NATIONAL OCEANOGRAPHY CENTRE, SOUTHAMPTON

CRUISE REPORT NO. XX

R.R.S. JAMES COOK

JC045 and JC046

23rd April – 12th May 2010

Volcanic debris avalanche and landslide deposits offshore Montserrat, Lesser Antilles

Principal Scientist

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2010

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ABSTRACT

The objectives of cruise JC045-046 were to provide key site survey information for three drill sites (CARI-02, 03 & 04) planned in IODP Proposal 681, and to obtain a detailed survey of landslide deposits offshore from the island of Montserrat, in the Lesser Antilles volcanic arc. The IODP drill sites are located in these landslide deposits, and the required survey information primarily comprised crossing 2D seismic reflection profiles around the proposed drill sites, using both boomer and air gun sources, and a 3D seismic cube covering CARI-02. This 3D survey (~28 km^2 surface area) produced the first data set of its type relating to a submarine volcanic debris avalanche deposit.

2D seismic reflection profiles were collected in a grid (~500 km of seismic lines) covering a wide area of debris avalanche and landslide deposits SE of Montserrat. In addition to these data, TOBI sidescan sonar, multibeam bathymetry and sub-bottom profiler data were collected. Together with samples from previous cruises (e.g., shallow sediment cores from JCR123), these results provide a uniquely detailed survey of landslide deposits around Montserrat. This comprehensive data set will allow the emplacement, dynamics and impacts of volcanic debris avalanches in this setting to be better understood, and will also provide detailed information regarding the submarine deposition and distribution of volcanic material produced by the ongoing eruption of the Soufriére Hills volcano, Montserrat.

Key words: Montserrat, submarine landslide, debris avalanche, volcano

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EXECUTIVE SUMMARY

Research cruise JC045-046 (R.R.S. James Cook), surveyed an area east and south of Montserrat, in the Lesser Antilles, from 23rd April to 12th May 2010. A variety of geophysical data, including 2D seismic reflection profiles (air gun and boomer sources), a 3D seismic survey (air gun source), TOBI sidescan sonar, swath bathymetry and sub-bottom profiler data, were collected during the cruise. These provided a comprehensive set relating to the surface and subsurface structures of a sequence of landslide deposits preserved SE of Montserrat. The objective of the cruise was to use these data to understand the source, emplacement dynamics and history of landslides in this area, and to provide detailed site survey information, necessary for future planned IODP drill sites.

The TOBI survey took place during the first part of the cruise (JC045), and lasted two days, covering approximately 750 km^2. The second part of the cruise (JC046) continued directly on from this, and principally collected seismic reflection data. This included around 500 km of 2D seismic reflection profiles, in addition to a 3D survey covering approximately 28 km^2. The 3D survey focussed on a near-surface landslide deposit and seafloor structures immediately east of Montserrat, while the 2D grid extended to more distal areas, and included higher resolution Boomer-source data around the distal margins of more deeply buried landslide deposits. During both parts of the cruise, swath bathymetry and sub-bottom profiler data were also collected.

The specific objectives of JC045-046 were all met. The combined 2D and 3D seismic results allow new constraints to be made regarding the origin, morphology, frequency and behaviour of mass-wasting events around Montserrat. They also provide key information in support of IODP proposal 681. The TOBI sidescan results give additional information on sedimentation in the region, including that from recent mass failures, some of which occurred as part of the ongoing eruption of Soufrière Hills volcano (1995 to present). In addition, the new swath bathymetry and extensive sub-bottom profiler data may be used to constrain sedimentation rates on shorter timescales, from the present eruption (February 2010 dome collapse) and over the past few thousand years, and have the potential to be linked to shallow sediment cores collected on cruises JC018 and JCR123.

SCIENTIFIC PERSONNEL

Pete Talling (PI)	National Oceanography Centre, Southampton, UK
Christian Berndt (Co-I)	IFM-Geomar, Kiel, Germany
Gareth Crutchley	IFM-Geomar, Kiel, Germany
Martin Wollatz-Vogt	IFM-Geomar, Kiel, Germany
Jens Karstens	IFM-Geomar, Kiel, Germany
Veit Hühnerbach	National Oceanography Centre, Southampton, UK
Mark Vardy	National Oceanography Centre, Southampton, UK
Morelia Urlaub	National Oceanography Centre, Southampton, UK
Sudipta Sarker	National Oceanography Centre, Southampton, UK
Sebastian Watt	National Oceanography Centre, Southampton, UK
Anne Le Friant	Institute de Physique du Globe de Paris (IPGP), France
Elodie Lebas	Institute de Physique du Globe de Paris (IPGP), France
Fukashi Maeno	University of Tokyo, Japan (visiting University of Bristol)
Adam Stinton	Montserrat Volcano Observatory (second part of cruise only)
Caroline Weir	Ketos Ecology (Marine Mammal Observer)
Susie Calderan	Ketos Ecology (Marine Mammal Observer)
Michele Paulatto	National Oceanography Centre, Southampton, UK (Marine Mammal Observer)
Charlotte Cantle	MA, Goldsmith College, UK

TECHNICAL STAFF

Leighton Rolley, Darren Young, Jason Scott, Mick Myers, Dave Teare, Dan Comben
Lee Sheldon

SHIP'S PERSONNEL

JC045 (Montego Bay, Jamaica to St Johns, Antigua): Master – Roger Chamberlain
JC046 (St Johns, Antigua to St Johns, Antigua): Master – Peter Sarjeant

ITINERARY

JC045

Departed	Montego Bay, Jamaica	23rd April 2010
Arrived	St Johns, Antigua	29th April 2010

JC046

Departed	St Johns, Antigua	30th April 2010
Arrived	St Johns, Antigua	12th May 2010

CRUISE OBJECTIVES

The first objective of JC045-046 was to provide the key site survey information (3D seismic data and/or additional 2D seismic crossing lines) for drill sites CARI-02, CARI-03 and CARI-04, located offshore from the island of Montserrat in the Lesser Antilles, for IODP Proposal 681 (Fig. 1).

The second objective was to produce an unusually detailed survey of submarine volcanic debris avalanche deposits resulting from large scale slope failure on (or around) Montserrat. The aim of this research is to use these results to understand the origin and emplacement dynamics of these landslides. The survey results include the first 3D seismic data set for a submarine volcanic debris avalanche deposit. In addition, TOBI sidescan sonar, 2D seismic reflection profiles (Air gun and boomer sources), multibeam bathymetry, and sub-bottom profiler data were collected (Fig. 1). Collected data are summarised in Table 1.

A further objective of this work is to better understand how volcanic material from the ongoing eruption of the Soufrière Hills Volcano (1995 to present) is redistributed around Montserrat. Marine sediments often provide a more complete record of eruption chronologies than sediments on land. This continues previous work that has linked near surface marine layers with eruptions that have been well monitored on land, based on a comprehensive collection of shallow sediment cores from around Montserrat (cf. Trofimovs et al., 2006; cores collected on JC018 and JCR123, Fig. 2), whose geometry is further constrained by SBP results collected during JC045-046.

Specific Objectives

1. Collect TOBI sidescan sonar data across the Bouillante graben (SE of Montserrat). This area contains volcanic debris avalanche and landslide deposits, as well as deposits of the 1995-recent eruption products.
2. Collect 3D and 2D seismic reflection data, in order to constrain the number, origin, morphology and emplacement dynamics of mass-wasting events around Montserrat.
3. Relate sub-bottom profiler data to the stratigraphy of relatively recent events seen in cores previously collected around the island, and constrain the marine deposit from the Feb 2010 dome collapse.
4. Support the IODP 681 Proposal with site survey data.

Summary of methods

The first cruise leg (JC045) from Montego Bay in Jamaica to St Johns in Antigua collected TOBI 27 kHz sidescan sonar data together with EM 120 and 710 multibeam bathymetric and backscatter data and SBP 120 sub-bottom profiler data (Fig. 1; Table 1).

The second leg (JC046) collected 2D seismic reflection data using the University of Southampton SOES streamer and a combination of dual air gun and boomer sources (with most data collected with the air gun source). This leg also collected 3D seismic reflection data across a 7 km x 4 km area with the dual air gun source. EM 120 and 710 multibeam bathymetric and backscatter data and SBP 120 sub bottom profiler data were also collected throughout this leg (although the sub-bottom profiler was not deployed when the boomer source was operating). ADCP data from the ship was also archived. Gravimeter data were collected throughout JC045 and 046.

Outcome

Data collected during JC045-046 successfully met objectives 1 to 3. Details of data collection, processing methods and of archived files are provided in the following sections. The data are currently being used to constrain the history of landslides off Montserrat on a range of scales, in accordance with objectives 2 and 3. Objective 4 has also been satisfied, in that data collected during JC045-046 have been submitted in support of IODP 681, providing new constraints on sampling sites. The proposal IODP 681 is currently under consideration.

SCIENTIFIC BACKGROUND

Geological Setting

The island of Montserrat is a British Overseas Territory and lies in the Lesser Antilles volcanic arc (Fig. 3). The arc is associated with subduction of the North America plate beneath the Caribbean plate, and in this part of the subduction system comprises two arcs of islands. The islands closer to the trench (eastward) are inactive, and are formed from eroded volcanic basement overlain by thick carbonate platforms, whilst the currently active volcanic arc lies to the west.

The island of Montserrat consists of four main volcanic centres (Harford et al., 2002). Silver Hills, the oldest centre (2.5 to 1.2 Ma), forms the northern end of the island, while the Centre Hills complex (1 to > 0.5 Ma) forms higher topography in the centre of the island, and the currently active Soufriére Hills centre (~170 ka to present) lies at the south end of the island. These centres are all andesitic, while the South Soufriére Hills centre, at the SE edge of Montserrat, was constructed by basaltic-andesitic volcanism at ~ 120 ka. Faults have uplifted the carbonate strata of Roche’s Bluff at the SE corner of the island by tens to hundreds of metres.

SE of Montserrat lies the Bouillante graben, bounded by the Montserrat-Bouillante fault system (Fig. 4), part of a trans-tensional array of normal faults accommodating oblique convergence along the volcanic arc (Feuillet et al., 2010). This study was conducted in the part of the graben adjacent to Montserrat. Seamounts occur on both sides of the graben, including the Kahounne volcanic centre to the east, which comprises two seamounts ~800 m in height.

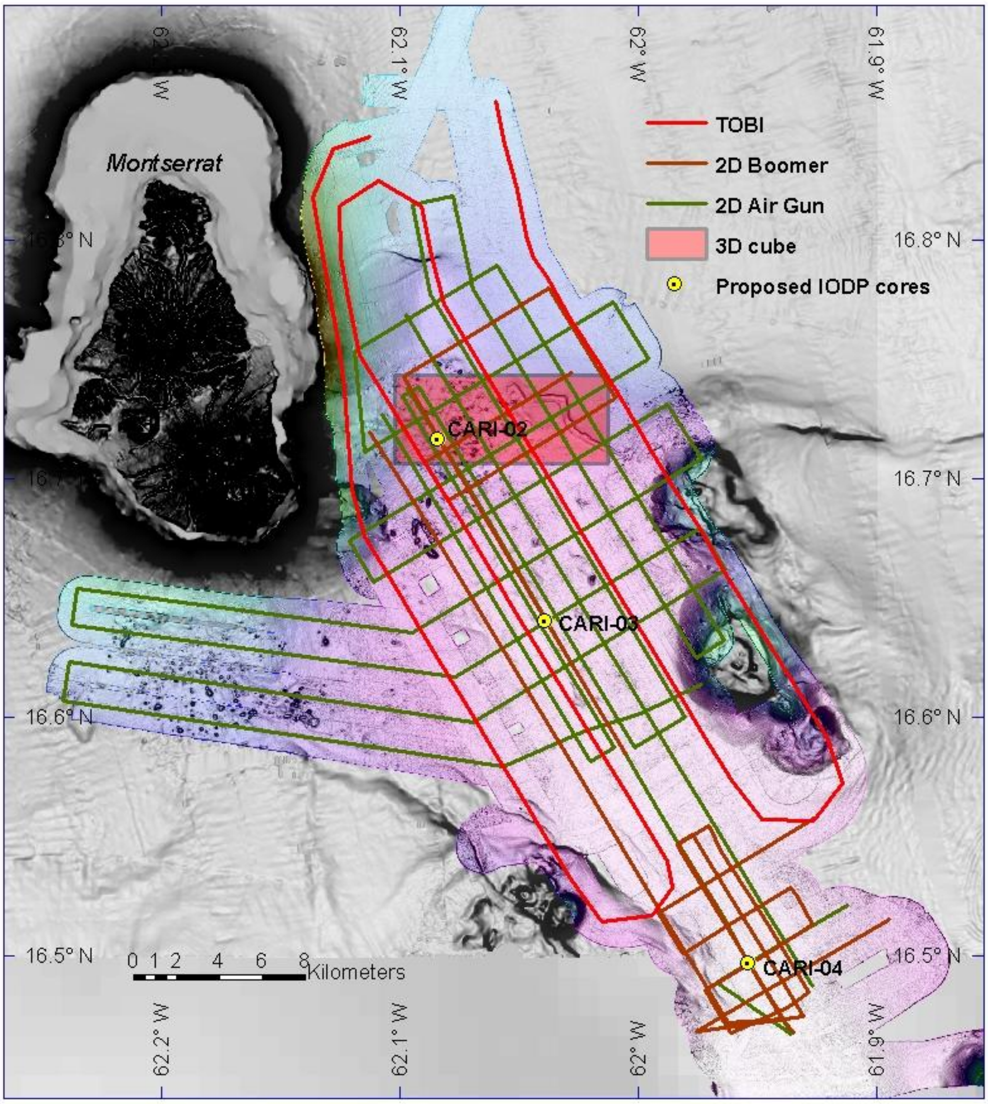


Figure 1. Track lines for JC045-046, showing 2D seismic acquisition (Air gun and boomer sources), the location of the 3D seismic data cube, and TOBI sidescan sonar tracks. New multibeam bathymetry, collected during this cruise, is shown in colour. Proposed IODP drill sites CARI-02, 03 and 04 are also shown.

Submarine deposits from Soufriére Hills

The recent activity at Montserrat (1995 to present) has been characterised by episodic andesitic lava dome extrusion, dome collapses and associated pyroclastic flows, and vulcanian explosions (Druitt and Kokelaar, 2002). About 1 km^3 of magma was erupted between 1995 and 2009. Major dome collapses (0.2 to 0.15 km^3) occurred in 2003 and 2006, representing the largest recorded historical dome collapses globally. Failure of the hydrothermally altered crater wall created an equally devastating pyroclastic surge in 1997. A partial dome collapse occurred on February 11, 2010, when ~20% of the dome failed. In total about 70% of eruption products produced since 1995 have been transported into the sea (Le Friant et al., 2009).

Previous marine expeditions have collected arguably the most complete set of shallow sediment cores from around the island (Trofimovs et al., 2006; 2008). Repeated bathymetric surveys have delineated the growth of a lobe of material built by pyroclastic flows entering the sea to the east of

Montserrat since 1997. This ridge of material extends ~7 km offshore to water depths of ~900 m, and is up to ~90m thick. This ridge was clearly imaged by our TOBI and multibeam data, and by the western part of the 3D seismic cube. Vibrocores show that the 1995 to recent deposits comprise multiple units with a complex stacking pattern. The 2003 dome collapse event produced proximal lobes tens of metres thick, while the finer fraction was flushed out of this pyroclastic flow was deposited from a turbidity current that continued for a further ~30 km. The thick proximal lobes are found on slopes of 9.5° to 2.5°, while the turbidite continued on slopes down to 0.02°.

The 1995-recent offshore deposits are underlain by two distinct layers rich in dome material (Trofimovs et al., 2006). Unlike the 1995-recent deposits these both represent single events, possibly related to the formation of the horseshoe shaped English's Crater on land (Le Friant et al., 2004). The lowest unit in many of the marine cores is a bioclastic turbidite, with multiple subunits. This bioclastic flow occurred at ~14 ka and most likely originated from very large scale collapse of the carbonate platform offshore Antigua (Trofimovs, 2008).

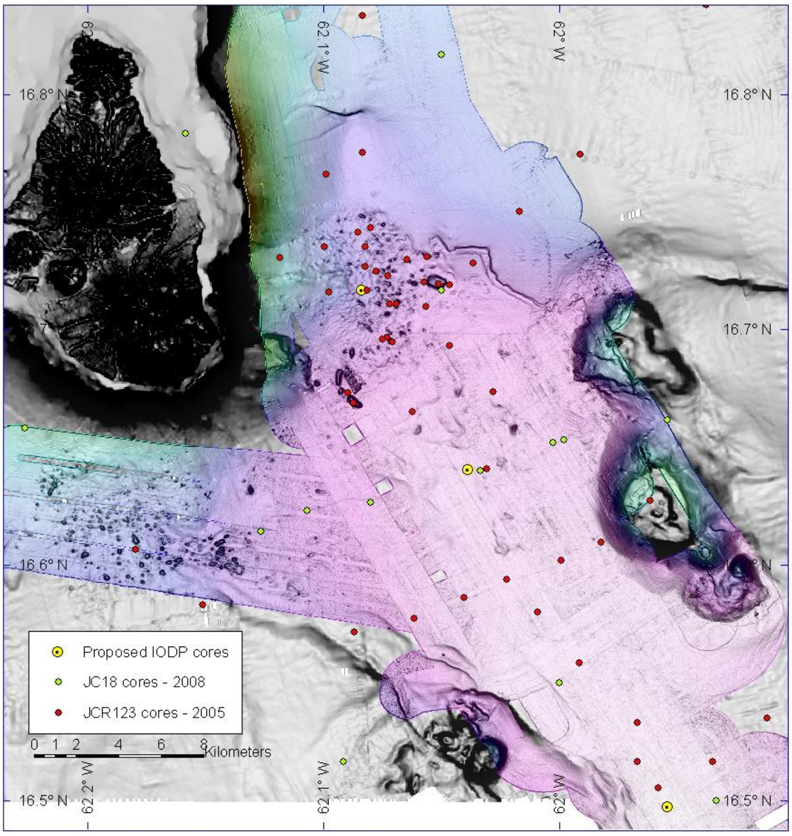
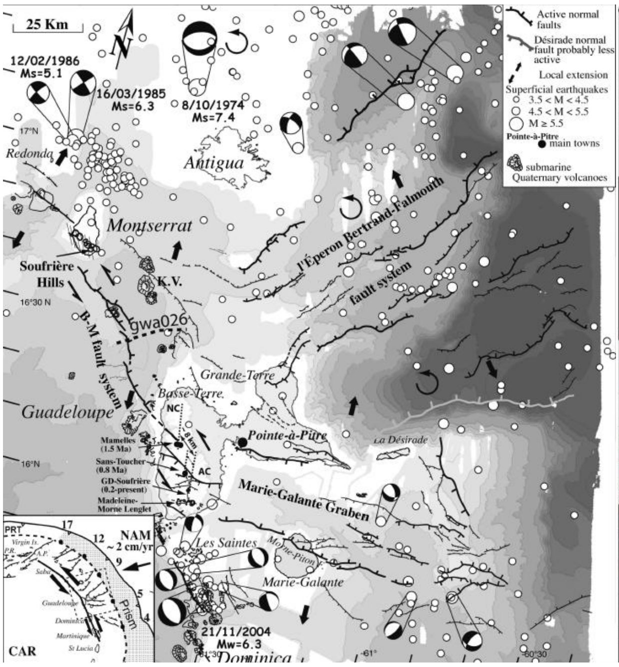


Figure 2. Location of shallow sediment cores collected on previous cruises around Montserrat. New bathymetry collected on JC045-046 is shown in colour.

