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BIOSTRATIGRAPHY OF THE LABRADOR SHELF, PART 1

by

F.M. Gradstein and G.L. Williams

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ABSTRACT

The Labrador Shelf covers approximately 90,000 square miles and is overlain by a sedimentary wedge thickening seaward, to a maximum of 20,000 to 30,000 feet. Hydrocarbon exploration in this inhospitable region commenced in the late sixties. To date nine wells have been drilled, of which two have been termed discoveries, and a further two may have encountered hydrocarbons. The wells discussed in the present paper are Tenneco *et al.* Leif E-38 drilled in 1971 and suspended at 3557 feet, and Eastcan *et al.* Leif M-48 and Bjarni H-81, drilled in 1973. The oldest sediments encountered in Leif E-38 are of apparently Early Miocene age. Leif M-48, located one mile away and with a TD of 6165 feet, bottoms in basalt dated as Early Cretaceous. Bjarni H-81, approximately 130 miles to the north of the two Leif wells has a TD of 8252 feet, also penetrating the Early Cretaceous basalt between 7400 and 8252 feet. Overlying the basalt in Bjarni H-81 is the porous "Bjarni Sandstone", which contains Early Cretaceous palynomorphs, and which has tested gas with small amounts of condensate. The "Bjarni Sandstone" is overlain by marine Upper Cretaceous Maastrichtian rocks, in turn followed by a Cenozoic sequence. The oldest sedimentary rocks encountered in Leif M-48 are Late Cretaceous (Maastrichtian). These are succeeded by a Cenozoic sequence; the Lower Paleocene appears to be absent and part of the (younger) Miocene may be missing. The depositional environment has shown considerable fluctuations, from nonmarine in the Early Cretaceous, to ?neritic in the Late Cretaceous-Paleocene, bathyal in the Eocene, neritic in the Oligocene-Miocene and littoral to nonmarine in the Plio-Pleistocene. Reworked microfossils are common in the Plio-Pleistocene.

INTRODUCTION

The Labrador Sea is bounded on the west by Labrador and Baffin Island and to the east by Greenland. It flows into the Atlantic Ocean southwards and to the north connects with the Arctic Ocean through Davis Strait and Baffin Bay. That part of its western Continental Shelf abutting against Labrador comprises the Labrador Shelf (Figure 1). This shelf extends northwards from approximately 53° N to 61°N or over 1000 miles, and ranges up to 200 miles in width. McMillan (1973) estimated the surface area of the Labrador Shelf as 88,000 square miles, with a calculated sedimentary volume of 350,000 cubic miles.

The eastern edge of the Labrador Shelf is marked by the 500 m contour (McMillan, 1973), unlike most Continental Shelves which extend offshore only to the 200 m contour. The shelf is composed of shallow banks separated from the seaward extension of the Labrador Shelf by a marginal channel up to 2000 feet deep, which parallels the present coastline (Grant, 1966, 1970). The Mesozoic-Cenozoic sedimentary cover is restricted to the east of the marginal channel. These sediments thicken seawards and may attain a total thickness of more than 10 kilometres (Van der Linden, 1975).

The Labrador Shelf to the east of the deep marginal channel has considerable potential for hydrocarbon accumulations. Exploration for such occurrences commenced in the fifties and early sixties with airborne magnetometer and geophysical surveys. Initial permits covering the shelf were issued in June 1966. The first exploration well was Tenneco *et al.* Leif E-38 (location of wells in Figure 1) located 510 miles north and slightly west of St. John's, Newfoundland. The Tenneco group then included besides the operator Eastcan, Amerada Hess and AGIP.

Leif E-38 was spudded in on August 13th, 1971 in 550 feet of water, by Storm Drilling Company's anchored drillship, Typhoon. The attempt was plagued by inclement weather including icebergs and boulder beds so that when the hole was suspended on October 8th, TD was only 3557 feet.

Tenneco relinquished the role of operator in 1971. The new operator for the group, Eastcan, re-entered the area in 1973 with the dynamically positioned drillship, Pelican. Two wells, Leif M-48, located approximately 1 mile NW of Leif E-38 and Bjarni H-81 130 miles to the northwest, were drilled, in 545 and 465' waterdepth respectively. Both wells bottomed in Lower Cretaceous volcanic rocks (McWhae and Michel, in press), Leif M-48 reaching 6165', Bjarni H-81 reaching 8251'. Bjarni was re-entered for testing in 1974, an open-hole DST yielding 13 MMCFPD 0.675 gravity gas with a small amount of 55° API condensate (McWhae and Michel, in press). Production was from Lower Cretaceous continental arkosic sandstones between 7400-7050'. This sandstone has been informally named the "Bjarni Sandstone" by McWhae and Michel (*op. cit.*). Also in 1974, Eastcan *et al.* drilled the Gudrid H-55 to 9311'. This well, which is located approximately half way between Bjarni H-81 and Leif M-48, logged 20 MMCFPD from a zone below 8740'.

1975 saw an upsurge of drilling on the Labrador Shelf with the Pelican being joined by another dynamically positioned drillship, the Sedco 445. In that year, five wells were drilled, Freydis B-87 to 7592'; Karlsefni H-13 suspended at 10,774', Snorri J-90 to 10,531', Cartier D-70 to 6320', and Indian Harbour M-52 to 7753'. Karlsefni and Snorri may have encountered hydrocarbon shows.

All these wells except for Indian Harbour, were drilled by the Eastcan group which now comprises Eastcan and Total Leonard, both subsidiaries of CFP, Amerada, Gulf, Aquitaine, AGIP and Sun Oil. Indian Harbour is a BP, Columbia *et al.* well.

The geological data discussed below is from the three currently released wells (off the confidental list) - Leif E-38, Leif M-48, and Bjarni H-81.

Leif M-48 and Bjarni H-81 both bottom in basalts of Early Cretaceous age. In Bjarni, the basalts are overlain by the non-marine "Bjarni Sandstone" which is the reservoir rock. This is in turn overlain by marine Maastrichtian sediments and a more or less complete Cenozoic section; part of the Miocene sediments appear to be missing. In Leif the succession is very similar, except for the absence of the "Bjarni Sandstone" and the apparent absence of early Paleocene sediments. Leif E-38 penetrates sediments of Miocene-Pleistocene age before bottoming at 3557'. The palynological and foraminiferal biozonations are treated under separate headings.

PALYNOLOGICAL BIOSTRATIGRAPHY

The palynomorphs present in sidewall cores and cuttings permit the correlation of the Cretaceous-Tertiary sediments in the three wells; Leif E-38, Leif M-48 and Bjarni H-81. Twelve informal biostratigraphic assemblages are proposed, based on the stratigraphic distributions of dinoflagellates and spores (Figures 2, 3). All the zones are assemblage zones (American Commission on Stratigraphic Nomenclature, 1961, Article 20). In a study based on well cuttings, it is necessary to use "fossil tops" (i.e., the latest and highest occurrence of a species) to define zones and in correlating wells. Each assemblage takes its name from a fossil not found in sediments above that assemblage. The "base" or oldest occurrence of a species is also useful for delineating assemblages or correlating, when it can be placed with some certainty, as when using sidewall cores.

Species common to the Grand Banks - Scotian Shelf and Europe, and which appear to have similar stratigraphic ranges in the two areas, have been used to correlate the Labrador sequence with other areas. Too much reliance should not, however, be placed on the ages at present. The palynological data and basis for the age assignments are discussed below under the appropriate assemblage headings.

1. *Cerebropollenites mesozoicus* Assemblage - Barremian

The Bjarni H-81 and Leif M-48 wells both bottom in basic volcanic rocks dated as Early Cretaceous (McWhae and Michel, in press). In Bjarni these are overlain by 350 feet of poorly sorted sandstone, the "Bjarni Sandstone", which contains some thin lignitic coal beds. This continental sandstone contains abundant spores and pollen between 7318-7074'. Species include *Appendicisporites bifurcatus* Singh, *Cerebropollenites mesozoicus* (Couper) Nilsson, *Cicatricosisporites australiensis* (Cookson) Potonié, *Contignisporites cooksonii* (Balme) Dettmann, *Trilobosporites purverulentus* (Verbitskaya) Dettmann and *Vitreisporites pallidus*

(Reissinger) Nilsson. *Appendicisporites bifurcatus* has been observed in Barremian - Aptian sediments in several Scotian Shelf - Grand Banks wells. *Cicatricosisporites australiensis,* according to Williams (1975), does not range above the Berriasian - Valanginian. Analysis of subsequent wells has extended the top of this species in the east coast offshore to the Barremian. Both *Cerebropollenites mesozoicus* and *Contignisporites cooksonii* are uncommon above the Barremian. The age of the interval 7318-7074' and hence the "Bjarni Sandstone" in the Bjarni well, would therefore appear to be Barremian. Based on palynological analyses undertaken by Robertson Research and CFP, McWhae and Michel (in press) assign a Barremian - Albian age to the Bjarni Sandstone.

2. *Deflandrea nucula - Hexagonifera chlamydata* Assemblage - Maastrichtian

The interval 7020-6860' in Bjarni H-81 is characterized by the *Hexagonifera chlamydata* assemblage, which is dominated by the index species *H. chlamydata* Cookson and Eisenack. This species has a known range of Albian - Maastrichtian (Harker and Sarjeant, 1975). Other species include *Palaeocystodinium benjaminii* Drugg which in the Scotian Shelf - Grand Banks wells has a known range of Maastrichtian - Danian. The interval 7020-6860' is accordingly dated Maastrichtian.

