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**Palynological Analysis of  
Amoco-Imperial Cormorant N-83,  
Jeanne d'Arc Basin, Grand Banks of Newfoundland**

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G.L. Williams

2006



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Palynological analysis of Amoco-Imperial Cormorant N-83, Jeanne d'Arc Basin, Grand Banks of Newfoundland.

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G.S.C. Locality No.: D-83

Location: 46°2'45"N, 48°58'2"W

Elevation Sea level to R.T.: 29.9 m (98.1')      Water Depth: 65.8 m (215.9')

Total Depth: 3160.5 m (10,369')

Spud Date: 30 August 1972      Interval Studied: 274.32-3154.69 m (900-10,350')

Casing Points: 762 mm at 146.3 m (30" at 480'); 508 mm at 256 m (20" at 840'); 340 mm at 765 m (13 5/8" at 2510'); 244 mm at 2972.7 m (9 5/8" at 9753')

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### Introduction

The Amoco-Imperial Cormorant N-83 well is located on the southern edge of the Jeanne d'Arc Basin. It was drilled on a salt structure, penetrating 350 m of Argo Salt before entering basalt at 2940 m. Underlying the basalt is 185 m of the Eurydice Formation.

The biostratigraphy presented in this report is based on the analysis of 139 drill cuttings samples from the interval 274-3154 m. All the slides are the property of the Geological Survey of Canada (GSC) and were processed at GSC Atlantic. Unfortunately, I was not able to obtain the Company sidewall cores, although I did manage to retrieve some data from my analysis sheets of the late seventies.

### Biostratigraphy

My stratigraphic breakdown for Cormorant N-83 (Figure 1) is based on the dinoflagellate cysts (dinocysts), spores and pollen. The known stratigraphic ranges of dinocysts in European sections (Williams *et al.*, 1999, 2001, in press) and in other wells and core holes on the Scotian Margin and Grand Banks [Williams, 1975; Williams and Brideaux, 1975; Barss *et al.*, 1979 (Table 1); Bujak Davies Group, 1987; Williams *et al.*, 1990; Williams, 2003a, b, c, d and in press] provide most of the age control. I have obtained compatible biostratigraphic data for spores and pollen from Batten and Koppelhus (1996) and from the PALYNODATA database, a copy of which is at GSC Atlantic. PALYNODATA has been compiled over the last 30 years by a consortium of several major oil companies and the GSC. The database stores taxonomic, bibliographic, geographic and biostratigraphic information from 20,000 pre-Quaternary palynological publications.

Cormorant N-83 has a total depth of 3154.7 m, with the deepest sample being a cuttings sample at 3145-3154 m. The interval 3154-2157 m contains poor to abundant spore and pollen assemblages but no dinocysts. From 3154 to 2980 m (probably slightly higher because this is in the basalt) I consider it to be Rhaetian. I pick the Rhaetian top on the last appearance datum (LAD) of the pollen *Chasmatosporites magnoloides* and *Tsugaepollenites pseudomassulae*. Both species were recorded from the Rhaetian of Austria by Morbey (1975). There are occasional records of *Chasmatosporites magnoloides* from post-Rhaetian strata (e.g. Riding *et al.*, 1991) but they are commonly from offshore (e.g. Warrington and Owens, 1977), where age assignments are often difficult. Post-Rhaetian records of *Tsugaepollenites pseudomassulae* are not convincing.

The Hettangian-Sinemurian extends from 2980 to 2139 m. This is based on the presence of the dinocyst *Mancodinium semitabulatum* in the sidewall core at 2130.4 m. Since the first appearance datum (FAD) of this species is at 181.73 Ma (Williams *et al.*, 1999), this sidewall core can be no older than Pliensbachian.

I assign from 2130.6 to 1911 m to the Pliensbachian, based on the presence of *Luehndea spinosa* in the cuttings sample at 1911-1920 m. Williams *et al.* (1999) placed the LAD of *Luehndea spinosa* at 188.26 Ma. This is just above the Pliensbachian-Toarcian boundary, which Gradstein and Ogg (1996) give as 189.6 Ma. The FAD of *Luehndea spinosa* is in a sidewall core at 1991.9 m. Williams *et al.* (1999) placed the FAD of this species at 191.73 Ma, which is within the late Pliensbachian.

Another dinocyst species with its LAD in the cuttings sample at 1911-1920 m is *Nannoceratopsis spiculata*. Bucefalo Palliani and Riding (1997) show a FAD for this species at about 187 Ma, within the Toarcian. I am assuming that this occurrence represents caving.

Several *Nannoceratopsis* taxa have their LADs in the interval 1892-1554 m, which I consider Toarcian. The Toarcian can be subdivided into early and late, based on the range of *Nannoceratopsis symmetrica*. Bucefalo Palliani and Riding (2000) described this species from the early Toarcian. Another species with its LAD in the early Toarcian is *Nannoceratopsis magnicornis*. Bucefalo Palliani and Riding (1997) described this from the Pliensbachian but Bucefalo Palliani (1999) also recorded it from the Toarcian.

I consider the interval 1700-1554 m to be late Toarcian. This is based on the LAD of *Kraeuselisporites reissingeri*, which marks the top of the Toarcian in the Skua E-41 well in the Carson Basin (Williams, 2003c). Bujak and Williams (1977) recorded the LAD of *Kraeuselisporites reissingeri* in their *Echinisporites* cf. *iliacoides* Zone of tentative early Sinemurian-early Pliensbachian age. Batten and Koppelhus (1996) noted, however, that *Kraeuselisporites reissingeri* can be common even in the early Aalenian.

Other dinocysts with their LADs in the Toarcian in Cormorant N-83 include *Scriniocassis priscus*, *Scriniocassis weberi*, *Nannoceratopsis dictyambonis* and *Nannoceratopsis ambonis*. According to Williams *et al.* (1999), *Scriniocassis priscus* has its LAD at 172.8 Ma, which is in the Bajocian, and *Scriniocassis weberi* has its LAD at 176.5 Ma, the top of the Aalenian. In northwest Europe, the LADs for the two species of *Nannoceratopsis* are: *Nannoceratopsis ambonis*, 169.2 Ma; and *Nannoceratopsis dictyambonis*, 174 Ma (Williams *et al.*, 1999).

It appears that the local range of some of the above species is more restricted than in northwest Europe, but there is only one other well with which to compare ranges. This is Skua E-41, in which Williams (2003c) considered the cuttings sample from 2956.6-2965.7 m to be Aalenian, based on the presence of *Scriniocassis weberi*.

