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MD 141/ALIENOR Cruise Report: First Leg Lisbon-Cardiff

Continental Shelf and Margins Programme
Internal Report IR/04/126

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/126

MD 141/ALIENOR Cruise Report: First Leg Lisbon-Cardiff

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Front cover

The RV Marion Dufresne

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BRITISH GEOLOGICAL SURVEY

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Foreword

This report describes the activities and aims of the first leg of the MD141/ALIENOR cruise aboard the IPEV (French Polar Institute) vessel the RV Marion Dufresne. The first leg of the ALIENOR cruise followed the Iberian margin, the Armorique Mount in the central Bay of Biscay, the western Irish margin, the Barra Fan, Rosemary Bank and the Scottish Loch Sunart.

Scientists and students from 10 scientific institutes representing 8 countries participated in this program funded by IPEV and CNRS of France and NERC and BGS in the United Kingdom. The 4th European Floating University was held on board the vessel during the transit from Lisbon to Cardiff comprising 26 students, the majority of whom were from British universities.

Acknowledgements

The author would like to thank Richard Holmes and the Offshore Mapping and Modelling Programme. I would also like to thank Bill Austin of St. Andrews University and Ian Hall of Cardiff University. Dr. Jeremy Young is thanked for his preliminary onboard analysis of a small selection of samples from the BGS piston core (MD04-2822 / +56-12/14). Carrie Lear of Cardiff University is thanked for providing several photographs used in this report.

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1 Cruise Aims

The ALIENOR cruise aimed to collect a number of samples from the Noth Atlantic from Lisbon (Portugal) to El Ferrol (Spain) via Cardiff (Wales), for paleoclimatic evolution studies. The R.V. Marion Dufresne is capable of recovering sediment cores up to 60m in length in water depths down to 5000m. The SEQUOIA programme was part of the first leg of this research expedition to the NE Atlantic that departed Lisbon on the 6th June 2004 and arrived in Cardiff on the 17th June 2004. The first leg of the ALIENOR cruise followed the Iberian margin, the Armorique Mount in the central Bay of Biscay, the western Irish Margin, the Barra Fan, Rosemary Bank and the Scottish Loch Sunart (Figure 1).

1.1 SEQUOIA – SEQUENCING OCEAN-ICE INTERACTION

Globally interconnected ocean currents, collectively known as the Ocean Conveyor-belt Circulation, distribute vast quantities of heat and moisture around the planet, playing a fundamental role in controlling Earth's climate. The circulation is an important mechanism in reducing the equator-to-pole temperature difference.

However, the Ocean Conveyor is sensitive and it is known to have slowed and shut down in the past. Approximately 12,700 years ago the Ocean Conveyor was disrupted. This reduced the delivery of heat to the North Atlantic and caused substantial cooling. Average temperatures cooled by 5ºC within 10 years in Europe.

Some evidence from ocean sediment cores suggests that fluctuations such as these are part of the climate cycle. Involving substantial variations in the ocean currents of the North Atlantic on an approximate 1500 year cycle. Therefore studying the previous behaviour of the climate system provides a potential insight into what the Ocean Conveyor may do in the future.

During the last Ice Age, the Laurentide Ice Sheet in North America periodically released many icebergs and their sediment loads into the North Atlantic. These 'Heinrich' events can be identified as distinctive layers of ice rafted debris (IRD). Dating of these layers demonstrates that these events occurred approximately every 7000 years. Currently there are two main schools of thought as to the cause of these events, firstly involving the internal dynamic of the ice sheet, secondly climate forcing linked to the Ocean Conveyor. Recent research on cores off SW Ireland has led to the discovery of grains of IRD supplied by the British Ice Sheet, in sediments that closely predate the main Heinrich layers. This suggests that the British Ice Sheet collapsed before the larger Laurentide Ice Sheet, possibly also contributing to it destabilisation.

As part of the Sequoia project it is intended to reconstruct the timing and geographic distribution of debris shedding by icebergs in the NE Atlantic related to variations in the Ocean Conveyor. The European Margin is a prime setting for determining the 'ice-ocean-climate' interaction as both the Laurentide and British ice sheets released icebergs into the area. The smaller, rapidly responding British Ice Sheet was adjacent to the route followed by the Gulf Stream. Its dependency on moisture and heat supply from the Gulf Stream and its links to the Ocean Conveyor makes it particularly sensitive recorder of past climate changes and ocean-ice-climate interaction.

1.2 CLIMATE STUDIES IN SCOTTISH SEA LOCHS

This study forms part of a collaboration between the University of Caen (France), the University of St Andrews and the Scottish Association for Marine Science. Geophysical surveys undertaken in Scottish sea lochs have allowed the distribution and thickness of sediments in these environments to be determined. Using the results from these surveys, sites have been identified for sampling from the R.V. Marion Dufresne. It is hoped these cores will recover high-resolution records of climate variability over the last 15,000 years. Using sediment size

characteristics that respond to bottom current strength and measuring the stable isotope composition of foraminifera, variation in climate change in these environments can be reconstructed.

Due to the expanded nature of the sediments (up to 0.7cm/yr), it is possible to reconstruct past climate since the last glacial period when ice sheets retreated from Loch Sunart. The position of sea lochs on the west coast of Scotland make them ideal for studying climate variability at a range of time-scales.

1.3 BGS RATIONALE FOR ROCKALL CALYPSO PISTON CORE SITE

Sites were discussed in relation to proposals first made 2001. It was decided that a site in the Rockall Trough would be scientifically most appropriate. The proposed BGS site is at approximately 56º 50' N and 11º 20' W in more than 2000m water depth.

The proposed site is west of the large-scale debris flows emanating from the Barra/Donegal Fan but in relatively thick acoustically well-layered sediments (Figure 2 and 3). These are likely to contain a high-resolution record of deposition. The site is located in the mid-Rockall Trough where there is least risk of eddies shed from fan lobes, slide debrites, or around the seamounts. This is important as it decreases the likelihood that complex oceanographic events (generated from local features) have influenced the site depositional history. The site is sufficiently far from the eastern shelf edge that it is unlikely to be dominated by rapid deposition from one glacial cycle and is far enough from the western margin to run least risk of discontinuous sedimentation.

OBJECTIVES

1. A high resolution sedimentary record is likely to be obtained for the comparison of at least 4 major glacial cycles extending possibly into the early Pleistocene. This has not been recovered before from the UK sector as shelfal sediments tend to contain a poor interglacial record. Questions to be addressed are what is the sedimentological signature for sediment transfer offshore during the severe mid to late Quaternary glaciations, how can the new data proxy for estimating sediment transfer during earlier glaciations and what is the typicality of the current interglacial record with former interglacials.
2. There is controversy as to whether the Elsterian glaciation (mid-Pleistocene, 0.44 Ma) was the first time when ice sheets extended from mainland Britain to the shelf edge at approximately 56N. It is possible that this question will be addressed by analysis of the new core.
3. Records of cooling and warming over millennial and sub-millenial scales will relate to *Dansgaard-Oeschger* cycles (approx. 1Ka) and *Bond cycles* (approx. >3ka) and possibly the contribution of N British mainland glaciations to *Heinrich events* (iceberg-dropstone) during sudden warming. Once precipitated these events appear to be characterized by further cycles of rapid climate change. For example, changes are linked to whether the Atlantic conveyor of warm water to N Britain is affected. Questions are whether events are synchronous across the N Atlantic, between Scandinavia and Britain, and between northern and southern Britain and so whether the N European or N American ice sheets registered the first major climate changes. A better understanding of the absolute and relative timing of these events may indicate the key sites for monitoring and predicting rapid climate change.
4. The site should record sediments extending into the early Pleistocene and possibly into the Pliocene. A question is what sedimentary record will be registered against the magnetic stratigraphy and oxygen isotope stratigraphy. As stages within the Quaternary are broadly defined on the basis of climate change, the site has potential for dating climate change and 'base Quaternary' for the British Isles at this latitude.

5. Sediments extending into the Pliocene might have significantly different sediment properties to the overlying Pleistocene sediments. Important questions are what are these differences characterized by and are they related to the first onset of very large-scale sediment failures (Peach Slide Event 1) on the Barra Fan.
6. There is also the possibility that changes of properties of fan-distal sediments at the proposed site may be may be used as indicators of the likely proportions of mud and sand prone sequences in the slope- and fan-proximal sites.

2 Equipment

The R.V. Marion Dufresne is a multi-purpose vessel with two main functions: 1) the resupply if the French austral islands and 2) oceanographic research. The ship is one of the largest scientific vessels and has an overall length of 120.5m, is 20.6m in width and has a draft of 6.95m with a displacement of 10,380 tonnes.

2.1 CALYPSO CORERS

Two calypso corers were used during this leg of the cruise. The first is the giant piston corer (Figure 4 and 5) which has a large diameter (11cm) and can sample up to 60m of soft to firm sediment. The second is the casq corer (Figure 6) which is approximately 35cm in diameter and can collect approximately 12m of sediment.

2.2 MULTI-SENSOR TRACK (MST)

Once the core is collected, labelled, cut and split, the archive half is described while the working half is run through the multi-sensor track (MST) (Figure 7). The MST includes ρ-wave logger devices that measure bulk density, porosity and seismic velocity, and also includes a meter that determines the volume magnetic susceptibility. As the working half is run through the MST it is also colour photographed.

2.3 SEISMICS

Upon approaching a sample site a reconnaissance 3.5 kHz pinger survey is carried out. This is used to check that ground conditions on site are such for safe deployment and recovery of the equipment and is also used to determine the final site for sampling.

