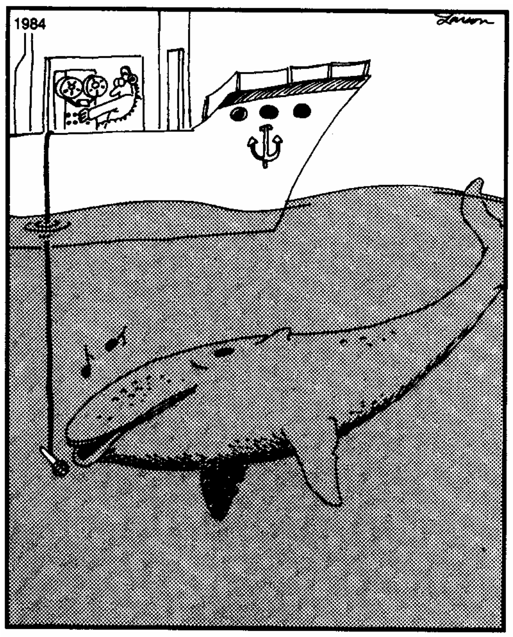
M2002 Cruise report

(R.V. Pelagia Cruise 64PE197)

A TOBI Side Scan Sonar Survey of Cold Water Coral Carbonate Mounds in the Rockall Trough and Porcupine Sea Bight

21 June – 14 July 2002
Texel-Southampton-Galway



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Andy Wheeler
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and shipboard scientific crew

Royal Netherlands Institute for Sea Research

Cover illustration: Gary Larson

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Summary and acknowledgements

The M2002 cruise was carried out with the Royal Netherlands Institute for Sea Research (NIOZ) owned R.V. Pelagia from 21 June to 14 July 2002. The purpose of the cruise was to record TOBI (Towed Ocean Bottom Instrument) side scan sonar data over various areas in the Porcupine Sea Bight and Rockall Trough (NE Atlantic Ocean) characterised by the presence of cold water coral carbonate mounds.
The carbonate mounds are buildups of up to 300 m above the surrounding sea bed consisting of mainly biogenic carbonate debris (cold water corals Lophelia pertusa, Madrepora occulata and other corals, foraminifera, etc.). The summits of the mound are covered with patches of living Lophelia pertusa, Madrepora occulata and associated fauna. The exact process of mound formation is not entirely clear yet. Several mechanisms have been proposed. One mechanism suggests the mounds to represent modern carbonate knolls, made up of active bioherms or living carbonate reefs composed of ahermatypic corals, possibly developed through seepage of hydrocarbons from below through faults and fissures. This cold seepage in turn would lead to a higher than normal concentration of bacteria and micro-organisms at the seabed and in the water immediately above, and would have a significant influence on local benthic community development. Prolonged seepage then would result in local accumulation of organisms, the accumulation of skeletal debris and formation of authigenic carbonate , and ultimately in the development of the carbonate mounds. Another suggested mechanism is that currents support abundant living corals and organisms by causing enhanced particulate and organic matter concentrations in the benthic boundary layer.

The carbonate mounds are studied within the framework of the European Union 5th Framework research projects GEOMOUND and ECOMOUND which form part of the OMARC cluster with amongst others the ACES project, which is also devoted to the study of these mounds.
Earlier cruises studying the mounds are ENAM99, M2000 and M2001 (with R.V. Pelagia, NIOZ), two with the research vessel Belgica (2000 and 2001, RCMG, Univ, Ghent), TTR7 (1997, Professor Logachev, MSU) and the CARACOLE cruise with R.V. l'Atalante (2001, IFREMER).

The main task of this cruise, the TOBI side scan sonar survey, was performed without any major problems. Three main research areas were visited: W and N Porcupine Seabight, SE Rockall Trough margin, and the SW Rockall Trough margin. Nearly the entire planned survey could be performed with only very little downtime of the instrument. In general the weather was favourable for side scan sonar recording (relatively low wind strength) resulting in high quality imagery with a high signal to noise ratio.
Besides performing the TOBI survey, a BOBO (Bottom Boundary) lander was recovered at the SW Rockall Trough margin. This lander was deployed on 5 July 2001 during the M2001 cruise (station M2001-28). Furthermore a seabed camera system was tested and some box cores were taken.

The principal scientists of this cruise would like to thank the captain and crew of the R.V. Pelagia for their assistance during the cruise and the SOC TOBI team for their continuous efforts to produce the best possible data and on board processing.
This cruise was undertaken with financial support of the European Union (EASSS III program) and the Porcupine Studies Group (PSG) of the Irish Petroleum Infrastructure Programme Group 3. The PSG comprises: Agip Ireland BV, Chevron UK Ltd, Elf Petroleum Ireland BV, Enterprise Energy Ireland Ltd, Marathon International Hibernia Ltd, Phillips Petroleum Company United Kingdom Ltd, Statoil Exploration (Ireland) and the Petroleum Affairs Division of the Irish Department of Communications, Marine and Natural Resources.
Detailed bathymetric data of the survey sites was supplied by Andreas Beyer and Hans-Werner Schenke (AWI-Bremerhaven) and the Geological Survey of Ireland.

Introduction

Background

The cruise described in this report was organized as an additional cruise to the planned cruises within the European Union sponsored GEOMOUND and ECOMOUND research projects. These projects form together with the ACES project a group of projects that study the geological, biological and environmental aspects of the carbonate mounds and associated corals and other fauna that are found along the European Atlantic continental margin from the Portugal to northern Norway.
Carbonate mound reefs have been features of of Earth history ever since Cambrium times. These mounds frequently form giant reservoir rocks for hydrocarbon accumulations. However, their formation and environmental controls are the subject of much discussion and disagreement. The discovery of modern coral covered carbonate mounds along the European continental margin provides an opportunity to study the processes that create carbonate mounds.
This cruise was partly funded by the European Access to Sea Floor Survey Systems (EASSS III), contract number HPRI-CT-1999-00047 (contract held by the Southampton Oceanography Centre, SOC) and the Porcupine Studies Group (PSG) of the Irish Petroleum Infrastructure Programme Group 3. The PSG comprises: Agip Ireland BV, Chevron UK Ltd, Elf Petroleum Ireland BV, Enterprise Energy Ireland Ltd, Marathon International Hibernia Ltd, Phillips Petroleum Company United Kingdom Ltd, Statoil Exploration (Ireland) and the Irish Petroleum Affairs Division.

The GEOMOUND project focuses on the geological evolution of giant deep-water carbonate mounds in the Porcupine Sea Bight and southern Rockall Trough off western Ireland and the United Kingdom. The objectives of this project are:

1. To produce a systematic inventory and data set of recorded giant mound occurences in the selected areas (from industrial data and surveys by the project team), documenting morphologies, structural associations, patterns and temporal relationships which might identify the underlying geological control point on the genesis of mounds and on their sustained or episodic growth.
2. In the light of available data, critically evaluate relevant hypotheses and test the diagnostic value of such mounds as potential indicators for hydrocarbons and for fluid expulsion events, delivering a genuine experimental validation scheme.
3. Develop a model for the fluid migration path processes, which might have fuelled surface vents in the considered mound provinces, and elucidate their chronology.
4. Prepare and define the terms of reference foe a conclusive Ocean Drilling action.

More information on the GEOMOUND project can be found on the project website: http://geomound.ucd.ie

ECOMOUND tries to relate the mounds to the environmental parameters. The objectives of this program are to define the environmental controls and processes involved in the development and distribution of carbonate mounds on the NW European continental margin through:

1. Establish the relationship between carbonate mound biota and recent water mass characteristics and dynamics, as well as with sedimentological properties of the surrounding seabed.
2. Based on growth rates of mound biota, a high-resolution record of recent short-term watermass composition and variability will be obtained based on stable isotope analyses of "well-dated" benthic carbonate skeletons. This will allow a better understanding of the effects of environmental forcing factors and their variability.
3. Differentiate between carbonate mounds and mud mounds and to determine whether they are indicators for hydrocarbon resources.

Information on ECOMOUND is available on:
http://www.geomar.de/projekte/ecomound

Geological setting

The present day morphology of the eastern Atlantic margin largely results from the rifting activities during the Mesozoic which resulted in the formation of the North Atlantic Ocean. The topographic highs and lows west of Ireland and the British Isles (Porcupine Seabight, Porcupine Bank, Rockall Trough, Rockall Bank, Hatton-Rockall Basin and Hatton Bank) are the product of several succesively failed attempts to extend the axis of mid-Atlantic sea-floor spreading to the north east. Porcupine Seabight, Rockall Trough and Hatton-Rockall Basin are the remainders of abandoned (initial) spreading centres, leaving Porcupine, Rockall and Hatton Bank as topographic highs. Syn- and postrifting (Mesozoic to Quaternary) sedimentary covering finally resulted in the present day morphology of the area (Naylor and Mounteney, 1975). The Rockall Trough margins and basin floor sediments are effected by small to large scale slope failure processes (Flood et al., 1979; Dingle et al., 1982; Kenyon, 1987). In the Rockall Trough and Hatton-Rockall Basin extensive sediment drifts are present wich were formed under the influence of North Atlantic Deep Water, Norwegian Sea Deep Water and Labrador Sea Water. The largest of these drift is the Feni Drift. The formation of these sediment bodies started during the Eocene (Stoker, 1998). From the shelf edge west of Ireland and Great Britain the continental slope deepens to a maximum depth of around 3000 m in the southeast Rockall Trough. In the northern part of the Rockall Trough, between Scotland and the islet of Rockall the maximum water depth is about 2 km. The top of Rockall Bank, bordering Rockall Trough in the west, is between 500 and 200 m below sealevel, with only Rockall islet emerging in the north. In the northern Rockall Trough seamounts are present with their tops around five to six hundred metres below sealevel. In the south Rockall Trough deepens into the almost 5 km deep Porcupine Abyssal Plain. Feni Drift is located along the western Rockal Trough margin as a northeast to southwest elongated body. Its maximum width is in the order of 125 km. The maximum crest height is about 2100 m below the sea surface.
An overview of the oceanographic circulation in the northeastern Atlantic Ocean is given by van Aken and Becker (1996). The Rockall Trough forms one of the gateways of relatively warm surface waters flowing to the north, and cold deep water flowing south, and thus is an important transport path in the global thermo-haline circulation. Subpolar Mode Water flows northwards through the Rockall Trough. In the north this flow is split into two branches, one

flowing across the Wyville-Thomson Ridge into the Faeroe-Shetland Channel and one flowing more to the northwest around the Faeroe Islands. The deep waters of Rockall Trough are composed of Labrador Sea Water between about 1200 and 1800 m. At greater depth, cold Norwegian Sea Overflow Water, flowing over the Wyville-Thomson Ridge into the Rockall Trough, moves southwards along the western Rockall Trough margin over Feni Drift. Lower Deep Water partly enters the southern Rockall Trough along the eastern margin. Around 56°N it turns southwards to join the Norwegian Sea Overflow Water.
The Porcupine Seabight is a dynamic area where hydrocarbons have been found and good quality oils have been flowed from test wells (Croker and Shannon, 1995). Its sedimentary environment is characterised by drift deposits (Van Rooij et al., subm.) and channel-and-levee complexes (Kenyon et al., 1978), influenced by the northward flowing 'slope current' which follows the North Atlantic continental slope contours (White, 2001).

