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Publications in this series have not been edited; they are released as submitted by the author.

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Introduction

The geology of the Labrador-Baffin Seaway (Labrador Sea, Davis Straight and Baffin Bay) has been described in several papers, including Srivastava (1978), Umpleby (1979), Rolle (1985), Balkwill and MacMillan (1990), Chalmers (1991), Chalmers and Laursen (1995) and Sønderholm et al. (2003a, 2003b). From these works it is clear that the Seaway contains oceanic crust, dated between Anomaly 27 (Danian) and Anomaly 13 (Priabonian-Rupelian). However, it failed to develop into an ocean. During the 1970s and early 1980s, there was extensive hydrocarbon exploration on the Canadian margin of the Labrador Sea, with 21 exploration wells drilled. Some of the wells are potential natural-gas producers but the remoteness of the area has discouraged development. However, the data from the wells has been invaluable in unravelling the lithostratigraphy and biostratigraphy of the region, and thus in an understanding of its geological evolution.

To refine our understanding of the biostratigraphy of the Labrador-Baffin Seaway, the Geological Survey of Denmark and Greenland (GEUS) and the Geological Survey of Canada (GSC) have been collaborating in a re-evaluation of the palynostratigraphy of several wells. These wells include Eastcan et al. Karlsefni A-13 and Petro-Canada et al. Rut H-11 (subsequently referred to as Karlsefni A-13 and Rut H-11), the results of which are presented below. This Open File supports two papers, one by Nøhr-Hansen, Williams and Fensome and the other by Fensome, Nøhr-Hansen and Williams, to be submitted to the Geological Survey of Greenland and Denmark Bulletin with anticipated publication in 2015.

Our understanding of dinoflagellate-cyst species ranges has increased considerably in recent decades (Williams et al. 1999, Fensome et al. 2008) and this report draws on data from both these publications as well as the two papers in preparation mentioned in the previous paragraph. For full citations for dinocyst taxa, please refer to Fensome and Williams (2004) or the DINOFLAJ2 database (http://dinoflaj.smu.ca/wiki/Main_Page).

Karlsefni A-13 and Rut H-11 are hydrocarbon exploration wells drilled on the northern Labrador Shelf in 1975 and 1981 respectively. Detailed statistics for Rut H-11 pertaining to the present study are:

GSC locality no.: D203
Location: 59.171242°N, 62.279764°W
Elevation: sea level to R.T. 11.6 m
Water depth: 124 m
Total depth: 4474 m
Sampled interval: 665–4093 m
Spud date: 14 July 1981
Interval studied: 665–4093 m

The details for Karlsefni A-11 are

GSC locality No.: D156
Location: 58.87084°N, 61.77835°W
Elevation: sea level to R.T. 12.2 m
Water depth: 174.7 m
Total depth: 4148.9 m
Sampled interval: 530.36–4145.33 m
Spud date: 10 August 1975

All measurements in Karlsefni A-11 were originally in feet. In this Open File, I have converted these to metres. Both wells are located in the Saglek Basin, which has had several gas shows. But Karlsefni A-13 did not yield any hydrocarbons during testing and results are available from Rut H-11.

The slides analyzed from Rut H-11, all cuttings, are a set of 114 samples processed in 2003–2004 and numbered P39316 to P39429. Because of enhanced processing techniques, these slides contain more and better preserved palynomorphs than an earlier set of slides processed in the 1980s. Similarly, the 131 slides analyzed from Karlsefni A-13 and numbered P39537 to 39667, processed in 2004, superseded an older set prepared in the 1970s.

This Open File includes three charts for each well. Two of the charts are spreadsheets showing sample by sample species occurrences for dinocysts and non-dinocyst palynomorphs (mainly spores and pollen — collectively miospores) respectively. On these charts, S = single specimen, R = rare (2–5 specimens), F = frequent (6–15 specimens), C = common (16–25 specimens) and A = abundant (more than 25 specimens). No attempt was made in this study to do controlled quantitative counts; hence the records are semi-quantitative. The third chart for each well shows biostratigraphic events and ages from the current study plotted against earlier biostratigraphically determined ages, lithostratigraphy, gamma-ray logs and sample locations. Dinocyst events (based on Williams et al. 1999, Fensome et al. 2008 and the paper to be submitted by Nøhr-Hansen, Williams and Fensome) provided almost all the useful information for determining the ages in the two wells; useful events based on miospores are rare, but this may in large part be based on a poor understanding of their taxonomy.

After the analyses were completed, I became aware of a thesis on Labrador Margin miospores V.E. Williams (Williams 1986) in which she presented a zonation for Karlsefni A-13. Her zonation is somewhat similar in its age calls to the present work; so future study of Williams's hesis and the contained miospore taxonomy may be fruitful, especially for non-marine parts of the section. One striking aspect of the pollen is the representation of species through the Paleogene and Neogene that are today found much farther south than today.

Two spreadsheet figures documenting taxon occurrences in Rut H-11 by sample are attached to this report. Figure 1 shows dinocyst occurrences and Figure 2 shows occurrences of other palynomorphs (miospores, acritarchs and algae). Similarly, I include two spreadsheet figures documenting taxon occurrences in Karlsefni A-13 by sample. Figure 4 shows dinocyst occurrences and Figure 5 shows occurrences of other palynomorphs (miospores, acritarchs and algae). An assessment of the ages represented by strata in the two wells is shown in Figure 7.

Age Determinations for Rut H-11

665 to 695 m — indeterminate Neogene

This interval incorporates a single sample at the top of the section with no diagnostic species. The only dinoflagellate identified is *Lingulodinium machaerophorum*, which extends to the present. Also present is several specimens of the acritarch *Microsphaeridium ancistroides*, the range of which has not been determined.

695 to 755 m — Middle Miocene

This interval includes two cuttings samples. The upper sample contains the consistent top of

Cleistosphaeridium diversispinosum (which has a last appearance datum (LAD) of Serravallian — Middle Miocene), and also includes *Operculodinium centrocarpum* and a form designated as "*Hystrichosphaeridium plectilum*", which is like *Homotryblium plectilum* but has an apical archeopyle. The lower sample contains *Apteodinium spiridoides* and *Apteodinium australiense*, the former having an LAD within the Middle Serravallian. The top for *Apteodinium australiense* is currently indicated as Rupelian (which would certainly be too low for this part of the section based on other evidence; so the single specimen is either reworked or the range for the species needs to be extended upward. Reworked Cretaceous dinocysts are common in this interval.

755 to 965 m — Early Miocene
There are seven samples in this interval, which is Early Miocene based on the occurrence in the top sample of *Cordosphaeridium cantharellus*, a species considered to have an intra-Middle Miocene LAD on the Scotian Margin, but a Burdigalian LAD in the Labrador-Baffin Seaway.
Other Miocene taxa include *Palaeocystodinium golzowense* (Late Miocene LAD on Scotian Margin) and *Spiniferites ovatus* (top Miocene LAD). The lowest sample in this interval contains single specimens of *Chiropteridium galea* and *Membranophoridium* sp. top Oligocene markers if in situ but here considered reworked.

965 to 1125 m — Late Oligocene (Chattian)
In this interval, the uppermost sample contains the consistent LAD of *Chiropteridium* spp., a convincing signal for Late Oligocene. The next four samples downsection contain nothing that is age indicative and, like many areas in the region and beyond, much or all the Late Oligocene may be mainly absent. Assemblages tend to be dominated by pollen, and reworked Cretaceous dinocysts are common. But most samples do contain a few seemingly in situ dinocysts; so maybe this section is marginal marine to littoral.

