

This document was produced  
by scanning the original publication.

Ce document est le produit d'une  
numérisation par balayage  
de la publication originale.



Geological Survey of Canada, Open File # 1658

**Palynological analysis of Amoco-Imperial-Skelly Skua E-41  
Carson Basin, Grand Banks of Newfoundland**

G.L. Williams

2003

# **GEOLOGICAL SURVEY OF CANADA**

## **OPEN FILE 1658**

### **Palynological analysis of Amoco-Imperial-Skelly Skua E-41**

#### **Carson Basin, Grand Banks of Newfoundland**

**G.L. Williams**

**Marine Resources Geoscience Subdivision**

**Geological Survey of Canada (Atlantic), Dartmouth**

**2003**

© Her Majesty the Queen in Right of Canada 2003

Available from

Geological Survey of Canada  
Bedford Institute of Oceanography  
1 Challenger Drive  
Dartmouth, Nova Scotia B2Y 4A2

#### **Important Notices**

Open files are products that have not gone through the GSC formal publication process.  
This report was released with the permission from the Director Geological Survey of Canada - Atlantic

#### **Recommended citation**

**Williams, G.L.**

**2003: Palynological analysis of Amoco-Imperial-Skelly Skua E-41, Carson Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 1658, 20 p., 1 poster.**

## Table of Contents

Well information .....	1
Introduction .....	1
Biostratigraphy .....	1
Paleoenvironments .....	6
Correlation of Palynology and Lithology .....	9
Summary .....	10
References .....	10
Figure 1 .....	15
Appendix A .....	17

Palynological analysis of Amoco-Imperial-Skelly Skua E-41, Carson Basin, Grand Banks of Newfoundland

---

"This report has restricted internal circulation, is not reviewed and must not be cited as a publication. Reference to data or interpretations in the report may be made only with prior approval from the author or the Marine Resources Geoscience Subdivision, Geological Survey of Canada (Atlantic), P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Tel. (902) 426-2740. If approval is granted, reference should be as a personal communication with the author."

---

G.S.C. Locality No.: D-132

Location: 45°33'98"N, 48°87'40"W

Elevation Sea level to R.T.: 29.9 m

Water Depth: 82.9 m

Total Depth: 3238.8 m

Spud Date: 31 August 1974

Interval Studied: 295.7-3229.4 m

Casing Points: 762 mm at 164.3 m; 508 mm at 277.4 m; 340 mm at 686.4 m; 244 mm at 2439.9 m

---

### Introduction

Amoco-Imperial-Skelly Skua E-41 is in the northern part of the Carson Basin, the Grand Banks of Newfoundland. This study is based on the palynological analysis of 100 cuttings samples covering the interval 295.7-3237 m (970-10,620') and 64 sidewall core samples from 702.6-3229.4 m (2305-10,595'). The Canada-Newfoundland Offshore Petroleum Board kindly loaned me the slides for the sidewall cores.

### Biostratigraphy

My age determinations, based on dinoflagellate cysts (dinocysts), spores and pollen are in Figure 1. I have derived the ages from 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 Grand Banks (Williams and Brideaux, 1975; Jansa *et al.*, 1976; Barss *et al.*, 1979; Bujak-Davies Group, 1987; Williams *et al.*, 1990; Williams, in press). Barss *et al.* (1979) provided ages, based on palynology, for the interval 3229.4-2956.6 m (10,595-9700').

The deepest sample in the well, a sidewall core at 3229.4 m (10,595') contains two specimens of the dinocyst *Ctenidodinium sellwoodii*. Feist-Burkhardt and Wille (1992) considered this species to have its First Appearance Datum (FAD) in the late Bajocian. This would mean that *Ctenidodinium sellwoodii* is not in place since the interval 3229.4-3016.9 m (10,595-9898') appears to be no younger than Toarcian. I base this on the presence of several specimens of the dinocyst *Nannoceratopsis gracilis* in the sidewall core at 3212.6 m (10,540'). Also in this sidewall core are the spores *Klukisporites pseudoreticulatus*, *Callialasporites dampieri* and *Callialasporites trilobatus*. Batten and Koppelhus (1996) considered *Callialasporites dampieri* to have its FAD in the late Toarcian. Numerous other studies have found it in older sediments. For example, Pocock (1970) recorded *Callialasporites dampieri* in the Pliensbachian-

Toarcian of western Canada.

Williams and Bujak (1977) noted that their *Nannoceratopsis gracilis* Zone, which they tentatively dated as Pliensbachian-Toarcian, is characterized by the FAD of *Callialasporites dampieri*, *Contignisporites* sp. and *Klukisporites pseudoreticulatus*. In Skua E-41, *Klukisporites pseudoreticulatus* is in the sidewall core at 3212.6 m (10,540'), *Contignisporites* is in the sidewall core at 3205 m (10,515') and *Leptolepidites* is in the sidewall core at 3016.9 m (9898'). Dybkjer (1991), in a study of the Danish Subbasin, considered the FADs of *Klukisporites* and *Leptolepidites* to denote the early Toarcian. This agrees with my age call of Toarcian for 3229.4-3017.9 m (10,595-9898').

I place the top of the Toarcian at 3016.9 m (9898'), because of the Last Appearance Datum (LAD) of *Kraeuselisporites reissingeri* and *Nannoceratopsis gracilis* var. in the sidewall core. Williams and Bujak (1977) recorded the LAD of *Kraeuselisporites reissingeri* in their *Echinotosporites* cf. *iliacoides* Zone of tentative Sinemurian-early Pliensbachian age. Batten and Koppelhus (1996) noted, however, that *Kraeuselisporites reissingeri* can be common even into the early Aalenian.

The sidewall core at 3013 m (9885') contains one specimen of *Gonyaulacysta jurassica* and one of *Lithodinia caytonensis*. These have their FADs in the Bajocian but I think they are probably caved. I regard the LADs of *Scriniocassis weberi* at 2987.1 m (9800') and *Dissiliodinium* sp. Feist-Burkhardt and Monteil, 1997 at 2956.6-2965.7 m (9700-9730') to denote the Aalenian. Williams *et al.* (1999) placed the LAD of *Scriniocassis weberi* at 176.54 Ma. So in Skua E-41, I extend the Aalenian from 3013-2956.6 m (9885-9700').

The Bajocian, from 2932.2-2610.6 m (9620-8565') is over 1000 m (3280') thick. This is not so surprising when you consider it lasted for over seven million years. Bajocian assemblages are characterized by the common occurrence of *Ctenidodinium sellwoodii* and the FADs of *Ctenidodinium sellwoodii*, *Rhynchodiniopsis? regalis*, *Valensiella ovulum* and *Valensiella vermiculata*. Feist-Burkhardt and Wille (1996) gave the FAD of the *Ctenidodinium sellwoodii* group as late Bajocian. Williams *et al.* (1999) placed the FAD of *Valensiella ovulum* at 170.4 Ma, that's within the Bajocian. Riding and Thomas (1992) showed *Rhynchodiniopsis? regalis* as first appearing in the early Bajocian. These authors noted that the Bajocian dinocyst assemblages of southern England are dominated by gonyaulacacean forms. And within these forms with epicystal archeopyles, such as *Ctenidodinium*, are prominent. From my observations, this is also true in Skua E-41.

Riding and Thomas (1992) defined an *Acanthaulax crispa* Zone, which spanned the Bajocian. In Skua E-41, the LAD of *Acanthaulax crispa* is fittingly at 2685 m (8809').

