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Palynological analysis of Petro-Canada *et al.* Terra Nova K-18  
Jeanne d'Arc Basin, Grand Banks of Newfoundland

G.L. Williams

2003

# GEOLOGICAL SURVEY OF CANADA

## OPEN FILE 1659

Palynological analysis of Petro-Canada *et al.* Terra Nova K-18

Jeanne d'Arc Basin, Grand Banks of Newfoundland

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Marine Resources Geoscience Subdivision  
Geological Survey of Canada (Atlantic), Dartmouth

2003

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G.S.C. Locality No.: D-259

Location: 46°46'22"N, 48°54'21"W

Elevation Sea level to R.T.: 24.3 m

Water Depth: 91.4 m

Total Depth: 3925 m

Spud Date: 19 July 1984

Interval Studied: 610-3925 m

Casing Points: 762 mm at 236 m; 508 mm at 601.5 m; 273 mm at 1980 m; 194 mm at 3776 m

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### Introduction

Petro-Canada *et al.* Terra Nova K-18 is in the southeastern part of the Jeanne d'Arc Basin, the Grand Banks of Newfoundland (McAlpine, 1990). K-18 is one of several wells drilled in the Terra Nova field, which is in production.

This study is based on the palynological analysis of 112 cuttings samples covering the interval 610-3925 m and 58 sidewall core samples from 616 to 3436 m. The Canada-Newfoundland Offshore Petroleum Board kindly loaned me the slides of the sidewall cores.

### Biostratigraphy

My age determinations, based on dinoflagellate cysts (dinocysts), spores and pollen are in Figure 1. Ages are based on known stratigraphic ranges of dinocysts in European sections (Williams *et al.*, 1999, 2001, in press) and in other wells and core holes on the Grand Banks (Williams and Brideaux, 1975; Bujak-Davies, 1987; Williams *et al.*, 1990).

The deepest sample is at 3915-3925 m and contains the spore *Trilobosporites obsitus* (citations for individual species are given in Appendix 1), which has a first appearance datum (FAD) of Kimmeridgian, according to Bujak-Davies (1987). I also recorded the dinocyst *Occisucysta balios*, which has a last appearance datum (LAD) of 145.6 Ma according to Williams *et al.* (1999). Those authors used the timescale of Gradstein and Ogg (1996), so the LAD of *Occisucysta balios* is Kimmeridgian. In studies of other Grand Banks wells, I have not recorded *Occisucysta balios* above the early Kimmeridgian. On this basis I consider the sample at 3915-3925 m to be that age.

I include the interval 3550-3925 m in the early Kimmeridgian, based on the LAD of the dinocyst *Geiselodinium paemosum*. Williams and Bujak (1985) restricted this species to the Kimmeridgian, not taking it to the top. In other Jeanne d'Arc wells, I have noted that it seems to have an LAD of early Kimmeridgian. Other species restricted to this interval are the dinocysts *Adnatosphaeridium caulleryi* and *Leptodinium millioudii* and the spores *Striatella* #EAB Davies in Bujak-Davies (1987) and *Polycingulatisporites reduncus*.

From 3530 to 3010 m is mid Kimmeridgian, based on the relative abundance of species of the dinocyst *Eiplosphaera*, including *Eiplosphaera areolata* (common to abundant in several samples), *Eiplosphaera gochtii* and *Eiplosphaera bireticulata*. Williams *et al.* (1999) placed the LAD of *Eiplosphaera areolata* at 149 Ma, the top of the Kimmeridgian. In Jeanne d'Arc wells, *Eiplosphaera* species, which show a wide range of morphologies, also extend to the top of the Kimmeridgian but have a highest common occurrence within that stage. I am taking this to equate with the top of the mid Kimmeridgian. Other species with LADs in the interval 3530-3010 m are the dinocysts *Mendicodinium rugulatum*, *Rhynchodiniopsis cladophora* subsp. *hemipolyedrica* and *Systematophora vestita* and the spores *Cicatricosisporites* #EM Davies in Bujak-Davies (1987), which he considered to be Portlandian (Bujak-Davies, 1987).

The late Kimmeridgian, from 2990-2800 m, is characterized by the presence of the dinocysts *Egmontodinium expiratum*, *Histiophora ornata*, *Hystrichodinium voigtii*, *Hystrichodinium voigtii* subsp. "brevispinum", *Lanterna sportula* (abundant), *Muderongia* sp.A Davey and *Senoniasphaera jurassica*. Riding *et al.* (2001) considered *Muderongia* sp.A to be a taxonomic synonym of *Muderongia simplex*, whose last consistent occurrence they placed in the Kerberus ammonite zone of the early Portlandian. Williams *et al.* (1999) placed the LAD of *Senoniasphaera jurassica* at 144.2 Ma, just within the early Portlandian. In the Scotian Basin, Williams (1975) regarded the LAD of *Senoniasphaera jurassica* as denoting the top of the Kimmeridgian. I take this evidence and the consistent occurrence of *Eiplosphaera reticulata* in this interval as confirming the late Kimmeridgian age.

It is generally difficult to pick the Portlandian in the Jeanne d'Arc wells, since dinocyst abundances are low. Tentatively I include the interval 2780-2620 m in this stage, based on the LAD of the dinocyst *Lanterna bulgarica* at 2620-2630 m. Stover *et al.* (1996) considered the genus *Lanterna* to have its LAD at the Jurassic-Cretaceous boundary, which agrees with my data in the Jeanne d'Arc Basin. Other dinocyst taxa having LADs from 2620-2780 m are *Gochteodinia mutabilis*, *Dichadogonyaulax pannea* and *Sentusidinium rioultii*. The distinctive pollen *Corollina echinata* has its LAD at 2710-2720 m. The LAD of this species has been commonly used by oil company palynologists to denote the top of the Jurassic. The LAD of the spore *Striatella* #EE Davies in Bujak-Davies (1987) is at 2710-2720 m. Davies (op.cit.) considered the stratigraphic range of this species to be Portlandian to Berriasian.

The Berriasian section extends from 2600-2260 m. I have picked the top on the LADs of the dinocyst *Achomosphaera neptunii* and the spores *Cicatricosisporites crassistriatus*, *Cicatricosisporites purbeckensis*, *Cicatricosisporites versiformis* and *Leptolepidites psarosus*. *Cicatricosisporites purbeckensis* was described by Norris (1969) from the uppermost Jurassic of southern England. *Cicatricosisporites crassistriatus*, according to Davies in Bujak-Davies (1987) is restricted to the Berriasian of the Jeanne d'Arc Basin. In other Jeanne d'Arc Basin wells, including Whiterose N22 and Skua E-41, I have noted that the LAD of *Leptolepidites psarosus* is Berriasian. Therefore, it seems reasonable to consider 2600-2260 m to be Berriasian.

Davies in Williams *et al.* (1990) considered his *Striatella* #EJ subzone to be early Berriasian. In Terra Nova K-18, the LAD of the taxon is in the cuttings sample at 2470-2480 m. Thus, I am assigning 2600-2470 m to the early Berriasian and 2450-2270 m to the late Berriasian. *Aequitriradites baculatus*, a spore

that I find does not extend into post-Berriasian sediments in the Jeanne d'Arc Basin, has its LAD at 2440-2450 m.

I consider from 2257 to 1941? m to be Valanginian. The sidewall core at 2257 m contains the dinocyst *Cymosphaeridium validum*, which has an FAD at the base of the Valanginian according to Williams *et al.* (1999). Also in this sidewall is *Cassiculosphaeridia magna*, which I have found to be a consistent Valanginian marker in Jeanne d'Arc wells. The LADs of both *Cassiculosphaeridia magna* and *Phoberocysta neocomica* are at 1941 m. Williams (1975) defined a *Phoberocysta neocomica* Zone for the Scotian Shelf, which he considered Berriasian-Valanginian. Duxbury (1977, 2001) had Aptian records of this species, but it appears to have a much more restricted range in offshore eastern Canada. I question the top of the Valanginian because I only had sidewall cores. Presumably this reflects environmental control.

