



## GEOLOGICAL SURVEY OF CANADA

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### **Palynological Analysis of Elf Hermine E-94, Scotian Basin**

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G.L. Williams

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1 Challenger Drive  
Dartmouth, NS B2Y 4A2

**Williams, G.L.**

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## Palynological Analysis of Elf Hermine E-94, Scotian Basin

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G.S.C. Locality No.: D-38

Unique ID: 300E944530054150

Location: 45°23'29"N, 54°29'54"W

Elevation Sea level to R.T.: 25.9 m (85')

Water Depth: 82.6 m (271')

Total Depth: 3267.5 m (10,720')

Spud Date: 18 October 1971

Interval Studied: 341.6-3261.36 m (1120-10.700')

Casing Points: 762 mm at 93 m (30" at 304'); 508 mm at 331.3 m (20" at 1087'); 340 mm at 986.6 m (13 3/8 at 3237'); 244 mm at 1830 m (9 5/8 at 6004')

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### Introduction

Elf Hermine is on the northeastern margin of the Scotian Basin. This study is based on the palynological analysis of 187 cuttings samples and 26 sidewall cores from the interval 3261.4-341.6 m. This report completes the second part of my study of Elf Hermine E-94. The first phase of the study covered the interval 664.5-341.4 m (2180-1120') (Williams, 2003a). There, I examined the interval 664.5 to 3261.4 m and determined the paleoenvironments for the intervals 1642-1252 m and 856-341.6 m.

### Biostratigraphy

My age determinations, based on the dinoflagellate (dinocyst) and spore/pollen assemblages, are given in Figure 1. The known stratigraphic ranges of dinocysts in European sections (Williams *et al.*, 1999, 2001, in press) and in other wells and coreholes on the Scotian Margin and Grand Banks (Williams, 1975; Williams and Brideaux, 1975; Barss *et al.*, 1979; Bujak and Davies Group, 1987; Williams *et al.*, 1990; Williams, 2003a, b, c, d, in press) provide most of the age control. Paleozoic spore data are taken directly from Barss *et al.* (1979). For stratigraphic information on Cretaceous spores and pollen, I have used Williams (2003b, c, d) and the PALYNODATA database.

PALYNODATA has been compiled over the last thirty years by a consortium of several major oil companies and the Geological Survey of Canada. The database stores taxonomic, bibliographic, geographic and biostratigraphic information from 20,000 pre-Quaternary palynological publications.

Hermine E-94 reached total depth at 3261.4 m. The interval 3261.4-1652 m at some horizons contains Paleozoic spore assemblages that have been described by Barss *et al.* (1979). These authors gave the age of the interval 3267-2386 m as indeterminate, assumed Paleozoic. The cuttings samples covering the interval contain carbonized spores and occasionally Tertiary pollen, which are either cavings or contamination.

Barss *et al.* (1979) considered the interval from 2235 to 1777 m to be questionable Late Viséan to Namurian, based on generally poorly preserved, sparse spore assemblages. Tertiary pollen are common. Barss *et al.* (op. cit.) considered the interval from 1777 to 1768 m to be late Westphalian B to early Westphalian C, and from 1768-1646 m to be Westphalian.

There is a major unconformity at 1634.9 m, where Cretaceous sediments directly overlie the Westphalian. The oldest Cretaceous is Barremian, which extends from 1642.9 to 1548.4 m. Age diagnostic events are the last appearance datum (LAD) of the pollen *Cerebropollenites mesozoticus* and *Callialasporites*

*dampieri* and the dinocysts *Endoceratium ludbrookiae*, *Muderongia simplex* subs. *microporforata* and *Systematophora complicata*. Williams (2003c) noted that the LAD of the pollen *Cerebropollenites mesozoicus* and *Callialasporites dampieri* is Barremian in the Skua E-41 well of the Carson Basin.

The stratigraphic ranges of the dinocysts also support a Barremian age. Williams (1975) set up a *Tenua anaphrissa* Peak Zone, which he considered Barremian. One of the species with its LAD in the zone was *Muderongia simplex*. *Systematophora complicata* was originally described from the late Hauterivian-mid Barremian by Neale and Sarjeant (1962). The occurrence of *Endoceratium ludbrookiae* is more contentious. According to Williams *et al.* (1999), this species has a stratigraphic range of 105-94.85 Ma, that's late Albian-Cenomanian. It would appear to be caved in Hermine E-94.

Barss *et al.* (1979) assigned 1646-1585 m to the Aptian *Subtilisphaera perlucida* Zone of Williams (1975). Within this zone, Barss *et al.* (op. cit.) considered from 1646-1597 m to represent the early Aptian *Cerbia tabulata* (as *Aptea attadalica*) Subzone of Williams (op. cit.). I was able to recognize Barremian because of the reprocessing of the samples and the much better recovery of dinocysts.

I include 1542-1426 m in the Aptian. This is confirmed by the LAD of the dinocyst *Cerbia tabulata* in the cuttings sample at 1426-1432 m. As noted in the previous paragraph, Williams (1975) erected the early Aptian *Cerbia tabulata* (as *Cyclonephelium attadalicum*) Subzone. However, Duxbury (2001) marked the LAD of *Cerbia tabulata* at the Aptian-Albian boundary. This seems to agree better with my data in Hermine. Further confirmation of the Aptian age is the LAD of the dinocyst *Gardodinium trabeculosum* in the cuttings sample 1438.7-1432.6 m. Williams *et al.* (1999) gave 113.96 Ma as the LAD for this species in high latitudes. Gradstein and Ogg (1996) placed the Aptian-Albian boundary at 112.2 Ma.

One characteristic of the Aptian in Hermine E-94 is the high degree of reworked Neocomian and Barremian species, including *Cerebropollenites mesozoicus*, *Subtilisphaera perlucida*, *Achomosphaera neptunii* and *Spiniferites speciosus*.

The Albian, which covers the interval 1420.4 to 1280 m, can be subdivided into early and late. Early Albian, 1420.4-1312 m, contains the LADs of the dinocysts *Stiphrosphaeridium anthophorum* and *Maghrebinia chleuh*. *Maghrebinia chleuh* was described from the Vraconian (late Albian)-Cenomanian of Morocco by Below (1981). Subsequently, Below (1984) and Masure (1988) recorded its stratigraphic range of Albian to Cenomanian. Schiøler (1992) recorded *Maghrebinia chleuh* from the Coniacian and Smelror and Riegraf (1996) observed it in the Campanian. In both these papers, however, the authors assumed the species to be reworked. On the Grand Banks, it has been found in one other well, Hebron I-13 in the Jeanne d'Arc Basin. There it was Albian.