Aalenian-Bajocian sediments extend from 1545 to 1261 m based on the LAD of *Nannoceratopsis gracilis* in the cuttings sample at 1261-1271 m. Williams *et al.* (1999) gave a LAD of 172.8 Ma for this species. Since the top of the Bajocian is at 169.2 Ma, I tentatively place the Bajocian top at 1261 m. Other species with their LADs in the Aalenian-Bajocian are the spore *Baculatisporites "giganteus"*, and the dinocysts *Korystocysta gochtii*, *Lithodinia deflandrei*, *Lithodinia valensii* and *Dissiliodinium* sp.1 Feist-Burkhardt and Monteil. Feist-Burkhardt and Monteil (1997), in a study of the type Bajocian, recorded the species *Nannoceratopsis gracilis*, *Dissiliodinium* sp.1, *Lithodinia valensii* and *Korystocysta gochtii*. In their accompanying range chart, they extended the stratigraphic range for *Nannoceratopsis gracilis* into the Bathonian of Great Britain. This agrees with Riding and Thomas (1992) but I follow the

data from the type section, which shows the LAD of *Nannoceratopsis gracilis* at the top of the *Humphriesianum ammonite* Zone in the Bajocian.

Perhaps a more reliable species for picking the top of the Bajocian is *Meiouronyaulax valensii*, which Feist-Burkhardt and Monteil (1997) restricted to the Bajocian, except for Great Britain and southwest Germany, where they extended its range into the zigzag Zone at the base of the Bathonian.

Bujak and Williams (1977) defined a *Nannoceratopsis* Zone of late Pliensbachian-Aalenian age for offshore eastern Canada. Barss *et al.* (1979; Table 1) included in this zone the interval 1955-1554 m in Cormorant N-83. As shown above, in this paper I include most of this interval in the Toarcian. This agrees closely with Barss *et al.* (1979; Table 1) but shows that the improved resolution is changing the stratigraphic range of taxa that were regarded previously as zonal index species.

The *Mancodinium semitabulatum* Zone of Bujak and Williams (1977) was recognized between 1545 and 1344 m in Cormorant N-83 by Barss *et al.* (1979; Table 1). According to Bujak and Williams (1977), this zone is Aalenian-Bajocian. Apparently, the base and top of the *Mancodinium semitabulatum* Zone in Cormorant was determined from analyses of sidewall cores. Bujak and Williams (op. cit.) stated that the index species, *Mancodinium semitabulatum*, has its LAD within the zone. Unfortunately, I did not have access to the sidewall core samples during this study. Regardless, the results are compatible, although I now take the Bajocian higher in the well. From 1243 to 1152 m, I regard as Bathonian. I base this on the FAD of the dinocysts *Ctenidodinium ornatum* and *Gonyaulacysta eisenackii* in the sidewall core sample at 1149 m. These two species have their FADs at 164.4 Ma (Williams *et al.*, 1999). Since this is the Bathonian-Callovian boundary, according to Gradstein and Ogg (1996), it seems reasonable to regard the sidewall core at 1149 m as being just above the top of the Bathonian.

Although the base of the Callovian appears to be at 1149 m, picking the top is more elusive. In Cormorant, I use the LAD of *Leptodinium subtile* at 960-969 m to denote the top of this stage. This is based on a comparison with the nearby Skua E-41, in which Williams (2003c) used the LAD of *Leptodinium subtile* to mark the top of the Callovian. Williams *et al.* (1999) placed the top of this species at 144 Ma at the Kimmeridgian-Portlandian boundary. However, Bujak and Williams (1977) noted that the LAD of *Leptodinium subtile* in offshore eastern Canada was in their *Valensiella vermiculata* Zone of Callovian age. My belief that the Callovian extends from 1149-960 m in Cormorant N-83 shows agreement with Barss *et al.* (1979; Table 1).

The interval 952-932 m appears to be Oxfordian to early Kimmeridgian. The sidewall core at 952.5 m contains the dinocysts *Rhynchodiniopsis cladophora* and *Gonyaulacysta jurassica*. *Rhynchodiniopsis cladophora* is also present in the cuttings sample from 941-932 m. Williams *et al.* (1999) placed the LAD of *Gonyaulacysta jurassica* at 149.36 Ma, which is close to the Kimmeridgian-Tithonian boundary. This approximates with the top of the early Kimmeridgian, if one subdivides the late Jurassic into the Oxfordian, Kimmeridgian and Portlandian. Stover *et al.* (1996), who used these three ages, placed the LAD of *Gonyaulacysta jurassica* at the top of the early Kimmeridgian. Bujak and Williams (1977) defined a *Gonyaulacysta jurassica* Zone, which is dominated by the index species in Grand Banks wells. They and Williams (1975) considered the zone Oxfordian, possibly extending into the early Kimmeridgian. Williams (2003c) used the LAD of common *Gonyaulacysta jurassica* as the top of the Oxfordian, a pick confirmed by the LAD of *Ctenidodinium ornatum* just below.

In Cormorant the LAD of *Gonyaulacysta jurassica* occurs immediately below the LAD of *Rhynchodiniopsis cladophora*. Williams *et al.* (1999) gave an LAD of 149.36 Ma for this species. The Kimmeridgian-Tithonian boundary is just below this at 150.7 Ma. Therefore I consider it reasonable to assign the interval 952-936 m to the Oxfordian-early Kimmeridgian.

From 914 to 850 m, I consider Portlandian. Species with LADs in this interval are *Ctenidodinium culmulum* and *Dichadogonyaulax pannea*. Stover *et al.* (1996) gave the LAD of *Ctenidodinium* (as *Dichadogonyaulax*) *culmulum* as the top of the Ryazanian and *Dichadogonyaulax pannea* as within the Portlandian. Bujak and Williams (1977) listed *Ctenidodinium culmulum* as one of the species with an LAD in the *Ctenidodinium panneum* Zone of Williams (1975). Both Williams (1975) and Bujak and Williams (1977) considered this zone to be Portlandian.

The cuttings sample at 832-822 m contains several spores and pollen, including *Aequitriradites spinulosus*, *Callialasporites dampieri*, *Densosporites microrugulatus* and *Klukisporites pseudoreticulatus*. Williams (2003b) gave the LAD of *Aequitriradites spinulosus* as Valanginian, my reason for assigning the interval 832-822 m to the Berriasian-Valanginian. *Callialasporites dampieri* and *Klukisporites pseudoreticulatus*, according to Williams (2003b), have their LADs in the Barremian.

A major unconformity at 822 m, picked on seismic and lithostratigraphy, separates the Berriasian-Valanginian from overlying Upper Cretaceous sediments. I recognize Cenomanian from 771-804 m based on the presence of the pollen *Corollina torosus* in the sidewall core at 771 m. Williams (1975) gave the LAD for this species as Cenomanian, a view confirmed by the Bujak-Davies Group (1987). Supporting evidence are the dinocysts *Cyclonephelium membraniphutum*, *Microdinium setosum* and *Xiphophoridium alatum* in a sidewall core at 792 m. Sarjeant (1966) described *Microdinium setosum* from the Cenomanian of southern England. Costa and Davey (1992) placed its definitive LAD at the top of the Cenomanian, although they questionably extended it into the Turonian. That this interval is probably Cenomanian is confirmed by the presence of *Xiphophoridium alatum*, which appears to have a LAD within the Cenomanian in other Grand Banks wells.