Carbonate mounds

Mound structures with a cross section between 100-1800 m at their basis, and rising over 100 m above the seabed and surrounded by a circular depression of 60-90 m deep were noticed recently in the Porcupine Bight in water depths of 650-1200 m.
These mounds were suggested to represent modern carbonate knolls, made up of active bioherms or living carbonate reefs composed of ahermatypic corals, possibly developed through seepage of hydrocarbons from below through faults and fissures (Hovland et al., 1994). This cold seepage in turn would lead to a higher than normal concentration of bacteria and micro-organisms at the seabed and in the water immediately above, and would have a significant influence on local benthic community development (Hovland and Thomsen, 1989, 1997; Hovland, 1998). Prolonged seepage then would result in local accumulation of organisms, the accumulation of skeletal debris and formation of authigenic carbonate , and ultimately in the development of the carbonate mounds. Recently Hovland (1998) proposed that the cold water carbonate reefs with their numerous and rich fauna, would represent a final phase in a natural seep sealing process, after which the ecosystem would be maintained in equilibrium with extant conditions at the seabed.
A comparable relationship between hydrocarbon seepage and the formation of carbonate knolls, mounds and massive carbonate build ups, covered with corals and extensive, deviating from normal, benthic community development as advocated above is well known from cold seeps and vents in the Gulf of Mexico (see overview in Aharon, 1994). Similar processes take place in the case of gashydrate/clathrate dissociation, as recently illustrated by the studies of the Hakon Mosby Mud Volcano complex (Gardner and Vogt, 1999).
By contrast, Kenyon et al. (1998) argue on the basis of sidescan sonar and underwater TV records that current induced structures around the mounds are evident. They suggest that these currents would support abundant living corals and organisms by causing enhanced particulate and organic matter concentrations in the benthic boundary layer. The TOBI side scan sonar data collected in 1998 from the Porcupine Bank margin indeed show an erosional moat in the front and along the rim of the mounds, with subsequent

sedimentation in the lee side of the mount (O'Reilly et al., 2000). Line ORAT 13 and derived side scan sonar mosaic collected by TTR-7 over part of the SW Rockall Trough carbonate mounds also shows current induced, westward directed sediment transport (Kenyon et al., 1998).
Similarly, the distribution of Lophelia (200-500 m depth) around the Faeroe margin and banks is considered to be due to enhanced food supply by topography induced resuspension on the slope, forced by internal waves or strong currents (Frederiksen et al., 1992) rather than by hydrocarbon seepage. Near-bed current velocity- and turbidity measurements in any of the areas indicated above however, are rare and show variation of current velocities between 1-100 cm s^{-1}. These observations might indicate that the SW and SE Rockall Trough mounds, after their initial formation due to seepage, now have reached a state of maturity and form a habitat for a specific benthic faunal community, supporting the opinion of Hovland (1998).

The cruise

This cruise was organised by the Royal Netherlands Institute for Sea Research (NIOZ, Texel, The Netherlands), the Department of Geology of the University College Cork (UCC, Cork, Ireland), the Renard Centre of Marine Geology of the University of Ghent (RCMG, Ghent, Belgium) and the Southampton Oceanography Centre (SOC, Southampton, United Kingdom). A list of participants is shown in Appendix 1.
TOBI side scan surveys where carried out in selected areas in the Porcupine Sea Bight and Rockall Trough (see Fig. 1). The areas where chosen based on the results of earlier cruises carried out within the framework of the GEOMOUND, ECOMOUND, ACES and ENAM (European North Atlantic Margin) projects (ENAM98, ENAM99, M2000, M2001 (all with R.V. Pelagia), CARACOLE (2001, R.V. l'Atalante), and several cruises with the R.V. Belgica (2000, 2001) and partly to fit in with existing TOBI data recorded earlier at the Rockall Trough margins (TRIM)). Although a large data set on the mounds is available from previous cruises, the extensive study of this subject lacked a general overview map giving an idea of the setting of the mounds. Therefore a project was set up within the European Programme for Access to Large Scale Facilities/EASSS, on behalf of the partners of the European projects GEOMOUND and ECOMOUND. The Pelagia M2002 cruise, recording TOBI sidescan sonar data in the Porcupine Seabight and Rockall Trough filled the gap in the data. The main topics of this cruise were :

1) A full coverage of the 3 mound provinces in the Porcupine Seabight: the Belgica mounds on the slightly steeper eastern flank of the Seabight; the Hovland province, containing fairly large and complex mound structures; and the Magellan province, comprising mainly buried mounds, of which many however have a faint expression at the seabed (due to differential compaction and draping effects of the burying sediment).
2) A reconnaissance survey over the heads of the Gollum Channels, in the area covered by the Polarstern multibeam data set. This impressive deepsea canyon system has been studied briefly during the TTR 7 cruise (Kenyon *et al.*, 1998) and also with a submersible (Tudhope & Scoffin, 1989).
3) A coverage of the mounds on the SW Rockall Trough margin, with the aim to investigate the morphology and relationship to local current conditions of the

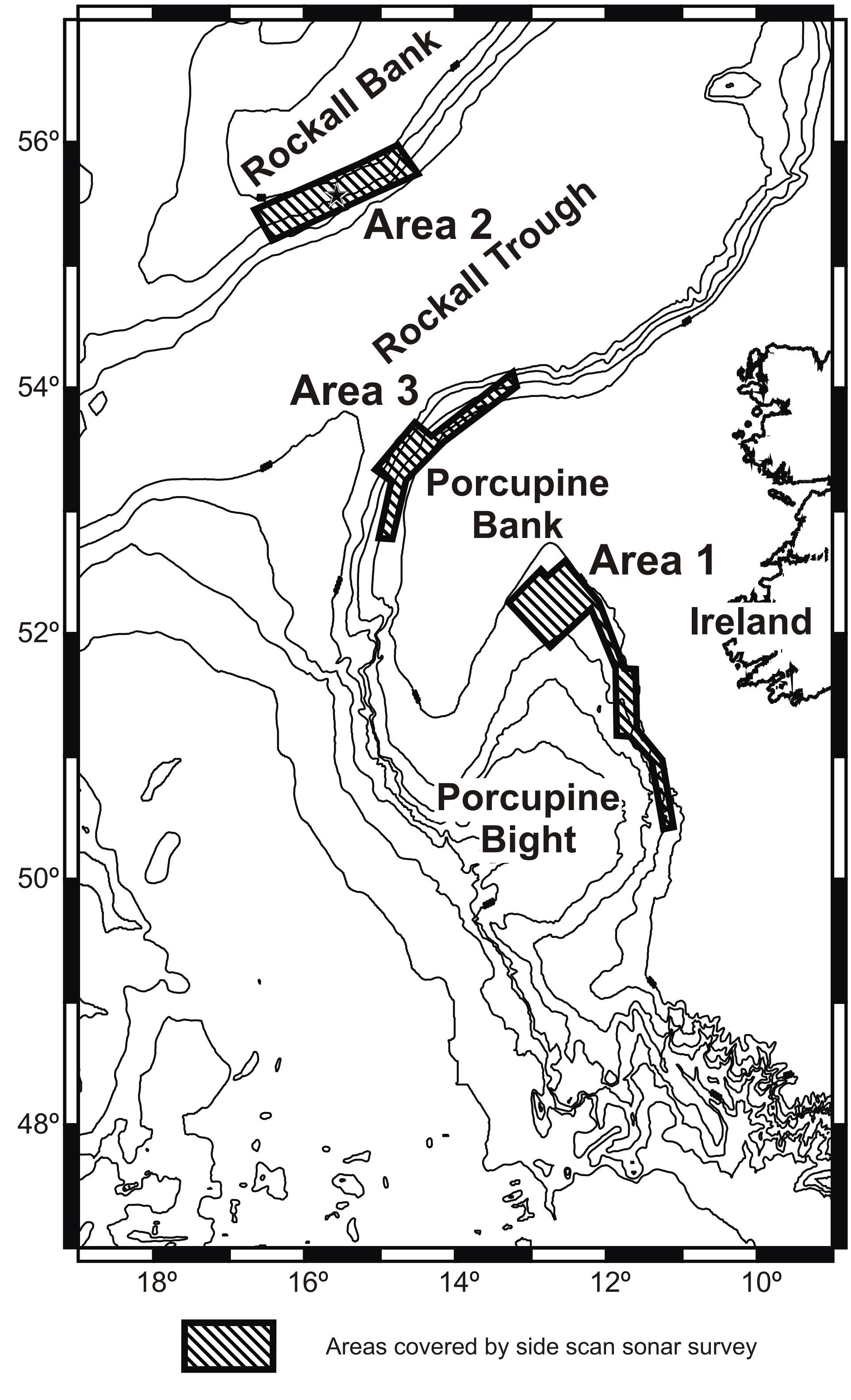

Fig. 1. Map of the Porcupine Bight and Rockall Trough area with research areas indicated.

complicated clustered mound complexes in this area (van Weering et al submitted; de Haas et al., 2000; de Stigter and de Haas, 2001; de Haas et al., in prep.; de Stigter et al., in prep.).

4) Covering the mounds on the SE Rockall Trough and study their morphology and the relationship to local current conditions. These are usually single mounds opposed to the mounds on the SW Rockall Trough margin (van Weering et al submitted; de Haas et al., 2000; de Stigter and de Haas, 2001; de Haas et al., in prep.; de Stigter et al., in prep.).

Although the start of this cruise was initially planned to be at July 20, due to technical problems R.V. Pelagia left Texel on June 21 in the afternoon with three members of the scientific crew on board. The ship arrived in Southampton on the evening of June 22. TOBI was loaded the following day and the remaining scientific crew came on board. The same day (June 23) R.V. Pelagia left Southampton harbour in the late afternoon and set course to the first area of interest, the western and northern Porcupine Sea Bight. From June 25 to July 2 side scan sonar data was recorded in this area. Operations in this area where abandoned before all planned lines could be recorded because of expected strong winds. If recording would have been continued then the recording would have ended during a sea state in which it is impossible to recover TOBI, so valuable time would have been lost. After this period of shorter then planned, but nearly flawless recording TOBI was recovered and Pelagia headed towards the SW Rockall Trough margin where the operations started on July 3. Unfortunately immediately after deployment a malfunction in the umbilical came to light and TOBI had to be recovered and a spare umbilical was installed. TOBI operations continued until July 8 when the side scan sonar was recovered and course was set towards the BOBO lander site. Recovery of BOBO went smoothly. Unfortunately the ADCP (acoustic doppler current profiler) with which the lander was equipped, appeared to have stored data over only a limited extend of time and most of it was of bad quality. On July 9 side scan sonar operations started on the SE Rockall Trough margin and continued until July 12 when the Pelagia returned to the northern Porcupine Sea Bight to record some additional short lines where mounds where expected to be present based on observations made earlier during the cruise. Unfortunately the weather forecast predicted an increase in wind speed to a maximum of wind force 8. This would mean that TOBI could not be recovered the next day and Pelagia would not be able to dock in Galway in time. Instead course was changed to a slightly more southern location in the northern Porcupine Bight to test a sea bed camera and take some box cores for the University of Ghent. The camera test was abandoned half way the testing because of a malfunctioning of the camera. Within the same area some box cores were taken. Box coring continued the following day (13 July), however also the boxcoring failed during the second station that day due to problems with the trigger mechanism. Since no other equipment was available, around lunch time Pelagia headed for Galway where it arrived on July 14 in the early morning.

Description of equipment and temporary results

TOBI side scan sonar

System Description:
TOBI - Towed Ocean Bottom Instrument - is Southampton Oceanography Centre's deep towed vehicle. It is capable of operating in 6000m of water. The maximum water depth encountered during the TOBI surveys during this cruise was around 1500m.
Although TOBI is primarily a sidescan sonar vehicle a number of other instruments are fitted to make use of the stable platform TOBI provides. This particular TOBI system was built for RVS in 1995 and has a different instrument suite to that of the SOC TOBI.
For this cruise the instrument complement was:

1. 30kHz sidescan sonar (Built by IOSDL)
2. 8kHz chirp profiler sonar (Built by IOSDL/SOC)
3. Three-axis fluxgate magnetometer. (Ultra Electronics Magnetics Division MB5L)
4. CTD (Falmouth Scientific Instruments Micro-CTD)
5. Pitch & Roll sensor (G + G Technics ag SSY0091)

A fuller specification of the TOBI instrumentation is given in Appendix 2. A Maplin GPS receiver provides the TOBI logging system with navigational data. An MPD 1604 9 tonne instrumented sheave provides wire out, load and rate information both to its own instrument box and wire out count signals to the logging system.
The TOBI system uses a two-bodied tow system to provide a highly stable platform for the on-board sonars. The vehicle weighs 1.8 tonnes in air but is made neutrally buoyant in water by using syntactic foam blocks. A neutrally buoyant umbilical connects the vehicle to the 600kg depressor weight. This in turn is connected via a conducting swivel to the main armoured coaxial tow cable. All signals and power pass through this single conductor.