The sixteen sidewall cores between 1312-1252 m give me the unusual opportunity of being able to use first appearance datums (FAD) for picking boundaries. Thus, I consider the sidewall at 1312 m to be late Albian, because it contains the FAD of *Rugubivesiculites rugosus*. This agrees with Williams (1975), who named the late Albian *Rugubivesiculites rugosus* Assemblage Zone, on the FAD of *Rugubivesiculites rugosus*. Other pollen species with their FADs in the late Albian are *Rugubivesiculites reductus*, *Retitricolpites georgensis* and *Retitricolpites virgens*.

I place the top of the Albian at 1280 m, where is the LAD of the dinocysts *Chichaouadinium cf. vestitum*, *Microdinium setosum*, *Ovoidinium cinctum* and *Pseudoceratium eisenackii*. Williams (1975) erected the *Chichaouadinium cf. vestitum-Eucoccommiidites minor* Zone of Albian age. Dinocyst species with their LADs within or at the top of the zone included *Chichaouadinium cf. vestitum*. Williams *et al.* (1999) gave the LAD for *Chichaouadinium vestitum* as 98.9 Ma and the LAD of *Ovoidinium cinctum* as 96.2

Ma. On the timescale of Gradstein and Ogg (1996), the Albian-Cenomanian boundary is at 98.9 Ma. Therefore I use these two species for determining the top of the Albian.

*Microdinium setosum*, described by Sarjeant (1966b) is generally accepted to be Aptian-Cenomanian (Foucher and Verdier, 1976), with most records being from the Albian-Cenomanian. It is rare in Grand Banks wells, which is understandable considering that Albian-Cenomanian sediments are either missing or very thin.

Several dinocyst species that have their LAD in the Albian in Hermine E-94 are known from younger ages. *Kiokansium williamsii* (as *Cleistosphaeridium* subsp. A), *Cribroperidinium orthoceras* and *Pseudoceratium* (as *Cyclonephelium*) *eisenackii* all had their LADs in the Cenomanian of offshore eastern Canada, according to Bujak and Williams (1978). And *Cleistosphaeridium huguoniotti* usually has a Cenomanian LAD in wells in the Jeanne d'Arc Basin. I attribute this to the overlying Cenomanian being very thin, plus my poor sample coverage above 1280 m.

Spores with LADs in the late Albian are *Appendicisporites jansonii*, *Appendicisporites problematicus* and *Cicatricosporites hallei*. Williams (1975) placed the LAD of *Appendicisporites hallei* in the *Spinidinium cf. vestitum-Eucommiidites minor* Zone of Albian age.

As in the Aptian, there are several reworked taxa in Hermine E-94. Reworked spores and pollen include *Coronatispora valdensis*, *Callialasporites dampieri*, *Cicatricosporites #EAK* of Davies in Bujak-Davies Group, 1987 and *Cicatricosporites #ECJ* of Davies in Bujak-Davies Group, 1987. Presumably, this reflects the aftermaths of the Cretaceous unconformity at 1634.9 m.

Barss *et al.* (1979) considered the Albian to be from 1536 to 1313 m, and the Cenomanian to be from 1295 to 1283 m. These differences with my interpretation are probably due to technical advances in sample processing and the available sidewall core samples.

From 1278-1261 m is Cenomanian, based on the LADs of the dinocyst species *Kiokansium williamsii* and *Oligosphaeridium totum*. Williams *et al.* (1999) gave the LAD of *Kiokansium williamsii* as 96.2 Ma. Brideaux (1971) described *Oligosphaeridium totum* from the Cenomanian. The vast majority of subsequent records have confirmed a Cenomanian LAD for this species.

I cannot recognize the Turonian in Hermine E-94 because of the paucity of Cretaceous dinocysts. But I can delineate a Turonian-Coniacian interval, which extends from 1252 to 1197 m. Dinocyst species with LADs in the Turonian-Coniacian are *Cyclonephelium vannophorum*, *Endoscrinium campanula*, *Heterosphaeridium difficile*, *Hystrichosphaeridium bowerbankii* and *Oligosphaeridium pulcherrimum*. Williams *et al.* (1999) gave an LAD of 85.8 Ma for *Cyclonephelium vannophorum* and *Endoscrinium campanula*, 84.7 Ma for *Heterosphaeridium difficile* and 81.1 Ma for *Hystrichosphaeridium bowerbankii*. Gradstein and Ogg (1996) placed the Coniacian-Santonian boundary at 85.8 Ma, which generally agrees with the LADs of the above species, except for *Hystrichosphaeridium bowerbankii*. However, Williams (2003d) noted that the LAD of *Hystrichosphaeridium bowerbankii* in the Terra Nova K-18 well of the Jeanne d'Arc Basin was Coniacian.

From 1188.7-1143 m is Santonian, based on the LADs of *Raetiaedinium truncigerum* and *Xiphophoridium alatum*. Williams and Brideaux (1975) noted that *Raetiaedinium* (as *Hystrichosphaeridium*) *truncigerum* had an LAD in the Santonian. And Williams (1975) erected a *Raetiaedinium* (as *Hystrichosphaeridium*) *truncigerum* Zone, which he considered Santonian. Williams *et al.* (in press) give the LAD of this species as 75.35 Ma, which approximates with the top of the early Campanian. But Williams (2003c, d) followed Williams (1975) and Bujak and Williams (1978) in

continuing to regard the LAD of *Raetiaedinium truncigerum* as denoting the top of the Santonian in offshore east coast wells.

The Campanian, which extends from 1133.6-1015 m, can be subdivided into early and late. I have picked the top of the early Campanian at 1069-1078 m, based on the LAD of *Surculosphaeridium cf. longifurcatum*. The closest related taxon *Surculosphaeridium? longifurcatum* has an LAD of 81.68 Ma, according to Williams *et al.* (in press). This is within the early Campanian. Other dinocyst taxa with LADs in the early Campanian are *Chatangiella tripartita*, *Trichodinium castanea*, *Palaeohystrichophora infusoriooides* and *Renidinium membraniphorum*. Williams *et al.* (1999) gave the following LADs for the above species: 69.6 Ma for *Chatangiella tripartita*, 75 Ma for *Trichodinium castanea* and 69.6 Ma for *Palaeohystrichophora infusoriooides*. According to PALYNODATA, *Renidinium membraniphorum* has a range of Maastrichtian-Paleocene. Presumably, in Hermine E-94, it results from caving.

From 1060-1015 m is late Campanian. This interval includes the LADs of *Odontochitina costata* and *Xenascus ceratoides*. Williams *et al.* (1999) give the LAD of *Odontochitina costata* as 69.6 Ma and the LAD of *Xenascus ceratoides* as 68.8 Ma. Gradstein and Ogg (1996) placed the Campanian-Maastrichtian boundary at 71.3 Ma. Accordingly, I use the LAD of *Odontochitina costata* to mark the top of the Campanian.