The R.V. Marion Dufresne is also equipped with a deep water multibeam echosounder (TSM 5265) which is used for bathymetry, imagery, seabed classification and sub-bottom profiling.

3 4th European Floating University

The leg played host to the 4th European Floating University. 26 students from different European universities attended (predominantly British). Mornings were dedicated to lectures given by the scientists on board on topics ranging from *Quaternary environmental change and climate* to *the physical and geophysical properties of marine sediments*. Afternoons, and occasionally evenings, were dedicated to group research projects and a brief rotation onto duty with the scientific personnel gaining first-hand knowledge on core cutting, core description and MST analysis. As well as this, practicals for micro- and macro-organism studies involving the deployment of plankton nets at each sample station (Figure 8) were also carried out by the students.

On the last day of the cruise, posters of each student group topic were presented to the scientific and ship crews. A formal committee evaluated the posters for their quality and originality. This experience, combining theory and fieldwork immersed the students in climate research and international collaboration.

4 Results

4.1 DETAILS OF CORES RECOVERED

The cruise collected 10 long, large diameter (11cm) Calypso giant piston cores and 11 Calypso square casq cores at 13 sites for a total of 402m of sediment, 230m of this as part of the SEQUOIA programme (Table 1 and Figure 9).

Table 1 Details of the cores recovered within the SEQUOIA programme during MD141 ALIENOR Cruise.

Core Name	Locality	Position	Type	Length (m)	Water Depth (m)
MD04-2819	Goban Spur	49º 04.19'N 13º 24.73'W	GPC[1]	36.80	3634
MD04-2820CQ	Goban Spur	49º 04.18'N 13º 24.77'W	CASQ[2]	10.04	3633
MD04-2821	Western Irish Margin	55º 18.66'N 10º 48.96'W	GPC	1.50	2545
MD04-2822	Barra Fan	56º 50.54'N 11º 22.96'W	GPC	37.70	2344
MD04-2823CQ	Barra Fan	57º 01.89'N 10º 03.07'W	CASQ	10.40	2104
MD04-2824	Barra Fan	57º 30.10'N 10º 07.26'W	GPC	35.50	2005
MD04-2824CQ	Barra Fan	57º 30.09'N 10º 07.26'W	CASQ	11.30	2005
MD04-2826CQ	Rosemary Bank	59º 26.27'N 10º 33.68'W	CASQ	9.86	1373
MD04-2827	Rosemary Bank	59º 26.27'N 10º 33.86'W	GPC	29.76	1373
MD04-2828	Rosemary Bank	58º 56.95'N 09º 34.32'W	GPC	36.78	1743
MD04-2829CQ	Rosemary Bank	58º 56.93'N 09º 34.30'W	CASQ	10.06	1743

[1]CALYPSO Giant Piston Core; [2]CALYPSO Giant Box Core; red text indicates BGS core

4.2 PRELIMINARY RESULTS FROM BGS CORE (+56-12/14)

The BGS Calypso giant piston core (onboard name: MD04-2822; BGS number +56-12/14) was collected on the 12th June 2004. Using the BGS scientific case (Chapter 1.3) for the proposed core we arrived on site at approximately 13:30 and carried out a reconnaissance 3.5 kHz pinger survey. This served the dual purpose of checking ground conditions for the deployment of the

equipment and also to choose the final site (Figure 10). Multibeam data was also collected in the area (Figure 11). A 42m barrel was fitted onto the piston corer.

The core was labelled and cut into 26 sections, split, described (Appendix 2) and run through the MST. Preliminary analysis of samples obtained from the core suggest that the sediments recovered include stage 7 and possibly even stages 9 or 11 (Dr. J. Young, Natural History Museum, personal communication). This suggests that the sediments recovered may hold a climate record going back 215,000 years.

The onboard BGS representative (Heather Stewart) completed the BGS sample station and sample description sheets for the core (+56-12/14) (Appendix 1). Initial observations indicate that the core comprises mainly hemipelagic sediments with few turbiditic layers. A number of smaller sandy layers were also identified.

5 Suggested Ways to Proceed

One method for studying the record of climate change is through the study of changes in oceanic circulation which strongly influence terrestrial climate change. This record is most complete in deep water. The 37.7m long BGS piston core (+56-12/14) located in the mid-Rockall Trough (2344m water depth) has been collected as part of the ALIENOR Cruise aboard the R.V. Marion Dufresne on the 12th June 2004. It is hoped that this core contains a high-resolution sedimentary record which contains evidence of a number of glacial cycles.

5.1 THE FIRST YEAR

It is suggested that the core is re-run through the MST as there were problems with the calibration of the MST onboard the R.V. Marion Dufresne.

The results from the MST could be plotted for immediate comparison with the MST results from BGS cores in the Hatton–Rockall region. It is also suggested that within the first year a sedimentological log is created for the core, allowing the results to be incorporated into the BGS database and existing offshore maps. The core should also be X-Radiographed in the first year and sub-sampled for $\delta^{18}O$.

$\delta^{18}O$ sampling is necessary for establishing a stratigraphy for the core. It is suggested that the sub-sampling is done at 2-5cm intervals, a minimum of 754 samples for the entire core.

5.2 FURTHER WORK AND POSSIBLE COLLABORATORS

Table 2 This table has been constructed following advice from C. Morri and details possible collaborators and analyses which could be undertaken on the piston core.

Institute	Method		Application		
			Geology	Oceanography	Climatology
University of Bergen/ University of St. Andrews	$^{12/13}C$ (stable isotopes)	Planktonic and benthic foraminifers		Productivity index and deep water ventilation – turnover	
University of Bergen/ University of St. Andrews	$^{18/16}O$ (stable isotopes)	Planktonic and benthic foraminifers			Sea-ice volume and sea surface temperature
University of Bergen	Nd/Sm (REE)	Decarbonated clay fraction		Deep-water palaeocurrent	

				tracer	
Southampton Oceanographic Centre	Magnetic susceptibility	Environmental magnetic properties and grainsize indicator			
British Geological Survey/University of St. Andrews	Ice-rafted debris	Grains >2mm at 2cm intervals	Coarse material overprinting the background sediment deposition		Iceberg material discharge or melting
University of St. Andrews	Partical Size Analysis	Laser diffraction and Sedigraph digested and undigested		Palaeocurrent strength indicator	
? Rex Haarland ?	Dinocysts				Sea surface conditions
? Rex Haarland ?/ British Geological Survey	Biostratigraphy	Planktonic species counts of >300 individuals			Warm vs. cold species indicates sea surface temperatures
British Geological Survey	Seismic reflection lines	sparker and airgun	Regional framework of depositional environments	Active areas of current influenced deposition	
British Geological Survey	Lithological logging	Gravity and vibrocore	Sediment characterisation and Lithofacies determination		
British Geological Survey	X-Radiographs	Split core	Internal structure sedimentary fabric		

