

**ROCKALL STUDIES GROUP**

**RSG Project 97/34**

**Biostratigraphic Report on Shallow Borehole Cores:**

11/20 - sb01

16/28 - sb01

83/20 - sb01

83/24 - sb01

83/24 - sb02

by

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## SUMMARY

This report details the biostratigraphy of five boreholes on the eastern flank of the Rockall Trough, offshore western Ireland. Calcareous nannofossils and both marine and terrestrial palynomorphs are the principal fossil groups under consideration. The stratigraphy of each well is discussed in latitudinal order and the depositional environment and patterns of reworking are also detailed. This study forms part of a wider research project run under the Rockall Studies Group of the Petroleum Infrastructure Programme.

Borehole **11/20-sb01** on the Erris High is composed of sediments that are highly unsuited for biostratigraphical research. Dates gained from this well are subject to considerable uncertainty but the succession probably ranges from the Pleistocene/Mid Miocene down to the Eocene (or younger). There is no apparent reworking present in this borehole.

Borehole **16/28 - sb01** north of the Porcupine High provides high quality information on calcareous nannofossils and palynomorphs. The succession ranges from Pleistocene (NN19b), which lies unconformably on top of the Mid Eocene (NP15), through to a thick Early Eocene (NP12) section that unconformably lies on a very thin wedge of Maastrichtian (or older) sediments (KN1). Reworking of calcareous nannofossils is restricted in this borehole from Cretaceous into Mid Eocene and Mid Eocene into the Pleistocene. Palynomorph biostratigraphy correlates very well with the nannofossil data. Palynomorphs show consistent reworking of Upper Carboniferous (Westphalian C/D) miospores into the Early Eocene.

Borehole **83/20 - sb01** is stratigraphically more complex than the preceding wells and contains a thick Miocene (NN6, NN5, NN4) section that unconformably overlies a Maastrichtian (KN1, KN2) to latest Campanian (KN5, KN6) interval which itself unconformably overlies a Middle Turonian (KN18, KN19, KN20) to Late Cenomanian interval (KN21). The bottom of the well is Late Jurassic (latest Early Kimmeridgian/Early Portlandian). Calcareous fossils indicate reworking of earliest Oligocene/Mid Eocene fossils into the Mid Miocene. Upper Carboniferous (Westphalian C/D) spores are reworked abundantly into Jurassic strata.

Borehole **83/24 - sb01** is short and only represents the Pleistocene (NN19a, NN19b) and late Pliocene (NN18-NN16) that unconformably overlies the Mid Eocene (NP16-NP15). A second borehole taken at the same locality, **83/24 - sb02**, is longer and records Pleistocene (NN19b) sediments unconformably overlying a short Mid to Early Eocene interval (NP16, NP15, NP14-NP12). The lower part of the well records poorly dated Jurassic sediments (Late Kimmeridgian/Early Portlandian) underlain by Upper Carboniferous (Westphalian) strata. There appears to be no reworking in borehole 83/24-sb01. However, calcareous Early Eocene specimens are reworked in borehole 83/24 - sb02 into the Mid Eocene. Palynomorphs show Silurian reworking into probable Upper Carboniferous strata.

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# 1. INTRODUCTION

## 1.1 PROJECT SCOPE

This report details the results of a biostratigraphic study of five shallow boreholes acquired in 1999 from the eastern flank of the Rockall Trough. Fossil groups covered by this report are restricted to palynomorphs, both marine and terrestrial, and calcareous nannofossils. In total, sixty-two core samples were analysed for nannopalaontology (presented in appendix 1) and one hundred and forty four palynological samples were analysed from the five wells. This report includes:-

- The stratigraphic dating of the sequences
- Identification of any stratigraphic hiatuses
- Interpretations of depositional environment,
- Any notable correlations between boreholes,
- Age provenance of any reworked fossils,
- Range charts of palynomorph and nannofossil occurrences.
- A set of plates is also presented and illustrates significant palynomorph taxa.

This project, including data and survey results acquired for the purpose, have been undertaken on behalf of the Rockall Studies Group (RSG) of the Irish Petroleum Infrastructure Programme Group 2 which was established by the Petroleum Affairs division of the Department of the Marine and Natural Resources on 4<sup>th</sup> June, 1997 in conjunction with the award of exploration licences under the Rockall Trough Frontier Licensing Round. The RSG comprises: Agip (UK) Ltd., Anadarko Ireland Company, ARCO Ireland Offshore Inc., BG Exploration and Production Ltd., BP Exploration Operating Company Ltd., British-Borneo International Ltd., Elf Petroleum Ireland BV, Enterprise Energy Ireland ltd, Mobil Oil North Sea Ltd, Murphy Ireland Offshore Ltd., Phillips Petroleum Exploration Ireland, Saga Petroleum Ireland Ltd., Shell EP Ireland BV, Statoil Exploration (Ireland) Ltd., Total Marine Plc., Union Texas Petroleum Ltd., and the Petroleum Affairs Division of the Department of the Marine and Natural Resources.

## **1.2 PERSONEL**

Given the wide stratigraphic age range of palynomorphs preserved in the cores, palynological analysis was split between Dr G. J. Harrington, who concentrated on the Cretaceous through to the Quaternary, and Dr K. T. Higgs who concentrated on identifying Palaeozoic reworking and Jurassic strata. Micropalaeontological analysis was carried out by Dr D. Zucchi from Millennia Ltd. who was subcontracted by University College Cork.

## **1.3 REPORT FORMAT**

Section two provides a summarised stratigraphic succession for each borehole. A full discussion of both nannopalaeontological and palynological results is given in sections 3 - 7. For nannofossil zonation, a modified version of the standard Martini (1971) scheme is employed for Cenozoic strata, while for the upper Cretaceous, the Millennia (in house) nannofossil zonation scheme is used. Authors of the palynomorph zonation schemes are detailed in sections 3 - 7 and the nannofossil equivalent zones are also documented, where appropriate.

Biostratigraphic occurrence data are documented in Enclosures 1 to 8. All occurrence charts are computer generated using StrataBugs version 1.6.

## **1.4 ABBREVIATIONS USED IN TEXT**

FDO	First downhole occurrence
LDO	Last downhole occurrence
FAD	First appearance datum
LAD	Last appearance datum

## 2. SUMMARIZED STRATIGRAPHIC SUCCESSIONS

The summaries below integrate both nannopalaentological and palynological age assignments.

### 2.1 **BOREHOLE 11/20 - sb01**

<b>Interval/top</b>	<b>Age</b>
7.50m	Pleistocene - Mid Miocene
9.68m	Indeterminate
18.75m	earliest Oligocene - Mid Eocene
20.75m	Eocene or younger

### 2.2 **BOREHOLE 16/28 - sb01**

<b>Interval/top</b>	<b>Age</b>
13.00m	Pleistocene
-----	Unconformity
24.70m-81.60m	Mid Eocene
89.25m-143.50m	Early Eocene
-----	Unconformity
146.00m	Late Cretaceous (Maastrichtian or older)

### 2.3 **BOREHOLE 83/20 - sb01**

<b>Interval/top</b>	<b>Age</b>
34.00-64.00m	Mid Miocene
67.00-83.32m	earliest Mid Miocene - Early Miocene
-----	Unconformity
86.50-96.00m	Cretaceous (Late Maastrichtian)
99.80-102.20m	Cretaceous (earliest Maastrichtian -latest Campanian)
-----	Unconformity
107.90m	Cretaceous (Middle Turonian)

117.78-125.55m	Cretaceous (Early Turonian)
130.70-142.00m	Cretaceous (Late Cenomanian)
146.75-155.00m	Indeterminate
-----	Unconformity?
166.10-177.35m	Late Jurassic (latest Early Kimmeridgian/Early Portlandian)

2.4                    **BOREHOLE 83/24 - sb01**

<b>Interval/top</b>	<b>Age</b>
9.40-19.00m	Pleistocene
19.30-19.87m	Late Pliocene
-----	Unconformity
19.57-30.80m	Mid Eocene

2.5                    **BOREHOLE 83/24 - sb02**

<b>Interval/top</b>	<b>Age</b>
18.80m	Pleistocene
19.82m	Late Pliocene
-----	Unconformity
20.50-30.65m	Mid Eocene
37.65-38.10m	Early Eocene
-----	Unconformity?
38.86-59.00m	Indeterminate
63.20-68.00	Late Jurassic/Early Cretaceous
68.10-71.18	Indeterminate
71.23	Late Jurassic (Kimmeridgian/Portlandian)
-----	Unconformity?
71.29-71.49	Late Carboniferous (Westphalian)

## BOREHOLE 11/20 - sb01

### Introduction:-

This borehole was drilled on the crest of the Erris High and is the most northerly borehole in the set of five under discussion. Sediments are predominantly volcanoclastic lapilli tuffs containing a number of limestone units. A short section of soft muds sits at the top of the core. In general, the sediments in this core are highly unsuitable for palynological analysis and no palynological samples were taken. The sediment type is also highly unsuitable for micropalaeontological analysis but four samples were taken in addition to the fourteen samples initially studied at the time of coring by Jacovides et al. 1999.