1125 to 2225 m — Early Oligocene (Rupelian)
This interval is based on the LAD of *Enneadocysta magna* in the top sample and the LADs of the following species in this and the next few samples downsection: *Phthanoperidinium coreoides*, *Licracysta corymbus*, *Wetzeliella symmetrica* and *Achomosphaera ramulifera*. The long interval interpreted as Early Oligocene in this well contains 36 cuttings samples. From 1125 to 1305 m there is a good mix of marine and non-marine elements, as well as reworked dinocysts, suggesting marine, nearshore conditions. Bisaccates are often common to abundant from the top of the entire well section down to 1185 m. At 1265 m the range chart shows a distinctive temporary base of *Cleistosphaeridium diversispinosum* and base of *Enneadocysta magna* (striking features, but of questionable significance in cuttings samples). From 1305 to 2225 m assemblages are dominated by pollen and reworked dinocysts, suggesting non-marine to littoral conditions. A peak of reworked Cretaceous dinocysts occurs in the sample at 1775–1785 m, and a peak of *Laevigatosporites* sp. occurs in the sample at 1955–1965 m. Samples from 2075 to 2225 m have a smattering of single occurrences of dinocyst species more common in the Eocene than in the Oligocene; they might suggest a slightly higher Eocene–Oligocene boundary than decided upon here, or they may represent reworking. The species involved are *Adnatosphaeridium vittatum*, *Cleistosphaeridium polypetellum*, *Phthanoperidinium stockmansii* and "*Phthanoperidinium hibernium*". Also towards the base, specimens of the long-ranging dinocyst *Lingulodinium* increase in number, with *Lingulodinium funginum* having a peak in the sample at 2135–2145 m.

2225 to 2705 m Late (Priabonian) and Middle (Bartonian–Lutetian) Eocene
This interval covers 16 cuttings samples that contain a diversity of Middle to Late Eocene assemblages without providing any very strong signals. Assemblages are mixed, with a diversity of pollen and dinocysts, and reworked Cretaceous dinocysts continue to be prominent. The top of the Eocene is

placed at the sample from 2225 to 2235 m as it contains the consistent LAD of *Lentinia glabra*. Other typical Middle to Late Eocene taxa in this interval are *Glaphyrocysta extensa* (suggesting that the sample at 2315–2325 m is intra-Priabonian), *Cordosphaeridium gracile*, *Cleistosphaeridium elegantulum* and *Dapsilidinium pseudoinsertum*. The presence of *Sophismatia tenuivirgula* in the sample at 2675–2685 m suggests an intra-Lutetian age. An overview of the assemblages of this section and comparison with neighbouring wells suggests that this section may represent a section of later Priabonian strata and earlier Lutetian strata, with a gap from middle Lutetian to earlier Priabonian.

2705 to 3025 m — Early Eocene (Ypresian)
This interval cover 12 cuttings samples. The topmost sample (2705–2715 m) contains the consistent LAD of *Apectodinium* spp., and the sample at 2765–2775 m contains frequent specimens of that species. The sample between these two contains the LADs of *Areoligera circumsenonensis* and *Deflandrea borealis* ("*Deflandrea minima*" in charts) and the consistent top of *Dapsilidinium pseudoinsertum*. Assemblages are increasingly (downsection) dominated by dinocysts. The Eocene–Paleocene boundary is difficult to place in this well. The top of *Cerodinium speciosum* in the sample at 2825–2835 m is possibly indicative of the boundary, but assemblages generally down to 3005 m are more suggestive of an Ypresian rather than a Thanetian age. In the lower few samples of this interval, *Ginginodinium*? *flexidentatum*, *Cleistosphaeridium palmatum* ("*Adnatosphaeridium superpetellum*" in charts), *Apectodinium parvum* and *Glaphyrocysta divaricata* have their LADs.

3035 to 4093 m — Late Paleocene (Thanetian)
Although debatable, I consider the top Thanetian to be marked by the LAD of *Cerodinium denticulatum* in the sample at 3035–3045 m. The presence also of *Cordosphaeridium delimurum* is consistent with a Thanetian age, though *Cordosphaeridium* spp. do not have significant peaks here as they can within the Thanetian at some localities. However, multiple peaks of *Glaphyrocysta divaricata* (at 3185–3195 m, 3605–3615 m, 3695–3705 m and 4025–4035 m) is characteristic for the later Paleocene.

No specimens of typical Selandian (Middle Paleocene) species (e.g. *Palaeoperidinium pyrophorum*, *Palaeocystodinium bulliforme* or *Alisocysta* spp.) were encountered, so it would seem that the entire interval from 2805 to 4093 m is Thanetian, an unusual development for this stage. The assemblages contain diverse dinocyst and so it is fully marine.

Discussion

A summary plot for Rut H-11 is presented as Figure 3 (attached). This plot shows selected lithological, lithostratigraphic and well log data, selected previous biostratigraphic age determinations, and age determinations and events as assessed in the present study.

Previous biostratigraphic studies for this well are as follows: Petro-Canada (1984), d'Eon-Miller and Associates Ltd. (1987), Bujak-Davies Group (1987) and Gradstein et al. (1994). The d'Eon-Miller study was mainly paleoenvironmental and no ages are recorded in BASIN. The Petro-Canada study records only broad intervals, with Miocene from 670 to 2030 m, Eocene from 2030 to 3475 m, and Paleocene from 3475 to 4450 m; in this study, no samples were available below 4093 m (as in the Bujak-Davies study). The Gradstein study was also broad based and recognized a Late Miocene interval from 650 to 2150 m, a Late Oligocene to Early Miocene interval from 2150 to 2270 m, an Early Oligocene interval from 2270 to 2950 m, and an "early part of) M Eocene" from 2950 m down.

The Bujak-Davies study provides more detailed results and includes schemes for both micropaleontology and palynology (plotted on Fig. 2), as well as an amalgamated scheme. I focus here on the two non-amalgamates schemes, which show significant differences between each other. I agree more of less with the Miocene and Oligocene designations for the Bujak-Davies palynology scheme down to about 1450 m, downsection from which Bujak Davies are ambivalent, calling the section down to 2235 m Late Eocene to Early Eocene (in contrast to my Early Oligocene call). Both Bujak-Davies schemes indicate top Early Eocene at 2585 m, a little higher than my call at 2705 m. I did find a specimen of *Apectodinium fleximorphum* in the sample at 2585–2595 m, but interpret this as reworked and consider other indications to suggest that this level is still in the Middle Eocene.

A major difference between my interpretation and the two Bujak-Davies schemes is that I place the top of the Paleocene significantly higher (and if anything it could be even higher if the LAD of Cerodinium spp. is taken into account). The evidence for a Late Paleocene age below 3165 m is convincing, with characteristic peaks of *Glaphyrocysta divaricata*.

Age Determinations for Karlsefni A-13

530.36 to 667.52 m — Pliocene–Pleistocene
This interval includes 5 cuttings samples, with sparse dinocysts, largely reworked (such as *Oligosphaeridium pulcherrimum*) or of problematic identity, but including a specimen of *Tuberculodinium vancampoae* in the sample at 557.8 to 566.9 m. Miospores are far more common and include *Ambrosia*; others may be reworked and include *Caryapollenites*, *Momipites*, *Pachysandra*, *Plicatopollis*, *Retitriletes* and *Tricolporopollenites*. The evidence points to deposition in nearshore or non-marine environments.