I consider from 704-658 m to be Turonian. The cuttings sample at 657-666 m contains *Cerbia* cf. *tabulata*, which in other wells on the Grand Banks has an LAD in the Turonian. The only other species having a LAD in this interval is *Triblastula utinensis*, but this usually extends into the Campanian.

Separating some of the late Cretaceous stages is difficult, so I have assigned the interval 658-530 m to the Coniacian-Santonian. The cuttings sample at 493-502 m contains the dinocyst *Raetiaadinium truncigerum*; the cuttings sample at 640-649 m contains *Canningia reticulensis*. According to Williams (2003d), these species have their LADs in the Santonian in the Terra Nova K-18 well in the Jeanne d'Arc Basin. Other dinocysts with LADs in the Coniacian-Santonian of Cormorant N-83 are *Pterodinium cingulatum*, *Senoniasphaera rotundata*, and *Trithyrodinium suspectum*.

The youngest Cretaceous sediments in the well are early Campanian from 493 to 457 m. That this interval can be no younger is denoted by the LAD of the dinocyst *Surculosphaeridium longifurcatum* in the cuttings sample at 457-466 m. Williams *et al.* (in press) gave the LAD of *Surculosphaeridium longifurcatum* as 81.68 Ma. Gradstein and Ogg (1996) placed the Santonian-Campanian boundary at 83.5 Ma, about 2 million years below the LAD of *Surculosphaeridium longifurcatum*. The dinocyst *Trichodinium castanea*, which also occurs in the cuttings sample at 466-457 m, has an LAD of 70.43 Ma (Williams *et al.*, in press). This is very close to the Campanian-Maastrichtian boundary at 71.3 Ma.

Selandian sediments immediately overlie the Campanian and extend from 457 to 411 m. The cuttings sample at 420-411 m contains the dinocyst *Palaeocystodinium bulliforme*. According to Williams *et al.* (in press), the LAD of *Palaeocystodinium bulliforme* is 57.9 Ma. This matches the position of the Selandian-Thauetian boundary, providing substantiation for the age. The LAD of *Spinidinium densispinatum* occurs in the cuttings sample at 438-448 m and those of *Palaeoperidinium pyrophorum* and *Gingidinium ornatum* at 438-429 m. Williams *et al.* (1999) placed the LAD of *Spinidinium densispinatum* at 59.38 Ma just above the Danian-Selandian boundary. *Palaeoperidinium pyrophorum*



has an LAD at 58.04 Ma (Williams *et al.*, in press) and that of *Gingiodinium ornatum* at 56 Ma (Williams *et al.*, 1999). It would appear that both these species have suppressed LADs in Cormorant N-83.

The LAD of *Cerodinium speciosum* occurs in the cuttings sample at 411-402 m. *Cerodinium speciosum* has an LAD at 53.96 Ma (Williams *et al.*, 1999). Therefore, I am considering this interval as Thanetian. In the same sample is the LAD of *Desmocysta "elegantula"*, a dinocyst not previously described.

The Selandian and Thanetian are characterized by abundant specimens of *Areoligera* cf. *medusettiformis* in the cuttings samples at 438-429 m, 429-420 m, 420-411 m and 411-402 m. As I have noted for the Skua E-41 and the Terra Nova K-18 wells (Williams 2003c, 2003d), the high abundance of this taxon also occur in the type Thanetian of southern England. This is discussed further under Paleoenvironments.

I am including the interval 402-377 m tentatively in the Ypresian. This is based on the common occurrence of the acritarch species *Baltisphaeridium scalenofurcatus* in the cuttings sample at 377-384 m. In other wells on the Grand Banks, this species is never common above the Ypresian and has its LAD in the Lutetian. There is also a single occurrence of *Areoligera* cf. *senonensis*. In a study of the nearby St. George J-55 well, Williams (2003b) noted that this taxon had an LAD in the Ypresian. The assemblage is mixed, with several dinocyst species with known Lutetian LADs having their LADs in the designated interval. These include *Glaphyrocysta ordinata* and *Rottnestia borassica* at 377-384 m, *Deflandrea eocenica* at 384-393 m and *Adnatosphaeridium multispinum* at 393-402 m.

Lutetian sediments extend from 377 to 350 m. They are characterized by the LAD of *Alterbidinium? bicellulum* in the cuttings sample at 350-359 m. *Rhombodinium rhomboideum* also has its LAD at 368-377 m.

I regard 350-310 m to be Bartonian because of the LAD of *Glaphyrocysta exuberans*, *Glaphyrocysta intricata*, *Glaphyrocysta pastielsii* and *Schematophora speciosa*. Williams (2003a) regarded the LAD of *Schematophora speciosa* as marking the top of the Bartonian in the Hermine E-94 well on the northeastern margin of the Scotian Basin. Williams *et al.* (1999) gave the range of *Schematophora speciosa* as 36.0 - 35.35 Ma in Southern Hemisphere mid latitudes. Thus, the youngest possible age would be early Priabonian.

The Priabonian appears to be restricted to one cuttings sample from 301-292 m. I determined this on the presence of the two dinocyst species *Areosphaeridium diktyoplokum* and *Corradinium reticulatum*. Williams *et al.* (in press) place the LAD of *Areosphaeridium diktyoplokum* at 33.3 Ma. This is just above the Eocene-Oligocene boundary, which is at 33.7 Ma, but close enough to consider from 301-292 m in Cormorant N-83 as Priabonian.

The two uppermost cuttings samples are at 292-283 m and 283-274 m. I include both in the Rupelian, which is early Oligocene. The sample from 282-274 m is earliest Rupelian. I base this on the LAD of *Svalbardella* cf. *cooksoniae*, which in the nearby St. George well occurs in the earliest Oligocene (Williams, 2003b). The topmost sample from 283-292 m contains *Enneadocysta "cingulomagna"* and *Samlandia chlamydophora*. *Enneadocysta "cingulomagna"* has its LAD in the Rupelian in wells on the Grand Banks (Williams, 2003b), being one of the most consistent markers. And *Samlandia chlamydophora* has an LAD of 30.86 Ma. This is within the Rupelian, which extends from 33.7 - 28.5 Ma.

Barss *et al.* (1979; Table 1) published the biostratigraphy of Cormorant N-83 following the palynological zonation of Williams (1975) and Bujak and Williams (1977). In Figure 1, I have compared their and my results. There is a surprising degree of continuity, especially in the late Triassic and Jurassic. The main differences are in the late Cretaceous and the Paleogene, although even here they are not extreme.

