BRITISH GEOLOGICAL SURVEY
TECHNICAL REPORT WB/99/22C

Prepared for the Rockall Studies Group (Project 97/50)

IRISH ROCKALL SHALLOW DRILLING 1999
STRATIGRAPHIC SUMMARY

by
Martyn S Stoker

COMMERCIAL-IN-CONFIDENCE

Petroleum Infrastructure Programme
Rockall Studies Group

British Geological Survey

1999 IRISH DRILLING PROGRAMME
M.V. BUCENTAUR
BGS NIGHT SHIFT - SITE 1 - 83/24-sb02
1 MILE OF PIPE BELOW DECK!

Frontispiece

Borehole 83/24-sb02 had a total drillstring of 1637.49m (1609m = 1 mile).
BGS night shift (clockwise from top left): James Glendinning,
Alister Skinner, Eileen Gillespie & Martyn Stoker.

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MARINE REPORT SERIES
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Martyn S Stoker

Geographical index:
Irish continental margin, eastern Rockall Trough, Erris Ridge

Subject index:
Shallow boreholes, Mesozoic & Cenozoic stratigraphy

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British Geological Survey

EXECUTIVE SUMMARY

This report was prepared by the British Geological Survey (BGS) on behalf of the Rockall Studies Group, as part of the post-cruise reporting of the 1999 shallow drilling programme undertaken north-west and west of Ireland.

The report presents a summary of the Mesozoic and Cenozoic stratigraphy encountered in the 4 drilling sites variously located on the slope off NW Ireland, and the north and western slopes of the Porcupine Bank. Collectively, the boreholes proved a Neogene succession unconformable on a lower Palaeogene succession, including volcaniclastics. At the Porcupine sites, the Palaeogene rests unconformable on a Lower to Upper Cretaceous succession that has been provisionally subdivided into 3 sequences; Campanian-Maastrichtian marls; Cenomanian-Campanian greensands; and, Early to 'mid'-Cretaceous 'brownsands'. These sequences are unconformity bounded. In the boreholes on the west Porcupine slope, the Cretaceous succession has been proved to unconformably overlie Upper Jurassic strata, including algal limestones, red, non-marine, clays, and marginal marine to shelf marine sandstones, siltstones and mudstones. The Upper Jurassic strata are locally faulted.

In addition to the geological success of the drilling programme, operational achievements included twice having in excess of 1 mile (>1609m) of drillpipe below the deck of the ship: borehole 16/28-sb01 had a total drillstring of 1613.25m, whilst borehole 83/24-sb02 had a drillstring length of 1637.49m.

CONTENTS

FIGURES

ENCLOSURES

INTRODUCTION

The British Geological Survey (BGS) undertook a shallow drilling programme on behalf of the Rockall Studies Group (RSG) in July 1999, to acquire stratigraphic information from 4 proposed sites to the north-west and west of Ireland. The main objective at each site was to penetrate below the base-Tertiary unconformity (BTU). All four sites (Fig. 1) were successfully occupied although the BTU was not reached at site 3A due to a combination of geological and operational constraints (see page 3). The respective borehole numbers are listed below in their assigned, pre-drilling, priority order (descending list signifies lesser priority):

Proposed Site No.	Borehole No.
3A	11/20-sb01
2	16/28-sb01
1A	83/20-sb01
1	83/24-sb01 & 02

This report presents a summary of the geology, especially the stratigraphic context, encountered at the four sites. For details of the operational aspects of the drilling, the reader is referred to the 'Operations Report' prepared by Skinner & Tulloch (1999)[1].

In this report, each borehole is summarised separately in terms of its site details, objectives, lithology and stratigraphy. Their order of description follows their assigned priority, as noted above. The stratigraphy is based on biostratigraphic information reported by Jacovides (1999)[2], both onboard the ship and subsequent post-cruise analysis. Additional post-cruise biostratigraphic information was provided by Higgs (1999)[3] and Jones (1999, and *pers comm*)[4]. The seismic-stratigraphic setting for each site is also included as figures, consisting of the original deep-seismic reflection profile upon which the site was based, and the shallow-seismic reflection profiles that were used during the drilling programme to interpret the geology of the borehole. Whilst there are no velocity

[1] Skinner, A.C. & Tulloch, G.J.T. 1999. ROCKALL STUDIES GROUP, Shallow Coring Programme in the Irish Rockall Trough. Operations Report. *British Geological Survey Technical Report,* **WB/99/17C**.
[2] Jacovides, J. 1999. Onsite biostratigraphic analysis of five boreholes from the Irish Rockall Trough. *Millennia Project No.* **387/99**
[3] Higgs, K. 1999. Rockall Trough Drilling Programme, Palynology Results From Site 1 and Site 1A. *University of Cork.*
[4] Jones, G.Ll. 1999. Report on two samples from borehole 83/20-sb01, site 1A, Rockall Trough. *Conodate*, Report No. **1999/33**

logs available for the boreholes, thus precluding direct ties to the seismic profiles, unconformities in the boreholes can be sensibly calibrated to those on the seismic data.

Individual borehole logs are presented in two formats:

1. Abbreviated A4 summary logs in the site chapters.
2. Detailed composite logs - generated by *Geologic version 4.0* - in transparent folders at the back of the report (Enclosures 1-5).

It should be noted that the A4 summary logs have been directly derived from the composite logs. Whilst the former have been colour coded in terms of their generalised lithologies, the reader should refer to the composite logs for a detailed lithological key and description. The stratigraphic observations presented on these logs have been refined to take into account the results of post-cruise analyses undertaken prior to the end of September 1999. At the request of the RSG management committee, the original shipboard descriptions for each core run are included as Appendix 1: however, it should be noted that these have not been modified in the light of post-cruise analyses.

A 'Stratigraphic Summary' section presents a stratigraphic-range chart which correlates the boreholes, and provides the basis for a provisional framework for the Mesozoic and Cenozoic successions preserved on the Irish continental margin

Acknowledgements

This publication uses data and survey results acquired during a project undertaken on behalf of the Rockall Studies Group (RSG) of the Irish Petroleum Infrastructure Programme Group 2. The RSG comprises: Agip (UK) Ltd, Anadarko Ireland Company, ARCO Ireland Offshore Inc, BG Exploration & Production Ltd, BP Exploration Operating Company Ltd, British-Borneo International Ltd, Elf Petroleum Ireland BV, Enterprise Oil plc, Mobil Oil North Sea Ltd, Murphy Ireland Offshore Ltd, Phillips Petroleum Exploration Ireland, Saga Petroleum Ireland Ltd, Shell EP Ireland B.V., Statoil Exploration (Ireland) Ltd, Total Oil Marine plc, Union Texas Petroleum Ltd and the Petroleum Affairs Division of the Department of the Marine and Natural Resources.

The following seismic companies are thanked for permission to use part of the following non-exclusive seismic lines in the compilation of this report:

TGS-NOPEC for line NWI-91-116

SPECTRUM for line ISROCK-96-34

SPECTRUM for line ISROCK-96-86

Saga Petroleum Ireland Ltd are also thanked for permission to use part of the following exclusive seismic line in the compilation of this report:

SG97-12-418-03A/B

The author would like to acknowledge the help and experience of the following people: Dave Tappin (BGS) who was the other geologist onboard the MV Bucentaur; Jake Jacovides (Millennia) for his excellent biostratigraphic input onboard the ship and from subsequent post-cruise analysis; Alister Skinner, Eileen Gillespie, Graham Tulloch, Colin Brett, Colin Graham and James Glendinning (all BGS) for their professionalism in their offshore duties; and finally, John Chamberlain (Philips) and Martin Davies (CSA) for their encouragement in the preparation of this report. Finally, I thank John Chamberlain and Alex Jones for their constructive review of this report.

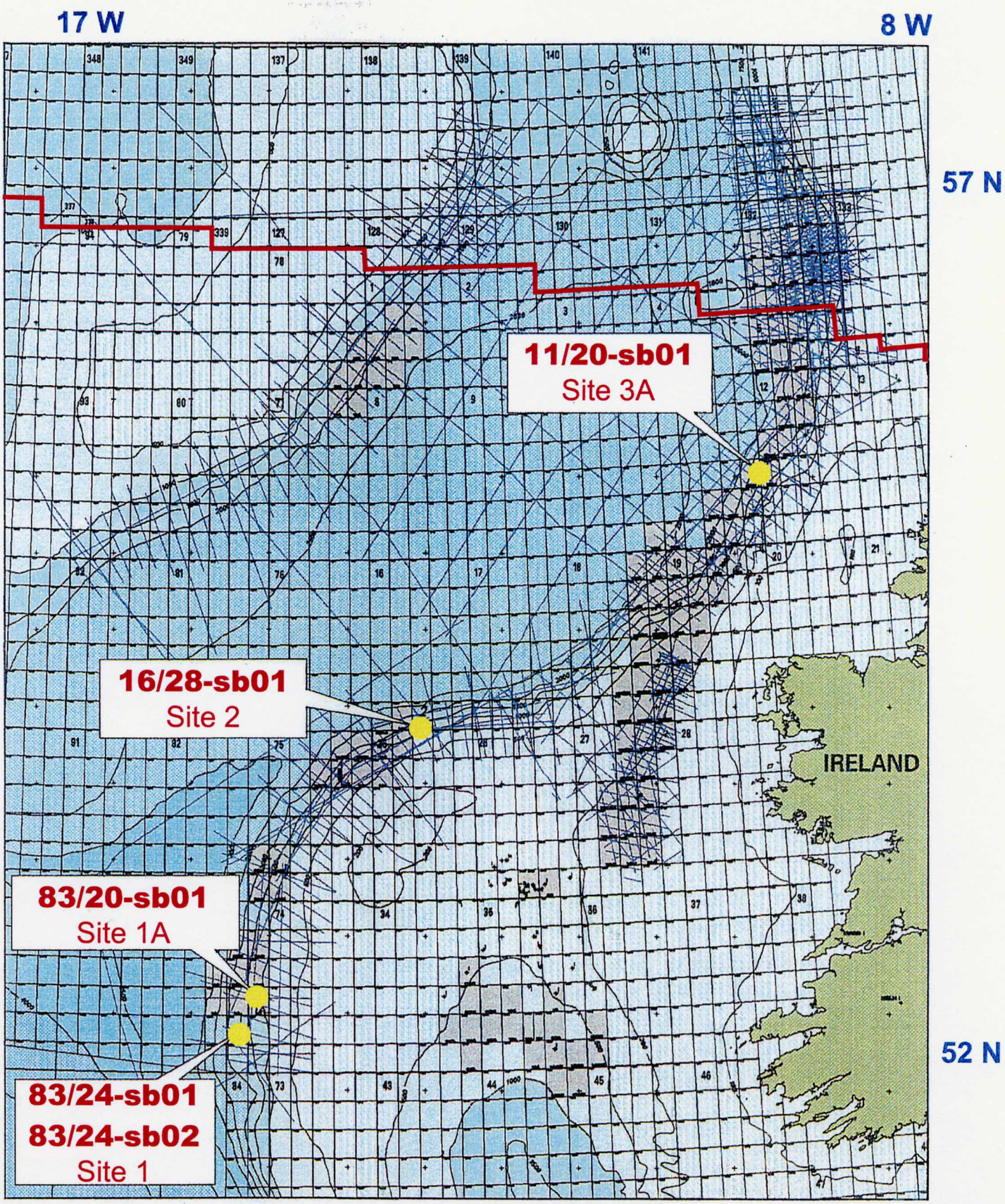


Fig. 1 Map showing location of boreholes

BOREHOLE 11/20-sb01

BOREHOLE: 11/20-sb01

Approximate position: Erris Ridge

Latitude:	55° 25' 9.125"N	**Total depth:**	20.80m
Longitude:	10° 01' 14.667"W	**Water depth:**	1092.15m
Navigation:	DGPS	**Vessel:**	BUCENTAUR
Map area:	Irish Rockall Trough	**Station keeping:**	DP
Licence block:	11/20	**Dates of drilling:**	7th-8th July 1999
PIP plan number:	3A	**Geologists:** **Biostratigrapher:**	M.Stoker, D.Tappin J.Jacovides

PRINCIPAL RESULTS:

The objective of this borehole was to test the age and lithologies encountered below the base-Tertiary unconformity on the Erris Ridge. The borehole was sited on the basis of deep-seismic profile NWI-91-116 (Fig. 2). The borehole cored the following succession, which is summarised in Fig. 3*:

0.00-7.67m: ***NEOGENE – Upper Pliocene.***
Mud, dark grey, soft to firm, sticky, with very thin sandy laminae, bioturbated, black sulphidic knots. **Marine, slope/bathyal.**
Seismic stratigraphy: correlates with acoustically well-layered slope apron which has been extensively eroded and canyonised (Fig. 4)

7.67-8.00m: ***?NEOGENE.***
Lag gravel, pebbles of dark grey siltstone, tuff and sandstone.
Seismic stratigraphy: overlies Palaeogene section

8.00-20.80m: ***PALAEOGENE.***
Tuff, yellowish-red to brown, lithic and crystal fragments, scattered dark grey basalt clasts, vesicular with zeolites, glass commonly altered to Palagonite, carbonate veins are common particularly towards base of section, thin tuffaceous limestone at about 18.8m, foraminifera and bivalve shell fragments are scattered throughout the core. **Marine, water depth uncertain.**
Seismic stratigraphy: correlates with irregular, discontinuous, acoustically-chaotic unit which overlies the Erris Ridge (Fig. 4)

NB: This borehole was terminated without penetrating the base-Tertiary unconformity, due to instability on the drillstring as the heave on the vessel increased during deteriorating weather conditions. This made it impossible to get the necessary bit weight to increase the slow drilling rate within the Palaeogene volcanics.

* **See enclosure 1 for detailed lithological log**

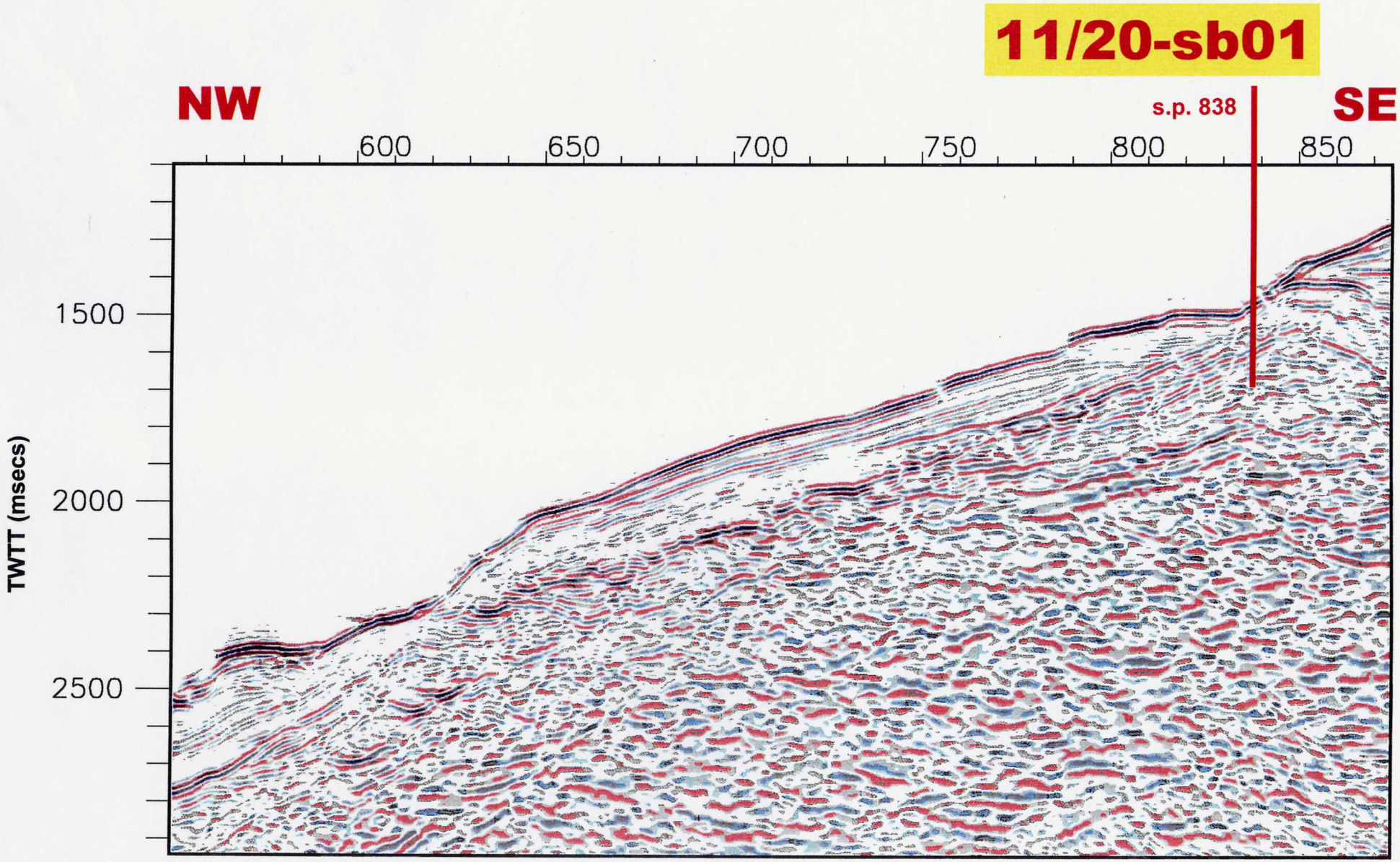
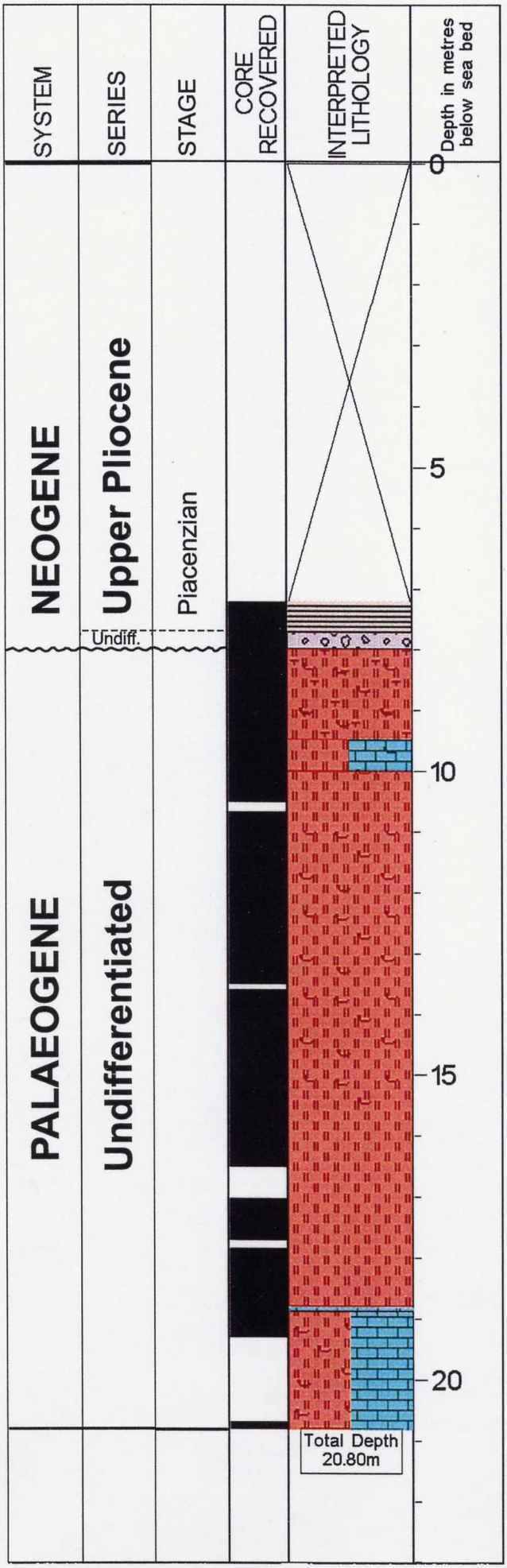


Fig. 2 Deep seismic setting of borehole 11/20-sb01 (seismic profile courtesy of TGS-NOPEC)



