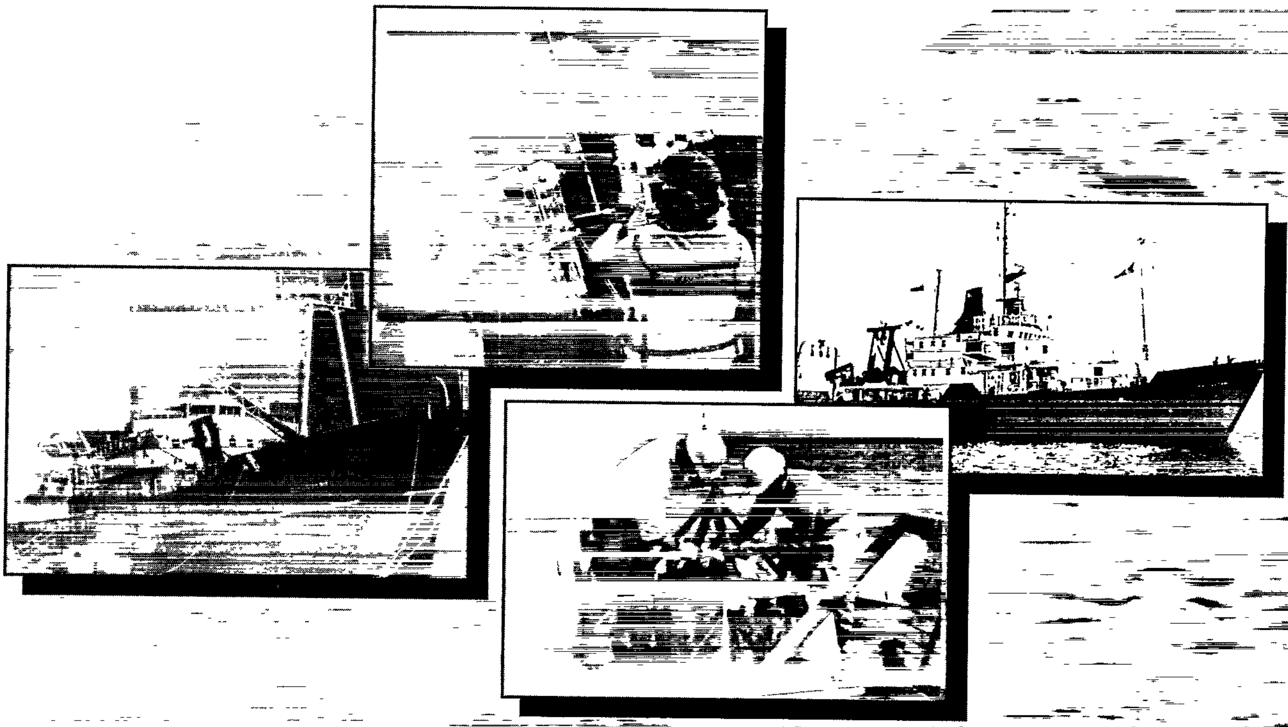
Southampton Oceanography Centre

Cruise Report



Natural Environment Research Council

University of Southampton

SOUTHAMPTON OCEANOGRAPHY CENTRE

CRUISE REPORT No. 6

RRS *CHARLES DARWIN* CRUISE 101C LEG 1
05 JUN-13 JUL 1996

TOBI surveys of the continental slope west of Shetland

Principal Scientist
D G Masson

1997

Challenger Division for Seafloor Processes
Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
UK
Tel: 01703 596568
Fax: 01703 596554
e-mail d.masson@soc.soton.ac.uk

DOCUMENT DATA SHEET

AUTHOR

MASSON, D G et al

PUBLICATION DATE

1997

TITLE

RRS *Charles Darwin* Cruise 101C Leg 1, 05 Jun-13 Jul 1996. TOBI surveys of the continental slope west of Shetland.

REFERENCE

Southampton Oceanography Centre, Cruise Report No. 6, 54pp.

ABSTRACT

This was the first of two cruises, the overall objective of which was to undertake an integrated baseline environmental survey of the continental slope west of Shetland. The major objective of this cruise was to obtain TOBI (30 kHz) and 100 kHz sidescan sonar imagery of the designated survey area west of Shetland. All the objectives of the cruise were achieved in full or exceeded. Over 14000 km^2 of seafloor was imaged with the TOBI system during 25 days of survey and 650 line km of 100 kHz data were obtained in 3.5 days of survey. Twelve sample stations were occupied during trials of the multicorer, box corer and Day grab. As anticipated, the mapped sediment facies variations are strongly related to waterdepth. Iceberg ploughmarks dominate the seafloor structure to depths of about 500 m. At mid slope depths, sediment bedforms and erosion due to current activity can be seen. At greater depths, less energetic depositional conditions prevail. Highlights of the sonar survey include the discovery of a field of barchan sand-dunes at a waterdepth of 300 m, a small sediment slide at 900-1000 m waterdepth, and an extensive sandy contourite sheet between the 850 and 1000 m depth contours between 61° and 61°20'N. The second cruise of the two cruises, mainly devoted to seabed sampling, is described in Southampton Oceanography Centre Cruise Report No. 7.

ACKNOWLEDGEMENTS:

All data and survey results presented herein were acquired on the Atlantic Frontiers Region Survey Project undertaken on behalf of the Atlantic Frontiers Environmental Network Consortium of operators comprising: Amerada Hess Ltd, Amoco (UK) Exploration Co, ARCO British Ltd, BP Operating Co, Chevron (UK) Ltd, Conoco (UK) Ltd, Deminex (UK) Oil and Gas Ltd, Elf Enterprise Caledonia Ltd, Esso Exploration and Production (UK) Ltd, Kerr McGee Oil (UK) Plc, Mobil North Sea Ltd, Shell UK Exploration and Production, Texaco North Sea UK Co and Total Oil Marine Plc, by the University of Southampton. The survey project was scoped and agreed between the Department of Trade and Industry, SOAEFD, the University of Southampton and the AFEN Consortium, and was commissioned and funded by the AFEN Consortium.

KEYWORDS

AFEN; BEDFORMS; *CHARLES DARWIN*/RRS; CONTINENTAL SLOPE; CRUISE 101C LEG 1 1996; ENVIRONMENTAL SURVEY; FAEROE-SHETLAND CHANNEL; NE ATLANTIC; PLOUGHMARKS; SEDIMENTS; SHETLAND; SIDESCAN SONAR; SONAR IMAGERY; TOBI

ISSUING ORGANISATION

Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
UK

Director: Professor John Shepherd

Copies of this report are available from: **The National Oceanographic Library, SOC**
Tel: 01703 596116
Fax: 01703 596115

PRICE: £12.00

CONTENTS

1. SCIENTIFIC PERSONNEL

MASSON, D. G. (Principal Scientist)	Southampton Oceanography Centre
ARMISHAW, J.	Southampton Oceanography Centre
BAKER, T. D.	Southampton Oceanography Centre
BETT, B. W.	Southampton Oceanography Centre
EVANS, J. M.	Southampton Oceanography Centre
KEETON, J. A.	Southampton Oceanography Centre
MATTHEW, D. R.	Southampton Oceanography Centre
ROUSE, I. R.	Southampton Oceanography Centre
WALLACE, R. F.	Southampton Oceanography Centre
FERN, A. M.	Research Vessel Services
JONES, J. L.	Research Vessel Services
PHIPPS, R. A.	Research Vessel Services
HOLMES, R.	British Geological Survey
WHITE, R.	JNCC

2. SHIPS PERSONNEL

HARDING, M. A.	Master
NEWTON, P. W.	Chief Officer
WARNER, R. A.	2nd Officer
HOLMES, J. C.	3rd Officer
BAKER, J. G.	Radio Officer
ADAMS, A. P.	Chief Engineer
CLARKE, J. R.	2nd Engineer
SHARP, D.	3rd Engineer
PARKER, P. G.	Electrician
HARRISON, M. A.	CPO (D)
LUCKHURST, K. R. G.	PO (D)
BUFFREY, D.	SG1A
DAY, S. P.	SG1A
DEAN, P. H.	SG1A
THOMSON, I. N.	SG1A
HEALY, A.	POMM
STAITE, E.	Senior Catering Manager
DANE, J. P.	Chef
HARDACRE, F.	Steward
SHIELDS, S.	Steward
THOMPSON, C. R. M.	Steward

3. ITINERARY

Sailed Fairlie	5th June, 1996
Arrived Aberdeen	13th July, 1996

4. INTRODUCTION AND CRUISE OBJECTIVES

The work described in this cruise report is the first part of a project sponsored by a consortium of oil companies, the Atlantic Frontiers Environmental Network (AFEN), operating in the NW Atlantic. The work was split into three phases :

1. Geophysical Survey (this report)

2. Sampling Programme (see Southampton Oceanography Centre Cruise Report 7)

3. Data processing and sample analysis (work in progress during 1997)

The major objective of the Geophysical Survey, the subject of this report, was to obtain TOBI (30 kHz) and 100 kHz sidescan sonar imagery of the designated survey area west of Shetland (Fig. 1). It was intended that preliminary sidescan image mosaics would be built up as the survey proceeded and an initial interpretation of the data undertaken on board. It was also planned that some trials of the various sampling devices to be used on the second leg should be undertaken.

4.1. TOBI survey plan

TOBI survey lines were planned in a southwest-northeast orientation, subparallel to the bathymetric contours, in water depths exceeding 200 m. Long straight survey lines (Figs 1, 2) ensured maximum survey efficiency by easing the task of 'flying' the deeptow vehicle at a constant height above the seabed and by maximising useful survey time (typically two to three hours survey time are lost on each 180° turn). TOBI survey lines are shown on figure 1 at a line spacing of 5.5 km (sidescan swath width is 6 km). The planned survey lines totalled 2800 km in length. Assuming an optimum survey speed of 3 knots and allowing for turns between survey lines, the survey depicted could just be achieved in the 23 days allowed. If significant time were to be lost to weather (perhaps 10% in an 'average' year; Fig. 3) then some reduction in the planned sidescan coverage would result. It was planned that this should be accommodated by slightly increasing the line spacing or shortening or omitting some survey lines. It was recognised that detailed planning of the response to weather problems could only be undertaken during the survey because this needs to take into account the survey lines already completed, weather forecast details, etc. TOBI downtime for routine servicing and repairs would be utilised for 100 kHz sidescan surveys and sampling trials, and should not result in overall loss of survey time.

It was planned that the three longest survey lines, between 300 and 500 m waterdepth, would be completed first, followed by the lines to the southeast along the shelf break, then progressively moving to deeper water. Should the survey area have to be reduced, then a need to obtain some data across the entire range of waterdepth was recognised.

4.2. 100 kHz survey plan

The choice of areas to be surveyed with the 100 kHz sidescan system should take into account the areas already surveyed using similar systems and the results obtained from the shallowest water TOBI line. Detailed line planning would therefore only be possible during the survey. The shaded rectangles on figure 2 show the total area which could be imaged in three days of 100 kHz survey. Discussions with AFEN representatives before the cruise indicated that attempts should be made to obtain representative 100 kHz sidescan data coverage over as much of the <200 m deep area as possible. Attempts should be made, using the 100 kHz system, to trace acoustic facies boundaries imaged by TOBI on the upper slope onto the shelf. Some overlap between areas of 30 kHz and 100 kHz sidescan data should be obtained so that a clear comparison of the imaging powers of the two systems can be made.

4.3. Interpretation of results

A preliminary interpretation of the data will be undertaken during the survey. A series of map sheets at a scale of 1:50,000 will be produced to facilitate planning of the following sampling programme.

4.4. Sampling trials

Seabed samples will be taken at a few selected sites (see sampling leg summary)

5. NARRATIVE

Wednesday 5th June (Julian Day 157)

Prior to sailing, the ship's first officer instructed the scientific party on basic safety at sea. R. R. S. Charles Darwin sailed from Fairlie at 1406 GMT (1506 BST) on passage to the working area. Fire and boat drill practice was completed immediately after sailing.

Thursday 6th June (Day 158)

Continued passage to the working area, intending to commence the first survey line at 59° 58.75' N, 5° 00' W. Passage speed 10.5 kts, weather excellent.

Friday 7th June (Day 159)

Ship's time was changed to GMT by retarding clocks by one hour at 0200 BST. Arrived in the survey area at 0100 GMT. The Ultra Short BaseLine (USBL) spar was deployed and tested for vibration at speeds up to 6 kts. The chief engineer confirmed that the installation was satisfactory. TOBI continued to give problems, and we stood by on station waiting for repairs to be completed. The main problem was noise on the sidescan system which became apparent only when the sidescan electronics were connected into the vehicle power supplies. However, while testing the electronics on the vehicle, a power supply failure on the profiler also occurred.

The engineers continued working on TOBI vehicle but by 1200 it became apparent that a solution was not imminent. At this point it was decided to proceed to the east to shallower water and deploy the 100 kHz sidescan sonar. The 3.5 kHz and 10 kHz fish were deployed at 1300. The sidescan fish was deployed at 1512, and trialed until 1707, at which time the first survey line commenced. Survey lines were laid out in an E-W direction, spaced approximately 6 nautical miles apart. A survey speed of 5 kts was found to be satisfactory, in line with the specification of the system.

Repairs to the TOBI vehicle continued during the remainder of the day. The vehicle electronics were stripped down to the minimum required for sidescan and profiler operation, and a new trial on the vehicle was assembled. This appeared to cure the previously persistent sidescan noise problem, but the profiler power unit failed again almost immediately, apparently due to a fault in the profiler or profiler wiring. At this point it was decided to continue 100 kHz sidescan surveys overnight, to allow the TOBI engineers to get some rest.

Saturday 8th June (Day 160)

Continued 100 kHz sidescan survey in deteriorating weather conditions. By 0900, wind speeds had increased to force 6/7, with some loss in quality of the sidescan data. Repairs to the TOBI profiler continued; one profiler transducer was replaced and the wiring harness was repaired. However, the profiler electronics again failed some 30 minutes after startup on deck. At this point it was decided that a complete dismantling and rebuild of the profiler hardware should be undertaken. This was completed by 2045, reinstallation into the vehicle was completed around 2300 and tested on deck by midnight. This time the entire system seemed to be functioning well, and it was agreed that it would be launched the following morning, following completion of the 100 kHz sidescan survey. This had continued throughout the day, in weather conditions ranging from 4 to 7, although always with a moderate swell running.

Sunday 9th June (Day 161)
Continued 100 kHz survey until 0730, by which time a complete reconnaissance of the southern, shallow water part of the AFEN survey area between 59° 20' and 60° 00' N had been completed. This amounted to a total of 325 km of sidescan track with a swath width of 750 m. The 100 khz fish was then recovered in board by 0800.

