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G.L. Williams

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Palynological analysis of Total Eastcan *et al.* **Gilbert F-53**, Saglek Basin, Labrador Shelf.

G.S.C. Locality No.: D-183

Location: 58°52'27"N, 62°18'23"W

Elevation Sea level to R.T.: 12.1 m Water Depth: 183 m

Total Depth: 3608 m

Spud Date: 9 October 1979 Interval Studied: 520-3605 m

Casing Points: 762 mm at 233.5 m; 473 mm at 507.8 m; 340 mm at 1435 m, 244 mm at 3178 m

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Introduction

Total Eastcan *et al.* Gilbert F-53 is at the southern edge of the Saglek Basin on the northern Labrador Shelf (Figure 1). This study is based on the palynological analysis of 208 cuttings samples covering the interval 3605-520 m. I thank the Canada-Newfoundland and Labrador Offshore Petroleum Board for providing the cuttings samples from which the palynology slides were prepared.

A comprehensive summation of the stratigraphy and maturation history of Gilbert F-53 was visually displayed in the Labrador Sea Basin Atlas (Bell, J.S, coordinator, 1989). This publication has provided me with a source of paleoenvironmental data, which I compare with my results.

Biostratigraphy

The age determinations in my study which are based on dinoflagellates (dinocysts), spores and pollen - are shown in Figure 2. I have derived the ages from the known stratigraphic ranges of dinocysts in European sections (Bujak, 1994; Williams *et al.*, 1999, 2001, 2004) and from other wells and core holes from offshore eastern Canada and western Greenland (Williams, 1975; Williams and Brideaux, 1975; Williams and Bujak, 1977; Barss *et al.*, 1979; Williams *et al.*, 1990; Sønderholm *et al.*, 2003; Nøhr-Hansen, 2003).

Bujak-Davies Group (1987) published the first account of the biostratigraphy of Gilbert F-53. This presented age determinations based on palynology and micripaleontology and paleoenvironmental interpretations based on micropaleontology. Paleoenvironmental determinations by Miller and d'Eon (1987) were based on lithological evidence.

In Gilbert F-53 the deepest cuttings sample is from 3605-595 m. At total depth, the rocks were Precambrian gneisses, which extend up to 3550 m. Thus the deepest cuttings sample and four overlying samples which were analysed are within the gneissic interval. Dinocysts recovered from 3605-3550 m, but representing caved material, include *Callaiosphaeridium asymmetricum, Chatangiella ditissima, Gillinia hymenophora* and *Senoniasphaera rotundata.* Williams *et al.* (2004) considered *Callaiosphaeridium asymmetricum* to have its Last Appearance Datum (This - the highest, latest or youngest occurrence of a taxon in a well or surface section - is commonly denoted by the acronym LAD. The First Appearance Datum - the lowest, earliest or oldest occurrence of a taxon in a well or surface section - is commonly denoted by the acronym FAD) or extinction at 78.15 Ma, within the early Campanian. This explains my designation of 3550 m as early Campanian, even though that is the top of the gneiss.

Nøhr-Hansen (2003b) recognized 20 intervals in the Aptian-Late Maastrichtian of onshore and offshore western Greenland and offshore eastern Canada. The Labrador Shelf well with the most complete Late Cretaceous section is Skolp E-07, also in the Saglek Basin. The oldest sediments in this well are Albian-Cenomanian, which are overlain by Campanian-Maastrichtian. Nøhr-Hansen (2003b) identified a late Campanian zone, based on the LAD of *Callaiosphaeridium asymmetricum*. I follow Williams *et al.* (2004) in placing the LAD at 78.15Ma, which would be within the mid Campanian on the Gradstein and Ogg (1996) scale.

I consider from 3550-3520 m to be late Campanian, based on the LADs of *Chatangiella coronata* and *Chatangiella ditissima*. Nøhr-Hansen (2003) placed the LAD of *Chatangiella decorosa*, a species closely related to *Chatangiella ditissima*, in the lower part of his *Callaiosphaeridium asymmetricum* zone. I extend it higher, based on the presence of *Chatangiella coronata*, the LAD of which is at 71.3 Ma according to Williams *et al.* (1999). That equates with the Campanian-Maastrichtian boundary.

The LAD of *Odontochitina costata* at 3280-3270 m marks the top of the mid late Campanian. Other dinocysts having their LADs in the interval 3520-3270 m are *Gillinia hymenophora, Heterosphaeridium heteracanthum, Hystrichosphaeridium arborispinum* and *Raphidodinium*. Nøhr-Hansen (2003b) placed the LAD of *Odontochitina costata* above that of *Chatangiella decorosa* but still within the *Callaiosphaeridium asymmetricum* zone. He recorded *Heterosphaeridium heteracanthum* from the *Odontochitina operculata* Zone of latest Campanian age, but did not observe *Gillinia hymenophora*.

Based on the LAD of *Odontochitina operculata* and *Xenascus ceratioides*, I place the top of the Campanian at 3250 m. Williams *et al.* (2004) gave the LAD of *Odontochitina operculata* as 70.43 Ma in mid latitudes and the LAD of *Xenascus ceratioides* as 72.34 Ma in mid latitudes. On the Gradstein and Ogg (1996) scale, the Campanian-Maastrichtian boundary is at 71.3 Ma. That is close enough to justify using *Odontochitina operculata* for the top of the Campanian. The Bujak-Davies Group placed the top of the Campanian at 3270 m.

Determining the Cretaceous-Tertiary boundary is complicated by the high degree of reworking in Gilbert F-53. One species, *Stiphrosphaeridium dictyophorum*, occurs only in samples at 3020-3010 m and 2990-2980 m. However, several specimens occur in the samples from 2750-2740 m and 2715-2705 m. I place the Maastrichtian-Danian boundary at 3100-3090 m. This is based on the LAD of *Circulodinium distinctum*, which Williams *et al.* (1999) gave as 65 Ma and which approximates with the Cretaceous-Tertiary boundary. Other species having their LADs in the Maastrichtian are *Isabelidinium belfastense* and *Palynodinium grallator*. Nøhr-Hansen (2003b) named his youngest Maastrichtian zone the *Palynodinium grallator* Zone.

My pick for the Cretaceous-Tertiary boundary differs from that of the Bujak-Davies Group (1987), who placed it between 2880 and 2860 m. These authors seem to have based the boundary on the palynological data, since they also gave the top of the Maastrichtian as 3090 m, as determined from the micropaleontology. Placing the boundary at 2880 m would mean that the LADs of *Cerodinium diebelii, Palaeocystodinium australinium* and *Spongodinium delitiense* are Maastrichtian. This is possible but does not agree with Nøhr-Hansen (2004), who placed the LADs of *Spongodinium delitiense* and *Cerodinium diebelii* at the top of the Danian. Until I have further evidence, I prefer to follow Nøhr-Hansen (2004).

The presence of Campanian-Maastrichtian is confirmed by Crux and Gard (2004), who studied the nannofossils. They recorded a relatively rich assemblage from 3200 m, which they noted could be no older than Campanian.

My placement of the Maastrichtian-Danian boundary at 3100-3090 m means that the Maastrichtian is about 140 m thick. This seems somewhat reduced considering the Maastrichtian spanned about 5 million years. One explanation may be that some of the Maastrichtian is absent: another is that the section is condensed.

The Early Paleocene or Danian is extremely thick extending from 3050 to 2530 m. It contains diverse dinocyst assemblages. Species having LADs in this stage are: *Cerodinium diebelii*, *Oligosphaeridium complex, Palaeocystodinium australinium, Phelodinium kozlowskii, Spinidinium densispinatum, Spongodinium delitiense, Tanyosphaeridium xanthiopyxides, Trithyrodinium evittii* and *Trithyrodinium "verrucatum"*.

Cerodinium diebelii has a LAD of 59.95 Ma in northern hemisphere mid latitudes (Williams *et al.*, 2004). Gradstein and Ogg (1996) placed the Danian-Selandian boundary at 61 Ma. In Gilbert F-53, the LAD of *Cerodinium diebelii* is at 2930-2920 m, about 400 m below where I place the top of the Danian. Nøhr-Hansen (2004) did not recognize a *Cerodinium diebelii* event. But in his analysis of the North Leif I-05 well in the Hopedale Basin, he marked the LAD of the species at the Danian-Selandian boundary.

Spongodinium delitiense has its LAD at 2870-2860 m. Williams *et al.* (2004) placed the LAD for this species at 63.72 MA in mid northern latitudes. This supports my conclusion that *Cerodinium diebelii* has a suppressed LAD in Gilbert F-53. Based on the LAD of *Spongodinium delitiense*, it would be reasonable to consider the interval 3170-2860 m as early Danian.