11/20-sb01

Site 3A

Fig. 3 Summary log of borehole 11/20-sb01. Colour key: Brown, muds; Pink, lag gravel; Blue, carbonate veins and thin beds; Orange, volcanic tuffs

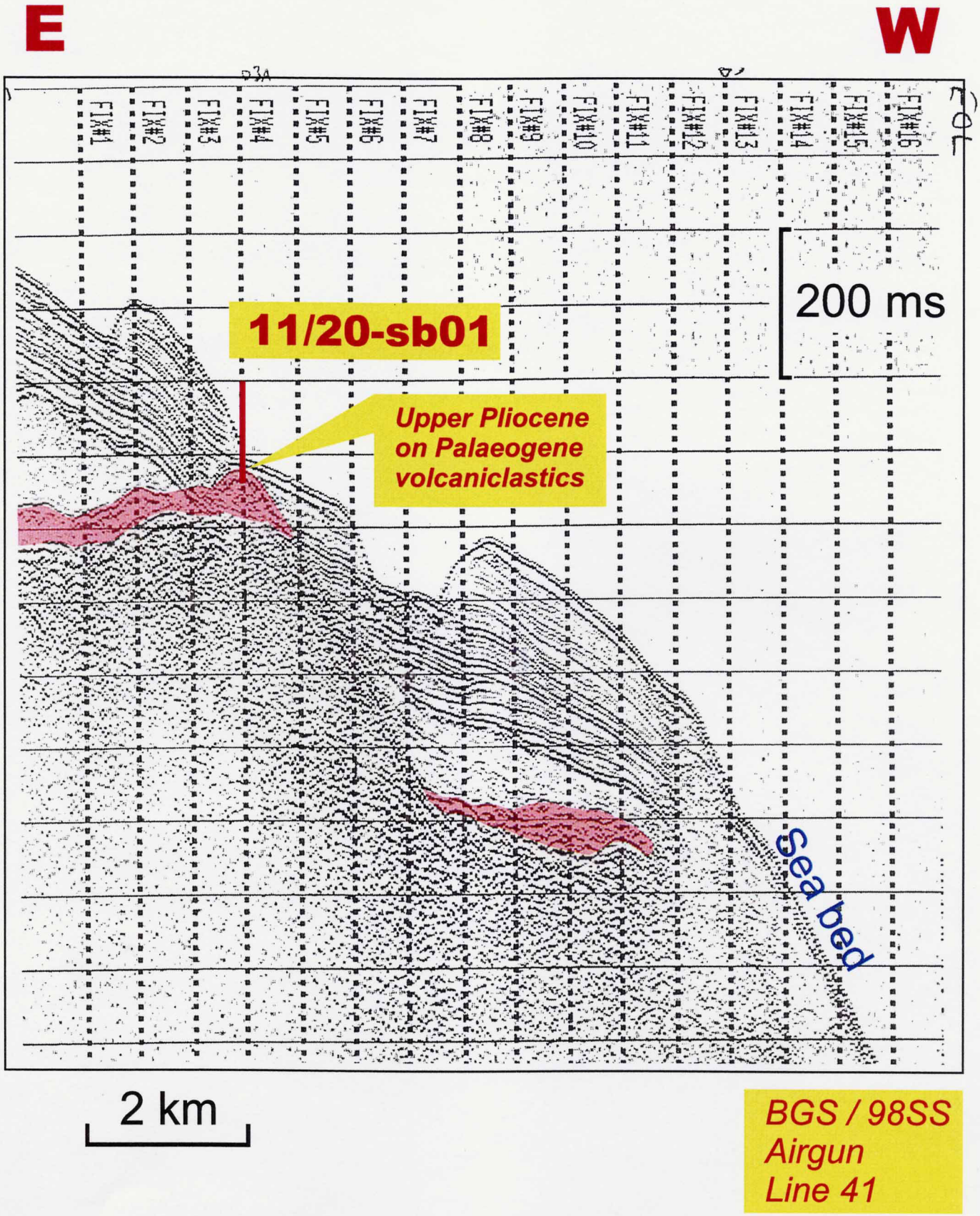


Fig. 4 Shallow seismic (airgun) setting of borehole 11/20-sb01 with geological interpretation

BOREHOLE 16/28-sb01

BOREHOLE: 16/28-sb01

Approximate position: Northern slope of Porcupine Bank

Latitude:	54° 01' 19.989"N	**Total depth:**	148.25m
Longitude:	13° 30' 51.575"W	**Water depth:**	1465m
Navigation:	DGPS	**Vessel:**	BUCENTAUR
Map area:	Irish Rockall Trough	**Station keeping:**	DP
Licence block:	16/28	**Dates of drilling:**	9th-14th July 1999
PIP plan number:	2	**Geologists:** **Biostratigrapher:**	M.Stoker, D.Tappin J.Jacovides

PRINCIPAL RESULTS:

The objective of this borehole was to test the age and lithologies encountered below the base-Tertiary unconformity on the northern slope of Porcupine Bank (Macdara Basin). The borehole was sited on the basis of deep-seismic profile ISROCK-96-34 (Fig. 5). The borehole cored the following succession, which is summarised in Fig. 6*:

0.0-14.47m: ***NEOGENE-QUATERNARY – Upper Pliocene-Pleistocene.***
Sand, foraminiferal, pale olive brown, well sorted, sporadic pebbles. **Marine, slope/bathyal.**
Seismic stratigraphy: correlates with acoustically-layered slope apron that displays onlap (upslope accretion) possibly associated with a small sediment drift.

14.47-145.95m: ***PALAEOGENE – Upper Paleocene-middle Eocene (basal 0.25m is undifferentiated Paleocene)***
Interbedded mudstones and siltstones, greenish grey, firm to hard, commonly massive, bioturbated, sporadic fractures, rare shell fragments, glauconitic. Basal 2-3m (Paleocene) displays inclined bedding of 20-30°, and is locally moderately cemented. **Marine, slope/bathyal, but basal 0.25m is shelfal.**
Seismic stratigraphy: correlates with acoustically-chaotic unit that shows evidence of disrupted layering (Fig. 7).

145.95-c.146.5m: ***UPPER CRETACEOUS – Upper Maastrichtian.***
Siltstone, sandy, pale olive grey, very hard and well cemented, calcareous, common brown glauconite, lithic fragments. **Marine, shelf.**
Seismic stratigraphy: uncertain if above or below main unconformity (Fig. 7)**.

c.146.5-147.24m: ***UPPER CRETACEOUS – ?Cenomanian***
Sandstone, dark yellowish-brown, well cemented (carbonate), coarse-medium grained, well sorted, common frosted quartz grains, secondary shell debris/carbonate fragments. **Marine, shelf.**
Seismic stratigraphy: uncertain if above or below main unconformity (Fig. 7).

147.24-148.25m: ***AGE UNKNOWN.***
Basalt, black, fractured with calcite veins up to 2cm thick, top is microphyric with flow-banded plagioclase laths, remainder is fine grained, highly altered.
Seismic stratigraphy: uncertain if above or below main unconformity (Fig. 7).

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* **See enclosure 2 for detailed lithological log**

** **See *STRATIGRAPHIC SUMMARY'* section for further discussion**

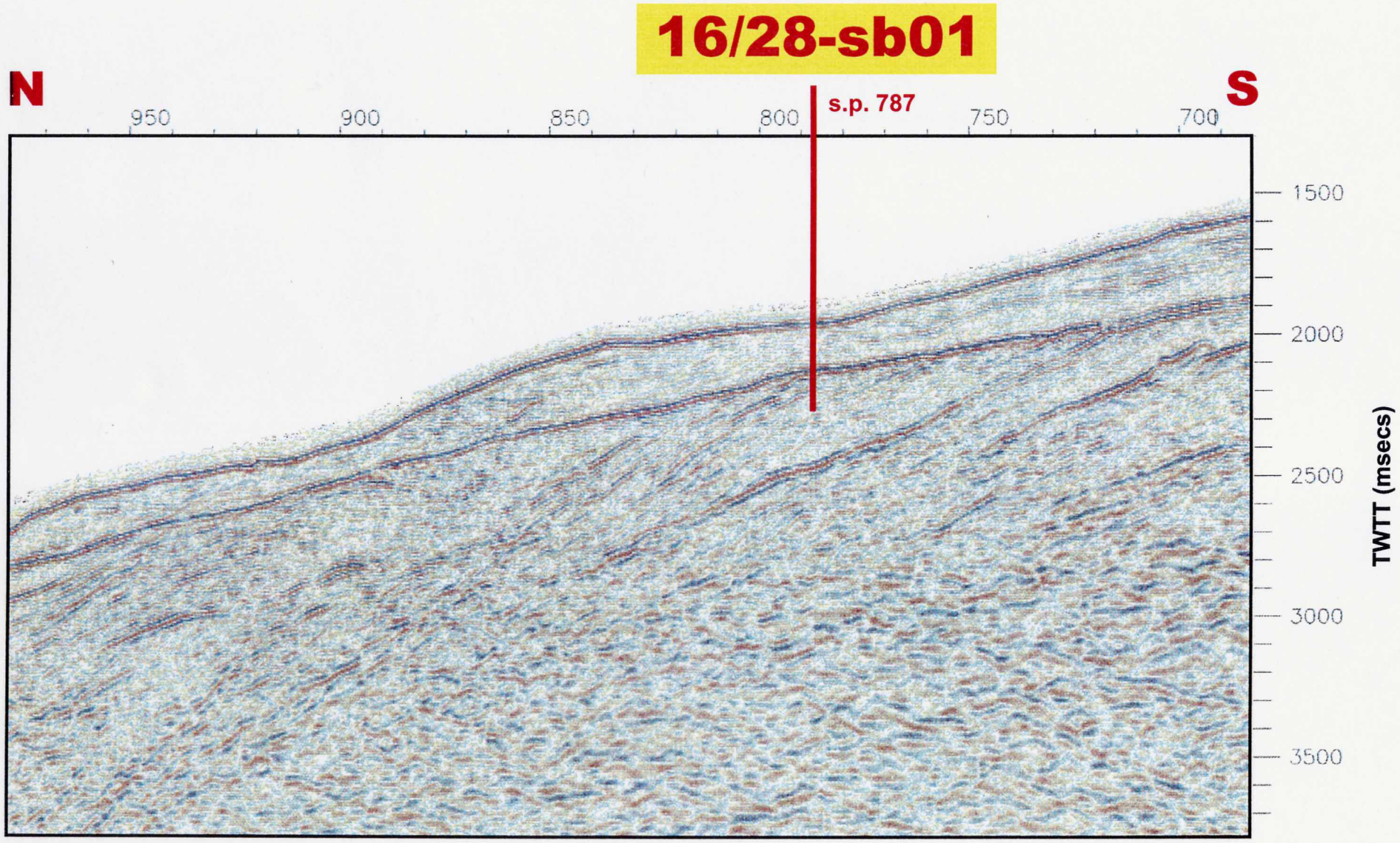

Fig. 5 Deep seismic setting of borehole 16/28-sb01 (seismic profile courtesy of SPECTRUM)

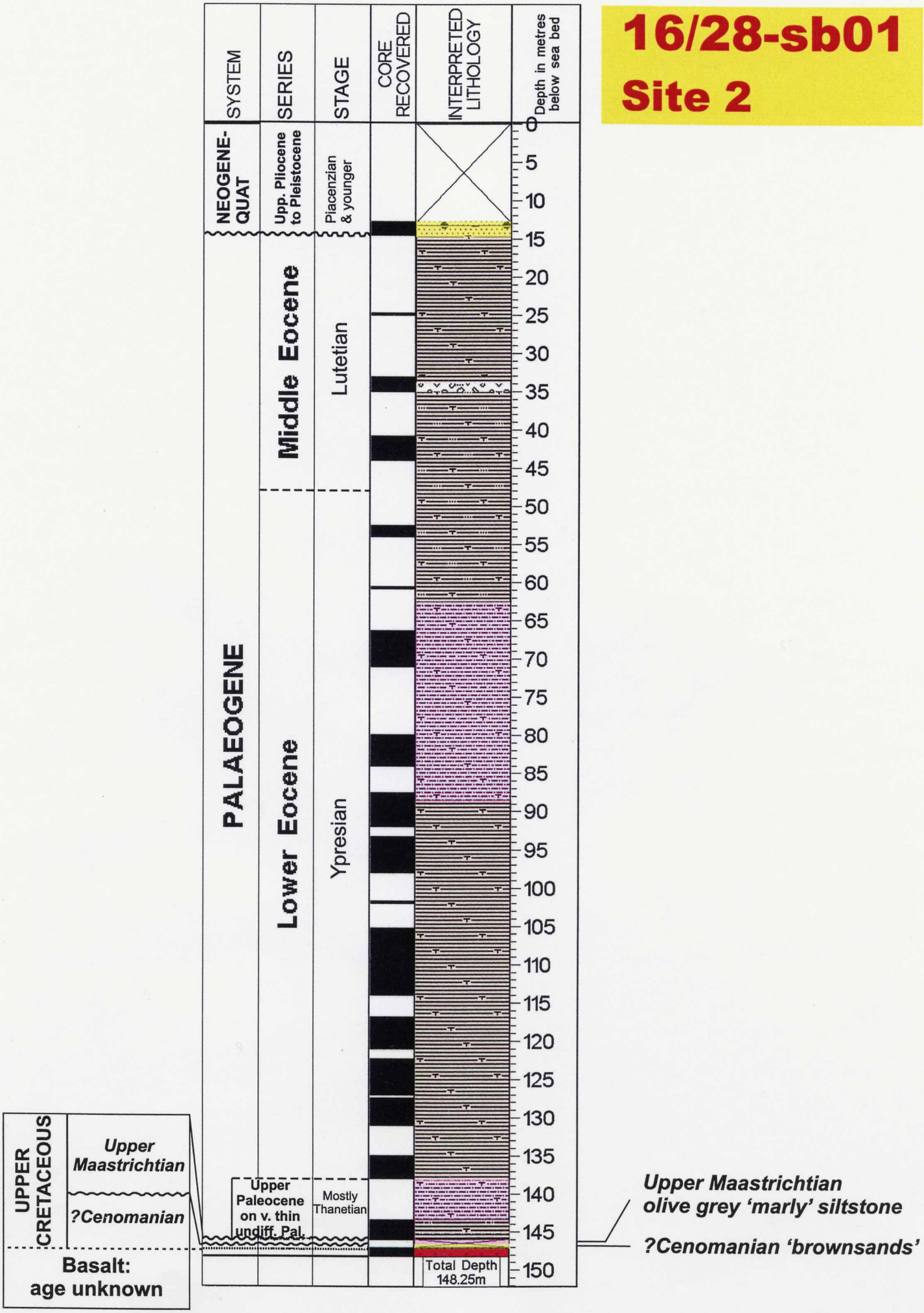

Fig. 6 Summary log of borehole 16/28-sb01. Colour key: Yellow, sand/sandstone; Brown, mudstone; Purple, siltstone; Red, basalt; White, cavings.

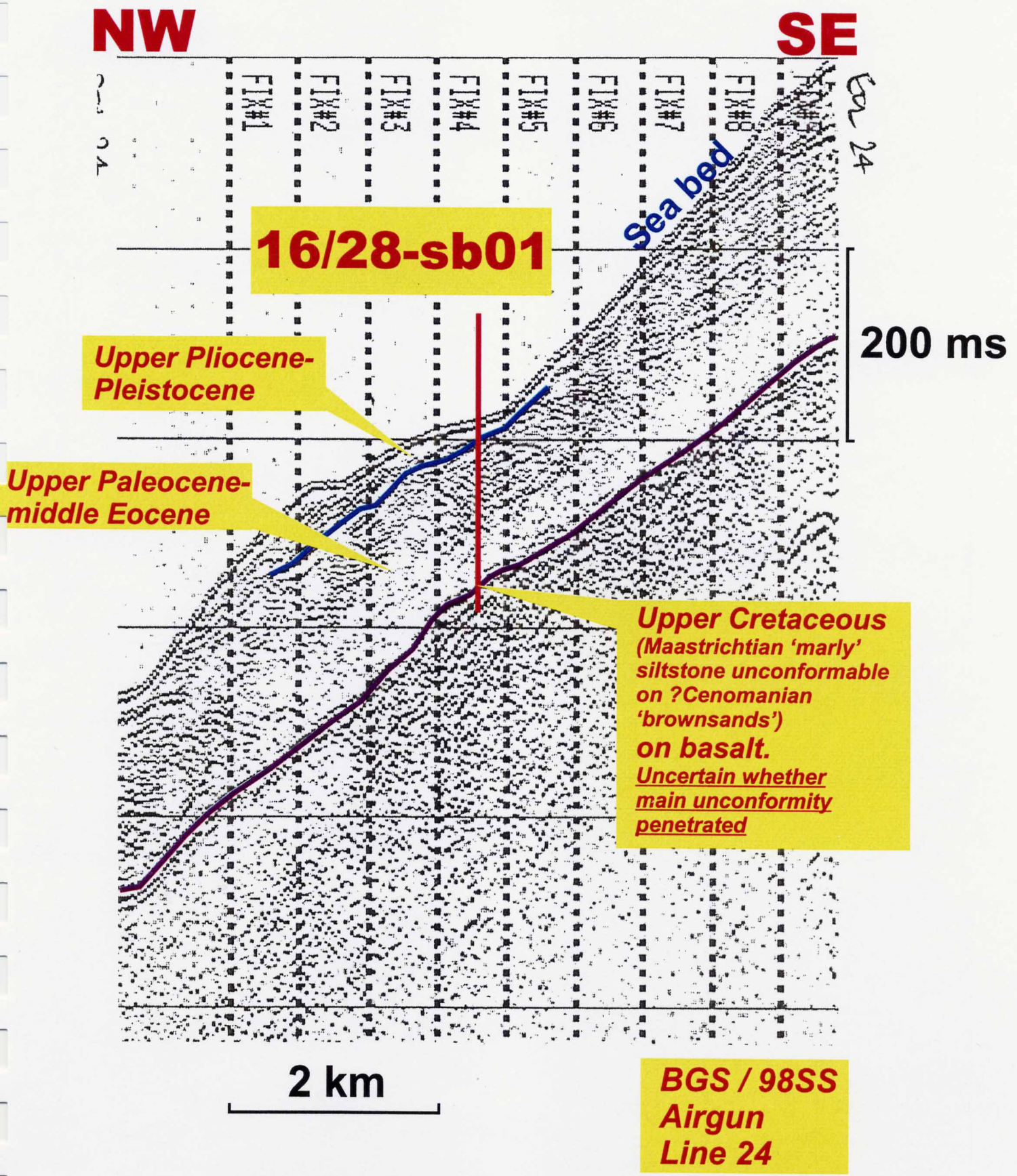

Fig. 7 Shallow seismic (airgun) setting of borehole 16/28-sb01 with geological interpretation

BOREHOLE 83/20-sb01

BOREHOLE: 83/20-sb01

Approximate position: Western slope of Porcupine Bank

Latitude:	52° 26' 38.990"N	**Total depth:**	177.4m
Longitude:	15° 06' 53.504"W	**Water depth:**	1045m
Navigation:	DGPS	**Vessel:**	BUCENTAUR
Map area:	Irish Rockall Trough	**Station keeping:**	DP
Licence block:	83/20	**Dates of drilling:**	15th-18th July 1999
PIP plan number:	1A	**Geologists:** **Biostratigrapher:**	M.Stoker, D.Tappin J.Jacovides

PRINCIPAL RESULTS:

The objective of this borehole was to test the age and lithologies below the base-Tertiary unconformity on the western slope of Porcupine Bank (North Brona Basin). The borehole was sited on the basis of deep-seismic profile SG97-12-418-03A/B (Fig. 8). The borehole cored the following succession, which is summarised in Fig. 9*:

0.0-33.7m: NO RECOVERY – open holed. Uppermost seismic-stratigraphic unit not sampled.

33.7-86.2m: ***NEOGENE – Middle Miocene-Pliocene***
Silty clays, greenish grey, soft to firm/stiff, bioturbated. **Marine, slope.**
Seismic stratigraphy: correlates with an unconformity-bounded, acoustically-layered unit which includes relict, infilled canyons (Fig. 10). Top of unit is an irregular erosion surface (Fig. 11); basal unconformity marked by a **lag gravel**.