Hermine E-94 is one of the few Grand Banks wells with identified Maastrichtian sediments. The cuttings sample from 929.6-920.5 m contains *Palynodinium grallator*, which in Northern Hemisphere mid latitudes has a stratigraphic range of 66.77-64.75 Ma (Williams *et al.*, in press). The Maastrichtian-Danian boundary is at 65 Ma (Gradstein and Ogg, 1996). Thus, I assume that 1002.8-920.5 m is Maastrichtian.

For the late Cretaceous in Hermine E-94, Barss *et al.* (1979) gave the following subdivision: Cenomanian (1295.4-1283.2 m), ?Turonian (1261.9-1252.7 m), Coniacian (1234.4-1197.9 m), late Cretaceous (1152-1088.1 m), Campanian (1015-1002.8 m) and Maastrichtian (984.5-920.5 m). This shows general agreement with my interpretation.

The interval 911.4-847.4 m is somewhat enigmatic. According to the lithostratigraphy, this is Wyandot Equivalent (MacLean and Wade, 1993), which would indicate a late Cretaceous age. Bartlett (1972) considered that the foraminifera indicated a Maastrichtian age for 847-902 m. Also using foraminifera, Frank Thomas (pers.comm.) has concluded that 957-865 m is Maastrichtian, showing good agreement with Bartlett. However, Barss *et al.* (1979) dated 902-865 m as early Eocene. I have analyzed four cuttings samples from the interval 911-847 m and recorded only one late Cretaceous specimen. All the other several hundred specimens are either Tertiary or non-diagnostic. Therefore, the palynomorphs indicate that from 911-801 m is Ypresian or early Eocene. My conclusion is that almost all the specimens are cavings.

Above 847 m must be early Ypresian, since the cuttings sample at 911-902 m contains *Dracodinium condyllos*. Williams *et al.* (in press) give a stratigraphic range of 52.5 Ma. The Ypresian extends from 54.8-49 Ma, according to Gradstein and Ogg (1996). This is the basis for predicting an early Ypresian age immediately above the cuttings sample at 847-856 m.

I include 829.1-806.7 m in the late Ypresian. Dinocysts are abundant with several taxa having their LADs. These include *Areoligera cf. medusettiformis*, *Areoligera cf. senonensis*, *Hystrichokolpoma bullatum*, *Spiniferella cornuta*, *Eatonicysta ursulae* and *Hystrichokolpoma spinosum*. Williams (1975) erected the early Eocene *Areoligera senonensis* Assemblage Zone. Williams *et al.* (1999) gave an LAD of 48 Ma for *Areoligera senonensis*, which is close to the Ypresian-Lutetian boundary at 49 Ma. *Hystrichokolpoma bullatum* and *Hystrichokolpoma spinosum* were described by Wilson (1988) from the

early Eocene of New Zealand. *Spiniferella cornuta* has been recorded from the early Miocene (Williams and Manum, 1999), but on the Grand Banks is rarely found in post lower Eocene sediments. *Eatonicysta ursulae* has a known stratigraphic range of 53.42-45.74 Ma (Williams *et al.*, 1999).

The LADs of the above species collectively support an Ypresian age. The dominance of Eocene dinocysts in the “Maastrichtian” section presumably reflects the lithology and the richness of the caved interval. Chalk is notoriously difficult rock from which to recover palynomorphs. The few successes in the past have been based on processing of at least 200 gms for each sample. Since we were allowed to take 25 gms only, our prospects for finding indigenous, as opposed to caved, specimens are low.

In Hermine E-94, the Lutetian is surprisingly thick, extending from 792.5 to 606.6 m. I include from 792.5-710.2 m in the early Lutetian, based on the LAD of *Diphyes ficusoides*. Bujak (1994) placed the LAD of this species at the boundary of planktonic foraminiferal zones P10 and P11, which is within the nannofossil NP15 Zone. Williams *et al.* (2001) gave a LAD of 45.2 Ma for *Diphyes ficusoides*. The Lutetian extends from 49-42 Ma (Gradstein and Ogg, 1996), so it seems reasonable to place the early-late Lutetian boundary at 45 Ma. Williams (2003b, c) also considered the LAD of *Diphyes ficusoides* to mark the top of the early Lutetian.

Other dinocyst species with LADs in the early Lutetian of Hermine E-94 include *Areoligera sentosa*, *Areoligera undulata*, *Glyphyrocysta preordinata*, *Charlesdownia coleothrypta* and *Wilsonidium lineidentatum*.

I place the interval 691.6-606.6 m in the late Lutetian. Most of the assemblages above 664.5 m have been discussed in Williams (2003a). The cuttings sample at 664.5-673.6 m contains abundant *Adnatosphaeridium multispinosum* abundant *Cordosphaeridium gracile* and *Batiacasphaera*. High abundances of *Adnatosphaeridium multispinosum* are characteristic of the Lutetian in several wells of offshore eastern Canada.

#### Paleoenvironments

The paleoenvironmental interpretations in Hermine E-94 are based primarily on cuttings. But, I need quantitative data. Accordingly, I did counts on some cuttings samples, while realising the limitations. These include the problems of caving and contamination, which bias any data. But equally difficult to assess is the effect of analysing composite samples that cover 10 m, rather than representing a specific depth. The above caused problems in Hermine E-94 but one of the few positive factors was the value of the spore-pollen:dinocyst ratio. Generally this gave reliable results in the Tertiary.

I was not able to interpret paleoenvironments for the Paleozoic section from total depth to 1730 m, the questionable Jurassic from 1730-1634.9 m, and the Late Cretaceous from 1252 to 841 m.

Where determinable, paleoenvironments are neritic, although there is fluctuation from close to shore to outer neritic. The interval 1642-1216 m is predominantly inner neritic, as indicated by the consistent occurrence of the dinocyst *Cribroperidinium*. Williams (2003d) considered this genus to be an indicator of inner shelf environments. From 1603-1609 m is dominated by spores and pollen with the occasional *Subtilisphaera perlucida*. I interpret this to denote very shallow, marginal marine conditions.

My first detailed quantitative data are from 16 sidewall cores, which span the interval 1312.5-1252.7 m. A sidewall core at 1312 m has a dinocyst:spore-pollen ratio of 54:100, suggesting an inner shelf milieu. This changes between 1269 and 1264 m, where there are about 10 spores and pollen to each dinocyst. I regard this as denoting marginal marine conditions. From 1261 m up, the environment deepens, judging from the increasing numbers of *Spiniferites*.