Why would there be any differences, especially when both studies are based on palynological data? I believe there are two reasons. The first is that my analysis was based on reprocessed material. Palynological processing techniques are more sophisticated than twenty years ago, so more specimens are recovered, which helps age determinations. The second major advance is in our understanding of stratigraphic ranges of individual taxa. Numerous publications - such as Williams and Bujak (1985), Stover *et al.* (1996), Williams *et al.* (1999, 2001, in press) - provide detailed information on ranges. And these are usually keyed to type sections or cored deep-sea sections. Thus, ages are more concise resulting in more precise biostratigraphy but much of the old data is still useful.

My reliance, primarily on cuttings samples for determining the stratigraphy in Cormorant N-83, has posed several problems. The most restrictive is having to base all ages on LADs or last occurrences. This removes one of the major controls for reliable age assignments. A second concern is caving which throughout, but especially in the late Cretaceous, is a serious problem. A typical example is the cuttings sample at 493-502 m. This contains hundreds of dinocysts but only three specimens are undisputedly late Cretaceous. A third concern is the difficulty of using quantitative data. I discuss this more in the following section.

#### Paleoenvironments

There are two major pitfalls in using cuttings samples for paleoenvironmental interpretations. One is the difficulty of separating the in situ from the caved palynomorphs. The other is the bias the caved specimens introduce when doing counts. It is still possible to make generalizations, however, providing one has confidence in the biostratigraphy. This explains why my paleoenvironmental plot for Cormorant N-83 does not cover the late Triassic, most of the early Jurassic and the late Cretaceous.

The lowest cuttings samples with consistent dinocysts in Cormorant N-83 are from 2331-2322 m. From this depth to 1664-1673 m, most of the samples contain specimens of *Nannoceratopsis*. The paleoenvironmental control on this genus is poorly understood but I am assuming from past records (e.g. Bucefalo Palliani and Riding, 1997) that *Nannoceratopsis* is more abundant in an inner rather than outer shelf setting. Thus its common occurrence from 2148-1664 m may reflect in part favourable paleoenvironments, which I interpret as fluctuating inner to middle neritic. This agrees with the Cormorant N-83 well history report (Amoco, 1973), which considered from 2316-1545 m as inner to middle neritic.

Dr. Bucefalo Palliani has informed me that *Nannoceratopsis* is the most abundant dinocyst taxon immediately prior to, and immediately following an anoxic event. She has related the fluctuations in abundance of the genus to the early Toarcian anoxic event in Europe. Perhaps in Cormorant N-83 there were restricted marine conditions, a necessary prelude to deposition of good source rocks.

A predominantly closer to shore inner neritic paleoenvironment from 1645 to 932 m is indicated by the widespread occurrence of *Ctenidodinium*. Smelror and Leereveld (1989), in a study of Bathonian-Oxfordian rocks of the Rhône Valley, defined a *Ctenidodinium combazii-Cleistosphaeridium varispinosum* assemblage that is indicative of shallow marine deposition. Following this, Williams (2003c) considered *Ctenidodinium* as an indicator of closer to shore, neritic environments.

Marginal marine conditions dominate from 914-832 m, with probably some non marine episodes, for example at 822-832 m. In the well history report (Amoco Canada, 1973), the interval 1545-923 m appears to be inner to middle neritic and from 932-832 is classified as marginal marine to inner-middle neritic.

I cannot draw any conclusions regarding paleoenvironments in the late Cretaceous (804-457 m) because of the poor recovery of palynomorphs. Amoco (1973) considered from 832-795 m to show deepening upward, or representing a transgressive phase, and from 795-777 m to be neritic to bathyal. The interval 676-384 m was designated as inner middle neritic and from 384-274 m as neritic, shallowing upwards.

My interpretations, based primarily on spores and pollen to dinocyst ratios, show considerable agreement with Amoco's (1973) results. I regard from 457-402 m as mid neritic. In the cuttings samples at 448-457 m, 429-438 m, 429-420 m, 420-411 m and 411-402 m, there are abundance peaks of the dinocyst *Areoligera* cf. *medusettiformis*. *Areoligera* abundance peaks or acmes have been characteristic of the Thanetian in other wells on the Grand Banks (Williams, 2003b). In Cormorant N-83 and St. George G-55 (Williams, 2003b), however, I consider the acmes also occurred in the Selandian. Powell *et al.* (1996) described *Areoligera* dominated assemblages from the type Thanetian of southern England. In the Pegwell Bay section, there are three levels where *Areoligera* is superabundant and three where it is abundant. According to Powell *et al.* (op. cit.), such horizons denote restricted, high energy, marginal marine settings, typical of a transgressive regime, although the species *Areoligera gippingensis* is considered indicative of offshore marine environments (Heilmann-Clausen, 1994). These authors believed the richest samples were close to the most condensed interval or maximum flooding surface (Figure 1).

*Desmocysta "elegantula"* is also abundant in three of the four horizons with high abundances of *Areoligera* cf. *medusettiformis*. The three horizons are at 429-438 m, 420-429 m and 411-420 m. This suggests similar environmental controls, with high concentrations close to the most condensed interval or maximum flooding surface.

There is a marked change in paleoenvironments at 393-402 m, where the spore and pollen to dinocysts ratio is 126/74. I interpret this as shallower water, inner neritic. These conditions prevail to 350-338 m, when there is a change to a more offshore, outer neritic environment. This more offshore setting is short-lived, however, with shallow water, inner neritic conditions returning at 310-301 m.

The Tertiary section in Cormorant N-83, that is from 457-274 m, contains rich dinocyst assemblages. These predominantly contain indigenous taxa but reworked Cretaceous taxa are common from 457-320 m. Most of the reworked taxa are Late Cretaceous, although occasionally they are Carboniferous and Early Cretaceous. I am surmising that Upper Cretaceous rocks were being eroded to the west or northwest and the sediments transported to the Cormorant vicinity. One reworked species, *Chatangiella decorosa*, is known only from the Cretaceous of the higher latitudes (McIntyre, 1975; Lentin and Williams, 1980), and so appears to denote long distance transportation from arctic Canada.

#### Correlation of Palynology and Lithostratigraphy

The lithostratigraphy of the Cormorant N-83 well was published by McAlpine (1990) and the Canada Newfoundland Offshore Petroleum Board (1998). Throughout my discussion, I shall use McAlpine (1990) for lithostratigraphic terminology, depths and thicknesses. According to McAlpine (op. cit.), the lowermost part of the well is in the Eurydice Formation, which extends from 3160-2975 m. Palynologically, the age of this interval is Rhaetian.

Unconformably overlying the Eurydice is a basalt, which is 35 m thick (2975-2940 m). For the basalt, Pe-Piper *et al.* (1992) gave a radiometric age of  $140 \pm 6$  Ma. According to Pe-Piper *et al.* (op. cit.), the younger age reflects a high degree of weathering. Pe-Piper *et al.* and I consider it probably equivalent to the North Mountain Basalt of the Fundy Basin. The North Mountain has been dated as  $202 \pm 1$  Ma by Hodych and Dunning (1992). This is very close to the Triassic-Jurassic boundary at 200 m (The Last Billion Years, 2001), showing good agreement with my Rhaetian age for the Eurydice.