Other taxa with LADs in the Valanginian of Terra Nova K-18 are the dinocysts *Canningia cf. reticulata* sensu Duxbury 1977, *Dingodinium cerviculum*, *Discorsia nanna*, *Druggidium apicopaucicum*, *Kleithrisphaeridium fasciatum*, *Spiniferites dentatus*, *Heslertonia heslertonensis*. Spore LADs are *Coronatispora valdensis*, *Aequitriradites spinulosus*, *Cicatricosisporites annulatus* and *Cicatrocosisporites pseudotripartitus*.

Aptian sediments may immediately overlies the Valanginian and extend from 1904 to 1558 m. Unfortunately, I cannot confirm this. I do not have cuttings samples between 2140 and 1490 m and the quality of the slides from the sidewall cores is abysmal. Since there are no age diagnostic palynomorphs in the samples from 1904 to 1589 m, I do not give an age for this interval.

That there is Aptian at 1558 m is confirmed by the presence of *Cerbia tabulata*, whose LAD is considered to mark the Aptian, according to Williams (1975) and subsequent workers (e.g. Duxbury, 2001).

The sidewall core from 1546 m contains the dinocyst *Pseudoceratium eisenackii*, described by Davey (1969a) from the Albian, and *Microdinium veligerum*. Also present is *Surculosphaeridium? longifurcatum*, which Williams *et al.* (1999) considered to have a latest Aptian LAD at 112 Ma. Overall, I consider these species to indicate an Albian age.

The Cenomanian may be restricted to a mere 18 metres or so, from 1500-1480 m. I base the Cenomanian age on the presence of the dinocysts *Cleistosphaeridium huguoniotii* and *Litosphaeridium siphoniphorum* in the cuttings sample from 1480-1490 m and *Psaligonyaulax deflandrei* and *Gonyaulacysta cassidata* in the 1482 m sidewall. Also, *Palaeohystrichophora infusorioides* in the 1500 m sidewall has an FAD of 100.27 Ma, according to Williams *et al.* (1999) and 99.85 Ma, according to Williams *et al.* (in press). I consider these data to be close enough to the basal Cenomanian to include 1500 m in that age.

I cannot separate the Turonian-Coniacian, which I extend from 1460 to 1338 m. The sidewall at 1338 m contains the LAD of the dinocysts *Florentinia ferox* and *Xenascus sarjeantii*. In Hibernia C-96, I found that the LAD of *Xenascus sarjeantii* was at the top of the Coniacian. Other dinocyst species with LADs in this interval are *Areoligera guembelii* at 1360-1370 m, *Hystrichosphaeridium bowerbankii* at 1367 m, *Florentinia radiculata* at 1402 m, *Oligosphaeridium pulcherrimum* at 1420 m and *Callaiosphaeridium asymmetricum* at 1450-1460 m. Williams (1975) erected the *Oligosphaeridium pulcherrimum* zone for the Coniacian. He considered the index species to have a Coniacian LAD in Scotian Shelf wells.

The base of the Coniacian may be at 1402 m, which sample contains *Isabelidium cooksoniae*. Williams and Bujak (1985) placed its FAD within the Turonian but their data was based on the concept

of a Coniacian of one million years. Further study may demonstrate that the FAD of *Isabelidinium cooksoniae* lies close to the Turonian-Coniacian boundary.

The cuttings sample at 1330-1340 m contains *Canningia reticulata* and *Raetiaedinium truncigerum*. Williams and Brideaux (1975) noted that *Raetiaedinium* (as *Hystrichosphaeridium*) *truncigerum* had an LAD in the Santonian. And Williams (1975) erected a *Raetiaedinium* (as *Hystrichosphaeridium*) *truncigerum* Zone, which he considered Santonian. This agrees with my designation.

The early Campanian, which extends from 1309-1286 m, is characterized by the LADs of the dinocysts *Kleithriasphaeridium loffrense* and *Surculosphaeridium? longifurcatum*. *Kleithriasphaeridium loffrense* has an LAD of 76.2 Ma and *Surculosphaeridium? longifurcatum* has an LAD of 81.68 Ma, according to Williams *et al.* (in press). These ages confirm an early Campanian age. *Palaeohystrichophora infusorioides* also has its LAD at 1286 m. Williams *et al.* (in press) consider this species to have an LAD close to the Campanian-Maastrichtian boundary.

Paleocene sediments appear to immediately overlie the Campanian section, but it is difficult to assign an age to the cuttings sample at 1370-1380 m. This sample contains abundant *Areoligera cf. medusettiformis* and *Cerodinium* is common. Both the above indicate Paleocene but do not allow differentiation of early or mid Paleocene. The answer would appear to lie in the LAD of the dinocyst *Spinidinium densispinatum* group, which occurs in the sample at 1180-1190 m. Williams *et al.* (1999) gave the LAD of *Spinidinium densispinatum* as 59.38 Ma, which is close to the Danian-Selandian boundary. I am therefore including 1280-1190 m in the Danian. Other dinocyst species with LADs in the Danian are *Cerodinium speciosum* and *Hystrichosphaeridium tubiferum*.

There is an abundance of *Palaeoperidinium pyrophorum* in the cuttings sample at 1240-1250 m. The LAD of *Palaeoperidinium pyrophorum* is 58.04 Ma (Williams *et al.*, in press), that's close to the top of the Selandian. In the Terra Nova K-18, the LAD of *Palaeoperidinium pyrophorum* is in the sidewall core at 1139 m. Other index taxa include *Palaeocystodinium bulliforme*, which has its LAD in the cuttings sample at 1150-1160 m and *Alisocysta margarita*, whose LAD occurs at 1120-1130 m. According to Williams *et al.* (in press), the LADs of *Alisocysta margarita* and *Palaeocystodinium bulliforme*, are 57.35 Ma and 57.9 Ma. The former is close to the top of the Selandian, the latter is at the Selandian-Thanetian boundary. Thus, I consider the interval 1169-1120 m to be Selandian.

The dinocyst species *Apectodinium augustum* in the cuttings sample at 1120-1130 m has a known stratigraphic range of 55.46 - 55 Ma (Williams *et al.*, in press), or within the late Paleocene. This explains the thin sliver of Thanetian (late Paleocene) from 1125-1110 m.

I consider from 1100 to 1060 m to be early Eocene (Ypresian). This is confirmed by the LAD of the dinocyst *Dracodinium condylos* at 1060-1070 m. Williams *et al.* (in press) gave the range of 52.5 - 51.5 Ma for this species, that's in the mid Ypresian. Also in the same sample is *Wilsonidium compactum*, described by Michoux (1985) from the type Lutetian (middle Eocene) of France. Thus, I place the Ypresian-Lutetian boundary at 1065 m.

Based on the LAD of *Glaphyrocysta divaricata*, the Lutetian extends from 1055 to 970 m. According to Williams *et al.* (1999), this species has an LAD at 44.5 Ma. *Rottnestia borussica*, which has an LAD in the early Lutetian in other Jeanne d'Arc wells, occurs in the sample at 1030-1040 m.

The middle Eocene has a twofold division, with the Lutetian being from 49 - 41.3 Ma and the Bartonian from 41.3 - 37 Ma (Gradstein and Ogg, 1996). I have designated 939-850 m as Bartonian, basing this on the LAD of the pollen *Extratropipollenites* in the cuttings sample from 850 to 860 m.

*Extratropipollenites* has its LAD within the Bartonian in several wells in the Jeanne d'Arc Basin. Further confirmation comes from the LADs of *Cyclonephelium* sp.A Williams and Brideaux, 1975 at 880-890 m and the LAD of *Deflandrea hialina* at 910-920 m. Both these taxa have their LADs in the Bartonian in other wells in the Jeanne d'Arc Basin.

Priabonian or late Eocene sediments occur from 842-700 m, based on the consistent LAD of *Lentinia serrata* and *Lentinia "glabra"*. Williams *et al.* (1999) gave the LAD for *Lentinia serrata* as 33.5 Ma, the top of the late Eocene which equates with the top of the Priabonian.

From 677-610 m appears to be early Rupelian or early early Oligocene. The highest sample at 610-620 m contains *Operculodinium divergens*, which has an LAD of 31.97 Ma (Williams *et al.*, 1999). The lowest sample in this interval, a sidewall core at 677 m, contains the pollen grain *Gramineae*. There are a few Eocene record of the *Gramineae*, but most are Oligocene or younger.