667.52 to 969.30 m — Miocene
This interval includes 11 cuttings samples. The topmost, at 667.52 to 676.66 m, has a single specimen of *Habibacysta tectata*, which has an LAD around the Miocene-Pliocene boundary, perhaps a weak signal. But the next sample down (694.95 to 704.10 m) has *Cleistosphaeridium ancyreum*, *Cleistosphaeridium diversispinosum* and *Spiniferites pseudofurcatus*, all of which have LADs in the Serravallian and Tortonian (Middle to Late Miocene). Other dinocyst LADs within this interval are *Reticulatosphaera actinocoronata* and *Palaeocystodinium golzowense* (in the sample at 722.40 to 731.50 m; LAD around the Miocene-Pliocene boundary and Tortonian respectively on the Scotian Margin — Fensome et al. 2008), *Impletosphaeridium insolitum* (777.20 to 786.40 m; LAD uncertain), *Labyrinthodinium truncatum* (832.10 to 841.20 m; Tortonian LAD on the Scotian Margin) and *Cordosphaeridium cantharellus* (941.80 to 951.00 m; Burdigalian LAD). A single specimen of *Chiropteridium galea* also occurred in the last-mentioned sample, but given its lone occurrence and the strong signal given by this species in the next sample down, I retain this sample in the Miocene.

Samples in this interval contain a varied assemblage of dinocysts, including *Spiniferites* spp., *Operculodinium centrocarpum* and *Lingulodinium* spp., as well as clearly reworded late Cretaceous and Paleogene forms. Sporadic occurrences of a distinctive long-spined acritarch *Microsphaeridium ancistroides* are intriguing, but its biostratigraphic range is not clear. Miospores are prominent in this interval, but appear to be quite mixed in terms of biostratigraphic derivation: they include *Alnipollenites*, bisaccates, *Brevitricolpites*, *Baculatisporites comaumensis*, *Caryapollenites*, *Ilexpollenites*, *Juglanspollenites*, *Laevigatosporites*, *Liquidambar*, *Momipites*, *Tiliaepollenites*, *Tricolpites*, *Tricolporites* and *Tsugaepollenites.*

969.30 to 1874.50 m — Oligocene

I'm dating this interval, the most problematic in the entire well, as Oligocene on the basis that the top samples (969.30–978.40 to 1133.90–1143.00 m) consistently contain *Chiropteridium galea*, albeit in low numbers and the sample below this interval contains a variety of low-relief *Phthanoperidinium.* The former is indicative of top Oligocene and the latter is of top Eocene. The samples cited as containing *Chiropteridium galea* contain a higher proportion of dinocysts relative to miospores compared to lower samples in the interval. Miospores dominate most samples in this interval, and the dinocysts that do occur are singles and probably reworked; they include *Palaeocystodinium teespinosum*, *Membranophoridium aspinatum* (perhaps in place and if so, supportive of a Late Oligocene age). *Enneadocysta magna* (possibly in place), *Lentinia serrata*, *Glaphyrocysta extensa*, *Glaphyrocysta ordinata* and *Adnatosphaeridium vittatum*. These are all Paleogene dinocyst, but reworked Cretaceous dinocysts such as *Chatangiella tripartita* and *Odontochitina costata* are also present in these samples.

Miospores are common through this interval, and include *Alnipollenites*, bisaccates (common in many samples), *Caryapollenites*, *Cicatricosisporites labatus*, *Corylus*, *Juglans*, *Jussiaea*, *Laevigatosporites*, *Liquidambar*, *Mancicorpus* (presumably reworked), *Momipites*, *Quercoidites*, *Retitricolpites*, *Retitriletes*, *Tilliaepollenites*, *Tricopoporopollenites*, *Tsugaepollenites*, *Ulmuspollenites*, *Zlivisporis multimurus*.

This is a thick Oligocene interval compared to that in most wells off eastern Canada. It is interesting to note that Gradstein (1978), using primarily marine microfossils, did not date the interval from 1115.58 to 1883.50 m, which exactly corresponds with the interval in the present study dominated by miospores. Evidence suggests therefore that the top few samples of this interval represent Late Oligocene marine strata and the rest of the interval may represent intermittent Oligocene non-marine deposits, with extensive reworked palynomorphs.

1874.54 to 2011.70 m — Late Eocene (Priabonian)
The top of this interval is dated on the basis of the LADs of species of low relief *Phthanoperidinium* — *Phthanoperidinium hibernium* and *Phthanoperidinium multispinum*. Although sparse relative to miospores, other dinocysts in this interval include "*Cribroperidinium australiense*", *Impletosphaeridium insolens* and *Spiniferites* spp., as well as reworked Cretaceous forms. Most samples are dominated by miospores, including many of those already mentioned for the above intervals. Notable occurrences are a single *Pistillipollenites trinudum* in the topmost sample of the interval, and "*Nyssa microreticulatus*", "*Nyssa scabratus*" and "*Tilia pilatus*" at 1956.80–1966.00 m.

2011.07 to 2423.19 m — Middle Eocene (Lutetian and Bartonian)
The top of this interval is drawn at the LAD of somewhat consistent LAD Normapolles pollen group. This is a weak signal, so an alternative might be to drop the Late/Middle Eocene boundary to 2148.87 m, where the LADs of several dinocysts indicate a Lutetian age. The top sample in this interval, like those above it, continues to be dominated by miospores, with samples at 2066.50–2075.70 m and 2094.00–2103.10 m having particularly diverse assemblages.

Reworked older dinocysts continue to be notable. The freshwater alga *Pediastrum* (found in non-marine sediments but commonly washed into marine environments) has a consistent top at 2066.57–2055.51 m. Marine influence picks up at 2203.70–2212.80 m, including the incoming of *Diphyes colligerum* and *Areoligera circumsenonensis* in that sample and *Homotryblium tenuispinosum*, *Cleistosphaeridium elegantulum*, *Hystrichostrogylon digitatum*, *Cordosphaeridium delimurum* and *Alterbidinium bicellulum* in the next sample down. Although these species are represented mostly by single specimens, their collective occurrence at this level supports a Lutetian age. The occurrence of the pollen *Pistillipollenites macgregorii* at 2267.74–2276.88 m and the dinocyst *Sophismatia*

tenuivirgula at 2286.03–2295.07 m support a Lutetian age. The acritarch species *Baltisphaeridium scalenofurcatum* and "*Baltisphaeridium volcanum*" are rare to frequent in many samples in the Middle Eocene interval.

2423.19 to 3328.46 m — Early Eocene (Ypresian)
The top of the Early Eocene is drawn at 2423.19, with the incoming of rare specimens of *Apectodinium*. The Early Eocene signal is not strong however until (going down-section) the sample at 2587.78–2596.93 m, in which *Areoligera circumsenonensis* is common, *Areoligera gippingensis* and *Dapsilidinium pseudoinsertum* appear, and *Apectodinium* spp. increase. Moving down in this interval, the following taxa have LADs: *Deflandrea minima* at 2642.65–2651.79 m; *Ginginodinium*? *flexidentatum* at 2752.38–2761.52 m; *Cleistosphaeridium palmatum* (one specimen) at 2807.24–2816.39 m; *Dracodinium prearticulatum* at 2807.24–2816.39 m, *Cleistosphaeridium polypetellum* and *Glaphyrocysta divaricata* at 2999.27–3008.41 m, *Rottnestia borussica* (one specimen) at 3054.13–3063.28 m, and *Cordosphaeridium gracile* at 3081.57–3090.71 m. *Lingulodinium bulbosum* has a peak at 2697.51–2706.66 m and *Homotryblium tenuispinosum* has a top peak range at 3026.70–3035.84 m.

Many samples in this section have abundant and diverse assemblages of both miospores and dinocysts. The increased proportion of dinocysts suggests greater marine influence than in higher intervals.