The basalt is unconformably overlain by the Argo Formation, which is from 2940-2590 m and which is conformably overlain by the Iroquois Formation. The Iroquois is 429 m thick, with its base at 2590 m and top at 2161 m. I consider the Argo and Iroquois to be Hettangian-Sinemurian, although the general paucity of palynomorphs makes it difficult to determine the age.

McAlpine (1989) considered the succeeding Downing Formation to extend from 2161 to 822 m, with 1516-1103 m being included in the Whale Member. This would mean that the Downing ranged from the Pliensbachian to the Berriasian-Valanginian. McAlpine (1990) considered the Downing to be Pliensbachian to Oxfordian-early Kimmeridgian and regarded it as being deposited in a progressively deepening marine environment, with periods of shallowing. In view of this, I consider the uppermost part from 932-822 m to be in part Fortune Bay Shale, in part Whiterose Shale. McAlpine (1990) recognized an unconformity at 822 m, the top of the Downing Shale. Sequentially overlying this are the Eider Formation (822-802 m) and the Dawson Canyon Formation (802-457 m). The lowermost 22 m of the Dawson Canyon (802-780 m) are included in the Petrel Member. Palynologically, the ages of these lithostratigraphic units in Cormorant N-83 are Cenomanian Eider Formation; Petrel Member, Cenomanian; Dawson Canyon Formation, Cenomanian-early Campanian.

The Dawson Canyon is unconformably overlain by the Banquereau Formation at 457 m. McAlpine (1989) included the lowermost 76 m (457-381 m) of the Banquereau in the South Mara Unit. Deptuck *et al.* (2003) formalized this as the South Mara Member of the Banquereau Formation and recognized it in Cormorant N-83. Palynologically the age of the South Mara is Selandian-Ypresian. In Cormorant the youngest age for the Banquereau is Rupelian.

### Summary

Cormorant N-83 contains a thick lower and middle Jurassic section, an attenuated upper Jurassic-lowermost Cretaceous sequence and (incomplete?) upper Cretaceous-lower Tertiary sediments. Age control is primarily from spores and pollen in the Rhaetian-Sinemurian and increasingly more dependent on dinocysts in the Pliensbachian-Portlandian, late Cretaceous and early Tertiary. Knowledge on the stratigraphic ranges of dinocysts, spores and pollen from other wells in this part of the Grand Banks (Williams 2003b, c) has been invaluable in helping me to delineate ages. It is surprising that regardless of this, however, my ages generally show good agreement with Barss *et al.* (1979; Table 1).

A major advance on previous palynological studies of Cormorant N-83 has been in the interpretation of paleoenvironments. From my assessment, inner shelf settings predominated throughout the Jurassic. I have insufficient data to draw conclusions on late Cretaceous paleoenvironments, but can make predictions on the Paleogene. The Selandian-Thantetian was a time of marginal marine to inner neritic environments with several transgressive pulses. Within the Eocene, water depths increased but there was a return to inner neritic conditions in the Rupelian. The paleoenvironmental interpretation for Cormorant N-83 should be of considerable help in future biostratigraphic studies of the Carson Basin to the south.

## References

### Atlantic Geoscience Society

- 2001: The Last Billion Years: a geological history of the Maritime provinces of Canada. Nimbus Publishing Ltd., Halifax, Nova Scotia, 212 p.

### Amoco Canada

- 1973: Well history report: Amoco-Imp A-1 Cormorant N-83.

### Barss, M.S., Bujak, J.P. and Williams, G.L.

- 1979: Palynological zonation and correlation of sixty-seven wells, eastern Canada. Geological Survey of Canada, Paper 78-24, 118 p.

### Batten, D.J. and Koppelhus, E.B.

- 1996: 20D. Biostratigraphic significance of uppermost Triassic and Jurassic miospores in northwest Europe. *In*: Jansonius, J. and McGregor, D.C. (eds.), *Palynology: Principles and Applications*, Volume 2, p.795-806. American Association of Stratigraphic Palynologists Foundation, Dallas, U.S.A.

### Bucefalo Palliana, R.

- 1999: Palynology of the Toarcian. *In*: Colacicchi, R. and Parisi, G. (eds.), *A multidisciplinary approach to the geology of the Italian Jurassic: twelve years of research into the Umbria-*

### Bucefalo Palliani, R. and Riding, J.B.

- 1997: The influence of palaeoenvironmental change on dinoflagellate cyst distribution. An example from the Lower and Middle Jurassic of Quercy, southwest France. (Influence des changements du paléoenvironnement sur la répartition des kystes de dinoflagellés. Exemple du Jurassique inférieur et moyen du Quercy, sud-ouest de la France.) *Bulletin du Centres de recherches Elf exploration-production*, v.21, no.1, p.107-123.

### Bucefalo Palliana, R. and Riding, J.B.

- 2000: A palynological investigation of the Lower and lowermost Middle Jurassic strata (Sinemurian to Aalenian) from North Yorkshire, U.K. *Yorkshire Geological Society, Proceedings*, v.53, pt.1, p.1-16.

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

- 1977: Jurassic palynostratigraphy of offshore eastern Canada. *In*: Swain, F.M. (ed.), *Stratigraphic Micropaleontology of Atlantic Basin and Borderlands, Developments in Palaeontology and Stratigraphy*, v.6, p.321-339. Elsevier Scientific Publishing Co., Amsterdam.

### 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.

### Canada Newfoundland Petroleum Board

- 1998: Schedule of Wells: Newfoundland offshore area. Canada Newfoundland Offshore Petroleum Board, St. John's, Newfoundland, June 1998.

- Costa, L.I. and Davey, R.J.  
 1992: Dinoflagellate cysts of the Cretaceous System. *In*: Powell, A.J. (ed.), A stratigraphic index of dinoflagellate cysts, p.99-153. British Micropalaeontological Society, Publication Series, Chapman and Hall, London, U.K.
- Deptuck, M.E., MacRae, R.A., Shimeld, J.W., Williams, G.L. and Fensome, R.A.  
 2003: Revised upper Cretaceous and Paleogene lithostratigraphy and depositional history for the Jeanne d'Arc Basin, offshore Newfoundland, Canada. American Association of Petroleum Geologists, Bulletin, v.87, no.9, p.1459-1483.
- Feist-Burkhardt, S. and Monteil, E.  
 1997: Dinoflagellate cysts from the Bajocian stratotype (Calvados, Normandy, western France). Kystes de dinoflagellés du stratotype du Bajocian (Calvados, Normandie, France). Bulletin des Centres de recherches exploration-production Elf-Aquitaine, v.21, no.1, p.31-105.
- Gradstein, F.M. and Ogg, J.  
 1996: Phanerozoic time scale. Episodes, v.19, pts.1-2, p.3-5.
- Heilmann-Clausen, H.  
 1994: Review of Paleocene dinoflagellates from the North Sea region. Geologiska Föreningens Förhandlingar, v.116, p.51-53.
- Hodych, J.P. and Dunning, G.R.  
 1992: Did the Manicouagan impact trigger end-of-Triassic mass extinction? Geology, v.20, p.51-54.
- Lentin, J.K. and Williams, G.L.  
 1980: Dinoflagellate provincialism with emphasis on Campanian peridiniaceans. American Association of Stratigraphic Palynologists, Contributions Series, no.7, p.1-47.
- McAlpine, K.D.  
 1989: 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.
- Morbey, S.J.  
 1975: The palynostratigraphy of the Rhaetian Stage, Upper Triassic in the Kendelbachgraben, Austria. Palaeontographica, Abteilung B, v.152, p.1-75.
- Pe-Piper, G., Piper, D.J.W., Keen, M.J. and McMillan, N.J.