Dinocysts are much more abundant than spores and pollen in the four samples between 911.35-841.3 m. This is the interval which is included in the Wyandot Chalk. From 922-847 m *Spiniferites* is common but presumably the specimens are all caved. In the cuttings samples from 829-819 m, the dinocyst *Homotryblium tenuispinosum* is abundant. Brinkhuis (1992) considered the genus *Homotryblium* to indicate lagoonal to restricted marine conditions. Following this, I consider 829-819 m to represent a marginal marine to innermost neritic environment. *Homotryblium tenuispinosum* is a warmer water species (Brinkhuis, 1992), indicating that not only was there climatic warming but also there was, in all likelihood, a proto Gulf Stream. In this interval, *Cleistosphaeridium diversispinosum* is common, suggesting that it was a major component of inner neritic assemblages. The cuttings sample from 810.8-801.6 m contains abundant *Cleistosphaeridium diversispinosum* but there are no *Homotryblium* specimens.

Continuing shallow-water conditions, probably marginal marine, existed in the interval covered by the cuttings sample 792.5-783.3 m. I determined this from the high numbers of *Azolla* spores. *Azolla* is a fresh water fern, which would not have been transported over any distance. Therefore, I am assuming that the sediments containing this genus were deposited in very shallow water. The sample also contains common *Cleistosphaeridium diversispinosum* and *Wetzelella*. Downie *et al.* (1971) suggested that *Wetzelella* was estuarine.

From 765 to 692 m, the paleoenvironments were shallow marine, with common to abundant specimens of *Wetzelella*. The fragmented nature of many specimens may reflect high energy environments. *Cleistosphaeridium diversispinosum* is also common in the cuttings sample from 728-737 and 682-691 m.

A deeper water setting existed at 673-664 m, marked by abundant *Cordosphaeridium gracile* and *Adnatosphaeridium multispinosum*. Islam (1984) and Köthe (1990) both regarded the genus *Cordosphaeridium* as reflecting open marine waters. In the same sample *Polysphaeridium zoharyi* is common, indicating tropical or subtropical temperatures.

The environment was primarily mid-shelf from 664 to 469 m, with *Spiniferites ramosus* common in several samples. *Lingulodinium machaerophorum* is common from 609.6-606.6 m and *Cleistosphaeridium diversispinosum* abundant from 591.3-588.3 m and common from 563.9-560.8 m. Although *Spiniferites ramosus* and *Cleistosphaeridium diversispinosum* are common to abundant in inner neritic settings, the occurrence in some samples and the occasional occurrence of *Nematosphaeropsis* and *Impagidinium* indicates more open-marine conditions.

In most of the samples from 463 to 341 m, pollen are more abundant than dinocysts, suggesting a shallowing or more inshore milieu. This is especially so for the interval 417-377 m. The sample from 417-414 m contains few dinocysts but has numerous carbonized wood fragments. From 390-387 m is similar but the wood fragments are not oxidized.

A more open-marine environment returns at 344.4-341.4 m, the topmost sample, as shown by the marked increase in numbers of dinocysts.

The paleoenvironmental settings at Hermine E-94 from the Barremian to Cenomanian and the Ypresian to early Lutetian were predominantly inner neritic, with occasional marginal marine and outer marine episodes. Marginal marine conditions occurred in the late Albian and within the Eocene. Outer neritic environments existed during much of the Lutetian to Rupelian, with shallowing in the Miocene. The data indicate that Hermine E-94 was located on the rim of the Scotian Basin.

### Correlation of Palynology and Lithostratigraphy

The lithostratigraphy of the Hermine E-94 well was published by MacLean and Wade (1993) and the Canada Newfoundland Offshore Petroleum Board (1998). I shall use MacLean and Wade (1993) for lithostratigraphic terminology, depths and thicknesses. For the Carboniferous rocks, MacLean and Wade (op. cit.) relied primarily on personal information from R.D. Howie.

The oldest lithologic unit in Hermine E-94 is Windsor Group salt, which extends from 3267.5 to 2406.1 m. Barss *et al.* (1979) considered this as Paleozoic, failing to find any evidence for a more concise age. The salt is overlain by Carboniferous redbeds, which MacLean and Wade (1993) included in the Canso Group and which goes up to 2104.9 m. Rocks of the overlying Riversdale Group span the interval 2104.9-1709.9 m. Barss *et al.* (1979) considered the Canso and most of the Riversdale as late Viséan to Namurian, although they recognized Westphalian from 1777-1645.9 m.

The presence of extensive glauconite and a dolomite in the upper Carboniferous has led to a suggestion that some of this section may be Jurassic. I have exhaustively checked several samples from 2112 to 1652 m, however, and found numerous Carboniferous spores but only one Jurassic-early Cretaceous spore. The question is where did that one come from. I have to conclude that, based on the evidence, the section is Carboniferous.

There is a major unconformity at 1634 m, where Cretaceous sediments of the Eider Member immediately overlie the Riversdale. McAlpine (1990) formally defined the Eider Member of the Logan Canyon Formation as the Eider Formation. He designated the interval 830-708 m in Amoco IOE A-1 Eider M-75 as the type section and gave the age of the formation as late Albian to late Cenomanian.

MacLean and Wade (1993) included the interval 1634.9-1459.4 m in the Eider. I consider from 1642.9-1548.4 m as Barremian and 1542-1426 m as Aptian. This suggests that some of the interval now considered the Eider Formation may be more appropriately assigned to the Ben Nevis and Avalon formations.

The Eider Formation is overlain by the Dawson Canyon Formation, which extends from 1459.4 to 946.1 m and includes the Petrel Member between 1343.6 and 1241.8 m. Thus the lowest part of the Dawson Canyon would be Aptian and the highest would be Maastrichtian. The Petrel is Albian to Turonian-Coniacian. Wade and MacLean (1990) gave the age of the Dawson Canyon Formation as Cenomanian to Santonian and the age of the Petrel Member as Turonian.

Obviously, the ages or the intervals included in the Dawson Canyon Formation and Petrel Member cannot be correct in Hermine E-94. I have extensive sidewall coverage from 1312.5-1252.7 m, which I regard as late Albian-Cenomanian. It is possible that the late Albian base occurs deeper in the well than shown, because that pick is on FADs or first appearance datums. But this would still make the Petrel late Albian to Turonian-Coniacian. I think that the designations and boundaries of the lithostratigraphic units need to be adjusted.

The interval 946.1-847.3 m was named Wyandot equivalent? by MacLean and Wade (1993). This is Maastrichtian, at least in part, which is somewhat younger than much of the Wyandot but acceptable. The overlying Banquereau, which extends to the top of the well, is Tertiary.

There are some concerns regarding the ages of the main lithostratigraphic units in Hermine. This may in part reflect the well's location and the uncertainty of correlation with adjacent wells. But I also think it would be worthwhile to re-evaluate the lithostratigraphic data to see if there are alternative interpretations that better fit the biostratigraphic data.