Major landslide deposits

There are at least three major landslide deposits in the Bouillante graben to the SE of Montserrat. A blocky deposit(s) extends ~10 km from a prominent re-entrant in the submarine shelf, at the base of the Tar River valley. This uppermost blocky unit has a volume of ~0.5 km^3, and is here termed deposit 1 (Le Friant et al., 2004; Fig. 5). Within this unit, individual megablocks up to 600 m long protrude up to 80 m above the surrounding sea floor, although it is possible that some of these largest blocks originate in older events. The youngest blocky material may have travelled down an inner narrow chute within the shelf re-entrant, and is potentially associated with the formation of

English’s Crater. A more deeply buried landslide (deposit 2; Fig. 5) extends from the vicinity of a jagged depression east of deposit 1 – which may represent a head or side scarp. This chaotic unit can be traced in seismic profiles for at least 30 km down the graben towards Guadeloupe, and has a total volume of ~10 km^3. This landslide is thought to have occurred between ~130 and 110 ka, and has variable drape thickness of, of up to >30 m. Other identified deposits occur to the south of Soufriére Hills: deposit 3 is blocky, with similar morphology to deposit 1, whilst deposit 4 has a smoother character and extends beyond deposit 3 (Fig. 5).



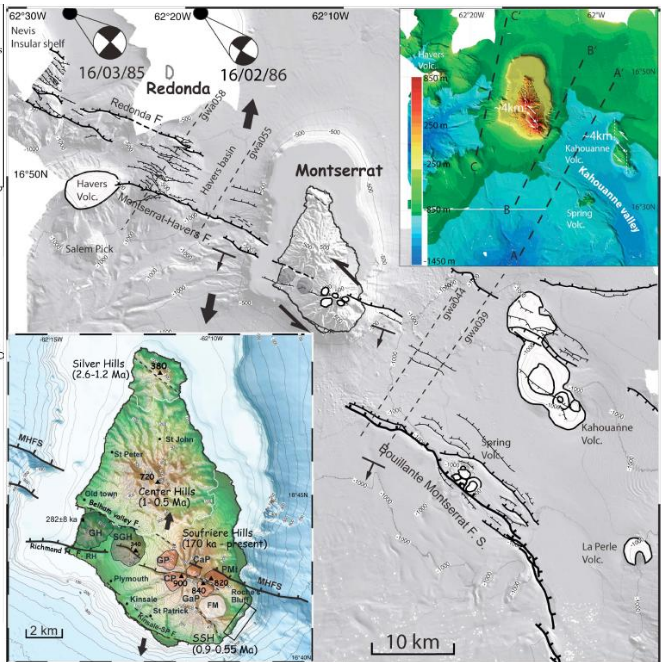


Figure 3 (left). Map showing the location of Montserrat in the Lesser Antilles. The map also shows major extensional and strike slip fault systems and the epicentres of recent earthquakes (from Feuillet et al., 2010).

Figure 4 (right). Map of the study area to the south east of Montserrat showing major fault systems (from Feuillet et al., 2010).

Previous seismic data shows that an even thicker and more deeply buried chaotic unit with a similar extent to deposit 2 also occurs in the graben. A chaotic unit also extends from the graben towards deposit 4. The temporal relationships of these units are not well understood, and this study aims to clarify the relative timing and nature of these large landslides.

Landslide deposits far larger than those off Montserrat occur offshore islands further south in the Lesser Antilles arc, including Martinique, Dominica, and St Lucia (Deplus et al., 2002). A total of 47 landslides have been identified along the arc, with 15 of these events thought to have occurred in last 12ka (Boudon et al., 2007). As well as sites around Montserrat, IODP proposal 681 aims to drill sites in deposits off Dominica and St Lucia.

Small tsunamis have been generated by pyroclastic flows entering the sea off Montserrat, following the 2003 and 2006 dome collapses. These tsunamis ran up for a few tens of centimetres in Guadeloupe and Antigua, and for several meters locally. However, much larger volume flank collapse events may generate much more devastating tsunamis, although the potential of these large landslides for tsunami generation is uncertain, and one aim of this project is to better constrain landslide emplacement dynamics in order to understand likely tsunami impacts.

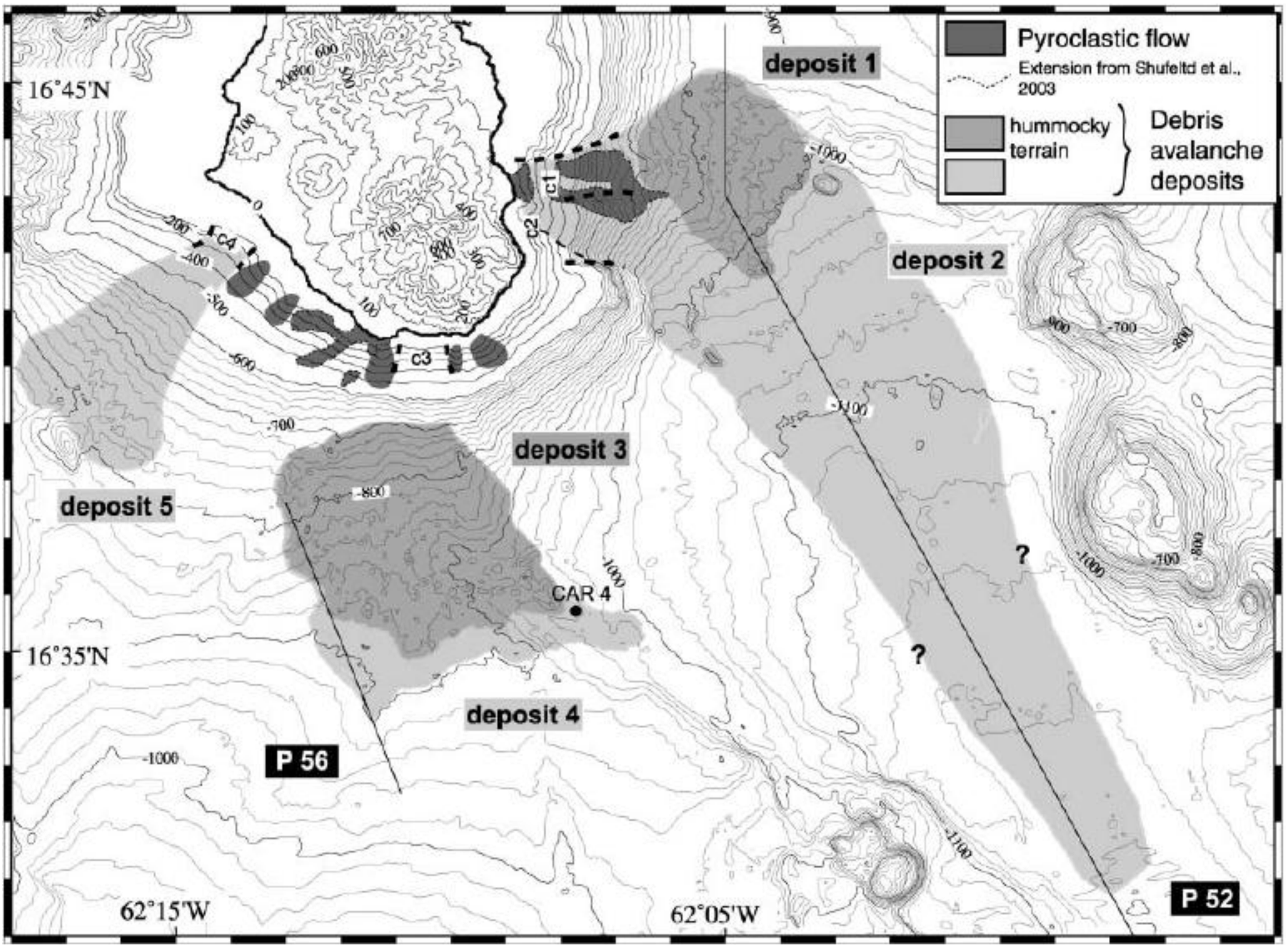


Figure 5. Identified large landslide deposits around Montserrat (from Le Friant et al., 2004).

NARRATIVE

Times in GMT except where otherwise stated

Wednesday 21.4.10: Icelandic ash causes cancellation of all flights in UK airspace; including those of NMFD technicians Young, Scott, Rolley and Sheldon.

Decision made to make port call in Antigua after completing TOBI survey en-route from Montego Bay to St Johns in Antigua. NMFD technicians will join vessel at Antigua. Passive Acoustic Monitoring equipment and some spares now being directed to Antigua.

Thursday 22.4.10: Flight situation was uncertain and complicated by Icelandic ash. British Airways Flights from London to Montego Bay arrived at 16.20 local for 12 of the science staff. Doug Masson was only scientist that could not make the flight, as he had a 48 hour trip back to UK from preceding Malta meeting.

Friday 23.4.10:

16.00: 12 of science party arrived ship.

17.00: Informed that TOBI engineer Duncan Matthew has highly inflamed elbow and will fly home to UK. Hühnerbach, Teare and Comben to operate TOBI.

Saturday 24.4.10:

03.00: Watt, Le Friant and Lebas arrive.

09.00: sailed from Montego Bay, Jamaica

Transit - Setting up equipment, life boat drill etc

Sunday 25.4.10:

Transit - Setting up equipment. Put GWADASEIS data into Kingdom Suite.

Monday 26.4.10:

Transit – Interpreting GWADASEIS seismic data with Kingdom Suite and setting up equipment.

Tuesday 27.4.10:

Transit – Interpreting GWADASEIS seismic data with Kingdom Suite and setting up equipment.

Wednesday 28.4.10:

Arrive work area: **TOBI SURVEY** (*Waypoints: Table 2*)

04:33: 16° 51'.601 TOBI in the water (waypoint 1)

04:49: 16° 51'.601 TOBI power on successful

10:00: Waypoints 4 and 5 shortened so that survey keeps to schedule

TOBI speeds 2.4 or 2.5 knots. Turns take ~ 1.5 hours.

'Fracture scarp' picked out well but no clear sign of edge of 1995-recent deposits.

12.20-13.50: Turn at end of line 1 of TOBI survey (waypoints 4 and 5)

16.00: Phoned Montserrat Volcano Observatory to find the seismicity associated with the Soufriere Hills Volcano has been minimal since February 2010.

21.00: Waypoints 7 and 8 lengthened

Thursday 29.4.10

00.00: TOBI survey. Some problems with SBP, but now running well.

11.30: Phoned Montserrat Volcano Observatory – all quiet

12.00: Ship making good time so survey lengthened slightly to include points 14 and 15. TOBI aiming to be recovered 15.30

21.00: Arrived St Johns 17.00 local time.

Friday 30.4.10

Change of ship's crew and arrival of NMFD technicians (Young, Scott, Rolley and Sheldon)

Arrival of Adam Stinton of the Montserrat Volcano Observatory

Setting up seismic equipment.

Saturday 01.5.10

11.00: Leaving from St Johns, Antigua, at 07.00 local time.

09.00 local: Reach work area. Air guns not ready, so completed swath bathymetry over the Feb 2010 deposit near to the shelf.

13.00 local: Started Boomer 2D survey line along axis of basin. Boomer has good penetration in distal basin, less so proximally.

17.00 local: Took in Boomer and deployed PAM for MMOs.

20.00 local: Deployed airguns as test. Worked well

20.30 local: Returned to Boomer survey over the distal CARI-04 IODP site.

Sunday 02.05.10

09.00: Recovered Boomer source and single streamer

10.00: Started to deploy p-cable from aft deck.

Initially a problem with how the doors were trimmed. Taken back in and retrimmed. During winch operation a cable broke and was fixed. One of the two airguns not working – so taken on board.

16.00: Incident. ***Operator error on bridge caused ship to sudden move to back and port.*** This resulted in the tail buoy drifting into boat. Data cable became wrapped around propeller and snapped. Remainder of p-cable system recovered on deck effectively.

Steam to St Johns in Antigua using one propeller.

Monday 03.05.10:

10.00: Picked up pilot at first light.

11.00-13.00: Dive team freed propeller from tangled cable.

15.20: Arrived work area and deployed air guns and single 2-d streamer.

Completed swath over recent deposits offshore Montserrat. Air guns malfunction due to leak and recovered onboard. Started along-basin 2D line with Boomer source. Boomer has good penetration distally but less so proximally.

~16.00: Air guns repaired and deployed on long line.

Tuesday 04.05.10:

05.00: Change from airgun to boomer

11.00: Change from boomer to air guns. Completed crossing line at IODP CAR04 site and headed up basin on axial line.

20.00: Onwards: p-cable system deployed in water and working. Some issues with turns and tail buoy falling over.

Wednesday 05.05.10

15.30: Lost tail bouy – frayed wire loop in attachment

23.30: resumed survey with 3D p-cable system.

Thursday 06.05.10

12.30: informed sailing 19.00 on 12th in Antigua.

Continued with air gun and p-cable 3D survey

Friday 07.05.10

Continued with air gun and p-cable survey. Three of the mini-streamers are producing suboptimal data – and this may be due to data cable.

Saturday 08.05.10

Continued with air gun and p-cable survey.

Sunday 09.05.10

Continued with air gun and p-cable survey.

Monday 10.05.10

Finished p-cable 3D seismic survey at ~05.30 GMT

Recovered p-cable system

07.00: Deployed single streamer with air gun source.

Tuesday 11.05.10

Continuing 2D seismic reflection survey with air gun source.

Wednesday 12.05.10

05:00: Recovered air guns, deploy boomer source.

13:00: Recover boomer and single streamer. End of survey. Steam to St Johns, Antigua.

17:00: Arrive St Johns, Antigua.

EQUIPMENT REPORTS

All archived file details are given in Appendix 1.

Waypoint positions for the TOBI survey are given in Table 2. The full watch log for the remainder of JC045-046, including positions, ship speed and heading, and data collection notes, is given in Appendix 2. During the survey planned 2D lines were given working numbers (JC45-X; Appendix 2), ordered sequentially, following on from the TOBI survey lines 1 to 4. These numbers have not been retained for the final data (see Results section, 2D seismic reflection data, below).

2D seismic systems

Two different seismic sources were used for the collection of 2D seismic profiles on JC045-046. An air gun source was used for the majority of the 2D survey, in order to achieve deep penetration across the range of seafloor deposits encountered SE of Montserrat, including blocky debris avalanche units. A boomer source was used to provide a second dataset, particularly around the planned IODP sites (in some cases repeating air gun lines) and over areas of structural interest. The boomer source provided higher resolution and gave good depth penetration away from the blocky landslide units, despite water depths of over 1000 m at the southern end of the survey area. Ship speed for all 2D data was approximately 4 knots.

The air gun source comprised two identical Sercel GI guns, each with a 150 cu. in. total volume. The same source was also used for the 3D P-cable system. Each gun had a generator chamber volume of 45 cu. in., and an injector chamber volume of 105 cu. in., giving a total array volume of 300 cu. in. The firing pressure was 190 bar. The array was towed approximately 30 m astern of the ship at a depth of 3 m. The firing interval was 7.0 s. The dominant frequency range of the source was 50-300 Hz. In total approximately 370 km of 2D profiles were collected with the air gun source (Fig. 1).

The boomer source, an Applied Acoustic Engineering AE200 system, is more commonly used in shallow water surveys, and operates using a stored charge at high voltage (4000 V) discharged through a boomer plate when the system is triggered. The system was towed 15 m behind the ship, and fired at 4.0 s intervals. The dominant frequency range of the source was 150-800 Hz. Approximately 140 km of 2D lines were collected with the boomer source (Fig. 1).

The 2D streamer was ~100 m in length, with a 59 m active section containing 60 hydrophone groups at a spacing of 1 m. Shot sampling rates from the air gun source were 1 ms, recording for 3 s, and 0.25 ms for the boomer source, recording for 2 s. Data were recorded on a Geometrics Strataview R60 seismograph connected to a PC running CNT1 Marine Controller software and a GPS clock system. Seismic data are logged as SEG-D files with a summary log file containing shot times in GPS-linked UTC. The source float position was calculated at each shot using the shipboard PosMV system, with a calculated layback according to the geometries in Fig. 6 (67.5 m for air gun; 61.1 m for boomer). Source-receiver distances (a and b; Fig. 6) for the first and last channel were then estimated using the timing of the direct arrival to determine more accurate inline and crossline source-streamer offsets. These distances varied slightly and were recalculated during processing for each line. From these, the position of each receiver relative to the source could be found (using x and y; Fig. 6). Throughout the survey, the streamer depth was ~1 m, and source depths ~3 m for the air gun and 0.5-1 m for the boomer. The distance astern of the source did not change, and the streamer direction was assumed to parallel the ship's heading. However, a small positioning error is likely due to unconstrained lateral movement of the source and feathering of the streamer, both of which are likely to have occurred to varying degrees during the survey.