The LAD of *Trithyrodinium evittii* at 2750-2740 m indicates that its youngest occurrence in Gilbert F-53 is between 60 and 63.72 Ma. For the high latitude Southern Hemisphere, Williams *et al.* (2004) gave a LAD of 57.3 Ma. For Northern Hemisphere mid latitudes they cite a LAD of about 60 Ma. Thus in the Southern Hemisphere, *Trithyrodinium evittii* has a younger LAD than in the mid or high latitudes of the Northern Hemisphere.

Other species with known Danian LADs are *Spinidinium densispinatum*, which last occurs at 2540-2530 m and *Phelodinium kozlowskii*, which I take to mark the top of the Danian at 2510-2500 m. Williams *et al.* (1999) gave LADs for these two species as follows: *Phelodinium kozlowskii* (as *Phelodinium tricuspe*; 61.33 Ma) and *Spinidinium densispinatum* (59.38 Ma).

In North Leif I-05, Nøhr-Hansen (2004) placed the top of the Danian at the LAD of *Cerodinium diebelii*, *Hystrichosphaeridium tubiferum*, *Spongodinium delitiense* and *Trithyrodinium evittii*. Further, he considered his *Trithyrodinium evittii* interval to equate with the Danian. Based on the LAD of *Trithyrodinium evittii*, the top of the Danian in Gilbert F-53 would be at 2780-2770 m, which would mean placing the LAD of *Phelodinium kozlowskii* and *Spinidinium densispinatum* in the late Paleocene. Since these two species have LADs in the Danian elsewhere (Williams *et al.*, 1999), I prefer to place the top of this stage higher at 2540-2530 m.

The Bujak-Davies Group (1987) designated 2380 m as the top of the early Paleocene. From an appraisal of their analysis sheets, I infer that this age pick is based on the LADs of *Tanyosphaeridium xanthiopyxides* and *Isabelidinium* #LP. I found one specimen of *Tanyosphaeridium xanthiopyxides* at 2390-2380 m, but considered it reworked, since I only recorded two other specimens of this species and both were considerably lower down in the well. I also found one specimen of *Cerodinium diebelii* in the sample from 2480-2470 m. Reworking is frequent in Gilbert F-53, and creates major problems.

Crux and Gard (2004) found Paleocene nannofossils between 2870-2510 m. Unfortunately, from 3230-2870 m did not contain any diagnostic palynomorph species.

The Selandian or mid Paleocene extends from 2510 to 2410 m. Several species with well-defined stratigraphic ranges have their LADs in this interval. These include *Alisocysta circumtabulata, Alisocysta margarita, Palaeocystodinium bulliforme* and *Palaeoperidinium pyrophorum*. Williams *et al.* (2004) gave the following LADs for these four species: *Alisocysta circumtabulata* (57 Ma for Southern Hemisphere high latitudes), *Alisocysta margarita* (53.5 Ma for Southern Hemisphere high latitudes and 57.35 Ma for Northern Hemisphere mid latitudes), *Palaeocystodinium bulliforme* (57.9 Ma for Northern Hemisphere mid latitudes) and *Palaeoperidinium pyrophorum* (58.04 Ma for Northern Hemisphere mid latitudes). Gradstein and Ogg (1996) placed the top of the Selandian at 57.9 Ma, which supports my conclusion that the Selandian-Thanetian boundary in Gilbert F-53 is at 2410 m.

According to my interpretation, the Selandian is about 100 m thick: Gradstein and Ogg (1996) gave its age as 61-57.9 Ma. This suggests that some of the Selandian is absent in Gilbert F-53.

Comparison with Nøhr-Hansen (2003a) shows close agreement. That author subdivided the Paleocene into the Danian, lower Thanetian, mid Thanetian and upper Thanetian. The three Thanetian intervals from oldest to youngest are: the *Palaeoperidinium pyrophorum* interval (P4), the *Areoligera gippingensis* interval (P5) and the *Apectodinium* Acme interval (P6). Although not recognizing the Selandian, Nøhr-Hansen (2003a) used several of the species that occur in Gilbert F-53. The top of his *Palaeoperidinium pyrophorum* interval is marked by the LADs of *Palaeoperidinium pyrophorum* and *Palaeocystodinium bulliforme*. In Gilbert F-53 the LAD of *Palaeocystodinium bulliforme* is at 2480-2470 m; the LAD of *Palaeoperidinium pyrophorum* is at 2420-2410 m. Thus, Nøhr-Hansen's (2003a, 2004) P4 zone or early Thanetian equates with my usage of Selandian.

There is a slight discrepancy, however, in my data from Gilbert F-53 and Nøhr-Hansen's zonation. His mid Thanetian *Areoligera gippingensis* interval (P5) is defined on the LAD of *Alisocysta margarita* and *Areoligera gippingensis*. In Gilbert F-53 the LAD of *Alisocysta margarita* is at 2450-2440 m, whereas *Areoligera gippingensis* is frequent in the sample at 2270-2260 m. I place the top of the Thanetian at 2270-2260 m, based on relative abundances of *Areoligera gippingensis*. The Bujak-Davies Group (1987) placed the top of the Late Paleocene at 2265 m. Crux and Gard (2004) recorded Paleocene to earliest Eocene nannofossils in the interval 2480-2270 m. They considered one of the species, *Prinsius martini*, as possibly restricted to the Paleocene. At 2420 m, a questionable specimen of *Neochistozygus imbriei* may denote an early (NP 2) to early late (NP 4) Paleocene age.

Dinocyst taxa with LADs in the Thanetian of Gilbert F-53 include *Areoligera gippingensis, Cerodinium speciosum* and *Cordosphaeridium "delimurum"*. The abundant specimens of *Areoligera gippingensis* allows correlation with the type Thanetian of southern England (Powell *et al.*, 1996) and with the Skua E-41 well (Williams, 2003b) and Terra Nova K-18 well (Williams, 2003c) on the Grand Banks.

The absence of the *Apectodinium* Acme Zone (P6) of Nøhr-Hansen (2004) in Gilbert F-53 may reflect missing section, paleoenvironmental differences, or the region not being influenced by warmer water currents. In North Leif I-05, Nøhr-Hansen (2004) attributed a condensed interval to his P6 Zone, with most of the sediments assigned to the Thanetian being included in the P5 or *Areoligera gippingensis* Zone. This seems comparable to the Thanetian in Gilbert F-53.

Basal Eocene sediments extend from 2250 to 2110 m in Gilbert F-53, with the top being picked on the LAD of *Deflandrea oebisfeldensis*. Williams *et al.* (2004) placed the LAD of this species at 52.85 Ma in Northern Hemisphere mid latitudes. This would be within the early Ypresian. Other dinocysts having their LADs in the basal Eocene of Gilbert F-53 are *Impagidinium victoriense, Palaeocystodinium golzowense* and *Komewuia*? *"unicornis"*. Nøhr-Hansen (2004) named his lowest Ypresian interval in offshore western Greenland the *Deflandrea oebisfeldensis* interval. The base of this interval is

presumably derived from the FAD of *Deflandrea oebisfeldensis* and the top on the LAD of *Cerodinium dartmoorium* and *Charlesdowniea crassiramosa*.

I include the interval 2250-1720 m in Gilbert F-53 in the Ypresian. This is based on the LAD of *Areoligera* cf. *medusettiformis* and *Achilleodinium biformoides* in the cuttings sample at 1730-1720 m. Williams *et al.* (1999) gave the LAD of *Areoligera medusettiformis* as 48 Ma, very close to the Ypresian-Lutetian boundary which is at 48 Ma. The Bujak-Davies Group (1987) placed the top of the Early Eocene at 1755 m. Crux and Gard (2004) recovered early Eocene nannofossils from a sample at 2180 m. Nøhr-Hansen (2003a) defined seven intervals in the Ypresian; these were determined from the zonation of Bujak (1994) for the North Sea. In ascending order the seven intervals are: E1, the *Cerodinium dartmoorium - Deflandrea oebisfeldensis* interval; E2a, the *Wetzeliella astra - Fibrocysta bipolaris* interval; E2b, the *Dracodinium condylos* interval; E2c, the *Areoligera medusettiformis* interval; E3a, the *Eatonicysta furensis* interval; E3b, the *Charlesdowniea columna* interval; and E3c-d, the *Eatonicysta ursulae* interval. The top of the Ypresian is within the *Eatonicysta ursulae* interval.

Most of the species that Nøhr-Hansen (2004) recognized as having LADs in the Ypresian are absent in Gilbert F-53. However, there are a few that allow comparison. *Areoligera* cf. *medusettiformis* occurs consistently from 2250-1720 m in Gilbert F-53, but is never abundant in the Ypresian. Nøhr-Hansen (2003a) placed the LAD of *Areoligera* cf. *medusettiformis* (as *Areoligera medusettiformis*) at the top of his *Eatonicysta furensis* zone. *Apectodinium homomorphum* occurs in the sample at 1850-1840 m and *Apectodinium quinquelatum* occurs in the sample at 1790-1780 m in Gilbert F-53. This is considerably higher then in the wells studied by Nøhr-Hansen (2004). *Homotryblium tenuispinosum* has its LAD at 1910-1900 m and is common in the sample from 2000-1990 m. According to Nøhr-Hansen (2004), *Homotryblium tenuispinosum* is abundant only within the Ypresian or earliest Lutetian.

