25. AUTOCHTHONOUS AND DISPLACED (ALLOCHTHONOUS) CRETACEOUS BENTHIC FORAMINIFERS FROM DEEP SEA DRILLING PROJECT LEG 77, SITES 535, 536, 537, 538, AND 540, GULF OF MEXICO[1]

William V. Sliter,[2] U.S. Geological Survey, National Center, Reston, Virginia
and
Isabella Premoli Silva, Dipartimento di Scienze della Terra, Università di Milano, Milano, Italy

ABSTRACT

Mesozoic benthic foraminifers, recovered from five single-bit holes drilled in the southern Gulf of Mexico on Deep Sea Drilling Project Leg 77 are rare, poorly preserved, and scattered throughout the dominantly redeposited sediments. The Mesozoic sequence at basin Sites 535 and 540 consists largely of laminated limestone with smaller amounts of skeletal limestone and pure pelagic limestone, whereas the Mesozoic sediments at basement Sites 536, 537, and 538 (Hole 538A) consist largely of oolitic-oncolitic limestone.

At all sites, benthic foraminifer assemblages consist mainly of mixed bathyal and neritic forms, with neritic material at times strongly diluting and masking the autochthonous bathyal fauna. The recurrent bathyal assemblage is indicative of water depths of 1000–1500 m with a possible increase to 1500 m or greater in the Late Cretaceous in Hole 538A. The present water depths of the sites range from 2742 m in Hole 538A to 3450 m at Site 535. All sites show evidence of reworked older pelagic and shallow-water material throughout the intervals cored.

Maximum influx of shallow-water and reworked material occurs in two pulses—in the Valanginian, and from the latest Albian through middle Cenomanian. In the early episode, the terranes eroded were mainly carbonate platforms of Jurassic and Berriasian age. This event was confined primarily to the western (Yucatan) side of the Gulf of Mexico. Later, in the Cenomanian, the erosional event is recorded on both sides of the Gulf, but was more intense on the eastern (Florida) side. Reworked and displaced shallow-water material was derived from carbonate platforms of late Aptian to middle Albian age.

INTRODUCTION

Mesozoic benthic foraminifers were recovered from five single-bit holes drilled in the southern part of the Gulf of Mexico during DSDP Leg 77 (Fig. 1, Table 1). The foraminifers are extremely rare, generally poorly preserved, and are scattered throughout the dominantly redeposited sediments that range in age from late Berriasian to middle Cenomanian and an abbreviated portion of the latest Cretaceous.

Nevertheless the benthic taxa, identified as to genus or species where possible from isolated specimens and thin sections, are sufficiently indicative of different paleoenvironments ranging from shallow-water carbonate platforms to middle bathyal environments to allow the tentative reconstruction of a paleobathymetric history of the southeastern portion of the Gulf of Mexico. Moreover, some of the benthic taxa are useful for dating the sediments in the absence of age-diagnostic planktonic fossil groups (e.g., foraminifers, calcareous nannofossils, radiolarians, etc.) and for emphasizing episodes of major reworking.

In order to better visualize the heterogeneous characteristics of the sediments recovered from the five holes, the distribution of selected biogenic and nonbiogenic components are plotted against lithologic logs, rock units, and age of sediments at each site complemented by photomicrographs of the most representative microfacies (Figs. 2–9). Occurrence of the major components of each sample analyzed is included on the range charts and in the appendices of the chapter by Premoli Silva and McNulty (this volume).

Sites 535 and 540, designated as "basin sites," are located some 30 km apart on the flank of an erosional valley belonging to the Florida Escarpment system. The other three sites (536, 537, 538), or "basement sites," are located on high-standing fault blocks and are characterized by a thin sedimentary cover resting on basement.

OCCURRENCE OF BENTHIC FORAMINIFERS AND STRATIGRAPHY OF LEG 77 SITES

Basin Sites

Sites 535 and 540 were drilled on a transect across the Florida Escarpment in order to recover as much of the Mesozoic sedimentary sequence as possible from the so-called mid-Cretaceous unconformity (MCU) downward and to utilize the maximum penetration of a single-bit hole. Site 540, the shallowest site, was drilled through the MCU, whereas Site 535 was drilled downslope beneath the MCU (see site chapter, Sites 535 and 540, this volume). The two sites overlap in the uppermost Albian to middle Cenomanian interval, but display disparate sedimentary characteristics. In Hole 535 the interval from Sample 535-17,CC through Section 535-43-2 (240 m) is dominantly laminated limestone with conspicuous shallow-water components (Fig. 2). Correlative sediments at

[1] Buffler, R. T., Schlager, W., et al., *Init. Repts. DSDP*, 77: Washington (U.S. Govt. Printing Office).
[2] Present address: U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025.

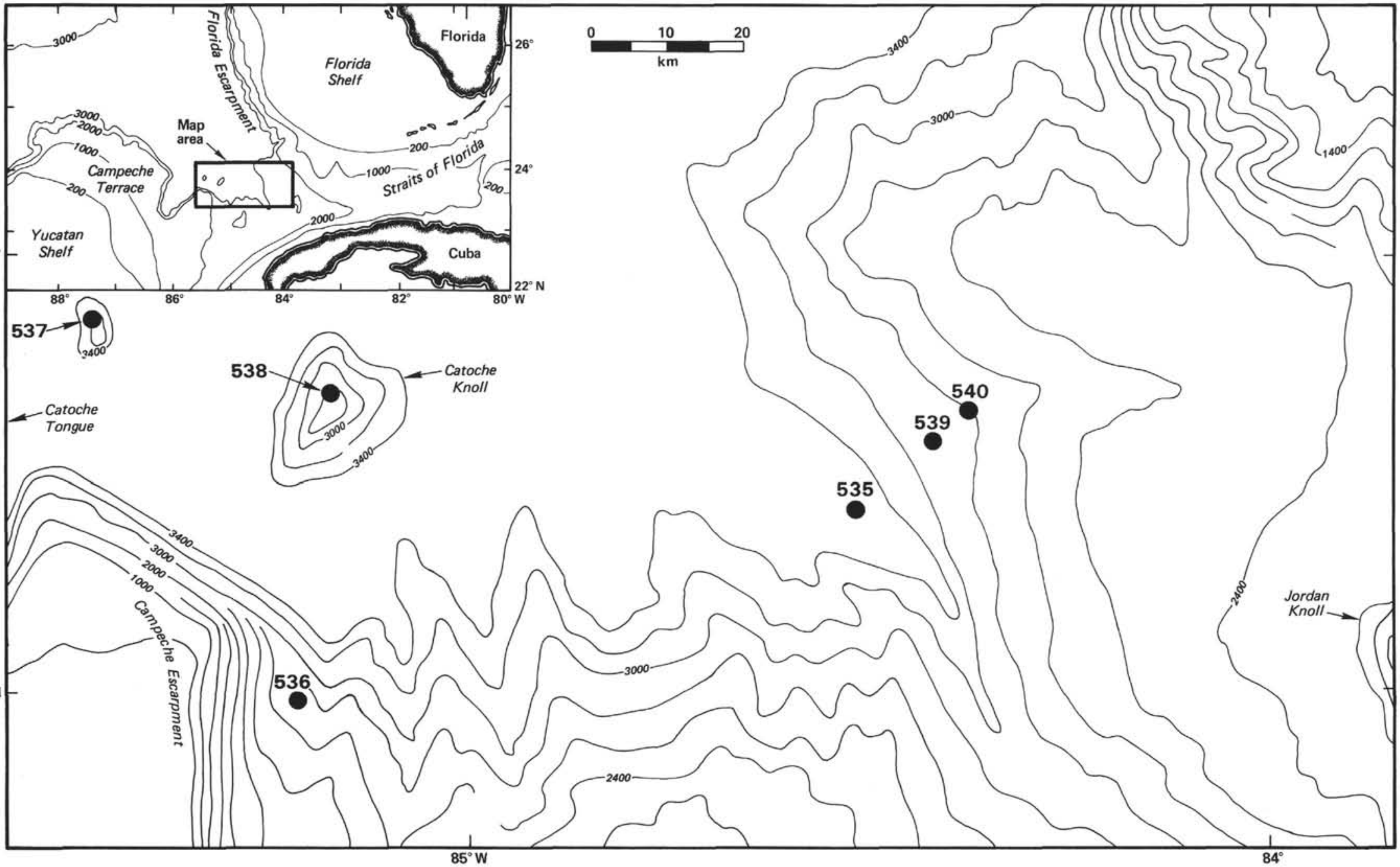


Figure 1. Location map of sites drilled during Leg 77. Bathymetric contours in meters.

Table 1. General data for Leg 77 holes.

Hole	535	540	536	537	538A
Latitude (all north)	23°42.48′	23°49.73′	23°29.39′	23°56.01′	23°50.95′
Longitude (all west)	84°30.97′	84°22.25′	85°12.58′	85°27.62′	85°09.93′
Water depth (m)	3450	2926	2790	3123	2742
Total sub-bottom depth	714.0	745.4	213.0	225.0	332.5
Total recovery (m)	505.07	335.75	65.73	15.87	137.67

Hole 540 (Cores 32 through 40, about 85 m) consist of an upper unit of pebbly mudstone with volcanic sandstone and a lower unit of limestone, laminated limestone, and rare chert (Fig. 3). The interval in Hole 540 from Core 41 to total depth (TD) (360 m) is a continuous sequence of upper Albian through middle Albian limestone and laminated limestone. Apparently this interval from Hole 540 is recorded in Hole 535 by only the scaphitid-bearing rubble of Core 535-45 (see site chapter, Site 535, this volume).

In Hole 535 the interval from Section 535-43-3 to TD (Core 535-79; 714 m) consists largely of laminated limestones that contain several layers of pure, or only slightly mixed, pelagic limestone, rich in nannoconids and calpionellids. Black marly layers rich in pyrite and organic carbon are interbedded with this interval and seem to represent *in situ* deposition. These layers contain, however, a mixture of benthic foraminifers from different environments. In Hole 540 all but a few samples from Cores 41 through 43 contain mixed foraminiferal assemblages.

The characteristics of the different benthic foraminifer assemblages from the basin sites are summarized as follows:

1. The assemblages in general are diverse, but very low in abundance, that is, most species are represented by one or two specimens.

2. Small benthic foraminifers from outer neritic and deeper environments are intensely size-sorted and occur mostly in the size fraction smaller than 150 μm. Typically, the maximum size of the specimens does not exceed 100 μm. This size restriction applies particularly to the taxa indicative of deeper-water environments.

3. Small benthic foraminifers from shallow-water environments and of near normal size occur only in layers (mainly dark and marly) associated with abundant large echinoid and crinoid fragments and occasional aptychi (Samples 535-36-1, 80–82 cm; 535-37-1, 22–24 cm; 535-79-2, 64–68 cm; 540-45-1, 80–82 cm; and 540-70-3, 20–23 cm). In all other cases the shallow-water foraminifers are small, size-sorted, oriented, and accumulated in preferential layers that we interpret as distal turbidites (see Fig. 2, Photographs A–D).

4. Large agglutinated benthic foraminifers, indicative of carbonate platform environments, are scattered throughout the coarse to very coarse layers (see Fig. 2, Photographs E–G).

5. Benthic foraminifer assemblages in general are poorly preserved, mainly recrystallized, and abraded. Shallow-water taxa are the most poorly preserved and some could not be identified specifically.

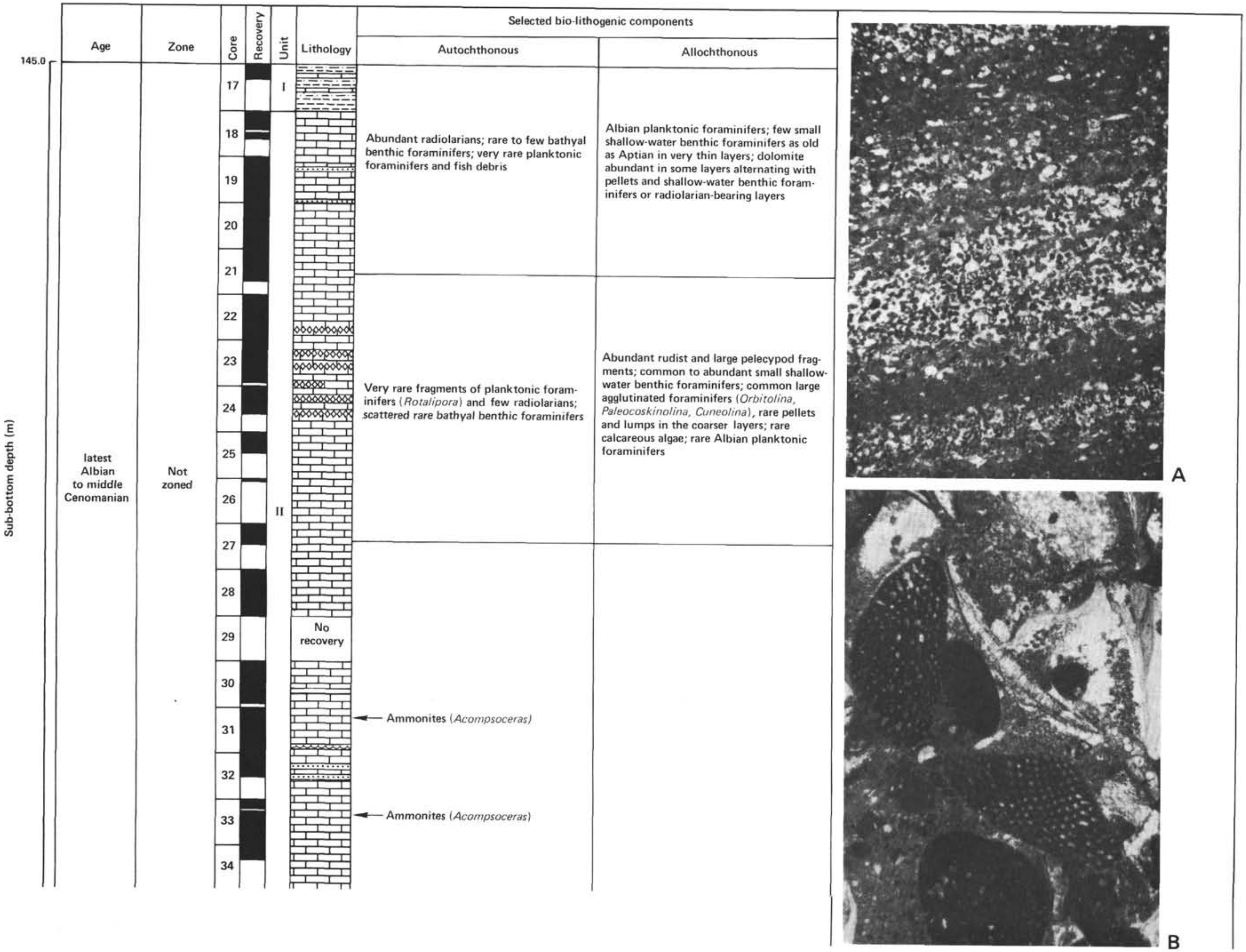
Among the small benthic foraminifers, the most recurrent taxa at Sites 535 and 540 are representatives of *Spirillina*, thin *Dentalina, Gavelinella, Osangularia, Ammodiscus, Ammobaculites*, valvulinids, primitive *Nezzazata, Lenticulina, Quinqueloculina, Textularia, Gyroidinoides, Conorotalites, Patellina, Pseudonodosaria*, other nodosariids, and *Trocholina*.

The most abundant assemblages of smaller foraminifers from Sites 535 and 540 are listed in Appendix A. Larger foraminifers, both calcareous and agglutinated, occur only occasionally in the coarser layers at Sites 535 and 540 with one to several specimens per sample. The most diagnostic occurrences are listed in Appendix B. With rare exception, few specimens of large foraminifers could be identified to a specific level because of either the inappropriate orientation of the thin sections or poor preservation (see, also, Cherchi and Schroeder, this volume).

Basement Sites

Mesozoic sediments from the basement sites range in age from Berriasian to latest Albian with a few layers attributed to the Late Cretaceous (see Premoli Silva and McNulty, this volume, and site chapters, Sites 536–538, this volume). These sediments consist of clean to slightly mixed pelagic chalk resting on limestone rich in shallow-water skeletal-oolitic-oncolitic debris and frequently cemented by pelagic limestone. The stratigraphic distribution of benthic foraminifers indicates that reworking is a common feature of the limestones at all three basement sites. It should be noted that recovery of this unit was very poor (4% in Hole 537; 2.8% in Hole 538A). Although grossly similar in lithology as mentioned previously, these three basement sites display some differences in depositional history and age because of the local geologic overprint.

Site 536 was located on a high-standing fault block belonging to the Campeche Escarpment (Yucatan Peninsula). In Hole 536 only rare Maestrichtian planktonic foraminifers, very poorly preserved, occur at the bottom of Core 536-9 in a unit of volcaniclastic sandstone to siltstone (Fig. 4). The underlying sediments consist of coarse, skeletal limestone that alternates with radiolarian-bearing or planktonic foraminifer–bearing layers. They range in age from late Aptian to latest Albian, but the recovered stratigraphic succession is not continuous. In particular, there is no evidence for the presence of early to middle Albian sediments (see Premoli Silva and McNulty, this volume). The basal dolomitic unit (Core 536-21 to TD) was devoid of any age-diagnostic fossils and its age remains uncertain.


Sub-bottom depth (m)
145.0
Age
Zone
Core
Recovery
Unit
Lithology
Selected bio-lithogenic components
Autochthonous
Allochthonous
latest Albian to middle Cenomanian
Not zoned
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
I
II
No recovery
Abundant radiolarians; rare to few bathyal benthic foraminifers; very rare planktonic foraminifers and fish debris
Albian planktonic foraminifers; few small shallow-water benthic foraminifers as old as Aptian in very thin layers; dolomite abundant in some layers alternating with pellets and shallow-water benthic foraminifers or radiolarian-bearing layers
Very rare fragments of planktonic foraminifers (Rotalipora) and few radiolarians; scattered rare bathyal benthic foraminifers
Abundant rudist and large pelecypod fragments; common to abundant small shallow-water benthic foraminifers; common large agglutinated foraminifers (Orbitolina, Paleocoskinolina, Cuneolina), rare pellets and lumps in the coarser layers; rare calcareous algae; rare Albian planktonic foraminifers
Ammonites (Acompsoceras)
Ammonites (Acompsoceras)
A
B