86.2-102.9m: ***UPPER CRETACEOUS – Upper Campanian-Maastrichtian.***
Marls, varicoloured, massive, bioturbated. **Marine, slope.**
Seismic stratigraphy: correlates with an acoustically-chaotic unit (Fig. 11). Top of unit is a regional unconformity surface (Fig. 10).

102.9-131.28m: ***UPPER CRETACEOUS – Cenomanian-?Campanian***
Sandstones, dark greenish grey, fine to coarse, poorly sorted, soft to hard, glauconitic, carbonate cemented, locally shelly. **Marine, slope.**
Seismic stratigraphy: correlates with acoustically well-layered unit (Fig. 11). Top of unit is eroded; dark brown and ?ferruginous (?weathered) in core.

131.28-169.7m: ***CRETACEOUS – Albian-Cenomanian (and older Early Cretaceous ?)***
Sandstones, yellowish brown, fine to very coarse, poorly sorted, common brown glauconite, frosted quartz, shell debris, carbonate cement, with thin **limestones**, grey, shelly, one of which marks top of sequence. **Marine, shelf.**
Seismic stratigraphy: correlates with acoustically well-layered unit (Fig. 11). Top of unit is eroded.

169.7-177.4m: ***UPPER JURASSIC – Upper Kimmeridgian***
Limestone, grey, biohermal, much broken coral and shell debris, pyritic; on, interbedded grey, very fine to fine, cross-bedded **sandstones** and grey, laminated, carbonaceous, pyritic **mudstones**. **Marine, shelf.**
Seismic stratigraphy: correlates with acoustically-layered unit, top of which is a regional unconformity surface, locally faulted (Figs 10 & 11).

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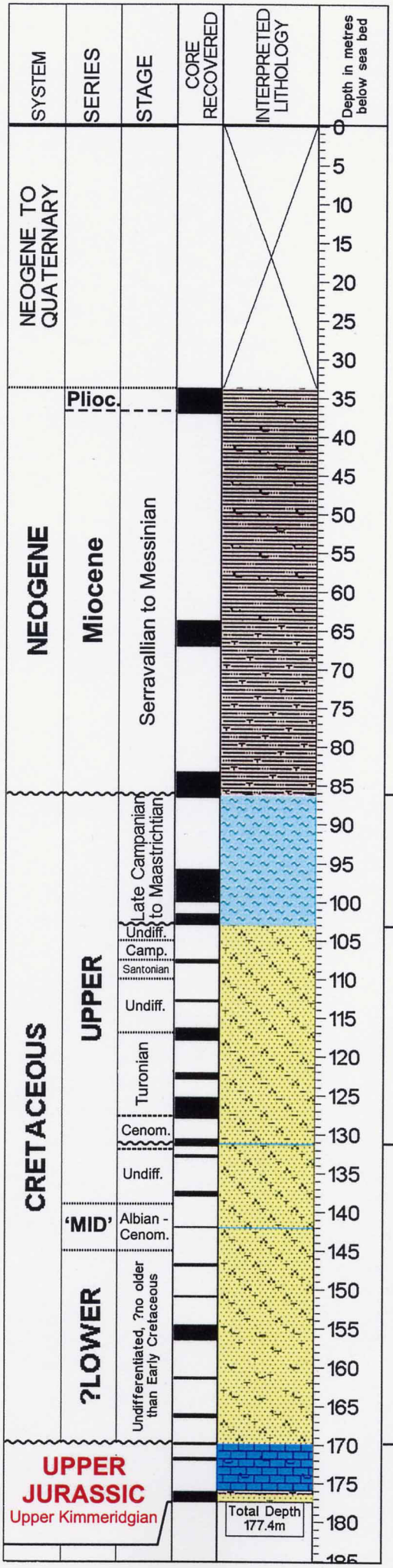
* **See enclosure 3 for detailed lithological log**

Fig. 8 Deep seismic setting of borehole 83/20-sb01 (seismic profile courtesy of Saga Petroleum Ireland Ltd)

SG97-12-418-03A/B
Site 1A

83/20-sb01
Site 1A



Due to long core run between 67.0 and 86.6m actual depth of unconformity is probably about 72.0m (see enclosure 3)

Varicoloured marls

Intra-Campanian unconformity?

'Greensands'

Intra-Cenomanian unconformity?

'Brownsands'

Fig. 9 Summary log of borehole 83/20-sb01
Colour key: Brown, clays, mud/mudstone; Pale blue, marls; Yellow, sandstones; Blue, limestone

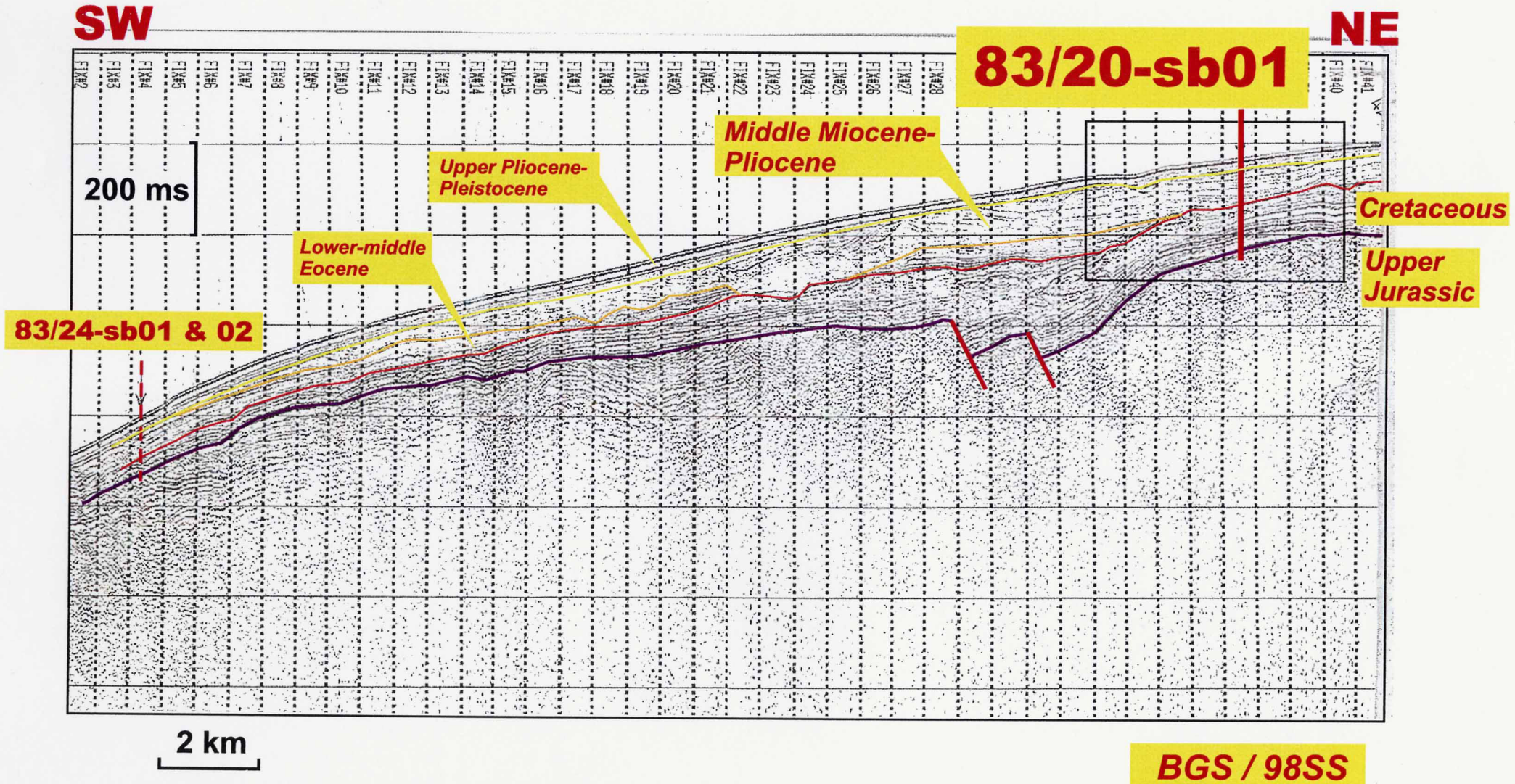


Fig. 10 Shallow seismic (airgun) setting of borehole 83/20-sb01 with geological interpretation. For detail of boxed area see Fig. 11

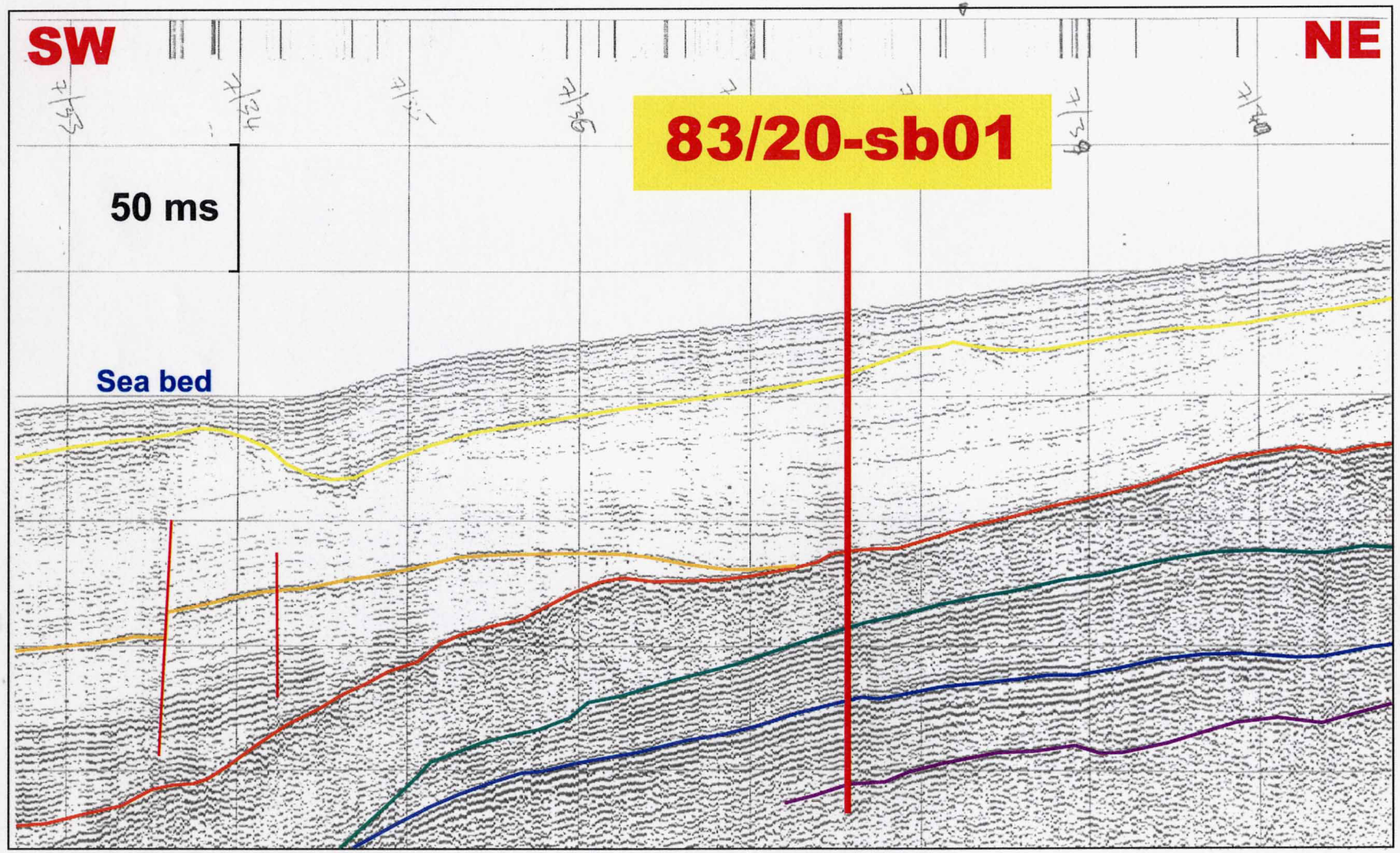


Fig. 11 Shallow seismic (sparker) setting of borehole 83/20-sb01 with detailed geological interpretation. See Fig. 10 for location of seismic panel

BOREHOLE 83/24-sb01 & 02

BOREHOLE: 83/24-sb01

Approximate position: Western slope of Porcupine Bank

Latitude:	52° 14' 43.697"N	**Total depth:**	30.8m
Longitude:	15° 17' 33.671"W	**Water depth:**	1571m
Navigation:	DGPS	**Vessel:**	BUCENTAUR
Map area:	Irish Rockall Trough	**Station keeping:**	DP
Licence block:	83/24	**Dates of drilling:**	19th-20th July 1999
PIP plan number:	1	**Geologists:** **Biostratigrapher:**	M.Stoker, D.Tappin J.Jacovides

PRINCIPAL RESULTS:

The objective of this borehole was to test the age and lithologies encountered below the base-Tertiary unconformity on the western slope of Porcupine Bank (South Brona Basin). The borehole was sited on the basis of deep-seismic profile ISROCK-96-86 (Fig. 12). The borehole cored the following succession, which is summarised in Fig. 13* (see also Fig. 14):

0.0-19.45m ***NEOGENE-QUATERNARY – Upper Pliocene to Pleistocene***
Clays, varicoloured, soft, calcareous, scattered pebbles, with subordinate **sands**, pale yellow to pale grey, rich in foraminifera, medium to fine, sporadic pebbles. Base of section marked by a **lag gravel**, a 1cm-thick pebble layer. **Marine, slope.**
Seismic stratigraphy: correlates with acoustically-layered uppermost unit on slope. Base of unit is a regional erosional unconformity which truncates underlying strata (Figs 15 & 16).

19.45-30.8m ***PALAEOGENE – Lower to middle Eocene***
Micritic limestone/calcareous mudstone, pale yellow, soft to hard, rich in foraminifera and sponge spicules, sporadic lithic pebbles, predominantly massive, common chertification, localised fractures coated with dendritic manganese. **Marine, upper slope.**
Seismic stratigraphy: unit correlates with acoustically-layered unit that is locally eroded out higher on the slope (Figs 15 & 16).

NB: Borehole was abandoned due to deteriorating weather conditions. Site re-drilled as borehole 83/24-sb02.

* **See enclosure 4 for detailed lithological log**

BOREHOLE: 83/24-sb02

Approximate position: Western slope of Porcupine Bank

Latitude:	52° 14' 44.710"N	**Total depth:**	71.49m
Longitude:	15° 17' 33.262"W	**Water depth:**	1566m
Navigation:	DGPS	**Vessel:**	BUCENTAUR
Map area:	Irish Rockall Trough	**Station keeping:**	DP
Licence block:	83/24	**Dates of drilling:**	22nd-24th July 1999
PIP plan number:	1	**Geologists:** **Biostratigrapher:**	M.Stoker, D.Tappin J.Jacovides

PRINCIPAL RESULTS:

The objective of this borehole was to test the age and lithologies encountered below the base-Tertiary unconformity on the western slope of Porcupine Bank (South Brona Basin). The borehole was sited on the basis of deep-seismic profile ISROCK-96-86 (Fig. 12). The borehole cored the following succession, which is summarised in Fig. 14*:

0.0-19.96m: ***NEOGENE-QUATERNARY – Upper Pliocene-Pleistocene***
Clays, very soft to soft, varicoloured, calcareous, bioturbated, sporadic thin sands, scattered pebbles. **Marine, slope.**
Seismic stratigraphy: SEE BOREHOLE 83/24-sb01 FOR DETAILS.

19.96-38.13m: ***PALAEOGENE – Lower to middle Eocene***
Micritic limestone, pale yellow, soft to hard, cherty. **Marine, upper slope.**
Seismic stratigraphy: unconformity-bounded, acoustically-layered unit; base is marked by regional erosion surface cutting down into Cretaceous strata (Fig. 15).

38.13m Composite Unconformity? ***UPPER CRETACEOUS – Upper Maastrichtian***
Cavings examined at 58.70m yielded evidence for an Upper Maastrichtian veneer that is most likely to occur at the Palaeogene/Cretaceous unconformity. This veneer itself must rest unconformable on the underlying strata.

38.13-63.25m: ***CRETACEOUS – ?Albian-Cenomanian (and older Early Cretaceous?)***
Sandstones, reddish yellow to strong brown, silt to very coarse, poorly sorted, carbonate cemented, common brown glauconite, shell debris and frosted quartz, common dissolution. **Marine, shelf.**
Seismic stratigraphy: correlates with acoustically well-layered unit that forms basal part of Cretaceous section penetrated by borehole 83/20-sb01 (Fig. 15). Top of unit is eroded (Fig. 16).

63.25-71.49m: ***UPPER JURASSIC – Kimmeridgian-Volgian (lower Portlandian)***
Clay, red, soft, massive, on **interbedded siltstones and mudstones**, hard, indurated, massive to laminated, reddish brown to greenish grey, sporadic reduction spots, reworked Upper Carboniferous spores. Rock is disrupted by cataclasis; zones of microbrecciation have locally destroyed the original rock fabric. Red clay is **non-marine**; siltstones and mudstones are **?marginal marine.**
Seismic stratigraphy: correlates with acoustically layered strata (Figs 12 & 15). Top of unit is regional erosion surface. Loss of acoustic layering at drillsite may be due to faulting and cataclasis, evident in cores and on seismic profiles.

