# Late Cretaceous to Early Tertiary agglutinated benthic foraminifera in the Labrador Sea

**Kenneth G. Miller**
*Woods Hole Oceanographic Institution*
*Massachusetts Institute of Technology*
*Joint Program in Oceanography*
*Woods Hole, Massachusetts 02543*

**Felix M. Gradstein**
*Geological Survey of Canada*
*Bedford Institute of Oceanography*
*Dartmouth, Nova Scotia, Canada*

**W. A. Berggren**
*Department of Geology and Geophysics*
*Woods Hole Oceanographic Institution*
*Woods Hole, Massachusetts 02543*
and
*Department of Geology*
*Brown University*
*Providence, Rhode Island 02912*

**ABSTRACT**

A major faunal change occurred at the end of the Eocene in the deep Labrador Sea (DSDP Site 112). Predominantly agglutinated Eocene benthic foraminiferal assemblages are replaced by an Oligocene calcareous assemblage. This replacement correlates with similar changes in the Canadian margin and the North Sea where the exit of agglutinated foraminifera is associated with a change in depositional environment. In Site 112, however, lithology, percent carbonate, and percent organic carbon are relatively constant across the faunal change. Thus, at least in the deep sea, these properties may not be critical to the development of predominantly agglutinated assemblages. We infer that certain hydrographic properties (low oxygen, high $CO_2$ , low pH, and thus more corrosive waters) favor the development of agglutinated assemblages. We suggest that the replacement of agglutinated foraminifera in the deep Labrador Sea was due to a change in hydrographic properties. Seismic evidence from this region indicates initiation of northern sources of bottom water in the late Eocene to early Oligocene which may have resulted in a change in hydrography and the exit of agglutinated foraminifera. Despite diachrony of certain occurrences in Site 112 and the Canadian margin, compared with previously reported ranges of agglutinated taxa from the North Sea, European flysch basin, and the deep sea, agglutinated foraminifera are useful in the zonation of Labrador Sea sediments.

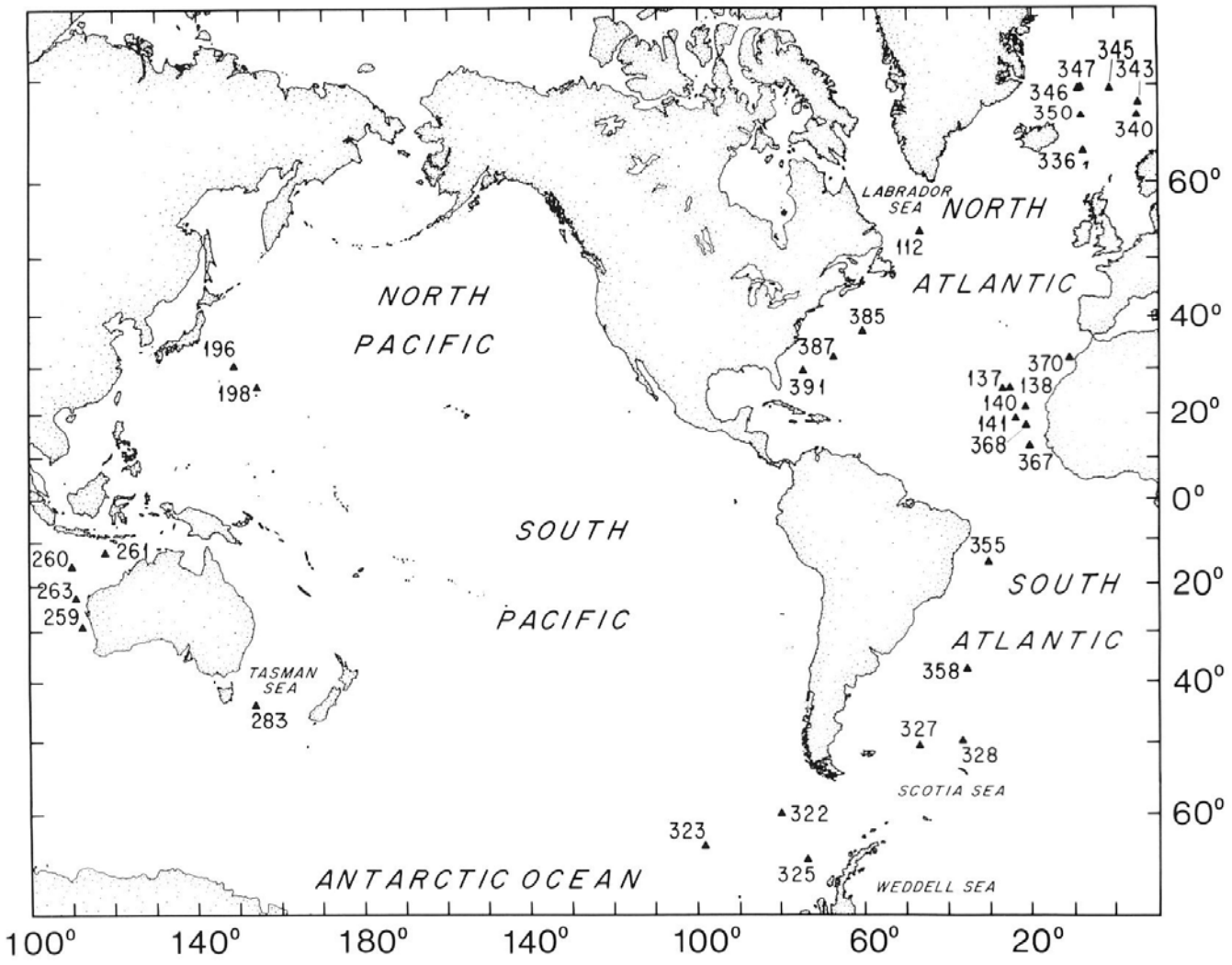
**INTRODUCTION**

Agglutinated (arenaceous) foraminiferal assemblages occur in Maestrichtian to Eocene mudstones of the Labrador Shelf/northeast Newfoundland Shelf and upper Paleocene to Eocene shales of the North Sea. These taxonomically similar assemblages resemble the *Rhabdammina* assemblages described (Brouwer, 1965) from pelitic intervals of flysch sediments throughout the world. Gradstein and Berggren (1981) described the taxonomy, zoogeography, and biostratigraphic utility of these Late Cretaceous to Tertiary "flysch-type" agglutinated assemblages, discussed paleoecologic implications of their distribution, and related their distribution to the tectonic history of the Labrador Sea and the North Sea.

Predominantly agglutinated assemblages resembling the flysch-type *Rhabdammina* assemblages also have been described from deep-sea sediments recovered by the Deep Sea Drilling Project/International Phase of Ocean Drilling (text-figs. 1, 2). Our study compares the distribution of the deep-sea assemblages as reported in the Initial Reports of the Deep Sea Drilling Project, examines in detail Eocene agglutinated assemblages of DSDP Site 112 (Labrador Sea), and compares the Site 112 assemblages with Maestrichtian to Eocene agglutinated assemblages of the Labrador and East Newfoundland shelves. Various paleoecologic models for agglutinated assemblages are evaluated, using lithologic and faunal data from Site 112. We conclude that a late Eocene to early Oligocene change in abyssal circulation resulted in the demise of the agglutinated assemblages in Site 112; local tectonic and sedimentologic events may have been important in the replacement of agglutinated assemblages in the Canadian margin and the North Sea.

**PREVIOUS WORK**

Berggren (1972) noted relatively diverse assemblages of predominantly agglutinated benthic foraminifera in the ?Paleocene to Eocene sediments of Site 112. Subsequently, Middle Cretaceous to Early Tertiary agglutinated benthic foraminiferal assemblages have been recorded in 30 DSDP sites in various parts of the world (text-figs. 1, 2; Beckman, 1972; Krasheninnikov, 1973, 1974; Webb, 1975; Rögl, 1976; van Hinte,




TEXT-FIGURE 1
Location map of DSDP-IPOD sites containing type A agglutinated benthic foraminiferal assemblages.

in Talwani, Udintsev et al., 1976; Krasheninnikov and Pflaumann, 1977; Tjalsma, 1977; Gradstein, 1978; McNulty, 1979). These assemblages consist of mostly agglutinated taxa, but calcareous benthic forms may be minor constituents. Planktonic foraminifera are, in general, rare or absent. Miller et al. (1979) and Gradstein and Berggren (1981) differentiated two types of deep-sea assemblages of agglutinated benthic foraminifera distinguishable by wall texture, test size, and taxonomic composition. Assemblage type A is found in bathyal and abyssal sediments; it is similar in taxonomic composition to agglutinated assemblages of the Carpathian and Alpine flysch basins (= "flysch-type" agglutinated assemblages of Gradstein and Berggren, 1981), the North Sea, and the Canadian margin. In general, this assemblage is characterized by coarse-grained, larger-sized tests. "Simple" forms including the single chambered and uniserial genera *Rhabdammina, Bathysiphon, Ammodiscus, Lituotuba, Reophax,* and *Hormosina* often dominate this assemblage (pl. 1). Biserial (*Spiroplectammina, Textularia*), multiserial (*Gaudryina, Dorothia*), trochoid (*Trochammina, Recurvoides, Trochamminoides*), and planispiral (*Cribrostomoides, Haplophragmoides, Cyclammina*) forms are less abundant (pl. 2). Assemblage type B has been recorded only from abyssal sediments. This assemblage is composed of small (generally less than 150 $\mu$m), thin, smooth walled, predominantly "complex" forms of the families Lituolidae, Trochamminidae, and Textulariidae. Krasheninnikov (1974) noted certain generic similarities between an Upper Cretaceous type B assemblage in Sites 260 and 261 and flysch-type (= type A) agglutinated foraminiferal assemblages. However, such genera as *Plecto-*

*recurvoides, Haplophragmium,* and *Labrospira,* which are usually rare to absent in type A assemblages, predominate in type B assemblages.

Some of the taxonomic differences between type A and type B assemblages may be due to different stratigraphic and facies distribution. Text-figure 2 shows the distribution of predominantly agglutinated foraminiferal assemblages and lithofacies versus age as reported from 21 DSDP/IPOD sites. Type A assemblages, reported from Sites 112, 137, 138, 140, 141, 367 (cores 15 to 18), 368, 327, 328, 323, and 283 are found in Late Cretaceous to Tertiary sediments. In the Tertiary, the only apparent post-Eocene occurrences of type A assemblages are at Sites 323 and 325 (Bellingshausen Sea; Rögl, 1976) and in the Norwegian-Greenland Sea (van Hinte, in Talwani, Udintsev et al., 1976); however, the Norwegian-Greenland Sea assemblages may be taxonomically distinct from both Type A and Type B assemblages. In contrast, type B assemblages, reported from Sites 196, 198A, 260, 261, 263 (Krasheninnikov, 1973, 1974), 385, 387 (McNulty, 1979), and 391C (Gradstein, 1978) are found only in Cretaceous sediments. A third type of agglutinated assemblage, the *Dorothia praehauteriviana* assemblage, has been reported from the deep sea by Luterbacher (1972), Krasheninnikov and Pflaumann (1977), and Kuznetsova and Seibold (1978) from Sites 101, 105, 367 (cores 26–29), 370 (cores 38–49), and 391C. This assemblage is found only in Lower Cretaceous sediments. The different agglutinated assemblages also occur in different lithofacies. Text-figure 2 shows that both type A and type B assemblages are found primarily in zeolithic and variegated clays, but type B assemblages (with the possible exception of Site 385, core 12) are restricted to such sediments, while type A assemblages are found in a wider variety of lithofacies. The *D. praehauteriviana* assemblage, in contrast, is found only in Neocomian limestones.

Type A and type B assemblages also occur at different paleodepths. We use the "backtracking" method (Sclater et al., 1971; Berger and Winterer, 1974) to estimate paleobathymetry for these deep-sea agglutinated assemblages. With the exception of the Norwegian-Greenland Sea (paleodepths less than 0.7 km to 3.0 km), assemblage A occurs above crust which may be backtracked to paleodepths of 2.5 to 4.5 km (table 1). Assemblage B, however, is restricted to paleodepths greater than 4.0 km.

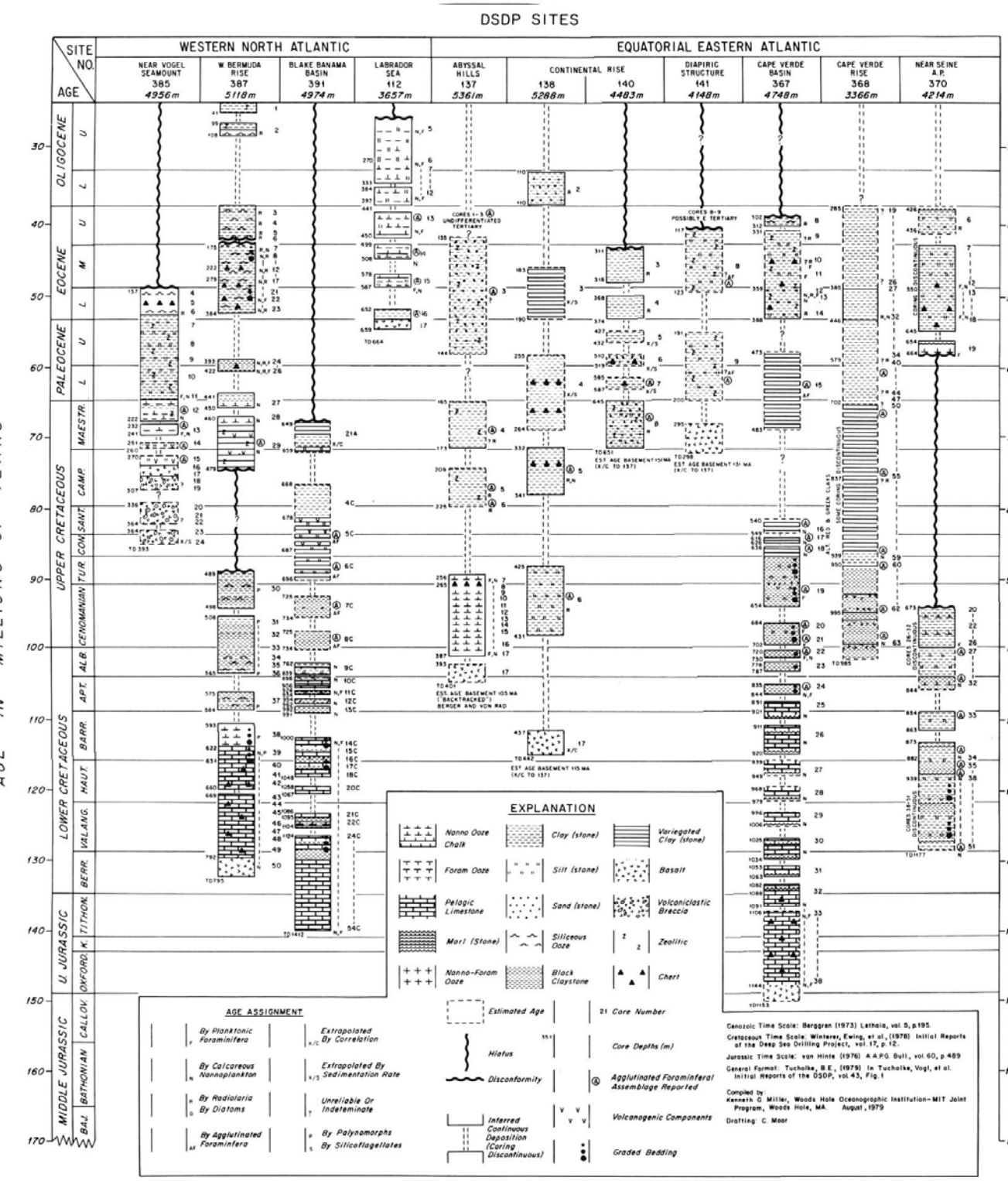
Predominantly agglutinated foraminiferal assemblages have been accounted for by water depth, carbonate availability, hydrographic properties, and substrate characteristics. The extensive paleobathymetric range of type A assemblages suggests that depth alone does not control the distribution of these deep-sea agglutinated foraminifera. Hesse and Butt (1976) suggested that flysch-type agglutinated foraminiferal assemblages result from the exclusion of calcareous benthic foraminifera below a local CCD (Carbonate Compensation Depth). Saidova (1960, 1965) explained the distribution of Recent abyssal agglutinated foraminiferal assemblages from the Pacific Ocean with hydrographic properties (high pressure, low temperature, low dissolved oxygen). Saidova's explanation does not exclude carbonate control, as these properties promote carbonate dissolution. Similarly, Hiltermann (1973) suggested that low temperature and low oxygen favored agglutinated foraminifera in flysch deposits. Ksiazkiewicz (1961, 1975) and Moorkens (1976) invoked substrates containing abundant organic matter as an important control on flysch-type agglutinated assemblages. This explanation does not exclude carbonate or hydrographic limitations, as low $O_2$, high $CO_2$, low pH, low Eh, and poor circulation are often associated with high organic matter. These explanations are not mutually exclusive, but they do differ in emphasis. We evaluate them using lithologic and faunal data from DSDP Site 112.