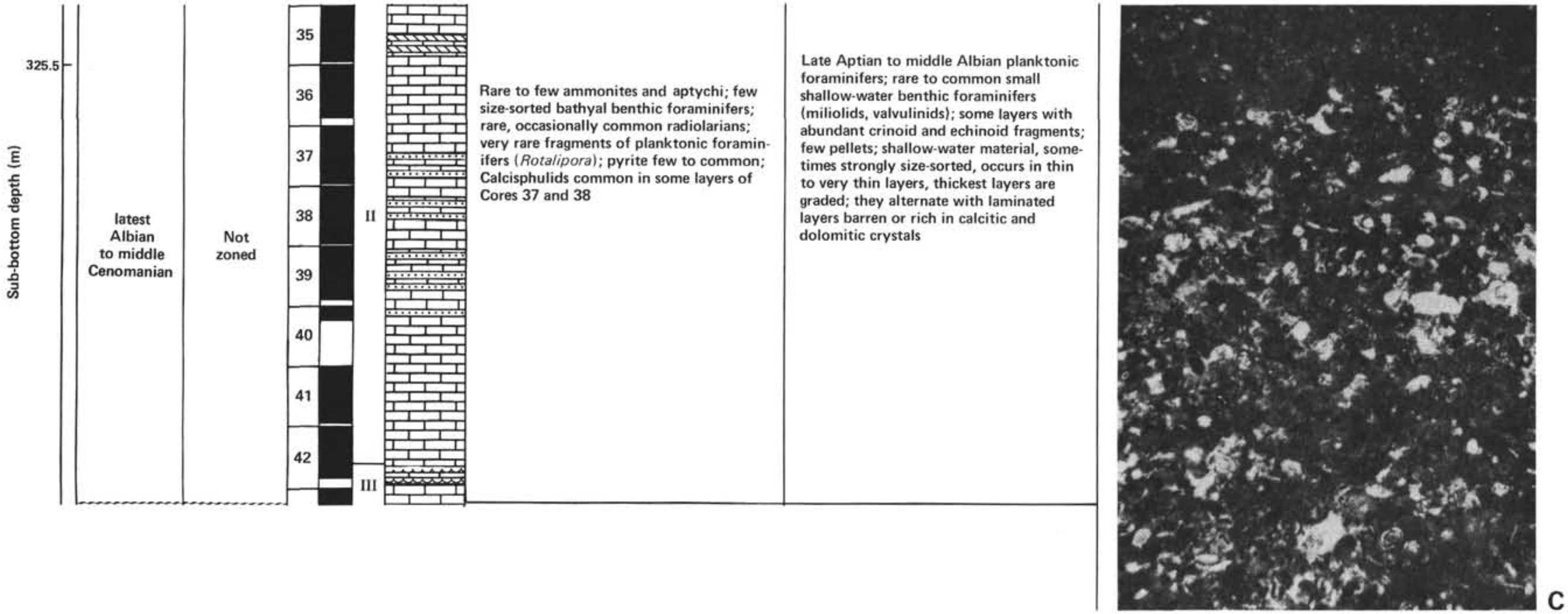
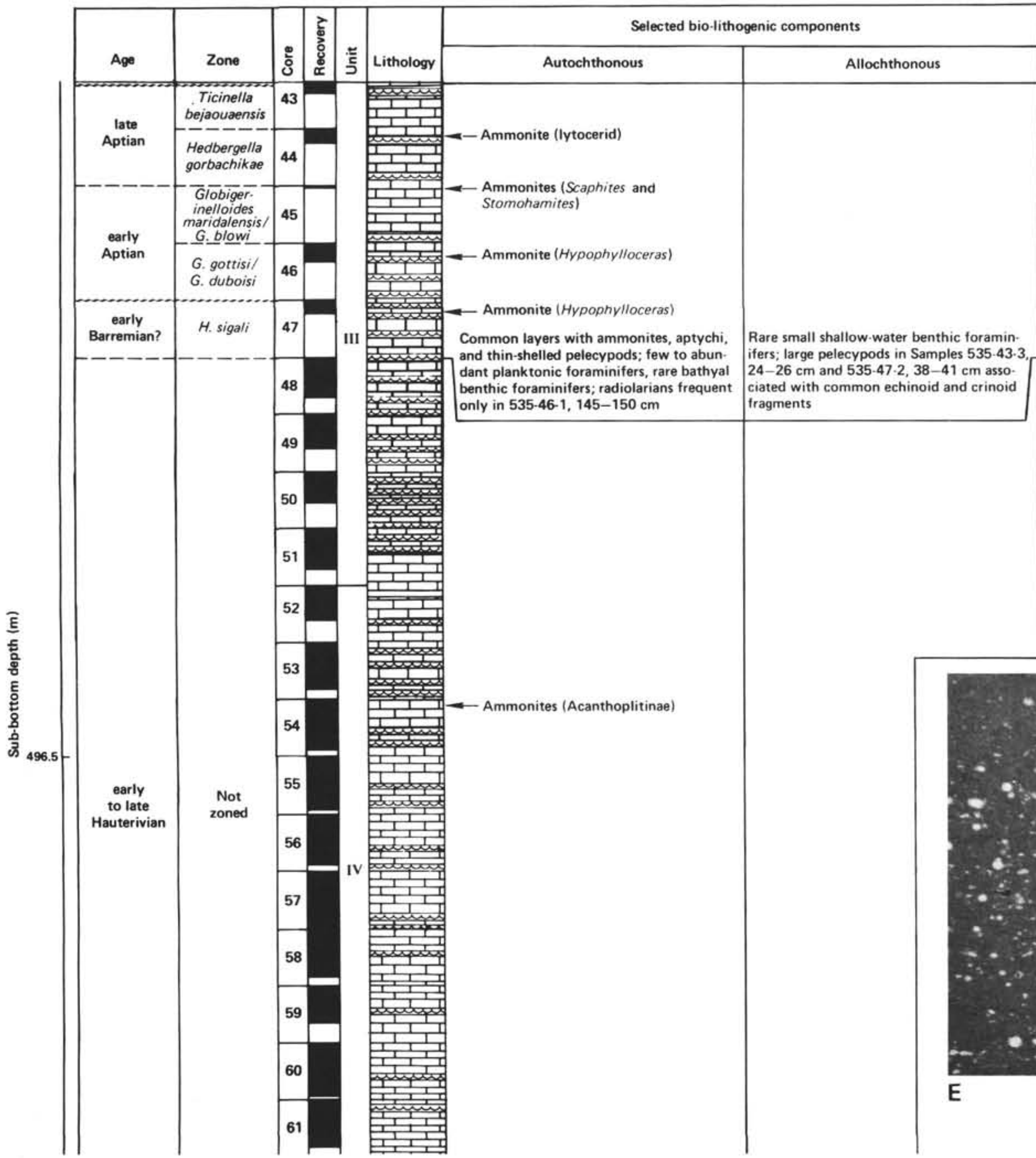
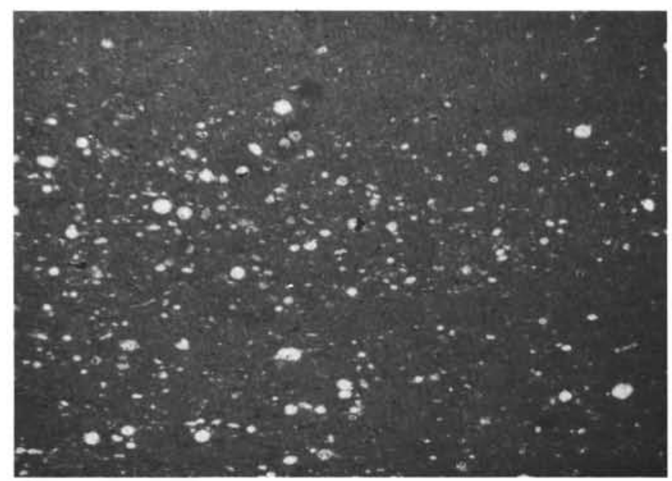


Figure 2. Distribution of autochthonous and allochthonous material at Site 535 plotted against lithology. A. Sample 535-20-2, 56–58 cm, ×15. Microfacies cutting two graded layers. Note the concentration of small miliolids and agglutinated foraminifers, in the coarser part. B. Sample 535-23-1, 55–56 cm, ×75. Skeletal limestone rich in *Orbitolina* (*O.* sp. cf. *O. texana*) and large fragments of rudists. C. Sample 535-37-5, 97–98 cm, ×15. Coarser part of graded layer rich in miliolids. D. Sample 535-43-3, 18–20 cm, ×15. Microfacies of indurated limestone (hardground?) rich in pelecypods, echinoid fragments, planktonic foraminifers, aptychi, and rare ammonites. E. Sample 535-73-3, 20–23 cm, ×22.5. Micrite with oriented radiolarians concentrated in a layer. F. Sample 535-76-1, 119–121 cm, ×60. Nannoconid-calpionellid micrite. Note *Calpionellites darderi* and *Tintinnopsella carpathica* in the center. G. Sample 535-79-1, 109–113 cm, 22.5. Microfacies of indurated limestone (hardground?). The lower part is rich in protoconchs and juveniles of ammonites with benthic foraminifers, and coated fragments of large pelecypods. The upper part is calpionellid-nannoconid micrite with rare radiolarians and aptychi.


Sub-bottom depth (m)
496.5
Age
Zone
Core
Recovery
Unit
Lithology
Selected bio-lithogenic components
Autochthonous
Allochthonous
late Aptian
Ticinella bejaouaensis
Hedbergella gorbachikae
early Aptian
Globigerinelloides maridalensis/ G. blowi
G. gottisi/ G. duboisi
early Barremian?
H. sigali
early to late Hauterivian
Not zoned
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
III
IV
Ammonite (lytocerid)
Ammonites (Scaphites and Stomohamites)
Ammonite (Hypophylloceras)
Ammonite (Hypophylloceras)
Common layers with ammonites, aptychi, and thin-shelled pelecypods; few to abundant planktonic foraminifers, rare bathyal benthic foraminifers; radiolarians frequent only in 535-46-1, 145–150 cm
Rare small shallow-water benthic foraminifers; large pelecypods in Samples 535-43-3, 24–26 cm and 535-47-2, 38–41 cm associated with common echinoid and crinoid fragments
Ammonites (Acanthoplitinae)

D



E

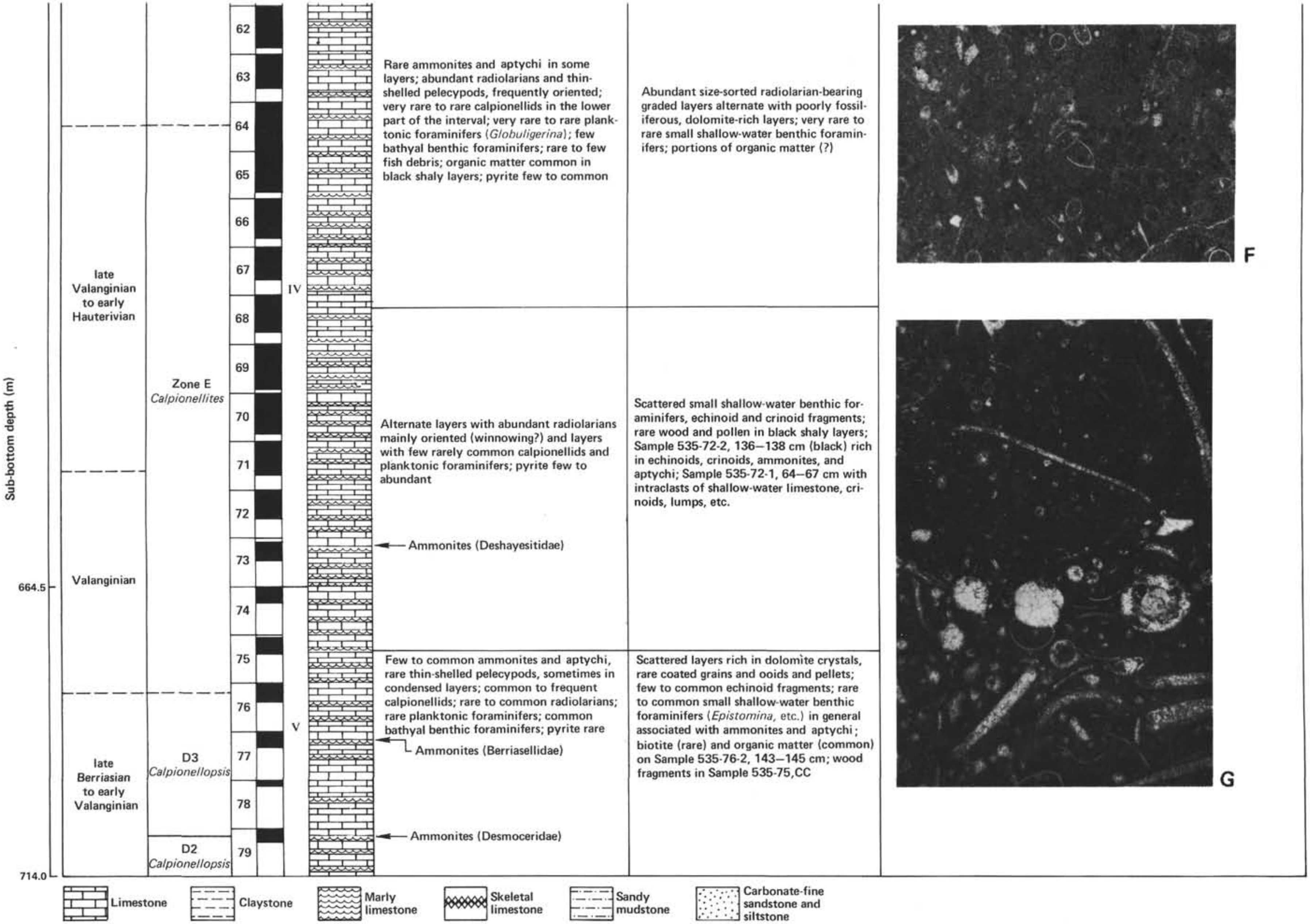


Figure 2. (Continued).

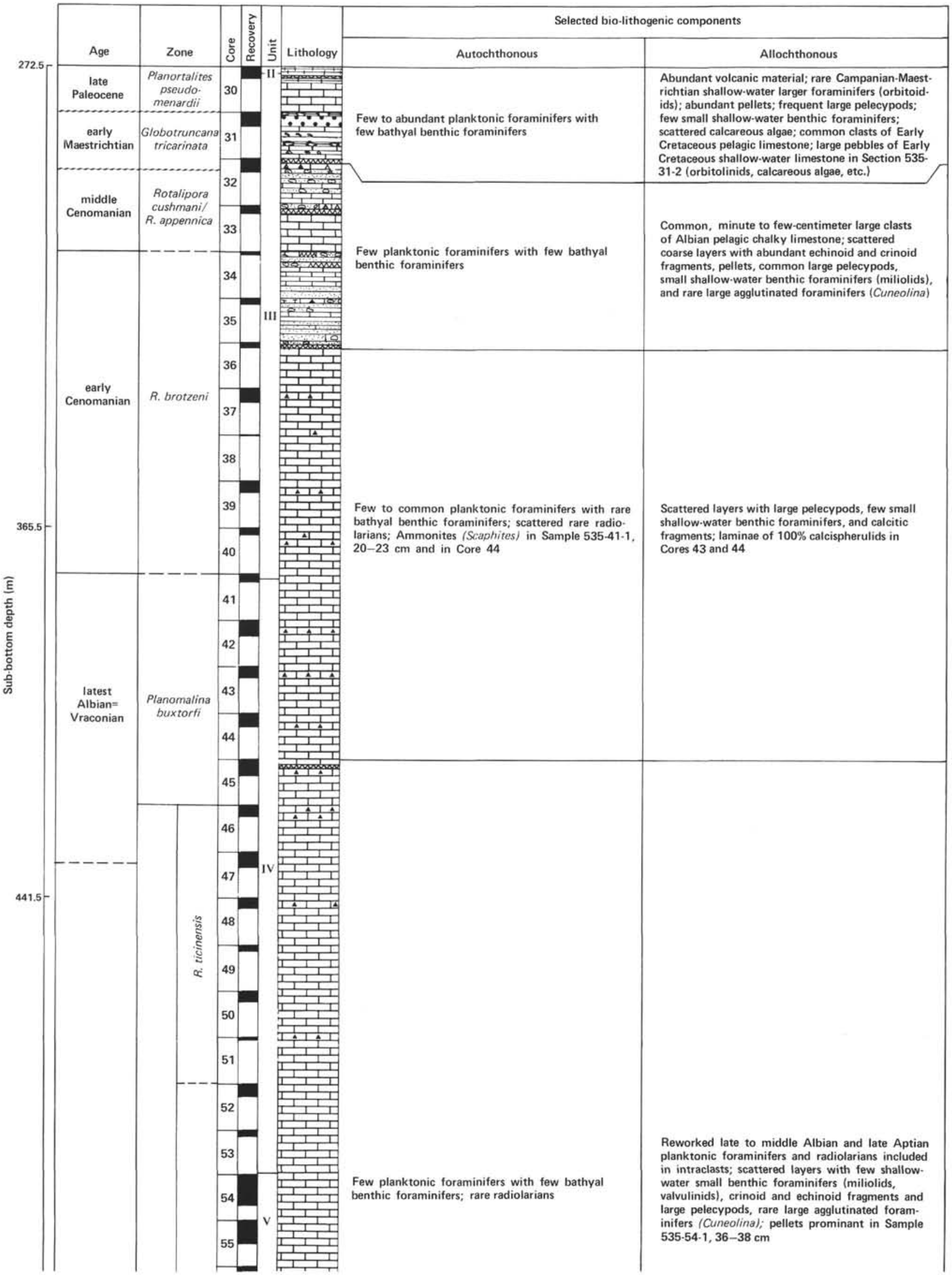


Figure 3. Distribution of autochthonous and allochthonous material at Site 540 plotted against lithology.

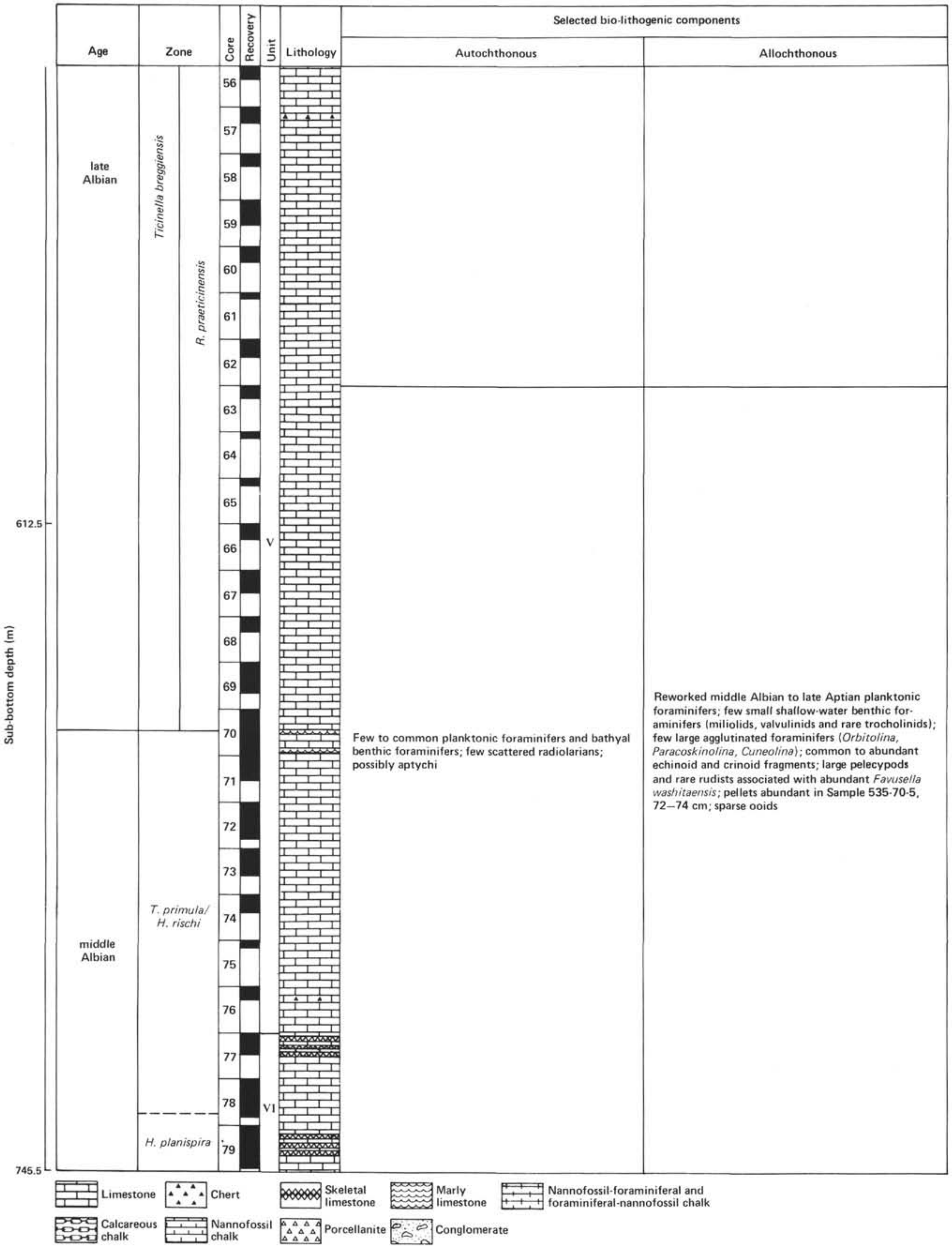


Figure 3. (Continued).

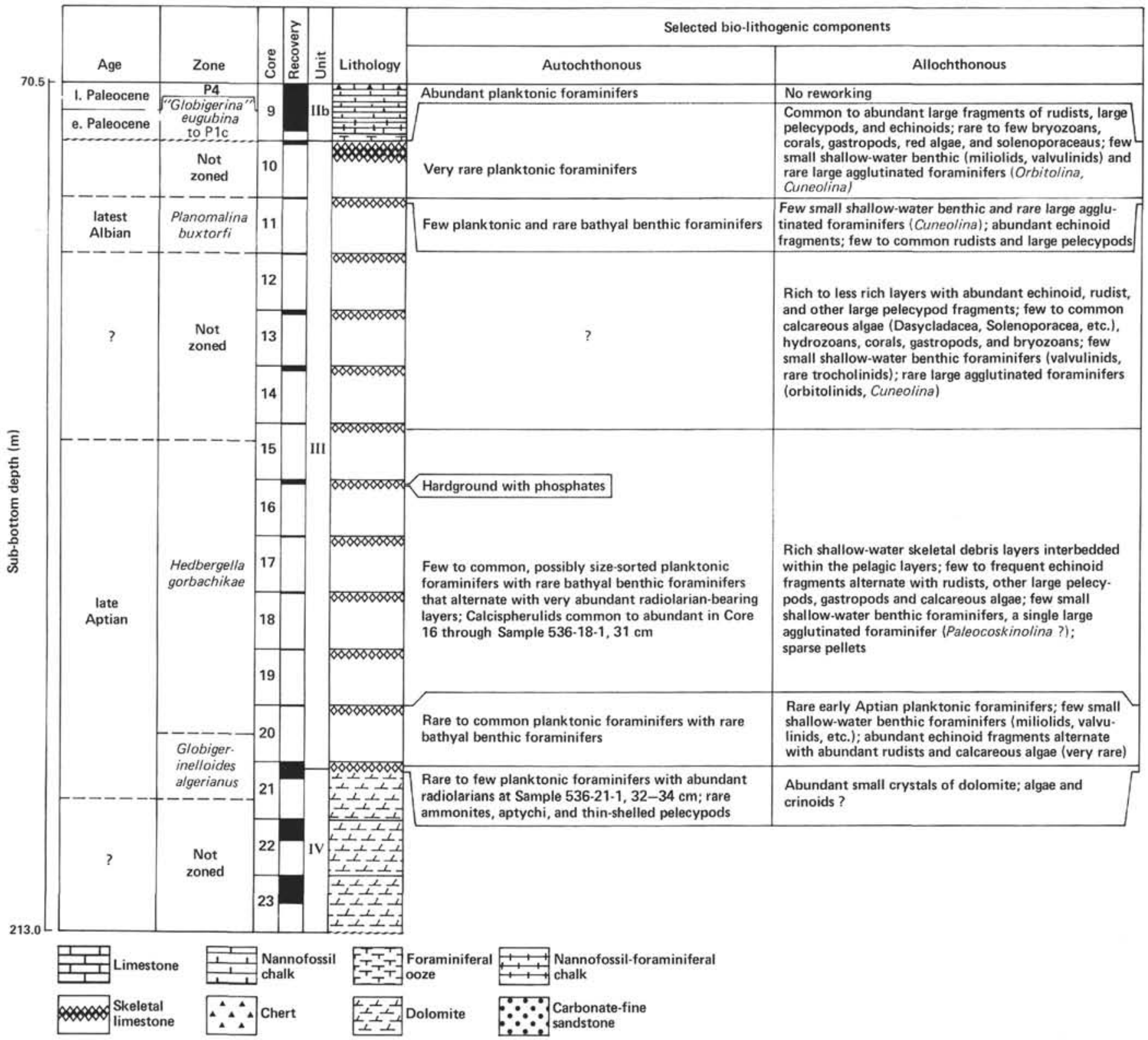


Figure 4. Distribution of autochthonous and allochthonous material at Site 536 plotted against lithology. A. Sample 536-10-1, 44–45 cm, ×75. Transverse section of *Trocholina*? in a skeletal limestone. B. Sample 536-11-1, 13–15 cm, ×70. Axial section of *Praeglobotruncana stephani* contained in a poorly cemented skeletal limestone. C. Sample 536-11-1, 13–15 cm, ×70. Axial section of *Planomalina buxtorfi*?. D. Sample 536-14-1, 56–58 cm, ×37.5. Unidentified agglutinated foraminifer with complex wall structure. E. Sample 536-16-1, 0–10 cm, ×75. Planktonic foraminifer micrite. F. Sample 536-16-1, 66–69 cm, ×60. Oblique section of *Orbitolina*. G. Sample 536-21-1, 5–10 cm, ×5. Unidentified uncrusting organism.