- 1990: Igneous rocks of the Continental Margin, p.75-85. *In*: Keen, C.E., Loncarevic, B.D., Reid, I., Woodside, J., Haworth, R.T. and Williams, H., Tectonic and geophysical overview; Chapter 2. *In*: Geology of the Continental Margin of Eastern Canada. M.J. Keen and G.L. Williams (eds.). Geological Survey of Canada, Geology of Canada, no.2, p.31-85. [also Geological Society of America, The Geology of North America, V.I-1.]
- 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. and Thomas, J.E.
- 1992: Dinoflagellate cysts of the Jurassic System. *In*: Powell, A.J. (ed.), A Stratigraphic Index of Dinoflagellate Cysts, p.7-97, pl.2.1-2.20. British Micropalaeontological Society Publication Series, Chapman and Hall, London, U.K.
- Riding, J.B., Walton, W. and Shaw, D.
- 1991: Toarcian to Bathonian (Jurassic) palynology of the Inner Hebrides, northwest Scotland. *Palynology*, v.15, p.115-179.
- Sarjeant, W.A.S.
- 1966: Dinoflagellate cysts with *Gonyaulax*-type tabulation. *In*: Davey, R.J., Downie, C., Sarjeant, W.A.S. and Williams, G.L., Studies on Mesozoic and Cainozoic dinoflagellate cysts. British Museum (Natural History) Geology, Bulletin, Supplement 3, p.107-156.
- Smelror, M. and Leereveld, H.
- 1989: Dinoflagellate and acritarch assemblages from the Late Bathonian to Early Oxfordian of Montagne Crussol, Rhône Valley, southern France. *Palynology*, v.13, p.121-141.
- 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.
- Warrington, G. and Owens, B.
- 1977: Micropalaeontological biostratigraphy of offshore samples from southwest Britain. Institute of Geological Sciences, Report, v.77, no.7, p.1-49.
- 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.
- Williams, G.L.
- 2003a: Palynological analysis of Elf Hermine E-94, Scotian Basin. Geological Survey of Canada, Open File 1654, 8 p.
- Williams, G.L.

- 2003b: Palynological analysis of Canterra PCI St. George J-55, Carson Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 1657, 18 p.
- Williams, G.L.  
2003c: Palynological analysis of Amoco-Imperial-Skelly Skua E-41, Carson Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 1658, 21 p.
- Williams, G.L.  
2003d: Palynological analysis of Petro-Canada *et al.* Terra Nova K-18, Jeanne d'Arc Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 1659, 19 p.
- 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.
- 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.
- Williams, G.L.  
In press: Palynological analysis of Amoco-Imperial-Skelly Osprey H-84, Carson Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File.



## Appendix A

References for dinoflagellate citations are given in Williams *et al.* (1998). References for spore and pollen citations are from PALYNODATA. Informal taxa will be illustrated in a forthcoming palyatlas.

*Achomosphaera alcicornu* (Eisenack, 1954b) Davey and Williams, 1966a  
*Adnatosphaeridium multispinosum* Williams and Downie, 1966c  
*Aequitriradites spinulosus* (Cookson and Dettmann, 1958) Cookson and Dettmann, 1961  
*Alisogymnium euclaense* (Cookson and Eisenack, 1970a) Lentin and Vozzhennikova, 1990  
*Alterbidinium? bicellulum* (Islam, 1983b) Lentin and Williams, 1985  
*Anapiculatisporites dawsonensis* Reiser and Williams, 1969  
*Apectodinium homomorphum* (Deflandre and Cookson, 1955) Lentin and Williams, 1977b  
*Appendicisporites problematicus* Burger, 1966  
*Areoligera medusettiformis* O. Wetzel, 1933b  
*Areoligera* cf. *medusettiformis* O. Wetzel, 1933b  
*Areoligera* cf. *senonensis* Lejeune-Carpentier, 1938a  
*Areoligera* sp.III Drugg, 1967  
*Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971  
*Areosphaeridium michoudii* Bujak, 1994  
*"Axiodinium" ovale*  
*Baculatisporites "giganteus"*  
*Baltisphaeridium "scalenoformatum"*  
*Callialasporites dampieri* (Balme, 1957) Sukh Dev, 1961  
*Callialasporites monoalaspurus* Sukh Dev, 1961  
*Callialasporites obrutus* Norris, 1969  
*Camarozonosporites rudis* (Leschik, 1955) Klaus, 1960  
*Canningia reticulata* Cookson and Eisenack, 1960b  
*Canningia* sp.  
*Carnisporites anterius* Morbey, 1975  
*Carpathodinium predae* (Beju, 1971) Drugg, 1978  
*Cerbia* cf. *tabulata* (Davey and Verdier, 1974) Below, 1981a  
*Cerodinium denticulatum* (Alberti, 1959b)  
*Cerodinium speciosum* (Alberti 1959b) Lentin and Williams, 1987  
*Chasmatosporites magnolioides* (Erdtman, 1948) Nilsson, 1958  
*Chatangiella decorosa* (McIntyre, 1975) Lentin and Williams, 1976  
*Chatangiella ditissima* (McIntyre, 1975) Lentin and Williams, 1976  
*Chatangiella tripartita* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Chatangiella victoriensis* (Cookson and Manum, 1964) Lentin and Williams, 1976  
*Chichaouadinium vestitum* (Brideaux, 1971) Bujak and Davies, 1983  
*Chichaouadinium* cf. *vestitum* (Brideaux, 1971) Bujak and Davies, 1983  
*Chlamydophorella nyei* Cookson and Eisenack, 1958  
*Cicatricosisporites augustus* Singh, 1971  
*Circulodinium paucispinum* (Davey, 1969a) Fauconnier in Fauconnier and Masure, 2004  
*Cometodinium* sp.1 Feist-Burkhardt and Monteil, 1997  
*Concavissimisporites juriensis* Chlonova, 1969  
*Contignisporites cooksoniae* (Balme, 1957) Dettmann, 1963  
*Converrucosisporites variverrucatus* (Couper, 1958) Norris, 1969  
*Cordosphaeridium* cf. *einodes* (Eisenack, 1958a) Eisenack, 1963b  
*Cordosphaeridium* cf. *einodes* subsp. "*brevispinum*"  
*Cordosphaeridium gracile* (Eisenack, 1954b) Davey and Williams, 1966b  
*Corollina simplex* (Danzé-Corsin and Laveine, 1963) Cornet and Traverse, 1973