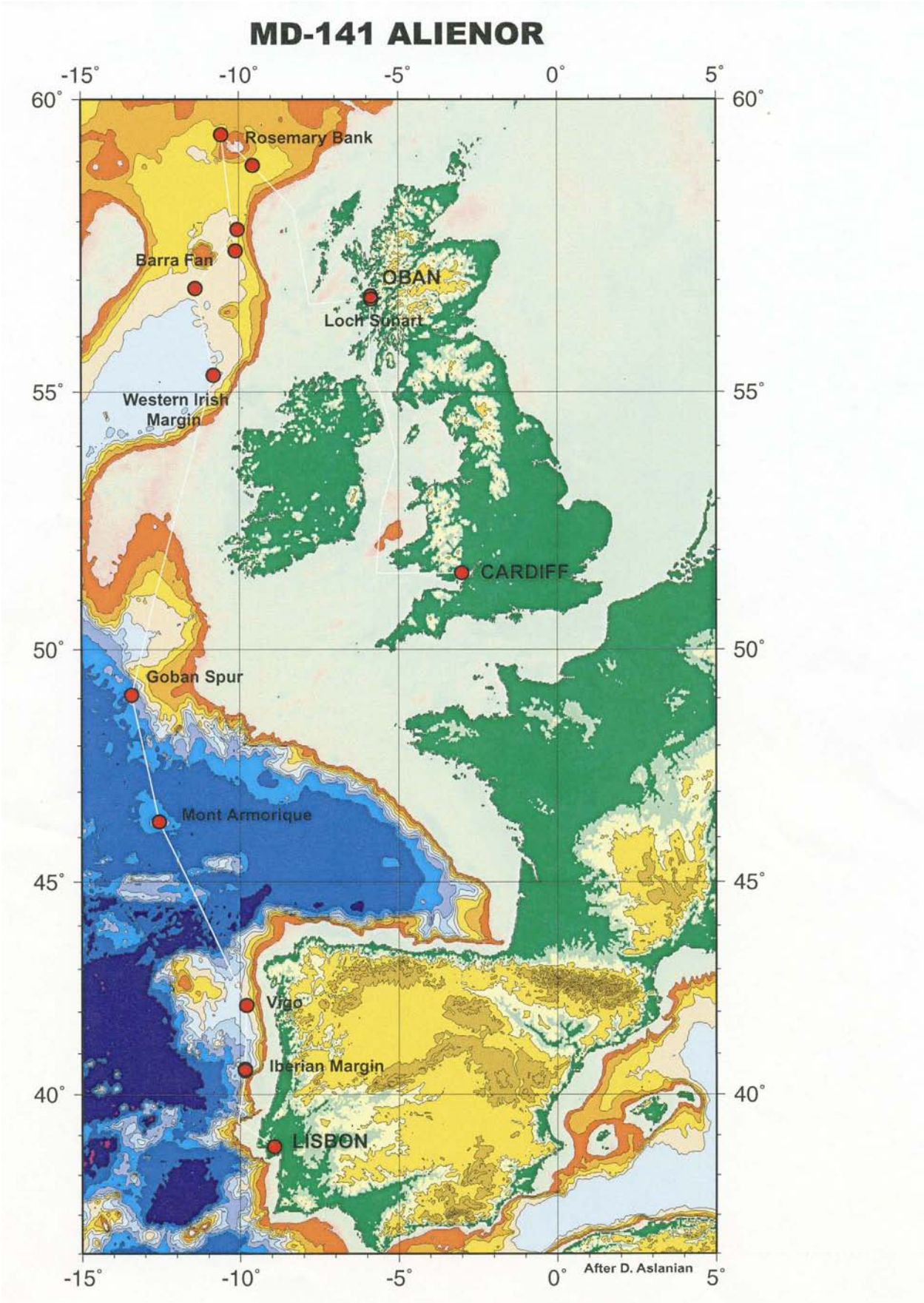


Figure 1 Image showing the proposed sample sites and route for the first leg of the ALIENOR cruise (6th-17th June) which followed the Iberian margin, the Armorique Mount in the central Bay of Biscay, the western Irish Margin, the Barra Fan, Rosemary Bank and the Scottish Loch Sunart.

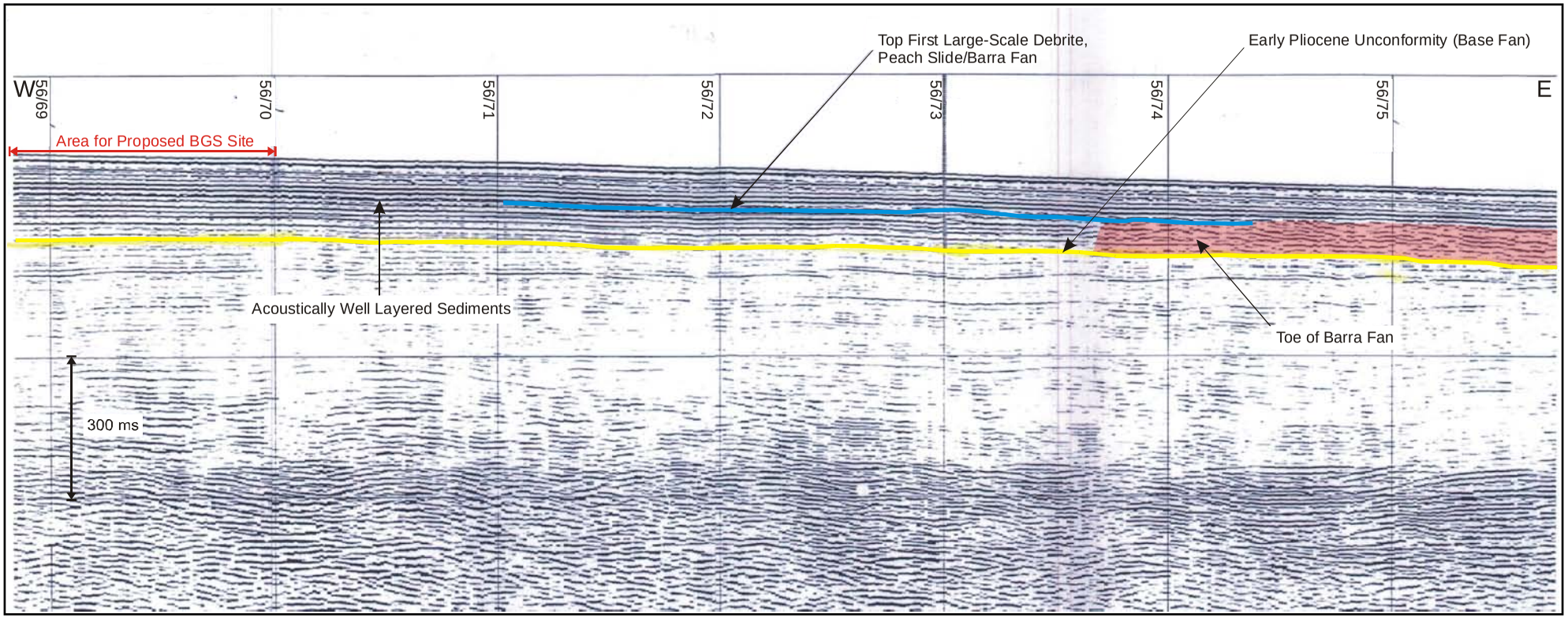


Figure 2 BGS Air Gun profile 92/01/56 located in the mid-Rockall Trough showing the proposed BGS sample site. The site is west of the large-scale debris flows emanating from the Barra/Donegal Fan but in relatively thick acoustically well-layered sediments.

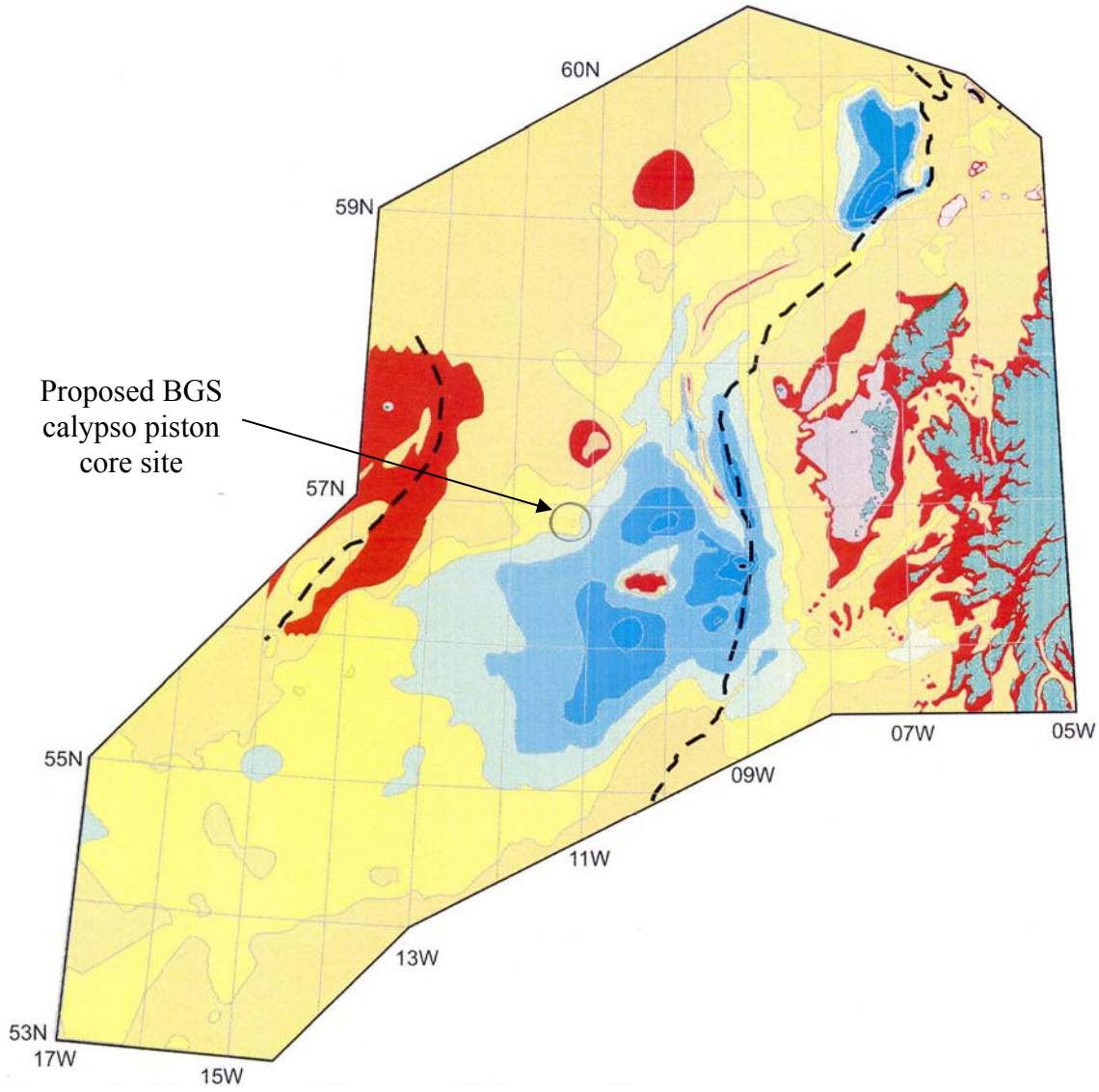


Figure 3 Composite thickness TWT Pliocene to Holocene sediments to the west of Scotland. Compiled by R. Holmes adapted from STRATAGEM research (Stoker et al., 2005)

(Colour guide: pink = <15m; red = <50m; orange = <100m; yellow = <200m;

deepest blue = >500m.)