We now proceeded to the start of TOBI line 1 (slightly amended, to 61° 01.5' N, 5° 00'W, from the previously chosen point, 59° 58.5' N, 5° 00' W, on the basis of improved bathymetric information gleaned from BGS seabed sediments maps). The USBL probe was deployed at 0900. Preparation for the TOBI launch continued until 0930, the TOBI vehicle was launched at 0938 and the depressor weight at 1001. All the TOBI systems were found to be functioning correctly, but both the sidescan and profiler were noisy because of breakthrough from the 10 kHz echosounder and the USBL transponder on the vehicle. The echosounder breakthrough was something which had not proved to be a major problem in the past, and seemed to result from the unusually close proximity of the TOBI vehicle to the ship, in turn resulting from operating with a short tow cable in the very shallow water. This noise was minimised by decreasing the gain and pulse length on the echosounder and reducing the transponder ping rate to one per minute. By trial and error, the USBL was found to function most consistently if the depth was fixed by manually entering the depth of the TOBI vehicle taken from the vehicle pressure sensor. This had been initially been suggested as a potentially successful operation strategy by the Nautronix engineer at the time of installation of the USBL. After some slight manoeuvring, the first TOBI survey line began at 1033. Considerable fishing vessel activity in the survey area (at times up to 5 vessels within 6 nautical miles of the Charles Darwin) created some problems in terms of survey line following, with a slight deviation from the planned course necessary at 1244 when a fishing vessel approached to less than 0.2 nautical miles. Some noise on the sidescan record, probably due to the trawler's winch, was seen at the point of closest approach of the two ships.

Some evidence of iceberg ploughmarks was seen on the uppermost slope near the start of the line. Occasional strong slope parallel lineaments up to 3 km long and 20-30 m wide were also seen during the day. These were marked by strong backscatter contrasts but little apparent relief. Trawl marks were suggested, but this interpretation requires confirmation. Most of the area surveyed during the day was characterised by patterns indicative of artefacts due to refraction in the water column. Adverse water column structure also caused severe range restrictions in the sidescan data (typically 50% range, 1.5 km, on each side). Problems with ship generated noise also continued through the day, due to both fishing vessels and to exploration activity in the Foinaven oilfield area. The field was passed on its west side between 1730 and 1900. Three drilling rigs were operating on the field. The most westerly rig, not yet in drilling position, was lying some 1 mile west of the defined operational limits of the field, necessitating a divertion of the survey track by the same distance. No evidence of disturbance of the seabed due to drilling activity was observed on the sidescan data.

Monday 10th June (Day 162)

Continued on TOBI line 1 all day! Water column problems became less as the water depth gradually decreased along the survey line, but the sidescan range remained restricted to 2 km or less. Very little geology evident in the sidescan data. A well defined gently meandering channel was seen between 0400 and 0600. Iceberg ploumarks became the dominant seabed structure after 2100, as the water depth beneath the ship decreased. Much less fishing and oil related activity in the northern part of the survey area, but long line bouys were sighted during the day and the danger of hanging up on long line equipment remains.

Tuesday 11th June (Day 163)

Completed TOBI line 1 at 0456. Decided to run next line parallel and to the southeast of the first. A line spacing of 4 km was selected to allow for the reduced range experienced on the first line. Started line 2 at 0600. Water depth at the start of the line was only 190 m, resulting in a sidescan range of only about 1 km either side of the ship's track. Iceberg scour marks completely covered the seafloor and at depths less than about 400 m, gave rise to abundant hyperbolic relflections on the 3.5 kHz. At approximately 2030, we crossed the abrupt downslope boundary of the iceberg ploughmark zone. A few individual ploughmarks, commonly of exceptional size, occurred downslope of the general boundary to a maximum depth of between 450 and 500 m. Some slope parallel lineaments (scours??) were seen below the depth at which the iceberg ploughmarks ended. At approximately 1700, it was noticed that the USBL clock was 2 minutes 26 seconds ahead of the ship's clock. It could not immediately be determined whether this was due to a jump of the USBL clock or to whether the USBL clock was drifting. In practice, because of the slow rate of change between TOBI and the ship, typical of the TOBI operation, changing the time stamp on the USBL navigation correction file by 2 min 25 s made no perceptible difference to the plotted track, even at a scale of 1 : 25,000. A decision to reset the clock was made at 1830, primarily so that any future drift was more likely to be spotted against a zero baseline. By 1000 it was clear that the clock had drifted by a further 12 seconds and that this was an ongoing problem. The self test programme on the USBL control unit was run, but did not find any relevant errors. The master clock test did not find any errors, perhaps not surprisingly, since it was probably testing time against itself.

Wednesday 12th June (Day 164)

Continued TOBI line 2. Slow progress over the ground (typically 1.5 kts) due to adverse current and wind (opposite of first line where speed over the ground was often 4kts). Images (covering the lower limit of the iceberg ploughmark zone) continued to show a few very large ploughmarks and a succession of broad alongslope scours (??). The USBL system continued to gain time at a rate of approximately 3 s per hour. The USBL clock was reset twice, at 0419 and 1016. Decided not to keep resetting USBL clock, for fear of upseting system further, but instead to log USBL time against ship's time. This should allow for a post processing correction of the USBL time. Contacted Nautronix through SOC, but they were unable to explain the problem. They had "no previous experience of this problem", but also said that most users were only interested in real-time positional information, with no requirement for accurate absolute time. Nautronix office in Aberdeen did not know how to input external time into their control unit, but said that they would contact their office in Australia to find the answer. A further response from Nautronix was promised before the end of the day (it didn't arrive). Ship's speed was increased to 3.5 kts through the water at 1730, to try to counter the lack of progress over the ground. However, only 7.5 nautical miles were covered in the four hours between 1730 and 2130.

Thursday 13th June (Day 165)

Continued TOBI line 2. Little change in geology. Began altering course to make detour around Foinaven oilfield operational area at 1004. Intended to pass 1000 m east of the easternmost rig. Three drilling rigs, each with a standby boat, two supply boats, one seismic boat with guard boat, and three fishing vessels within a 6 mile radius circle around the Charles Darwin. A further course change was required at 1111, when the standby vessel with the nearest drilling rig informed us that rig anchors extended up to 2 km from the rig, and that we should not encroach within this distance. Cleared rig area by 1400 and began to manoeuvre back onto line . However, a uncooperative Norwegian long-liner prevented us getting back onto line until 1726. Speed over the ground again reduced to between 1.5 and 1.8 kts, indicating a surface current of about 1.7 kts from the southwest. Between 1800 and 2000 we were forced to run slightly to the west of the planned line because of a string of long line buoys. During the day received a fax from Nautronix confirming that it was not possible to input an external clock into the USBL unit, but they were unable to offer any ideas as to how the drifting clock problem could be addressed. We decided to continue to log our clock against the USBL clock, so that a time correction could be added during post-cruise data procesing.

Friday 14th June (Day 166)

Finished TOBI line 2 at 0309, began line 3 at 0423. Geology shows a great variety of iceberg ploughmarks. Between 0850 and 1500 we were forced to make a wide detour to the east to avoid a combination of the seismic vessel Ramform Explorer and the rigs on the Foinaven oilfied. The seismic vessel requested and was given a clearance of 2 miles to the side and 3 miles astern. Fewer features seen on the sidescan data as we crossed the Foula Bight, primarly because line 3 crossed this area below the deeeper limit of the iceberg ploughmark zone, at about 450 m.

Saturday 15th June (Day 167)

Bad day for Anglo-Scottish relations as England beat Scotland at football. End TOBI line 3 at 1457, start line 4 at 1626. Speed over the ground averaged 3.5 kts along the northern part of line 3. Several close encounters with a Norwegian long liner who seems to know nothing of the rules of the road and at one time cut across our bows at less than 100 m range. Weather exceptionally good, except for temperature. Rather few geological features seen on the records. In particular, the poor record of iceberg ploughmarks towards the northern end of line 3, even in waterdepths as shallow as 350 m, contrasts with areas both to the south and north, where these features commonly extend to 450 m depth.

Sunday 16th June (Day 168)

Continued TOBI line 4, making the usual slow progress against the surface current. Weather continues to be excellent. Most of the area covered in iceberg ploughmarks, with evidence also for some moraine ridges. One area where where iceberg ploughmarks were absent was characterised by a field of lunate features, each 100-300 m long and oriented transverse to the slope and facing into the northward flowing current. These had the appearance of a field of barchan dune like features. Distinct current parallel lineations stretching over 2km or more, and apparently deflected where they intersected a moraine ridge, were seen in the same area. It was not immediately obvious why iceberg ploughmarks were absent from the area, at water depths between 250 and 350 m. One suggestion was that the shelf topography immediately landward of the dune field might be deflecting sediment over the shelf edge in this area, burying any pre-existing ploumarks and supplying sediment to build the dunes.

Monday 17th June (Day 169)

Finished TOBI line 4 at 0230. Then ran line 5, towards the NE, starting at 0315 and ending at 1541. Started line 6 at 1700. Geological features consist entirely of iceberg ploughmarks interspersed with a few hummocky patches (moraine remnants?). Weather deteriorated during the day, reaching 6/7 in the evening, but little affect on the quality of the survey.

Tuesday 18th June (Day 170)

Finished TOBI line 6 at 0615, started line 7 at 0716. Line 7 is the furthest east line, along the shelf break, in depths ranging from 180 to 300 m. Limited swath width in this very shallow water (typically 1 to 1.5 km per side). Weather still poor, but very slowly improving.

Wednesday 19th June (Day 171)

Finished line 7 at 0800 and began TOBI recovery. All safely on deck by 0908, despite moderate swell and considerable ship movement. Retracted USBL transducer probe without difficulty prior to steaming 70 miles to the SW to start TOBI line 8. During this time, the TOBI vehicle was checked out and the swivel was serviced. The new swivel unit was found to virtually unaffected by deterioration of the oil, despite 10 days of constant use. Arrived at the start of line 8 at 1630 and redeployed USBL probe. TOBI launched without problems between 1640 and 1705. Started line 8 at 1715. Initially 'flew' TOBI at 300 m above seabed, but this gave poor range and considerable water column refraction effects. Some sort of sound reflection or refraction noise also resulted in random triggering of the USBL acoustic beacon, with the worry that this would markedly shorten the beacon life. Tried going to 250 m, but this made the problem worse. Tried 400 m which much improved both the quality of the record and decreased the false triggering of the beacon.

Thursday 20th June (Day 172)

Weather deteriorated again overnight, with winds increasing to force 7 and a moderate swell. Fortunately, weather is from the NNE and we are heading into it, so we are able to continue TOBI survey. Very few geological features seen, except for a very rare iceberg ploughmarks extending to depths as great as 600 m. Had problems with USBL positioning between 0530 and 1000. These were initially blamed on the pitching motion of the ship, but the cause was eventually discovered to be operator error, a depth offset inadvertently having been entered into the system menu while a manual TOBI depth entry was being made. This clearly is an easy mistake to make given the layout of the USBL system menu, and all watch keepers were warned to guard against a repeat. Weather continued to worsen during the day, gusting to force 8 and occasionally 9. At 1801, electrical contact with TOBI became intermittent, and almost immediately was lost completely. A short circuit in the umbilical, probably due to the excessive heave transmitted to the depressor by the short main tow cable, was diagnosed as the most likely cause. With the weather as it was, no prospect of recovering TOBI could be considered. The vessel therefore continued into the weather at the minimum speed required to maintain forward motion, while awaiting improvement in the weather. The 3.5 and 10 kHz systems were placed on standby, and the watch was stood down.

Friday 21st June (Day 173)

Weather improved slightly overnight, but still too much ship movement to attempt TOBI recovery. The vessel continued to head slowly into the weather until 1900 when it was judged that the weather had moderated sufficiently to allow us to turn back toward the point where we had broken off the survey. Improving weather forecast suggests that it will be possible to recover TOBI early tomorrow.

Saturday 22nd June (Day 174)

Weather and sea moderated significantly overnight. Began TOBI recovery at 0807. The depressor was recovered at 0815, at which point the cause of the failure was immediately obvious, since the cable connecting the umbilical to the swivel was bent back and almost completely severed. This was clearly not damage related to ship heave. Entanglement with a longline or other submarine obstruction would have been required to cause this type of damage. The cable was repaired on deck while TOBI was still in the water. Repairs were complete by 0910. We were then able to check that all the vehicle systems were operational and confirm that damage was limited to the depressor cable. The TOBI vehicle was recovered at 0932 and we then steamed back towards the redeployment point at 61 20.9N, 01 36.7W. En route, we stopped briefly at 61° 24.15' N, 01° 39.45' W, where a bathysnap mooring had been deployed in September, 1995. The ship hove to approximately 2 cables off the nominal deployed position of the Bathysnap system (WoS#1). Acoustic contact with the bathysnap, which will be recovered during the second leg of the current cruise, was established immediately. Transmission of three 'off' commands to the release unit elicited three 'received' and 'executed' returns, giving a mean slant range of 725 m. With a sounding of 560 m, horizontal range from the ship to the mooring was under 500 m, suggesting that the mooring is essentially in the position it was laid at (61° 24.15' N, 01° 39.45' W: SE quadrant of Block 208/17). A 'pinger on' command was also transmitted, and 'received' and 'executed' returns received. Pinger function was confirmed by reference to the waterfall display unit and a printed record. One further 'off' command was transmitted and the release unit successfully returned to a quiescent state. TOBI was then redeployed at 61° 20.76'N, 01° 36.57'W between 1243 and 1320. Survey line TOBI 8 was restarted at 1338 and completed at 2218. Line 9 was started at 2338.

Sunday 23rd June (Day 175)

Continued TOBI line 9 in good weather and calm seas. Slow progress on southwesterly line due to strong adverse currents. Few geological features imaged on sonographs.

Monday 24th June (Day 176)

Continued TOBI line 9 in good weather and calm seas. Making an average of 2 kts over the ground, due to adverse currents. Crossed a field of long wavelength sediment waves during the first half of the day. Best seen on 3.5 kHz record, but some subtle wave crest trends also seen on sidescan images. Crossed three incised channels between 1600 and 2000, with the remnants of three others seen on the sidescan images.

Tuesday 25th June (Day 177)

Finished TOBI line 9 at 0000, started line 10 at 0115. Maintained 4 km line spacing in view of limited sidescan range. Noted that water temperature at the TOBI vehicle varied between 2.3 and 8.3° C along the early part of this line, with little variation in vehicle depth. Some improvement in the sidescan range and record quality when the vehicle was in cooler water. Later in the day however, during a period of poor record quality, the vehicle was allowed to sink by 100 m without any substantial temperature change and without noticably affecting the record. Re-crossed the field of channels seen on line 9 between 0300 and 0600. At least nine channels seen on this crossing. A few weak downslope features seen on the sidescan record in the latter part of the day - these appear to be related to (largely) buried debris flow tongues seen on the 3.5 kHz. Weather continues good, with force 4/5 westerly winds. Raining again!!

Wednesday 26th June (Day 178)

Finished TOBI line 10 at 0314, started line 11 at 0531. Weather continues to be excellent. England lose to Germany in European championship - oh dear. At 2300, forced to make a detour to starboard to allow a siesmic vessel to pass. Very few geological features to report.

Comparison of survey speed over the ground between lines 9 and 10 shows that the vessel averaged 2.3 kts over the 113 nautical miles of line 9 and 4.2 kts over the 107 miles of line 10.