Benthic foraminifers are scattered throughout. They are rare to very rare in the pelagic layers where only few representatives of the genera *Dentalina, Dorothia, Pseudonodosaria, Lenticulina*, and *Textularia* are recorded. More abundant benthic assemblages occur in the coarse, skeletal limestone that yielded more diversified faunas including some age-diagnostic species of large agglutinated and small benthic foraminifers.

Among the small benthic foraminifers, miliolids and the valvulinids are constant components in all samples. In contrast, specimens of *Lenticulina, Patellina, Ammobaculites*, and *Trocholina* are rare. Specimens of *Trocholina* in particular are well represented in Samples 536-15-1, 31–34 cm and 536-20-1, 10–11 cm with the species *Trocholina infragratulata* Noth and *T. valdensis* (Reichel).

Benthic taxa from Site 536 identified in thin section are listed in Appendix C.

Larger foraminifers are present throughout Cores 536-10 to 536-16, but their preservation is very poor. In particular, identifiable forms occur in the following samples:

536-10-1, 44–45 cm *Cuneolina pavonia parva* Henson
536-14-1, 29–30 cm *Orbitolina* sp. aff. *O. texana* (Roemer)

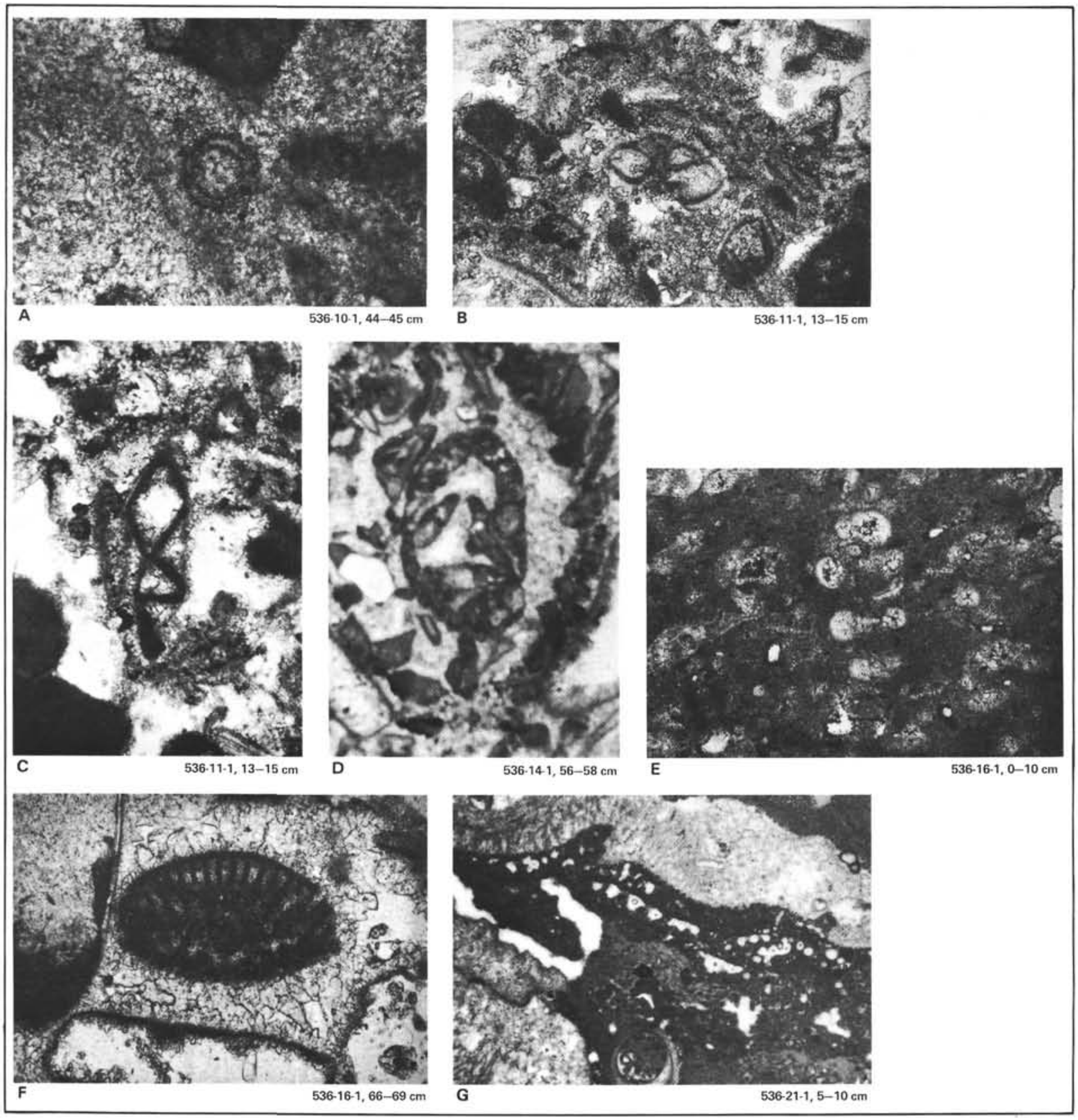


Figure 4. (Continued).

536-14-1, 56–58 cm	complex lituolids
536-15-1, 26–28 cm	orbitolinid
536-16-1, 66–69 cm	*Orbitolina* sp.

Site 537 was located on an isolated, unnamed, high-standing fault block north of the Campeche Escarpment. The contact between Cenozoic and Mesozoic sediments at this site was strongly disturbed during the core-cutting procedures, largely because of the different induration of the sediments (Figs. 5 and 6). Nevertheless, this interval that occurs in Section 537-3-2 is reconstructed as follows:

From 20 to 43 cm

Volcaniclastic sandstone with rare Maestrichtian planktonic foraminifers and a single specimen of the larger foraminifer *Pseudorbitoides.*

At 45 cm

An assumed thin veneer of Maestrichtian chalk with abundant, well-preserved planktonic foraminifers.

From 45 to 52 cm

A hardground consisting of indurated limestone with manganese and possibly phosphorite of early Aptian age.

From 53 to 75 cm

Soft white chalk of early Aptian age.

The assumption that a thin veneer of Maestrichtian chalk was present in Sample 537-3-2, 45 cm is supported by the occurrence of a large, well-preserved fauna of planktonic foraminifers mixed in the soupy sediments that now envelop the indurated limestone of the hardground. These foraminifers display a much better and

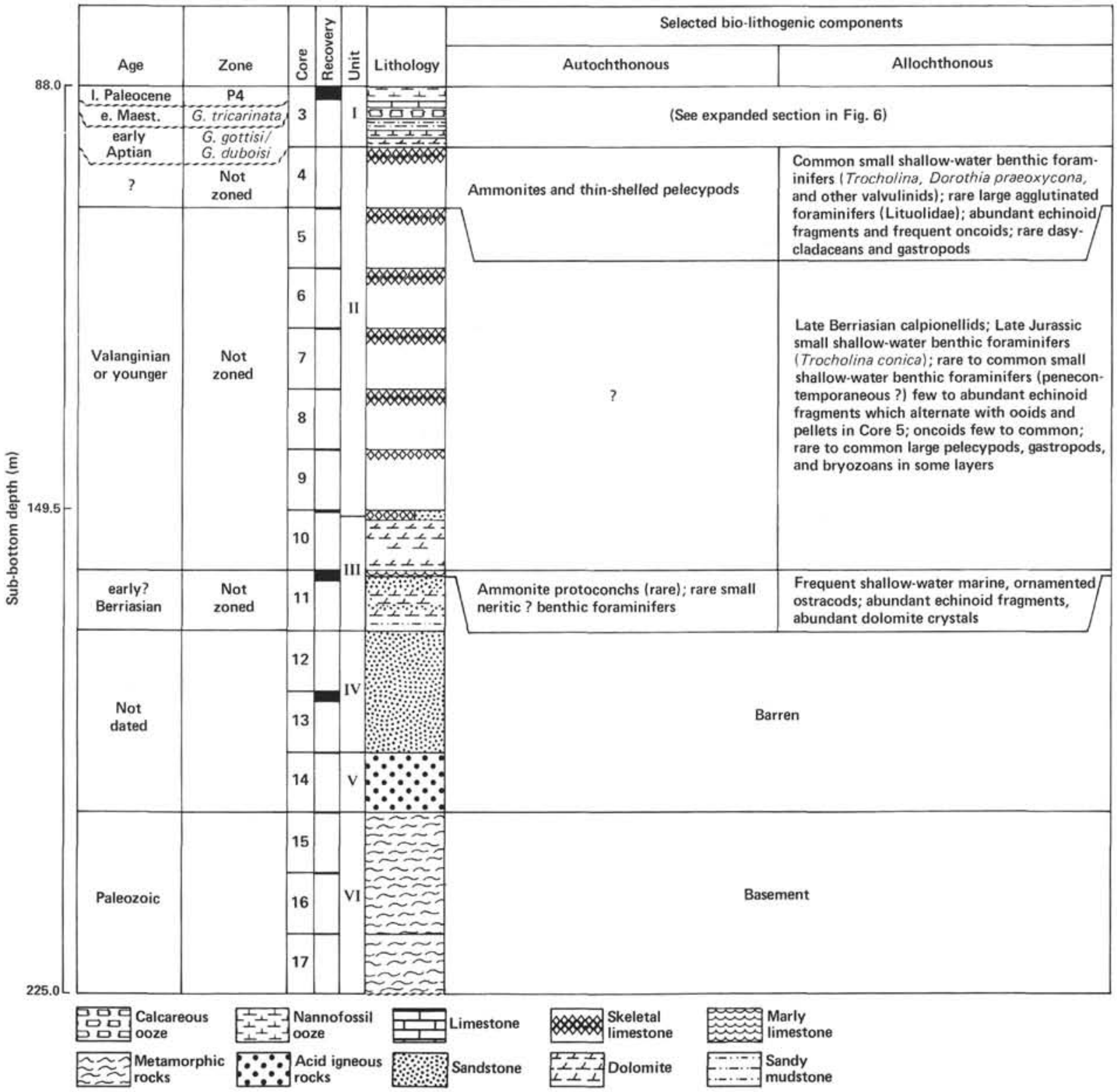


Figure 5. Distribution of autochthonous and allochthonous material at Site 537 plotted against lithology. A. Sample 537-9-1, 3–6 cm, ×75. Micrite? with *Caucasella hoterivica*. B. Sample 537-10-1, 5 cm, ×25. Unidentified dasycladacean in skeletal limestone. C. Sample 537-10-1, 23–24 cm, ×75. Skeletal limestone with *Trocholina infragranulata* and calpionellids. D. Same as C without trocholinid.

totally different preservation than those of comparable age (above) or much older (below) that were found in the volcaniclastic sandstone and the hardground, respectively.

Abundant benthic foraminifers occur in the interval 537-3-2, 42–75 cm. Species identifications based on isolated specimens from this interval include:

537-3-2, 42–43 cm

Conorotalites sp. cf. *C. aptiensis* (Bettenstaedt)
Gavelinella sp.
Hyperammina sp.
Patellina subcretacea Cushman and Alexander
Praebulimina cushmani (Sandidge)
Praebulimina nannina (Tappan)
Spirillina minima Schacko
Trocholina infragranulata Noth

537-3-2, 50–57 cm

Astacolus crepidularis (Roemer)
Astacolus planiusculus (Reuss)
Dorothia subtrochus (Bartenstein)
Gaudryina sp.
Gyroidinoides sp.
Lagena sztejnae Dieni and Massari
Lagena sp.
Lenticulina gaultina (Berthelin)
Lenticulina muensteri (Roemer)
Lenticulina subalata (Reuss)
Lenticulina subangulata (Reuss)
Osangularia sp.
Patellina subcretacea Cushman and Alexander
Praebulimina cushmani (Sandidge)
Praebulimina sp.
Spirillina minima Schacko
Stensioina granulata (Olbertz)

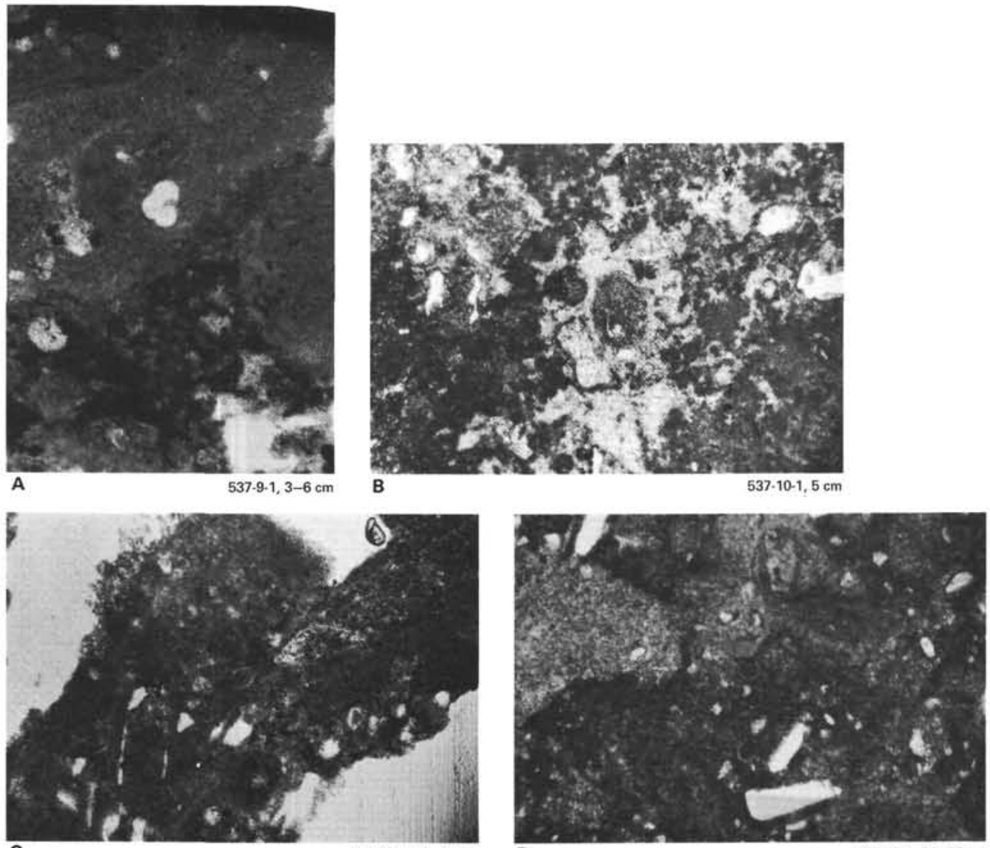


Figure 5. (Continued).

Textularia foeda Reuss
Trocholina valdensis (Reichel)

537-3-2, 64–66 cm
Astacolus sp.
Conorotalites aptiensis (Bettenstaedt)
Dentalina communis (d'Orbigny)
Dentalina gracilis (d'Orbigny)
Dentalina guttifera (d'Orbigny)
Dorothia subtrochus (Bartenstein)
Gavelinella barremiana (Bettenstaedt)
Gavelinella intermedia (Berthelin)
Lenticulina muensteri (Roemer)
Lenticulina subalata (Reuss)
Marginulinopsis cephalotes (Reuss)?
Neobulimina sp.
Spirillina minima Schacko
Trocholina infragranulata Noth

Except for Sample 537-3-2, 64–66 cm, the benthic assemblages also are highly mixed. In addition, specimens of *Trocholina* and *Stensioina* were found reworked in the overlying Tertiary sediments.

Below the chalk (from Cores 537-4 to 537-10), skeletal-oolitic limestone was recovered that contained rare to few calpionellids, but the recovery from this section was only 4% of the total interval cored. The fossiliferous sequence consisting of silty marls ends in Sample 537-11-1, 137 cm. Small benthic foraminifers are a constant, but inconspicuous, component of the assemblages recorded from the skeletal limestone (Fig. 7).

Large agglutinated foraminifers are, instead, very rare and include a few specimens that belong to the Lituolidae. Their preservation is so poor that they could not be identified even at the generic level.

The more abundant foraminiferal assemblages identified from thin sections occur in the following samples:

537-4-1, 20 cm
Ammobaculites sp.
Dorothia praeoxycona Moullade
Lenticulina sp.
Pseudonodosaria sp.
Trocholina infragranulata Noth
Trocholina sp. cf. *T. valdensis* (Reichel)
complex lituolids

537-5-1, 7–8 cm
Dorothia praeoxycona Moullade
Lenticulina sp.
Trocholina conica (Schlumberger)
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel) (common)
Trocholina valdensis (Reichel) (common)
verneuilinids

537-5-1, 24–25 cm
Astacolus sp.
Dorothia praeoxycona Moullade
Lenticulina sp.
sessile forms

537-5-1, 37–38 cm
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)
Trocholina valdensis (Reichel)

537-5-1, 40 cm
Ammobaculites sp.
Dorothia praeoxycona Moullade
Lenticulina sp.
Spirillina sp.

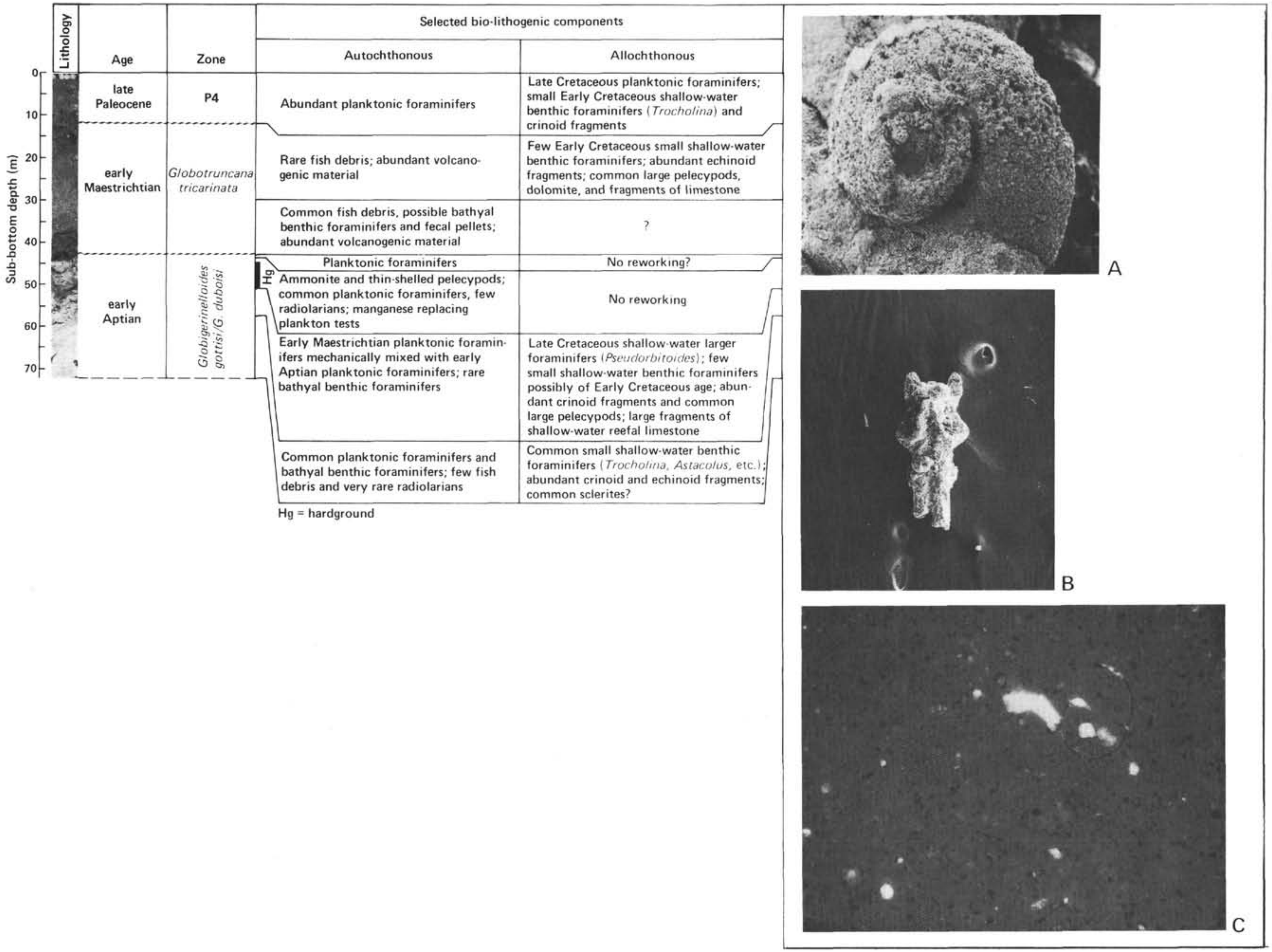


Figure 6. Expanded section of Section 537-3-2 showing detailed distribution of autochthonous and allochthonous material. Photomicrographs all from Sample 537-3-2, 43–50 cm (hardground). A. Ammonite mold on broken surface, ×3. B. Crinoid, ×3. C. Microfacies of the hardground, ×15. Note the manganese(?)-impregnated casts of ammonites and planktonic foraminifers.