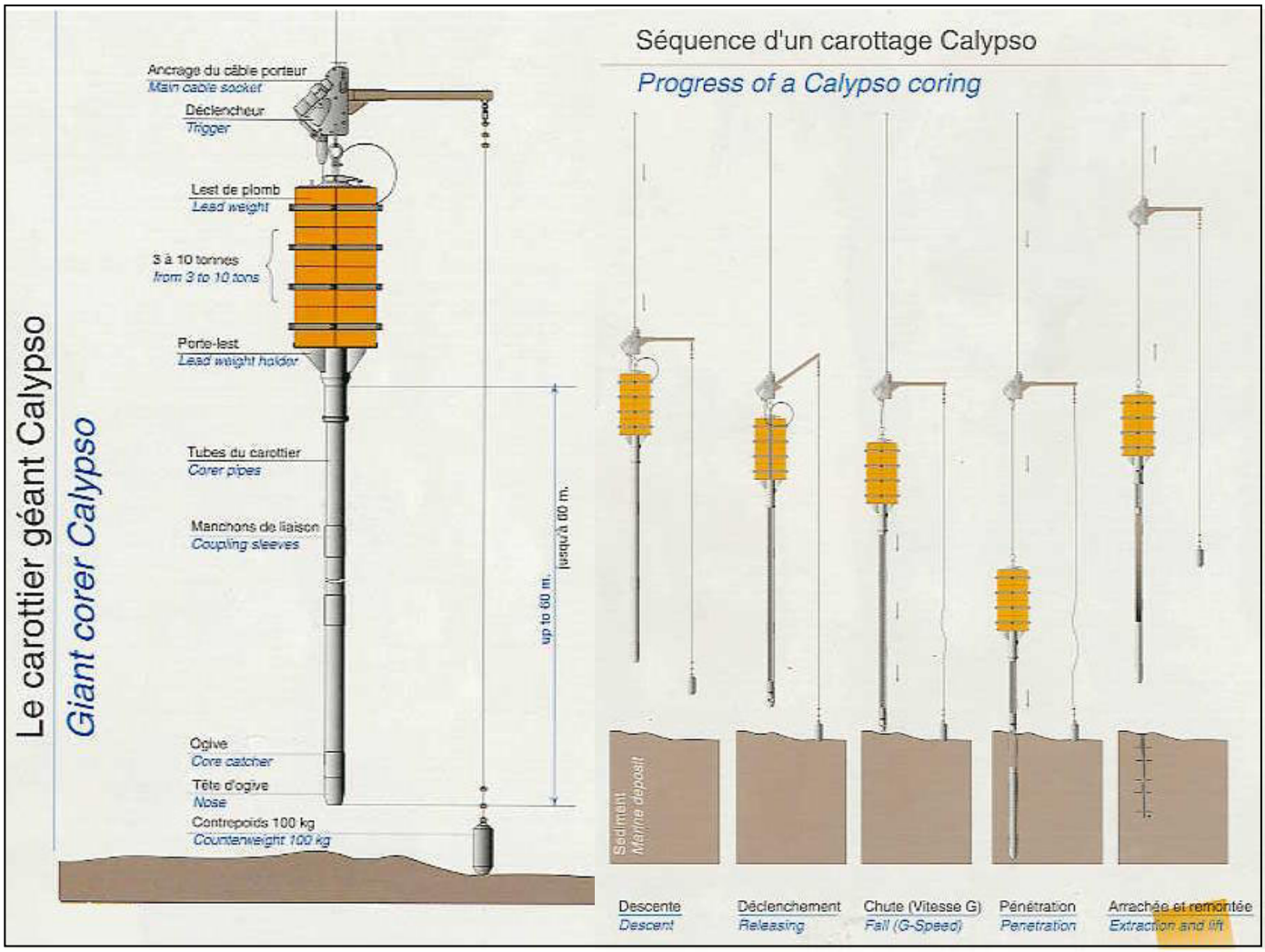


Figure 4 Diagram illustrating the Calypso giant piston corer. The cores are large diameter (11cm) and can be up to 60m in length. The system can operate in water depths up to 5000m.

Figure 5 Calypso giant piston corer being deployed.

Figure 6 The Calypso square Casq corer that recovers sediment cores approximately 35cm in width and up to approximately 12m length. Photograph A) shows the Casq being recovered and B) illustrates the types of sediments sampled; here a gravelly layer is identified which may be a part of a debris flow. C) illustrates a Casq core which has been sub-sampled using three sizes of u-channels and is now being cleaned in preparation for another site.

Figure 7 After the core is split, the working halves are run through the MST. The MST includes ρ-wave logger devices and a meter that determines volume magnetic susceptibility. A digital camera is also attached to the MST to colour photograph the core.

Figure 8 As part of the 4th Floating University's practicals micro- and macro-organism sampling was carried out using plankton nets.

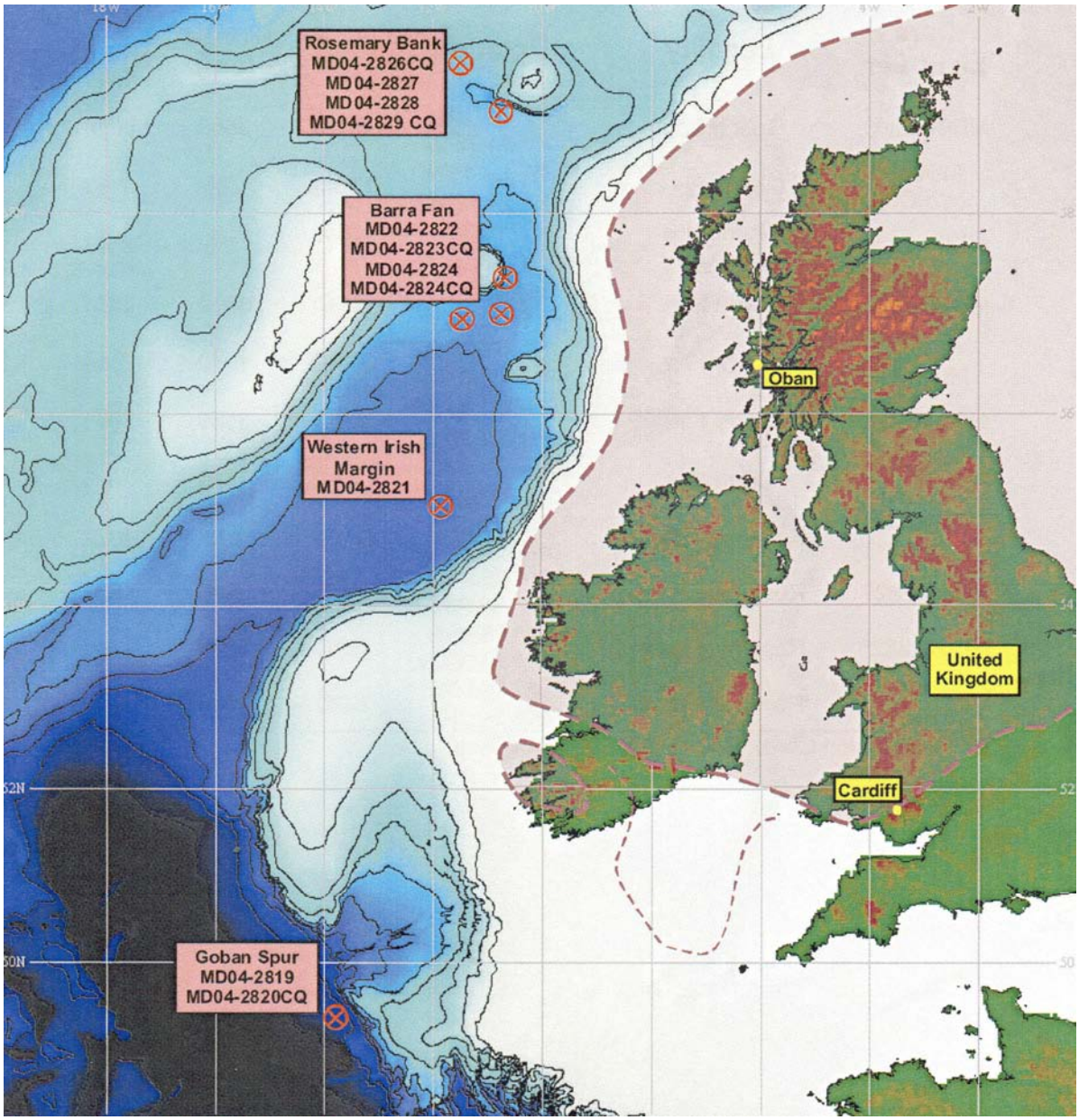


Figure 9 SEQUOIA core locations. The shaded area shows the approximate location of the British sector of the European Ice Sheet during the last glacial maximum. (Taken from SEQUOIA notes supplied by Dr. I. Hall and Dr. J. Scourse)