A major problem with the cuttings samples from 1100 to 610 m is the high degree and variability of reworked material. There are Carboniferous spores, Cretaceous dinocysts and spores, but especially Late Cretaceous dinocysts, and early to mid Eocene dinocysts. Some of the Late Cretaceous dinocysts, such as *Laciniadinium arcticum* and *Chatangiella ditissima*, are reworked from higher latitudes. Manum and Cookson (1964) described *Laciniadinium arcticum* from the late Cretaceous of Ellef Ringes Island; *Chatangiella ditissima* was described from Campanian sediments of the Northwest Territories by McIntyre (1975). Presumably, Upper Cretaceous rocks to the northwest were being eroded and the material was transported by rivers to the Grand Banks, where it found a final resting place.

#### Paleoenvironments

Paleoenvironmental interpretations based on cuttings can be misleading but generalizations can be made. Sidewall core samples usually provide more reliable data. The Company slides were disappointing, however, yielding few or no palynomorphs. A striking feature of the lowermost samples from 3925-3340 m was the high proportion of degraded herbaceous material and well-preserved dinocysts. This, plus the common occurrence of the dinocyst *Cribroperidinium*, indicate deposition in an inner neritic environment. Deeper water, more offshore conditions but still on the shelf, existed from 3790-3700 m, 3640-3650 m and 3430-3400 m. Abundant woody fragments at 3840-3850 m suggest a closer to shore paleoenvironment of high energy. A single sidewall core at 3436 m contained only the pollen *Corollina torosus*, indicative of fluctuating wet and dry, seasonal conditions according to Cornet and Traverse (1975).

There is a marked reduction in percentage of degraded herbaceous from 3310-3100 m and an increase in dinocysts, indicating continuing deposition in an inner neritic environment.

The cuttings sample at 3100-3110 m contains a higher pollen count but with good dinocyst representation. This suggests a shallowing, marginal marine setting. Again, there is a mixed signal from the sidewall cores, with the two at 3083 and 3074.7 m containing only *Corollina torosus*. The absence of dinocysts may indicate nonmarine episodes, although the cuttings samples continue to contain common, well-preserved specimens. There is an influx of degraded herbaceous at 3070-3080 m, followed by shallowing from 3040-3050 m.

Greater water depth and a more offshore setting occurred briefly at 3010-3020 m. This is marked by the dominance of the dinocysts and the increase in degraded herbaceous. But there is a rapid return to more marginal marine conditions from 2980-2860 m, with a strong indication of very close to shore to nonmarine episodes.

A flood of dinocysts, with species of *Cribroperidinium* at 2840-2810 m, supports an offshore inner neritic setting. However, *Cribroperidinium* has been regarded by some authors as denoting close to shore settings. There is another conundrum at 2794 m, where the sidewall core contains only the gymnosperm pollen *Pinuspollenites*. From 2780-2546.5 m, the paleoenvironments show little change, with little lateral migration in a marginal marine setting.

At 2530-2540 m, the assemblage includes the dinocysts *Cribroperidinium muderongense*, *Cribroperidinium orthoceras* and *Phoberocysta neocomica*, all regarded as inner shelf to marginal marine. The mixed dinocyst spore assemblages, usually with at least two of the above species, continue at 2260 m, with a possible nonmarine pulse at 2500-2510 m, and more marine conditions in the sidewall core at 2384 m, which contains the more open marine *Muderongia* (Monteil, 1991).

Increasing water depths and a more open marine setting is marked by a sidewall core at 2257 m but there is a return to marginal marine from 2240-2210 m. A brief, more open marine spell occurs from 2180-2110 m, then the signal is lost for most of the interval 2110-1628 m. The reason is the poor recovery from the sidewall cores and the unavailability of cuttings. One sidewall at 1904 m is devoid of dinocysts but contains a microforaminifera, presumably indicating open marine conditions. At 1589 and 1546 m, the mixed dinocyst/spore assemblage indicates a shallow marine paleoenvironment.

Deeper, open marine conditions are encountered at 1500 m, where the sidewall sample contains exclusively dinocysts and microforaminifera. This paleoenvironment persists to 1286 m, another sidewall core. There is a dramatic change in the cuttings sample from 1270-1280 m, which contains exclusively dinoflagellates, but of an unusual composition. The dominant species is *Areoligera* cf. *medusettiformis* but small forms of *Cerodinium* are also common. Powell *et al.* (1996) observed an analogous situation in samples from the type Thanetian of southern England. In the Pegwell Bay section, are three levels where *Areoligera* is superabundant and three levels where it is abundant. The authors considered these horizons to represent a restricted, high-energy, marginal marine setting typical of a transgressive regime. They interpreted the richest samples as being close to the most condensed interval or maximum flooding surface. Presumably the assemblages denote blooms. This would explain the common occurrences of *Cerodinium*. If this were a heterotrophic dinocyst, it should be attracted to and be successful where there are blooms of autotrophic taxa such as *Areoligera*. Successive *Areoligera* blooms occur at 1240-1250 m, 1180-1190 m, and 1150-1160 m.

A major signal related to the climatic regime occurs in the cuttings samples from 1120-1130 m and 1090-1100 m. These contain abundant specimens of the dinocyst *Apectodinium homomorphum*, which is considered to be a warmer-water species (Bujak and Brinkhuis, 1998). Crouch *et al.* (2001) have taken this a step further and shown that the onset of *Apectodinium*-dominated assemblages seem to be synchronous on a global scale. One occurred during the late Paleocene thermal maximum (LPTM) which lasted for about 220 ky at about 55 Ma. And it can be correlated with a negative carbon isotope excursion (CIE), a benthic foraminifera extinction event and the calcareous nannofossil zonation. The *Apectodinium* influx denotes higher sea-surface temperatures and a major increase in marginal-marine, surface-water productivity. And a marked decline in *Apectodinium* abundances towards the end of the LPTM may show a corresponding temperature decrease. Assuming the specimens are autochthonous, the paleoenvironments would not be dissimilar to those existing during the *Areoligera* blooms.

From 1070-873 m, the mixed dinocyst, pollen assemblages indicate an open marine neritic setting. Pollen dominate the interval from 873 to 820 m, from which I analysed two sidewalls and two cuttings. Strangely, this may represent deeper water, more oligotrophic conditions. From 812 to 600 m, the paleoenvironment is more or less uniformly open marine, although deeper water episodes are indicated at 760 and 600 m.

### Correlation of Palynology and Lithology

The lithostratigraphy of the Terra Nova K-18 well was published by McAlpine (1989) and the lithostratigraphic terminology was formalized in McAlpine (1990). Throughout, I shall adhere to McAlpine (1989) for all depths and thicknesses. According to McAlpine (1989), the well bottomed in the Rankin Formation, which extends from 3926-3413 m. Therefore, the age of the Rankin is early to mid Kimmeridgian. McAlpine (1990) stated that the Rankin Formation was early Oxfordian-early Kimmeridgian at the type section in Rankin M-36, but could extend into the middle Kimmeridgian elsewhere. This agrees with my age determination for this formation in Terra Nova K-18, although McAlpine (1989, 1990) was designating the Tithonian as the youngest Jurassic stage. This is the more widely accepted approach but I still use the Portlandian, which is of shorter duration. This allows a satisfactory threefold subdivision of the Kimmeridgian and lets me correlate the Jeanne d'Arc section with southern England, geographically the logical choice. Bujak-Davies (1987) also use the Portlandian and recognize a threefold subdivision of the Kimmeridgian.

The Egret Member of the Rankin Formation, which is at 3790-3635 m, is exclusively early Kimmeridgian. This member was deposited primarily in an inner, but also partly outer, neritic environment.

Unconformably overlying the Rankin at 3413 m is the Jeanne d'Arc Formation, which extends to 3050 m. I consider this interval to be mid Kimmeridgian and do not recognize a hiatus. McAlpine (1990), who designated the K-18 section as the type section for the Jeanne d'Arc Formation, gave the age as Kimmeridgian-Tithonian. He noted, however, that the Bujak-Davies Group (1988) considered the formation to be consistently Kimmeridgian. Since the Bujak-Davies Group did not analyse any samples from Terra Nova K-18, the age given in McAlpine (1990) is by extrapolation from other Jeanne d'Arc wells.

