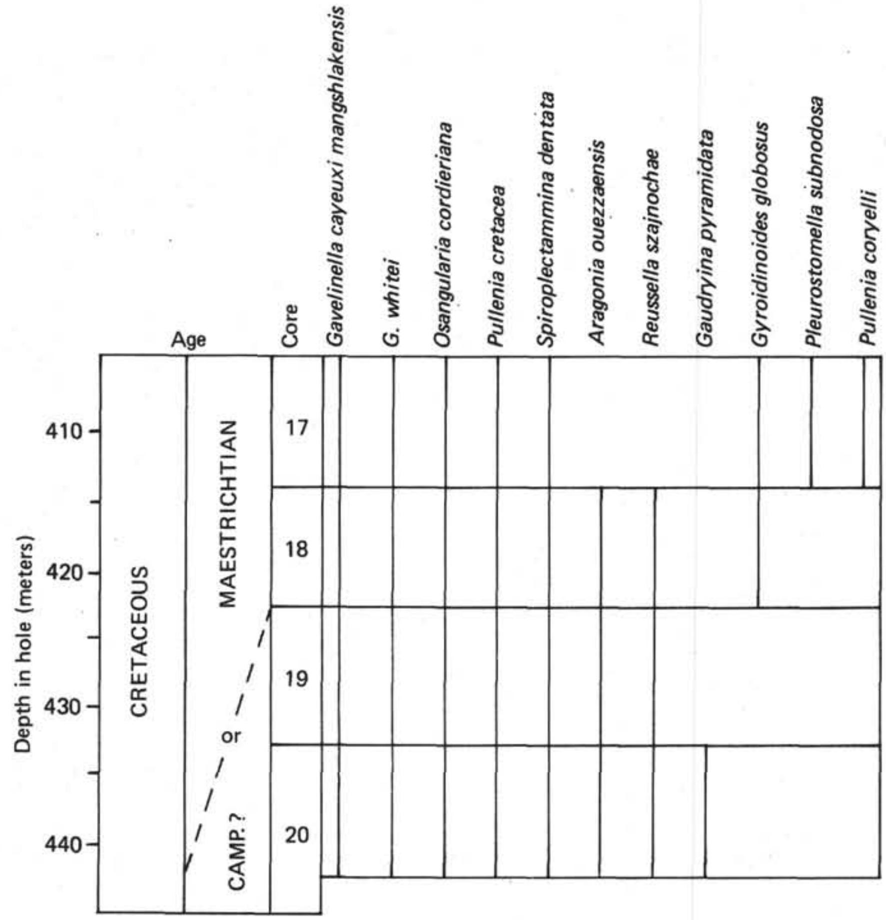

Figure 3. *Distribution of selected benthic indicator species at Site 355.*

and fragmented. The total assemblage in both Cores 15 and 16 is much less diverse, but several species remain quite plentiful (Figure 8). Both samples are placed in the Maestrichtian, on the basis of the assemblage that includes *Aragonia ouezzaensis*, *Gavelinella cayeuxi mangshlakensis*, and *Pullenia minuta*.

CORRELATION

Figure 9 shows the correlation of the Cretaceous cores examined from Leg 39. Correlation of Maestrichtian sediments from the four sites relies on similar occurrences and stratigraphic ranges of selected

Age		Sample (Interval in cm)	*Dorothia oxycona*	*Quadrimorphina allomorphinoides*	*Dentalina cylindroides*	*Astacolus bradyiana*	*Ammodiscus cretaceus*	*Dentalina communis*	*Fissurina oblonga*	*Frondicularia* cf. *F. ungeri*	*Gaudryina cushmani*	*Gavelinella intermedia*	*G.* cf. *G. tormarpensis*	*Gyroidinoides infracretacea*	*Lenticulina gaultina*	*Marginulina inaequalis*	*Pleurostomella obtusa*	*P. reussi*	*Pseudonodosaria mutabilis*	*P. humilis*	*Spiroplectammina nuda*	*Saracenaria bononiensis*	*Textularia losangica*	*Tribrachia excavata*	*Tritaxia gaultina*	*T. aspera*	*Dentalina gracilis*	*Globulina subsphaerica*	*Praebulimina reussi*	*Lenticulina muensteri*	*Conorboides* cf. *C. scania*	*Hyperammina elongata*	*Praebulimina carseyae*	*Ramulina pseudoaculeata*	*Spiroplectammina semicomplanata*	*Ellipsoidella binaria*	*Gavelinella sandidgei*	*Osangularia whitei*	*Pleurostomella subnodosa*	*Dorothia bulletta*	*Ellipsoglandulina* cf. *E. exponens*	*Frondicularia tetragona*	*Lenticulina ovalis*	*Nodosaria aspera*	*Pleurostomella austinana*	*P.* sp.	*Ramulina aculeata*	*Saracenaria navicula*	*Spiroplectammina praelonga*	*Gavelinella whitei*	*Pyrulina apiculata*	*Reussella pseudospinulosa*	*Gyroidinoides depressus*
Cretaceous	Maestrichtian	29-5, 102-104	1																								2	1	3			2			2															12			3
Cretaceous	Maestrichtian	30-5, 100-102	2																							10	1	1	2	4	2								1											3		12	
Cretaceous	Maestrichtian	31-5, 101-103																								3		1																						3	1		
Cretaceous	Maestrichtian	32-5, 101-103	2	1																						9	3		4	6			2	1					1											1	3	5	
Cretaceous	Camp.	34-5, 102-104	1																							1		1	4	2	1		2		1															2	1	3	1
Cretaceous	Santonian	35-5, 100-102	1																							1	2					6		1		1	2	1												2	1	1	2
Cretaceous	Santonian	37-5, 97-99	1	7	1																					9	1	1	1	1	2	10	1	3	1	11	2	18	1	1	1	2	2	1	1	1	7	2	1				
Cretaceous	Albian	42-5, 100-102	8	1	2	1	1	2	3	1	9	18	2	13	6	2	5	3	2	2	1	1	14	3	11																												

Figure 4. *Distribution of Cretaceous benthic foraminifers at Site 356. Numbers represent specimens counted.*

Age		Sample (Interval in cm)	*G. nitidus*	*Praebulimina cushmani*	*Pullenia cretacea*	*Ellipsoglandulina obesa*	*Globulina lacrima*	*Lagena paucicosta*	*Bandyella greatvalleyensis*	*Globorotalites multiseptus*	*Gyrodinoides praeglobosus*	miliolid	*Pyrulina cylindroides*	*Saccammina complanata*	*Globorotalites conicus*	*Osangularia cordieriana*	*Dentalina basiplanata*	*Gavelinella nacatochensis*	*Bolivina decurrens*
Cretaceous	Maestrichtian	29-5, 102-104					1	1							4	7	4		1
Cretaceous	Maestrichtian	30-5, 100-102	5	4											10	4	2	6	1
Cretaceous	Maestrichtian	31-5, 100-103													1	5		3	
Cretaceous	Maestrichtian	32-5, 100-103	2		3	1	3								1	15	1	1	
Cretaceous	Camp.	34-5, 102-104		4	2										1	7	2	1	1
Cretaceous	Santonian	35-5, 100-102	3	2	1	2	1	1	1	8	3	1	1	1					
Cretaceous	Santonian	37-5, 97-99																	
Cretaceous	Albian	42-5, 100-102																	

Age		Sample (Interval in cm)	*Ellipsoidella divergens*	*Gavelinella stephensoni*	*Allomorphina cretacea*	*Gyroidinoides beisseli*	*G. globosus*	*Reussella szajnochae*	*Fissurina* sp.	*Globorotalites spineus*	*Stensioeina pommerana*	*Pullenia minuta*	*P. coryelli*	*Allomorphina trochoides*	*Fissurina orbignyana*	*Astacolus jarvisi*	*Fissurina alata*	*Gyroidinoides quadratus*	*Lingulina pygmaea*
Cretaceous	Maestrichtian	29-5, 102-104	2	1								2	1	3	2				
Cretaceous	Maestrichtian	30-5, 100-102		2				2				2							
Cretaceous	Maestrichtian	31-5, 100-103										1	1						
Cretaceous	Maestrichtian	32-5, 100-103	2		2	5	5					1	1	2	1	1	3	5	1
Cretaceous	Camp.	34-5, 102-104	1	3	2	2	5	1	1	3	1								
Cretaceous	Santonian	35-5, 100-102																	
Cretaceous	Santonian	37-5, 97-99																	
Cretaceous	Albian	42-5, 100-102																	

Age		Sample (Interval in cm)	*Nonionella robusta*	*Praebulimina spinata*	*Thalmannammina subturbinata*	*Serovaina orbicella*	*Dentalina velascoensis*	*Lingulina* aff. *L. taylorana*	*Lenticulina acuta*	*Globorotalites michelinianus*	*Heterolepa* cf. *H. sparksi*	*Lagena acuticosta*	*Nodosaria aspera*	*Dentalina legumen*	*Ellipsoidella subnodosa*	*Gaudryina laevigata*	*G. pyramidata*	*Gavelinella velascoensis*	*Marginulina* cf. *M. curvatura*
Cretaceous	Maestrichtian	29-5, 102-104				1			1					1	1	1	2	1	1
Cretaceous	Maestrichtian	30-5, 100-102				2	1		1	1	2	1	1						
Cretaceous	Maestrichtian	31-5, 100-103				2	1	1											
Cretaceous	Maestrichtian	32-5, 100-103	1	1	2														
Cretaceous	Camp.	34-5, 102-104																	
Cretaceous	Santonian	35-5, 100-102																	
Cretaceous	Santonian	37-5, 97-99																	
Cretaceous	Albian	42-5, 100-102																	

Figure 4. *(Continued).*

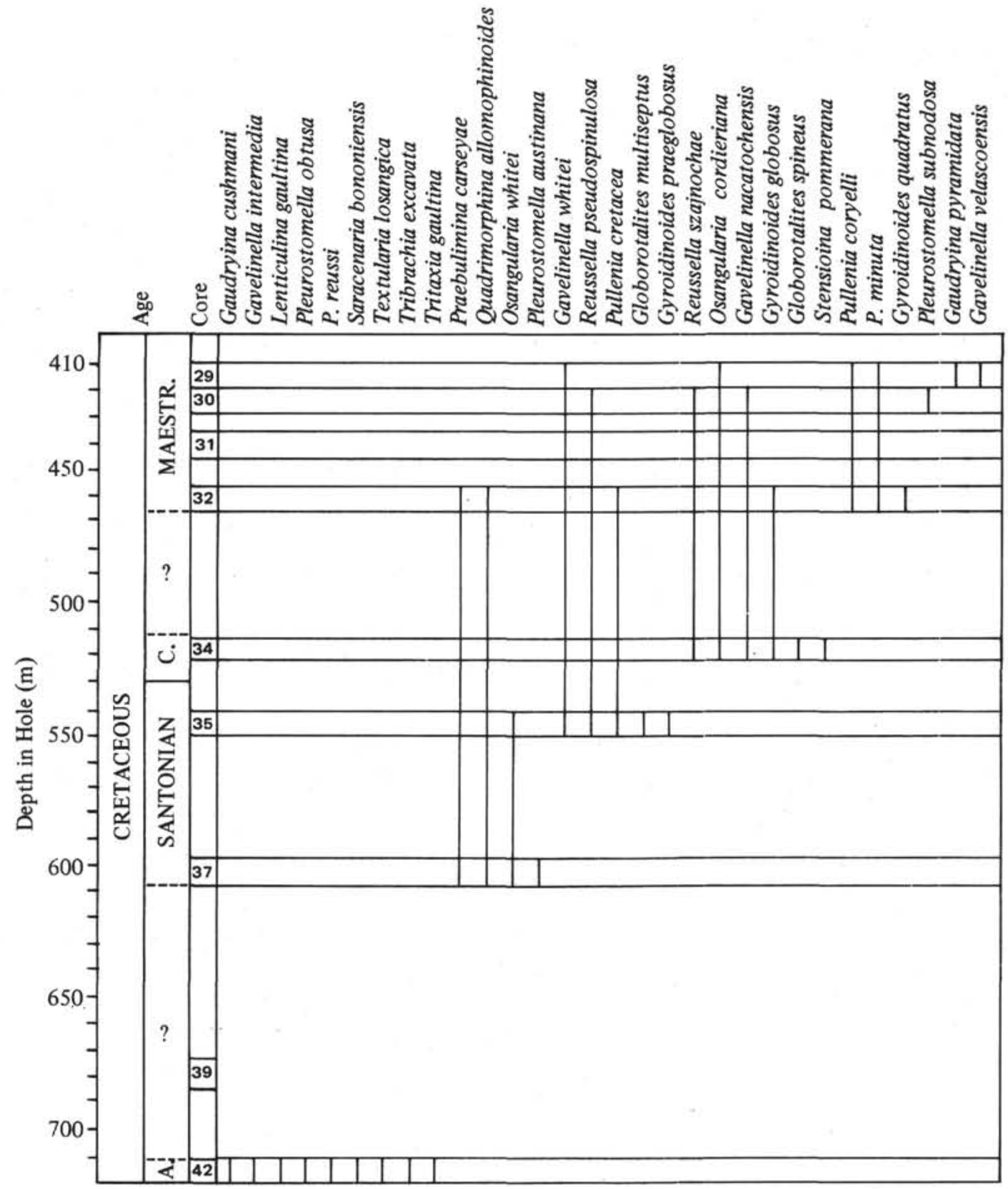

Figure 5. *Distribution of selected benthic indicator species at Site 356.*

benthic indicator species. The same is true of the correlation between Campanian and Santonian assemblages of Sites 356 and 357. The Santonian or possibly Coniacian assemblages in Cores 47 and 48 of Site 357 do not appear in the samples from Site 356. The barren interval represented by Core 50 of Site 357 is analogous to Core 39 of Site 356. And finally, the Albian calcareous mudstones in Core 42 of Site 356 are the oldest sediments cored during Leg 39.

PALEOECOLOGY

Interpretation of depositional environments represented by Leg 39 Cretaceous sediments relies primarily on the taxonomic composition of benthic foraminiferal assemblages and the relative abundance of associated fossils (Sliter and Baker, 1972; Sliter, in press). In addition, preservation and fragmentation of foraminifers, along with lithology, aid in determination of the lysocline, the carbonate compensation depth (CCD), and the presence of an oxygen-minimum zone, and provide possible evidence of transported and mixed foraminiferal assemblages and post-depositional changes. The goal is recognition of any of these factors and any others indicating that chemical or mechanical processes may have selectively removed or enriched foraminiferal species, thereby affecting paleoecologic and biostratigraphic interpretation of the foraminifer assemblages.

The lysocline is the ocean depth at which rapid solution of calcium carbonate begins. As used here, the term refers to a level or zone based on the solution of less-resistant foraminifers. The CCD denotes the transition from deep-sea calcareous to noncalcareous sediment at a specific site. Again, this concept is largely defined by the character of the foraminiferal assemblages. The carbonate compensation surface (CCS) is

Age	Sample (Interval in cm)	*Gavelinella whitei*	*Lenticulina muensteri*	*Praebulimina reussi*	*Tritaxia aspera*	*Gyroidinoides nitidus*	*Dentalina gracilis*	*Dorothia bulletta*	*D. ellisorae*	*D. oxycona*	*Marginulina curvatura*	*Ellipsoidella gracillima*	*Ellipsodimorphina subtuberosa*	*Gavelinella eriksdalensis*	miliolid	*Quadrimorphina allomorphinoides*	*Allomorphina trochoides*	*Globorotalites multiseptus*	*Gyroidinoides praeglobosus*	*Osangularia whitei*	*Frondicularia mucronata*	*Nonionella austinana*	*Oolina delicata*	*Praebulimina carseyae*	*Pseudospiroplectinata compressiuscula*	*Ramulina aculeata*	*Saracenaria navicula*	*Tappanina selmensis*	*Valvulinaria lenticula*	*Pullenia cretacea*	*Lenticulina discrepans*	*Dentalina cylindroides*	*Gaudryina austinana*	*Astacolus richteri*	*Lagena ellipsoidalis*	*L. stavensis*	*Reussella pseudospinulosa*	*Bolivina* sp.	*Frondicularia* cf. *F. aclis*	*Marginulina hamuloides*	*Gyroidinoides depressus*	*Spiroplectammina sigmoidina*	*Astacolus liebusi*	*Lagena paucicosta*	*Ramulina pseudoaculeata*	*Dentalina solvata*	*Pleurostomella austinana*	*P.* sp.	*Bifarina hispidula*	*Bolivinoides strigillatus*	*Ellipsoidella* sp.	*Nodosaria aspera*	*Lagena hispida*	*Pseudonodosaria manifesta*	*Dentalina basiplanata*	*Gyroidinoides beisseli*	*Pyrulina apiculata*	*Ellipsoglandulina obesa*
Cretaceous, Maestrichtian	32-4, 99-101	7	2	13	1	5	2				1			2		1														1											7														2	9		
Cretaceous, Maestrichtian	33-4, 100-102	14	1	1	1	3	2	1	6	1	1			1			1							1						5											1	1		1											3	9	2	
Cretaceous, Campanian	36-4, 100-102	2	1	18	1	1								8													1			2											2	3			1										1	9	1	4
Cretaceous, Campanian	40-4, 100-102	4	1	19	10	3		1	4	4	1	2	2	5	5	4	3				1					1	3			1	5	1		1							8	3	6	1	1			1							2	19	2	1
Cretaceous, Santonian	42-4, 100-102	6	17	2	5		3	5	6	7		2	1		7	5		5	3	2			2			2	4	2			3	2	5	1			6				2	2	3			2	2								2	7	2	1
Cretaceous, Santonian	44-4, 100-102	19	10	13	9	16	5	6	10	6	2	4	1		1	15		12	6	10	1	1			1			1		10	3		13	1	3	2					3	2	1	1	1	1	2	2	1	15	2	1	1	1				
Cretaceous, or Coniac.?	47-4, 100-102	19	3	12	10	8	1	3	5	4	1	2	2		3	5	8	15	11	6		2	2	2	1		1		8	4	1	1	1	4	2	1	1	1	1	3																		
Cretaceous, or Coniac.?	48-4, 100-102	11	6	3	3	10	1	2	5	1	2	5	2	10	1	2	1	3	11	15	1	1	3	2	1	1	3	1	1																													