* **See enclosure 5 for detailed lithological log**

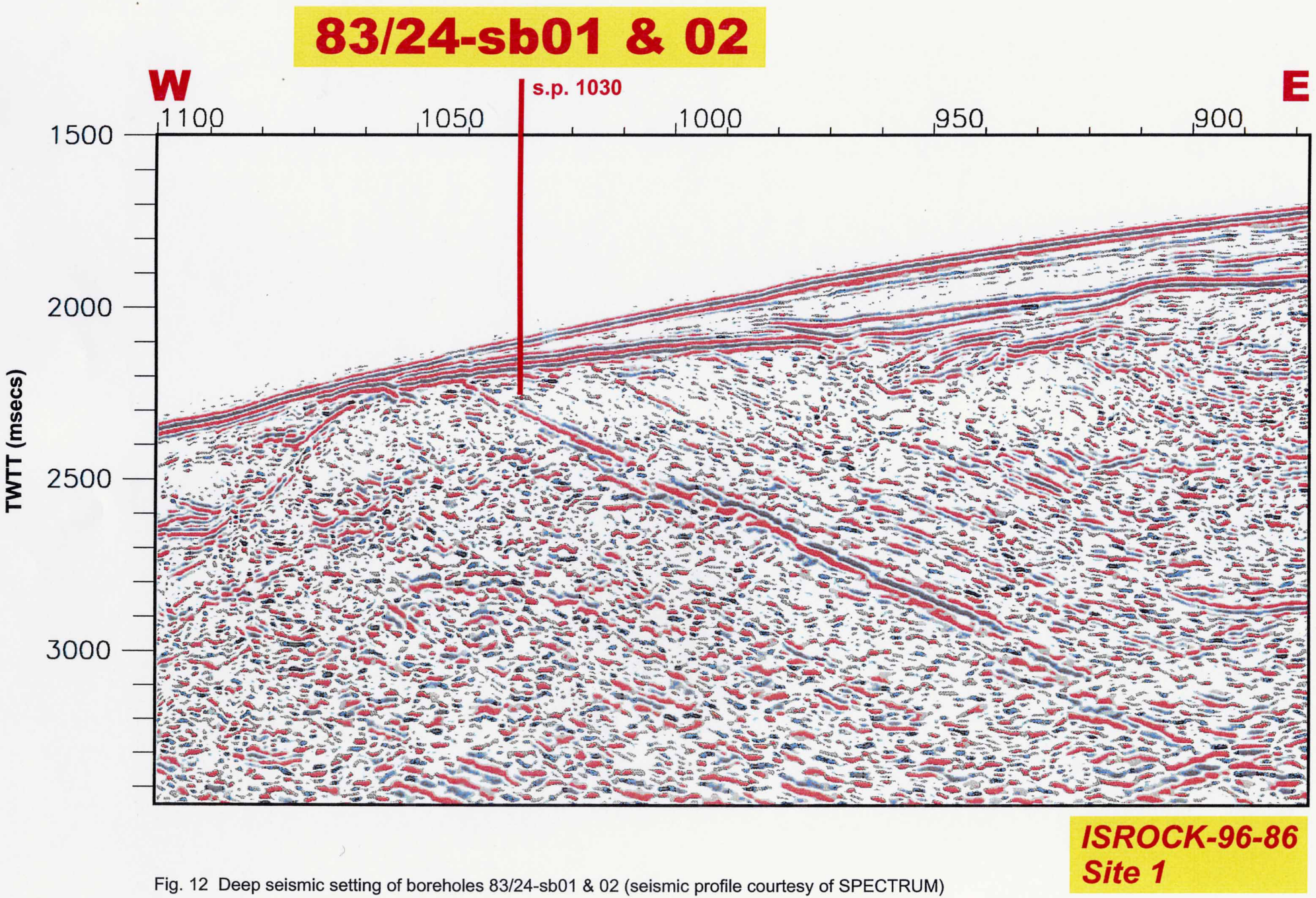


Fig. 12 Deep seismic setting of boreholes 83/24-sb01 & 02 (seismic profile courtesy of SPECTRUM)

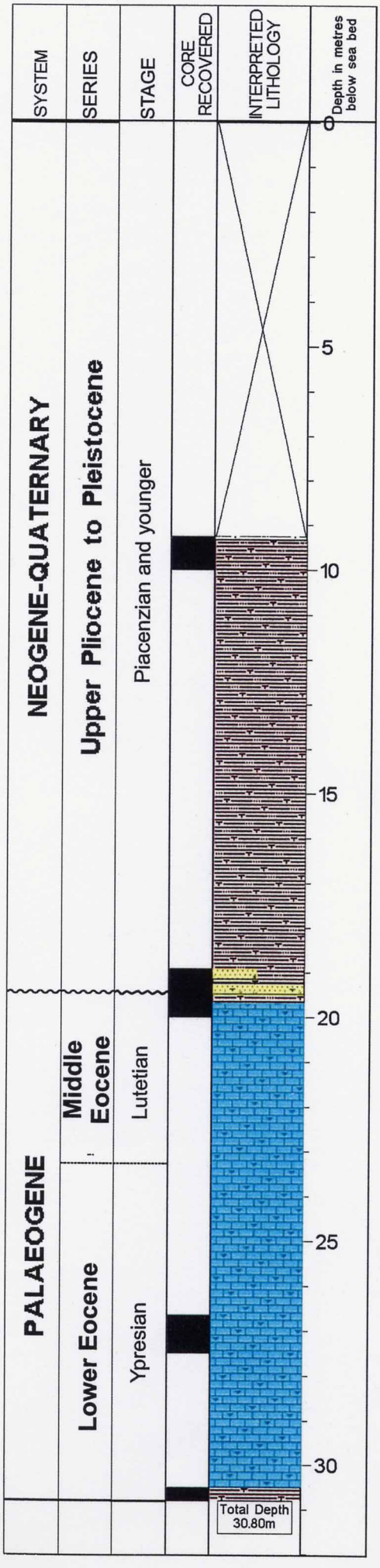
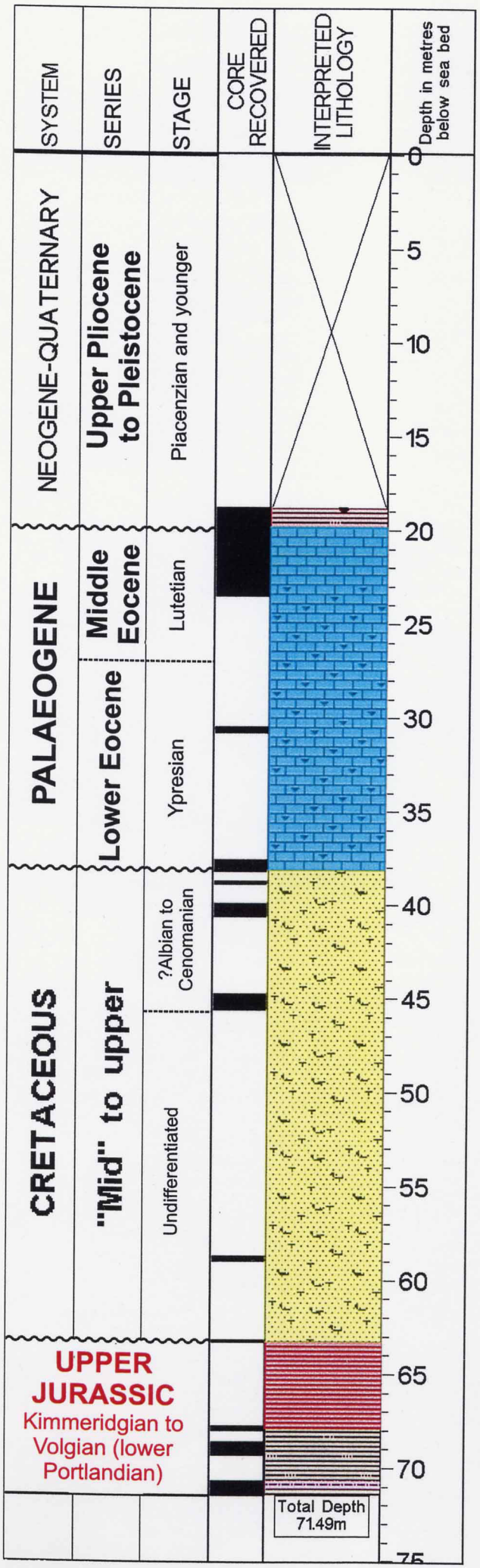


Fig. 13 Summary log of borehole 83/24-sb01. Colour key: Brown, clays, mud/mudstone; Yellow, sand; Blue, limestone



83/24-sb02
Site 1

Upper Maastrichtian veneer unconformable on 'Brownsands'

'Brownsands'

Red clay

Strong cataclastic deformation

Fig. 14 Summary log of borehole 83/24-sb02. Colour key: Brown, clay, mud/mudstone; Blue, limestone; Yellow, sandstone; Red, red clay; Purple, siltstone

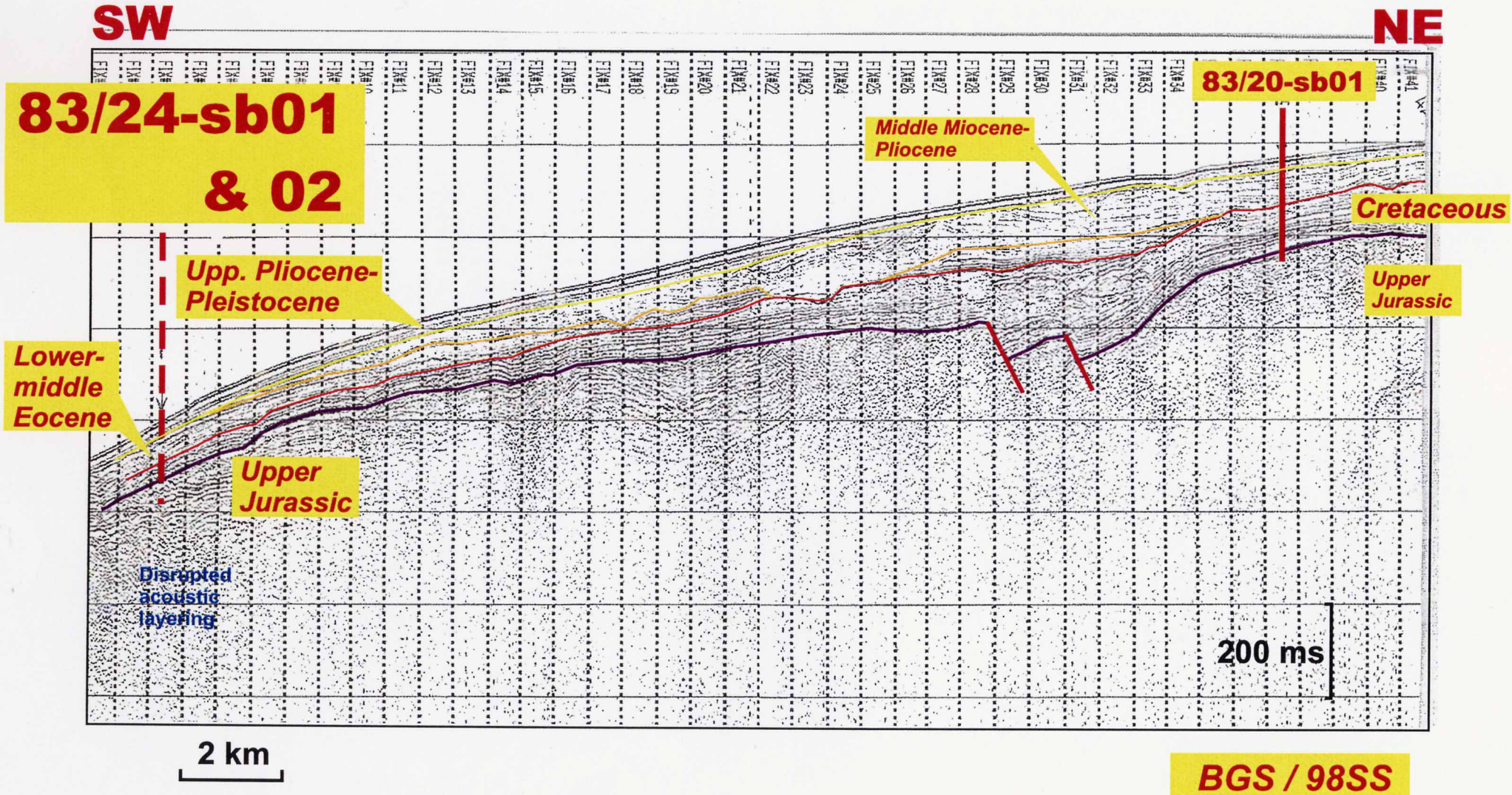


Fig. 15 Shallow seismic (airgun) setting of boreholes 83/24-sb01 & 02 with geological interpretation

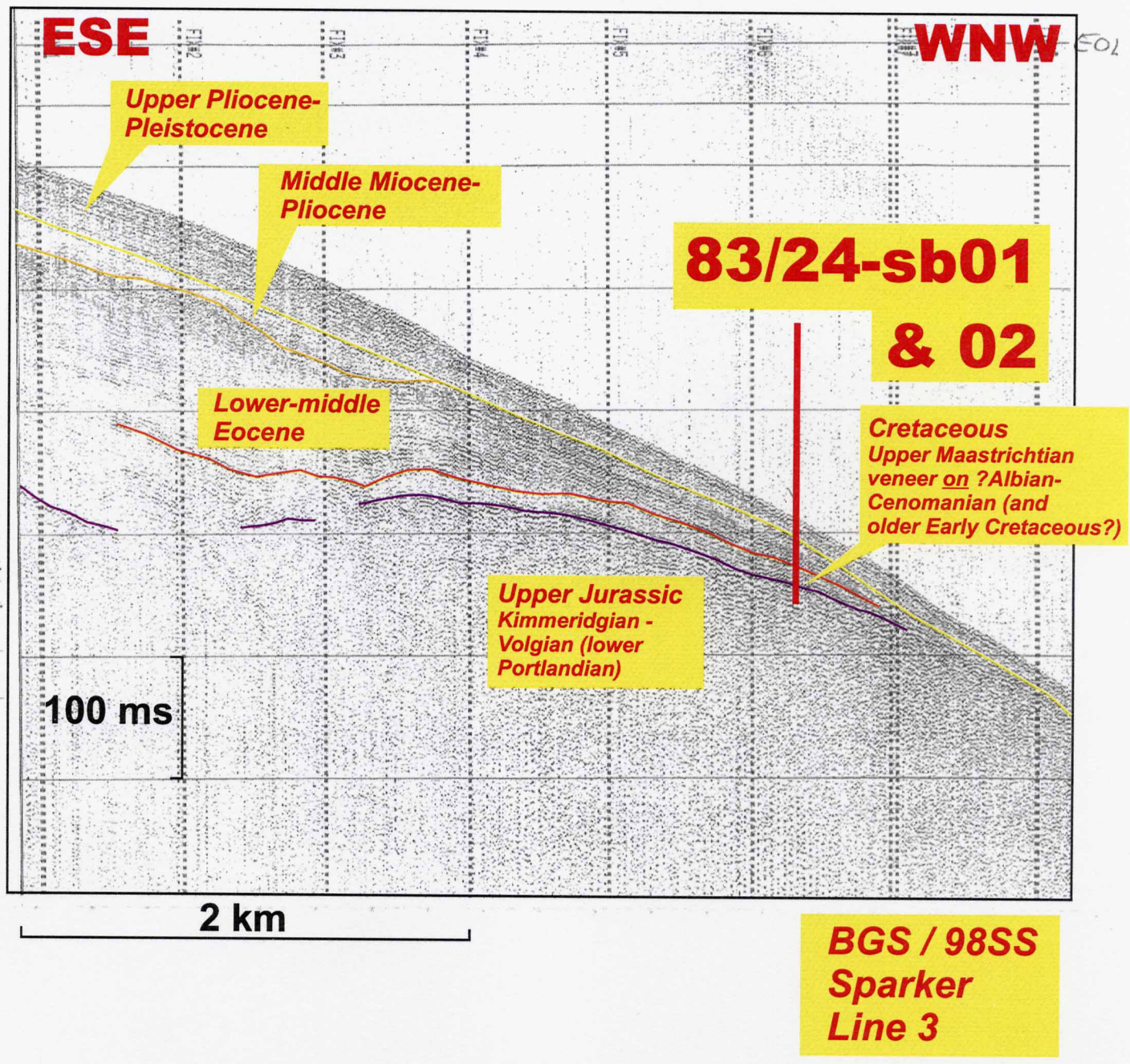


Fig. 16 Shallow seismic (sparker) setting of boreholes 83/24-sb01 & 02 with detailed geological interpretation

STRATIGRAPHIC SUMMARY

STRATIGRAPHIC SUMMARY

The stratigraphic-range and correlation of the various rock units tested by the boreholes is illustrated in Fig. 17. The main stratigraphic points arising from the correlation exercise are summarised below:

- **Intra-Pliocene unconformity** – This is confirmed by combining the information from boreholes 83/20-sb01 and 83/24-sb01, and is represented by the yellow reflector shown on Figs 10, 11, 15 & 16. This is consistent with regional studies recently completed in the Rockall and Faroe-Shetland region (Stoker 1999; Stoker *et al.* In press), and is a margin-wide expression of major Neogene, circum-North Atlantic uplift.

- **Mid-Cenozoic missing section** – The boreholes proved the absence of upper Eocene to lower Miocene rocks on the flanks of the Rockall Trough. This observation is also in accord with regional studies in the UK sector, where the Oligocene record, in particular, is somewhat fragmentary on the flanks of the basin. Oligocene reefal and upper slope deposits (Stoker *et al.* 1994; Stoker 1997; Stoker *et al.* In press), and terrestrial strata (see Stoker *et al.* 1993 and references therein) have been proved on the Hebridean margin, whilst lowstand-fan deposits have been described on the flanks of the Rockall Trough (Stoker 1997; Egerton 1998). The occurrence of significant Oligo-Miocene, basinal, sediment-drift deposits in the Rockall Trough (Stoker *et al.* In press) probably attests to major erosion of the flanking shelves.

- **Early Palaeogene record** – The Palaeogene – Paleocene/Eocene – sequence can be readily correlated with equivalent strata throughout the Rockall Trough (Stoker 1997; Stoker *et al.* In press). The indications of slumping within the section recovered in borehole 16/28-sb01 support regional evidence for mass failure reported elsewhere within the Palaeogene section, on both flanks of the Trough. The occurrence of volcaniclastic rocks in borehole 11/20-sb01 is not unexpected given the widespread extent of volcanics in the Hebrides/Malin shelf region.

- **Cretaceous stratigraphy (1)** – The Cretaceous sections recovered in boreholes 16/28-sb01, 83/20-sb01 and 83/24-sb02 show remarkable correlation, and a preliminary threefold, unconformity-bounded, subdivision is here proposed:
  - Campanian-Maastrichtian *marls.*
  - Cenomanian-Campanian *greensands.*
  - Early to 'mid'-Cretaceous *'brownsands'.*

- **Cretaceous stratigraphy (2)** – It should be noted that the term *'brownsands'* is here used informally to distinguish those sandstones dominated by green glauconite (greensands) from those which have common brown glauconite.

- **Cretaceous stratigraphy (3)** – The seismic-stratigraphic expression of this threefold subdivision is best developed at borehole 83/20-sb01 (Fig. 11), and is easily extended to boreholes 83/24-sb01 & 02 (Figs 15 & 16). However, it is important to note that the Cretaceous section in borehole 16/28-sb01 and the Maastrichtian section in borehole 83/24-sb01 are beyond the limit of seismic resolution, even on the high-resolution seismic profiles. Consequently, this serves as a cautionary reminder of the limits of seismic interpretation of the lower-resolution commercial seismic data.

- **Cretaceous tectonics** – The intra-Cretaceous unconformities may provide the basis upon which to develop tectonic models, with respect to compressive events for the north and west Porcupine Margin. At this stage, two intraformational breaks are provisionally distinguished and tentatively correlated to North Sea compressional pulses, the latter taken from Oakman & Partington (1998):
  - Intra-Cenomanian – which may be linked to the North Sea early Turonian event.
  - Intra-Campanian – which may be linked to the Campanian/Maastrichtian boundary event in the North Sea.

- **The 'Main Unconformity'** – The 'main unconformity' depicted in Fig. 17 represents the target horizon (the main objective) at each site. On the original site prognosis this horizon was interpreted as the 'base Tertiary unconformity'; however, the drilling results have shown conclusively that this unconformity represents a Mesozoic surface separating Cretaceous and Upper Jurassic strata. One consequence of this concerns the stratigraphic context of the Cretaceous section in borehole 16/28-sb01 from the

northern slope of Porcupine Bank. Correlation of this borehole with the sections in boreholes 83/20-sb01 and 83/24-sb02, from the western slope of Porcupine Bank, implies that the Cretaceous deposits in 16/28-sb01 must overlie the main unconformity, if the unconformity is the same one at the two locations. Until the age of the basalt (intrusive or extrusive?) recovered at the base of 16/28-sb01 is proved, together with its relationship to the overlying Cretaceous sediments, it remains uncertain whether the main unconformity was penetrated at this site. It remains a possibility that the basalt represents the unconformity.

- **Upper Jurassic** – Boreholes 83/20-sb01 and 83/24-sb02 proved Upper Jurassic strata, and recovered a variety of lithologies, both clastic and carbonate. Interestingly, the section penetrated by borehole 83/24-sb02 proved a strongly cataclasised succession, albeit the deformation as observed in the cores is commonly restricted to zones of intense shattering. Essentially, well-bedded strata lose their cohesion and fabric over short intervals and are replaced by intensely shattered microbreccias. This is a common feature of faulted strata, and the author has observed similar sharp transitions, over distances from 0.5-1.0m, in major fault zones, such as the Great Glen fault zone (Stoker 1983). The structure of the recovered Jurassic section is consistent with the indications of faulting observed on the seismic profiles (Figs 12 & 15).

- **Reworking** – The Upper Jurassic section in borehole 83/24-sb02 contains reworked Upper Carboniferous spores which may provide useful provenance information.