### NANNOPALAEONTOLOGY:-

Sample	7.50 m
Number of samples:	1
Age	Pleistocene - Mid Miocene
Nannozone	Unassigned
Notes:	Extensive Cretaceous and Palaeogene reworking dominates the assemblages. Presence of small <i>Gephyrocysta</i> indicates a broad age range and the presence of <i>Reticulofenestra minuta</i> group and <i>Coccolithus pelagicus</i> do not constrain this age. Initial age assessment of 7.67 m by Jacovides indicated a Pliocene age determination based on the presence of <i>Neogloboquadrina atlantica</i> .
Sample	9.68 m
Number of samples:	1
Age	Indeterminate
Nannozone	Indeterminate
Notes	Sample is barren of nannofossils

Sample 18.75 m  
 Number of samples: 1  
 Age earliest Oligocene - Mid Eocene  
 Nannozones **NP21-NP15**  
 Notes The sample at 18.75m yielded a very sparse and poorly preserved assemblage. Co-occurrence of *Ericsonia formosa* and *Reticulofenestra bisecta* suggests earliest Oligocene to Mid Eocene.

Sample 20.75 m  
 Number of samples: 1  
 Age Eocene or younger  
 Nannozones **NP12 or younger**  
 Notes Sample yielded an impoverished assemblage. *Reticulofenestra* indicates only an Eocene or younger age.

#### **Ship board biostratigraphy:-**

Micropalaeontological analyses on-board the ship during the time of logging do not enhance the resolution of the later analyses despite the greater number of samples analysed. Samples 8.18 m, 9.45 m, 10.21 m, 10.50 m, 11.09 m, 11.98 m, 13.50 m, 13.78 m, 14.36 m, 16.37 m, 18.88 m, and 19.18 m that come from the tuff and limestone units all contain very sparse assemblages that suggest a broad Palaeogene age assignment.

#### **PALYNOLOGY:-**

No palynological samples were taken due to unfavourable lithologies.

#### **Summary bioevents in 11/20 - sb01:-**

<b>Depth (m)</b>	<b>BIOEVENT</b>
7.50	Presence of small <i>Gephyrocapsa</i> spp. (small)
18.75	FDO <i>Reticulofenestra bisecta</i> and <i>Ericsonia formosa</i>
20.75	Occurrence of <i>Reticulofenestra</i> spp.

## BOREHOLE 16/28 sb01

### Introduction:-

16/28 - sb01 represents the longest cumulative core section in the five wells under investigation. Most of the sediments are a monotonous set of thick calcareous mudstones of Palaeogene age. The boundary between these mudstones and the basal sandy limestone is sharp. The core terminates at a basalt sill. Seventeen nannopalaeontological samples have been analysed and the sediments are most conducive for calcareous microfossil work. Eighty palynological samples were taken and generally yielded well preserved palynomorphs.

### NANNOPALAEONTOLOGY:-

Sample	13.00 m
Number of samples:	1
Age	Pleistocene
Nannozone	<b>NN19b</b>
Notes:	Samples yielded a rich but low diversity assemblage. The co-occurrence of superabundant <i>Gephyrocapsa</i> spp. (small) and <i>Pseudoemiliana lacunosa</i> and the absence of Pliocene markers suggests an intra- Pleistocene age.
Interval:	24.70 m - 81.60 m.
Number of samples:	7
Age:	Mid Eocene
Nannozone:	<b>NP15</b>
Notes:	All samples analysed from this interval yielded rich and diverse assemblages, dominated by <i>Reticulofenestra</i> spp. The continued occurrence of <i>Rhabdosphaera gladius</i> , marker species for the NP15 Nannozone, from 24.70 m to 81.60 m, indicates a Mid Eocene age, the subsequent occurrence of <i>Chiasmolithus grandis</i> at 42 m and 60.55 m further supports this assignment. Other taxa consistent with NP15 Nannozone

include *Sphenolithus furcatolithoides* at 34.00 m, *Discoaster wemmelensis* and *Chiasmolithus grandis* at 42.00 m, *Pemma basquense* and *Cruciplacolithus vanheckae* at 52.70 m and *Chiasmolithus solitus* throughout the interval.

Interval: 89.25 m - 143.50 m.  
 Number of samples: 8  
 Age: Early Eocene  
 Nannozone: **NP12 (intra)**  
 Notes: Most samples yielded rich assemblages dominated by *Reticulofenestra minuta* group and *Coccolithus pelagicus*. The continual occurrence of *Chiphragmalithus barbatus* from 89.25 m to 143.50 m indicates an Early Eocene age and an intra NP12 zonal assignment. Other taxa consistent with this age determination include *Discoaster lodoensis*, *Discoaster kuepperi*, *Toweius* spp. and at 143.50 m *Tribrachiatus orthostylus*.

Sample: 146.00 m  
 Number of samples: 1  
 Age: Late Cretaceous (Maastrichtian or older.)  
 Nannozone: **KN1 or older.**  
 Notes: The sample yielded a sparse assemblage, characterised by long ranging taxa such as *Eiffellithus turriseiffelii*, *Gartnerago obliquum* and *Prediscosphaera cretaceus*, which only suggest a Maastrichtian or older age.

#### PALYNOLOGY:-

Interval: 25.6 m - 81.87 m  
 Number of samples: 9  
 Age: Indeterminable  
 Zones: Indeterminable  
 Notes: Samples in this interval are barren of palynomorphs.

Interval: 82.72 m - 88.88 m  
 Number of samples: 7  
 Age: ? Early Eocene  
 Zones: Indeterminable  
 Notes: **Dinocysts:** Samples in this zone yielded sparse assemblages but typical Early Eocene dinocysts are present including *Phthanoperidinium echinatum*, *Cerebrocysta bartonensis*, a single *Eatonicysta ursulae* at 88.6 m and *Charlesdowniea coleothrypta* at 88.9 m, and *Hystrichosphaeridium tubiferum*. There are no dinocysts that would indicate a late Early Eocene or Mid Eocene age except for *Homotryblium oceanicum*.

**Sporomorphs:** Pollen and spores are not abundant in this interval and are mainly restricted to bisaccate pollen and *Nypa* palm pollen. The composition of the terrestrial palynofloras is characteristic of the Early Eocene but none of the taxa present have any biostratigraphical usefulness.

Interval: 89.51 m - 137.93 m  
 Number of samples: 54  
 Age: Early Eocene  
 Zones: **B1 - LC3** (Bujak et al. 1980), **Ccl/Pla** (Powell 1992), ***Charlesdowniea coleothrypta/Areosphaeridium diktyoplokus* Zones** (Heilmann-Clausen 1988), **D8-basal D9** (Costa and Manum 1988).  
 Nannozone: **NP12 equivalent**  
 Notes: **Dinocysts:** Samples in this interval generally have good dinocyst and sporomorph yields. Both fossil groups are diverse but sporomorphs are more abundant in the lower half of this interval. The above zonal assignments are based on the presence of *Dracodinium condylos* which is restricted in range to NP12 Nannozone, *Charlesdowniea coleothrypta*, *Pentadinium laticinctum*, and *Homotryblium abbreviatum*.