For this cruise the SOC TOBI winch system, purchased using European funding, was utilised. This system combines tow, launch and umbilical winches onto one standard 20' container-sized base plate enabling one driver to control all operations. The winch was secured to the aft deck using a custom made base plate that made use of the container fixings on the deck of the Pelagia. This fixing method has been used on the three previous occasions that TOBI has been used on Pelagia and provides a very strong and secure mount for the 28T winch. During the surveys the winch was controlled from a remote station in the TOBI laboratory.
The deck electronic systems and the logging and monitoring systems were set up in the small laboratory on the starboard side of the ship. The TOBI replay computer was mounted in the chemistry laboratory just forward of the TOBI laboratory. As TOBI has been used previously on the ship, mobilisation was easily accomplished in less than 12 hours.

TOBI Deployments:
TOBI was launched and recovered a total of 3 times during the cruise. The times are listed below along with relevant comments:

Deployment	Start time/day	End time/day	Comments
1	11:28/176	18:28/183	First work area.
2	22:43/184	08:03/189	Second work area.
3	00:28/190	07:55/193	Third work area.

The M-O disks used and their relevant numbers, files and times are listed in Appendix 3.

The Pelagia is equipped with a wide stern mounted hydraulic 'A' frame that allows TOBI to be deployed and recovered in an athwartships position. This gives good control of the vehicle during these operations. The main sheave was used for deploying and recovering the depressor weight, a smaller block used with a ship's winch was used to deploy and recover the TOBI vehicle. The main sheave was used for towing during the survey. No problems were encountered during any of the launch or recovery operations, which is a very great credit to the deck crews involved.

TOBI Watchkeeping:
TOBI watchkeeping was split into three, four-hour watches repeating every 12 hours. Watchkeepers kept the TOBI vehicle flying at a height of ideally 350 to 400m above the seabed by varying wire out and/or ship speed. Ship speed was usually kept at 2.5 knots over the ground with fine adjustments carried out by using the winch. As well as flying the vehicle and monitoring the instruments watchkeepers also kept track of disk changes and course alterations.
The bathymetry charts of the work area were found to be quite accurate which helped immensely when flying the vehicle. The ship's ORETECH profiler was used with the SOC profiler display and control system mounted in the TOBI lab to give the watchkeepers a read out of water depth.

Instrument Performance:

Vehicle
The vehicle finished the cruise in good condition. Only a rubber bumper strip had to be taken off as it had become unstuck from the foam blocks.
The only major problem was with the original umbilical. This exhibited an intermittent open circuit that caused the vehicle to reset itself. This occurred during the first survey run. At one point the depressor was brought back on board and some checks made but the fault had 'cured itself' by then – the open circuit only manifesting itself under tension and even then only once every 24 hours or so. During deployment at the start of the second survey the umbilical was found to be open circuit so the vehicle was recovered and the umbilical swapped for the spare. No problems were experienced with the spare. Also no fault could be found with the original once it had been replaced. More investigations will be carried out at SOC when the equipment returns.

Profiler
The profiler provided excellent tracking of the seafloor to give height information for the TOBI vehicle. The results were not as good as expected although further processing could well improve upon the first replays.

Sidescan
This performed well throughout the cruise. Some slight noise was occasionally observed at far ranges usually from rain or shipping.

Magnetometer
The magnetometer functioned well throughout. The data had low noise – a few nT – and was smooth.
The magnetometer data is used to give magnetic heading of the vehicle. This has to be adjusted for magnetic variation to give true heading.
An incorrect reading of the x value was observed in the logged data every 12 seconds, which may be explained by the asynchronous nature of the A/D converter for the unit leading to readings during a sonar transmission.
No calibration of the magnetometer in the vehicle was undertaken although there should be enough data within the survey to carry one out post cruise.

CTD
The CTD unit gave no problems at all and was totally reliable: a major achievement given its recent history. The CTD data is used to give derived local sound speed and salinity.

Pitch/Roll
These were fine during the survey. It was noted that the raw output of this device is in the opposite sense to that of the SOC TOBI. This was easily overcome in software but needs to be repositioned so that there is compatibility between the systems.

Deck Unit
The system proved very reliable in operation throughout the cruise. A voltage of 320V was used to power the vehicle with a current of approximately 190mA.

Instrumented Sheave
The sheave performed mechanically very well throughout the cruise. The wire out meter proved extremely accurate, being less than 2m out at the end of each survey run.

Winch
The winch was reliable throughout the cruise. A hose was connected to the scroll of the winch to act as a washing system for the final recovery haul.

Data Recording and Display
Data from the TOBI vehicle is recorded onto 1.2Gbyte magneto-optical (M-O) disks. One side of each disk gives approximately 16 hours 9 minutes of recording time. All data

from the vehicle is recorded along with the ship position taken from the GPS receiver and wire out from the sheave. Data was recorded using TOBI programme LOG.
As well as recording sidescan and digital telemetry data LOG displays real-time slant range corrected sidescan and logging system data, and outputs the sidescan to a Raytheon TDU850 thermal recorder. PROFDISP displays the chirp profiler signals and outputs them to a Raytheon TDU850. DIGIO8A displays the real-time telemetry from the vehicle – magnetometer, CTD, pitch and roll – plus derived data such as sound speed, heading, depth, vertical rate and salinity.
LOG, PROFDISP and DIGIO8A are all run on separate computers, each having its own dedicated interface systems.
Data recorded on the M-O disks were copied onto CD-ROMs for archive and for importation into the on board image processing system.
A program called HITSCOPY was used to strip off magnetic and attitude data from the raw TOBI data files and store it in ASCII format for direct importation into a spreadsheet.
Although old the logging and display computer systems ran reliably throughout the cruise. During the third survey run it was noticed that the day number was not incrementing correctly on the logging computer. This should be updated by the GPS system. For these times the M-O data was corrected before being copied onto CD-ROMs. Further searching in the logging programme, an error was found in parsing the GPS string year information. This has now been corrected and will hopefully cure the problem.
The replay computer suffered a corrupted registry during the first week of the cruise. Despite many efforts to re-install the software, due to a lack of a Windows 98 system disk, Windows 2000 had to be installed as the operating system. Although this was fine for regular tasks such as copying M-O disks to CD-ROM, it did not allow running of the old DOS replay programmes. A dual boot system was eventually installed to allow the older programmes to run under DOS.

TOBI Image Processing:

Onboard processing equipment during this cruise consisted of a UNIX workstation (SUN ULTRA 10) with 36Gb of disk space. Final maps containing side-scan sonar imagery were plotted on an A0 plotter. All data were also archived using Exabyte tapes and CD-ROM (via a networked PC).

The ship's navigation was recorded online on a UNIX server of the ship. The data were transferred on a daily basis and then tested for time-continuity and abnormal speed values. It was noticed that the ship's GPS positions were not recorded with its GPS time. The time of the UNIX server storing the positions was recorded instead. Often the navigation file revealed gaps of up to 3 minutes during which no GPS position, nor any other ship's data was logged. A cause is yet unknown.
The winch data (wireout) were also recorded online and stored in the sidescan raw data. The winch data were tested for abnormal wireout values mainly caused by cable counter resets.
Good navigation data is essential for processing, because the vehicle position and hence the sidescan image position is calculated from it.

The TOBI imagery was downloaded from the CD-ROMs using a subsample and average factor of 8. This gave a pixel resolution of 6 metres and an almost 3-fold improvement of the signal-to-noise ratio.

The survey was divided into three areas to facilitate processing (Figs. 1, 2, 6 an 8). The first one in the south consists of 23 blocks (processed at 51.5 degrees standard latitude). The second and third areas in the north were divided into 14 blocks each, processed at 55.5 degrees and 53 degrees standard latitude, respectively. The approximate size of the blocks was approximately 0.25 by 0.2 degrees for all areas. As each survey in an area was completed the imagery was processed using the PRISM (v4.0) and ERDAS Imagine (v8.4) software suites to produce geographically registered imagery which could then be composed onto a series of mapsheets. These were produced at a scale of 1:25000, and printed on the A0 plotter.

The processing of TOBI imagery has two main phases: Pre-processing and Mosaicing. The pre-processing stage involves correcting of the side-scan sonar characteristics, removal of sonar specific-artefacts and geographical registration of each individual ping. This processing stage is solely composed of PRISM programs and runs from a graphical user interface. The PRISM software uses a modular approach to 'correct' the imagery, which is predefined by the user in a 'commands.cfg' file. For this data it was defined as:

```
suppress_tobi -i %1 -o %0
tobtvg -i %1 -o %0 -a
mrgnav_inertia -i %1 -o %0 -t -u 236 -n navfile.veh_nav
tobtvg -i %1 -o %0 -h -l 50
tobslr -i %1 -o %0 -r res , res
edge16 -i %1 -o %0 –m
drpout -i %1 -o %0 -u -f -p -k 201
drpout -i %1 -o %0 -u -f -p -k 51
shade_tobi -i %1 -o %0 -t1,4095
```

To explain this in sonar terms (in order):

- Removal of any surface reflection (i.e. from vehicle to the sea surface and back) – generally only a problem in shallower water depths, where a bright stripe or line is seen semi-parallel to the ship's track. Removal is only done when the imagery is unambiguous, whether the line is true artefact and not an actual seafloor feature. The result can sometimes be seen on the final imagery as a faint dark line.
- Smoothing of the altitude of the vehicle above the seafloor. The altimeter sometimes cannot locate the seafloor, possibly due to very soft sediment thus reducing the return profiler signal. Smoothing is done by a median filter of the given values, comparing this with the first return seen on the port and starboard sides, and applying a maximum threshold for altitude change if first return and altitude value differ. Generally first return values are used, as these values will be used in the slant-range correction too.
- Merging of ship navigation and cable data with the imagery and calculation of the TOBI position using an inertial navigation algorithm. The 'navfile.veh_nav' file contains ship position and cable values and an umbilical length of 200 metres is assumed (default) plus an additional 36 metre for the distance between the GPS receiver and the point where the cable enters the water. The recorded cable values

in the TOBI data are used. Various assumptions are applied: the cable is assumed to be straight, the cable value is assumed to be correct, and zero cable is set when the depressor enters the water.

- Replaces the TOBI compass heading with track heading. A smoothing filter of 50 pings is applied. The heading values are used in the geographic registration process to angle each ping relative to the TOBI position.
- Slant-range correction assuming a flat bottom. This is a simple Pythagoras calculation assuming that the seafloor is horizontal across-track and sound velocity is $1500ms^{-1}$. Each pixel is 8ms and generally equates to 6 metre resolution; any pixel gaps on the output file are filled by pixel replication.
- Median filter to remove any high or bright speckle noise. A threshold is defined for the maximum deviation for adjoining pixels over a small area above which the pixel is replaced by a median value.
- Dropout removal for large imagery dropouts. When the vehicle yaws excessively, it is possible for the 'transmit' and 'receive' phase of each ping to be angled apart. If this exceeds the beam sensitivity value (0.8º) little or no signal is received, creating a dark line on the imagery. The program detects the dropout lines and interpolates new pixel values. If more than 7 dropouts are present concurrently (28 seconds) no interpolation is done.
- More dropout removal but for smaller, partial line dropouts. If more than 7 partial dropouts are present concurrently (28 seconds) no interpolation is done.
- Across-track equalisation of illumination on an equal range basis. This assumes that the backscatter from a particular range should average a given amount for each piece of data. The near-range pixels and far-range pixels are generally darker than mid-range pixels. This is due to the transducer's beam pattern and differences in seafloor backscatter response in terms of angle of incidence. The result of this is to amplify the near and far-range pixels by about 1.5 and reduce the mid-range pixels by 0.8.

Once these calculations have been applied to a piece of data the individual pings are placed on a geographic map. To emulate beamspreading the pixels are smeared over a small angle (0.8º) if no other data is present in those pixels. As survey tracks are designed to overlap the imagery at far-range, any overlapping data pieces are placed on separate layers of the same map. This allows user intervention to define the join where one piece touches the other. If small pixel gaps are visible between the geographically mosaiced pings, these are filled with an interpolated value plus a random amount of noise (but having the same variance as the surrounding data pixels).