Bathonian sediments extend from 2600-2347 m (8530-7700'), based on the LAD of *Energlynia acollaris* in the sidewall core at 2347 m and *Adnatosphaeridium* sp.A Stancliffe and Sarjeant, 1990 in the cuttings sample at 2347-2356.1 m (7700-7730'). Williams and Bujak (1985) gave the LAD for *Energlynia acollaris* as within the Bathonian, but Feist-Burkhardt and Wille (1992) placed its LAD in the Callovian. *Adnatosphaeridium* sp.A, however, is known only from the Bathonian of southern England (Stancliffe and Sarjeant, 1990). In Skua E-41, other taxa with LADs in the Bathonian include *Korystocysta gochtii*, *Kalyptea diceras*, *Mendicodinium groenlandicum*, *Leptodinium regale*, *Ctenidodinium cornigerum* and *Wanaea indotata*. Bathonian dinocyst assemblages are much richer and more diverse than those of the Bajocian.

The Callovian, from 2331.7 to 2194.6 m (7650 to 7200'), also contains numerous dinocysts, with *Ctenidodinium* being especially abundant. In Skua E-41, the top of the stage is marked by the LAD of *Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* and *Leptodinium subtile*. Sarjeant (1982) described

*Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* from the Callovian of Scotland. In southwest Germany (Feist-Burkhardt and Wille, 1992), the LAD of *Gonyaulacysta jurassica* subsp. *adecta* is mid Oxfordian and the LAD of *Leptodinium subtile* is Kimmeridgian. Williams and Bujak (1977) noted that the LAD of *Leptodinium subtile* in offshore eastern Canada, however, was in their *Valensiella vermiculata* Zone of Callovian age.

In Skua E-41, species with their FADs in the Callovian include *Gonyaulacysta jurassica* subsp. *adecta*, which is restricted to this stage, *Ctenidodinium ornatum* and *Tubotuberella dangeardii*. Species with their LADs in this stage are *Meiourogonaulax caytonensis* and *Meiourogonaulax valensii*.

I consider 2173.3 to 1889.8 m (7130 to 6200') to be Oxfordian, because of the common occurrence of *Gonyaulacysta jurassica* in the cuttings sample at 1889.8-1898.9 m (6200-6230'). Williams *et al.* (1999) placed the LAD of this species 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 Oxfordian, Kimmeridgian and Portlandian, as I have. Stover *et al.* (1996), who also used these subdivisions, 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 northeastern Grand Banks wells. Following Williams (1975), they considered the zone Oxfordian, possibly in part Early Kimmeridgian. My belief that in Skua E-41 the LAD of common *Gonyaulacysta jurassica* marks the top of the Oxfordian, is confirmed by the LAD of the dinocyst *Ctenidodinium ornatum* in the cuttings sample at 1920.7-1929.4 m (6300-6330'). Williams *et al.* (1999) placed the LAD of this species at 143.1 Ma, the top of the Oxfordian.

Species with their LADs in the Oxfordian are *Histiophora ornata* at 2164.1-2173.3 m (7100-7130'), *Valensiella ovulum* at 2103.1-2112.3 m (6900-6930'), *Lithodinia jurassica* at 2011.7-2020.8 m (6600-6630'), *Ctenidodinium pachydermum* at 1947.7 m (6390') and *Stephanelytron redcliffense* at 1920.7-1929.4 m (6300-6330').

I can subdivide the Kimmeridgian, which extends from 1868.4-1585 m (6130-5200') into a lower and upper. The lower, from 1767.9-1868.4 m (5800-6130') seems to equate with the early to mid Kimmeridgian. The top of this division is marked by the consistent LAD of *Epiplosphaera areolata*, which in Jeanne d'Arc wells seems to equate with the mid Kimmeridgian. Williams *et al.* (1999) gave the LAD of *Epiplosphaera areolata* as 149 Ma, the top of the Kimmeridgian. Feist-Burkhardt and Wille (1992), however, placed the last consistent occurrence within their early Kimmeridgian. In Skua E-41, my early to mid Kimmeridgian agrees with the LAD of *Gonyaulacysta jurassica*.

The late Kimmeridgian, from 1758.7-1585 m (5770-5200') is denoted by the LAD of the spore *Ischyosporites amplireticosus* and the dinocyst *Rhynchodiniopsis cladophora*, both at 1585 m (5200'). Riding and Thomas (1992) gave the LAD of *Rhynchodiniopsis cladophora* as late Kimmeridgian, although it's consistent LAD is early Kimmeridgian. Bujak and Williams (1977), following Williams (1975) recognized a *Rhynchodiniopsis* (as *Gonyaulacysta*) *cladophora* Zone, which they considered Kimmeridgian. Other dinocyst species with LADs in this interval are *Gonyaulacysta eisenackii*, *Geiselodinium inaeffectum*, *Systematophora areolata* and *Systematophora orbifera*. Williams *et al.* (1999) gave the LAD for *Systematophora orbifera* as 142 Ma, within the Kimmeridgian.

An attenuated Portlandian section occurs from 1585-1560.6 m (5200-5120'). I base this interpretation on the LAD of the dinocysts *Ctenidodinium culmulum* and *Tubotuberella apatela* in the sidewall core at 1560.6 m (5120'). Stover *et al.* (1996) gave the LAD of *Ctenidodinium culmulum* as the top of the Ryazanian and that of *Tubotuberella apatela* as the top of the Valanginian. Bujak and Williams (1977), however, 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 as Portlandian.

From 1539.3 to 1357.9 m (5050 to 4455') has to be Neocomian, since the pollen *Callialasporites dampieri* and *Callialasporites obrutus* have their LADs at 1357.9 m (4455'). In wells in the Jeanne d'Arc Basin, these species consistently have their LADs in the Barremian. Also, *Subtilisphaera perlucida* and *Subtilisphaera cheit*, have their LAD at 1374.7 m (4510'). In Jeanne d'Arc Basin wells, the genus *Subtilisphaera* has its LAD in the Barremian (Davies in Williams *et al.*, 1990). Further subdivision is difficult. I have recorded *Leptolepidites major*, *Leptolepidites psarosus* and *Rubinella major* also at 1357.9 (4455'). In the Whiterose N-22 well, *Leptolepidites psarosus* has its LAD in the Berriasian. Based on this, I am tentatively dating 1539.3 to 1357.9 m (5050 to 4455') as Berriasian.

Spores with their LADs in the Berriasian are *Coronatispora valdensis* at 1539.3 m (5050'), *Aequitriradites spinulosus* at 1493.5-1502.7 m (4900-4930'), *Converrucosisporites exquisitus* at 1429.5-1438.7 m (4690-4720') and *Converrucosisporites variverrucatus* at 1357.9 m (4455'). Davies in Bujak-Davies (1987) gave the LAD for *Aequitriradites spinulosus* as early Valanginian. I have also found that *Aequitriradites spinulosus* has an LAD within the Valanginian and *Coronatispora valdensis* an LAD in the Berriasian-Valanginian in wells of the Jeanne d'Arc Basin.

One of the difficulties of determining ages for the interval 1554.5-1374.7 m (5100-4510') is the absence of sidewall cores. And the dominance of caved material of Late Cretaceous-early Tertiary age in the cuttings samples adds to the problems. Fortunately, there is the sidewall core at 1357.9 m (4455'), which does appear to be Berriasian.

The sample immediately above the 1357.9 m (4455') sidewall core represents a cuttings sample at 1347.2-1356.4 m (4420-4450'). I cannot provide a definite age for this. The cuttings sample at 1319.8-1328.9 m (4330-4360') may be Albian, however, based on the presence of the dinocysts *Microdinium* and a poorly preserved *Chichaouadinium* species. Confirmation of this is in the sidewall core at 1314.3 m (4312'), in which I found the dinocysts *Ovoidinium cinctum* and *Litosphaeridium arundum*. Williams *et al.* (1999) gave an LAD of 97.55 Ma for *Litosphaeridium arundum* and 96.2 Ma for *Ovoidinium cinctum*. On the timescale of Gradstein and Ogg (1996), the Albian-Cenomanian boundary is at 98.9 Ma. Occurring in the same sample is *Rugubivesiculites rugosus*, which has a FAD in the late Albian in offshore eastern Canada. So, I conclude that the age of the sidewall core at 1314.3 m (4312') is late Albian. By extrapolation, I am taking the late Albian to 1341.7 m (4402'), where McAlpine (pers.comm.) recognized an unconformity.