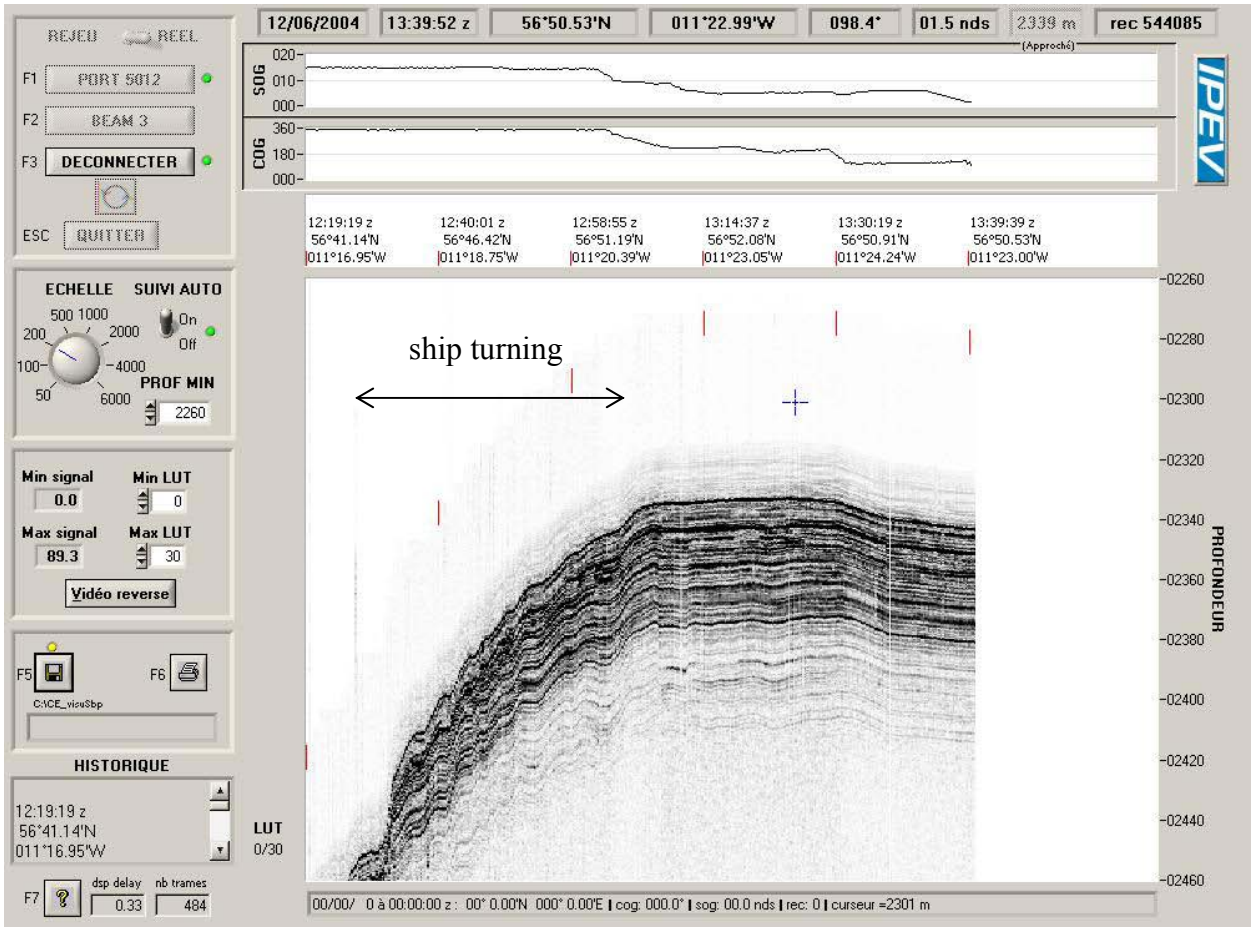


Figure 10 Reconnaissance 3.5 kHz pinger survey over the BGS sample site. The image shows acoustically well-layered sediments and the final sample site was chosen based on this data.

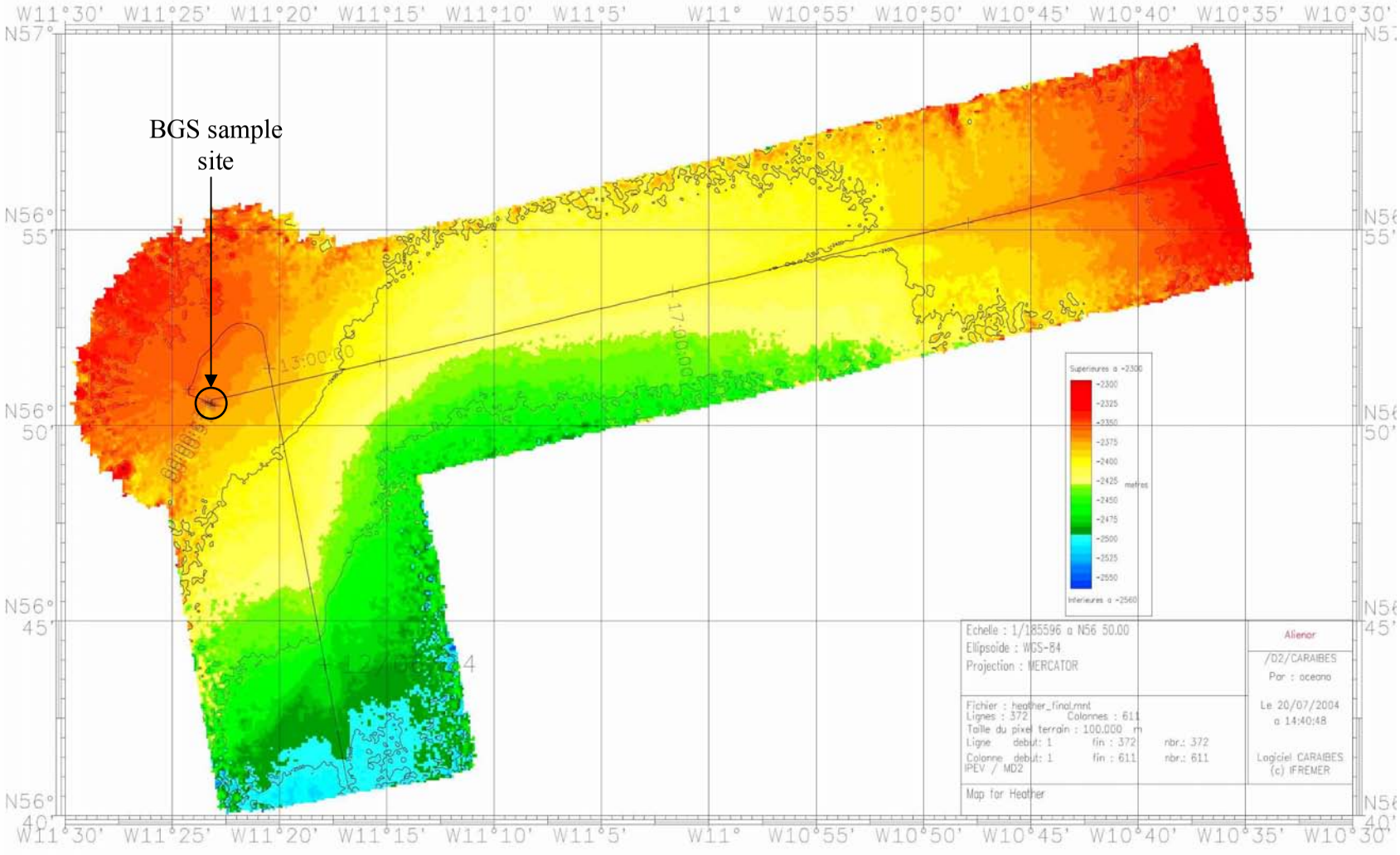


Figure 11 TSM 5265 Multibeam Echosounder Data collected over the BGS sample site. The colour shading indicates the presence of deeper water to the south of the sample site and shallower water to the far east with a depression in between.

Appendix 1

Sample Sheet Descriptions for BGS sample +56-12/14 (MD04-2822). Completed by Heather Stewart.

SAMPLE STATION DATA

BRITISH GEOLOGICAL SURVEY — MARINE OPERATIONS

SAMPLE NO. F (1) +56 (± lat) -12 (± long) 14 (no.) (11)

CRUISE NO. 04 MD (year : ship : no 18)

DATE 06 12 (mnth : day 22)

TIME (local) 14 43 (hrs : mins 26)

WATER DEPTH 2305 metres (30)

POSITION FIXING METHOD H

COMMENT (32)

NAVIGATIONAL READINGS (tick lanes with best intersection)

CHAIN

RED (41)

GREEN (48)

PURPLE (55)

POSITION

LATITUDE +56 50·54 (± degs : mins (decimal) 63)

LONGITUDE -11 22·96 (± degs : mins (decimal) 71)

ADDITIONAL INFORMATION :

MARION DUFRESNE CRUISE SAMPLE NUMBER MD 04-2822

CALYPSO GIANT PISTON CORER

EQUIPMENT TYPE: 1 = sample recovered; 2 = no sample (geological reasons); 3 = no sample (equipment failure); 4 = no sample (undifferentiated)

G (1) dup cols 2–11

GS | VE | CS | CR | DM | DR | BH | SD | RD | SU | PS | DI | BS | OC | OG | PISTON CORER

1 (12–32)

T.D. metres 3707 (50–55)

SUMMARY SAMPLE DESCRIPTION : (Free text – max. 69 characters)

H (1) dup cols 2–11

INTERBEDDED CLAY & SILTY MUD WITH (12–40)

OCCASIONAL DROPSTONES & MOTTLED OOZE (50–80)

GEOTECHNICAL DATA :

RAW DATA

PENETROMETER: Head | Readings

HAND VANE: Head | Readings

AVERAGED DATA

DEPTH | PENETROMETER (KPa) | HAND VANE (KPa)