Figure 6. *Distribution of Cretaceous benthic foraminifers at Site 357. Numbers represent specimens counted.*

Age		Sample (Interval in cm)	*Fissurina orbignyiana*	*Globulina subsphaerica*	*Gaudryina frankei*	*Bandyella greatvalleyensis*	*Dentalina pertinens*	*Ellipsoidella kugleri*	*Frondicularia linearis*	*Globorotalites spineus*	*Osangularia cordieriana*	*Gyroidinoides globosus*	*Nuttallinella florealis*	*Coryphostoma plaitum*	*Dentalina legumen*	*Loxostomum eleyi*	*Marginulinopsis texasensis*	*Pleurostomella subnodosa*	*Pseudonodosaria obesa*	*Reussella szajnochae*	*Fissurina bicornis*	*Frondicularia frankei*	*F. lomaensis*	*Gaudryina laevigata*	*Gyroidinoides quadratus*	*Marginulina juncea*	*Saracenaria triangularis*	*Gavelinella velascoensis*	*Ellipsopdymorphina velascoensis*	*Ellipsoidella elongata*	*Globorotalites tappanae*	*Lenticulina revoluta*	*Pullenia coryelli*	*Conorboides* cf. *C. scanica*	*Globulina lacrima*	*Hyperammina elongata*	*Saccammina complanata*	*Bolivinoides australis*	*Globorotalites michelinianus*	*Pullenia minuta*	*Stilostomella pseudoscripta*	*Aragonia ouezzaensis*	*A. velascoensis*	*Astacolus jarvisi*	*Gavelinella cayenxi mangshlakensis*	*Gyroidinoides lunata*	*Lingulina pygmaea*	*Marginulina armta*	*Oolina apiculata*	*Ramulina arkadelphiana*	*Bolivina incrassata*	*Bolivinoides sidestrandensis*	*Dentalina velascoensis*	*Globulina prisca*	*Gyroidina* cf. *G. nonionoides*	*Osangularia velascoensis*	*Praebulimina cushmani*	*P. taylorensis*	*Quadrimorphina camerata*
Cretaceous	Maestrichtian	32-4, 99-101	1	2							12		1	1		1												7		1	1		2					2	1	2	1										4	3	2	1	1	1	10	1	2
		33-4, 100-102	1								16	1	5				1											5	1			3						5	4	1	2	1	7	2	2	6	1	1	1	1	1								
	Campanian	36-4, 100-102									5	7			2			1	1	4								2	1	2	2	1	1	2	1	1	1																						
		40-4, 100-102			1						17	4	3	1	2	2	2	1	1	1	1	1	1	1	2	1	2																																
	Santonian	42-4, 100-102	3	1	3	2	1	1	1	1																																																	
		44-4, 100-102																																																									
	Coniac.? or	47-4, 100-102																																																									
		48-4, 100-102																																																									

Figure 6. *(Continued).*

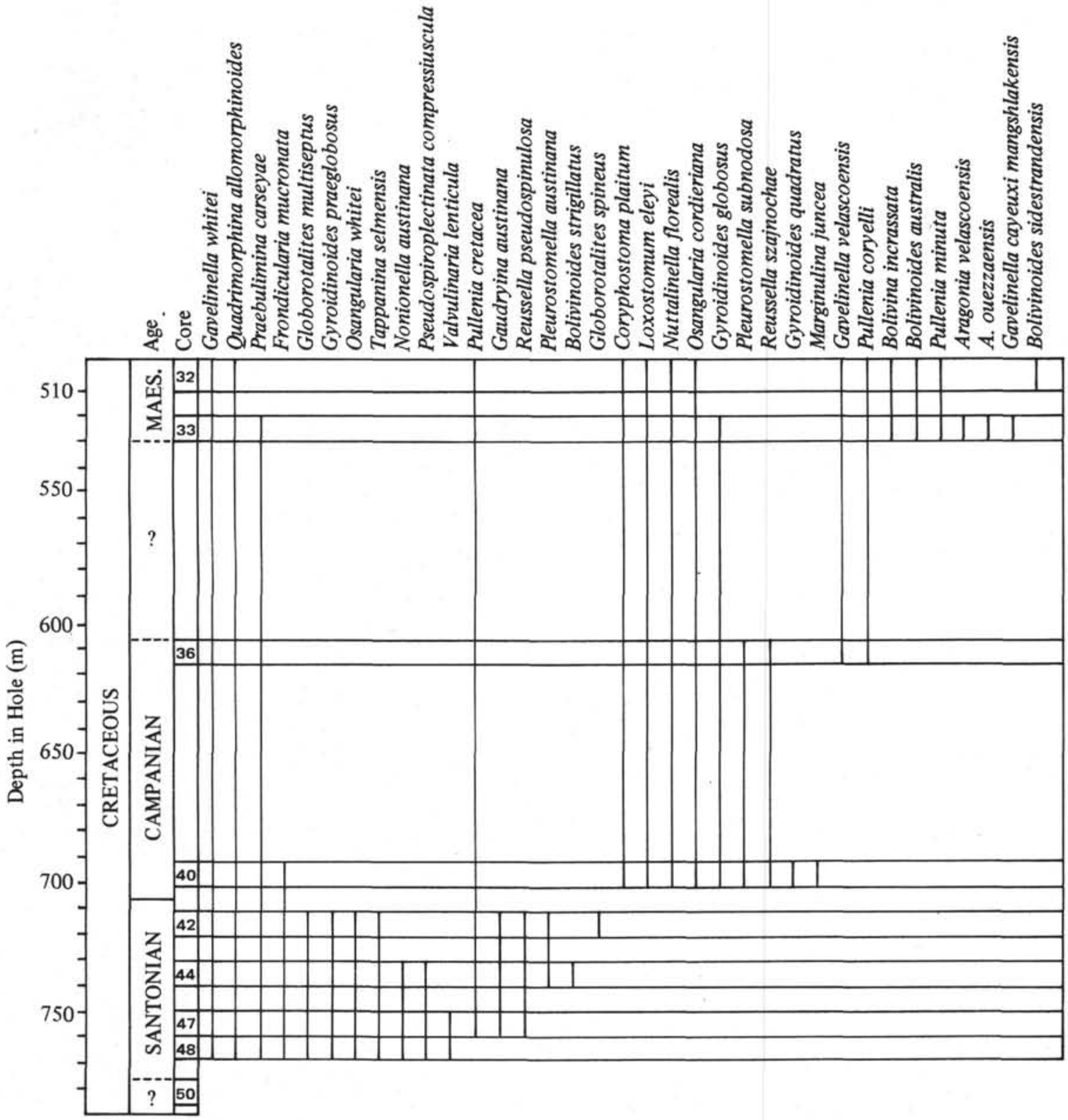

Figure 7. *Distribution of selected benthic indicator species at Site 357.*

Age		Sample (Interval in cm)	*Aragonia ouezzaensis*	*Ellipsopolymorphina velascoensis*	*Globorotalites conicus*	*Gyroidinoides beisseli*	*G. quadratus*	*Osangularia cordieriana*	*Pullenia minuta*	*Ammodiscus cretaceus*	*Astacolus* cf. *A. jarvisi*	*Dentalina velascoensis*	*Dorothia bulletta*	*Ellipsoglandulina concinna*	*E. obesa*	*Gavelinella cayeuxi mangshlakensis*	*G. whitei*	*Glomospira corona*	*Gyroidinoides depressus*	*G. globosus*	*G. nitidus*	*Lenticulina muensteri*	*L. velascoensis*	*Marginulinopsis texasensis*	*Nuttallinella florealis*	*Praebulimina reussi*	*Reussella szajnochae*	*Tritaxia aspera*	*Alabamina dorsoplana*
Cretaceous	Maestrichtian	15-2, 102-104	1	1	3	2	4	11	1																				2
		16-2, 92-94	4	2	2	14	2	15	1	1	1	2	1	5	3	3	8	1	2	7	1	2	1	1	1	1	1	1	

Figure 8. *Distribution of Cretaceous benthic foraminifers at Site 358. Numbers represent specimens counted.*

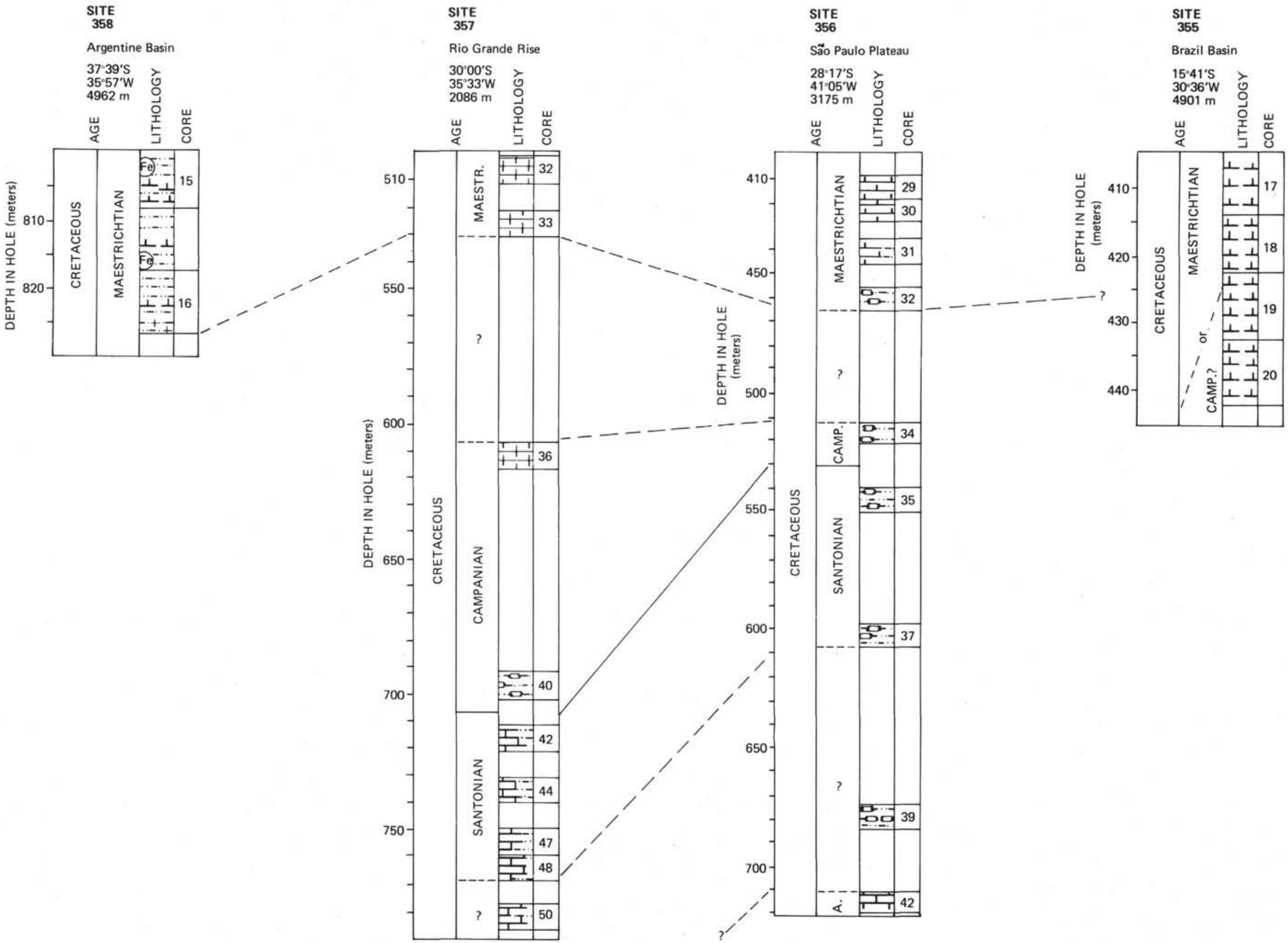

Figure 9. *Stratigraphic correlation of selected Cretaceous cores from Leg 39, Sites 355 to 358. Vertical scale for Sites 355 and 358 is exaggerated for clarity. Lithology symbols follow standard DSDP usage.*

the surface defined by compensation depths within a geographic area.

Water depth ranges used in the following interpretations are:

neritic (0-200 m)
upper bathyal (200-500 m)
middle bathyal (500-1500 m)
lower bathyal (1500-2500 m)
abyssal (>2500 m)

Site 355

Benthic foraminifer assemblages from the upper Cretaceous samples of Site 355 are abyssal in character and suggest water depths of 3000 to 4000 meters. Benthic assemblages are dominated by genera such as *Aragonia*, *Gavelinella*, *Gyroidinoides*, *Osangularia*, and several agglutinated genera (Figure 2). Nodosariids and praebuliminids characteristic of bathyal and outer neritic water depths are notably lacking, whereas agglutinated genera and solution-resistant species, such as the thicker walled members of the Cassidulinacea, increase in numbers. Several deep-water genera occur (Figure 10), such as *Cribrostomoides*, *Glomospira*, *Lituotuba*, *Paratrochamminoides* (?), *Recurvoides*, and *Rhabdammina*. Planktonic species occur as scarce fragments, and the benthic species are corroded and fragmented. Associated fossils in all samples are infrequent and occur only as corroded *Inoceramus* prisms and fragments and fish debris.

The foraminiferal assemblages from Site 355 imply water depths beneath the lysocline but above the CCD. Evidence from Leg 36 in the South Atlantic indicates that the carbonate compensation surface (CCS) in the Southern Hemisphere during the late Cretaceous ranged between 3000 and 4000 meters (Sliter, in press). The present depth estimate for Site 355 environments, interpreted to have been beneath the lysocline but above the CCD, would fall within that range.

Site 356

Benthic foraminiferal assemblages from Hole 356 are generally more diverse and better preserved than those from Hole 355. Depositional environments for samples containing foraminifers were above the foraminiferal lysocline, and ranged from middle to lower bathyal water depths.

The Albian benthic foraminiferal assemblage from Hole 356 (Core 42) indicates middle bathyal water depths (500-1500 m). Gavelinellids, gyroidinoidids, and agglutinated genera dominate; nodosariids represent approximately 48% of the assemblage (Figures 4 and 11). The poor preservation of this sample can be attributed largely to post-depositional alteration.

Planktonic species are abundant but poorly preserved; associated fossils comprise common *Inoceramus* prisms, scarce ostracodes, fish debris, and common echinoid spines and fragments. Fragmented, elongate nodosariids and the composition and preservation of associated calcareous fossils suggest admixtures of neritic elements. The terrigenous nature of the calcareous mudstone and the coarse sand-sized graded layers within this sequence support an interpretation that includes such displaced forms.