I have identified Cenomanian-Turonian palynomorphs in the cuttings sample from 1292.4-1301.5 m (4240-4270'), which contains *Stephodinium coronatum*. According to Williams *et al.* (in press), this species has its LAD at 87.81 Ma, which is close to the Turonian-Coniacian boundary. A sidewall core also at 1292.4 m (4240') has *Chlamydothorella ambigua*. Stover *et al.* (1996) gave the LAD for this species (as *Dapsilidinium ambiguum*) as Turonian. Accordingly, I consider the interval 1301.5-1292.4 m (4270-4240') to be Cenomanian-Turonian.

The succeeding cuttings sample from 1264.9-1274.1 m (4150-4180') appears to be Coniacian. I base this on the presence of *Cyclonephelium vannophorum*. Williams *et al.* (1999) gave the LAD for this species as 89 Ma, which is the Coniacian-Turonian boundary.

Although the upper Cretaceous sequences are condensed, I can recognize the Santonian. The cuttings sample from 1237.5-1246.6 m (4060-4090') contains *Raetiaedinium truncigerum*. Williams *et al.* (in press) give an LAD at 75.35 Ma for this species. This is close to the boundary between the early and late

Campanian. However, Bujak and Williams (1978) noted that in offshore eastern Canada, *Raetiaedinium* (as *Hystrichosphaeridium*) *truncigerum* had a Santonian LAD. Since Skua E-41 is also an offshore east coast well, I agree with Bujak and Williams (op.cit.). Accordingly, I consider 1246.6-1237.5 m (4090-4060') to be Santonian.

I subdivide the Campanian, from 1219.2-1124.7 m (4000-3690'), into early 1219.2-1155.2 m (4000-3790') and late 1136.9-1124.7 m (3730-3690'). My early Campanian top is based on the LAD of *Kleithriasphaeridium loffrense* in the cuttings sample at 1155.2-1164.4 m (3790-3820'). Williams *et al.* (in press) gave the LAD for this species as 76.34 Ma, which approximately equates with the early-late Campanian boundary. Other dinocysts having their LADs in the early Campanian are *Chatangiella victoriensis* at 1207.4-1219.2 m (3970-4000') and *Gillinia hymenophora*, *Odontochitina costata* and *Odontochitina operculata* at 1158.3 m (3800'). According to Williams *et al.* (in press), *Odontochitina operculata*'s LAD is at 70.43 Ma and that of *Odontochitina costata* is at 70.43 Ma, both in Northern Hemisphere mid latitudes. Thus in Skua E-41, both species have suppressed LADs.

The upper Campanian, from 1136.9-1124.7 m (3730-3690'), is characterized by the LAD of *Trichodinium castanea* at 1130.8-1136.9 m (3710-3730') and the LAD of *Spiniferites scabrosus* in the sidewall core at 1124.7 m (3690').

Palynologically, it is impossible to pick the Cretaceous-Tertiary boundary, although there is extensive mixing of Early Tertiary pollen and Paleogene dinocysts in a sidewall core at 1106.4 m (3630'). The significance of this became apparent when I checked the lithostratigraphy. McAlpine (pers.comm.) placed an unconformity at 1117 m (3664.7'). This would explain the reworking in 1106.4 m (3630').

A cuttings samples from 1100.3-1109.5 m (3610-3640') contains some excellent mid Paleocene markers, including the dinocyst *Alisocysta margarita*. According to Williams *et al.* (in press) this species has a range of 61.68-57.35 Ma, which is essentially mid Paleocene. The interval 1100.3-1109.5 m (3610-3640') must be Danian, however, since a cuttings sample at 1072.9-1082.1 m (3520-3550'), is Danian. I base this on the presence of *Cerodinium diebelii*, which Williams *et al.* (in press) give an LAD of 59.95 Ma and *Spinidinium densispinatum*, for which Williams *et al.* (1999) gave an LAD of 59.38 Ma.

I have identified Selandian dinocysts in the cuttings sample at 1045.8-1054.6 m (3430-3460'). This sample contains the dinocyst *Alisocysta circumtabulata*, which has an LAD of 58.53 Ma (Williams *et al.*, in press). And the cuttings sample from 1072.9-1082.1 m (3520-3550'), which is Danian, marks the LAD of *Alisocysta margarita*. As noted above, this taxon is an excellent mid Paleocene index species.

The Thanetian, from 1018-993.7 m (3340-3260') is characterized by abundant specimens of *Areoligera* cf. *medusettiformis* in the sidewall core at 993.7 m (3260'). Also in the same sample are the dinocysts *Apectodinium homomorphum*, *Cerodinium speciosum* and *Hafniasphaera hyalospinosa*. This sample must lie close to the Paleocene-Eocene boundary. As I have noted for Terra Nova K-18 (Williams *et al.*, in press), the high abundance of *Areoligera* cf. *medusettiformis* allows correlation with the type Thanetian beds of southern England.

I am placing the Paleocene-Eocene boundary within the cuttings sample at 990.6-999.8 m (3250-3280'). This is based on considering the sidewall sample at 993.7 m (3260') to be Thanetian, although it may be basal Eocene. The lower Eocene (Ypresian) extends from 993.4 to 929.7 m (3259 to 3030'). The sidewall core at 929.7 m (3050') contains *Dracodinium* cf. *condylos*, which is common in the Ypresian of the Labrador Shelf (Williams and Bujak, 1977). This strongly indicates a Ypresian age for the sidewall.

In the cuttings sample at 908.3-917.5 m (2980-3010') are the dinocysts *Deflandrea denticulata*, *Diphyes*

*brevispinum*, *Diphyes ficusoides* and *Glaphyrocysta ordinata*. Williams *et al.* (2001) gave the following LADs: 45.8 Ma for *Glaphyrocysta ordinata*, 49 Ma for *Diphyes brevispinum* and 45.2 Ma for *Diphyes ficusoides*. Based on the presence of *Diphyes ficusoides* and *Glaphyrocysta ordinata*, I consider this sample Lutetian. I also include in this stage the sidewall sample at 906.8 m (2975'), which contains *Diphyes colligerum*, *Diphyes pseudoficusoides*, *Rottnestia borussica* and *Wilsonidium compactum*.

In Skua E-41, a feature of the overlying Bartonian (the younger of the two mid Eocene stages), is the abundance of the dinocyst genus *Phthanoperidinium*. I am including in this stage the section from 890-824.5 m (2920-2705'). The LADs of *Cyclonephelium* sp.B Williams and Brideaux, 1975 and *Glaphyrocysta exuberans* occur in the sidewall core at 824.5 m (2705'). These taxa are characteristic of the mid Eocene in Jeanne d'Arc Basin wells. Other taxa with LADs in the Bartonian are *Phthanoperidinium echinatum*, *Phthanoperidinium eocenicum* and *Phthanoperidinium levimurum*.

Upper Eocene or Priabonian sediments extend from 807.7-702.6 m (2650-2305'). The LADs of *Areosphaeridium diktyoplokum* and *Lentinia serrata* occur in the sidewall core at 702.6 m (2305'). 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 confidently place the top of the Priabonian at 702.6 m (2305'). In Skua E-41, dinocyst species with LADs in the Priabonian are *Eocladopyxis peniculata*, *Phthanoperidinium multispinum* and *Schematophora speciosa*. Williams *et al.* (1999) gave the range of *Schematophora speciosa* as 36.0-35.35 Ma in Southern Hemisphere mid latitudes. Its occurrence in the cuttings sample at 798.6-807.7 m (2620-2650') indicates an early Priabonian age.