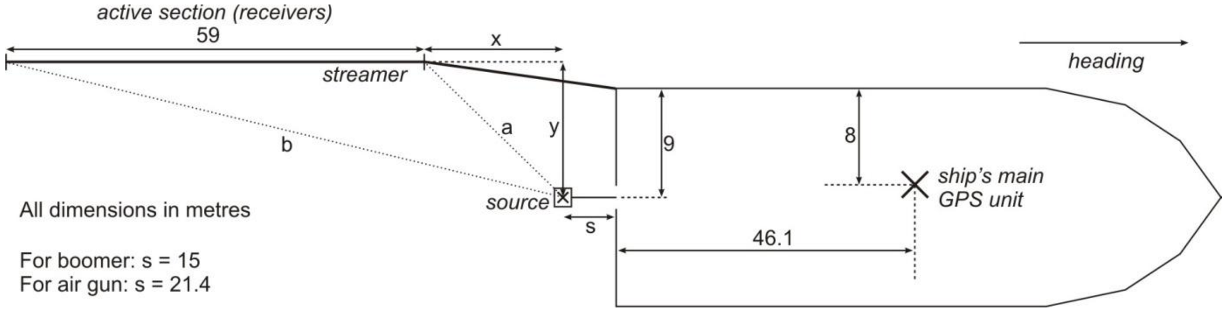


Figure 6. Ship and streamer configuration for multichannel seismic acquisition, JC045-046.

3D seismic acquisition system

3D seismic data were collected on JC045-046 using the P-Cable, a new type of low-fold, high-resolution 3D seismic acquisition system developed by Volcanic Basin Petroleum Research (VBPR) in collaboration with National Oceanography Centre, Southampton (NOCS), University of Tromsø (UiTø), and Fugro Survey AS, Oslo. For this cruise we used the proto-type system of the National Oceanography Centre, Southampton. The data cube covered a 7 × 4 km area over the debris avalanche deposit on the seafloor east of the Tar River valley (Fig. 1), with individual track spacings of 60 m collected in multiple overlapping loops (2.04 km width). During the survey lines were numbered from north to south, in the order of collection, as 1-67 (Table 7; such that line 2 was 2040 m south of line 1, and line 3 was 60m south of line 1). Line 12 was repeated at the end of the survey, due to problems with initial data collection following loss of the tail buoy. The repeat was labelled line 68 (Table 7). Ship speed was approximately 4 knots, although this was reduced slightly when travelling east due to prevailing currents.

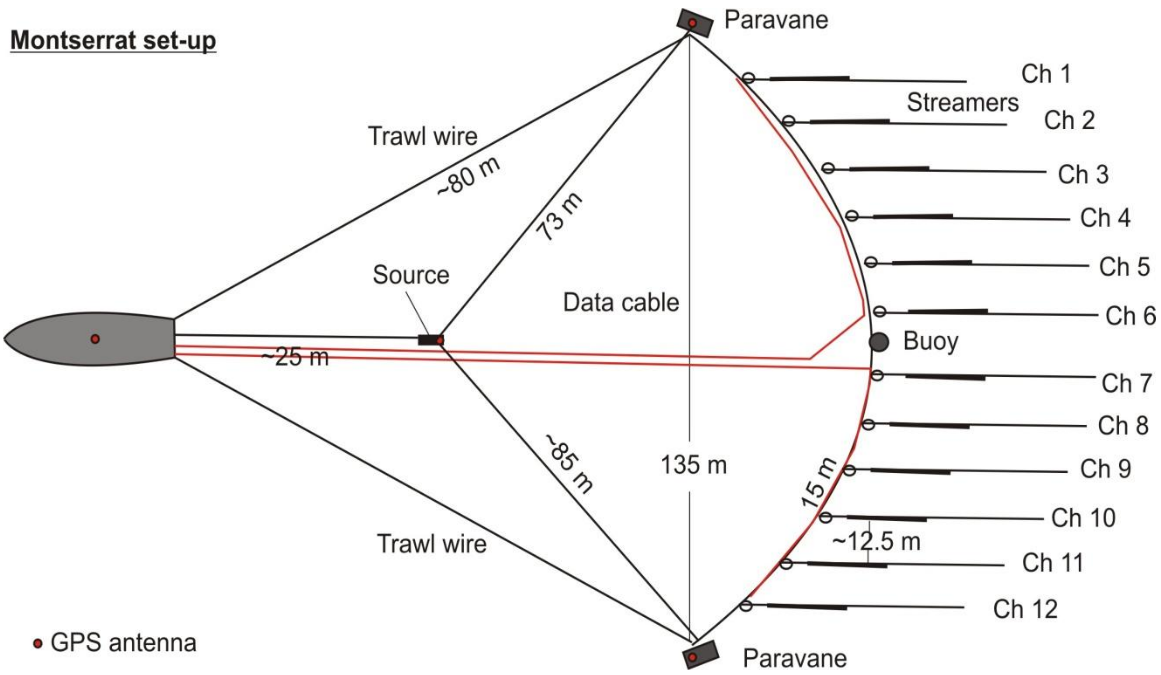


Figure 7. Initial P-Cable configuration for JC045-046.

The NOCS P-Cable system consists of a wire that is towed perpendicular to the ship's steaming direction using two specially designed paravanes (Fig. 7). Twelve single-channel Teledyne Geophysical Instruments analogue streamers were connected to this wire (Fig. 8). The paravanes (Fig. 9) and a tail boat are designed to keep the cross wire at approximately 1 m depth. The paravanes are towed behind the ship using reinforced power cables that power the GPS receivers on each door. Two data cables transmit data from the streamers back to the ship. A Geometrics Geode 24 seismic recording system digitizes the seismic data on-board. System details are summarised in Table 3.

Navigation and positioning data for the P-cable system were recorded and calculated using the Kongsberg Seatex RGPS tracking system, Seadiff, with four GPS antennas (one on the ship, two on the paravanes and one on the air gun float). GPS receiver locations were recorded at 1 s intervals with the time and position of each FFID.

The GPS positioning data were used to locate each individual receiver. Initial positions were calculated for each streamer, assuming a catenary geometry, given the paravane positions and the known streamer intervals along the cross cable. Thus, the relative positions of streamers may vary between shots, depending on the paravane separation. This initial geometry was then corrected using the picked timing of the first arrivals, to give the final processing geometry (Appendix 1). The tidal effect was shown to be negligible, so no static correction was made for this.

Figure 8. Streamers laid out on deck prior to deployment. Each streamer is summed into a single channel.

Figure 9. One of two Paravanes that connect to the cross wire and used to separate streamers. See Fig 7 for diagrammatic arrangement of the paravanes.

Sub Bottom Profiler (SBP 120)

The SBP 120 is an extension of the EM 120 multibeam bathymetry system. The addition of a secondary, low frequency transmitter (recorded using the EM 120 transceiver array) affords imaging of sedimentary layers and buried objects in the shallow subsurface. Mounting the transducer and receiver arrays orthogonally to each other acts to beam form the recorded signal into a fan of narrow beams across-track that are automatically stabilized for roll and pitch.

The acquisition parameters used during JC045-046 were:

Sweep type:	Linear Chirp up
Sweep envelope:	Gaussian (Blackmann-Harris)
Sweep length:	40 ms
Sweep frequency range:	2.5 – 7.0 kHz
Sample window length:	150 ms
Sample interval:	0.048 ms
Beam width:	3°
Number of beams:	3 (for brief periods 1 and 5 beams; see Appendix 1)
Ping interval/Acquisition delay:	Vessel speed and water depth dependant

SBP 120 data were recorded throughout the cruise, with the single exception of when the Boomer source was in operation. Data quality was, in general, excellent, with penetration observed to >25 m in places, and on average c. 10–15 m away from the blocky debris avalanche deposits offshore the Tar River valley. Data were logged as raw uncorrelated SEG-Y files to facilitate post-processing in ProMAX. An initial 5-stage processing flow was implemented on board:

1. Stacking of beams into a single trace to improve S/N.
2. Correlation with theoretical Chirp sweep, collapsing reflections to the Klauder wavelet.
3. Minimum phase predictive deconvolution tightened seafloor and subseabed reflectors.
4. Amplitude recovery to compensate for spherical divergence and attenuation in the subsurface.
5. Envelope function to increase S/N.

Further post-processing has been applied post-cruise, including swell filtering to correct for heave motion observed particularly at slow speeds.

Multibeam Bathymetry (EM 120)

The James Cook carries two swath bathymetry systems. Data from both the Kongsberg Simrad EM 710 and the EM 120 systems were collected. The EM 710 system operates with 128 beams perpendicular to the ship's long axis in the 70-100 kHz frequency range. Since this system is used most effectively at water depths of <500 m, the results have not been further processed, and the bathymetric results from this cruise are based on data from the EM 120 system, designed for use in deep water and capable of high resolution seafloor mapping to full ocean depths.

The EM 120 system uses two linear transducer arrays in a Mills cross configuration with separate units for transmit and receive. The nominal sonar frequency is 12 kHz, with a ping rate of 3 Hz. The angular coverage sector was 90°, giving a swath width of approximately twice the water depth. The manufacturer claims a depth accuracy of better than 0.2%.

The EM120 output was observed throughout the entire survey, and worked reliably, although several system restarts were necessary due to errors in the navigation data. The final area covered measures approximately 50 km N-S and 30 km E-W. The quality of the data was generally good, with repeated coverage in many areas during different parts of the seismic and TOBI surveys. Particularly good coverage was achieved in the area of the 3D seismic cube.

Gravity Meter

Gravity data were logged throughout the cruise, with a sampling rate of 1 s, using the Micro-G Air Sea gravity meter S84, positioned in the ship's gyro/gravimeter room close to the centre of motion. The ship's Micro-G LaCoste Air-Sea gravity meter consists of a highly damped, spring-type gravity sensor mounted on a gyro-stabilised platform. Output data are logged on the TECHSAS system, the primary data logger on the ship that also stores all navigation data.

Reference measurements, to tie the relative gravity from the ship's gravimeter to absolute values were made with a Lacoste Romberg landmeter. Ties were made in Montego Bay, Jamaica and St Johns, Antigua, as well as after the ship's transit leg at the end of JC046, in St John's, Newfoundland, Canada. Gravity data have not been further processed at this stage. Gravity base ties details and drift corrections were as follows:

	Offset to add to ship reading	Date/Time UTC
Jamaica tie	968708.3558 mgal	22/04/10 13:50
Offset drift rate	*-0.226849607 mgal/day*	
Antigua tie initial	968706.5359 mgal	30/04/10 14:23
Offset drift rate	*-0.008650845 mgal/day*	
Antigua tie end	968706.4306 mgal	12/05/10 18:30
Offset drift rate	*0.552274803 mgal/day*	
Newfoundland tie	968713.5852 mgal	25/05/10 17:25

Towed Ocean Bottom Instrument (TOBI) – written by Veit Hühnerbach

TOBI Team: Veit Hühnerbach, Dan Comben, Dave Teare. and Mick Myers

Executive Summary

TOBI was launched and recovered once for a 34.5 hour survey. The full survey was completed in one run, with no downtime recorded:

Deployment	Start time/Day	End time/Day	Comments
Run#1	05:03:42/118	15:21:42/119	One run was required to complete survey area. Numerous CTD reboots were required during the survey. Recommend change over to second CTD and cable harness for following cruise JC045/6.

The system performed well overall, with some excellent sidescan data. This provided vital information to aid in nominating sites for the multibeam and 3D-seismic surveys later in the cruise. This successful outcome was only possible by the dedication and effort of the interdisciplinary team that operated TOBI under these extraordinary circumstances.

The system will be reviewed, in light of any reported faults, back at NOC in preparedness for further cruises this year.

System Description

TOBI - Towed Ocean Bottom Instrument - is the National Oceanography Centre's deep towed vehicle. It is capable of operating in 6000m of water. The maximum water depth encountered during the TOBI surveys during this cruise was around 1300m.

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

1. 30kHz sidescan sonar with swath bathymetry capability (Built by IOSDL)
2. 6 - 10kHz chirp profiler sonar (Built by IOSDL/SOC)
3. Three-axis fluxgate magnetometer. (Ultra Electronics Magnetics Division MB5L)
4. CTD (Falmouth Scientific Instruments Micro-CTD)
5. Pitch & Roll sensor (G + G Technics ag SSY0091)
6. Fibre Optic Gyroscope (Octans 6000), replaces Gyrocompass (S.G.Brown SGB 1000U)
7. Light backscattering sensor (WET labs LBSS)

A fuller specification of the TOBI instrumentation is given in Appendix 3.

The ship's GPS data feed provided the TOBI logging system with navigational data. This required a modification to the software module OPTFNC.C to accommodate the GGA format as opposed to the GLL output of the TOBI portable GPS antenna. This was then compiled to a new version of LOG.EXE, the main logging application program. It was noted that the GPS positions were partly corrupted during an interval of about one hour on JD118 and about 45 minutes on JD119.

An MPD 1604 9 tonne instrumented sheave provides wire out, load and rate information both to its own instrument box and wire out count signals to the logging system. The instrumented sheave is an optional extra if such an item is not available on the chosen ship. If available on the ship, then the wire out is recorded on the ship's own data network. This facility was available on the James Cook (JC).

The TOBI system uses a two-bodied tow system to provide a highly stable platform for the on-board sonars. The vehicle weighs 2.5 tonnes in air but is made neutrally buoyant in water by using syntactic foam blocks. A neutrally buoyant umbilical connects the vehicle to the 600kg depressor weight. This in turn is connected via a conducting swivel to the main armoured coaxial tow cable. All signals and power pass through this single conductor.

The deck electronic systems and the logging and monitoring systems were set up in the Main Laboratory on the starboard side. The TOBI replay computer was mounted on the next spare bench space, starboard side. As TOBI has been used previously on the ship, mobilisation of the major components was easily accomplished.

TOBI Deployments

The James Cook (JC) is equipped with a wide stern mounted hydraulic 'A' frame that allows TOBI to be deployed and recovered in an athwartships position. This gives good control of the vehicle during these operations. A main sheave block on the 'A' frame was used for deploying and recovering the TOBI vehicle as well as deploying and recovering the depressor weight and towing the complete system during the survey. No major problems were encountered during any of the launch or recovery operations, which is a very great credit to the deck crew involved. The Magneto-Optical (M-O) disks used and their relevant numbers, files and times, are given in Table 4.

TOBI Watch Keeping

TOBI watch keeping was split into three, four-hour watches repeating every 12 hours. Watch keepers kept the TOBI vehicle flying at a height of ideally 400–600 m above the seabed by varying wire out and/or ship speed. Ship speed was kept at 2.0-2.5 knots over the ground with fine adjustments carried out by using the winch. The higher survey altitudes (normally 350–400 m) were required for a greater safety margin due to the extremely rugged terrain and the imprecise old bathymetry maps that were available. As well as flying the vehicle and monitoring the instruments watch keepers also kept track of disk changes and course alterations.

The bathymetry charts of the work area consisted of previously surveyed blocks and using the JC's EM120 system, running during the TOBI survey. Both of these aided in determining the flight profile of the vehicle. The bathymetry maps were of an older era so care in flying was required but between the ship's EM120 data and the TOBI data a more precise bathymetric mapping of the area has been achieved.

Instrument Performance

These are real time observations of the instrumentation performance. A more detailed engineering analysis, involving the data collected, will home in on any problem areas highlighted by these observations.

Vehicle: During the Run #1 the vehicle performed well apart from numerous remote 'reboots' of the CTD/Gyro instruments. The software, connectors and electronics had been reviewed at base prior to this cruise and nothing discernable was found. It can only be concluded that it is a pressure cycling problem. It was planned to change the CTD and cable from the one used on JC44 for a spare one, but operational circumstances prohibited this.

Umbilical and Swivel: The umbilical performed perfectly with no faults. We are now no longer using swivels and it has to be noted that overall system reliability has dramatically increased due to this. On this trip there was no down time recorded. It should be noted that the 'umbilical' winch, a former old (>15 years) hydrophone winch, is really not up to the job of handling the TOBI umbilical in any sea state above calm states.

The newly acquired Evergrip terminations proved a success although refinement in techniques in building them up is required. A review of the new termination bottle will also be conducted based on the findings of this cruise. Overall the new combination works very well and interfaces easily to the other deep towed / powered vehicles, Hybis and SHRIMP.

Sidescan: The system performed well with excellent records of the slope, flank of the volcanic island of Montserrat, and mass wasting features offshore, which aided in planning of the multibeam and 3D seismic survey sites later in the cruise.

Magnetometer: The unit worked well throughout the cruise. The magnetometer was calibrated at the end of JC44 involving 180 and 360 degree turns in the vehicle track, at a shallow vehicle depth (300-400m), prior to recovery of the vehicle on-board (see JC44 cruise report).

Gyro: This was the first cruise with the Octans6000 fibre optic gyroscope.

The unit performed well with the data stream only being corrupted when the CTD locked up. The system returned to normal once the CTD had been correctly rebooted. The gyro proved a valuable aid to processing and geographically referencing sidescan data.

CTD (FSI Serial No. 1429m-16apr99): For the majority of the cruise the CTD worked well but required a high number of remote reboots to keep the system operating. The system had been fully tested at base. The only conclusion is a possible pressure cycling causing connection *problems. The CTD and cable could not be swapped out for the spare unit (1425-09nov98) and cable as planned for JC045/6.*

Pitch/Roll: This unit performed well for the whole cruise.

LSS: The light scattering sensor was used throughout the cruise.

Swath bathymetry: The unit performed well during the complete survey run with no restarts required.

Deck Unit: The system proved very reliable in operation throughout the cruise. A voltage of 320V was used to power the vehicle with a current of approximately 400 – 450 mA.

Instrumented Sheave: Not required on this cruise, JC had the facilities in place and wire out data made available in a text file.

Winch – TOBI Portable: Not required on this cruise, JC had a fully operational deep tow winch with an inner coaxial cable for power, communication and data streams.

Data Recording and Display: 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 9 minutes of recording time. All data from the vehicle is recorded along with the ship position taken from the TOBI portable GPS receiver. Data was recorded using TOBI programme LOG.

As well as recording sidescan and digital telemetry data LOG displays real-time slant range corrected sidescan and logging system data, and outputs the sidescan to a Raytheon TDU850 thermal recorder. PROFDISP normally displays the chirp profiler signals and outputs them to a Raytheon TDU850. On this cruise an Octopus 360+ Geophysical Acquisition System was used to display sub-bottom profiler data and log to an industrial standard SEGY format. DIGIO9 displays the real-time telemetry from the vehicle – magnetometer, CTD, pitch and roll, LSS – plus derived data such as sound speed, heading, depth, vertical rate and salinity.

LOG, PROFDISP and DIGIO9 are all run on separate computers, each having its own dedicated interface systems.

Data recorded on the M-O disks were copied onto CD-ROMs for archive and for importation into the portable (NOC), available on board, image processing system (PRISM).

A few time jumps were detected in the data files but were easily corrected by the processing software. It was likely to have been occasional GPS dropouts in the ship’s system.

Image Processing

Onboard processing equipment during this cruise consisted of a standard PC laptop with a virtual Linux partition and a total of 90 Gigabyte of disk space. A final map containing preliminary side-scan sonar imagery was plotted on an A0 plotter. All data were also archived onto an external 1 Terabyte hard disk and CD-ROM.