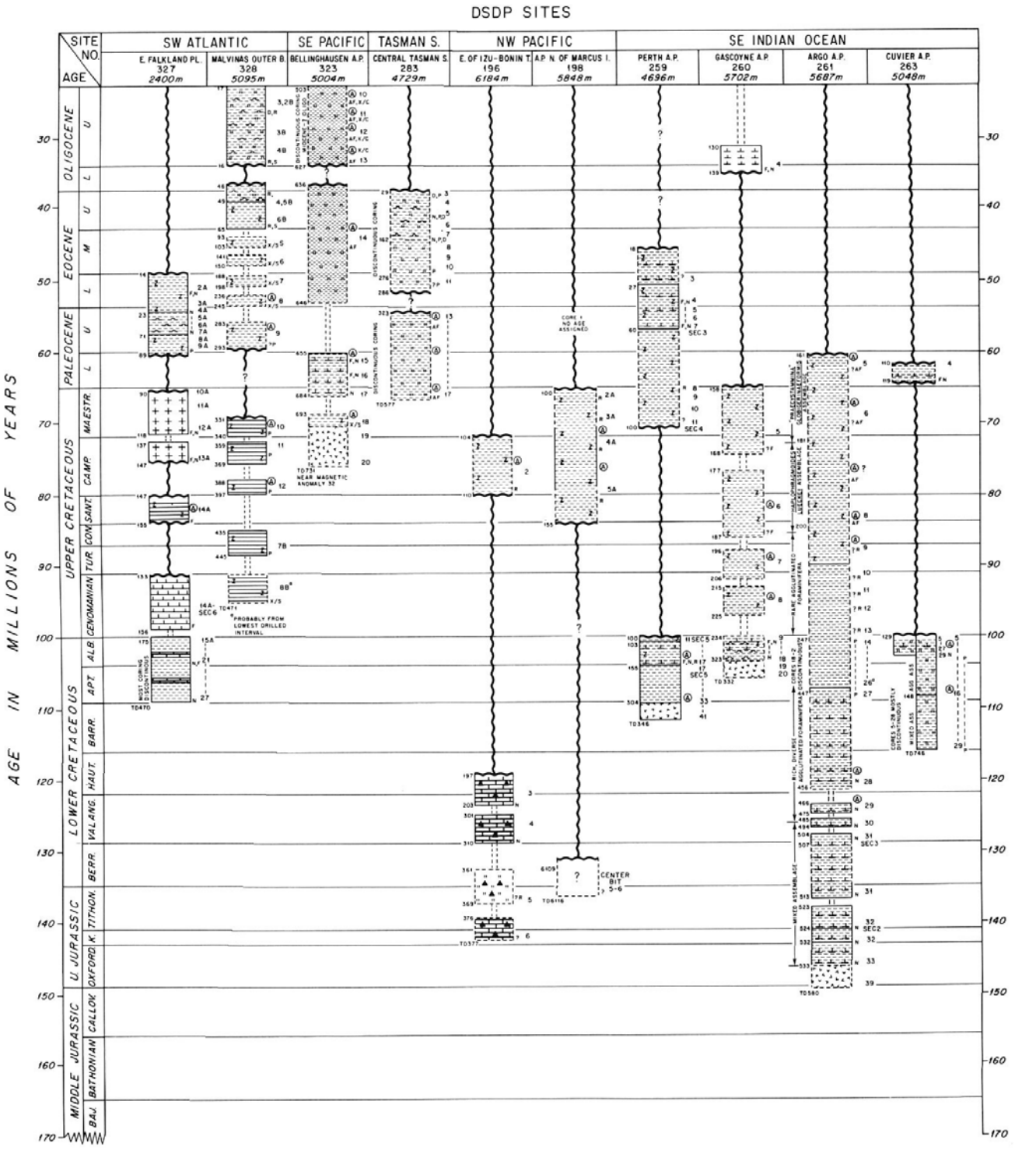
TABLE 1
Paleobathymetry of DSDP sites containing type A agglutinated benthic foraminifera. Pr = present depth (km), Pa = paleodepth (km) obtained by "backtracking."

| Area | Site no. | Depth *in* km | |
|---|---|---|---|
| | | Pr | Pa |
| Norwegian-Greenland Sea | 343 | 3.1 | 3.0 |
| | 346 | 0.7 | 0.7 |
| | 347 | 0.7 | 0.7 |
| | 349 | 0.9 | 0.9 |
| | 350 | 1.3 | 1.3 |
| Atlantic Ocean | 112 | 3.6 | 3.0 |
| | 140 | 4.5 | 4.0 |
| | 141 | 4.1 | 4.0 |
| | 367 | 4.7 | 4.5 |
| | 368 | 3.3 | 4.0 uplifted in Neogene |
| | 328 | 5.1 | 3.5–4 |
| Tasman Sea | 283 | 4.7 | 3.0 |
| Subantarctic | 323 | 5.0 | 3–3.5 |

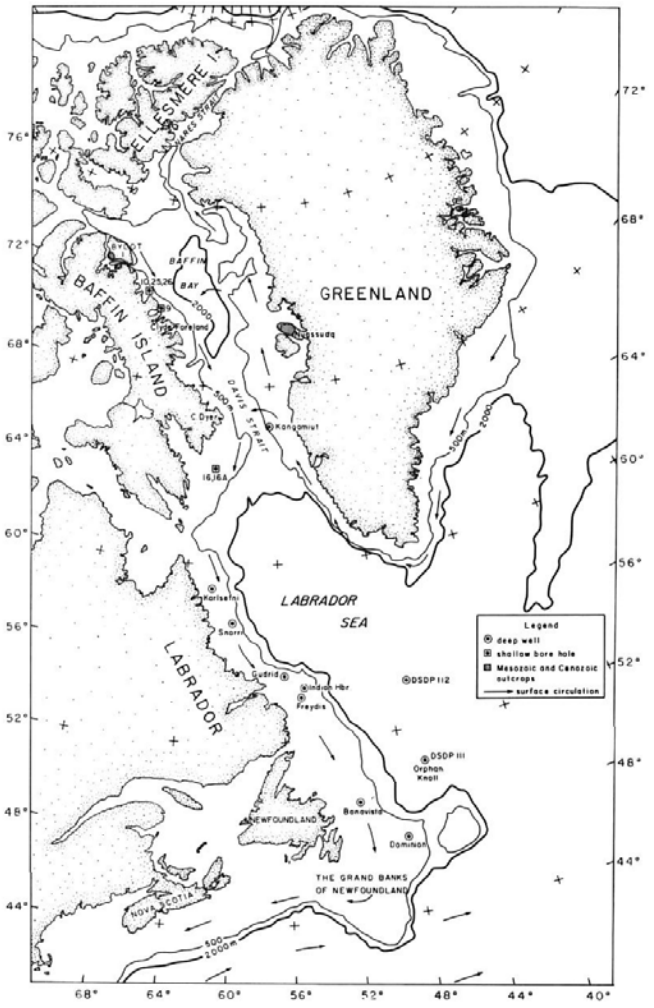
## METHODS

Twenty samples from the Eocene to lower Oligocene sediments of Site 112 were examined for benthic foraminiferal content (cores 11–16). All benthic foraminifera were picked from the greater than 150 $\mu$m size-fraction. The less than 150 $\mu$m size-fraction was examined to ensure that the larger size-fraction con-


DSDP SITES
WESTERN NORTH ATLANTIC
EQUATORIAL EASTERN ATLANTIC
SITE NO.
AGE
NEAR VOGEL SEAMOUNT 385 4956m
W BERMUDA RISE 387 5118m
BLAKE BAHAMA BASIN 391 4974m
LABRADOR SEA 112 3657m
ABYSSAL HILLS 137 5361m
CONTINENTAL RISE 138 5288m
CONTINENTAL RISE 140 4483m
DIAPIRIC STRUCTURE 141 4148m
CAPE VERDE BASIN 367 4748m
CAPE VERDE RISE 368 3366m
NEAR SEINE A.P. 370 4214m
AGE IN MILLIONS OF YEARS
OLIGOCENE
EOCENE
PALEOCENE
UPPER CRETACEOUS
LOWER CRETACEOUS
U JURASSIC
MIDDLE JURASSIC
MAESTR.
CAMP.
CONSANT.
TUR.
CENOMANIAN
ALB.
APT.
BARR.
HAUT.
VALANG.
BERR.
TITHON.
KIMM.
OXFORD.
CALLOV.
BATHONIAN
BAJ.
EXPLANATION
Nanno Ooze / Chalk
Foram Ooze
Pelagic Limestone
Marl (Stone)
Nanno-Foram Ooze
Clay (stone)
Silt (stone)
Sand (stone)
Siliceous Ooze
Black Claystone
Variegated Clay (stone)
Basalt
Volcaniclastic Breccia
Zeolitic
Chert
AGE ASSIGNMENT
By Planktonic Foraminifera
By Calcareous Nannoplankton
By Radiolaria
By Diatoms
By Agglutinated Foraminifera
Extrapolated By Correlation
Extrapolated By Sedimentation Rate
Unreliable Or Indeteminate
By Palynomorphs
By Silicoflagellates
Estimated Age
Hiatus
Disconformity
Inferred Continuous Deposition (Coring Discontinuous)
21 Core Number
Core Depths (m)
Agglutinated Foraminiferal Assemblage Reported
Volcanogenic Components
Graded Bedding
Cenozoic Time Scale: Berggren (1973) Lethaia, vol. 5, p.195.
Cretaceous Time Scale: Winterer, Ewing, et al., (1978) Initial Reports of the Deep Sea Drilling Project, vol. 17, p. 12.
Jurassic Time Scale: van Hinte (1976) A.A.P.G. Bull., vol. 60, p. 489
General Format: Tucholke, B.E., (1979) in Tucholke, Vogt, et al. Initial Reports of the DSDP, vol. 43, Fig. 1
Compiled by: Kenneth G. Miller, Woods Hole Oceanographic Institution–MIT Joint Program, Woods Hole, MA August, 1979
Drafting: C. Moor




TEXT-FIGURE 2
Stratigraphic distribution of lithofacies and agglutinated foraminiferal assemblages. Sites containing agglutinated foraminifera from Miocene to Eocene of Norwegian-Greenland Sea (Sites 336, 340, 343, 344, 345, 347, 350) and ?Oligocene to early Miocene of the Bellingshausen Sea (Sites 332, 325) not shown.




TEXT-FIGURE 3
Location of wells, Labrador Sea and environs.

tained representatives of all agglutinated species present in Site 112. This was necessary because species typical of type B agglutinated assemblages are found predominantly in the smaller size-fraction. No species restricted to the smaller size-fraction were noted. Sample size is approximately 25 to 50 g; exact size is not available as most of the samples were taken on shipboard.

Most of the wells available from the Canadian margin (text-fig. 3) contain only cuttings. All foraminifera were picked from the greater than 63 $\mu$m size-fraction.

The agglutinated foraminifera were identified using the taxonomy outlined by Gradstein and Berggren (1981), which is further described in the Systematic Paleontology section of this paper. Abundance (table 3), presence/absence data of agglutinated species (text-fig. 4), and percent calcareous benthic foraminifera (table 4; text-figs. 5, 6) have been compiled for Site 112. No estimate of foraminiferal abundance was made for the Canadian margin wells; only exits were used in computing ranges of agglutinated taxa in these wells.

Estimating the relative abundance of agglutinated benthic foraminifera is complicated by the fact that many taxa occur as fragments rather than whole tests. Species of *Rhizammina, Bathysiphon, Hyperammina, Rhabdammina, Hormosina,* and *Reophax* are usually recovered only as fragments. These species, however, are often abundant, and neglecting them results in an inadequate assemblage description. Thus, all identifiable fragments of agglutinated taxa were counted. All identifiable fragments of calcareous taxa were counted for consistency. Although some duplication undoubtedly resulted, we believe that the observed changes in agglutinated assemblages and the relative abundance of agglutinated versus calcareous taxa are valid.

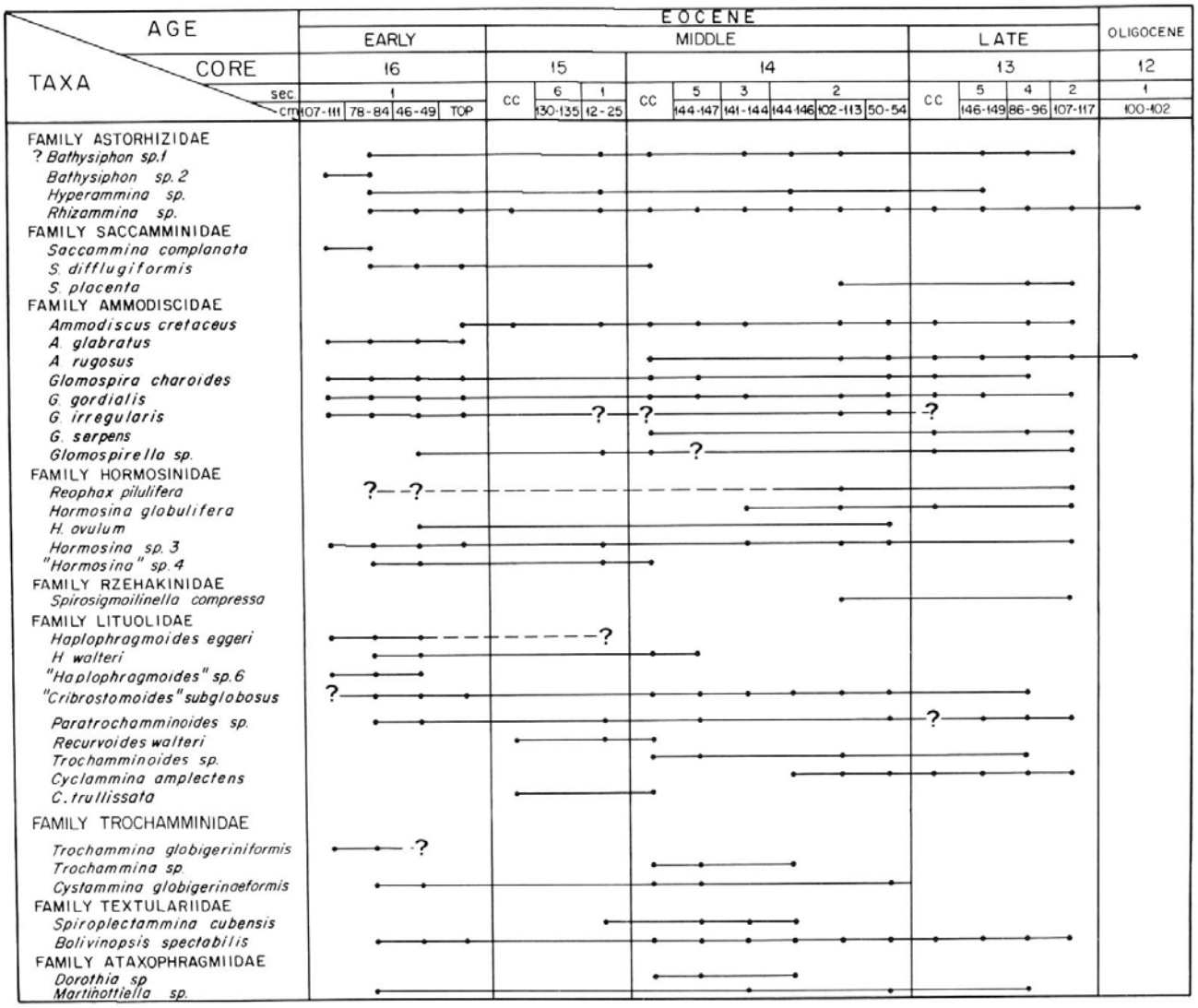
## AGGLUTINATED ASSEMBLAGES FROM SITE 112, LABRADOR SEA

### Planktonic biostratigraphy and lithology

Site 112 was drilled in 3657-m water depth in the southern Labrador Sea (text-fig. 3). Cores 1A to 5A (79–124 m subbottom) and 5 to 11 (270–293 m subbottom) were continuously cored; however, the Eocene/Oligocene boundary (between cores 12 and 13) was not cored. Basaltic basement was penetrated at 661 m (text-fig. 5).

The cored Paleogene section consists of indurated red clays and claystones with palagonite sills (core 16), indurated, burrow mottled gray pelagic nannofossil clay and marls (cores 12 to 15), and gray pelagic burrow mottled siliceous nannofossil clay and silt and siliceous ooze (cores 3 to 11; text-fig. 5). Cores 12 to 15 are distinguished from the overlying sediments by finer grain size, greater lithification and burrowing, and increased amounts of pyrite, authigenic calcite, and goethite (Laughton, Berggren et al., 1972).

Nannofossils and planktonic foraminifera were originally used to place cores 5 and 6 in the late Oligocene, cores 7 to 12 in the early Oligocene, and cores 13 to 15 in the Eocene. Radiolarians and diatoms also indicated an Oligocene age for cores 5 to 11. Core 16 was placed in the ?Paleocene-early Eocene on the basis of extrapolation of a 1.5 cm/1000 yr (= 15 m/my) sedimentation rate for the Eocene sediments in Site 112. An unconformity was inferred from the low sedimentation rate (less than 5.5 m/my) between the upper Oligocene in the top of core 5 (270 m subbottom) and middle Miocene sediments in the base of core 4 (209 m subbottom). No other evidence for Paleogene unconformities is present (Laughton, Berggren et al., 1972).