The Oligocene consists of an early (Rupelian) stage and a late (Chattian) stage. In Skua E-41, however, I can recognize a four-fold division. The interval 698-615.7 m (2290-2020') is early Rupelian, based on the LAD of *Operculodinium divergens* in the cuttings sample at 615.7-624.8 m (2020-2050'). Williams *et al.* (1999) gave an LAD of 31.97 Ma, which is within the Rupelian. Other species with LADs at 615.7-624.8 m (2020-2050') are *Heteraulacacysta pustulosa* and *Heteraulacacysta "stoveri"*. The cuttings sample at 588.3-597.4 m (1930-1960') is late Rupelian, based on the LAD of *Operculodinium microtriainum* and *Spiniferites "procerus"*. The latter occurs extensively in the early Oligocene of the Jeanne d'Arc Basin.

I place the interval 542.6-506 m (1780-1660') in the early Chattian because of the presence of *Wetzeliella articulata* and *Wetzeliella gochtii* in the cuttings sample at 506-515.1 m (1660-1690'). Williams *et al.* (1999) gave an LAD of 24.5 Ma for *Wetzeliella articulata* and 26.6 Ma for *Wetzeliella gochtii*. The Oligocene-Miocene or Chattian-Aquitainian boundary is at 23.8 Ma. Therefore, it seems logical to consider 542.6-506 m (1780-1660') as early Chattian. Other species with LADs at 506-515.1 m (1660-1690') are *Chiropteridium galea* and *Homotryblium tenuispinosum*. *Chiropteridium galea* has an LAD of 22.36 Ma, just within the Aquitainian. But in offshore eastern Canada, its LAD is taken as the top of the Oligocene at 23.8 Ma (Williams and Bujak, 1977).

The late Chattian top at 478.5-487.7 m (1570-1600') is based on the LAD of *Deflandrea phosphoritica*. Williams *et al.* (in press) consider the LAD of *Deflandrea phosphoritica* to be at 21.9 Ma, that's within the early Aquitainian. In offshore eastern Canada, however, the LAD of *Deflandrea phosphoritica* is taken as at the top of the Oligocene (Williams and Bujak, 1977). *Phthanoperidinium amoenum* also has its LAD in the same sample.

It is difficult to subdivide the overlying sediments from 460.3 to 295.7 m (1510 to 970'). Provisionally, I am considering 460.3-423.7 m (1510-1390') to be early Miocene (Aquitainian-Burdigalian), because of the LAD of *Operculodinium multispinosum* at 423.7-432.8 m (1390-1420'). The dinocyst *Distatodinium*

*paradoxum* has its LAD at 451.1-460.3 m (1480-1510'). Williams *et al.* (1999) gave an LAD of 13.6 Ma or mid Miocene for this species. Williams and Bujak (1977) in their zonation of the Tertiary of offshore eastern Canada, however, considered its LAD as early Miocene.

Middle Miocene sediments appear to extend from 387.1 m (1270') to the topmost sample at 295.7-304.8 m (970-1000'). Diagnostic species are the dinocysts *Hystrichosphaeropsis obscura*, *Spiniferites pseudofurcatus* and *Sumatradinium hispidum* and the pollen *Bombacacidites* sp.A Williams and Brideaux, 1975. According to Williams *et al.* (1999), *Hystrichosphaeropsis obscura* has an LAD at 7.34 Ma (within the late Miocene) and *Spiniferites pseudofurcatus* has an LAD at 11.2 Ma. Gradstein and Ogg (1996) placed the mid to late Miocene boundary at 11.2 Ma. Therefore, I believe the youngest sediments studied in Skua E-41 at 295.7-304.8 m (970-1000') are mid Miocene. Further confirmation is the presence of *Bombacacidites* sp.A. Williams (1975) placed the LAD of this taxon in the mid Miocene of the Scotian Basin.

### Paleoenvironments

My paleoenvironmental interpretations are based primarily on sidewall cores but there is some reliance on cuttings samples. Although sidewall core samples provide an in situ glimpse of palynomorph abundances, the Company slides often contained assemblages that were too sparse to give meaningful data. The lowest sample in Skua E-41, at 3229.4 m (10,595') was a sidewall sample of predominantly carbonized wood. The dinocyst to spore/pollen ratio is roughly equal but I don't regard any of the dinocysts as denoting a specific environment. The high degree of carbonized wood, however, indicates deposition in a shallow marine setting.

From 3229.4-3057.2 m (10,595-10,030'), the dinocyst to spore/pollen ratio fluctuates between 40 and 60%. I consider the continuing high melanogen (carbonized organic material) and hylogen (wood) to denote continuing deposition in a marginal marine to shallow water environment. At 3046.5 m (9995') there is a marked decrease in the dinocyst to spore/pollen ratio, indicating brackish to possibly freshwater deposition. This seems to have been a very brief interlude, with shallow marine conditions returning at 3017.6 m (9900').

I interpret from 3017.6 to 2856 m (9900 to 9370') as shallow, inner neritic deposition, with more offshore conditions at 3013 m (9885'). From 2834.7 to 2645.7 m (9300 to 8680') deposition was inner neritic to marginal marine, with lower dinocyst to spore and pollen ratios. This was accompanied by an increase in the pollen genera *Callialasporites* and *Inaperturopollenites* and the bivesiculates.

There is a strong signal in the sidewall cores at 2631.7 and 2618.3 m (8634 and 8590'), which has a dinocyst to spore/pollen ratio much lower than deeper horizons in Skua E-41. This has to represent brackish and even nonmarine deposition. Conditions quickly return to inner neritic at 2610.6 m (8565'). The closest cuttings sample from 2590.8-2600 m (8500-8530') contains an unusually high number of *Ctenidodinium* specimens. 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. The variation in *Ctenidodinium* abundance in Skua E-41 indicates that this genus is indeed an indicator of closer to shore, neritic environments.

The sidewall core at 2539 m (8330') is very similar to those at 2631.7 and 2618.3 m (8634 and 8590'), showing a temporary return to brackish to freshwater milieu.

In several samples, from 2529.9 to 2318.9 m (8300 to 7603'), the dinocyst to spore/pollen ratio and the *Ctenidodinium* counts indicate inner shelf deposition. A stronger marine pulse occurs at 2316.5-2325.7 m (7600-7630'). In this cuttings sample there are several specimens of *Gonyaulacysta jurassica*.

Smelror and Leereveld regarded *Gonyaulacysta jurassica* as indicative of middle shelf environments. Thus, I postulate a more offshore location for 2325.7-2316.5 m (7630-7600').

Middle shelf conditions occur again between 2304.3 and 2225.1 m (6570 and 7300'), before inner shelf conditions again prevail at 2194.6-2203.7 m (7200-7230'). The cuttings sample at this depth contains specimens of *Cribroperidinium* a genus with a thick wall. Sarjeant (1992) regarded such forms as indicating closer to shore deposition. Since the environmental significance of *Cribroperidinium* is contentious, I shall class the interval 2203.7-2072.7 m (7230-6800') as inner neritic.

The cuttings sample from 2051.3-2042.9 m (6730-6700') has a major influx of chorate cysts. Smelror and Leereveld (1989) regarded such cysts as indicative of middle shelf environments. By applying this concept in Skua E-41, I can classify the interval 2051.3-2011.7 m (6730-6600') as middle to outer shelf. There is a change at 1990.4-1981.2 m (6530-6500'), where the dinocyst to spore/pollen ratio is about 1, perhaps suggesting more inshore deposition. These conditions persist to 1859.3 m (6100').