Thursday 27th June (Day 179)

Back on line 11 by 0100 following detour to avoid seismic vessel. Seafloor during early part of day completely featureless and incredibly low backscatter - accurately described as "the acoustic equivalent of matt black" by one of the scientific party. Crossed a series of narrow channels between 1920 and 2315. Eleven channels in all.

Friday 28th June (Day 180)

Weather much less friendly, wind 30 kts from SE, with 35 kts forecast. Finished line 11 at 0035, started line 12 at 0130. Recrossed the field of shallow channels between 0330 and 0730. Again eleven channels were seen. Gradual progression from low backscatter to 'matt black' facies between 0730 and 1400. Distinct northern boundary of black facies crossed at 1800. A small surficial sediment slide was crossed between 1820 and 1850.

Saturday 29th June (Day 181)

Weather improved again. Finished line 12 at 0516, started line 13 at 0755. Recrossed the debris flow seen on line 12 at 2200, but it was much less obvious on the sidescan images on this line compared to the previous. During the latter part of the day the USBL became increasingly unreliable as the vehicle range increased to around 1900 m and its depth to 700 m. Loss of contact between the USBL on the ship and beacon on the vehicle for periods of more than five minutes results in the system going into a 'search' mode, automatically increasing the ping rate to one per eight seconds until a response is received. This rapid ping rate both adds noise to the sidescan and profiler records and rapidly depletes the beacon battery. To prevent this, the system was turned off for short periods when it proved totally impossible to get a response. It was noted that responses were often received when wire was being hauled in, tilting the vehicle head up towards the ship. This presumably improved the geometry of the acoustics. It should be noted here that the omnidirectional beacon was being used on TOBI, rather than the directional unit supplied by Nautronixs, because the latter had been modified to allow it to be run on power supplied from TOBI, but the modifications made to the TOBI electronics at the start of the cruise made this impossible.

Sunday 30th June (Day 182)

USBL system largely inoperable from 0000 until 0630, but it became usable again as the water shallowed and some wire was hauled. Finished line 13 at 1454, started line 14 at 1618. Very few geological features seen on sidescan data. Weather now the best seen on the cruise, with no wind and almost calm seas.

Monday 1st July (Day 183)

Continued on TOBI line 14. Weather still excellent. Sidescan images still completely featureless. USBL intermittent between 0600 and 1930. End of line TOBI 14 at 2334.

Tuesday 2nd July (Day 184)

Started line TOBI 15 at 0123. Weather still excellent. Sidescan images still completely featureless. USBL intermittent for periods throughout the entire day. 3.5 kHz records showing penetration of several tens of metres. End of line 15 at 1752, started line 16 at 1953.

Wednesday 3rd July (Day 185)

Continued TOBI line 16. Progress towards the NE now slow because of adverse surface currents of up to about 1 kt. No features on sidescan images for some 48 hr prior to the end of day 185. Weather still excellent. 3.5 kHz penetration continues to increase as we move towards the axis of the Faeroe Shetland channel. Terminated line 16 at 1835, some 4 miles early, because of a Russian seismic vessel crossing our intended track. Line 17, started at 1955, was also shortened by about 1 mile because of the diversion around the seismic vessel.

Thursday 4th July (Day 186)

Finished TOBI line 17 at 0951, started line 18 at 1125. Progress on line 18 again slow (average 2.2 kts over the ground between 1200 and 2100) because of adverse current from the NE. No features on sidescan images. 3.5 kHz profile shows layered acoustic facies with good penetration (typically 50 m). Wind continues to be light, although cloudy with rain.

Friday 5th July (Day 187)

Finished TOBI line 18 at 0730, started the final line 19 at 0907. All as Day 186, except that wind has risen to 20-25 kts. Finished line 19 at 1900, completing 100% of the anticipated TOBI survey. Final run lasted for 13 days 5.5 hr, beating the previous longest TOBI deployment by some way. After hauling 2.5 km of wire, the depressor was recovered on deck at 2007, and TOBI was recovered with minimum fuss at 2033. The USBL probe was then retracted and we set off for the first coring station at 2040.

Saturday 6th July (Day 188)

The first three core sites, designed primarily to test the relative capabilities of the megacorer and box corer were located in the vicinity of 61° 15'N, 02° 30 'W, in a water depth of around 900 m, so as to opportunistically sample three different acoustic facies observed on the TOBI images. Arrived at the first coring site, station 53701, at 0030. The megacorer was deployed at 0059, and a pinger attached to the wire 50 m above the corer. The core reached the bottom at 0135 and was recovered by 0210. All 12 multicore tubes was recovered full of muddy sediment. The second core site (53702) was reached at 0603 and the megacorer was deployed, reaching the seabed at 0637. On recovery at 0704, however, only 2 of the twelve tubes contained around 10 cm of sandy sediment. It was decided to redeploy the corer at the same site, with the centre tube of the three on each side removed, in order to increase the force on each of the remaining tubes. This deployment (53702 #2) was completed successfully at 0849, with 7 of the 8 tubes being recovered full of mud beneath a layer of sand. The box corer was tested at the next site, station 53703. Deployed at 1107 and recovered at 1220, this was a successful coring attempt, recovering a good quality box core some 32 cm long. The core was composed entirely of homogenous silty sand with no indication of structure. At station 57304, in an area characterised by large scale sediment waves some 10 miles to the east of the first three sites, BGS maps suggested that the seabed sediments consisted of gravelly mud, cautioning against use of the megacorer. The box corer was used again, being deployed at 1414 and recovered at 1502. Again, a full box was recovered (40 cm long good quality core). As predicted the core consisted of gravelly mud overlying more homogenous mud. The largest cobbles were > 10 cm in diameter and many had an attached fuana of bryazoans and other organisms. At this point we broke off coring and restarted the 100 kHz survey in the shallower eastern part of the survey area. The 100 kHz fish was deployed at 1705. ORE line 14 was completed between 1730 and 1839, line 15 between 1853 and 1941, line 16 between 1952 and 2130, line 17 between 2140 and 2305, line 18 between 2311 and 0032 on Day 189. All lines were completed at a nominal speed of 5 kts.

Sunday 7th July (Day 189)

Continued 100 kHz survey in freshening weather. Completed line ORE18 at 0032, line 19 between 0108 and 0230, and line 20 between 0300 and 0746. At this point we broke off the 100 kHz survey to continue with the sampling trials. The 100 kHz fish was recovered at 0807 and we moved off to the first sampling station. The Day Grab was tested at station 53705 between 0916 and 1014, where three deploymenys yielded two samples of sand and one empty grab in a water depth of 157 m. A further Day Grab deployment was undertaken between 1205 and 1304 at station 53706, on a predicted gravel substrate. Three deployments yielded two empty grabs (except for a few pebbles) and the third a quantity of sand, although the grab jaws were not completely closed and it seemed that the sample had been well washed during recovery. The box corer was then tested at two sites on the upper slope where gravel and sand substrates were predicted on existing maps. Two deployments were made between 1439 and 1624 at station 53707, in 360 m water depth. The first yielded a core of mainly gravelly sand, varying between 0 and 22 cm in thickness, and with an apparently tilted upper surface, initially suggesting that the corer had not penetrated in a vertical orientation. The second core yielded a full box containing an obvious sand wave prograding over a gravel surface, these resting on a layer of homogenous mud. Cobbles up to 15 cm was recovered from the gravel layer. This core suggested that the tilted surface of the first core may, in fact, also have been natural, probably being part of the trailing edge of a sandwave. The final box core station (53708), occupied between 1845 and 1943, yielded a full core with a few cm of gravelly mud overlying more homogenous mud. A spectacular assemblage of sponges, almost covering the core surface, was also recovered. Between 2045 and 2120, we then performed a test of the USBL system with the beacon mounted on the megacorer. The corer was lowered to within 50 m of the bottom in 500 m of water (the gravelly nature of the seabed cautioned against trying to take a core) whilst being tracked from the ship. The system worked perfectly, with no problems encountered in tracking the corer, which stayed within a 10 m diameter circle directly below the deployment point. This station completed the AFEN sampling programme for the first leg. The 100 kHz survey programme then continued. The 100 kHz fish was deployed at 2310, with line ORE commencing at 2314.

Monday 8th July (Day 190)

Continued 100 kHz survey in excellent weather. Line ORE 21 was completed at 0319, line 22 between 0334 and 0730, line 23 between 0747 and 1004, line 24 between 1014 and 1439, line 25 between 1452 and 1608, and line 26 between 1620 and 1948. The 100 kHz fish was then recovered and safely stowed on deck by 2004. The ship then moved off towards the first 'NERC' Kasten coring site.

Tuesday 9th July (Day 191)

Ship stopped between 0014 and 0145 due to seawater pipe burst in the engine room cooling system. Arrived on station 53709 #1 at 0215 and deployed the Kasten corer at 0223. The aim of this station was to sample the slope sediments in an area between two channels. Recovered a good 1.8 m core at 0321. The next Kasten core station (53710), in the depositional area west of the channel complex, was occupied between 0803 and 0940. Two attempts were required before a 1.5 m core was recovered. Veering speed was increased from 20 to 40 m s^{-1} for the second attempt. Kasten core station 53711, designed to sample the very low backscatter 'black hole' acoustic facies, was occupied between 1417 and 1632. Despite three attempts, no core was recovered from this site. Our experience from a box core taken earlier in the cruise and evidence from BGS seabed sediment maps suggests that the coring difficulties experienced at this site can be attributed to a relatively thick sand layer at the seabed. Kasten core station 53712, in the debris flow depositional area, was occupied between 1735 and 2040. The first attempt recovered a short 0.7 m core, the second a full 1.8 m core, with sediment on the core head suggesting a few tens of cm overpenetration. As with station 53710, the veering speed was increased from 20 to 40 m s^{-1} for the second attempt.

Wednesday 10th July (Day 192)

Reached the start of the final 100 kHz survey area at 0030. The fish was deployed at 0035 but the system failed almost immediately. The fault was quickly traced to the fish which was brought back on board at 0110. The fault was confirmed as being in the fish, so it was replaced with the spare fish and the survey recommenced at 0130. Line ORE 27 was completed between 0136 and 0238, line 28 between 0310 and 0352, line 29 between 0403 and 0418, line 30 between 0430 and 0507, and line 31 between 0528 and 0627. The 100 kHz fish was then recovered at 0645 and the vessel steamed to the TOBI deployment point. The USBL probe was deployed at 0852 and TOBI at 0930. For the remainder of the day, a TOBI survey line was run northward from the AFEN area towards the Miller Slide scar between 60° 50' and 62°N. At 1750, severe elctrical noise problems were noted on the TOBI records. The survey was broken off and the depressor brought onboard so that tests could be run to locate the problem. This was traced to the winch slip rings, to which repairs were carried out between 1835 and 2208. Survey recommenced at 2215.

Thursday 11th July (Day 193)

Continued TOBI survey in the Miller Slide area. Some good sonographs of part of the slide headwall and of the northward truncation of the fault system observed on the slope to the south, but the structure is obviously relict and largely buried. The survey was completed at 2312 and recovery of TOBI began.

Friday 12th July. (Day 194)
Recovery of TOBI, the USBL probe and the 3.5 kHz and 10 kHz fish was completed at 0022. The remainder of the day was spent on passage to Aberdeen.

Saturday 13th July (day 195)
Docked in Aberdeen at approximately 0800 local time

6. TOBI OPERATIONS

6.1 System Description

TOBI - Towed Ocean Bottom Instrument - is Southampton Oceanography Centre's deep towed vehicle. It is capable of operating in 6000 m of water although on this cruise the depth requirement was only up to 1500 m, with most of the area under investigation significantly shallower than this.

Although TOBI is primarily a sidescan sonar vehicle a number of other instruments are fitted to make use of the stable platform provided by TOBI. For this cruise the instrument compliment was:

1. 30 kHz sidescan sonar (Built by IOSDL)
2. 7.5 kHz profiler (Built by IOSDL)
3. Three axis fluxgate magnetometer. (Ultra Electronics Magnetics Division MB5L)
4. CTD (Falmouth Scientific Instruments Micro-CTD)
5. Gyrocompass (S. G. Brown SGB 1000U)
6. Pitch & Roll sensor (G + G Technics ag SSY0091)

Although the gyrocompass was installed it was not operated due to power supply noise problems.

For this cruise the vehicle was fitted with a Nautronix transponder beacon to give TOBI positions using the ship mounted Nautronix Ultra Short Base Line (USBL) navigation package.

The TOBI system uses a two bodied tow system to provide a highly stable platform. The vehicle weighs two tonnes in air but is made neutrally buoyant in water by using syntactic foam blocks. A neutrally buoyant umbilical connects the vehicle to the 600 kg 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.

6.2. Operations

TOBI watchkeeping was split into three four hour watches repeating every 12 hours. Watchkeepers kept the TOBI vehicle flying at a height of between 350 to 400m above the seabed by varying wire out and/or ship speed. Ship speed was usually kept between 3.0 and 3.5 kts and 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.

Four TOBI deployments were made during the survey. Launch and recovery times are summarised in Table 1 (below). Full details of all survey lines are given in figures 4 and 5 and in Tables A1 and A2 (Appendix 1). Average survey speed was 3.2 kt. The first three deployments, covering the AFEN area, produced a total of 3039 line km of data (excluding turns between survey lines) resulting in coverage of 14040 km^2 of seafloor.

Table 1. Summary of TOBI deployments

Run	Start Time	End Time	Comments
1	1002/161	0802/171	
2	1706/171	1801/172	Curtailed due to open circuit fault
3	1324/174	1957/187	13.25 day run - a TOBI record
4	0933/192	2350/193	'NERC' survey in area north of AFEN area. Includes 4 hr break to fix fault in winch slip rings

The sidescan sonar performed well given the shallow water and large sound velocity gradient encountered. Performance was better in the deeper water where the refraction experienced in shallow water were reduced.

A long standing fault in the profiler array was traced and cured prior to the first deployment of the cruise and performance was noticeably improved, with sensitivity improved compared to recent cruises.

Half way through the cruise the magnetometer mounting was found to be twisted. This probably happened during the previous cruise when the vehicle was damaged on recovery. It was decided to leave the position unchanged and make a compensation for the whole cruise. The error was calculated to be about 12 degrees. Otherwise the unit performed well with clean data.

The CTD operated without drama for the whole cruise.

Overall the vehicle had to be recovered only once for a failure to the umbilical electrical connection. The reason for this is unclear although it looks like it may have been severed by being cut by another wire, possibly part of a long line.

The only other operational failure was due to the slip rings on the ship's winch which developed a short to case. This problem was temporarily solved by swapping over the cables through the slip rings so that 0 V went through the shorting connection. This worked satisfactorily but the slip rings need to be serviced and our modification returned to its original state after the end of the cruise.

6.4. Data Recording and Replay

Data from the TOBI vehicle is recorded onto 1.2 Gbyte magneto-optical (M-O) disks. One side of each disk gives approximately 16 hours 10 minutes of recording time. All data from the vehicle is recorded along with ship position taken from a GPS receiver and wire out from the ship's winch readout. However, during this survey, the wire out did not function automatically due to intermittent noise on the ship's winch wire out signals. Manual entry was done throughout the cruise whenever winch movements occurred.