### Summary

Hermine E-94 contains a thick Paleozoic section extending from TD at 3267.5 to 1634.9 m. As noted earlier, there is a suggestion that the uppermost part may be Jurassic. To prove this one way or the other beyond a doubt would require resampling, with far more than the statutory 25 grams being taken.

My re-appraisal of the biostratigraphy of Hermine has answered some questions, such as the completeness of the Tertiary section, but raised far more imponderables. A major one is: why do the lithostratigraphic and biostratigraphic data not show closer agreement. Since this well is key to understanding the regional geology of the northern part of the Scotian Basin, I recommend continuing study in the years ahead to resolve this conflict.

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## 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.

- Acanthotriletes varigranosus* Pocock, 1963  
*Achilleodinium biformoides* (Eisenack, 1954b) Eaton, 1976  
*Achromosphaera andalousiensis* (Eisenack, 1954b) Davey and Williams, 1966a  
*Achromosphaera neptuni* (Eisenack, 1958a) Davey and Williams, 1966a  
*Achromosphaera "procerus"*  
*Adnatosphaeridium multispinosum* Williams and Downie, 1966c  
*Adnatosphaeridium vittatum* Williams and Downie, 1966c  
*Apectodinium homomorphum* (Deflandre and Cookson, 1955) Lentin and Williams, 1977b  
*Apiculatisporis setulosus* (Kosanka, 1950) Potonié and Kremp, 1955  
*Apiculatisporis* sp.  
*Apiculatisporites aculeatus* (Ibrahim, 1933) Potonié and Kremp, 1955  
*Appendicisporites jansonii* Pocock, 1962  
*Appendicisporites problematicus* Burger, 1966  
*Apteodinium deflandrei* (Clarke and Verdier, 1967) Lucas-Clark, 1987  
*Apteodinium granulatum* Eisenack, 1958a  
*Areoligera cf. medusettiformis* O. Wetzel, 1933b  
*Areoligera cf. senonensis* Lejeune-Carpentier, 1938a  
*Areoligera sentosa* Eaton, 1976  
*Areoligera undulata* Eaton, 1976  
*Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971  
*Atopodinium chleuh* (Below, 1981a) Masure, 1991  
*Auroraspora solisortus* Hoffmeister, Staplin and Malloy, 1955  
“*Awilsonidium*” *echinosuturatum*  
“*Axiodinium*” *articulatum*  
“*Axiodinium*” *symmetricum*  
*Azolla* spp.  
*Baltisphaeridium “scalenofurcatum”*  
*Batiacasphaera compta* Drugg, 1970b  
*Batiacasphaera micropapillata* Stover, 1977  
*Calamospora microrugosa* (Ibrahim, 1933) Schopf, Wilson and Bentall, 1944  
*Calamospora minuta* Bharadwaj, 1954  
*Calamospora pallida* (Loose, 1934) Schopf, Wilson and Bentall, 1944  
*Caligodinium amicum* Drugg, 1970b  
*Callaiosphaeridium asymmetricum* (Deflandre and Courteville, 1939) Davey and Williams, 1966b  
*Callialasporites dampieri* (Balme, 1957) Sukh Dev, 1961  
*Callialasporites monoalasporus* Sukh Dev, 1961  
*Callialasporites obrutus* Norris, 1969  
*Callialasporites trilobatus* (Balme) Sukh Dev, 1961  
*Camarozonosporites insignis* Norris, 1967  
*Canningia reticulata* Cookson and Eisenack, 1960b  
*Caryapollenites* spp.  
*Cerbia tabulata* (Davey and Verdier, 1974) Below, 1981a  
*Cerebrocysta bartonensis* Bujak in Bujak et al., 1980  
*Cerebropollenites mesozoicus* (Couper, 1958) Nilsson, 1958  
*Charlesdowniea coleothrypta* (Williams and Downie, 1966b) Lentin and Vozzhennikova, 1989  
*Charlesdowniea columna* (Michoux, 1988) Lentin and Vozzhennikova, 1990  
*Charlesdowniea proserpina* van Mourik et al., 2001

- Chatangiella tripartita* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Chatangiella victoriensis* (Cookson and Manum, 1964) Lentin and Williams, 1976  
*Chatangiella cf. vnigri* (Vozzhennikova, 1967) Lentin and Williams, 1976  
*Chichaouadinium cf. vestitum* (Brideaux, 1971) Bujak and Davies, 1983  
*Chiropteridium galea* (Maier, 1959) Sarjeant, 1983  
*Cicatricosporites annulatus* Archangelsky and Gamerro, 1966  
*Cicatricosporites augustus* Singh, 1971  
*Cicatricosporites australiensis* (Cookson, 1953) Potonié, 1956  
*Cicatricosporites crassistriatus* Burger, 1966  
*Cicatricosporites hallei* Delcourt and Sprumont, 1955  
*Cicatricosporites magnus* Doring, 1965  
*Cicatricosporites subrotundus* Brenner, 1963  
*Cicatricosporites #EAK* Davies in Bujak-Davies, 1987  
*Cicatricosporites #ECJ* Davies in Bujak-Davies, 1987  
*Cicatricosporites #EQ* Davies in Bujak-Davies, 1987  
*Circulodinium colliveri* (Cookson and Eisenack, 1960b) Helby, 1987  
*Circulodinium distinctum* (Deflandre and Cookson, 1955) Jansonius, 1986  
*Cleistosphaeridium diversispinosum* Davey et al., 1966  
*Cleistosphaeridium huguoniottii* (Valensi, 1955a) Davey, 1969a  
*Cleistosphaeridium polypetallum* (Islam, 1983) Stover and Williams, 1995  
*Cometodinium whitei* (Deflandre and Courteville, 1939) Stover and Evitt, 1978  
*Con verrucosporites variverrucatus* (Couper, 1958) Norris, 1969  
*Convolutispora mellita* Hoffmeister, Staplin and Malloy, 1955  
*Convolutispora vermiformis* Hughes and Playford, 1961  
*Convolutispora* sp.  
*Cordosphaeridium cantharellus* (Brosius, 1963) Gocht, 1969  
*Cordosphaeridium cf. eoinodes* (Eisenack, 1958a) Eisenack, 1963b  
*Cordosphaeridium gracile* (Eisenack, 1954b) Davey and Williams, 1966b  
*Corollina torosus* (Reissinger) Klaus, 1960  
*Coronatispora valdensis* (Couper, 1958) Dettmann, 1963  
*Coronifera kirae* Prössl, 1992a  
*Corrudinium* sp.  
*Costatacyclus crenatus* (Felix and Burbridge, 1967) Urban, 1971  
*Costatoperforosporites fistulosus* Deák, 1962  
*Crassispora kosankei* (Potonié and Kremp) Bharadwaj, 1957b  
*Cribroperidinium? intricatum* Davey, 1969a  
*Cribroperidinium globatum* (Gitmez and Sarjeant, 1972) Hellenes, 1984  
*Cribroperidinium "major"*  
*Cribroperidinium orthoceras* (Eisenack, 1958a) Davey, 1969a  
*Cribroperidinium sepimentum* Neale and Sarjeant, 1962  
*Cristatisporites* sp.  
*Cyclonephelium vannophorum* Davey, 1969a  
*Cymosphaeridium validum* Davey, 1982b  
*Dapsilidinium laminaspinosum* (Davey and Williams, 1966b) Lentin and Williams, 1981  
*Dapsilidinium pastielsii* (Davey and Williams, 1966b) Bujak et al., 1980  
*Deflandrea heterophlycta* Deflandre and Cookson, 1955  
*Deflandrea phosphoritica* Eisenack, 1938b  
*Deflandrea truncata* Stover, 1974  
*Deltoidospora hallii* Miner, 1935  
*Densoisporites microrugulatus* Brenner, 1963  
*Densosporites* sp.