The volcanic rocks in Leif M-48 are immediately overlain by sediments from 6025-5867' containing the *Deflandrea nucula* assemblage. Species present include *Deflandrea diebeli* Alberti, *D. nucula* (Cookson and Eisenack) Lentin and Williams, *Isabelia cretacea* (Cookson) Lentin and Williams, *Hystrichosphaeridium* sp. A and *Spiniferites scabrosus* (Clarke and Verdier) Lentin and Williams. *Isabelia cretacea* and *Deflandrea nucula* are restricted to the Late Cretaceous. *Deflandrea diebeli* has a known range of Maastrichtian - early Paleocene (Williams, 1975). The interval 6025-5867' is therefore dated Maastrichtian. There is little similarity in either Leif M-48 or Bjarni H-81 to the Maastrichtian of the Scotian Shelf and Grand Banks. According to McWhae and Michel (in press) the interval 7050-6480' in Bjarni may be Cenomanian - Senonian. There is no evidence palynologically for a pre Maastrichtian age.

3. <u>*Palaeoperidinium pyrophorum* Assemblage</u> - early Paleocene.

The Paleocene of Bjarni appears to represent a more complete sequence than that in Leif M-48 if the palynological data is compared with that of the Scotian Shelf and Grand Banks. This has been determined from the presence of the *Palaeoperidinium pyrophorum* assemblage in Bjarni H-81 between 6770-6740' and its absence in Leif M-48. In the Scotian Shelf and Grand Banks wells, the *Palaeoperidinium pyrophorum-Deflandrea diebeli* Zone has been dated as early Paleocene or Danian (Williams, 1975). *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant has a known range of Maastrichtian-Early Paleocene. Other species present in the *P. pyrophorum* assemblage are *Deflandrea diebeli* Alberti and *D. magnifica* Sarjeant. The interval 6770-6740' in Bjarni is dated early Paleocene.

4. <u>*Eisenackia circumtabulata* Assemblage - "middle Paleocene"</u>

The *P. pyrophorum* assemblage is succeeded by the *Eisenackia circumtabulata* assemblage in Bjarni H-81. This assemblage extends from 6690-6460' and is included within the Paleocene. On the Scotian Shelf *E. circumtabulata* ranges throughout the Paleocene but is never common. Other species not extending into younger sediments are *Hystrichosphaeridium* sp. A and *Palaeocystodinium benjaminii* Drugg.

In Leif M-48 the sidewall core at 5800 feet contains the *Eisenackia circumtabulata* assemblage which apparently overlies sediments containing the *Deflandrea nucula* assemblage. *Eisenackia circumtabulata* Drugg is common, with occasional specimens of *Podocarpidites* being present. This suggests that some of the early Paleocene is absent from this well.

5. <u>*Deflandrea speciosa* Assemblage - late Paleocene</u>

The *Deflandrea speciosa* assemblage is present in both Leif M-48 from 5750-5712' and Bjarni H-81 from 6390-6360'. The *Deflandrea speciosa* Zone in the Scotian Shelf - Grand Banks has been assigned a late Paleocene age by Williams (1975). Besides *D. speciosa*, other species in the assemblage include *Deflandrea* *dartmooria* Cookson and Eisenack and one specimen of *Eisenackia circumtabulata*. Sediments containing the *D. speciosa* assemblages in Leif M-48 and Bjarni H-81 are provisionally dated late Paleocene.

6. *Areoligera senonensis* Assemblage - early Eocene

The *Areoligera senonensis* assemblage present in both Leif M-48 between 5650-5010', and Bjarni H-81 from 6290 to 6010' can be correlated with the *Areoligera senonensis* Zone of Williams (1975). This Zone is characteristic of the early Eocene of the Scotian Shelf - Grand Banks wells. Other species present in the *A. senonensis* assemblage are *Deflandrea extensa* Stover, *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey and Williams, *Wetzeliella condylos* Williams and Downie, *W. homomorpha* Deflandre and Cookson and *W. tenuivirgula* Williams and Downie. The above species are also common in the early Eocene of the Scotian Shelf, Grand Banks and southern England. The *A. senonensis* assemblage is accordingly dated early Eocene.

7. *Wetzeliella lunaris* Assemblage - middle-late Eocene

The succeeding *Wetzeliella lunaris* assemblage is well developed in both Leif M-48 and Bjarni H-81. It extends from 5990-4560' in Bjarni and 4960-4120' in Leif M-48. The assemblage is characterized by *Adnatosphaeridium reticulense* (Pastiels) De Coninck sensu Gocht, 1969, *Cyclonephelium ordinatum* Williams and Downie, *Deflandrea* sp., *Diphyes colligerum* (Deflandre and Cookson) Cookson, *Eocladopyxis peniculatum* Morgenroth, *Leptodinium incompositum* (Drugg) Lentin and Williams, *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall, *Pterocaryapollenites* sp., *Tiliaepollenites* sp., *Triatriopollenites* sp., *Wetzeliella articulata* Eisenack, *W. coleothrypta* Williams and Downie, *W. lunaris* Gocht and *W. tenuivirgula* Williams and Downie. Williams (1975) proposed the *Adnatosphaeridium reticulense* Zone for middle Eocene, and the *Diphyes colligerum* Zone for late Eocene sediments. As yet it is not possible to separate the middle from the late Eocene on the Labrador Shelf, so that sediments with the *Wetzeliella lunaris* assemblage are provisionally dated middle to late Eocene.

8. *Wetzeliella ovalis* Assemblage - early Oligocene

The *Wetzeliella ovalis* assemblage occurs in Leif M-48 between 4060-3940'. This assemblage is characterized by the last occurrence of *Cordosphaeridium cantharellum* (Brosius) Gocht, *Systematophora placacantha* (Deflandre and Cookson) Davey *et al.*, *Thalassiphora pelagica* (Eisenack) Eisenack and Gocht and *Wetzeliella ovalis* Eisenack. According to Williams, (1975) and Williams and Brideaux (1975), species of *Wetzeliella* do not range above early Oligocene. The *W. ovalis* assemblage is accordingly dated early Oligocene. The assemblage is not recognized in Bjarni H-81.

9. *Cordosphaeridium fibrospinosum - Deflandrea* sp. Assemblage - Oligocene

The interval 3920-3850' in Leif M-48 is included in the *Cordosphaeridium fibrospinosum* assemblage. The species characteristic of this assemblage are *Cordosphaeridium fibrospinosum* Davey and Williams and *Deflandrea* sp.; *Cordosphaeridium fibrospinosum* is not known from post-Oligocene sediments according to Williams (1975). This assemblage is therefore assigned an Oligocene age.

The Oligocene of Bjarni (4490-4360') is distinguished by the presence of *Deflandrea* sp. (as found in Leif M-48). Comparison with Bjarni H-81 indicates that this assemblage is Oligocene.

10. *Epicephalopyxis indentata* Assemblage - early Miocene

The *Epicephalopyxis indentata* assemblage is recognized in three wells, Leif E-38 (3330-2920'), Leif M-48 (3790-2890'), and Bjarni H-81 (4290-3360'). The index species *E. indentata* Deflandre and Cookson ranges upwards unto the early Miocene on the Grand Banks, where Williams and Brideaux (1975) recorded it under the name *Xenikoon* sp. A. The species was originally recorded from Paleocene to Miocene sediments in Australia. Elsik, (1975) noted that the species is characteristic of marginal marine to marine environments. Its presence may therefore indicate shallower water conditions. The two species not ranging into younger sediments are *Epicephalopyxis indentata* and *Systematophora ancyrea* Cookson and Eisenack. There is considerable reworking of Senonian species including *Areoligera coronata* (O. Wetzel) Lejeune-Carpentier *Chatangiella tripartita* (Cookson and Eisenack) Lentin and Williams, *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson, *Oligosphaeridium complex* (White) Davey and Williams and *Spinidinium echinoideum* (Cookson and Eisenack) Lentin and Williams.

The interval 3557-3330' in Leif E-38 contains the species *Areoligera senonensis, Lingulodinium machaerophorum, Pentadinium laticinctum granulatum* Gocht, *Phthanoperidinium* sp. and *Wetzeliella coleothrypta.* Prior to examination of Leif M-48 this interval was dated Eocene (Gradstein *et al.*, 1975). It appears more likely however that the Eocene species are reworked since correlation with Leif M-48 suggests an early Miocene age.

11. *Lejeunia* sp. - *Operculodinium centrocarpum* Assemblage - middle-late Miocene

The middle to late Miocene sediments, which contain the *Lejeunia* sp. - *Operculodinium centrocarpum* assemblage, cannot be subdivided. The assemblage is recognized in Leif E-38 from 2870-1990', Leif M-48 from 2890-2400', and Bjarni H-81 from 3190-2860'. It is characterized by the species *Bombacacidites* sp. A Williams and Brideaux, 1975, *Lejeunia* sp., *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall and *Osmundacidites* sp.