Eatonicysta ursulae has its LAD at 1940-1930 m in Gilbert F-53. According to Nøhr-Hansen (2004), the LAD of *E. ursulae* approximates with the top of the *Eatonicysta ursulae* interval, which spans the Ypresian-Lutetian boundary. This agrees with Williams *et al.* (2004) who considered the LAD of this species to be at 48.5 Ma. Gradstein and Ogg (1996) placed the Ypresian-Lutetian boundary at 49 Ma. Because the LAD of *Eatonicysta ursulae* is well below the Ypresian-Lutetian boundary in Gilbert F-53, I interpret it as suppressed, that means of an older age than normal.

The LAD of the dinocyst species *Diphyes brevispinum* is taken to mark the top of the *Charlesdowniea columna* interval by Nøhr-Hansen (2004). In Gilbert F-53, the LAD of *Diphyes brevispinum* is at 1850-1840 m, showing reasonable agreement.

In his analysis of North Leif I-05, Nøhr-Hansen (2004) recognized the E2b, E3a and E3b intervals. The E2b was marked by the LAD of *Dracodinium condylos*, the E3a by the LAD of *Achilleodinium biformoides* and *Dapsilidinium pseudocolligerum*, and the E3b by the LAD of *Charlesdowniea columna, Diphyes ficusoides* and *Diphyes colligerum*. I find two of these species, *Achilleodinium biformoides* and *Diphyes colligerum*, in Gilbert F-53. *Achilleodinium biformoides* has its LAD at 1730-1720 m, which I consider the top of the Ypresian, and *Diphyes colligerum* occurs at 1610-1600 m, where I placed the top of the Lutetian.

Gradstein and Ogg (1996) recognized two stages within the Mid Eocene, the Lutetian and the Batonian. These authors gave ages of 49-41.3 Ma for the Lutetian and 41.3-37 Ma for the Bartonian. In Gilbert F-53, the Lutetian must be condensed or more probably absent, because it extends only from 1710 to 1600 m. This is thinner than the Bartonian, which I consider to be from about 1580 to 1450 m. My age determinations differ from those of the Bujak-Davies Group (1987). These authors assigned 1735-1605 m to the Mid Eocene, which is similar to my Lutetian interval. From 1585 to 1455 m was considered mid

to late Eocene. That is almost identical to my Bartonian interval.

Alterbidinium bicellulum was described from the Earnley Formation of the middle Eocene Bracklesham Group of southern England by Islam (1983). The age of the Bracklesham is latest Ypresian-Lutetian. Since the LAD of *Alterbidinium bicellulum* occurs in the cuttings sample at 1610-1600 m, I consider this to be the top of the Lutetian. *Diphyes colligerum* also has its LAD in the same sample. Williams *et al.* (2004) placed the LAD of this species at 37 Ma, somewhat younger than in Gilbert F-53.

Nøhr-Hansen (2004) defined the top of his late Lutetian interval on the LAD of four species, one of which is *Alterbidinium* cf. *bicellulum*. This agrees closely with my findings.

The three intervals that Nøhr-Hansen (2004) recognized in the Lutetian are modified from Bujak (1994), who presented a fourfold subdivision of the stage. Bujak recognized in ascending order, the *Eatonicysta ursulae* Zone of which only one subzone of the four was considered Lutetian, the *Diphyes ficusoides* Zone with four subzones, the *Systematophora placacantha* Zone with two subzones, and the *Diphyes colligerum* Zone with three subzones. Nøhr-Hansen (2004) has named his intervals for species that have their LADs within the Lutetian, based on Bujak's (1994) findings.

Comparing the data from Gilbert F-53 with that from North Leif I-05 (Nøhr-Hansen, 2004) is not easy because of the paucity of species having LADs in more than one well with Lutetian section. Only *Alterbidinium bicellulum* allows correlation between Gilbert F-53 and offshore west Greenland. And there is no overlap between North Leif I-05 and Gilbert F-53.

One distinctive pollen species, *Pistillipollenites mcgregori* has its LAD at 1640-1630 m, that is in the Lutetian. Williams and Bujak (1977) recorded the species from so-called upper Eocene rocks on the Labrador Shelf but there is some uncertainty concerning the age. Nøhr-Hansen, Fensome and Williams (pers. comm.) placed the LAD of *Pistillipollenites mcgregori* in the Bartonian. Thus I regard the LAD of this species in Gilbert F-53 to be below its LAD elsewhere on the Labrador Shelf.

As noted earlier, I include the section from 1580 to 1450 m in the Bartonian. This is based primarily on the LAD of *Extratriporopollenites* at 1460-1450 m and the LAD of *Deflandrea eocenica* at 1490-1480 m. *Deflandrea eocenica* is often confused with *Deflandrea hialina*. The pericyst outline of the two species is similar but *Deflandrea eocenica* has an extreme latideltaform 2a plate. In *Deflandrea hialina* the 2a plate is a latideltaform. Whether this difference justifies separation of the morphotypes into two species is dabatable, because the stratigraphic ranges appear to be similar.

Other taxa having their LADs in the Bartonian of Gilbert F-53 are the pollen *Cupaneidites* sp. and *Cicatricososporites auritus* and the dinocysts *Hystrichokolpoma* "*gilbertii*" and *Cordosphaeridium fibrospinosum*. *Hystrichokolpoma* "*gilbertii*" is common in the Bjarni O-82 well in the adjacent Hopedale Basin, where it appears to have its LAD in the Bartonian. Nøhr-Hansen, Fensome and Williams (pers. comm.) have come to the same conclusion.

Based on Bujak (1994), Nøhr-Hansen (2003a) delineated two events in the Bartonian. These are the *Glaphyrocysta semitecta* (E7a) and the *Glaphyrocysta texta* (E7b) intervals. Species which have their LADs in these intervals include *Phthanoperidinium* spp., *Wetzeliella spinula, Rhombodinium draco* and *Heteraulacacysta porosa.* Williams (2003b) noted an abundance of *Phthanoperidinium* in the Bartonian of Skua E-41 in the Carson Basin on the Grand Banks of Newfoundland.

Nøhr-Hansen (2004) considered the interval from 1470 to 690 m in North Leif I-05 to be Bartonian. Species with their LADs in this interval included *Glaphyrocysta divaricata, Glaphyrocysta semitecta,*

Glaphyrocysta spineta, Phthanoperidinium geminatum, Phthanoperidinium alectrolophum and *Rhombodinium draco.* Species of *Phthanoperidinium* and *Glaphyrocysta* are rare in Gilbert F-53, possibly reflecting environmental effects.

The Priabonian extends from 1435 to 1360 m in Gilbert F-53. The LAD of *Phthanoperidinium multispinum*, which occurs at 1370-1360 m in Gilbert F-53, defines the top of the Priabonian in some Grand Banks wells (Williams, 2003a, 2003b). *Lentinia "glabra"* has its LAD at 1405-1395 m, just below the top of the Priabonian. The LAD of this species and the closely related *Lentinia serrata* commonly indicate the top of the Eocene in Grand Banks wells (Williams, 2003a, 2003c). Williams *et al.* (2004) gave the LAD for *Lentinia serrata* as 33.5 Ma. This is 0.2 Ma above the Priabonian-Rupelian boundary, which Gradstein and Ogg (1996) placed at 33.7 Ma.

The Bujak-Davies Group (1987) considered the interval from 1435-1215 m to be late Eocene. I have checked their analyses and cannot determine which species has an LAD that marks the late Eocene top. All the taxa listed are pollen.

Nøhr-Hansen (2003a) recognized only one interval, named for *Areosphaeridium diktyoplokum*, in the Priabonian. In North Leif I-05, Nøhr-Hansen (2004) placed the LAD of *Lentinia serrata* and *Enneadocysta* cf. *michoudii* at the top of the Priabonian. Although I did not find any species of *Enneadocysta* in the Priabonian of Gilbert F-53, the presence of *Lentinia "glabra"* and *Lentinia serrata* shows general agreement in placement of the top of the Priabonian in the North Leif I-05 and Gilbert F-53 wells.