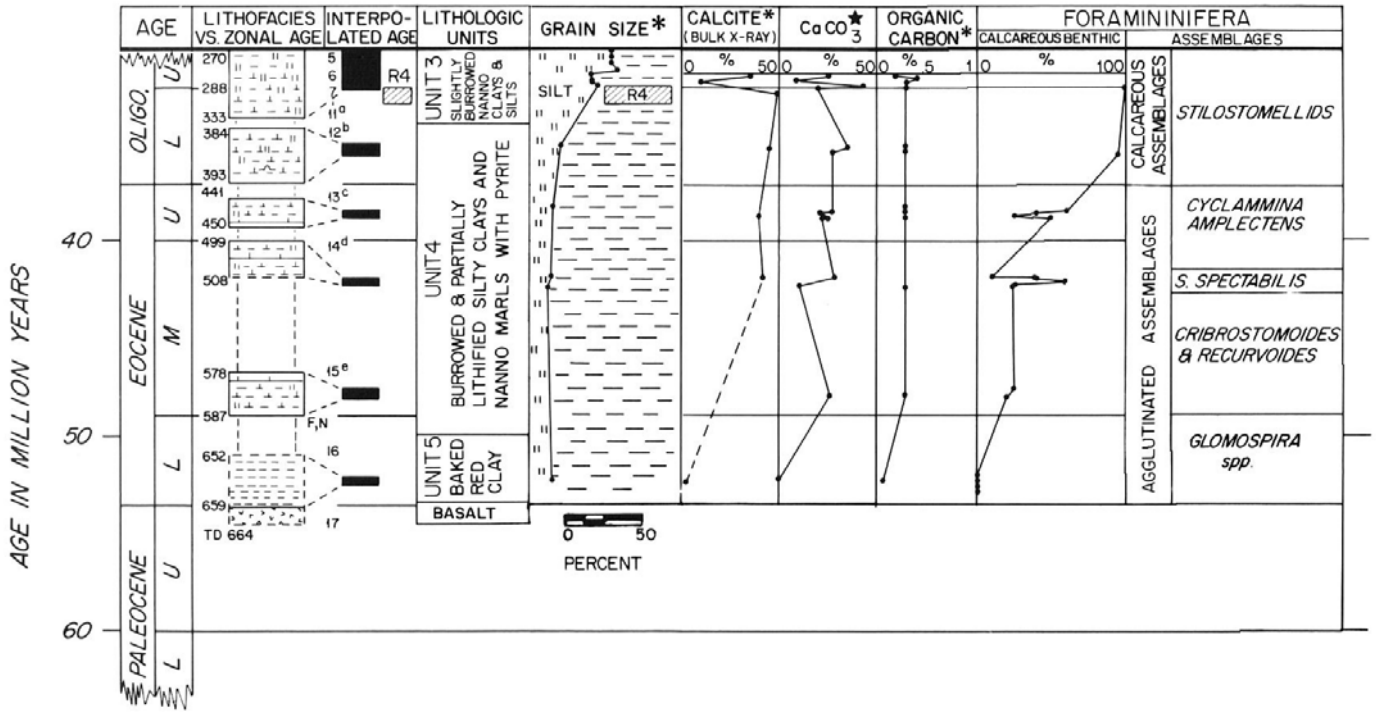

TEXT-FIGURE 4
Range chart of agglutinated taxa, DSDP Site 112. Following agglutinated species not listed: *Labrospira pacifica, Reophax nodulosus, Ammolagena clavata, Uvigeriniformis* sp., *Spiroplectinata* sp., and *Lituotuba* sp.

Type A agglutinated benthic foraminifera assemblages occur in the ?Paleocene to Eocene section of Site 112 (cores 13 to 16; text-fig. 5). We have re-examined planktonic foraminifera and calcareous nannoplankton and have refined the biostratigraphic zonation of these cores as described below.

**Core 16 (revised)**

No planktonic foraminifera or nannoplankton were originally reported from core 16, although ?late Paleocene-early Eocene nannoplankton were reported from the center bit just above core 16 (Perch-Nielsen, 1972). We note rare specimens of *Subbotina* sp. and *Subbotina* cf. *S. linaperta* Finlay in 16 center bit sample and sample 16-1, 107–111 cm, which agrees with the late Paleocene-early Eocene age assignment. The center bit sample contains a mixture of green marl and red clay, suggesting that the lithologic change from nannofossil clays and marls to baked red clay occurs just above core 16 at approximately 650 m.

Sedimentation rates for the lower Oligocene to Eocene clays and marls were recomputed after assigning core 15 to middle Eocene using planktonic foraminifera (Zone P10; 47–49 Ma; this paper), core 13 to the late Eocene using nannoplankton (Zone NP19, 37.5–39 Ma; Perch-Nielsen, 1972) and core 12 to the




TEXT-FIGURE 5

DSDP Site 112. Lithofacies symbols as in text-figure 2. Interpolated ages determined using a 15 m/my sedimentation rate assuming core 13 and core 15 lie in the middle of zones NP19 and P10, respectively. Correlation of reflector R4 shown by cross-hatched areas.

[a,b]*E. obruta, E. subdisticha* Zone—K. Perch-Nielsen (NP21, e. Oligo.); *H. reticulata* Zone—D. Bukry (NP22, e. Oligo).

[c]*I. recurvus* s.l. Zone—K. Perch-Nielsen (NP19, late Eocene); *D. barbadiensis* Zone—D. Bukry (late Eocene).

[d]*D. tani nodifer* s.l. Zone—K. Perch-Nielsen (NP16, middle Eocene); *D. barbadiensis* Zone—D. Bukry (late Eocene); NP17 M.-P. Aubry (middle Eocene).

[e]P10, this paper; *D. sublodoensis* Zone—K. Perch-Nielsen, D. Bukry (NP14, middle Eocene).

*G. W. Bode and R. E. Boyce, in: Laughton, Berggren, et al., 1972.

★Pow-Foong Fan and I. Zemmels, in: Laughton, Berggren, et al., 1972.

early Oligocene using nannoplankton (Zones NP21/NP22; 34–37 Ma; Perch-Nielsen, 1972; Bukry, 1972). The fossil zones are dated using the time scale of Hardenbol and Berggren (1978).

Sedimentation rates range from 12–19 m/my depending on whether an upper or lower boundary age is taken for each zone; this agrees well with the original estimate of 15 m/my.

Extrapolating this rate downward yields an age of 50–53 Ma (earliest Eocene) for the top of core 16. An age of 51–54 Ma is estimated for the base of core 16 assuming a constant sedimentation rate across the lithologic change. Core 16 is thus probably early Eocene, but possibly latest Paleocene in age.

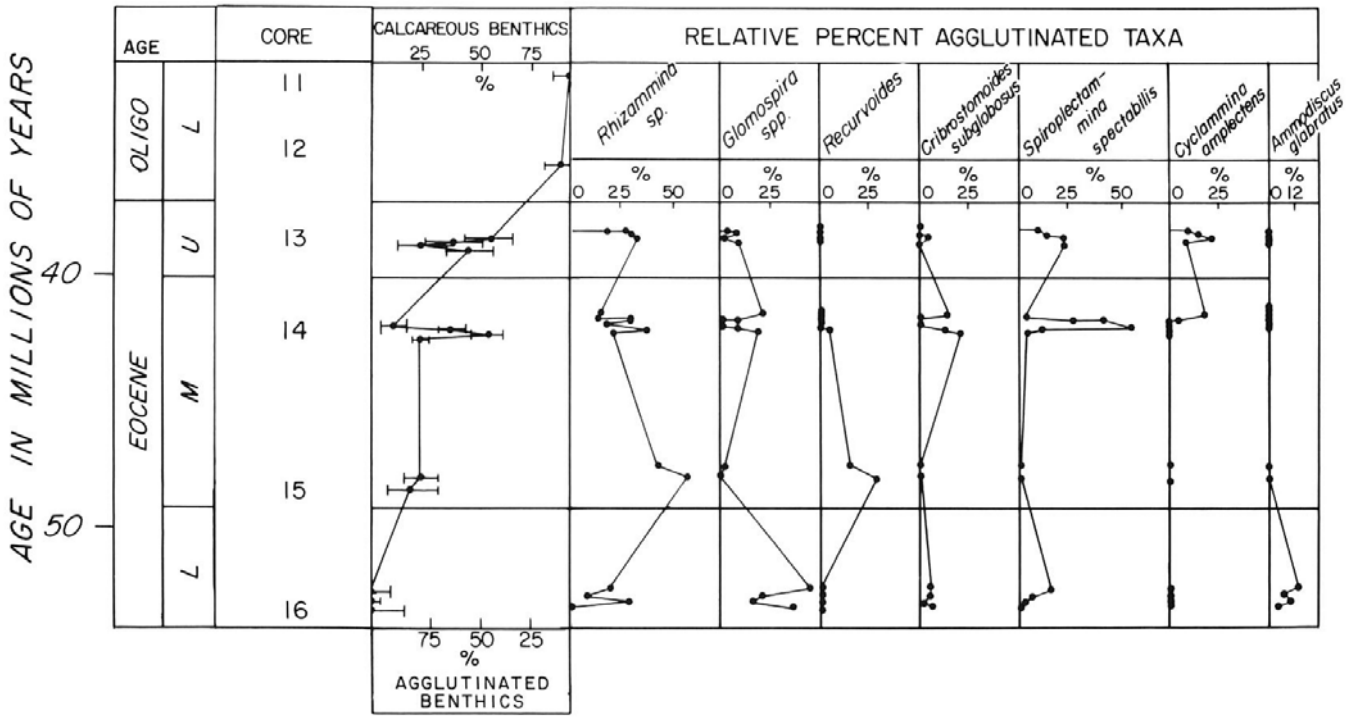
**Core 15 (revised)**

*Subbotina frontosa* (Subbotina) and *S. linaperta* are abundant in core 15. The first appearance of *S. frontosa* occurs at the base of Zone P10 (*S. frontosa frontosa/Globorotalia pseudomayeri* Bolli CRZ; Blow, 1979). *Subbotina frontosa* exits at the top of P11 (Blow, 1979).

*Acarinina bullbrooki* (Bolli) [= *A. densa* (Cushman)] occurs in core 15. Berggren (1971) suggested the first appearance of *A. densa* as an alternative criterion to *Planorotalites palmerae* in the recognition of Zone P9. Stainforth et al. (1975) cited the first appearance of *A. bullbrooki* as an alternative criterion for the recognition of the base of the early middle Eocene *Hantkenina aragonensis* Zone of Bolli (1957a, 1957b, 1966; = P10 of Blow 1969, 1979). The occurrence of both *S. frontosa frontosa* and *A. bullbrooki* suggests an assignment of P10 to P11 (early middle Eocene) for core 15.

The presence of *Pseudohastigerina wilcoxensis* (Cushman and Ponton) (FAD P7; LAD P10[1]; Blow,

[1]This last appearance datum for *P. wilcoxensis* is considered unreliable in light of the discussion below (Core 13).




TEXT-FIGURE 6
Relative percent of agglutinated taxa in DSDP Site 112. *Glomospira* spp. includes relative percent of agglutinated foraminifera of *G. charoides, G. gordialis,* and *G. irregularis.* Error bars on percent calcareous/agglutinated taxa indicate 95% confidence level.

1979), *Catapsydrax turgidus* (Finlay) (FAD P10; LAD P11; Blow, 1979). *Dentoglobigerina galavasi* (Bermudez) (FAD P9; Blow, 1979), and *Acarinina broedermanni* Cushman and Bermudez (FAD P8; LAD P11; Blow, 1979) support the assignment of core 15 to the interval of Zones P10 to P11 of Blow (1979).

Both Perch-Nielsen (1972) and Bukry (1972) placed core 15 in the *Discoaster sublodoensis* (NP14) Zone. Perch-Nielsen followed Martini's (1970) assignment of this zone to the early Eocene (= P9), while Bukry (1972) placed it in the middle Eocene (= P10). Zone NP14 has been correlated with Zone P10 (Bukry and Kennedy, 1969), and nannoplankton typical of this zone have been correlated with the type Lutetian stage (= middle Eocene; Bouche, 1962; Hay et al., 1967). Our study agrees with the correlation of NP14 with P10. Thus, nannofossils and planktonic foraminifera support an early middle Eocene age (P10, NP14) for this core.

**Core 14 (revised)**

Planktonic foraminifera are rare in core 14; predominantly long-ranging *Subbotina linaperta, Dentoglobigerina galavisi, Turborotalia* sp., and *Catapsydrax* sp. were found. The occurrence of *C. unicavus* Bolli (FAD P14; Stainforth et al., 1975) suggests a late middle to late Eocene age. On the basis of calcareous nannoplankton, core 14 was originally assigned to the late Eocene *Discoaster barbadiensis* (= NP18 to NP20) Zone by Bukry (1972) and to the middle Eocene *D. tani nodifer* s.l. (= NP16) Zone by Perch-Nielsen (1972), although Perch-Nielsen acknowledged possible assignment to the *Reticulofenestra umbilicata* Zone (= NP17 to 18, late Eocene in her study; middle to late Eocene of Martini, 1970). Calcareous nannoplankton from core 14-2 were examined and assigned to the late middle Eocene Zone NP17 of Martini's (1970) zonation (M.-P. Aubry, personal communication, 1980) based upon the simultaneous occurrence of *D. saipanensis* Bramlette and Riedel and *Neococcolithus minutus* Perch-Nielsen and the absence of both *Chiasmolithus oamaruensis* Deflandre and *C. solitus* (Bramlette and Sullivan) (table 2). This latest middle Eocene age assignment agrees well with interpolations of the sedimentation rate. If core 15 is assigned to Zone P10 (48 Ma), a 15 m/my sedimentation rate would place core 14 in the late middle Eocene (40 Ma; text-fig. 5).

TABLE 2
Nannofossil age documentation sample: 12-112-14-2/102–103 cm. Zonal assignment NP17 of Martini's zonation. Age: late middle Eocene.

| Assemblage |
|---|
| *Coccolithus pelagicus* (Wallich) |
| *Reticulofenestra umbilica* (Levin) |
| *R. dictyoda* Deflandre |
| *R.* cf. *R. insignata* Roth and Hay |
| *R. samodurovi* Hay, Mohler and Wade |
| *R.* cf. *R. hillae* Bukry and Perceival |
| *R. bisecta* Hay, Mohler and Wade |
| *Ericsonia formosa* (Kamptner) |
| *Discoaster saipanensis* Bramlette and Riedel |
| *D. barbadiensis* Bramlette and Riedel |
| *Chiasmolithus expansus* Bramlette and Sullivan |
| *Zygrhablithus bijugatus* (Deflandre) |
| *Markalius inversus* Bramlette and Martini |
| *Pemma* sp. |
| *Neococcolithites minutus* Perch-Nielsen |
| *Cyclococcolithus pseudogammation* Bouche |

Zonal determination based on absence of *Chiasmolithus oamaruensis* Deflandre and *C. solitus* (Bramlette and Sullivan) and the simultaneous occurrences of *Discoaster saipanensis* and *Neococcolithites minutus*. (After M.-P. Aubry, personal communication.)

**Core 13 (revised)**

*Subbotina linaperta* (LAD P17; Stainforth et al., 1975; Blow, 1979) and *Catapsydrax dissimilis* (Cushman and Bermudez) are the predominant planktonic foraminifera in core 13. The simultaneous occurrence of *C. unicavus* Bolli (FAD P14; Stainforth et al., 1975) and *S. linaperta* suggests latest middle to late Eocene age (P14 to P16). This agrees with the assignment of core 13 to the late Eocene nannoplankton *Isthmolithus recurvus* (= NP19; Perch-Nielsen, 1972) and *Discoaster barbadiensis* (= NP18 to 20; Bukry, 1972) Zones. *Acarinina* cf. *A. rotundimarginata* Subbotina [= *Truncorotaloides collacteus* (Finlay)] also occurs in this core. Berggren (1977) noted that *A. rotundimarginata* ranges into the late Eocene in high latitudes at least as far up as the *I. recurvus* Zone; this supports the assignment of core 13 to this zone.

The presence of *Pseudohastigerina wilcoxensis* in this core is apparently anomalous. Cordey et al. (1970), Stainforth et al. (1975), and Blow (1979) suggested a middle Eocene extinction of this species (middle Eocene; P12, P11, respectively). The specimens we have identified as *P. wilcoxensis* (pl. 3, figs. 11–12) are larger and less compressed than *P. micra* (Cole) and have a much more rounded, inflated axial-apertural aspect to the last chamber which is cited by Blow (1979) as characteristic of *P. wilcoxensis*. Our species can be differentiated from *P. danvillensis* (Howe and Wallace) by lack of an ovoid to pinched axial-apertural aspect (Blow, 1979). Only if we assume that *P. wilcoxensis* extends into the late middle Eocene as inferred by Cordey et al. (1970) and core 13 is reassigned as latest middle Eocene (P14) can this distribution be explained in terms of previous authors' ranges. As this results in a significant disagreement with the nannoplankton age assignment (late Eocene), we accept core 13 as late Eocene (NP19; P15–16) and note the occurrence of *P. wilcoxensis* as anomalous.

**Core 12 (revised)**

Core 12 is assigned to the early Oligocene *Heliocosphaera reticulata* (= NP22) by Bukry (1972) and the *Ericsonia obruta* (= *E. subdisticha* = NP21) Zone by Perch-Nielsen (1972). Planktonic foraminifera include rare *Catapsydrax dissimilis* and *Subbotina* spp. which are not age diagnostic.

The Eocene/Oligocene boundary may lie in a 48 m uncored interval between cores 12 and 13. Assuming a 15 m/my sedimentation rate, the unsampled interval represents 3 my. The assignment of core 13 to NP19 and core 12 to NP21/NP22 requires a separation of 1 to 4 my. This suggests that either continuous sedimentation or only a short hiatus (less than 1 my) occurs across the Eocene/Oligocene in this corehole.