The ship's navigation was recorded online on a server of the ship. The data were transferred at the end of the TOBI survey and then tested for time-continuity and abnormal speed values. Navigation data stored directly in the TOBI raw file, coming from the ship’s DP system, showed abnormal, erratic navigation data on both survey days for up to an hour. The navigation data for processing was taken from the POS-MV system. Good navigation data is essential for processing, because the vehicle position and hence the sidescan image position is calculated from it.

The winch data (wireout) were recorded separately and stored in a separate file. The TOBI imagery was downloaded from the CD-ROMs using a subsample and average factor of 4. This gave a pixel size of 3 metres and an almost 2-fold improvement of the signal-to-noise ratio.

SUMMARY OF RESULTS

All archived data file details are given in Appendix 1.

2D Seismic reflection data

2D seismic reflection profiles were successfully collected throughout the survey area, using both air gun and boomer sources (Tables 5 and 6). The air gun results provide a comprehensive grid coverage, including multiple crossing lines, that improve on and add to previous survey lines from the area. The boomer lines augment this data set in locations of finer sediment, such as around CARI-04, where the source provided good penetration, and around areas of structural interest beyond the eastern edge of the debris avalanche deposits east of the Tar River valley.

2D air gun and boomer data were each collected with sequential FFIDs during the whole survey. These data were divided into logical lines at regular (hourly) intervals (see Tables 5 and 6) for data collection purposes, but these do not correspond to geographical survey lines. For this purpose, using the ship's navigation data, all 2D seismic results were plotted and divided into straight line sections. These lines are labelled 1-17 for those orientated N-S, and A-U for those orientated E-W, counting from the east and from the north, respectively (Table 8). These lines have each been individually processed.

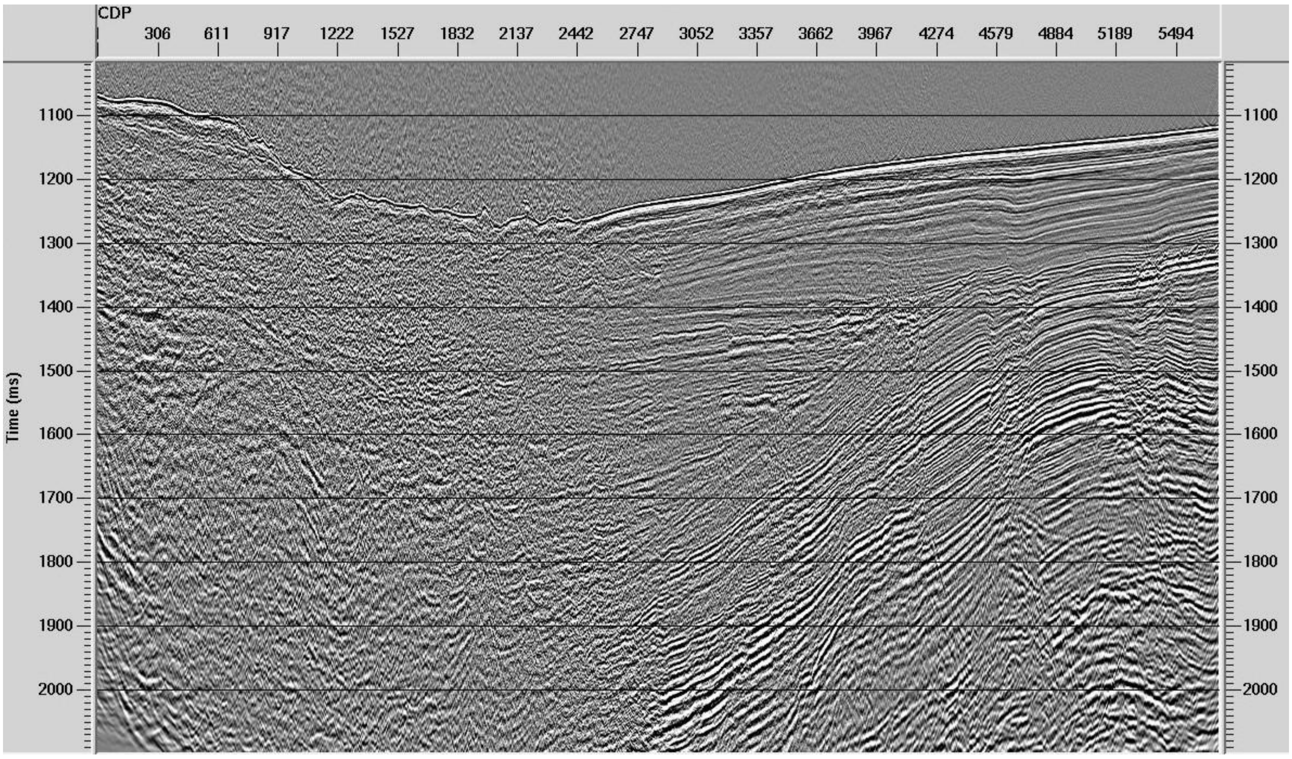


Figure 10. Example of 2D air gun reflection profile after preliminary processing, for a line across the region covered by the 3D cube. The blocky debris avalanche unit is on the left of the image.

Processing of the air gun lines, using ProMAX, involved geometry correction, bandpass filtering, minimum phase predictive deconvolution, amplitude recovery and normal moveout correction, before stacking the lines at 5 m binned CDPs. An f-k Stolt migration using time varying velocities was then applied, followed by final time variant scaling and bandpass filtering. The results indicate a good resolution and penetration outside the blockiest parts of the debris avalanche deposit, of >2 s TWT. An example of a line after preliminary processing is given in Fig. 10. Processing of the boomer lines is ongoing, and is a more involved process due to the lower signal to noise ratio. Initial results suggest that data around the southern end of the survey provide a much improved resolution of the area around CARI-04 than had been obtained by previous air gun data, and will be useful in selecting the best location for this core site.

The 2D profiles will allow improved mapping of the edges and extents of buried landslide deposits, and in conjunction with the 3D cube will allow the relationships between the debris avalanche units east of the Tar River valley and the landslide unit deposited southward in the graben to be better understood. Early results, combined with bathymetric data, suggest that a scarp structure around the northern and eastern edges of the avalanche deposits may be important to understand these relationships, both in terms of the source of landslide material, the amount of movement, and the order of events.

3D seismic data

The high-resolution 3D data acquisition system worked reliably throughout the entire cruise. Given the fair weather conditions this could be expected. The spread of up to 145 m between the paravanes was better than on previous cruises. This is most likely the effect of the wide beam of the RRS James Cook which resulted in a larger than usual separation of the towing points. The wide spread was also caused by the trim of the doors which was more aggressive than normal. This however limited the maximum vessel speed to 3-4 knots depending on the sailing direction, i.e. against the weather or not.

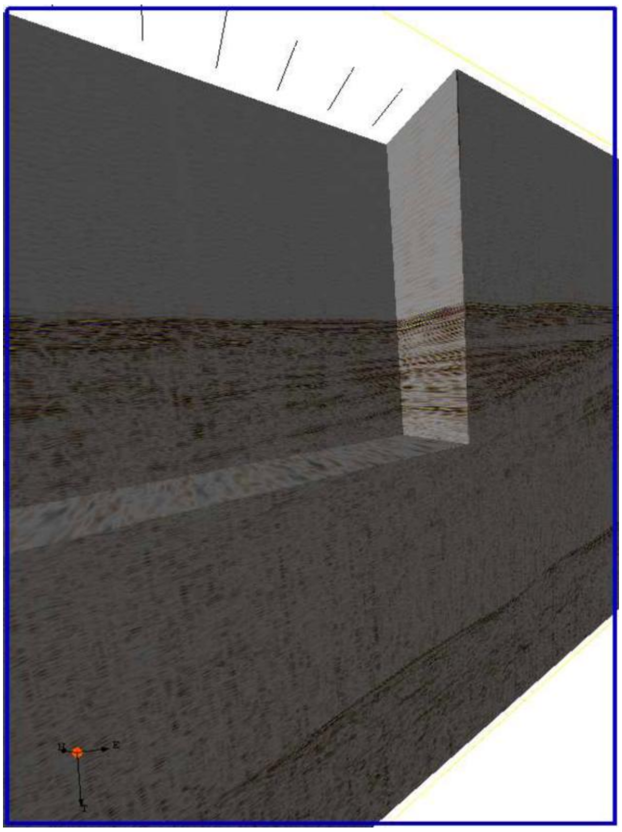


Figure 11. 3D visualization of the 20 m binned P-Cable cube generated during the survey.

The incident when the ship was going astern across the data cable caused loss of the new data cable and damage to one of the streamers. These should both be replaced before the system is deployed next time. As a precautionary measure we have made a disk image of the hard drive of the navigation computer. This disk image is located on a spare hard drive in the Kongsberg box.

During the cruise nominal receiver locations for each streamer were calculated assuming a catenary distribution behind the paravanes, and then corrected based on picked first arrivals. This navigation file has been archived (Appendix 1). These locations were then used to bin the data at 20 m bin spacing followed by an ensemble stack. The resulting cube (Fig. 4) has a penetration of more than 2 s TWT. Especially in the northern part the data have a very good signal to noise ratio. In the southern half of the cube the lines were shot into the wind and currents and some are channels were considerably more noisy, but still at acceptable levels.

The first rough processing of the cube (Fig. 11) shows that the area SE of Montserrat was mainly filled by sediments that are derived from Montserrat itself or its eastern shelf. The preliminary processed data show that these deposits lap onto the drape that covers a major anticline further to the east which seems to be an extension of the arc platform contiguous with Antigua and the eastern, extinct part of the Antilles arc. This suggests that the structure has been may be older than Montserrat. Although the data are not processed completely one can identify similar seismic arrivals underneath the proximal blocky debris flow off Tar River valley perhaps indicating that the present slope processes have been active for some time. This would imply that the IODP site CARI-02c is well placed to obtain a representative section through these deposits. Given the early state of processing it is premature to propose another even better suited location for the CARI-02c site, but we expect that it can be refined after the data have been completely analyzed.

The deposit of the 1996 eruption can be clearly seen in the 3D data when the pre-1996 bathymetry is plotted on top of the seafloor reflection. We will thus be able quantify the volume of debris that was deposited by that eruption within the survey area.

Processing of the cube has been done by CDP binning at 15 m bin size. An initial stack (bandpass filtering (low cut: 24 Hz, low pass: 50 Hz, high pass: 300 Hz, high cut: 400 Hz), automatic gain control (2000 ms window), normal moveout correction (1500 m s^{-1})) showed that the geometry was good but that noisy traces reduced overall data quality. The signal to noise ratio for each trace in each channel was calculated from a cross-correlation between neighbouring traces in each channel, and the extracted peak and rms amplitudes used in conjunction with the signal to noise ratio to isolate noisy traces. Each channel was then evaluated individually to determine a reasonable S/N ratio and noisy traces removed: traces with strong spikes were identified from anomalous peak and rms amplitudes; traces with little to no recorded signal were identified from anomalously low rms amplitudes. As a result of this processing sequence, 18% of the traces were removed. The final stack then repeated the earlier stack processing with the filtered data.

Post-stack processing involved 3D trace interpolation to fill gaps in the CDP grid, done in the frequency-space (f-x) domain. Signal to noise ratio extraction was repeated, as before, to remove poorly interpolated traces. Post-stack amplitude balancing was done with repeated automatic gain control (2000 ms window), and a 3D post-stack time migration (Kirchhoff) applied.

Sub-Bottom Profiler

Raw data files were filtered for those with errors in header information, and processed as individual sequences of SEG-Y files with continuous trace numbers (Appendix 1). These file sequences were processed individually. The output SEG-Y files were then combined, in their order of original acquisition, with reassigned and continuous ffid numbers, as a single file. The plotted navigation from this file was used, based on the reassigned ffids, to split the SBP data into lines. Where these were coincident with air-gun or boomer lines, these were given the same identifier (i.e., JC45sbp_2). Otherwise, lines have been defined counting sequentially from JC45sbp18 (Table 9). This final SBP coverage is shown in Fig. 13. Lines have not been defined at this stage over the 3D cube, where there is particularly dense coverage.

Sub-bottom profiler data were collected during the entire cruise, except when the Boomer source was operating, and thus provide a comprehensive data set of the structure of subsurface sediments throughout the survey area. Penetration, outside the blocky avalanche deposit, was in some cases

>20 m, indicating multiple sediment packages and providing information on shallow fault structures and unconformities (Fig. 12). Several lines were taken either directly over or nearby previous shallow sediment core sites (cruises JC018 and JCR123; Fig. 2), and the results thus have the potential to be used in conjunction with core data to understand the wider distribution of sediment units identified within these cores. The SBP data will also be useful in understanding drape thickness and accumulation in different parts of the survey area, and may thus provide information on the ages and timings of large landslide deposits buried beneath. Multiple profiles across the scarp structure covered by the 3D cube provide detailed information regarding the form of this structure, that will be used to understand how this relates to the failure of material forming the landslide deposits extending south through the graben. Around the debris avalanche deposit, including the pyroclastic deposits originating from the 1995-present eruption, the SBP gave very poor penetration, indicating relatively course sediments throughout this area.

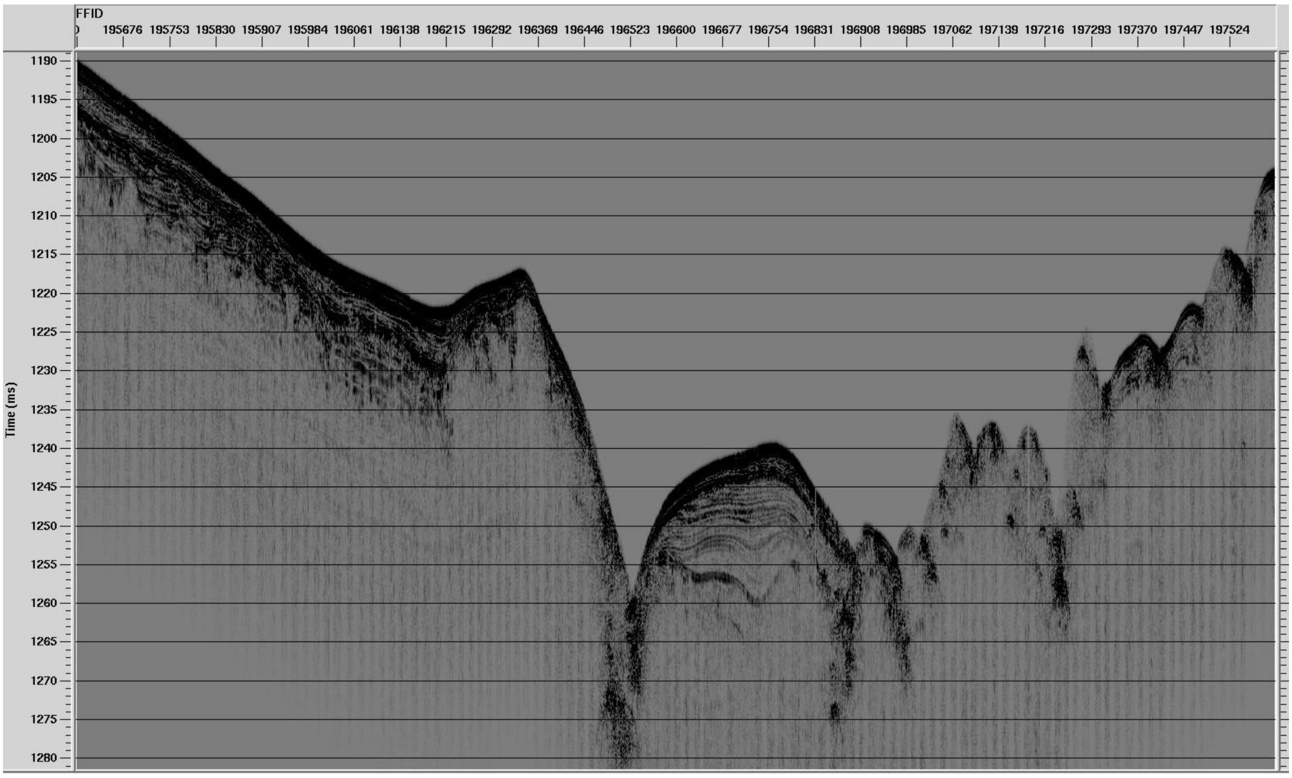


Figure 12. Example of sub-bottom profiler data showing sediment stratigraphy at the edge of the blocky debris avalanche deposits off the Tar River valley (right of image).

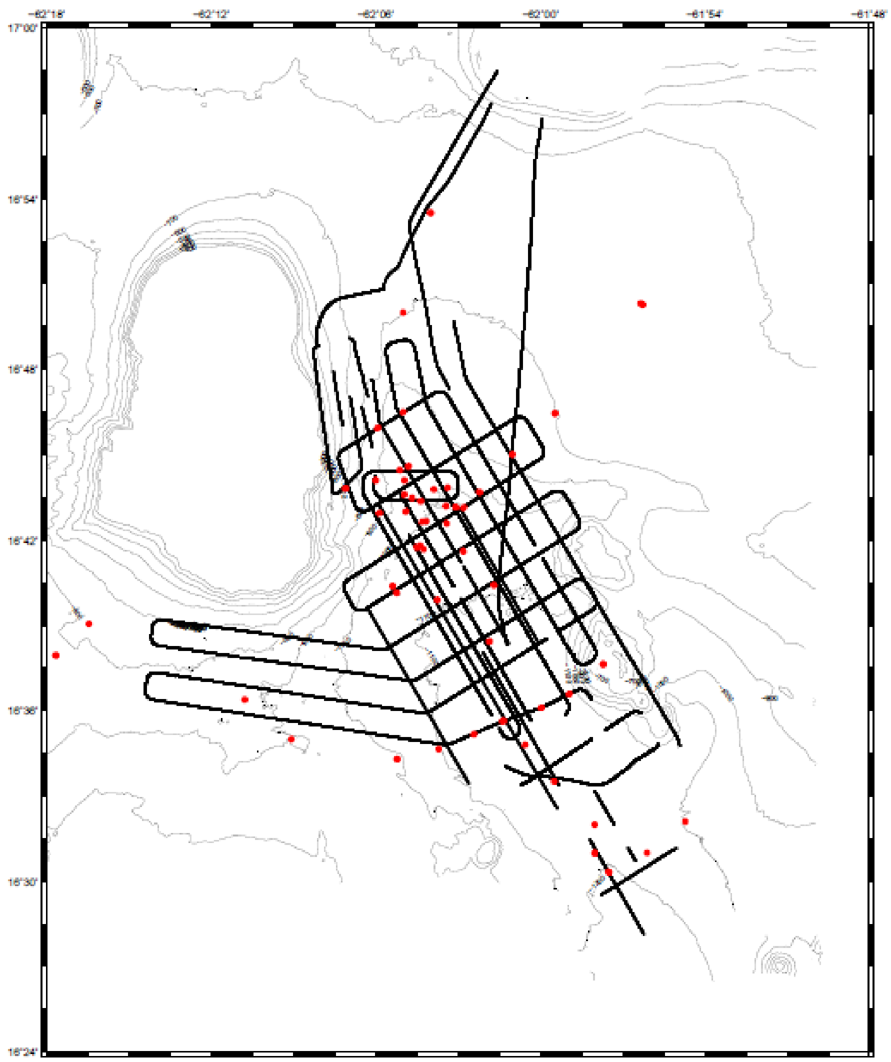


Figure 13. Final SBP coverage of processed data across the survey area. Core positions from JCR123 are shown for comparison. Coverage over the 3D cube is not shown.