Dinocysts are sparse in the Oligocene and Miocene of Gilbert F-53, so that I have also utilized spores and pollen for determining ages. In this I have been helped by comparing stratigraphic ranges of species in other Labrador Shelf wells. In Bjarni O-82 (Williams, in press a), the top of the Rupelian or early Oligocene seems to equate with the LADs of the dinocysts *Areoligera semicirculata* and *Rhombodinium draco*, with the LADs of the spore *Zlivisporis* and the pollen *Pterocaryapollenites* just below. Williams *et al.* (2004) placed the LAD of *Areoligera semicirculata* at 28.5 Ma and the LAD of *Rhombodinium draco* at 30.5 Ma. Gradstein and Ogg (1996) gave an age of 28.5 Ma for the Rupelian-Chattian boundary, showing close agreement with my use of the LADs of these two species to denote the top of the Rupelian. Thus it seems reasonable to assume that in Bjarni O-82, *Zlivisporis* and *Pterocaryapollenites* have LADs in the Rupelian. In Gilbert F-53, *Zlivisporis* and *Pterocaryapollenites* have their LADs at 890-880 m, where I place the top of the Rupelian. Williams and Bujak (1977) illustrated a specimen of *Pterocaryapollenites*, which they stated was from the Oligocene of the Labrador shelf.

Reworked Cretaceous and Paleocene dinocysts are common, including *Chatangiella decorosa, Spinidinium densispinatum, Palaeoperidinium pyrophorum* and *Odontochitina operculata.* There is also the occasional reworked spore. The Bujak-Davies Group (1987) assigned the interval 1195-915 m to the early Oligocene. This appears to have been based on the LAD of *Glaphyrocysta* (as *Cyclonephelium*) sp.A of Williams and Brideaux (1975).

The late Oligocene (Chattian) extends from 860-760 m. This interval contains the Oligocene marker species *Chiropteridium galea.* Williams *et al.* (2004) cited the stratigraphic range of *Chiropteridium galea* as 33.5 to 22.36 Ma in Northern Hemisphere mid latitudes. According to Gradstein and Ogg (1996), the Oligocene extended from 33.7 to 23.8 Ma. Therefore, the LAD of *Chiropteridium galea* is 1.5 million years later than the Oligocene-Miocene boundary. I consider this close enough to regard the LAD of *Chiropteridium galea* as equating with the top of the Oligocene. The Bujak-Davies Group (1987) placed the top of the Oligocene at 825 m, based on the LAD of *Chiropteridium galea.* I agree

with their LAD for *C. galea*, but found *Glaphyrocysta* "*aexuberans*" in a higher interval.

Glaphyrocysta is uncommon in the Oligocene. But in Gilbert F-53, several specimens of the species *Glaphyrocysta* "*aexuberans*" occur in the sample from 770-760 m. I am assuming that these are in place rather than reworked, so consider the interval to represent the top of the Oligocene.

That the Chattian is only about 100 m thick is surprising, considering it lasted from 28.5 to 23.8 Ma (Gradstein and Ogg, 1996). My conclusion is that there is a hiatus with much of the Chattian absent in Gilbert F-53.

Lower to Middle Miocene sediments occur between 745 and 555 m. My age designation is based on the occurrence of *Cleistosphaeridium diversispinosum* in the sample from 565-555 m. Williams (2006) noted that the LAD of *Cleistosphaeridium diversispinosum* was in the mid Miocene. This agrees with Williams (1975), who recorded the LAD of the closely related species *Cleistosphaeridium* (as *Systematophora*) *ancyreum* in the Mid Miocene; separation of the two species is difficult, with intermediate forms being common. Williams and Bujak (1977) listed *Cleistosphaeridium* (as *Systematophora*) *ancyreum* as one of the species with an LAD in their *Operculodinium centrocarpum* assemblage. The authors considered this assemblage to be mid to late Miocene. Also occurring in the *Operculodinium centrocarpum* assemblage, was *Distatodinium paradoxum*, which Williams *et al.* (1999) regarded as having an LAD of 13.6 Ma. That would be within the Serravallian, which extends from 14.8 to 11.2 Ma, according to Gradstein and Ogg (1996). Thus, the *Operculodinium centrocarpum* assemblage should be considered no younger than mid Miocene.

Other taxa with LADs in the early to mid Miocene are the pollen *Gramineae, Tiliaepollenites* and *Multiporopollenites*, and the dinocyst *Lingulodinium machaerophorum*. *Tiliaepollenites* (as *Bombacacidites* sp.A) was recorded from the *Operculodinium centrocarpum* assemblage of the Labrador Shelf by Williams and Bujak (1977).

The only dinocyst taxa in the interval 555-520 m are species of *Spiniferites*. One of these, *Spiniferites ovatus*, was described from the late Miocene by Matsuoka (1983). This explains my inclusion of the interval 555-520 m in the late Miocene. The Bujak-Davies Group (1987) included all of the interval 805-525 m in early to mid Miocene.

Reworking of Cretaceous and older Paleogene dinocysts is common in the Paleogene to early to mid Miocene. For example, the late Cretaceous taxa - *Chatangiella tripartita, Circulodinium distinctum* and *Pterodinium cingulatum* - occur in the interval 680-670 m. But in the upper part of Gilbert F-53 there is a marked decrease in reworked specimens. This presumably denotes a decrease in sediment influx from onshore sources where Cretaceous or Paleogene rocks are exposed.

Paleoenvironments

Use of dinocysts for interpreting Tertiary paleoenvironments has made impressive progress, especially in the last fifteen years. The recognition of the importance of species diversity was reflected in the papers of Gocht (1969), Downie *et al.* (1971), Islam (1984) and Köthe (1990). Brinkhuis (1992), in a study of the Priabonian type area, presented a schematic model showing changes in dinocyst species for a continental margin transect, which extended from a lagoonal to open ocean setting. This model has been modified by Sluijs *et al.* (2005) and is used as a working hypothesis for some of the conclusions provided here.

In Gilbert F-53, I have based the paleoenvironmental curve and interpretations exclusively on composite 10 m cuttings samples. Paleoenvironmental data based on cuttings can be misleading, one obvious

concern being the lag between the given depth and the sample processed. But there were no other samples in Gilbert F-53 and generalizations can be made, albeit with some degree of caution. I have used almost exclusively quantitative data, where possible counting 200 specimens. However, some samples were so poor that counts were restricted to less. The paleoenvironmental curve is shown in Figure 2. I have not included the spore-pollen to dinocyst ratio, which provides useful information that I have summarized in the text.

The deepest sample examined, from 3605-3595 m, is from the Precambrian gneiss, so strictly reflects conditions higher up the well. Moir (1987) included the interval 3608 m, which is total depth, to 3550 m in Precambrian gneiss. Thus, the deepest sample that I could use for in situ paleoenvironmental interpretations is from 3550-3540 m. This is unfortunate since the sparse assemblage provides insufficient evidence, but the sample below (3560-3550 m) suggests a shallower environment, as indicated by the several specimens of *Chatangiella ditissima* and *Isabelidinium*.

Chatangiella ditissima is a higher latitude species described by McIntyre (1975) from Campanian sediments of the Northwest Territories. Lentin and Williams (1980) delineated the McIntyre suite in the Campanian and considered it represented a boreal assemblage. The McIntyre suite is characterized by species of *Chatangiella* and *Laciniadinium*. Especially prominent are the large species of *Chatangiella* described by McIntyre (1975). This suite occurs in several wells on the Labrador Shelf.

I interpret the interval 3550-3300 m as inner shelf, with gradual deepening. From 3550 to 3390 m the dinocyst counts are high, generally exceeding the spore/pollen counts by a ratio of 3 to 1. Species of *Hystrichosphaeridium* are common and *Spiniferites* occurs in most samples.

From 3390-3270 m there is a marked decrease in dinocyst abundances, which I believe indicates more oligotrophic, middle shelf environments. This decrease is also accompanied by a decrease in the spores and pollen, suggesting a drop in the influx of clastic sediments.

At 3260-3250 m, dinocyst concentrations show a marked increase, with *Spiniferites* and *Palaeoperidinium pyrophorum* being common. I have taken this to indicate a more open marine, outer shelf setting, although little is known about the environmental preferences of *Palaeoperidinium pyrophorum*. Evitt *et al.* (1998) noted that Alaskan specimens of closely related *Palaeoperidinium cretaceum* were recovered from a fully marine environment. Sluijs *et al.* (2005) did not mention *Palaeoperidinium*, because their main focus was on Eocene and younger intervals. But several authors (e.g. Eshet *et al.*, 1994; Brinkhuis *et al.*, 1998; van Mourik *et al.*, 2001) have concluded that the high abundances of *Palaeoperidinium* (peridinioid) cysts indicate higher nutrient levels reflecting terrigenous input.

In an innovative study of the Campanian Bearpaw Formation of Alberta, Harland (1973) provided a plot of the gonyaulacacean ratio. This ratio was defined as the number of species that have a gonyaulacacean affinity divided by the number of species having a peridiniacean affinity. It is thus qualitative in that there is no count of specimens. Harland assumed that when the number of gonyaulacacean species is higher than the number of peridiniacean species, more open marine conditions prevail. The interpretations based on this approach were in agreement with the foram data for the Bearpaw Formation.