The second phase (of mosaicing) allows the user to view all the 'layers' of data for an area. The software used is a commercial package named ERDAS Imagine (v8.4). Within this software the different layers can be displayed in different colours to distinguish the layers with data that will overlap data from another layer. In order to merge the different layers and their data together, polygons (Areas of Interest –or AOI) are drawn by the user to define the join lines between layers and then applied to create a single layer final image map. This procedure can also be used to remove shadow zones and areas of no data. The program that merges all data within selected AOIs into the final single layer image is called ‘addstencil’. Several of these final images can then be mosaiced together into a big image from which maps can be created in different projections and spheroids, including scales, co-ordinates and text. Also annotation such as ship's track, vehicle track and dates and times can be added to the map. The map can then be plotted on the A0 plotter and/or converted into other format e.g. TIFF, JPEG, generic postscript etc. to be used for further analysis on PC, Macintosh or UNIX workstations.

Summary

The system performed well overall with some excellent sidescan imagery producing detailed mosaics of the three survey areas.

TOBI technical reference: ‘TOBI, a vehicle for deep ocean survey’, C. Flewellen, N. Millard and I. Rouse, Electronics and Communication Engineering Journal April 1993.

BOBO lander

For recording the temporal variability of bottom water hydrodynamic conditions on and around the mounds, along with variations in bottom water temperature, salinity, turbidity and sediment flux a NIOZ-designed and –built BOBO (BOttom BOundary) lander mark 2 was deployed during the M2001 cruise with R.V. Pelagia on July 5 2001 (station M2001-28). The modular lander is a free-falling tripod lander with an array of industrially available and/or specifically designed or adapted instruments, designed or long (up to one year) in-situ measurements in the lowermost 3 metres of the benthic boundary layer, in water depths down to 5000 m.
A downward looking 1200 kHz RD-Instruments ADCP is mounted at 2 m above the seabed for high-resolution (5 cm vertical intervals) of near-bed current velocity and direction and acoustical backscatter in the lower 2 m of the water column. A Seabird SBE-16 CTD is mounted at about 3 m above the seabed to obtain simultaneous records of temporal variability of salinity and temperature with an interval of 5 minutes. In addition two Seapoint OBS sensors are mounted at respectively 1 and 3 m above the seabed for the detection of particles in suspension. On the lander a Technicap PPS 4/3 sediment trap with 12 cups is built into the frame to record particle flux. A new cup was put under the funnel every 30 days. The lander is equipped with two Benthos acoustic releases. The location of the lander is given in Appendix 4.

On July 8 the BOBO lander was recovered without any problems. The entire lander and all instruments were covered hydroids. A fair amount of anemones, several shrimp species, worms tubes, corals (< 2 mm) and other fauna were also found on the lander frame and equipment. Of all species samples were collected. The iron bars attached to the acoustic releases were covered in a several cm thick layer of very soft iron oxide. The sediment trap had worked without any problems. All twelve cups where filled with sediments and the last cup was removed from the funnel, indicating that all cups have been collecting sediments for a period of 30 days. At a first look the temperature and salinity data appears fine. The OBS results are negatively influenced by the presence of hydroids on the window. Concluding from the data already after a few weeks hydroids started to grow on the OBS's resulting in permanent high back scatter not related to sediment erosion, -transport or deposition. The results of the ADCP are bad as well. Only a period of 111 days is covered by the measurements (instead of a whole year). Of this data less then 5% shows meaningful results. The rest of the time no data is given. This might be related to a strong tilt of BOBO at the sea bed. At high tilts the software automatically ignores measurements since the accuracy of the measurements and calculations drops dramatically. Further analysis has to show whether this is the case or not.

Sea bed photography

Sea bed photography was performewd with a PhotoSea 5000 deep water system (camera and flash light) mounted in a frame. The frame was lowered on the ship CTD cable that relayed the signal of a bottom detector (a Benthos compass hanging on a rope 1.5 m below the frame) to the deck of the ship. In this way a fairly constant distance range between camera and seabed could be maintained, thus improving the quality of the photographs. The camera was equiped with a Kodak Ektachrome 400X daylight colour film. The location of the camera station is given in Appendix 4. During the M2001 cruise the same camera was used, also with daylight colour film. It appeared that the absorption of (red) light by the seawater results in a strong shift of the colour of the photographs towards green. During the present cruise the camera was equipped with several URPRO colour correction filters in order to test whether the shift in colours can be avoided and during a cruise with R.V. Pelagia in November 2002 seabed photographs showing colours which represent the natural colours can be made. Unfortunately as a result of a break in one of the cables of the camera the test had to be abandoned. The few photographs that were made could not be developed on board, so results can not be given at this stage.

Box coring

Surface sediment cores were collected using a NIOZ designed 600-kg box corer with a cylindrical box of 50 cm diameter and 55 cm penetration depth. The corer is equipped with a lid that closes the top of the box at the moment of retrieval of the corer, and which under normal conditions allows collection of relatively undisturbed sediment cores together with the overlying bottom water. During the present cruise, however, several coring attempts failed. For unknown reasons the corer did not trip upon reaching the seabed. In two occasions highly disturbed cores were taken, either because the corer did not close properly because of boulders getting stuck underneath the bottom knife, or movement of the corer during closing. Only one good quality core was taken.
After recovery of the corer on board of the ship, the water standing on top of the box core was siphoned off. The surface of the core was then photographed, and the biological and sedimentological characteristics of the seabed as appearing in the box core were described. Subcores for sedimentological and radionuclide analysis were subsequently

made by inserting wet PVC liners of 9 cm diameter into the sediment. After full description and sampling of the box core surface, the coring barrel was removed to allow sedimentological description of a vertical section of the core. The liners were stored at 4°C. Coring positions are listed in Appendix 4. Sedimentary logs are presented in Appendix 5.

Preliminary interpretations

Porcupine Seabight

The survey in Area 1, the Porcupine Seabight, is presented in a set of 23 maps (Fig. 2) and can be divided in 4 zones :

1. Gollum Channels
The Gollum Channels are pictured on maps 1 to 3 of Area 1. They are steep-flanked canyons of about 200 m deep, as can be seen from the multibeam bathymetry. The flanks show a strong backscatter on the sidescan sonar images because they face the the instrument, but most probably also because of their different nature: they might consist of more compacted material, or coarser sediments.
Channels of different types can be recognised: V-shaped channels (e.g. the most southern channel surveyed) and U-shaped ones (further to the N). The U-shaped channel flanks often are affected by slope failure, such as sliding or debris flows (Fig. 3). In some channels the depositional lobes can be seen on the channel floor, but this is not always the case. Generally the channel floors seem to consist of coarser material than the areas between the channels. They show slightly higher backscatter, and high-backscatter features can be seen which could be large blocks of sediment or debris. Also on the rim of some channel flanks some positive features can be seen (Fig. 3). The widest channels seem to be affected the most by the debris flows, and therefore, and because of their width are suggested to be the oldest ones. They also show lines on the channel floor, indicating the down slope current meandering on the fairly wide channel bottom.
In some cases the steep channel flanks also are affected by sharp down slope gullies, appearing very clearly on the side scan images (Fig. 3).
The areas between the channels generally show a much more homogeneous and lower backscatter. On the 3.5 kHz subbottom profiler they could be recognised as depositional areas with smooth, parallel reflections. Some areas appear a little hummocky or undulating on the side scan records. This could probably suggest the presence of mud waves.

2. Belgica mounds
The Belgica mound province is pictured on maps 6 to 9 of Area 1. Most of the mounds recognised from the bathymetry can easily be found on the sidescan sonar images too. They have a high backscatter on the flanks and often a clear acoustic shadow. Especially the mounds arranged in an 'en echelon' pattern can easily be seen, they seem to form a ridge. Mound Thérèse and its surroundings are pictured in Fig. 4. The Moira mounds, small high-backscatter points to the E of Thérèse are visible as well. They are placed against a background of darker backscatter material. This is interpreted as well-sorted sand, as could be recognised on the ROV images of the CARCOLE-cruise in 2001. Similar high-backscatter dots (sometimes a little elongated in a N-S direction) can be seen on other locations (e.g. on the W side of map 7). The very low backscatter material is repeated on other locations in the imagery as well. Striations formed by dark material similar to those described by Kenyon *et al.* (1998) from the TTR7 sidescan sonar imagery

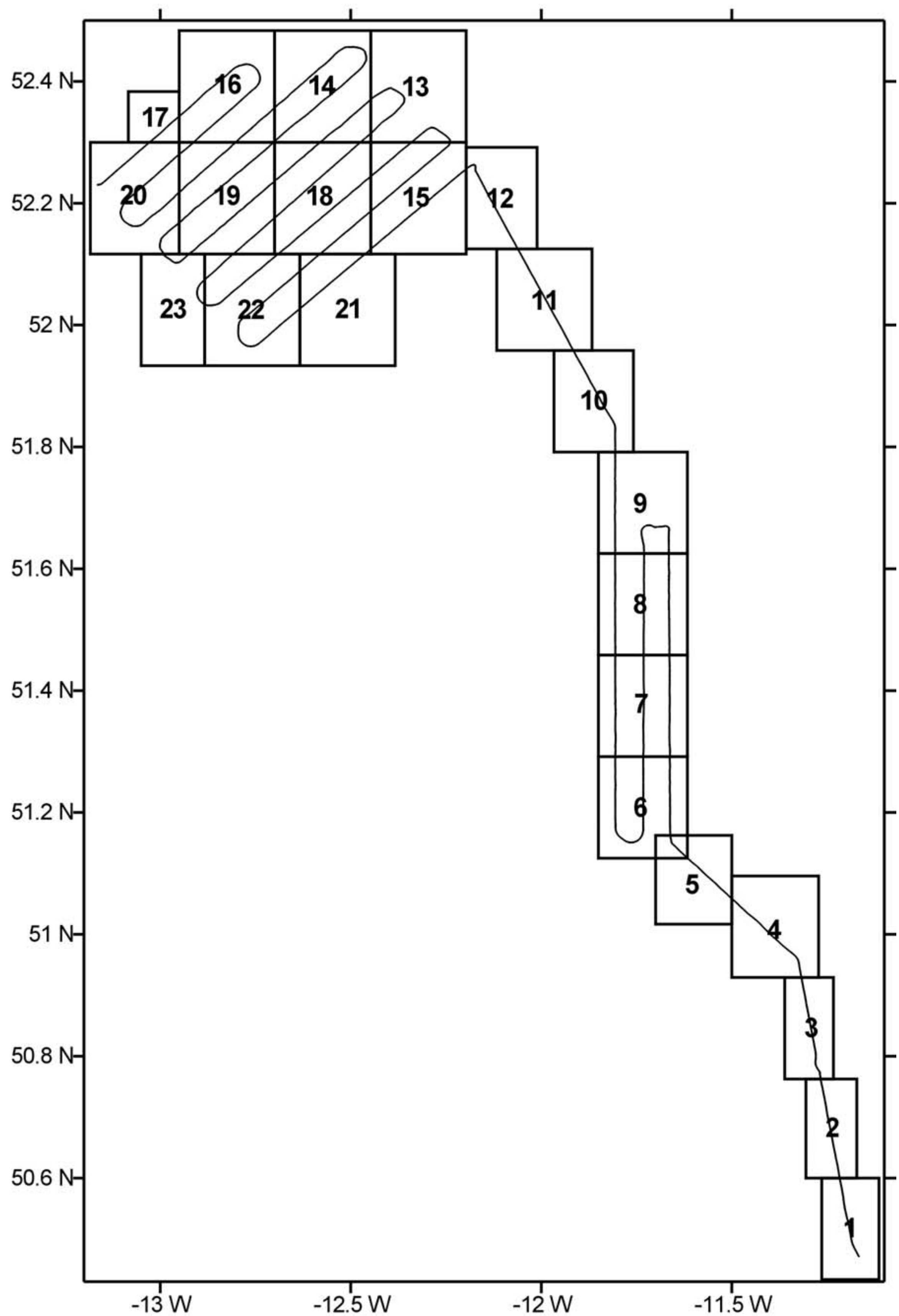

Fig. 2. Map showing the mosaic maps of the Porcupine Bight survey (area 1).