Benthic foraminifers from the Santonian interval (Cores 35 and 37) suggest lower bathyal water depths (1500-2500 m). *Ellipsoidella*, *Globorotalites*, *Hyperammina*, *Osangularia*, and *Tritaxia* dominate, and several species of *Gavelinella* and *Gyroidinoides* also

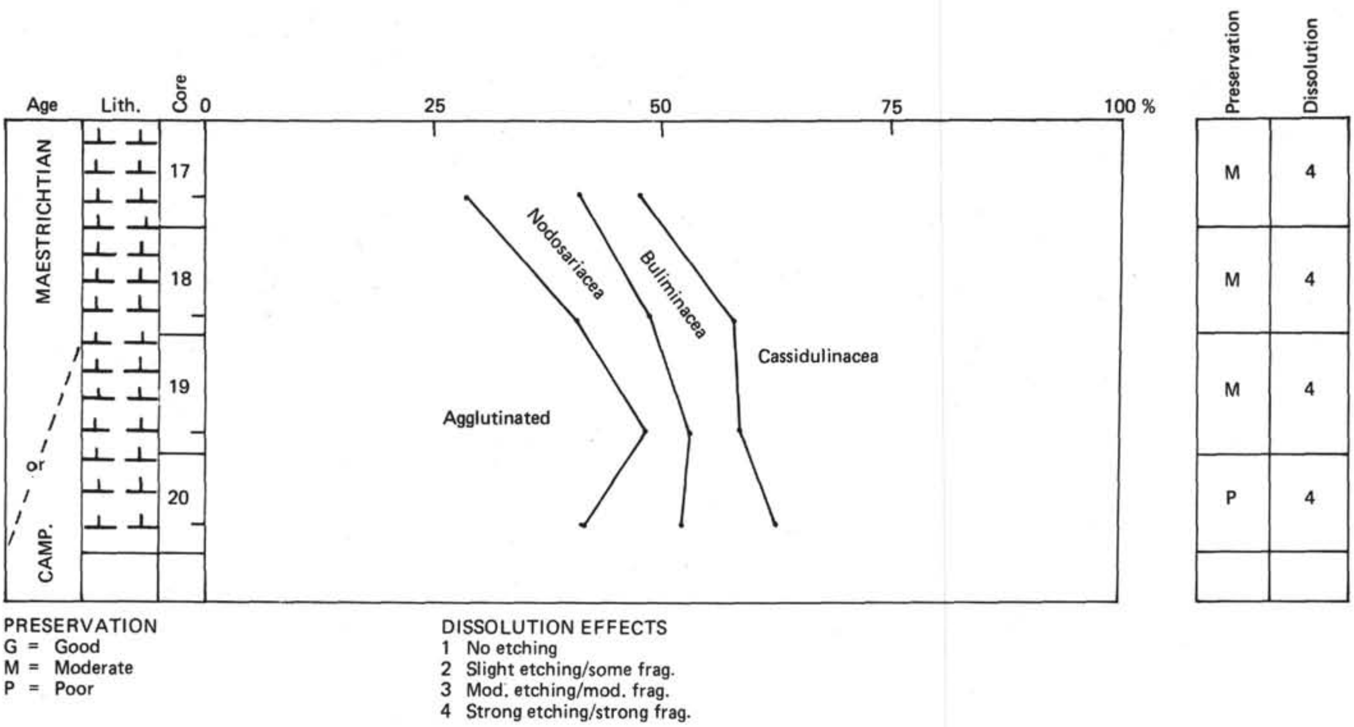

Figure 10. *Comparison of benthic foraminiferal groups (cumulative percent) and preservation at Site 355.*

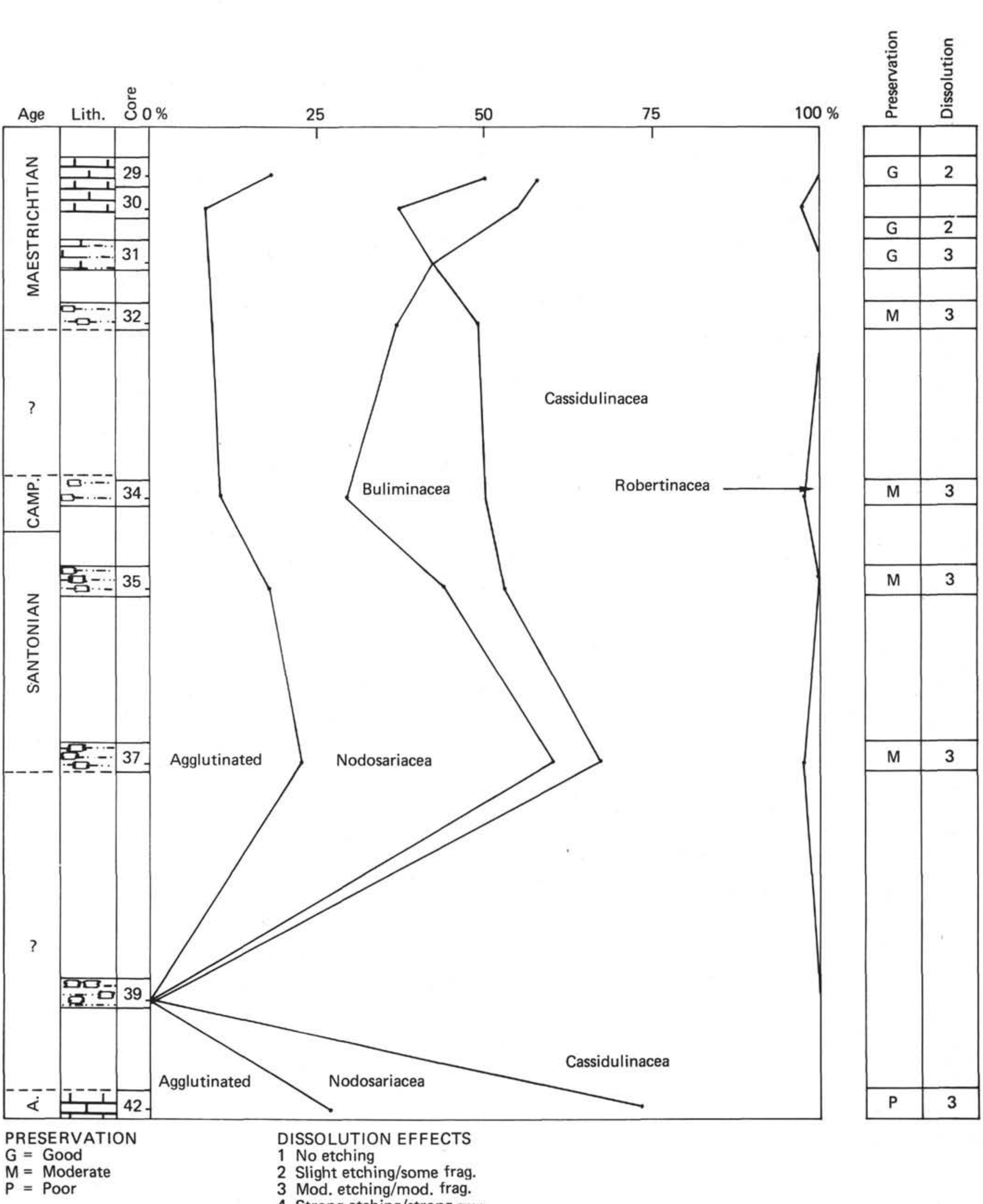

Figure 11. *Comparison of benthic foraminiferal groups (cumulative percent) and preservation at Site 356.*

occur. Nodosariids represent 26% to 37% of the faunas. Agglutinated species make up 17% or more of the assemblages, and members of the Buliminacea make their first appearance (Figure 11). Associated fossils are scarce and comprise *Inoceramus* prisms and fish debris. Fragmented nodosariids, a worn miliolid, a fistulose polymorphinid, *Inoceramus* prisms, and rare glauconite grains offer evidence of downslope transport.

The Campanian assemblage (Core 34) most closely resembles those of the Santonian interval in numbers of individuals, species diversity, and generic composition. Water depths again seem to have been in the lower bathyal range, as suggested by a fauna in which *Globorotalites*, *Gyroidinoides*, and *Osangularia* dominate, with *Allomorphina* and *Pullenia* and several gavelinellids also present. Planktonic species remain abundant and moderately well preserved. Nevertheless, a faunal change is evident in the disappearances of *Hyperammina* and *Pleurostomella*, a reduction of agglutinated species, and an increase in praebuliminids. A marked increase in *Inoceramus* prisms and fragments accompanies this change.

Several hypotheses would explain the faunal variation. First, it could be explained by a reduction in water depth. This seems unlikely, since the dominant benthic fauna remains unchanged. Second, gravity-controlled bottom currents could have brought about the changes. Following this interpretation, the indigenous lower bathyal faunas would have been flooded by transported *Inoceramus* debris and upslope foraminifers such as the typically shallower slope praebuliminids and specimens of *Conorboides*, *Globulina*, and *Stensioina*. The effects of dilution on the already rare deep-water benthic fauna would have accompanied this influx. This explanation is quite plausible, judged by the terrigenous component of the marly chalks and the occasional coarse-graded layers in this sequence.

A third hypothesis, with effects independent of or allied with gravity currents, supposes a depth just below an oxygen-minimum layer. This hypothesis is based on certain similarities between the Core 34 assemblage and an assemblage from a presumed late Cretaceous oxygen-minimum environment in California that lay at about 1000 meters water depth (Sliter, 1975). An increase in praebuliminids and a reduction of *Hyperammina* and *Pleurostomella* characterize faunas in both cases. The Core 34 assemblage, however, differs notably in other faunal constituents and in the abundance of planktonic species. The marly bioturbated sediments clearly were not deposited within a strongly developed oxygen-minimum layer. But they may have been adjacent to such a layer, or a weakly developed layer, in which case the association or gravity currents flowing through the oxygen-minimum layer could have altered the fauna.

The Maestrichtian samples (Cores 29-32) indicate lower bathyal water depths of 2000 to 2500 meters. The benthic fauna contains dominant *Gavelinella*, *Globorotalites*, *Osangularia*, *Reussella*, and *Tritaxia*, as well as *Allomorphina*, *Ellipsoidella*, *Gyroidinoides*, *Hyperammina*, *Pleurostomella*, *Praebulimina*, *Pullenia*, and *Thalmannammina*. Diversity remains about the same, but numbers of individuals are generally smaller. Dissolution effects remain about the same as in the Campanian sample, with perhaps a slight increase in fragmentation and corrosion. Displaced benthic species include large, commonly fragmented nodosariids and worn, fistulose polymorphinids. Very rare echinoid spines and ostracodes and rare fish debris also occur.

Site 357

Compared with Site 356 samples, Site 357 samples contain a more diverse and somewhat better preserved benthic foraminifer fauna, and a greater abundance of associated fossils. Water depths ranged from middle to lower bathyal, and were somewhat shallower than those for Site 356. The increase in Nodosariacea, as shown in Figure 12, reflects these depths.

Santonian assemblages (Cores 42-48) appear to fall within the middle to lower bathyal range of 1000 to 1500 meters. Dominant in the faunas are *Gaudryina*, *Gavelinella*, *Globorotalites*, *Gyroidinoides*, *Osangularia*, *Pullenia*, *Quadrimorphina*, and *Tritaxia*. Agglutinated species represent about 18% of the fauna, nodosariids 26% to 40% (Figure 12). Planktonic foraminifers are abundant in these samples; foraminifer preservation ranges from poor to moderate. Associated fossils are varied and relatively abundant, and include common *Inoceramus* prisms and fragments, scarce to common bivalve fragments, common echinoid spines, and scarce ostracodes and fish debris. The abundance of associated fossils, in addition to worn miliolids, large fragmented nodosariids, and polymorphinids, provides ample evidence of gravity-controlled bottom flows and proximity to shelf and upper slope environments.

The Campanian benthic assemblages are characteristic of lower bathyal water depths, and probably fall within the upper reaches of the 1500 to 2500 meters range. The Core 40 fauna is dominated by *Gyroidinoides*, *Osangularia*, *Praebulimina*, and *Tritaxia*, with occurrences of *Allomorphina*, *Dorothia*, *Ellipsoidella*, *Gaudryina*, *Gavelinella*, *Nuttallinella*, *Pleurostomella*, *Pullenia*, and *Quadrimorphina*. Species diversity increases over the Santonian assemblages, but the number of specimens remains about the same. Planktonic species are abundant; associated fossils are scarce *Inoceramus* prisms, echinoid spines, fish debris, and very scarce ostracodes. A worn fistulose polymorphinid indicates downslope transport, as do the associated calcareous fossils and fragmented and worn nodosariids.

The Core 36 Campanian fauna records a marked environmental change that resulted in increased dissolution of carbonate. The benthic fauna is much less diverse, and planktonic specimens are absent. Preservation of foraminifers is poor and specimens are corroded and fragmented. The fauna is characterized by species of *Ellipsoglandulina*, *Gavelinella*, *Gyroidinoides*, *Osangularia*, *Praebulimina*, and *Reussella*, with lesser occurrences of *Ellipsoidella*, *Hyperammina*, *Pleurostomella*, *Pullenia*, and *Saccammina*. Several agglutinated species are absent or present in reduced numbers. Still, agglutinated species represent about 13% of the reduced fauna (Figure 12), and the Cassidulinacea increase to 48%. Only very scarce fish debris represents associated fossils. The foraminiferal assemblage indicates lower bathyal water depths of 1500 to 2500 meters.

The abundance of praebuliminids and reduced diversity of agglutinated forms in Core 36 recall the Campanian fauna of Site 356, Core 34. Dissolution of

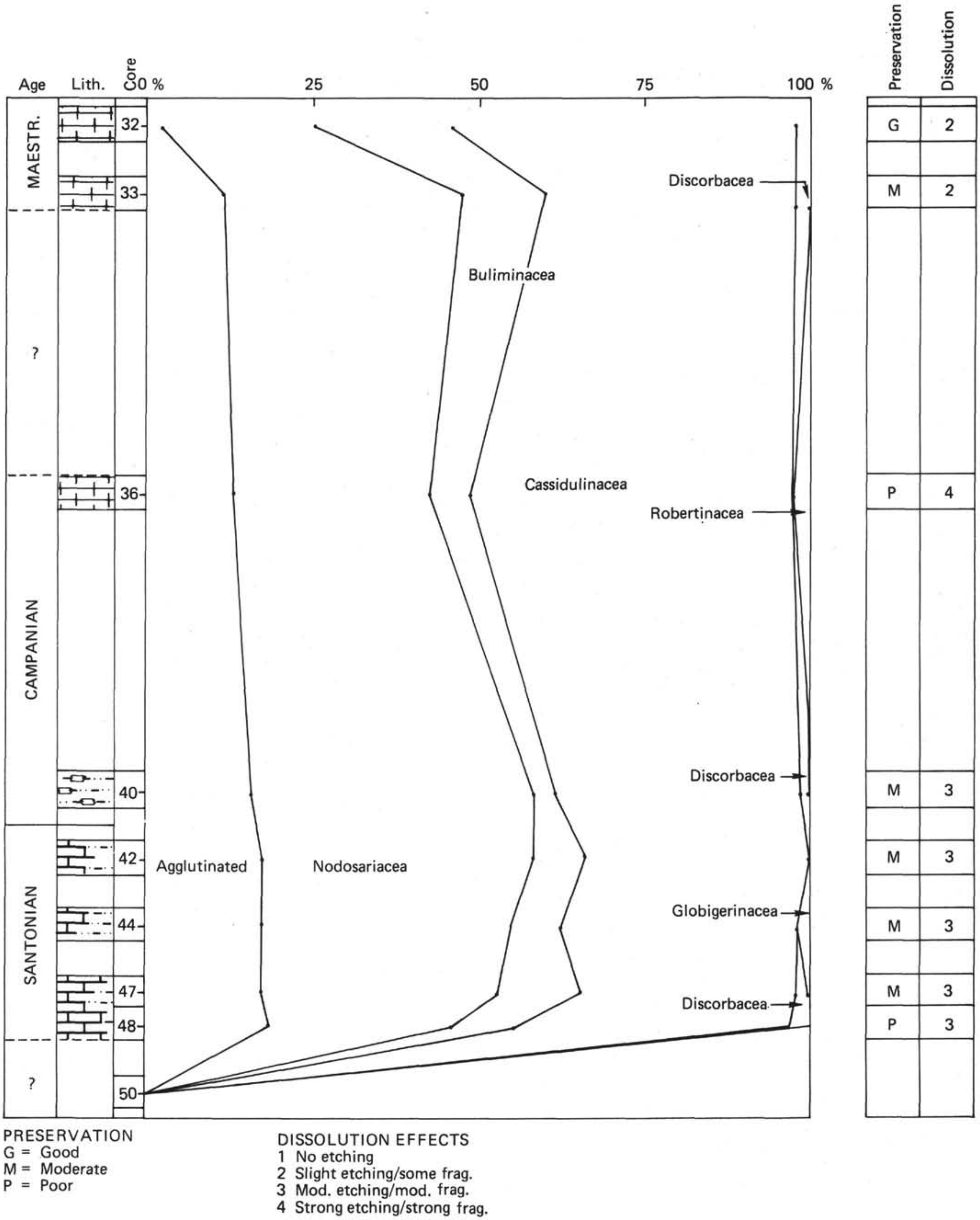

Figure 12. *Comparison of benthic foraminiferal groups (cumulative percent) and perservation at Site 357.*

the planktonic species and of selected members of the benthic fauna, however, clearly distinguishes Core 36. Several explanations are again possible. First, a fluctuation of the CCD may have produced the dissolution effects. This is unlikely, since the water depths inferred from the Campanian to Maestrichtian sequence would require a 1500 to 2500 meter rise and fall of the CCD at this locality. Second, an influx of corrosive bottom waters from the south, through the Rio Grande Gap into the Brazil Basin, as the rise continued to subside, may have produced the dissolution effects. Third, the faunal characteristics and dissolution effects again suggest an oxygen-minimum layer, as with Site 356, Core 34. This hypothesis is strengthened in Core 36 by the lack of planktonic species, by greenish-gray sedimentary layers intercalated with the brownish chalks, and by the preservation of some laminae despite extensive bioturbation—all of which implies reducing conditions. The similarities in the Campanian interval at Sites 356 and 357 indicate a regional event, at least within the Brazil Basin, not confined to the Rio Grande Rise. It is possible that an inflow of bottom water migrated under an oxygen-minimum layer within the Brazil Basin and caused it to rise during the Campanian.