Following Harland's (1973) approach, produces mixed results. For example, the interval 3260-3250 m and 3230-3220 m are more open marine than 3220-3210 m. I have found that specimen counts are more meaningful. These show a marked increase in number of *Palaeoperidinium pyrophorum* in the interval 3260-2740 m, apart from 2860-2760 m. I interpret from 3260-2740 m as predominantly outer shelf, with open ocean (probably bathyal) environments around 3040 and 2770 m. The open ocean milieu is based

on the presence of *Impagidinium* in some of the samples (Dale, 1996).

Postulating *Palaeoperidinium pyrophorum* as indicative of more open marine environments agrees with the increase in abundance of *Spiniferites* in some of the samples. Also occurring in some of the samples is *Phelodinium kozlowskii*, which must be a protoperidiniacean dinocyst. Protoperidiniaceans are predominantly heterotrophic, as opposed to the gonyaulacaleans which are autotrophic. Thus protoperidiniaceans are often abundant in areas of upwelling where there are blooms of autotrophic dinocysts, and so food is readily available. It seems reasonable to assume that during the time representing deposition of the interval 3200 to 2740 m, there were several blooms as denoted by the increase in specimens of *Phelodinium kozlowskii*.

The usefulness of palynological data in determining paleoenvironments can be evaluated by comparison with the results in Bell (1989; Figure 2). In this Atlas, the paleoenvironments in Gilbert F-53 are shown as a bar-graph. This was compiled by F.M. Gradstein, J. Helenes, P.E. Miller and P.N. Moir and represented a compromise between the lithological and foraminiferal data generated by these authors.

Gradstein, Helenes, Miller and Moir *in* Bell (1989) interpreted the interval 3330 to 3230 m as middle to outer neritic (Figure 2). From 3230 to 2520 m was bathyal, with 2940 to 2750 m possibly outer neritic. These are somewhat deeper water conditions than the outer neritic paleoenvironments with open-ocean or bathyal episodes, which I determined from the dinocyst assemblages.

The palynological assemblages indicate that outer shelf paleoenvironments presumably prevailed from 2740 to 2115 m (Figure 2), with some episodes of open oceanic (bathyal) episodes from 2690-2680 m and 2245-2205 m, as indicated by the presence of *Impagidinium*. Within the interval 2740-2115 m are abundance peaks of *Areoligera gippingensis* at 2715-2705 m, 2570-2560 m, 2540-2530 m, 2510-2500 m, 2480-2470 m, 2450-2440 m, 2410-2400 m, 2390-2380 m, and 2330-2320 m. In several wells on the Grand Banks, *Areoligera* acmes have been characteristic of the Thanetian (Williams, 2003a). In Gilbert F-53, however, from 2715 to 2530 m is Danian, and from 2510 to 2410 m if Selandian. This leads one to assume that the peak abundances of *Areoligera* can occur in the Danian, the Selandian and the Thanetian.

Powell *et al.* (1996) described *Areoligera* dominated assemblages from the Thanetian type section of southern England. In this, the Pegwell Bay section, there are three levels where *Areoligera* is "superabundant" and three where it is "abundant". According to Powell *et al.* (op. cit.), such horizons denote restricted, high-energy, marginal marine settings typical of a transgressive regime, although the species *Areoligera gippingensis* is considered indicative of offshore marine environments (Heilmann-Clausen, 1994). Powell *et al.* (1996) believed that the richest samples were close to the most condensed interval or maximum flooding surface. Since it is a gonyaulacacean cyst, *Areoligera* is presumably the cyst of an autotrophic dinoflagellate. Its presence in such dominant numbers suggests that it was in an area of high-nutrient concentrations, presumably where there was upwelling and thus possibly outer shelf.

In Gilbert F-53, the associated taxa, especially *Impagidinium,* indicate deeper water, more open marine conditions existed during deposition of the interval 2740-2115 m (Figure 2). This is somewhat at variance with the bar-graph of Gradstein, Helenes, Miller and Moir *in* Bell (1989). These authors concluded that lower bathyal paleoenvironments prevailed in the vicinity of Gilbert F-53 over the interval 2520 to 2230 m and upper bathyal prevailed over the interval 2230 to 1750 m. With such strong supporting data, I have to conclude that the *Areoligera* acmes in Gilbert F-53 do not denote marginal marine settings.

From 2740 to 2115 m, there appears to be an interval, represented by 2270-2170 m, of oligotrophic but

deeper water conditions. This is suggested by the dramatic drop in the dinocyst ratio. For example, there are 112 spores and pollen and 88 dinocysts in the sample from 2300-2290 m. However, the sample from 2270-2260 m contains only 8 dinocysts but 92 spores and pollen. And the count for the sample at 2210-2200 m is almost identical, with 8 dinocysts and 93 spores and pollen.

At about 2110 m the palynomorphs indicate a change with the environment becoming more middle shelf. But this does not agree with the foraminiferal and lithologic data (Bell, 1989), which indicate a bathyal paleoenvironment. I base this on an influx of *Homotryblium tenuispinosum* and *Azolla* in the sample at 2060-2050 m. Brinkhuis (1992) and Sluijs *et al.* (2005) considered the genus *Homotryblium* to indicate lagoonal to restricted marine conditions. *Homotryblium tenuispinosum* is a warmer water species (Brinkhuis, 1992), indicating that there was salt-water warming in the vicinity of Gilbert F-53 in the early Eocene above the Paleocene/Eocene Thermal Maximum (PETM).

Azolla, a fresh-water fern, is common in the two wells Gjoa G-37 and Hekja O-71 to the north (Williams, in press b,c). The presence of *Azolla* indicates closer proximity to a shoreline, because it would be less likely to be transported over any distance. A possibility, advanced by Brinkhuis *et al.* (2006) is that *Azolla* represents transported assemblages resulting from freshwater spills from the Arctic Ocean in the earliest middle Eocene, *Azolla* is also a nitrogen fixer, so could indicate fertile conditions for fresh water algal growth. Such algae are the major contributions to type I kerogen, so large numbers would suggest the potential for lower Eocene source rocks, assuming the organic material accumulated in an anoxic environment.

Inner shelf conditions did not prevail for long, with the paleoenvironment reverting to outer shelf to open ocean (bathyal) from 2020 to 1450 m, apart from some shallowing at 1880-1870 m. Oligotrophic settings existed for much of the time represented by this interval, as shown by the extremely low dinocyst counts above 1960 m. For example, there are 9 dinocysts compared to 95 spores and pollen at 1940-1930 m, 2 dinocysts and 96 spores and pollen at 1855-1840 m, 2 dinocysts and 198 spores and pollen at 1710-1700 m and 1 dinocyst and 200 spores and pollen at 1670-1660 m. The deeper water environment is indicated by the presence of *Impagidinium* and *Hystrichokolpoma*.

From 1435 m to the highest sample in the well at 520 m, there is a marked change in the paleoenvironmental settings (Figure 2). These fluctuate between inner neritic and marginal to non-marine, suggesting major changes in the vicinity of Gilbert F-53. There is a major drop in number of palynomorphs from 1435 to 1125 m. Inner neritic conditions prevailed from 1435 to 1270 m, as indicated by the low but persistent occurrence of peridinioid taxa, especially species of *Deflandrea*. The interval 1225-1000 m is predominantly marginal marine, with 1190-1150 m possibly being non-marine. There are rarely dinocysts in the sample but there are occasional acritarchs and at 1070-1060 m *Pediastum*, a fresh-water green alga.

A more marine environment is indicated from 1000 to 760 m. Brinkhuis and Schiøler (1996) regarded a dominance of the species *Paralecaniella indentata* to denote very shallow marine environments, based on the findings of Elsik (1977). Although never abundant in Gilbert F-53, *Paralecaniella indentata* presumably indicates a shallow marine environment. Somewhat more offshore, deeper water conditions from 895-880 m are indicated by the occurrence of *Spiniferites*.

Dinocysts are rare between 740 and 520 m, indicating a marginal marine to innermost shelf domain. The sample at 740-730 m contains a high percentage of wood but no cuticle, which I assume is because it was a high-energy, well oxygenated environment. There are occasional specimens of *Spiniferites* and *Hystrichokolpoma* but there is a concern that they may be reworked. Throughout spores and pollen are common but never abundant.

Gradstein, Helenes, Miller and Moir *in* Bell (1989) arrived at different conclusions regarding the paleoenvironments between 2100 and 530 m (Figure 2). Their interpretations were: 2100 to 1750 m, initially upper bathyal changing to outer shelf; 1750 to 1450 m, middle to outer neritic; 1450 to 880 m, inner to middle neritic; 880 to 550 m, transitional to inner neritic; and 550 to 525 m, inner to middle neritic. Thus, the dinocysts generally indicate shallower paleoenvironments. For example, according to the dinocyst data, the paleoenvironments from 2120 to 1980 m are middle shelf and from about 1250 to 1110 m it is coastal or marginal marine.