Other numerically important taxa that are consistent with a Early Eocene assignment are *Cerebrocysta bartonensis*, *Duosphaeridium nudum*, *Phthanoperidinium echinatum*, *Eatonicysta ursulae*, *Achilleodinium biformoides*, *Wetzeliella articulata*, and *Systematophora placacantha*. *Cerebrocysta bartonensis* is abundant at the base of this zone. *Charlesdowniea coleothypta* is consistently present in the lower half of this interval. The recognition of this zone may be supported by bioevents punctuated throughout (table 1) that may have regional biostratigraphic importance.

**Sporomorphs:** Pollen and spores from this zone include many tropical/paratropical species such as *Bombacacidites*, *Calamuspollenites*, *Cyrillaceaepollenites*, Euphorbiaceae pollen, Sterculiaceae pollen and palm pollen such as *Monocolpopollenites tranquillus*, *Proxapertites* and *Nypa* that are wholly consistent with the Early Eocene temperature maximum floras (NP12 to ?NP15). The tropicality of the floras and the presence of abundant *Nypa* suggests that the samples are no older than NP12. Sporomorphs are more abundant at the base of this interval than at the top although count sizes are generally much smaller at the top of the interval.

Interval:	145.78 m - 143.56 m
Number of samples:	11
Age:	Early Eocene
Zones:	<b>?Dva</b> (Powell 1992), <b><i>Dracodinium varielongitudum</i></b> (Heilmann-Clausen 1988), <b>lower D8</b> (Costa & Manum 1988).
Nannozone:	<b>latest NP11-earliest NP12</b> equivalent.
Notes:	<b>Dinocysts:</b> The assemblages of this zone are highly similar to those in the 89.51 m - 137.93 m interval except <i>Charlesdowniea coleothypta</i> is absent. This interval is potentially an extension of the preceding interval and has every characteristic of Ypresian assemblages from NP12.

*Adnatosphaeridium robustum* and *Areoligera* cf. *senonensis* are relatively common together with *Deflandrea oebisfeldensis* and *D. phosphoritica*. The zonal index taxon, *Dracodinium varielongitudum* is present in 145.78 m.

**Sporomorphs:** Pollen and spores are not abundant in this interval and are restricted to ubiquitous taxa such as bisaccate pollen, *Inaperturopollenites hiatus*, and trilete spores such as *Deltoidospora*.

#### Summary bioevents in 16/28 - sb01:-

Metre	BIOEVENT
13.00	Superabundant <i>Gephyrocapsa</i> spp. (small), no Pliocene markers
24.70	FDO of <i>Rhabdosphaera gladius</i>
34.00	FDO of <i>Chiasmolithus gigas</i>
88.55	FDO <i>Eatonicysta ursulae</i>
88.88	FDO <i>Charlesdowniea coleothrypta</i>
89.25	Occurrence of <i>Chiphragmolithus barbatus</i>
90.90	FDO of abundant <i>Eatonicysta ursulae</i>
93.40	FDO <i>Ceridinium depressum</i>
94.13	FDO abundant <i>Phthanoperidinium echinatum</i>
106.8	FDO <i>Hafniasphaera septata</i>
112.98	FDO <i>Dracodinium varielongitudum</i>
113.48	FDO <i>Dracodinium condylos</i>
118.19	LDO <i>Cleistodinium ?insolitum</i>
124.94	Abundant <i>Nypa</i>
130.00	FDO <i>Dracodinium simile</i>
146.00	FDO <i>Eiffellithus turriseiffelii</i> , <i>Gartnerago obliquum</i> , and <i>Prediscosphaera cretaceus</i>

## BOREHOLE 83/20 - sb01

### Introduction:-

Borehole 83/20 sb01 was drilled on the slope west of Porcupine Bank. The core penetrated a highly fossiliferous Neogene section that unconformably rests on a Mesozoic section with satisfactory nannofossil yield but poor palynomorph yield. Palynomorphs are most successful at dating the lower sections of the borehole where nannofossil recovery is very poor. A total of eighteen samples were analysed for nannofossils and forty-seven samples were analysed for palynomorphs.

### NANNOPALAEONTOLOGY:-

Interval: 34.00 m - 64.00 m

Number of samples: 3

Age: Mid Miocene

Nannozones: **NN6, NN5**

Notes: Extremely rich assemblages, dominated by *Reticulofenestra minuta* group was recovered at 34.00 m. The co-occurrence of *Cyclicargolithus floridanus* and *Calcidiscus premacintyreii*, if not reworked, would suggest a zonal assignment of NN6 - NN4, that can be further restricted to the NN6 Nannozone on the basis of the absence of *Sphenolithus heteromorphus* marker species for the top of NN5 Nannozone. The presence of consistent *Hayella aperta* is consistent with this age determination.

The first downhole occurrence of *Sphenolithus heteromorphus* at 35.85 m, if not reworked, would indicate penetration of the NN5 Nannozone of the Mid Miocene. At 64.00 m the occurrence of *Sphenolithus heteromorphus* (common) with an absence of *Helicosphaera ampliapertura* still suggests a zonal assignment to NN5 Nannozone.

Interval: 67.00 m - 83.32 m  
 Number of samples: 2  
 Age: earliest Mid Miocene - Early Miocene  
 Nannozone: **NN4**  
 Notes: The co-occurrence of *Helicosphaera ampliaperta* and *Sphenolithus heteromorphus* at 67.00 m and below, indicates penetration of the NN4 Nannozone of the earliest Mid to early Mid Miocene. Other taxa consistent with this zonal assignment include *Cyclicargolithus floridanus*, *Discoaster variabilis*, *Discoaster deflandrei* and *Calcidiscus macintyreii*.

Interval: 86.50 m - 96.00 m  
 Number of samples: 2  
 Age: Late Cretaceous (Late Maastrichtian)  
 Nannozones: **KN1 - KN2**  
 Notes: A Late Maastrichtian age equivalent to the KN1 - KN2 Nannozones is assigned to samples 86.50 m and 96.00 m on the basis of the first downhole occurrence of late Cretaceous taxa such as *Arkhangelskiella cymbiformis*, *Prediscosphaera cretacea*, *Micula decussata* and *Eiffellithus turriseiffelii* in the absence of older Maastrichtian markers.

Interval: 99.80 m - 102.20 m  
 Number of samples: 2  
 Age: Late Cretaceous (earliest Maastrichtian - latest Campanian)  
 Nannozones: **KN5-KN6**  
 Notes: The samples yielded rich and diverse assemblages. The co-occurrence of *Broinsonia parca constricta* and *Reinhardtites levis* indicates earliest Maastrichtian to latest Campanian. The occurrence of *Zeugrhabdotus compactus* is consistent with this age determination.

Sample:	107.90 m
Number of samples:	1
Age:	Late Cretaceous (Middle Turonian)
Nannozones:	<b>KN18</b>
Notes:	The first dowehole occurrence of <i>Rhagodiscus achlyostaurion</i> at 107.90m indicates penetration of Middle Turonian sediments. The overall assemblage including <i>Stoverius achylosum</i> , <i>Eprolithus floralis</i> , <i>Helicolithus compactus</i> and <i>Helicolithus trabeculatus</i> is consistent with this age assignment.
Interval:	117.00 m - 125.55 m
Number of samples:	3
Age:	Late Cretaceous (Early Turonian)
Nannozones:	<b>KN19 - KN20</b>
Notes:	The samples analysed from this interval yielded rich and diverse assemblages, dominated by <i>Watnaueria barneasae</i> . Penetration of early Turonian sediments is indicated by the first downhole occurrence of <i>Radiolithus planus</i> at 117.90m. Other taxa consistent with this age determination include <i>Ahmuellerella octoradiata</i> , <i>Rhagodiscus reniformis</i> and <i>Eprolithus eptapetalus</i> . Cenozoic and younger late Cretaceous contaminants were also noted in all samples.
Interval:	130.70 m - 142.00 m
Number of samples:	3
Age:	Late Cretaceous (Late Cenomanian)
Nannozone:	<b>KN21</b>
Notes:	Samples at 130.70 m and 142.00 m yielded rich and diverse assemblages, while recovery was extremely sparse at 137.65 m. The first downhole occurrences of <i>Axopodorhabdus albianus</i> and <i>Rhagodiscus asper</i> at 130.70 m suggest penetration of late Cenomanian sediments and the KN21 nannozone. The LDO of <i>Ephrolithus eptapetalus</i> at 142.00 m, if <i>in-situ</i> , would imply an

age no older than late Cenomanian. Cenozoic contaminants (Miocene) were observed at 137.65m and 142.00m.