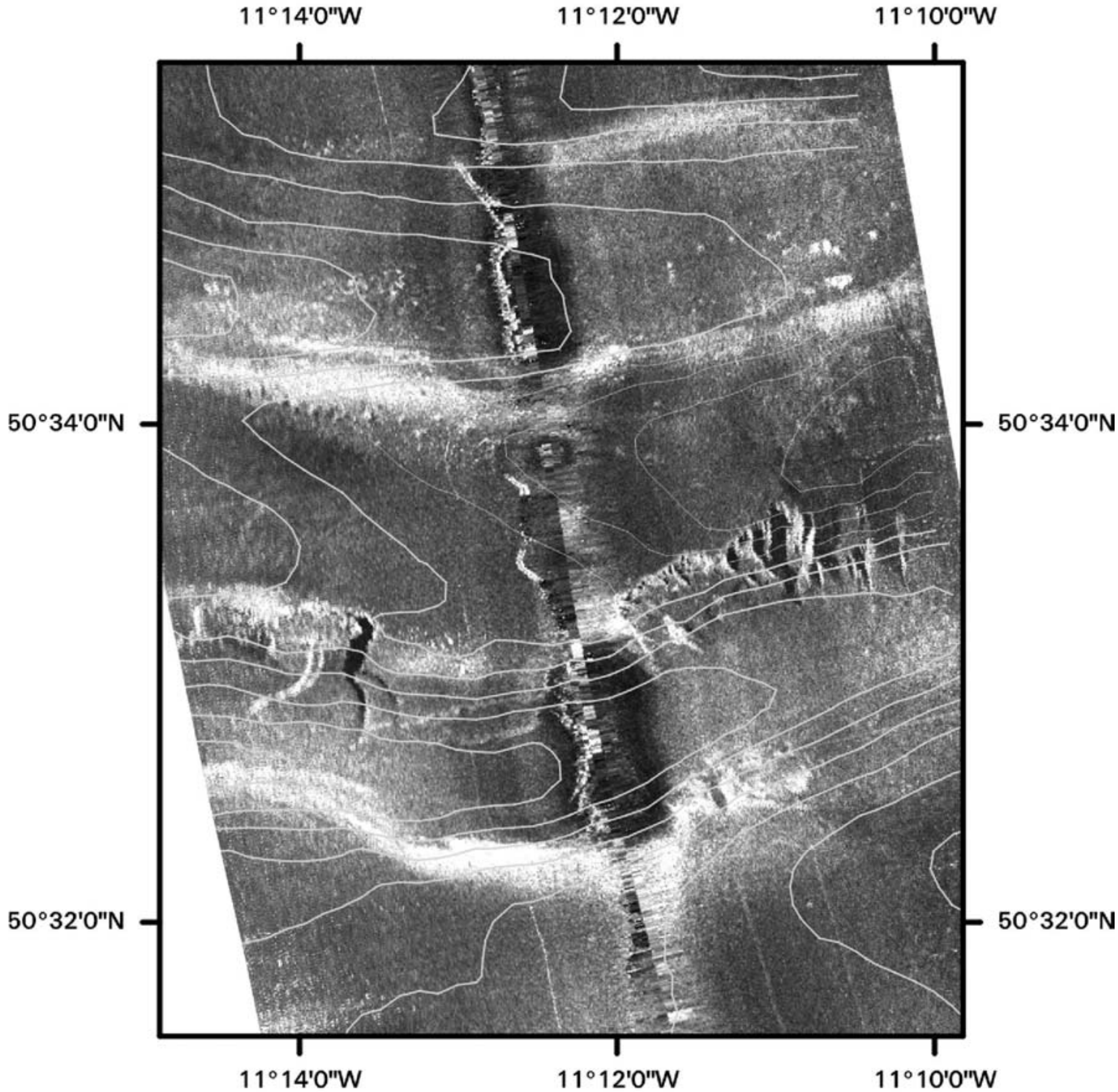

Fig. 3. Data example of the Porcupine Bight survey (area 1) showing slope failures and gullies within the Gollum Channels.

can be found on map 7. They also can be interpreted as well sorted sands moving over the seabed, their pattern being shaped by the current.

A very remarkable feature is the channel on the W flank of the Belgica mounds. It can be seen from the bathymetry contours, and can be recognised in the backscatter contrasts of the sidescan imagery. It meanders slightly, and on some locations low backscatter material seems to be concentrated in the bends. This could be interpreted as sands, similar to those found around the Moira mounds. Other, smaller channels are present between the mounds, and N of them (maps 8 and 9). The northern ones show a lower backscatter on the slopes facing the sidescan instrument, than on the opposite slopes. This most probably

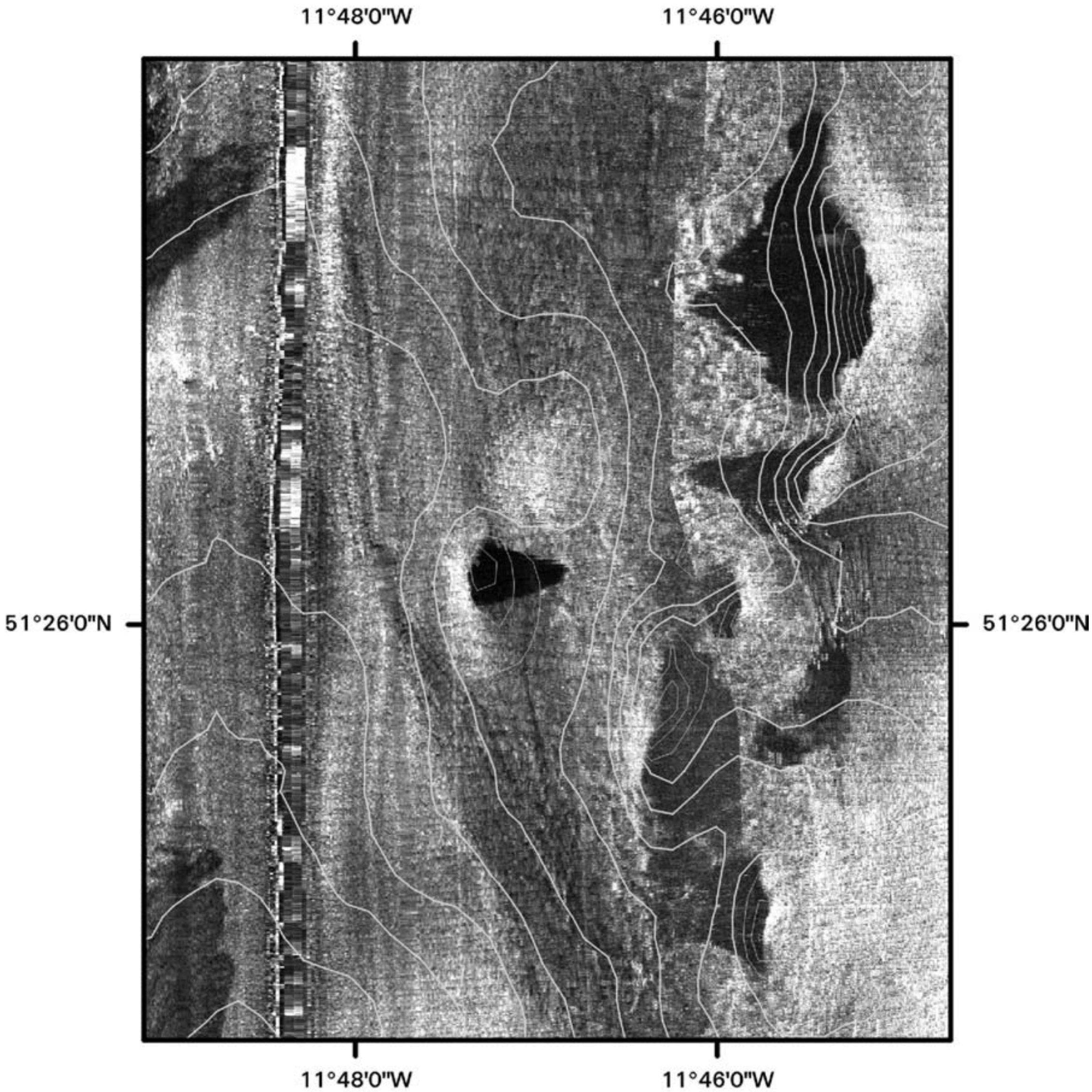

Fig. 4. Data example of the Porcupine Bight survey (area 1) showing Mound Thérèse and its surroundings in the Belgica Mounds province.

is due to the interaction between the sound frequency/wavelength and the sediment characteristics : compaction, texture, sorting, layering.

Some areas between the mounds show a very characteristic acoustic facies, with a very irregular texture (Fig. 4). Based on video results from the TTR7 and CARACOLE cruises, they possibly could be interpreted as zones with an irregular seabed, consisting of fairly coarse materials, combined with dropstones and some coral debris.

3. Hovland/Magellan mound province

Maps 13 to 23 of Area 1 comprise the Hovland and Magellan mound provinces. In general this sidescan mozaic shows a homogeneous grey seabed, with a slight gradation in backscatter from the SE to the NW (lower to higher backscatter).

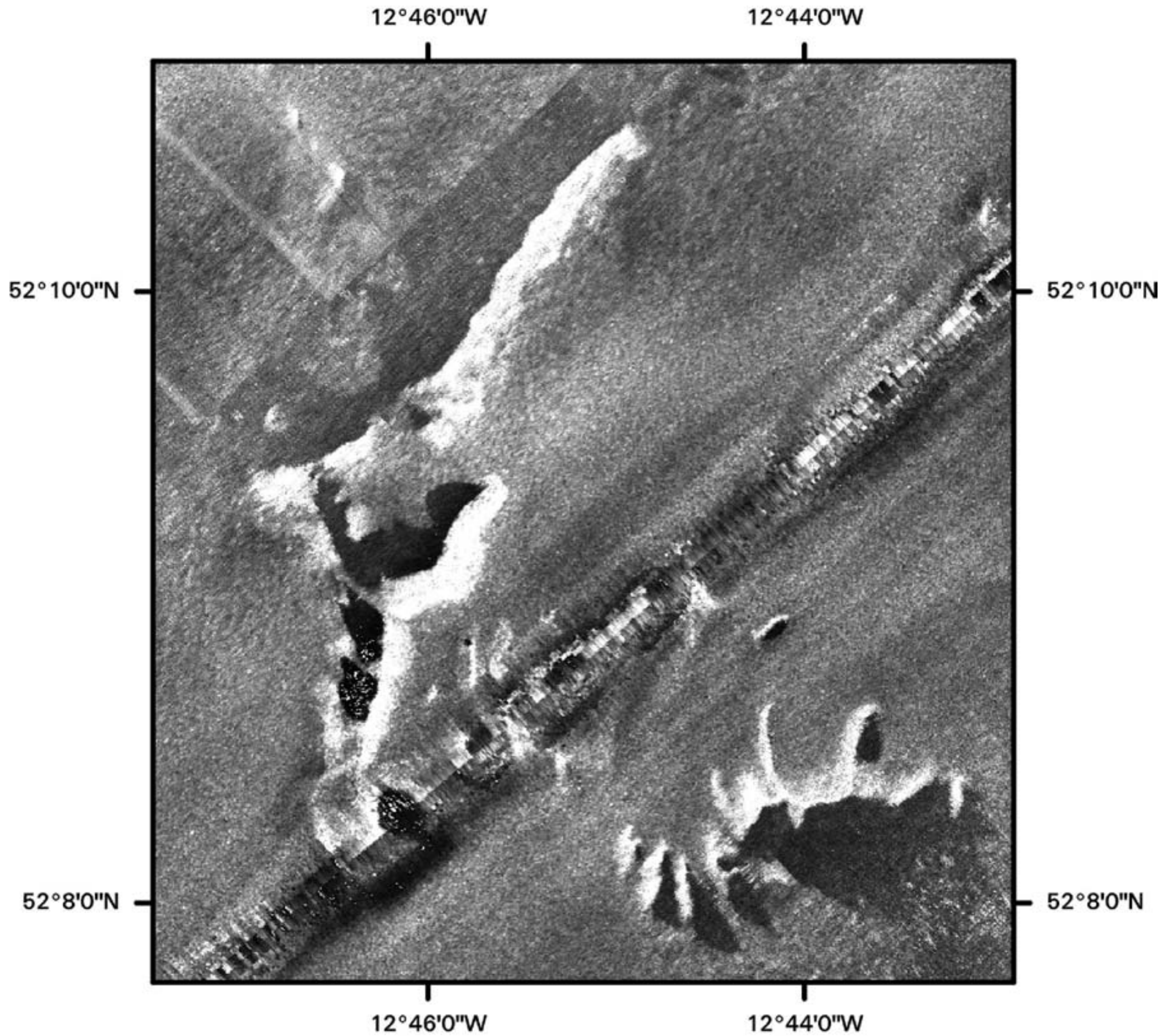

Fig. 5. Data example of the Porcupine Bight survey (area 1) showing Propellor Mound in the Hovland Mound province as a typical example of the forked and steep flanked mound ridges as they appear in this province.