- Dictyotriletes* sp.
- Dictyotriletes clatriformis* (Artüz) Sullivan, 1964
- Dictyotriletes fragmentimurus* Neville
- Dinopterygium cladooides* Deflandre, 1935
- Diphyes brevispinum* Bujak, 1994
- Diphyes colligerum* (Deflandre and Cookson, 1955) Cookson, 1965a
- Diphyes ficusoides* Islam, 1983b
- Diphyes pseudoficusoides* Bujak, 1994
- Discernisporites irregularis* Neves, 1958
- Distaltriangulispores perplexus* (Singh, 1964) Singh, 1971
- Distatodinium "cavatum"* Zevenboom and Santarelli in Zevenboom, 1995
- Dracodinium "ovale"*
- Dracodinium varielongitudum* (Williams and Downie, 1966b) Costa and Downie, 1979
- Eatonicysta sequestra* Stover and Williams, 1995
- Eatonicysta ursulae* (Morgenroth, 1966a) Stover and Evitt, 1978
- Elytrocysta druggii* Stover and Evitt, 1978
- Endoceratum ludbrookiae* (Cookson and Eisenack, 1958) Loeblich Jr. and Loeblich III, 1966
- Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967
- Endosporites minutus* Hoffmeister, Staplin and Malloy, 1955
- Endosporites* sp.
- Enneadocysta "annulata"*
- Enneadocysta arcuata* (Eaton, 1971) Stover and Williams, 1995
- Enneadocysta multicornuta* (Eaton, 1971) Stover and Williams, 1995
- Enneadocysta pectiniformis* (Gerlach, 1961) Stover and Williams, 1995
- Enneadocysta* sp.
- Eocladiopyxis "brevispinosa"*
- Eocladiopyxis peniculata* Morgenroth, 1966a
- Exesipollenites tumulus* Balme, 1957
- Exochosphaeridium bifidum* (Clarke and Verdier, 1967) Clarke et al., 1968
- Extratriporopollenites* spp.
- Florentinia buspina* (Davey and Verdier, 1976) Duxbury, 1980
- Florentinia cooksoniae* (Singh, 1971) Duxbury, 1980
- Florentinia ferox* (Deflandre, 1937b) Duxbury, 1980
- Florentinia perforata* Firth, 1993
- Florentinia radiculata* (Davey and Williams, 1966b) Davey and Verdier, 1973
- Florinites eremus* Balme and Hennelly, 1955
- Florinites similis* Kosanke
- Florinites visendus* (Ibrahim, 1933) Schopf, Wilson and Bentall, 1944
- Florinites* sp.
- Gardodinium trabeculosum* (Gocht, 1959) Alberti, 1961
- Glaphyrocysta divaricata* (Williams and Downie, 1966c) Stover and Evitt, 1978
- 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 ex de Coninck, 1965) Stover and Evitt, 1978
- Glaphyrocysta "preordinata"*
- Glaphyrocysta spineta* (Eaton, 1976) Stover and Evitt, 1978
- Gramineae* spp.
- Grandispora spinosa* Hoffmeister, Staplin and Malloy, 1955
- Hafniasphaera fluens* Hansen, 1977
- Hafniasphaera* sp.
- Heslertonia heslertonensis* (Neale and Sarjeant, 1962) Sarjeant, 1966b

- Heteraulacacysta leptalea* Eaton, 1976  
*Heteraulacacysta "stoveri"*  
*Heterosphaeridium difficile* (Manum and Cookson, 1964) Ioannides, 1986  
*Homotryblium abbreviatum* Eaton, 1976  
*Homotryblium floripes* (Deflandre and Cookson, 1955) Stover, 1975  
*Homotryblium tenuispinosum* Davey and Williams, 1966b  
*Hystrichodinium pulchrum* Deflandre, 1935  
*Hystrichokolpoma bullatum* Wilson, 1988  
*Hystrichokolpoma cinctum* Klumpp, 1953  
*Hystrichokolpoma globulus* Michoux, 1985  
*Hystrichokolpoma rigaudiae* Deflandre and Cookson, 1955  
*Hystrichokolpoma salacium* Eaton, 1976  
*Hystrichokolpoma spinosum* Wilson, 1988  
*Hystrichokolpoma truncatum* Biffi and Manum, 1988  
*Hystrichosphaeridium bowerbankii* Davey and Williams, 1966b  
*Hystrichosphaeropsis obscura* Habib, 1972  
*Hystrichostrogylon clausenii* Bujak, 1994  
*Hystrichostrogylon membraniphorum* Agelopoulos, 1964  
*Hystrichostrogylon "procerus"*  
*Impagidinium maculatum* (Cookson and Eisenack, 1961b) Stover and Evitt, 1978  
*Impagidinium victoriense* (Cookson and Eisenack, 1965a) Stover and Evitt, 1978  
*Impagidinium* spp.  
*Impardecispora apigranulosa* (Doring, 1965) Davies in Bujak-Davies, 1987  
*Invertocysta tabulata* Edwards, 1984  
*Isabelidinium bakeri* (Deflandre and Cookson, 1955) Lentin and Williams, 1977a  
*Isabelidinium glabrum* (Cookson and Eisenack, 1969) Lentin and Williams, 1977a  
*Kenleyia* sp.  
*Kiokansium williamsii* C. Singh, 1983  
*Kleithriasphaeridium loffrense* Davey and Verdier, 1976  
*Knoxisporites stephanophorus* Love, 1960  
*Knoxisporites triradiatus* Hoffmeister, Staplin and Malloy, 1955  
*Laciniadinium arcticum* (Manum and Cookson, 1964) Lentin and Williams, 1980  
*Laternosphaeridium lanosum* Morgenroth, 1966a  
*"Latiwetzelilla" ovalis*  
*Lentinia "glabra"*  
*Lentinia serrata* Bujak in Bujak et al., 1980  
*Lentinia? wetzelii* (Morgenroth, 1966a) Bujak in Bujak et al., 1980  
*Lophotriletes microsaetus* (Loose, 1934) Potonié and Kremp, 1955  
*Lophotriletes pseudoaculeatus* Potonié and Kremp, 1955  
*Lycospora noctuina* var. *noctuina* Butterworth and Williams,  
*Lycospora punctata* Kosanke, 1950  
*Lycospora* sp.  
*Melitasphaeridium choanophorum* (Deflandre and Cookson, 1955) Harland and Hill, 1979  
*Melitasphaeridium pseudorecurvatum* (Morgenroth, 1966a) Bujak et al., 1980  
*Membranilarnacia polycladiata* Cookson and Eisenack in Eisenack, 1963  
*Microdinium angulare* (Below, 1987b) Lentin and Williams, 1989  
*Microdinium ornatum* Cookson and Eisenack, 1960a  
*Microdinium setosum* Sarjeant, 1966b  
*Muderongia simplex* subsp. *microperforata* Davey, 1982b  
*Nematosphaeropsis lemniscata* Bujak, 1984  
*Neoraistrickia truncata* (Cookson, 1953) Potonié, 1956