3328.46 to 3822.24 m — Late Paleocene (Thanetian)
The top of this interval is drawn at a sample (3328.46–3337.60 m) with a flood of *Glaphyrocysta divaricata*, typical for Paleocene assemblages. A similar acme of this species occurs in the sample at 3438.19–3447.33 m. *Cordosphaeridium fibrospinosum* has its LAD at 3520.48–3529.63 m; this species is a typical Paleocene form, but can go higher in smaller numbers. In the sample at 3794.81–3803.95 m, a form denoted as "*Deflandrea elegantula*" has its LAD; the specimens are thermally mature, but may represent a species of *Cerodinium*, which again would fit with a Paleocene age. Other dinocyst species in this interval are *Apectodinium* spp., *Achomosphaera ramulifera*, *Areoligera circumcoronata*, *Areoligera circumsenonensis*, *Areoligera gippingensis*, *Deflandrea phosphoritica* (caved?), *Diphyes colligerum*, *Glaphyrocysta ordinata*, *Homotryblium tenuispinosum*, *Hystrichostrogylon digitatum*, *Hystrichostrogylon postcingulatum*, "*Lingulodinium multivirgulum*", *Operculodinium* spp., *Palaeocystodinium* sp., *Rottnestia borrusica* and *Spiniferites* spp. Many samples have a diversity of both miospores and dinocysts, again suggesting a strong marine influence.

3822.24 to 3904.54 m — Middle Paleocene (Selandian)
The top sample of this short interval contains another flood of *Glaphyrocysta divaricata* and, more importantly, the LADs of *Palaeoperidinium pyrophorum* and *Palaeocystodinium bulliforme*, both good downwell markers for a Middle Paleocene (Selandian) age. The sample at 3874.06–3883.20 contains *Alisocysta margarita*, supporting a Selandian age. Other dinocysts in this interval include *Achomosphaera ramulifera*, *Apectodinium* spp. (caved?), *Cerodinium diebelii*, *Cerodinium striatum*, *Cordosphaeridium fibrospinosum*, *Cordosphaeridium inodes*, "*Deflandrea elegantula*" (*Cerodinium*?), *Ginginodinium*? *flexidentatum*, *Hystrichosphaeridium tubiferum*, "*Impletosphaeridium delicatulum*", *Minisphaeridium* sp. and *Palaeocystodinium golzowense*. Dinocysts are the most prominent in this interval, but miospores include *Caryapollenites veripites*, *Coryluspollenites* sp., *Cupanieidites* sp. *Momipites annellus*, "*Nyssa microreticulata*" and "*Tricolporopollenites scabratus*".

3904.54 to 4145.33 m — Early Paleocene (Danian)
This is the basal interval in the well. Its top is placed at the sample 3904.54–3913.68 m as it contains a specimen of the Early Paleocene (Danian) marker *Damassadinum* sp., albeit a problematic specimen. Hence this top boundary is tentative, but is supported by the presence of *Tanyosphaeridium*

xanthiopyxides in the next sample down (3931.97–3941.11). *Fibrocysta bipolaris* has an LAD in the next-to-bottom sample, at 4123.99–4133.94 m. This interval is dominated by diverse dinocyst assemblages with sparse miospores, indicating a strong, fully marine influence.

Discussion

A summary plot for Karlsefni A-13 is presented as Figure 6 (attached). This plot shows selected lithological, lithostratigraphic and well log data, selected previous biostratigraphic age determinations, and age determinations and events as assessed in the present study.

Age calls in this study are somewhat at variance with those of previous studies. The topmost interval, determined as Plio-Pleistocene here, matches the age given by Gradstein (1978) and Williams in Barss et al. (1979), but in the present study the section passes down into Miocene at 667.52 m in contrast to around 859.55 m in Gradstein and 1271.03 in Williams. Similarly top Oligocene in the present study is at 969.30, in contrast to 2039.14 in Williams; Gradstein implies that Miocene rests on Eocene at 2066.57. There is less divergence among the three studies in the Paleocene-Eocene section, as can be seen in the attached chart, and all include a similar section of Early Paleocene at the base of the well. Over the past three or four decades, the precedence of dinocysts over microfossils for data east-coast Cenozoic wells has become evident; and our understanding of dinocyst ranges has advanced significantly (Williams et al. 1999, Fensome et al. 2008). The dating of top Miocene and top Oligocene in this study, within a sample or two, is confident. Dating within the Eocene could be flexible, but the rich Paleocene dinocyst assemblages make the tops of Late, Middle and Early Paleocene reasonably secure.

The Oligocene section is intriguing, with very few markers between its top, indicated by *Chiropteridium galea* and the top of the Eocene suggested by multiple compact *Phthanoperidinium* species. Although Gradstein implied that what I call Oligocene was within the Miocene, a gap in his age determinations suggests a lack of marine microfossils, which parallels the miospores dominance in this section and lack of meaningful dinocyst events. Thus, the interval dated as Oligocene here would seem to be non-marine.

Although lack of quantitative counts for this well precludes a detailed paleoenvironmental assessment, from general observations it would seem that the Paleocene section consists of fully marine deposits either distant from shore or with minimal influx of sediment. The Eocene section is also clearly marine, but with generally increasing non-marine influence upwards, before non-marine conditions prevailed through much of the Oligocene. In latest Oligocene times, marine conditions returned, and the presence of miospores with relatively sparse dinocysts through the Neogene suggests fluctuating nearshore to marginal marine conditions.

Conclusions

On the basis of palynostratigraphy, the sections in both Rut H-11 and Karlsefni A-13 can be divided into three parts. In Rut there is: an upper part (~665 to ~1035 m) with consistent marine palynomorph content that extends down to probably latest Oligocene; an interval (~1035 to ~2300 m) dominated by miospores but with sporadic dinocysts including reworked Cretaceous species, which may represent a predominantly non-marine Oligocene strata; and a generally dinocyst-rich interval (~2300 m to TD) that appears to represent predominantly marine strata of Late Paleocene to Late Eocene age,. The bottom 1000 m or more may represent a very thick Late Paleocene section, as discussed below. This broad division is paralleled in Karlsefni A-13: an upper part (~530 to ~1150 m) with consistent marine palynomorph content that extends down to probably latest Oligocene; an interval (~1150 to ~1875 m) dominated by miospores and with sporadic,

probably only reworked dinocysts that may represent non-marine Oligocene strata; and a generally dinocyst-rich interval (~1875 m to TD) that appears to represent Early Paleocene to Late Eocene, predominantly marine strata.

Acknowledgements

I'm greatly indebted to Graham Williams for ongoing discussions about dinocysts and their ranges, as well as for reviewing this report; the last resulted in major improvements. Thanks are due also to Lynn Dafoe for help with the formulation of well plots using Strater and to Bill MacMillan, Krista Boyce and Philip Spencer for technical support.