Multibeam Bathymetry

The multibeam bathymetry data collected on JC045-046 were processed during the cruise and completed subsequently using the interactive software CARIS HIPS & SIPS. Navigation and ship's attitude were checked and erroneous data points deleted. The tide was assumed to be negligible, and no tide gauge data were available. Data were processed at a constant velocity, of 1542.3 m s^{-1}. Outliers and artefacts were manually deleted. The edited data were then averaged to produce depth values for a 20 m grid. This grid spacing was chosen based on the assumption of an average speed of about 4 knots and an average water depth of 1000 m. This gives a resolution of approximately one beam per 10.5 m across track and one beam per 0.7 m along track. A grid was produced with a continuous-curvature-splines-in-tension algorithm (spline tension 0.35). The final 20 m grid (Fig. 14), provides a resolution that is much improved compared to previously available data. In conjunction with the TOBI sidescan results, this will allow the shape and structure of the seafloor to be examined in detail, including the morphology of the debris avalanche deposits (Fig. 15) and of structures partially buried further south in the graben. The new data around the debris avalanche indicate both radial and concentric structures. The roughness of the seafloor to the south of this deposit, where drape overlies buried landslide units, contrasts strongly with the smooth seafloor to the north and around the scarp structure to the east. Boundaries of uneven morphology further south in the graben indicate subtle variations that may relate to the edges of more deeply buried landslide units; these data will be examined in comparison with the SBP and 2D seismic results. Further detail of the shape of the seafloor, particularly with reference to the recent pyroclastic deposits, is provided by examination of gradient and curvature (both plan and profile) maps produced from the new bathymetry.

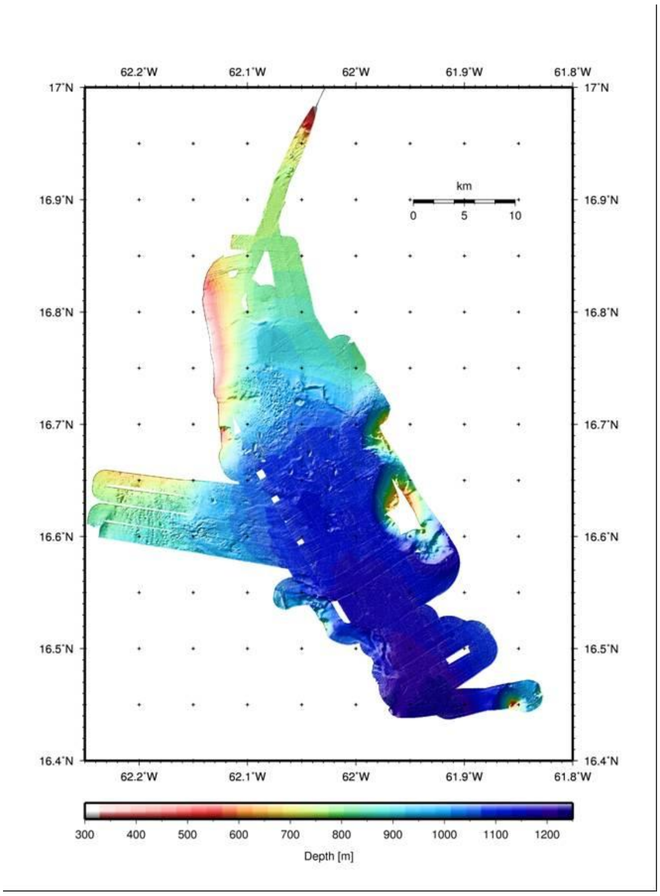


Figure 14. Bathymetric chart of the survey area showing data collected in JC045-046.

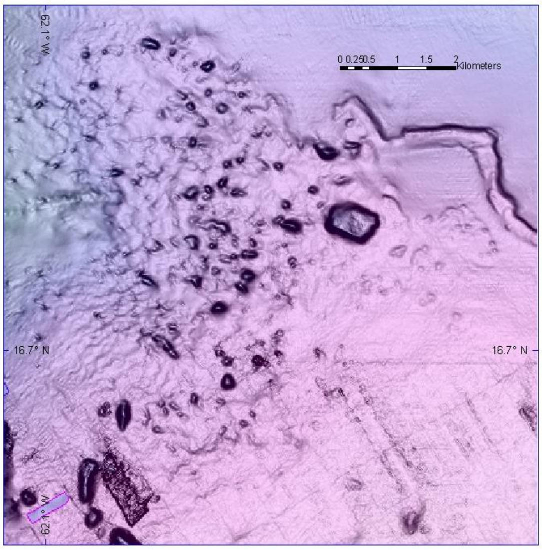


Figure 15. Detail of the new bathymetry data, shown with a transparent gradient map overlay, around the debris avalanche deposit east of the Tar River valley. The blocky unit is seen on the left, with a scarp structure bounding smooth seafloor morphology at the top right.

TOBI

TOBI results were initially processed onboard, and then reprocessed at NOCS. The survey consisted of one run, which was split into 4 blocks (processed at 16 degrees standard latitude) to facilitate processing. The approximate size of the blocks was approximately 0.25 by 0.25 degrees for most areas. After each survey run was completed, the imagery was processed using the PRISM (v4.0) and ERDAS Imagine (v9.3) software suites to produce geographically registered imagery which could then be composed onto a single mapsheet. This was produced at a scale of 1:45000, and printed on the A0 plotter. The digital version of the imagery was also made available for the onboard Geographical Information System (GIS) of the area to plan later parts of the survey. Further image processing details are given in Appendix 4.

The archived data have been corrected for altitude, and also include further corrections for true slant-range based on the processed bathymetry dataset, in comparison to the flat-bottom assumption used for initial processing. The image in Fig. 16 shows the version created using a flat-bottom assumption. The results highlight a range of interesting structures. Streaky deposits are visible off the edge of the shelf, in some cases related to recent inputs of pyroclastic material, including the February 2010 event, although the recent deposits off the Tar River valley are less clear in this respect, perhaps in part due to the travel direction of the instrument, perpendicular to the structure of these deposits. The blocky debris avalanche deposit and scarp structure is picked out in detail, while subtle textural variations around the survey area may provide further information on relative differences in sediment properties and structures. The morphology of the seamounts, including apparent failure surfaces and slab-like structures on their steep slopes, on both sides of the graben, are clearly visible.

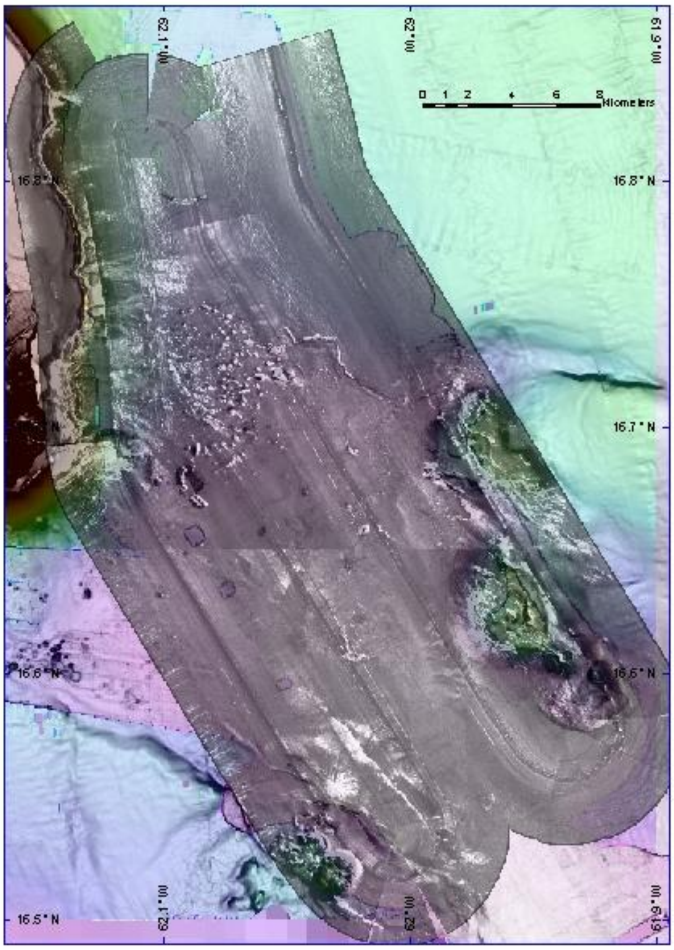


Figure 16. TOBI data collected during JC045-046.

Equipment performance and future recommendations

Overall, the equipment used during JC045-046 performed well and led to successful acquisition of the data required to meet the cruise objectives. In spite of loss of time due to disrupted travel, a good coverage of 2D seismic reflection profiles was acquired over the graben, a TOBI survey completed over the same area, and a relatively large 3D seismic cube collected covering the proposed IODP core site CARI-02 and areas of structural interest around the debris fan east of the Tar River valley. Sub-bottom profiler data were collected at all times (other than when the boomer source was in use) and EM120 swath bathymetry also collected during the entire cruise. Performance was consistent with all this equipment, and no significant loss of time or data occurred due to equipment problems. Minor problems were encountered with paravane stability on the 3D P-cable system, resulting in occasional temporary loss of positioning data, and necessitating slower ship speeds when travelling against the current. Some adjustment of the paravane shape for strong currents, particularly when more than ten streamers are towed off the cable, may improve this for future surveys.

The most significant loss of time occurred following a temporary reversal in ship motion that resulted in that tail buoy drifting towards the stern. The slack data cable became wrapped around the propeller, and had to be replaced following removal. In general, the input of navigation data into the ship system, particularly for a survey of this type, involving multiple navigation positions and occasionally requiring changes during surveying, could be improved. The present system, involving the transfer of printed coordinates to the bridge, which are then retyped into the ship navigation system by hand, is open to human error. It is also not easily adjusted once positions have been entered. An electronic transfer of positions would make this process far easier for the bridge, and also greatly reduce the possibility of errors.

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TABLES

Table 1. Data collection summary for JC045-046

Dates	Data type	Distance covered (km)	Notes
28/4-29/4	TOBI	160	
30/4	-	-	Crew change, St Johns, Antigua
1/5-2/5	Boomer 2D	72	
2/5-3/5	P-cable	-	Data cable damaged, returned to port for repair
3/5-4/5	Air gun 2D	40	
4/5	Boomer 2D	30	
4/5	Air gun 2D	36	
4/5-10/5	P-cable	476	7×4 km area, at 60 m line spacing
10/5-12/5	Air gun 2D	300	
12/5	Boomer 2D	51	
28/4-12/5	SBP	~1100	Logging continuously, except when boomer source in use
28/4-12/5	Multibeam	~1300	Bathymetry logging continuously (EM120)

Table 2. TOBI Survey Waypoints

Latitude	Longitude	Waypoint
-62.03600	16.51600	1
-62.03000	16.49020	2
-62.02724	16.47690	3
-61.54436	16.34137	4
-61.56661	16.32767	5
-62.04970	16.46510	6
-62.05616	16.49704	7
-62.07800	16.49248	8
-62.07039	16.45139	9
-61.58776	16.31584	10
-62.00768	16.30384	11
-62.07158	16.41040	12
-62.07464	16.45000	13
-62.08208	16.49200	14
-62.07	16.522	15

Table 3. Summary of 3D P-cable system and navigational details

Recording system	*Geometrics – Geode 24*	Survey datum	*WGS84*
Data channels	*12*	Map projection	*Transverse Mercator*
Recording device	*Disk (no tape)*	Map projection system	*UTM Zone 20*
Record format	*SEGY*	Latitude of origin	*0° N*
Record length	*3.0 s (3000 samples)*	Scale factor	*0.9996*
Sampling rate	*1 ms*	Shot line spacing	*60 m*
Deep water delay	*0*	Positioning equipment	*Kongsberg Seatex*
Streamer length	*30 m*		*RGPS tracking system, Seadiff*
Streamer separation	*~12.5 m (Fig.7)*		

Table 4. TOBI data logging record

M-O Number[a]	File Name (*.DAT)	Time/ J. Day START	Time/ J. Day STOP	**Comments / Run #**
446	TOBIE	05:03:42/118	20:41:08/118	START OF RUN#1 TOBIA.DAT to TOBID.DAT was deck test data for M-O 446.
447	TOBIA	20:41:12/118	12:50:14/119	Logging time went backward for 30minutes @ 1100 hrs.
448	TOBIA	12:50:18/119	15:21:42/119	END OF RUN#1 END OF SURVEY

[a] For each magneto-optical disk, file names (TOBI.dat) are stored counting from A onwards. For each disk, the raw data image is on the file name listed in the second column.

Table 5. 2D air gun logbook. SOL: start of line; EOL: end of line.

Julian Day	UTC	Line Num.	Log File Num.	Start FFID	End FFID	Comments
						NB - Airgun line 1 was a test of the guns
123	21:25	2	2	229		Airgun and MCS streamer deployed - Start of line 2
123	22:00	2	2	229	526	EOL 2
123	22:01	3	3	527		SOL 3
123	23:00	3	3	527	1032	EOL 3
123	23:00	4	4	1033		SOL 4
124	00:00	4	4	1033	1527	EOL 4
124	00:00	5	5	1528		SOL 5
124	01:04	5	5	1528	2085	EOL 5
124	01:04	6	6	2086		SOL 6
124	01:55	6	6	2086	2512	EOL 6
124	01:55	7	7	2513		SOL 7
124	03:00	7	7	2513	3070	EOL 7
124	03:00	8	8	3071		SOL 8
124	03:07			3105	3208	Quite strong swell noise
124	04:00	8	8	3071	3588	EOL 8
124	04:00	9	9	3589		SOL 9
124	04:38	9	9	3589	3911	EOL 9 - Taking guns out to deploy boomer
125	12:14	10	10	3912		Deployed Airguns - SOL 10
125	13:14	10	10	3912	4433	EOL 10
125	13:15	11	11	4434		SOL 11
125	14:14	11	11	4434	4935	EOL 11
125	14:14	12	12	4936		SOL 12
125	15:14	12	12	4936	5449	EOL 12
125	15:15	13	13	5450		SOL 13
125	16:00	13	13	5450	5840	EOL 13
125	16:00	14	14	5841		SOL 14
125	16:04					One of gun's was spotted leaking between shots - but it wasn't affecting the pressure so we continued
125	17:20	14	14	5841	6515	EOL 14 - Take out MCS to deploy P-Cable
130	07:12	15	15	6516		Airguns and MCS deployed - SOL 15
130	08:03	15	15	6516	6952	EOL 15
130	08:03	16	16	6953		SOL 16
130	08:58	16	16	6953	7420	EOL 16
130	08:58	17	17	7421		SOL 17
130	10:00	17	17	7421	7942	EOL 17
130	10:00	18	18	7943		SOL 18
130	11:00	18	18	7943	8452	EOL 18
130	11:00	19	19	8453		SOL 19
130	12:00	19	19	8453	8963	EOL 19
130	12:00	20	20	8964		SOL 20
130	13:02	20	20	8964	9489	EOL 20
130	13:02	21	21	9490		SOL 21
130	14:10	21	21	9490	9982	EOL 21
130	14:10	22	22	9983		SOL 22
130	15:01	22	22	9983	10504	EOL 22
130	15:01	23	23	10505		SOL 23
130	16:00	23	23	10505	11010	EOL 23
130	16:00	24	24	11011		SOL 24
130	17:02	24	24	11011	11539	EOL 24
130	17:02	25	25	11540		SOL 25
130	18:10	25	25	11540	12114	EOL 25
130	18:10	26	26	12115		SOL 26
130	18:58	26	26	12115	12519	EOL 26

130	18:58	27	27	12520		SOL 27
130	19:56	27	27	12520	13018	EOL 27
130	19:56	28	28	13019		SOL 28
130	20:57	28	28	13019	13550	EOL 28
130	20:57	29	29	13551		SOL 29
130	22:00	29	29	13551	14076	EOL 29
130	22:00	30	30	14077		SOL 30
130	23:00	30	30	14077	14585	EOL 30
130	23:00	31	31	14586		SOL 31
131	00:00	31	31	14586	15096	EOL 31
131	00:00	32	32	15097		SOL 32
131	01:02	32	32	15097	15620	EOL 32
131	01:02	33	33	15621		SOL 33
131	02:00	33	33	15621	16112	EOL 33
131	02:00	34	34	16113		SOL 34
131	03:08	34	34	16113	16705	EOL 34
131	03:08	35	35	16706		SOL 35
131	04:02	35	35	16706	17160	EOL 35
131	04:02	36	36	17161		SOL 36
131	05:02	36	36	17161	17668	EOL 36
131	05:02	37	37	17669		SOL 37
131	06:02	37	37	17669	18180	EOL 37
131	06:02	38	38	18181		SOL 38
131	07:05	38	38	18181	18719	EOL 38
131	07:05	39	39	18720		SOL 39
131	07:54	39	39	18720	19137	EOL 39
131	07:54	40	40	19137		SOL 40
131	08:59	40	40	19138	19692	EOL 40
131	09:00	41	41	19693		SOL 41
131	10:00	41	41	19693	20211	EOL 41
131	10:00	42	42	20212		SOL 42
131	11:00	42	42	20212	20718	EOL42
131	11:00	43	43	20719		SOL43
131	12:00	43	43	20719	21228	EOL43
131	12:00	44	44	21229		SOL 44
131	13:00	44	44	21229	21736	EOL 44
131	13:00	45	45	21737		SOL 45
131	14:03	45	45	21737	22288	EOL 45
131	14:03	46	46	22289		SOL 46
131	15:00	46	46	22289	22767	EOL 46
131	15:00	47	47	22768		SOL 47
131	16:00	47	47	22768	23279	EOL 47
131	16:00	48	48	23280		SOL 48
131	17:01	48	48	23280	23798	EOL 48
131	17:01	49	49	23797		SOL 49
131	17:56	49	49	23797	24265	EOL 49
131	17:56	50	50	24266		SOL 50
131	19:07	50	50	24266	24876	EOL 50
131	19:07	51	51	24877		SOL 51
131	19:57	51	51	24877	25299	EOL 51
131	19:57	52	52	25300		SOL 52
131	20:57	52	52	25300	25819	EOL 52
131	20:57	53	53	25820		SOL 53
131	22:00	53	53	25820	26354	EOL 53
131	22:00	54	54	26355		SOL 54
131	23:00	54	54	26355	26859	EOL 54

131	23:00	55	55	26860		SOL 55
132	00:00	55	55	26860	27371	EOL 55
132	00:00	56	56	27372		SOL 56
132	01:00	56	56	27372	27893	EOL 56
132	01:00	57	57	27894		SOL 57
132	02:00	57	57	27894	28400	EOL 57
132	02:00	58	58	28401		SOL 58
132	03:00	58	58	28401	28909	EOL 58
132	03:00	59	59	28910		SOL 59
132	04:00	59	59	28910	29411	EOL 59
132	04:00	60	60	29412		SOL 60
132	04:58	60	60	29412	29914	EOL 60 - End of Airgun survey

Table 6. 2D boomer logbook. SOL: start of line; EOL: end of line.