A closer to shore setting is indicated for 1833.4 m (6015'), which has a low dinocyst to spore/pollen ratio. This must have been the dominant setting to 1429.5-1438.7 m (4690-4720'), with several non- to marginal marine episodes and an occasional transgressive phase. I have identified brackish water to non-marine episodes in the sidewall cores at 1833.4 m (6015'), 1792.2 m (5880'), 1560.6 m (5120') and 1539.3 m (5050') and several cuttings samples. More marine episodes occur at 1758.7 m (5770'), 1548.4-1533.2 m (5080-5030') and 1374.7-1383.8 m (4510-4540').

There is a major change at 1374.7-1383.8 m (4510-4540') with deposition being much farther offshore. A temporary return to closer to shore, inner shelf occurs at 1357.9 m (4455') before the onset of extended outer shelf conditions at 1347.2-1356.4 m (4420-4450').

There is an impressive consistency in the environmental setting from 1356.4 to 1124.7 m (4450 to 3690') with spores and pollen being rare to absent in the samples. I have interpreted this interval as representing offshore, outer shelf, possibly slope environments. A problem with the cuttings samples from 1356.4-1124.7 m (4450-3690') is that most of the assemblages are dominated by caved late Cretaceous-Tertiary specimens.

The sidewall core at 1106.4 m (3630') appears to reflect a return to more inshore conditions but this is deceptive. I found a high percentage of spores in this sample but they are reworked early Cretaceous taxa. Immediately above the 1106.4 m (3630') sample is a sidewall core at 1079 m (3540'), which shows a continuation of farther offshore, deeper water environments. I interpret 1100.3-1109.5 m (3610-3640') as also being deposited in deeper water, with the reworked palynomorphs indicating uplift and erosion landwards.

From 1082.1-1072.9 m (3550-3520'), there are some significant changes in the dinocyst assemblages. The cuttings sample at 1072.9-1082.1 m (3520-3550') contains many small deflandreoids. Köthe (1990) considered *Deflandrea* to indicate reduced marine conditions. In Skua E-41, I interpret the influx as a sign of a closer to shore environment. There is a significant change in the composition of the assemblages from the cuttings sample at 1045.8-1054.6 m (3430-3460') and the sidewall core at 993.7 m (3260'). Both samples contain only dinocysts and in both one species, *Areoligera* cf. *medusettiformis*, is dominant. Powell *et al.* (1996) have described similar 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. Powell *et al.* (op.cit.) interpreted these horizons as representing restricted, high-energy, marginal marine settings typical of a transgressive regime, although they considered the species *Areoligera gippingensis* to be indicative of more open marine settings. They believed the richest samples

were close to the most condensed interval or maximum flooding surface. *Areoligera* was presumably the cyst of an autotrophic dinoflagellate. Its presence in such dominant numbers suggests that it was in an area of intense nutrient concentrations, possibly where there was upwelling.

A related sample from 1018-1027.2 m (3340-3370') contains numerous specimens of the dinocyst *Apectodinium homomorphum*. Bujak and Brinkhuis (1998) considered *Apectodinium homomorphum* to be a warmer water species, whose presence in high concentrations reflected climatic warming. Crouch *et al.* (2001) have correlated the onset of *Apectodinium* peaks with the late Paleocene thermal maximum, which lasted for about 220 ky at about 55 Ma. Thus, close to the time of deposition of 1018-1027.2 m (3340-3370'), there must have been higher sea-surface temperatures in the vicinity of Skua E-41. This would have been accompanied by a major increase in surface water productivity.

From 999.8-702.6 m (3280-2305'), the dinocyst dominated assemblages generally indicate an open marine, presumably outer shelf setting. The common to abundant occurrence of *Phthanoperidinium* from 890-826 m (2920-2710'), however, may indicate a change. Köthe (1990) defined several dinocyst eco-groups from the Paleogene of northeast Germany. She regarded the *Phthanoperidinium* eco-group as indicating shallow, near shore settings. If correct, this would indicate a closer to shore environment for 890-826 m (2920-2710') in Skua E-41.

There definitely appears to be a change to more inshore conditions at 698-688.9 m (2290-2260'), where pollen increase in abundance. *Homotryblium tenuispinosum* occurs in four samples between 652.3 and 506 m (2140 and 1660'). Brinkhuis (1992a) believed this species to be warmer water and marginal marine. Its LAD at 506-515.1 m (1660-1690') indicates that either cold water currents entered the Jeanne d'Arc Basin or there was a general cooling. The inner neritic conditions appear to have persisted at Skua E-41 up to 295.7-304.8 m (970-1000'), the highest sample studied.

#### Correlation of Palynology and Lithology

The lithostratigraphy of Skua E-41 has not been published but I have been provided with a breakdown (K.D. McAlpine, pers.comm.). The well bottomed in the Downing Formation, which extends from 3239-2337 m (10,626.5-7667.2'). McAlpine (1990) erected the Downing Formation and included in it the Whale Member. The Downing is primarily shale but with a limestone unit separating the lower and upper beds. The term "Whale unit" was first used by Jansa and Wade (1975) for the section in Murre G-67, which McAlpine (op.cit.) designated as the type section of the Downing. McAlpine used Whale Member for the middle limestone unit, with the type section also in Murre G-67. In Skua E-41, McAlpine included from 2832 to 2814 m (9291.2 to 9232.2') in the Whale Member. The interval 3239-2337 m (10,626.5-7667.2') would span the Toarcian-Bathonian based on the ages I give in this paper.

McAlpine (1990) formally defined most of the Jurassic-Cretaceous lithostratigraphic units in the Jeanne d'Arc Basin. The Voyager Formation and overlying Rankin Formation are lateral equivalents of part of the Downing Shale. Sequentially overlying the Rankin are the Jeanne d'Arc Formation, the Fortune Bay Shale, the Hibernia Formation, the "B" marker, the Catalina Formation, the Eastern Shoals Formation, the Avalon Formation, the Ben Nevis Formation, and the Eider Formation. The basinal shales equivalent of the Hibernis, Catalina, and Eastern Shoals formations, is the Whiterose Shale. This is overlain by the Nautilus Shale, the basinal facies of the Avalon, Ben Nevis and Eider formations.

In Skua E-41 the Downing Shale is conformably and sequentially overlain by the Voyager (2337-1994 m; 7667.2-6541.9') and Rankin (1994-1749 m; 6541.9-5738.1') formations. I consider the Voyager to be Callovian to Oxfordian and the Rankin to be Oxfordian to predominantly early Kimmeridgian.

The Fortune Bay Shale (1749-1369 m; 5738.1-4491.4') unconformably overlies the Rankin and is

conformably overlain by the Hibernia Formation (1369-1342 m; 4491.4-4402.8'). Based on my ages from palynology, the Fortune Bay is late Kimmeridgian to probable Berriasian and the Hibernia Formation is probable Berriasian. Based on the palynology, I cannot recognize a hiatus between the Rankin and Fortune Bay units.

According to McAlpine (pers.comm.), there is an unconformity at 1342 m (4402.8'), which is overlain by the Eider Formation (1342-1319 m; 4402.8-4327.4'). The palynology substantiates this, since I have dated a cuttings sample at 1319.8-1328.9 m (4330-4360') to be probable Albian. And slightly higher at 1314.3 m (4312') is a sidewall core that has to be late Albian. Terminology for the overlying lithostratigraphic units is based on the Scotian Basin lithostratigraphy proposed by McIver (1972) and modified by Jansa and Wade (1975) and Wade and MacLean (1990).

In Skua E-41, the Eider is conformably overlain by the Dawson Canyon Formation, which extends from 1319 to 1181 m (4327.4 to 3874.6'). Within this interval, the Petrel Member is at 1303-1274 m (4274.9-4179.7'). The chalky Petrel was deposited in an outer neritic environment. In Skua E-41, the Dawson Canyon is late Albian to early Campanian and the Petrel is probably Turonian-Coniacian.