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List of accompanying figures

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5) Summary plot of Rut H-11
6) Summary plot of Karlesfni A-13
7) Interpretative plot of stratal representation and hiatuses in the two wells

FIGURE 1. SAMPLE BY SAMPLE DINOCYST OCCURRENCES IN RUT H-11

| D number | F number | Depth (top) | Depth (bottom) | DINOFLAGELLATES | Danum | Achomosphaera ramulata | Achomosphaera sp. | Adnatosphaeridium caulleryi/multibrevis | Adnatosphaeridium sp. | Alterbidinium sp. | Alterbidinium ? sp. | Apectodinium dictyoplokum | Apectodinium homomorphum | Apectodinium parvum | Apectodinium sp. | Apectodinium ? sp. | Apectodinium cf. augustum | Apectodinium spp/aff/cf | Apteodinium sp. | Arcodinium ? arcuatum | Arcuatera gippsiensis | Arcuatera spp. | Bitectatodinium spongium | Bitectatodinium ? sp. | Cannosphaeropsis | Canningia sp. | Cassidium fragile | Cerodinium diebelii | Cerodinium speciosum | Cerodinium ? sp. | Chatangiella niveus | Chatangiella ? niveus | Charlesdownie sp. | Chatangiella crassipes | Chatangiella ? crassipes | Chlamydella sphaerica | Chlamydella ? sp. | Chlamydella ? cf. | Chlorophyrida ? sp. | Chlorophyrida ? cf. | Chlorophyrida ? ? sp. | Chlorophyrida ? ? cf. | Chlorophyrida ? ? aff. | Chlorophyrida ? ? spp. | Chlorophyrida ? ? ? sp. | Cleistosphaeridium diaphanum | Cleistosphaeridium ? diaphanum | Cleistosphaeridium ? placacanthum | Cleistosphaeridium ? sp. | Cleistosphaeridium ? ? sp. | Cleistosphaeridium ? ? ? sp. | Cleistosphaeridium ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cleistosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium cantharellus | Cordosphaeridium fibrospinosum | Cordosphaeridium ? fibrospinosum | Cordosphaeridium gracilium | Cordosphaeridium ? gracilium | Cordosphaeridium ? cf. gracilium | Cordosphaeridium ? ? sp. | Cordosphaeridium ? ? ? sp. | Cordosphaeridium ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ? sp. | Cordosphaeridium ?

FIGURE 2. SAMPLE BY SAMPLE OCCURRENCES OF SPORES, POLLEN, ACRITARCHS AND ALGAE IN RUT H-11

| D number | P number | Depth (top) | Depth (bottom) | MIOSPORES | Angiosperm pollen spp. | Bisaccates spp. | Spores spp | Spores spp. (reworked) | Spores spp. (monolete) | Fungal spores spp. | Nonpaolles spp. | Monosaccates spp | Foram linsers | Aequitriradites verrucilatus | Alnipollenites sp. | Amulsporites sp. | Appendicipollenites sp. | Aquilapollenites microreticulatus | Aquilapollenites scabratus | Aquilapollenites spinulosus | Aquilapollenites sp. | Aldeckiasporites wirthii | Auritulinasporites sp. | Aoilla cretacea | Baculatisporites extremus | Baculatisporites sp. | Betulaccoipollenites sp. | Brevicolpites microreticulatus | Brevitricolpites granulatus | Brevitricolpites ragonus | Camarozonosporites sp. | Carypollenites inelegans | Carypollenites veripies | Carypollenites sp. | Chenopodimpollenites sp. | Cicatricosisporites labatus | Cicatricosisporites minutaeporites | Cicatricosisporites sp. | Classopollis sp. | Compositarpollenites sp. | Concavisporites sp. | Corylusapollenites sp. | Costaperiforoporites sp. | Cranwellia striata | Cycadijtes sp. | Deltoidospora australis | Deltoidospora sp. | Densoisporites sp. | Dictyophyllidites harrisii | Dictyophyllidites sp. | Distaltriangulisporites sp. | Foveosporites sp. | Fustiferniisporites sp. (fung) | Gleichenidites senonicus | Graminidites sp. | Ilexpollenites sp. | Juglanspollenites sp. | Justiaea sp. | Laevigatosporites sp. | Liquidambarpollenites sp. | Lilacidites complexus | Manicorpus moderatus | Manicorpus tripodiformis | Manicarya imperalis | Manicarya prodromu | Manipites sp. | Malticellasporites sp. (fung) | Neoraistrickia sp. | Nyssapollenites microreticulatus | Nyssapollenites scabratus | Nyssapollenites sp. | Osmundacites comunemis | Osmundacites wellmanii | Osmundacites sp. | Paramicrorhaitlites sp. (fung) | Perinopollenites sp. | Pilosisporites sp. | Pistillopollenites sp. | Plurcellasporites sp. (fung) | Polycarya sp. | Polycingulatisporites sp. | Pterocarypollenites sp. | Quercoidites major | Retipilocpolis sp. | Retitricolpites flapperiqeus | Retitricolpites macroreticulatus | Retitricolpites maximus | Retitricolpites virgeus | Retitricolpites vulparis | Retitriolpites sp. | Retirtiites auxenclouvatidites | Retirtites sp. | Rousrrosporites varians | Rousrrosporites sp. | Sapotaceoidaepollenites sp. | Suaeria sp. | Sequoiapitlenites sp. | Steresporites antipapollenites | Steresporites crassus | Steresporites generalis | Steresporites sp. | Stereoplites scabratus | Tamaucum sp. | Tasudiacrepollenites sp. | Tetracolpites virgeus | Tilliapollenites generalis | Tilliapollenites pilatus | Tilliapollenites sp. | Tricolpites flapagranulatus | Tricolpites granulatus | Tricolpites reticulatus | Tricolpites scabratus | Tricolpites sp. | Tricolporopollenites granulatus | Tricolporopollenites microreticulatus | Tricolporopollenites scabratus | Tricolporopollenites sp. | Tsugapollenites sp. | Umipollenites sp. | Valliatosporites sp. | Zlivisporis multimurus | Zlivisporis oligomurus | Zlivisporis sp. | ACRITARCHS & ALGAE | Acritarch sp. | Alga spp. | Baltisphaerdium scolemoforcatus | Baltisphaerdium vulcomum | Baltisphaerdium sp. | Comosphaerdium sp. | Cyclopsiella robustum | Cyclopsiella sp. | Fromea sp. | Leiosphaerdium sp. | Micrhystridium sp. | Microphaerdium anciscroides | Microphaerdium sp. | Oxoidites gramulatus | Oxoidites rugulatus | Oxoidites sp. | Plambagos sp. | Pseudoceniella indentatus | Pseudoceniella sp. | Pediastrum sp. | Schizocystia sp. | Schizosporis reticulatus | Schizosporis sp. | Soliphaerdium sp. | Tetraporina tetrapoda | Verychaetium sp. |
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Figure 3. Summary plot for Rut H-11.