Interval: 146.75 m - 155.00 m  
 Number of samples: 2  
 Age: Indeterminate  
 Nannozone: Indeterminate  
 Notes: The sample at 146.75 m proved to be barren of nannofossils, while the sample at 155.00 m contained mostly Cenozoic contaminants (e.g. *Cyclicargolithus floridanus*, *Coccolithus pelagicus*) and to a lesser extent presumed Late Cretaceous contaminants (e.g. *Arkhangelskiella cymbiformis*).

#### PALYNOLOGY:-

Interval: 34.47 m - 36.15 m  
 Number of samples: 5  
 Age: early Mid Miocene  
 Zones: **Intra- *Unipontidinium aquaeductum* Interval Biozone (Uaq)** of Powell 1988, **D17/D18** of Costa and Manum 1988.  
 Nannozone: **NN5/NN6** equivalent  
 Notes: **Dinocysts:** Most samples from this highly calcareous interval yielded excellently preserved dinocysts in high abundance but relatively low diversity. The presence and abundance of *Unipontidinium aquaeductum* together with the continued presence of *Hystrihostrogylon membraniphorum* and *Palaeocystodinium obscurata* define this zone. Abundant taxa include *Cannosphaeropsis* sp. A (Costa & Downie), *Operculodinium centrocarpum* and *Tectatodinium pellitum*. Taxa apparently restricted to this zone include *Unipontidinium aquaeductum*, *Achomosphaera* sp. A (Brown & Downie 1984), cf. *Cannosphaeropsis utinensis* and cf. *Chiropteridium mesplinanum*.

**Sporomorphs:** pollen and spores are extremely rare in this interval and may represent contamination. Only 36.15 m yielded any sporomorphs (4 specimens) of *Pinus* and *Carya* that could have emanated from contamination during sample processing. Terrestrially derived organic matter is extremely sparse in this interval.

Interval: 65.87 m - 85.70 m  
 Number of samples: 7  
 Age: Early Miocene  
 Zone: late *Tuberculodinium vancompoae* Interval Biozone (Tva) of Powell 1992, **D16/D17** of Costa and Manum 1988.  
 Nannozone: ?**NN3** - **NN4** equivalent  
 Notes: **Dinocysts:** Most samples from this interval yielded abundant and excellently preserved dinocyst assemblages with low diversity. The zonal index species, *Tuberculodinium vancompoae* is absent from the studied samples but the presence of *Apteodinium spiroides*, *Hystriosphaeopsis obscurata*, *Impaginidium patulum*, *Operculodinium crassum*, *Palaeocystodinium* sp. A (Costa and Downie 1979) and cf. *Cleistosphaeridium ancoriferum* (cf. Piasecki 1980) define this zone in the absence of *Unipontidinium aquaeductum*. The upper part of Tva Biozone is represented here because *Apteodinium spiroides* has a LAD sometime in NN2/NN3 (Powell 1992) and *Hystriosphaeopsis obscurata*, *Impaginidium patulum*, and cf. *Cleistosphaeridium ancoriferum* have FADs in NN3/NN4. Sample 83.34 m marks the FDO of *Apteodinium spiroides* in 83/20 sb01. Abundant species include *Operculodium centrocarpum*, *Spiniferites ramosus*, *Spiniferites mirabilis*, and *Tectatodinium pellitum*.

**Sporomorphs:** pollen and spores are sparse in this interval. 66.12 m yields the most abundant assemblage that includes subtropical genera such as *Carya*, *Engelhardtia*, and others

such as *Alnus*, *Corylus* and *Nyssa*. Terrestrially derived organic matter is sparse.

Interval: 86.47 m - 112.73 m  
 Number of samples: 7  
 Age: Indeterminate  
 Notes: All samples in this interval are barren of palynomorphs, both terrestrially and marine derived. There is no evidence of reworking from these samples either.

Interval: 117.17 m - 127.37 m  
 Number of samples: 8  
 Age: Late Cretaceous (Early - Mid Turonian)  
 Notes: **Dinocysts:** Most samples in this interval contain low diversity and low abundance dinocyst assemblages. *Heterosphaeridium difficile* has a LDO at 127.37 m together with *Isabelidinium cooksoniae* and *Tanyosphaeridium variecalamus* that all appear in the Early to Mid Turonian. *Surculosphaeridium?* *longifurcatum* and *Xiphoridium alatum* are still present in this interval suggesting that the Coniacian/Early Santonian is absent from this interval. Contamination from the Miocene is rife in this interval and contaminants are as abundant as the primary Cretaceous palynomorphs.

**Sporomorphs:** Spores and gymnosperm pollen are consistently present in most samples but are generally restricted to long ranging taxa that have little biostratigraphic significance. *Cicatricosisporites ornatus* at 125.30 m, *Klukisporites* at 117.43 m and *Retitriletes mirabilis* at 117.17 m indicate a middle to upper Cretaceous age. *Appendicisporites* spp. is also present in this interval. Terrestrially derived organic matter is abundant.

Sample: 127.53 m  
 Number of samples: 1  
 Age: Indeterminate  
 Notes: This sample contains no dinocysts and the spores present in the palynofloras contain no taxa that can be used to date this sample.

Interval: 127.70 m - 127.97 m  
 Number of samples: 2  
 Age: Indeterminate  
 Notes: This interval is barren of palynomorphs.

Interval: 130.74 m - 131.04 m  
 Number of samples: 3  
 Age: ?Early Cretaceous to earliest Late Cretaceous  
 Notes: **Dinocysts:** Samples yield sparse palynofloras that lack stratigraphically significant taxa. A questionable Late Cretaceous age is suggested by the similarity of sample composition to the 117.17 - 127.37 m interval but the 130.74 - 131.04 m interval lacks Turonian species. Presence of *Cleistosphaeridium huguoniotii* at 130.85 m may signify a pre-Turonian age since this species does not cross the Cenomanian/Turonian boundary.

**Sporomorphs:** Spores and gymnosperm pollen are present in this interval but are poorly preserved and restricted to long ranging taxonomic groups.

Interval: 166.10 m - 177.35 m  
 Number of samples: 13  
 Age: Late Jurassic (latest Early Kimmeridgian/early Portlandian)  
 Notes: **Dinocysts:** Dinocysts are inconsistently present in this sample interval but where present yield low to moderate diversity assemblages. The presence of *Gochteodinia mutabilis*, *Senoniasphaera jurassica* and *Cribroperidinium* sp A Davey (1982) is indicative of a Late Jurassic age, in particular to the latest Early Kimmeridgian to early Portlandian (Stover *et al.* 1996). The most commonly occurring taxa are *Systematophora areolata*, and *Cribroperidinium* sp A .

**Sporomorphs:** Spores and pollen commonly occur in the majority of the samples in this interval. The most abundant spore taxa include *Classopollis torosus*, *Dictyophyllidites equixinus*, *D. harissii*, and *Ischyosporites variegatus* and the most abundant pollen taxa include, *Perinopollenites elatoides*, *Cerebropollenites mesozoicus*, *C. macroverrucosus*, and *Alisporites* sp. The most significant spore taxon for stratigraphy present in these samples is *Cicatricosporites austrialensis*, a form which first appears in the Late Jurassic (Kimmeridgian)

**Alga :** Two carbonate samples from 171.4m and 171.93m contain well preserved red alga *Arhaeolithophyllum valihanithat* which belong to the Rhodophyta, Corallinacea together with the green alga ? *Eovelebitella occitannica* and some indeterminable calcareous sponges. These alga are of little stratigraphic value but are palaeoenvironmentally useful as they are suggestive of a relatively shallow water facies for this interval. The alga have been identified by Mr. Gareth Jones, Conodate, Dublin, see Appendix 7.3, pages 41-46.