The overlying Fortune Bay Shale, from 3050-2840 m, is 210 m thick. The interval 3050-2840 m, I consider late Kimmeridgian with the bottom 50 m being mid Kimmeridgian. McAlpine (1990) designated Terra Nova K-18 as the type section for the Fortune Bay Shale and considered it Tithonian. He acknowledged, however, that the Bujak-Davies Group (1988b) stated it was mid to late Kimmeridgian. As I have said above, the Bujak-Davies Group did not study Terra Nova K-18.

McAlpine (1989) included 2840-2371 m in the Hibernia Formation, with 2510-2371 m being assigned to the Hebron Well Member. Sequentially overlying the Hibernia are the "B" Marker from 2371-2305 m, the Catalina Formation from 2305-2204 m and the Whiterose Shale from 2204-1928 m. I consider the Hibernia Formation as latest Kimmeridgian-Berriasian, with the Hebron Well Member being Berriasian. McAlpine (1990) designated from 3839-4062 m in Hibernia K-14 as the type section for the Hibernia Formation. Since the palynology of this well has not been done by the Bujak-Davies Group, McAlpine based the age on the reference section in Hebron I-13. The age, according to Williamson (1987) and Ascoli (1988) is Tithonian-Berriasian. This is similar to my determination. The Hebron Well Member in the type section, Hebron I-13, is Berriasian according to McAlpine (1990). This age is based on both micropaleontology (Williamson, 1987; Ascoli, 1988) and palynology (E.H. Davies, pers. comm. to K.D. McAlpine, 1983). This agrees with my results.

In Terra Nova K-18, I consider the "B" marker to be late Berriasian, the Catalina Formation to be late Berriasian-early Valanginian, and the Whiterose Shale to be Valanginian. McAlpine (1990) gave a Valanginian age for the "B" Member at the type section, Ben Nevis I-45. But he considered its overall range late Berriasian-Valanginian, which shows some agreement with my ages.

The type section for the Catalina Formation is from 3300-3130 m in Hibernia O-35 (McAlpine, 1990).

E.H. Davies (pers. comm. to K.D. McAlpine, 1986) said that the age, based on palynology, was late Berriasian-Valanginian. This matches my results. My age for the overlying Whiterose Shale is more restricted than in McAlpine (1990), who generally considered it to be late Tithonian-Berriasian. Bujak-Davies (1988c) considered the unit's age to be late Kimmeridgian-Barremian at the type section, 3357-2728 m in Whiterose N-22. The problem in Terra Nova K-18 is that I do not have cuttings samples over the critical interval from 2110-1480 m and so cannot determine the age from above 1941 m to below 1558 m.

Conformably overlying the Whiterose Shale is the Eastern Shoals Formation (1928-1800 m), which is bounded by an unconformity at the top according to McAlpine (1989). The succeeding Avalon Formation (1800-1665 m) is in here unconformably overlain by the Ben Nevis Formation (1665-1590 m). I cannot confirm the above unconformities because of poor sample control. McAlpine (1990) considered the Eastern Shoals to be Hauterivian to Barremian, the Avalon to be late Barremian to late Aptian or early Albian, and the Ben Nevis to be late Aptian to early Albian. Because of inadequate sample control, I cannot give an age for these formations.

Succeeding the Ben Nevis is another unconformity-bounded sequence, the Nautilus Shale, which extends from 1590-1521 m (McAlpine, 1989). I consider this interval to be in part Aptian-early Albian. McAlpine (1990) in assigning an early Aptian to Albian-Cenomanian age to the Nautilus, stated that it potentially had the same age range as its lateral equivalents. Since these are the Avalon, Ben Nevis and Eider formations, the overall age would be Barremian to late Cenomanian-Turonian.

McAlpine (1989) recognized an unconformity at 1521 m, above which sequentially lie the Petrel Member of the Dawson Canyon Formation (1521-1460 m) and the rest of the Dawson Canyon Formation from 1460-1227 m. For the Jeanne d'Arc Basin, McAlpine (1990) believed the Dawson Canyon Formation to be late Cenomanian-Maastrichtian and the Petrel Member to be Turonian-Coniacian. In Terra Nova K-18, the Petrel is late Cenomanian to Turonian-Coniacian; the Dawson Canyon is late Cenomanian-Campanian.

The Banquereau Formation was erected by McIver (1972) for a predominantly mudstone sequence with locally abundant sandstone and siltstone on the Scotian Shelf. According to palynology, the type section from 1355-165 m in the well Sable Island C-67 is Campanian to Plio-Pleistocene. Hardy (1975) subdivided the Banquereau into four informal units but these appear to be locally restricted in the Scotian Basin. Subsequent authors, including McAlpine (1990), have extended the Banquereau to the Jeanne d'Arc Basin and recognized an informal subdivision, the South Mara unit. Sinclair (1988) was the first to refer to the South Mara member, which he defined as a set of submarine fans from 1895-1864 m in the South Mara C-13 well. He regarded them as reworked Upper Cretaceous sands. Although using the term South Mara in his lithostratigraphic column (his fig.8), McAlpine (1990) did not give any definition other than considering it basal Banquereau. McAlpine (1989), however, designated the interval 1227-1100 m in Terra Nova K-18 as the South Mara unit and 1227 to -1.0 as Banquereau. My age for the South Mara is Danian-Thantian early to late Paleocene. Thomas (1994, 1995) considered the South Mara unit to be Ypresian and deposited in bathyal waters at the type section, South Mara C-13.

### Summary

Terra Nova K-18 has a Kimmeridgian-Valanginian section, which contains rich dinocyst, spore and pollen assemblages indicative of neritic environments. Within this interval are the type sections for the Jeanne d'Arc Formation (3413-3050 m) and the Fortune Bay Shale (3050-2840 m). Based on the dinocysts and spores, I have designated the Jeanne d'Arc as mid Kimmeridgian and the Fortune Bay as late Kimmeridgian. Because of the poor quality of the sidewall core samples and the unavailability of the cuttings samples, I could not determine the age of the Eastern Shoals, Avalon and Ben Nevis

formations. This leaves a major gap in our knowledge, especially as there are three unconformities according to McAlpine (1989).

In the Late Cretaceous, the relatively sparse palynomorph assemblages make age determinations more problematic. The Tertiary, however, contains abundant dinocysts that I can correlate with northwest European sections. In the Selandian-Thanetian (mid-late Paleocene), there are three *Areoligera* abundance peaks and one *Apectodinium* abundance peak. The *Areoligera* events relate to Thanetian maximum-flooding events seen in the type section. The *Apectodinium* event probably equates with the worldwide late Paleocene thermal maximum event (LPTM).

Another important result from my study of the Terra Nova K-18 palynomorphs is that I can extend the age of the South Mara unit down into the Selandian-Thanetian. This should provide further age control for this unit, which Deptuck *et al.* (in press) are formalizing. Such a step is necessary, because the Banquereau Formation is too all-encompassing. I'm convinced that with more detailed studies, we can further subdivide this formation in its younger part and elevate it to group status, a long overdue division.

Figure 1. Stratigraphy and paleoecology of Petro-Canada *et al.* Terra Nove K-18. The lithological picks are from McAlpine (1989).

#### References

Ascoli, P.

1988: Mesozoic-Cenozoic foraminiferal, ostracod and calpionellid zonation of the north Atlantic margin of North America: Georges Bank-Scotian basins and northeast Grand Banks (Jeanne d'Arc, Carson and Flemish Pass basins). Biostratigraphic correlation of 51 wells. Geological Survey of Canada, Open File 1791, 41 p.

Bujak-Davies Group

1987: Palynological atlas and zonation for the Oxfordian to Turonian of North America and Europe: terrigenous miospores. Bujak Davies Group Report for the Geological Survey of Canada, v.A-M.

Bujak-Davies Group

1988b: Palynological analysis charts of 19 wells from the Grand Banks - Report No. 87-0066, 88-0008. Geological Survey of Canada Open File 1886, 2 volumes

Bujak-Davies Group

1988c: Palynological biostratigraphy of the interval 935-4625 m, Whiterose N-22, Grand Banks - Report No. 87-0066. Geological Survey of Canada, Open File 1885, 25 p.