Julian Day	UTC	Line Num.	Log File Num.	Start FFID	End FFID	Comments
121	17:55	1	1	1		Boomer and MCS Streamer deployed - Start Data Collection
121	18:10					Adjusted cable to relieve tension on MCS streamer
121	18:56	1	1	1	942	EOL 1
121	18:57	2	2	943		SOL 2
121	19:08					As the afternoon progressed started to get more noise from a long period swell
121	19:56	2	2	943	1840	EOL 2
121	19:57	3	3	1841		SOL 3
121	21:04	3	3	1841	2852	EOL 3
121	21:05	4	4	2853		SOL 4
121	22:13	4	4	2853	3874	EOL 4
121	22:14	5	5	3875		SOL 5
121	23:02	5	5	3875	4606	EOL 5
121	23:03	6	6	4607		SOL 6
121	23:07	6	6	4607	4672	EOL 6 - Boomer taken out to deploy airguns
122	01:45	7	7	4673		Redeployed Boomer - SOL 7
122	03:00	7	7	4673	5782	EOL 7
122	03:01	8	8	5783		SOL 8
122	03:55	8	8	5783	6607	EOL 8
122	03:56	9	9	6608		SOL 9
122	04:05	9	9	6608	6744	EOL 9
122	04:06	10	10	6745		SOL 10
122	04:25					Slowed down acquisition speed - Ship was doing 5 knots
122	05:15	10	10	6745	7779	EOL 10
122	05:15	11	11	7780		SOL 11
122	05:53	11	11	7780	8340	EOL 11
122	05:53	12	12	8341		SOL 12
122	06:32	12	12	8341	8924	EOL 12
122	06:32	13	13	8925		SOL 13
122	07:19	13	13	8925	9637	EOL 13
122	07:19	14	14	9638		SOL 14
122	08:40	14	14	9638	10835	EOL 14
122	08:40	15	15	10836		SOL 15
122	09:56	15	15	10836	11997	EOL 15 - Boomer recovered to deploy P-Cable
123	19:06	16	16	11998		Redeployed Boomer - SOL 16. Hydrophone data cable length was slightly less this time, by 4.2 m
123	19:22	16	16	11998	12241	EOL 16
123	19:23	17	17	12242		SOL 17
123	20:03	17	17	12242	12847	EOL 17
123	20:04	18	18	12848		SOL 18
123	20:25	18	18	12848	13160	EOL 18 - Boomer recovered, switch to airguns
124	04:58	19	19	13161		Boomer redeployed - SOL 19

124	05:21					Constant noise at about 100 Hz
124	06:08	19	19	13161	14194	EOL 19
124	06:08	20	20	14195		SOL 20
124	06:52	20	20	14195	14863	EOL 20
124	06:53	21	21	14864		SOL 21
124	08:01	21	21	14864	15873	EOL 21
124	08:01	22	22	15874		SOL 22
124	09:03	22	22	15874	16811	EOL 22
124	09:04	23	23	16812		SOL 23
124	10:02	23	23	16812	17670	EOL 23
124	10:02	24	24	17671		SOL 24
124	11:00	24	24	17671	18541	EOL 24
124	11:00	25	25	18542		SOL 25
124	11:12	25	25	18542	18722	EOL 25 - Boomer recovered, changed to airguns
132	05:25	26	26	18723		Boomer deployed - SOL 26
132	05:50	26	26	18723	19108	EOL 26
132	05:50	27	27	19109		SOL 27
132	06:35	27	27	19109	19758	EOL 27
132	06:35	28	28	19759		SOL 28
132	07:03	28	28	19759	20178	EOL 28
132	07:03	29	29	20179		SOL 29
132	08:01	29	29	20179	21052	EOL 29
132	08:01	30	30	21053		SOL 30
132	09:01	30	30	21053	21949	EOL 30
132	09:01	31	31	21950		SOL 31
132	10:00	31	31	21950	22830	EOL 31
132	10:00	32	32	22831		SOL 32
132	11:04	32	32	22831	23782	EOL 32
132	11:04	33	33	23783		SOL 33
132	12:04	33	33	23783	24666	EOL 33
132	12:04	34	34	24667		SOL 34
132	12:50	34	34	24667	25363	EOL 34 - Boomer recovered, end of survey.

Table 7. 3D P-cable survey logbook. SOL: start of line; EOL: end of line.

Line no.	FFID	SGY-File	Nav-File	S 1	S 2	S 3	Comment
1	~980	790.sgy	monty_100504_2055_asc	s	p	g	SOL1 line recording started before
1	1275	790.sgy	monty_100504_2055_asc	s	p	g	stb paravane toppled over
1	1350	790.sgy	monty_100504_2055_asc	s	p	g	slowing down to 1 kt
1	1574	790.sgy	monty_100504_2055_asc	s	p	g	EOL 1 at the beginning of the turn
2	1575	1575.sgy	monty_100504_2055_asc	s	p	g	SOL2
2	1700	1575.sgy	monty_100504_2055_asc	s	p	g	stb paravane toppled over
2		1575.sgy	monty_100504_2055_asc	s	p	g	paravane back again
2	1920	1575.sgy	monty_100504_2055_asc	s	p	g	S1 back up
2	2395	1575.sgy	monty_100504_2055_asc	s	p	g	
2	2766	1575.sgy	monty_100504_2055_asc	s	p	g	EOL2, half way through the turn
3	2767	2767.sgy	monty_100504_2055_asc	s	p	g	SOL3
3	2805	2767.sgy	monty_100504_2055_asc	s	p	g	ship to speed up for 2nd half of turn
3	2820	2767.sgy	monty_100504_2055_asc	s	p	g	ship to commence 2nd half of turn
3	~2845	2767.sgy	monty_100504_2055_asc	s	p	g	ship to speed up again to get back on track
3	2936	2767.sgy	monty_100504_2055_asc	s	p	g	ship (almost) back on track
3	2950	2767.sgy	monty_100504_2055_asc	s	p	g	speed up to 4 knots
3	~3285	2767.sgy	monty_100504_2055_asc	s	p	g	stbd paravene S1 toppled over
3	3335	2767.sgy	monty_100504_2055_asc		p	g	stbd paravene S1 back up again
3	3486	2767.sgy	monty_100504_2055_asc	s	p	g	ship starting to turn
3	3622	2767.sgy	monty_100504_2055_asc	s	p	g	EOL3, half way through turn
4	3623	3623.sgy	monty_100504_2055_asc	s	p	g	SOL4

4	3664	3623.sgy	monty_100504_2055_asc	s	p	g	ship speed to 2.5 knots & commencing 2nd half of turn
4	3783	3623.sgy	monty_100504_2055_asc	s	p	g	turn complete, reduce ship speed to 1.5 knots as stbd paravene S1 threatens to topple over
4	3823	3623.sgy	monty_100504_2055_asc	s	p	g	bringing stbd paravene S1 back in to let itself turn up again
4	3904	3623.sgy	monty_100504_2055_asc	s	p	g	ship speed up to 3.5 knots
4	4726	3623.sgy	monty_100504_2055_asc	s	p	g	EOL4
5	4727	4727.sgy	monty_100504_2055_asc	s	p	g	SOL5
5	5629	4727.sgy	monty_100504_2055_asc	s	p	g	EOL5
6	5629	5629.sgy	monty_100504_2055_asc	s	p	g	SOL6
6	6845	5629.sgy	monty_100504_2055_asc	s	p	g	EOL6
7	6846	6846.sgy	monty_100504_2055_asc	s	p	g	SOL7
7		6846.sgy	monty_100504_2055_asc	s	p	g	
7	7480	6846.sgy	monty_100504_2055_asc	s	p	g	
7	7749	6846.sgy	monty_100504_2055_asc	s	p	g	EOL7
8	7750	7750.sgy	monty_100504_2055_asc	s	p	g	SOL8
8	8824	7750.sgy	monty_100504_2055_asc	s	p	g	EOL8
9	8831	8831.sgy	monty_100504_2055_asc	s	p	g	SOL9
9	9144	8831.sgy	monty_100504_2055_asc	s	p	g	ship speed up to 3.5 knots
9	9741	8831.sgy	monty_100504_2055_asc	s	p	g	EOL9
10	9741	9741.sgy	monty_100504_2055_asc	s	p	g	SOL10
10	9741	9741.sgy	monty_100504_2055_asc		p	g	stbd paravene S1 back up again
10	10901	9741.sgyt	monty_100504_2055_asc	s	p	g	EOL10
11	10902	10902.sgy	monty_100504_2055_asc	s	p	g	SOL11
11	11880	10902.sgy	monty_100504_2055_asc	s	p	g	EOL11
12	11881	11881.sgy	monty_100504_2055_asc	s	p	g	SOL12
12	12256	12256.sgy	monty_100504_2055_asc	s	p	g	new file for download
12	12423	12256.sgy	monty_100504_2055_asc	s	p	g	stopped shooting to retrieve cable…
13	12256	12256.sgy	monty_100504_2055_asc	s	p	g	SOL13
13	12940	12256.sgy	monty_100504_2055_asc	s	p	g	on line 13
14	13545	13545.sgy	monty_100504_2055_asc	s	p	g	EOL13
14	13839	13545.sgy	monty_100504_2055_asc	s	p	g	SOL14
14	14630	13545.sgy	monty_100504_2055_asc	s	p	g	second pulse after 105m after first
14	14703	13545.sgy	monty_100504_2055_asc	s	p	g	pulse back to normal
15	14704	14704.sgy	monty_100504_2055_asc	s	p	g	SOL 15
15	15018	14704.sgy	monty_100504_2055_asc	s	p	g	turn completed
15	15156	14704.sgy	monty_100504_2055_asc	s	p	g	tailbuoy link 1 checksum error / no convergence in tailbuoy fix / problem with GPS fix on gunframe
15	15310	14704.sgy	monty_100504_2055_asc	s	p	g	all GPS signals lost / slow down to 3.5 knots
15	15369	14704.sgy	monty_100504_2055_asc	s	p	g	all GPS signals back / speed up to 4.0 knots
15	15412	14704.sgy	monty_100504_2055_asc	s	p	g	no convergence in tailbuoy ax / lost gun-GPS
15	15425	14704.sgy	monty_100504_2055_asc	s	p	g	all GPS lost
15	15483	14704.sgy	monty_100504_2055_asc	s	p	g	all signals back
15	15539	14704.sgy	monty_100504_2055_asc	s	p	g	EOL 15 / start of turn
16	15547	15547.sgy	monty_100504_2055_asc	s	p	g	SOL 16 / reboot navigation system
16	15660	15547.sgy	monty_100504_2055_asc	s	p	g	navigation PC back / still on turn
16	15840	15547.sgy	monty_100504_2055_asc	s	p	g	end of turn / SOL 16
16	16727	15547.sgy	monty_100504_2055_asc	s	p	g	EOL 16
17	16733	16733.sgy	monty_100504_2055_asc	s	p	g	SOL 17 / start of turn
17	17690	16733.sgy	monty_100504_2055_asc	s	p	g	EOL 17
18	17690	17690.sgy	monty_100504_2055_asc	s	p	g	SOL 18
18	17840	17690.sgy	monty_100504_2055_asc	s	p	g	SOL 18
18	18600	17690.sgy	monty_100504_2055_asc	s	p	g	GPS problems because of incoming swells
18	18720	17690.sgy	monty_100504_2055_asc	s	p	g	
18	18889	18889.sgy	monty_100504_2055_asc	s	p	g	SOL 19/ mid way between turn
19	19606	18889.sgy	monty_100504_2055_asc	s	p	g	EOL 19

19	19722	19722.sgy	monty_100504_2055_asc	s	p	g	SOL 20/ midway between turn from 19 to 20
20	20268	19722.sgy	monty_100504_2055_asc	s	p	g	PC Qusmio was suddenly shutdown. Blue colored screen with emergency message
20	20312	19722.sgy	monty_100504_2055_B_asc	s	p	g	Computer recovered, relogging to new file called 1005_2055_B.asc (note: file name date is not important)
20	20450	19722.sgy	monty_100504_2055_B_asc	s	p	g	channel 5 is very noisy (possibly tangled). Channel 4 is very weak
20	20620	19722.sgy	monty_100504_2055_B_asc	s	p	g	EOL 20
21	20621	20621.sgy	monty_100504_2055_B_asc	s	p	g	SOL 21
21	20889	20621.sgy	monty_100504_2055_B_asc	s	p	g	end of turn.
21	21395	20621.sgy	monty_100504_2055_B_asc	s	p	g	EOL 21, start turn
22	21402	21402.sgy	monty_100504_2055_B_asc	s	p	g	SOL 22. West-to-East lines now at 3 knots
22	21517	21402.sgy	monty_100504_2055_B_asc	s	p	g	channel 6 with problems
22	21689	21402.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
22	22429	22434.sgy	monty_100504_2055_B_asc	s	p	g	EOL 22, channel 5,6 bad
22	22500-22506	22434.sgy	monty_100504_2055_B_asc	s	p	g	testing channels
23	22670	22434.sgy	monty_100504_2055_B_asc	s	p	g	SOL 23
23	23210	23210.sgy	monty_100504_2055_B_asc	s	p	g	EOL23/turn
24	23474	23210.sgy	monty_100504_2055_B_asc	s	p	g	SOL24
24	24191	23210.sgy	monty_100504_2055_B_asc	s	p	g	Turn started
24	24313	23210.sgy	monty_100504_2055_B_asc	s	p	g	EOL 24
25	24314	24314.sgy	monty_100504_2055_B_asc	s	p	g	SOL 25
25	24456	24314.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
25	25508	24314.sgy	monty_100504_2055_B_asc	s	p	g	EOL25
26	25008	25508.sgy	monty_100504_2055_B_asc	s	p	g	SOL26
26	25270	25508.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
26	25982	25508.sgy	monty_100504_2055_B_asc	s	p	g	EOL26
27	25983	25983.sgy	monty_100504_2055_B_asc	s	p	g	SOL27
27	26899	25983.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
28	26900	26900.sgy	monty_100504_2055_B_asc	s	p	g	SOL28
28	27081	26900.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
28	27291	26900.sgy	monty_100504_2055_B_asc	s	p	g	GPS problems (tail buoy lost signal)
28	27544	26900.sgy	monty_100504_2055_B_asc	s	p	g	streamers 2, 4, 5, 6 with problems
28	27747	26900.sgy	monty_100504_2055_B_asc	s	p	g	end of line 28, streamers 5 and 6 constantly bad, 2 and 4 with interruptions
29	27752	27752.sgy	monty_100504_2055_B_asc	s	p	g	SOL29, navigation pc reboot
29	27780	27752.sgy	monty_100504_2055_B_asc	s	p	g	navigation PC back / still on turn, all streamers (except 5 and 6) OK during turning
29		27752.sgy	monty_100504_2055_B_asc	s	p	g	end of turn,
29	28227	27752.sgy	monty_100504_2055_B_asc	s	p	g	decrease speed due to nearby boat
29	28384	27752.sgy	monty_100504_2055_B_asc	s	p	g	speed up to 4 knots
29	28582	27752.sgy	monty_100504_2055_B_asc	s	p	g	EOL 29
30	28589	28589.sgy	monty_100504_2055_B_asc	s	p	g	start turn, SOL 30
30	28867	28589.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
30	29007	28589.sgy	monty_100504_2055_B_asc	g	p	s	Nav PC reboot - position of S1,2,3 changed
30	29574	28589.sgy	monty_100504_2055_B_asc	g	p	s	EOL 30
31	29575	29575.sgy	monty_100504_2055_B_asc	g	p	s	SOL 31, streamers 2,4,5,6 all poor quality
31	29830	29575.sgy	monty_100504_2055_B_asc	g	p	s	End of turn. Streamers 4,5,6 poor, 2 with interruptions, mostly bad
31	30044	29575.sgy	monty_100504_2055_B_asc	g	p	s	Navigation stopped receiving, crashed
31	30100	29575.sgy	monty_100504_2055_B_asc	g	p	s	Navigation restarted - some data lost?
31	30371	29575.sgy	monty_100504_2055_B_asc	g	p	s	EOL 31
32	30371	30371.sgy	monty_100504_2055_B_asc	g	p	s	SOL 32, on turn
32	30685	30371.sgy	monty_100504_2055_B_asc	g	p	s	End of turn
32	31358	30371.sgy	monty_100504_2055_B_asc	g	p	s	EOL32
33	31359	31359.sgy	monty_100504_2055_B_asc	g	p	s	SOL 33
33	31649	31359.sgy	monty_100504_2055_B_asc	g	p	s	End of turn
33	32153	31359.sgy	monty_100504_2055_B_asc	g	p	s	EOL33