Overlying this assemblage in Leif M-48 and Bjarni H-81 are approximately 400 feet of sediments which cannot be dated other than Mio-Pliocene. They contain the palynomorphs *Bombacacidites* sp. A Williams and Brideaux, 1975, *Impletosphaeridium transfodum* Morgenroth, *Operculodinum centrocarpum* (Deflandre and Cookson) Wall, *Podocarpidites* sp., *Polysphaeridium cf. pastielsi* Davey and Williams and *Tanyosphaeridium paradoxum* (Brosius) Gocht. There is so much caved and reworked material in this interval in both wells that the few specimens recorded of the above species, cannot be used as the basis for a reliable age call. None of the species range into the Pliocene and *Tanyosphaeridium paradoxum* does not even extend into the Miocene, but correlation of Leif M-48 with E-38 suggests a possible Miocene age for this interval.

12. *Tsugaepollenites igniculus* Assemblage - Plio-Pleistocene

The Plio-Pleistocene cannot be subdivided in the three released Labrador Shelf wells. This is due in part to the large amount of reworked material ranging in age from Senonian to Miocene and in part to the paucity of presumed indigenous species. The *Tsugaepollenites igniculus* assemblage, which permits recognition of Plio-Pleistocene sediments, is present in Leif E-38 (from 1920-1130'), in Leif M-48 (from 1890-1290'), and in Bjarni H-81 (from 2400-1250'). Indigenous taxa include *Alnipollenites verus* (Potonié) ex Potonié, *Betulaepollenites*, *Caryapollenites simplex* (Potonié) Raatz, *Ilexpollenites*, *Quercoidites*, *Pinus*, *Tsugaepollenites igniculus* (Potonié) Potonié and Venitz and *Ulmipollenites*.

In Bjarni the reworked taxa are of Oligocene-Miocene age and include *Cordosphaeridium cantharellum* (Brosius) Gocht, *Deflandrea spinulosa* Alberti, *Operculodinium centrocarpum* and *Systematophora ancyrea*. In the two Leif wells the reworked taxa fall into one of four groups. The first group is characterized by reworked Senonian species including *Chatangiella tripartita* (Cookson and Eisenack) Lentin and Williams, *C. victoriensis* (Cookson and Manum) Lentin and Williams, *Isabelia belfastensis* (Cookson and Eisenack) Lentin and Williams, *Oligosphaeridium anthophorum* (Cookson and Eisenack) Eisenack and Kjellström, *Rugubivesiculites rugosus* Pierce and *Spinidinum echinoideum* (Cookson and Eisenack) Lentin and Williams. These are common throughout the Plio-Pleistocene. The second group is distinguished by the presence of reworked Maastrichtian-early Paleocene taxa including *Deflandrea diebeli* and *Palaeoperidinium pyrophorum*. These are not common. Reworked Eocene taxa form the third and least abundant group. These are *Cordosphaeridium gracile* (Eisenack) Davey and Williams, *Cyclonephelium* sp. and *Deflandrea phosphoritica* Eisenack. Possibly the most significant, because of the difficulty of separating from the indigenous assemblages, is the Oligocene-Miocene reworked species group. Included here are *Apteodinium* sp. B, Williams and Brideaux, 1975, *Bombacacidites* sp. A Williams and Brideaux, 1975, *Cannosphaeropsis* sp. A Williams and Brideaux, 1975, *Chiropteridium lobospinosum* (Gocht) Gocht, *Lingulodinium machaerophorum*, *Osmundacidites* and *Phthanoperidinium* sp. It is not possible to recognize sequential reworking of the four groups in the two Leif wells. They are intermingled to the extent that any original pattern is obscured.

FORAMINIFERAL BIOSTRATIGRAPHY

The foraminiferal assemblages in the Leif E-38, Leif M-48, and Bjarni H-81 wells contain very few planktonics. Benthonics, however, are common, especially in the lower part of the stratigraphic section where arenaceous forms predominate, probably reflecting deeper marine conditions. No foraminifera were recovered from the "Bjarni Sandstone" (7318-7074'), the upper part of the "Lutite sequence" (2730-2377') and the "Coarse Arkosic Sands" (2377-1247') in Bjarni H-81 (figures 5, 8).

The biostratigraphy is based on the stratigraphically highest occurrence of groups of taxa, arranged in eight informal zones designated assemblages 1 to 8 (Figures 5, 6). Exceptions are "assemblages" 4 and 7 delineated by the highest occurrence of single taxa. Chronostratigraphic interpretations are derived from literature data on individual taxa ranges in other regions, notably the North Sea Basin, Scotian Shelf, and Grand Banks of Newfoundland. Several of the Labrador zones also have been recognized in the Amoco Imp Skelly Egret K-36 well, drilled in 1973 on the northern Grand Banks (Figures 4, 5).

A comparison to DSDP sites 111, 112 in the Labrador Sea (Berggren 1972,) is hampered by the lack of planktonics in the wells discussed herein. Some of the benthonics appear similar but seem to be primarily of limited stratigraphic value. The difference in depositional environment, the DSDP sites being from a deeper marine realm, may explain differences in composition and stratigraphic occurrence of benthos assemblages.

1. <u>*Glomospira corona* Assemblage - Late Cretaceous-Paleocene</u>

Characteristic taxa of the exclusively silicious arenaceous assemblage are *Glomospira corona* Cushman and Jarvis, *Recurvoides walteri* (Grzybowski), cf *Cribrostomoides trinitatensis* Cushman and Jarvis, *Haplophragmoides* aff. *excavatus* Cushman and Waters, H. sp. 8, *Ammobaculites* aff. *polythalamus* Loeblich, A. sp. 7 and sp. 8, *Saccammina placenta* (Grzybowski), *Bathysiphon brosgei* Tappan, B. sp. 4, *Trochamminoides* sp. 1 and sp. 2, *Ammodiscus cretaceus* (Reuss), *Karreriella* sp. 2, *Spiroplectammina* sp. 2, *Rheophax velascoensis* (Cushman), *Rhizammina* sp. and *Rhabddammina* sp. Also present megaspore sp. 2.

The assemblage occurs in Leif M-48 between 5950' and 5620' and in Bjarni H-81 from about 7000' to 6060'; it is absent in Egret K-36. In this well there is a Late Cretaceous Globotruncana fauna at 2610', overlain by apparently Eocene sediments with the Pteropod sp. 1 assemblage. Samples from the Upper Cretaceous - Danian of Nuggssuaq, (Figure 1) West Greenland, made available through the courtesy of G. Henderson, (Greenland Geological Survey, Copenhagen) contain arenaceous foraminifera also present in the *Glomospira corona* assemblage.

Elements of the *Glomospira corona* assemblage occur in Scotian Shelf wells containing Campanian to Paleocene planktonics. Many of the taxa of the assemblage seem cosmopolitan and occur with morphologically similar forms in the Late Cretaceous-Paleocene elsewhere in North America (Cushman and Jarvis 1932, Cushman 1946, Frizzel 1954, Cushman 1927, Tappan 1962, Morris 1971), and the Late Cretaceous - Paleogene of Borneo (Key 1965), New Zealand and DSDP leg 29 in the Tasman Basin (Webb 1975), the Carpathians (Hanzlikova 1972), and Switzerland, Italy and France (Brouwer 1965).

2. <u>*Spiroplectammina spectabilis* Assemblage - Paleocene-early Eocene</u>

This assemblage consists of *Spiroplectammina spectabilis* (Grzybowsky), *Ammomorphina* sp. 1, *Epistomina* sp. 5, *Karreriella* sp. 1, *Eponides* sp. 5, *Plecto-*

frondicularia sp. *Cibicides alleni* Plummer, *Cibicides* aff. *blanpiedi* Toulmin and *Lenticulina ulatisensis* Boyd. Simple arenaceous taxa predominate but may include cavings from the overlying *Pteropod* sp. 1 assemblage.

According to Hiltermann (1972), *Spiroplectammina spectabilis* ranges from late Cretaceous to early Paleogene with optimal occurrence in Paleocene sediments. *Cibicides alleni* is known from Paleocene - Lower Eocene beds (Berggren and Aubert 1975). Both species are cosmopolitan.

In Leif M-48 the assemblage occurs between 5620' and 5060' and in Bjarni H-81 from 6060' to 5660'. It is absent in Egret K-36.

3. *Pteropod* sp. 1 Assemblage - middle - late Eocene

The *Pteropod* sp. 1 assemblage has been named after a pyritized *Pteropod* species which is conspicuous in Grand Banks wells such as Amoco Imp Petrel A-62, Amoco Imp Kittiwake P-11 and Amoco Imp Skelly Osprey H-84. In these wells, it occurs with specimens of middle-late Eocene planktonics such as *Globorotalia centralis* Cushman and Bermudez, *Globigerina yeguaensis* Weinzierl and Applin and/or *G. linaperta* Finlay. Also present are the benthonic species *Turrilina brevispira* Ten Dam known from the Eocene of northwestern Europe (Kaasschieter 1958, Hansen 1972), *Gavelinella* sp. 2, *Marginulina* ex gr. *decorata* (Reuss) and *Cyclammina* aff. *pusilla* (Brady). The underlying assemblage in these wells contains *Globorotalia spinuloinflata* Bandy, *G. spinulifera* Cushman and *Truncarotaloides rohri* (Bronniman and Bermudez) indicative of middle Eocene beds.