- Ochetodinium vermiculatum* Wilson, 1988  
*Odontochitina costata* Alberti, 1961  
*Odontochitina operculata* (O. Wetzel, 1933a) Deflandre and Cookson, 1955  
*Oligosphaeridium albertaine* (Pocock, 1962) Davey and Williams, 1969  
*Oligosphaeridium complex* (White, 1842) Davey and Williams, 1966b  
*Oligosphaeridium dividuum* Williams, 1978  
*Oligosphaeridium pulcherrimum* (Deflandre and Cookson, 1955)  
*Operculodinium divergens* (Eisenack, 1954b) Stover and Evitt, 1978  
*Operculodinium eirikianum* Head et al., 1989b  
*Osmundacidites* sp.  
*Ovoidinium cinctum* (Cookson and Eisenack, 1958) Davey, 1970  
*Palaeocystodinium golzowense* Alberti, 1961  
*Palaeohystrichophora infusorioides* Deflandre, 1935  
*Palaeoperidinium cretaceum* (Pocock, 1962) Lentin and Williams, 1976  
*Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b  
*Palynodinium grallator* Gocht, 1970a  
*Pareodinia ceratophora* (with kalyptra)  
*Parvisaccites amplus* Brenner, 1963  
*Pentadinium goniferum* Edwards, 1982  
*Pentadinium laticinctum* Gerlach, 1961  
*Perotriletes magnus* Hughes and Playford, 1961  
*Perotriletes* sp.  
*Phthanoperidinium coreoides* (Benedek, 1972) Lentin and Williams, 1976  
*Phthanoperidinium echinatum* Eaton, 1976  
*Phthanoperidinium "hibernium"*  
*Phthanoperidinium levimurum* Bujak in Bujak et al., 1980  
*Phthanoperidinium multispinum* Bujak in Bujak et al., 1980  
*Phyllocladidites inchoatus* (Pierce, 1961) Norris, 1967  
*Plicatella bifurcata* (Singh, 1971) Dörhöfer, 1977  
*Podocarpidites canadensis* Pocock, 1962  
*Podocarpidites tricocca* (Maljavkina) Bolchovitina  
*Pseudoceratium anaphrissum* (Sarjeant, 1966c) Bint, 1986  
*Pseudoceratium eisenackii* (Davey, 1969a) Bint, 1986  
*Pterodinium cingulatum* (O. Wetzel, 1933b) Below, 1981a  
*Pterodinium* sp.  
*Punctatisporites limbatus* Hacquebard, 1957  
*Punctatisporites planus* Hacquebard, 1957  
*Punctatisporites* sp.  
*Raetiaedinium truncigerum* (Deflandre, 1937b) Kirsch, 1991  
*Reticulatosphaera actinocoronata* (Benedek, 1972) Bujak and Matsuoka, 1986  
*Rhombodinium draco* Gocht, 1955  
*Rhombodinium perforatum* (Jan du Chêne and Châteauneuf, 1975) Lentin and Williams, 1977b  
*Rhombodinium rhomboideum* (Alberti, 1961) Lentin and Williams, 1973  
*Raistrickia crocea* Kosanke, 1950  
*Renidinium membraniferum* Morgenroth, 1968  
*Retitricolpites georgensis* Brenner, 1963  
*Retitricolpites virgens* (Groot, Penny and Groot, 1961) Brenner, 1963  
*Rottnestia borussica* (Eisenack, 1954b) Cookson and Eisenack, 1961b  
*Rugubivesiculites reductus* Pierce, 1961  
*Rugubivesiculites rugosus* Pierce, 1961  
*Samlandia chlamydophora* Eisenack, 1954b

- Samlandia reticulifera* Cookson and Eisenack, 1965a  
*Savitrisporites nux* (Butterworth and Williams) Sullivan, 1964  
*Schematophora obscura* Wilson, 1988  
*Schematophora speciosa* Deflandre and Cookson, 1955  
*Schopfipollenites ellipsoides* (Ibrahim, 1933) Potonié and Kremp, 1956  
*Schopfites claviger* Sullivan, 1964  
*Senoniasphaera microreticulata* Brideaux and McIntyre, 1975  
*Senoniasphaera rotundata* Clarke and Verdier, 1967  
*Sestrosporites pseudoalveolatus* (Couper, 1958) Dettmann, 1963  
*Spinidinium echinoideum* (Cookson and Eisenack, 1960a) Lentin and Williams, 1976  
*Spiniferella cornuta* (Gerlach, 1961) Stover and Hardenbol, 1994  
*Spiniferites crassipellis* (Deflandre and Cookson, 1955) Sarjeant, 1970  
*Spiniferites ovatus* Matsuoka, 1983b  
*Spiniferites "procerus"*  
*Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970  
*Spiniferites ramosus* (Ehrenberg, 1838) Mantell, 1854  
*Spiniferites speciosus* (Deflandre, 1937b) Sarjeant, 1970  
*Spiniferites sp. "W"*  
*Spinozonotriletes uncatus* Hacquebard, 1957  
*Stiphrosphaeridium anthophorum* (Cookson and Eisenack, 1958) Lentin and Williams, 1985  
*Stiphrosphaeridium dictyophorum* (Cookson and Eisenack, 1958) Lentin and Williams, 1985  
*Striatella #EAB* Davies in Bujak-Davies, 1987  
*Striatella #EK* Davies in Bujak-Davies, 1987  
*Subtilisphaera perlucida* (Alberti, 1959b) Jain and Millepied, 1973  
*Sumatradinium druggii* Lentin et al., 1984  
*Sumatradonium soucouyantiae* de Verteuil and Norris, 1992  
*Surculosphaeridium longifurcatum* (Firton, 1952) Davey et al., 1966  
*Surculosphaeridium cf. longifurcatum*  
*Systematophora ancyrea* Cookson and Eisenack, 1965a  
*Systematophora complicata* Neale and Sarjeant, 1962  
*Systematophora urbini* Biffi and Manum, 1988  
*"Talladinium" coleothryptum*  
*Tanyosphaeridium variecalatum* Davey and Williams, 1966b  
*Taraxacum* spp.  
*Thalassiphora patula* (Williams and Downie, 1966c) Stover and Evitt, 1978  
*Thalassiphora pelagica* (Eisenack, 1954b) Eisenack and Gocht, 1960  
*Tigrisporites scurrandus* Norris, 1967  
*Trichodinium castanea* Deflandre, 1935  
*Trigonopyxidia ginella* Cookson and Eisenack, 1960a  
*Trilobosporites apiverrucatus* Couper, 1958  
*Trilobosporites trioreticulosus* Cookson and Dettmann, 1958  
*Trithyrodinium sabulum* Mao Shaozhi and Norris, 1988  
*Trithyrodinium "verrucosum"*  
*Tuberculodinium vancampoae* (Rossignol, 1962) Wall, 1967  
*Unipontidinium aqueductum* (Piasecki, 1980) Wrenn, 1988  
  