**Summary bioevents in 83/20 - sb01:-**

<b>Metre</b>	<b>BIOEVENT</b>
34.00	Occurrence of <i>Cyclicargolithus floridanus</i>
34.47	Occurrence of <i>Unipontidinium aquaeductum</i> , and <i>Achomosphaera</i> sp. A,
36.15	LDO of <i>Unipontidinium aquaeductum</i>
35.85	Occurrence of <i>Sphenolithus heteromorphus</i>
64.00	<i>Sphenolithus heteromorphus</i> (common)
67.00	Co-occurrence of <i>Helicosphaera ampliaperta</i> and <i>Sphenolithus heteromorphus</i>
83.34	Occurrence of <i>Apteodinium spiroides</i>
89.50	Occurrence of abundant <i>Arkhangelskiella cymbiformis</i> , <i>Prediscosphaera cretacea</i> and <i>Watznaueria barnesae</i>
99.80	Occurrence of <i>Broinsonia parca constricta</i>
107.90	Occurrence of <i>Rhagodiscus achlyostaurion</i>
117.00	Occurrence of <i>Radiolithus planus</i>
122.80	Occurrence of <i>Ahmuellerella octoradiata</i>
127.37	LDO <i>Heterosphaeridium difficile</i> , <i>Isabelidinium cooksoniae</i> and <i>Tanyosphaeridium variecalamus</i>
130.70	Occurrence of <i>Axopodorhabdus albianus</i> and <i>Rhagodiscus asper</i>
142.00	Occurrence of <i>Ephrolithus eptapetalus</i>
166.10	FDO <i>Gochteodinia mutabilis</i>

## BOREHOLE 83/24 - sb01

### Introduction:-

Borehole 83/24 - sb01 is located on the western slope of the Porcupine Bank at latitude 52°15' and penetrated sediments highly unsuitable for palynological work. Due to poor weather conditions, only a small section of core was retrieved. A total of ten samples were analysed for nannofossils. No samples were taken for palynomorphs.

### NANNOPALAEONTOLOGY:-

Interval: 9.40 m - 19.00 m

Number of samples: 3

Age: Pleistocene

Nannozones: **NN19a, NN19b**

Notes: The co-occurrence of *Pseudoemiliana lacunosa* and *Helicosphaera inversa* at 9.40 m and 10.00 m suggests Pleistocene, restricted to the NN19a Nannozone.

At 19.00 m the co-occurrence of *Pseudoemiliana lacunosa* and *Gephyrocapsa caribbeanica* suggests a zonal assignment of NN19, that can be restricted to the NN19b subzone on the basis of the FDO of superabundant *Gephyrocapsa* spp. (small).

Sample: 19.30

Number of samples: 1

Age: Late Pliocene

Nannozones: **NN18-NN16**

Notes: The co-occurrence of *Discoaster triradiatus* and *Pseudoemiliana lacunosa* (common), indicates late Pliocene. The FDO of *Calcidiscus macintyreii* and *Helicosphaera sellii* is consistent with this age assignment.

Interval: 19.57 m - 30.80 m  
 Number of samples: 6  
 Age: Mid Eocene  
 Nannozones: **NP16 - NP15, NP15 (intra)**  
 Notes: At 19.57m, the FDO of *Sphenolithus furcatolithoides* indicates penetration of Mid Eocene sediments and the zonal assignment to NP16 - NP15. Other taxa consistent with this age assignment include *Reticulofenestra bisecta*, *Chiasmolithus solitus* and *Reticulofenestra umbilica*.

Samples at 30.70 m and 30.80 m yielded rich but poorly preserved assemblages that are dominated by *Reticulofenestra* spp. Zonal assignment to NP15 (intra) is based on the occurrence of the marker species, *Chiasmolithus gigas*. The presence of *Reticulofenestra umbilica* at 30.70 m and *Pemma* spp. at 30.80 m is consistent with this age determination.

#### PALYNOLOGY:-

No palynological samples were taken from this borehole.

#### Summary bioevents in 83/24 - sb01:-

Metre	BIOEVENTS
9.40	Co-occurrence of <i>Pseudoemiliana lacunosa</i> and <i>Helicosphaera inversa</i>
19.00	Co-occurrence of <i>Pseudoemiliana lacunosa</i> and <i>Gephyrocapsa caribbeanica</i> . Superabundant <i>Gephyrocapsa</i> spp. (small)
19.30	Occurrence of <i>Discoaster triradiatus</i> and <i>Pseudoemiliana lacunosa</i> (common).
19.57	FDO <i>Sphenolithus furcatolithoides</i>
30.70	Occurrence of <i>Chiasmolithus gigas</i>
30.70	Occurrence of <i>Reticulofenestra umbilica</i>

## BOREHOLE 83/24 sb02

### Introduction:-

Borehole core 83/24 - sb02 is located adjacent to 83/24 sb01 on the western slope of the Porcupine Bank at latitude 52°15' and it duplicates and extends the section retrieved from 83/24 - sb01. Calcareous nannofossil yields are generally satisfactory but palynological yields are very poor for this well. A total of thirteen samples were analysed for nannofossils and eighteen samples for palynomorphs.

### NANNOPALAEONTOLOGY:-

Horizon:	18.80m
Number of samples	1
Age:	Pleistocene
Nannozone:	<b>NN19b</b>
Notes:	The sample yielded a rich, but not very diverse assemblage that is dominated by <i>Gephyrocapsa</i> spp. (small), <i>Reticulofenestra minuta</i> group and to a lesser extent <i>Calcidiscus leptoporus</i> . A Pleistocene age is suggested by the presence of superabundant <i>Gephyrocapsa</i> spp. (small) in the absence of Pliocene markers.
Interval:	20.50 m - 30.65 m
Number of samples:	4
Age:	Mid Eocene
Nannozones:	<b>NP16 - NP15</b>
Notes:	The samples analysed from this interval yielded rich and moderately preserved assemblages. The occurrence of <i>Sphenolithus furcatolithoides</i> from 20.50 m to 23.00 m indicates Mid Eocene, while at 30.65 m the age assignment is based on the occurrence of <i>Reticulofenestra bisecta</i> and <i>Ellipsolithus lajollaensis</i> . At 30.65m, Early Eocene taxa such as <i>Toweius occultatus</i> and <i>Toweius</i> spp. are present that are interpreted as reworked.

Interval: 37.65 m - 38.10 m  
 Number of samples: 2  
 Age: Early Eocene  
 Nannozones: **NP14 (lower) - NP12**  
 Notes: Samples yielded moderately rich, but poorly preserved assemblages, dominated by *Reticulofenestra minuta* group and *Coccolithus pelagicus*. The co-occurrence of *Toweius* spp. and *Reticulofenestra minuta* group suggests an Early Eocene age, despite lacking more typical marker species.

Interval: 38.86 m - 59.00 m  
 Number of samples: 6  
 Age: Indeterminate  
 Nannozones: Indeterminate  
 Notes: All the samples analysed from this interval proved to be barren of calcareous nannofossils.

#### PALYNOLOGY:-

Sample: 19.82 m  
 Number of samples: 1  
 Age: Late Pliocene  
 Notes: This sample yields only terrestrially derived palynomorphs that are present in abundance and good preservation. Subtropical species such as *Carya*, *Engelhardtia*, *Liquidamber*, *Nyssa*, *Sequoia* and *Taxodium* are present that become regionally extinct at high latitude in the latest Pliocene/Pleistocene. The presence of subtropical/temperate pollen together with Quaternary species suggests a Late Pliocene age. Some spores such as *Cicatricosisporites* and some pollen such as *Pompeckipollis* may be reworked from the Palaeogene.