Data was recorded using TOBI programme LOG.C. The profiler data was corrected for the depth of the vehicle and replayed in programme PROFRAY.C. The CTD data was copied off the M-O disks and onto floppy disk in ascii format for importation into a spreadsheet using programme CTDCOPY.C. Using positions for the TOBI vehicle derived from the DGPS and USBL navigation systems, accurate 1/2 hour distance travelled could be calculated. These were integrated into the TOBI replay system and correctly scaled sidescan sonar replays were generated at a scale of 1:50,000 using programmes ERASDISC.C and DISSCRAY.C.

7. TOBI LAUNCH AND RECOVERY PROCEDURE

7.1. Overview

TOBI - Towed Ocean Bottom Instrument - is Southampton Oceanography Centre's deep towed vehicle, equipped with sidescan sonar and sub-bottom profiler sonars and a range of other scientific instruments.

The vehicle itself measures 4.5 m long by 1.5 m high by 1.5 m wide and weighs between 2 and 2.5 tonnes in air depending on payload. When deployed the vehicle is towed from a 200 m neutrally buoyant umbilical which is in turn attached to a 600 kg depressor weight. The weight is connected to the main conducting cable via a swivel unit. The use of this two bodied tow system makes for a very stable towing arrangement but has the disadvantage of being more complicated to deploy and recover.

Since its first scientific cruise TOBI has been used on 7 different ships. The detailed method of deployment and recovery varies from ship to ship but the overall tactics remain the same. This document is based on the procedure used on NERC fleet ships.

7.2. Deck Equipment

Deck equipment required for TOBI operations consists of the following:

- Moving 'A' frame with 3 m height and ideally >4.5 m width.
- 3 tonne launch winch.
- Umbilical winch.
- Two capstans, one either side of the 'A' frame.
- Double block with launch and tow sheaves mounted centrally on the 'A' frame or separate sheaves mounted close together.
- 3 tonne deck crane for manoeuvring the vehicle.

The launch winch is mounted in line with the launch sheave a suitable distance (5-10 m) from the 'A' frame. The umbilical winch can be mounted off centre but ideally between the line of the 'A' frame legs.

In addition to the above the main winch carries the 10 km conducting tow cable.

7.3. Pre-launch Vehicle Rigging

In order to be able to safely recover the vehicle, recovery lines must be stowed on the vehicle. Lines are attached to the port side forward and aft quarters of the vehicle and a recovery hoisting line attached to the central lifting bridle. The aft line is attached along the port side towards the front using thin cable ties. The forward line and the hoisting line are then coiled with the aft line into a cradle at the front of the vehicle. The forward and aft lines are shorter than the hoisting line and are taped to it at their ends. Care must be taken not to twist the lines as this could impair recovery. Once coiled the lines are tied to the forward frame using thin cable ties.

The final procedure is the attachment of the recovery hoop. A thin rope running through the hoop is attached at both ends to the loop in the end of the hoisting line. The loop is tied to the front of the vehicle using cable ties so that it forms a target that can be easily grappled.

7.4. Vehicle Launch

The umbilical is attached to the vehicle and both electrical and mechanical connections are completed. The vehicle is then placed into the launch position athwartships under the 'A' frame. Stay lines are tied to fixing points on the outside of each 'A' frame leg, passed outboard around each 'A' frame leg, around the nearest inboard TOBI vehicle frame leg, then back around the 'A' frame before being coiled around their respective capstans. These stay lines must be long enough to allow the vehicle to be placed into the water under their control.

Two more stay lines are used inside the 'A' frame. These are made fast to a suitable eye, run around the nearest vehicle frame leg and back through another eye or cleat. These lines are hand held and are used to control the vehicle before the outside lines take control. They need to be long enough to enable this.

The launch winch cable is paid out through the launch block and attached to a large shackle. The two loops in the lifting bridle strops are passed through the shackle and held in place by a greased spike. The spike is attached to a rope such that it can be pulled out of the lifting bridle strops when the vehicle is in the water, so detaching the launch cable.

Once the vehicle is in position, with the stay lines and launch cable attached and the 'A' frame inboard, the ship is slowed to 0.5 kts and brought into the wind. About 10 m of umbilical cable is paid off the winch and laid out on deck, so that the vehicle can be launched without straining the umbilical. A minimum of seven people are required for the TOBI launch - four to man the stay lines, one each to operate the 'A' frame, the launch winch and the main winch.

With the stay lines manned the tension is taken up - the outer ones using the capstans and the inner ones by hand. The launch winch lifts the vehicle off the deck and the 'A' frame is paid out. Once clear of the stern the winch pays out and the inner stay lines loosed off the vehicle. The outer lines are now in control and it is imperative that they remain tight to prevent unwanted movement of the vehicle. Once in the water the outer lines are loosed and the spike pulled, freeing the vehicle. The 'A' frame is then brought in.

The umbilical is then paid out and the ship's speed increased to 1.0 kts to stream the vehicle.

7.5. Depressor Weight Launch

Whilst the umbilical is being paid out the depressor weight can be brought into position (with the tail facing aft) underneath the 'A' frame using the crane. A cradle is used to hold the weight. The main cable is fed over the towing sheave and connected to the swivel unit on the depressor weight.

The umbilical is paid out until the tie loop is reached, stopping briefly before this to free the electrical connection from the inside of the winch. The umbilical is made off temporarily to an eye or cleat using the loop. The remainder is taken off by hand and the terminated end taken over to the tail of the depressor weight. The ship should now be slowed to 0.5 kts.

The umbilical is terminated mechanically to the depressor weight tail and electrically to the swivel unit. At this point the vehicle can be turned on and tested. If tests are successful then the depressor can be launched by hauling on the main cable, paying out on the 'A' frame, then paying out on the main winch. Hand held stay lines may be used to steady the weight as it is deployed.

Once deployed the ship can be brought up to towing speed and the main cable paid out to working depth.

7.6. Depressor Weight Recovery

The recovery process is essentially the reverse of the deployment. The weight is brought to the surface using the main winch, ship speed brought down to 0.5 kts (into the wind) and the 'A' frame brought in. The launch winch cable is paid out to hook onto the nose of the weight when it comes aboard. A stay line may be slipped down the cable to restrict movement of the weight.

The weight is lifted from the water using the main winch under the control of the stay line. As soon as possible another line can be attached and the launch cable attached to the nose of the weight using a shackle or carribiner clip. The weight is then hauled up the deck using the launch winch and onto the cradle. The recovery loop on the umbilical is made off to an eye or cleat. The mechanical and electrical connections to the weight/swivel can then be disconnected. The mechanical connection is tied off to the umbilical winch and the electrical connection fed inside the winch for protection. The umbilical can then be hauled in whilst the depressor weight is stowed.

The ship may be sped up to 1.0 kts to keep the vehicle directly behind the ship.

The weight may be stowed with the main cable attached if no maintenance is required on the swivel unit.

7.7. Vehicle Recovery

The same personnel are needed for recovery as for launch.

As the umbilical is being recovered a long boathook equipped with a carribiner clip is readied. The inner stay lines, as used for deployment, are also made ready. The launch cable is fed through the launch block to accept the hoist line. As the vehicle approaches the ship the rate of umbilical recovery is reduced. When in range of the boathook the umbilical winch is stopped and the hoop on the vehicle grabbed by the carribiner. A pull on this will release the hoisting line and stay lines from the coil on the front of the vehicle.

This is the most dangerous part of the operation as the vehicle could get caught under the ship and damaged. It is good policy to pay out about 10 m on the umbilical as soon as the recovery hoop is grabbed. In severe conditions the ship speed can be increased to prevent the vehicle from surging under the stern.

Once the hoist line has been grabbed and uncoiled from the vehicle then the two stay lines are passed around their respective 'A' frame legs and fed over their capstan. The hoist line is attached to the launch cable and the slack taken up. The vehicle is then brought under the control to the stay lines to the stern of the ship and the 'A' frame brought half-way in. The vehicle is then lifted out of the water using the launch winch pulling on the hoisting line. The outer stay lines must be kept taut at this point to prevent unwanted motion of the vehicle. As soon as possible the inner stay lines are fed around the vehicle frame legs and passed through an eye or cleat to increase purchase. The 'A' frame is then brought fully in with the vehicle under the control of the four stay lines and the launch winch, and the vehicle is placed onto the deck underneath the 'A' frame.

8. 100 KHZ SIDESCAN SONAR OPERATIONS

8.1. System description

In areas where water depth was too shallow to allow use of TOBI, sidescan sonar data was collected using an ORE 100 kHz dual sidescan system. This was hired from Seatronics Ltd of Aberdeen. The system supplied consisted of the 100 kHz sidescan fish (with spare), an electrically powered winch with 1000 m tow cable and appropriate deck cables. Data display was on an Ultra 3710 thermal recorder and data was also recorded on a Sony DAT recorder.

The fish was 'flown' between 35 and 40 m above the seabed, following the manufacturer's instructions that the flying height should approximate to 10% of the range. A sweep time of 500 ms was used, since this proved to be the maximum effective range of the system. This gave a slant range (and effectively a ground range) of approximately 375 m either side of the fish. Tow speed was generally in the range 5 to 5.5 kts, although slower speeds (4 to 4.5 kts) were required where the water depth approached 200 m, in order to get the sidescan fish down to the required survey depth. Paper speed on the recorder was set at 1 mm s^{-1}, giving an approximately true scale record at a nominal tow speed of 5 kts.

8.2. Operations

Four deployments of the 100 kHz system were made during CD101C. Launch and recovery times are summarised in Table 2 (below). Full details of all survey lines are given in figures 4 and 5 and in Tables A3 (Appendix 1). Average speed over the whole survey was 4.9 kt. A total of 666 line km of data were acquired, resulting in coverage of 500 km^2 of seafloor.

Although none of the technical staff on board had previous experience of the ORE 100 kHz system, it proved simple to operate and gave trouble on only two occasions. The first problem arose with the DAT tape drive, which failed at 2156/160 due to accumulation of dirt on the recording heads. Regrettably, an appropriate cleaning kit had not been supplied with the unit and it proved impossible to clean the heads using cleaning kit available onboard. The tape drive could not therefore be repaired and subsequent data could only be recorded in paper record form. The second problem occurred at the beginning of the fourth deployment at 0130/192, when, on deployment, the fish proved to be inoperative. This was quickly deduced using the diagnostic features available within the transceiver unit and the problem was rectified by deploying the spare fish.

Table 2. Summary of 100 kHz sidescan sonar deployments

Run	Start Time	End Time	Comments
1	1512/159	0800/161	Lines 1 to 13
2	1705/188	0807/189	Lines 14 to 20
3	2310/189	2004/190	Lines 21 to 26
4	0130/192	0645/192	Lines 27 to 31

9. 3.5 KHZ OPERATIONS

High-resolution sub-bottom profiles were routinely collected along all survey and passage lines using a standard SOC 3.5 kHz profiling system supplied by RVS. Approximately 4500 line km of data were collected within the AFEN area during the survey. No problems were experienced with the system. Archived data consists of paper records printed to in real time.

10. DATA LOGGING AND SHIPBOARD DATA PROCESSING

10.1 Research Vessel Services shipboard logging (ABC System)

The distributed data acquisition and processing system used on board RRS Charles Darwin is built on a three layer architecture. The bottom layer (Level A) consists of a group of intelligent instrument interfaces which are responsible for collecting, conditioning and time stamping data from associated instruments. Each Level A interface constructs and transmits datagrams that conform to a common Ship Message Protocol (SMP). The transmitted SMP datagrams are collected using secure V24 transfer by the next layer in the architecture (Level B). The Level B data logger "funnels" data into a single stream that is written to two "mirrored" hard disk FIFO queues. Data in the queues are checked and cross-checked for error and timeout conditions and an appropriate system state display is provided for watchkeepers. Data are also copied to 150 Mbyte cartridge tapes which form a baseline backup from which all products could be re-worked should a disaster occur. The Level B also forwards data via Ethernet to the next layer (Level C). The Level C data processing system comprises a suite of software which reside on a SUN SPARCstation IPC. Incoming Level A SMP datagrams sent by Level B are parsed into associated binary data files for processing and archiving. The Level C is connected to the ship's Ethernet LAN and has access to a number of plotting and output devices.

10.2 Operations

(i) Level A instrument interfaces logged

GPS_TRIM : Trimble 4000DS DGPS

LOG_CHF : ship's log

BIN_GYRO : ship's gyro

DECMK53G : Decca mk53 navigation system

ATS : Nautronix ultra short baseline (USBL) acoustic tracking system

EA500D1 : Simrad single beam EA500 echosounder

ADCP data were logged directly by Level C via serial port connection.

(ii) Level B data logger

The Level B data logging system operated reliably during the cruise generating 12 ASCII DC150 cartridge tape archives. New tapes were used throughout the survey and the tape drives were cleaned regularly. Each tape generated by the Level B was verified by reading on the Level C data processing system. The archives were compressed and appended to the final data product tape. It should be noted that the third tape had an unrecoverable read error at about 15%. No error had been reported by the Level B.

(iii) Level C data processing system

The Level C enjoyed a relatively light processing load throughout the cruise, being used only to produce ship and TOBI navigation and correct the single beam echosounder data by Carter area. Ship's log and gyro were combined into a relative motion 'relmov' file for the purposes of dead reckoning positions during gaps in the differential GPS. However, as there was 100% DGPS coverage, all subsequent navigation processing was based purely on DGPS positions. A 10 second navigation window was used to generate 'bestnav' and the time aligned processed files.

The ultra short baseline automated tracking system (USBL) was installed prior to sailing. A beacon was fitted to the TOBI vehicle and xy offsets were logged at approximately one minute intervals. The system worked very well for the majority of the TOBI survey. There were problems in deeper water where complicated water structure impaired the operation of the system. Throughout TOBI surveying, the USBL operated successfully for over 90% of the time.

A Level C application 'proc_xy' was developed to calculate TOBI positions using the ship's position and the USBL beacon's xy offset. The application was incorporated into a procedure 'nav_xy' which automated provision of TOBI navigation. TOBI navigation was also used as input to 'trackmm' enabling generation of anamorphically correct strips of image data for manual mosaicking. A second Level C application called 'layback' was developed which approximated TOBI positions during USBL dropouts. This was done by calculating the vehicle range using the watch keepers wire-out log and working backwards through the ship's navigation 'bestnav' file until the distance run variable plus vehicle range equals the current ship's distance run.

The raw Simrad EA500 echosounder data (ea500d1) were resampled into 'rawdep' using the RVS average application with a 10 second average window. The 'rawdep' file was checked and de-spiked using the RVS Data Editor package prior to being processed with 'prodep'. Data were collected using a flat 1500 m/s sound velocity profile and corrected by Carter area.

A simple tool 'cd101nav' was provided for watch keepers to verify and cross-check their log entries. When started, 'cd101nav' listed the raw variables Time, Heading, Speed, Latitude, Longitude and Depth using the last time from the 'relmov' file as it's start time.