*Vallatisporites ciliaris* (Luber) Sullivan  
*Vallatisporites vallatus* Hacquebard, 1957  
*Vestispora costata* (Balme) Bharadwaj, 1957b  
*Vitreisporites pallidus* (Reissinger) Potonié, 1960  
*Wetzeliella ovalis* Eisenack, 1954b

- Wetzeliella simplex* (Bujak, 1979) Lentin and Vozzhennikova, 1989  
*Wetzeliella spinula* (Bujak, 1979) Lentin and Vozzhennikova, 1989  
*Wetzeliella symmetrica* Weiler, 1956  
*Wilsonidium echinosuturatum* (Wilson, 1967c) Lentin and Williams, 1976  
*Wilsonidium lineidentatum* (Deflandre and Cookson, 1955) Lentin and Williams, 1976  
*Wrevittia cassidata* (Eisenack and Cookson, 1960) Helenes and Lucas-Clark, 1997  
*Xenascus ceratioides* (Deflandre, 1937b) Lentin and Williams, 1973  
*Xenascus sarjeantii* (Corradini, 1973) Stover and Evitt, 1978  
*Xiphophoridium alatum* (Cookson and Eisenack, 1962b) Sarjeant, 1966b

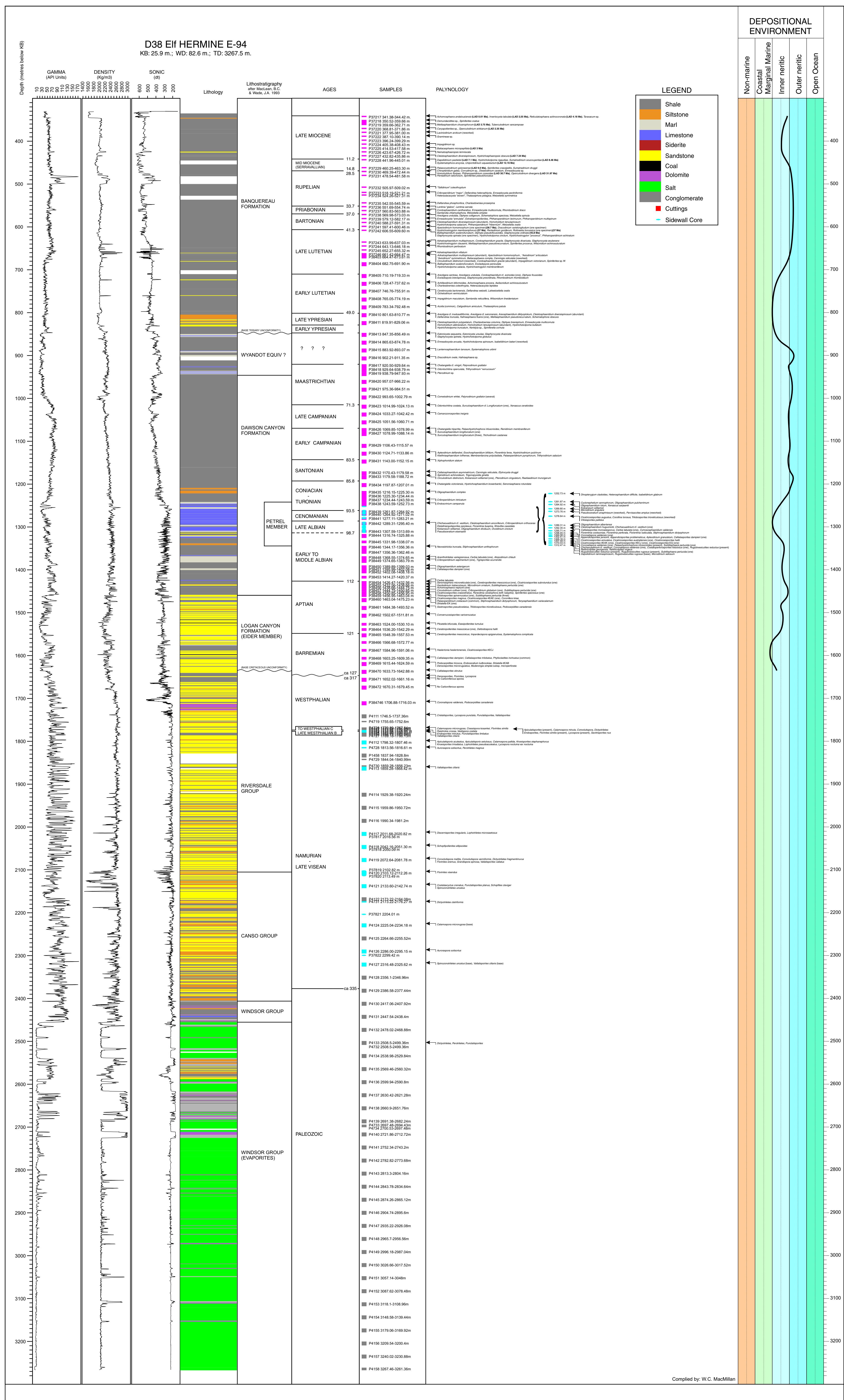


Figure 1. D38 Elf HERMINE E-94