Several mound features can be easily recognised against this background. The Hovland mounds are mostly fairly large, multiple, complex structures. They can be divided in 2 types : One type of Hovland mounds appears as quite sharp ridges, often forked, with several summits, relatively steep flanks and a clear acoustic shadow. They can be up to 4 km long. Propellor mound (Fig. 5) is a good example of these. The other type consists of rounder, smoother, less sharp mounds with a less obvious acoustic shadow. They are associated with extensive patches of high backscatter. One of these mounds has been sampled through boxcoring. The boxcore taken on the top (M2002-02) contained several large dropstones, and coral debris in a muddy matrix. This seems to indicate that the mound top consists of older materials which have been set free by erosion. The box taken in the high-backscatter zone (M2002-03) contained sandy materials with shell fragments in the upper centimeters, but further down the core a very stiff clay was found. This

facies could be responsible for the high backscatter, and could also indicate the erosion higher up on the mound.
Some of the Hovland mounds are surrounded by clear moats, recognisable as a ‘halo’ or rim of slightly darker backscatter around them.
The Magellan mounds are much smaller, single structures, each encircled by a N/S directed moat. Some of these moats persist in the sedimentary structure, even after burial of the mounds (as can be seen from high-resolution seismic data). At some places they can be recognised in the far-range response of the sidescan sonar data, e.g. in map 16. Several Magellan mounds however were seen on the 3.5 kHz subbottom profiler, but did not appear on the sidescan sonar mozaic, because they were buried too deep to influence the reflected signal.

4. Transit
Maps 4, 5, and 10 to 12 of area 1 basically contain transit lines between the different zones described in §1 to 3. They generally show a homogeneous grey backscatter without many features. The most remarkable features are a field of depressions, possible pockmarks, seen on map 5. Map 12 shows 2 larger features consisting of dark backscatter patches with a high-backscatter point in the middle. They could be very small build-ups or incipient mounds.

<u>SW Rockall Trough margin</u>

The side scan sonar mosaic of the SW Rockall Trough margin (=SE Rockall Bank) has a length of about 100 km and is in the order of 25 km wide (Fig. 6). It is oriented parallel to the slope. At a first glance the mosaic looks very chaotic. The largest part of the area shows irregular patterns of strongly varying backscatter which have dimensions in the order of one hundred metres to several kilometres.
In the NW part of the area (maps 2, 4, 6 and vaguely in 8 and 10) EW elongated structures are present showing parallel lineaments of high and low backscatter. These structures are several km long and upto 500 m wide. They are interpreted as giant ripples or dunes which have an orientation that is slightly oblique to the general depth contours. Further to the east (map 10) these dunes grade into an area showing a more patchy appearance, interpreted as a field with small mounds, eventually grading into a more featureless, low backscatter sea bed (maps 12 and 14). The mounds seen on map 10 do not have to be of the same nature as the mounds that will be described below. Downslope the dunes grade into mounds present in the middle section of the mosaic which is described below. The structures mentioned above are located in an area that runs parallel to the general depth countours from NW to NE in the mosaic and is at maximum about 4-5 km wide.
South of this area, within a zone that is about 15 km wide at maximum, an irregular pattern of low to high backscatter is present. This pattern is interpreted as mounds with diameters in the order of hundreds of metres to a few kilometres. Many of these mounds are grouped in more or less elongated clusters which show a downslope orientation of their longest axis. The largest mounds and clusters appear in maps 4 to 11. East of these mound complexes (map 12) worm like structures showing high backscatter are present. These are tentatively interpreted as low relief features covered with coarse grained

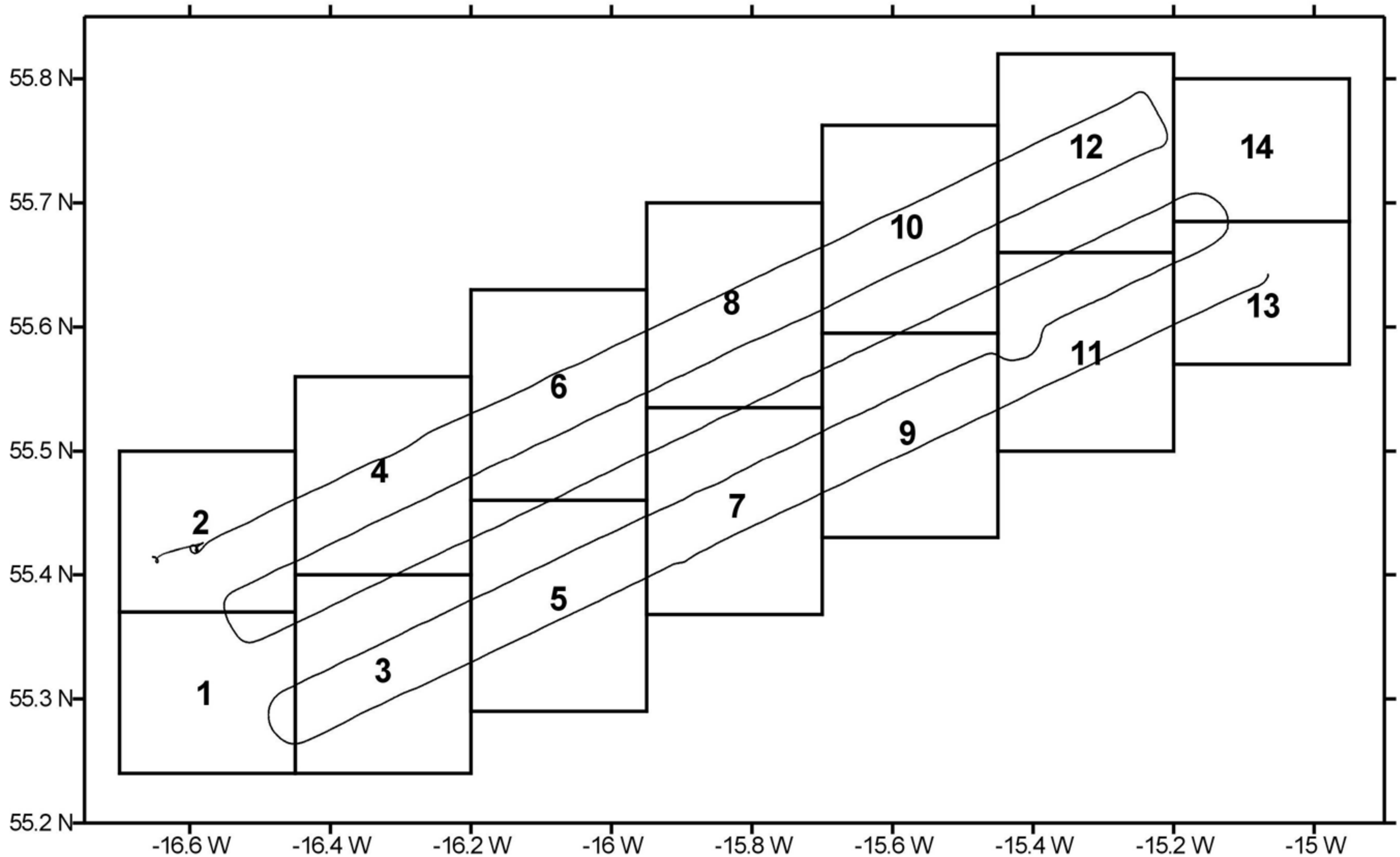

Fig. 6. Map showing the mosaic maps of the Rockall Bank survey (area 2).

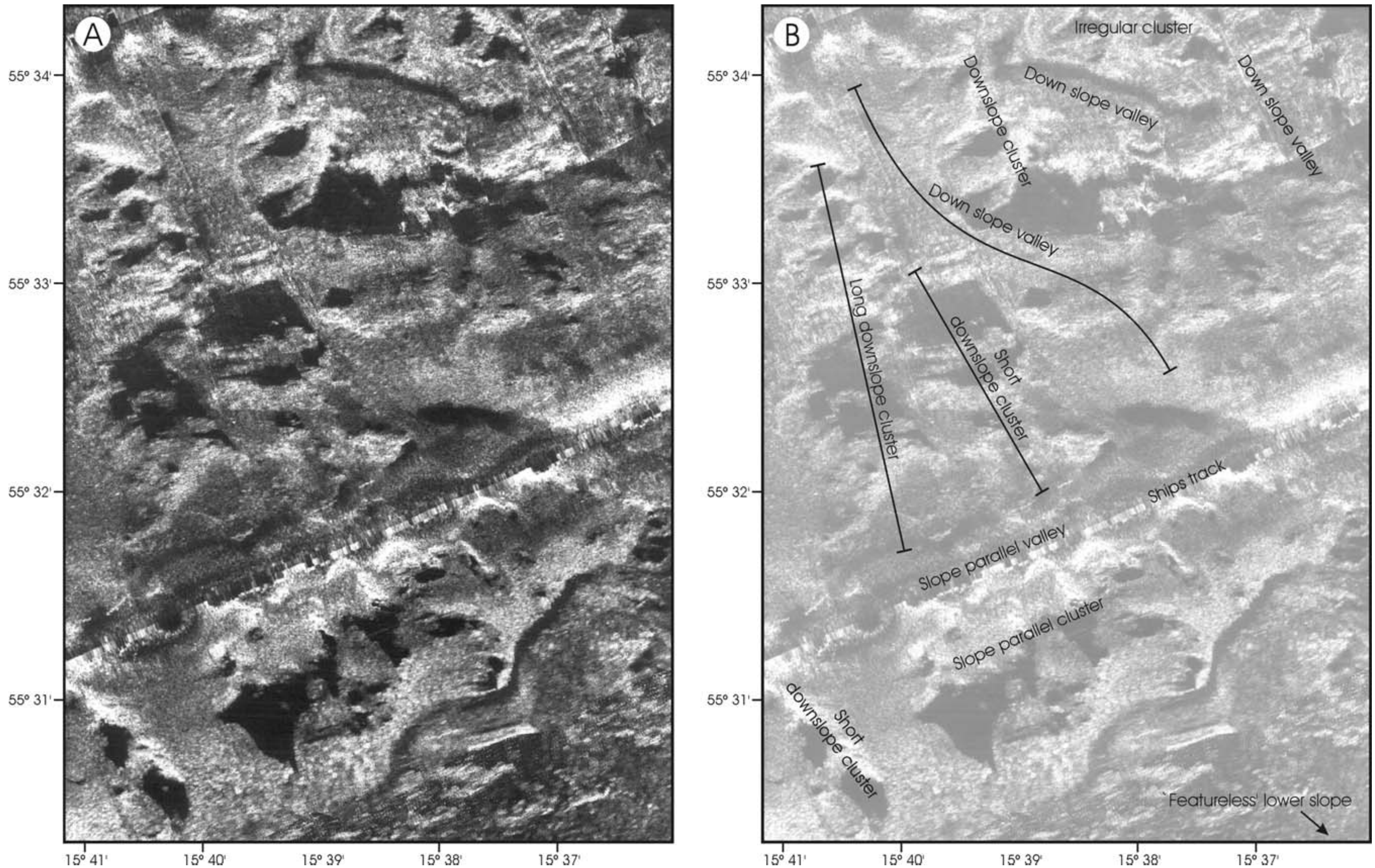

Fig. 7. A. Data example of the SW Rockall Trough margin (area 2) showing the mound morphology in this area.
B. Interpretation of figure A showing mound clusters and valleys.

sediments. These structures seem to be of a very different nature than the large clustered mounds. In between the mound clusters narrow and elongated areas of low backscatter are present running perpundicular to or under a large angle with the general pattern of depth contours of the margin. Only sometimes these structures run more or less parallel to the margin. The structures are interpreted as valleys in between the mounds acting as channels through which the (tidal) current is funneled in between the mounds, resulting in high current velocities. This also explains the pebbles and boulders found in box cores from these areas taken during earlier cruises (de Haas et al., 2000; de Stigter and de Haas, 2001). This interpretation of the topography agrees very well with the results of the 3.5 kHz survey (located on map no. 9) carried out during the M2000 and M2001 cruises (de Haas et al., 2000; de Stigter and de Haas, 2001). Fig. 7 shows an interpretation of the above mentioned area covered during cruises M2000 and M2001 and which was also visited during the CARACOLE cruise (area R2, Olu-Le Roy et al., 2001). The southern boundary of the central zone of the mosaic is formed by relatively high mounds, sometimes grouped in cluster running parallel to the margin.
Downslope of the central zone an about 5 km wide area of in general very low backscatter is present. Only a limited amount of medium to higher backscatter features can be observed. They are tentatively interpreted as slope parallel flow features (maps 1 and 3) and slide escarpments (maps 3, 5 and 9). Other, presently uninterpreted features, are also present.