Pteropod sp. 1 is present on the northern Grand Banks in Amoco IOE Murre G-67 and in Amoco Imp Skelly Egret K-36, from 1510' to 1200' and from 2270' to 1850' respectively, where it is considered to indicate Eocene strata. This age assignment is supported by the presence of *Globigerina linaperta* at 2240' in Egret K-36. In Murre G-67 and Egret K-36 a few specimens of *Marginulina* ex gr. *decorata* range into the overlying *Turrilina alsatica* assemblage, but may be reworked.

Pteropod sp. 1 was not found in Leif M-48 and Bjarni H-81. The presence of middle-upper Eocene beds is inferred by the presence of *Gavelinella* sp. 2, *Marginulina* ex gr. *decorata*, and *Cyclammina* aff. *pusilla*, which occur in Leif M-48 between 5060' and 4060', and in Bjarni H-81 between 5560' and 4860'. The absence of more reliable markers makes this interpretation tentative.

4. *Turrilina alsatica* "Assemblage" - Oligocene

"Assemblage" 4 is based on the presence of *Turrilina alsatica* Andreae, which is widespread on the Grand Banks. This species is distinguished from *Turrilina brevispira* Ten Dam through the radiate rather than granular extinction of the wall when viewed under crossed nicols (Hansen 1972).

T. alsatica is known from the Oligocene of northwestern Europe (Batjes 1958, Hansen 1972). Dinoflagellate stratigraphy from Grand Banks wells (G.L. Williams and W.A.M. Jenkins,pers. comm.) and other foraminiferal data confirm its Oligocene age in offshore eastern Canada.

Turrilina alsatica occurs in Leif M-48 at 3880', in Bjarni at 4260' and in Egret K-36 from 1640-1580'. In Amoco IOE Murre G-67, which lies close to Egret K-36, it occurs from 1200-990' (Jansa *et al.*, 1976).

At 3880' in Leif M-48, there are also single specimens of *Globigerina* aff. *venezuelana* Hedberg and *Pseudohastigerina* sp. These occurrences are compatible with an Oligocene age interpretation at that depth.

5. *Spiroplectammina carinata* Assemblage - Oligocene - (middle) Miocene

In the interval immediately overlying the *Turrilina alsatica* 'assemblage', the following species have their highest occurrences: *Spiroplectammina carinata* (d'Orbigny), *Gyroidina girardana* (Reuss), *Guttulina problema* d'Orbigny, *Alabamina wolterstorffi* (Franke), *Globigerina* ex. gr. *praebulloides* Blow, *Epistomina elegans* and *Nodosaria* sp 8. These species together form the "*Spiroplectammina* *carinata* assemblage. *Ceratobulimina contraria* (Reuss) is also present. According to Marks and van Vessem (1979), *Globigerina praebulloides* forms part of a plexus with intergrading morphotypes comprising the taxa *Globigerina officinalis* Subbotina, *G. ouachitensis* Howe and Wallace, *G. praebulloides leroyi* Blow and Banner and *G. praebulloider occlusa* Blow and Banner. The group ranges from about the top of the middle Eocene to the lowermost Miocene (see also Postuma 1971, p. 268) and seems to be widespread in the Rupel clay (Oligocene) of northwestern Europe. Berggren (1972) reports *G. praebulloides* from the middle Miocene of DSDP site 112, Labrador Sea. J. Aubert (in G.L. Johnson *et al.* 1975) noted *G. praebulloides* in an Oligocene dredge sample off S.W. Greenland, together with *Almaena osnabrugensis* (Roemer) and many other taxa. On the Grand Banks *G. praebulloides* has been found in the Eocene of Amoco Imp Bittern M-62 well (with *Globorotalia centralis*) and in the Oligocene of Amoco Imp. Kittiwake P_11 (with *Globorotalia opima opima Bolli*) and Amoco IOE Murre G-67 (with *Turrilina alsatica*). In Leif M-48 and Bjarni H-81, it is present above the Oligocene *Turrilina alsatica* assemblage, and may indicate an early to middle Miocene Age.

Spiroplectammina carinata and *Gyroidina girardana* have been recorded in northwestern Europe from middle Eocene to middle Miocene strata, with a peak in the Oligocene - Miocene (Batjes 1958, Simon and Bartenstein 1962). Batjes (1958) also reported *Alabamina wolterstorffi* from Eocene - Oligocene sediments and *Guttulina problema* from Oligocene - middle Miocene strata. A comparison of Batjes specimens with the ones from the Labrador Shelf has confirmed our identifications.

Summarizing the ranges of individual species, a middle Eocene - middle Miocene age is likely for the *Spiroplectammina carinata* assemblage. The stratigraphically highest occurrence of the assemblage, immediately above assemblage 4 of Oligocene age may be indicative of early - middle Miocene beds.

Due to the absence of Oligocene-Miocene Boundary markers and the fact that *Turrilina alsatica* does not necessarily characterize the whole of the Oligocene, the age of the *Spiroplectammina carinata* assemblage has been taken as Oligocene - (middle) Miocene.

The assemblage occurs in Bjarni H-81 from 4260' to 3460', in Leif E-38 from 3557' (T.D.) to 3230', in Leif M-48 from 3880' to 3290', and in Egret K-36 from 1540' to 950'.

6. *Ceratobulimina contraria* Assemblage - Miocene

This assemblage is based on the last or top occurrence of *Ceratobulimina contraria* (Reuss), of 'tubes' probably representing a scaphopod species and of the diatoms *Coscinodiscus* sp. 1 and sp. 2. The foraminifers *Cyclogyra involvens* (Reuss) and *Nonion affine* (Reuss) are also sometimes present. The specimens of *Ceratobulimina contraria* closely resemble Batjes' (1958) specimens from the Oligocene and Miocene of Belgium and W. Germany. Simon and Bartenstein (1962) also report it from German Oligocene and Miocene beds.

In the Labrador wells Bjarni H-81, Leif M-48 and Leif E-38, assemblage 6 immediately overlies assemblage 5; in Bjarni H-81 it occurs from 3460' to 2860'; in Leif E-38 from 3230' to 2110' (?1690'), and in Leif M-48 from 3290' to 2080'. In both Leif wells its top is not clearly defined due to a scarcity of fossils. The presence of some unusually well preserved and robust specimens of *Globigerinoides* sp., *G.* aff. *sacculifera* (Brady), *Hastigerina* aff. *aequilateralis* (Brady), *H.* aff. *Globoquadrina altispira* (Cushman and Jarvis), *Orbulina suturalis* Bronniman, and *Orbulina universa* d'Orbigny between 3000' and 1790' in Leif E-38 is problematic. In Leif M-48, about 1 mile from the Leif E-38 site, these planktonics are absent, and only single and poorly preserved specimens of *Globorotalia* aff. *siakensis* Leroy (at 3290'), *G.* cf *puncticulata* (Deshayes) (at 2890') and *G.* sp. (at 2470') occur. There is no reason to assume that the Leif M-48 planktonics are not autochthonous, but the Leif E-38 record seems anomalous because of the occurrence of several, well preserved specimens. From a chronostratigraphic point of view the specimens may be *in situ*.

Since such specimens have also been reported from independently processed samples by Robertson Research micropaleontologists (Ken Laborde, pers. comm.) laboratory contamination is unlikely. It is possible that the specimens are due to drilling contamination. Previous to drilling Leif E-38, the Typhoon drilling vessel had operated in low latitude areas where such pelagics may be expected to occur in abundance.

In the Grand Banks well Egret K-36 the *Ceratobulimina contraria* assemblage is difficult to distinguish, (figure 1); there is evidence that on the Grand Banks this assemblage and the *Spiroplectammina carinata* assemblage cannot be separated.

7. *Asterigerina gurichi* "Assemblage" - Miocene

The interval overlying the *Spiroplectammina carinata* assemblage in Amoco Imp Skelly Egret K-36 and Osprey H-84 on the Grand Banks contains common *Asterigerina* specimens resembling *A. gurichi* (Francke) and *A. staeschi* and *A. frankei* described by Ten Dam and Reinhold (1941, 1942). The Grand Banks specimens are closely comparable to the specimens which Batjes (1958) incorporated in *Asterigerina gurichi* (Francke). Batjes (1958) considered *A. frankei* and *A. staeschi* as variants of *A. gurichi* and stated (p. 159): "Considering the data above [i.e. the variation observed] the supposed value of distinct *A. gurichi* and *A. gurichi* var. *staeschi* as index fossils for the middle - upper Oligocene and the middle Miocene in northwestern Europe respectively (Ten Dam and Reinhold 1941, 1942) does not appear to be absolute."

The common occurrence of *Asterigerina gurichi* (Francke) sensu Batjes in Egret K-36 from 950-800' (fig 4) and in Osprey H-84, has been taken as indicative of Miocene beds. This agrees with the palynological data.

The interval above the *Spiroplectammina carinata* assemblage in Bjarni H-81 is barren of foraminifera except for isolated specimens belonging to the *Islandiella* *teretis* assemblage. No *Asterigerina* specimens were found in the well. The absence of the *Asterigerina gurichi* assemblage is explained by the occurrence of a diastem, with part of the (younger) Miocene beds missing. In Leif M-48 and Leif E-38 *Asterigerina gurichi* occurs in an assemblage considered to be Pliocene-Pleistocene. The specimens, which have abraded tests, are probably reworked. Cavings obscure the presence or absence of the *Asterigerina gurichi* assemblage.