Maestrichtian assemblages (Cores 32-33) resemble the Campanian fauna of Core 40. Foraminiferal species resume their former diversity, planktonic species are abundant, and preservation improves. Members of the Nodosariacea and Cassidulinacea remain dominant; agglutinated species increase in diversity and abundance in Core 33, only to decrease again in Core 32. The benthic assemblage in the Maestrichtian samples reflects lower bathyal water depths of 1500 to 2000 meters, probably somewhat shallower than coeval samples from Site 356. The assemblages are dominated by species of *Gavelinella*, *Gyroidinoides*, *Osangularia*, and *Praebulimina*, with occurrences of *Allomorphina*, *Aragonia*, *Ellipsoidella*, *Nuttallinella*, *Pullenia*, and *Quadrimorphina*. Associated fossils vary from scarce bivalve fragments in Core 33 to common echinoid spines, rare ostracodes, and worn bivalve fragments in Core 32. Worn, fragmented, large nodosariids, rare polymorphinids, and the associated fossils indicate gravity flows.

Site 358

Maestrichtian sediments from Site 358 (Cores 15 and 16) contain a poorly preserved, low-diversity benthic foraminiferal assemblage (Figure 8). Planktonic species are absent, associated organisms are limited to rare fish debris. Foraminifers in Core 16 are more diverse, and include chiefly *Aragonia*, *Ellipsoglandulina*, *Gavelinella*, *Gyroidinoides*, and *Osangularia*, with fewer specimens of *Ammodiscus*, *Glomospira*, *Nuttallinella*, and *Pullenia*. Agglutinated foraminifers and nodosariids are equally abundant, and the Cassidulinacea dominate the assemblage (Figure 13). Core 15 foraminifers comprise only seven species, with species of *Gyroidinoides* and *Osangularia* the most abundant. Interestingly, all seven species belong to the Cassidulinacea. The Maestrichtian samples from both Cores 15 and 16 appear to represent abyssal water conditions of 3500 to 4000 meters. The limited, corroded, and fragmented benthic fauna and the predominantly ferruginous mudstones of this sequence indicate a depth near the CCD.

PALEOECOLOGIC SUMMARY

Site 355 in the Brazil Basin and Site 358 in the Argentine Basin were of abyssal water depths throughout the late Cretaceous. Site 358 was deeper than Site 355, and close to the late Cretaceous CCD (perhaps 4000 m water depth). Foraminiferal faunas are of limited diversity, and specimens are more poorly preserved. The sediments are oxidized, ferruginous mudstones.

Site 355 faunas are better preserved and more diverse; the sediments are nannofossil ooze, with a minor terrigenous component. Planktonic species and less-resistant benthic species are absent, which indicates a water depth above the CCD but below the lysocline, or between 3000 and 4000 meters.

Holes 356 and 357 both record deepening environments that ranged from middle bathyal in the older sequences to lower bathyal in the Maestrichtian. Despite this parallelism, Site 357, throughout its late Cretaceous history, remained slightly shallower than Site 356, by perhaps 500 to 1000 meters. The difference is indicated primarily by the foraminifer content, diversity, and abundance, the abundance and diversity of associated organisms, and the lithology at each site.

Sediments at Sites 356 and 357 are generally bioturbated, except for some minor laminated intervals in the Campanian sequence of Hole 357 and the laminated marly limestone of Section 357-50-4, which contains no foraminifers. The laminae and occasional reduced sediments in the Campanian interval correspond to faunal characteristics, in both Cores 356-34 and 357-36, that suggest a Campanian oxygen-minimum layer, at least within the Brazil Basin. Confirmation of this oxygen-minimum layer at about 1000 to 1500 meters in other oceanic basins must await further studies and recognition of more specific faunal characteristics.

The Santonian, and to a lesser degree Campanian, sequences of Holes 356 and 357 show a decreasing terrigenous influence and contain persistent *Inoceramus* prisms and fragments. Much of the terrigenous material was derived from gravity-controlled bottom flows, as indicated by coarse graded layers, intervals of clay-pebble conglomerate (as in Core 356-39), coarse layers of rounded glauconite grains and *Inoceramus* prisms, rare glauconite grains throughout much of the sequence, and transported shallower water foraminifers, many of which are worn, fragmented, or size-sorted. The period of terrigenous influence corresponds to similar periods recognized at other DSDP sites, such as Sites 327A and 260, and is attributed largely to changes in sea level that occurred primarily during the Cenomanian to Santonian period (Sliter, in press).

The persistent association of *Inoceramus* prisms and fragments with shallow-water material indicates transportation and reworking by gravity currents, and possible redistribution by contour currents in laminated deposits. In addition, a dissolution sequence involving *Inoceramus* prisms, similar to that at Site 327A, occurs

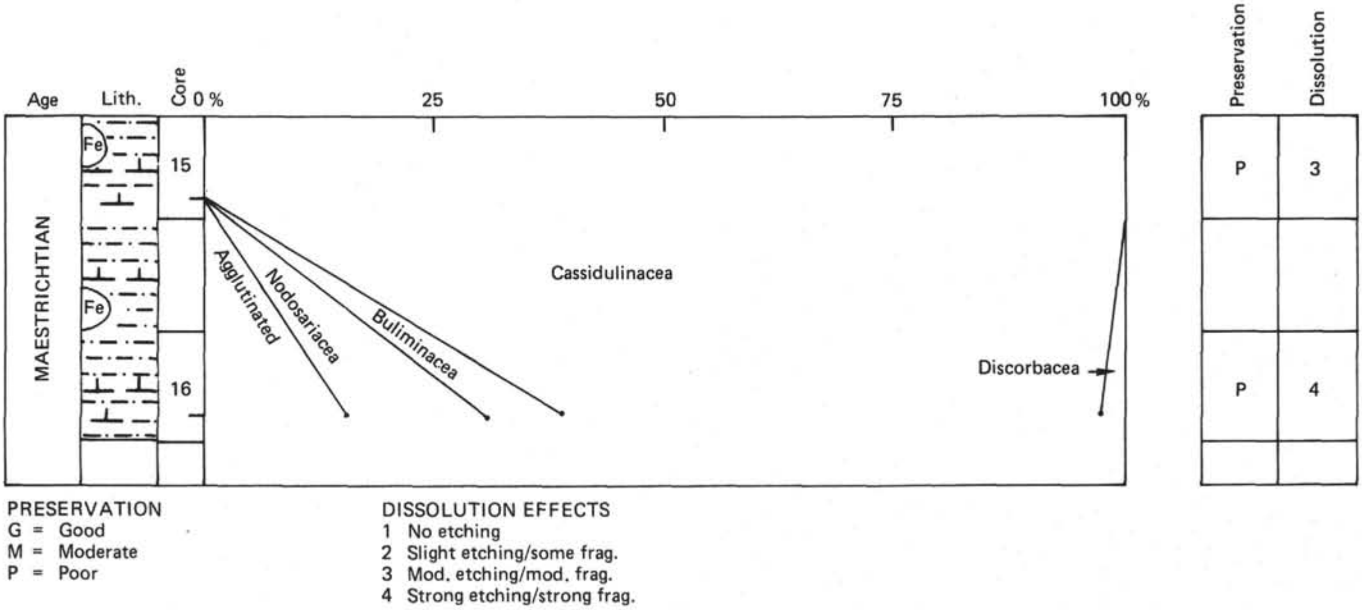

Figure 13. *Comparison of benthic foraminiferal groups (cumulative percent) and preservation at Site 358.*

at Sites 356 and 357. In samples showing increasing carbonate dissolution, the sequence extends from planktonic-benthic foraminifers and prisms, to benthic foraminifers and prisms, to prisms alone, which become increasingly etched until they too disappear. Apparently the prisms are more resistant to dissolution than most, if not all, of the foraminifers associated with them in these samples.

BENTHIC SUCCESSION

The foraminifer assemblages from Leg 39 have added considerably to our understanding of the deep-water Cretaceous benthic succession. Neritic and upper bathyal assemblages from continental exposures have been most accessible for study. The composition of deep abyssal assemblages in the North Pacific and Indian oceans has been well documented by Krasheninnikov (1973, 1974). Interpretation of foraminifer assemblages from middle bathyal to abyssal water depths in different latitudes and facies has been lacking. It is within this range of water depths that the Leg 39 Cretaceous samples studied here are believed to have been deposited.

In general, the upper Cretaceous benthic assemblages from the South Atlantic show the succession described below.

Genera such as *Gavelinella*, *Globorotalites*, *Gyroidinoides*, *Osangularia*, and *Praebulimina* characterize middle bathyal faunas. Nodosariids range up to 40%, agglutinated species up to 18% of the fauna.

Gavelinella, *Gyroidinoides*, and *Osangularia* continue to dominate in lower bathyal faunas, which also contain species of *Aragonia*, *Ellipsoglandulina*, *Ellipsoidella*, *Hyperammina*, *Nuttallinella*, *Pleurostomella*, and *Pullenia*. Nodosariids are less abundant, as are agglutinated genera and the Buliminacea, but the Cassidulinacea increase to 40% or more of the fauna.

Genera such as *Aragonia*, *Ellipsoglandulina*, *Gavelinella*, *Gyroidinoides*, and *Osangularia* characterize abyssal assemblages; species added include *Cribrostomoides*, *Glomospira*, *Lituotuba*, *Paratrochamminoides*(?), *Recurvoides*, and *Rhabdammina*. Members of the Nodosariacea represent 15% or less of the assemblage, the Buliminacea 10% or less. In contrast, the Cassidulinacea progressively increase from 40% to 100% of the fauna. These assemblages apparently give way—by progressive loss of calcareous species and by an increase in the deeper water agglutinated genera—to deep abyssal faunas like those (described by Krasheninnikov, 1973, 1974) from modern water depths between 5000 and 6000 meters. Such a succession would seem to follow directly from the assemblages at Site 355.

The faunas from Site 358 offer an interesting intermediate step between the abyssal assemblages of Site 355 and the deep-abyssal agglutinated assemblages from beneath the late Cretaceous CCD. Samples from Site 358 contain the foraminiferal assemblage composed entirely of dissolution-resistant Cassidulinacea that apparently represents the last vestige of the abyssal calcareous fauna at the CCD. The absence of agglutinated genera indicates that at this locality they too are susceptible to dissolution. This was tested by treating agglutinated species with a 5% solution of HCl. Specimens were selected from the upper Cretaceous abyssal assemblages of Sections 355-20-2 and 355-18-3 and the Santonian bathyal assemblages of Sections 356-37-5 and 357-44-4. The following species dissolved in 5 minutes:

Tritaxia aspera—Samples 355-20-2, 100-102 cm; 356-37-5, 97-99 cm

Dorothia oxycona—Sample 355-20-2, 100-102 cm

D. bulletta—Sample 357-44-4, 100-102 cm

Gaudryina laevigata—Sample 355-20-2, 100-102 cm

G. frankei—Sample 357-44-4, 100-102 cm

Spiroplectammina dentata from Sample 355-20-2, 100-102 cm, was moderately corroded, and the following species showed no reaction:

Ammodiscus cretaceus—Sample 355-18-3, 120-122 cm

Glomospira corona—Sample 355-18-3, 120-122 cm

Hyperammina elongata—Sample 356-37-5, 97-99 cm

The dissolved species represent the dominant members of the bathyal-to-abyssal agglutinated assemblage of Leg 39. Further, specimens of the same species dissolved whether they came from bathyal or abyssal sites. Dispersive X-ray analysis of the wall material of these species shows them to be calcareous, thus explaining their scarcity or absence in samples that have undergone dissolution. Three of the species, *Dorothia bulletta*, *D. oxycona*, and *Gaudryina laevigata*, occur in bathyal deposits of Southern California, where they and their associated agglutinated species are resistant to acid.

Several explanations of these differences come to mind. First, the susceptibility to dissolution probably reflects the difference between the clastic, terrigenous facies of Southern California and the largely pelagic carbonates of the Leg 39 sites. Accordingly, the Leg 39 agglutinating species had to use the calcareous materials available, such as the coccoliths employed by *Textularia losangica* (Plate 2, Figures 4, 6). Upon dissolution, the cement, whether silica or organic, would be unable to bind the material together. Agglutinated species from the clastic environment would consist of detrital material and cement, and would thus resist dissolution.

Second, the oxidized abyssal environments of Leg 39 may have removed an organic cement or protective coating that would remain to protect species in the largely reducing clastic environments of California. This seems a less likely alternative, since specimens from Leg 39 dissolved even in the stronger reducing environments of Sites 356 and 357. A third possibility is that the Leg 39 species are homeomorphs of the shallower water California species. This does not seem likely, on the basis of the present comparisons.

The resistant species belong to the group that includes *Haplophragmoides*, *Paratrochamminoides*(?), *Recurvoides*, and *Saccammina*, among others, and which occurs above and below the CCS. Dispersive X-ray analysis of the walls of *Ammodiscus cretaceus* and *Glomospira corona*, from Sample 355-18-3, 120-122 cm, shows the wall to be mostly silica, with smaller amounts of iron, manganese, potassium, aluminum, and titanium. At magnifications up to 24,500 ×, the structure of the wall looks extremely fine grained, perhaps secreted. Determination of whether these species are using colloidal material or secreting silica must await further studies. Intriguingly, X-ray analysis of the material remaining after dissolution of the nonresistant agglutinated species shows that it is nearly identical in composition to the wall material of the resistant species. This siliceous material used in wall construction by the resistant species may also be the cement used by the nonresistant agglutinated species.

MID-CRETACEOUS HIATUS

The Cenomanian-to-Santonian hiatus or barren interval at Site 356 is similar in duration to the hiatus at Site 327A of Leg 36 on the Falkland Plateau. At Site 356, a sequence containing Albian foraminifers of outer neritic to upper bathyal depths is succeeded by an abbreviated Cenomanian sequence of predominantly nannofossil chalk. The intervals represent an acceleration, during the Cenomanian, of deepening which began during the Albian. Preservation of the Cenomanian fauna indicates a water depth near or below the foraminiferal lysocline. Succeeding this fauna is a short Santonian sequence of mottled zeolitic clay that contains a strongly corroded foraminiferal fauna of resistant calcareous species and rare agglutinated specimens. Water depths appear to have been abyssal, 2500 to 4000 meters. The succeeding Campanian to Maestrichtian faunas indicate lower bathyal water depths of 1500 to 2500 meters.

Site 356 faunas, as seen above, indicate Albian middle bathyal water depths in Core 42, succeeded by Santonian lower bathyal depths in Core 37. Intervening samples, other than the barren sample from Core 39, were not examined in the present investigation, but studies of planktonic foraminifers and nannofossils from samples within this interval indicate that the early Turonian and the Cenomanian are missing (Premoli-Silva and Boersma, this volume; Bukry, this volume). Santonian assemblages from Sites 356 and 357 do show faunal changes that, although not as extreme as those from the Falkland Plateau, seem to record a deepening. This is best seen by the abundance of *Ellipsoidella*, *Hyperammina*, *Osangularia*, and *Tritaxia*, in Section 356-37-5, and to a lesser extent by the abundance of *Gavelinella*, *Gyroidinoides*, *Osangularia*, *Pullenia*, and *Tritaxia* in Sections 357-48-4 to 357-44-4. These faunal variations suggest that conditions contributing to the events on the Falkland Plateau must have involved eustatic changes and fluctuations in termperature; similar evidence of tectonic events appears in the sediments of the South Atlantic north of the Rio Grande Rise.

ACKNOWLEDGMENTS

I wish to thank P.R. Supko and K. Perch-Nielsen (Co-chief Scientists, Leg 39) for making available the material for this study. Thanks are also extended to A. Boersma (Leg 36 Paleontologist) for alerting me to the project and sending me the necessary material.

K. McDougall and R.Z. Poore (U.S. Geological Survey, Menlo Park, California) kindly read and commented upon the manuscript. I am particularly indebted to R.L. Oscarson for operating the Cambridge S-180 scanning electron microscope and the attached EDAX energy dispersive X-ray analyzer, and for taking scanning electron micrographs; and to S.E. Murphy for her help in several phases of manuscript preparation. The help of A.G. Coffman and M.A. Breeden in sample and illustration preparation was also appreciated.