Correlation of Palynology and Lithostratigraphy

Moir (1987), in an internal Geological Survey of Canada report, published what I consider the definitive lithostratigraphy of the Gilbert F-53 well (Figure 2). He assigned from 3550 to 3195 m to the Freydis Member of the Markland Formation. McWhae *et al.* (1980) proposed the Markland Formation for a shale, with occasional siltstone, sandstone and then dolomitic limestone. The Freydis Sand Member of the Cartwright Formation was erected by Umpleby (1979) and revised as the Freydis Member of the Markland Formation by McWhae *et al.* (1980). Most of the Member in Gilbert F-53 is late Campanian, with the lowermost 10 m early Campanian and the uppermost 55 m Maastrichtian.

In Gilbert F-53, the only regional unconformity of those recognized by McWhae *et al.* (1980) is the Beaufort Unconformity of Miocene age. But there are apparent hiati in the Maastrichtian, Selandian, Lutetian and Chattian. Some of these have been recognized in other Labrador Shelf wells (e.g. Williams, in press a).

The Markland Formation extends from 3550-2460 m. Since I place the Danian-Selandian boundary at 2470 m, the age of the formation is Campanian-Danian. McWhae *et al.* (1980) considered the Markland to have been deposited in an inner neritic to bathyal environment, with some shallow water clastic fans. From 3195 to 2460 m, the paleoenvironments were outer shelf to oceanic (bathyal).

Moir (1987) recognized a thin wedge of the Gudrid Formation between 2460 and 2453 m, overlain by the Cartwright Formation, which extends from 2453 to 2069 m. Umpleby (1979) formally erected the Gudrid Sand Member of the Cartwright Formation. McWhae *et al.* (1980) raised the Gudrid to formation status and considered it Paleocene to Eocene. In Gilbert F-53, the age is early Selandian.

The Cartwright Formation, as defined by Umpleby (1979), is a claystone-siltstone sequence with thin sandstone and carbonate beds. According to Umpleby the formation was deposited in a marginal to shallow marine environment. McWhae *et al.* (1980), however, considered the sands to be turbidites and the lutite sequence to be outer shelf or upper slope. My interpretations of predominantly outer shelf to oceanic (bathyal) agree with McWhae *et al.* (1980).

In Gilbert F-53, the age of the Cartwright Formation is Selandian to basal Ypresian. This shows good agreement with the age of middle Paleocene to early Eocene, as determined from the foraminifera (McWhae *et al.*, 1980).

Moir (1987) included 2069-1527 m in the Kenamu Formation, with the Leif Member equivalent from 1727 to 1709 m. The Kenamu Formation of McWhae *et al.* (1980) is an Eocene shale, siltstone, sandstone sequence that can be glauconitic and calcareous. McWhae *et al.* regarded it as being deposited in outer shelf to slope environments. I agree with these authors' interpretations, since the palynomorphs confirm similar environments. The Leif Sandstone Member was named by Umpleby (1979), who included it in his Saglek Formation. McWhae *et al.* (1980) regarded the renamed Leif Member as a subdivision of their Kenamu Formation.

Based on my age determinations, the Kenamu Formation in Gilbert F-53 is Ypresian to Bartonian, with the Leif Member being close to the Ypresian-Lutetian boundary. Barss *et al.* (1979) considered the age of the Leif Member at the type section to be middle to late Eocene.

In Gilbert F-53, the Kenamu Formation is successively overlain by the Mokami and Saglek formations. The Mokami Formation is from 1527-1163 m; the Saglek Formation is from 1163 to 303 m. McWhae *et al.* (1980) defined the Mokami Formation as a predominantly claystone and soft shale unit. The age was given as late Eocene to mid Miocene. In Gilbert F-53, the age of the Mokami Formation is Bartonian to early Oligocene. The paleoenvironments are initially outer shelf but there is rapid shallowing to inner neritic and marginal marine.

The Saglek Formation, as defined by Umpleby (1979), is predominantly silty and sandy mudstones with two members, the Brown Mudstone Member and the Leif Member. McWhae *et al.* (1980) restricted the Saglek Formation to include only the uppermost pre-Quaternary part of the sequence. They stated that the age "is probably mid-late Miocene to Pliocene ...". McWhae *et al.* considered the Saglek Formation to be coarser clastics with some conglomerate and lignite, deposited in shallow-neritic to littoral, predominantly paralic environments. In Gilbert F-53, the Saglek Formation is early Oligocene to late Miocene and was deposited in a marginal marine to inner neritic setting.

McWhae *et al.* (1980) and McWhae (1981) recognized five regional unconformities in the Mesozoic-Cenozoic of the Labrador Shelf. These were: the Labrador Unconformity, 130-120 Ma; the Avalon Unconformity, 100-85 Ma or Cenomanian-Santonian; the Bylot Unconformity, 63-60 Ma or late Danian-Selandian; the Baffin Bay Unconformity, 38-34 Ma or Priabonian; and the Beaufort Unconformity, 20-10 Ma or Burdigalian to early Tortonian. As noted above, only the Beaufort Unconformity has been recognized in Gilbert F-53.

Summary

Gilbert F-53 contains Campanian to late Miocene rocks, but the Maastrichtian, Selandian, Lutetian, Chattian and Miocene appear to be incomplete. This suggests several hiati that can be correlated with hiati of the same ages in other Labrador Shelf wells (e.g. Williams, in press a). Age control is based primarily on dinocysts in the Campanian to early Bartonian and dinocysts, pollen and spores from the late Bartonian to the late Miocene. Correlating the LADs of the dinocyst species with those recorded by the Bujak-Davies Group (1987) and Nøhr-Hansen (2003) has given me more precise control and helped in determining the stratigraphic range of some of the spore and pollen species. This will be useful when analyzing other Labrador Shelf wells.

The sediments in Gilbert F-53 were deposited in non-marine to oceanic environments with deeper water conditions in the Maastrichtian, Paleocene and early and mid Eocene. Shallow marine (inner neritic) to marginal and occasionally non-marine conditions persisted in the late Eocene to late Miocene. I have based these interpretations on the palynomorph assemblages, using primarily the spore and pollen to dinocyst ratio and counts of dinocyst species. Using the Gilbert F-53 data as a base, I hope to develop a model that will provide paleoenvironmental control in the Cretaceous-Cenozoic of the Labrador Shelf and possibly Baffin Bay.

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Figures

Figure 1 Location of wells discussed in text.

Figure 2 Stratigraphy and paleoenvironments of Total Eastcan *et al*. Gilbert F-53.

Appendix A

Palynomorph taxa recorded in Gilbert F-53. References for dinocyst citations are from Fensome and Williams (2004). Informal taxa will be illustrated in one of the proposed palyatlases.

Achilleodinium biformoides (Eisenack, 1954b) Eaton, 1976
Achomosphaera ramulifera (Deflandre, 1937b) Evitt, 1963
Achomosphaera ramulifera subsp. "*granosa*"
Adnatosphaeridium filiferum (Cookson and Eisenack, 1958) Williams and Downie, 1969
Alisocysta circumtabulata (Drugg, 1967) Stover and Evitt, 1978
Alisocysta margarita (Harland, 1979a) Harland, 1979a
Alterbidinium? *bicellulum* (Islam, 1983b) Lentin and Williams, 1985
Apectodinium "*fleximorphum*"
Apectodinium homomorphum (Deflandre and Cookson, 1955) Lentin and Williams, 1977b
Apectodinium quinquelatum (Williams and Downie, 1966b) Costa and Downie, 1979
Aquilapollenites "*curvus*"
Areoligera cf. *coronata* (O. Wetzel, 1933b ex Deflandre, 1937b) Lejuene-Carpentier, 1938a
Areoligera gippingensis Jolley, 1992
Areoligera cf. *medusettiformis* O. Wetzel, 1933b
"*Axiodinium articulatum*"
Azolla spp.
Baltisphaeridium "*scalenofurcatum*"
Callaiosphaeridium asymmetricum (Deflandre and Courteville, 1939) Davey and Williams, 1966b
Caryapollenites spp.
Cerebrocysta bartonensis Bujak in Bujak et al., 1980
Cerodinium diebelii (Alberti, 1959b) Lentin and Williams, 1987
Cerodinium "*glabrum*"
Cerodinium speciosum (Alberti 1959b) Lentin and Williams, 1987
Cerodinium speciosum subsp. "*brevicornum*"
Charlesdowniea columna (Michoux, 1988) Lentin and Vozzhennikova, 1990
Chatangiella coronata (McIntyre, 1975) Lentin and Williams, 1976
Chatangiella decorosa (McIntyre, 1975) Lentin and Williams, 1976
Chatangiella tripartita (Cookson and Eisenack, 1960a) Lentin and Williams, 1976
Chatangiella victoriensis (Cookson and Manum, 1964) Lentin and Williams, 1976
Chiropteridium galea (Maier, 1959) Sarjeant, 1983
Chlamydophorella grossa Manum and Cookson, 1964
Cicatricosisporites hallei Delcourt and Sprumont, 1955
Cicatricososporites "*labatus*"
Cicatricososporites auritus
Circulodinium distinctum (Deflandre and Cookson, 1955) Jansonius, 1986
Cleistosphaeridium ancyreum (Cookson and Eisenack, 1965a) Eaton et al., 2001
Cleistosphaeridium diversispinosum Davey et al., 1966
Cleistosphaeridium polypetellum (Islam, 1983) Stover and Williams, 1995
Cordosphaeridium "*delimurum*"
Cordosphaeridium fibrospinosum Davey and Williams, 1966b
Cordosphaeridium gracile (Eisenack, 1954b) Davey and Williams, 1966b
Cordosphaeridium inodes (Klumpp, 1953) Eisenack, 1963
Cupaneidites spp.
Dapsilidinium? *simplex* (White, 1842) Bujak et al., 1980
Deflandrea "*borealis*"