**Benthic assemblages of Site 112**

We recognize 43 agglutinated species belonging to 23 genera and 8 families in the Eocene section of Site 112 (cores 13 to 16). The generic composition and number of species identified are similar to those reported from other DSDP sites where special studies were made of type A agglutinated assemblages (Sites 367, 368—Krasheninnikov and Pflaumann, 1977; Site 323—Rögl, 1976; Site 283—Webb, 1975; see table 3 of Gradstein and Berggren, 1981). All principal genera (i.e. those noted by more than two authors) noted in previous studies of type A assemblages in the deep sea are present in Site 112. In addition, 20 of the agglutinated species in Site 112 have been noted from the central North Sea, Labrador Shelf, Newfoundland Shelf, and West Greenland (Gradstein and Berggren, 1981). These taxa are indicated with an asterisk in table 3. The presence of the same taxa in Site 112 (paleodepth approximately 3 km; table 1) and the Labrador Shelf and central North Sea (both paleodepths less than 1 km) illustrates the wide bathymetric ranges of these agglutinated taxa.

Several of the stratigraphic ranges (text-fig. 4) of the agglutinated taxa in Site 112 are significantly restricted. The stratigraphic utility of these species is discussed in conjunction with the Canadian margin wells (below).

Abundances of benthic foraminifera range from 0 to 168 individuals/sample in Site 112. In the Eocene section, agglutinated foraminifera comprise from 40 to 100% of the benthic foraminifera, and agglutinated diversity ranges from 5 to 22 species/sample (table 4).

TABLE 3
Abundance of agglutinated species, DSDP Site 112. Number of each specimens/sample is given. Asterisks indicate species noted from Canadian margin or North Sea by Gradstein and Berggren (1981).

| SPECIES \ SAMPLES | 13-2 107-117 cm | 13-4 86-96 cm | 13-5 146-149 cm | 13-cc | 14-2 50-54 cm | 14-2 102-113 cm | 14-2 144-146 cm | 14-3 141-144 cm | 14-5 144-147 cm | 14-cc | 15-1 12-25 cm | 15-cc | 16-1 TOP | 16-1 46-49 cm | 16-1 78-84 cm | 16-1 107-111 cm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ? Bathysiphon sp. | 2 | 1 | 1 | 0 | 0 | 6 | 6 | 6 | 0 | 3 | 3 | 0 | 0 | 0 | 1 | 0 |
| Saccammina complanata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| S. difflugiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 2 | 0 |
| S. placenta * | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ammodiscus cretaceus * | 8 | 1 | 0 | 1 | 1 | 7 | 0 | 1 | 1 | 4 | 1 | 2 | 1 | 0 | 0 | 0 |
| A. glabratus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 11 | 11 | 1 |
| A. rugosus | 1 | 1 | 2 | 3 | 1 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Glomospira charoides * | 0 | 2 | 0 | 1 | 6 | 0 | 0 | 0 | 1 | 12 | 0 | 0 | 6 | 9 | 1 | 2 |
| G. gordialis * | 1 | 0 | 1 | 2 | 6 | 1 | 0 | 1 | 4 | 8 | 0 | 0 | 5 | 10 | 2 | 2 |
| G. irregularis * | 0 | 0 | 0 | 1 | 5 | 7 | 0 | 0 | 0 | 4 | 1 | 0 | 4 | 12 | 14 | 3 |
| G. serpens | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Glomospirella sp. | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 13 | 0 | 0 |
| Reophax pilulifera * | 1 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| Hormosina globulifera | 2 | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| H. ovulum * | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 |
| H. sp. 3 | 2 | 0 | 0 | 2 | 1 | 3 | 0 | 4 | 0 | 0 | 3 | 0 | 1 | 2 | 4 | 2 |
| "Hormosina" sp. 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 1 | 0 |
| Spirosigmoilinella compressa * | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Haplophragmoides *eggeri* * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 23 | 2 | 1 |
| H. walteri * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 3 | 0 |
| "Haplophragmoides" sp. 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 2 |
| Cribrostomoides subglobosus * | 0 | 1 | 0 | 0 | 10 | 1 | 0 | 1 | 7 | 24 | 0 | 0 | 1 | 4 | 1 | 1 |
| Paratrochamminoides * | 1 | 2 | 1 | 3 | 4 | 0 | 0 | 0 | 1 | 7 | 2 | 0 | 0 | 3 | 3 | 0 |
| Reophax walteri * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 5 | 0 | 0 | 0 | 0 |
| Trochamminoides sp. | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclammina amplectens * | 3 | 3 | 5 | 3 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C. trullissata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 0 |
| Trochammina globigeriniformis * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 13 | 1 |
| Trochammina sp. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cystammina globigerinaeformis * | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 11 | 6 | 0 |
| Spiroplectammina cubensis | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| S. spectabilis * | 3 | 3 | 5 | 9 | 2 | 22 | 9 | 40 | 6 | 2 | 0 | 0 | 5 | 7 | 2 | 0 |
| Dorothia sp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathysiphon sp. 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| Rhizammina sp. | 7 | 7 | 8 | 15 | 13 | 15 | 6 | 12 | 24 | 27 | 24 | 11 | 6 | 12 | 32 | 0 |
| Labrospira pacifica * | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Hyperammina sp. | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 1 | 0 | 0 |
| Martinottiella sp. | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Reophax nodulosus | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Lituotuba sp. * | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ? Spiroplectinata sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ? Karreriella sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ammolagena clavata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 4
Benthic foraminifera from DSDP Site 112.

| Core | Depth (cm) | % Calcareous benthic foraminifera | # Specimens benthic foraminifera | # Species agglutinated benthic foraminifera |
|---|---|---|---|---|
| 11-1 | 145–147.5 | 100 | 35 | 0 |
| 12-1 | 100–102 | 94 | 71 | 2 |
| 12-CC | — | barren | | |
| 13-2 | 107–117 | 60 | 94 | 15 |
| 13-4 | 86–96 | 40 | 42 | 13 |
| 13-5 | 144–149 | 25 | 36 | 11 |
| 13-CC | — | 49 | 91 | 15 |
| 14-2 | 50–54 | 10 | 86 | 17 |
| 14-2 | 102–113 | 39 | 167 | 22 |
| 14-2 | 144–146 | 40 | 37 | 4 |
| 14-3 | 141–144 | 60 | 183 | 11 |
| 14-5 | 144–149 | 27 | 94 | 14 |
| 14-CC | — | 24 | 168 | 22 |
| 15-1 | 12–25 | 25 | 88 | 16 |
| 15-6 | 130–135 | barren | | |
| 15-CC | — | 16 | 32 | 5 |
| 16-1 | top | 0 | 34 | 10 |
| 16-1 | 46–49 | 0 | 154 | 22 |
| 16-1 | 78–84 | 0 | 108 | 22 |
| 16-1 | 107–111 | 0 | 20 | 12 |

Although 43 agglutinated species are found in Site 112, only 9 species constitute more than 10% of agglutinated foraminifera in two or more samples. The relative abundances of these nine species are used to identify four agglutinated assemblages in the Eocene section: the *Glomospira, Cribrostomoides/Recurvoides, Spiroplectammina spectabilis* (Grzybowski), and *Cyclammina amplectens* assemblages (text-fig. 6). *Rhizammina* sp. is abundant (approximately 25% of agglutinated foraminifera) in all assemblages.

The *Glomospira* assemblage is found in core 16 and is composed of highest abundances of *G. charoides* (Jones and Parker), *G. gordialis* (Jones and Parker), *G. irregularis* (Grzybowski), and *Ammodiscus glabratus* Cushman and Jarvis. This assemblage is characterized by exclusively agglutinated foraminifera (table 4; text-fig. 5) and is associated with the baked red clay lithologic unit (unit 5; text-fig. 5). *Haplophragmoides eggeri* Cushman, *H.* sp., and *Trochammina globigeriniformis* (Parker and Jones) are restricted to this early Eocene assemblage.

The following assemblages occur within the silty clays and nannofossil marls of lithologic unit 4.

The middle Eocene *Cribrostomoides/Recurvoides* assemblage occurs in core 15 and core 14 (14-CC; 14-5). It is distinguished from the overlying assemblage by the low percentages of *Spiroplectammina spectabilis* and the high percentages of *"Cribrostomoides" subglobosus* (Sars) and *Recurvoides* ex. gr. *walteri* (Grzybowski). It is associated with approximately 25% calcareous benthic foraminifera.

The *S. spectabilis* assemblage (14-3; 14-2, 144–146 cm; 14-2, 102–113 cm) is composed predominantly of the nominate species (25–50% of the agglutinated foraminifera) and high relative abundances of calcareous benthic foraminifera (39–60% of total benthic foraminifera).

The sample with highest abundance of *S. spectabilis* and calcareous foraminifera (14-2, 140–142 cm) is described in the initial core description as a light gray indurated layer distinct from overlying and underlying lithologies (Laughton, Berggren et al., 1972). We noted abundant sand-sized planktonic foraminifera in this sample which are not found in any other Eocene sample. Since *S. spectabilis* is thought to have calcareous cement, this assemblage may reflect a paleoenvironment favorable for the deposition or preservation of calcium carbonate. Unfortunately, no carbonate percentage data are available for this interval.

The middle to late Eocene assemblage found in core 14 (14-2, 50–54 cm) and core 13 contains abundant *Cyclammina amplectens* and variable percentages of calcareous benthic species (10–60%; table 4). These variable percentages of calcareous species are not correlative with the fluctuations of calcium carbonate (24% ± 3%) in the bulk sediment.

As was first noted by Berggren (1972), the Eocene agglutinated assemblages are replaced in cores 12 and above by an Oligocene calcareous benthic assemblage. This exit is shown in text-fig. 4, where the diverse (15 species/sample) late Eocene *C. amplectens* assemblage is replaced by an early Oligocene benthic foraminiferal assemblage with sparse agglutinated species (0–2 species/sample). Table 4 shows moderate percentages of calcareous taxa in core 13 (25–60%) which increase to nearly 100% in cores 11 and 12. This faunal turnover occurred between the upper Eocene at 444 m subbottom and the lower Oligocene cored at 385 m subbottom (discontinuous coring). Assuming a 15 m/my sedimentation rate, this interval represents approximately 4 my.

#### AGGLUTINATED ASSEMBLAGES OF THE EASTERN CANADIAN MARGIN AND NORTH SEA

Diverse agglutinated foraminiferal assemblages resembling flysch-type and type A assemblages occur in Maestrichtian through Eocene beds on the Labrador and Newfoundland shelves (text-figs. 3, 8). Similar assemblages have been noted from the late Paleocene through Eocene strata in the central North Sea. Lithologies associated with these assemblages are predominantly mudstones and shales. Localized late Paleocene to early Eocene intercalations termed Gudrid sands occur on the Labrador shelf (Umpleby, 1979); stratigraphic equivalents occurring in the central North

Sea form oil and gas producing horizons in the Forties, Montrose, Frigg, Lomond, Cod, and other oil and gas fields (e.g. Ziegler, 1980). These sandy layers are largely devoid of indigenous microfauna. Both in the North Sea and on the Canadian margin the agglutinated fauna largely disappear at the end of the Eocene.

The stratigraphic ranges of the agglutinated taxa are calibrated to foraminiferal zonations developed for the Canadian margin (16 wells) and central North Sea (15 wells). The central North Sea correlation is based on last appearance levels of planktonic and benthic taxa. However, in the Paleocene section, such exits are rare (see Berggren and Gradstein, 1981); therefore, the dinoflagellate biostratigraphy of Ioakim (1979) was also used. On the Canadian margin, we used a probabilistic approach to Cenozoic foraminiferal stratigraphy. Exits of over 150 benthic and planktonic taxa were used in conjunction with a locally derived planktonic zonation (see Gradstein and Agterberg, in press). Rather than emphasizing individual wells, these zonations aim at a broad regional application. As a result, stratigraphic resolution is relatively conservative with an eight- to tenfold subdivision of the Cenozoic beds.

Approximately 60 agglutinated species representing 32 genera have been recognized in wells from the Canadian margin and North Sea. Most of these taxa have been described by Gradstein and Berggren (1981). Few taxa are endemic within these two regions.

In the Maestrichtian through Paleocene shales of Labrador wells, *Bathysiphon, Saccammina, Glomospira, Karreriella, Trochammina, Haplophragmoides,* and *Recurvoides* are dominant genera. In the Maestrichtian of the Indian Harbour well (text-figs. 3, 8), *Reophax* and *Uvigerinammina* are also important. Eocene mudstones both on the Canadian margin and in the North Sea contain frequent *Bathysiphon, Ammodiscus, Haplophragmoides, Trochammina, Cribrostomoides,* and *Karreriella. Cyclammina* spp. are locally abundant (e.g. Karlsefni H-13); species include *Cyclammina placenta* (Reuss), *C. amplectens* Grzybowski, *C. rotundidorsata* (Hantken), and forms classified as *C. placenta* (Reuss) or *C. cancellata* Brady.

In the Labrador Shelf shales (Indian Harbour M-52 well) agglutinated foraminifera are found associated with *Globotruncanella mayaroensis* (Bolli) (also reported by Dufaur et al., 1976, from the adjacent Gudrid U-55 well) and a rich assemblage of *G. havanensis* (Voorwijk), *Globigerinelloides messinae* Bronnimann, *Rugoglobigerina* aff. *rotundata* Bronnimann, and *Bolivinoides draco* (Marsson). These species indicate a late Maestrichtian age. The agglutinated taxa *Uvigerinammina jankoi* Majzon, *Dorothia oxycona* (Reuss), and *Arenobulimina dorbignyi* (Reuss) are restricted to these Maestrichtian shales. Of these species *U. jankoi* has been reported from many Upper Cretaceous flysch deposits in Europe and from the Upper Cretaceous clays in the Atlantic and Indian oceans (Geroch, 1959; Krasheninnikov, 1974; Krasheninnikov and Pflaumann, 1977). *Dorothia oxycona* (Reuss) is a cosmopolitan Cretaceous form; it locally extends in Paleocene beds (Aubert and Berggren, 1976). *Arenobulimina dorbignyi* (Reuss) was reported by Hanzlikova (1972) from Turonian-Campanian strata in Europe.

In the North Sea, *Rzehakina epigona* (Rzehak) is restricted to Upper Cretaceous deposits. On the Canadian margin *R. epigona* is found more frequently in Upper Cretaceous shales, but also consistently occurs in Paleocene beds. Isolated individuals occur as high as Zone P9 (= *Acarinina densa* Zone; late early Eocene).

A distinctive species of *Ammobaculites* with 10 or more chambers in the last whorl and undulating, dark sutures is common in the Labrador and Newfoundland Shelf wells. It is rare in the North Sea. It ranges from Maestrichtian through Eocene beds and is provisionally assigned to *A.* aff. *A. polythalamus* Loeblich.

Three distinct taxa, important in the North Sea, are absent from the Canadian margin. *Trochammina subvesicularis* Homola and Hanzlikova and a form provisionally assigned to *T.* aff. *T. albertensis* Wickenden are both homeomorphic with "conical" planktonic foraminifera. Occurring in North Sea wells in beds overlying Danian carbonates and underlying *Cyclammina* bearing (Eocene) strata, they are probably Paleocene in age. *Thurammina* sp. has been reported by Bettenstaedt et al. (1962) from lower middle Eocene beds; it has a similar range in the central North Sea.

The absence of pre-Maestrichtian and post-Eocene to Miocene agglutinated foraminiferal assemblages in the Canadian margin and North Sea probably results in the limited stratigraphic ranges of some of the taxa mentioned. These truncated ranges may result from paleoenvironmental changes, and therefore may be useful only in local zonations.