Trochammina sp.
miliolids
sessile forms
537-6-1, 14–15 cm
Ammodiscus sp.
Astacolus sp.
Dorothia sp.
Trochammina sp.
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)
Trocholina valdensis (Reichel)
Turrespirillina sp.
537-7-1, 3–4 cm
Astacolus sp.
Dorothia praeoxycona Moullade
Gavelinella?
Spirillina sp.
Trocholina valdensis (Reichel)
miliolids
textulariids
537-8-1, 3–4 cm
Astacolus sp.
Dorothia praeoxycona Moullade
Lenticulina sp.
Textularia sp.
Trocholina conica (Schlumberger) (few)
Trocholina sp. cf. *T. alpina* (Leupold)
Trocholina valdensis (Reichel)
nodosariids
large agglutinated foraminifers
537-9-1, 10–11 cm
Spirillina sp.
Trocholina infragranulata Noth (few)
Trocholina sp.
lituolids
537-10-1, 5 cm
Trocholina infragranulata Noth
nodosariids
textulariids
537-10-1, 13 cm
Ammobaculites sp.
Dorothia
Lenticulina sp.
Trocholina sp. cf. *T. conica* (Schlumberger)
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)
complex lituolids
miliolids
nodosariids
incrusting foraminifers
537-10-1, 23–24 cm
Trocholina infragranulata Noth

The silty marls in Core 537-11, the oldest fossiliferous lithotype recovered, yielded rare benthic foraminifers of very small size associated with large amounts of crinoid fragments and ostracodes (see Oertli, this volume). They are:

Sample 537-11-1, 1–10 cm
Hyperammina sp.
Glomospira sp.
Dentalina sp.
Pseudonodosaria sp.

Hole 538A at Site 538 was located on Catoche Knoll, a high-standing fault block to the east of Site 537. It is the only hole among those drilled during Leg 77 in which latest Cretaceous sediments were recovered. Planktonic foraminifers from Sample 538A-21-1, 63 cm to Sample 538A-21-4, 110 cm date this apparently uniform interval to the early Maestrichtian at the top, the early Campanian in the middle portion, and the Santonian at the base (Figs. 8–9). However, this is a condensed sequence, in which the biostratigraphic horizons mentioned previously are separated by hiatuses that do not result in any obvious lithologic break. Moreover, the layers at the bottom of this interval (Sample 538A-21-4, 19–110 cm) do become coarser and slightly graded (Fig. 9).

Benthic foraminifers are very rare except in the lowermost coarser portion mentioned previously, where more abundant assemblages occur. Of particular importance are specimens recorded from the following samples:

538A-21-4, 27–29 cm
Aragonia sp.
Trocholina sp.
538A-21-4, 53–54 cm
Aragonia sp.
Dorothia oxycona (Reuss)
Lenticulina sp.
Nuttallinella sp.
Ramulina sp.
Reophax sp.
Stensioina pommerana Brotzen
Trocholina sp.
538A-21-4, 72–73 cm
Aragonia sp.
Tristix sp.
Tritaxia disjuncta (Cushman and Jarvis)

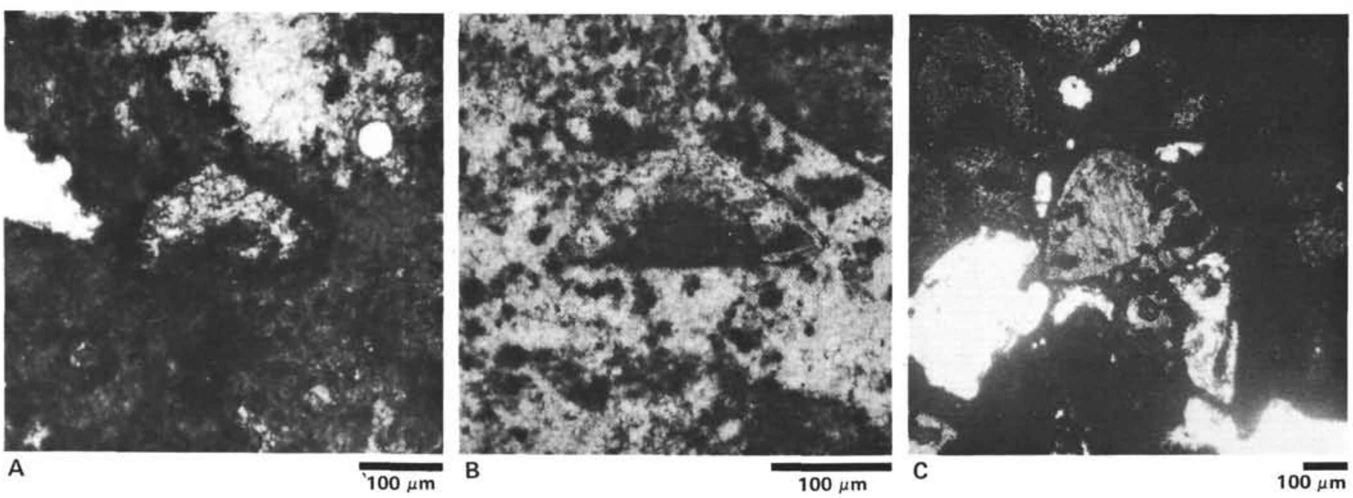


Figure 7. A. *Trocholina infragranulata* Noth. Sample 537-10-1, 5 cm. B. *Trocholina infragranulata* Noth. Sample 537-10-1, 23–24 cm. C. *Trocholina* sp. cf. *T. alpina* (Leupold). Sample 537-8-1, 3–4 cm. All scales 100 μm.

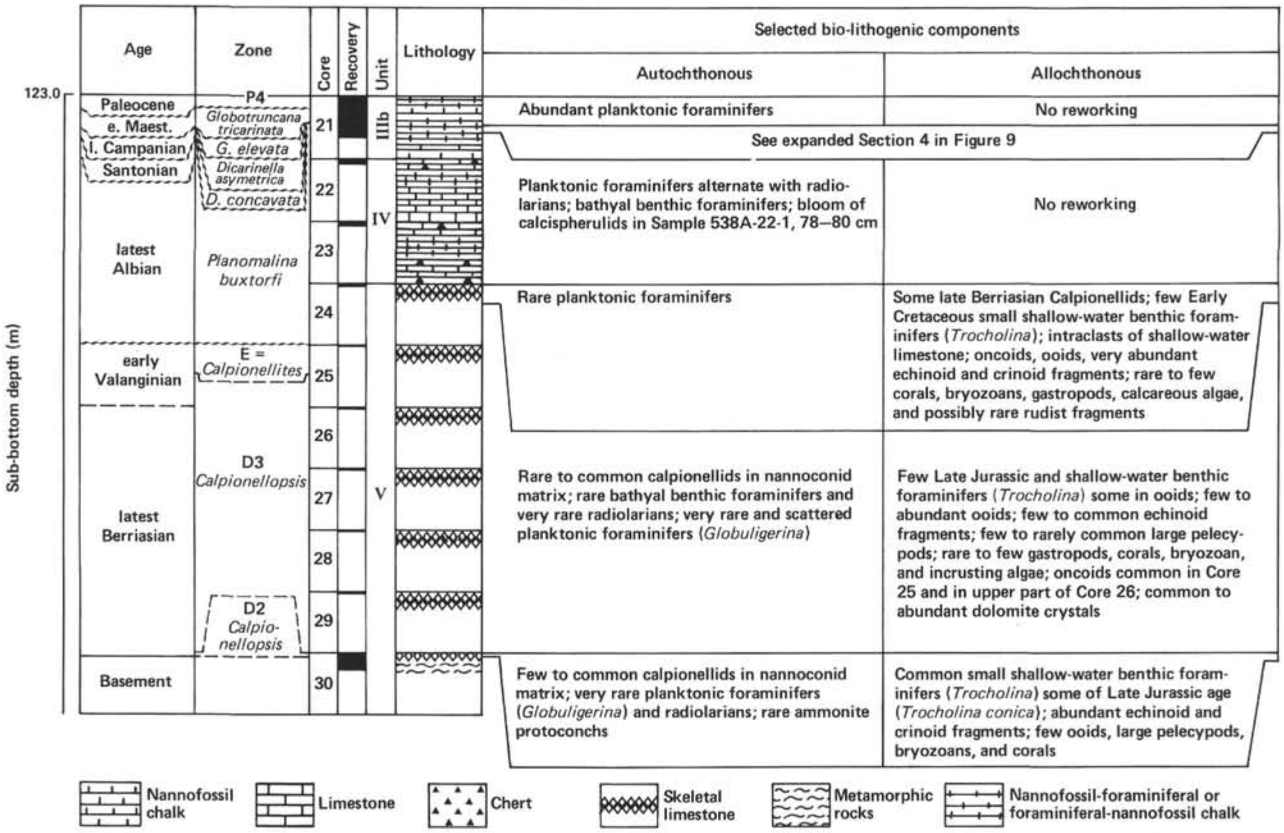


Figure 8. Distribution of autochthonous and allochthonous material in Hole 538A plotted against lithology. A. Sample 538A-24-1, 5–8 cm, ×37.5. Oosparite. Note *Lenticulina* in one ooid. B. Sample 538A-24-1, 15–16 cm, ×75. Oncolites with calpionellids in the matrix. C. Sample 538A-24-1, 15–16 cm, ×70. Axial section of *Rotalipora appenninica* associated with oncolites and other coated fragments. D. Sample 538A-25-1, 7–9 cm, ×75. Note some calipionellids in the matrix and in a micritic grain. E. Sample 538A-27-1, 4–5 cm, ×75. More micritic portion of skeletal limestone containing several calpionellids (*Calpionelites darderi*) and dolomite crystals. F. Sample 538A-27-1, 12–13 cm, ×75. More micritic portion of skeletal limestone containing few calpionellids (*Calpionellopsis simplex*) and dolomite crystals. G. Sample 538A-29-1, 11–12 cm, ×200. Nannoconid micrite with calpionellid. H. Sample 538A-30-1, 2–3 cm, ×75. Recrystallized radiolarian(?). I. Sample 538A-30-1, 2–3 cm, ×75. Note several specimens of *Calpionella alpina* in the matrix. J. Sample 538A-30-1, 2–3 cm, ×75. Skeletal limestone with large fragments of megafossils, trocholinids (oblique cut), possible *Spirillina* associated with *Calpionella alpina* (in the center). K. Sample 538A-30-1, 2–3 cm, ×75. Two specimens of *Calpionella alpina* with obliquely cut *Trocholina* and crinoid fragments.

Tritaxia trilatera (Cushman)
Trocholina sp.

538A-21-4, 78–80 cm
Aragonia materna kugleri Beckmann and Koch
Dorothia oxycona (Reuss)
Gaudryina laevigata Franke
Gavelinella barremiana Bettenstaedt
Gyroidinoides sp. cf. *G. beisseli* (Schijfsma)
Lenticulina sp.
Osangularia corderiana (d'Orbigny)
Osangularia sp. cf. *O. whitei* (Brotzen)
Pleurostomella sp. cf. *P. austinana* Cushman
Pseudotextularia?
Reussella pseudospinulosa Troelsen
Stensioina pommerana Brotzen
Tritaxia aspera (Cushman)
Trocholina sp. cf. *T. infragranulata* Noth
Trocholina valdensis (Reichel)
Valvulineria lenticula (Reuss)

538A-21-4, 83–84 cm
Patellina feifeli (Paalzow)
Patellina turriculata (Dieni and Massari)
Trocholina infragranulata Noth
Trocholina valdensis (Reichel)

538A-21-4, 93–94 cm
Aragonia materna kugleri Beckmann and Koch
Astacolus sp.
Conorotalites aptiensis (Bettenstaedt)
Dentalina sp.
Dorothia conula (Reuss)
Dorothia subtrochus (Bartenstein)
Ellipsoidella sp.
Gaudryina laevigata Franke
Gaudryina pyramidata Cushman
Gavalinella intermedia (Berthelin)
Gyroidinoides sp.
Lenticulina sp.
Osangularia sp.
Patellina feifeli (Paalzow)
Patellina subcreatcea Cushman and Alexander
Patellina turriculata Dieni and Massari
Pleurostomella sp.
Praebulimina sp.
Tristix sp.
Trocholina infragranulata Noth
Valvulineria loetterli (Tappan)

538A-21-4, 107–109 cm
Same species as in previous sample with the loss of *Ellipsoidella* sp.

The remaining part of Core 538A-21 except the core-catcher sample consists of yellowish green to dark green claystone devoid of foraminifers and separated from the overlying Santonian chalk by a fault.

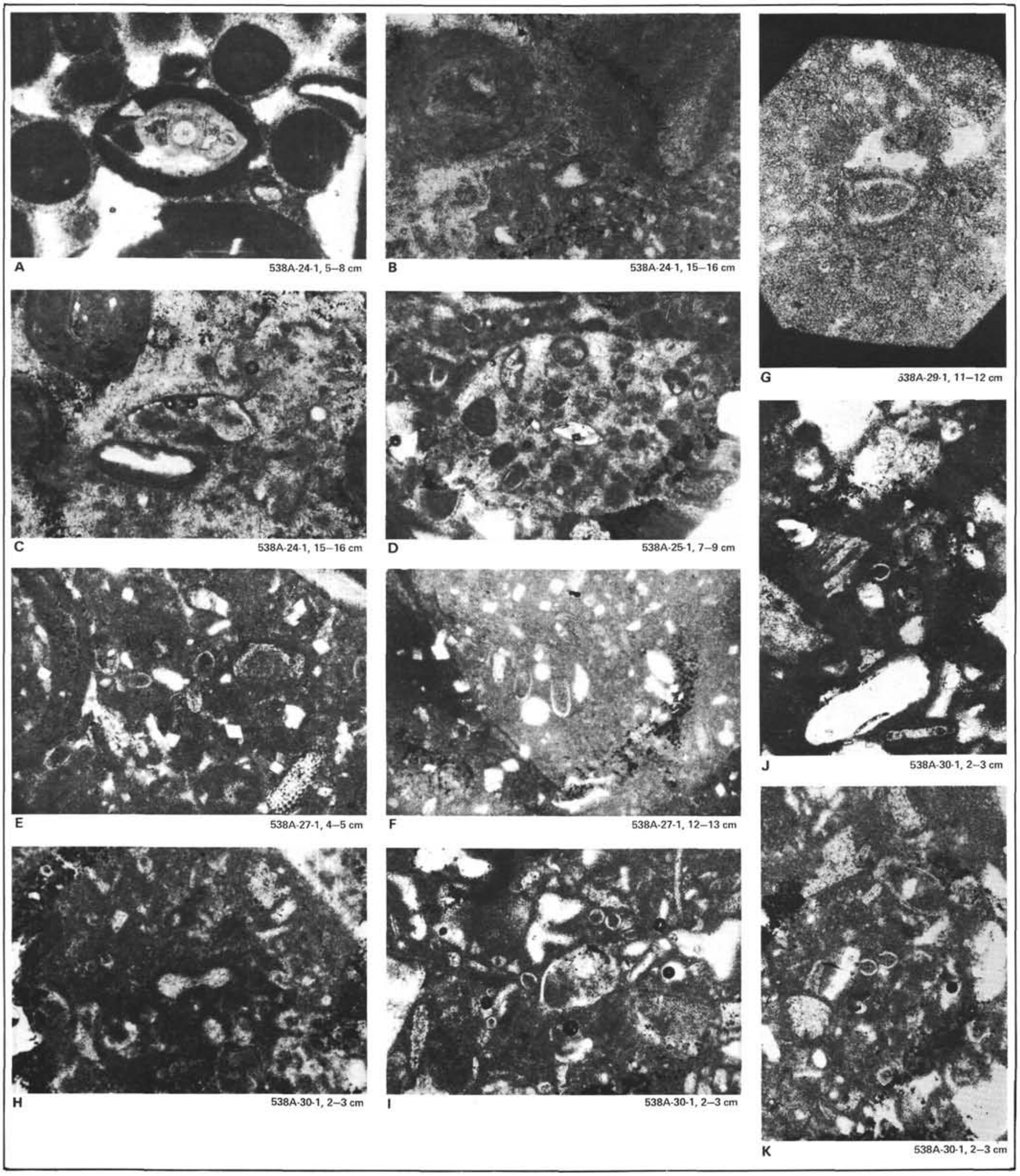


Figure 8. (Continued).

Below the barren claystone, the interval from Sample 538A-21,CC through Core 538A-23 consists of light tan nannofossil chalk with intercalated black marls (rare) and radiolarian limestone dated as latest Albian. Some samples from the nannofossil chalk yielded more abundant benthic assemblages as follows:

538A-21,CC
Ellipsonodosaria sp.
Neobulimina minima Tappan
538A-22-1, 18–20 cm
Bolivina minuta Natland
Gavelinella intermedia (Berthelin)
Lenticulina sp.

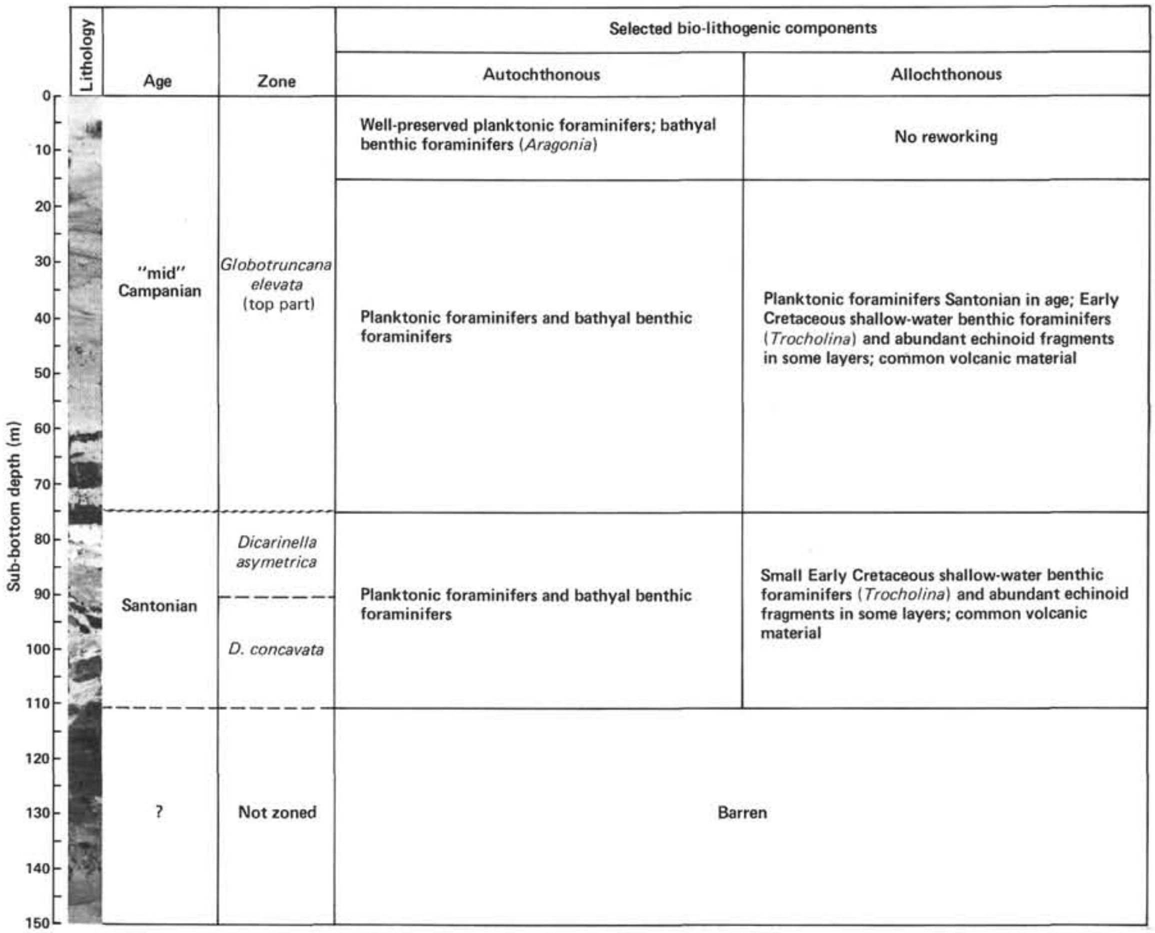


Figure 9. Distribution of autochthonous and allochthonous material in Section 538A-21-4.

Praebulimina nannina (Tappan)?
Tristix sp.
Tritaxia sp. cf. *T. aspera* (Cushman)
Tritaxia gaultina (Morozova)
538A-23-1, 37–40 cm
Astacolus planiusculus (Reuss)
Dentalina gracilis (d'Orbigny)
Ellipsonodosaria sp.
Eoguttulina sp. cf. *E. fusus* Fuchs
Gavelinella intermedia (Berthelin)
Lagena apiculata Reuss
Lingulina furcillata Berthelin
Neobulimina minima Tappan (common)
Praebulimina reussi (Morrow)?
Spirillina minima Schacko

A thin veneer of nannofossil chalk occurs in Sample 538A-30-1, 6–7 cm lying directly on metamorphic rocks. No foraminifers were recovered from this layer, but based on nannofossils, it is dated as early Berriasian. Limestone dominates the interval from the top of Core 538A-24 to Sample 538A-30-1, 0–4 cm that lies between the chalk layers. Core 538A-24 is dated as latest Albian based on the occurrence of rare planktonic foraminifers. A few benthic foraminifers occur mainly in ooids within a lithofacies that is dominated by large skeletal debris and oncoids that envelop calpionellids (see Fig. 8, Photographs A–C).