Bujak-Davies Group

1988d: Palynological analysis charts of 19 wells from the Grand Banks - Report No. 87-0066, 88-0008. Geological Survey of Canada, Open File 1886, 2 volumes.

Bujak, J.P. and Brinkhuis, H.

1998: Global warming and dinocyst changes across the Paleocene/Eocene Epoch boundary. *In:* Aubry, M.-P. *et al.* (eds.), Late Paleocene-early Eocene biotic and climatic events in the marine and terrestrial records. Columbia University Press, New York, p.277-295.

Bujak, J.P. and Williams, G.L.

1978: Cretaceous palynostratigraphy of offshore southeastern Canada. Geological Survey of

Canada, Bulletin, no.297, 19 p., 3 pl.

Cornet, B. and Traverse, A.

1975: Palynological contributions to the chronology and stratigraphy of the Hartford Basin in Connecticut and Massachusetts. *Geoscience and Man*, v.11, p.1-33, pl.1-8.

Crouch, E.M., Heilmann-Clausen, C., Brinkhuis, H., Morgans, H.E.G., Rogers, K.M., Egger, H. and Schmitz, B.

2001: Global dinoflagellate event associated with the late Paleocene thermal maximum. *Geology*, v.29, no.4, p.315-318.

Davey, R.J.

1969: Non-calcareous microplankton from the Cenomanian of England, northern France and North America, part I. *British Museum (Natural History) Geology, Bulletin*, v.17, p.103-180, pl.1-11.

Deptuck, M.E., MacRae, R.A., Shimeld, J.W., Williams, G.L. and Fensome, R.A.

In press: Revised upper Cretaceous and Paleogene lithostratigraphy and depositional history for the Jeanne d'Arc Basin, offshore Newfoundland, Canada. *American Association of Petroleum Geologists, Bulletin*.

Dettmann, M.E.

1963: Upper Mesozoic microfloras from south-eastern Australia. *Proceedings of the Royal Society of Victoria, new series*, v.77, pt.1, p.1-148.

Duxbury, S.

1977: A palynostratigraphy of the Berriasian to Barremian of the Speeton Clay of Speeton, England. *Palaeontographica, Abteilung B*, v.160, no.1-3, p.17-67, pl.1-15.

Duxbury, S.

2001: A palynological zonation scheme for the Lower Cretaceous - United Kingdom Sector, Central North Sea. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, v.219, p.95-137.

Elsik, W.C.

1977: *Paralecaniella indentata* (Defl. & Cooks. 1955) Cookson and Eisenack 1970 and allied dinocysts. *Palynology*, v.1, p.95-102, pl.1-2.

Gradstein, F.M. and Ogg, J.

1996: Phanerozoic time scale. *Episodes*, v.19, pts.1-2, p.3-5.

Hardy, I.A.

1975: Lithostratigraphy of the Banquereau Formation of the Scotian Shelf. In: Van der Linden, W.J.M. and Wade, J.A. (eds.), *Offshore Geology of Eastern Canada, Volume 2, Regional Geology*, Paper 74-30, vol.2, p.163-174.

Manum, S.B. and Cookson, I.C.

1964: Cretaceous microplankton in a sample from Graham Island, arctic Canada, collected during the second "Fram" expedition (1898-1902). With notes on microplankton from the Hassel Formation, Ellef Ringnes Island. *Norske Videnskaps-Akademi i Oslo*, I.

Matematisk-Naturvidenskapelig Klasse, Skrifter, Ny Serie, no.17, p.1-36, pl.1-7.

McAlpine, K.D.

1979: Lithostratigraphy of fifty-nine wells, Jeanne d' Arc Basin. Geological Survey of Canada, Open File 2201, 97 p.

McAlpine, K.D.

1990: Mesozoic stratigraphy, sedimentary evolution, and petroleum potential of the Jeanne d' Arc Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Paper 89-17, 50 p.

McIntyre, D.J.

1975: Morphologic changes in *Deflandrea* from a Campanian section, District of Mackenzie, N.W.T., Canada. *Geoscience and Man*, v.11, p.61-76, pl.1-4.

McIver, N.L.

1972: Cenozoic and Mesozoic stratigraphy of the Nova Scotia Shelf. *Canadian Journal of Earth Sciences*, v.9, p.54-70.

Michoux, D.

1985: Wetzelloideae from southwestern France. *In: Dino III, Abstract Handout*, p.2.

Monteil, M.

1990: Interet des dinokystes dans le Crétacé inférieur: morphologie, systématique, bio- et morphostratigraphie. Unpublished Doctor of Science thesis, University of Geneva, Switzerland, 224 p, 27 pl.

Norris, G.

1969: Miospores from the Purbeck and marine Upper Jurassic of southern England. *Palaeontology*, v.12, pt.4, p.574-620, pl.102-113.

Powell, A.J., Brinkhuis, H. and Bujak, J.P.

1996: Upper Paleocene-Lower Eocene dinoflagellate cyst sequence biostratigraphy of southeast England. *In: Knox, R.W O'B., Corfield, R.M. and Dunay, R.E. (eds.), Correlation of the Early Paleogene in Northwest Europe. Geological Society Special Publication, no.101, p.145-183.*

Riding, J.B., Poulsen, N.E. and Bailey, D.A.

2001: A taxonomic study of the dinoflagellate cyst *Muderongia simplex* Alberti 1961 and related species. *Palynology*, v.24, p.21-35, pl.1.

Sinclair, I.K.

1988: Evolution of Mesozoic-Cenozoic sedimentary basins in the Grand Banks area of Newfoundland and comparison with Falvy's (1974) rift model. *Bulletin of Canadian Petroleum Geology*, v.36, p.255-273.

Singh, C.

1971: Lower Cretaceous microfloras of the Peace River area, northeastern Alberta. *Research Council of Alberta Bulletin*, v.28, 542 p.

Stover, L.E., Brinkhuis, H., Damassa, S.P., de Verteuil, L., Helby, R.J., Monteil, E., Partridge, A.D.,

- Powell, A.J., Riding, J.B., Smelror, M. and Williams, G.L.  
 1996: 19. Mesozoic-Tertiary dinoflagellates, acritarchs and prasinophytes. *In*: Jansonious, J, and McGregor, D.C. (eds.), *Palynology: Principles and Applications*, Volume 2, p.641-750; American Association of Stratigraphic Palynologists Foundation, Dallas, U.S.A.
- Thomas, F.C.  
 1994: Preliminary Cenozoic micropaleontological biostratigraphy of 16 wells, Jeanne d'Arc Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 2799, 54 p.
- Thomas, F.C.  
 1995: A Paleogene radiolarian event of the South Mara unit, Banquereau Formation, Jeanne d'Arc Basin, offshore Newfoundland and its implications. *In*: Geological Survey of Canada, Current Research, 1995-E, p.211-220.
- Williams, G.L.  
 1975: Dinoflagellate and spore stratigraphy of the Mesozoic-Cenozoic, offshore eastern Canada. Geological Survey of Canada, Paper 74-30, v.2, p.107-161, pl.1-8.
- Williams, G.L. and Brideaux, W.W.  
 1975: Palynologic analyses of upper Mesozoic and Cenozoic rocks of the Grand Banks, Atlantic continental margin. Geological Survey of Canada, Bulletin, no.236, 163 p., 47 pl.
- Williams, G.L. and Bujak, J.  
 1985: Mesozoic and Cenozoic dinoflagellates. *In*: Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K. (eds.), *Plankton Stratigraphy*. Cambridge University Press, Cambridge, p.847-964.
- Williams, G.L., Lentin, J.K. and Fensome, R.A.  
 1998: The Lentin and Williams index of fossil dinoflagellates 1998 edition. American Association of Stratigraphic Palynologists Foundation, 817 p.
- Williams, G.L., Ascoli, P., Barss, M.S., Bujak, J.P., Davies, E.H., Fensome, R.A. and Williamson, M.A.  
 1990: Chapter 3. Biostratigraphy and related studies. *In*: Keen, M.J. and Williams, G.L. (eds.), *Geology of the continental margin of eastern Canada*; Geological Survey of Canada, Geology of Canada, no.2 (also Geological Society of America, the Geology of North America, v. I-1), p.87-137.
- Williams, G.L. Bujak, J.P., Brinkhuis, H., Fensome, R.A. and Weegink, J.W.  
 1999: Mesozoic-Cenozoic dinoflagellate cyst course, Urbino, Italy, May 17-22, 1999.
- Williams, G.L., Boessenkool, K.P, Brinkhuis, H., Pearce, M.A., Fensome, R.A. and Weegink, J.W.  
 2001: Upper Cretaceous - Neogene dinoflagellate cyst course: morphology, stratigraphy and (paleo)ecology, Urbino, Italy, June 4-8, 2001.
- Williams, G.L., Brinkhuis, H., Pearce, M.A., Fensome, R.A. and Weegink, J.W.  
 In press: Southern Ocean and global dinoflagellate cyst events compared: index events for the Late Cretaceous-Neogene. Ocean Drilling Program, College Station, Scientific Reports.