<u>SE Rockall Trough margin</u>

The side-scan sonar mosaic of the SE Rockall Trough margin (=northeastern Porcupine Bank area) (Fig. 8) consists of a long NE-SW run-in line that runs parallel to existing TOBI TRIM98 data, a coherent mosaic of 4 lines in the middle of the area and a southerly 2-line mosaic extension. The mosaic covers the mid- to upper slope of the outer northwesterly Porcupine Bank covering areas of carbonate mounds, sediment drifts, erosional features and canyon heads.

A number of sinuous ridges, “erosional ridges”, are identified on the mosaic that have a slight topographic rise upslope and a steep scarp-face downslope. The shape and down slope acoustic facies suggest that these are not slope failures but represent the edges of erosional scours where shallow bedding planes are exposed. Comparable exposures of consolidated sediment exposures have been identified in this area during the CARACOLE ROV cruise (Olu–Le Roy et al., 2002) and previous imaged on high-resolution side-scan sonar (Wheeler et al., 2000). The ridges run sub-parallel to the isobaths and are more dominant in mid- to upslope areas. In the middle of the mosaic, the erosional ridges coalesce to form “erosional windows” clearly defined as depressions with steep walls. These can be 500-700m across. Downslope of this area, the “windows” become elongated to form shallow downslope gullies extending up to 1.5km.
A large number of carbonate mounds are identified on the mosaic being predominantly 100->300m across a ranging in height up to c. 200m. These occur as both isolated features and associations with the “erosional ridges”. Mound shapes range from ovoid, to ridge-shaped running sub-parallel to the isobaths, to complex forms. Some of the

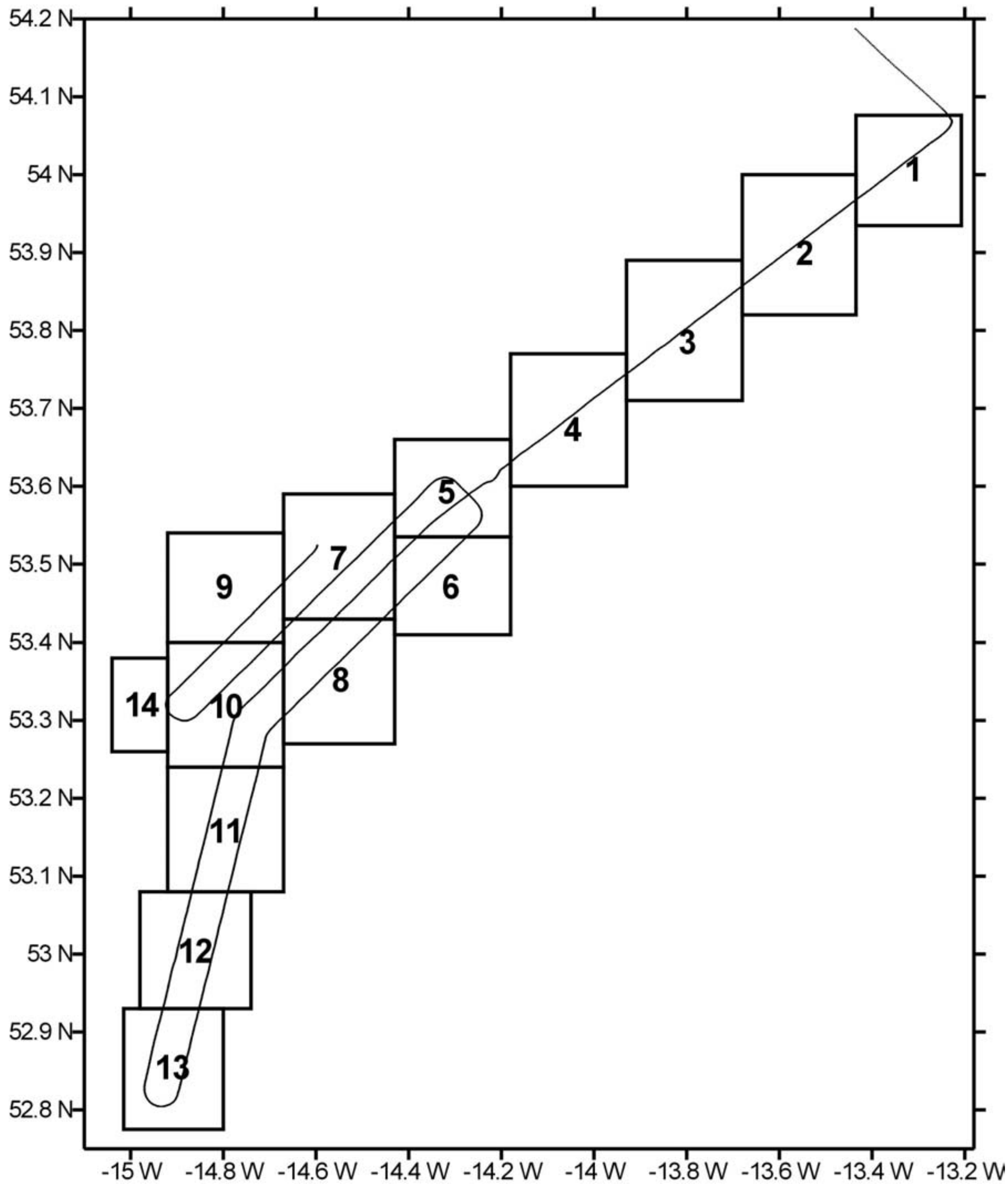

Fig. 8. Map showing the mosaic maps of the Porcupine Bank survey (area 3).

mounds, especially those occurring as groups, are also surrounded by zones of high backscatter seabed. A good example of such a feature is the east-west trending high backscatter region (4 km E-W, 2 km N-S) in the southern part of the survey area (map 11). A few mounds also show low backscatter moats, similar to those observed in the

TRIM98 dataset. There is a clear tendency for some mounds to be aligned along "erosional ridges". This is observed in the central surveyed region (Map 5 hedge mounds) where large mounds are present on the upper slope of such a ridge. It is speculated that this is probably the result of a combination of suitable substrates for mound growth as well as an indication of high currents speed resulting in increase biological food supply. One group of well-developed mounds are aligned along the crest of a topographic spur at the head of a canyon system and are probably also benefiting from hydrodynamically enhanced organic food supply.
The heads of two canyon systems (c.2km across) are also imaged. These show scarp-faces bounding parts of the heads and very low backscatter sediment fills. Feeder "chutes" to the canyons are also observed and a low backscattering, sinuous channel (width ~ 125m) is also imaged at the head of the most northerly, and larger, of the two canyons.
A number of very small (12-15m wide) high backscatter features are also identified which may represent localised coral colonises or very small mound features. These proto-mound features are generally found downslope from the larger (>100m diameter) mound features. Another possible explanation for these features is that they are large dropstones or accumulation of dropstones. In the CARACOLE R1 site, a number of very large (>~2.5m) boulders were observed on video data (Olu–Le Roy et al., 2002).
Upslope, in the middle of the mosaic, a large area of iceberg plough-marks is observed. The longest continuous iceberg plough mark is ~ 2 km long. The TOBI image from this region is very similar to those obtained in other glacially scoured regions such as the proximal areas of the Barra and Donegal fans (Armishaw, et al. 2000,). These features occur at water depths slightly deeper than expected and may have implications for our interpretation of sea-level, palaeo-iceberg dimensions and the extent of past glaciation events on the Irish margin.
In the far north of the area, a board zone of high backscatter is noted crossing the mosaic east-west bounded by one of the "erosional ridges". This is probably a sediment drift. Other low backscatter drifts are also identified on the mosaic and seem to bend around mounds or abut against erosional ridges.

In summary, the TOBI Pelagia M2002 mosaic of the SE Rockall Trough margin provides detailed views of upper to mid slope features. The distribution of these features highlights a complex interplay between along-slope processes such as current scour, contourite drift sedimentation and downslope processes such as mass wasting and canyon formation.

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Appendix 1. Shipboard party

Scientific party

Name	**Institute**
Andy Wheeler (Co-chief scientist)	Dept. of Geology & Env. Res. Inst., Univ. College Cork, Cork, Ireland
Chris Flewellen (Technician)	Southampton Oceanography Centre, Southampton, United Kingdom
Colin Jacobs (Scientist)	Southampton Oceanography Centre, Southampton, United Kingdom
Furu Mienis (Student)	Dept. of Earth Sc., Free Univ. Amsterdam, Amsterdam, The Netherlands
Henk de Haas (Chief scientist)	Royal Netherlands Institute for Sea Research, Texel, The Netherlands
Ian Rouse (Technician)	Southampton Oceanography Centre, Southampton, United Kingdom
Serkan Kulaksiz (Student)	International University of Bremen, Bremen, Germany
Steve Whittle (Technician)	Southampton Oceanography Centre, Southampton, United Kingdom
Veerle Huvenne (Co-chief scientist)	Renard Center of Marine Geology, University of Ghent, Ghent, Belgium
Veit Hühnerbach (Data processor)	Southampton Oceanography Centre, Southampton, United Kingdom
Vikram Unnithan (Scientist)	Department of Geology, University College Dublin, Dublin, Ireland
Vincent Hinsinger (Student)	Renard Center of Marine Geology, University of Ghent, Ghent, Belgium

Ships crew

Name	**Rank**
Bert Puijman	First officer
Cor Stevens	Sailor
Feite Bos	Captain
Felix Prins	Cook
Guilherme Santos Cardoso	Sailor
Henk Douma	Second Officer
Jan de Kraker	Sailor
John Betsema	Sailor
Joris Valentijn	Engineer
Menno Hogeweg	Engineer

Appendix 2. TOBI2 brief technical specification

Mechanical	
Towing method	Two bodied tow system using neutrally buoyant vehicle and 600kg depressor weight.
Size	4.5m x 1.5m x 1.1m (lxhxw).
Weight	1800kg in air.
Tow cable	Up to 10km armoured coax.
Umbilical	200m long x 50mm diameter, slightly buoyant.
Tow speed	1.5 to 3 knots (dependent on tow length).
Sonar Systems	
Sidescan Sonar	
Frequency	30.414kHz (starboard) 32.904kHz (port).
Pulse Length	2.8ms.
Ouput Power	600W each side.
Range	3000m each side.
Beam Pattern	0.8° x 45° fan.
Profiler Sonar	
Frequency	6 to 10kHz Chirp.
Pulse Length	26ms.
Output Power	1000W.
Range	>50ms penetration over soft sediment.
Resolution	0.25ms
Beam Pattern	25° cone.
Standard Instrumentation	
Magnetometer	Ultra Electronics Magnetics Division MB5L.
Range	+/- 100,000nT on each axis.
Resolution	0.2nT.
Noise	+/- 0.4nT.
CTD	Falmouth Scientific Instruments, Micro CTD.
Conductivity	
Range	0 to 65 mmho/cm.
Resolution	0.0002 mmho/cm.
Accuracy	+/- 0.005 mmho/cm.
Temperature	
Range	-2 to 32° Celcius.
Resolution	0.0001° C.
Accuracy	+/- 0.005° C.
Depth	
Range	0 to 7000 dbar.
Resolution	0.02 dbar.
Accuracy	+/-0.12% F.S.
Pitch/Roll	Dual Axis Electrolytic Inclinometer.
Range	+/- 20 degrees.
Resolution	0.2 degrees.
Altitude	Taken from profiler sonar.
Range	1000m.
Resolution	1m.