Deflandrea eocenica Balteş, 1969
Deflandrea oebisfeldensis Alberti, 1959b
Deflandrea phosphoritica Eisenack, 1938b
Densosporites sp.
Dinogymnium acuminatum Evitt et al., 1967
Dinogymnium heterocostatum (Deflandre, 1936b) Evitt et al., 1967
Diphyes brevispinum Bujak, 1994
Diphyes colligerum (Deflandre and Cookson, 1955) Cookson, 1965a
Diphyes pseudoficusoides Bujak, 1994
Downiesphaeridium armatum (Deflandre, 1937b) Islam, 1993
Eatonicysta ursulae (Morgenroth, 1966a) Stover and Evitt, 1978
Elytrocysta sp.
Enneadocysta sp.
Eocladopyxis "brevispinosa"
Extratriporopollenites spp.
Fibrocysta bipolaris (Cookson and Eisenack, 1965b) Stover and Evitt, 1978
Fromea fragilis (Cookson and Eisenack, 1962b) Stover and Evitt, 1978
Gillinia hymenophora Cookson and Eisenack, 1960a
Glaphyrocysta "aexuberans"
Glaphyrocysta divaricata (Williams and Downie, 1966c) Stover and Evitt, 1978
Glaphyrocysta ordinata (Williams and Downie, 1966c) Stover and Evitt, 1978
Gothanipollis Krutzsch, 1959
Gramineae spp.
Heteraulacacysta pustulata Jan du Chêne and Adediran, 1985
Heterosphaeridium heteracanthum (Deflandre and Cookson, 1955) Eisenack and Kjellström, 1972
Histiocysta palla Davey, 1969a
Homotryblium tenuispinosum Davey and Williams, 1966b
Hystrichodinium pulchrum subsp. *"brevispinum"*
Hystrichokolpoma "gilbertii"
Hystrichokolpoma manipulatum Islam, 1983a
Hystrichokolpoma proprium (Marheinecke, 1992) Foucher in Fauconnier and Masure, 2004
Hystrichokolpoma rigaudiae Deflandre and Cookson, 1955
Hystrichokolpoma salacia Eaton, 1976
Hystrichosphaeridium salpingophorum Deflandre, 1935
Hystrichosphaeridium tubiferum (Ehrenberg, 1838) Deflandre, 1937b
Hystrichosphaeridium tubiferum subsp. *brevispinum* (Davey and Williams, 1966b) Lentin and Williams, 1973
Hystrichosphaeridium tubiferum subsp. *"perforatum"*
Hystrichosphaeropsis quasicribrata (Wetzel, 1961) Gocht, 1976
Hystrichostrogylon sp.
Ilexpollenites
Impagidinium maculatum (Cookson and Eisenack, 1961b) Stover and Evitt, 1978
Impagidinium victorianum (Cookson and Eisenack, 1965a) Stover and Evitt, 1978
Impletosphaeridium "delicatulum"
Impletosphaeridium insolitum Eaton, 1976
Isabelidinium acuminatum (Cookson and Eisenack, 1958) Stover and Evitt, 1978
Isabelidinium belfastense (Cookson and Eisenack, 1961a) Lentin and Williams, 1977a
Isabelidinium cooksoniae (Alberti, 1959b) Lentin and Williams, 1977a
Jussiaea oculus
Kenleyia sp.

Kleithriasphaeridium loffrense Davey and Verdier, 1976
Komewuia "unicornis"
Laciniadinium arcticum (Manum and Cookson, 1964) Lentin and Williams, 1980
Leberidocysta chlamydata (Cookson and Eisenack, 1962b) Stover and Evitt, 1978
Lejeunecysta cinctoria (Bujak in Bujak et al., 1980) Lentin and Williams, 1981
Lentinia "glabra"
Lentinia serrata Bujak in Bujak et al., 1980
Lentinia? wetzelii (Morgenroth, 1966a) Bujak in Bujak et al., 1980
Lingulodinium "brevispinosum"
Lingulodinium funginum (Morgenroth, 1966a) Islam, 1983b
Lingulodinium machaerophorum (Deflandre and Cookson, 1955) Wall, 1967
Luxadinium sp.
Manumiella seelandica (Lange, 1969) Bujak and Davies, 1983
Microdinium sp.A Ioannides, 1986
"Minisphaeridium latirictum"
Momipites spp.
Multiporopollenites sp.
Nyktericysta sp.
Nyssapollenites spp.
Odontochitina costata Alberti, 1961
Odontochitina operculata (O. Wetzel, 1933a) Deflandre and Cookson, 1955
Oligosphaeridium complex (White, 1842) Davey and Williams, 1966b
Oligosphaeridium "complex/pulcherrimum"
Oligosphaeridium pulcherrimum (Deflandre and Cookson, 1955) Davey and Williams, 1966b
Oligosphaeridium totum Brideaux, 1971
Operculodinium centrocarpum (Deflandre and Cookson, 1955) Wall, 1967
Operculodinium microtriainum (Klumpp, 1953) Islam, 1983a
Operculodinium multispinosum Ashraf, 1979
Ovoidinium verrucosum (Cookson and Hughes, 1964) Davey, 1970
Palaeocystodinium australinum (Cookson, 1965b) Lentin and Williams, 1976
Palaeocystodinium bulliforme Ioannides, 1986
Palaeocystodinium golzowense Alberti, 1961
Palaeohystrichophora infusorioides Deflandre, 1935
Palaeoperidinium pyrophorum (Ehrenberg, 1838) Sarjeant, 1967b
Palambages spp.
Palynodinium grallator Gocht, 1970a
Paralecaniella indentata (Deflandre and Cookson, 1955) Cookson and Eisenack, 1970b
Pareodinia ceratophora Deflandre, 1947d
Pediastrum
Pervosphaeridium pseudhystrichodinium (Deflandre, 1937b) Yun Hyesu, 1981
Pervosphaeridium tubuloaculeatum Slimani, 1997
Phelodinium kozlowskii (Górka, 1963) Lindgren, 1984
Phelodinium magnificum (Stanley, 1965) Stover and Evitt, 1978
Phthanoperidinium coreoides (Benedek, 1972) Lentin and Williams, 1976
Phthanoperidinium multispinum Bujak in Bujak et al., 1980
Phthanoperidinium stockmansii (de Coninck, 1975) Lentin and Williams, 1977b
Pistillipollenites mcgregori
Podocarpidites sp.
Polysphaeridium zoharyi (Rossignol, 1962) Bujak et al., 1980
Pseudoceratium eisenackii (Davey, 1969a) Bint, 1986

Pterocaryapollenites sp.
Pterodinium cingulatum (O. Wetzel, 1933b) Below, 1981a
Raphidodinium sp.
Retitricolpites vulgaris Pierce, 1961
Rhoipites sp.
Rottnestia borussica (Eisenack, 1954b) Cookson and Eisenack, 1961b
Rugubivesiculites reductus Pierce, 1961
Senoniasphaera rotundata Clarke and Verdier, 1967
Sequioapollenites sp.
Solisphaeridium stimuliferum (Deflandre, 1938) Pocock, 1972
Spinidinium echinoideum (Cookson and Eisenack, 1960a) Lentin and Williams, 1976
Spinidinium echinoideum subsp. "*minor*"
Spiniferites ovatus Matsuoka, 1983b
Spiniferites porosus (Manum and Cookson, 1964) Harland, 1973
Spiniferites "*digitatus*"
Spiniferites sp. "W"
Spongodinium delitiense (Ehrenberg, 1838) Deflandre, 1936b
Spongodinium sp.
Stiphrosphaeridium dictyophorum (Cookson and Eisenack, 1958) Lentin and Williams, 1985
Tanyosphaeridium xanthiopyxides (O. Wetzel, 1933b ex Deflandre, 1937b) Stover and Evitt, 1978
Thalassiphora pelagica (Eisenack, 1954b) Eisenack and Gocht, 1960
Tiliaepollenites spp.
Trinovantedinium "*brevispinosum*"
Trinovantedinium sp.
Trithyrodinium? "*circellum*"
Trithyrodinium evittii Drugg, 1967
Trithyrodinium suspectum (Manum and Cookson, 1964) Davey, 1969b
Trithyrodinium "*verrucatum*"
Tritonites Marshall and Partridge, 1988
Wetzeliella articulata O. Wetzel in Eisenack, 1938b
Wetzeliella gochtii Costa and Downie, 1976
Wilsonidium echinosuturatum (Wilson, 1967c) Lentin and Williams, 1976
Xenascus ceratioides (Deflandre, 1937b) Lentin and Williams, 1973
Xenascus cf. *sarjeantii*
Zlivisporis