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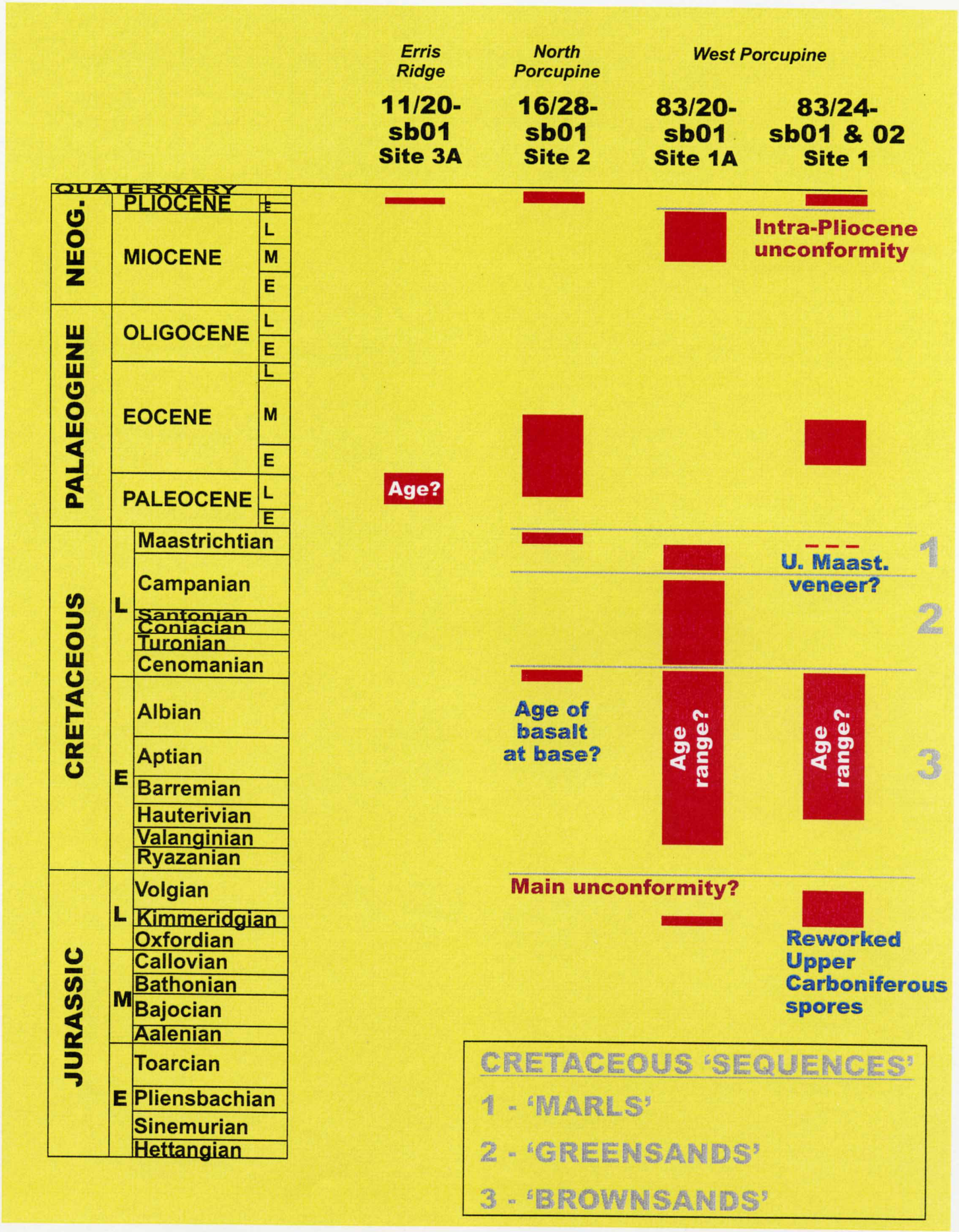


Fig. 17 Stratigraphic-range chart showing correlation between boreholes

ENCLOSURE 1

Composite log of borehole 11/20-sb01

British Geological Survey

PIPCo RSG

LOG OF BOREHOLE: 11/20-sb01

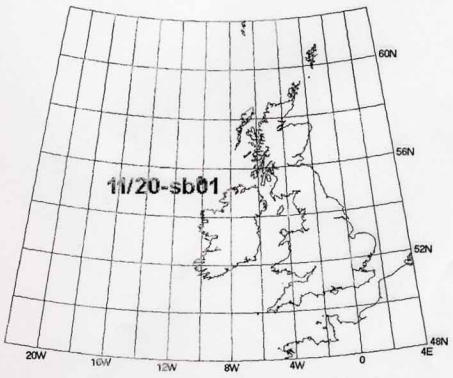
BH No. 11/20-sb01

APPROXIMATE POSITION:	Erris Ridge		
LATITUDE:	55 25' 9.125"N	TOTAL DEPTH:	20.80m
LONGITUDE:	10 01' 14.667"W	WATER DEPTH:	1092.15m
NAVIGATION:	DGPS	VESSEL:	BUCENTAUR
MAP AREA:	Irish Rockall Trough	STATION KEEPING:	DP
LICENCE BLOCK:	11/20	DATES OF DRILLING:	7th-8th July 1999
PIP PLAN NO:	3A	GEOLOGISTS:	M.Stoker, D.Tappin, J.Jacovides

COMMENTS:

Pliocene mud passes at 8.0m bsb into a Tertiary (?Palaeogene) lithic/crystal tuff in which the hole terminated. The tuff is interpreted as deposited in a shallow water environment on the basis of its restricted faunal assemblage and lithologic character. It is probable that the hole penetrated a fault or fissure.

The borehole was drilled in deteriorating weather conditions. Poor recovery in the Pliocene is attributed to the spud-in and its very soft nature. The unexpectedly thin, soft sediment cover at shallow depth reduced the stability of the drill string as the drill collars were not buried before extra bit weight was required. As the heave on the vessel increased this instability became more marked.



Scale 1:50 **Interpretation 24th September 1999**

LITHOLOGICAL KEY

Mudstone; Conglomerate; Tuff; Limestone; Shell; Calcareous

TS = Thin section MPal = Micropalaeontology

SYSTEM	SERIES	STAGE	CORE RECOVERED	INTERPRETED LITHOLOGY	Depth in metres below sea bed	DESCRIPTIONS	COMMENTS SUBSAMPLES
NEOGENE	Pliocene	Piacenzian			0	NB. No recovery to 7.22m.	
	Undiff.					Mud. Dark grey (5Y to 2.5Y4/1) soft to firm, sticky, massive, with very thin sandy laminae and knots, and black sulphide knots, bioturbated. Gravel. Pebbles of dark grey siltstone, pebbles/cobbles of tuff, and quartzose sandstone/quartzite.	7.66 M'Pal Late Pliocene. Low diversity fauna with N. atlantica
PALAEOGENE	Undifferentiated					Tuff. Lithic to crystal, with rare bivalve shells and forams. Olive (5Y4/3). The lithic clasts are up to 10mm and mainly devitrified, vesicular glass with vesicles both infilled with ?zeolites and empty. Crystals are secondary and comprise glass shards and altered olivines and plagioclase. There are clasts of pale grey clay with a steel blue unidentified mineral. Carbonate veins are common.	8.18 TS/M'Pal Sparse ?Palaeogene planktic forams in limestones
						Tuff as above with a carbonate ?vein, brown (7.5YR5/4). Hard and well cemented, with benthic and planktic forams and ?ash grains. Clasts of white carbonate.	9.45 TS/M'PAL As for 8.18
					10	Tuff as above.	10.21 TS/M'PAL Sparse faunas ?Palaeogene age 10.25 TS/M'Pal a/a 10.50 TS/M'PAL a/a
						Tuff. Yellowish red (5YR5/6). Very similar to the olive tuff above but is heavily oxidised. No carbonate veins. Very rare forams and bivalves. Common dark grey basalt clasts. Vesicular ash/devitrified glass clasts are up to 20/30mm with vesicles infilled with zeolite, and glass mainly altered to clay (?palagonite). Variable matrix, some sections are mainly clasts others are matrix supported with the matrix ?zeolite. One bivalve of 40mm.	11.09 TS/M'PAL a/a 11.98 TS/M'PAL a/a
					15		13.50 TS/M'PAL a/a 13.78 TS/M'PAL Sparse ?Palaeogene faunas 14.36 TS/M'PAL Sparse ?Palaeogene faunas
						Tuff. Variagated, yellowish-red (5YR5/8) to yellowish-brown (10YR5/4). Clasts are mainly devitrified glass with vesicles, some infilled and some not. Mainly matrix supported with the matrix a milky coloured ?zeolite. No fossils seen. Glass clasts up to 100mm.	16.37 TS/M'PAL a/a
						Tuff. Probably similar to the tuff above, but the core is extensively broken up.	
						Tuffaceous limestone. Grey. Hard and well cemented. With ash altered glass and numerous forams and shell fragments.	18.88 TS/M'Pal Tertiary, planktics and benthics 18.18 M'PAL
					20	Contact between tuff and limestone as seen previously above 10m. Tuff. Commonly strong brown (7.5Y5/6). Generally as above, hard and comprising altered glass and ?zeolites in clast and matrix supported relationship. Limestone is yellowish-brown (10YR5/4), hard, micritic and with numerous forams and shell fragments.	Rare Lenticulina spp., Textularia sp., fish teeth and bryozoa
						Total Depth 20.80m	

ENCLOSURE 3

Composite log of borehole 83/20-sb01

British Geological Survey

PIPCo RSG

LOG OF BOREHOLE: 83/20-sb01

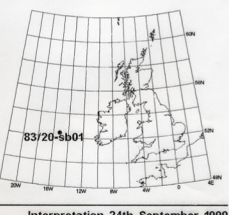
BH No. 83/20-sb01

APPROXIMATE POSITION:	Western Slope of Porcupine Bank		
LATITUDE:	52 26' 38.990"N	TOTAL DEPTH:	177.4m
LONGITUDE:	15 06' 53.504"W	WATER DEPTH:	1045m
NAVIGATION:	DGPS	VESSEL:	MV BUCENTAUR
MAP AREA:	Irish Rockall Trough	STATION KEEPING:	DP
LICENCE BLOCK:	83/20	DATES OF DRILLING:	15th-18th July 1999
PIP PLAN NO:	1A	GEOLOGISTS:	M Stoker, D Tappin, J Jacovides

COMMENTS:

The boundary between the Cenozoic (Neogene) and Upper Cretaceous was penetrated in the interval between 67.0 and 86.6m (see note on log). The Cretaceous section extends down to 169.7m, and may be punctuated by minor unconformities at about 103.29m and 131.28m, which possibly calibrate, respectively, with unconformity surfaces seen on the sparker record at about 125 and 155msecs TWTT. The base of the Cretaceous is estimated to occur at about 169.7m, about 185msecs TWTT, below which coral-rich limestones and interbedded sandstones and mudstones of Late Jurassic age were proved. The hole was terminated at 177.4m.

The borehole was drilled in generally good weather conditions apart from one interval corresponding to 130-145 metres downhole where the weather was very bad and drilling had to virtually cease for a while. The top hole section was open holed until it was realised that the pre-Tertiary unconformity had been reached earlier than predicted. Thereafter coring was attempted with retrieval of the wireline corebarrel at approximately 5m intervals. T.D. was reached after penetrating the final unconformity seen on the high resolution seismic and the original target unconformity. At this point little penetration was being made as the bit had run its useful life.



Scale 1:100

Interpretation 24th September 1999

LITHOLOGICAL KEY

Mudstone/claystone; Siltstone; Sandstone; Limestone; Marl; Clay gravel; Calcareous; Arenaceous; Argillaceous; Glauconitic; Shell

MPAL=Micropalaeontology TS=Thin Section

SYSTEM	SERIES	STAGE	CORE RECOVERED	INTERPRETED LITHOLOGY	Depth in metres below sea bed	DESCRIPTIONS	COMMENTS SUBSAMPLES
NEOGENE TO QUATERNARY					0	No recovery to 33.7	
					30	Clay. Grading between light greenish-grey (5GY7/1) and greenish-grey (5GY6/1). Soft and sticky, sandy with abundant (30%) mainly planktic forams and common silt grade glauconite. Very uniform sediment.	35.75 MPAL Pliocene 37.0 MPAL Mid- to late Miocene
NEOGENE	Miocene	?Serravallian to lMessinian			60	Silty clay, as above. Light greenish-grey (5GY7/1) to greenish-grey (10Y6/1). Variably calcareous. Variably soft to firm/stiff, with the harder bands 10-15cm thick and bioturbated as evidenced by burrow mottling. Forams and glauconite throughout, but may be concentrated in silty and very fine sandy 1-3cm beds that are light olive grey (5Y6/2) to olive grey (5Y5/2). Sporadic organic black spots and streaks. At 66.59m a sharp colour change and reworking of underlying strata exemplified by rip-up clasts. The underlying beds are Mudclay. Light olive grey (5Y6/2) grading to dark greyish-brown (2.5Y4/2). Silty to very fine sandy, firm, bioturbated, with extensive burrow mottling by Zoophycos and silt-filled chondrites. Sporadic black subhde streals and specks, very calcareous, common disseminated glauconite abundant forams and scattered lithics.	66.52 MPAL Mid- to late Miocene 66.81 MPAL Mid- to late Miocene
					70	NOTE ON DEPTH OF NEOGENE/CRETACEOUS UNCONFORMITY Due to the long core run between 67.0 and 86.6, the exact depth of the unconformity between the Neogene and Cretaceous is uncertain. However there was a drilling break at 72m, that correlates with an unconformity surface on the sparker record at 90msec (TWT), assuming a velocity of 1600m/sec. Thus, the actual depth of the unconformity is most probably at about 72m below seabed.	
					80	The cored interval between 83.29 and 86.95m is interpreted as misplaced down-section, see note above. Silty mud and clay as previously. Light greenish-grey (10Y7/1) to greenish grey (5Y6/1). Soft to firm/stiff, perhaps more consistently silter to very fine sandier, than previously. Burrow mottled, calcareous, forams and scattered glauconite. MAJOR UNCONFORMITY. Very sharp contact marked by a cobble - ?flag gravel - at the top. Marl, light grey (2.5Y7/2) to pale yellow (2.5Y7/3) but with darker and paler (white) banding and streak. Soft to firm, massive, weakly calcareous, forams, scattered lithics and quartz. Cobble or nodule at 86.35m is micritic limestone.	86.7 MPAL Mid Miocene 86.72 TS 86.22 MPAL Mid- to late Miocene 86.59 TS 86.6 MPAL Maastrichtian
		Upper Campanian to Maastrichtain			90	Marl, as above but colour change to very pale brown (10YR8/2) to pale yellow (2.5Y8/4). Common black patches and bands up to 1cm and rare 2cm brownish yellow (10YR6/8) bands. Calcareous, predominantly massive. Black patches have harder very firm centres. These may be ?nodule structures and are prevalent in core sampled between 95.81 and 97.55, present, bt less abundant in rest of sampled core.	
					100		100 MPAL Maastrichtian
					110	Marl. Pinkish-white (7.5YR8/2) to very pale brown (10YR8/5). Soft to firm, massive, burrow mottled, very sporadic dissemnated lithic grains, possibly including glauconite. ?UNCONFORMITY. Top of weathered sandstone. Dark brown. ?Ferruginous A sequence of interbedded soft and hard, well cemented sandstones, with only the latter recovered. These are generally dark greenish grey (10GY4/1), fine to coarse	102.87 MPAL Maastrichtian to Late Campanian 103.0 MPAL Late Cretaceous (undifferentiated)
		Undifferentiated			120	Interbeds of hard and soft sandstone. The former is dark greenish-grey (10GY4/1), well cemented with calcite. Clear quartz, fine grade, muddy. Common green glauconite of medium grade. The sand is fine to very fine and grades to a sandy mud at the base. There is clear quartz, sub-angular to sub-round, with medium-fine green glauconite (that is brown at the base) and rare to common mica. It is calcareous. There are forams present.	117.78 MPAL Early to mid-Turonian 118 MPAL Early to mid-Turonian
		Turonian			130		122.88 MPAL ?Turonian 127.86 MPAL Late Cenomanian to early to mid-Turonian
		Cenom-anian			130	?UNCONFORMITY Below is: Limestone. Olive yellow (2.5Y6/6). Moderate hard, recrystallised, common brown glauconite, and less common quartz grains and shell debris. Lithics. Micrite matrix. Sandstone. Yellowish brown (10YR5/4). Hard, variable carbonate cement from hard to friable. Coarse frosted grains, well sorted, sub-round to round with subsidiary clear angular quartz. Common very coarse brown glauconite. Shell debris. Interbeds of friable and indurated sandstone with only the latter sampled. Sand is yellow-brown (10YR5/4) to pale brown (10YR6/3) frosted, fine to coarse, to very coarse to granule grade, poorly sorted, sub- to well round. Subsidiary subangular clear quartz. Common brown glauconite, abundant bivalves 1-5cm and fragments and ?coral. Lithics. Carbonate cement is locally recrystallised and with a vuggy style infill. Mica. Matrix support. Internal exposure surfaces. Massive.	131.11 MPAL Mid Cenomanian 131.28 MPAL Late Cretaceous, ?Cenomanian 131.4 MPAL Late Cretaceous, ?Cenomanian 133.0 MPAL Indeterminate, barren sample
		?Late Cretaceous			140		138.2 MPAL Indeterminate, sparse non-age diagnostic microflora
		Undifferentiated			140	Limestone. Grey (5Y5/1). Fine grained, sugary, recrystallised texture. Slightly sandy with common green glauconite, fine to medium grade. ?Dark brown mineral, coarse grade, well rounded and lath-like. Shell fragments range from fine/medium to 45cm. Strongly ribbed bivalves. Massive.	142.0 MPAL Mid Cretaceous, Cenomanian to Albian
		Albian to Cenomanian			150	Interbeds of friable and indurated sand as described above. The latter is pale brown (10YR6/3) to brown (10YR5/3) clear and frosted quartz, variably fine-medium and fine-very coarse grade, poorly sorted, subsidiary lithics and brown glauconite. Large white micas. Common shell fragments 2-5cm. Carbonate cement, this and shell fragments partly recrystallised and infilling vugs. Matrix supported.	148.8 MPAL Indeterminate, barren sample
					150		150.9 MPAL Indeterminate, barren sample
		Uncdifferentiated, ?no older than Early Cretaceous			160	Unconsolidated sand. Light olive brown (2.5Y3/4). Represents the friable sand not sampled before. Mainly frosted grains, very coarse, well sorted, sub-round to round, some are sub-angular. Rare lithic grains. Common sandy limestone fragments, that are either the matrix of the sand or limestone stringers. These have fine-medium quartz. Common shell fragments. Rare ?ferruginous grains. Muddy sand. Light olive brown (2.5Y5/4). Soft, fine to very coarse yellow-orange frosted grains, poorly sorted. Shell fragments. Limestone fragments. Interbeds of friable and indurated sandstone with only the latter recovered. This is dark grey (5Y4/1) to dark greyish-brown (2.5Y4/2) , carbonate cement, hard, weakly calcareous with clear quartz fine to (rarely) very coarse, sub-angular to sub-round, moderate to poor sorting. Common brown glauconite, carbonaceous fragments and bivalve shells and fragments and hexagonal cross-sectioned columnar beast? as hash and throughout the core. Trace mica.	156.5 MPAL Mesozoic (undifferentiated) 161.23 MPAL ?No older than Early Cretaceous
					170	Again the friable/indurated sandstone interbeds. These appear to grade down from the dark grey rocks above to brown (10YR4/3 to 7.5YR4/3) calcareous sandstone. The sandstones consist of clear quartz, medium to coarse, sub-round, poorly sorted, carbonaceous, abundant brown coarse grade glauconite, and with common disarticulated bivalve shells and ?corals. The matrix is hard carbonate, recrystallised. The rock grades in parts to a sandy limestone.	169.5 MPAL Indeterminate, barren sample
JURASSIC	UPPER	Upper Kimmeridgian			170	Limestone. Grey (5Y6/1 to 2.5Y6/1). Fossiliferous, biohermal, much broken coral debris, some disarticulated bivalves. A sugary recrystallised texture, though some micritic/clay present along solution cracks. Locally vuggy with partial infill with calcite. Pyrite and ?ash. Becomes arenaceous at top, with medium-very coarse lithics and soft, white ?ash fragments. Shelly. Mudstone to claystone, colour banded grey (7.5Y6/1) to dark grey (10YR6/1). Massive, but becoming thinly laminated towards the base. Rare silty/sandy laminae with pyrite, weakly calcareous. Firm to stiff. No fauna. Sandstone. Grey (5Y5/1). Very fine to fine grained, quartzose, well sorted. Rare glauconite, common dark mineral ?carbonaceous forming within laminae that are 1mm. Rare lithics. Well sorted. Calcareous. Pyrite replacing carbonaceous material. Carbonate cement. ?Cross-bedding.	169.7 MPAL Indeterminate, barren sample 169.8 MPAL Indeterminate, barren sample 171.7 MPAL ?Jurassic 171.89 MPAL ?Jurassic 172.0 MPAL Indeterminate, barren sample
					180	Mudstone. ?Cavings. Sandstone, as above. Grey. Well laminated, cross-bedded with possible lenticular bedding. Common organic flecks being replaced by pyrite. Rare coarse sandy and pebbly horizon. Poorly sorted. Mudstone. Grey (5Y5/1). Sandy. Hard, well cemented, very calcareous, horizontal lamination with colour banding and with grain tne and variable concentration of carbonaceous material that is being replaced to pyrite. Carbonaceous wisps and laths extend along the laminae. Mudstone, slightly sandy with clear quartz grains and very cacareous. Soft. Pyritic. Carbonaceous. Hammer sample.	175.28 MPAL Indeterminate, barren sample 176.48 MPAL Barren sample 176.48 MPAL Indeterminate, barren sample 176.78 MPAL Indeterminate, barren sample 177.25 MPAL Late Jurassic (Late Kimmeridgian) 177.30 MPAL Indeterminate, barren sample 177.4 MPAL Indeterminate, barren sample
			Total Depth 177.4m		190		

ENCLOSURE 4

Composite log of borehole 83/24-sb01

British Geological Survey

PIPCo RSG

LOG OF BOREHOLE: 83/24-sb01

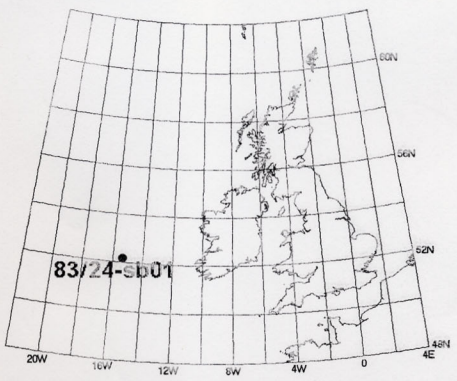
BH No. 83/24-sb01

APPROXIMATE POSITION:	Western slope of Porcupine Bank		
LATITUDE:	52 14' 43.697"N	TOTAL DEPTH:	30.80m
LONGITUDE:	15 17' 33.671"W	WATER DEPTH:	1571m
NAVIGATION:	DGPS	VESSEL:	MV Bucentaur
MAP AREA:	Irish Rockall Trough	STATION KEEPING:	DP
LICENCE BLOCK:	83/24	DATES OF DRILLING:	19th-20th July 1999
PIP PLAN NO:	1	GEOLOGISTS:	M.Stoker, D.Tappin, J.Jacovides

COMMENTS:

19.45 metres of upper Pliocene to Pleistocene calcareous muds and foram rich sands were penetrated unconformably overlying lower Eocene cherty, micritic limestones and calcareous muds. The unconformity correlates with a seismic break on the sparker record at 20msecs (TWTT).