Williamson, M.A.

1987: A quantitative foraminiferal biozonation of the Late Jurassic and Early Cretaceous of the East Newfoundland Basin. *Micropaleontology*, v.33, no.1, p.37-65.

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## Appendix A

References for dinoflagellate citations are from Williams *et al.* (1998). References for spore and pollen citations are from Dettmann (1963) and Singh (1971). Informal taxa will be illustrated in one of the proposed palyatlas.

*Achomosphaera neptuni* (Eisenack, 1958a) Davey and Williams, 1966a  
*Achomosphaera neptuni* subsp. “*brevispina*”  
*Adnatosphaeridium caulleryi* (Deflandre, 1939a) Williams and Downie, 1969  
*Adnatosphaeridium multispinosum* Williams and Downie, 1966c  
*Aequitriradites baculatus* Doring, 1964  
*Aequitriradites spinulosus* (Cookson and Dettmann, 1958) Cookson and Dettmann, 1961  
*Aequitriradites subverrucosus* Doring, 1966  
*Alisocysta margarita* (Harland, 1979a) Harland, 1979a  
*Amphorula delicata* van Helden, 1986  
*Amphorula metaelliptica* Dodekova, 1969  
*Apectodinium augustum* (Harland, 1979c) Lentin and Williams, 1981  
*Apectodinium quinquelatum* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Areoligera guembelii* Kirsch, 1991  
*Areoligera* cf. *medusettiformis* O. Wetzel, 1933b  
*Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971  
*Auritulinasporites deltaformis* Burger, 1966  
“*Axiodinium*” *ovale*  
*Baltisphaeridium* “*scalenofurcatum*”  
*Batioladinium jaegeri* (Alberti, 1961) Brideaux, 1975  
*Batioladinium longicornutum* (Alberti, 1961) Brideaux, 1975  
*Batioladinium* “*mutabilis*”  
*Callaiosphaeridium asymmetricum* (Deflandre and Courteville, 1939) Davey and Williams, 1966b  
*Callialasporites dampieri* (Balme, 1957) Sukh Dev, 1961  
*Callialasporites obrutus* Norris, 1969  
*Callialasporites trilobatus* (Balme) Sukh Dev, 1961  
*Camarozonosporites insignis* Norris, 1967  
*Canningia reticulata* Cookson and Eisenack, 1960b  
*Canningia* cf. *reticulata* sensu Duxbury, 1977  
*Cantulodinium arthuriae* van Helden, 1986  
*Cassiculosphaeridia magna* Davey, 1974  
*Cerbia tabulata* (Davey and Verdier, 1974) Below, 1981a  
*Cerebropollenites* sp.  
*Cerebropollenites macroverrucosus* (Thiergart) Schultz, 1967  
*Cerodinium* “*glabrum*”  
*Cerodinium speciosum* (Alberti 1959b) Lentin and Williams, 1987  
*Chatangiella ditissima* (McIntyre, 1975) Lentin and Williams, 1976  
*Chatangiella tripartita* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Chlamydophorella nyei* Cookson and Eisenack, 1958  
*Cicatricosisporites* #EM Davies in Bujak-Davies, 1987  
*Cicatricosisporites* #ES Davies in Bujak-Davies, 1987  
*Cicatricosisporites annulatus* Archangelsky and Gamero, 1966  
*Cicatricosisporites crassistriatus* Burger, 1966  
*Cicatricosisporites hughesii* Dettmann, 1963  
*Cicatricosisporites pseudotripartitus* (Bolkhovitina, 1961) Dettmann, 1963  
*Cicatricosisporites purbeckensis* Norris, 1969

*Cicatricosisporites subrotundus* Brenner, 1963  
*Cicatricosisporites versiformis* Doring, 1965  
*Cingutriteles "terranovae"*  
*Circulodinium distinctum* (Deflandre and Cookson, 1955) Jansonius, 1986  
*Circulodinium distinctum* subsp. "*brevispinum*"  
*Circulodinium distinctum* subsp. "*magnum*"  
*Cleistosphaeridium diversispinosum* subsp. "*brevispinum*"  
*Cleistosphaeridium huguoniotii* (Valensi, 1955a) Davey, 1969a  
*Cleistosphaeridium "terranovae"*  
*Comasphaeridium* cf. *cometes*  
*Contignisporites cooksoniae* (Balme, 1957) Dettmann, 1963  
*Contignisporites fornicatus* Dettmann, 1963  
*Contignisporites glebulentus* Dettmann, 1963  
*Convrrucosisporites exquisitus* Singh, 1971  
*Convrrucosisporites variverrucatus* (Couper, 1958) Norris, 1969  
*Cordosphaeridium gracile* (Eisenack, 1954b) Davey and Williams, 1966b  
*Cordosphaeridium* cf. *eoinodes* (Eisenack, 1958a) Eisenack, 1963b  
*Corollina echinata* (Burger, 1965) Dörhöfer, 1979  
*Corollina itunensis* (Pocock, 1962) Cornet and Traverse, 1973  
*Corollina torosus* (Reissinger) Klaus, 1960  
*Corollina vignollensis* (Reyre, 1970)  
*Coronatisporites valdensis* (Couper, 1958) Dettmann, 1963  
*Coronifera oceanica* Cookson and Eisenack, 1958  
*Corrudinium incompositum* (Drugg, 1970b) Stover and Evitt, 1978  
*Cribroperidinium longicorne* (Downie, 1957) Lentin and Williams, 1985  
*Ctenidodinium elegantulum* Millioud, 1969  
*Ctenidodinium schizoblatum* (Norris, 1965) Lentin and Williams, 1973  
*Cyclonephelium* sp. A Williams and Brideaux, 1975  
*Cyclonephelium* sp. B Williams and Brideaux, 1975  
*Cyclonephelium hughesii* Clarke and Verdier, 1967  
*Cyclonephelium vannophorum* Davey, 1969a  
*Cymososphaeridium validum* Davey, 1982b  
*Dapsilidinium laminaspinosum* (Davey and Williams, 1966b) Lentin and Williams, 1981  
*Deflandrea denticulata* Alberti, 1959b  
*Deflandrea heterophlycta* Deflandre and Cookson, 1955  
*Densoisporites microrugulatus* Brenner, 1963  
*Densosporites* sp.  
*Dichadogonyaulax pannea* (Norris, 1965) Sarjeant, 1969  
*Dingodinium cerviculum* Cookson and Eisenack, 1958  
*Dingodinium "endocornum"*  
*Dinogymnium* Evitt *et al.*, 1967  
*Dinogymnium heterocostatum* (Deflandre, 1936b) Evitt *et al.*, 1967  
*Dinopterygium cladoides* Deflandre, 1935  
*Diphyes colligerum* (Deflandre and Cookson, 1955) Cookson, 1965a  
*Discorsia nannus* (Davey, 1974) Duxbury, 1977  
*Dissiliodinium* sp.  
*Dracodinium condylos* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Dracodinium varielongitudum* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Druggidium apicopaucicum* Habib, 1973  
*Egmontodinium expiratum* Davey, 1982b  
*Egmontodinium toryna* (Cookson and Eisenack, 1960b) Davey, 1979c  
*Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967