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APPENDIX

Faunal Reference List

Alabamina dorsoplana (Brotzen) = *Eponides dorsoplana* Brotzen
Allomorphina cretacea Reuss
A. trochoides (Reuss) = *Globigerina trochoides* Reuss
Ammodiscus cretaceus Reuss
A. glabratus Cushman and Jarvis
Aragonia ouezzaensis (Rey) = *Bolivinoides ouezzaensis* Rey
A. velascoensis (Cushman) = *Textularia velascoensis* Cushman
Arenobulimina preslii (Reuss) = *Bulimina preslii* Reuss
Astacolus bradyiana (Chapman) = *Cristellaria bradyiana* Chapman
A. liebusi (Brotzen) = *Planularia liebusi* Brotzen
A. richteri (Brotzen) = *Planularia richteri* Brotzen
A. jarvisi (Cushman) = *Marginulina jarvisi* Cushman
Bandyella greatvalleyensis (Trujillo) = *Pleurostomella greatvalleyensis* Trujillo
Bifarina hispidula (Cushman) = *Rectogümbelina hispidula* Cushman
Bolivina decurrens (Ehrenberg) = *Grammostomum*? *decurrens* Ehrenberg
B. incrassata Reuss
Bolivinoides australis Edgell
B. sidestrandensis Barr
B. strigillatus (Chapman) = *Bolivina strigillata* Chapman
Conorboides cf. *C. scanica* (Brotzen) = *Discorbis scanica* Brotzen
Coryphostoma plaitum (Carsey) = *Bolivina plaita* Carsey
Cribrostomoides cretaceus Cushman and Goudkoff
Dentalina basiplanata Cushman
D. communis (d'Orbigny) = *Nodosaria (Dentalina) communis* d'Orbigny
D. cylindroides Reuss
D. gracilis (d'Orbigny) = *Nodosaria (Dentalina) gracilis* d'Orbigny
D. legumen (Reuss) = *Nodosaria (Dentalina) legumen* Reuss
D. pertinens Cushman
D. solvata Cushman
D. velascoensis (Cushman) = *Nodosaria velascoensis* Cushman
Dorothia bulletta (Carsey) = *Gaudryina bulletta* Carsey
D. ellipsorae (Cushman) = *Marssonella ellisorae* Cushman
D. oxycona (Reuss) = *Gaudryina oxycona* Reuss
Ellipsoglandulina concinna Olbertz
E. cf. *E. exponens* (Brady) = *Ellipsoidina exponens* Brady
E. obesa Hanzlíková
Ellipsoidella binaria Belford
E. elongata (Storm) = *Ellipsodimorphina elongata* Storm
E. divergens (Storm) = *Ellipsodimorphina divergens* Storm

E. gracillima (Cushman) = *Nodosarella gracillima* Cushman
E. kugleri (Cushman and Renz) = *Nodosarella kugleri* Cushman and Renz
E. subnodosa (Guppy) = *Ellipsonodosaria subnodosa* Guppy
Ellipsodimorphina subtuberosa Liebus
Ellipsopolymorphina velascoensis (Cushman) = *Ellipsoglandulina velascoensis Cushman*
Fissurina alata Reuss
F. bicornis Neagu
F. oblonga Reuss
F. orbignyiana Sequenza
Frondicularia cf. *F. aclis* Morrow
F. frankei Cushman
F. linearis Franke
F. lomaensis Sliter
Frondicularia mucronata Reuss
F. tetragonia (Reuss) = *Nodosaria tetragona* Reuss
F. cf. *F. ungeri* Reuss
Gaudryina austinana (Cushman) = *Gaudryina* (*Siphogaudryina*) *austinana* Cushman
G. cushmani Tappan
G. frankei Brotzen
G. laevigata Franke
G. pyramidata Cushman
Gavelinella cayeuxi mangshlakensis (Vassilenko) = *Anomalina* (*Pseudovalvulineria*) *cayeuxi mangshlakensis* Vassilenko
G. eriksdalensis (Brotzen) = *Cibicides* (*Cibicidoides*) *eriksdalensis* Brotzen
G. intermedia (Berthelin) = *Anomalina intermedia* Berthelin
G. nacatochensis (Cushman) = *Planulina nacatochensis* Cushman
G. sandidgei (Brotzen) = *Cibicides sandidgei* Brotzen
G. stephensoni (Cushman) = *Cibicides stephensoni* Cushman
G. cf. *G. tormarpensis* Brotzen
G. velascoensis (Cushman) = *Anomalina velascoensis* Cushman
G. whitei (Martin) = *Anomalina whitei* Martin
Globorotalites conicus (Carsey) = *Truncatulina refulgens* (Montfort) var. *conica* Carsey
G. michelinianus (d'Orbigny) = *Rotalina michelinianus* d'Orbigny
G. multiseptus (Brotzen) = *Globorotalia multiseptus* Brotzen
G. spineus (Cushman) = *Truncatulina spineus* Cushman
G. tappanae Sliter
Globulina lacrima (Reuss) = *Polymorphina* (*Globulina*) *lacrima* Reuss
G. prisca Reuss
G. subsphaerica (Berthelin) = *Polymorphina subsphaerica* Berthelin
Glomospira corona (Cushman and Jarvis) = *Glomospira charoides* (Jones and Parker) var. *corona* Cushman and Jarvis
G. gordialis (Jones and Parker) = *Trochammina squamata* var. *gordialis* Jones and Parker
Gyroidina cf. *G. nonionoides* (Bandy) = *Valvulinaria nonionoides* Bandy
Gyroidinoides beisseli (Schijfsma) = *Eponides beisseli* Schijfsma
G. depressus (Alth) = *Rotalina depressa* Alth
G. globosus (Hagenow) = *Nonionina globosa* Hagenow
G. infracretacea (Morozova) = *Gyroidina nitida* Reuss var. *infracretacea* Morozova
G. nitidus (Reuss) = *Rotalina nitida* Reuss
G. praeglobosus (Brotzen) = *Gyroidina praeglobosus* Brotzen
G. quadratus (Cushman and Church) = *Gyroidina quadratus* Cushman and Church
G. lunata (Brotzen) = *Eponides lunata* Brotzen
Heterolepa cf. *H. sparksi* (White) = *Gyroidina sparksi* White
Hyperammina elongata Brady
Lagena acuticosta Reuss
L. apiculata Reuss
L. ellipsoidalis Schwager
L. hispida Reuss
L. paucicosta Franke
L. stavensis Bandy
Lenticulina acuta (Reuss) = *Cristellaria acuta* Reuss
L. discrepans (Reuss) = *Robulina discrepans* Reuss
L. gaultina (Berthelin) = *Cristellaria gaultina* Berthelin
L. muensteri (Roemer) = *Robulina münsteri* Roemer
L. ovalis (Reuss) = *Cristellaria ovalis* Reuss
L. revoluta (Israelsky) = *Robulus revoluta* Israelsky
L. velascoensis White
Lingulina pygmaea Reuss
L. aff. *L. taylorana* Cushman
Lituotuba lituoformis (Brady) = *Trochammina lituoformis* Brady
Loxostomum eleyi (Cushman) = *Bolivinita eleyi* Cushman
Marginulina armata Reuss
M. bullata Reuss
M. curvatura Cushman
M. hamuloides Brotzen
M. inaequalis Reuss
M. juncea Cushman
Marginulinopsis texasensis (Cushman) = *Marginulina texasensis* Cushman
Nonionella austinana Cushman
N. robusta Plummer
Nodosaria aspera Reuss
Nuttallinella florealis (White) = *Gyroidina florealis* White
Oolina apiculata Reuss
O. delicata Sliter
Osangularia cordieriana (d'Orbigny) = *Rotalina cordieriana* d'Orbigny
O. velascoensis (Cushman) = *Truncatulina velascoensis* Cushman
O. whitei (Brotzen) = *Eponides whitei* Brotzen
Paratrochamminoides? *intricatus* Krasheninnikov
Pleurostomella austinana Cushman
P. obtusa Berthelin
P. reussi Berthelin
P. subnodosa Reuss
Praebulimina carseyi (Plummer) = *Buliminella carseyae* Plummer
P. cushmani (Sandidge) = *Buliminella cushmani* Sandidge
P. reussi (Morrow) = *Bulimina reussi* Morrow
P. spinata (Cushman and Campbell) = *Bulimina spinata* Cushman and Campbell
P. taylorensis (Cushman and Parker) = *Bulimina taylorensis* Cushman and Parker
Pseudonodosaria humilis (Roemer) = *Nodosaria humilis* Roemer
P. manifesta (Reuss) = *Glandulina manifesta* Reuss
P. mutabilis (Reuss) = *Glandulina mutabilis* Reuss
P. obesa (Loeblich and Tappan) = *Rectoglandulina obesa* Loeblich and Tappan.
Pseudospiroplectinata compressiuscula (Chapman) = *Bigenerina compressiuscula* Chapman
Pullenia cretacea Cushman
P. coryelli White
P. minuta Cushman
Pyrulina apiculata (Marie) = *Pyrulina cylindroides* (Roemer) var. *apiculata* Marie
P. cylindroides (Roemer) = *Polymorphina cylindroides* Roemer
Quadrimorphina allomorphinoides (Reuss) = *Valvulineria allomorphinoides* Reuss
Q. camerata (Brotzen) = *Valvulineria camerata* Brotzen
Ramulina aculeata (d'Orbigny) = *Dentalina aculeata* d'Orbigny
R. arkadelphiana Cushman
R. pseudoaculeata (Olsson) = *Dentalina pseudoaculeata* Olsson
Recurvoides globulosus (Grzybowski) = *Cyclammina globulosus* Grzybowski
Reussella pseudospinulosa Troelsen
R. szajnochae (Grzybowski) = *Verneuilina szajnochae* Grzybowski
Rhabdammina discreta Brady
Saccammina complanata (Franke) = *Pelosina complanata* Franke
Saracenaria bononiensis (Berthelin) = *Cristellaria bononiensis* Berthelin
S. navicula (d'Orbigny) = *Cristellaria navicula* d'Orbigny
S. triangularis (d'Orbigny) = *Cristellaria triangularis* d'Orbigny
Serovaina orbicella (Bandy) = *Gyroidina globosa* (Hagenow) var. *orbicella* Bandy
Spiroplectammina dentata (Alth) = *Textularia dentata* Alth
S. nuda Lalicker
S. praelonga (Reuss) = *Textularia praelonga* Reuss
S. semicomplanata (Carsey) = *Textularia semicomplanata* Carsey
S. sigmoidina Lalicker
Stensioina pommerana Brotzen
Stilostomella pseudoscripta (Cushman) = *Ellipsonodosaria pseudoscripta* Cushman
Tappanina selmensis (Cushman) = *Bolivinita selmensis* Cushman
Textularia losangica Loeblich and Tappan
Thalmannammina subturbinata (Grzybowski) = *Haplophragmium subturbinatum* Grzybowski

Cushman
T. gaultina (Morozova) = *Clavulina gaultina* Morozova
Valvulineria lenticula (Reuss) = *Rotalina lenticula* Reuss
Tribrachia excavata (Reuss) = *Rhabdogonium excavatum* Reuss
Tritaxia aspera (Cushman) = *Clavulina trilatera* Cushman var. *aspera*

PLATE 1

Figures 1, 4	*Hyperammina elongata* Brady. 1. Sample 357-42-4, 100-102 cm. Dot width 300 μm. 4. Sample 356-29-5, 102-104 cm. Dot width 100 μm.
Figure 2	*Saccammina complanata* (Franke). Sample 357-26-4, 100-102 cm. Dot width 100 μm.
Figure 3	*Ammodiscus cretaceus* Reuss. Sample 358-16-2, 92-94 cm. Dot width 100 μm.
Figures 5, 6	*Glomospira corona* (Cushman and Jarvis). 5. Sample 355-18-3, 120-122 cm. Dot width 30 μm. 6. Sample 355-19-3, 120-122 cm. Dot width 30 μm.
Figure 7	*Glomospira gordialis* (Jones and Parker). Sample 355-19-3, 120-122 cm. Dot width 100 μm.
Figure 8	*Paratrochamminoides*? *intricatus* Krasheninnikov. Sample 355-18-3, 120-122 cm. Dot width 100 μm.
Figure 9	*Spiroplectammina dentata* (Alth).

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PLATE 2

Figure 1	*Spiroplectammina nuda* Lalicker. Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figures 2, 3	*Spiroplectammina sigmoidina* Lalicker. 2. Sample 355-17-5, 58-60 cm. Dot width 30 μm. 3. Sample 357-33-4, 100-102 cm. Dot width 100 μm.
Figures 4, 6	*Textularia losangica* Loeblich and Tappan. 4. Sample 356-42-5, 100-102 cm. Dot width 100 μm. 6. Enlargement of Figure 4 showing wall composed in part of corroded coccoliths. Dot width 3 μm.
Figure 5	*Gaudryina austinana* (Cushman). Sample 357-34-4, 100-102 cm. Dot width 100 μm.
Figure 7	*Gaudryina cushmani* Tappan. Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 8	*Gaudryina laevigata* Franke. Sample 357-40-4, 100-102 cm. Dot width 100 μm.
Figure 9	*Gaudryina pyramidata* Cushman. Sample 356-29-5, 102-104 cm. Dot width 100 μm.

(see page 679)