The borehole was drilled down to 30.8 metres until deteriorating weather conditions forced abandonment.



Scale 1:100 **Interpretation 24th September 1999**

LITHOLOGICAL KEY

Mudstone/claystone; Siltstone; Sandstone; Limestone; Marl; Lag gravel; Calcareous; Arenaceous; Argillaceous; Glauconitic; Shell

MPAL=Micropalaeontology TS=Thin Section

SYSTEM	SERIES	STAGE	CORE RECOVD	INTERPRED LITHOLY	Depth ines below bed	DESCRIPTIONS	COMMENTS
NEOGENE-QUATERNARY	Upper Pliocene to Pleistocene	Piacenzian and younger			0	No recovery to 9.25m.	
					9.25	Silty clay. Light grey (5Y7/2) with intermixed light yellowish-brown (2.5Y6/3) lumps of clay, probably due to mixing during drilling. Very soft, foram rich, scattered lithics, common granules to small pebbles. Calcareous.	9.3 MPAL Late Pliocene to Pleistocene
					9.70	Silty clay. White (5Y8/1) to light grey (2.5Y7/2). Very soft, foram rich, scattered silt-grade lithics, fewer obvious granules or pebbles compared to above. Calcareous.	9.7 MPAL Late Pliocene to Pleistocene
					10.00	Sandy silty clay/mud. Olive grey (5Y4/2) grading to dark grey olive (5Y3/2) at the base. Soft, very poorly sorted, common silt to coarse sand grade lithics and quartz, occasional granules and pebbles, forams. Firmer mud lumps/clasts at base of same compostition as the soft matrix. Calcareous.	10.0 MPAL Late Pliocene to Pleistocene
					19.00	Foram rich sand. Pale yellow (2.5Y7/3) to light yellowish brown 2.5Y6/3). Fine grained, well sorted, about 90% forams and scattered minor lithics and quartz.	19.0 MPAL Late Pliocene to Pleistocene
					19.19	Silty clay. Very soft, common granules and small pebbles scattered throughout.	19.19 MPAL Late Pliocene to Pleistocene
					19.38	Clay. Light yellowish brown (2.5Y6/3) very soft, calcareous. Sharp contact with underlying sand.	19.38 MPAL Late Pliocene
					19.44	Foram rich sand. Light grey (2.5Y7/2) to pale yellow (2.5Y7/3) similar to above, but slightly coarser, fine-medium grained, well sorted, calcareous.	
					19.45	UNCONFORMITY. 1cm pebble layer, between 19.44 and 19.45 metres. Concentration of lithic granules and small pebbles. Sharp contact with underlying muds.	
PALAEOGENE	Middle Eocene	Lutetian			19.50	Sandy calcareous mud. Pale yellow (2.5Y8/4). Soft, abundant forams, common sponge spicules, rare scattered lithics. Becomes an indurated and friable micritic limestone, light yellowish brown (2.5Y7/3-7/4), with a cherty nodule at 19.7m and a distinct cherty band between 19.90 and 19.97m. Massive throughout.	19.50 MPAL Earliest mid-Eocene
					20.00		20.0 MPAL Earliest mid-Eocene
	Lower Eocene	Ypresian			25.00	Micritic limestone. Pale yellow (2.5Y7/3 to 7/4) soft and easily broken to hard and indurated. Foram rich, common sponge spicules. Predominantly massive but with traces of thin lamination shown as subtle colour banding. Carbonate is locally being replaced by darker coloured chert between 27.0-27.26. Limestone is fractured with local infills of dendritic manganese.	27.5 MPAL Early Eocene
					30.65	Calcareous mud. Pale yellow (2.5Y7/3 to 7/4). Same as above only not lithified. Soft, massive, foram rich, common sponge spicules, partial chertification between 30.55 and 30.65.	30.8 MPAL Early Eocene
					30.80	Total Depth 30.80m	

ENCLOSURE 5

Composite log of borehole 83/24-sb02

British Geological Survey

PIPCo RSG

LOG OF BOREHOLE: 83/24-sb02

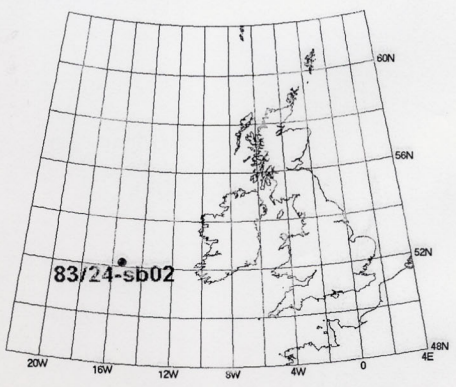
BH No. 83/24-sb02

APPROXIMATE POSITION:	Western slope of Porcupine Bank		
LATITUDE:	52 14' 44.710" N	TOTAL DEPTH:	71.49m
LONGITUDE:	15 17' 33.262" W	WATER DEPTH:	1566m
NAVIGATION:	DGPS	VESSEL:	MV Bucentaur
MAP AREA:	Irish Rockall Trough	STATION KEEPING:	DP
LICENCE BLOCK:	83/24	DATES OF DRILLING:	22nd-24th July 1999
PIP PLAN NO:	1	GEOLOGISTS:	M.Stoker, D.Tappin, J.Jacovides

COMMENTS:

19.96m of Plio-Pleistocene sediments were penetrated unconformable on lower to middle Eocene limestones. The Eocene rests unconformably on Upper Cretaceous sandstones at 38.13m. At about 63.25m, the Cretaceous strata overlie red clays and varicoloured mudstones which are highly fractured and of late Jurassic age. These unconformities calibrate, respectively, with seismic reflectors at 15-20ms (TWTT), 45-50ms, and 65-70ms.

The borehole was drilled adjacent to 83/24-sb01 which was abandoned due to weather. As much open hole as possible was made until the T.D. of the previous borehole was reached. From there on the hole was cored for at least 50% of the time, until the next unconformity was reached at 63.25m. Thereafter as much core as possible was collected. The borehole terminated in fractured rocks or a fracture zone which proved extremely difficult to core and caused bit blocking which, in turn required a wireline trip of the core barrel to clear.



Scale 1:100 **Interpretation 24th September 1999**

LITHOLOGICAL KEY

Clay/mud/mudstone; Siltstone; Sand; Limestone; MPAL = Micropalaeontology

Cherty; Calcareous; Arenaceous; Pebbly

SYSTEM	SERIES	STAGE	Depth in metres below sea bed	DESCRIPTIONS	COMMENTS SUBSAMPLES
NEOGENE-QUATERNARY	Upper Pliocene-Pleistocene	Piacenzian and younger	0	No recovery to 18.79m.	
			5		
			10		
			15		
			20	Interbedded clays, muds, sandy muds and sporadic thin sands, very soft to soft, bioturbated, scattered lithic pebbles, weakly to strongly calcareous. Varicoloured: light olive grey (5Y6/2), lighht grey (5Y7/1), light olive brown (2.5Y5/3), white (5Y8/1) and olive grey (5Y5/2). These cidepict colour banding, with beds ranging from 1 to 30cm thick. Sandy intervals are cclean, foram rich, fine grained with scattered lithics.	19.93 MPAL Late Pliocene
				UNCONFORMITY. Very sharp. Top of micritic limestone is broken up/rubbly.	20.08 MPAL Earliest mid-Eocene
				Limestone, pale yellow (2.5Y8/3-8/4), micritic, soft to hard and indurated but easily broken, becoming clcherty at 23.4m, sporadic silt-grade lithics, massive, calcareous.	
					23.32 MPAL Earliest mid-Eocene
PALAEOGENE	Lower Eocene	Ypresian	30	Limestone, pale yellow (2.5Y8/3), micritic, soft to hard and indurated but easily broken, massive, strongly calcareous, scattered silt-grade lithics, chertification - bands and nodules - common between 30.44 and 30.57m.	30.75 MPAL Early Eocene
			35		
				Limestone, pale yellow (2.5Y8/3), hard to firm, silty, massive, weakly calcareous as a fine-grained micritic mud.	38.1 MPAL Early Eocene
				UNCONFORMITY.	38.2 MPAL ?Late Cretaceous (?early Santonian-late Cenomanian)
				Sandstone, brown (7.5YR4/3-4/4) to strong brown (7.5YR5/6), hard and indurated, well cemented by carbonate, very poorly sorted, dominated by brown glauconite up to very coarse sand grade, coarse grade shell debris, and medium to coarse grained, angular to subangular, quartz - a mix of clear and frosted grains. Shell debris also includes whole bivalves up to 5cm, including Inoceramus prisms.	38.82 MPAL Barren
			40		40.6 MPAL Barren
			45	Sandstone, reddish yellow (7.5YR6/6) to strong brown (7.5YR5/6), hard and indurated, very poorly sorted, silt to very coarse sand grade with scattered granule-grade clasts, and abundant shells (bivalves) and shell debris to 5cm. Calcareous, carbonate cement, sand grains commonly matrix supported. Common dissolution holes - removal of carbonate cement and shell debris - in which sand grains bear a black coating. Abundant quartz grains are a mix of clear and frosted types, subang-subrded.	45.51 MPAL ?Mid-Cretaceous
CRETACEOUS	"Mid" to upper	?Albian to Cenomanian	50		
				NOTE ON SIGNIFICANCE OF CAVED LATE MAASTRICHTIAN FORMS IN MPAL SAMPLE FROM 58.7M	
				Moderately rich and well preserved late Maastrichtian microfaunas were observed in the cavings sample at 58.7m. These faunas were not previously observed/sampled in this borehole but must originate from the unconformable contact somewhere between 38.10 and 38.13m. Their presence signifies that the Palaeogene sequence must rest unconformably on a very thin upper Maastrichtian section, which itself rests unconformably on older Upper Cretaceous sediments at 38.13m.	
			55		
				Sandy cavings on crudely-bedded sandstones and pebbly sandstones, yellowish brown (10YR5/4) to light yellowish brown (10YR6/4), hard and indurated. Moderate to poorly sorted, silt to very coarse sand grade, with common granules and well rounded pebbles to 3cm. Quartz (clear and frosted), lithics, shells (bivalves) and shell debris predominate, subordinate brown glauconite. Calcareous, carbonate cemented. Calcite and dendritic manganese in voids.	58.7 MPAL See note on log.
			60		58.9 MPAL Barren
				UNCONFORMITY.	63.3 MPAL ? Late Jurassic
				Clay, red (2.5YR5/8), soft, calcareous, very smooth and buttery, homogenous.	
JURASSIC	Upper	Kimmeridgian to Volgian (lower Portlandian)	65		
				Clay, red (2.5YR5/8) to light yellowish brown (2.5YR5/8), similar to above but non-calcareous, micaceous, soft to firm, slightly silty, massive, homogenous.	67.8 MPAL ? Late Jurassic
				Mudstone/claystone, very stiff to hard, brittle/fissile, reddish brown (5YR5/3) to greenish grey(10Y5/1), massive, non-calcareous, micaceous; with interbedded laminae and very thin to thin beds and lenses of silty to very fine-grained sandstone, well sorted, quartzose. Sharp bed contacts. Core is heavily disrupted by post-depositional cataclasis: abundant microfracturing with intense brecciation has locally destroyed the original fabric of the rock.	69.21 MPAL Barren
			70		70.82 MPAL Barren
					71.0 MPAL Barren
				Interbedded siltstone and mudstone. Siltstone is hard and indurated, grey (5Y5/1), quartzose, micaceous, massive, non-calcareous; mudstone is hard but easily broken, reddish grey (10YR5/1) to dark reddish grey (10YR4/1) with sporadic light greenish grey reduction spots and patches, non-calcareous. Core is cut by jointing.	71.04 MPAL Barren
				Total Depth 71.49m	71.23 MPAL Barren (Forams)
					71.23 MPAL Late Jurassic (palynology)
				Silty mudstone/mudstone, hard and indurated, brittle/fissile, very thin to medium laminations, with laminae depicted by colour banding which varies from grey (5Y5/1), grey (N5/), dark grey (N4/), and greenish grey (5G6/1) to weak red (2.5YR5/2). Sharp laminae contacts. Micromicaceous, non-calcareous. Core becomes increasingly fractured towards base, and displays in situ brecciation, and is easily broken.	71.49 MPAL Age indeterminate
			75		

APPENDIX 1

Shipboard summary log descriptions

APPENDIX 1: SHIPBOARD SUMMARY LOG DESCRIPTIONS

The following summary descriptions represent lithological interpretations made onboard the ship as the cored intervals were recovered. These descriptions formed the basis of the daily reports to the oil company consortium of the Rockall Studies Group (RSG). For the purpose of this report, the format of the descriptions has been standardised, although none of them has been modified from the original datasheets. The only changes that have been incorporated relate to any modified biostratigraphic interpretations that have arisen subsequent to the end of the cruise; this is intended to avoid any unnecessary confusion. These lithological descriptions also formed the basis of the summary text which appears on the composite logs presented in Enclosures 1-5, and which were also transmitted to the RSG upon completion of each borehole. It is probable that some of these descriptions may be refined and/or revised during post-cruise study of the boreholes.

Shipboard Geological Summary of Borehole 11/20 – sb01 (Site 3A)

Run: 0-8.0m
No recovery to 7.22m

7.22 – 7.76m
Mud: dark grey (5Y to 2.5Y4/1), soft to firm, sticky, massive, with very thin sandy laminae and knots, and black sulphide knots, bioturbated.
7.66. Dated as early Pliocene

7.76 – 8.00m
Gravel: pebbles of dark grey siltstone, pebbles/cobbles of coarse lithic pebbly sandstone, and quartzose sandstone/quartzite.

Runs: 8.0-9.5m & 9.5-10.5m
8.00 to 10.5m
Tuff: lithic to crystal, with rare bivalve shells and forams. Olive (5Y4/3) The lithic clasts are up to 10mm and mainly devitrified vesicular glass with vesicles both infilled with ?zeolites and empty. Crystals are secondary and comprise glass shards and altered olivines and plagioclase. There are clasts of pale grey clay with a steel-blue mineral. Carbonate veins common. Between 9.24 and 10.07m there is a carbonate ?vein, brown (7.5YR5/4). Hard and well cemented, with benthic and planktonic forams and ?ash grains. Clasts of white carbonate.
9.45. Dated as ?Palaeogene
10.21. a/a
10.5. a/a

Run: 10.5-13.5m
10.67 – 13.5m
Tuff: yellowish red (5YR5/8). Very similar to the olive tuff above but is oxidised. No carbonate veins. Very rare forams and bivalves. Common dark grey basalt clasts. Vesicular ash/ devitrified glass clasts are up to 20-30mm with vesicles infilled with zeolite and the glass mainly altered to clay (?palagonite). Variable matrix, some sections are mainly clasts others matrix supported with the matrix ?zeolite. One bivalve of 40mm.
11.09. ?Sparse ?Palaeogene faunas a/a
11.98. a/a
13.5. a/a

Run: 13.5-16.5m
13.6 – 16.5m
Tuff: variegated yellowish red (5YR5/8) to yellowish-brown (10YR5/4) clasts are mainly devitrified glass with vesicles, some infilled and some not. Mainly clast supported with the matrix a milky coloured ?zeolite. No fossils seen. Glass clasts up to 100mm.
13.78. Sparse ?Palaeogene faunas.
14.36. a/a
16.37. a/a

Run:16.5-17.7m
17.0 – 17.7m
Tuff: much as above, zeolite vein at 17.23m

Run: 17.7-19.3m

17.88 – 19.3m

Tuff: broken up between 17.88 and 18.8m. In interval between 18.8 and 19.22m commonly brownish tuff (as above) but also includes a grey tuff in vertical contact with brown tuff, locally separated by a micritic carbonate vein. The grey tuff contains abundant flecks of dark mica?, devitrified glassy matrix, lithic and crystal fragments, forams and shell debris. A micritic limestone occurs at the base of the core (19.22-19.3m), yellowish brown (10YR5/4), grades locally into a microsparite. Some pressure solution veins, sporadic 'clasts' of yellowish brown, soft micritic mud.

19.18. Rare *Lenticulina* spp, *Textularia* sp., fish teeth and bryozoa.

Run:19.3-20.8m TD.

20.7-20.8m

A boundary between a limestone and a tuff – 60% lst / 40% tuff. Limestone is micritic, strong brown (7.5YR5/6), very hard, well cemented, trace forams, weakly calcareous, finely disseminated volcanic debris. Tuff, as before, hard, strong brown (7.5YR4/6), clast/matrix supported volcanic clasts of glass and ash.

Shipboard Geological Summary of Borehole 16/28 – sb01 (Site 2)

Run: 0.0-14.5m
Seabed to 12.78m
No recovery

12.78 – 13.22m
Foram ooze. Light olive brown (2.5Y6/4 to 2.5Y6/4). 95%forams, 5%silt. Massive, strongly calcareous , sporadic lithic pebbles.
12.78. Dated as latest Pliocene-Pleistocene

13.22 to 13.42m
a/a but becoming more muddy and sandy, poorly sorted with increased sand/silt content, including sporadic medium-coarse grained lithic sand grains. Light olive-brown (2.5Y5/4) to olive-brown (2.5Y4/4). Dropstones common.

13.42 to 14.47m
Foram-rich sand, 90-95% forams, fine grained but with sporadic lithic fragments of medium to coarse grain size, moderate to well sorted, varicoloured, brown (2.5Y5/3) to 10YR5/5) yellowish brown (10YR5/4) light olive brown (2.5Y5/3) and white (8/1). With dropstones up to 5.5cm.
13.8. Dated as Late Pliocene-Pleistocene

MAJOR BOUNDARY – Between the Plio-Pleistocene and the Eocene: Sharp contact

14.47 to 14.50m
Mud. Very calcareous soft to hard and locally indurated (? Nodule) massive, greenish grey (6/1 to 5/1). Predominantly forams, with glauconite and sponge spicules.
14.5. Dated as Mid- Eocene.