34	32154	32154.sgy	monty_100504_2055_B_asc	g	p	s	SOL 34
35 (34)	32304	32304.sgy	monty_100504_2055_B_asc	g	p	s	End of turn
35 (34)	32440	32304.sgy	monty_100504_2055_B_asc	g	p	s	Power off gps
35 (34)	32457	32304.sgy	monty_100504_2055_B_asc	g	p	s	Power back on gps, start of the line 34
35 (34)	33160	32304.sgy	monty_100504_2055_B_asc	g	p	s	EOL 34, start turning
99 (35)	33306	33306.sgy	monty_100504_2055_B_asc	g	p	s	SOL 35 (file line number 99)
99 (35)	33393	33306.sgy	monty_100504_2055_B_asc	g	p	s	end turn (actual line 35)
99 (35)	33917	33306.sgy	monty_100504_2055_B_asc	g	p	s	EOL 35 (file 99), start turn
36	33925	33925.sgy	monty_100504_2055_B_asc	g	p	s	SOL 36
36	34818	33925.sgy	monty_100504_2055_B_asc	g	p	s	end of turn
36	34337	33925.sgy	monty_100504_2055_B_asc	g	p	s	slowing down due to yacht on collision course
36	34477	33925.sgy	monty_100504_2055_B_asc	g	p	s	speed up to 4. 1knts
36	34643	33925.sgy	monty_100504_2055_B_asc	g	p	s	slow down to 3.5 knts due to bad quality data
36		33925.sgy	monty_100504_2055_B_asc	p	g	s	reboot navigation pc, S1,2,3 change
37	34819	34819.sgy	monty_100504_2055_B_asc	p	g	s	EOL 36, start turn, SOL 37
37	35102	34819.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
37	35625	34819.sgy	monty_100504_2055_B_asc	p	g	s	EOL 37, start of turn
38	35930	35930.sgy	monty_100504_2055_B_asc	p	g	s	SOL38
38	35942	35930.sgy	monty_100504_2055_B_asc	p	g	s	End turn. Streamer 3 also poor quality now (2 to 6 all bad)
38	36428	35930.sgy	monty_100504_2055_B_asc	p	g	s	data not saved (shot)
38	36429	35930.sgy	monty_100504_2055_B_asc	p	g	s	data not saved (shot)
38	36615	35930.sgy	monty_100504_2055_B_asc	p	g	s	EOL 38, start turn
38	36739	35930.sgy	monty_100504_2055_B_asc	p	g	s	
39	36740	36740.sgy	monty_100504_2055_B_asc	p	g	s	SOL 39, still on turn
39	36890	36740.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
39	37430	36740.sgy	monty_100504_2055_B_asc	p	g	s	EOL 39, start of turn
40	37560	37560.sgy	monty_100504_2055_B_asc	p	g	s	SOL 40
40	37728	37560.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
40	38412	37560.sgy	monty_100504_2055_B_asc	p	g	s	Start of turn
40	38571	37560.sgy	monty_100504_2055_B_asc	p	g	s	EOL40, midway of the turn
41	38572	38572.sgy	monty_100504_2055_B_asc	p	g	s	SOL41
41	38693	38572.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
41	39202	38572.sgy	monty_100504_2055_B_asc	p	g	s	EOL 41, start of turn
42	39327	39327.sgy	monty_100504_2055_B_asc	p	g	s	SOL 42, midway through turn
42	39468	39327.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
42	40176	39327.sgy	monty_100504_2055_B_asc	p	g	s	EOL 43, start turn
43	40179	40179.sgy	monty_100504_2055_B_asc	p	g	s	SOL 43, turning
43	40379	40179.sgy	monty_100504_2055_B_asc	s	p	g	reboot navigation pc, S1,2,3 change
43	40460	40179.sgy	monty_100504_2055_B_asc	s	p	g	end of turn
43	40974	40179.sgy	monty_100504_2055_B_asc	s	p	g	EOL 43, start turn
44	40976	40976.sgy	monty_100504_2055_B_asc	s	p	g	SOL 44, turning
44	41245	40976.sgy	monty_100504_2055_B_asc	s	p	g	end of turn, streamers 4,5 poor, 2 and 6 variable
44	41934	40976.sgy	monty_100504_2055_B_asc	s	p	g	EOL 44
45	41934	41934.sgy	monty_100504_2055_B_asc	s	p	g	SOL 45
45	42212	41934.sgy	monty_100504_2055_B_asc	s	p	g	All streamers except 5 and 6 ok (6 noisy, interrupted)
45	42737	41934.sgy	monty_100504_2055_B_asc	s	p	g	start of turn
45	42757	41934.sgy	monty_100504_2055_B_asc	s	p	g	EOL 45
46	42757	42751.sgy	monty_100504_2055_B_asc	s	p	g	SOL 46, on turn
46	43039	42751.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
46	43731	42751.sgy	monty_100504_2055_B_asc	s	p	g	EOL46

47	43732	43732.sgy	monty_100504_2055_B_asc	s	p	g	SOL 47
47	44010	43732.sgy	monty_100504_2055_B_asc	s	p	g	End of turn.
47	44542	43732.sgy	monty_100504_2055_B_asc	s	p	g	EOL47
48	44543	44543.sgy	monty_100504_2055_B_asc	s	p	g	SOL 48
48	44805	44543.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
48	45509	44543.sgy	monty_100504_2055_B_asc	s	p	g	EOL 48
49	45518	45518.sgy	monty_100504_2055_B_asc	s	p	g	SOL 49, on turn
49	45784	45518.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
49	46297	45518.sgy	monty_100504_2055_B_asc	s	p	g	EOL 49
50	46302	46302.sgy	monty_100504_2055_B_asc	s	p	g	SOL 50, turning
50	46558	46302.sgy	monty_100504_2055_B_asc	s	p	g	End of turn
50	47261	46302.sgy	monty_100504_2055_B_asc	s	p	g	EOL 50, start turning
51	47266	47266.sgy	monty_100504_2055_B_asc	s	p	g	SOL 51, turning
51	47299	47266.sgy	monty_100504_2055_B_asc	p	s	g	reboot navigation pc
51	47538	47266.sgy	monty_100504_2055_B_asc	p	s	g	End of turn
51		47266.sgy	monty_100504_2055_B_asc	p	s	g	
51	48051	47266.sgy	monty_100504_2055_B_asc	p	s	g	EOL51
51	48184	47266.sgy	monty_100504_2055_B_asc	p	s	g	SOL 52
52	48185	48185.sgy	monty_100504_2055_B_asc	p	s	g	
52	48345	48185.sgy	monty_100504_2055_B_asc	p	s	g	End of turn
52	49093	48185.sgy	monty_100504_2055_B_asc	p	s	g	EOL52, on turn
53	49094	49094.sgy	monty_100504_2055_B_asc	p	s	g	SOL 53, still turn
53	49308	49094.sgy	monty_100504_2055_B_asc	p	s	g	End of turn
53	49857	49094.sgy	monty_100504_2055_B_asc	p	s	g	EOL53
54	49858	49858.sgy	monty_100504_2055_B_asc	p	s	g	SOL 54
54	50136	49858.sgy	monty_100504_2055_B_asc	p	s	g	End of turn
54	50852	49858.sgy	monty_100504_2055_B_asc	p	s	g	EOL54, start of turn to line 55
55	51001	51001.sgy	monty_100504_2055_B_asc	p	s	g	SOL 55, midway on turn
55	51130	51001.sgy	monty_100504_2055_B_asc	p	s	g	End of turn.
55	51635	51001.sgy	monty_100504_2055_B_asc	p	s	g	EOL 55, start of turn to 56
56	51786	51786.sgy	monty_100504_2055_B_asc	p	s	g	SOL 56, turning
56	51904	51786.sgy	monty_100504_2055_B_asc	p	s	g	end of turn
56	52612	51786.sgy	monty_100504_2055_B_asc	p	s	g	EOL 56, start turn, reboot navigation pc
57	52624	52624.sgy	monty_100504_2055_B_asc	p	g	s	SOL 57, turning
57	52886	52624.sgy	monty_100504_2055_B_asc	p	g	s	end turn
57	53323	52624.sgy	monty_100504_2055_B_asc	p	g	s	slow down to 3 knts due to yacht
57	53381	52624.sgy	monty_100504_2055_B_asc	p	g	s	down to 2.3 knts, doors very narrow, airguns close to ship
57	53399	52624.sgy	monty_100504_2055_B_asc	p	g	s	back to 4knts
57	53430	52624.sgy	monty_100504_2055_B_asc	p	g	s	EOL 57, start turn
58	53432	53432.sgy	monty_100504_2055_B_asc	p	g	s	SOL 58, turning
58	53708	53432.sgy	monty_100504_2055_B_asc	p	g	s	End turn
58	54417	53432.sgy	monty_100504_2055_B_asc	p	g	s	EOL 58
59	54418	54418.sgy	monty_100504_2055_B_asc	p	g	s	SOL 59
59	54667	54418.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
59	55179	54418.sgy	monty_100504_2055_B_asc	p	g	s	EOL 59
60	55197	55197.sgy	monty_100504_2055_B_asc	p	g	s	SOL 60
60	55460	55197.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
60	56167	55197.sgy	monty_100504_2055_B_asc	p	g	s	EOL60
60	56168	56168.sgy	monty_100504_2055_B_asc	p	g	s	SOL 61, on turn
61	56446	56168.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
61	56968	56168.sgy	monty_100504_2055_B_asc	p	g	s	Start turn
62	57128	57128.sgy	monty_100504_2055_B_asc	p	g	s	EOL 61, SOL 62, mid-way on turn
62	57248	57128.sgy	monty_100504_2055_B_asc	p	g	s	End of turn
62	57931	57128.sgy	monty_100504_2055_B_asc	p	g	s	EOL 62
63	57932	57932.sgy	monty_100504_2055_B_asc	p	g	s	SOL 63, on turn
63	58205	57932.sgy	monty_100504_2055_B_asc	p	g	s	end of turn

63	58718	57932.sgy	monty_100504_2055_B_asc	g	s	p	EOL 63, start turn
64	58725	58725.sgy	monty_100504_2055_B_asc	g	s	p	SOL 64
64	58997	58725.sgy	monty_100504_2055_B_asc	g	s	p	end of turn
64	59714	58725.sgy	monty_100504_2055_B_asc	g	s	p	EOL 64, reboot navigation PC, start turn
65	59718	59718.sgy	monty_100504_2055_B_asc	g	s	p	turning, SOL 65, reboot navigation PC
65	59985	59718.sgy	monty_100504_2055_B_asc	g	s	p	End of turn
65	60507	59718.sgy	monty_100504_2055_B_asc	g	s	p	EOL 65
66	60536	60536.sgy	monty_100504_2055_B_asc	g	s	p	SOL 66
66	60793	60536.sgy	monty_100504_2055_B_asc	g	s	p	End of turn
66	61493	60536.sgy	monty_100504_2055_B_asc	g	s	p	EOL 66
67	61622	61622.sgy	monty_100504_2055_B_asc	g	s	p	SOL 67
67	61766	61622.sgy	monty_100504_2055_B_asc	g	s	p	End of turn
67	62335	61622.sgy	monty_100504_2055_B_asc	g	s	p	EOL67, start of turn to line 12repeat (68)
68	62715	62715.sgy	monty_100504_2055_B_asc	g	s	p	SOL 68 (mid-way on turn)
68	62925	62715.sgy	monty_100504_2055_B_asc	g	s	p	End turn, start straight line repeat
68	63680	62715.sgy	monty_100504_2055_B_asc	g	s	p	EOL 68
69	63857	63857.sgy	monty_100504_2055_B_asc	g	s	p	SOL 69
69	64001	63857.sgy	monty_100504_2055_B_asc	g	s	p	End of turn, on straight
69	64497	63857.sgy	monty_100504_2055_B_asc	g	s	p	EOL 69
69	65420	63857.sgy	monty_100504_2055_B_asc	g	s	p	stop shooting and recording, end of survey

Table 8. 2D seismic reflection profiles, line identifier details

Air-gun source		Boomer source	
Line identifier	FFID range	Line identifier	FFID range
A	16700-17200	D	24550-25363
B	17550-18450	F	23300-24300
C	6700-7100	P	11200-11998
E	18750-19850	Q	9900-10950
G	20050-21050	R	9000-9600
H	22400-23400	T	8100-8700
I	21350-22400	U	17400-18600
J	23550-24650	1	22550-23200
K	24650-25600	6	11998-12848
L	26600-27750	7	6450-7450
M	25750-26600	9	15400-16600
N	27900-29250	10	19200-21600
O	29250-29914	12	5000-6350
S	3050-3550	13	13600-14900
2	15300-16650	16	1-4672
3	13500-15150		
4	11500-13350		
5	4000-6515		
8	9900-11250		
11	231-2650		
14	8550-9850		
15	7200-8450		
17	17200-17550		

Table 9. Sub bottom profiler, processed line identifier details. The gap between 278000 and 1054000 reflects the sequence of profiles over the 3D cube area, which have not been subdivided into separate lines at this stage.

Line Number	Start FFID	End FFID
JC45sbp.02	1192000	1212000
JC45sbp.03	1165000	1192000
JC45sbp.04	1134000	1165000
JC45sbp.05	235500	248000
JC45sbp.08	1113600	1132000
JC45sbp.11	217400	226000
JC45sbp.14	1096000	1113400

JC45sbp.15	1076000	1096000
JC45sbp.17	1219500	1224000
JC45sbp.A	1212000	1219500
JC45sbp.B	1224000	1240000
JC45sbp.C	1069000	1076000
JC45sbp.E	1240000	1259000
JC45sbp.G	1259000	1278000
JC45sbp.H	1296000	1312000
JC45sbp.I	1278000	1296000
JC45sbp.J	1312000	1330000
JC45sbp.K	1330000	1346000
JC45sbp.L	1360000	1378000
JC45sbp.M	1346000	1360000
JC45sbp.N	1378000	1398000
JC45sbp.O	1398000	1410000
JC45sbp.S	227500	230000
JC45sbp.18	1054000	1069000
JC45sbp.19	46300	49000
JC45sbp.20	49000	53500
JC45sbp.21	34300	46000
JC45sbp.22	1425000	1430000
JC45sbp.23	1419000	1425000
JC45sbp.24	167000	202000
JC45sbp.25	1000	17000
JC45sbp.26	20000	22300
JC45sbp.27	23700	29000
JC45sbp.28	31000	34000
JC45sbp.29	110000	130000
JC45sbp.30	140000	148000
JC45sbp.31	134000	140000
JC45sbp.32	54500	57200
JC45sbp.33	22350	23650

APPENDIX 1

Archived data files

Navigation

Raw data in *Cruise Data/GPS_and_attitude* directory): GPS-ADU5; GPS-DPS116; GPS-POSMV; GPS-SP200.

GPS-POSMV gives the primary science positioning and attitude data, with backup positioning data in GPS-SP200. The POSMV data are those that have been used in the geophysical processing. The final navigation files are provided in the *Navigation* directory, as a set of ASCII files, labelled for each day of the cruise. For each day there is a *_nav* file, with columns as *time, x, y* (time in days since 31/12/1899, x and y in degrees), and a *_att* file, with columns as *time, heading* (heading in degrees relative to north).

2-D seismic reflection

All in *seismic data* directory, in sub-directories with the following names:

Log files:

> Summary log files. MontyBoomer files refer to boomer source logs, MontyGun files to air gun source. These are numbered sequentially (from 0000 to 0034 for Boomer, and to 0060 for air gun), corresponding to the line numbers in Tables 5 and 6. For each line there is a .DAT file (named as .Gather1), which contains shot times in GPS-linked UTC, accompanied by a text file detailing the shot recording.

MontyBoomer:

> Data as .sgd files (SEG-D format) for each ffid (1 to 25363). See Table 6.

MontyGuns:

> Data as .sgd files (SEG-D format) for each ffid (1 to 29914). See Table 5.

3-D seismic reflection

In directory *JC45-46_3D*

Data files: The 3D volume is provided as three files. These have had bad channels removed and have had the geometry recalculated using the first arrival travel times. Files are *mont-finalgeom-SNRed-raw-part1* etc.

Geometry files:

> Navigation data used for processing (based on catenary geometry and picked first arrivals), in file named *mont12-tunedhdrs.asc*. This file has seven columns, in format: shot id; receiver number; source_x (UTM); source_y (UTM); receiver_x (UTM); receiver_y (UTM); offset. All positions and distances in cm.
>
> CDP positions for the final 7.5 m volume, in *cdp_positions.txt*, giving trace number, FFID, channel and cdp_x and cdp_y.

Sub-bottom profiler

Data in *Cruise data/Acoustics_Systems/SBP 120 Sub Bottom Profiler*.

> Raw data as SEG-Y files in *Raw_Data* directory. Files here are all from second part of cruise (JC046; 2-12 May). The sub-directory *Jc045-1* contains raw SEG-Y files for the first part of the cruise (JC045).

These raw files have a complex naming system, relating to changes in acquisition parameters or gaps in data. However, all raw file names start with JC045-n, where n counts sequentially from the start of the cruise, from 1-24. Initial sorting of all the files was done according to this naming. These sorted files are in the *sbp_raw_sorted* directory. Folders *JC45-1* to *JC45-24* contain sorted files. The *file_name_details* text file explains this sorting.

The sorted .seg files were then filtered, and files with bad position of time data in the headers, or with repeated or reversed trace numbers were rejected. Furthermore, due to repetition of trace numbers, some of the above sorted directories (1-24) had to be further subdivided. Each of these subdivided sequences of .seg files were then processed, as described in the main text. The spreadsheet *catalogue_final* describes this final subdivision. The first column in the data sheet lists the Sequence number (i.e., 1, 2, 5a, 5b, 5c... 23d, 23e, 24), with the .seg files that make up each continuous sequence of traces listed. The number of beams used for acquisition is also given (Five for 1, one for 5b to 7, but otherwise three). The files that were rejected in the filtering are given on the second 'rejected' worksheet.

As described in the main text, the filtered sequences of files were processed individually, and then combined in their order of acquisition as a single SEG-Y file, with reassigned FFIDs. These were then into lines that coincided with those in the boomer and air gun processing (Table 9). Thus, the raw sampling file names have not been retained in the final output.

TOBI

Raw data copies stored on site (NOC, Southampton). Processed data will be stored on completion of the project.

EM120 swath bathymetry

Raw data:

In *Cruise_Data/Acoustics/Systems/EM120 (Deep Water Swath)/Raw_Data*.

Stored as sequential files, counting from 0000 to 0134 for the second part of the cruise (1-12 May). In the subdirectory, *JC045*, for the first part of the cruise (24-29 April), counting from 0000 to 0064.

Processed data:

In *Cruise_Data/Acoustics/Systems/EM120 (Deep Water Swath)/Caris_bathymetry*.