8. *Islandiella teretis* Assemblage - Pliocene-Pleistocene

The youngest foraminiferal assemblage recognized is the *Islandiella teretis* assemblage which contains *I. teretis* Tappan, *I. islandica* (Norvang), *Elphidium* sp. aff. *E. bartletti* Cushman, *Buliminella* sp. aff. *B. subfusiformis* Cushman. All these species are rare, and in part abraded, probably reflecting very shallow, high energy conditions.

In the absence of any markers for Pliocene beds *sensu stricto* the age of the *Islandiella teretis* assemblage is taken as Pliocene-Pleistocene, extending into the Recent (compare Tappan 1959, Todd and Low 1967; Feyling - Hanssen *et al.* 1971; Vilks 1969; Sen Gupta 1971).

There is no indication of an *Elphidium oregonense* zone which represents Pliocene-Pleistocene boundary beds in the North Sea Basin (Van Voorthuysen *et al.* 1972).

The *I. teretis* assemblage occurs in Leif M-48 from ?2080-1210', in Leif E-38 from ?1690-1300' and in Bjarni H-81 at 2760'. Few samples, poor recovery and reworked Miocene taxa hamper recognition of the lower boundary of this assemblage in the Leif wells. In the Bjarni H-81 well the interval above 2760' is barren of foraminifera, except for a silicious arenaceous specimen reworked from the *Glomospira corona* assemblage.

COMPARISON OF PALYNOLOGICAL AND FORAMINIFERAL CHRONOSTRATIGRAPHY

The palynological and foraminiferal chronostratigraphy (Figure 7) is similar in most instances. A close comparison is, however, hampered by a lack of chronostratigraphic resolution in the Labrador foraminiferal zonation as compared to the Labrador dinoflagellate biostratigraphy and the use of both cuttings and side wall cores for the palynological investigation and only cuttings samples for the foraminiferal study.

The biostratigraphic subdivision of the three wells shown below (see also Figure 8) is obtained by combining the palynological and foraminiferal data.

Eastcan *et al.* Bjarni H-81

Depth	Age
2760 - 1247	Pliocene-Pleistocene
± 2800	hiatus
3260 - 2860	Miocene
4160 - 3360	early Miocene
4560 - 4260	Oligocene
5660 - 4560	middle - late Eocene
6290 - 5660	early Eocene
6390 - 6360	late Paleocene
6690 - 6460	'middle' Paleocene
6770 - 6740	early Paleocene
7020 - 6860	Maastrichitian
± 7050	hiatus
7318 - 7074	Barremian
8252 - 7400	early Cretaceous (basalt)

<u>Tenneco *et al.* Leif E-38</u>

Depth (in feet)	Age
?1590 - 1130	Pliocene - Pleistocene
2920 - ?2110	Miocene
3557 - 2920	early Miocene

<u>Eastcan *et al.* Leif M-48</u>

Depth (in feet)	Age
?2080 1210	Pliocene- Pleistocene
2870 - 2380	Miocene
3790 - 2890	early Miocene
4060 - 3850	Oligocene
5010 - 4120	middle - late Eocene
5650 - 5010	early Eocene
5750 - 5712	late Paleocene
5800	'middle' Paleocene
	hiatus
6025 - 5876	Maastrichtian
	hiatus
6165 - 6034	early Cretaceous (basalt)

CORRELATION OF BIOSTRATIGRAPHY AND LITHOSTRATIGRAPHY

The lithostratigraphy of the wells Bjarni M-81, Leif E-38 and Leif M-48 (Figure 8) has been described in detail by McWhae and Michel (in press), and Hardy and Umpleby (in press). The Bjarni H-81 and Leif M-48 wells both bottom in basic volcanic rocks dated as Early Cretaceous (McWhae and Michel, *op. cit.*). In Bjarni these are 852 feet thick extending from 8252-7400' and in Leif M-48 are 131 feet, extending from 6165-6034'. The volcanics in Bjarni H-81 are overlain by 350 feet of poorly sorted sandstone informally named the "Bjarni Sandstone" by McWhae and Michel *(op. cit.)*. This continental sandstone, which contains some thin lignitic coal beds has been dated Barremian palynologically.

The "Bjarni sandstone" in Bjarni H-81 is overlain by dark shales which extend from 7050' to 6480' and have been termed the "Uniform Shale" by McWhae and Michel (*op. cit.*). In Leif M-48 these shales immediately overlie the Lower Cretaceous volcanics and attain a thickness of 196 feet (6034-5838'). The age of the "Uniform Shale" in Bjarni is Maastrichtian-Paleocene; in Leif it is Maastrichtian.

McWhae and Michel (*op. cit.*) place the interval 5838-4000' in Leif M-48, and 6480-4467' in Bjarni H-81 in the "Shale, Sandstone, Limestone Sequence" to which they assign a Paleocene-Eocene age. Within this sequence they recognize a threefold subdivision, above the upper of which is the "Leif Sandstone", a fine grained, well sorted glauconite and micaceous sandstone occurring between 4228' and 4124' in Leif M-48. The present authors recognize Paleocene sediments at the base of this unit in both wells. They place the top of the Eocene at 4560' in Bjarni and 4120' in Leif M-48 close to the top of the "Shale, Sandstone, Limestone Sequence". There is therefore close agreement as to the age of this unit between McWhae and Michel, *(op. cit.)* and this paper.

The overlying "Lutite Sequence" is assigned an Oligocene-Miocene age by McWhae and Michel (*op. cit.*) and is present in Leif M-48 (4000-1490') and Bjarni H-81 (?4375-2377'). According to the present authors the interval 4060-1490' in Leif M-48 is Oligocene to Plio-Pleistocene, the interval 4560-2377' in Bjarni H-81 is also Oligocene to Plio-Pleistocene.

The succeeding Upper Tertiary "Coarse Arkosic Sands" extend from ?1490-663' in Leif M-48, 1440-1097' in Leif E-38 and 2377-1247' in Bjarni H-81 (McWhae and Michel, *op. cit.*). These intervals are dated Plio-Pleistocene in this paper. Samples from the youngest sediments, the "Glacial deposits", have not been recovered.

PALEOECOLOGY

"Bjarni Sandstone" - Barremian

The oldest sedimentary unit in the released Labrador wells is the "Bjarni Sandstone" dated Barremian-Albian in McWhae and Michel (in press). In this report it is dated Barremian on the basis of spores and pollen. The absence of marine microfossils indicate that the environment was non-marine (Figure 8).

"Uniform Shale" - Maastrichtian to Paleocene

Immediately above the basalt in Leif M-48 and the "Bjarni Sandstone" in Bjarni H-81 are Maastrichtian - Paleocene sediments, the "Uniform Shale" of McWhae and Michel (1975). These contain abundant dinoflagellates which, if not transported, suggest shallow marine, inner neritic conditions. The exclusively silicious arenaceous foraminifera resemble the *'Rhabdammina'* fauna of Brouwer (1965; J. Brouwer pers. comm.). Rather than great depth, as favoured by Brouwer *(op. cit.)*, the Labrador assemblage may indicate somewhat restricted marine conditions which apparently resulted in carbonate undersaturation. Tentatively the depth is taken as neritic. Data from more wells and paleogeographic information through seismostratigraphy is needed for a more detailed determination.

"Shale with Intercalated Sand and Limestone Beds" - Paleocene to Oligocene

The neritic environment in the vicinity of both wells may have continued in the Paleocene and early Eocene. Dinoflagellates are common and there is a relatively low species diversity in the arenaceous and calcareous foraminifera fauna.

During the Eocene there was a deepening of the sea in the vicinity of both the Leif M-48 and Bjarni H-81 wells as interpreted from a rich *Cyclammina* spp. fauna, including *C. cancellata* Brady and other large, coarse arenaceous taxa. The environment may have been upper bathyal, deep shelf or slope. The rareness of planktonics, which is characteristic of these Labrador wells may be due to an absence of "Gulf Stream" influence at the sites and/or restriction of open marine circulation. This may also explain why the calcareous benthonics are of a lower diversity and less common than in coeval faunas in some Grand Banks and Scotian Shelf wells. Carbonate-poor water, resulting in low productivity of calcareous species, and/or post-sedimentary dissolution in a carbonate-poor sediment may also be contributing factors.

The dinoflagellate assemblages throughout the Eocene are commonly dominated by species of *Wetzeliella*. The presence of this genus has been used to indicate inner neritic to lagoonal deposition in the Paleogene of England (Downie *et al.* 1971). Presumably the dinoflagellates are allochthonous, being brought in from a nearby inner neritic environment.

"Lutite and Coarse Arkosic Sand" - Oligocene to Pleistocene

The disappearance in Oligocene to early Miocene times of the *'Cyclammina'* fauna indicates a shallowing of the sea, a trend which continues into younger sediments. The Oligocene-Miocene foraminiferal fauna in the Leif wells and in Bjarni H-81 comprises rare to common *Spiroplectammina, Nodosaria, Guttulina, Gyroidina, Lenticulina,* rare *Epistonima, Pullenia, Alabamina* and *Turrilina* and rare to frequent bryozoa, molluscs, otoliths and pyritized diatoms of the genus *Coscinodiscus*.