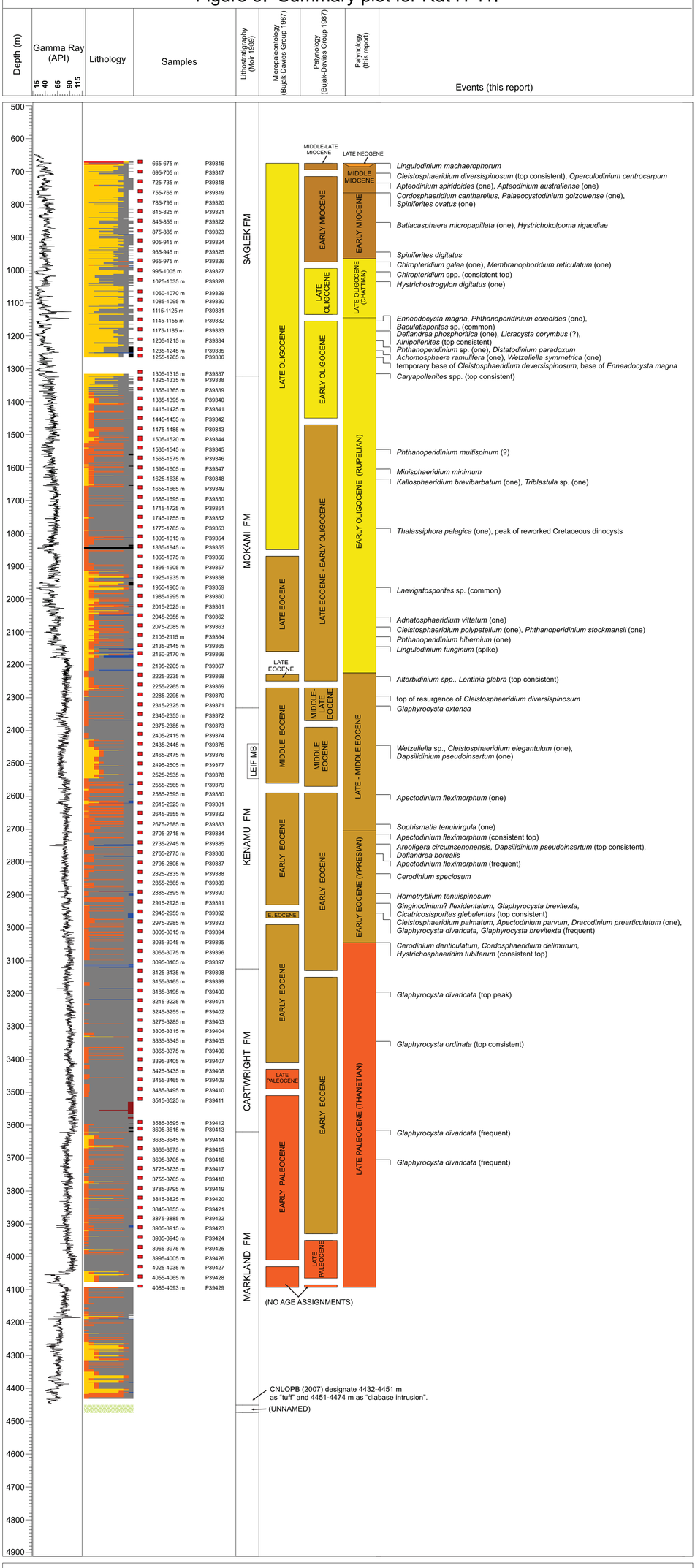

FIGURE 4. SAMPLE BY SAMPLE OCCURRENCES OF DINOCYSTS IN KARLSEFNI A-13

| D number | P number | Depth (mcp) | Depth (bottom) | DINOFLAGELLATES | Achomosphaera ramulifera | Achomosphaera sirii/ramu | Alisocysta cf. tappeyorum | Alisocysta margarita | Alisocysta sp. | Adnatosphaeridium vittatum | Adnatosphaeridium sp. | Alterbidinium bicellulum | Alterbidinium sp. | Apectodinium homomorphum | Apectodinium quinquelatum | Apectodinium sp. | Apectodinium spiridoides | Areoligera circumcoronata | Areoligera coronata complex | Areoligera gippingensis | Areoligera sp. | Batiacasphaera sp. | Cribroperidinium sp. | Cribroperidinium muderongense | Cribroperidinium perlongum | Cribroperidinium sp. | Cyclopsiellum amicum | Cyclonephelium sp. | Cerodinium denticulatum | Cerodinium depressum | Cerodinium diebelii | Cerodinium fragile | Cerodinium striatum | Cerodinium sp. | Charlesdownie sp. | Chatangiella bihokomensis | Chatangiella sp. | Chatangiella spp. | Chiangmaiella gelina | Chiangmaiella procerum | Chiangmaiella sp. | Chiangmaiella spp. | Chiangmaiella mayi | Cleistosphaeridia sp. | Cleistosphaeridium diversispinosum | Cleistosphaeridium ferox | Cleistosphaeridium polygonalum | Cleistosphaeridium sp. | Cometodinium obscurum | Cometodinium sp. | Cordosphaeridium inodes | Cordosphaeridium fenestratum | Cordosphaeridium fibrospinosum | Cordosphaeridium funiculum | Cordosphaeridium gracile | Cordosphaeridium inodes | Cordosphaeridium sp. | Coronifera sp. | Crussolia sp. | Cribroperidinium sp. | Cribroperidinium tenuitenue | Cribroperidinium sp. | Dapsilidinium sp. | Dapsilidinium pseudocolligerum | Dapsilidinium pseudosiderum | Dapsilidinium simplex | Dapsilidinium sp. | Deflandrea phosphoritica | Deflandrea sp. | Deflandrea minima | Deflandrea phosphoritica | Deflandrea sp. | Diacanthum hexacoronatum | Diphyes colligerum | Diphyes ferox/spinum | Druxidinia protoviolaceum | Druxidinia sp. | Eocenopsis magna | Emodo/cyste sp. | Emodo/cyste sp. | Emodo/cyste spp. | Eocladopyxis sp. | Eocladopyxis/Eocenopsis | Eocladopyxis/Eocenopsis sp. | Eocladopyxis/Eocenopsis spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta | Eocladopyxis/Eocenopsis/Glaphyrocysta sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Hetaerosphaeridium/Systematophora sp. | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | 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sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites spp. | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora sp. | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Hetaerosphaeridium spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | 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Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora spp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites sp. | Eocladopyxis/Eocenopsis/Glaphyrocysta/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Systematophora/Spiniferites spp. | 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FIGURE 5. SAMPLE BY SAMPLE OCCURRENCES OF SPORES, POLLEN, ACRITARCHS AND ALGAE IN KARLSEFNI A-13