Recurrent benthic foraminifers identified in thin section from Core 538A-24 are:

Ammodiscus sp.	*Trocholina infragranulata* Noth
Dorothia praeoxycona Moullade	*Trocholina valdensis* (Reichel)
Gavelinella sp.	miliolids
Lenticulina sp.	valvulinids
Pseudonodosaria sp.	complex lituolinids
Textularia sp.	
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)	

In the interval from Core 538A-25 through Sample 538A-30-1, 5 cm skeletal-oolitic-oncolitic limestone appears to alternate with or to be cemented by nannoconid–calpionellid limestone (see Fig. 8, Photographs E–G). Based on calpionellids, the age of this interval ranges from late Berriasian to early Valanginian. Benthic foraminifers occur mainly as separate sedimentary particles. Except for minor variations, the benthic foraminifer assemblages are very similar to those previously mentioned. Recurrent taxa identified in thin sections are:

Ammobaculites	*Pseudonodosaria*
Ammodiscus	*Spirillina*
Dorothia praeoxycona Moullade	*Trocholina* (common)
Frondicularia (rare)	miliolids
Guttulina (rare)	textulariids
Lenticulina	valvulinids
Marginulina (very rare)	complex agglutinated foraminifers
Pseudobolivina	sessile foraminifers (rare)

In particular, trocholinids occur in the following samples:

538A-25-1, 3–4 cm	*Trocholina* sp. aff. *T. friburgensis* (Guillaume and Reichel)

	Trocholina infragranulata Noth
538A-25-1, 7–9 cm	*Trocholina infragranulata* Noth
	Trocholina valdensis (Reichel)
538A-25-1, 10–11 cm	*Trocholina infragranulata* Noth
	Trocholina valdensis (Reichel)
538A-26-1, 4–5 cm	*Trocholina* sp. cf. *T. valdensis* (Reichel)
538-26-1, 10–11 cm	*Trocholina valdensis* (Reichel)
538A-27-1, 3–4 cm	*Trocholina valdensis* (Reichel)
538A-27-1, 4–5 cm	*Trocholina valdensis* (Reichel)
	Trocholina conica (Schlumberger)
538A-27-1, 12–13 cm	*Trocholina* sp. cf. *T. conica* (Schlumberger)
538A-28-1, 3–4 cm	*Trocholina valdensis* (Reichel)
538A-28-1, 9–11 cm	*Trocholina* sp.
538A-29-1, 4–5 cm	*Trocholina conica* (Schlumberger)
538A-29-1, 11–12 cm	*Trocholina valdensis* (Reichel)
	Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)
538A-30-1, 1–2 cm	*Trocholina valdensis* (Reichel)
	Trocholina conica (Schlumberger)
	Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)
538A-30-1, 2–3 cm	*Trocholina* sp. cf. *T. alpina* (Leupold)
	Trocholina conica (Schlumberger)
	Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel)

PALEOECOLOGY AND AGE

Shallow-Water Assemblages

Among the benthic foraminifers representative of shallow-water environments, two major groups are identified—the larger foraminifers and the small benthic foraminifers. Representatives of the two groups occasionally occur in the same layers, but the more common assemblages consist of small foraminifers. Other biogenic and lithogenic components in general are associated with the benthic foraminifers, varying quantitatively and qualitatively throughout the cored stratigraphic successions. Several of these associations may be distinguished within the studied sequences.

1. The youngest assemblage is characterized by rare isolated specimens of larger calcareous foraminifers belonging to the genera *Pseudorbitoides, Sulcoperculina, Vaughanina, Orbitocyclina*?, and *Lepidorbitoides*. This assemblage occurs at only two sites—Core 540-31 and Sample 537-3-2, 50–52 cm in the mixed layer. Only fragments of pelecypods were found associated with these larger foraminifers. The cited genera have a restricted stratigraphic range (see Fig. 10) and indicate an age ranging from late Campanian (*Pseudorbitoides*) to late Maestrichtian (based on *Lepidorbitoides socialis*).

2. The next older assemblage consists of large agglutinated, complex foraminifers and fragments of rudists along with other unidentified large pelecypods and some dasycladacean algae such as *Salpingoporella*, nearly all identified from thin sections. The large agglutinated foraminifers belong to the species *Orbitolina texana, Dictyoconus walnutensis, Paracoskinolina sunnilandensis, Coskinolinoides texanus* (rare), and *Cuneolina pavonia parva*. This assemblage is recorded from Hole 540 (Cores 34–79), Hole 535 (Cores 21–27), and Hole 536 (Cores 10 through 16). Small benthic foraminifers such a valvulinids, miliolids, and primitive *Nezzazata* are a constant component of this assemblage. They are never abundant, but typically may be the only foraminifers present in the fine-grained layers.

All the large agglutinated foraminifers identified are indicative of an Early Cretaceous age. In particular, *Orbitolina texana* ranges from late Aptian to middle Albian with *Paracoskinolina sunnilandensis* having a similar range. *Dictyoconus walnutensis* is mainly a middle Albian form, whereas *Coskinolinoides texanus* seems to range upward to the early late Albian (see Cherchi and Schroeder, this volume; Coogan, 1977). The evolutionary stage of *Cuneolina pavonia parva* corroborates the early to middle Albian age based on the orbitolinids. Thus, it appears that the eroded carbonate platform that was the source of this material was middle Albian or older in age.

3. The oldest assemblage is characterized by the common occurrence of echinoid and crinoid fragments associated with common small benthic foraminifers and rare calcareous algae, including Solenoporacea, Codiacea, and Dasycladacea, all identified in thin sections. Ooids, oncoids, and carbonate pellets are commonly associated with the assemblage but in different amounts from layer to layer. Among the large foraminifers, only rare, poorly preserved, complex Lituolidae are recorded. Small benthic foraminifers display high diversity, but single species typically are represented by one to a few specimens. Trocholinids, in contrast, may be represented by 5–10 specimens in some samples.

In this assemblage trocholinids are the only foraminifers identified specifically that are age-diagnostic. Their ranges are plotted in Figure 10. Among them *Trocholina infragranulata, T. valdensis*, and *T. friburgensis* are Early Cretaceous in age, with the former species ranging from early Valanginian to late Aptian (possibly also earliest Albian); *T. valdensis* from late Berriasian? to Valanginian; and *T. friburgensis* from late Hauterivian? to Barremian. *Trocholina alpina* and *T. conica*, in contrast, have been described from the Jurassic and specifically the former indicates a Middle Jurassic age. The range of *T. alpina* is longer and seems to span the Late Jurassic to the early Valanginian (Sampo, 1969; Ramalho, 1971).

Representatives of this assemblage occur either as isolated specimens and/or fragments mixed with bathyal faunas of a much younger age (i.e., Sections 538A-21-4 and 537-3-2), or in indurated skeletal limestone (i.e., Hole 537, Cores 8 and 10; Section 538A-30-1) where they are also mixed with species of a different age.

Bathyal and Neritic Foraminifers

Bathyal and neritic smaller foraminifers, both calcareous and agglutinated, are discussed together because they occur typically in mixed assemblages in sediments from the Leg 77 sites. The fauna, although meager and small sized (45–150 μm), in general indicate a bathyal environment as the depositional setting. Admixture of neritic material at times strongly dilutes or masks the autochthonous bathyal fauna; nevertheless, the recurrent bathyal assemblage is indicative of water depths of 1000–1500 m (Sliter and Baker, 1972).

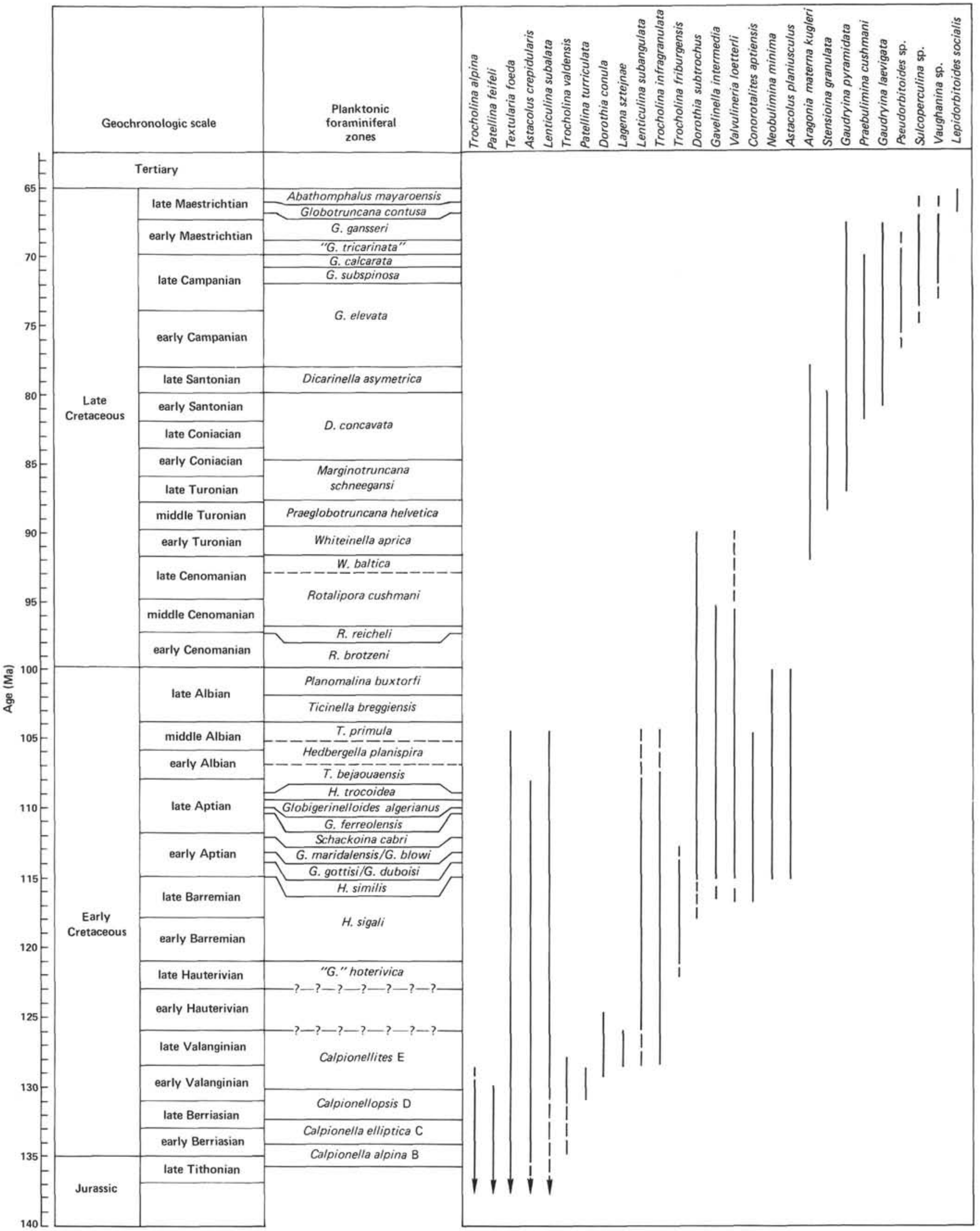


Figure 10. Stratigraphic distribution of selected species of benthic foraminifers. Stratigraphic ranges in part after Bartenstein et al. (1957); Bartenstein et al. (1971); Bartenstein and Bolli (1973,1977); Bartenstein and Kaever (1973); Dieni and Massari (1966); Hanzlikova (1972); Moullade (1966); Ramalho (1971); Sampo (1969); Seibold and Seibold (1960); and van Gorsel (1978).

The bathyal assemblage is especially apparent at Sites 540 and 535. The recurrent association in Cores 17-79 of Hole 535 and in Cores 34-79 of Hole 540 includes species of *Conorotalites, Spirillina, Conorboides, Osangularia, Gavelinella, Praebulimina, Bathysiphon, Glomospira, Tritaxia, Pleurostomella, Dorothia, Ammodiscus, Pseudonodosaria, Neobulimina, Textularia, Bigenerina, Pyrulina*, and *Bolivina* among others that are strongly suggestive of middle bathyal water depths of 1000-1500 m (Sliter, 1977, 1980).

The admixture of upper bathyal and neritic material is indicated by the occasional occurrence of larger-sized nodosariids (e.g., *Frondicularia, Lenticulina, Astacolus, Marginulina, Dentalina*); specimens of *Arenobulimina, Trocholina, Patellina, Guttulina;* poorly preserved epistominids; and rare agglutinated species with complex wall structure. Nevertheless, elements of the bathyal assemblage continue throughout the intervals with admixtures of coarse inner-neritic material such as in Cores 535-68 to 535-72, and 535-22 to 535-24 and Cores 540-66 to 540-79, and 540-32 to 540-35. The interpretation of a middle bathyal environment for Sites 535 and 540 is in keeping with their location on the Florida Escarpment at present water depths of 3450 and 2926 m, respectively.

Several benthic foraminifers of biostratigraphic importance occur in Hole 535. A Valanginian age is indicated by *Trocholina valdensis* in Sample 535-76-2, 138-140 cm, and *Lenticulina* sp. cf. *L. busnardoi* in Samples 535-73-3, 121-122 cm and 535-74-1, 51-52 cm. The age suggested by the small benthic foraminifers is in agreement with that inferred from calpionellids and calcareous nannofossils. The occurrence of *Dorothia subtrochus* and *Gavelinella intermedia* in Sample 535-37-1, 22-24 cm indicates an Aptian to early Cenomanian age. *Conorotalites aptiensis* in Sample 535-35-1, 80-82 cm indicates an Aptian to early Albian age. However, the age of this core based on ammonites is middle Cenomanian. Thus, it is probable that *C. aptiensis* along with the associated Albian planktonic foraminifers (see Premoli Silva and McNulty, this volume) has been reworked.

At Site 537 a more complex bathymetric situation emerges from the interpretation of the benthic foraminifers. The oldest sample from 537-11-1, 1-10 cm yields a few benthic foraminifers suggestive of middle bathyal or deeper environments especially with the presence of *Hyperammina* and *Glomospira* in the silty marls. An open-marine environment for these deposits is corroborated by the occurrence of a few protoconchs of ammonites and aptychi. Thus, the large fragments of crinoids and the common ostracodes, indicative of an inner-neritic environment (see Oertli, this volume) must be interpreted as out of place. The overlying Cores 537-4 to 537-10, consisting of skeletal-oolitic limestone and analyzed in thin section, contain a mixture of mostly neritic genera with some indications of bathyal environments based on specimens of *Spirillina, Dorothia, Ammodiscus, Gavelinella*?, and *Turrispirillina*. The majority of specimens are largely inner neritic as evidenced by encrusting forms, agglutinated foraminifers with complex walls, and miliolids among others that one would expect to recover in association with skeletal-oolitic limestone.

Section 537-3-2 clearly is middle bathyal on the basis of recurrent specimens of *Praebulimina, Gavelinella, Osangularia, Conorotalites, Spirillina, Hyperammina*, and *Lituotuba*. The latter two genera somewhat suggest depths approaching 1500 m or greater. Assemblages characteristic of abyssal water depths such as those reported by Krasheninnikov (1974a, b) and Sliter (1980) were not recovered. Neritic or upper bathyal admixtures are still noted by the presence of *Trocholina, Stensioina*, and rare valvulinids, together with other shallow-water skeletal material (see Figs. 5 and 6). In summary, the interpretation based on benthic foraminifers indicates that Cores 537-3 to 537-11 were deposited at bathyal depths with the addition of skeletal material in Cores 537-4 to 537-10 that strongly dilutes the bathyal assemblage.

Most benthic foraminifers found in Cores 537-11 to 537-4 are of little use stratigraphically with the exception of the trocholinids. Ostracodes suggest an earliest Cretaceous age for Core 537-11. The whole interval from Core 537-10 to 537-4 is Valanginian or younger based on the presence of *Trocholina infragranulata*, which first appears in Sample 537-10-1, 23-24 cm. Thus, the associated Berriasian calpionellids must be reworked. Moreover, the Jurassic species *Trocholina conica* was found in Sample 537-8-1, 3-4 cm. Its occurrence is interpreted to be due to reworking from Jurassic strata on the adjacent platform.

Sample 537-3-2, 64-66 cm, below the level of mixing in the upper part of Section 537-3-2, contains an early Aptian assemblage with *Gavelinella barremiana, G. intermedia, Conorotalites aptiensis*, and *Trocholina infragranulata*.

Hole 538A on Catoche Knoll is similar to Hole 537 in that the bathyal assemblage in the lower cores is strongly masked by the influx of skeletal-oolitic-oncolitic material. Thin sections of limestone in the interval from 538A-1-24 to 538A-1-30, 5 cm contain a dominantly neritic assemblage of agglutinated forms with complex walls, miliolids, *Trocholina, Guttulina*, and valvulinids mixed with elements of the bathyal assemblage such as *Spirillina, Dorothia, Pseudonodosaria, Pseudobolivina*, and *Ammodiscus*.

Cores 538A-22 and 538A-23 of nannofossil chalk above the skeletal-oolitic-oncolitic limestone contain a bathyal assemblage with *Gavelinella, Praebulimina, Tritaxia, Neobulimina*, and *Spirillina* among others. As before, this assemblage is interpreted as being middle bathyal. Interval 538A-21-4, 27-110 cm contains the same assemblage with the addition of specimens of *Aragonia, Nuttallinella, Valvulineria, Pleurostomella, Gyroidinoides*, and *Osangularia*. This assemblage with the addition of the first two genera is suggestive of lower bathyal to abyssal depths of 1500-2500 m. Neritic specimens continue to be found through Section 538A-21-4 because of obvious reworking from older levels and downslope transport.

In summary, sediments in Core 538A-30 to Section 538A-21-4 were deposited at middle bathyal depths with a possible increase in water depth to near abyssal depths in Core 538A-21. The present water depth at Site 538 is 2742 m.

Based on benthic foraminifers, the interval from Sample 538A-30-1, 5 cm through Core 538A-25 can be dated from latest Berriasian to early Valanginian. In fact, *Trocholina valdensis* is present throughout. This age is in agreement with a late Berriasian age given by calcareous nannofossils from the thin veneer of chalk resting on the underlying basement rocks as well as by the calpionellids occurring associated with *T. valdensis*. Moreover, reworking from the Jurassic platform as at Site 537 is attested to by the occurrences of *T. conica* that range upward to Core 538A-27 and is further supported by faunal mixing within the calpionellid assemblages (see Premoli Silva and McNulty, this volume).

Age-diagnostic benthic foraminifers also are found in Core 538A-22 where *Gavelinella intermedia, Tritaxia gaultina*, and *Neobulimina minima* indicate an Albian age. In Samples 538A-21-4, 107–109 cm and 538A-21-4, 93–94 cm, the occurrence of *Aragonia materna kugleri* indicate a Santonian age. Above, in Sample 538A-21-4, 78–80 cm, the association of *Gaudryina laevigata, Dorothia oxycona, Osangularia cordieriana*, and *Stensioina pommerana* provide a Campanian age. *S. pommerana* and *D. oxycona* in conjunction with planktonic foraminifers in Sample 538A-21-4, 53–54 cm extend the Campanian age upward through this sample.

Fossiliferous Mesozoic sediments from Site 536 consist of skeletal limestone that alternate with radiolarian and/or planktonic foraminifer limestone. Meager benthic foraminifer faunas, identified from thin sections of limestone from Cores 536-10 to 536-21 consist mostly of neritic forms, that is, miliolids, valvulinids, rare nodosariids, and *Trocholina*. Bathyal representatives are reduced to a few specimens of *Spirillina, Pseudonodosaria, Glomospira, Dorothia, Gaudryina*, and *Dentalina*. No further depth interpretation is possible other than to include the data with the occurrence of planktonic foraminifers and radiolarians and imply a bathyal environment throughout Cores 536-21 to 536-10.

Age diagnostic benthic foraminifers at Site 536 are limited to *Trocholina* sp. cf. *T. infragranulata* in Cores 536-14 and 536-15 that corroborate the Aptian age based on the planktonic fauna.

CONCLUSIONS

Comparison of five sites drilled on Leg 77 show the following general conclusions:

1. The basin sites (535, 540) consist largely of laminated limestone with smaller amounts of limestone containing coarse skeletal debris and pure pelagic limestone.
2. The basement sites (536, 537, 538) consist largely of skeletal limestones.
3. All sites show evidence of reworked older pelagic and shallow-water material throughout the intervals cored.
4. All sites show evidence of shallow-water material displaced into bathyal water depths by mechanical transport.

The following comparisons provide a broad depositional history for the southern part of the Gulf of Mexico during Cretaceous time (Fig. 11).

Neocomian (Berriasian to Barremian)

Dominantly pelagic sediments were deposited at basin Site 535 on the Florida Escarpment with no obvious evidence of reworked older fossil material. The Neocomian sequence does contain, however, conspicuous shallow-water foraminifers and biogenic material, possibly contemporaneous, displaced from an adjacent carbonate platform.

Neocomian sediments from basement Sites 538 (Hole 538A) and 537 contain reworked Jurassic fossils and displaced shallow-water material from older carbonate platforms. A thin veneer of upper Berriasian nannofossil chalk in Hole 538A rests on metamorphic rocks and attests to an early pelagic depositional phase. Skeletal limestone containing abundant displaced shallow-water foraminifers and biogenic material with evidence of reworked Jurassic foraminifers and Berriasian calpionellids constitute the bulk of the Neocomian sequence.

A similar Neocomian sequence was recovered at Site 537, consisting of skeletal-oolitic-oncolitic limestones, reworked Jurassic and Berriasian fossils, and abundant displaced shallow-water material. The initial phase of deposition at Site 537 differs, however, from Hole 538A as sediments apparently deposited at bathyal depths, but containing Berriasian neritic ostracodes and other shallow-water material immediately overlie continental deposits. In both basement sites the Neocomian sequence is incomplete and there is no evidence of sediments younger than Valanginian.