A predominantly sandstone interval, the South Mara unit, unconformably overlies the Dawson Canyon Formation at 1117 m (3664.7'). McAlpine (pers.comm.) placed the top of the South Mara at 1076.9 m (3533'), where it is unconformably overlain by the rest of the Banquereau Formation. According to my palynological data, the South Mara is Danian. McAlpine (1990) regarded the South Mara unit as an informal subdivision of the Banquereau Formation. Sinclair (1988) who first used the term, referred to the South Mara as reworked Upper Cretaceous sands. Deptuck *et al.* (in press) intend to treat the unit more formally. Since the highest sample I studied is at 295.7-304.8 m (970-1000'), I can only date part of the Banquereau. I can state, however, that in Skua E-41 it is Danian to mid Miocene, an impressive span of time.

### Summary

The only previously published biostratigraphic study of Skua E-41 is by Bujak *in Barss et al.* (1979). Bujak recognized Pliensbachian to Miocene or younger in the interval 3229.4-295.7 m (10,595-970'). Below an indeterminate interval from 1356.4-1319.8 m (4450-4330'), Bujak dated the sediments as Neocomian and above he regarded as Albian-Senonian. I have determined that the interval 3229.4-295.7 m (10,595-970') spans the Toarcian-mid Miocene and that there is a major unconformity, first identified by McAlpine (pers.comm.), at 1342 m (4402.8'). Bujak's analysis is remarkably accurate, especially when one realizes that he did not have any sidewall control. Although of poor quality, the sidewall cores provided invaluable information at critical intervals, and permitted more detailed biostratigraphic control.

An important development in palynological studies over the last two decades has been the realization that fossil dinocyst assemblages are excellent environmental and climatic indicators. And when the dinocyst data are correlated with the spore/pollen analyses, even more impressive results can be drawn. I have demonstrated this in Skua E-41, especially in recognizing the *Areoligera* and *Apectodinium* assemblages in the Paleocene. Another aspect of the data that I need to evaluate is the fluctuations in reworking. Careful plotting of this would be helpful to the geochemical analyses, so that discrepancies could be more readily determined.

The palynological processing and analyses of both cuttings and sidewall cores is time consuming. In Skua E-41, I examined 112 cuttings samples and 56 sidewall cores but only the cuttings samples were processed in-house. I recommend that, where possible, sidewall core samples be obtained and processed in-house for analysis. This would guarantee the best results.

## References

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.

Brinkhuis, H.

1992: Late Eocene to Early Oligocene dinoflagellate cysts from central and northeast Italy. Ph.D. thesis, University of Utrecht, 169 p., 23 pl. (Published thesis)

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

1978: Cretaceous palynostratigraphy of offshore southeastern Canada. Geological Survey of Canada, Bulletin, no.297, 19 p., 3 pl.

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.

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.

Dybkjær, K.

1991: Palynological zonation and palynofacies investigation of the Fjerritslev Formation (Lower Jurassic-basal Middle Jurassic) in the Danian Subbasin. *Danmarks Geologiske Undersøgelse, DGU Serie A*, nr.30, 150 p., 22 pl.

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, pl.1-25.

Feist-Burkhardt, S. and Wille, W.

1992: Jurassic palynology in southwest Germany - state of the art. Cahiers de micropaléontologie, v.7, no.1/2, p.141-163.

Gradstein, F.M. and Ogg, J.

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

Jansa, L.F. and Wade, J.A.

1975: Geology of the continental margin off Nova Scotia and Newfoundland. *In*: van der Linden, W.J.M. and Wade, J.A. (eds.), Offshore Geology of Eastern Canada, Volume 2, Regional Geology. Geological Survey of Canada, Paper 74-30, v.2, p.51-106.

Jansa, L.F., Gradstein, F.M., Harris, I.M., Jenkins, W.A.M. and Williams, G.L.

1976: Stratigraphy of the Amoco-IOE Murre G-67 well, Grand Banks of Newfoundland. Geological Survey of Canada, Paper 75-30, 14 p.

Köthe, A.

1990: Paleogene dinoflagellates from northwest Germany - biostratigraphy and paleoenvironment. Geologisches Jahrbuch, Reihe A, no.118, p.3-111, pl.1-33.

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.

McIver, N.L.

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

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.

Pocock, S.A.J.

1970: Palynology of the Jurassic sediments of western Canada. Part I. Terrestrial species. Palaeontographica, Abteilung B, v.130, p.12-136, pl.5-26.

Powell, A.J.

1992: Dinoflagellate cysts of the Tertiary System. *In*: Powell, A.J. (ed.), A stratigraphic index of dinoflagellate cysts, p.155-229, pl.4.1 - 4.11. British Micropaleontological Society, Publication Series, Chapman and Hall, London, U.K.

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.

Sarjeant, W.A.S.

1982: The dinoflagellate cysts of the *Gonyaulacysta* group: a morphological and taxonomic restudy. American Association of Stratigraphic Palynologists, Contributions Series, no.9, p.1-81, pl.1-12.

Sarjeant, W.A.S.

1992: Microfossils other than pollen and spores in palynological preparations. *In*: Nilsson, S. and Praglowski, J. (eds.), Erdtman's Handbook of Palynology, second edition, Copenhagen, Munksgaard, p.468-525.

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.

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, pl.1-6.

Stancliffe, R.P.W. and Sarjeant, W.A.S.

1990: The complex chorate dinoflagellate cysts of the Bathonian to Oxfordian (Jurassic): their taxonomy and stratigraphic significance. Micropaleontology, v.36, no.3, p.197-228, pl.1-5.

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*: Jansonius, 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.

Wade, J.A. and MacLean, B.C.

1990: The geology of the southeastern margin of Canada. *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.167-238.

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.

In press: 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.

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.

1977: Distribution patterns of some North Atlantic Cenozoic dinoflagellate cysts. *Marine Micropaleontology*, v.2, p.223-233, pl.1

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 - Neogen 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.

4 February 2003

Graham L. Williams

Marine Resources Geoscience Subdivision

GLW/nk

c.c. A.E. Jackson, MResG Subdivision, Dartmouth  
MResG Subdivision Files, Dartmouth  
CNSOPB, Dartmouth (attention M.-J. Verrall)

Figure 1. Stratigraphy and paleoecology of Amoco-Imperial Skelly Skua E-41. The lithostratigraphic picks are provided by K.D. McAlpine (pers. comm.).

## 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).

- Acanthaulax crispera* (W. Wetzel, 1967a) Woollam and Riding, 1983  
*Adnatosphaeridium* sp.A Stancliffe and Sarjeant, 1990  
*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  
*Aldorfia dictyota* (Cookson and Eisenack, 1960b) Davey, 1982b  
*Alisocysta circumtabulata* (Drugg, 1967) Stover and Evitt, 1978  
*Alisocysta margarita* (Harland, 1979a) Harland, 1979a  
*Apectodinium homomorphum* (Deflandre and Cookson, 1955) Lentin and Williams, 1977b  
*Apectodinium quinquelatum* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Apteodinium australiense* (Deflandre and Cookson, 1955) Williams, 1978  
*Areoligera* cf. *senonensis* Lejeune-Carpentier, 1938a  
*Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971  
*Auritulasporites deltaformis* Burger, 1966  
"Axiodinium" *articulatum*  
"Axiodinium" *ovale*  
*Baculatisporites* "giganteus"  
*Batiacasphaera micropapillata* Stover, 1977  
*Bombacidites* sp.A Williams and Brideaux, 1975  
*Callialasporites dampieri* (Balme, 1957) Sukh Dev, 1961  
*Callialasporites monoalaporus* Sukh Dev, 1961  
*Callialasporites obrutus* Norris, 1969  
*Cerebrocysta magna* Bujak, 1994  
*Cerebropollenites mesozoicus* (Couper, 1958) Nilsson, 1958  
*Cerodinium* cf. *depressum* (Morgenroth, 1966a) Lentin and Williams, 1987  
*Cerodinium diebelii* (Alberti, 1959b) Lentin and Williams, 1987  
*Cerodinium speciosum* (Alberti 1959b) Lentin and Williams, 1987  
*Charlesdowniea tenuivirgula* (Williams and Downie, 1966b) Lentin and Vozzhennikova, 1989  
*Charlesdowniea variabilis* (Bujak in Bujak *et al.*, 1980) Lentin and Vozzhennikova, 1989  
*Chatangiella victoriensis* (Cookson and Manum, 1964) Lentin and Williams, 1976  
*Chiropteridium galea* (Maier, 1959) Sarjeant, 1983  
*Chlamydothorella nyei* Cookson and Eisenack, 1958  
*Chytroeisphaeridia chytroides* (Sarjeant, 1962a) Downie and Sarjeant, 1965  
*Cicatricosisporites augustus* Singh, 1971  
*Cicatricosisporites subrotundus* Brenner, 1963  
*Cleistosphaeridium diversispinosum* Davey *et al.*, 1966  
*Cleistosphaeridium huguoniotii* (Valensi, 1955a) Davey, 1969a  
*Cleistosphaeridium iaculigerum* (Klement, 1960) Brenner, 1988  
*Comasphaeridium* cf. *cometes*  
*Compositosphaeridium polonicum* (Górka, 1965) Erkmén and Sarjeant, 1980  
*Contignisporites cooksoniae* (Balme, 1957) Dettmann, 1963  
*Contignisporites fornicatus* Dettmann, 1963  
*Contignisporites glebulentus* Dettmann, 1963