11. ULTRA SHORT BASELINE NAVIGATION

The Nautronix ultra short baseline (USBL) acoustic tracking system (ATS) was installed prior to CD101C Leg 1 by an engineer from Nautronix. A Level A application was prepared that sampled the XY offset and other parameters from the deck-unit. The Level A was first set up to read the clock (timestamp) from the USBL as we had been assured that the internal clock was accurate and would not drift. However, after three days of operation, the internal clock was observed to have drifted by some 2 minutes and 26 seconds. With observation, it became apparent that the drift was constant and it was decided that the Level A application should be rewritten so that the ship's scientific clock provided the timestamp. The USBL clock was also sampled by the new Level A so that comparisons could be made. The early data, collected with a USBL clock timestamp, were corrected using the RVS utility 'modtime', using a constant clock drift rate.

The USBL system was, in general, 'user friendly' and relatively simple to use. An effective instruction 'seminar' in system operation was given to a selection of cruise personnel by the Nautronix engineer immediately prior to sailing. Although the USBL system is capable of calculating xyz positions, it was operated in 'manual entry' depth mode throughout the TOBI survey, since TOBI carries an accurate depth sensor. Watchkeepers were required to change the depth entry if any significant (> 10 m) changes in TOBI depth occurred. This mode removes one of the variables (z) which would otherwise have to be calculated by the USBL system, allowing for better accuracy in xy position calculation.

During periods of operation in deeper water and where complicated water structure impaired the system's ability to acquire positions, the USBL required special attention. Watch keepers were required to monitor system's operation and, if lock was lost, attempt to re-acquire position by altering filter width and entering approximate beacon positions manually.

From time to time, the system appeared to generate a wildly inaccurate fix, and the beacon position would "walk" back to it's correct position over a period of several samples. To overcome this it was necessary to set the system into a high filter state, thus rejecting the large jumps. The high filter setting worked well while the ship was engaged in straight line survey work, but caused the system to drop out during major course changes and turns. It was therefore important for the watch keepers to alter the filter settings accordingly.

12. SAMPLING TRIALS

The leg 1 plan called for 24 hours to be devoted to seabed sampling, with the objective of assessing the performance of sampling equipment to be used during leg 2. As originally envisaged, this work was to be carried out during the servicing periods of the TOBI vehicle. However, as a result of the near-continuous successful operation of TOBI, the sampling trials were instead carried out during two intensive periods towards the end of the first leg. The intensive working posed some problems, with relatively few staff available to process back-to-back cores. The trial sampling was, nevertheless, highly constructive and significantly aided the planning and conduct of the second leg of the survey. A full summary of the sample stations occupied during CD101C Leg 1 is given in Appendix 1, Table A4.

The first phase of sampling trials was undertaken in the deeper waters of the northern part of the survey area. Three stations were selected in the vicinity of a debris flow imaged by TOBI. Station 53701 was selected to sample a 'typical' deep (>1000 m) water situation; station 53702 was selected to investigate the 'black zone' (region of low acoustic reflectivity) dominant in the 800-1000 m stratum of this part of the survey area, and station 53703 was located within the debris flow itself. A fourth station, 53704, was then occupied to investigate the area of 'wave like' features imaged in the 600-800 m stratum of the northern part of the survey area.

The Megacorer was deployed for the first time at station 53701. This deployment, in a muddy substrate, yielded 12 perfect cores of about 30 cm length. Most of the core tops had emerged 'worm' tubes; on recovery, sabellid polychaetes with fully extended tentacles were visible in three of the cores. The megacorer was then deployed at station 53702. This deployment only yielded two useful, short (11 cm) cores. Two additional cores contained sediment but the presence of large burrow structures caused the top water to drain from the samples on recovery. The sediment recovered was of a very uniform (very well sorted) fine sand. The Megacorer was then redeployed at the same station with only eight core units attached, producing 7 perfect cores of 38 cm length. Both deployments at station 53702 recovered an enteropneust (acorn worm) of 4-5 cm length.

The box corer was then deployed at station 53703, in the debris flow. This yielded a good full core of around 45 cm depth. The final deployment of the first phase was of the box corer in the 'wave' area (station 53704) producing a good full core of 40 cm length. The surface layer of this core contained gravel and a number of small stones on which an extensive macro-epifauna was developed.

Four further stations were sampled during the second phase, all located in the mid region of the survey area (Appendix 1, Table A4). Station 53705 was located on the on the shelf (< 200 m stratum), 53706 in the major coral area indicated on the 'Kingfisher' chart (200-300 m stratum), 53707 in the area of dense iceberg plough marks (300-400 m stratum), and 53708 below the iceberg plough marks (500-600 m stratum).

The Day grab was deployed three times at station 53705 producing two good samples. On sieving (500 μm mesh) these samples reduced very little in volume, yielding residues of 2.5 to 3 litres. Of note among the obvious fauna in these samples were a 6 cm long specimen of the tubicolous polychaete Hyalinoecia and an anemone of column length 3 cm and disk diameter 2 cm. Three deployments of the Day grab at station 53706 yielded no useful samples. Two were recovered empty, the third with the jaws partly open (jammed by small stones) and the sample partially washed out.

The box core was deployed twice at station 53707. The first produced a full width core but with a highly sloping surface. It seems likely that this surface was largely natural and not a sampling artefact. The otherwise good quality of the sample, the high degree of slope (beyond the range of movement of the core head within the gimbals of the frame) and the form of the subsequent core all suggest that the observed slope was a consequence of local-scale seafloor topography. The second box core at this station produced a core with a stepped surface with c. 10 cm relief. The junction between the step surfaces was marked by a linear arrangement of gravel and small stones, the exposed surfaces of which had a well developed epifauna (solitary coral, bryozoans, brachiopods etc).

The final trial deployment of the box core at station 53708 produced the greatest surprise. The core recovered was of good quality and of approximately 50 cm depth. However, about 75% of the core's surface was obscured by sponges (several specimens and species). The core also contained a considerable catch of 'sponge associated' fauna (ophiuroids, natant and reptant decapods).

With the late start to the sampling trials and the sea state being less than ideal for microscope work, only two samples were sorted onboard. The primary object of shipboard sorting was to assess the suitability of the proposed Megacorer macrobenthos sampling protocol: i.e. pooling eight cores to produce a single sample. Table 3 details the results obtained. Four cores (10 cm ID) from Megacorer deployment 53702#2 were sectioned into 0-5 cm horizons, pooled and elutriated over a 500 µm mesh sieve. A total of 107 macrobenthos specimens were counted in the resultant residue, of which 85 were polychaetes. A full protocol sample in this deep-water (922 m) sand substrate would, by extrapolation, be expected to yield over 200 macrobenthos specimens. The second sample sorted was from box core deployment 53703#1. This sample was produced by pooling the 0-5 cm horizons of four 10 cm ID sub-cores. The 500 µm residue of this sample contained 164 macrobenthos specimens, of which 103 were polychaetes. By extrapolation, a 0.1 m^2 box core sub-sample from this deep-water (942 m) sandy mud substrate would be expected to yield over 500 macrobenthos specimens.

Table 3. Macrobenthos samples processed during CD101C Leg 1.

MEGACORE 53702#2	Counts	Equivalents	
TAXON	**4 cores**	**8 cores**	**0.1 m^2**
Polychaeta	85	170	271
Bivalvia	8	16	25
Amphipoda	5	10	16
Ophiuroidea	3	6	10
Sipuncula	2	4	6
Cumacea	2	4	6
(Nematoda)	(2)		
(Harpacticoida)	(1)		
Mysidacea	1	2	3
indeterminate	1	2	3
Totals	**107**	**214**	**340**
MEGACORE 53703#1	**Counts**	**Equivalents**	
TAXON	**4 cores**	**8 cores**	**0.1 m^2**
Polychaeta	103	206	328
Bivalvia	38	76	121
Amphipoda	10	20	32
(Nematoda)	(7)		
Tanaidacea	4	8	13
Gastropoda	3	6	10
Isopoda	1	2	3
Sipuncula	1	2	3
Pycnogonida	1	2	3
Hydrozoa	1	2	3
indeterminate	2	4	6
Totals	**164**	**328**	**522**

13. BATHYSNAP TEST

At 1150/174 (22 June 1996), RRS Charles Darwin hove at 61° 24.11'N, 01° 39.01' W immediately to the west of the nominal position at which the Bathysnap system (WoS#1) had been deployed. Acoustic commands were transmitted to the bathysnap unit using a towed 'dolphin' acoustic fish. The transmission of three 'off' commands to the release unit elicited three 'received' and 'executed' returns, giving a mean slant range of 725 m. With a sounding of 560 m, horizontal range from the ship to the mooring was approximately 460 m, suggesting that the mooring was essentially in the position it was laid at (61° 24.15' N, 01° 39.45' W, in the SE quadrant of Block 208/17). A 'pinger on' command was also transmitted, and 'received' and 'executed' returns received. Pinger function was confirmed by reference to the waterfall display unit and a printed record obtained on the Waverley recorder. One further 'off' command was transmitted and the release unit successfully returned to a quiescent state. Release and recovery of the Bathysnap unit is planned to take place during the CD101C Leg 2.

14. SUMMARY OF PRELIMINARY RESULTS

14.1. Operations

All of the objectives of CD101C Leg 1 were achieved in full or exceeded. No significant time was lost to equipment failure and less than two days to bad weather. Excellent weather during the passage legs to and from the working area resulted in considerable time savings relative to the planned cruise timetable. As a result, we were able to allocate almost 25 days to TOBI operations and in excess of 3.5 days to 100 kHz sidescan sonar operations, exceeding the planned quotas by a total of 2.5 days. A full breakdown of the cruise operations is give in Table A5 (Appendix 1).

14.2. Interpretation

A brief summary of the preliminary sidescan sonar interpretation undertaken during CD101C Leg 1 is given below. This interpretation was based almost entirely on data collected during the cruise, and will inevitably change when the results of leg 2 and previous data from the area are taken into account. Note that at water depths greater than 200 m, the interpretation is based on near 100% TOBI sidescan sonar coverage. At depths less that 200 m, the continental shelf was surveyed in reconnaissance manner only using the 100 kHz sidescan system.

As expected, the mapped acoustic facies variations (probably indicative of sediment facies variations over most of the area) are, to a large extent, strongly related to waterdepth. Their description is most easily presented in a series of depth dependent zones. The exception are features related to downslope sediment transport and some structural features, which are discussed in a separate section.

(i) Outer continental shelf (120-200 m waterdepth)

The entire continental shelf within the AFEN area is typified by variability on a scale of metres to hundreds of metres. At a regional scale, however, two main acoustic facies can be recognised, although the boundaries between these are rarely well defined.

Facies 1 consists of subparallel streaks and patches of low acoustic backscatter superimposed on a high backscatter background. This facies is interpreted as indicative of a variable cover of sandy bedforms (longitudinal streaks and patches) overlying a gravel substrate. Sand cover varies from <5% to >95%, but is typically in the 25-50% range. Sand patches occasionally show transverse ripple fabrics. Facies 2 consists of an irregular jumble of randomly oriented patches of high and low backscatter. In some areas, this is partially to almost entirely buried beneath a sheet-like low backscatter layer. Facies 2 is interpreted as indicative of areas of iceberg ploughmarks, in some areas partially buried beneath a sheet-like sand body.

Facies 1 is characteristic of the continental shelf from 60° 35' to 60° 58' N and from 60° 17' N to the southern limit of the surveyed area at 59° 22' N. Bedform orientations indicate predominant current flow towards the northeast and east-northeast. Facies 2 occurs between 60° 17' and 60° 35' N immediately west of the Shetland Islands. Here, the degree of burial of the iceberg ploughmarks beneath a sheet sand appears to increase towards the east, reaching almost 100% sand coverage in a small area near 60° 25' N and 02° 45' W. The small area of continental shelf surveyed using the 100 kHz system in the extreme NE of the AFEN area is also characterised by the occurrence of facies 2, with a sand cover ranging between about 20 and 80%.

(ii) Iceberg ploughmark zone (<200 to about 500 m waterdepth)

Iceberg ploughmarks dominate the present-day seafloor morphology from the shelf edge down to about 500 m water depth along the entire upper continental slope (Fig. 6). Towards the upper part of the ploughmark zone, the 100 kHz sidescan data indicate that ploughmarks originally extended at least on to parts of the outer continental shelf, but these have largely been erased or buried by post-glacial sediment redistribution. Towards the deeper limit of the zone, ploughmarks become fewer in number, but larger and more continuous. A few ploughmarks are seen at depths greater than 500 m, with the deepest ploughmark extending to about 570 m. Few of the ploughmarks are seen as relief features on either surface towed echosounder or the deep towed TOBI profiles. Most ploughmarks thus appear to have been largely or entirely filled with younger sediments, with the sidescan images appearing to show differences in sediment type between the sediments into which the ploughmarks were cut and the infilling sediments.

Initial analysis of the ploughmarks suggests that it is possible to sub-divide them into at least four types on the basis of their morphology, and that these types reflect variations in the processes of their formation and/or later modification by post-glacial sedimentary processes. The four types are :

(a) Randomly oriented cross-cutting ploughmarks, tending to become sub-parallel to the contours in deeper water. The commonest ploughmark type, covering more than 50% of the ploughmarked area, these are interpreted as 'typical' ploughmarks cut by floating icebergs. The slope parallel nature of some of the deeper water ploughmarks may indicate control of ice movement by slope topography in combination with currents or wind.

(b) As (a), but partly to largely buried or erased by later sedimentary processes. This ploughmark type occurs in discrete patches, mainly between 300 and 500 m water depth. Boundaries between (a) and (b) are usually gradational. The initial, speculative, interpretation is that this ploughmark type corresponds to areas of relatively finer-grained sediments on the upper slope. These may be more susceptible to reworking by post-glacial currents than the coarser sediments in adjacent areas.

(c) Strongly lineated, parallel ploughmarks or scourmarks. This ploughmark type is restricted to areas shallower than about 350 m. Orientation is north-northeast to northeast. Interpreted as due to scour beneath a floating or grounded icesheet moving towards the northeast.

(d) Circular to elongate cross-shelf (filled) depressions, restricted to narrow contour parallel bands. Best developed between 200 and 300 m waterdepth in the southern part of the AFEN area between 60° 05' and 60° 20' N. The depressions are characterised by infill of low backscatter, presumably relatively fine-grained material. They are interpreted as scour holes formed at (or beneath?) the margin of an icesheet which extended to the shelf edge. Only a few random ploughmarks cut across this ploughmark type, suggesting that they formed at a late stage in the last glacial period.

Few post-glacial sedimentary features can be seen superimposed on the dominant iceberg ploughmark morphology. An exception is a field of barchan dunes covering an elongate contour-parallel area of some 50 km^2 near 61° N, 02° 10' W, in about 300 m waterdepth. Individual dunes are oriented perpendicular to the inferred current direction (towards the northeast) and are 50 to 150 m in length.