Aptian

Basin Site 535 contains a complete Aptian sequence (lower to upper) that consists mainly of pelagic limestone with some displaced (contemporaneous?) shallow-water material from an adjacent carbonate platform. There is no evidence of reworked older material. At basement Site 537, only part of the lower Aptian was recovered. The largely pelagic sequence contains common displaced shallow-water material. Again, there was no evidence of reworked material.

Unconformities occur at the base of the Aptian sequence at both sites. At Site 535 most of the Barremian is missing, whereas at Site 537, an unconformity separates an unzoned interval from the lower Aptian. At Sites 535 and 537 the Aptian is overlain unconformably by upper Albian and Maestrichtian sediments, respectively.

Basement Site 536 contains upper Aptian coarse skeletal limestone with abundant displaced shallow-water material resting on dolomite of unknown age. The sequence includes rare reworked early Aptian planktonic foraminifers. The overlying unzoned interval also may be late Aptian as suggested by the benthic foraminifers.

Albian

Basin Site 540 contains the most complete Albian sequence, which ranges in age from middle to latest Albian. Included in the predominantly limestone sequence is abundant displaced (possibly contemporaneous) shallow-water material and reworked Neocomian and late Aptian to early Albian foraminifers.

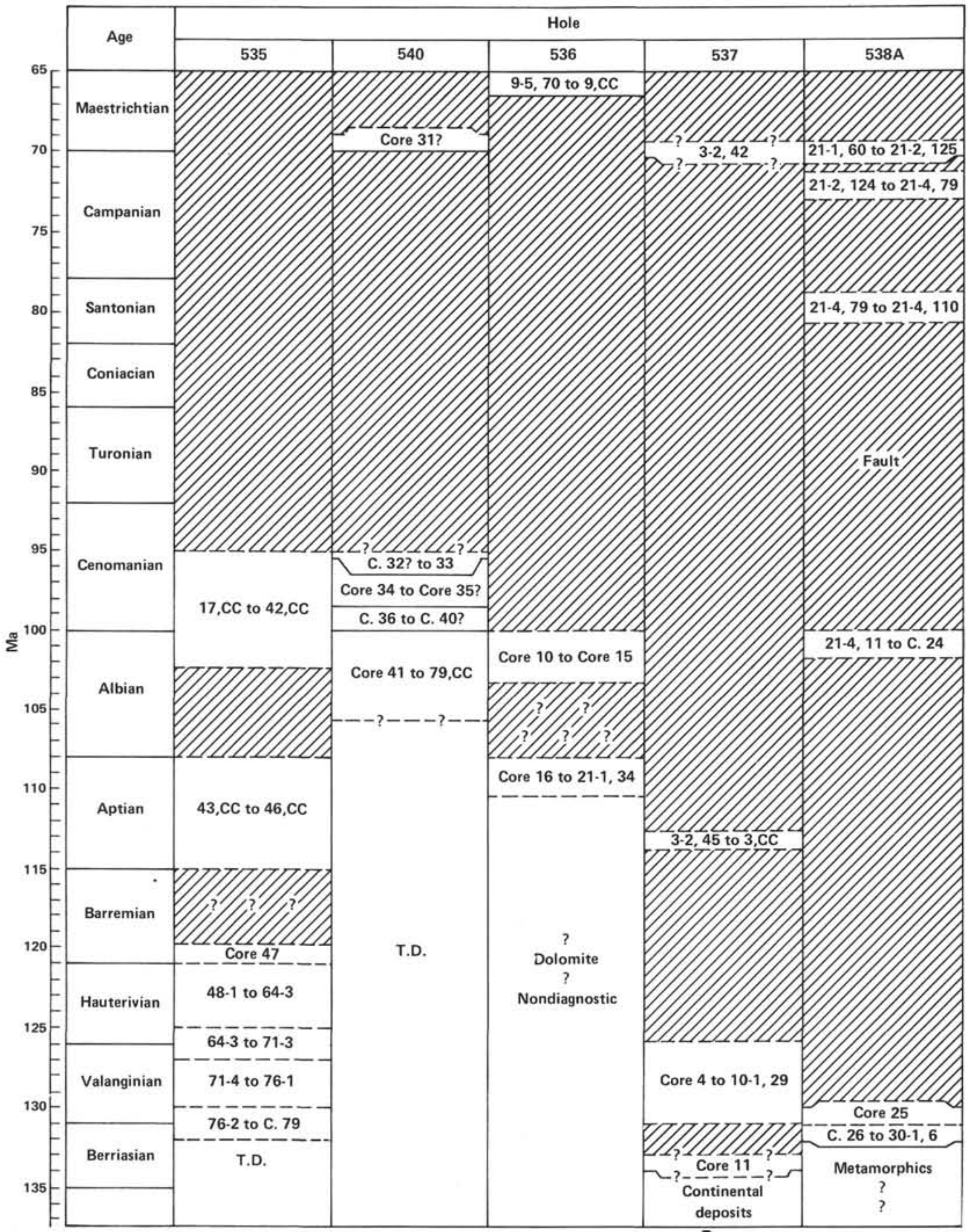


Figure 11. Age distribution of sediments recovered at Sites 535 and 540 (basin sites) and Sites 536, 537, and 538; Hole 538A (basement sites), Leg 77, Gulf of Mexico. Core and section numbers, interval in cm, given in each column. Dashed patterns = hiatuses. Absolute age after van Hinte, 1976.

Basement Sites 536 and 538 (Hole 538A) contain only the uppermost Albian. Site 536 consists of skeletal limestone and includes abundant displaced, possibly contemporaneous, shallow-water material and reworked late Aptian to early Albian large agglutinated foraminifers. In Hole 538A, the Albian section rests unconformably on Neocomian (Valanginian) skeletal-oolitic-oncolitic limestone and contains reworked Berriasian calpionellids and abundant Neocomian shallow-water material derived from an adjacent carbonate platform. The remainder of the Albian sequence consists of pelagic chalk; there is no evidence of reworked or displaced material.

Albian to Cenomanian (undifferentiated)

Cores 17–42 of basin Site 535, are assigned to an unzoned uppermost Albian to middle Cenomanian interval of laminated limestone with reworked Neocomian and late Aptian to middle Albian shallow-water foraminifers throughout the interval, and Albian planktonic foraminifers in the Cenomanian portion.

Cenomanian

The only sediments positively identified as Cenomanian in age were found at basin Site 540. Reworked elements in this interval include late Aptian to middle Albian shallow-water foraminifers, clasts of Albian limestone, and some displaced contemporaneous foraminifers enclosed in a predominantly limestone sequence.

Late Cretaceous

At basement Hole 538A, Santonian chalk with reworked Early Cretaceous shallow-water foraminifers unconformably overlies an unzoned unit. The Santonian in turn is unconformably overlain by Late Cretaceous chalk with reworked Early Cretaceous shallow-water foraminifers in the basal portion. The upper portion of the Campanian interval and the unconformable overlying lower Maestrichtian contain no evidence of displaced material. This latter sequence of pelagic chalks apparently was deposited far from sources of shallow-water material.

Basin Site 540 and basement Site 537 contain lower Maestrichtian volcanogenic sediments associated with shallow-water material from adjacent carbonate platforms. At Site 540, the Maestrichtian rests unconformably on the Cenomanian and includes shallow-water foraminifers, abundant displaced material, and reworked Campanian and Maestrichtian shallow-water foraminifers. At Site 537, the lower Maestrichtian rests unconformably on the lower Aptian and includes a few shallow-water foraminifers and abundant displaced shallow-water material of Early Cretaceous age and rare reworked Late Cretaceous larger foraminifers.

In conclusion, within the Cretaceous two major erosional phases are detectable in the Gulf of Mexico. The oldest phase, dated as Valanginian, affected Jurassic and Berriasian terranes represented mainly by carbonate platforms and their seaward margins. This phase is confined to the western side of the Gulf. The younger phase began in the latest Albian and reached the maximum intensity during the early to middle Cenomanian. During this time, displaced shallow-water material was provided to the basin from carbonate platforms of late Aptian to middle Albian age. This phase, recorded on both sides of the Gulf of Mexico (Sites 535, 536, 540), was more intense on the eastern or Florida side. No evidence of this phase was recorded at basement Sites 537 and 538. At the latter site, however, small amounts of Lower Cretaceous reworked material occur in sediments as young as Campanian. The youngest influx of shallow-water material, recorded again on both sides of the Gulf, is Maestrichtian in age. It is interpreted to be related to volcanic activity and not to an erosional phase of regional scale.

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APPENDIX A
Most Abundant Assemblages of Smaller Foraminifers from Sites 535 and 540

Core-Section (interval in cm)	Foraminifer
535-17,CC	*Conorotalites* sp. *Dentalina* sp. *Frondicularia* sp. *Trocholina valdensis* (Reichel) miliolids
535-18,CC	*Ammodiscus* sp. *Astacolus* sp. *Bigenerina* sp. *Conorboides* sp. *Pseudonodosaria* sp. *Quinqueloculina* sp. (common) *Spirillina minima* Schacko
535-19-2, 51–52	*Ammodiscus* sp. *Arenobulimina* sp. *Dentalina* spp. *Quinqueloculina* sp. *Trocholina*? other lagenids miliolids
535-20,CC	*Ammodiscus* sp. *Dentalina* sp. *Pseudonodosaria* sp. *Spirillina* sp. miliolids
535-28,CC	*Arenobulimina* sp. *Conorboides* sp. *Dentalina* sp. *Dorothia* sp. *Gavelinella* sp. *Lagena* sp. *Patellina* sp. *Pseudonodosaria* sp. *Quinqueloculina* sp. miliolids
535-32-3, 110–114	*Spirillina* sp. (very rare)
535-33-1, 82–86	*Bathysiphon* sp. *Guttulina* sp. lagenids
535-33-6, 100–104	*Dentalina* sp. *Guttulina* sp. *Quinqueloculina* sp. *Spirillina* sp. } very small-sized
535-35-3, 29–32	*Dentalina* sp. *Reophax* sp. *Spirillina* sp. (common) *Trocholina infragranulata* Noth
535-35,CC	*Bathysiphon* sp. *Dentalina* sp. *Guttulina* sp. *Neobulimina* sp. *Pyrulina* sp. *Spirillina* sp. } very small-sized
535-36-1, 80–82	*Arenobulimina* sp. *Astacolus gratus* (Reuss) *Conorotalites aptiensis* (Bettenstaedt) *Dentalina* sp. *Dorothia* sp. cf. *D. oxycona* (Reuss) *Gavelinella* sp. *Lenticulina* sp. *Praebulimina* sp. *Pseudonodosaria* sp. *Rhizammina* sp. *Spirillina* sp. *Turrispirillina* sp. miliolids

Appendix A. (Continued).

Core-Section (interval in cm)	Foraminifer
535-37-1, 22–24	*Conorboides* sp. *Dorothia subtrochus* (Bartenstein) *Gavelinella intermedia* (Berthelin) *Lenticulina* sp. *Patellina* spp. *Spirillina* sp.
535-38-1, 0–1	*Gavelinella* sp. *Guttulina* sp. *Patellina* sp. *Quinqueloculina* sp. *Spirillina* sp. *Trocholina infragranulata* Noth miliolids
535-39-1, 46–48	*Allomorphina*? *Gavelinella*? *Glomospira* sp. (few) lagenids (few) miliolids
535-39-2, 65–67	*Patellina* sp. (very rare)
535-39-6, 64–66	*Guttulina* sp. *Pseudonodosaria* sp. *Quinqueloculina* sp. miliolids
535-42-4, 51–55	*Dentalina* sp. *Glomospira* sp. miliolids (rare)
535-42,CC	*Bathysiphon* sp. *Dentalina* sp. *Dorothia* sp. *Rhizammina* sp.
535-43-3, 19–20	*Bathysiphon* sp. *Spirillina* sp.
535-47-2, 38–41	*Dorothia* sp. *Lenticulina* sp.
535-50-2, 10–12	*Dorothia* sp.
535-57-7, 56–59	*Dentalina communis* d'Orbigny *Dentalina* sp. cf. *D. nana* Reuss *Dentalina varians* Terquem *Gavelinella* sp. *Haplophragmium*? *Neobulimina*? *Spirillina tenuissima* Guembel
535-65-2, 25–27	*Lenticulina* sp.
535-68-2, 119–122	*Lenticulina* sp.
535-70-1, 110–111	*Dentalina communis* d'Orbigny *Dentalina nana* Reuss *Quinqueloculina* sp. *Spirillina tenuissima* Guembell *Textularia foeda* Reuss
535-71-4, 39–42	*Dentalina communis* d'Orbigny
535-71-4, 139–142	*Lenticulina* sp.
535-72-1, 115–119	*Bigenerina* sp. *Dentalina* sp. *Dorothia* sp. *Gavelinella*? *Lenticulina* sp. *Spirillina* sp.
535-72-3, 87–89	*Ammodiscus* sp. *Dentalina* sp. *Praebulimina* sp. *Spirillina* sp.
535-73-3, 121–122	*Ammodiscus rotularius* Loeblich and Tappan *Ammodiscus* sp. *Epistomina*? *Lenticulina* sp. cf. *L. busnardoi* Moullade

Appendix A. (Continued).

Core-Section (interval in cm)	Foraminifer
535-73-3, 121–122	*Spirillina* sp.
535-74-1, 51–52	*Ammodiscus* sp.
	Dentalina sp.
	Epistomina?
	Lenticulina sp. cf. *L. busnardoi* Moullade
	Lenticulina ouachensis (Sigal)
	Nodosaria?
	Osangularia sp.
	Spirillina sp.
535-76-2, 3–4	*Ammobaculites* sp.
	Ammodiscus sp.
	Dorothia sp.
	Lenticulina sp.
535-76-2, 6–7	*Dorothia* sp.
	Lenticulina?
	Spirillina sp.
	Turrispirillina sp.
	large lagenids
535-76-2, 138–140	*Ammobaculites* sp.
	Ammodiscus sp.
	Dentalina sp.
	Lenticulina sp.
	Reophax sp.
	Spirillina sp.
	Trocholina valdensis (Reichel)
	miliolids
535-76-2, 143–145	*Ammodiscus* spp. (common)
	Dentalina sp.
	Spirillina sp.
	Trocholina sp.
535-76-2, 148–150	*Dentalina communis* d'Orbigny
	Spirillina sp.
	Textularia sp.
	miliolids (rare)
	valvulinids
535-78-2, 41–44	*Praebulimina* sp.
	Spirillina sp.
535-78-2, 82–84	*Praebulimina* sp.
	Spirillina sp.
535-78,CC	*Praebulimina* sp.
	Spirillina sp.
535-79-1, 21–22	*Ammodiscus* sp.
	Epistomina sp. (distorted)
	Lenticulina sp.
	Spirillina sp.
	calcareous biserial sp.
535-79-1, 52–54	*Bathysiphon* sp. (small sized)
	noncalcareous agglutinated forms
535-79-2, 64–68	*Ammodiscus* sp.
	Bathysiphon sp.
	Lenticulina sp. (normal sized)
	Spirillina sp.
535-79-2, 79–81	*Ammodiscus* sp.
	Dentalina sp.
	Quinqueloculina sp.
	Spirillina sp.
	Turrispirillina sp.
535-79-2, 106–108	*Ammodiscus* sp.
	Epistomina sp.
	Lenticulina sp.
	Spirillina sp.
	Turrispirillina sp.
540-34-1, 33–36	*Dentalina* sp.
	Glomospira sp.
	Lenticulina?
	Textularia sp.
540-36-1, 23–27	*Conorboides* sp.
	Marginulina sp.

Appendix A. (Continued).

Core-Section (interval in cm)	Foraminifer
540-36-1, 23–27	*Pseudonodosaria* sp.
	Textularia sp.
	miliolids
	valvulinids
540-41-1, 45–47	*Ammodiscus* sp.
	Gavelinella sp. (few)
	Spirillina sp.
540-43-1, 137–139	*Lenticulina* sp.
540-45-1, 80–83	*Ammodiscus* sp.
	Gavelinella sp.
	Patellina sp.
540-45,CC	*Ammobaculites* sp.
	Nezzazata sp. (primitive)
	valvulinids
540-49-1, 74–76	*Spirillina* sp.
540-50-2, 62–64	*Nezzazata* sp. (primitive)
	lagenids
	miliolids
	large agglutinated forms
540-50-2, 67–69	*Dentalina* sp.
	Glomospira sp.
	Quinqueloculina sp.
	miliolids
540-50-2, 75–79	*Ammobaculites* sp.
	Dentalina sp.
	Glomospira sp.
	Lenticulina sp.
	Nezzazata sp. (primitive)
	Pseudobolivina?
	textulariids
	valulinids
540-53-1, 71–73	*Ammobaculites* sp.
	Conorboides sp.
	Dentalina sp.
	Gavelinella sp.
	Patellina sp.
	miliolids
540-59-1, 55–57	*Dorothia oxycona* (Reuss)
540-59-1, 119–120	*Astacolus* sp.
	Nezzazata sp. (primitive)
	Quinqueloculina sp.
	Textularia sp.
	lagenids
	miliolids (common)
	valvulinids
	complex agglutinated forms
540-63-2, 50–52	*Ammodiscus* sp.
	Haplophragmoides sp.
	Lenticulina sp.
540-67-1, 144–150	*Conorboides* sp.
	Dentalina sp.
	Lenticulina sp.
	Marginulina sp.
	Patellina sp.
	Spirillina sp.
540-69-5, 28–30	*Lenticulina* sp. (common)
	Patellina sp.
540-70-3, 20–23	*Conorboides* sp.
	Gavelinella sp.
	Lenticulina sp.
540-70-5, 72–74	*Astacolus* sp.
	Gavelinella sp.
	Glomospira sp.
	Guttulina sp.
	Lenticulina sp.
	Praebulimina sp.
	Pseudobolivina sp.
	textulariids
540-71-1, 30–32	*Bathysiphon* sp.

Appendix A. (Continued).

Core-Section (interval in cm)	Foraminifer
540-71-1, 30–32	*Dentalina* sp.
	Haplophragmoides sp.
	Lingulonodosaria sp.
	Oolina sp.
	Pleurostomella sp.
	Spirillina sp.
	other elonated forms (common)
540-77-1, 47–49	*Ammobaculites* sp.
	Dentalina sp.
	Nezzazata sp. (primitive)
	Trocholina sp.
	miliolids (small)
	valvulinids
	complex agglutinated forms
540-77-3, 104–106	*Ammodiscus* sp.
	Gavelinella sp.
	Gyroidinoides sp.
	Osangularia sp.
	Spirillina sp.
	Trocholina sp.
	valvulinids
540-78-2, 41–44	*Ammodicus cretaceus* (Reuss)
	Ammodiscus sp.
	Patellina sp.
	Spirillina sp.
540-78-2, 82–84	*Arenobulimina*?
	Guttulina sp.
	Patellina sp.
540-79-6, 113–115	*Ammobaculites* sp.
	Conorboides sp.
	Glomospira sp.
	Quinqueloculina sp.
	miliolids (common)
	complex agglutinated forms

APPENDIX B
Diagnostic Larger Foraminifers from Sites 535 and 540

Core-Section (interval in cm)	Foraminifer
535-21-4, 106–108	*Coskinolinoides texanus* Keijzer
	Cuneolina sp.
535-22-5, 144–146	*Orbitolina* sp.
535-22-6, 43–45	*Cuneolina* sp.
	Orbitolina sp.
535-22,CC	*Dictyoconus walnutensis* (Carsey)
	Paracoskinolina sp. cf. *P. sunnilandensis* (Maync)
535-23-1, 11–14	*Cuneolina* sp.
	Orbitolina ex gr. *O. texana* (Roemer)
	Paracoskinolina sp. cf. *P. sunnilandensis* (Maync)
535-23-1, 30–32	*Cuneolina pavonia parva* Henson
	Nummoloculina heimi Bonet
	Orbitolina ex gr. *O. texana* (Roemer)
	Paracoskinolina sunnilandensis (Maync)
535-23-1, 55–56	*Cuneolina* sp.
	Orbitolina sp. (common)
535-23-4, 21–22	*Orbitolina* sp.
	Paracoskinolina sp.
535-23-5, 39–41	*Cuneolina* sp. (primitive)
535-23,CC	*Cuneolina* sp.
	Orbitolina sp.
	Paracoskinolina sunnilandensis (Maync)
535-24-2, 49–51	*Cuneolina*?
535-25-2, 32–34	*Cuneolina* sp.
	orbitolinids
535-25-3, 82–84	*Cuneolina* sp.
	Orbitolina sp.
535-27-3, 26–28	fragment of orbitolinid
540-31-1, 41–43	*Pseudorbitoides* sp.
540-31-2, 34–35	*Lepidorbitoides* sp. cf. *L. socialis* (Leymerie)
540-31,CC	*Sulcoperculina* sp.
	Vaughanina sp.
540-31-2, 137–144	*Orbitolina* sp.
(pebble)	*Paracoskinolina* sp.
540-34-1, 63–65	*Cuneolina* sp. aff. *C. pavonia* d'Orbigny
540-36-1, 23–27	*Cuneolina* sp.
540-37-2, 100–103	*Coskinolinoides* sp. aff. *C. texanus* Keijzer
540-45,CC	*Paracoskinolina* sp.
540-50-2, 62–64	*Cuneolina* sp.
540-50-2, 75–79	*Cuneolina* sp.
540-77-1, 47–49	*Cuneolina* sp.
540-77-2, 130–134	*Cunoelina*?
	Orbitolina sp.
	Paracoskinolina sp.
540-77-3, 6–9	*Cuneolina pavonia parva* Henson
	possible orbitolinid
540-79-6, 113–115	*Cuneolina*?