Run: 14.5-25.0m
24.7 to 25.0m
Mud as above, with (?) nodules to 8cm size.
24.7. Dated as middle Eocene.

Run: 25.0-35.0m
33.08 to 35.0m
Sediments reworked by the coring process. Vessel had to change heading by 90 degrees, drilling stopped and bit blocked for some time on restart. During this run the driller noted two drilling breaks: one at 32.0m where it appeared the drillstring was rotating in cobbles/boulders or some such layer and at 34.0m where a 'harder layer' was encountered.
33.39. This sample revealed mixed mid-Eocene and Plio-Pleistocene species
It should be noted that the middle / lower Eocene boundary must occur between 25.0m and 40.8m; the nature of the boundary remains uncertain.

Run: 35.0-44.0m
40.8 to 44.0m
Mud as described above. Seems to be mainly soft and friable mudstone with 10cm inter-bed of hard mudstone of the same lithology.
44.0. Dated as mid-Eocene.

Run: 44.0-54.0m
52.44-54.0m
Mud/Mudstone as described above. No sponge spicules seen.
53.99. Dated as early Eocene

Run: 54.0-60.8m
60.52-60.8m
Mudstone as described above. Soft to hard and indurated, slightly sandy (very fine-grained) and silty, massive, mottled (?bioturbated) texture. Hard band in upper part of core 10-12cm thick; softer and friable in lower part of core.

Run: 60.8-71.0m
66.21-71.0m
Interbedded siltstones/very fine-grained sandstones, silty mudstones and mudstones, massive, bioturbated (varying from bioturbate texture to burrow mottling), including burrow patterns of ?*Chondrites,* and predominantly hard. As described above, sediments are strongly calcareous and rich in glauconite and foraminifera; some sponge spicules noted in upper part of section.
70.79. Dated as early Eocene.

Run: 71.0-84.0m
79.86-84.0m
Interbedded silty mudstones and siltstones as described above. Predominantly massive but with indications of colour banding in the lower half of the core, primarily attributed to the concentration of glauconite. Distinct fracture noted between 81.8 and 82.2m: subvertical but curved fracture surface; hard, smooth, lustrous, ?glauconite-smeared surface. Colour change at about 83.64m: greenish grey (10Y 6/1) above, greenish grey to olive grey (5Y 5/2) below.
83.92. Dated as early Eocene

Run: 84.0-92.0m
87.49-88m
Fine mudstone to claystone, dark greenish grey (10Y4/1), firm, calcareous, micaceous. Bioturbated ?*Chondrites*. Forams. Massive.

88.0-88.5m
Siltstone. Dark greenish grey (10GY4/1). Firm, quartzose, sandy to fine sand grade, very glauconitic, micaceous, forams. Laminated with concentrations of glauconite.
88.35. Dated as early Eocene

88.5-92.00m
Fine mudstone, as above. Dark greenish grey (10Y4/1). Firm calcareous, micaceous, glauconitic, bioturbated ?*Chondrites*, forams. Variably glauconitic and micaceous. Massive. At the base a 1cm laminae of pale olive (5Y6/3) claystone, soft-firm, homogeneous, calcareous, finely micaceous, sparse glauconite.
92.0. Dated as early Eocene

Run: 92.0-98.0
93.32-98.0m
Mudstone dark greenish grey (10Y4/1). Firm to stiff, homogeneous, massive, bioturbated, weakly calcareous, finely disseminated mica very common and sparse glauconite. Pretty much as before.
98.0. Dated as early Eocene.

Run: 98.0-102.0m
101.63-102.0m
Mudstone/claystone, hard, massive, strongly bioturbated (mainly bioturbate texture), calcareous. Silt fraction includes lithic grains, finely disseminated mica and sparse (?) glauconite. Dark greenish grey (10Y 4/1).
102.0. Dated as early Eocene.

Run: 102.0-110.0m
105.23-110.0m
Mudstone/claystone, dark greenish grey (10Y 4/1), very hard, massive, extensively bioturbated including rare sand/silt-filled burrows of (?)*Chondrites* type. Calcareous. Silt fraction includes lithic grains and finely disseminated mica. Pretty much as before!
109.86. Dated as early Eocene.

Run: 110.0-114.0m
110.14-114.0m
Mudstone/claystone, much as before. Greenish grey (10Y5/1) to dark greenish grey (10Y4/1), occasionally grading to a more greyish brown colouration (2.5Y5/2-4/2). Very hard, massive though with occasional indications of colour banding, including glauconite-rich bands. Extensive bioturbation – bioturbate texture and burrow mottling: ?*Chondrites*, ?*Zoophycos* – and some of burrows are infilled with grey-brown mud and have glauconite reaction rims. Rare sporadic, disseminated, shell fragments. Core is locally fractured (?due to drilling process) with C.45° shear planes.
114.0. Dated as early Eocene.

Run: 114.0-121.0m
116.78-121.0m
Mudstone/claystone. As above, traces of disturbed lamination in the basal metre of the run, identified by colour variation. Most of the core is massive,, some bioturbation. Lithology is firm to hard, weakly calcareous, common mica (micromicaceous) less glauconite, greenish-grey 10Y5/1.
121.0. Dated as early Eocene.

Run: 121.0-127.0m
122.28-127.0m
Mudstone/claystone. Dark greenish grey 10Y4/1. Hard. Massive with colour banding on a cm scale. Micromicaceous, weakly calcareous, ?finely disseminated glauconite. Probably finer grained than the last run. Minor bioturbation (burrow mottling).
126.6. Dated as early Eocene.

Run: 127.0-131.0m
127.35-131.0m
Mudstone/claystone, very hard, very thin to thinly laminated – depicted by subtle colour banding 1-3mm thick – but with distinct burrow mottling, although the degree of

bioturbation is greatly reduced in comparison to previous cores. Dark greenish grey (10Y3/1-4/1) to dark grey (5Y4/1). Calcareous. Silt fraction includes lithic grains to very fine sand grade, some glauconite and mica. Parts of the core have been cut and scoured by the core cutter (in the inner barrel) during the coring process; whilst some of the core has been reworked most of it remains intact.
129.55. Dated as early Eocene.

Run: 131.0-138.0m
134.95-138.0m
Mudstone/claystone (134.95-137.98), much as before, dark greenish grey (10Y4/1), very hard, very thin to thinly laminated, occasionally medium lamination (3-10mm), burrow mottled, some of infills silty in lower part of core. High angle fractures and some scoring of core during coring and retrieval. Sharp contact with underlying siltstones at 137.98m: marked colour change, and contact is slightly irregular possibly due to some bioturbational or erosional reworking. Siltstones (137.98-138.0), greenish grey (5GY6/1-10GY6/1), compact, very calcareous, glauconitic, micaceous, some grains to very fine sand grade, becomes interlaminated with overlying mudstone/claystone in top few millimetres possibly due to reasons already stated for 'nature of contact'.
137.92. Dated as Early Eocene
138.0. Late Paleocene

Run: 138.0-146.0m
143.38-144.1m
Silty mudstone. Greenish-grey (10GY5/1). Hard, moderately cemented, slightly calcareous, glauconitic, micaceous. Bioturbated with cm burrows. Forams. Bedded with a dip of ~40degrees.

144.1-145.1m
Mudstone. Greenish-grey (5GY5/1). Finer grained than above, slightly calcareous, hard, moderately cemented, micaceous, forams, sparse glauconite. Very bioturbated with bedding/lamination at a 20 degree dip. Varicoloured with wisps and streaks due to bioturbation and the colour ranges to greenish grey 10Y5/1, and a streak of greyish-green (5G4/2). At the base a major 40 degree dipping slip face.

145.1-145.35m
Siltstone. Streaky colour around greenish-grey (10GY5/1) very hard, calcareous, bryozoa, glauconite, quartzose, micaceous. Dipping at 20-30 degrees.

145.35-145.95m
Mudstone, as above, but finer grained, softer, laminated. Dipping.
145.66. Dated as Late Paleocene
145.95. Dated as Palaeocene undifferentiated.

MAJOR BREAK TO LATE CRETACEOUS

145.95-146.0m
Siltstone, sandy. Light olive-grey (5Y6/2). Very hard, well cemented, calcareous, common brown glauconite, lithic fragments, forams
146.0. Dated as Late Maastrichtian

Run: 146.0-148.25m TD

147.06-147.24m

Sandstone. Dark yellowish-brown (10Y4/4). Well cemented. Coarse-medium grained, well sorted with calcite cement. Mainly mature sub-round to sub-angular quartz grains, mostly frosted. Secondary shell debris/carbonate fragments. Rare clear angular quartz grains.
147.17. Dated as ?Late Cretaceous
147.23. Dated as ?Late Cretaceous

Sharp break to:

147.24-148.25m

Basalt. Black (2.5Y2.5/1). Hard, altered and very fractured with calcite veins up to 20mm infilling fractures. At the top of the core the basalt is microphyric with plagioclase laths, and altered pyrite (to oxide). Plagioclase laths are flow banded/ The remainder is a homogeneous fine grained basalt with ?chlorite alteration and very fine clasts of very black glassy basalt. As noted above the rock is much altered to calcite, pyrite and chlorite. It may be extrusive or intrusive but there are no clasts of basalt in the overlying sandstone.
Undated.

Shipboard Geological Summary of Borehole 83/20 – sb01 (Site 1A)

Run: 0.0-17.0m
No recovery except a smear of creamy sandy mud

Run: 17.0-37.0m
33.7-37.0m
Clay or ooze. Grading between light greenish grey (5GY7/1) and greenish grey (5GY6/1). Soft and sticky. Non-calcareous, sandy with abundant,mainly planktic forams, and common silt grade glauconite. Very uniform sediment, probably ~30% forams. A few granules clinging to the outside of the core caved from the seabed.
35.73. Dated as Pliocene.
37.0. Dated as mid- to late Miocene

Run: 37-67m
63.75-66.59m
Silty clay, much as before, light greenish grey (5GY7/1) to greenish grey (10Y6/1), variably calcareous, occasionally silty and very fine sandy, including discrete beds 1-3cm thick, rich in forams, light olive grey (5Y6/2) to olive grey (5Y5/2). Forams, sporadic glauconite and lithic grains throughout, but most prevalent in the silty/sandy bands. Sporadic black organic spots and streaks. Variably soft to firm/stiff; the harder bands are commonly 10-15cm thick and show clear evidence of bioturbation preserved as burrow mottling.

66.59m
Very sharp contact – colour change and (?)erosional reworking of underlying strata with mud rip-ups preserved in basal 2cm of overlying sediments.

66.59-67.0m
Mudstone/claystone, light olive grey (5Y6/2) to olive grey (5Y5/2) at top of section grading to dark greyish brown (2.5Y4/2) towards the base of the core. Silty to very fine sandy, firm, bioturbated with extensive burrow mottling including Zoophycos and silt-sand-filled Chondrites. Sporadic black monosulphidic streaks and specks, very calcareous, common disseminated glauconite, abundant forams, and scattered lithics.
66.52. Dated as mid- to late Miocene.
66.81. Dated as mid- to late Miocene.

Run: 67.0-86.6m.
83.29-86.17m
Silty mud/clay, much as before, light greenish grey (10Y7/1) to greenish grey (10Y6/1), soft to firm/stiff, perhaps more consistently siltier/very fine sandier than above, burrow mottled, calcareous, forams, scattered glauconite.
86.1. Dated as mid-Miocene.

86.17m
MAJOR UNCONFORMITY: Very sharp contact marked by a cobble (lag layer?).
NB. Due to the long core run (almost 20m) the exact depth of the unconformity remains uncertain. Note, however, that the driller noted a change to a harder layer (the cobble layer?) at about 72m. Calibration with the high-resolution seismic records for this site (e.g. profiles SS007 and SS011) strongly suggests that this boundary occurs at about 90msecs TWTT which, using a velocity of 1600m/sec, converts to a depth of about 72m! Basically, this unconformity seems to mark the change from an acoustically well-layered section to

an acoustically structureless section indicated by the first really strong reflector on these records.

86.17-86.6m
Marl? Light grey (2.5Y7/2) to pale yellow (2.5Y7/3) but with darker and paler (white) banding/streaks, soft to firm, predominantly massive, weakly calcareous, forams, scattered lithics and quartz. Second cobble or nodule of micritic limestone at 86.35m.
86.22. Dated as Maastrichtian
86.6. Dated as Maastrichtian.

Run: 86.6-100.0m
95.81-100.0m
Marl, much as before, but change of colour. Very pale brown (10YR8/2) to pale yellow (2.5Y8/4) with common black patches and bands (up to 1cm thick), and rare brownish yellow (10YR6/8) bands (1-2cm thick). Calcareous. Predominantly massive. Black patches have harder centres – nodular structures? – which are very prevalent between 95.81m and 97.55m; present but less abundant in the lower half of the core.
100.0. Dated as Maastrichtian.

Run: 100.0-103.0m
101.59-102.9m
Marl, pinkish white (7.5YR8/2) to very pale brown (10YR8/3), soft to firm, massive, burrow mottled, very sporadic disseminated lithic grains possibly including glauconite, calcareous.
102.87. Dated as Maastrichtian-late Campanian

102.9m
MAJOR UNCONFORMITY: very sharp contact, with an up to 1cm thick weathered zone at the top of the underlying sandstone. On seismic profiles SS007 and SS011, the unconformity occurs at about 125msecs TWTT where an angular unconformity is clearly observed. An acoustic velocity of 1600m/sec gives a depth of 100m, whilst 1700m/sec gives 106m: this is consistent with the observed depth in the core.

102.9-103.0m.
Sandstone, green, glauconite rich, poorly sorted, fine to very coarse grained, the glauconite grains are very well rounded, lithics and quartz vary from well rounded to sub-angular, some disseminated mica. Carbonate cemented, with sand grains matrix supported. Top of sandstone is weathered to a dark brown colour.
103.0. Barren, but based on stratigraphy, is considered to be Late Cretaceous

Run: 103.0-108.0m
107.48-107.72m.
Muddy sand/sandy mud, rich in glauconite, some lithics and quartz, calcareous, soft to hard (indurated bands).

107.42-108.8m
Sandstone, much as before, green, rich in glauconite, scattered quartz and lithics, fine grained though some quartz and lithics to coarse/very coarse sand grade, moderately sorted, carbonate cemented, sand grains are matrix supported, calcareous, abundant

bivalve shells and fragments up to 5cm in basal 10cm of core, discrete shell layer (?hash) at 107.95m.
107.53 Campanian or older
107.70 Early Santonian or older.

Run: 108.0-115.0
112.73-113
Sandstone. Dark greenish-grey (10GY4/1). Hardm well cemented. Very calcareous, quartzose with clear grains, fine-medium grained, moderate sorting, very common glauconite to medium grain size. Possibly a little muddy. Probably finer grained than the preceding sample. Rare whole disarticulated bivalves.
The run comprised only .27m of core, but there was a lot of slush in the barrel. This represents comminuted soft sand degraded by the drilling process. A sample revealed medium to coarse glauconite, trace of fine sand. Rare Inoceramus prisms. Barren of forams.

Run: 113.0-118
116.37-118
Sand, muddy. Dark greenish-grey (10GY4/1). Soft, uncemented, fine to medium grained. Quartzose with clear fine-very fine subangular-subround grains and abundant medium-fine grained green glauconite. Trace mica (white). Calcareous. Rare forams. Only the basal metre is intact.
117.78 Early to mid-Turonian
118.00 Early to mid-Turonian

Run 118.0-123.0
122.15-123.0
Looks like we are back into interbeds of hard well cemented sandstone and soft unconsolidated sandstone again. The 15cm of well cemented sandstone is at the base of the core. It is dark greenish-grey (10GY4/1) hard, well cemented, with a very calcareous matrix. The sand is quartzose, fine grained, and with common green glauconite of medium grain size. Thus the sand is fine-medium grained, probably a little muddy. Very similar to the well cemented bands seen above. The soft sand is also similar.
122.88 ?Turonian)

Run 123.0-128.0
125.3-128.0m.
Muddy sandstone. Dark greenish-grey (10GY4/1). Soft, friable. Unconsolidated, very calcareous. The sand is very fine-fine, clear quartz, sub-angular- sub-round, common glauconite; medium to fine grained, green. Common muscovite as large flakes (1-2mm). Rare shell fragments.
The top 2metres is very slushy and almost liquid. The next metre is firm as described above. The shoe sample is 7cm of well lithified muddy sandstone, dark greenish-grey (10Y4/1) hard, lithified, very calcareous, very fine grained with medium grained green glauconite common. Commonly micaceous, calcareous, muddy cement.
127.86 Late Cenomanian to early to mid-Turonian

Run 128-131.5
130.64-130.83
Sandy mud. Dark greyish –green (10Y4/1) Soft, very weakly calcareous, clear quarrtz grains that are fine grained, clear, sub-angular, common green and brown , medium-fine

grained glauconite, common muscovite mica. Finer grained sediment than above, slightly different and barren of fossils.

130.83-131.28
Muddy sand. Dark olive grey (5Y3/2) Similar to above but coarser grained, soft, non-calcareous, fine grained, clear, sub-angular quartz grains, ,common to abundant medium grained brown glauconite. Rare lithic grains and common muscovite mica.
131.11 Mid-Cenomanian)
131.28. ?Cenomanian

MAJOR BREAK

131.28-131.39
Limestone. Olive-yellow (2.5Y6/6). Moderate hard, recrystallised,, common brown glauconite, and less common quartz grains. Shell debris. Micrite matrix. Well cemented.

131.39-131.5
Sandstone. Yellowish brown (10YR5/4 to 5/6). Hard, variably cemented by carbonate, thus a calcareous sandstone. In part porous and part tight. Quartz grains are coarse , well sorted, frosted, sub-round to round, very mature. Subsidiary clear angular quartz. Some areas with coarse to very coarse grained brown glauconite. Shell debris. Lithologically very similar to the sandstone overlying the basalt in borehole 16/28-sb01
131.4 ?Cenomanian

Run: 131.5-133.0m
132.6-133.0m.
Sandstone, predominantly fine-coarse grained but with common very coarse to granule grade lithic grains, poorly sorted, grains mostly sub-rounded to well-rounded, though some of quartz grains also appear sub-angular, possibly faceted. Calcareous, carbonate cemented, localised carbonate dissolution with partial vuggy-type infills of larger pore spaces by ?calcite crystals. Sand grains are commonly matrix supported. Abundant shells (bivalves), and shell fragments up to 1-2cm size, brown glauconite, disseminated large mica flakes. Rare internal bedding surface shows a weathered, darkened top. Indurated but friable. Yellowish brown (10YR5/4-5/6)
133.0. Dated as 'mid' Cretaceous.

Run: 133.0-138.0m
137.35-138.0m.
Sandstone, a/a, very shelly with bivalve fragments up to 2.5cm scattered throughout the core. Massive, calcareous, medium to coarse grained, moderate to poorly sorted, carbonate cemented (sparite), grains are matrix supported, includes both clear and frosted quartz, brown glauconite. Common carbonate dissolution occurring especially in areas of high shell concentration, with the development of voids up to 2cm diameter. Indurated, pale brown (10YR6/3).
130.8. Dated as 'mid' Cretaceous

Run: 138.0-142.0m
141.91-142.0m.
Limestone, grey (5Y5/1), massive, fine-grained, sugary recrystallised texture, slightly sandy with common green glauconite grains, fine-medium sand grade, also unidentified dark brown mineral, coarse sand grade, occurs both as well-rounded and lath like grains.

Highly calcareous, shelly with bivalve fragments ranging from fine/medium sand grade to larger fragments up to 4.5cm, including the remnants of a strongly ribbed bivalve.
142.0. Dated as Albian-Cenomanian.

Run: 142.0-147.0m.