The fauna becomes much less diversified in the younger sediments and specimens with abraded tests are more common; reworked material becomes evident. These factors indicate shallower, higher energy conditions than below. In Pliocene-Pleistocene time the environment was littoral.

Oligocene dinoflagellates indicate a relatively open marine deposition in the vicinity of Leif M-48. In the early Miocene, however, very shallow marine to littoral conditions prevailed in the vicinity of Leif M-48 and Leif E-38, with farther-from-shore deposition in Bjarni H-81.

There is considerable reworking of Senonian, Maastrichtian-Paleocene, Eocene, and Oligocene-Miocene palynomorphs in the Plio-Pleistocene of Leif M-48 and E-38, and reworking of Oligocene-Miocene palynomorphs in the Plio-Pleistocene of Bjarni H-81. The increase in the pollen species, including *Pinus* and *Tsugaepollenites igniculus*, and the apparent absence of indigenous dinoflagellates in the Plio-Pleistocene, indicates littoral or even non-marine deposition. This is supported by the presence of coarse arkosic sands and glacial boulder beds in Leif M-48 and Bjarni (McWhae and Michel, in press).

CONCLUSIONS

Biostratigraphic examination of samples from the Bjarni H-81, Leif E-38 and Leif M-48 wells, has delineated 12 palynomorph assemblages ranging in age from Early Cretaceous to Plio-Pleistocene, and 8 foraminiferal assemblages ranging in age from Late Cretaceous to Plio-Pleistocene. All age assignments are tentative since correlation of the Labrador Shelf assemblages with other well-dated assemblages is difficult. Comparisons have however been made, where possible, with presumably coeval assemblages from the Grand Banks, Scotian Shelf, Greenland and Europe. Effects of local environments on the stratigraphic ranges of foraminferal and palynomorph species are unknown, thereby necessitating caution in age designations.

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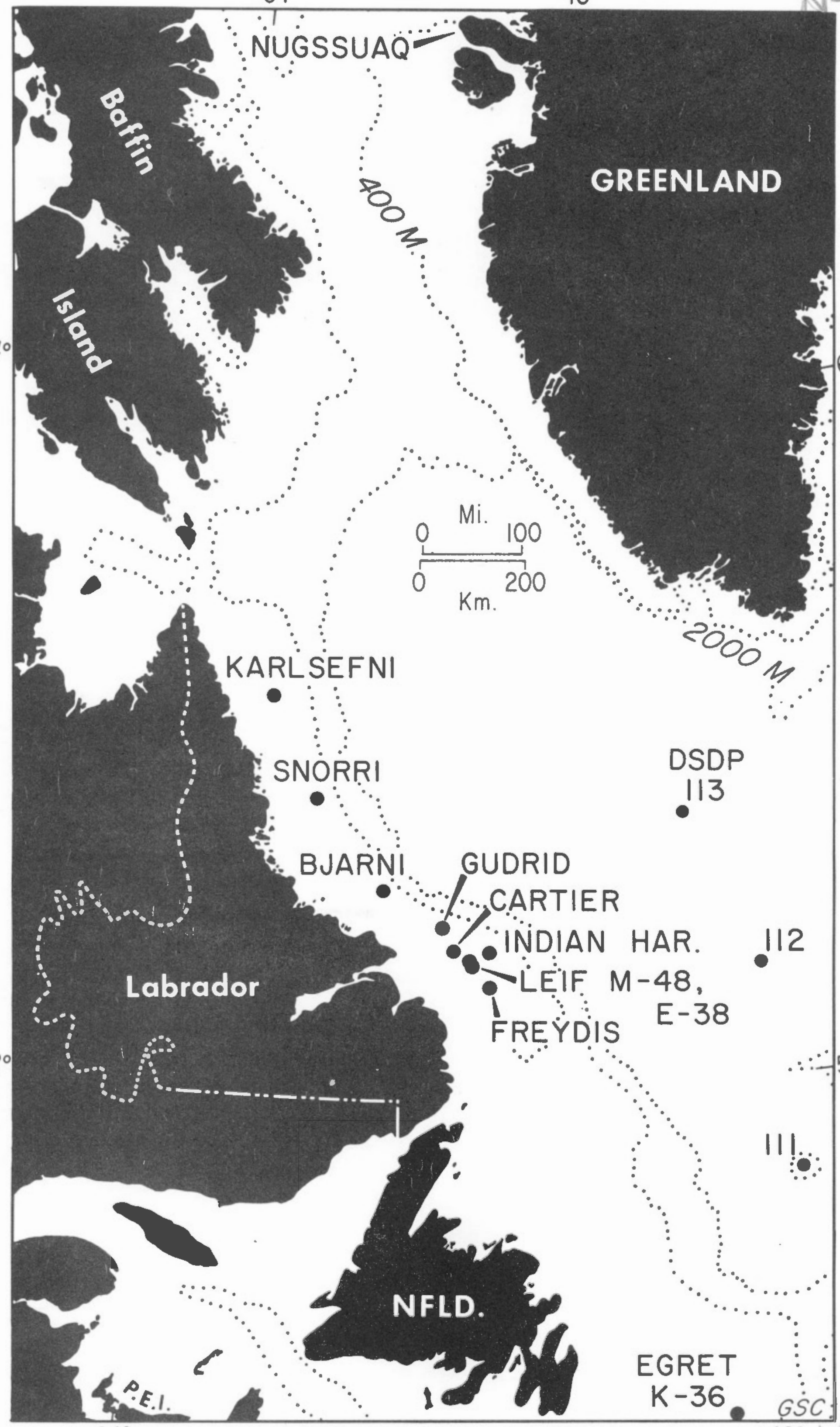

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Figure 1 Location of the wells used for a preliminary Labrador Shelf biozonation; Tenneco *et al.* Leif E-38, Eastcan *et al.* Leif M-48, Bjarni H-81, Labrador Shelf and Amoco Imp Skelly Egret K-36, Grand Banks. Also shown are location of some adjacent wells and DSDP sites.

	ASSEMBLAGE	AGE
12	Tsugaepollenites igniculus	PLIO.-PLEISTOCENE
11	Lejeunia sp. Operculodinium centrocarpum	MIOCENE
10	Epicephalopyxis indentata	EARLY MIOCENE
9	Cordosphaeridium fibrospinosum Deflandrea sp.	OLIGOCENE
8	Wetzeliella ovalis	EARLY OLIGOCENE
7	Wetzeliella lunaris	M-L EOCENE
6	Areoligera senonensis	EARLY EOCENE
5	Deflandrea speciosa	LATE PALEOCENE
4	Eisenackia circumtabulata	"MID" PALEOCENE
3	Palaeoperidinium pyrophorum	EARLY PALEOCENE
2	Deflandrea nucula Hexagonifera chlamydata	MAASTRICHTIAN
1	Cerebropollenites mesozoicus	BARREMIAN

Figure 2 Informal palynological zonation in the wells Leif E-38, Leif M-48 and Bjarni H-81, Labrador Shelf.