*Epiplosphaera areolata* Klement, 1960  
*Epiplosphaera areolata* subsp. “*magna*”  
*Epiplosphaera bireticulata* Klement, 1960  
*Epiplosphaera gochtii* (Fensome, 1979) Brenner, 1988  
*Epiplosphaera gochtii* subsp. “*magna*”  
*Epiplosphaera reticulata* (Valensi, 1953) Courtinat, 1989  
*Exochosphaeridium bifidum* (Clarke and Verdier, 1967) Clarke *et al.*, 1968  
*Extratropopollenites* spp.  
*Florentinia buspina* (Davey and Verdier, 1976) Duxbury, 1980  
*Florentinia ferox* (Deflandre, 1937b) Duxbury, 1980  
*Florentinia perforata* Firth, 1993  
*Florentinia radiculata* (Davey and Williams, 1966b) Davey and Verdier, 1973  
*Geiselodinium paemosum* Drugg, 1978  
*Glaphyrocysta* “*aexuberans*”  
*Glaphyrocysta divaricata* (Williams and Downie, 1966c) Stover and Evitt, 1978  
*Glaphyrocysta intricata* (Eaton, 1971) Stover and Evitt, 1978  
*Glaphyrocysta laciniiformis* (Gerlach, 1961) Stover and Evitt, 1978  
*Glaphyrocysta ordinata* (Williams and Downie, 1966c) Stover and Evitt, 1978  
*Glaphyrocysta* “*preordinata*”  
*Glaphyrocysta spineta* (Eaton, 1976) Stover and Evitt, 1978  
*Galphyroxysta texta* (Bujak, 1976) Stover and Evitt, 1978  
*Glossodinium* cf. *dimorphum* Ioannides *et al.*, 1977  
*Gochteodinia mutabilis* (Riley in Fisher and Riley, 1980) Fisher and Riley, 1982  
*Gochteodinia* “*unimutabilis*”  
*Gothanipollis* Krutzsch, 1959  
Gramineae spp.  
*Hafniasphaera hyalospinosa* Hansen, 1977  
*Heslertonia heslertonensis* (Neale and Sarjeant, 1962) Sarjeant, 1966b  
*Heteraulacacysta leptalea* Eaton, 1976  
*Histiophora ornata* Klement, 1960  
*Horologinella* Cookson and Eisenack, 1962a  
*Hystrichodinium furcatum* Alberti, 1961  
*Hystrichodinium pulchrum* Deflandre, 1935  
*Hystrichodinium voigtii* (Alberti, 1961) Davey, 1974  
*Hystrichodinium voigtii* subsp. “*brevibrevispinum*”  
*Hystrichodinium voigtii* subsp. “*brevispinum*”  
*Hystrichodinium voigtii* subsp. *membranobrevispinum*  
*Hystrichokolpoma* “*septarientonense*”  
*Hystrichosphaeridium bowerbankii* Davey and Williams, 1966b  
*Hystrichosphaeridium petilum* Gitmez, 1970  
*Hystrichosphaeridium salpingophorum* Deflandre, 1935  
*Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre, 1937b  
*Hystrichosphaeridium tubiferum* subsp. “*perforatum*”  
*Hystrichosphaerina schindewolfii* Alberti, 1961  
*Hystrichostrogylon* sp.  
*Impardecispora* #A Dörhöfer, 1977  
*Impardecisporites macrotuberculata* (Kara Murza, 1957)  
*Impletosphaeridium insolitum* Eaton, 1976  
*Inperturopollenites* sp. #EA Davies, 1987  
*Isabelidinium cooksoniae* (Alberti, 1959b) Lentin and Williams, 1977a  
*Ischyosporites amplireticosus* Doring, 1973  
*Kiokansium williamsii* C. Singh, 1983

*Kleithriasphaeridium "aculeatum"*  
*Kleithriasphaeridium fasciatum* (Davey and Williams, 1966b) Davey, 1974  
*Kleithriasphaeridium "hibernium"*  
*Kleithriasphaeridium loffreense* Davey and Verdier, 1976  
*Kleithriasphaeridium simplicispinum* (Davey and Williams, 1966b) Davey, 1974  
*Klukisporites foveolatus* Pocock, 1964  
*Klukisporites pseudoreticulatus* Couper, 1958  
*Laciniadinium arcticum* (Manum and Cookson, 1964) Lentin and Williams, 1980  
*Lanterna bulgarica* Dodekova, 1969  
*Lanterna sportula* Dodekova, 1969  
*Lentinia "glabra"*  
*Lentinia serrata* Bujak in Bujak *et al.*, 1980  
*Leptodinium "amoco"*  
*Leptodinium millioudii* (Sarjeant, 1963c) Sarjeant, 1969  
*Leptolepidites psarosus* Norris, 1969  
*Litosphaeridium siphoniphorum* (Cookson and Eisenack, 1958) Davey and Williams, 1966b  
*Lycopodiacidites cerniipites* (Ross, 1949) Norris, 1969  
*Lycopodiumsporites austroclavatidites* (Cookson, 1954) Potonié, 1956  
*Meiourogonyaulax stoveri* Millioud, 1969  
*Membranophoridium aspinatum* Gerlach, 1961  
*Mendicodinium reticulatum* Morgenroth, 1970  
*Mendicodinium "rugulatum"*  
*Microdinium irregulare* Clarke and Verdier, 1967  
*Microdinium veligerum* (Deflandre, 1937b) Davey, 1969a  
*"Muderongia sp.A* Davey, 1979  
*Muderongia staurota* Sarjeant, 1966c  
*Nodosporites babsae* (Brenner, 1963) Davies, 1985  
*Nyktericysta vitrea* (Duxbury, 1983) Bint, 1986  
*Occisucysta balios* Gitmez, 1970  
*Occisucysta "distincta"*  
*Occisucysta tentoria* Duxbury, 1977  
*Odontochitina costata* Alberti, 1961  
*Oligosphaeridium asterigerum* (Gocht, 1959) Davey and Williams, 1969  
*Oligosphaeridium complex* (White, 1842) Davey and Williams, 1966b  
*Oligosphaeridium diluculum* Davey, 1982b  
*Oligosphaeridium cf. patulum* Riding and Thomas, 1988  
*Oligosphaeridium pulcherrimum* (Deflandre and Cookson, 1955)  
*Oligosphaeridium "terranovae"*  
*Operculodinium divergens* (Eisenack, 1954b) Stover and Evitt, 1978  
*Palaeocystodinium bulliforme* Ioannides, 1986  
*Palaeohystrichophora infusorioides* Deflandre, 1935  
*Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b  
*Paralecaniella indentata* (Deflandre and Cookson, 1955) Cookson and Eisenack, 1970b  
*Parvisaccites* sp.  
*Perisseiasphaeridium ingegerdiae* Nøhr-Hansen, 1986  
*Pervosphaeridium monasteriense* Yun Hyesu, 1981  
*Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969  
*Phoberocysta neocomica* subsp. *cruciformis* (Gocht, 1957) Lentin and Williams, 1973  
*Phthanoperidinium amoenum* Drugg and Loeblich Jr., 1967  
*Phthanoperidinium coreoides* (Benedek, 1972) Lentin and Williams, 1976  
*Phthanoperidinium crenulatum* (de Coninck, 1975) Lentin and Williams, 1977b  
*Phthanoperidinium "hibernium"*