APPENDIX C
Diagnostic Smaller Foraminifers from Site 536 Identified in Thin Section

Core-Section (interval in cm)	Foraminifer
536-10-1, 0-2	miliolids nodosariids agglutinated forms?
536-10-1, 5-7	*Ammobaculites* sp. *Glomospira* sp. *Lenticulina* sp. miliolids (few and large sized) valvulinids (few)
536-10-1, 38-41	valvulinids complex lituolids
536-10-1, 41-42	valvulinids? sessile forms
536-10-1, 43-46	*Lenticulina* sp. miliolids sessile forms
536-10-1, 47-50	ghosts of miliolids valvulinids sessile forms
536-10-1, 50-52	miliolids? sessile forms (few)
536-10-1, 58-60	only ghosts of foraminifers
536-11-1, 1-5	*Nezzazata* sp. (primitive) (very rare) miliolids (rare) sessile forms (few)
536-11-1, 13-15	*Dorothia* sp. cf. *D. oxycona* (Reuss) *Lenticulina* miliolids (rare)
536-13-1, 39-42	*Trocholina* sp. small agglutinated benthics
536-13-1, 68-70	*Dorothia* sp. verneuilinids
536-14-1, 13-16	*Dorothia* sp. valvulinids sessile forms
536-14-1, 20-23	valvulinids
536-14-1, 29-30	sessile forms (common) small unidentified foraminifers (few)
536-14-1, 44-49	one valvulinid?
536-14-1, 56-58	verneuilinids complex lituolid sessile forms
536-14-1, 80-82	*Trocholina* sp. cf. *T. infragranulata* Noth
536-15-1, 20-22	*Trocholina* sp. cf. *T. infragranulata* Noth
536-16-1, 38-44	*Spirillina* sp.
536-16-1, 56-63	*Dentalina communis* d'Orbigny
536-16-1, 66-69	sessile forms? (few)
536-17-1, 4-8	miliolids valvulinids
536-18-1, 28-31	*Dentalina communis* d'Orbigny miliolids (few) } in coarser fraction valvulinids (rare) } in coarser fraction
536-18-1, 32-35	*Dentalina* sp. miliolids (few) nodosariids
536-18-1, 40-42	valvulinids (rare)
536-19-1, 2-4	*Patellina* miliolids (rare)
536-19-1, 3-5	*Gaudryina* sp. *Quinqueloculina* sp. miliolids
536-19-1, 9-11	*Dentalina communis* d'Orbigny other unidentified benthics
536-20-1, 5-7	*Dentalina* sp. *Nodosaria* sp. valvulinids (few) other agglutinated forms (rare)
536-20-1, 7-8	*Ammobaculites* sp. *Trocholina*? (rare) nodosariids (rare) valvulinids (rare)
536-20-1, 10-11	*Lenticulina* sp. *Trocholina* sp. (common) verneuilinids other small foraminifers
536-20-1, 12-15	*Dorothia subtrochus* (Bartenstein) *Lenticulina* sp. *Pseudonodosaria* sp. large agglutinated foraminifers
536-20-1, 20-21	nodosariid
536-22-1, 0-2	*Textularia*

APPENDIX D
List of Identified Species[a]

Ammodiscus cretaceus (Reuss) (= *Operculina cretacea* Reuss)
Ammodiscus rotularius Loeblich and Tappan
Aragonia materna kugleri Beckman and Koch
Astacolus crepidularis (Roemer) (= *Planularia crepidularis* Roemer)
Astacolus gratus (Reuss) (= *Cristellaria grata* Reuss)
Astacolus planiusculus (Reuss) (= *Cristellaria planiuscula* Reuss)
Bolivina minuta Natland
Conorotalites aptiensis (Bettenstaedt) (= *Globorotalites aptiensis* Bettenstaedt)
Coskinolinoides sp. aff. *C. texanus* Keijzer. Coogan, 1977, fig. 7
Cuneolina sp. aff. *C. parva* d'Orbigny
Cuneolina pavonia parva Henson. Sartoni and Crescenti, 1962, p. 278, pl. 32; pl. 47, figs. 4-6
Dentalina communis (d'Orbigny) (= *Nodosaria (Dentalina) communis* d'Orbigny)
Dentalina gracilis (d'Orbigny) (= *Nodosaria (Dentalina) gracilis* d'Orbigny)
Dentalina guttifera d'Orbigny
Dentalina nana (Reuss) (= *Nodosaria (Dentalina) nana* Reuss)
Dentalina varians Terquem
Dorothia conula (Reuss) (= *Textularia conulus* Reuss). Kuznetsova, 1974, pl. 1, figs. 11a-c.
Dorothia oxycona (Reuss) (= *Gaudryina oxycona* Reuss)
Dorothia praeoxycona Moullade
Dorothia subtrochus (Bartenstein) (= *Marssonella subtrochus* Bartenstein). Kuznetsova, 1974, pl. 1, figs. 13a-b
Dictyoconus walnutensis (Casey) (see Cherchi and Schroeder, this volume)
Eoguttulina sp. aff. *E. fusus* Fuchs
Gavelinella barremiana Bettenstaedt
Gavelinella intermedia (Berthelin) (= *Anomalina intermedia* Berthelin)
Gaudryina laevigata Franke
Gaudryina pyramidata Cushman
Gyroidinoides sp. cf. *G. beisseli* (Schijfsma) (= *Eponides beisseli* Schijfsma)
Lagena apiculata Reuss
Lagena sztejnae Dieni and Massari
Lenticulina sp. cf. *L. busnardoi* Moullade
Lenticulina gaultina (Berthelin) (= *Cristellaria gaultina* (Berthelin)
Lenticulina muensteri (Roemer) (= *Robulina muensteri* Roemer)
Lenticulina ouachensis (Sigal) (= *Cristellaria ouachensis* Sigal)
Lenticulina subalata (Reuss) (= *Cristellaria subalata* Reuss)
Lenticulina subangulata (Reuss) (= *Cristellaria subangulata* Reuss)
Lepidorbitoides socialis (Leymerie) (= *Orbitolites socialis* Leymerie). van Gorsel, 1978, figs. 15 and 16
Lingulina furcillata Berthelin
Lituotuba incerta Franke
Marginulinopsis cephalotes (Reuss) (= *Cristellaria cephalotes* Reuss)
Neobulimina minima Tappan
Nummoloculina heimi Bonet
Orbitolina texana (Roemer) (see Cherchi and Schroeder, this volume)
Osangularia cordieriana (d'Orbigny) (= *Rotalina cordieriana* d'Orbigny)
Osangularia sp. cf. *O. whitei* (Brotzen) (= *Eponides whitei* Brotzen)
Paracoskinolina sunnilandensis (Maync) (see Cherchi and Schroeder, this volume)
Patellina feifeli (Paalzow) (= *Trocholina feifeli* Paalzow)
Patellina subcretacea Cushman and Alexander
Patellina turricolata Dieni and Massari
Pleurostomella sp. cf. *P. austinana* Cushman
Praebulimina cushmani (Sandidge) (= *Buliminella cushmani* Sandidge)
Praebulimina nannina (Tappan) (= *Bulimina nannina* Tappan)
Praebulimina reussi (Morrow) (= *Bulimina reussi* Morrow)
Reussella pseudospinulosa Troelsen
Spirillina minima Schacko
Spirillina tenuissima Guembel
Stensiona granulata (Olbertz) (= *Rotalia exculpta granulata* Olbertz)
Stensiona pommerana Brotzen
Textularia foeda Reuss
Tritaxia aspera (Cushman) (= *Clavulina trilatera aspera* Cushman)
Tritaxia disjuncta (Cushman) (= *Clavulina disjuncta* Cushman)
Tritaxia gaultina (Morozova) (= *Clavulina gaultina* Morozova)
Tritaxia trilatera (Cushman) (= *Clavulina trilatera* Cushman)
Trocholina sp. cf. *T. alpina* (Leupold) (= *Coscinoconus alpinus* Leupold) Ramalho, 1971, p. 154, pl. 21, figs 1, 2
Trocholina conica (Schlumberger) (= *Involutina conica* Schlumberger)
Trocholina sp. aff. *T. friburgensis* (Guillaume and Reichel) (= *Neotrocholina friburgensis* Guillaume and Reichel)
Trocholina infragranulata Noth
Trocholina valdensis (Reichel) (= *Neotrocholina valdensis* Reichel)
Valvulineria lenticula (Reuss) (= *Rotalina lenticula* Reuss)
Valvulineria loetterli (Tappan) (= *Gyroidina loetterli* Tappan)

[a] In alphabetic order by genera and species, listing selected reference illustrations.

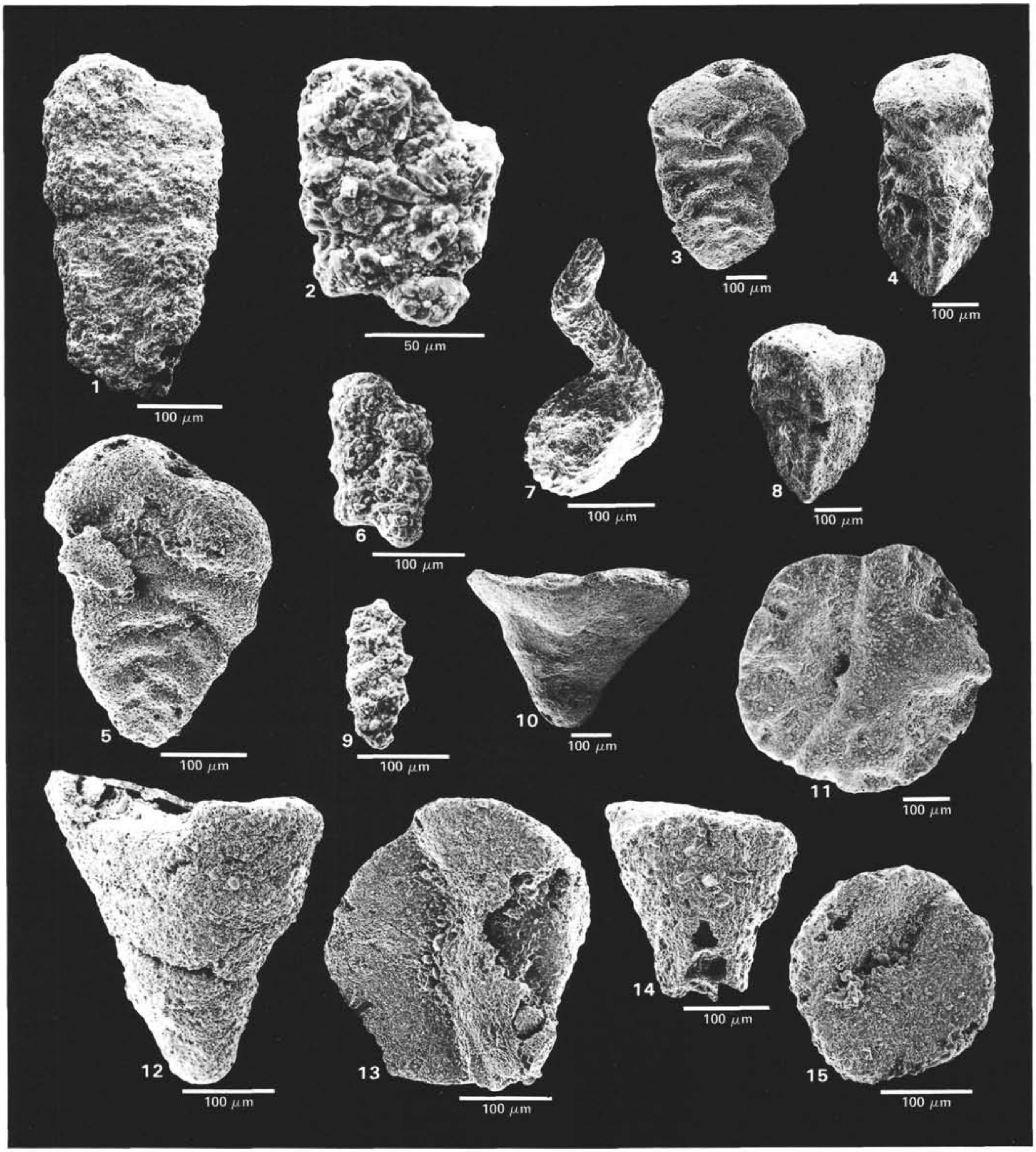

Plate 1. (All scales 100 μm except in Fig. 2, which is 50 μm). **1.** *Textularia foeda* Reuss, Sample 537-3-2, 50–52 cm. **2.** *Textularia foeda* Reuss, Sample 535-70-1, 110–111 cm. **3–4.** *Gaudryina laevigata* Franke, Sample 538A-21-4, 107–109 cm, (3) side view, (4) peripheral view. **5.** *Dorothia conula* (Reuss), Sample 538A-21-4, 107–109 cm. **6.** *Textularia foeda* Reuss, Sample 535-70-1, 110–111 cm. **7.** *Lituotuba incerta* Franke, Sample 537-3-2, 50–52 cm. **8.** *Gaudryina pyramidata* Cushman, Sample 538A-21-4, 107–109 cm. **9.** *Textularia foeda* Reuss, Sample 535-70-1, 110–111 cm. **10–11.** *Dorothia subtrochus* (Bartenstein), Sample 538A-21-4, 107–109 cm, (10) side view, (11) apertural view. **12–13.** *Dorothia subtrochus* (Bartenstein), Sample 537-3-2, 50–52 cm, **(12)** side view, **(13)** apertural view. **14–15.** *Dorothia subtrochus* (Bartenstein), Sample 537-3-1, 50–52 cm, (14) side view, (15) apertural view.

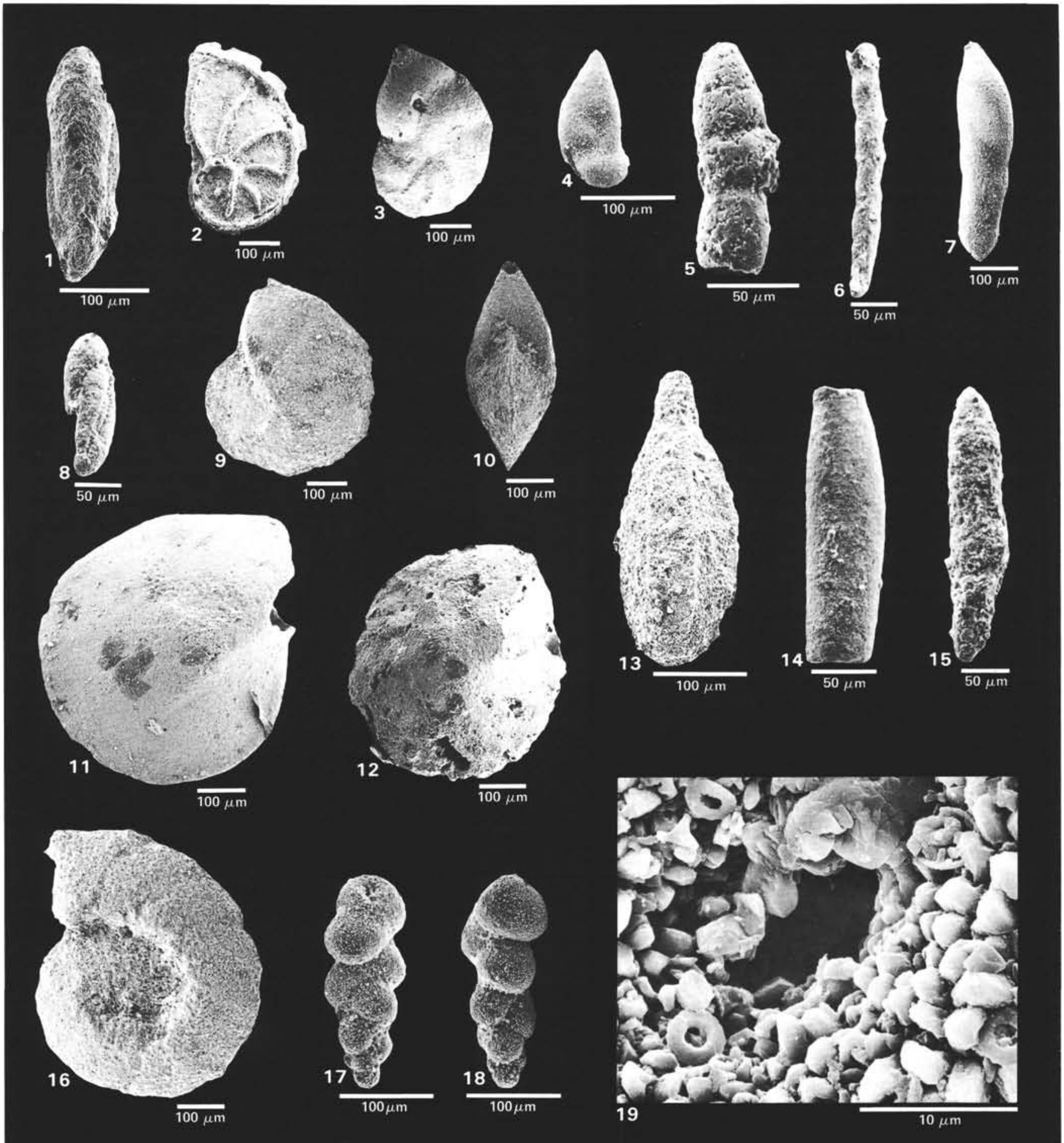

Plate 2. (Figs. 1–4, 7, 9–13, 16–18 scale is 100 μm; Figs. 5, 6, 8, 14, 15 scale is 50 μm; Fig. 19 scale is 10 μm.) **1.** *Quinqueloculina* sp., Sample 535-38-1, 1–3 cm. **2.** *Astacolus crepidularis* (Roemer), Sample 537-3-2, 50–52 cm. **3.** *Astacolus gratus* (Reuss), Sample 535-36-1, 80–82 cm. **4.** *Astacolus planiusculus* (Reuss), Sample 538A-23-1, 37–40 cm. **5.** *Dentalina communis* d'Orbigny, Sample 535-57-7, 56–59 cm. **6.** *Dentalina communis* d'Orbigny, Sample 535-70-1, 110–111 cm. **7.** *Dentalina nana* Reuss, Sample 535-70-1, 110–111 cm. **8.** *Quinqueloculina* sp., Sample 535-70-1, 110–111 cm. **9–10.** *Lenticulina subangulata* (Reuss), Sample 537-3-2, 50–52 cm, **(9)** spiral view, **(10)** side view. **11.** *Lenticulina subalata* (Reuss), Sample 537-3-2, 50–52 cm, spiral view. **12.** *Lenticulina muensteri* (Roemer), Sample 537-3-2 50–52 cm, spiral view. **13.** *Lagena sztejnae* Dieni and Massari, Sample 537-3-2, 50–52 cm. **14.** *Dentalina varians* Terquem, Sample 535-57-7, 56–59 cm. **15.** *Dentalina* sp. cf. *D. nana* Reuss, Sample 535-57-7, 56–59 cm. **16.** *Lenticulina subalata* (Reuss), Sample 537-3-2, 50–52 cm, spiral view. **17–19.** *Neobulimina minima* Tappan, Sample 538A-23-1, 37–40 cm, (17) apertural view, (18) side view, (19) detail of the aperture in Fig. 17.

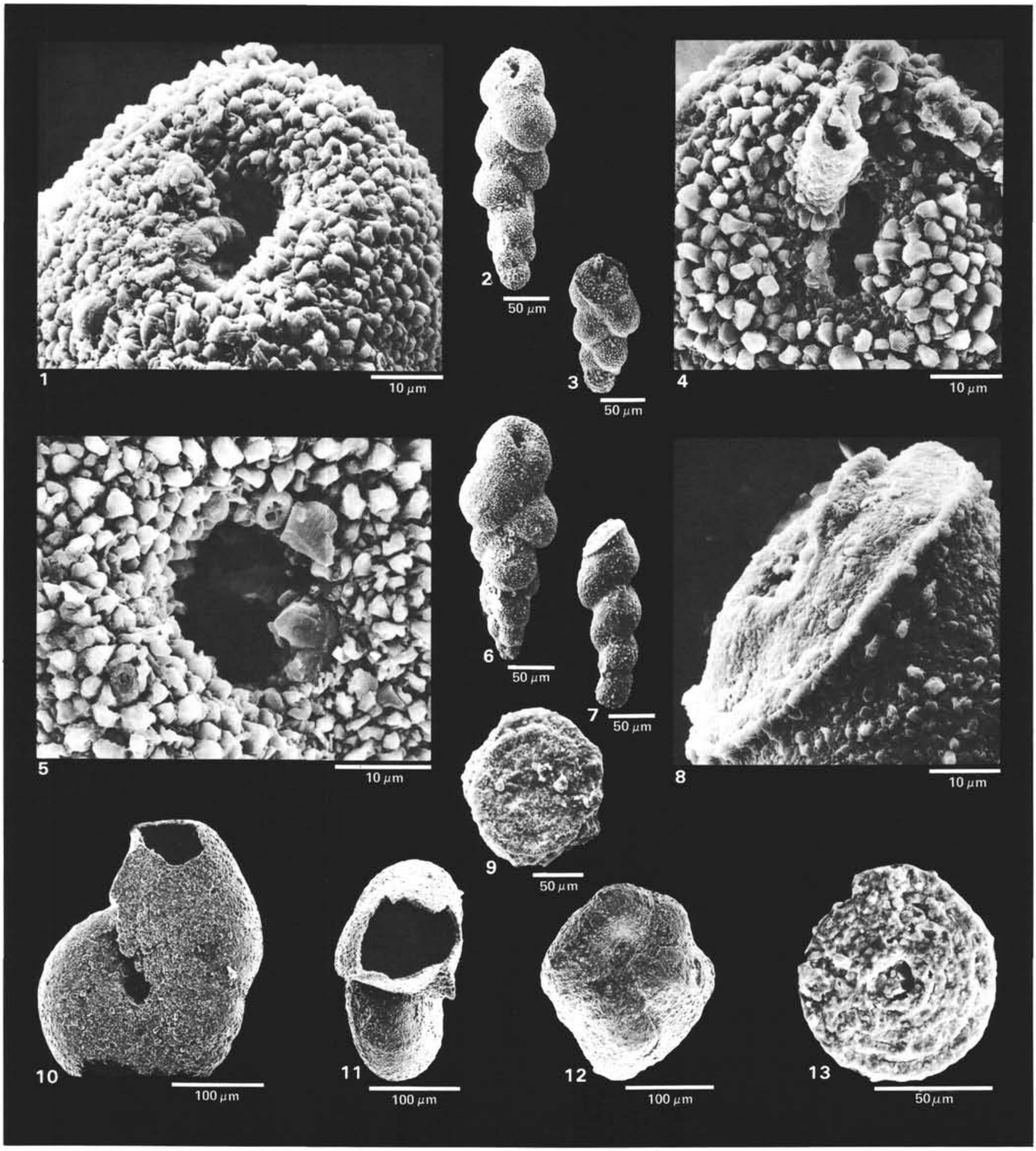

Plate 3. (Figs. 1, 4, 5, 8 scale is 10 μm; Figs. 2, 3, 6, 7, 9, 13 scale is 50 μm; Figs. 10–12, 100 μm.) **1–2.** *Neobulimina minima* Tappan, Sample 538A-23-1, 37–40 cm, (1) enlarged view of aperture showing tooth plate, (2) same specimen. **3–4.** *Neobulimina minima* Tappan, Sample 538A-23-1, 37–40 cm, (3) specimen with broken ultimate chamber showing projecting tooth plate, (4) enlarged view of same specimen. **5–6.** *Neobulimina minima* Tappan, Sample 538A-23-1, 37–40 cm, (5) enlarged view of aperture and tooth plate, (6) same specimen. **7–8.** *Neobulimina minima* Tappan, Sample 538A-23-1, 37–40 cm, (7) specimen with broken ultimate chamber, (8) enlarged view of same specimen. **9.** *Spirillina tenuissima* Guembel, Sample 535-57-7, 56–59 cm. **10–11.** *Valvulineria loetterli* (Tappan), Sample 538A-21-4, 107–109 cm, (10) umbilical view, (11) peripheral view. **12.** *Praebulimina cushmani* (Sandidge), Sample 537-3-2, 50–52 cm. **13.** *Spirillina tenuissima* Guembel, Sample 535-70-1, 110–111 cm.