I (1) dup cols 2–11

14 | 18 | 22

25 | 29 | 33

36 | 40 | 44

47 | 51 | 55

58 | 62 | 66

69 | 73 | 77

I (1) dup cols 2–11

14 | 18 | 22

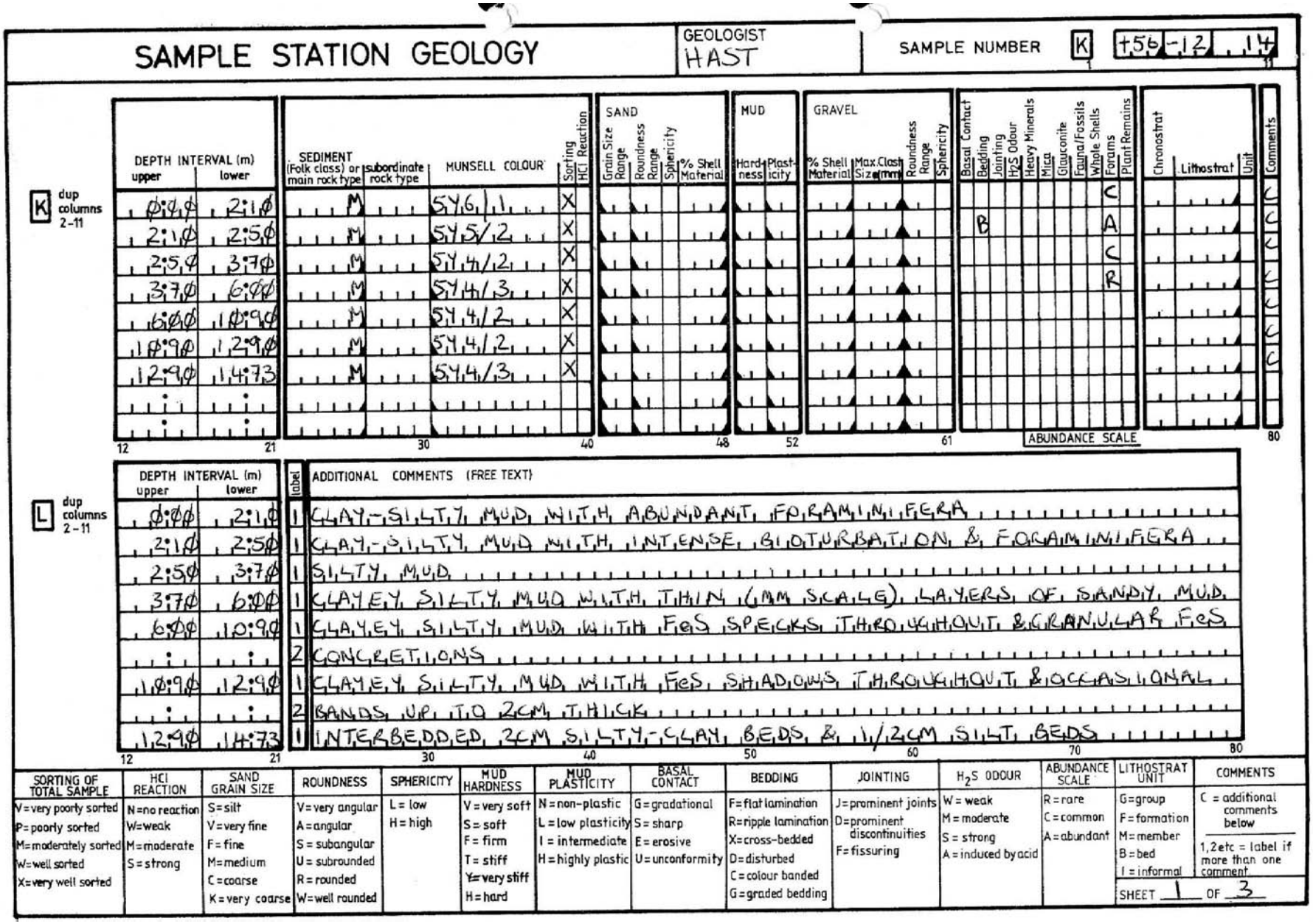
25 | 29 | 33

36 | 40 | 44

47 | 51 | 55

58 | 62 | 66

69 | 73 | 77



SAMPLE STATION GEOLOGY

GEOLOGIST: HAST

SAMPLE NUMBER: K 456-12.14

K dup columns 2-11

DEPTH INTERVAL (m) upper	lower	SEDIMENT (Folk class) or main rock type	subordinate rock type	MUNSELL COLOUR	Sorting	HCl Reaction	SAND Grain Size Range	Roundness Range	Sphericity	% Shell Material	MUD Hardness	Plasticity	GRAVEL % Shell Material	Max. Clast Size (mm)	Roundness Range	Sphericity	Basal Contact	Bedding	Jointing	H_2S Odour	Heavy Minerals	Mica	Glauconite	Fauna/Fossils	Whole Shells	Forams	Plant Remains	Chronostrat	Lithostrat	Unit	Comments
0:0ϕ	2:1ϕ	M		5Y 6/1	X																					C					
2:1ϕ	2:5ϕ	M		5Y 5/2	X													B								A					
2:5ϕ	3:7ϕ	M		5Y 4/2	X																					C					
3:7ϕ	6:0ϕ	M		5Y 4/3	X																					R					
6:0ϕ	10:9ϕ	M		5Y 4/2	X																										
10:9ϕ	12:9ϕ	M		5Y 4/2	X																										
12:9ϕ	14:73	M		5Y 4/3	X																										

12 21 30 40 48 52 61 ABUNDANCE SCALE 80

L dup columns 2-11

DEPTH INTERVAL (m) upper	lower	label	ADDITIONAL COMMENTS (FREE TEXT)
0:0ϕ	2:1ϕ	1	CLAY-SILTY MUD WITH ABUNDANT FORAMINIFERA
2:1ϕ	2:5ϕ	1	CLAY-SILTY MUD WITH INTENSE BIOTURBATION & FORAMINIFERA
2:5ϕ	3:7ϕ	1	SILTY MUD
3:7ϕ	6:0ϕ	1	CLAYEY SILTY MUD WITH THIN (MM SCALE) LAYERS OF SANDY MUD
6:0ϕ	10:9ϕ	1	CLAYEY SILTY MUD WITH FeS SPECKS THROUGHOUT & GRANULAR FeS
		2	CONCRETIONS
10:9ϕ	12:9ϕ	1	CLAYEY SILTY MUD WITH FeS SHADOWS THROUGHOUT & OCCASIONAL
		2	BANDS UP TO 2CM THICK
12:9ϕ	14:73	1	INTERBEDDED 2CM SILTY-CLAY BEDS & 1/2CM SILT BEDS

12 21 30 40 50 60 70 80

SORTING OF TOTAL SAMPLE	HCl REACTION	SAND GRAIN SIZE	ROUNDNESS	SPHERICITY	MUD HARDNESS	MUD PLASTICITY	BASAL CONTACT	BEDDING	JOINTING	H_2S ODOUR	ABUNDANCE SCALE	LITHOSTRAT UNIT	COMMENTS
V=very poorly sorted	N=no reaction	S=silt	V=very angular	L=low	V=very soft	N=non-plastic	G=gradational	F=flat lamination	J=prominent joints	W=weak	R=rare	G=group	C=additional comments below
P=poorly sorted	W=weak	V=very fine	A=angular	H=high	S=soft	L=low plasticity	S=sharp	R=ripple lamination	D=prominent discontinuities	M=moderate	C=common	F=formation	1,2etc=label if more than one comment
M=moderately sorted	M=moderate	F=fine	S=subangular		F=firm	I=intermediate	E=erosive	X=cross-bedded	F=fissuring	S=strong	A=abundant	M=member	
W=well sorted	S=strong	M=medium	U=subrounded		T=stiff	H=highly plastic	U=unconformity	D=disturbed		A=induced by acid		B=bed	
X=very well sorted		C=coarse	R=rounded		Y=very stiff			C=colour banded				I=informal	
		K=very coarse	W=well rounded		H=hard			G=graded bedding					SHEET 1 OF 3

SAMPLE STATION GEOLOGY

GEOLOGIST: HAST

SAMPLE NUMBER: K +56 -12 . . 14

K dup columns 2-11

DEPTH INTERVAL (m) upper	lower	SEDIMENT (Folk class) or main rock type	subordinate rock type	MUNSELL COLOUR	Sorting	HCl Reaction	SAND Grain Size Range	Roundness Range	Sphericity	% Shell Material	MUD Hardness	Plasticity	GRAVEL % Shell Material	Max. Clast Size (mm)	Roundness Range	Sphericity	Basal Contact	Bedding	Jointing	H_2S Odour	Heavy Minerals	Mica	Glauconite	Fauna/Fossils	Whole Shells	Forams	Plant Remains	Chronostrat	Lithostrat	Unit	Comments
14:73	19:36	M		5Y 4/3	X																										C
19:36	20:05	M		5Y 5/2	X																										C
20:05	23:41	M		5Y 4/2	X																										C
23:41	23:60	M		5Y 4/1	X																										C
23:60	23:77			5Y 7/3	X		V																								C
23:77	23:82	M		5Y 5/2	X																										C
23:82	24:02			5Y 6/2	X		V																								C

12 21 30 40 48 52 61 ABUNDANCE SCALE 80

L dup columns 2-11

DEPTH INTERVAL (m) upper	lower	label	ADDITIONAL COMMENTS (FREE TEXT)
14:73	19:36	1	FeS LAYERS & INTERBEDDED SILT LAYERS (SOMETIMES ABSENT)
19:36	20:05	1	CLAYEY SILTY MUD LIGHTENING IN COLOUR DOWNWARDS WITH
		2	OCCASIONAL DARK HORIZON, DROPSTONE AT APPROX 19.73 M
20:05	23:41	1	CLAYEY, SILTY MUD WITH OCCASSIONAL FeS & SILT BAND, DROPSTONE
		2	AT APPROX 20:9.2 & 22:8.6 M
23:41	23:60	1	CLAYEY SILTY MUD
23:60	23:77	1	OOZE WITH PURPLE & GREEN MOTTLING
23:77	23:82	1	CLAYEY SILTY MUD
23:82	24:02	1	OOZE