#### COMPARISON OF SITE 112 WITH EASTERN CANADIAN MARGIN

Calibration of the distribution of benthic agglutinated taxa with the zonations discussed above allowed us to compare their ranges from the deep Labrador Sea (Site 112) with the Canadian margin and previously reported ranges from the North Sea, flysch deposits of Europe, and the deep sea. The long stratigraphic ranges of agglutinated species poses one of the major problems in the use of these taxa in biostratigraphy. For example, 12 agglutinated species range throughout the Eocene in Site 112. Other biostratigraphic

TABLE 5
Stratigraphic ranges of agglutinated taxa.

| Species | Age |
|---|---|
| *Uvigerinammina jankoi* Majzon | Maestrichtian shales (C.M.)<br>Late Cretaceous (E.F., D.S.) |
| *Dorothia oxycona* (Reuss) | Maestrichtian shales (C.M.)<br>Paleocene (Tunisia) |
| *Arenobulimina dorbignyi* (Reuss) | Maestrichtian shales (C.M.)<br>Turonian-Campanian (E.F.) |
| *Rzehakina epigona* (Rzehak) | Late Cretaceous (N.S.)<br>acme Late Cretaceous (C.M.)<br>Cretaceous-early Eocene (C.M.) (rare in Eocene) |
| *Cystammina globigerinaeformis* (Krasheninnikov) | Late Cretaceous (D.S.)<br>Maestrichtian to Eocene (C.M., N.S.)<br>early to middle Eocene (112) |
| *Spiroplectammina spectabilis* (Grzybowski) | Maestrichtian to middle Eocene<br>rare above Paleocene (C.M.)<br>late Paleocene to early Eocene (N.S., E.F.)<br>Eocene (112) |
| *Cyclammina* spp. | post-Paleocene (C.M., 112, D.S.)<br>latest Paleocene and younger (N.S.) |
| *C. amplectens* (Grzybowski) | Eocene (C.M)<br>early to middle Eocene and possibly late Eocene (N.S.)<br>middle to late Eocene (112) |
| *C. placenta* (Reuss) and *C. rotundidorsata* (Hantken) | Eocene (acme in middle Eocene; E.F.)<br>to Oligocene, possibly Miocene (C.M., N.S.) |
| *Spirosigmoilinella compressa* Matsunaga | middle Eocene to early Miocene (N.S.)<br>middle to late Eocene (112)<br>Miocene (Japan) |
| *Ammobaculites* aff. *polythalamus* Loeblich | Maestrichtian-Eocene (C.M., N.S.) |
| *Trochammina subvesicularis* Homola and Hanzlikova and *T.* aff. *albertensis* Wickenden | late Paleocene (N.S.) |
| *Thurammina* sp. | early middle Eocene (N.S., E.F.) |

C.M. = Canadian Margin; N.S. = North Sea; E.F. = European flysch basins; D.S. = deep sea; 112 = Site 112.

problems arise from agglutinated taxa that have diachronous ranges. This is illustrated by the genus *Glomospira,* which is represented in our samples by *G. charoides* (Jones and Parker), *G. gordialis* (Jones and Parker), and *G. irregularis* (Grzybowski). On the Canadian margin these species are fairly common to abundant in Maestrichtian through Paleocene beds; they disappear in the early middle Eocene. These same species are found throughout the Eocene in Site 112, exit in the middle Micene in the North Sea (text-fig. 7), but are found in the present-day Atlantic (Brady, 1884), Pacific (Brady, 1884; Saidova, 1961), and Gulf of Mexico (Phleger and Parker, 1951; Pflum and Frerichs, 1976). Despite these problems, we have been able to use many agglutinated taxa for regional zonations (see text-figs. 4, 7 and table 5 for summary of ranges).

The taxonomic position and stratigraphic range of the genus *Praecystammina* is unclear. Krasheninnikov (1973) used the new taxon *Cystammina globigerinaeformis* (Krasheninnikov) as a Late Cretaceous marker in abyssal Pacific and Indian Ocean deposits. Specimens resembling this form occur in the Maestrichtian of the Labrador Shelf (Indian Harbour M-52 well) and Paleocene to Eocene of the central North Sea. In Site 112, *C. globigerinaeformis* exits at the end of the middle Eocene. Further studies are needed to determine to what extent *Praecystammina* really differs from *Cystammina* and the chronostratigraphic range of *C. globigerinaeformis.*

On the Canadian margin, *Spiroplectammina spectabilis* (Grzybowski), *S. navarroana* Cushman, and *S. dentata* (Alth) have been found from Maestrichtian to middle Eocene beds. *Spiroplectammina spectabilis* is rare above the Paleocene. In the central North Sea *S. spectabilis* and *S. navarroana* were observed in beds overlying Danian carbonates and locally range into or just above sediments with *Subbotina patagonica* (Todd and Knicker) and rare *Acarinina* aff. *pentacamerata* (early Eocene). *Spiroplectammina spectabilis* has been reported from West Germany from upper Paleocene to lower Eocene beds (Bettenstaedt et al., 1962). In Site 112 *S. spectabilis* is found throughout the Eocene, suggesting that it has a longer range in the deep sea.

In the regions under discussion, *Cyclammina* is thought to be restricted to post-Paleocene beds, although in the North Sea some relatively small specimens occur slightly below the tuff marker at the Paleocene-Eocene boundary. Otherwise, in the North Sea *C. amplectens* occurs in strata with *Acarinina pentacamerata* (Zones P8 to P12; lower to middle Eocene; Stainforth et al., 1975) and *Spiroplectammina spectabilis.* Although it may range higher, it is mostly restricted to the Eocene. On the Canadian margin *C. amplectens* occurs throughout the Eocene (associated with *Subbotina patagonica, Acarinina densa,* and *Turborotalia pomeroli*). In Site 112 it is restricted to the middle to upper Eocene section. In Central Europe (Carpathians) *C. amplectens* has been reported from the Eocene; it occurs in greatest abundance in middle Eocene strata (Geroch, 1960).

In the central North Sea and on the Canadian margin both *Cyclammina placenta* (Reuss) and *C. rotundidorsata* (Hantken) are longer ranging than *C. amplectens*; these species extend into beds with *Turrilina alsatica* (Andreae) (Oligocene) and *Globigerinoides*/*Globorotalia* (Miocene). These species are absent from Site 112.

In the North Sea, *Spirosigmoilinella compressa* Matsunaga extends from the upper part of the range of *Cyclammina amplectens* into beds with *Globigerinoides* and *Globorotalia acrostoma*; the chronostratigraphic range is middle Eocene to early Miocene. This species occurs in the *Areosphaeridium diktyoplokus* Zone of Ioakim (1979) of Bartonian age (middle Eocene). It also occurs in the middle upper Eocene in Site 112; it was not found in the Canadian margin wells. Specimens of *S. compressa* Matsunaga differ from *Rzehakina epigona* by having an evolute rather than involute test, a variable but often slenderer width of the test, and an early stage which coils in a different plane from the last few chambers. *Rzehakina epigona,* in contrast, is planispiral. *S. compressa* was originally described from the Miocene of Japan. *Hormosina ovulum* (Grzybowski) disappears in the lower Eocene in the Carpathians, Caucasus, Eastern Alps (Geroch, 1959), and Site 112.

Of the important indicator taxa noted in the Canadian margin and North Sea, *Trochammina subvesicularis, T.* aff. *T. albertensis, Thurammina* sp., *Ammobaculites* aff. *A. polythalamus, Uvigerinammina jankoi, Dorothia oxycona, Arenobulimina dorbignyi,* and *Rzehakina epigona* were not found in Site 112.

In addition to the replacement of the late Eocene agglutinated assemblage by an early Oligocene calcareous assemblage in Site 112, agglutinated assemblages also exit across the Eocene/Oligocene boundary in many of the Canadian margin wells (text-fig. 8). In the North Sea, Gradstein and Berggren (1981) noted the disappearance of agglutinated foraminifera in most of the wells studied at the end of the Eocene. Only in a few wells in the center of the basin do agglutinated taxa extend into stratigraphically younger beds. Thus, a major faunal turnover occurs in the late Eocene to early Oligocene of the North Sea, Labrador Shelf, Newfoundland Shelf, and the Labrador Sea.

#### PALEOENVIRONMENT OF AGGLUTINATED FORAMINIFERA

Agglutinated foraminifera in the Labrador Shelf and North Sea are associated with high sedimentation rates, high organic content, and deepest paleowater depths. The best preserved and highest diversity agglutinated assemblages are found in shales high in organic matter in wells in the depositional center of the basins. In general, these centrally situated wells have relatively high sedimentation rates and calcareous benthic foraminifera which suggest deeper water conditions than in updip wells that have a lower diversity agglutinated assemblage dominated by *Bathysiphon* and *Trochammina.*

Paleoenvironmental factors controlling the distribution of flysch-type agglutinated assemblages in the Labrador and East Newfoundland shelves and the North Sea may be related to the model suggested by Ksiazkiewicz (1961, 1975) and Moorkens (1976), which invokes rapid deposition of organic-rich, fine-grained clastics with restricted bottom water circulaton (see discussion in Gradstein and Berggren, 1981). Such conditions developed in the Maestrichtian through Eocene of the Labrador Shelf and in the late Paleocene to Eocene of the central North Sea. Differential subsidence, leading to paleogeographically separated and paleoceanographically restricted basins, coincided with rapid deltaic outbuilding into the deeper, more centrally situated parts of the basins (Gradstein and Berggren, 1981). Nevertheless, evidence from Site 112 suggests that, at least in the deep sea, high organic matter is not a prerequisite for the development of predominantly agglutinated foraminiferal assemblages.

Few cores are available from the North Sea and Canadian margin; therefore, the cored Eocene-lower Oligocene section of Site 112 was used to make a detailed comparison of lithologic characteristics with the distribution of agglutinated benthic foraminifera.

The change from agglutinated to calcareous benthic foraminiferal assemblages occurs in Site 112 within lithologic unit 4. Grain size (silty clays), percent calcium carbonate (approximately 30%), and percent organic carbon (0.3%) do not change in the upper Eocene to lower Oligocene section (text-fig. 5). The constancy of these lithologic parameters across this faunal change shows that the exit of the agglutinated assemblages was not caused by a change in substrate.

The presence and relatively constant values of abundant calcium carbonate throughout the middle Eocene to lower Oligocene section does not support the suggestion by Hesse and Butt (1976) that the dominant factor controlling flysch-type (type A) agglutinated assemblages is deposition below the CCD. With the exception of core 16, which is barren of calcium carbonate and calcareous benthic foraminifera, and possibly the *Spiroplectammina spectabilis* assemblage, there is no clear correlation between percent carbonate and agglutinated and/or calcareous benthic foraminiferal abundance (text-fig. 5). Despite this, carbonate availability may play a role in the development of predominantly agglutinated foraminiferal assemblages, for the exit in Site 112 correlates with a global drop in the CCD (Heath, 1969; Berger, 1973; van Andel et al., 1975; Kennett and Shackleton, 1976). Nevertheless, factors which caused this drop (see below) may also be related to the faunal change.

Due to diagenetic reduction of the carbon content of

marine sediments (Heath et al., 1977), the absolute carbon values observed in Site 112 may reflect only a portion of the carbon present at the time of deposition. Nevertheless, the constant values of organic carbon associated with the faunal turnover (text-fig. 5) do not support the idea that organic carbon is the dominant control on flysch-type agglutinated foraminiferal assemblages. Although agglutinated foraminifera may be favored in areas of high organic matter, high organic carbon is not a prerequisite for predominantly agglutinated foraminiferal assemblages. This is shown by the presence of exclusively agglutinated foraminiferal assemblages in the present-day deep North Pacific by Saidova (1960) and Bernstein et al. (1978), where carbon values are invariably low (Heath et al., 1977).

The exit of the agglutinated foraminifera and their replacement by a deep-water calcareous assemblage may have resulted from changes in hydrographic properties. The Tertiary climatic record shows that a major period of cooling occurred in the middle Eocene to early Oligocene, and that the greatest temperature drop occurred close to the Eocene/Oligocene boundary (Dorman, 1966; Devereaux, 1967; Savin et al., 1975; Shackleton and Kennett, 1975; Wolfe, 1978; Vergnaud-Grazzini et al., 1979). The development of the psychrosphere (the deep, cold water layer of the oceans; Benson, 1975), and the formation of cold bottom water production in the southern ocean (Kennett and Shackleton, 1976) also began near the end of Eocene time. This initiation of cold bottom water resulted in an inferred 4 to 5°C temperature decrease in bottom water temperatures in the southern ocean (Site 277) in the earliest Oligocene time (Kennett and Shackleton, 1976).

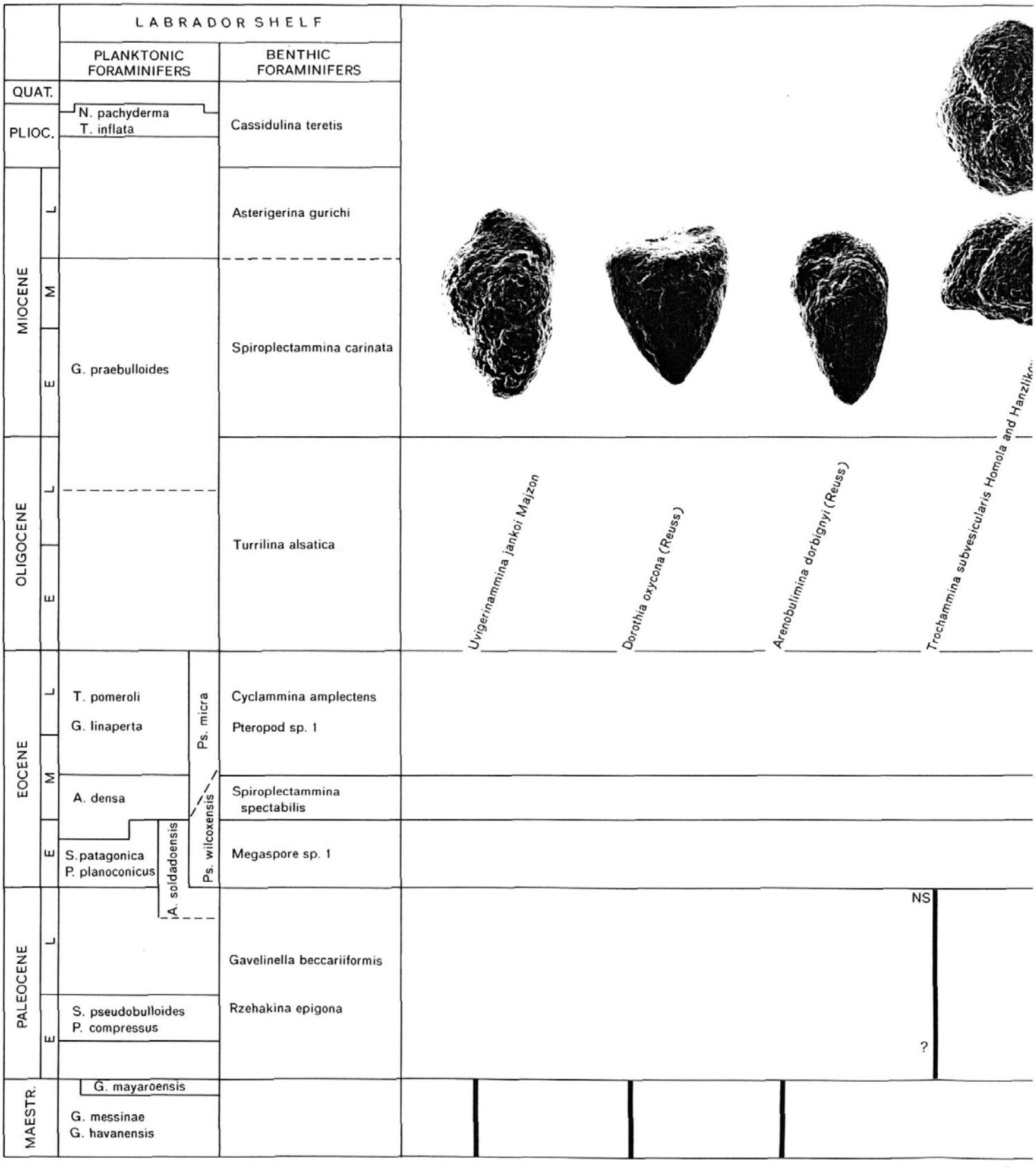
In addition to lowering the temperature and supplying more oxygen to bottom waters, a presumed increase in oceanic turnover in the late Eocene to early Oligocene (Kennett and Shackleton, 1976) may have decreased $CO_2$ and thereby increased pH. This turnover contributed to the lowering of the CCD which is reflected in the deep-sea stratigraphic record as a well-documented increase in preservation of calcium carbonate (Heath, 1969; Berger, 1973; van Andel et al., 1975; Kennett and Shackleton, 1976).

Such changes in hydrography could have eliminated the indigenous agglutinated benthic foraminiferal assemblages and favored the migration of calcareous benthic assemblages to Site 112. Moorkens (1976) and Saidova (1960, 1965) both explain the preponderance of agglutinated foraminifera in abyssal depths by the tolerance of these foraminifera to low oxygen and pH. The modern deep North Pacific, with its low oxygen, high $CO_2$, and low pH (Sverdrup et al., 1942), and exclusively agglutinated benthic foraminiferal assemblages (Saidova, 1961, 1965, 1970, 1976; Bernstein et al., 1978) may be a modern analog to the Eocene deep Labrador Sea, although carbonate sediments are absent from the former but are present in the Eocene Labrador Sea.

Although the faunal turnover in Site 112 approximately coincides with the formation of the psychrosphere, increased oceanic turnover, and the initiation of southern sources of bottom waters, it is not clear that the only late Eocene to early Oligocene source of low-temperature, high-oxygen bottom water in the Labrador Sea is from the Antarctic region. Despite the contention of some authors (Shor and Poore, 1979; Blanc et al., 1980; Schnitker, 1980a, 1980b) that bottom water from northern sources (i.e. the Arctic, Norwegian-Greenland Sea, or other northern North Atlantic sources including the Labrador Sea) did not form until the early to middle Miocene, seismic evidence from the northern North Atlantic suggests the presence of a northern cold-water source as early as late Eocene.

Johnson and Schneider (1969), Jones et al. (1970), and Ruddiman (1972) have clearly demonstrated that bottom water circulation (predominantly North Atlantic Deep Water, NADW) profoundly influences sedimentation patterns in the northern North Atlantic (north of 45°N). The earliest effect of this deep circulation is in the form of sediment drifts overlying a subhorizontal sedimentary reflector, R4 (Roberts, 1975; = reflector R of Jones et al., 1970). In this region, reflector R4 has been firmly established as pre-late Oligocene by Jones et al. (1970). It has been suggested that reflector R4 is latest Eocene age in the Rockall Plateau and Rockall Trough (Roberts, 1975) and Iceland Basin (Ruddiman, 1972).