*Coronatipora valdensis* (Couper, 1958) Dettmann, 1963  
*Corrudinium incompositum* (Drugg, 1970b) Stover and Evitt, 1978  
*Corrudinium reticulatum* Grabowska in Malinowskiej and Piwockiego, 1996  
*Cribroperidinium orthoceras* (Eisenack, 1958a) Davey, 1969a  
*Ctenidodinium "cauliflorum"*  
*Ctenidodinium continuum* Gocht, 1970b  
*Ctenidodinium cornigerum* (Valensi, 1953) Jan du Chêne et al., 1985b  
*Ctenidodinium culmulum* (Norris, 1965) Lentin and Williams, 1973  
*Ctenidodinium "delicatum"*  
*Ctenidodinium "delicatum" subsp. "brevispinum"*  
*Ctenidodinium ornatum* (Eisenack, 1935) Deflandre, 1939a  
*Cyclonephelium membraniphorum* Cookson and Eisenack, 1962b  
*Cyclonephelium* sp. A Williams and Brideaux, 1975  
*Cyclonephelium* sp. A subsp. "brevispinum"  
*Cyclonephelium* sp. B Williams and Brideaux, 1975  
*Deflandrea eocenica* Balteş, 1969  
*Deflandrea phosphoritica* Eisenack, 1938b  
*Densoisporites microrugulatus* Brenner, 1963  
*Densosporites* sp.  
*Desmocysta "elegantula"*  
*Dichadogonyaulax panneae* (Norris, 1965) Sarjeant, 1969  
*Dinogymnium acuminatum* Evitt et al., 1967  
*Dinopterygium cladoides* Deflandre, 1935  
*Diphyes colligerum* (Deflandre and Cookson, 1955) Cookson, 1965a  
*Dissiliodinium?* sp.1 Feist-Burkhardt and Monteil, 1997  
*Durotrigia filapicata* (Gocht, 1970b) Riding and Bailey, 1991  
*Echinitosporites cf. iliacoides* sensu Bujak and Williams, 1977  
*Echinitosporites* sp. A Bujak and Williams, 1977  
*Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967  
*Enneadocysta arcuata* (Eaton, 1971) Stover and Williams, 1995  
*Enneadocysta "cingulomagna"*  
*Eocladopyxis "brevispinosa"*  
*Epiplosphaera cf. gochtii* (Fensome, 1979) Brenner, 1988  
*Exochosphaeridium bifidum* (Clarke and Verdier, 1967) Clarke et al., 1968  
*Extratropopollenites* spp.  
*Foraminisporis wonthaggiensis* (Cookson and Dettmann, 1958) Dettmann, 1963  
 Gen. et sp.2 Gocht, 1970  
*Gingiodinium ornatum* (Felix and Burbridge, 1973) Lentin and Williams, 1976  
*Glaphryocysta exuberans* (Deflandre and Cookson, 1955) Stover and Evitt, 1978  
*Glaphryocysta intricata* (Eaton, 1971) Stover and Evitt, 1978  
*Glaphryocysta ordinata* (Williams and Downie, 1966c) Stover and Evitt, 1978  
*Glaphryocysta pastielsii* (Deflandre and Cookson, 1955) Stover and Evitt, 1978  
*Glaphryocysta "preordinata"*  
*Gonyaulacysta eisenackii* (Deflandre, 1939a) Górka, 1965  
*Gonyaulacysta jurassica* (Deflandre, 1939a) Norris and Sarjeant, 1965  
*Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* Sarjeant, 1982b  
*Hafniasphaera hyalospinosa* Hansen, 1977  
*Heteraulacacysta pustulosa* Jan du Chêne and Adediran, 1985  
*Heteraulacacysta stoveri*  
*Homotryblum tenuispinosum* Davey and Williams, 1966b

*Horologinella* sp.  
*Hystrichodinium pulchrum* Deflandre, 1935  
*Hystrichokolpoma eisenackii* Williams and Downie, 1966a  
*Hystrichosphaeridium* cf. *bowerbankii*  
*Hystrichosphaeridium salpingophorum* Deflandre, 1935  
*Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre, 1937b  
*Hystrichosphaeropsis ovum* Deflandre, 1935  
*Impagidinium victoriense* (Cookson and Eisenack, 1965a) Stover and Evitt, 1978  
*Klukisporites pseudoreticulatus* Couper, 1958  
*Korystocysta gochti* (Sarjeant, 1976a) Woollam, 1983  
*Korystocysta pachyderma* (Deflandre, 1939a) Woollam, 1983  
*Kraeuselisporites reissingeri* (Harris, 1957) Morbey, 1975  
*Kuylisporites* sp.  
*Laciniadinium arcticum* (Manum and Cookson, 1964) Lentin and Williams, 1980  
*Lanterna sportula* Dodekova, 1969  
*Lentinia "glabra"*  
*Leptodinium italicum* Biffi and Manum, 1988  
*Leptodinium subtile* Klement, 1960  
*Luehndea spinosa* Morgenroth, 1970  
*Luehndea* cf. *spinosa*  
*Lycopodiacidites rhaeticus* Schulz, 1967  
*Lycopodiacidites spinatus* Doring, 1966  
*Lycopodiumsporites rosewoodensis* (de Jersey, 1959) de Jersey, 1963  
*Mancodinium semitabulatum* Morgenroth, 1970  
*Mancodinium semitabulatum* subsp. *fossatum* (Below, 1987b) Lentin and Williams, 1989  
*Manumiella? cretacea* (Cookson, 1956) Bujak and Davies, 1983  
*Meiouroganyaulax caytonensis* (Sarjeant, 1959) Sarjeant, 1969  
*Meiouroganyaulax deflandrei* Sarjeant, 1968  
*Meiouroganyaulax valensii* Sarjeant, 1966b  
*Mendicodinium groenlandicum* (Pocock and Sarjeant, 1972) Davey, 1979c  
*Mendicodinium "rugulatum"*  
*Microdinium setosum* Sarjeant, 1966b  
*Moesiodinium* sp.  
*Nannoceratopsis ambonis* Drugg, 1978  
*Nannoceratopsis deflandrei* Evitt, 1961b  
*Nannoceratopsis dictyambonis* Riding, 1984a  
*Nannoceratopsis gracilis* Alberti, 1961  
*Nannoceratopsis gracilis* subsp. *superba* Bucefalo Palliani and Riding, 1998  
*Nannoceratopsis magnicornis* Bucefalo Palliani and Riding, 1997b  
*Nannoceratopsis raunsgaardii* Poulsen, 1996  
*Nannoceratopsis spiculata* Stover, 1966  
*Nannoceratopsis symmetrica* Bucefalo Palliani and Riding, 2000  
*Neoraistrickia elongata* Reiser and Williams, 1969  
*Odontochitina costata* Alberti, 1961  
*Odontochitina operculata* (O. Wetzel, 1933a) Deflandre and Cookson, 1955  
*Oligosphaeridium complex* (White, 1842) Davey and Williams, 1966b  
*Palaeocystodinium bulliforme* Ioannides, 1986  
*Palaeohystrichophora infusorioides* Deflandre, 1935  
*Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b  
*Pareodinia ceratophora* Deflandre, 1947d