12 21 30 40 50 60 70 80

SORTING OF TOTAL SAMPLE	HCl REACTION	SAND GRAIN SIZE	ROUNDNESS	SPHERICITY	MUD HARDNESS	MUD PLASTICITY	BASAL CONTACT	BEDDING	JOINTING	H_2S ODOUR	ABUNDANCE SCALE	LITHOSTRAT UNIT	COMMENTS
V = very poorly sorted	N = no reaction	S = silt	V = very angular	L = low	V = very soft	N = non-plastic	G = gradational	F = flat lamination	J = prominent joints	W = weak	R = rare	G = group	C = additional comments below
P = poorly sorted	W = weak	V = very fine	A = angular	H = high	S = soft	L = low plasticity	S = sharp	R = ripple lamination	D = prominent discontinuities	M = moderate	C = common	F = formation	1,2 etc = label if more than one comment
M = moderately sorted	M = moderate	F = fine	S = subangular		F = firm	I = intermediate	E = erosive	X = cross-bedded	F = fissuring	S = strong	A = abundant	M = member	
W = well sorted	S = strong	M = medium	U = subrounded		T = stiff	H = highly plastic	U = unconformity	D = disturbed		A = induced by acid		B = bed	
X = very well sorted		C = coarse	R = rounded		Y = very stiff			C = colour banded				I = informal	
		K = very coarse	W = well rounded		H = hard			G = graded bedding					

SHEET 2 OF 3

SAMPLE STATION GEOLOGY

GEOLOGIST: HAST

SAMPLE NUMBER: K +56 -13 .14

K dup columns 2-11

DEPTH INTERVAL (m) upper	lower	SEDIMENT (Folk class) or main rock type	subordinate rock type	MUNSELL COLOUR	Sorting	HCl Reaction	SAND Grain Size Range	Roundness Range	Sphericity	% Shell Material	MUD Hardness	Plasticity	GRAVEL % Shell Material	Max. Clast Size (mm)	Roundness Range	Sphericity	Basal Contact	Bedding	Jointing	H_2S Odour	Heavy Minerals	Mica	Glauconite	Fauna/Fossils Whole Shells	Forams	Plant Remains	Chronostrat	Lithostrat	Unit	Comments
24.02	24.09	M		5Y 4/4	X																				C					C
24.09	24.40			5Y 3/1	X		V																		C					C
24.40	24.65	M		5Y 5/2	X																				C					C
24.65	25.24			5Y 3/1	X		V										B								C					C
25.24	25.79	M		5Y 4/1	X																									C
25.79	37.70	M		5Y 4/2	X																									C

12 21 30 40 48 52 61 ABUNDANCE SCALE 80

L dup columns 2-11

DEPTH INTERVAL (m) upper	lower	label	ADDITIONAL COMMENTS (FREE TEXT)
24.02	24.09	1	CLAYEY, SILTY, MUD
24.09	24.40	1	MOTTLED, OOZE DARKENING DOWNWARDS FROM 5Y 3/1 TO 5Y 4/2
24.40	24.65	1	CLAYEY SILTY MUD LIGHTENING DOWNWARDS
24.65	25.24	1	MOTTLED, OOZE WITH BIOTURBATION
25.24	25.79	1	CLAYEY SILTY MUD WITH ZOOPHYCOS BANDS
25.79	37.70	1	CLAYEY SILTY MUD WITH FeS AND SILT LAYERS. 1-2CM SAND (FINE)
		2	BED PRESENT AT 33.47, 33.52 & 33.53, DROPSTONE AT 34.36M
		3	MINOR BIOTURBATION BETWEEN 36.41M & 36.59M

12 21 30 40 50 60 70 80

SORTING OF TOTAL SAMPLE	HCl REACTION	SAND GRAIN SIZE	ROUNDNESS	SPHERICITY	MUD HARDNESS	MUD PLASTICITY	BASAL CONTACT	BEDDING	JOINTING	H_2S ODOUR	ABUNDANCE SCALE	LITHOSTRAT UNIT	COMMENTS
V=very poorly sorted	N=no reaction	S=silt	V=very angular	L=low	V=very soft	N=non-plastic	G=gradational	F=flat lamination	J=prominent joints	W=weak	R=rare	G=group	C=additional comments below
P=poorly sorted	W=weak	V=very fine	A=angular	H=high	S=soft	L=low plasticity	S=sharp	R=ripple lamination	D=prominent discontinuities	M=moderate	C=common	F=formation	
M=moderately sorted	M=moderate	F=fine	S=subangular		F=firm	I=intermediate	E=erosive	X=cross-bedded	F=fissuring	S=strong	A=abundant	M=member	1,2 etc=label if more than one comment
W=well sorted	S=strong	M=medium	U=subrounded		T=stiff	H=highly plastic	U=unconformity	D=disturbed		A=induced byacid		B=bed	
X=very well sorted		C=coarse	R=rounded		~~V~~=very stiff			C=colour banded				I=informal	
		K=very coarse	W=well rounded		H=hard			G=graded bedding				SHEET 3 OF 3	

SAMPLE DESCRIPTION SHEET

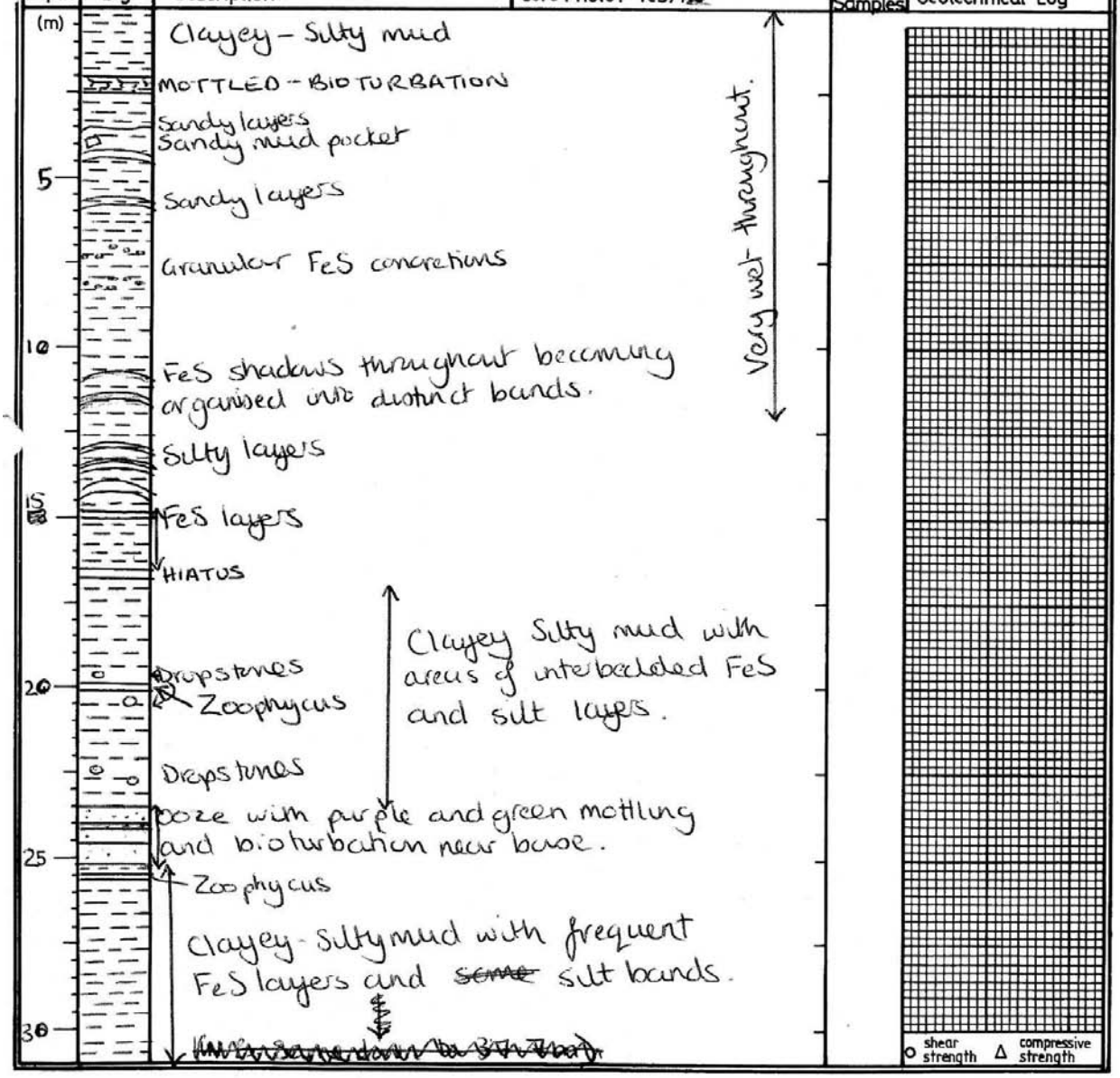
BRITISH GEOLOGICAL SURVEY — MARINE OPERATIONS

SAMPLE NO. 56 -12 14

SURFACE SAMPLE | Equipment Used: ~~CALYPSO~~ PISTON | Seabed Photo: Yes/No | Stored in: Jars, Bags.