(iii) 'Sediment wave' zone (approximately 500 to 850 m)

TOBI sidescan images from this area shows moderate to relatively high backscatter levels but relatively few features. North of about 61° N, 3.5 kHz profiles show a two fold depth related subdivision of this zone, with inferred long wavelength mud waves in the shallower water part and sand waves at greater water depths. TOBI images show the sand wave crests to be oriented approximately west Northwest, but do not detect the mud waves. South of 61° N, both 3.5 kHz profiles and TOBI images show a relatively featureless seafloor, with the exception of some indistinct contour parallel lineations seen on the TOBI images. These are most abundant in the area 60° 50' to 61° N, 03° 50' to 03°20' W, where they appear to occur on a subtle seafloor high of a few tens of metres height. The lineations are tentatively interpreted as erosional furrows.

(iv) Ultra-low backscatter zone (approximately 850 to 1000 m waterdepth)

This is an unusual zone of very low backscatter at the TOBI frequency of 30 kHz. It is best developed between the 850 and 1000 m depth contours between 61° and 61° 20' N, but extends both to the north and south with less extreme low backscatter values. Boundaries with adjacent (relatively) higher backscatter zones are gradational, except on the northwest side of the zone near 61° 10' N, where a series of wave-like features of low backscatter character can be seen to overly the slightly higher backscatter material which occurs to the northwest. Cores taken during Leg 1 indicate that the seabed in this area is composed of well-sorted fine sand, extending to several tens of cm depth. The low backscatter zone is thus tentatively interpreted as a sandy contourite sheet.

(v) Faeroe-Shetland Channel floor

The floor of the Faeroe-Shetland Channel, below 1000 m waterdepth, was imaged only north of 60° 50'N; further south, the channel floor lies west of the AFEN area. All of the imaged area within this zone is characterised by relatively featureless even moderate/low backscatter. 3.5 kHz profiles show several tens of metres penetration into acoustically layered sediments, suggesting a mainly fine grained mud sequence.

(vi) Features associated with downslope sediment transport

Unequivocal evidence for significant 'post-glacial' downslope sediment transport was not found during the TOBI survey. One area of channels and another affected by slope failure/debris flow were discovered. Although it is not possible to date the last period of activity of these features, it seems likely that neither has been active since early post-glacial time.

The channels occur in an area 60° 40' to 60° 55' N and 03° 30' to 04° W. Twelve channels were mapped. Typical channel widths are 50 to 150 m, and depths range from a few metres to over 40 m. Nine of the twelve channels start abruptly at about 700 m waterdepth and end abruptly at 1000 m, ranging from 15-18 km in length, while the others are shorter and cross only part of the zone. All are straight-sided and sub-parallel along most of their lengths; only one example of channels merging and one of a possible poorly developed distributary system at a channel mouth were imaged. We have no evidence as to why the channels start abruptly in mid-slope or whether, for example, they might have originally extended further upslope. It does appear that the channels are situated on a slight bulge in the slope contours which has previously been interpreted as a (glacial) debris flow fan, although there is no evidence as to how the channels relate to fan development. Seaward of the channel complex, the presumed depositional lobe is characterised by slightly higher backscatter than the area further north, perhaps indicating some contrast is sedimentation style.

(vii) Structural features

The only (possible) structural features imaged during this survey are a series of lineations, some extending to 30 km in length, which are associated with possible slump folding in the northern part of the survey area. Two groups of lineations were mapped, one at around 400 m waterdepth between 61° 10' to 61° 20' N, the other at 1000 m waterdepth between 60° 25' and 60° 40' N. The lineations, imaged either as subtle seabed furrows or as narrow zones of contrasting (usually low) backscatter, appear to occur within the bathymetric lows which occur upslope from each slump fold ridge. At 60° 16' N, 01° 36' W, one of the lineations is associated with a series of pits, up to 150 m across and perhaps a few metres deep, of unknown origin. The geological cause of the lineations is not known, nor is it clear whether or not the features are currently active.

APPENDIX 1 - SURVEY LINE AND SAMPLE STATION LOCATIONS

Table A1. List of TOBI line waypoints

Line No	Waypoint No	Latitude N	Longitude W
TOBI 1	A	60° 01.40'	05° 00.00'
	B	60° 30.00	04° 00.00'
	C	61° 34.35'	00° 47.30'
TOBI 2	D	61° 31.40'	00° 48.00'
	E	60° 23.70'	04° 10.00'
	F	60° 16.20'	04° 23.00'
	G	59° 58.60'	05° 00.00'
TOBI 3	H	59° 55.40'	05° 00.00'
	I	60° 10.80'	04° 28.00'
	J	60° 17.10'	04° 08.00'
	K	60° 22.70'	04° 05.50'
	L	61° 08.70'	01° 48.00'
TOBI 4	M	61° 06.30'	01° 48.00'
	N	60° 20.00'	04° 05.00'
TOBI 5	O	60° 18.20	04° 03.20'
	P	60° 43.70'	02° 47.00
TOBI 6	Q	60° 40.60'	02° 48.20'
	R	60° 17.00'	03° 59.00'
TOBI 7	S	60° 16.40'	03° 54.00'
	T	60° 21.30'	03° 38.00'
	U	60° 37.70'	02° 49.40'
	V	60° 45.30'	02° 43.30'
	W	61° 03.60'	01° 48.00'
TOBI 8	X	60° 32.50'	04° 00.00'
	* (see note)	61° 20.90'	01° 36.70'
	Y	61° 37.00'	00° 48.00'
TOBI 9	Z	61° 39.50'	00° 48.00'
	A1	60° 35.50'	04° 00.00'
TOBI 10	B1	60° 38.20'	04° 00.00'
	C1	61° 40.00'	00° 55.00'

Table A1 (contd)

Line No	**Waypoint No**	**Latitude N**	**Longitude W**
TOBI 11	D1	61° 40.00'	01° 04.70'
	E1	60° 41.40'	04° 00.00'
TOBI 12	F1	60° 46.60'	04° 00.00'
	G1	61° 40.00'	01° 14.70'
TOBI 13	H1	61° 40.00'	01° 24.80'
	I1	60° 48.00'	04° 00.00'
TOBI 14	J1	60° 51.30'	04° 00.00'
	K1	61° 40.00'	01° 34.80'
TOBI 15	L1	61° 40.00'	01° 44.90'
	M1	61° 02.75'	03° 36.00'
TOBI 16	N1	61° 06.00'	03° 36.00'
	O1	61° 40.00'	01° 54.80'
TOBI 17	P1	61° 40.00'	02° 04.50'
	Q1	61° 09.30'	03° 36.00'
TOBI 18	R1	61° 12.50'	03° 36.00'
	S1	61° 40.00'	02° 14.20'
TOBI 19	T1	61° 40.00'	02° 23.80'
	U1	61° 15.70'	03° 36.00'

Note * - line broken at this point due to equipment failure and bad weather

Table A2 - summary of TOBI survey lines

Line number	Start			End			Length (km)
	Latitude N	Longit. W	Time	Latitude N	Longit. W	Time	
TOBI 1	60° 01.65'	05° 01.98	1033/161	61° 34.34'	00° 47.27'	0456/163	283
TOBI 2	61° 32.75'	00° 44.02'	0600/163	59° 59.03'	04° 59.06'	0309/166	296
TOBI 3	59° 57.03'	04° 56.43'	0423/166	61° 09.43'	01° 46.79'	1500/167	230
TOBI 4	61° 06.13'	01° 48.70'	1626/167	60° 20.46'	04° 03.45'	0230/169	146
TOBI 5	60° 18.50'	04° 03.20'	0315/169	60° 41.93'	02° 47.08'	1541/169	80
TOBI 6	60° 40.51'	02° 48.64'	1700/169	60° 17.14'	03° 58.51'	0615/170	75
TOBI 7	60° 16.25'	03° 54.00'	0715/170	61° 03.86'	01° 47.90'	0800/171	145
TOBI 8	60° 32.54'	03° 59.98'	1715/171	61° 37.36'	00° 47.43'	2218/174	206
TOBI 9	61° 39.53'	00° 47.99'	2338/174	60° 35.79'	03° 59.10'	0000/175	207
TOBI 10	60° 37.90'	04° 00.95'	0115/175	00° 56.03'	61° 39.97'	0314/177	199
TOBI 11	61° 40.00'	01° 04.60'	0531/177	60° 41.56'	03° 59.43'	0035/179	188
TOBI 12	60° 44.99'	03° 58.76'	0230/180	61° 39.99'	01° 14.80'	0516/181	177
TOBI 13	60° 39.92'	01° 24.80'	0755/181	60° 47.93'	04° 00.51'	1454/182	165
TOBI 14	60° 51.27'	03° 59.99'	1618/182	61° 39.90'	01° 34.92'	2334/183	156
TOBI 15	61° 40.00'	01° 44.90'	0123/184	61° 02.68'	03° 35.90'	1752/184	119
TOBI 16	61° 05.94'	03° 36.17'	1953/184	61° 37.19'	02° 03.27'	1835/185	102
TOBI 17	61° 39.13'	02° 07.25'	1955/185	61° 09.35'	03° 35.87'	0951/186	98
TOBI 18	61° 12.40'	03° 35.64'	1125/186	61° 40.05'	02° 13.94'	0730/187	89
TOBI 19	61° 41.11'	02° 23.69'	0907/187	61°15.69'	03° 35.92'	1900/187	78

Table A3 - summary of 100 kHz survey lines

Line number	Start			End			Length (km)
	Latitude N	Longit. W	Time	Latitude N	Longit. W	Time	
ORE 1	59° 59.70	04° 20.00'	1707/159	60° 00.50'	04° 03.00'	1905/159	19
ORE 2	60° 00.50'	04° 03.00'	1919/159	59° 52.70'	04° 03.00'	2037/159	14
ORE 3	59° 52.70'	04° 03.80'	2048/159	59° 53.00'	04° 56.50'	0330/160	50
ORE 4	59° 53.00'	04° 56.50'	0357/160	59° 46.00'	04° 56.50'	0447/160	13
ORE 5	59° 46.00'	04° 56.50'	0500/160	59° 46.00'	04° 27.50'	0755/160	28
ORE 6	59° 46.00'	04° 27.50'	0814/160	59° 40.00'	04° 27.50'	0917/160	11
ORE 7	59° 40.00'	04° 27.50'	0926/160	59° 40.00'	04° 56.50'	1245/160	28
ORE 8	59° 40.00'	04° 56.50'	1300/160	59° 34.00'	04° 56.50'	1430/160	11
ORE 9	59° 34.00'	04° 56.50'	1443/160	59° 34.00'	04° 27.50'	1712/160	28
ORE 10	59° 34.00'	04° 27.50'	1726/160	59°24.50'	04° 57.00'	2102/160	33
ORE 11	59°24.50'	04° 57.00'	2122/160	59° 22.00'	04° 42.50'	2237/160	14
ORE 12	59° 22.00'	04° 42.50'	2250/160	59° 58.00'	04° 38.00'	0621/161	65
ORE 13	59° 58.00'	04° 38.00'	0632/161	59° 59.86'	04° 49.17'	0730/161	11
ORE 14	60° 57.56'	02° 01.04'	1730/188	60° 57.47'	01° 52.36'	1839/188	10
ORE 15	60° 56.65'	01° 49.69'	1853/188	60° 52.61'	01° 50.41'	1941/188	9
ORE 16	60° 52.11'	01° 52.01'	1952/188	60° 52.35'	02° 10.19'	2130/188	18
ORE 17	60° 51.76'	02° 12.01'	2140/188	60° 46.67'	02° 23.11'	2305/188	15
ORE 18	60° 46.60'	02° 23.00'	2311/188	60° 46.69'	02° 39.18'	0032/189	16
ORE 19	60° 46.70'	02° 40.80'	0108/189	60° 44.49'	02° 24.55'	0230/189	16
ORE 20	60° 42.32'	02° 23.81'	0300/189	60° 25.82'	03° 06.57'	0746/189	49
ORE 21	60° 33.79'	03° 05.18	2314/189	60° 24.05'	02° 38.80'	0319/190	30
ORE 22	60° 23.92'	02° 40.21'	0334/190	60° 24.42'	03° 13.16'	0730/190	31
ORE 23	60° 23.50'	03° 06.20'	0747/190	60° 14.41'	03° 05.57'	1004/190	18
ORE 24	60° 14.20'	03° 06.99'	1014/190	60° 14.18'	03° 53.20'	1439/190	42
ORE 25	60° 13.57'	03° 52.75'	1452/190	60° 06.98'	03° 48.19'	1608/190	14
ORE 26	60° 06.49'	03°49.63'	1620/190	60° 06.97'	04° 25.59'	1948/190	35
ORE 27	61° 21.29'	01° 05.30'	0130/192	61° 22.00'	00° 55.02'	0238/192	11
ORE 28	61° 22.01'	00° 55.04'	0310/192	61° 23.67'	01°01.40'	0352/192	6
ORE 29	61° 24.56'	01° 01.11	0403/192	61° 25.88'	01° 00.06'	0418/192	4
ORE 30	61° 26.26'	00° 58.53'	0430/192	61° 27.07'	00° 52.09'	0507/192	7
ORE 31	61° 27.87'	00° 52.75'	0528/192	61° 28.60'	01° 01.57'	0627/192	10

Table A4. List of sample stations

Station number	Latitude (N)	Longitude (W)	Station type	Water depth (m)	Time on bottom	Comments
53701 #1	61° 16.33'	02° 29.15'	Mega-corer	1028	0135 Day 188	12 full tubes. 27 cm core, muddy sand over mud
53702 #1	61° 14.85'	02° 26.80'	Mega-corer	896	0637 Day 188	2 tubes from 12 with 10 cm cores, fine sand
53702 #2	61° 14.96'	02° 27.97'	Mega-corer	922	0849 Day 188	Reduced to 8 tubes. 7 full. 28 cm core, muddy fine sand over sandy mud; gradational contact
53703 #1	61° 16.45'	02° 24.05'	Box corer	942	1147 Day 188	32 cm core, homogenous sandy mud
53704 #1	61° 09.83'	02° 15.05'	Box corer	620	1436 Day 188	40 cm core, 10 cm gravely (up to 15 cm pebbles) mud over mud
53705 #1	60° 25.15'	02° 55.85'	Day Grab	170	0924 Day 189	Coarse sand
53705 #2	60° 25.00'	02° 54.56'	Day Grab	147	0953 Day 189	Empty except for three pebbles
53705 #3	60° 25.03'	02° 54.97	Day Grab	165	1002 Day 189	Well sorted sand
53706 #1	60° 35.89'	03° 00.12'	Day Grab	220	1215 Day 189	Empty
53706 #2	60° 35.98'	03° 00.98'	Day Grab	220	1236 Day 189	Empty except for six pebbles
53706 #3	60° 36.07'	03° 00.82'	Day Grab	220	1256 Day 189	Incomplete closure, sand with gravel, well washed
53707 #1	60° 35.27'	03° 14.95'	Box corer	360	1452 Day 189	0-22 cm core, 13 cm fine sand over muddy sand, probably the edge of a ripple
53707 #2	60° 35.77'	03° 15.50'	Box corer	373	1612 Day 189	45-55 cm core, sand ripple prograding over gravel with homogenous mud below 11 cm
53708 #1	60° 37.17'	03° 34.95'	Box corer	520	1928 Day 189	50 cm core, 5 cm gravely muddy sand over homogenous mud, lots of sponges on core surface
53709 #1	60° 46.18'	03° 46.94'	Kasten corer	808	0249 Day 192	1.8 m core, thin gravel/sand layer over mud, with thin sand layer at base
53710 #1	60° 51.71'	03° 51.91'	Kasten corer	1072	0704 Day 192	Empty
53710 #2	60° 51.03'	03° 52.49	Kasten corer	1062	0909 Day 192	Corer run into bottom twice. No pullout on 1st attempt, 2nd gave 1.5 m core, sandy top with gravely mud below
53711 #1	61° 11.19'	02° 42.87'	Kasten corer	980	1417 Day 192	Empty
53711 #2	61° 11.49'	02° 41.42'	Kasten corer	984	1555 Day 192	Empty. Corer run into bottom twice, but no pullout or recovery
53712 #1	61° 18.60'	02° 26.53'	Kasten corer	1073	1812 Day 192	0.73 m core, 3 cm sand over soft plastic mud
53712 #2	61° 18.66'	02° 26.95'	Kasten corer	1071	2003 Day 192	1.8 m core, all mud with rare gravel, corer probably over penetrated.