*Phthanoperidinium levimurum* Bujak in Bujak *et al.*, 1980  
*Phthanoperidinium multispinum* Bujak in Bujak *et al.*, 1980  
*Pilosisorites verus* Delcourt and Sprumont, 1955  
*Pilosisorites* sp.A Bujak and Williams, 1977  
*Pilosisorites trichopapillosus* (Thiergart) Delcourt and Sprumont, 1955  
*Plicatella bilateralis* (Singh, 1971) Dörhöfer, 1977  
*Plicatella potomacensis* (Brenner, 1963) Davies, 1985  
*Polycingulatisporites reduncus* (Bolkhovitina, 1953) Playford and Dettmann, 1965  
*Prolixosphaeridium granulosum* (Deflandre, 1937b) Davey *et al.*, 1966  
*Psalinonyaulax deflandrei* Sarjeant, 1966b  
*Pseudoceratium eisenackii* (Davey, 1969a) Bint, 1986  
*Pseudoceratium pelliferum* Gocht, 1957  
*Pterospermopsis helios* Sarjeant, 1959  
*Raetiaedinium truncigerum* (Deflandre, 1937b) Kirsch, 1991  
*Rhynchodiniopsis cladophora* subsp. *hemipolyedrica* (Klement, 1960) Below, 1981a  
*Rottnestia borussica* (Eisenack, 1954b) Cookson and Eisenack, 1961b  
*Rubinella major* (Couper, 1958) Norris, 1969 sensu Norris, 1969  
*Rugubivesiculites rugosus* Pierce, 1961  
*Samlandia chlamydotheca* Eisenack, 1954b  
*Schematophora speciosa* Deflandre and Cookson, 1955  
*Scriniodinium crystallinum* (Deflandre, 1939a) Klement, 1960  
*Scriniodinium inritibile* Riley in Fisher and Riley, 1980  
*Senegalinium* sp.  
*Senoniasphaera jurassica* (Gitmez and Sarjeant, 1972) Lentin and Williams, 1976  
*Sentusidinium rioultii* (Sarjeant, 1968) Stover and Sarjeant, 1978  
*Sentusidinium rioultii* subsp. "*minispinum*"  
*Sequoapollenites* sp.  
*Spinidinium echinoideum* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Spiniferites* sp. "W"  
*Spiniferites dentatus* (Gocht, 1959) Lentin and Williams, 1973  
*Spiniferites "duplifurcatus"*  
*Spiniferites "procerus"*  
*Spiniferites pseudofurcatus* subsp. "*brevispinus*"  
*Spiniferites speciosus* (Deflandre, 1937b) Sarjeant, 1970  
*Spongodinium delitiense* (Ehrenberg, 1838) Deflandre, 1936b  
*Striatella* #EAB Davies in Bujak-Davies, 1987  
*Striatella* #EE Davies in Bujak-Davies, 1987  
*Striatella* #EJ Davies in Bujak-Davies, 1987  
*Striatella* #ET Davies in Bujak-Davies, 1987  
*Surculosphaeridium longifurcatum* (Firtion, 1952) Davey *et al.*, 1966  
*Surculosphaeridium* cf. *longifurcatum*  
*Systematophora complicata* Neale and Sarjeant, 1962  
*Systematophora "diversispinosa"*  
*Systematophora penicillata* (Ehrenberg, 1843b) Sarjeant, 1980a  
*Systematophora "scotensis"*  
*Systematophora silybum* Davey, 1979a  
*Systematophora valensii* (Sarjeant, 1960a) Sarjeant, 1961b  
*Systematophora vestita* (Deflandre, 1939a) Davey, 1982b  
"*Talladinium*" *coleothryptum*  
*Tanyosphaeridium magdali* (Drugg, 1967) Heisecke, 1970  
*Tanyosphaeridium variecalamum* Davey and Williams, 1966b  
*Tectatodinium pellitum* Wall, 1967

*Trichodinium castanea* Deflandre, 1935  
*Trilobosporites apiverrucatus* Couper, 1958  
*Trilobosporites bernissartensis* (Delcourt and Sprumont, 1959) Potonié, 1956  
*Trilobosporites granulatus* Doring, 1965  
*Trilobosporites marylandensis* Brenner, 1963  
*Trilobosporites obsitus* Norris, 1969  
*Triquitrites* spp.  
*Trithyrodinium* “*granulatum*”  
*Trithyrodinium* “*scabratum*”  
*Tubotuberella apatela* (Cookson and Eisenack, 1960b) Ioannides *et al.*, 1977  
*Turbiosphaera filosa* (Wilson, 1967a) Archangelsky, 1969a  
*Uvaesporites glomeratus* Doring, 1965  
*Vitreisporites pallidus* (Reissinger) Potonié, 1960  
*Wetzeliella gochtii* Costa and Downie, 1976  
*Wilsonidium compactum* Michoux, 1988  
*Xenascus australiensis* Cookson and Eisenack, 1969  
*Xenascus ceratioides* (Deflandre, 1937b) Lentin and Williams, 1973  
*Xenascus ceratioides* subsp. “*perforatus*”  
*Xenascus sarjeantii* (Corradini, 1973) Stover and Evitt, 1978  
*Xenascus serpaglio* (Corradini, 1973) Stover and Evitt, 1978  
*Xiphophoridium alatum* (Cookson and Eisenack, 1962b) Sarjeant, 1966b



D259 Petro-Canada et al. TERRA NOVA K-18  
KB: 24.4 m; WD: 91.4 m; TD: 3925.6 m

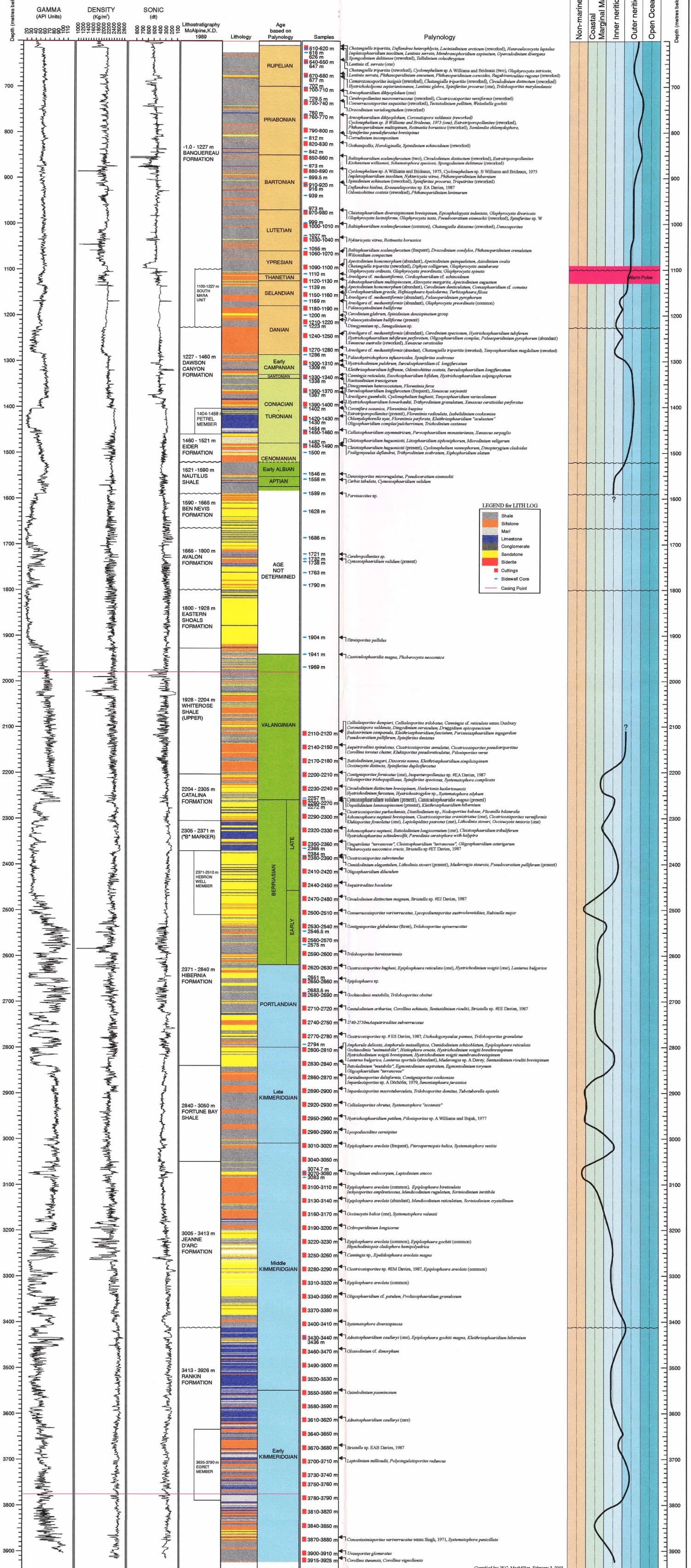


Figure 1. Stratigraphy and paleoecology of Petro-Canada et al. Terra Nova K-18. The lithostratigraphic picks are from McAlpine (1989)

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