Interval: 21.21 m - 40.06 m  
 Number of samples: 6  
 Age: Indeterminate  
 Notes: Samples in this interval proved to be barren of both marine and terrestrial palynomorphs. Organic matter is present in very low abundance.

Interval: 67.95m – 71.18m  
 Number of samples: 7  
 Age: Indeterminate  
 Notes: Samples in this interval proved to be barren of palynomorphs

Interval: 71.23m  
 Number of samples: 1  
 Age: ? Late Jurassic (Early Kimmeridgian / Middle Portlandian)  
 Notes: A sample provided from "on-ship sampling" yielded a microflora that contains both Late Jurassic and Upper Carboniferous palynomorphs. The Late Jurassic microflora is composed of dinocysts such as, *Senoniasphaera jurassica*, *Systematophora areolata*, *Leptodinium subtile*, and *Oligosphaeridium* sp. that indicate an Early Kimmeridgian to Middle Portlandian age. Also abundant in the sample are thermally mature organic particulate matter and Upper Carboniferous (Westphalian C/D) sporomorph taxa such as, *Thymnosporra thiessenii*, *Puntatosporites granifer*, *Lycospora pusilla*, *Laevigatosporites* sp.

Note -the stratigraphic age of this 'on ship' sample should be treated with caution as the possibility of sample contamination cannot be ruled out, particularly in the light of the palynological assemblages obtained from the immediate underlying samples between 71.29 m –71.49m (see below).

Interval:	71.29 m –71.49m
Number of samples:	4
Age:	?Upper Carboniferous (Westphalian)
Notes:	The three productive samples from this 71.29m, 71.43m and 71.49m yielded abundant and thermally mature organic particulate matter together with assemblages of Upper Carboniferous sporomorphs. Although no stratigraphically diagnostic zonal forms were recorded, the presence of <i>Raistrickia saetosa</i> , <i>Raistrickia fulva</i> , <i>Verrucosisporites verrucosus</i> , <i>Florinites similis</i> , <i>Vestispora pseudoreticulata</i> , <i>Laevigatosporites vulgaris</i> , <i>Lycospora</i> spp. and <i>Schopfipollenites ellipsoides</i> is indicative of Westphalian age. An alternative interpretation for the samples from 71.29 - 71.49 m is that they may represent barren Jurassic sediments that only contain reworked Upper Carboniferous and Silurian palynomorphs.

#### Summary bioevents for 83/24 - sb01:-

Metres	BIOEVENTS
19.80	Superabundant <i>Gephyrocapsa</i> spp. (small)
19.82	FDO of <i>Carya</i> , <i>Engelhardtia</i> , <i>Liquidamber</i> , <i>Nyssa</i> and <i>Taxodium</i> pollen
20.50	FDO of <i>Sphenolithus furcatolithoides</i>
23.00	LDO of <i>Sphenolithus furcatolithoides</i>
30.65	FDO co-occurrence of <i>Reticulofenestra bisecta</i> and <i>Ellipsolithus lajollaensis</i>
37.65	FDO co-occurrence of <i>Toweius</i> spp. and <i>Reticulofenestra minuta</i> group
71.23	Occurrence of <i>Senoniasphaera jurassica</i> , <i>Systematophora areolata</i> , <i>Leptodinium subtile</i> , and <i>Oligosphaeridium</i> sp
71.29	Occurrence of <i>Raistrickia saetosa</i> , <i>R. fulva</i> , <i>Verrucosisporites verrucosus</i> , <i>Florinites similis</i> , <i>Vestispora pseudoreticulata</i> , <i>Laevigatosporites vulgaris</i> , <i>Lycospora</i> spp. and <i>Schopfipollenites ellipsoides</i>

## 4.0 REWORKING

Reworked fossils have been noted in some sections of the five cores under review, and particularly in the palynological assemblages. Contamination is also a problem detected in both the nannofossil and palynological studies in borehole 83/20 - sb01 and potentially in the lower part of borehole 83/24 - sb02.

### 4.1 BOREHOLE 11/20 - sb01

There is no apparent reworking in this core although the fossil assemblages are so poorly preserved that accurate identification of species is not always possible.

### 4.2 BOREHOLE 16/28 - sb01

#### **Calcareous nannofossils:-**

Reworking is restricted to sample 34.00 m that has a specimen of *Micula decussata* and to sample 13.00 m that has two specimens of *Clausicoccus fenestratus* and one specimen each of *Prediscosphaera cretacea* and *Zygrhablithus bijugatus*. Reworking of *Micula decussata* and *Prediscosphaera cretacea* suggests a erosion of Late Cretaceous strata (Maastrichtian, or older) whereas *Clausicoccus fenestratus* and *Zygrhablithus bijugatus* are abundant in the Mid Eocene of 16/28 -sb01.

#### **Palynomorphs:-**

Reworked Jurassic / Early Cretaceous and Upper Carboniferous sporomorphs are consistently recovered from the more palynomorph rich samples in the Early Eocene. In particular, samples 109.95m, 124.21m, 125.54m, 126.18m, 127.00m, 127.71m, 128.89m, 135.07m, 137.93m and 139.93m yielded numerous reworked Upper Carboniferous taxa such as *Thymnospora pseudothiessenii*, *Torispota securis*, *Vestispota cancellata*, *V. pseudoreticulata*, *Endosporites globiformis*, *Cingulispores loricatus*, and abundant specimens of *Densosporites* and *Lycospora*. The composition of the reworked material in this interval is clearly Westphalian C/D in age. Specimens of cf. *Coronifera oceanica* and ?*Tanyosphaeridium regulare* are probably reworked from the Cretaceous.

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**REWORKED CARBONIFEROUS**


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*Apiculatisporis variocorneus*  
*Campotriletes bucculentus*  
*Cingulizonates loricatus*  
*Cirratiradites saturnii*  
*Crassispora kosankei*  
*Cyclogranisporites aureus*  
*Densosporites annulatus*  
*Densosporites intermedius*  
*Endosporites globiformis*  
*Endosporites zonalis*  
*Florinites* sp. (small)  
*Florinites similis*  
*Florinites visendus*  
*Grumosisporites varioreticulatus*  
*Laevigatosporites* cf. *vulgaris*  
*Lophotriletes* cf. *gibbosus*  
*Lycospora pusilla*  
*Radiizonates* sp.  
*Raistrickia fulva*  
*Raistrickia seatosa*  
*Reticulatosporites reticulatus*  
*Schopfipollenites ellipsoides*  
*Thymospora pseudothiessenii*  
*Torispora securis*  
*Vertispora pseudoreticulata*  
*Vertispora* cf. *cancellata*

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Table 1: Reworked palynomorphs in well 16/28-sb01

#### 4.3 BOREHOLE 83/20 - sb01

##### **Calcareous nannofossils:-**

Reworking is very limited in this borehole. The presence of *Ericsonia formosa* at 34.00 m signifies reworking of earliest Oligocene to Mid Eocene fossils into the Mid Miocene. No other reworking is recorded.

##### **Palynomorphs:-**

There is no obvious reworking in the Miocene and Cretaceous samples of this borehole and this is complimentary to the nannofossil record that indicates very low levels of reworking. The only possible exception is at level 97.30m where there is an unusual abundance of thermally mature, dark brown to black organic particulate

matter in the sample. Rare dark spormorphs are present but they are unidentifiable because of the degraded state of preservation.

In the latest Early Kimmeridgian/Portlandian interval there is a distinctive reworking event between 176.4m-176.5m, where two samples contain abundant brown coloured sporomorphs and particulate matter. The composition of the reworked assemblage is shown in Table 2 and it is of Upper Carboniferous, Westphalian C/D age.