Table A5. Summary of operations (hours)

Date	Mob	Passage	TOBI	100 kHz	Coring	NERC	Weather
Mon 3/6/96 start 0900	15.00						
Tues 4 (Julian day 156)	24.00						
Wed 5 (157)	14.00	10.00					
Thurs 6 (158)		24.00					
Fri 7 (159)		13.00		11.00			
Sat 8 (160)				24.00			
Sun 9 (161)			16.50	7.50			
Mon10 (162)			24.00				
Tues 11 (163)			24.00				
Wed 12 (164)			24.00				
Thurs 13 (165)			24.00				
Fri 14 (166)			24.00				
Sat 15 (167)			24.00				
Sun 16 (168)			24.00				
Mon 17 (169)			24.00				
Tues 18 (170)			24.00				
Wed 19 (171)			24.00				
Thurs 20 (172)			18.00				6.00
Fri 21 (173)							24.00
Sat 22 (174)			11.25				12.75
Sun 23 (175)			24.00				
Mon 24 (176)			24.00				
Tues 25 (177)			24.00				
Wed 26 (178)			24.00				
Thurs 27 (179)			24.00				
Fri 28 (180)			24.00				
Sat 29 (181)			24.00				
Sun 30 (182)			24.00				
Mon 1 July (183)			24.00				
Tues 2 (184)			24.00				
Wed 3 (185)			24.00				
Thurs 4 (186)			24.00				
Fri 5 (187)			20.66		3.33		
Sat 6 (188)				8	16		
Sun 7 (189)				10.75	13.25		
Mon 8 (190)				20.00		4.00	
Tues 9 (191)						24.00	
Wed 10 (192)				6.17		17.83	

Table A5 (contd)

Date	Mob	Passage	TOBI	100 kHz	Coring	NERC	Weather
Thurs 11 (193)						24.00	
Fri 12 (194)		23.00				1.00	
Sat 13 (195) end 2400	16.00	8.00					
TOTAL (hr)	69.00	78.00	594.41	87.42	32.58	70.83	42.75
TOTAL (days)	2.88	3.25	24.77	3.64	1.36	2.95	1.78
Planned (days)	3.00	5.00	23.00	3.00	1.50	3.00	2.00
Total at sea (days)	37.75						
Mob/demob (days)	2.88						
Overall total (days)	40.62						

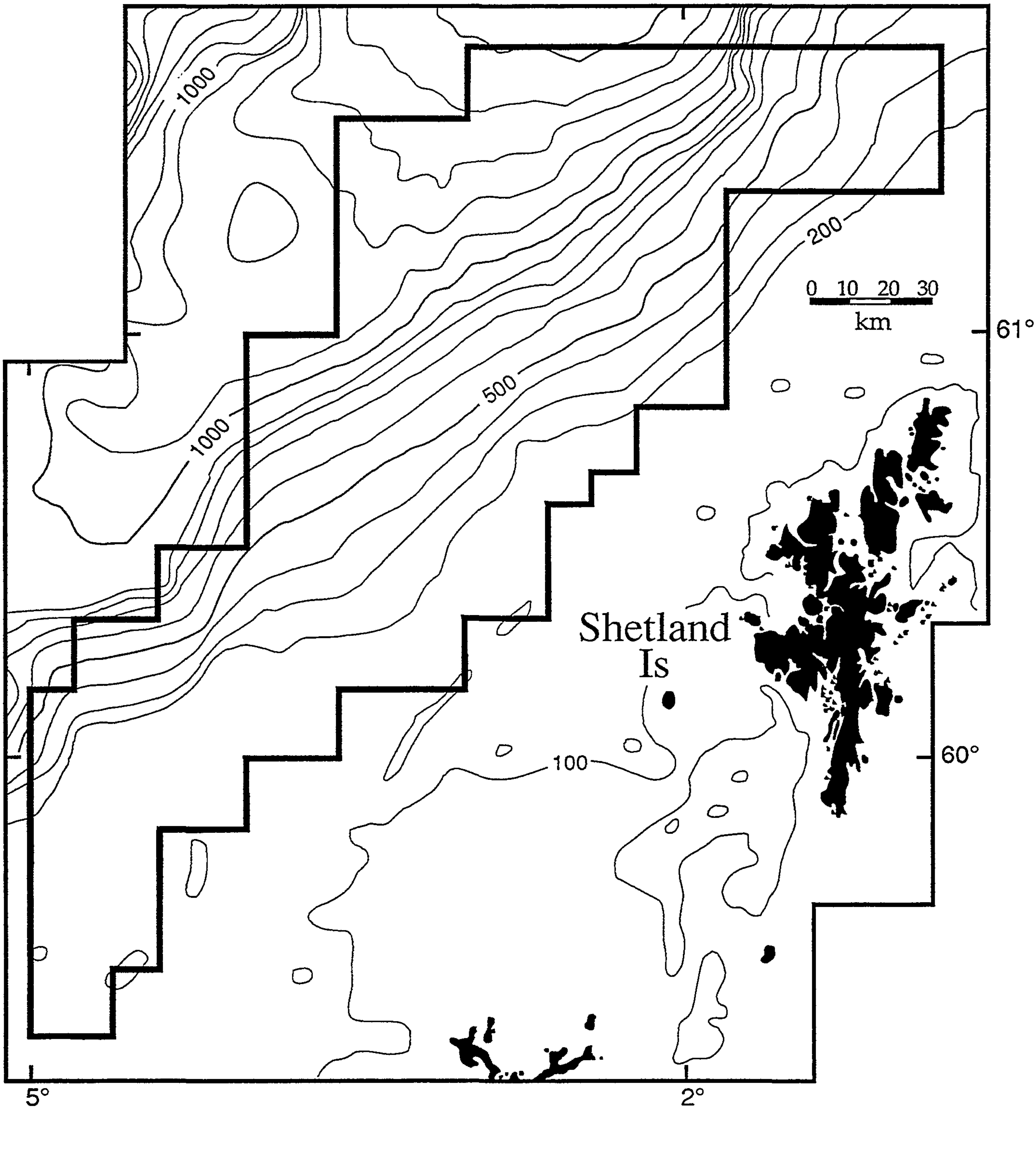


Fig. 1. Bathymetry of West of Shetland survey area. Contour interval is 100 m. Irregular bold outline shows area licenced for hydrocarbon exploration and forming the study area.

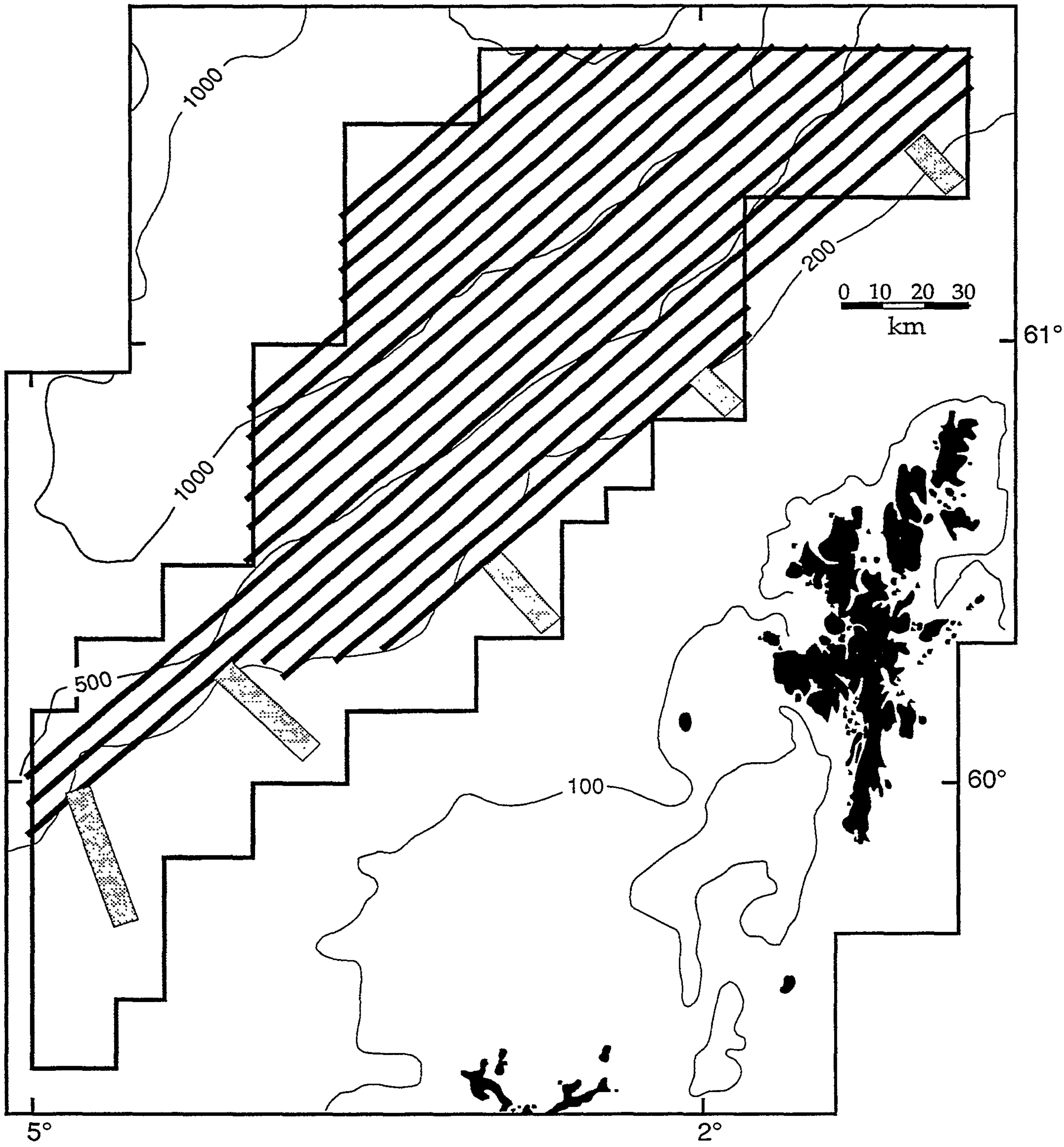
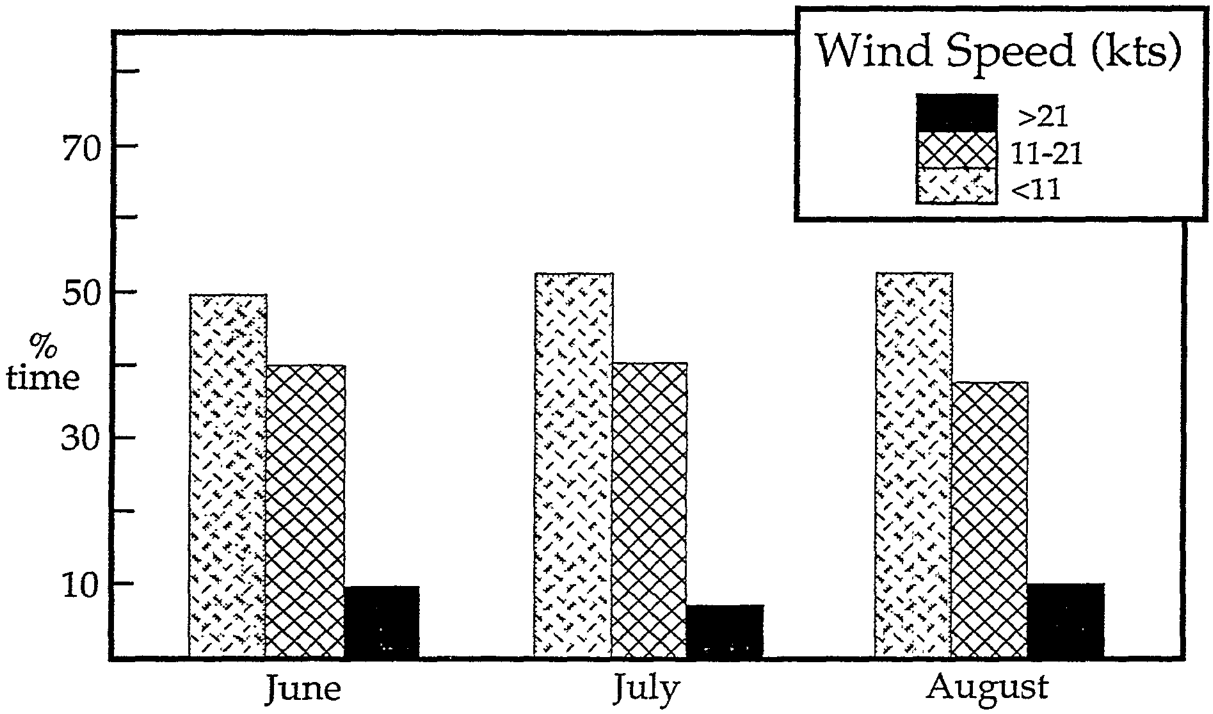


Fig. 2. Proposed survey plan, showing idealised TOBI survey tracks (bold lines)and potential area that could be covered with a 100 kHz sidescan system (shaded rectangles).