In the Labrador Sea near Site 112, reflector R4 lies at 0.41 seconds two-way travel time (Laughton, Berggren et al., 1972). A hard layer encountered in Site 112 in core 10 (upper lower Oligocene) at 315 m subbottom was thought to correspond to this reflector (Laughton, Berggren et al., 1972); however, this correlation is not in agreement with evidence suggested by sediment velocity and changes in grain size. Placing reflector R4 at a depth of 315 m, results in a mean seismic velocity of 1536 m/sec in the drifted sediments. This velocity is considerably lower than that expected for sediments of this thickness. In addition, a grain size change might be expected in the change from pelagic clay to current-controlled deposition. A grain size increase from clays to silty clays and clayey silts occurs between cores 11 and 12 in Site 112 (text-fig. 5), suggesting that a major change in depositional regime occurred in the lower Oligocene section between 333 and 383 m subbottom. Assuming reflector




**FORAMINIFERAL ZC**

*Uvigerinammina jankoi Majzon*

*Dorothia oxycona (Reuss)*

*Arenobulimina dorbignyi (Reuss)*

*Trochammina subvesicularis Homola and Hanzlikova*

*Trochammina aff. albertensis Wickenden*

*Rzehakina epigona (Rzehak)*

*Glomospira spp.*

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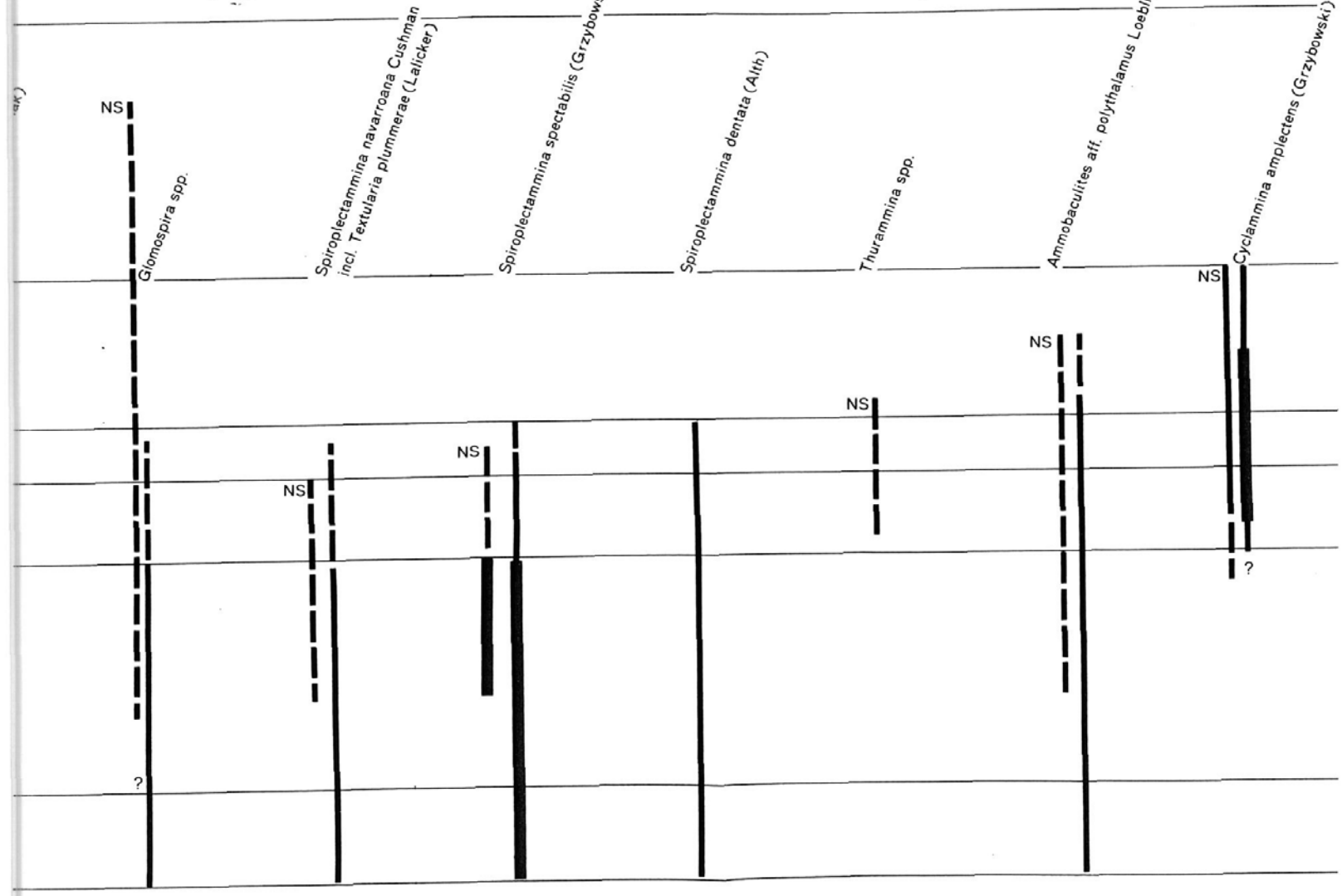
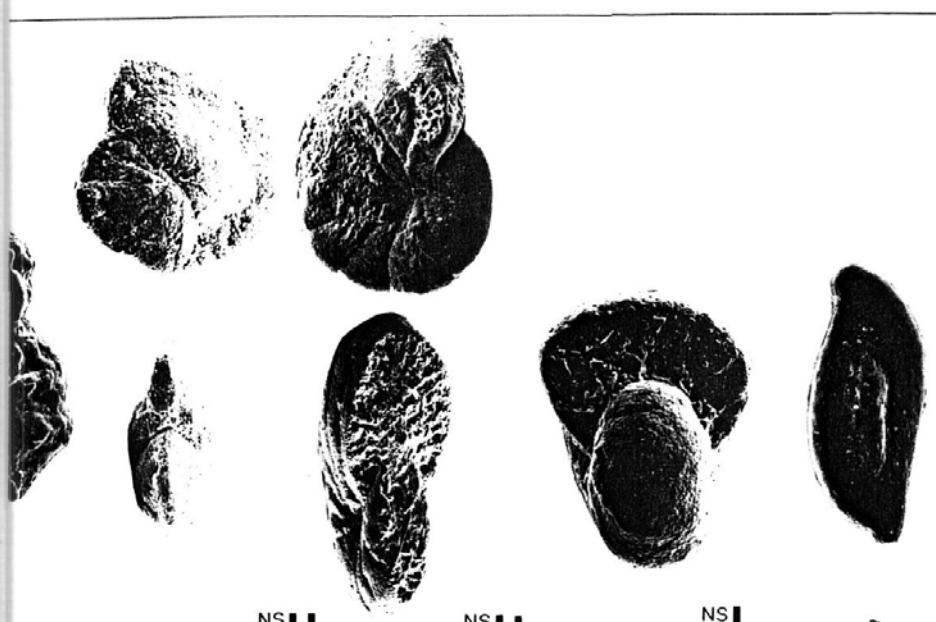
**FORAMINIFERAL ZONATIONS FOR THE LABRADOR SHELF A**




BRADOR SHELF AND CENTRAL NORTH SEA AND STRATIGRAPHICAL RANGES OF SELECTED AGGLUTIN



NS Cyclammina amplectens (Grzybowski)

NS Cyclammina placenta (Reuss)

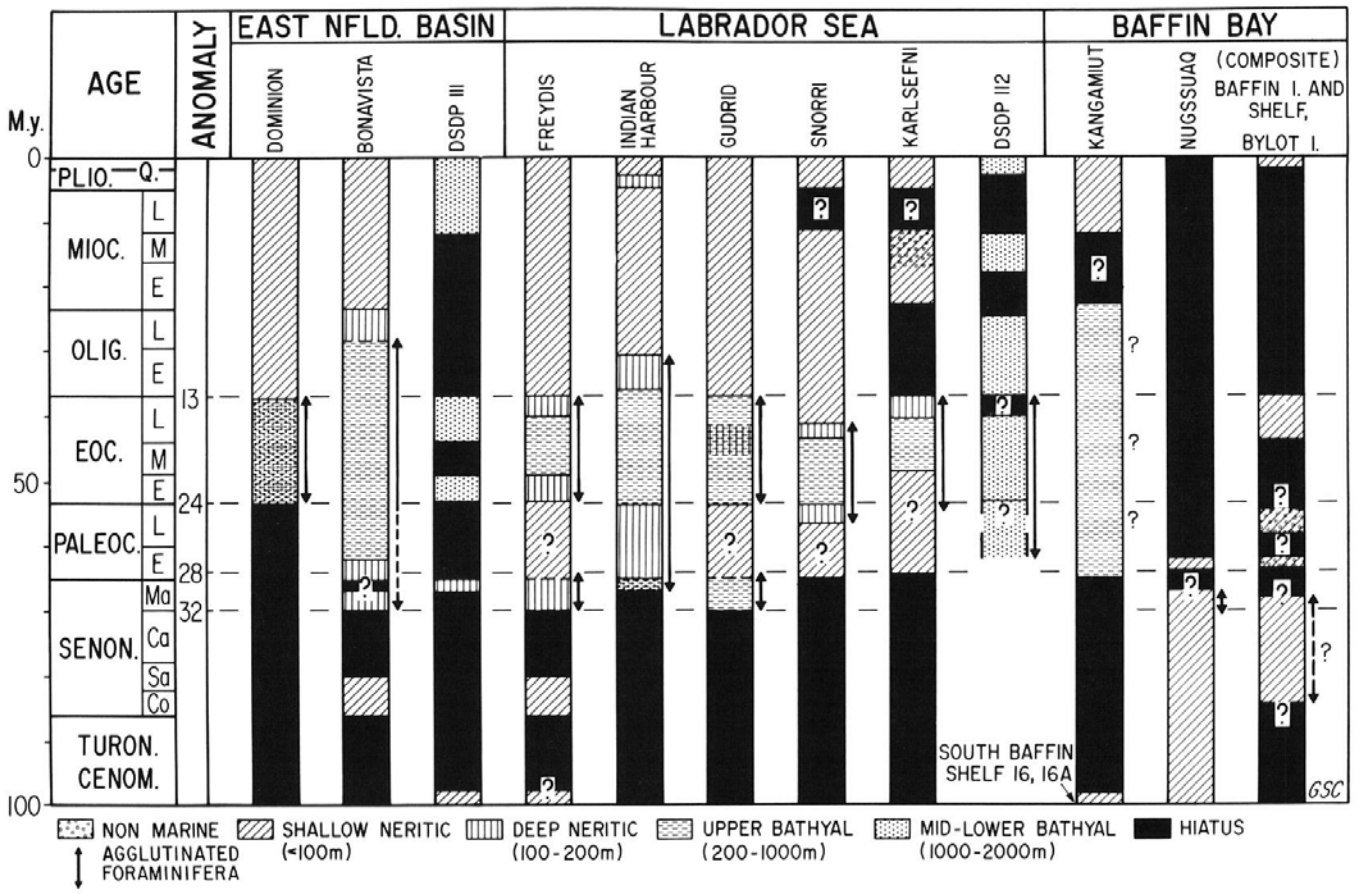
NS Cyclammina rotundidorsata (Hantken)

NS Spirosigmoilinella compressa Matsunaga

| CENTRAL NORTH SEA | | | |
|---|---|---|---|
| PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | | |
| T. inflata | Elphidiella arctica | QUAT. | |
| N. pachyderma-atlantica | Buccella tenerrima<br>Cassidulina teretis | PLIOC. | |
| T. acostaensis | Asterigerina gurichi<br>Uvigerina canariensis<br>Cibicidoides mediocris | L | MIOCENE |
| G. praescitula-zealandica<br>G. acrostoma, G. trilobus | Martinotiella communis<br>Spiroplectammina carinata | M | |
| | | E | |
| G. angulofficinalis | Rotaliatina bulimoides<br>Turrilina alsatica<br>Uvigerina aff. galloway | L | OLIGOCENE |
| G. ampliapertura<br>G. tripartita | | E | |
| G. index | Marginulopsis decorata<br>Cibicidoides granulosus | L | EOCENE |
| | | M | |
| A. pentacamerata<br>S. patagonica | | E | |
| | Bulimina trigonalis | L | PALEOCENE |
| S. pseudobulloides<br>P. compressus | Gavelinella beccariiformis | E | |
| G. daubjergensis | | | MAESTR. |
| not studied in detail | | | |

GSC

) AGGLUTINATED TAXA




TEXT-FIGURE 8
Late Mesozoic-Cenozoic depositional history of Canadian margin and DSDP Sites 111 and 112.

R4 correlates with this change in grain size (text-fig. 5) in Site 112 we obtain a 1625–1875 m/sec mean seismic velocity which is more realistic for sediments of this thickness from this region (cf. typical mean velocities for the upper 300–350 m of sediment from Leg 48 determined from sonic logs of approximately 1750 m/sec; Montadert, Roberts et al., 1979). This correlation of R4 in the Labrador Sea as a lower lower Oligocene reflector separating pelagic from current-controlled deposition suggests that the formation of northern sources of bottom water influenced the Labrador Sea by early Oligocene time.

Within the biostratigraphic limits of error, reflector R4 has been identified as a synchronous reflector in other parts of the northern North Atlantic. The correlation of reflector R4 in this region as latest Eocene to earliest Oligocene (Ruddiman, 1972; Roberts, 1975) suggests that the change in depositional regime associated with reflector R4 occurred throughout the northern North Atlantic at this time (for further discussion, see Miller and Tucholke, in press).

Hiatuses are widespread in the late Eocene to Oligocene sections of the World Ocean, particularly the North Atlantic (Moore et al., 1978). Of the DSDP sites drilled in the northern North Atlantic (Legs 12, 38, 48, 49) only Sites 112 and 116 may be inferred to have continuous deposition across the Eocene/Oligocene boundary (cf. fig. 3 of Shor and Poore, 1979; figs. 3–6 of Miller and Tucholke, in press). Although factors other than bottom water flow influence the development of deep-sea hiatuses (Moore et al., 1978 and references therein), the development of a regional late Eocene to Oligocene hiatus in the northern North Atlantic supports the idea that bottom water formation began in this region at this time.

The change in depositional regime and the inferred initiation of bottom water in the northern North Atlantic approximately coincides with the disappearance of agglutinated assemblages from Site 112. Still, we cannot firmly extrapolate the faunal change to the entire deep southern Labrador Sea, and therefore the possibility exists that the faunal turnover resulted from a local

phenomenon restricted to the immediate environs of Site 112.

The early Oligocene change in depositional regime (between cores 11 and 12) in Site 112 slightly postdates the exit of the agglutinated foraminiferal assemblages (between cores 12 and 13) by 1–7 my (text-fig. 5). This time lag may be due to the gradual intensification of currents during the middle Eocene to Oligocene due to increased climatic cooling. As bottom water began to form in the middle to late Eocene, hydrographic properties began to change, resulting in the replacement of agglutinated foraminifera in Site 112. By the early Oligocene, bottom currents were sufficiently competent to transport silty sediments into the Labrador Sea. There is, in fact, a slight suggestion that percent calcareous taxa gradually increased and replaced the agglutinated foraminifera in Site 112 in the middle Eocene to Oligocene (text-fig. 5). This scenario would agree with the gradual development of the psychrosphere proposed by Corliss (1979). Unfortunately, due to coring gaps and the uncertainties attached to the relative percentages of calcareous species (text-fig. 6) our data are insufficent to convincingly show a gradual change in benthic foraminifera in Site 112.

## CONCLUSIONS

(1) Late Cretaceous to Paleogene predominantly agglutinated benthic foraminifera reported from the deep sea (= flysch-type, type A assemblages) are taxonomically similar to assemblages noted on the Canadian margin, in the North Sea, and in European flysch basins. These assemblages range from bathyal (hundreds of meters) to abyssal (approximately 4.5 km) paleodepths. Smooth-walled, smaller-sized (< 150 $\mu$m) Cretaceous assemblages (= type B assemblages) noted only from abyssal paleodepths are easily differentiated from these type A assemblages.

(2) Comparison of ranges of type A assemblages in Site 112, the Canadian margin, and the North Sea shows that some taxa are biostratigraphically useful (text-fig. 4; table 5).

(3) Although high organic content, deposition below the CCD, and inferred poor circulation are often associated with many type A assemblages, these properties are not necessary for faunal development. Rather, we infer that, at least in the deep sea, hydrographic properties (low oxygen, low pH, high $CO_2$, and thus more corrosive waters) are critical to the development of the predominantly agglutinated assemblages. Since these properties affect carbonate availability, the development of agglutinated assemblages may co-vary with percent calcium carbonate, although this is not the case in Site 112. In addition, similar conditions may develop in reducing substrates associated with high organic matter and poor circulation. Predominantly agglutinated assemblages are probably favored in such substrates and/or in areas with the given hydrographic properties.

(4) The late Eocene exit of agglutinated foraminifera from Site 112, the Canadian margin, and the North Sea coincides with changes in hydrographic properties associated with the development of a more vigorous abyssal circulation and the psychrosphere. We speculate that the late Eocene to early Oligocene initiation of bottom water formation in the northern North Atlantic and/or Norwegian-Greenland Sea, inferred from sediment distribution patterns, caused the replacement of the agglutinated assemblage in Site 112 by a calcareous assemblage, but that local tectonic and sedimentologic changes may have been important in the elimination of agglutinated assemblages in the Canadian margin and North Sea.