*Converrucosisporites exquisitus* Singh, 1971  
*Converrucosisporites variverrucatus* (Couper, 1958) Norris, 1969  
*Cordosphaeridium gracile* (Eisenack, 1954b) Davey and Williams, 1966b  
*Corollina itunensis* (Pocock, 1962) Cornet and Traverse, 1973  
*Corollina meyeriana* (Klaus, 1960) Venkatachala and Góczán, 1964  
*Corollina torosus* (Reissinger) Klaus, 1960  
*Coronatisporites valdensis* (Couper, 1958) Dettmann, 1963  
*Corrudinium incompositum* (Drugg, 1970b) Stover and Evitt, 1978  
*Cribroperidinium granuligerum* (Klement, 1960) Stover and Evitt, 1978  
*Cribroperidinium* “*pachydermum*”  
*Ctenidodinium* “*acuminatum*”  
*Ctenidodinium combazii* Dupin, 1968  
*Ctenidodinium continuum* Gocht, 1970b  
*Ctenidodinium culmulum* (Norris, 1965) Lentin and Williams, 1973  
*Ctenidodinium* “*delicatum*”  
*Ctenidodinium ornatum* (Eisenack, 1935) Deflandre, 1939a  
*Ctenidodinium pachydermum* (Deflandre, 1939a) Gocht, 1970b  
*Ctenidodinium pachydermum* subsp. “*brevispinum*”  
*Ctenidodinium sellwoodii* (Sarjeant, 1975a) Stover and Evitt, 1978  
*Ctenidodinium sellwoodii* subsp. “*extensum*”  
*Cyclonephelium* sp. A Williams and Brideaux, 1975  
*Cyclonephelium* sp. B Williams and Brideaux, 1975  
*Cyclonephelium vannophorum* Davey, 1969a  
*Deflandrea denticulata* Alberti, 1959b  
*Deflandrea phosphoritica* Eisenack, 1938b  
*Diconodinium arcticum* Manum and Cookson, 1964  
*Dictyophyllidites equixinus* (Couper, 1958) Dettmann, 1963  
*Dingodinium jurassicum* Cookson and Eisenack, 1958  
*Dinogymnium euclaense* Cookson and Eisenack, 1970a  
*Dinopterygium cladoides* Deflandre, 1935  
*Diphyes brevispinum* Bujak, 1994  
*Diphyes colligerum* (Deflandre and Cookson, 1955) Cookson, 1965a  
*Diphyes ficusoides* Islam, 1983b  
*Diphyes pseudoficusoides* Bujak, 1994  
*Dissiliodinium* sp.2 Feist-Burkhardt and Monteil, 1997  
*Distatodinium paradoxum* (Brosius, 1963) Eaton, 1976  
*Dracodinium condylos* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Dracodinium varielongitudum* (Williams and Downie, 1966b) Costa and Downie, 1979  
*Druggidium apicopaucicum* Habib, 1973  
*Durotrigia asketa* Bailey, 1990  
*Durotrigia daveyi* Bailey, 1987  
*Echinitosporites* sp.A Bujak and Williams, 1977  
*Endoscrinium luridum* (Deflandre, 1939a) Gocht, 1970b  
*Energlynia acollaris* (Dodekova, 1975) Sarjeant, 1978a  
*Enneadocysta multicornuta* (Eaton, 1971) Stover and Williams, 1995  
*Enneadocysta pectiniformis* (Gerlach, 1961) Stover and Williams, 1995  
*Eocladopyxis* “*brevispinosa*”  
*Eocladopyxis peniculata* Morgenroth, 1966a  
*Epiplosphaera areolata* Klement, 1960  
*Exochosphaeridium striolatum* (Deflandre, 1937b) Davey, 1969a

*Extratropopollenites* spp.  
*Florentinia perforata* Firth, 1993  
*Foveosporites canalis* Balme, 1957  
*Geiselodinium inaeffectum* Drugg, 1978  
*Geiselodinium paemosum* Drugg, 1978  
 Gen. et sp.2 Gocht, 1970  
*Gillinia hymenophora* Cookson and Eisenack, 1960a  
*Glaphyrocysta exuberans* (Deflandre and Cookson, 1955) Stover and Evitt, 1978  
*Glaphyrocysta ordinata* (Williams and Downie, 1966c) Stover and Evitt, 1978  
*Glaphyrocysta pastielsii* (Deflandre and Cookson, 1955) Stover and Evitt, 1978  
*Glaphyrocysta spineta* (Eaton, 1976) Stover and Evitt, 1978  
*Gonyaulacysta eisenackii* (Deflandre, 1939a) Górka, 1965  
*Gonyaulacysta jurassica* (Deflandre, 1939a) Norris and Sarjeant, 1965  
*Gonyaulacysta jurassica* subsp. *adepta adepta* Sarjeant, 1982b  
*Gramineae* spp.  
*Hafniasphaera hyalospinosa* Hansen, 1977  
*Heteraulacacysta leptalea* Eaton, 1976  
*Heteraulacacysta pustulosa* Jan du Chêne and Adediran, 1985  
*Heteraulacacysta "stoveri"*  
*Histiophora ornata* Klement, 1960  
*Homotryblium tenuispinosum* Davey and Williams, 1966b  
*Hystrichokolpoma truncatum* Biffi and Manum, 1988  
*Hystrichosphaeridium bowerbankii* Davey and Williams, 1966b  
*Hystrichosphaeridium petilum* Gitmez, 1970  
*Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre, 1937b  
*Hystrichosphaeropsis obscura* Habib, 1972  
*Hystrichostrogylon membraniphorum* Agelopoulos, 1964  
*Hystrichostrogylon "procerus"*  
*Impagidinium brevisulcatum* Michoux, 1985  
*Impardecispora mirabilis* (Bolchovitina, 1956)  
*Impletosphaeridium tribuliferum* (Sarjeant, 1962a) Islam, 1993  
*Isabelidinium acuminatum* (Cookson and Eisenack, 1958) Stover and Evitt, 1978  
*Ischyosporites amplireticosus* Doring, 1973  
*Ischyosporites punctatus* Cookson and Dettmann, 1958  
*Kleithriasphaeridium loffrense* Davey and Verdier, 1976  
*Klukisporites areolatus* Singh, 1971  
*Klukisporites foveolatus* Pocock, 1964  
*Klukisporites pseudoreticulatus* Couper, 1958  
*Korystocysta gochtii* (Sarjeant, 1976a) Woollam, 1983  
*Kraeuselisporites* #EB Davies in Bujak-Davies, 1987  
*Kraeuselisporites reissingeri* (Harris, 1957) Morbey, 1975  
*Lanterna sportula* Dodekova, 1969  
*Lentinia serrata* Bujak in Bujak *et al.*, 1980  
*Lentinia? wetzelii* (Morgenroth, 1966a) Bujak in Bujak *et al.*, 1980  
*Leptodinium subtile* Klement, 1960  
*Leptolepidites major* Couper, 1958  
*Leptolepidites psarosus* Norris, 1969  
*Lithodinia jurassica* Eisenack, 1935  
*Litosphaeridium arundum* (Eisenack and Cookson, 1960) Davey, 1979b  
*Mancodinium semitabulatum* Morgenroth, 1970