SHEET 1 OF 2

CORE SAMPLE | Equipment Used: ~~CALYPSO~~ PISTON CORER | Stored in: Cut Cores, ✓ ~~Uncut Cores,~~ Jars, ~~Bags.~~ | Core Photo: Yes/~~No~~



SAMPLE DESCRIPTION SHEET

BRITISH GEOLOGICAL SURVEY — MARINE OPERATIONS

SAMPLE NO. +56 | -12 | 14

SURFACE SAMPLE	Equipment Used:	Seabed Photo: Yes/No	Stored in: Jars, Bags.

SHEET 2 OF 2

CORE SAMPLE	Equipment Used: PISTON CORE	Stored in: Cut Cores ✓ ~~Uncut Cores~~, ~~Jars~~, ~~Bags~~.

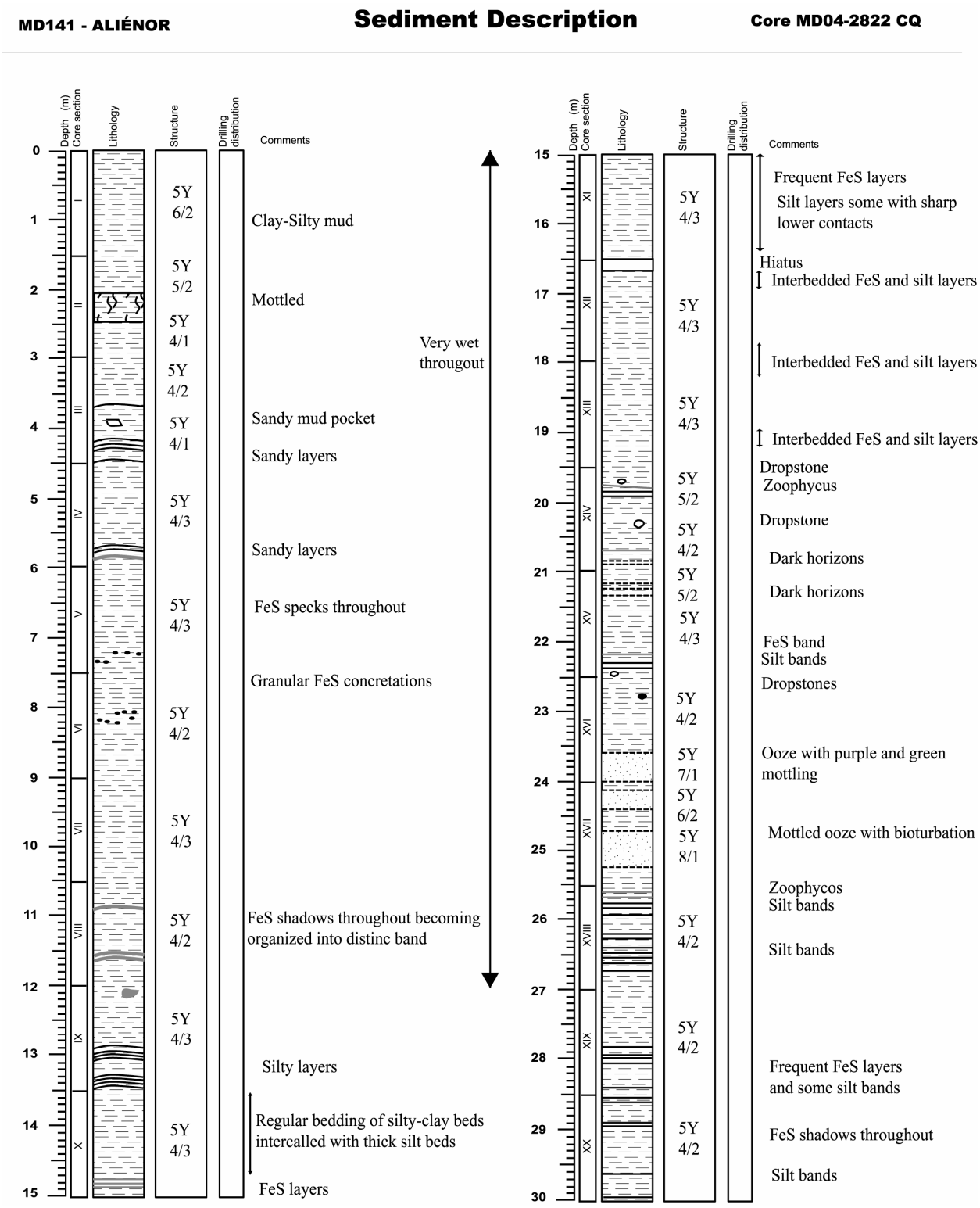
Core Photo: Yes/~~No~~

Depth (m)	Log	Description	Sub Samples	Geotechnical Log
		SEE SHEET 1 OF 2		
30		prominent FeS layers becoming thinner		clayey silty mud with frequent silt layers
		3 fine sand beds		
35		green layer		clayey silty mud
		End of core		
40				
4				
5				
6				

o shear strength Δ compressive strength

Appendix 2

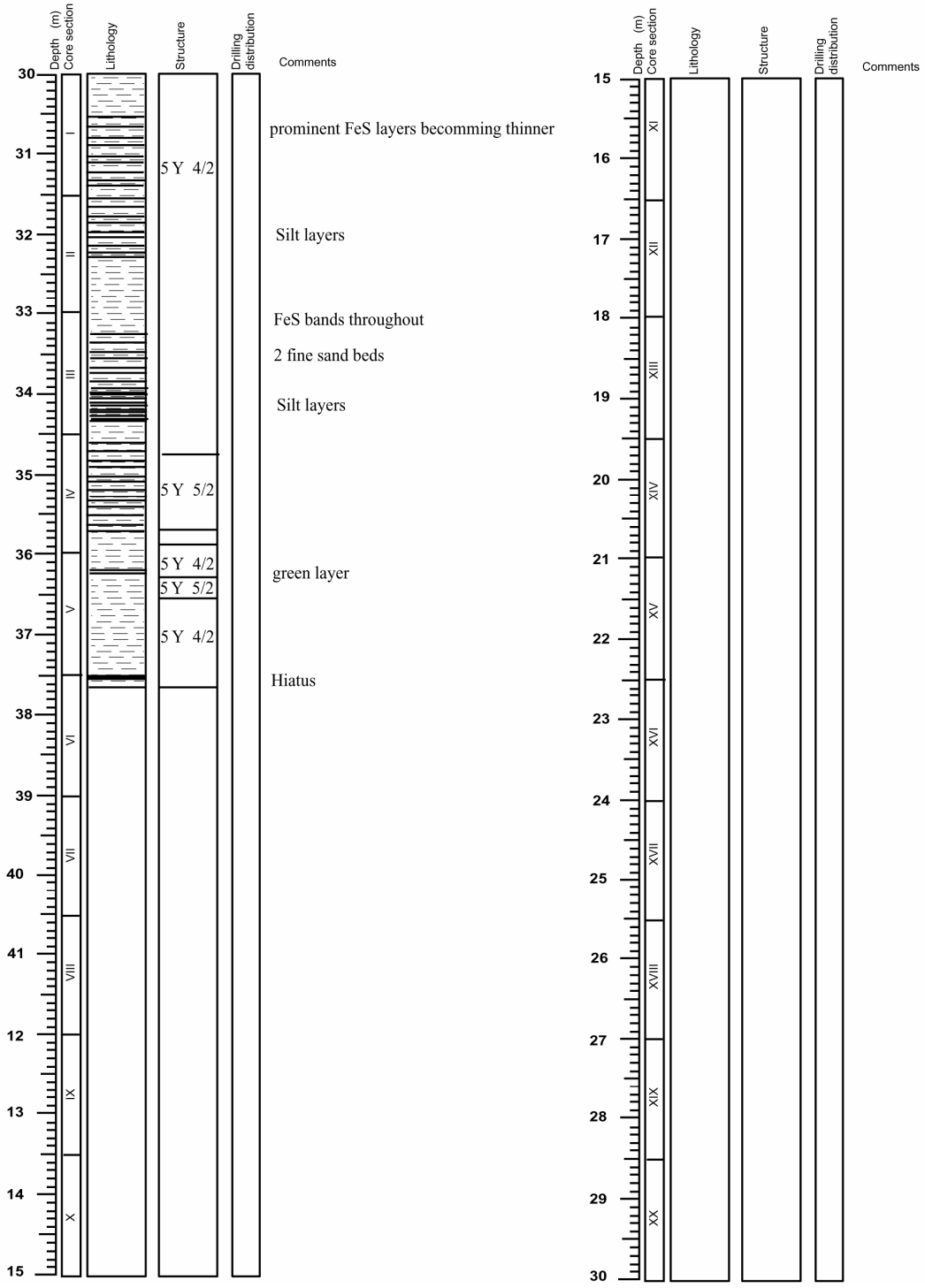
Overview core description sheet completed onboard the RV Marion Dufresne. Authors: Paul Knutz, James Scourse and Victoria Peck.



MD141 - ALIÉNOR

Sediment Description

Core MD04-2822



References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

STOKER, M S, PRAEG, D, SHANNON, P M, HJELSTUEN, B O, LABERG, J S, NIELSON, T, VAN WEERING, T C E, SEJRUP, H P and EVANS, D. 2005. Neogene evolution of the Atlantic continental margin of NW Europe (Lofoten Islands to SW Ireland): anything but passive. In *Petroleum Geology of Northwest Europe and Global Perspectives – Proceedings of the 6th Petroleum Geology Conference* (DORÉ, A G, and VINING, B A. Editors). (London: The Geological Society, London.)