## SYSTEMATIC PALEONTOLOGY

### Agglutinated foraminifera Site 112

Rare = less than 5 individuals in all samples
Common = 5 to 25 individuals/sample
Abundant = greater than 25 individuals/sample

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily AMMODISCACEA Reuss, 1862
Family ASTRORHIZIDAE Brady, 1881
Subfamily RHIZAMMININAE Rhumbler, 1895

***Rhizammina*** sp.
Plate 1, figure 2

*Remarks:* Short, curved, coarse-walled tubes. Indistinguishable from *R. indivisa* Brady of Gradstein and Berggren (in press) and *R. algaeformis* Brady of Webb, 1975. Abundant.

?***Bathysiphon*** sp.
Plate 1, figure 1

*Remarks:* Very fine-grained straight tube with lateral projection similar to *Bathysiphon* of the North Sea and Canadian margin; may be a central chamber characteristic of the genus *Rhabdammina*. Common.

***Bathysiphon*** sp.

*Remarks:* Straight, fine-grained tubes similar to smooth-walled *Bathysiphon discreta* Brady var. A of Gradstein and Berggren (in press). Present only in core 16. Common.

Subfamily HIPPOCREPINNAE Rhumbler, 1895

***Hyperammina*** sp.

*Remarks:* Initially globular, later as in *Rhizammina* and *Bathysiphon*. Rare.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884

***Saccammina complanata*** (Franke)
Plate 1, figure 3

*Pelosina complanata* FRANKE, 1912, pl. 3, fig. 1—CUSHMAN and JARVIS, 1932, p. 5, pl. 1, figs. 4–6.
*Saccammina placenta* Grzybowski.—GEROCH, 1960, pp. 37–38, pl. 2, figs. 1–6—JURKIEWICZ, 1967, p. 41, pl. 1, fig. 5.—GRADSTEIN and BERGGREN, 1981, pl. 2, fig. 5.
*Saccammina complanata* (Franke).—RÖGL, 1976, pl. 3, figs. 7–8.—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 1, fig. 14.

*Remarks:* Franke illustrated a specimen with a pronounced neck and a disk-shaped depression similar to our specimens. Found only in core 16. Rare.

***Saccammina placenta*** (Grzybowski)
Plate 1, figure 4

*Reophax placenta* GRZYBOWSKI, 1898, pl. 10, figs. 9–10.
*Saccammina placenta* (Grzybowski).—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 1, fig. 16.

*Remarks:* Grzybowski did not describe the type of aperture but, as he illustrated a specimen with no neck, we assign specimens without a neck to *S. placenta* and those with a distinct neck to *S. complanata.* As noted by Krasheninnikov, *S. placenta* has a thin lip. Found only in cores 13 and 14. Rare.

***Saccammina difflugiformis*** (Brady)
Plate 1, figure 5

*Reophax difflugiformis* BRADY, 1879, pl. 4, fig. 3.

*Remarks:* Vaselike test; may be initial chamber of uniserial form such as *"Hormosina"* sp. 4. Rare.

Family AMMODISCIDAE Reuss, 1862
Subfamily AMMODISCINAE Reuss, 1862

***Ammodiscus cretaceus*** (Reuss)
Plate 1, figure 6

*Operculina cretacea* REUSS, 1845, p. 35, figs. 64–65.
*Ammodiscus cretaceus* (Reuss).—FRIZZEL, 1954, p. 58, pl. 1, fig. 15.—KRASHENINNIKOV, 1974, pl. 7, fig. 8.—WEBB, 1975, p. 834, pl. 1, fig. 9.—RÖGL, 1976, pl. 2, fig. 22.—GRADSTEIN and BERGGREN, 1981, pl. 2, figs. 12–13.
*Ammodiscus cretaceus cretaceus* (Reuss).—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 2, fig. 6.

*Remarks:* Large, very fine-grained, numerous whorls (more than 8), tightly coiled test, biconcave in axial view. Common.

***Ammodiscus rugosus*** Schijfsma (not Terquem)
Plate 1, figure 7

*Ammodiscus cretaceus* (Reuss) var. *rugosa* SCHIJFSMA, 1946, pl. 6, fig. 2.
*Ammodiscus cretaceus rugosus* Schijfsma.—KRASHENINNIKOV, 1974, pl. 7, fig. 9.—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 2, fig. 6.

*Remarks:* Smaller, coarser grained, more loosely coiled, with a tendency toward irregular coiling, and fewer whorls (2½ to 4) than *A. cretaceus.*

***Ammodiscus glabratus*** Cushman and Jarvis
Plate 1, figure 8

*Ammodiscus glabratus* CUSHMAN and JARVIS, 1928, pl. 12, fig. 6.—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 2, figs. 8–9.

*Remarks:* Small, finer grained than *A. rugosus* and often coarser grained than *A. cretaceus,* very slightly concave in axial view, numerous whorls (more than 9). Common.

***Glomospira charoides*** (Jones and Parker)
Plate 1, figures 10–11

*Trochammina squamata* Jones and Parker var. *charoides* JONES and PARKER, 1860, p. 304.
*Ammodiscus charoides* (Jones and Parker).—GRZYBOWSKI, 1896, figs. 39–43.
*Glomospira charoides* (Jones and Parker).—BARKER, 1960, pl. 2, figs. 8–10.—GEROCH, 1960, pp. 46–47, pl. 4, figs. 1, 2, 5.—JURKIEWICZ, 1967, pp. 58–59, text.-fig. 7, pl. 2, figs. 16–17.—WEBB, 1975, pl. 1, figs. 13–14.—RÖGL, 1976, pl. 2, figs. 26–27.—GRADSTEIN and BERGGREN, 1981, pl. 3, figs. 5–7.
*Glomospira charoides* (Jones and Parker) var. *corona* CUSHMAN and JARVIS, 1928, p. 89, pl. 12, figs. 9–11; 1932, p. 10, pl. 2, figs. 8–10.
*Glomospira corona* (Cushman and Jarvis).—KRASHENINNIKOV, 1974, pl. 7, fig. 5.—KRASHENINNIKOV and PFLAUMANN, 1977, pl. 2, fig. 2.

*Remarks:* More regularly coiled than *G. gordialis* (cf. pl. 1, figs. 10–11, figs. 14–15). Krasheninnikov (1974, 1977) used *G. corona, G. charoides,* and *G. gordialis* as progressively irregularly coiling species. In our view, these progressively irregularly coiling species correspond to *G. charoides, G. gordialis,* and *G. irregularis,* respectively. Common.

***Glomospira gordialis*** (Jones and Parker)
Plate 1, figures 14–15

*Trochammina squamata* Jones and Parker var. *gordialis* JONES and PARKER, 1860, p. 304.
*Ammodiscus gordialis* (Jones and Parker).—GRZYBOWSKI, 1896, figs. 44–45.
*Glomospira gordialis* (Jones and Parker).—BARKER, 1960, pl. 38, figs. 7–9.—GEROCH, 1960, pp. 46–47, pl. 4, figs. 1, 2, 5.—JURKIEWICZ, 1967, pp. 59–60, text-fig. 8, pl. 2, fig. 23.—WEBB, 1975, pl. 1, fig. 12.—RÖGL, 1976, pl. 2, fig. 28.—GRADSTEIN and BERGGREN, 1981, pl. 3, figs. 2–3.

*Remarks:* More irregularly coiled than *G. charoides.* Common.

***Glomospira irregularis*** (Grzybowski)
Plate 1, figure 12

*Ammodiscus irregularis* GRZYBOWSKI, 1898, pl. 11, figs. 2–3.
*Glomospira irregularis* (Grzybowski).—GEROCH, 1960, pp. 47–48, pl. 4, figs. 9–10.—JURKIEWICZ, 1967, pp. 61–62, text-fig. 9, pl. 2, figs. 18–19.—RÖGL, 1976, pl. 3, fig. 12.—GRADSTEIN and BERGGREN, in press, pl. 3, figs. 1–4.

*Remarks:* Irregularly coiled. Common.

***Glomospira serpens*** (Grzybowski)
Plate 1, figure 13

*Ammodiscus serpens* GRZYBOWSKI, 1898, pl. 10, figs. 31–33.
*Glomospira serpens* (Grzybowski).—GEROCH, 1960, pp. 47–48, pl. 4, fig. 13.—JURKIEWICZ, 1967, pp. 61–62, pl. 2, figs. 24–27.—WEBB, 1975, pl. 1, fig. 15.

*Remarks:* Oval, slightly irregularly coiling. Found only in cores 13 and 14. Rare.

***Glomospirella*** sp.
Plate 1, figures 16–17

*Remarks:* Initial coil as in *G. irregularis,* later as in *Ammodiscus.* Common.

Subfamily TOLYPAMMININAE Cushman, 1928

***Ammolagena clavata*** (Jones and Parker)
Plate 1, figure 9

*Trochammina irregularis* (d'Orbigny) var. *clavata* JONES and PARKER, 1860.
*Ammolagena clavata* (Jones and Parker).—WEBB, 1975, pl. 10, figs. 31–33.

*Remarks:* Bulbous test with elongate tubular neck found attached to *Ammodiscus cretaceus.* Rare.

Superfamily LITUOLACEA de Blainville, 1825
Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894

***Hormosina ovulum*** (Grzybowski)
Plate 1, figure 20

*Reophax (Rheophax) ovulum* GRZYBOWSKI, 1896, pl. 8, figs. 19–21.
*Hormosina ovulum* (Grzybowski).—GEROCH, 1960, p. 43, pl. 2, figs. 20–22; pl. 10, figs. 8–9.—JURKIEWICZ, 1967, pp. 52–53, pl. 1, fig. 28.—KRASHENINNIKOV, 1974, pl. 17, fig. 12.—WEBB, 1975, pl. 1, figs. 1–2.—RÖGL, 1976, pl. 2, figs. 24–25; pl. 3, fig. 36.—KRASHENINNIKOV, 1977, pl. 1, figs. 17–18.—GRADSTEIN and BERGGREN, in press, pl. 2, figs. 1–2.

*Remarks:* Found only as single chambers. Rare.

***Hormosina globulifera*** Brady
Plate 1, figure 19

*Hormosina globulifera* BRADY, 1879, pl. 4, figs. 4–5.—RÖGL, 1976, pl. 3, fig. 29.

*Remarks:* Common.

***Hormosina*** sp. 3
Plate 1, figure 21

*Remarks:* Fine-grained, smaller-sized tests. Occur predominantly as multi-chambered individuals. Common.

*"**Hormosina**"* sp. 4
Plate 1, figure 18

*Remarks:* Found only as single chambers, and therefore may belong to the genus *Pelosina.* One or both "apertures" are often jagged, suggesting that whole individuals are uniserial. We assign these oval-chambered individuals to *Hormosina.* Common.

***Reophax pilulifera*** Brady
Plate 1, figure 22

*Reophax pilulifera* BRADY, 1884, p. 292, pl. 30, figs. 18–20.
*Reophax pilulifer* Brady.—BARKER, 1960, pl. 30, figs. 18–20.—JURKIEWICZ, 1967, pp. 48–49, text-fig. 4, pl. 1, fig. 24.—RÖGL, 1976, pl. 4, fig. 7.—GRADSTEIN and BERGGREN, 1981, pl. 2, figs. 10–11.

*Remarks:* Two or more overlapping, flattened chambers. Rare.

***Reophax nodulosus*** Brady
Plate 1, figure 23

*Reophax nodulosus* BRADY, 1879, pl. 4, figs. 7–8.—BARKER, 1960, pl. 31, figs. 1–9.

*Remarks:* Rare.

Family RZEHAKINIDAE Cushman, 1933

***Spirosigmoilinella compressa*** Matsunaga
Plate 2, figure 5

*Spirosigmoilinella compressa* MATSUNAGA, 1955, figs. 1–2.

*Remarks:* First described from the middle Miocene of Japan, occurs in the late middle to late Eocene of site 112 and the later Eocene of the North Sea associated with *Cyclammina amplectens.* Noted by Gradstein and Berggren (1981) as *"Rzehakina"* sp. 1. Evolute test is insoluble in HCl and lacks a tooth; it is therefore distinct from *R. epigona.* Rare.

Family LITUOLIDAE de Blainville, 1825
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

***Haplophragmoides eggeri*** Cushman
Plate 2, figure 6

*Haplophragmoides fontinense* EGGER (not Terquem), 1910, p. 10, pl. 3, figs. 16–18.
*Haplophragmoides eggeri* CUSHMAN, 1926, p. 583, pl. 15, fig. 1; 1946, p. 20, pl. 2, figs. 9–10.—JURKIEWICZ, 1967, p. 77, pl. 4, fig. 11.—GRADSTEIN and BERGGREN, 1981, pl. 6, figs. 1–4.

*Remarks:* Small, 5½ to 6½ chambers in last whorl. Fine-grained, smooth-walled as opposed to Cushman's coarser grained specimens. The interior of some specimens appears to be complex, and thus may be referred to *Aveolophragmium.* Occurs only in core 16. Common.

***Haplophragmoides walteri*** (Grzybowski)
Plate 2, figure 7

*Trochammina walteri* GRZYBOWSKI, 1898, pl. 11, fig. 31.
*Haplophragmoides walteri* (Grzybowski).—GEROCH, 1960, pp. 49–50, 127, pl. 5, fig. 5.—JURKIEWICZ, 1967, pp. 73–74, text-fig. 16, pl. 3, fig. 14; pl. 4, fig. 5.—GRADSTEIN and BERGGREN, in press, pl. 6, figs. 5–7.
(?)*Haplophragmoides excavata* CUSHMAN and WATERS, 1927, p. 82, pl. 10, fig. 3.—CUSHMAN and JARVIS, 1932, p. 12, pl. 3, fig. 1.

*Remarks:* Only flattened specimens found. Rare.

***"Haplophragmoides"*** sp.
Plate 2, figure 8

*Remarks:* This species is similar to *H. eggeri,* except for more rounded chambers, incised sutures, and a tendency toward trochospiral (as in *Trochammina*) development. Common.

***"Cribrostomoides" subglobosus*** (Sars)
Plate 2, figure 9

*Lituola subglobosa* G. SARS, 1872 (1871), p. 253.
*Alveolophragmium subglobosum* (G. Sars).—BARKER, 1960, pl. 34, figs. 7, 8, 10.
*Cribrostomoides subglobosus* (G. Sars).—LEROY and HODGKINSON, 1975, p. 432, pl. 4, figs. 2–4.—RÖGL, 1976, pl. 4, fig. 21.
*Haplophragmoides suborbicularis* (Grzybowski).—GEROCH, 1960, pl. 5, fig. 1.—JURKIEWICZ, 1967, p. 77, pl. 4, figs. 12–13.—WEBB, 1975, p. 834, pl. 2, figs. 8–9.
*"Cribrostomoides" subglobosus* (G. Sars).—GRADSTEIN and BERGGREN, 1981, pl. 6, figs. 10–11.

*Remarks:* Ranges from flaring to narrow final chanber. Latter specimens approach *C. scitulus* (Brady) of Gradstein and Berggren (1981) and Barker (1960) in axial view but are more like *C. subglobosus* in plane view. Included here are specimens with and without visible aperture slit. Common.

***Paratrochamminoides*** sp.
Plate 2, figure 10

*Remarks:* Large, irregularly coiled tests. Sutures may be poorly developed, therefore, some specimens are difficult to differentiate from *Glomospira irregularis.* Rare.

***Recurvoides walteri*** (Grzybowski)
Plate 2, figure 11

*Haplophragmoides walteri* GRZYBOWSKI, 1898, pl. 10, fig. 24.
*Recurvoides walteri* (Grzybowski).—JURKIEWICZ, 1967, p. 78, pl. 4, fig. 14.
*Thalmanammina walteri* (Grzybowski).—HANZLIKOVA, 1972, p. 44, pl. 7, fig. 6.
*Recurvoides* ex. gr. *walteri* (Grzybowski).—GRADSTEIN and BERGGREN, 1981, pl. 8, figs. 1–7.

*Remarks:* In poorly preserved specimens, this streptospirally coiled species may be difficult to differentiate from *Cribrostomoides subglobosus.* Occurs only in cores 15 and 14-CC (*Cribrostomoides-Recurvoides* assemblage). Common.

***Trochamminoides*** sp.
Plate 2, figure 18

*Remarks:* Planispiral, multi-chambered (greater than 10 chambers in last whorl), partially evolute form. Probably equivalent to *T. subtrullissatus* (Grzybowski).

***Labrospira pacifica*** Krasheninnikov

*Labrospira pacifica* KRASHENINNIKOV, 1973, pl. 2, figs. 4–5; 1974, p. 638, pl. 3, figs. 1–2.

*Remarks:* One individual noted in core 16.

Subfamily CYCLAMMININAE Marie, 1941

***Cyclammina amplectens*** Grzybowski
Plate 2, figure 16

*Cyclammina amplectens* GRZYBOWSKI, 1898, pl. 12, figs. 1–3.—MUYLAERT, 1966, p. 128, pl. 40, figs. 15–16.—JURKIEWICZ, 1967, pp. 82–85, pl. 10, fig. 10, text-fig. 17.—MJATLIUK, 1970, pp. 90–91, pl. 21, figs. 5, 11, 12; pl. 25, figs. 4–6; pl. 28, figs. 2–3.—GRADSTEIN and BERGGREN, 1981, pl. 7, figs. 13–17.

*Remarks:* Found in the middle to late Eocene in Site 112. Common.

***Cyclammina trullissata*** Brady
Plate 2, figures 14–15

*Trochammina trullissata* BRADY, 1879, pl. 5, fig. 10.
*Cyclammina bradyi* CUSHMAN, 1910, fig. 174.
*Cyclammina trullissata* (Brady).—PARKER, 1952, p. 400.—BARKER, 1960, pl. 40, fig. 13.