D number	P number	Depth (top)	Depth (bottom)
D156	P 39537	530.4	539.5
D156	P 39538	557.8	566.9
D156	P 39539	585.2	594.4
D156	P 39540	612.6	621.8
D156	P 39541	640.1	649.2
D156	P 39542	667.5	676.7
D156	P 39543	694.9	704.1
D156	P 39544	722.4	731.5
D156	P 39545	749.8	759.0
D156	P 39546	777.2	786.4
D156	P 39547	804.7	813.8
D156	P 39548	832.1	841.2
D156	P 39549	859.5	865.6
D156	P 39550	880.9	890.0
D156	P 39551	911.4	920.5
D156	P 39552	941.8	951.0
D156	P 39553	969.3	978.4
D156	P 39554	996.7	1005.8
D156	P 39555	1024.1	1033.3
D156	P 39556	1051.6	1060.7
D156	P 39557	1079.0	1088.1
D156	P 39558	1106.4	1115.6
D156	P 39559	1133.9	1148.0
D156	P 39560	1161.3	1170.4
D156	P 39561	1188.7	1197.9
D156	P 39562	1216.2	1225.3
D156	P 39563	1240.5	1249.7
D156	P 39564	1271.0	1280.2
D156	P 39565	1298.4	1304.5
D156	P 39566	1325.9	1335.0
D156	P 39567	1353.3	1362.5
D156	P 39568	1380.7	1389.9
D156	P 39569	1408.2	1417.3
D156	P 39570	1435.6	1444.8
D156	P 39571	1463.0	1472.2
D156	P 39572	1490.5	1499.6
D156	P 39573	1517.9	1527.0
D156	P 39574	1545.3	1554.5
D156	P 39575	1572.8	1581.9
D156	P 39576	1600.2	1609.3
D156	P 39577	1627.6	1636.8
D156	P 39578	1655.1	1664.2
D156	P 39579	1709.9	1719.1
D156	P 39580	1737.4	1746.5
D156	P 39581	1764.8	1773.9
D156	P 39582	1792.2	1801.4
D156	P 39583	1819.7	1828.8
D156	P 39584	1847.1	1856.2
D156	P 39585	1874.5	1883.7
D156	P 39586	1902.0	1911.1
D156	P 39587	1929.4	1938.5
D156	P 39588	1956.8	1966.0
D156	P 39589	1984.2	1993.4
D156	P 39590	2011.7	2020.8
D156	P 39591	2039.1	2048.3
D156	P 39592	2066.5	2075.7
D156	P 39593	2094.0	2103.1
D156	P 39594	2121.4	2130.6
D156	P 39595	2148.8	2158.0
D156	P 39596	2176.3	2185.4
D156	P 39597	2203.7	2212.8
D156	P 39598	2231.1	2240.3
D156	P 39599	2267.7	2276.9
D156	P 39600	2286.0	2295.1
D156	P 39601	2313.4	2322.6
D156	P 39602	2340.9	2350.0
D156	P 39603	2368.3	2377.4
D156	P 39604	2395.7	2404.9
D156	P 39605	2423.2	2432.3
D156	P 39606	2450.6	2459.7
D156	P 39607	2478.0	2487.2
D156	P 39608	2505.5	2514.6
D156	P 39609	2532.9	2542.0
D156	P 39610	2560.3	2569.5
D156	P 39611	2587.8	2596.9
D156	P 39612	2615.2	2624.3
D156	P 39613	2642.6	2651.8
D156	P 39614	2670.0	2679.2
D156	P 39615	2697.5	2706.6
D156	P 39616	2724.9	2734.1
D156	P 39617	2752.3	2761.5
D156	P 39618	2779.8	2788.9
D156	P 39619	2807.2	2816.5
D156	P 39620	2834.6	2843.8
D156	P 39621	2862.1	2874.3
D156	P 39622	2889.5	2898.6
D156	P 39623	2916.9	2926.1
D156	P 39624	2944.4	2953.5
D156	P 39625	2971.8	2980.9
D156	P 39626	2999.2	3008.4
D156	P 39627	3026.7	3038.9
D156	P 39628	3054.1	3063.2
D156	P 39629	3081.5	3090.7
D156	P 39630	3109.0	3118.1
D156	P 39631	3136.4	3145.5
D156	P 39632	3163.8	3173.0
D156	P 39633	3191.3	3200.4
D156	P 39634	3218.7	3227.8
D156	P 39635	3246.1	3255.3
D156	P 39636	3273.6	3282.7
D156	P 39637	3301.0	3310.1
D156	P 39638	3328.4	3337.6
D156	P 39639	3355.8	3365.0
D156	P 39640	3380.2	3392.4
D156	P 39641	3413.8	3422.9
D156	P 39642	3438.1	3447.3
D156	P 39643	3465.6	3474.2
D156	P 39644	3493.0	3502.2
D156	P 39645	3520.4	3529.6
D156	P 39646	3575.3	3584.4
D156	P 39647	3602.7	3614.9
D156	P 39648	3630.2	3639.3
D156	P 39649	3657.6	3666.7
D156	P 39650	3685.0	3694.2
D156	P 39651	3712.5	3721.6
D156	P 39652	3739.9	3749.0
D156	P 39653	3767.3	3779.5
D156	P 39654	3794.8	3834.4
D156	P 39655	3822.2	3831.3
D156	P 39656	3843.5	3852.7
D156	P 39657	3874.0	3883.2
D156	P 39658	3904.5	3913.6
D156	P 39659	3931.9	3941.1
D156	P 39660	3959.4	3968.5
D156	P 39661	3989.8	3999.0
D156	P 39662	4014.2	4023.4
D156	P 39663	4038.6	4047.7
D156	P 39664	4069.1	4078.2
D156	P 39665	4096.5	4105.7
D156	P 39666	4123.9	4133.1
D156	P 39667	4136.1	4145.3

MIOSPORES

Angiosperm pollen spp.
Bisaccates spp.
Spores spp
Spores spp. (reworked)
Spores spp. (monolete)
Fungal spores spp.
Normapolles spp.
Monosulcate spp.
Aequitriradites verrucilatus
Alnipollenites sp.
Ambrosia sp.
Annulispora sp.
Appendicipollenites sp.
Aquilapollenites spinulosus
Aquilapollenites sp.
Aralia cretacea
Aralia sp.
Baculatisporites sp.
Betulacosipollenites sp.
Brevicolpites microreticulatus
Brevitricolpites granulatus
Brevitricolpites verrucosus
Brevitricolpites sp.
Callialasporites dampieri
Camarozonosporites sp.
Callimothallus sp. (fung)
Carypollenites inelegans
Carypollenites quadriporus
Carypollenites verripies
Carypollenites sp.
Castanepollenites sp.
Chenopodiumpollenites sp.
Cicatricosisporites lobatus
Cicatricosisporites sp.
Cicatricosisporites sp.
Classopollis sp.
Clavatisporites sp.
Concavissimisporites montanous
Corylapollenites sp.
Cupanieidites sp.
Deltoidospora australis
Deltoidospora sp.
Dictyophyllidites harrisii
Dictyophyllidites sp.
Diporocellaesporites sp. (fung)
Distatrianguliporites sp.
Fractisporonites sp. (fung)
Gleichenidites senonicus
Gleichenidites sp.
Ilexpollenites sp.
Insulapollenites rugulatus
Ischyosporites sp.
Juglanspollenites sp.
Justiaea sp.
Lacrimasporonites sp. (fung)
Laevigatosporites sp.
Liquidambarpollenites sp.
Manicorpus moderatus
Microthallites sp. (fung)
Monicarya imperalis
Monicarya prodroma
Monicarya sp.
Monipites annulus
Monipites coryloides
Monipites sp.
Multicellaesporites sp. (fung)
Neoraistrickia sp.
Nyssapollenites granulatus
Nyssapollenites microreticulatus
Nyssapollenites scabratus
Osmundacidites comunemsis
Osmundacidites sp.
Pachysandra sp.
Pistillipollenites mcgregorii
Pistillipollenites trinudus
Pistillipollenites sp.
Plicatopollis triechiularis
Pluricellaesporites sp. (fung)
Polypodiaceoisporites sp. (fung)
Polycoryas sp.
Polycingulatisporites sp.
Proteacidites sp.
Pterocarypollenites sp.
Quercoidites major
Retitricolpites flagocriopus
Retitricolpites georgensis
Retitricolpites macroreticulatus
Retitricolpites virgens
Retitricolpites vulgaris
Retitricolpites sp.
Retitriletes sp.
Rhoipites sp.
Rousseoxylon major
Rousseoxylon sp.
Rousseoxylon varians
Rugubivesiculites rugosus
Sagopteridopollenites sp.
Sequoiapollenites sp.
Sughdaipollenites sp. (fung)
Stereoporites cranwellii
Stereoporites tridens
Stereoporites sp.
Synnotipites microreticulatus
Tricolpites sp.
Tricolpopollenites sp.
Trivestibulopollenites sp.
Tricolpollenites generalis
Tricolpollenites pilatus
Todisporites brevimodes
Tricolpites flagogranulatus
Tricolpites granulatus
Tricolpites scabratus
Tricolpites sp.
Tricolporopollenites crassimurus
Tricolporopollenites granulatus
Tricolporopollenites microreticulatus
Tricolporopollenites rugoverrucatus
Tricolporopollenites scabratus
Tricolporopollenites sp.
Tsugapollenites sp.
Ulmipollenites sp.
Ulmipoors multimurus
Zlivisporis oligomurus
Zlivisporis sp.

ACRITARCHS & ALGAE

Acritarch sp.
Alga spp.
Baltisphaeridium scolenoferatus
Baltisphaeridium vulcanum
Baltisphaeridium sp.
Cymosphaeridium sp.
Cyclopsiella sp.
Leiosphaeridia crucifera
Leiosphaeridia sp.
Micrhystridium sp.
Microsphaeridium anciestroides
Microsphaeridium sp.
Ovoidites scabratus
Ovoidites sp.
Pseudoconiella indentatus
Pediastrum sp.
Scenedesmus sp.
Schizosystia delicatula
Solisphaeridium sp.
Tetraporina reducta
Tetraporina tetrappola
Veryhachium sp.