PLATE 1

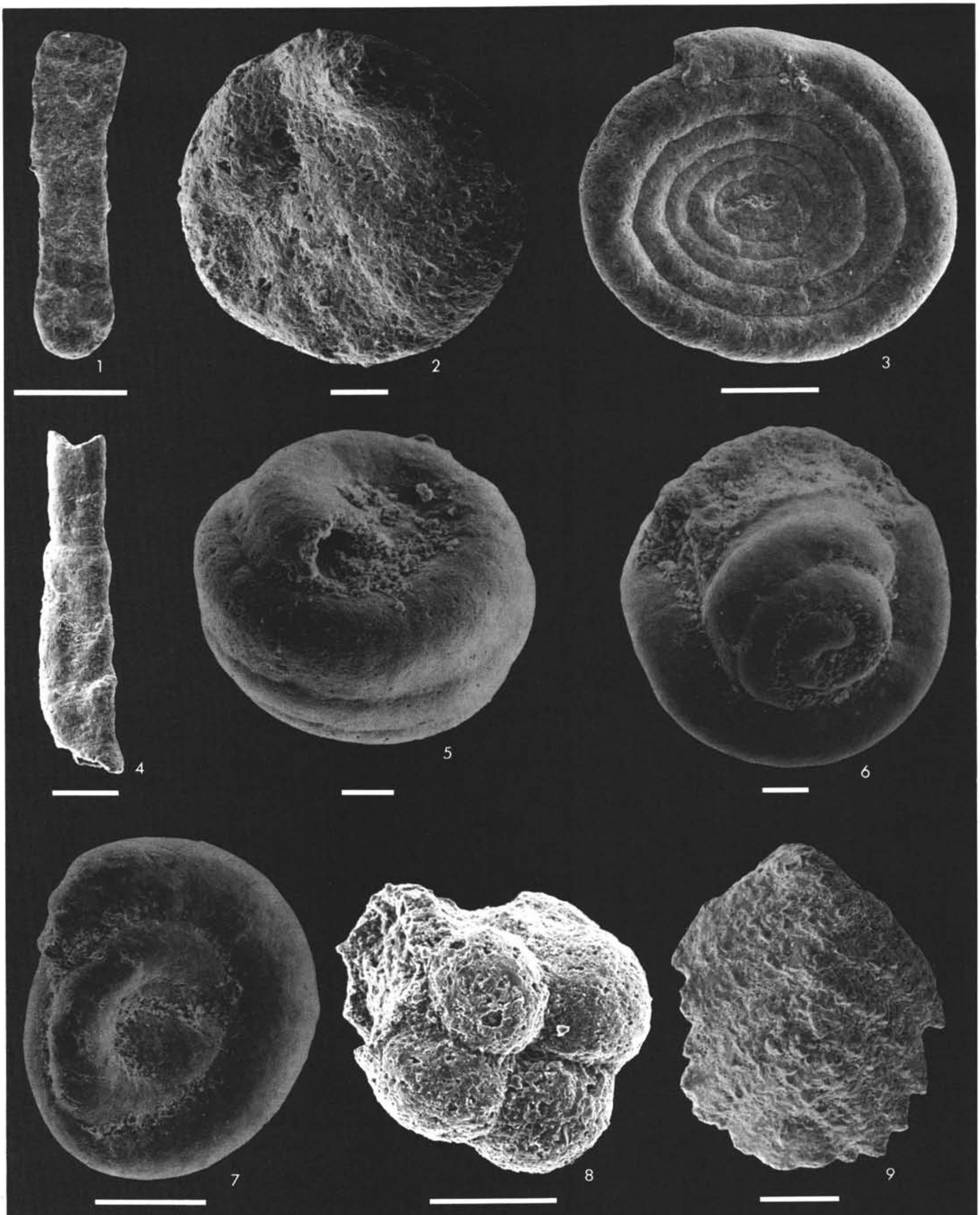

PLATE 2

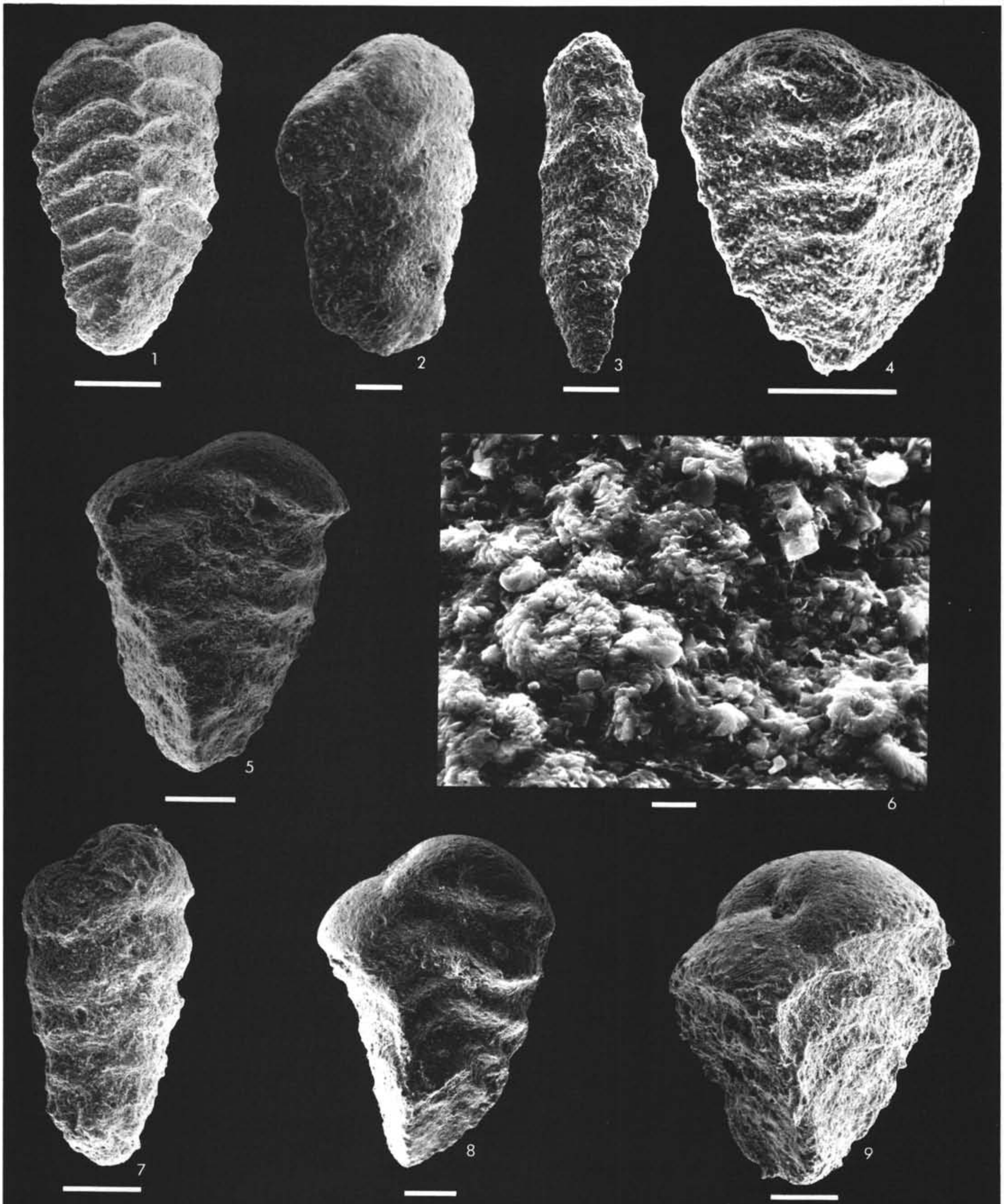

PLATE 3

Figure 1	*Pseudospiroplectinata compressiuscula* (Chapman). Sample 357-44-4, 100-102 cm. Dot width 100 μm.
Figures 2-4	*Tritaxia aspera* (Cushman). 2. Sample 357-44-4, 100-102 cm. Dot width 300 μm. 3. Sample 356-32-5, 101-103 cm. Dot width 100 μm. 4. Juvenile specimen, Sample 356-32-5, 101-103 cm. Dot width 100 μm.
Figures 5, 6	*Tritaxia gaultina* (Morozova). Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 7	*Dorothia bulletta* (Carsey). Sample 357-40-4, 100-102 cm. Dot width 100 μm.
Figure 8	*Dorothia oxycona* (Reuss). Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 9	*Astacolus bradyiana* (Chapman). Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 10	*Frondicularia* cf. *F. ungeri* Reuss. Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 11	*Lenticulina gaultina* (Berthelin). Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Figure 12	*Marginulina juncea* Cushman. Sample 357-40-4, 100-102 cm. Dot width 100 μm.

PLATE 3

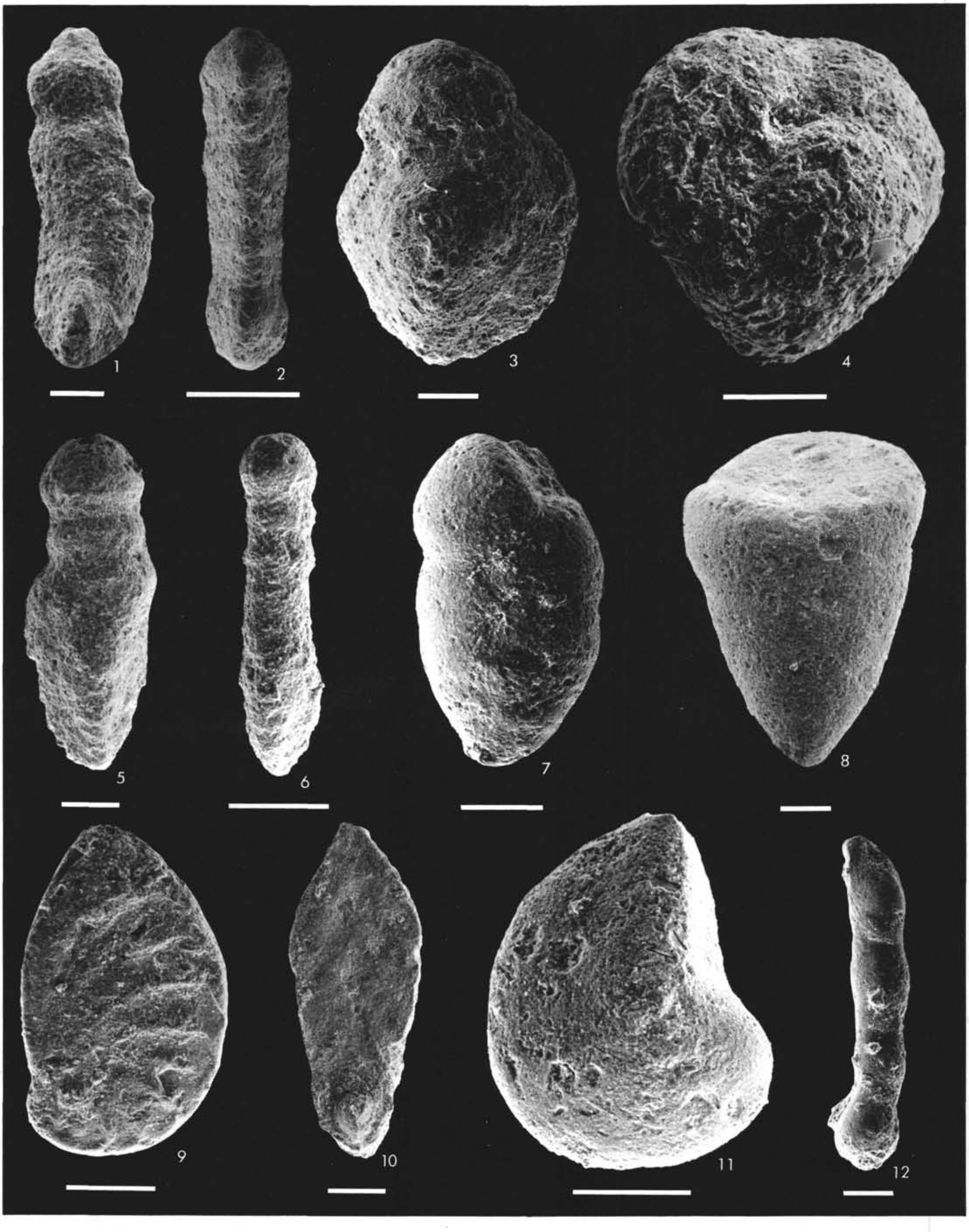

PLATE 4

Figure 1 *Saracenaria bononiensis* (Berthelin).
Sample 356-42-5, 100-102 cm. Dot width 100 μm.

Figure 2 *Tribrachia excavata* (Reuss).
Sample 356-42-5, 100-102 cm. Dot width 100 μm.

Figure 3 *Lingulina pygmaea* Reuss.
Sample 356-32-5, 101-103 cm. Dot width 100 μm.

Figure 4 *Globulina lacrima* (Reuss).
Sample 356-29-5, 102-104 cm. Dot width 100 μm.

Figure 5 *Globulina subsphaerica* (Berthelin).
Sample 356-30-5, 100-102 cm. Dot width 100 μm.

Figure 6 *Fissurina* sp.
Sample 356-32-5, 101-103 cm. Dot width 100 μm.

Figures 7, 8 *Praebulimina cushmani* (Sandidge).
Sample 357-32-4, 99-101 cm.
7. Dot width 100 μm.
8. Dot width 30 μm.

Figures 9, 10 *Praebulimina reussi* (Morrow).
Dot width 100 μm.
9. Sample 356-29-5, 102-104 cm.
10. Sample 356-32-5, 101-103 cm.

PLATE 5

Figure 1 *Bolivina incrassata* Reuss.
Sample 357-33-4, 100-102 cm. Dot width 100 μm.

Figures 2, 3 *Bolivinoides australis* Edgell.
Sample 357-33-4, 100-102 cm. Dot width 100 μm.

Figure 4 *Bolivinoides sidestrandensis* Barr.
Sample 357-32-4, 99-101 cm. Dot width 100 μm.

Figures 5, 6 *Bolivinoides strigillatus* (Chapman).
Sample 357-44-4, 100-102 cm. Dot width 100 μm.

Figure 7 *Stilostomella pseudoscripta* (Cushman).
Sample 357-33-4, 100-102 cm. Dot width 100 μm.

Figures 8, 11 *Reussella pseudospinulosa* Troelsen.
8. Sample 356-30-5, 100-102 cm. Dot width 100 μm.
11. Sample 356-34-5, 102-104 cm. Dot width 300 μm.

Figures 9, 10 *Reussella szajnochae* (Grzybowski).
Dot width 100 μm.
9. Sample 355-19-3, 120-122 cm.
10. Sample 355-18-3, 120-122 cm.

(see page 684)

PLATE 4

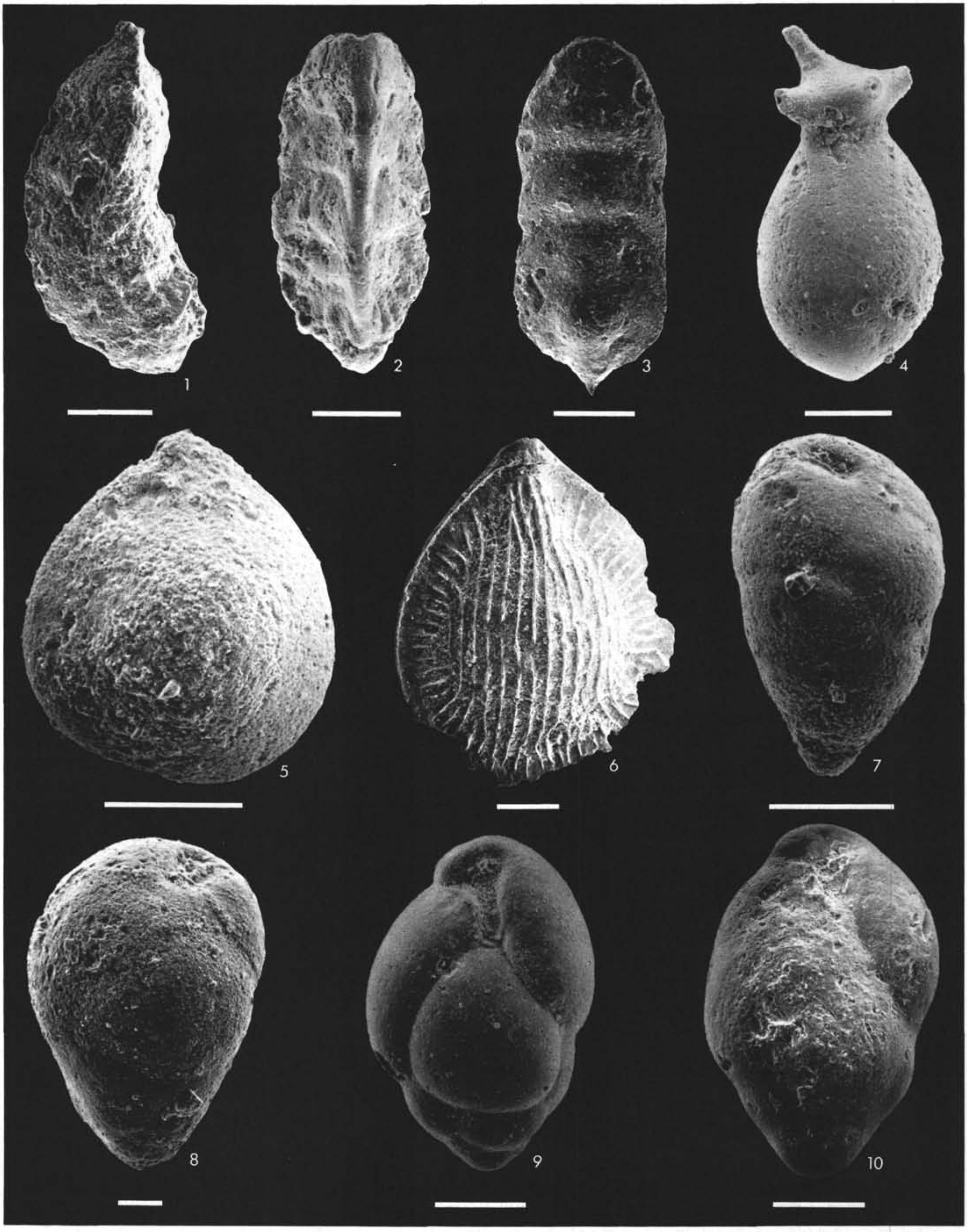

PLATE 5

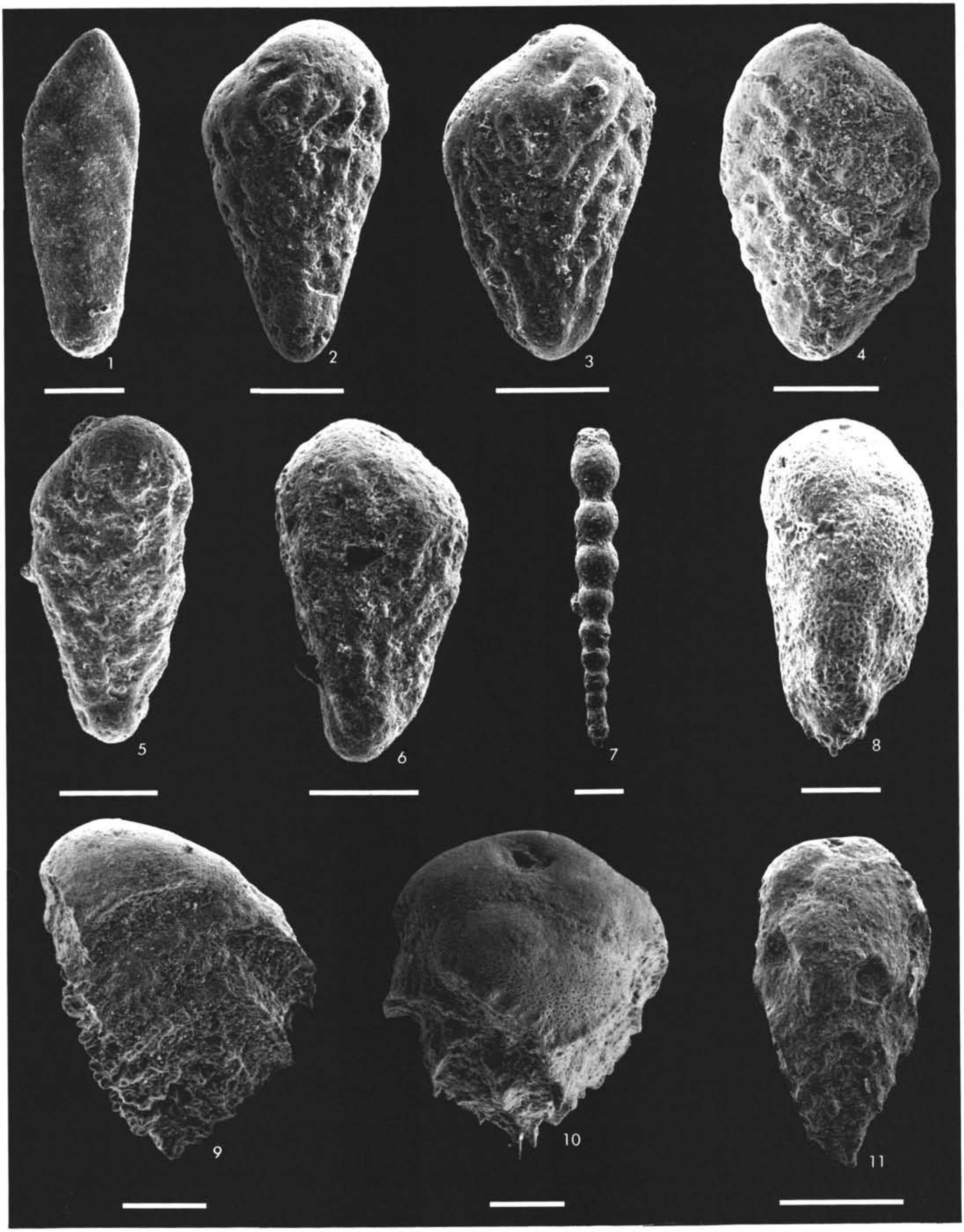

PLATE 6

Figures 1, 4 — *Valvulineria lenticula* (Reuss).
Sample 357-47-4, 100-102 cm. Dot width 100 μm.
1. Umbilical view.
4. Spiral view.