*Remarks:* Fewer chambers (approximately 9) in last whorl than in *C. amplectens,* axial periphery more pinched, chambers more incised. Rare.

Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877

***Trochammina globigeriniformis*** (Parker and Jones)
Plate 2, figure 19

*Lituola nautiloidea* Lamarck var. *globigeriniformis* PARKER and JONES, 1865, p. 407, pl. 15, figs. 46–47; pl. 17, figs. 96–98.
*Trochammina globigeriniformis* (Parker and Jones).—CUSHMAN, 1946, p. 51, pl. 15, figs. 8, 10, 11.—JURKIEWICZ, 1967, p. 92, pl. 6, fig. 13.—HILTERMANN, 1972, pp. 643–652.—GRADSTEIN and BERGGREN, 1981, pl. 8, fig. 13.

*Remarks:* This globigeriniform agglutinated species varies from quadrate with an umbilical aperture and a higher spire similar to *T. globigeriniformis* var. *altiformis* Cushman and Renz to a low-spired form with an umbilical-extraumbilical aperture as illustrated in plate 2, figure 19. Typically 8½ chambers in final whorl. Restricted to core 16. Common.

***Trochammina*** sp.
Plate 2, figure 12

*Remarks:* Distinguishable from *Trochamminoides* sp. by greater number of chambers (greater than 10) in the last whorl and trochospiral development.

***Cystammina globigerinaeformis*** (Krasheninnikov)
Plate 2, figures 13, 17, 21

*Praecystammina globigerinaeformis* KRASHENINNIKOV, 1973, p. 211, pl. 2, figs. 1–2; 1974, p. 641, pl. 6, figs. 1–3.—GRADSTEIN and BERGGREN, in press, pl. 9, figs. 11–15.

*Remarks:* This streptospiral, globigeriniform agglutinated species is characterized by its distinct, narrow areal aperture with prominent lip. Common.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily SPIROPLECTAMMININAE Cushman, 1927

***Spiroplectammina cubensis*** (Cushman and Bermudez)
Plate 2, figure 1

*Spiroplectoides cubensis* CUSHMAN and BERMUDEZ, 1937, pl. 1, figs. 44–46.
*Bolivinopsis cubensis* (Cushman and Bermudez).—DOUGLAS, 1973, pl. 3, fig. 5.

*Remarks:* Two initial planispiral whorls; later biserial portion has a tendency to flare slightly. Rare.

***Spiroplectammina spectabilis*** (Grzybowski)
Plate 2, figures 2–3

*Spiroplecta spectabilis* GRZYBOWSKI, 1898, pl. 12, fig. 12.
*Bolivinopsis spectabilis* (Grzybowski).—HANZLIKOVA, 1972, p. 48, pl. 10, fig. 8.—WEBB, 1975, pl. 3, figs. 1–3.—RÖGL, 1976, pl. 3, figs. 23–25.
*Spiroplectammina spectabilis* (Grzybowski).—HILTERMANN, 1972, pp. 43–61, pls. 1–2.—JURKIEWICZ, 1967, pp. 88–90, text-fig. 19, pl. 5, figs. 12, 15.—GRADSTEIN and BERGGREN, in press, pl. 5, figs. 1–5.

*Remarks:* Narrower cross section than Maestrichtian to Paleocene forms in the North Sea and Canadian margin. Both megalospheric and microspheric forms noted. Ranges throughout the Eocene. Abundant.

Family ATAXOPHRAGMIIDAE Schwager, 1877
Subfamily GLOBOTEXTULARIINAE Cushman, 1927

***Dorothia*** sp.

*Remarks:* Rapidly inflating chambers. Rare.

Subfamily VALVULININAE Berthelin, 1880

***Martinottiella*** sp.
Plate 2, figure 4

*Remarks:* Uniserial portion not always preserved. Common.

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## PLATE 1

"Simple" agglutinated foraminfera
Astorhizidae, Saccamminidae, Ammodiscidae and Hormosinidae

1 *?Bathysiphon* sp.
Sample 14-2, 102–113 cm, × 30.

2 *Rhizammina* sp.
Sample 15-CC, × 40.

3 *Saccammina complanata* (Franke)
Sample 16-1, 107–111 cm, × 112.

4 *Saccammina placenta* (Grzybowski)
Sample 14-2, 102–113 cm, × 74.

5 *Saccammina difflugiformis* (Brady)
Sample 16-1, 46–49 cm, × 93.

6 *Ammodiscus cretaceus* (Reuss)
Sample 15-CC, × 42.

7 *Ammodiscus rugosus* Schijfsma (not Terquem)
Sample 13-CC, × 93.

8 *Ammodiscus glabratus* Cushman and Jarvis
Sample 16-1, 78–84 cm, × 88.

9 *Ammolagena clavata* (Jones and Parker)
Sample 14-3, 141–144 cm, × 42.

10–11 *Glomospira charoides* (Jones and Parker)
10, sample 16-1, 78–84 cm, × 200; 11, sample 16-1, 46–49 cm, × 163.

12 *Glomospira irregularis* (Grzybowski)
Sample 16-1, 78–84 cm, × 70.

13 *Glomospira serpens* (Grzybowski)
Sample 14-CC, × 47.

14–15 *Glomospira gordialis* (Jones and Parker)
14, sample 16-1, 46–49 cm, × 151; 15, sample 16-1, 78–84 cm, × 153.

16–17 *Glomospirella* sp.
16, sample 16-1, 46–49 cm, × 130; 17, sample 16-1, 46–49 cm, × 128.

18 *"Hormosina"* sp. 4
Sample 16-1, 46–49 cm, × 70.

19 *Hormosina globulifera* Brady
Sample 14-2, 102–113 cm, × 53.

20 *Hormosina ovulum* (Grzybowski)
Sample 16-1, 46–49 cm, × 93.

21 *Hormosina* sp. 3
Sample 16-1, 107–111 cm, × 47.

22 *Reophax pilulifera* Brady
Sample 14-2, 102–113 cm, × 84.

23 *Reophax nodulosus* Brady
Sample 15-1, 12–25 cm, × 27.

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## PLATE 2

"Complex" agglutinated foraminifera, Site 112
Lituolidae, Trochamminidae, Textulariidae and Ataxophragmiidae

1 *Spiroplectammina cubensis* (Cushman and Bermudez)
Sample 14-3, 141–144 cm, × 116.

2–3 *Spiroplectammina spectabilis* (Grzybowski)
2, sample 16-1, 78–84 cm, × 37; 3, sample 13-5, 146–149 cm, × 37.

4 *Martinottiella* sp.
Sample 14-CC, × 98.

5 *Spirosigmoilinella compressa* Matsunaga
Sample 13-2, 107–117 cm, × 88.

6 *Haplophragmoides eggeri* Cushman
Sample 16-1, 46–49 cm, × 130.

7 *Haplophragmoides walteri* (Grzybowski)
Sample 16-1, 78–84 cm, × 112.

8 *"Haplophragmoides"* sp.
Sample 16-1, 46–49 cm, × 56.

9 *"Cribrostomoides" subglobosus* (G. Sars)
Sample 14-CC, × 70.

10 *Paratrochamminoides* sp.
Sample 16-1, 78–84 cm, × 70.

11 *Recurvoides* ex. gr. *walteri* (Grzybowski)
Sample 16-1, 12–25 cm, × 70.

12 *Trochammina* sp.
Sample 14-CC, × 116.

13, 17, 21 *Cystammina globigerinaeformis* (Krasheninnikov)
13, sample 14-5, 144–147 cm, × 163; 17, sample 16-1, 46–49 cm, × 130; 21, sample 16-1, 78–84 cm, × 112.

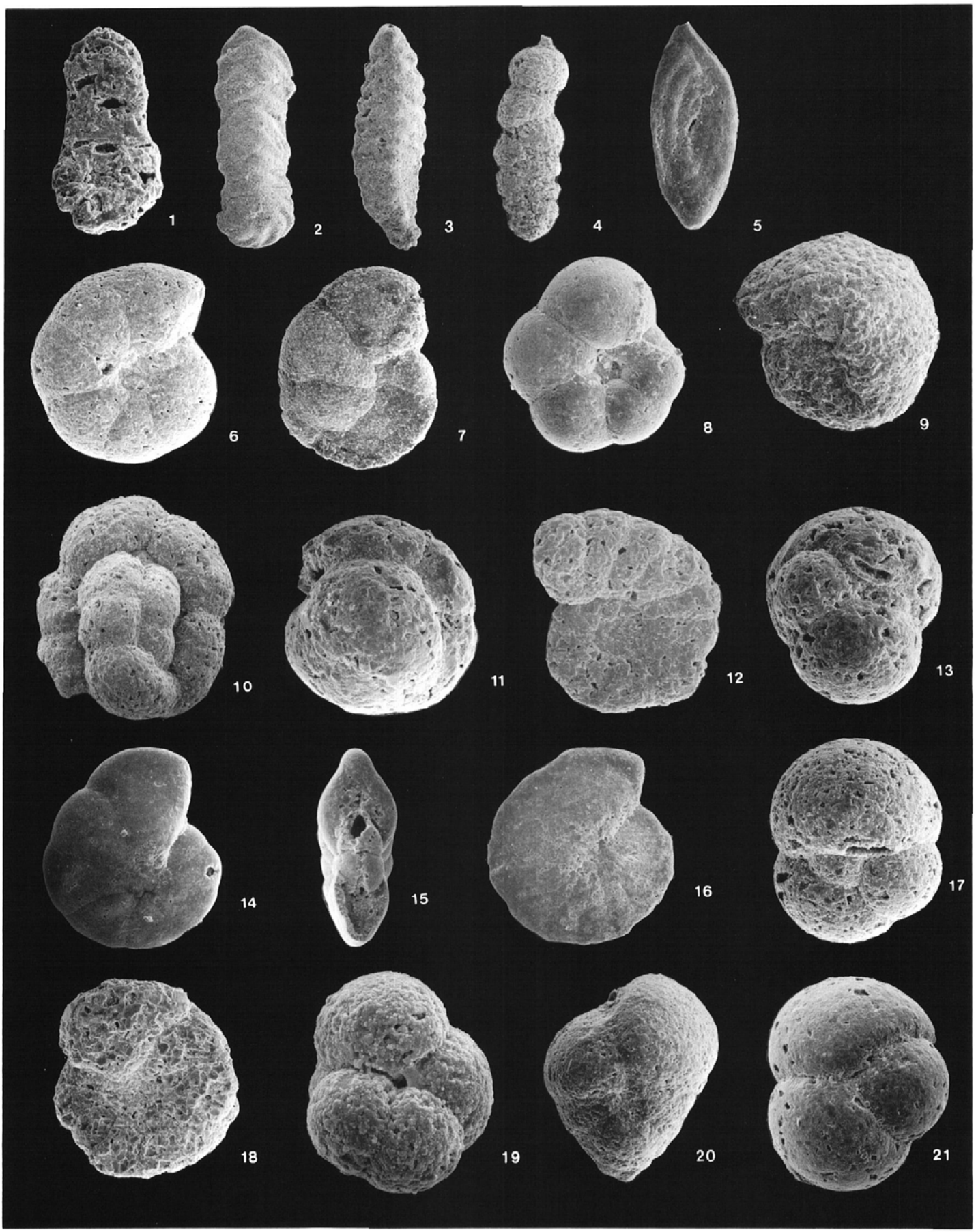
14–15 *Cyclammina trullissata* (Brady)
14, sample 15-CC, × 60; 15, sample 15-CC, × 63.

16 *Cyclammina amplectens* Grzybowski
Sample 14-2, 102–113 cm, × 51.

18 *Trochamminoides* sp.
Sample 14-CC, × 88.

19 *Trochammina globigeriniformis* (Parker and Jones)
Sample 16-1, 107–111 cm, × 221.

20 *Dorothia* sp.
Sample 14-CC, × 112.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## PLATE 3

### Calcareous foraminifera, Site 112

1 *Pleurostomella* sp.
Sample 13-4, 86–96 cm, × 44.

2 *Stilostomella aculeata* (Cushman and Jarvis)
Sample 15-CC, × 37.

3 *Stilostomella* sp.
Sample 14-3, 141–144 cm, × 140.

4 *Dentilina* sp.
Sample 12-1, 100–102 cm, × 34.

5 *Gyroidina* sp.
Sample 14-CC, × 120.

6 *Nuttallides truempyi* Nuttall
Sample 14-3, × 242.

7 *Pullenia quinqueloba* (Reuss)
Sample 14-3, 141–144 cm, × 140.

8 *Pullenia eocenica* Cushman and Siegfus
Sample 14-CC, × 140.

9 *Globobulimina* sp.
Sample 13-CC, × 74.

10 *Alabamina* sp.
Sample 14-3, 141–144 cm, × 237.

11–12 *Pseudohastigerina wilcoxensis* (Cushman and Ponton)
11, sample 15-CC, × 191; 12, sample 13-5, 146–149 cm, × 195.

13 *Acarinina bulbrooki* (Bolli)
Sample 15-CC, × 233.

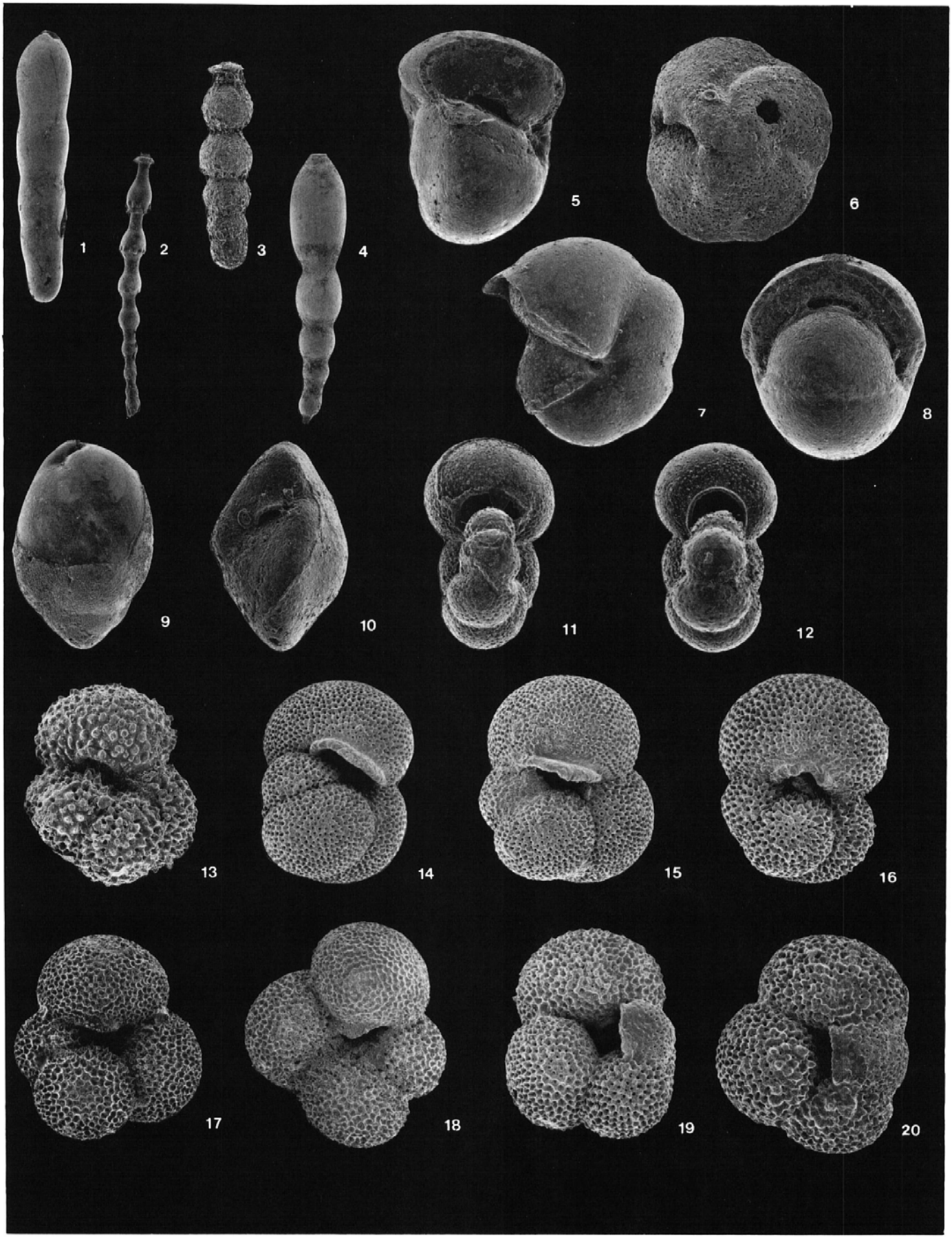
14–15 *Subbotina linaperta* Finlay
14, sample 15-CC, × 112; 15, sample 15-CC, × 116.

16 *Subbotina frontosa* Subbotina
Sample 15-CC, × 126.

17–18 *Dentoglobigerina galavasi* (Bermudez)
17, sample 14-2, 102–113 cm, × 116; 18, sample 14-2, 102–113 cm, × 177.

19 *Catapsydrax unicavus* Bolli
Sample 14-2, 144–146 cm, × 149.

20 *Catapsydrax perus* (Todd)
Sample 15-1, 12–25 cm, × 153.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