*Pareodinia halosa* (Filatoff, 1975) Prauss, 1989  
*Pareodinia prolongata* Sarjeant, 1959  
*Paucisphaeridium inversibuccinum* (Davey and Williams, 1966b) Bujak et al., 1980  
*Phallocysta elongata* (Beju, 1971) Riding, 1994  
*Phthanoperidinium geminatum* Bujak in Bujak et al., 1980  
*Phthanoperidinium multispinum* Bujak in Bujak et al., 1980  
*Pollenites oculus*  
*Polycolpites* sp.  
*Polysphaeridium zoharyi* (Rossignol, 1962) Bujak et al., 1980  
*Pterodinium cingulatum* (O. Wetzel, 1933b) Below, 1981a  
*Raetiaedinium truncigerum* (Deflandre, 1937b) Kirsch, 1991  
*Rhombodinium rhomboideum* (Alberti, 1961) Lentin and Williams, 1973  
*Rhynchodiniopsis cladophora* (Deflandre, 1939a) Below, 1981a  
*Rhynchodiniopsis? nealei* (Sarjeant, 1962a) Jan du Chêne et al., 1985a  
*Rottnestia borussica* (Eisenack, 1954b) Cookson and Eisenack, 1961b  
*Rugubivesiculites* sp.  
*Samlandia chlamydophora* Eisenack, 1954b  
*Schematophora speciosa* Deflandre and Cookson, 1955  
*Schizocystia rugosa* Cookson and Eisenack, 1962a  
*Scriniocassis weberi* Gocht, 1964  
*Senoniasphaera rotundata* Clarke and Verdier, 1967  
*Sentusidinium "granulatum"*  
*Sentusidinium rioultii* (Sarjeant, 1968) Stover and Sarjeant, 1978  
*Sentusidinium rioultii* subsp. "*minispinum* *Sentusidinium "granulatum"*"  
*Sentusidinium verrucosum* (Sarjeant, 1968) Sarjeant and Stover, 1978  
*Spinidinium densispinatum* Stanley, 1965  
*Spinidinium echinoideum* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Spiniferites "procerus"*  
*Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970  
*Spiniferites* sp. "W"  
*Staplinisporites caminus* (Balme, 1957) Pocock, 1962  
*Subtilisphaera perlucida* (Alberti, 1959b) Jain and Millepied, 1973  
*Subtilisphaera pontis-mariae* (Deflandre, 1936b) Lentin and Williams, 1976  
*Surculosphaeridium longifurcatum* (Firtion, 1952) Davey et al., 1966  
*Svalbardella* cf. *cooksoniae* Manum, 1960  
*"Talladinium" coleothryptum*  
*Tasmanites* sp.  
*Tenua hystrix* Eisenack, 1958a  
*Tenua* cf. *hystrix*  
*Thalassiphora delicata* Williams and Downie, 1966c  
*Triblastula utinensis* O. Wetzel, 1933b  
*Trichodinium castanea* Deflandre, 1935  
*Trithyrodinium evittii* Drugg, 1967  
*Trithyrodinium "granulatum"*  
*Trithyrodinium suspectum* (Manum and Cookson, 1964) Davey, 1969b  
*Tsugaepollenites? pseudomassulae* Mädler, 1964b  
*Uvaesporites glomeratus* Doring, 1965  
*Valensiella ampulla* Gocht, 1970b  
*Valensiella ovulum* (Deflandre, 1947d) Eisenack, 1963a  
*Valensiella vermiculata* Gocht, 1970b

*Valvaeodinium armatum* Morgenroth, 1970  
*Valvaeodinium punctatum* (Wille and Gocht, 1970) Below, 1987b  
*Valvaeodinium* sp.  
*Valvaeodinium vermicylindratum* Below, 1987b  
*Wallodinium laganum* Feist-Burkhardt and Monteil, 1994  
*Wetzeliiella gochtii* Costa and Downie, 1976  
*Willeidinium baiocassinum* Feist-Burkhardt, 1995a  
*Xenascus ceratioides* (Deflandre, 1937b) Lentin and Williams, 1973  
*Xenascus serpaglii* (Corradini, 1973) Stover and Evitt, 1978  
*Xiphophoridium alatum* (Cookson and Eisenack, 1962b) Sarjeant, 1966b



**Table 1.** Comparison of age determinations.

Age				Barss <i>et al.</i> , 1979	Herein
TERTIARY	OLIGOCENE	E	RUPELIAN	265-329 m	274-292 m
	EOCENE	L	PRIABONIAN	378-384 m	292-301 m
		M	BARTONIAN		310-350 m
			LUTETIAN		350-377 m
		E	YPRESIAN	384-402 m	377-402 m
	PALEOCENE	L	THANETIAN		402-411 m
			SELANDIAN		411-457 m
		E	DANIAN	402-466 m	
CRETACEOUS	LATE		MAASTRICHTIAN		
			CAMPANIAN	475-485 m	457-493 m
			SANTONIAN	494-640 m	530-658 m
			CONIACIAN	658-668 m	
			TURONIAN	771-777 m	658-704 m
			CENOMANIAN	792 m	771-804 m
	EARLY		ALBIAN		
			APTIAN		
			BARREMIAN		
			HAUTERIVIAN		
			VALANGINIAN		822-832 m
			BERRIASIAN		
JURASSIC	LATE		PORTLANDIAN	832-881 m	850-914 m
			KIMMERIDGIAN	933-942 m	
				952 m	932-952 m
	MID		CALLOVIAN	960-1149 m	960-1149 m
			BATHONIAN	1152-1326 m	1152-1243 m
			BAJOCIAN	1344-1545 m	1261-1545 m
			AALENIAN		
	EARLY		TOARCIAN	1554-1955 m	1554-1892 m
			PLIENSCHACHIAN	1992-2358 m	1911-2131 m
			SINEMURIAN	2369-2984 m	2139-2980 m
			HETTANGIAN		
TRIASSIC	LATE		RHAETIAN	2993-3142 m	2980-3154 m