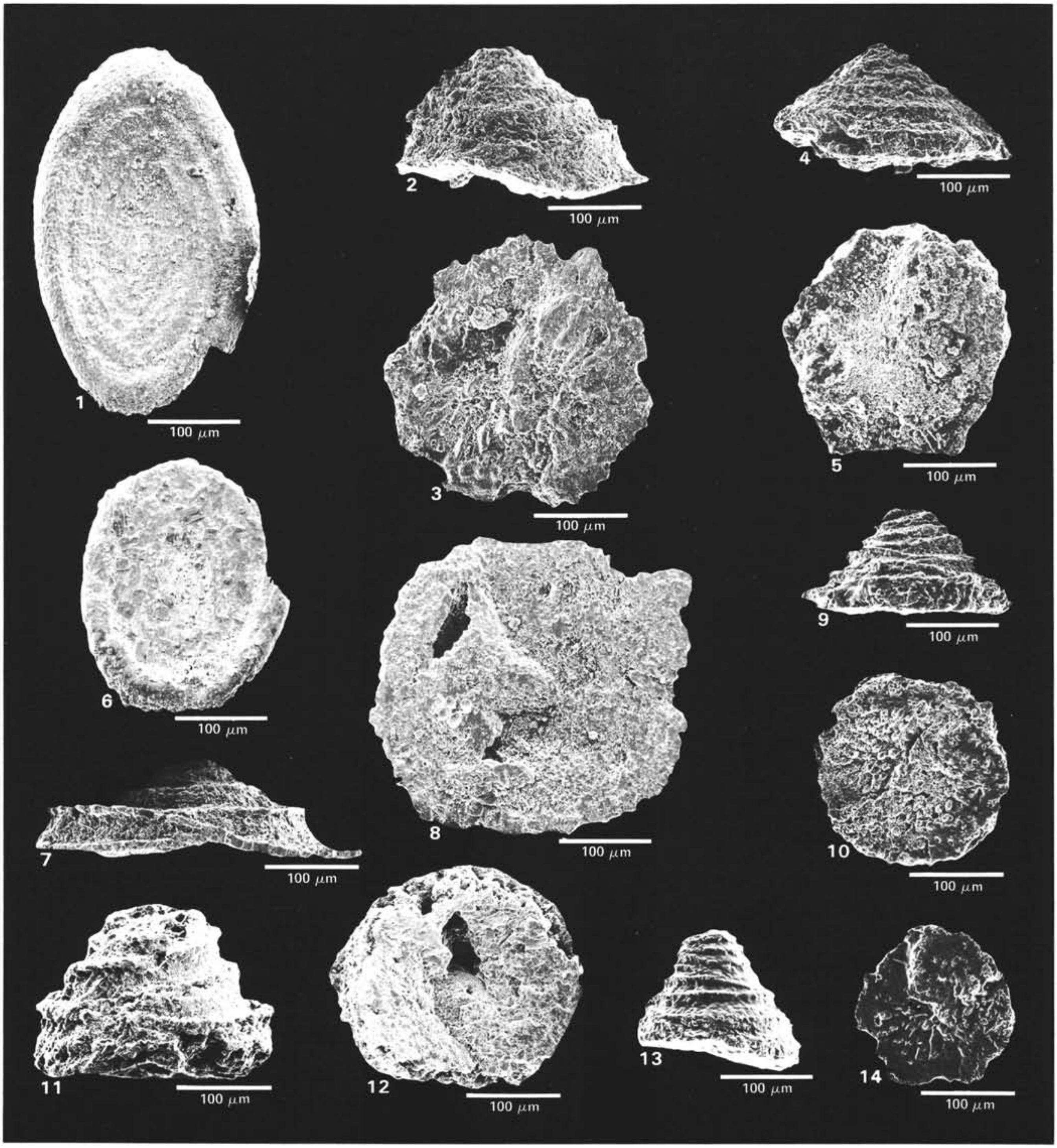

Plate 4. (All scales 100 µm.) **1, 6.** *Spirillina minima* Schacko, Sample 537-3-2, 50–52 cm. **2–3.** *Patellina subcretacea* Cushman and Alexander, Sample 537-3-2, 50–52 cm, (2) side view, (3) umbilical view. **4–5.** *Patellina subcretacea* Cushman and Alexander, Sample 538A-21-4, 107–109 cm, (4) side view, (5) umbilical view. **7–8.** *Patellina feifeli* (Paalzow), Sample 538A-21-4, 83–84 cm, (7) side view, (8) umbilical view. **9–10.** *Patellina feifeli* (Paalzow), Sample 538A-21-4, 107–109 cm, (9) side view, (10) umbilical view. **11–12.** *Patellina turriculata* Dieni and Massari, Sample 538A-21-4, 83–84 cm, (11) side view, (12) umbilical view. **13–14.** *Patellina turriculata* Dieni and Massari, Sample 538A-21-4, 107–109 cm, (13) side view, (14) umbilical view.

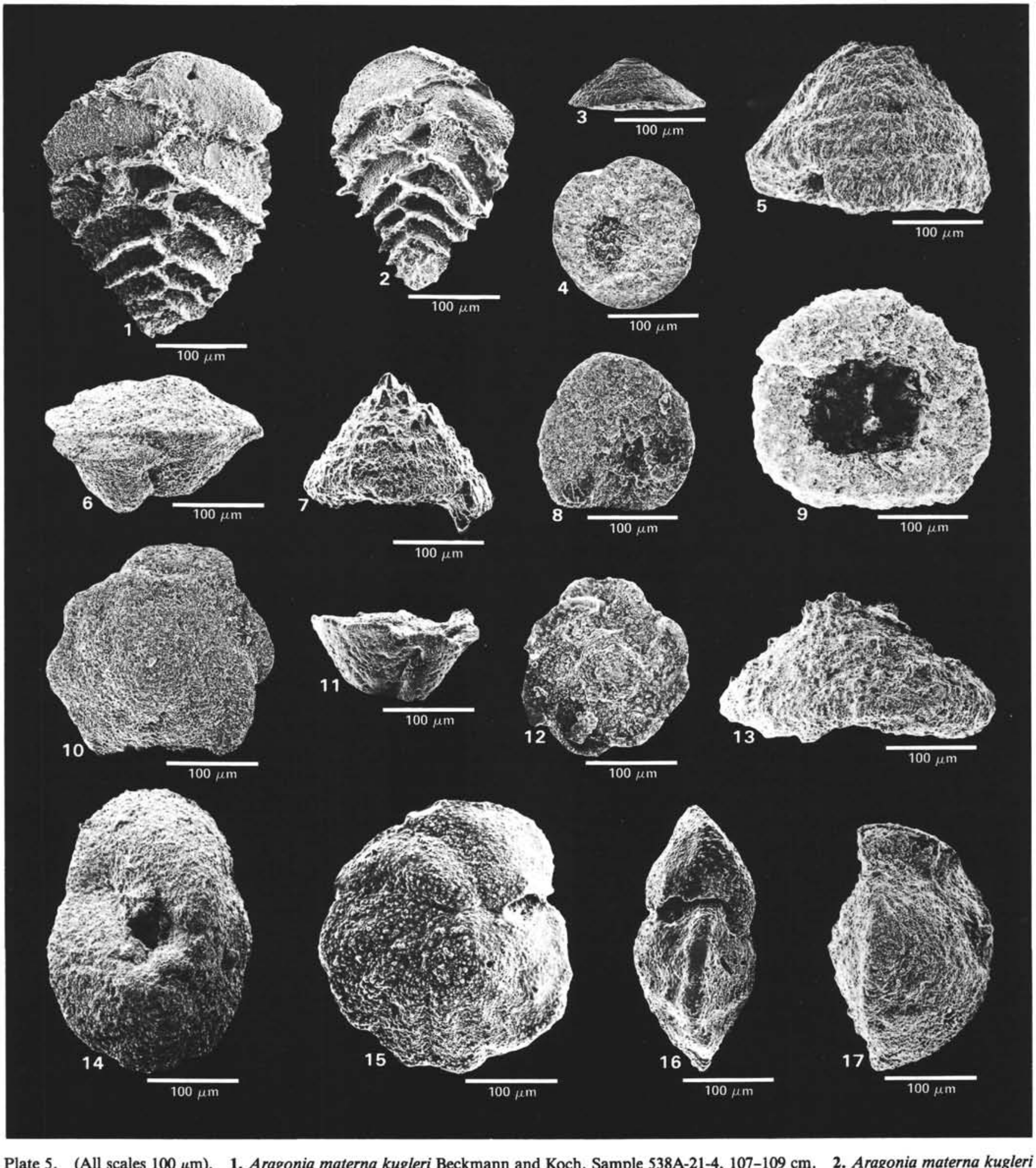

Plate 5. (All scales 100 μm). **1.** *Aragonia materna kugleri* Beckmann and Koch, Sample 538A-21-4, 107–109 cm. **2.** *Aragonia materna kugleri* Beckmann and Koch, Sample 538A-21-4, 107–109 cm. **3–4.** *Trocholina infragranulata* Noth, Sample 535-38-1, 1–3 cm, (3) side view, (4) umbilical view. **5, 9.** *Trocholina valdensis* (Reichel), Sample 537-3-2, 50–52 cm, (5) side view, (9) umbilical view. **6, 10.** *Conorotalites aptiensis* (Bettenstaedt), Sample 538A-21-4, 107–109 cm, (6) side view, (10) spiral view. **7–8.** *Trocholina valdensis* (Reichel), Sample 537-3-2, 50–52 cm, (7) side view, (8) umbilical view. **11–12.** *Conorotalites aptiensis* (Bettenstaedt), Sample 538A-21-4, 107–109 cm, (11) side view, (12) spiral view. **13.** *Trocholina infragranulata* Noth, Sample 538A-21-4, 83–84 cm, peripheral view. **14.** *Conorotalites aptiensis* (Bettenstaedt), Sample 535-36-1, 80–82 cm, umbilical view. **15–16.** *Gavelinella intermedia* (Berthelin), Sample 538A-21-4, 107–109 cm, (15) spiral view, (16) peripheral view. **17.** *Stensioina granulata* (Olbertz), Sample 537-3-2, 50–52 cm, peripheral view.

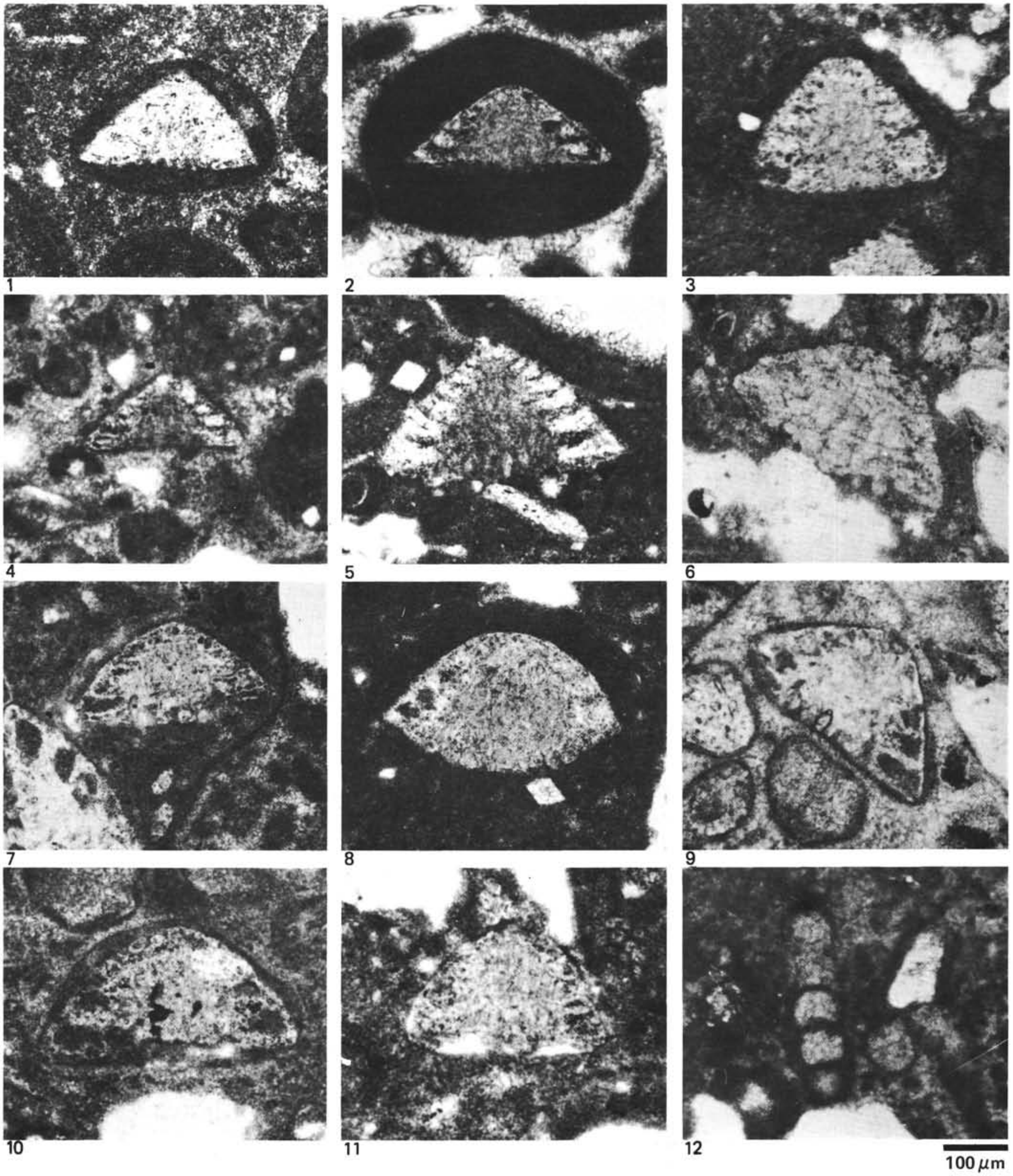

Plate 6. (All scales 100 μm.) **1.** *Trocholina valdensis* (Reichel), Sample 538A-24-1, 5-8 cm. **2.** *Trocholina infragranulata* Noth, Sample 538A-24-1, 5-8 cm. **3.** *Trocholina* sp. aff. *T. friburgensis* (Guillaume and Reichel), Sample 538A-24-1, 5-8 cm. **4.** *Trocholina infragranulata* Noth, Sample 538A-25-1, 3-4 cm. **5.** *Trocholina valdensis* (Reichel), Sample 538A-27-1, 4-5 cm. **6.** *Trocholina valdensis* (Reichel), Sample 538A-30-1, 1-2 cm. **7.** *Trocholina valdensis* (Reichel) and fragment of *Trocholina conica* (Schlumberger), Sample 538A-30-1, 1-2 cm. **8.** *Trocholina* sp. aff. *T. friburgensis* (Guillaume and Reichel), Sample 538A-30-1, 1-2 cm. **9.** *Trocholina conica* (Schlumberger), Sample 535A-30-1, 1-2 cm. **10.** *Trocholina conica* (Schlumberger), Sample 538A-30-1, 1-2 cm. **11.** *Trocholina* sp. aff. *T. friburgensis* (Guillaume and Reichel), Sample 538A-30-1, 2-3 cm. **12.** *Ammobaculites* sp., Sample 537-10-1, 13 cm.

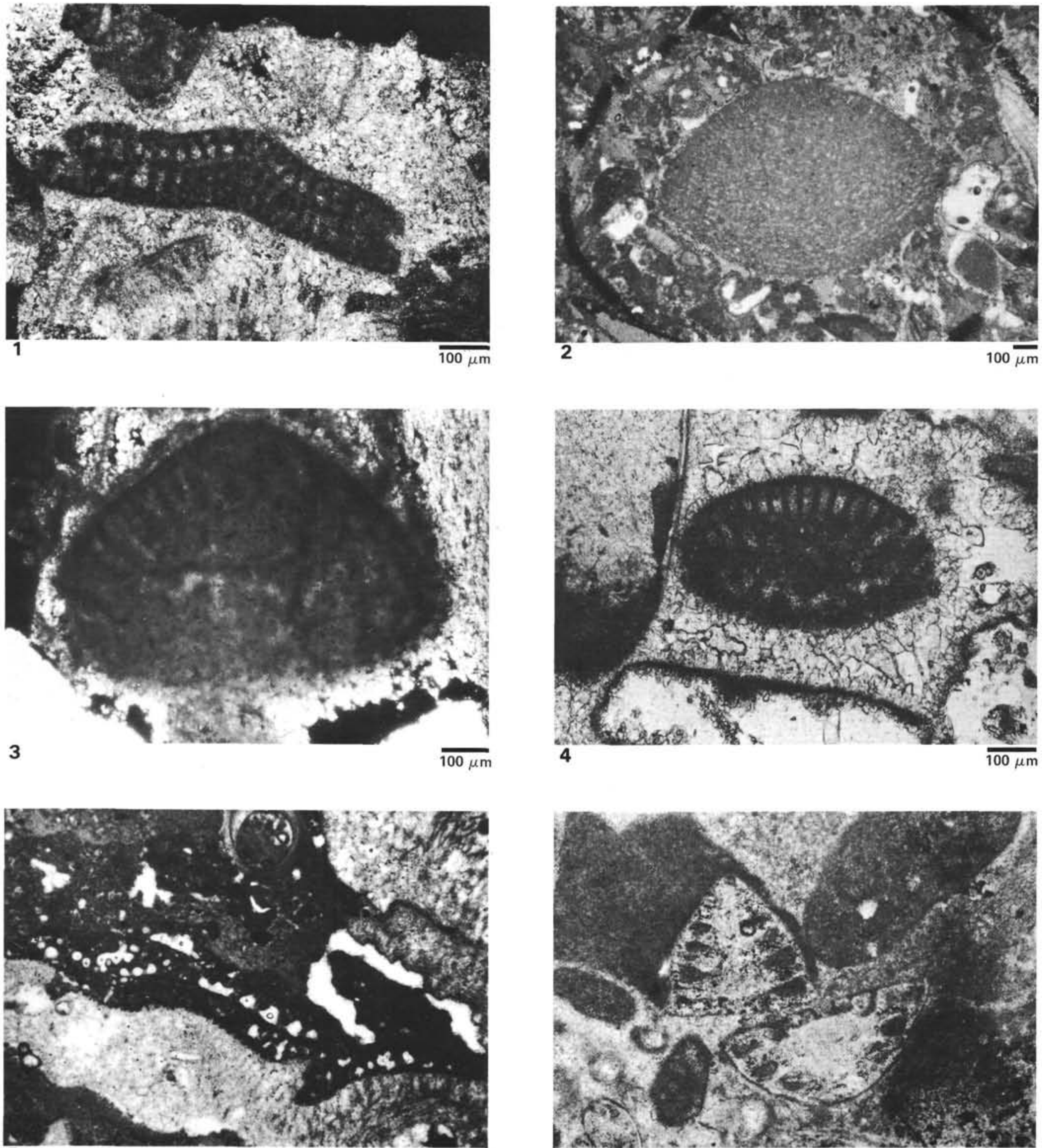

Plate 7. (All scales 100 μm except in Fig. 5, which is 500 μm.) **1.** *Cuneolina pavonia parva* Henson, Sample 536-10-1, 44–45 cm. **2.** *Orbitolina* sp. aff. *O. texana* (Roemer), Sample 536-14-1, 29–30 cm. **3.** Orbitolinid, Sample 536-15-1, 26–28 cm. **4.** *Orbitolina* sp., Sample 536-16-1, 66–69 cm. **5.** Unidentified encrusting organism, Sample 536-21-1, 5–10 cm. **6.** *Trocholina conica* (Schlumberger) and *Trocholina* sp. cf. *T. alpina* (Leupold), Sample 538A-30-1, 1–2 cm.