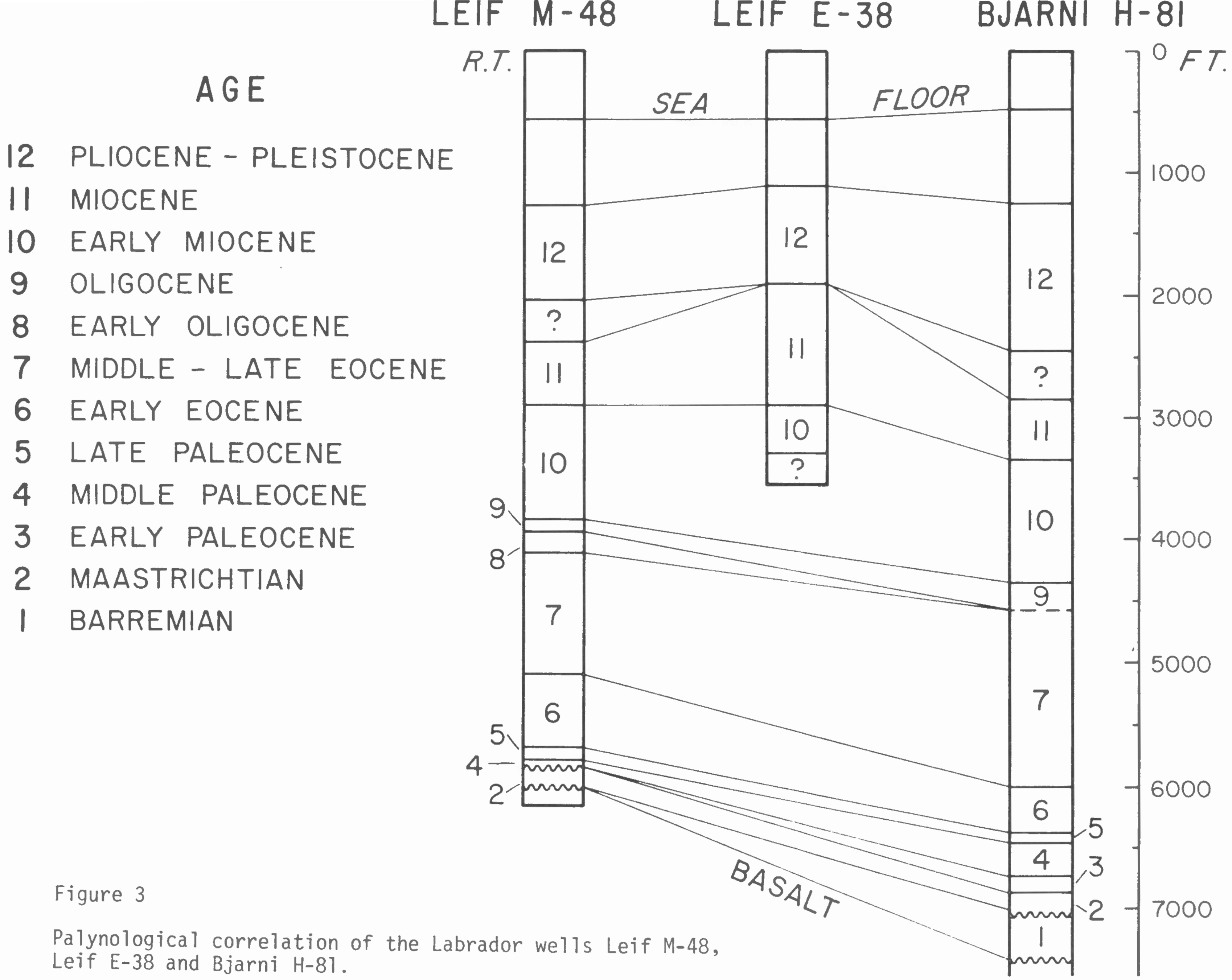

Figure 3

Palynological correlation of the Labrador wells Leif M-48, Leif E-38 and Bjarni H-81.

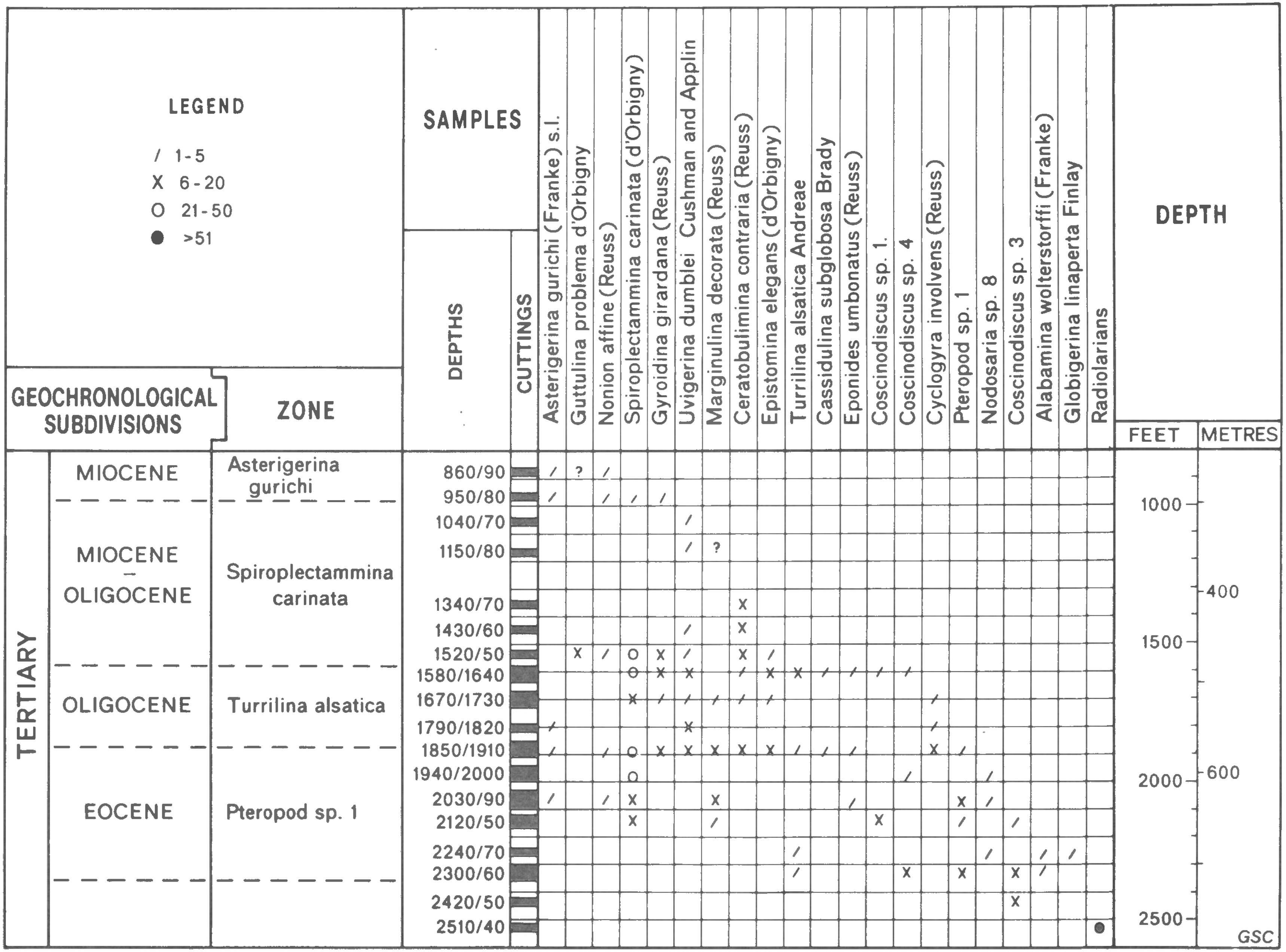

Figure 4 Distribution of Tertiary Foraminifera in cuttings samples of Egret K-36, Grand Banks.

	ASSEMBLAGE	AGE
8	Islandiella teretis	PLIOCENE-PLEISTOCENE
7	Asterigerina gurichi	MIOCENE
6	Ceratobulimina contraria	MIOCENE
5	Spiroplectammina carinata	OLIGOCENE-M. MIOCENE
4	Turrilina alsatica	OLIGOCENE
3	Pteropod sp. 1	M-L EOCENE
2	Spiroplectammina spectabilis	PALEOCENE-E. EOCENE
1	Glomospira corona	LATEST CRET. -PALEOCENE

Figure 5 Informal foraminiferal zonation of the wells Leif E-38, Leif M-48 and Bjarni H-81, Labrador Shelf and Egret K-36 on the northern Grand Banks.

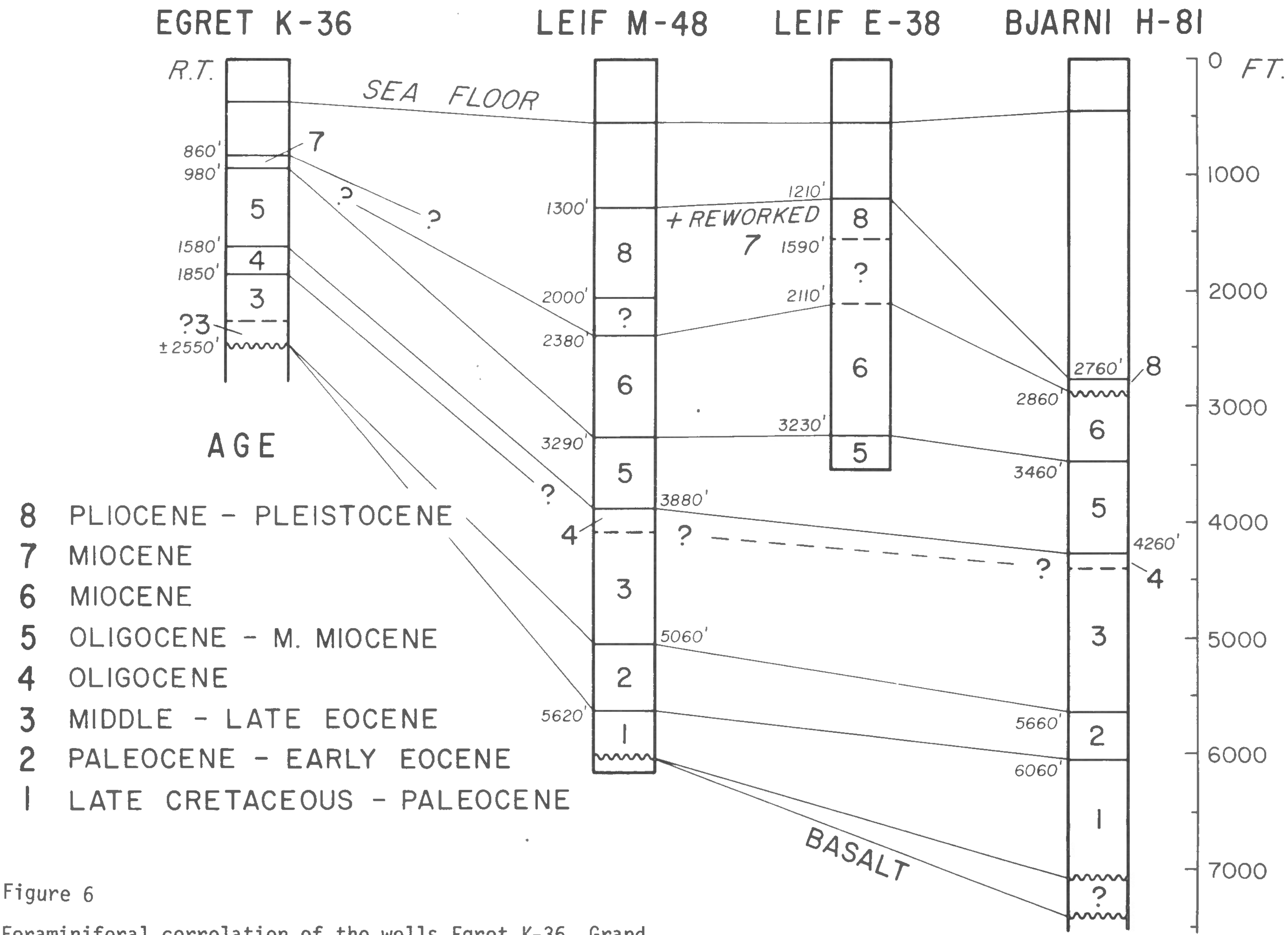

Figure 6

Foraminiferal correlation of the wells Egret K-36, Grand Banks and Leif M-48, Leif E-38 and Bjarni H-81, Labrador Shelf.