FIGURE 6. KARLSEFNI A-13 SUMMARY PLOT

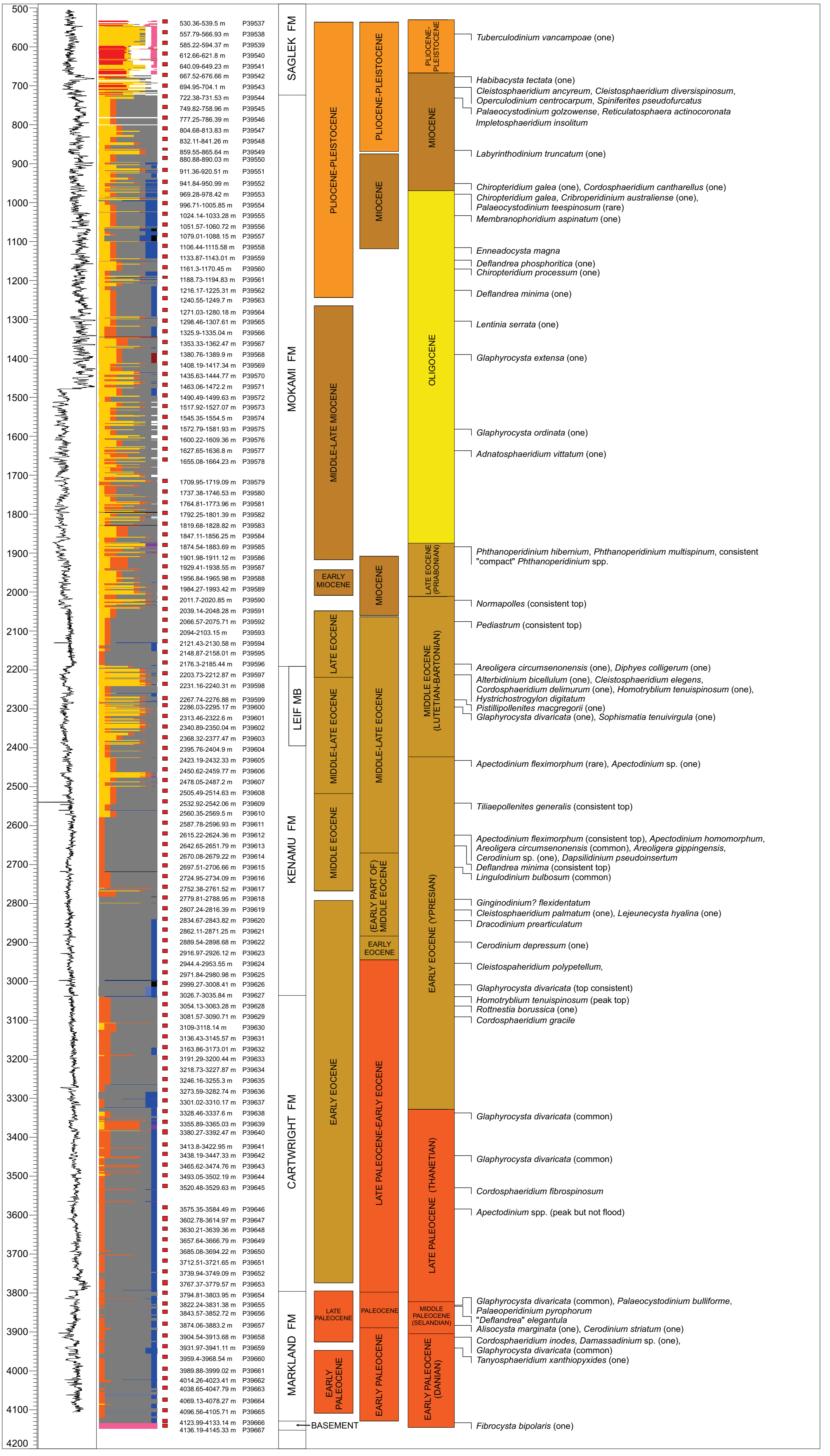
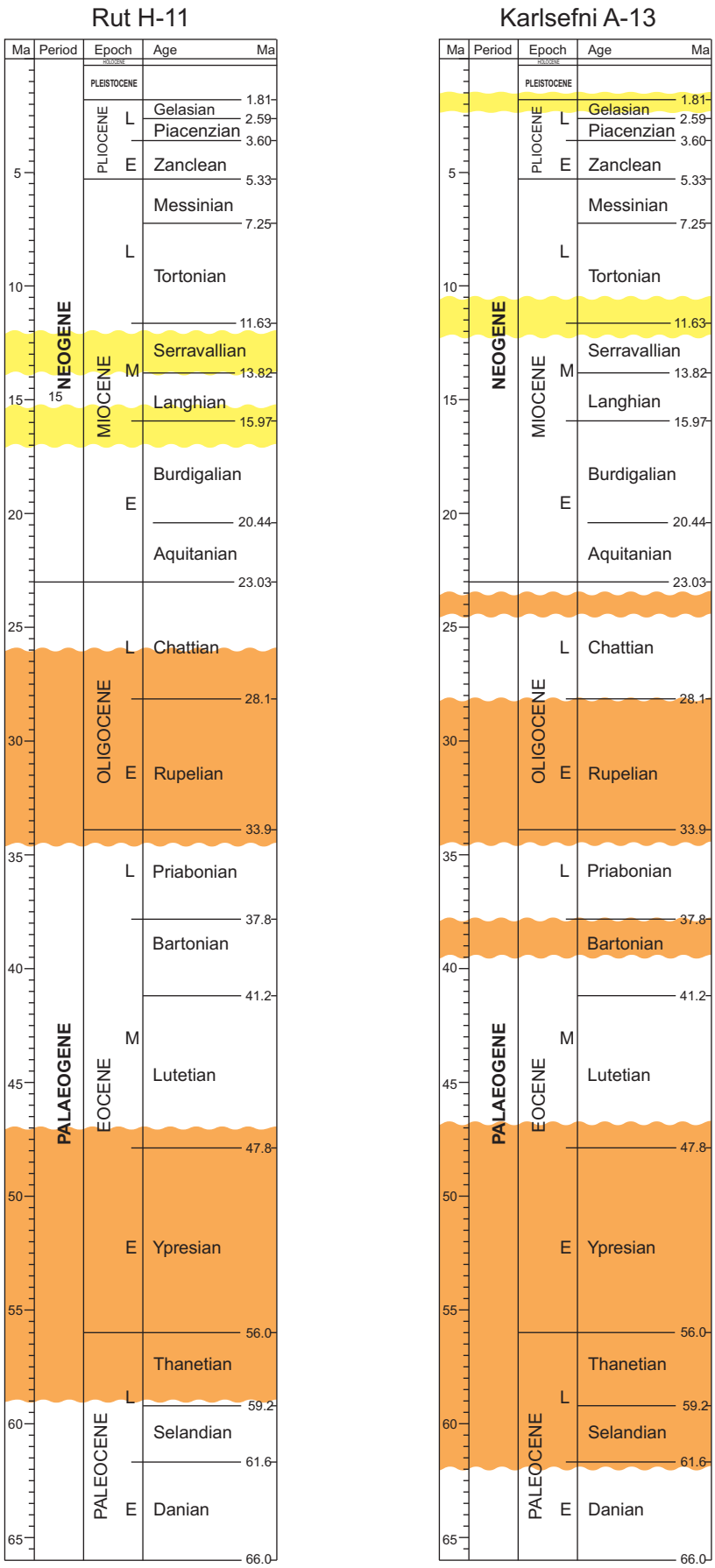
FIGURE 7.
ASSESSMENT OF AGES REPRESENTED BY STRATA IN RUT H-11 AND KARLSEFNI A-13