Appendix 3. MO times

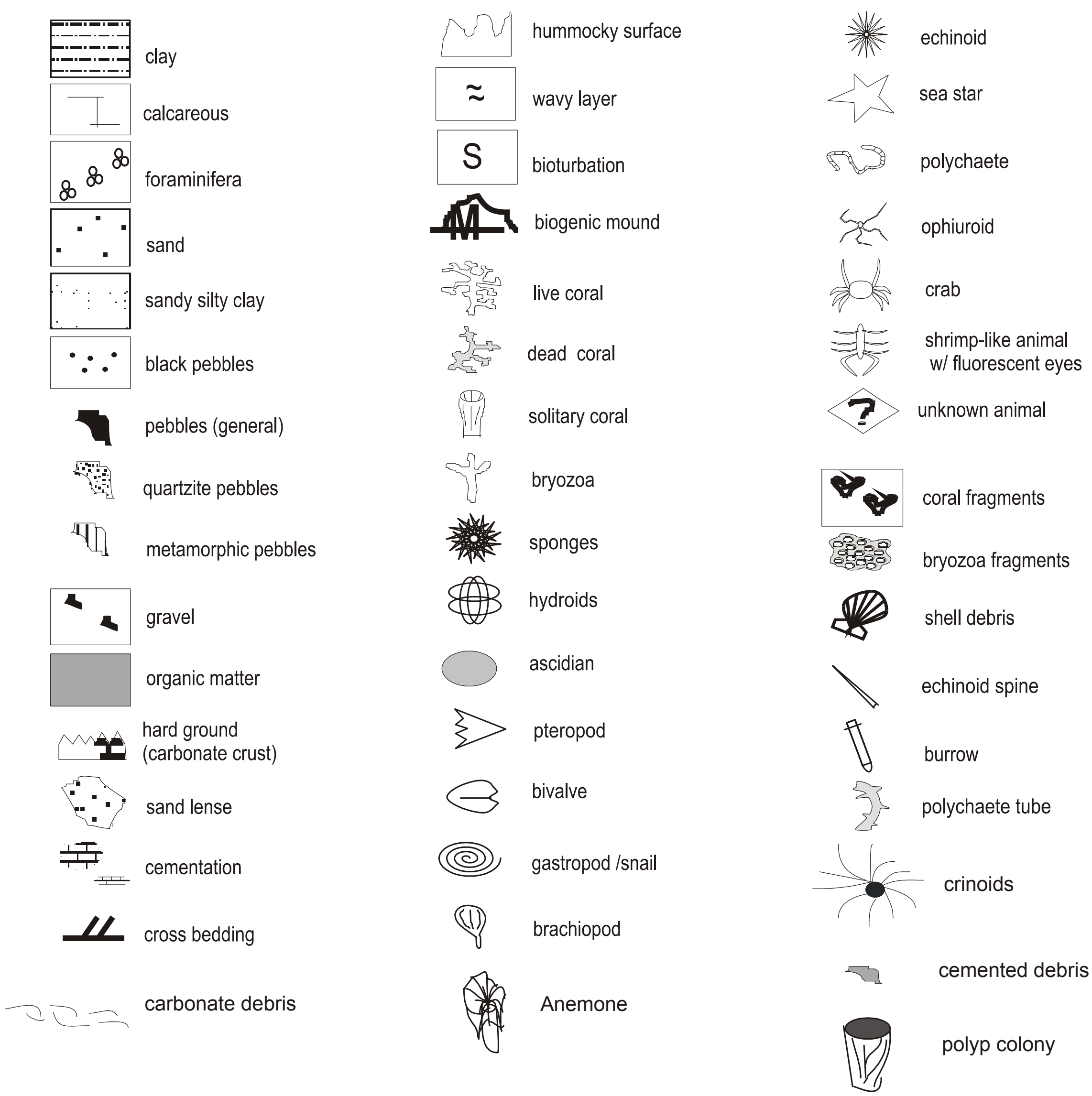
MO	FILE	START	END	COMMENTS
270	TOBI.DAT	11:28/176	19:50/176	Start of run 1
	TOBIA.DAT	20:12/176	04:31/177	
271	TOBI.DAT	04:31/177	20:36/177	
272	TOBI.DAT	20:43/177	11:23/178	
	TOBIA.DAT	11:24/178	12:53/178	
273	TOBI.DAT	12:53/178	05:02/179	
274	TOBI.DAT	05:02/179	21:11/179	
275	TOBI.DAT	21:11/179	13:20/180	
276	TOBI.DAT	13:20/180	05:29/181	
277	TOBI.DAT	05:29/181	12:17.181	
	TOBIA.DAT	12:20/181	21:42/181	
278	TOBI.DAT	21:43/181	13:52/182	
279	TOBI.DAT	13:52/182	06:01/183	
280	TOBI.DAT	06:01/183	18:28/183	End of run 1
281	TOBI.DAT	22:43/184	14:57/185	Start of run 2
282	TOBI.DAT	14:57/185	07:10/186	
283	TOBI.DAT	07:10/186	23:25/186	
284	TOBI.DAT	23:25/186	15:40/187	
285	TOBI.DAT	15:40/187	07:58/188	
286	TOBI.DAT	07:58/188	00:16/189	
287	TOBI.DAT	00:16/189	08:03/189	End of run 2
288	TOBI.DAT	00:28/190	16:46/190	Start of run 3
289	TOBI.DAT	16:46/190	09:04/191	
290	TOBI.DAT	09:04/191	01:21/192	
291	TOBI.DAT	01:22/192	17:33/192	
292	TOBI.DAT	17:36/192	07:55/193	End of run 3

Appendix 4. Station list

Station no.	Date	Activity	Latitude North	Longitude West	Waterdepth (m)	Remarks
M2001-28	08-07-2002	BOBO recovery	55 º 32.85 '	15 º 39.79 '	677	Deployed 05-07-2001
M2002-01	12-07-2002	Hopper camera test	52 º 8.88 '	12 º 45.78 '	846	Camera cable broken
M2002-02	12-07-2002	Boxcoring	52 º 8.90 '	12 º 49.90 '	653	Core disturbed
M2002-03	12-07-2002	Boxcoring	52 º 9.00 '	12 º 49.10 '	810	
M2002-04	12-07-2002	Boxcoring	52 º 9.30 '	12 º 50.30 '	700	Failed
M2002-05	13-07-2002	Boxcoring	52 º 13.90 '	12 º 19.60 '	8??	Core disturbed
M2002-06	13-07-2002	Boxcoring	52 º 14.00 '	12 º 19.40 '	738	Failed

Appendix 5. Boxcore logs

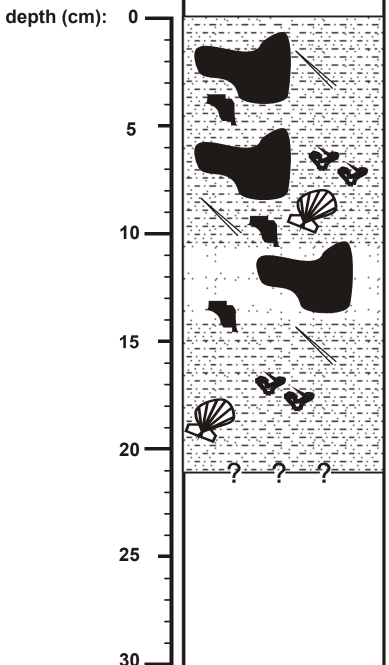
NIOZ box- and piston core legend



Pelagia CRUISE M2002 BOXCORE M2002-02

12-07-02, GMT: 21:04
Lat.: 52° 08.9 N / Lon.: 012° 49.9 W
Waterdepth: 653 m.

LITHOLOGY COLOUR DESCRIPTION



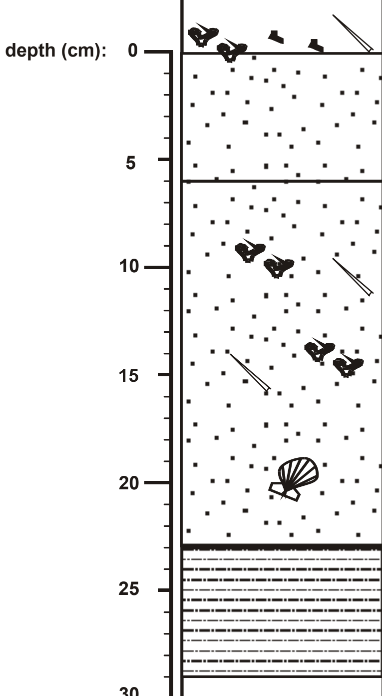
Core disturbed (knife did not close)

Whole core:
Carbonate silt-coarse sand
3 Boulders (<30 cm)
Biogenic debris: coral debris (mm-cm sized), bivalve shells, echinoid spines
Some pebbles

Penetration unknown

Pelagia CRUISE M2002 BOXCORE M2002-03

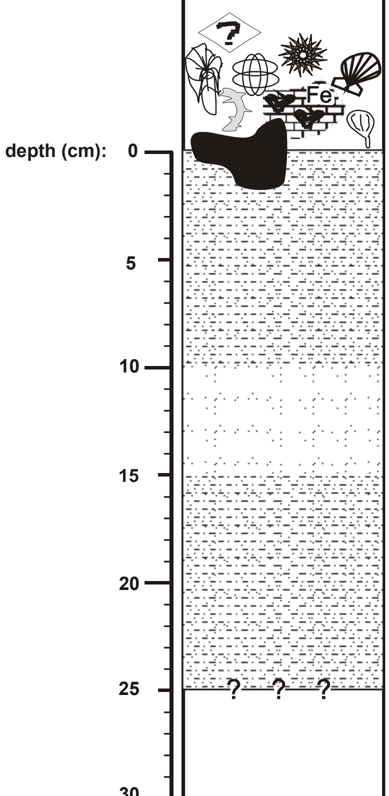
12-07-02, GMT: 21:50
Lat.: 53°09.0 N / Lon.: 12° 49.1 W
Waterdepth: 810 m.

LITHOLOGY	COLOUR	DESCRIPTION
	7.5 Y 5/2 olive grey 7.5 Y 5/2 olive grey 5 Y 5/1 grey	***surface:*** Silt-coarse carbonate sand Some coral and other biogenic carbonate debris (<1cm) Some lithic pebbles (<1%) echinoid spines Colour 2.5Y4/4 (olive brown) ***downcore:*** 0-23 cm: silt-coarse sand •<u>0-6 cm:</u> waterrich sand •6-<u>23 cm:</u> downcore transition to lower water content mm sized carbonate debris •2<u>3-29 cm:</u> Silty sandy clay

Penetration : 29 cm
Core compaction NIOZ : 2 cm
Core compaction Gent : 2 cm

Pelagia CRUISE M2002 BOXCORE M2002-05

13-07-02, GMT: 08:07
Lat.: 52° 13.9 N / Lon.: 012° 19.6 W
Waterdepth: 8?? m.

LITHOLOGY	COLOUR	DESCRIPTION
	5 Y 5/2 olive grey	Core disturbed: tilted *Surface:* Carbonate silt-coarse sand Shells and coral debris Cobble (17 cm) Many pebbles + Fe-oxide concretion (originally coral?) overgrown with living sponge, brachiopods, worms, anemones Dead bivalves Colour 5Y5/3 (greyish olive) *Subsurface:* *carbonate silt- coarse sand* Penetration ca. 25 cm