Figures 2, 3 — *Nuttallinella florealis* (White).
Sample 357-33-4, 100-102 cm. Dot width 100 μm.
2. Umbilical view.
3. Peripheral view of same specimen.

Figure 5 — *Pleurostomella austinana* Cushman.
Broken specimen from Sample 357-44-4, 100-102 cm. Dot width 300 μm.

Figure 6 — *Pleurostomella obtusa* Berthelin.
Sample 356-42-5, 100-102 cm. Dot width 100 μm.
Oblique view.

Figure 7 — *Pleurostomella reussi* Berthelin.
Sample 356-42-5, 100-102 cm. Dot width 100 μm.

Figures 8, 9 — *Pleurostomella subnodosa* Reuss.
Dot width 300 μm.
8. Sample 356-30-5, 100-102 cm.
9. Sample 356-32-5, 101-103 cm.

Figure 10 — *Ellipsodimorphina subtuberosa* Liebus.
Sample 357-40-4, 100-102 cm. Dot width 100 μm.

Figure 11 — *Ellipsoglandulina concinna* Olbertz.
Sample 358-16-2, 92-94 cm. Dot width 100 μm.

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PLATE 6

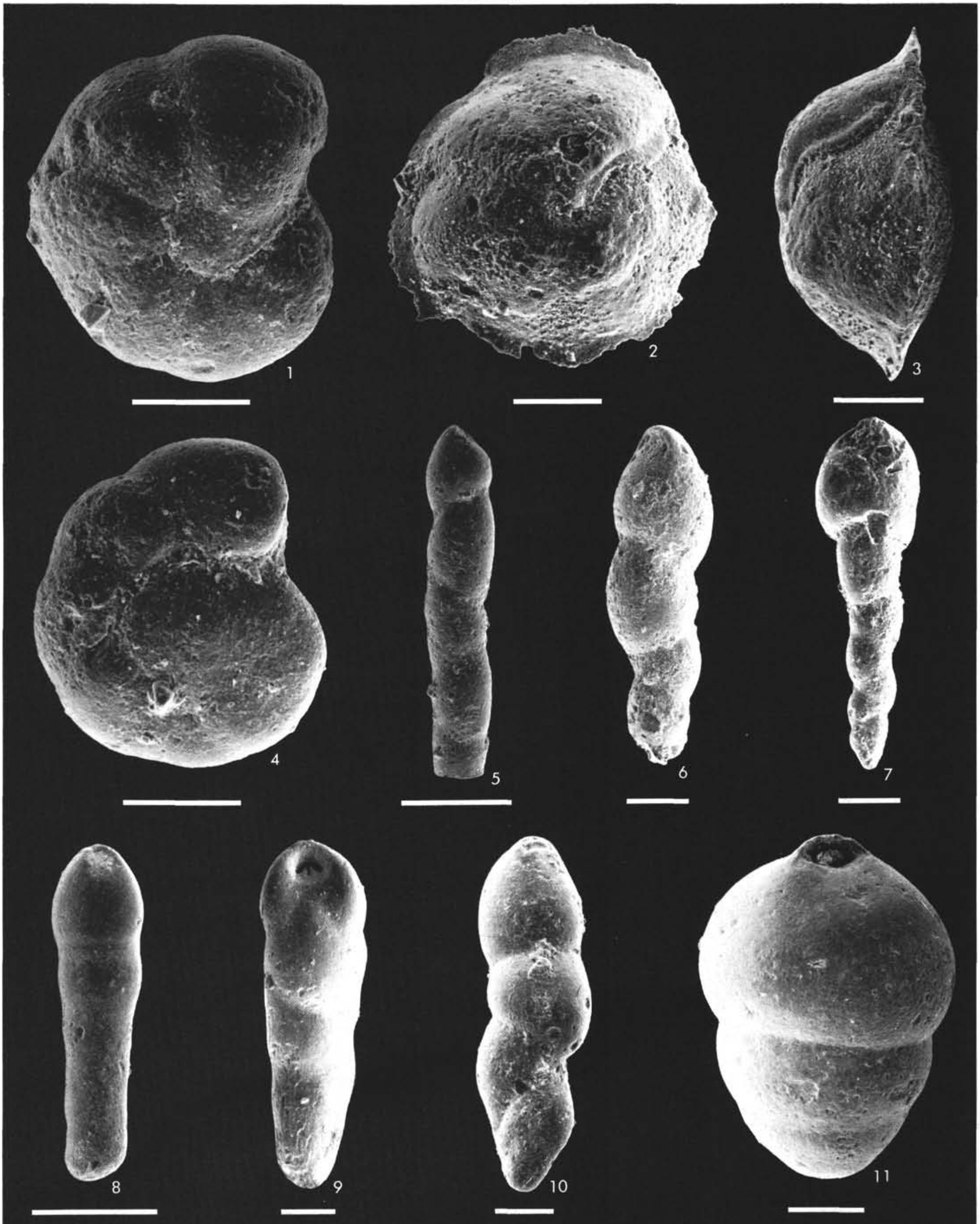

PLATE 7

Figures 1, 2	*Ellipsoidella divergens* (Storm). Dot width 100 μm. 1. Side view. Sample 356-32-5, 101-103 cm. 2. Apertural view. Sample 356-29-5, 102-104 cm.
Figure 3	*Ellipsoidella gracillima* (Cushman). Sample 357-40-4, 100-102 cm. Dot width 100 μm.
Figure 4	*Ellipsoidella* sp. Sample 357-33-4, 100-102 cm. Dot width 100 μm.
Figure 5	*Ellipsoidella*? sp. Sample 356-29-5, 102-104 cm. Dot width 100 μm. Side view.
Figure 6	*Ellipsopolymorphina velascoensis* (Cushman). Sample 357-33-4, 100-102 cm. Dot width 100 μm.
Figure 7	*Coryphostoma plaitum* (Carsey). Sample 357-32-4, 99-101 cm. Dot width 100 μm. Side view.
Figure 8	*Loxostomum eleyi* (Cushman). Sample 357-40-4, 100-102 cm. Dot width 30 μm.
Figures 9, 10	*Aragonia ouezzaensis* (Rey). Sample 355-19-3, 120-122 cm. Dot width 30 μm. 9. Side view. 10. Oblique apertural view of same specimen, showing etched surface.
Figure 11	*Aragonia velascoensis* (Cushman). Sample 357-33-4, 100-102 cm. Dot width 100 μm.
Figure 12	*Quadrimorphina allomorphinoides* (Reuss). Sample 357-32-4, 99-101 cm. Dot width 100 μm.

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PLATE 7

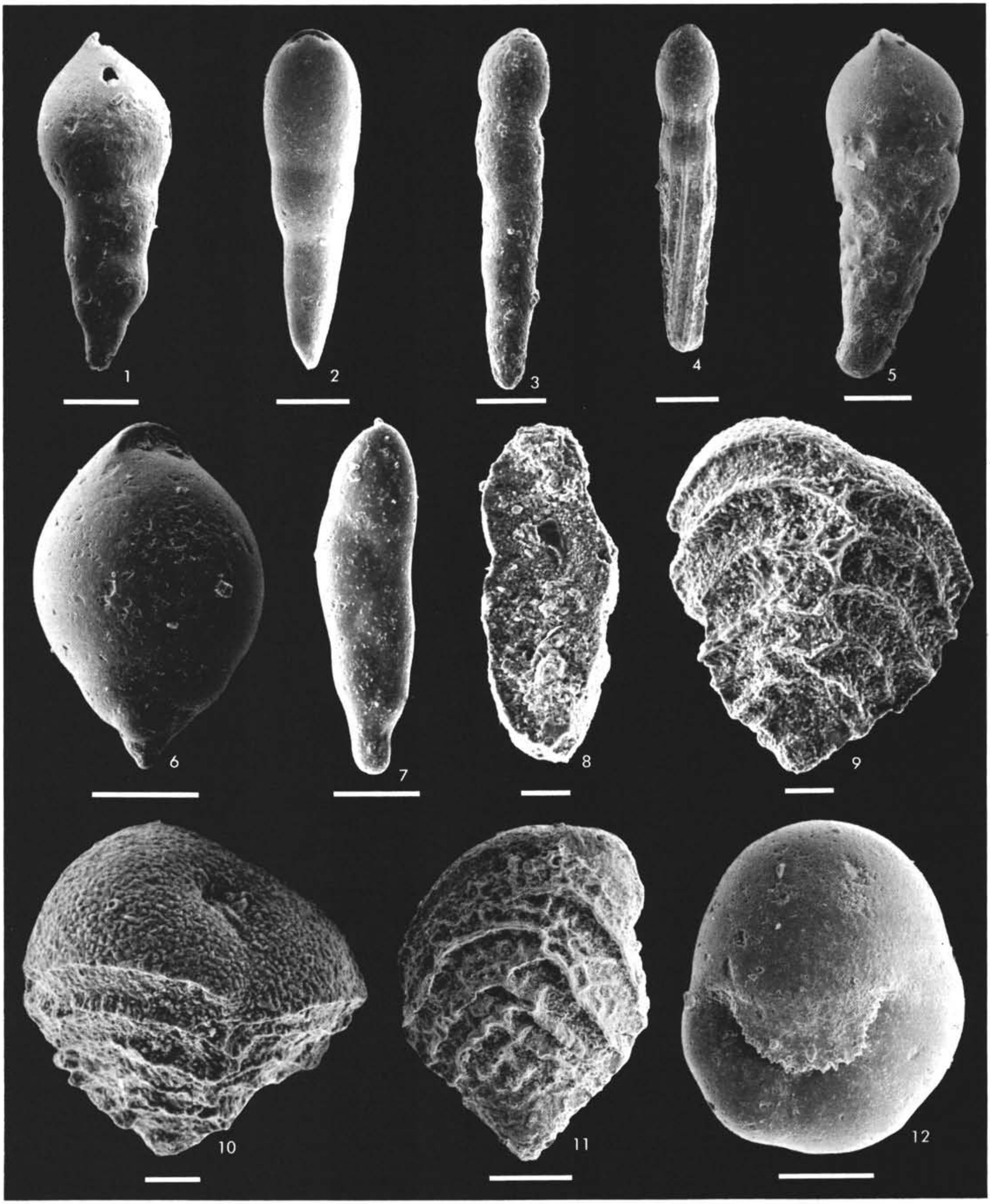

PLATE 8

Figure 1	*Allomorphina cretacea* Reuss. Sample 356-34-5, 102-104 cm. Dot width 30 μm.
Figure 2	*Allomorphina trochoides* (Reuss). Sample 356-29-5, 102-104 cm. Dot width 100 μm.
Figure 3	*Nonionella austinana* Cushman. Sample 357-47-4, 100-102 cm. Dot width 30 μm.
Figure 4	*Nonionella robusta* Plummer. Sample 356-32-5, 101-103 cm. Dot width 30 μm.
Figure 5	*Pullenia coryelli* White. Sample 355-17-5, 58-60 cm. Dot width 100 μm.
Figures 6, 7	*Pullenia cretacea* Cushman. Dot width 100 μm. 6. Sample 356-32-5, 101-103 cm. 7. Sample 357-33-4, 100-102 cm.
Figures 8, 9	*Pullenia minuta* Cushman. Sample 356-29-5, 102-104 cm. Dot width 30 μm. 8. Side view. 9. Apertural view of same specimen.

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PLATE 9

Figures 1-3, 6	*Osangularia cordieriana* (d'Orbigny). Sample 356-29-5, 102-104 cm. Dot width 30 μm. 1. Umbilical view. 2. Peripheral view of same specimen. 3. Umbilical view. 6. Peripheral view of same specimen.
Figures 4, 5	*Osangularia whitei* (Brotzen). Sample 357-44-4, 100-102 cm. Dot width 100 μm. 4. Umbilical view. 5. Peripheral view of same specimen.
Figures 7, 8	*Globorotalites conicus* (Carsey). Sample 355-18-3, 120-122 cm. Dot width 100 μm. 7. Umbilical view. 8. Peripheral view of same specimen.

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PLATE 8

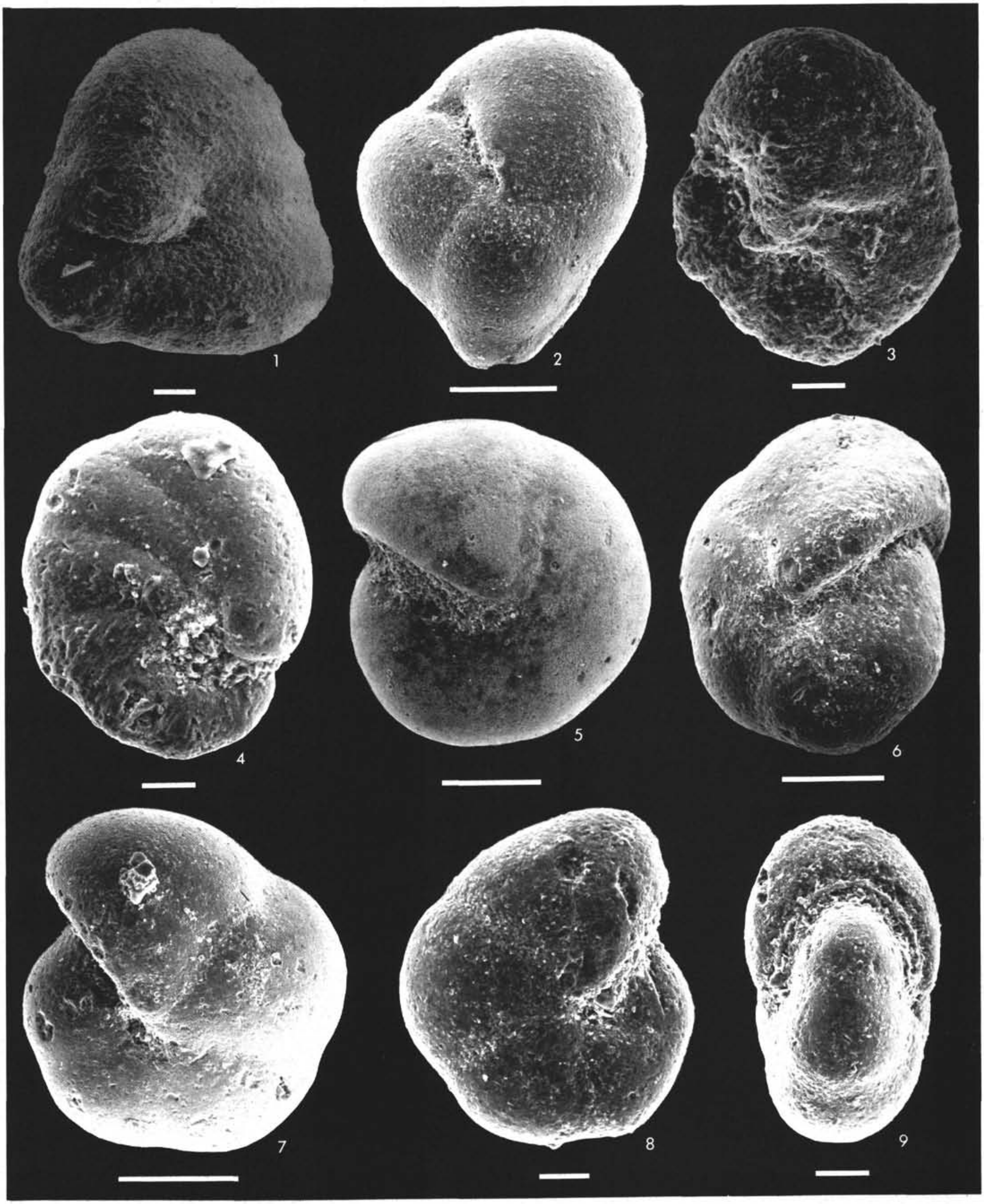

PLATE 9

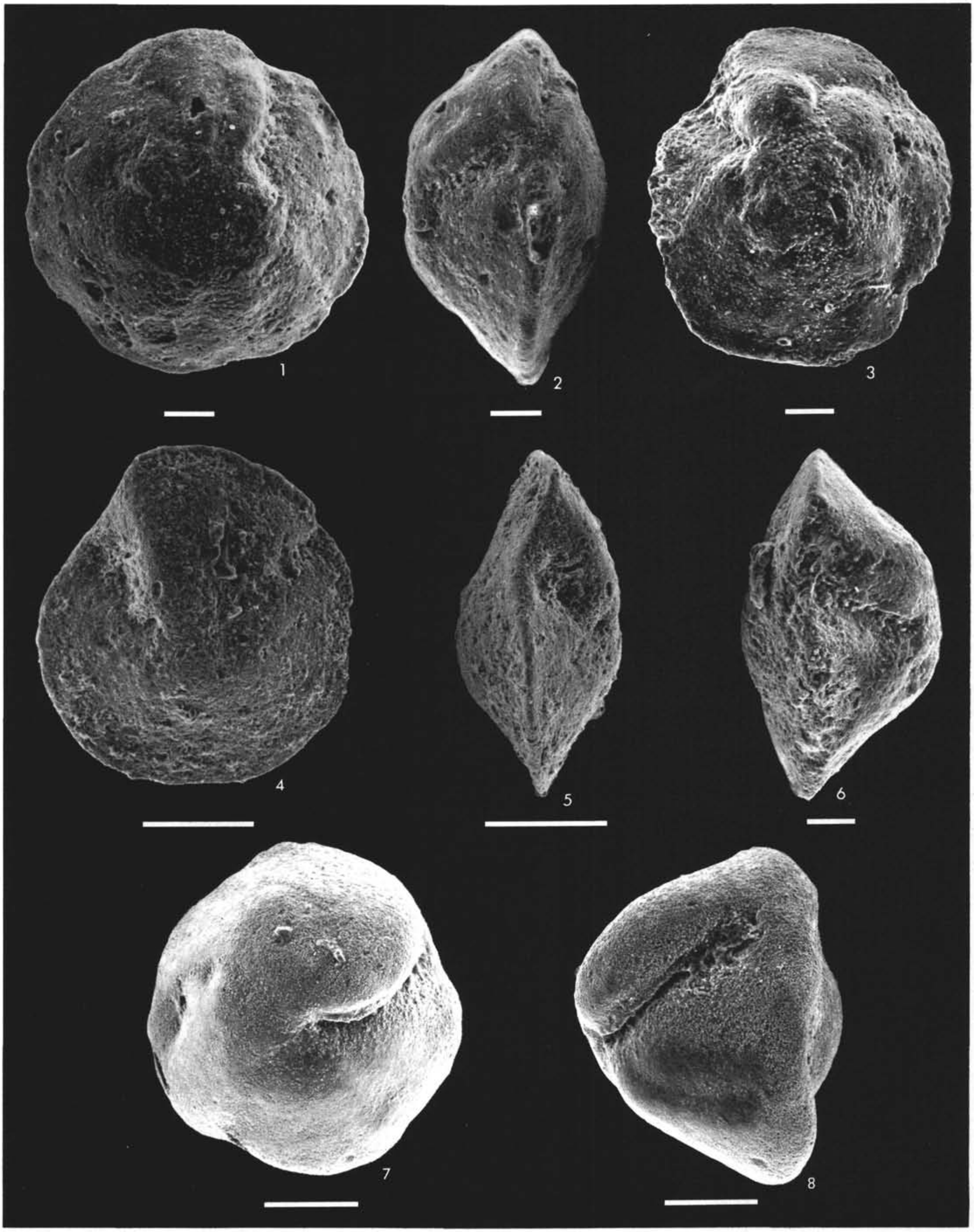

PLATE 10

Figures 1, 2 — *Globorotalites multiseptus* (Brotzen).
Sample 357-47-4, 100-102 cm. Dot width 100 μm.
1. Umbilical view.
2. Peripheral view of same specimen.