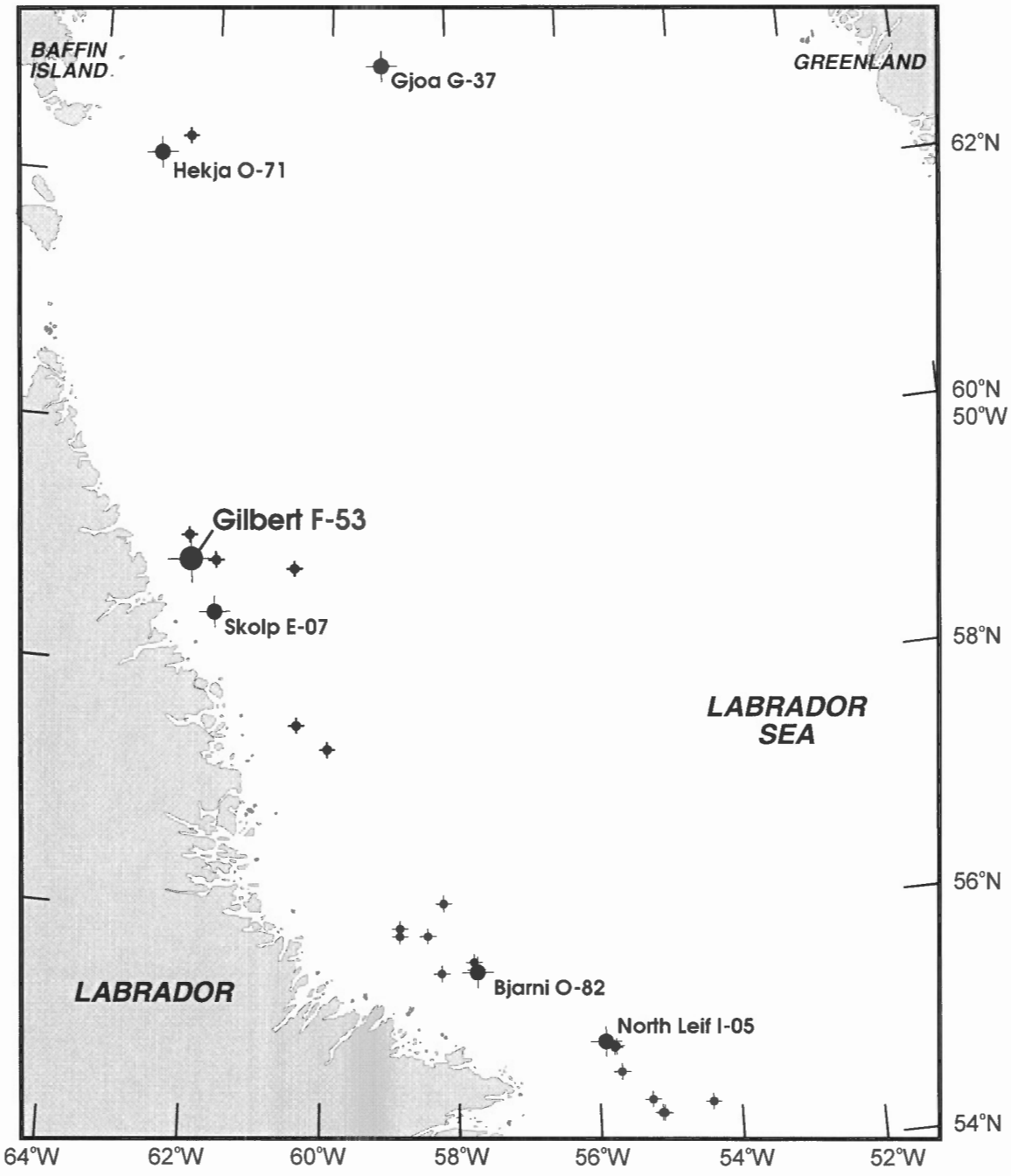

Figure 1. Location of wells discussed in text.

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D183 Total Eastcan et al. GILBERT F-53

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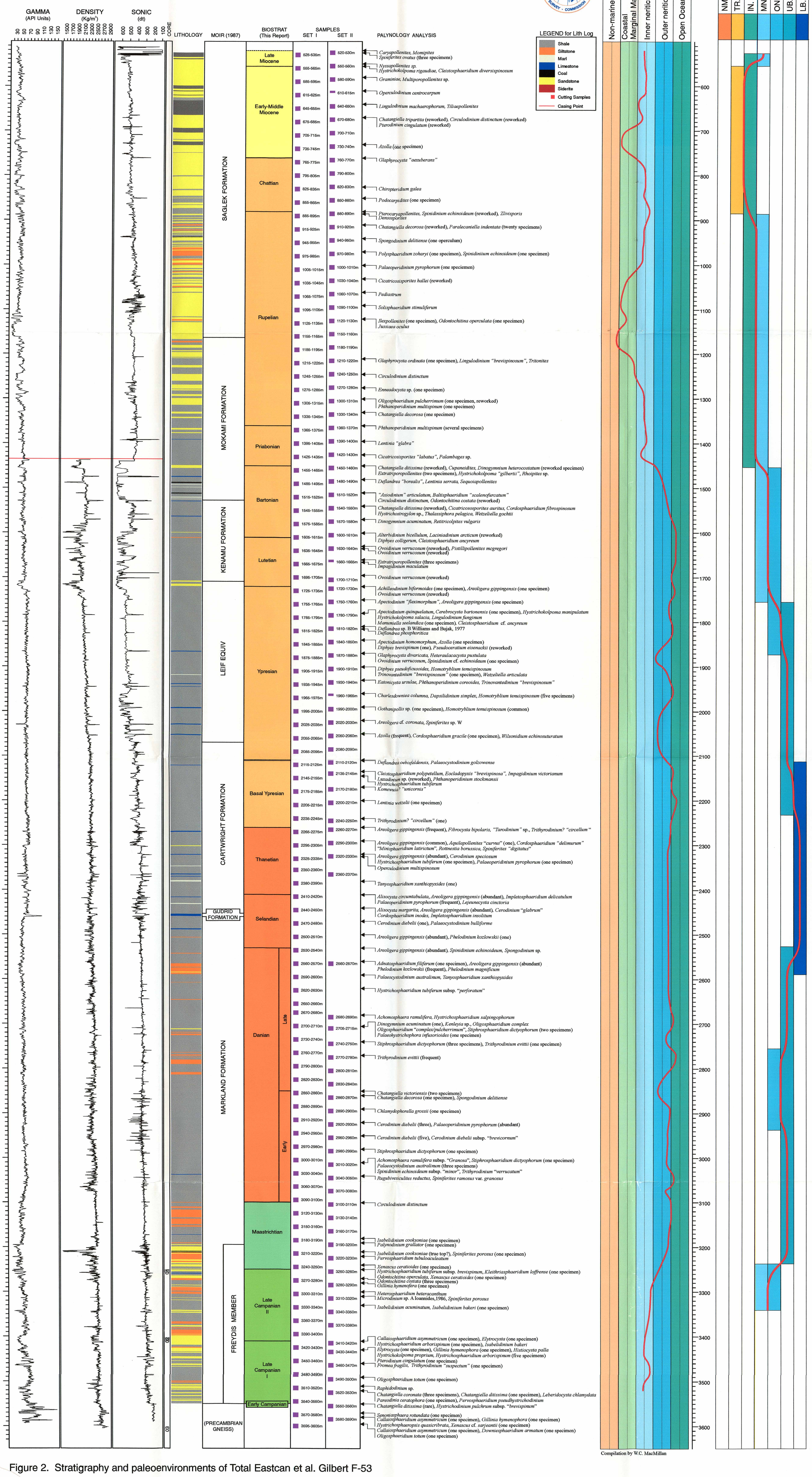

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Figure 2. Stratigraphy and paleoenvironments of Total Eastcan et al. Gilbert F-53

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