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### **REWORKED CARBONIFEROUS**

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*Camptotriletes* sp.  
*Cingulizonates bialatus*  
*Crassispora kosankei*  
*Florinites* cf. *florini*  
*Laevigatosporites vulgaris*  
*Lophotriletes tribulosus*  
*Lycospora pusilla*  
*Punctatosporites granifer*  
*Raistrickia saetosa*  
*Thymnospora pseudothiessenii*  
*Tripartites* sp.  
*Triquitrites* cf. *bransonii*  
*Triquitrites* cf. *trilinquis*  
*Vestispora pseudoreticulata*

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Table 2: Reworked spores present in the latest early Kimmeridgian - Early Portlandian of Borehole 83/20 - sb01

#### 4.4 BOREHOLE 83/24 - sb01

##### **Calcareous nannofossils:-**

There appears to be no reworking in this borehole

##### **Palynomorphs:-**

No palynology samples were taken.

## 4.5 BOREHOLE 83/24 -sb02

**Calcareous nannofossils:-**

Reworking in this borehole is restricted to sample 30.65 m (Mid Eocene) that records the Early Eocene taxa *Toweius occultatus* and *Toweius* spp. No other reworking is reported.

**Palynomorphs:-**

Reworking is restricted in this borehole to the Upper Carboniferous interval (samples 71.49m, 71.43m and 71.29m) where three samples contain small numbers of Lower Palaeozoic marine acritarchs and terrestrial miospores. The composition of the reworked material (table 3) is broadly indicative of a Silurian age.

<b>ACRITARCHS</b>	<b>SPORES</b>
<i>Dictyodinium</i> sp.	<i>Ambitisporites avitus</i>
<i>Diexallophasis</i> sp.	<i>Ambitisporites chulus</i>
<i>Multiplicisphaeridium</i> sp.	<i>Retusotriletes</i>
<i>Micrhystridium</i> sp.	
<i>Polygonium</i> sp.	
<i>Pterospermella</i> sp.	

Table 3: Palynomorph reworking in Borehole 83/24-sb02

## 5.0 DEPOSITIONAL ENVIRONMENTS

The following section presents some palaeoenvironmental observations of the borehole sequences based on semi-quantitative palaeontological data obtained from the nannofossil and palynological investigations. These data compliment the sedimentological interpretations of the sequences as reported by Haughton and Amy (2000).

### 5.1 BOREHOLE 11/20 - sb01

- Nannofossils recovered from the 7.50m (Pleistocene to Mid Miocene) and the 18.7 - 20.75m (earliest Oligocene to Eocene) intervals are very poorly preserved but confirm that all the sediments in these intervals are marine in nature.
- Abundant reworking of Cretaceous and lower Cenozoic nannofossils into sediments at 7.50 m would be consistent with a high energy environment.

### 5.2 BOREHOLE 16/28 - sb01

- Calcareous nannofossils are consistently present throughout this core and confirm that sediments were deposited in marine conditions and under considerable water depths.
- The palynological data from the Early Eocene section reveal that in general, dinoflagellate cysts are preserved in greater proportions than terrestrial sporomorphs which suggests that the marine sediments were deposited on a continental shelf slope margin not too distant from the palaeo-shoreline since *in situ* and reworked sporomorphs are preserved with some diversity.
- The progressive decrease in the proportion of sporomorphs relative to dinocysts from the 124.94 m interval up to the 81.60 –89.25m interval indicates an increase in water depth from the Early Eocene up to the Early / Mid Eocene boundary.
- The Mid Eocene is essentially barren of palynomorphs; presumably a result of the coarse grain size and calcareous lithologies that are usually associated with higher energy environments and poor palynomorph yields.
- Throughout the Early / Mid Eocene nannofossils are very well preserved and appear to be unaffected by taphonomic factors.

### 5.3 BOREHOLE 83/20 -sb01

- The palaeontological data indicate there is a range of marine depositional environments represented by the strata in this borehole.
- The Late Jurassic strata in (166.10 - 177.35m interval) contain a mix of marine dinoflagellate cysts and terrestrial sporomorphs that indicates oxygenated open marine conditions not too distant from the palaeo-shoreline. However, the distinct reworking event at 176.4 – 176.5m indicates a period of erosion and detrital influx into this marine depositional environment.
- The Early to earliest Late Cretaceous (Cenomanian) sand dominated sequence (130.70 – 166.50m) is generally poorly fossiliferous and contains low palynomorph yields of both marine dinoflagellate cysts and terrestrially derived palynomorphs. This evidence is consistent with high-energy and well oxygenated marine depositional environments.
- Sediments from the Late Cretaceous, Early to Mid Turonian (107.90m – 125.55m) interval contain predominantly well preserved calcareous nannofossils together with moderate yields of marine dinoflagellate cysts and rare terrestrial sporomorphs, which is consistent with open well oxygenated marine waters.
- The Late Cretaceous, Maastrichtian to latest Campanian (86.22 – 102.9m) chalky micrite interval is characterised by an abundance of calcareous nannofossils and a notable absence of marine palynomorphs (dinoflagellates). This evidence points to very deep marine depositional conditions.
- Miocene sediments (34.00 – 83.32m) possess calcareous nannofossils in abundance and some samples also contain abundant and well preserved dinoflagellate cysts. This evidence, together with the rarity of terrestrially derived organic matter in these sediments is indicative of an open marine and well oxygenated environment, that was distant of the palaeo-shoreline and starved of terrestrial sediment input. Some shallowing may be interpreted at the 66.21m and 65.87m horizons as evidenced by significant yields of subtropical (non-Quaternary) pollen.

#### 5.4 BOREHOLE 83/24 - sb01 and BOREHOLE 83/24 - sb02

- The basal mudstone interval (71.29 –71.49m) contains a Late Carboniferous microflora, the composition of which is indicative of a terrestrial environment. The presence of reworked Silurian acritarchs in this microflora indicates active erosion of a Lower Palaeozoic marine sediment source area.
- A mudrock sample at 71.23m contains both Late Jurassic marine dinoflagellates and sporomorphs plus Late Carboniferous terrestrial palynomorphs. However, the possibility of sample contamination is suspected and this precludes any meaningful biostratigraphical and palaeoenvironmental interpretations of the sample.
- A Jurassic Red clay interval between 63.20 – 68.00m represents a terrestrial environment based on the report of non-marine Jurassic ostracods by Jacovides *et al.*, (1999)
- The biostratigraphically indeterminate 38.86m - 59.00m interval is assumed to be Cretaceous in age based on lithological correlation. Samples from this interval lack both nannofossil and palynological remains which may result from unfavourable depositional conditions and /or the extensive bioturbation noted in this interval.
- Eocene sediments (20.50 – 30.10m) yield abundant calcareous nannofossils and are interpreted as being deposited in an open and probably deep marine environment. The absence of *in situ* terrestrial sporomorphs and reworked palynomorphs suggests that the depositional environment was well away from coastal margins and the shallower sections of the continental shelf.
- The late Pliocene/Pleistocene sections at the top of both 83/24 cores contain an association of marine nannofossils and palynomorphs that suggests proximity to the shoreline. Terrestrial palynomorphs are abundant in sample 19.84m and there are no marine fossil indicators. However, the overlying Pleistocene sample at 18.80m contains abundant calcareous marine nannofossils, which suggests that sea levels fluctuated widely at this time and that deposition most likely took place on a shallow continental shelf.