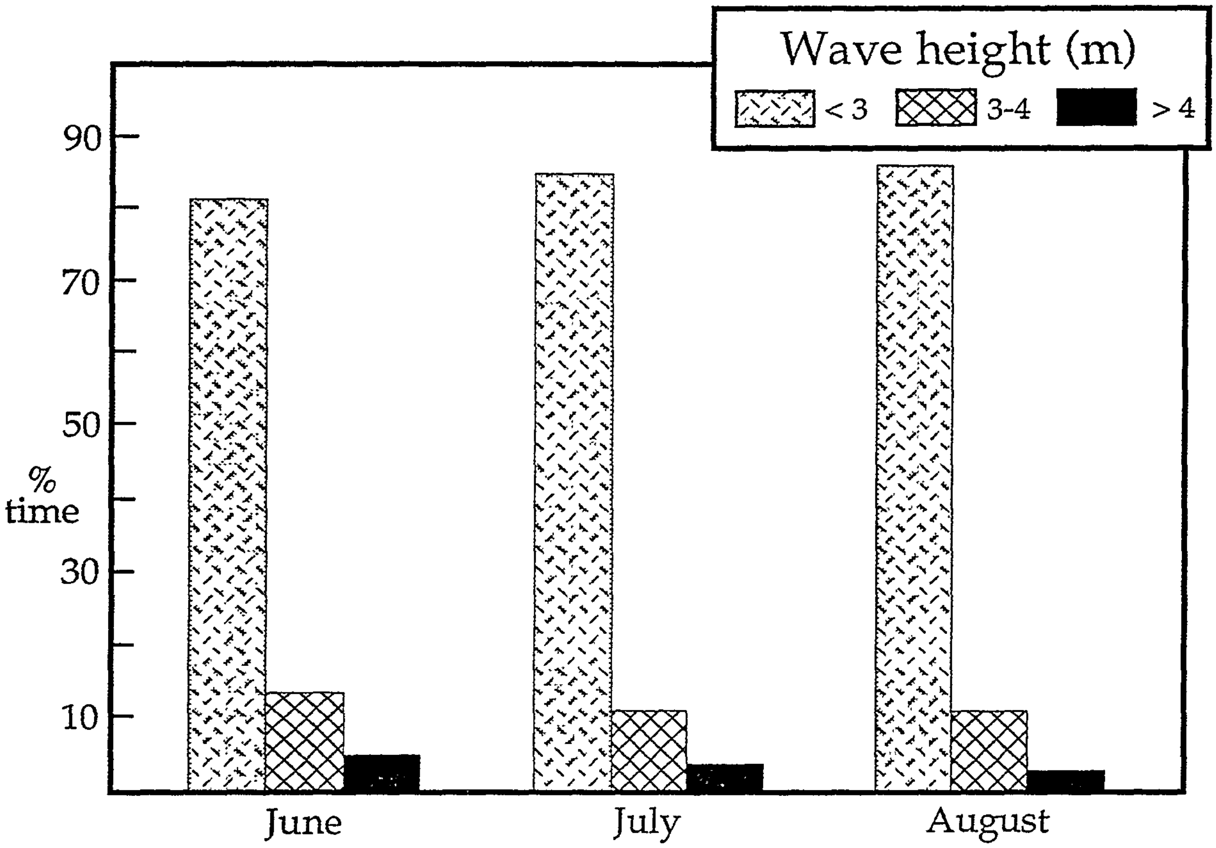


Fig. 3. Predicted weather conditions west of Shetland for the months June to August. Winds in excess of 20-25 kts and seas in excess of 3-4 m are likely to hamper or prevent TOBI operations. In practice just under 5% of survey time was lost due weather related problems (see Table A5).

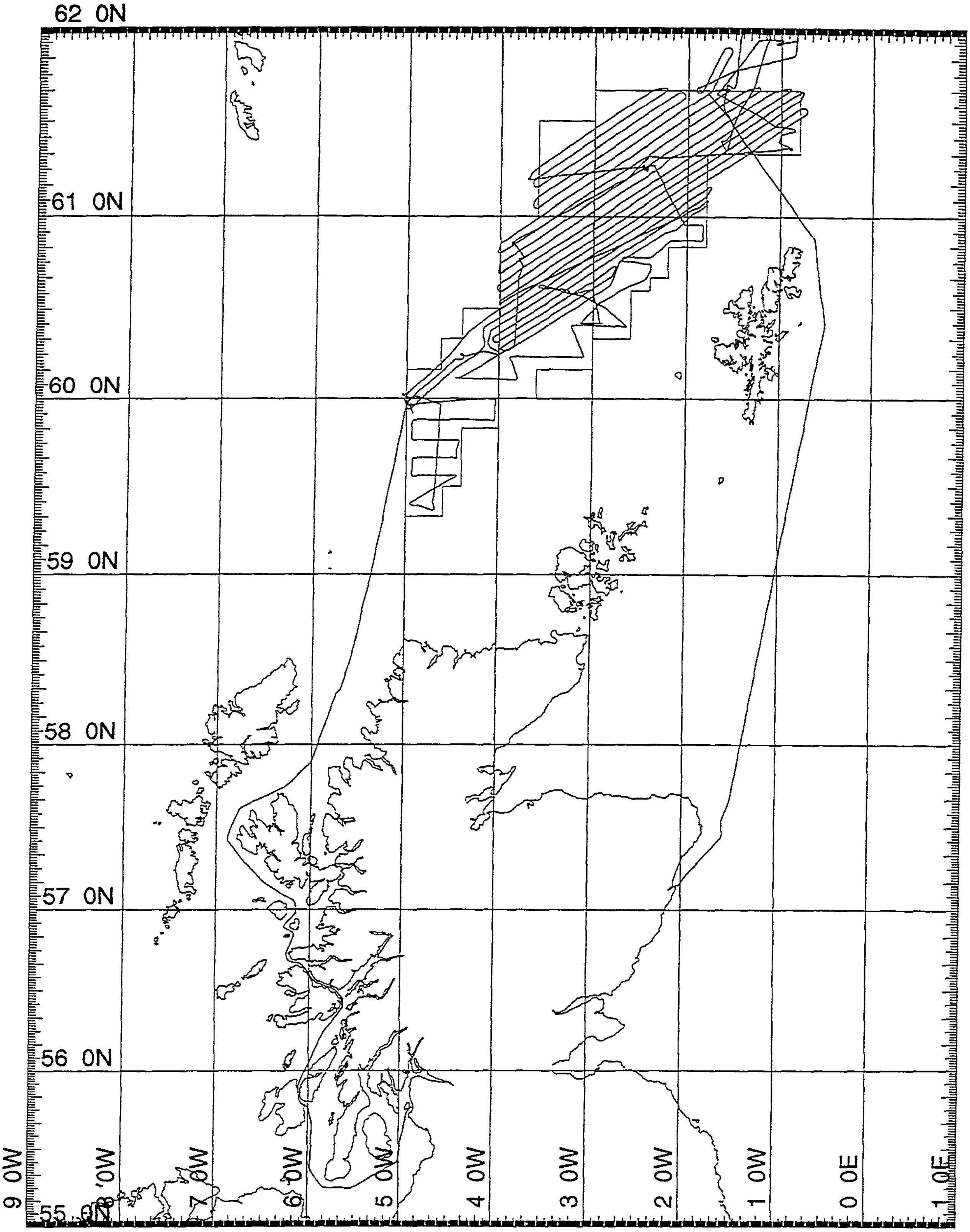


Fig. 4. Summary track chart for Charles Darwin 101C Leg 1. Outlined box shows the hydrocarbon licence area.

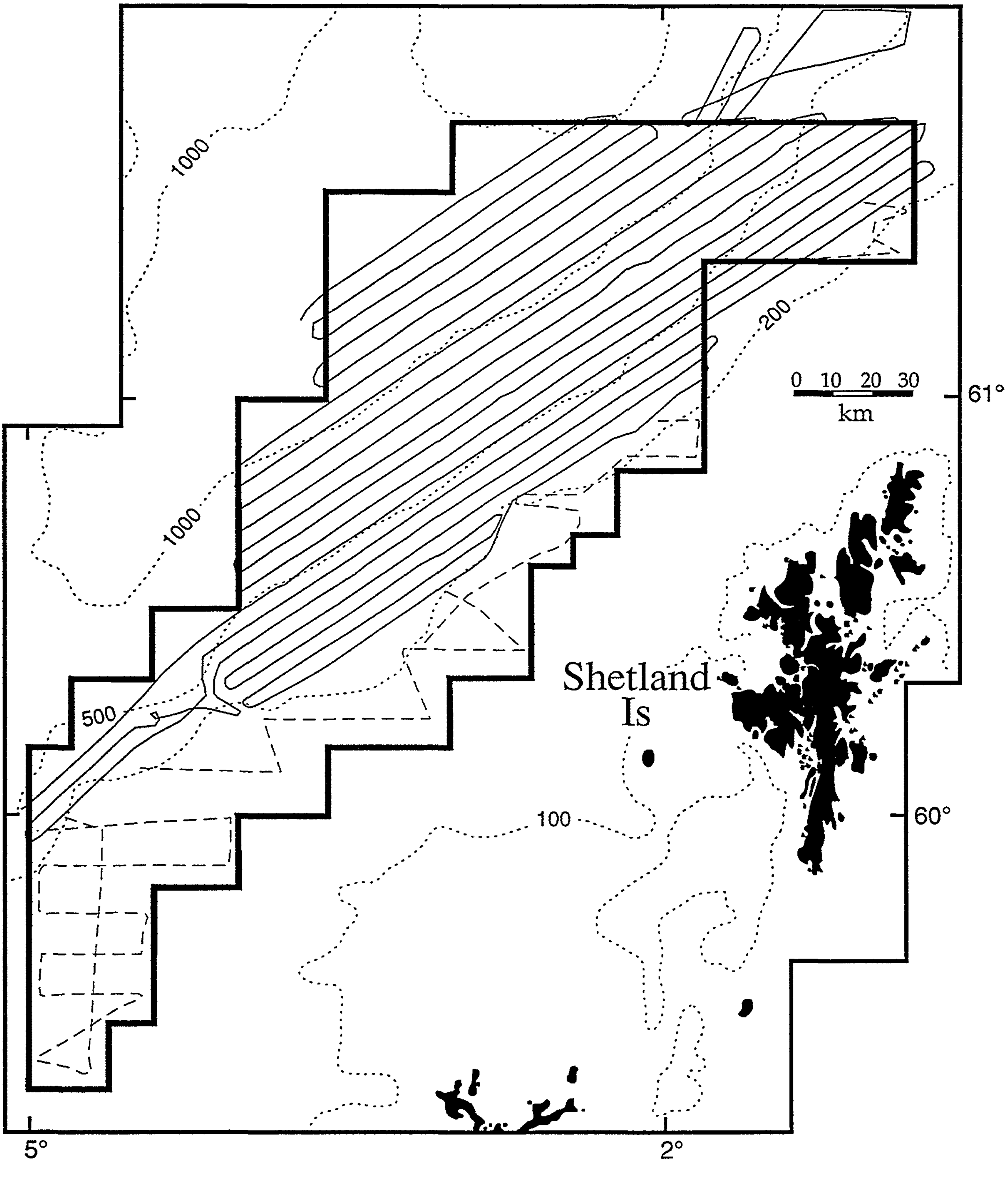


Fig. 5. Survey tracks occupied during the sidescan sonar survey. TOBI survey track is shown by continuous line with line spacing set to give 100% coverage. Dashed line shows 100 kHz sidescan survey track, with a swath width of 750 m. Bold outlined box shows the hydrocarbon licence area.

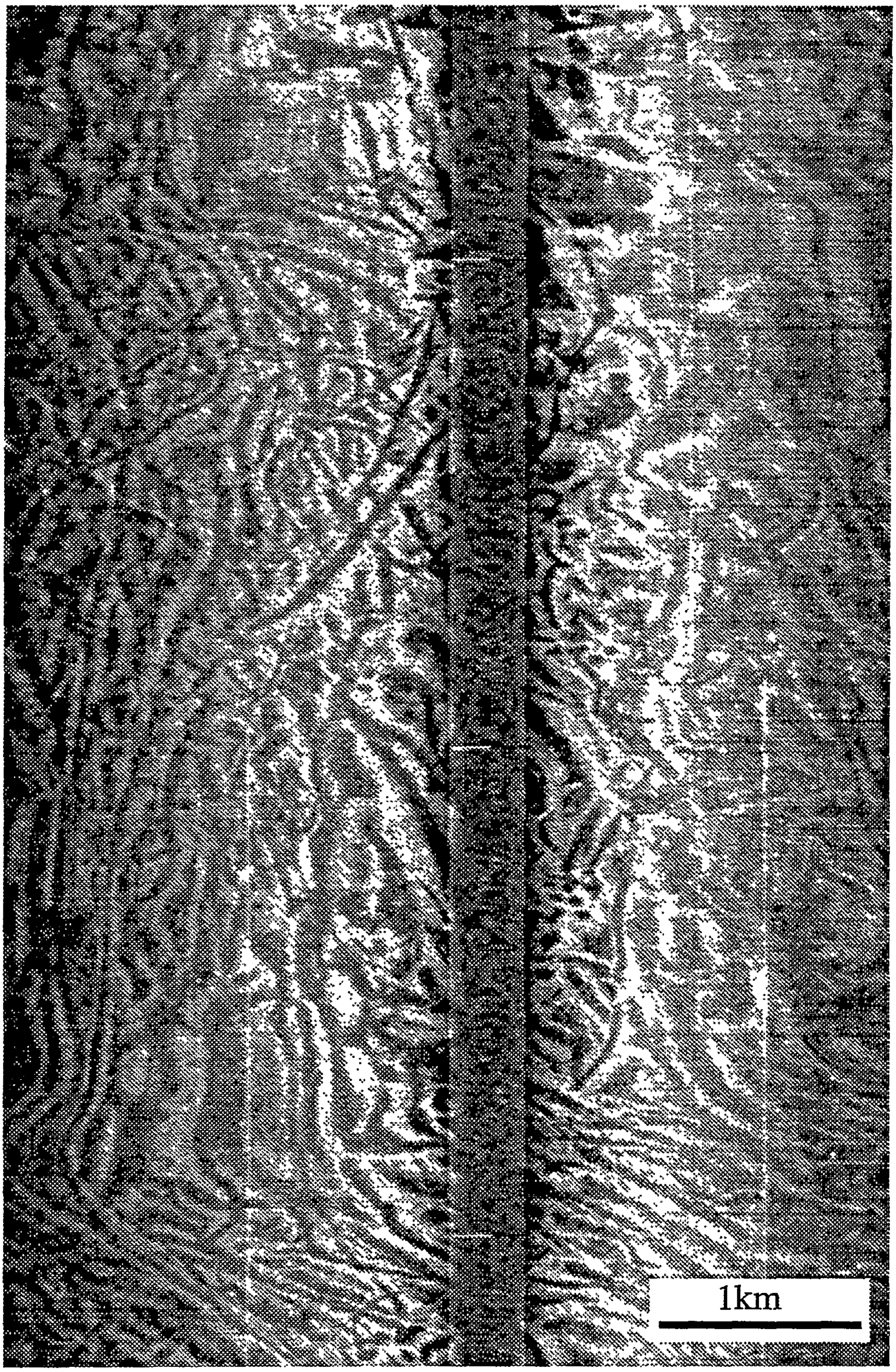


Fig. 6. Example of unprocessed TOBI sidescan sonar image of iceberg ploughmarks. Light tones show high backscatter. TOBI vehicle track follows the centre of the image from top to bottom. Most ploughmarks have been largely infilled by post glacial sediment transport processes, but are visible because of acoustic contrast between the infilling and surrounding sediments.

Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
United Kingdom
Tel: +44 (0)1703 596666
Fax: +44 (0)1703 596667