*Manumiella seelandica* (Lange, 1969) Bujak and Davies, 1983  
*Meiourogonyaulax caytonensis* (Sarjeant, 1959) Sarjeant, 1969  
*Meiourogonyaulax deflandrei* Sarjeant, 1968  
*Meiourogonyaulax valensii* Sarjeant, 1966b  
*Membranoporphidium aspinatum* Gerlach, 1961  
*Mendicodinium groenlandicum* (Pocock and Sarjeant, 1972) Davey, 1979c  
*Microdinium irregulare* Clarke and Verdier, 1967  
“*Minisphaeridium*” *fibrospinosum*  
“*Minisphaeridium*” *minimum*  
*Nannoceratopsis ambonis* Drugg, 1978  
*Nannoceratopsis gracilis* Alberti, 1961  
*Nannoceratopsis gracilis* subsp. “*perforatus*”  
*Occisucysta balios* Gitmez, 1970  
*Odontochitina costata* Alberti, 1961  
*Odontochitina operculata* (O. Wetzel, 1933a) Deflandre and Cookson, 1955  
*Oligosphaeridium* cf. *patulum* Riding and Thomas, 1988  
*Oligosphaeridium perforatum* (Gocht, 1959) Davey and Williams, 1969  
*Operculodinium divergens* (Eisenack, 1954b) Stover and Evitt, 1978  
*Operculodinium microtriainum* (Klumpp, 1953) Islam, 1983a  
*Operculodinium multispinosum* Ashraf, 1979  
*Operculodinium tiara* (Klump, 1953) Stover and Evitt, 1978  
*Ovoidinium cinctum* (Cookson and Eisenack, 1958) Davey, 1970  
*Palaeocystodinium bulliforme* Ioannides, 1986  
*Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b  
*Pareodinia ceratophora* Deflandre, 1947d  
*Parvisaccites radiatus* Brenner, 1963  
*Perisseiasphaeridium* “*extreme*”  
*Perisseiasphaeridium ingegerdiae* Nøhr-Hansen, 1986  
*Perisseiasphaeridium pannosum* Davey and Williams, 1966b  
*Phthanoperidinium amoenum* Drugg and Loeblich Jr., 1967  
*Phthanoperidinium coreoides* (Benedek, 1972) Lentin and Williams, 1976  
*Phthanoperidinium echinatum* Eaton, 1976  
*Phthanoperidinium eocenicum* (Cookson and Eisenack, 1965a) Lentin and Williams, 1973  
*Phthanoperidinium* “*hibernium*”  
*Phthanoperidinium levimurum* Bujak in Bujak *et al.*, 1980  
*Phthanoperidinium multispinum* Bujak in Bujak *et al.*, 1980  
*Prolixosphaeridium mixtispinosum* (Klement, 1960) Davey *et al.*, 1969  
*Raetiaedinium truncigerum* (Deflandre, 1937b) Kirsch, 1991  
*Reticulosphaera actinocoronata* (Benedek, 1972) Bujak and Matsuoka, 1986  
*Rhynchodiniopsis cladophora* (Deflandre, 1939a) Below, 1981a  
*Rhynchodiniopsis? regalis* (Gocht, 1970b) Jan du Chêne *et al.*, 1985b  
*Rottnestia borussica* (Eisenack, 1954b) Cookson and Eisenack, 1961b  
*Rubinella major* (Couper, 1958) Norris, 1969 sensu Norris, 1969  
*Rugubivesiculites reductus* Pierce, 1961  
*Schematophora speciosa* Deflandre and Cookson, 1955  
*Scriniocassis weberi* Gocht, 1964  
*Senoniasphaera rotundata* Clarke and Verdier, 1967  
*Sentusidinium asymmetrum* (Fenton *et al.*, 1980) Lentin and Williams, 1981  
*Sentusidinium rioultii* (Sarjeant, 1968) Stover and Sarjeant, 1978  
*Sentusidinium verrucosum* (Sarjeant, 1968) Sarjeant and Stover, 1978

*Sentusidinium villersense* (Sarjeant, 1968) Sarjeant and Stover, 1978  
*Spinidinium densispinatum* Stanley, 1965  
*Spiniferites ovatus* Matsuoka, 1983b  
*Spiniferites* “*procerus*”  
*Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970  
*Spiniferites scabrosus* (Clarke and Verdier, 1967) Lentin and Williams, 1975  
*Spiniferites velatus* (Clarke and Verdier, 1967) Stover and Evitt, 1978  
*Staplinisporites* sp.  
*Stephanelytron redcliffense* Sarjeant, 1961a  
*Subtilisphaera cheit* Below, 1981a  
*Subtilisphaera perlucida* (Alberti, 1959b) Jain and Millepied, 1973  
*Sumatradinium druggii* Lentin *et al.*, 1984  
*Surculosphaeridium cribrotubiferum* (Sarjeant, 1960a) Davey *et al.*, 1966  
*Systematophora areolata* Klement, 1960  
*Systematophora* “*diversispinosa*”  
*Systematophora fasciculigera* Klement, 1960  
*Systematophora orbifera* Klement, 1960  
*Systematophora palmula* Davey, 1982b  
*Systematophora penicillata* (Ehrenberg, 1843b) Sarjeant, 1980a  
*Systematophora turonica* (Alberti, 1961) Downie and Sarjeant, 1965  
*Systematophora valensii* (Sarjeant, 1960a) Sarjeant, 1961b  
*Taeniophora iunctispina* Klement, 1960  
*Tanyosphaeridium regulare* Davey and Williams, 1966b  
*Thalassiphora reticulata* Morgenroth, 1966b  
*Triblastula utinensis* O. Wetzel, 1933b  
*Trichodinium castanea* Deflandre, 1935  
*Trilobosporites obsitus* Norris, 1969  
*Trithyrodinium evittii* Drugg, 1967  
*Tubotuberella apatela* (Cookson and Eisenack, 1960b) Ioannides *et al.*, 1977  
*Tubotuberella dangeardii* (Sarjeant, 1968) Stover and Evitt, 1978  
*Turbiosphaera magna* Eaton, 1976  
*Uvaesporites glomeratus* Doring, 1965  
*Valensiella ovulum* (Deflandre, 1947d) Eisenack, 1963a  
*Valensiella vermiculata* Gocht, 1970b  
*Valvaeodinium spinosum* (Fenton *et al.*, 1980) Below, 1987b  
*Wanaea indotata* Drugg, 1978  
*Wetziella articulata* O. Wetzel in Eisenack, 1938b  
*Wetziella gochtii* Costa and Downie, 1976  
*Wetziella symmetrica* Weiler, 1956  
*Wilsonidium compactum* Michoux, 1988  
*Wilsonidium echinosuturatum* (Wilson, 1967c) Lentin and Williams, 1976  
*Xenascus ceratioides* (Deflandre, 1937b) Lentin and Williams, 1973  
*Xenascus sarjeantii* (Corradini, 1973) Stover and Evitt, 1978