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## 7.0 APPENDICES

### 7.1 NANNOPALAEONTOLOGY SAMPLE LISTS:

#### BOREHOLE 11/20 - sb01

7.50	9.68	18.75	20.75
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#### BOREHOLE 16/28 - sb01

13.00	60.55	109.30	143.50
24.70	68.00	118.60	146.00
34.00	81.60	122.90	
42.00	89.25	128.80	
52.70	95.00	136.10	

#### BOREHOLE 83/20 - sb01

34.00	86.50	117.00	142.00
35.85	96.00	122.80	146.75
64.00	99.80	125.55	155.00
67.00	102.20	130.70	
83.32	107.90	137.65	

#### BOREHOLE 83/24-sb01

9.40	19.30	26.60	30.80
10.00	19.57	27.10	
19.00	19.70	30.70	

#### BOREHOLE 83/24 -sb02

18.80	30.65	40.15	59.00
20.50	37.65	40.60	
22.10	38.10	44.75	
23.00	38.86	45.60	

## 7.2 PALYNOLOGY SAMPLES

BOREHOLE 11/20 - sb01

No samples taken

BOREHOLE 16/28 - sb01

25.60	91.47	109.95	130.23
41.43	91.65	110.95	130.67
42.62	91.73	112.02	135.07
52.99	92.00	112.98	136.22
61.22	92.34	113.48	136.9
67.07	93.43	116.99	137.30
69.68	94.13	118.19	137.68
80.31	95.59	119.72	137.93
81.87	96.51	120.30	143.38
82.72	97.41	120.88	143.56
83.96	97.77	122.85	143.93
87.75	101.90	124.21	144.13
88.12	102.58	124.94	144.32
88.25	106.09	125.54	144.40
88.55	106.84	126.18	144.95
88.88	107.14	127.00	145.33
89.51	107.72	127.71	145.46
89.91	108.36	128.44	145.69
90.19	108.99	128.89	145.78
90.90	109.37	130.00	145.83

## BOREHOLE 83/20 - sb01

34.47	86.40	125.30	176.20
34.99	96.00	126.12	176.28
35.33	96.80	126.91	176.40
35.57	97.30	127.37	176.50
36.15	98.62	127.53	176.62
65.87	102.10	127.70	176.66
66.21	107.63	127.97	176.80
66.67	112.73	130.74	177.0
83.34	117.17	130.85	177.10
84.00	117.43	131.04	177.25
84.55	117.90	131.18	177.35
85.70	122.60	166.10	

## BOREHOLE 83/24-sb01

No samples taken

## BOREHOLE 83/24 -sb02

19.82	38.75	68.20	71.29
21.21	40.06	68.95	71.36
23.10	67.95	71.10	71.43
37.95	68.10	71.18	71.49
38.05	68.15	71.23	

### 7.3 ALGAL LIMESTONES FROM WELL 83/20 sb01

PALÆOZOIC DATING  
INDUSTRIAL MINERALS  
SHOW CAVE DEVELOPMENT  
MATURATION AND KARST STUDIES

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Report No. 1999/33

To UCC

Report on  
two samples from borehole

**83/20 sb01**

**Site 1A**

**Rockali Trough**

**Rockall Studies Group Project 97/34**

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BSc, MSc, PGeo

7 November 2000

**Introduction:-**

Two samples from a limestone unit in the drillcore were examined both in hand specimen and in thin section. They were found to be highly pyritised, red algal limestones.

<u>Depth (m)</u>	<u>Age Determination</u> <u>Method</u>	<u>Fossils</u>
171 .70m-	probably Late Jurassic or early Cretaceous	A, S, F
171 .74m	TS, HS	

171 .89m-	probably Late Jurassic or early Cretaceous	F, A, S
171 .93m	TS, HS	

A = Algae, F = Foraminifera, S = Calcareous sponges; HS = Hand Specimen, TS = Thin Section.

**Comment:-**

Both sections are from the same biohermal limestone unit. The dominance of red alga and the presence of some grains with micritised margins, suggest that this is a relatively shallow water facies, though red alga can be found down to 200m depth.

The foraminifera are not well preserved, but resemble Lower Carboniferous archædiscids and palæotextulariids. However the well-preserved red alga belong to the Corallinaceæ (Carboniferous to Recent) and can probably be attributed to late Jurassic or early Cretaceous species. Therefore it can be seen that the section is not older than Carboniferous and might belong to the Dinantian. However this fades has not been recorded so that it is more likely that the unit is younger, possibly of late Jurassic to Early Cretaceous age, but it could be younger still.

The red alga are well preserved and it is expected that they will provide further information.

**Recommendation:-**

It is suggested that sections are taken from adjacent parts of the limestone core to augment the data base. It may be possible to consider disaggregation of the limestones to view the foraminifera in whole specimens.

## DETAILED MICROPALAEONTOLOGY, MINERALISATION AND PETROGRAPHY:-

83/20 sbOl Site 1A

**171.70 - 171.74m**

### HAND SPECIMEN:-

Grey fossiliferous limestone with calcite filled vugs (<2cm). Many vugs have dense fine pyrite. One example shows a calcite fill above a geopetal fill of micrite. The bioclastic debris is dominantly composed of short calcite cylinders, similar to crinoid debris. However, in one place these can be seen to be organised in a radial pattern, suggesting a coral. Other bioclasts include crinoid ossicles and brachiopods. The presence of the coral *Lithostrotion* is not confirmed.

### POROSITY

There is some millimetre scale porosity.

### THIN SECTION

#### Petrography:

Porous, very coarse, bioclastic floatstone / packstone with pebble-grained bioclasts and intraclasts. The pores are variable from 5 – 20% in places. The very coarse bioclasts are dominated by the calcareous red alga *Corallimaccæ* at ~50%. There are rounded clasts of calcareous sponges. The matrix consists of micrite / fine calcisilt. There is minor, angular, medium to very coarse quartz grains <1% and some more rounded chert grains. Pyrite is scattered throughout, dense in places.

Bioclasts: Corallinacea\*\*\*, calcareous sponge, brachiopod, bryozoa, ostracod and crinoid.

Algae: Rhodophyta: Corallinacea ?*Archæolithophyllum valihani* or *Amphiroa* sp.

Chlorophyta: Diploporeae ? *Eovelebitella occitannica*

Foraminifera: -Only seen in thin section, no whole specimens found to allow identification.

-Comparable to Archædiscids, somewhat altered so that sutures are not visible.

cf. *Uralodiscus bucculentas* (/Paraarchædiscus stilus)

cf. *Uralodiscus* sp.

-Trochoid or biserial form, Textulariina Miliolina

? *Paalzowella feifelli* (Paalzow)

Sponges: Spongy calcareous skeleton

Discussion: Although foraminifera might suggest Lower Carboniferous, Arundian, Cf4 $\beta$ - $\delta$  or younger, the Red algæ do advise late Jurassic or early Cretaceous or younger

DATE: probably Late Jurassic or early Cretaceous

83/20 sbOl Site 1A

**171.89 - 171.93m**

HAND SPECIMEN:-

Very porous and crumbly, light grey bioclastic limestone with pink patches of more strongly pyritised matrix. The matrix is calcite with minor fine pyrite crystallisation, in the pink patches, the matrix is strongly pyritised. The bioclasts are dominantly calcite rods (0.5mm diameter by <3mm long) as above.

POROSITY:-

Highly porous

THIN SECTION:-

Petrography:

Due to the crumbly nature of the sample it was necessary to impregnate the specimen in order to cut the thin section.

Very coarse algal floatstone with very high porosity, 40-60% (though maybe some loss of material during sectioning). Occasional coarse lithoclasts. When matrix is present it is micrite with <50% medium-grained, angular quartz grains. Fine pyrite is present throughout affecting both matrix and bioclasts.

- Bioclasts: Rhodophyta, Corallinacea\*\*\* ~30% (or 80% of matrix)  
 cf. *Amphiroa* sp. early Cretaceous - Recent.  
 Crinoid, bryozoa, ostracod, sponges
- Alga: Rhodophyta: Corallinacea ?*Archæolithophyllum valihani* or  
*Amphiroa* sp.  
 Chlorophyta: Diploporeae: ?*Eovelebitella occitannica*
- Foraminifera: -Only seen in thin section, no whole specimens found to allow  
 identification.  
 -Comparable to Archædiscids, somewhat altered so that sutures are  
 not visible.  
 cf. *Uralodiscus bucculentas* (*Paraarchædiscus stllus*)  
 cf. *Uralodiscus* sp.  
 -Trochoid or biserial form, Textulariina  
 -indeterminate plurilocular foraminifer
- Discussion: Although foraminifera might suggest Lower Carboniferous,  
 Arundian, Cf4 $\beta$ - $\delta$  or younger, the Red algæ do advise late Jurassic or  
 early Cretaceous (or younger).
- DATE: probably Late Jurassic or early Cretaceous