146.65-147.0m.
Sandstone, much as before, pale brown (10YR6/3) to brown (10YR5/3), hard, indurated, predominantly fine-medium grained, but locally fine-coarse grained, poorly sorted, abundant quartz (both clear and frosted grains), common lithics and disseminated brown glauconite, some large flakes of white mica. Shell fragments are pervasive throughout the core, but not as obviously abundant as in previous cores in this interval. Calcareous, carbonate cemented with many grains matrix supported. Common carbonate dissolution with some partial infilling of the pores/vugs by ?calcite crystals.
146.8. Barren.

Run: 147.0-151.0m.

150.8-151.0m.
Sandstone, a/a, pale brown (10YR6/3) to brown (10YR5/3), indurated but friable, fine-coarse/very coarse, poorly sorted, quartzose, scattered lithics and brown glauconite, common shell debris (mostly bivalves) up to 2.5cm. Calcareous, carbonate cemented. Dissolution both of the shell fragments and the matrix is creating pores and vugs, and much of the unconsolidated sand is being washed away during drilling.
150.9. Barren.

Run: 151.0-156.5

154.53-154.65
Muddy sand. Greyish- brown (2.5Y5/2). Soft, unconsolidated, fine to very fine grade, clear quartzose sand, sub-angular to sub-round with subsidiary yellow-orange frosted grains. Rare white mica. Common Neogene forams. Thus the sample is contaminated.

154.65-156.11
Sand. Light olive brown (2.5Y5/4). Completely unconsolidated and probably represents a friable sandstone dis-aggregated by drilling and preserved by a plugged shoe. The sand is very coarse grained, well sorted, frosted and rounded and subrounded, rarely sub-angular grains. Sparse lithic grains. Shell fragments. Rare ?ferruginous grains. A mature sediment.. Common sandy limestone or calcareous sandstone fragments; probably the matrix of the loose sand or thin limestone interbeds in which the sand is fine to medium grade.

156.11-156.29
Muddy sand. Light olive-brown (2.5Y5/4). Soft, fine to very coarse, yellow-orange frosted grains, poorly sorted. Shell fragments and limestone fragments. Generally as above but muddy.

156.29-156.5
Sandstone. Dark grey (5Y4/1). Well cemented, hard, weakly calcareous, common shell debris of bivalves and a hexagonal stem of something?? Fine to occasionally very coarse, clear quartz grains; sub-angular to sub-round, poorly sorted. Soft brown grains ?ferruginous. Comon carbonaceous fragments. Trace mica. The rock may represent a hard ground.
156.5. Sparse fauna that may be Mesozoic.

Run156.5-161.5m

161.24-161.5m

Sandstone. Dark grey (5Y4/1) to dark greyish-brown (2.5Y4/2). Medium to coarse grained, moderate sorting, sub-round to sub-angular clear and opaque quartz grains. Calcite cement. Thus a calcareous sandstone. Rare to common carbonaceous fragments. Rare glauconite. Rare whole disarticulated bivalve shells. Rare mica. Well cemented, hard rock. Similar to the above but more calcareous.

161.33. Sparse fauna that may be no older than Early Cretaceous.

Run 161.5-166.5

166.0-166.5m

Quite a few rubbly fragments at the top of the sample that grade down to a 11cm piece of core. The topmost fragments are similar to the previous sandstone sample. They are dark grey, fine to coarse grained, quartzose sandstone with a hard recrystallised calcite matrix and carbonaceous fragments, glauconite and disarticulated bivalve shells and fragments. The fragments grade down to a muddy, hard, very calcareous sandstone; well lithified and very hard, variegated from brown (10Y4/3) to brown (7.5YR4/3), with abundant brown glauconite up to coarse grade size, clear, medium to coarse grade quartz grains that are sub-round to sub-angular, mica, and bivalve shell fragments. The matrix appears to be of the same volume as the grains so the rock may be termed either an arenaceous limestone or a calcareous sandstone. It has the appearance of a remanie bed? Is the unconformity close???

166.5. Barren.

Major change in lithologies. ?Major unconformity most likely in the interval between 166.5 and 169.7m.

Run: 166.5-170.2m.

169.7-169.8m

Arenaceous limestone, grey (2.5Y6/1), medium-coarse grained, poorly sorted, quartzose, clear, angular-subangular, common lithics, scattered glauconite and soft white grains of ?ash. Very calcareous, sugary, recrystallised carbonate cement, matrix supported sandy grains. Common scattered shell debris including disarticulated bivalves and coral. Scattered pyrite and rare unidentified black mineral partially filling voids and also occuring in the matrix.

169.7. Barren.

169.8-170.0m

Limestone, grey (5Y6/1-2.5Y6/1), coarse, sugary, recrystallised, fossiliferous including coral and bivalves, also large ?altered crystals of ash (up to 2-3cm). Locally vuggy with partial infill of calcite crystals. Scattered, disseminated pyrite.

169.9. Barren

Run: 170.0-172.0m.

171.66-172.0m.

Limestone, grey (5Y6/1), fossiliferous, predominantly coral debris consisting mostly of a broken colonial coral, which in both cross-section view and colony structure resembles *Lithostrotion*. Some disarticulated bivalve shells also noted. Limestone displays a sugary, recrystallised matrix texture, though some clayey material appears to be concentrated along ?solution cracks. Scattered pyrite. Very soft, silty, black material is common filling

vugs/holes in the limestone. Unsure if this is some kind of mineralisation or just silty/clayey material infilling the voids. Driller reports marked variation in drilling rate: slow then suddenly fast, as if we are drilling through holes – karstic rock structure?
171.7. ?Jurassic **(Post-cruise analysis)**
171.89. ?Jurassic **(Post-cruise analysis)**
172.0. Barren.

Run: 172.0-176.5m.
176.08-176.33m.
Mudstone/claystone, slightly silty, colour banded varying from grey (7.5Y6/1-10YR6/1) to dark grey (10YR4/1-2.5Y4/1), massive but possibly becoming thinly laminated towards base. Firm to stiff. Rare, very thin-thin, very fine sandy/silty laminae including pyrite. Very weakly calcareous. No macrofauna, in contrast to overlying sediments. Rests with sharp contact on the underlying sandstone.
176.29. Barren.

176.33-176.50m.
Sandstone, grey (5Y5/1), soft and friable, very fine-fine grained, quartzose, sporadic ?glauconite, common black mineral (?similar to that described in limestones above) which depicts very thin laminae, sporadic lithics. Well sorted. Calcareous, carbonate cement. Laminae appears to depict thicker bedding units – very thin to thin bedded (<1-2cm) – with possible indications of cross-bedding. Pyrite is very common in association with the black mineral laminations, either as a replacement or being replaced. Absence of macrofauna.
176.48. Barren.

Run: 176.5-177.0m.
176.5-177.0m.
Sandstone, colour banded; predominantly dark grey (2.5Y4/1-5Y4/1) but with distinct paler grey (2.5Y6/1) bands and black laminae. Silty, poorly sorted, very calcareous matrix, very rare shell fragment associated with discrete very coarse sand-pebbly layer, which also includes soft clayey/altered ?ash clasts, very common organic fragments which probably account for the very thin, black laminae. Some of these laminae appear to have been almost replaced by pyrite. Laminations depict cross bedding, and there are also indications of lenticular bedding. This interval, and the one above, resemble deltaic sediments. Core is cut by a thin ?calcite vein.
176.78m. Barren.

Because of the recovery situation the next description covers material cored during the last run but recovered during this one. There was no change in depth so it should be included in the description from the last run.

Run 177.0-177.0

To 177.0m
Sandstone much as above. The core is continuous.
Sandstone. Grey (5Y5/1). Very fine grained, ?muddy, quartzose, common carbonaceous material. Very calcareous. The core is finely laminated to mm scale with laminae defined by greater or lesser concentrations of black carbonaceous material with more carbonaceous material in the darker bands where it is lathlike and orientated along the

laminae. The laminae dip at 10-25 degrees and there are rare cut-out structures. There is rare pyrite and vertical to sub-vertical fractures. Basal 8cm of core becomes horizontal.

Run 177.0-177.35

177.0-177.08
Sandstone. Grey (5Y5/1). As before. Breaks to:

177.08-177.35
Mudstone. Grey (5Y5/1). Sandy, hard and well cemented, very calcareous, laminated with colour banding, that probably is finer and coarser mudstone to sandy mudstone and with variable concentrations of carbonaceous fragments. The laminae are mm scale, and are horizontal, with some wavy bedding evident. Carbonaceous fragments are aligned parallel to the laminae as wisps and streaks. Pyrite is common and replaces the carbonaceous material.
177.26. Late Jurassic (Late Kimmeridgian) – **(Post-cruise analysis)**

Hammer sample
177.35-177.40 TD
The final sample, a grey (5Y5/1) muddy sand was acquired from a hammer sample taken to clear the bit. It is soft to firm, finely sandy, very calcareous and the sand is quartzose, clear, sub-angular. Common pyrite. Carbonaceous fragments.
177.35. Barren.
177.4. Barren.

Shipboard Geological Summary of Borehole 83/24 – sb01 (Site 1)

Run: 0.0-10.0m

0.0-9.25m
No recovery

9.25-9.65m
Silty clay, very soft, foram rich, scattered lithics, common granules to small pebbles, calcareous, varicoloured – light grey (5Y7/2) to pale yellow (5Y7/3) with light yellowish brown (2.5Y6/3) lumps intermixed (may be a function of the coring process).
9.3. Dated as Late Pliocene-Pleistocene.

9.65-9.82m
a/a, but fewer dropstones, white (2.5Y8/1) to light grey (2.5Y7/2).
9.7. Dated as Late Pliocene-Pleistocene.

9.82-10.0m
Sandy silty mud/clay, soft, very poorly sorted, dark olive grey (5Y3/2), becomes darker down core, common silt to coarse sand grade lithics and quartz, forams, occasional pebbles, harder mud lumps/clasts at base, calcareous.
10.0. Late Pliocene-Pleistocene

Run: 10.0-20.0m

18.91-19.16m
Mixture of foram-rich sand, pale yellow (2.5Y7/3) to light yellowish brown (2.5Y6/3), fine grained, well sorted, scattered lithics; and, white silty clay, common granules and pebbles, very soft, strongly calcareous.
19.0. Late Pliocene-Pleistocene

19.16-19.22m
Clay, light yellowish brown (2.5Y6/3), very soft, calcareous, sharp contact with underlying sand.
19.18. Late Pliocene-Pleistocene.

19.22-19.44m
Foram-rich sand, a/a albeit slightly coarser grained, light grey (2.5Y7/2) to pale yellow (2.5Y7/3), well sorted, strongly calcareous.
19.38. Late Pliocene.

19.44-19.45m
Pebble layer (?lag gravel), lithic granules and small pebbles. Represents a sharp contact with the underlying sandy calcareous muds.

19.45-20.0m
Sandy calcareous muds, soft, becoming indurated and chalky/micritic limestone towards base, pale yellow (2.5Y8/4), foram rich, sponge spicules, rare scattered lithics, calcareous, flinty/cherty nodules at 19.7 and 19.9-19.97, light yellowish brown (2.5Y6/4), massive throughout.
19.5. Earliest mid-Eocene.
20.0. Earliest mid-Eocene.

Run: 20.0-27.5m

26.65-27.5m

Micritic limestone, pale yellow (2.5Y7/3-7/4), soft and easily broken to hard and indurated, being replaced by chert between 27.0-27.26m, with fragments of limestone enclosed within the cherty layer. Predominantly massive but with traces of thin lamination depicted by subtle colour banding, foram rich, sponge spicules. Rock is cut by thin subvertical fractures along which dendritic manganese is locally developed.

27.5. Early Eocene.

Run: 27.5-30.8m TD

30.5-30.8m

Calcareous mud, a/a but not indurated, chertification between 30.55-30.65, pale yellow (2.5Y7/3-7/4), foram rich, sponge spicules.

30.8. Early Eocene.

Shipboard Geological Summary of Borehole 83/24 – sb02 (Site 1)

Run: 0.0-23.5m.
18.79-19.96m
Interbedded clays, muds, sandy muds and sporadic thin sands, very soft to soft, bioturbated, scattered lithic pebbles, weakly to strongly calcareous. Varicoloured: light olive grey (5Y6/2), light grey (5Y7/1), light olive brown (2.5Y5/3), white (5Y8/1) and olive grey (5Y5/2) – depict colour banding with beds ranging from 1-30cm thick. Sandy intervals are clean, foram rich, fine grained, with scattered lithics.
19.93. Dated as late Pliocene.

19.96m. UNCONFORMITY. Very sharp. Top of micritic limestone is broken up/rubbly.

19.96-23.5m
Limestone, pale yellow (2.5Y8/3-8/4), micritic, soft to hard and indurated but easily broken, becoming cherty at base (23.4-23.5m) with nodules and discrete layers, foram rich, common sponge spicules, sporadic scattered silt-grade lithics. Massive, calcareous.
20.08. Dated as earliest mid-Eocene.
23.32. Dated as earliest mid-Eocene.

Run: 23.5-30.0m.
No recovery

Run: 30.0-30.80m
30.44-30.80m.
Limestone, a/a, pale yellow (2.5Y8/3), micritic, soft to hard and indurated but easily broken, massive, strongly calcareous, foram rich, scattered silt-grade lithics, chertification – bands and nodules – between 30.44 and 30.57m
30.75. Dated as early Eocene.

Run: 30.80-38.20m
37.58-38.13m
Limestone. As above. Pale yellow (2.5Y8/3). Hard to firm, silty, massive, weakly calcareous as a fine grained micrite mud.
38.10. Dated as early Eocene

MAJOR UNCONFORMITY

38.13-38.20m
Glauconitic sandstone. Brown (7.5YR4/4). Hard, well cemented and dominated by brown glauconite up to very coarse grade and coarse grade shell debris with subsidiary clear quartz, sub-round to sub-angular, fine to medium grained. Rare shell debris with Inoceramus prsms.
38.20. Dated as ?Late Cretaceous (?early Santonian-late Cenomanian)

Run: 38.20-38.90m
38.72-38.90m
Glauconitic sandstone, as above. Brown, 7.5YR4/3 to 4/4). Hard, and well cemented by carbonate. Brown glauconite up to very coarse grade and shell debris make up 90% of the clasts with subsidiary clear and frosted quartz up to coarse grade, sub-round to sub-

angular. Shells comprise whole bivalves up to 50mm and fragments including Inoceramus prisms. The matrix is carbonate, probably ferroan.
38.82. Barren

Run: 38.90-40.60m
38.90-39.92m.
Sandstone as above.

39.92-40.60m.
Sandstone. Strong brown (7.5YR5/6). Very hard and very indurated, with a partly recrystallised ferroan carbonate cement. A mix of frosted and clear quartz grains. The frosted grains are dominantly medium to very coarse grade, round to sub-round. The clear quartz is medium to coarse and angular to sub-angular. There is very subsidiary glauconite. There are infills of finer grained sediment that comprises fine to medium grains of clear and frosted quartz and brown glauconite. In all a very poorly sorted sediment. Abundant shell debris and some whole bivalve shells.
40.60. Barren.

Run: 40.60-45.60m
44.74-45.60m.
Sandstone, a/a, reddish yellow (7.5YR6/6) to strong brown (7.5YR5/6), hard and indurated, very poorly sorted, silt to very coarse sand grade, with scattered granule-grade clasts, and abundant shells and shell debris, particularly bivalves, to 5cm. Calcareous, carbonate cement, sand grains commonly matrix supported. Common dissolution holes – removal of carbonate cement and shell debris – in which sand grains bear a black coating. Abundant quartz grains are a mix of clear and frosted types, subangular to subrounded.
45.51. Dated as ?Mid-Cretaceous.

Run: 45.60-50.00m
No recovery.

Run: 50.00-59.00m.
58.70-59.00m.
Sandy cavings on crudely bedded sandstones and pebbly sandstones, yellowish brown (10YR5/4) to light yellowish brown (10YR6/4), hard and indurated. Sandstone bed between 58.7 and 58.85m is silty to fine grained, whilst pebbly sandstone between 58.85 and 59.0m ranges from silt to very coarse sand grade, with common granules and pebbles (to 2.5cm). The sand component is dominated by quartz and lithics with subordinate ?brown glauconite and shell debris; the gravel fraction is dominated by quartz and lithic clasts and common shells (bivalves) and shell debris (to 3cm), with subordinate ?brown glauconite. Grain shapes range from subangular to well rounded; the pebbles are especially well rounded. Quartz includes both clear and frosted types. Very calcareous, grains commonly matrix supported in a carbonate cement. Calcite crystals and black, dendritic manganese coatings are preserved in localised voids.
58.7. Barren (broken bivalve debris), but cavings incorporate Plio-Pleistocene and Late Cretaceous (late Maastrichtian) forms.
58.9. Barren (broken bivalve debris).

NOTE ON SIGNIFICANCE OF CAVED LATE MAASTRICHTIAN FORMS IN M'PAL SAMPLE FROM 58.7M.

Moderately rich and well preserved Late Maastichtian microfaunas were observed in the cavings sample at 58.7m. These faunas were not previously observed/sampled in this borehole but must originate from the unconformable contact somewhere between 38.10m and 38.13m. Their presence signifies that the Palaeogene sequence must rest unconformably on a very thin Late Maastrichtian, which itself rests unconformably on older Late Cretaceous glauconitic sandstones at 38.13m.

Run: 59.00-63.30m
63.20-63.30m
Rounded 10cm cobble of very fine calcareous sandstone, yellowish brown (10YR6/6). Very hard and well cemented, homogeneous, massive. CAVED
?UNCONFORMITY

Adhering to the cobble. Clay, red (2.5YR5/8). Soft, calcareous, very smooth and buttery, a slipper clay, homogeneous.
63.30. Dated as ?Late Jurassic

Run: 63.30-68.00m
67.75-67.80m
Clay sample mixed up by the drilling process. Clay; red 2.5YR5/8) soft to firm, buttery, as above but non-calcareous. With Clay. Light yellowish brown 2.5Y6/4) non-calcareous, micaceous, soft to firm.
67.80. Dated as ?Late Jurassic

67.80-67.92m
Clay. Red (2.5YR5/8). Soft to firm, non-calcareous, slightly silty, massive and homogeneous.

67.92-68.00m
Cobble of calcareous sandstone as above, yellowish brown (10YR6/6) very hard and well cemented by carbonate, very fine to fine grained, quartzose, homogeneous and massive. CAVED

Run: 68.00-69.30
68.82-69.30m.
Mudstone/claystone, very stiff to hard, locally brittle/fissile, reddish brown (5YR5/3) to greenish grey (10Y5/1), massive, non- to weakly calcareous, scattered white mica; with interbedded laminae and very thin to thin beds and lenses of sandstone at the base of the core, silty to very fine sand grade, well sorted, quartzose. Very sharp bed contacts between mudstone and sandstone. Whole core is heavily disrupted by post-depositional cataclasis: abundant microfaulting with locally brecciation has locally destroyed original fabric of rock. NB. Cobble at top of core is probably caved.
69.21. Barren.

Run: 69.30-71.00m.
70.68-71.00m.
Interbedded siltstone and mudstone. Siltstone is hard and indurated, grey (5Y5/1) but with slight reddening due to fe-staining, quartzose, scattered white mica, massive, non-calcareous; mudstone is hard but easily broken, reddish grey (10YR5/1) to dark reddish grey (10YR4/1) with sporadic light greenish grey (10Y7/1) reduction spots and patches,

massive, non-calcareous. Bed contacts are difficult to discern due to the broken nature of the core. Core is cut by joint surfaces, one of which was smeared with red clay.
70.82. Barren.
71.00. Barren.

Run: 71.00-71.23m.
71.00-71.23m.
Silty mudstone, grey (5Y5/1) to dark grey (5Y4/1), hard, indurated, non-calcareous, very thin to medium laminations (though core is scored by drilling process also), fissile, homogenous.
71.04. Barren.
71.23. Late Jurassic (**Post-cruise analysis**).

Run: 71.23-71.49m. T.D.
71.23-71.49m.
Mudstone, hard and indurated, brittle/fissile, very thin to medium laminated, with laminae depicted by colour banding which varies from grey (N5/), dark grey (N4/), and greenish grey (5G6/1) to weak red (2.5YR5/2). Sharp contacts between laminae. Micromicaceous, non-calcareous. Core is locally highly microfractured, displays in situ brecciation, and is easily broken.
71.49. Age indeterminate.