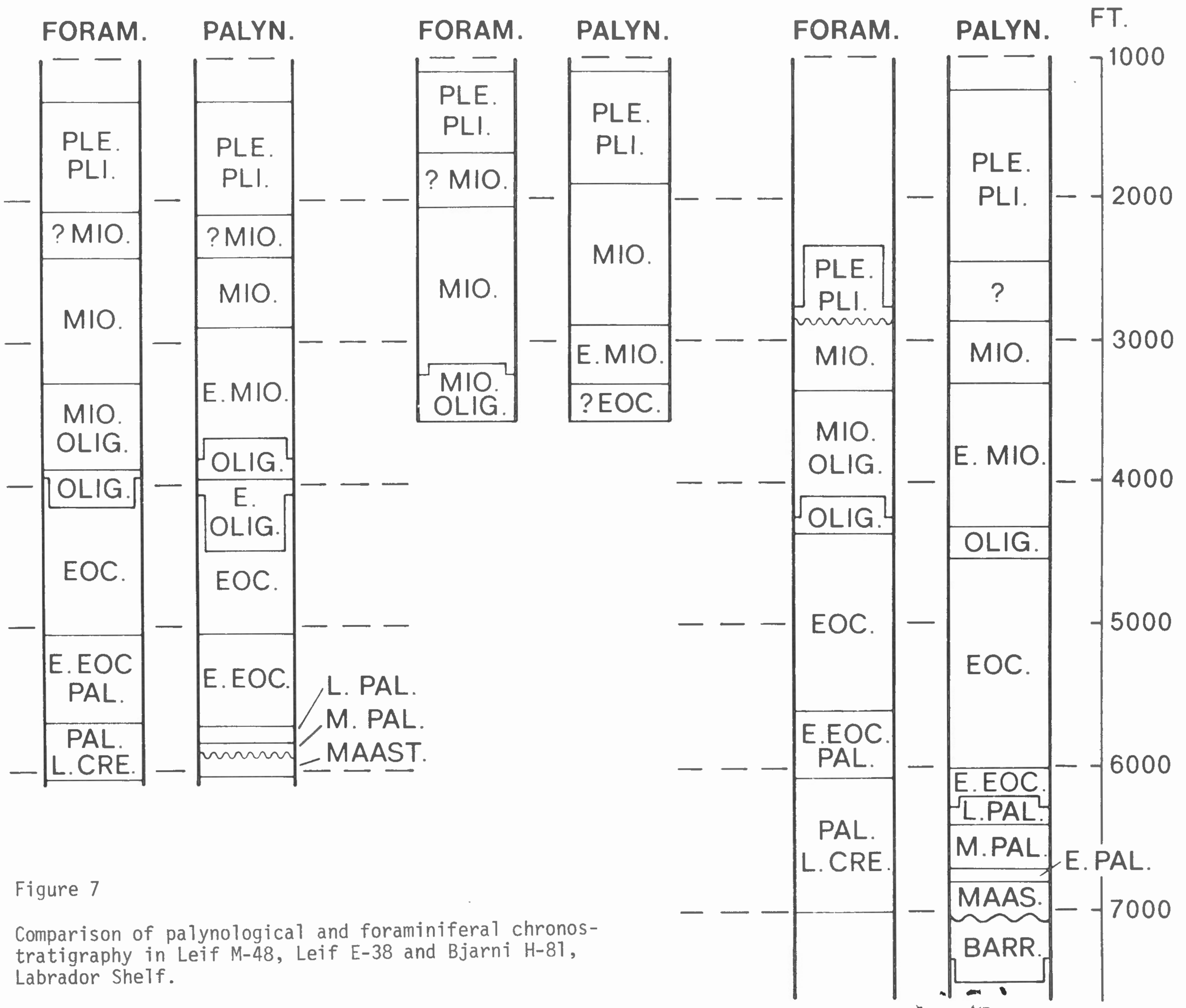

Figure 7

Comparison of palynological and foraminiferal chronostratigraphy in Leif M-48, Leif E-38 and Bjarni H-81, Labrador Shelf.

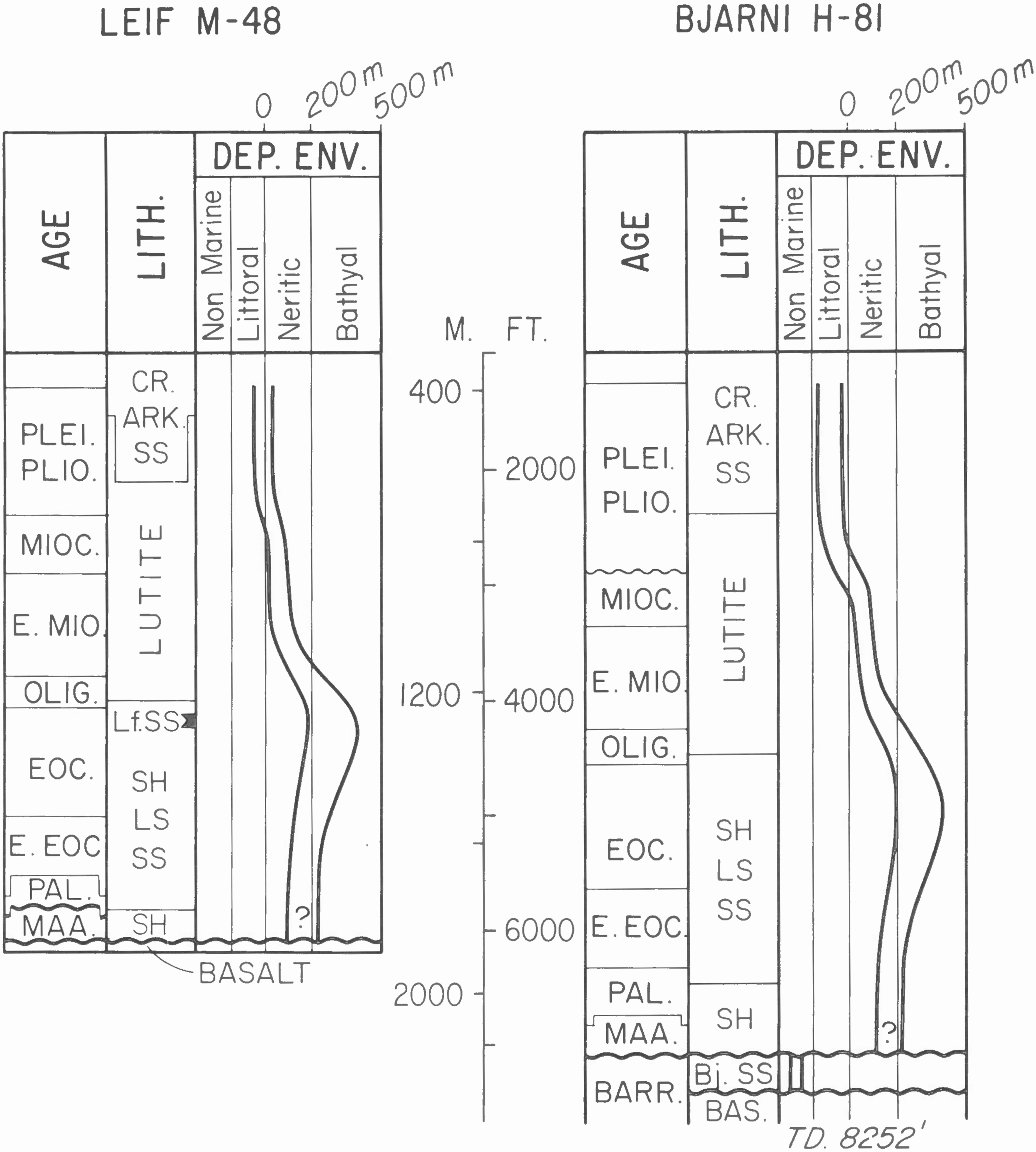

Figure 8 Stratigraphy and Depositional environment in the wells Leif M-48 and Bjarni H-81, Labrador Shelf. Lithostratigraphic data are according to McWhae and Michel (in press) and Hardy and Umpleby (in press).