Figures 3-6 — *Gyroidinoides beisseli* (Schijfsma).
3, 6. Sample 357-33-4, 100-102 cm. Dot width 100 μm.
3. Umbilical view.
6. Peripheral view of same specimen.
4, 5. Sample 357-36-4, 100-102 cm. Dot width 100 μm.
4. Umbilical view.
5. Peripheral view of same specimen.

Figures 7, 8 — *Gyroidinoides globosus* (Hagenow).
Dot width 100 μm.
7. Sample 358-16-2, 92-94 cm.
8. Sample 356-32-5, 101-103 cm.

PLATE 11

Figures 1, 2 — *Gyroidinoides infracretacea* (Morozova).
Sample 356-42-5, 100-102 cm.
1. Umbilical view. Dot width 100 μm.
2. Peripheral view of same specimen. Dot width 30 μm.

Figures 3, 6 — *Gyroidinoides praeglobosus* (Brotzen).
Sample 357-44-4, 100-102 cm. Dot width 100 μm.
3. Umbilical view.
6. Peripheral view of same specimen.

Figures 4, 5, 7 — *Gyroidinoides quadratus* (Cushman and Church).
Dot width 100 μm.
4, 5. Sample 358-16-2, 92-94 cm.
4. Spiral view.
5. Peripheral view of same specimen.
7. Sample 356-32-5, 101-103 cm. Peripheral view.

Figure 8 — *Globorotalites spineus* (Cushman).
Sample 355-18-3, 120-122 cm. Dot width 100 μm.
Umbilical view.

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PLATE 10

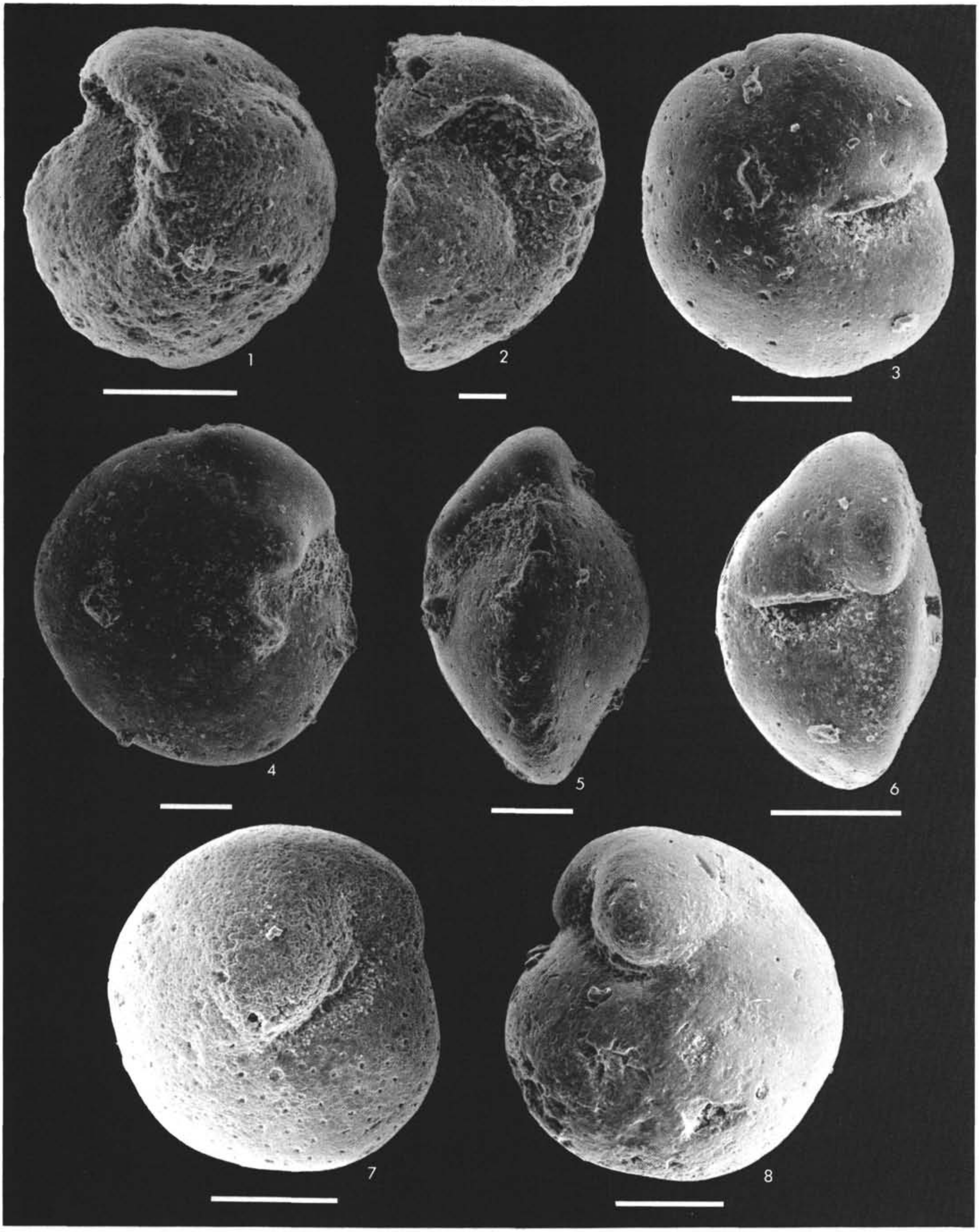

PLATE 11

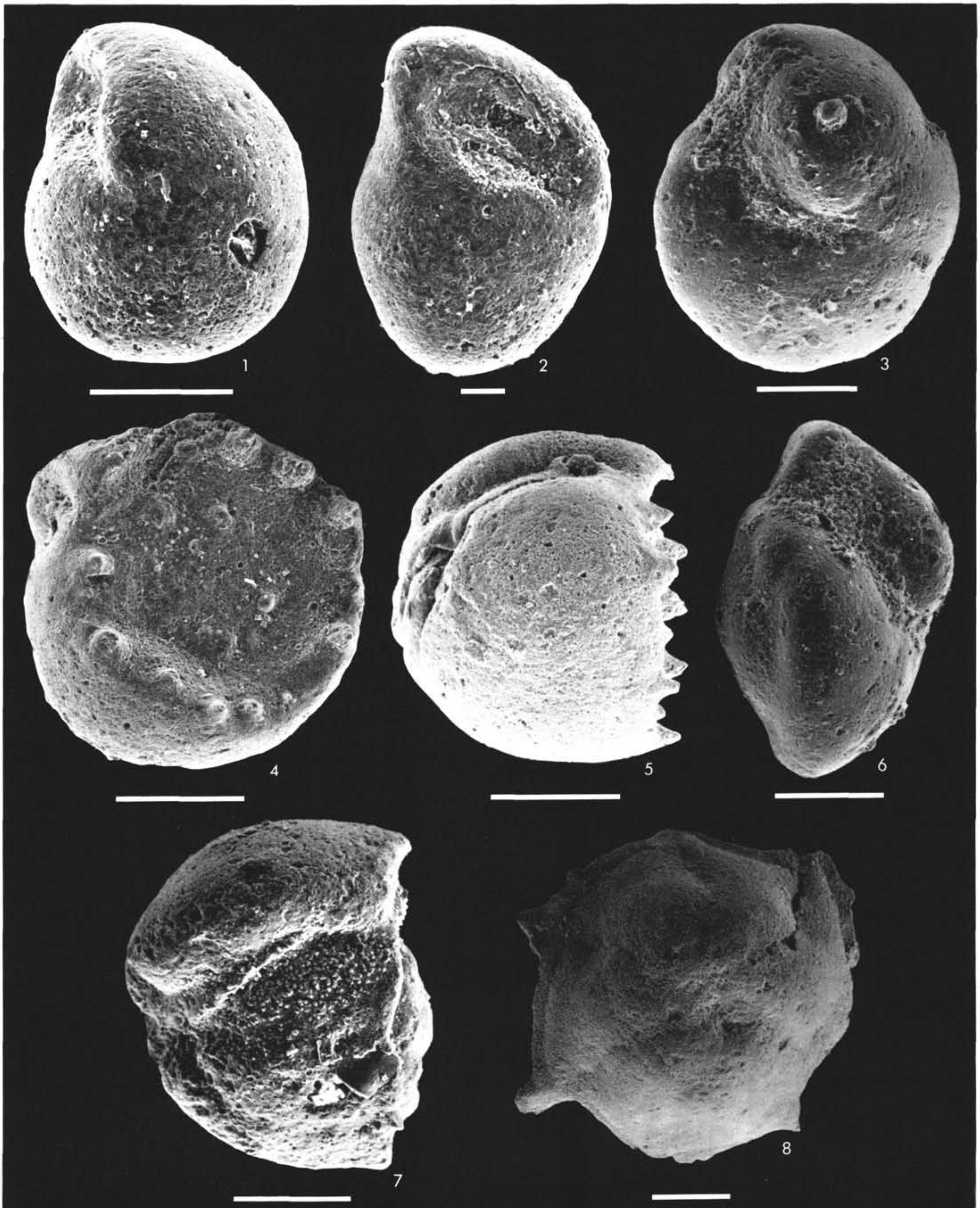

PLATE 12

Figures 1-3 — *Gavelinella cayeuxi mangshlakensis* (Vassilenko). Dot width 100 μm.
1, 2. Sample 355-18-3, 120-122 cm.
1. Peripheral view.
2. Umbilical view of same specimen.
3. Sample 355-19-3, 120-122 cm. Oblique umbilical view.

Figure 4 — *Gavelinella eriksdalensis* (Brotzen). Sample 357-36-4, 100-102 cm. Dot width 100 μm.

Figure 5 — *Gavelinella intermedia* (Berthelin). Sample 356-42-5, 100-102 cm. Dot width 100 μm. Umbilical view.

Figure 6 — *Gavelinella nacatochensis* (Cushman). Sample 356-30-5, 100-102 cm. Dot width 100 μm.

Figures 7, 8 — *Gyroidinoides nitidus* (Reuss). Sample 356-32-5, 101-103 cm. Dot width 100 μm.
7. Umbilical view.
8. Peripheral view of same specimen.

Figure 9 — *Gavelinella stephensoni* (Cushman). Sample 356-34-5, 102-104 cm. Dot width 100 μm.

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PLATE 13

Figure 1 — *Gavelinella velascoensis* (Cushman). Sample 357-33-4, 100-102 cm. Dot width 100 μm.

Figures 2-5 — *Gavelinella whitei* (Martin).
2-4. Sample 357-33-4, 100-102 cm. Dot width 100 μm.
2. Umbilical view.
3. Peripheral view of same specimen.
4. Umbilical view.
5. Sample 355-19-3, 120-122 cm. Dot width 30 μm. Umbilical view.

Figures 6, 7 — *Stensioina pommerana* Brotzen. Sample 356-34-5, 102-104 cm. Dot width 100 μm.
6. Spiral view.
7. Peripheral view.

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PLATE 12

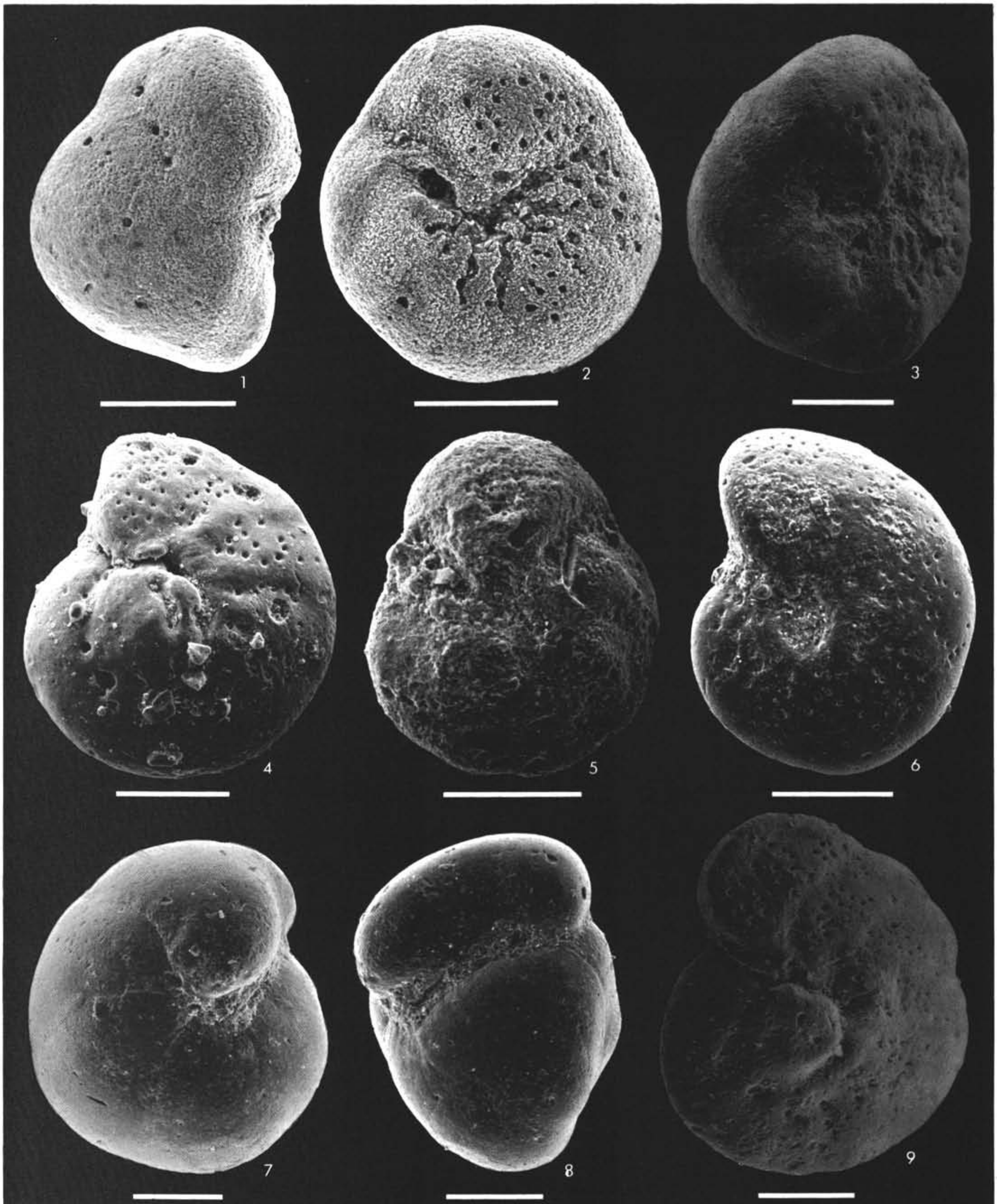

PLATE 13