Contains a version of the EM120 swath bathymetry processed using CARIS HIPS and SIPS software. The raw CARIS data files are in the *RRS James Cook* directory, divided into original ship lines as separate folders, with data files (date and time) within these.

Gravity

In *Cruise Data/Gravity_Meter* directory.

AirSeaII logged data files, for each day, in *Techsas Netcdf* directory.

Single file in *Level-C Data Stream (gravity)*.

Base tie details given in *Gravity_Reference-Measurements_JC45.doc*, with correction and drift rate details in *JC45_46_gravimeter.xls*

Other

Air gun performance and shot files:

In *Gundata* directory. Text file, named *Gunlog Monterrat May 10* details start and end times of gun deployment. Subdirectory named *Monterrat May 2010*. This contains air gunshot time data and performance summaries for ~12 hour periods from 4-12 May.

In *Cruise Data* directory, including:

In *Acoustics_Systems* directory. Other raw data for EA600 single beam echosounder, and ADCP75 and ADCP150 current profilers.

Ship gyro heading data files.

Ship speed files.

APPENDIX 2

Watch Log

Julian Day	Working profile	Operation	Time GMT	Lat (N)	Long (W)	Speed (knot)	Water depth (m)	Course (deg)	Heading (deg)	Multibeam file no.	Notes
121	-	Multibeam	14:30	16.8119	62.1220	-	633	334	334.91	0001	Air gun problems - running multibeam lines
121	JC45-05	Multibeam	14:43	16.8103	62.1201	-	700	161	160.6	0001	Start of line 1 (near Feb2010 deposit)
121	JC45-05	Multibeam	15:00	16.7867	62.1159	-	702	159	159.33	0001	
121	JC45-05	Multibeam	15:30	16.7464	62.1087	-	804	159	159	0002	End of first line / past Waypoint 121-2, start turn
121	JC45-06	Multibeam	16:00	16.7448	62.1282	-	364	1	0.48	0002	On second line - past Waypoint 121-3
121	JC45-06	Multibeam	16:18	16.7719	62.1326	-	325	1	0.56	0002	EM710 stopped, switched on again
121	JC45-06	Multibeam	16:29			-					Changed from in front to across slope for SBP
121	JC45-06	Multibeam	16:31	16.7901	62.1350	-	381	1	0.94	0002	On second line
121	JC45-06	Multibeam	16:45	16.8097	62.1376	-	464	7	7.05	0002	Turning, end of second line, Waypoint 121.4
121	-	Multibeam	17:00	16.8197	62.1236	-	641	86	86.77	0002	On turn
121	JC45-07	Multibeam	17:09	16.8155	62.1130	-	706	155	153.84	0003	On course, slow down to deploy boomer
121	JC45-07	Multibeam	17:30	16.8053	62.1106	-	731	132	132	0003	moving sideways, using thrusters
121	JC45-07	Multibeam	17:44	16.7979	62.1083	-	756	151	150.8	0003	back to course
121	JC45-07	Multibeam	17:55			-					Boomer in water
121	JC45-07	Multibeam	17:59	16.7820	62.1041	-	820	152	151.51	0003	SBP turned off
121	JC45-07	Multibeam	18:26	16.7514	62.0965	-	893	165	166.83	0003	Change in course
121	JC45-07	Multibeam	18:31	16.7462	62.0988	-	888	210	209.96	0003	end of third line, heading to main boomer line
121	-	Multibeam	18:51			-	757		203.5	0003	change in course, gps lost
121	JC45-08	MB/Boomer	19:00	16.7196	62.1124	-	747	134	134.44	0003	On Boomer axial line - past Waypt 121.7
121	JC45-08	MB/Boomer	19:30	16.6921	62.0950	-	975	133	133.07	0004	
121	JC45-08	MB/Boomer	19:48	16.6732	62.0835	-	1057	133	133.53	0006	EM120 switched off and on again
121	JC45-08	MB/Boomer	20:00	16.6628	62.0771	-	1077	133	131.35	0006	
121	JC45-08	MB/Boomer	20:30	16.6308	62.0583	-	1105	133	132.12	0006	
121	JC45-08	MB/Boomer	21:00	16.6027	62.0412	-	1125	131	131.27	0006	
121	JC45-08	MB/Boomer	21:30	16.5733	62.0232	-	1153	130	130.08	0006	
121	JC45-08	MB/Boomer	22:00	16.5456	62.0072	-	1156	128	127.43	0007	
121	JC45-08	MB/Boomer	22:30	16.5169	61.9896	-	1152	127	127.49	0007	Past Waypoint 121.8
121	JC45-08	MB/Boomer	23:00	16.4891	61.9727	-	1162	126	125.98	0007	
121	-	Multibeam	23:13	16.4725	61.9628	-	1209	128	128.1	0007	Boomer off, air gun testing
121	-	Multibeam	23:30	16.4617	61.9586	-	1212	127	127	0007	SBP on temporarily
122	-	Multibeam	00:00	16.4489	61.9593	-	1212	79	78.27	0008	Air gun still testing
122	-	Multibeam	00:30	16.4512	61.9284	-	1216	80	79.66	0008	
122	-	Multibeam	01:00	16.4547	61.8902	-	1150	80	79.64	0009	
122	-	Multibeam	01:30	16.4531	61.8615	-	861	80	79.16	0009	
122	JC45-09	MB/Boomer	01:51	16.4516	61.8427	-	942	76	74.86	0009	Boomer on/SBP off
122	JC45-09	MB/Boomer	02:10	16.4628	61.8448	-	986	270	270.42	0009	
122	JC45-09	MB/Boomer	02:30	16.4572	61.8695	-	1109	265	265.52	0009	
122	JC45-09	MB/Boomer	03:00	16.4478	61.9148	-	1217	296	298.11	0010	Strong westerly current
122	JC45-09	MB/Boomer	03:30	16.4738	61.9393	-	1211	343	342.83	0010	
122	JC45-09	MB/Boomer	04:00	16.5085	61.9604	-	1194	347	346.38	0010	
122	JC45-09	MB/Boomer	04:30	16.5439	61.9824	-	1164	349	348	0010	end of profile, past waypoint 121-11
122	JC45-10	MB/Boomer	04:50			-					on course / start of new profile
122	JC45-10	MB/Boomer	05:00	16.5440	61.9651	-	1168	130	130	0011	
122	JC45-10	MB/Boomer	05:30	16.5128	61.9454	-	1180	129	129.37	0011	
122	JC45-10	MB/Boomer	05:50			-					started turn at waypoint 121.13. Start of new line.
122	JC45-11	MB/Boomer	06:00	16.4786	61.9377	-	1211	255	254.89	0011	drifted south of planned line.
122	JC45-11	MB/Boomer	06:17	16.4706	61.9597	-					Turn to starboard at WPT 121.14
122	JC45-12	MB/Boomer	06:30	16.4789	61.9680	-	1176	345	344.67	0011	Turn to starboard at WPT 121.15
122	JC45-12	MB/Boomer	07:00	16.5028	61.9443	-	1188	56	55.44	0012	drifted south of planned line.
122	-	MB/Boomer	07:18			-					Turn to Port
122	JC45-13	MB/Boomer	07:30	16.5253	61.9336	-	1158	349	348.61	0012	Turn to Port
122	JC45-13	MB/Boomer	08:00	16.5115	61.9651	-	1188	240	239.21	0012	
122	JC45-13	MB/Boomer	08:12	16.5023	61.9800	-	1135	272	276.52	0012	Start of turn (just inside Waypt 121.18)
122	-	MB/Boomer	08:30	16.5119	61.9921	-	1117	341	340.59	0012	On turn
122	JC45-14	MB/Boomer	08:40	16.5183	61.9926	-	1160	59	57.71	0013	End of turn/Start of line (waypoint 19), 4.3knots
122	JC45-14	MB/Boomer	09:00	16.5299	61.9727	-	1172	57	56.93	0013	speed: 4.4 knots
122	JC45-14	MB/Boomer	09:45	16.5590	61.9248	-	1128	57	56.37	0013	End of line/Start to turn (speed:4.3Kn)
122	JC45-14	MB/Boomer	09:58	16.5736	61.9286	-	1163	350	350.44	0013	End of boomer - preparing for P-cable.
122	-	MB	10:31	16.5704	61.9930	-	1159	260	259.87	0013	

122	-	MB	11:00	16.5447	62.0667	-	1021	118	114.55	0014	
122	-	MB	11:30	16.5460	62.0590	-	1024	76	78.15	0014	
122	-	MB	12:00	16.5464	62.0575	-	1024	80	79.73	0014	
122	-	MB	12:30	16.5477	62.0484	-	1051	79	79.37	0014	
122	-	MB	13:00	16.5486	62.0428	-	1092	69	69.2	0015	
122	-	MB	13:30	16.5494	62.0387	-	1112	70	69.35	0015	
122	-	MB	14:00	16.5505	62.0337	-	1143	69	68.99	0015	
122	-	MB	14:30	16.5515	62.0279	-	1153	79	79.02	0015	
122	-	MB	15:00	16.5522	62.0236	-	1156	80	79.24	0016	
122	-	MB	15:30	16.5530	62.0194	-	1157	58	58.76	0016	
122	-	MB/SBP	16:00	16.5549	62.0155	-	1155	55	54.88	0016	SBP turned on
122	-	MB/SBP	16:30	16.5585	62.0077	-	1165	62	62.45	0016	
122	-	MB/SBP	17:00	16.5656	61.9962	-	1161	56	56.17	0017	
122	-	MB/SBP	17:30	16.5713	61.9873	-	1159	56	55.95	0017	
122	-	MB/SBP	18:00	16.5790	61.9752	-	1152	56	55.91	0017	
122	-	MB/SBP	18:10			-					SBP stopped & restarted
122	-	MB/SBP	18:13			-					SBP stopped (system crash)
122	-	MB/SBP	18:21			-					SBP restarted, now logging
122	-	MB/SBP	18:22			-					Airguns started
122	-	MB/SBP	18:30	16.5934	61.9531	-	1100	56	55.86	0017	
122	-	MB	18:50	16.5994	61.9414	-	926	99	99.62	0018	Thrusters on, SBP lost seafloor, started turn.
122	-	MB	19:00	16.5983	61.9384	-	986	145	145	0018	
122	-	MB	19:04			-					Airguns stopped snd brought in - leak in pipe
122	-	MB	19:30	16.5847	61.9284	-	1010	135	135.4	0018	SBP still with problems
	-		19:53			-					SBP ok again
122	-	MB/SBP	20:00	16.5719	61.9402	-	1158	238	237.3	0018	
122	-	MB/SBP	20:03	16.5692	61.9442	-	1158	211	210.7	0018	P-cables underneath ship. All stop.
122	-	MB/SBP	20:30	16.5569	61.9666	-	1162	298	293.09	0018	
122	-	MB/SBP	21:00	16.5612	61.9989	-	1163	301	300.66	0019	
122	-	MB/SBP	21:30	16.5697	62.0260	-	1148	322	318.8	0019	
122	-	MB/SBP	22:00	16.5501	62.0333	-	1148	97	95.4	0019	Headed to Antigua (propellor damage)
122	-	MB/SBP	22:30	16.5780	62.0263	-	1148	28	28.3	0019	
122	-	MB/SBP	23:00	16.6030	62.0211	-	1141	21	19.2	0020	speed:3.6knots
122	-	MB/SBP	23:30	16.6260	62.0189	-	1124	46	45.6	0020	
123	-	MB/SBP	00:00	16.6585	62.0247	-	1108	8	7.7	0020	
123	-	MB/SBP	00:30	16.6967	62.0229	-	1063	22	22.11	0020	
123	-	MB/SBP	01:07	16.7413	62.0181	-	894	23	22.62	0021	
123	-	MB/SBP	01:32	16.7707	62.0151	-	843	23	22.48	0021	
123	-	MB/SBP	02:00	16.8020	62.0120	-	814	22	22.07	0021	
123	-	MB/SBP	02:35	16.8400	62.0085	-	777	22	22.31	0021	
123	-	MB/SBP	03:08	16.8795	62.0054	-	772	23	22.5	0022	
123	-	MB/SBP	03:37	16.9128	62.0037	-	737	23	22.62	0022	
123	-	MB/SBP	04:00	16.9404	61.9997	-	601	23	23.03	0022	
123	-	MB/SBP	04:30	16.9518	62.0031	-	434	330	329.69	0022	
123	-	MB/SBP	04:45	16.9557	62.0069	-	352	42	42.5	0023	
123	-	MB/SBP	05:00	16.9569	62.0108	-	321	337	336.46	0023	
123	-		05:30			-					stopped logging
123	-	PORTCALL	11:00			-					Port Call St. Johns
123	-	PORTCALL	00:00			-					started
123	-	MB	14:30	17.1478	61.9107	-	36	296	295.24	0025	
123	-	MB	15:00	17.1136	61.9698	-	44	225	223.49		EM120 not yet recording. EM710 on.
123	-	MB	15:30	17.0617	62.0312	-	385	222	221.46		Problem with GPS. EM120 and 710 not working
123	-	MB/SBP	15:41	17.0413	62.0575	-	506	241	239.37	0025	EM120/710 switched on. SBP switched on.
123	-	MB/SBP	16:00	17.0240	62.1056	-	562	250	248.85	0025	
123	-	MB/SBP	16:24			-					EM710 turned off.
123	-	MB/SBP	16:30	16.9745	62.1517	-	704	203	202.79	0025	
123	-	MB/SBP	17:00	16.9059	62.1869	-	722	199	198.13	0025	
123	-	MB/SBP	17:07	16.8834	62.1982	-	562	105	104.3	0025	Ship turning/stopping.
123	-	MB/SBP	17:30	16.8855	62.1922	-	591	79	78.98	0025	Air gun deployed. Speed increased to 4 kn
123	-	MB/SBP	17:40			-					Air gun soft start
123	-	MB/SBP	18:00	16.8977	62.1614	-	690	77	76.98	0026	Air gun to full pressure
123	-	MB/SBP	18:15	16.8994	62.1449	-	701	130	131	0026	Airguns out due to leakage
123	-	MB/SBP	18:26	16.8923	62.1401	-	698	144	143.4	0026	
123	-	MB/SBP	18:33	16.8884	62.1387	-	696	145	145.8	0026	recovered airguns
123	-	MB/SBP	18:44	16.8825	62.1371	-	694	145	144.71	0026	deploying boomer
123	-	MB/SBP	18:50	0.0000	0.0000	-					deploying streamer

123	-	MB/SBP	19:00	16.8740	62.1348	-	686	145	144.72	0026	
123	-	NB/Boomer	19:02	16.8728	62.1443	-	684	144	144.45	0026	SBP stopped. Boomer started.
123	JC45-15	MB/Boomer	19:30	16.8574	62.1302	2.9	671	145	144.21	0026	
123	JC45-15	MB/Boomer	20:00	16.8257	62.1216	4.2	673	145	144.67	0027	Boomer out at 20:25
123	JC45-15	MB/Boomer	20:30	16.7927	62.1124	3.5	748	146	145.18	0027	Airguns in at 20:45
123	JC45-15	MB/SBP	20:51	16.7784	62.1085	3.9	788	144	144.26	0027	Start of the SBP
123	JC45-15	MB/SBP/Air Gun	21:00	16.7698	62.1061	3.8	802	145	145.11	0027	Air gun testing
123	JC45-15	MB/SBP/Air Gun	21:30	16.7374	62.0970	4.0	880	133	131.91	0027	Air gun testing; guns ok, collecting 2D air gun
123	JC45-15	MB/SBP/Air Gun	22:00	16.7085	62.0783	3.7	972	130	130.37	0028	Past waypoint 23
123	JC45-15	MB/SBP/Air Gun	22:30	16.6808	62.0621	4.1	1062	130	130.23	0028	Problem with EA600
123	JC45-15	MB/SBP/Air Gun	23:00	16.6508	62.0446	4.1	1105	130	130.76	0028	
123	JC45-15	MB/SBP/Air Gun	23:30	16.6219	62.0274	3.7	1126	120	118.95	0028	
124	JC45-15	MB/SBP/Air Gun	00:00	16.5926	62.0101	4.0	1148	120	120.21	029	
124	JC45-15	MB/SBP/Air Gun	00:30	16.5638	61.9930	4.0	1164	121	120.54	0029	
124	JC45-15	MB/SBP/Air Gun	00:48	16.5478	61.9836	4.1	1164	120	120.1	0029	SBP went off, rest OK
124	JC45-15	MB/SBP/Air Gun	00:52	16.5435	61.9811	4.3	1165	120	119.99	0029	SBP back, but not recording SBP
124	JC45-15	MB/SBP/Air Gun	01:02	16.5342	61.9756	4.0	1170	120	120.5	0029	SBP back, but not recording SBP
124	JC45-15	MB/SBP/Air Gun	01:10	16.5163	61.9640	3.9	1181	120	120.24	0029	SBPstarted to record
124	JC45-15	MB/SBP/Air Gun	01:34	16.5041	61.9577	3.8	1198	120	119.6	0029	All OK
124	JC45-15	MB/SBP/Air Gun	01:40	16.4952	61.9525	4.0	1202	120	119.58	0030	On IODP site (waypoint 25)
124	JC45-15	MB/SBP/Air Gun	02:00	16.4768	61.9410	3.9	1210	129	129.51	0030	
124	JC45-15	MB/SBP/Air Gun	02:08	16.4677	61.9361	3.8	1212	140	141.19	0030	End of axial line, turn begins, waypoint 26
124	JC45-15b	MB/SBP/Air Gun	02:30	16.4686	61.9553	3.9	1211	287	287.09	0030	
124	JC45-15b	MB/SBP/Air Gun	02:47	16.4780	61.9742	4.0	1150	343	343.42	0030	SBP went off, rest OK, waypoint 28
124	JC45-16	MB/SBP/Air Gun	03:01	16.4895	61.9672	3.8	1194	59	59.33	0030	
124	JC45-16	MB/SBP/Air Gun	03:30	16.5058	61.9400	3.9	1178	58	56.82	0030	Past waypoint 29 (IODP site)
124	JC45-16	MB/SBP/Air Gun	03:53	16.5190	61.9172	4.0	1132	75	75.11	0031	Turn begins, waypoint 30
124	JC45-16b	MB/SBP/Air Gun	04:00	16.5185	61.9092	4.0	1118	109	108.62	0031	
124	JC45-16b	MB/SBP/Air Gun	04:10	16.5137	61.8938	4.1	1095	106	105.9	0031	restart SBD
124	JC45-16b	MB/SBP/Air Gun	04:30	16.4987	61.8847	3.8	1091	167	167.31	0031	
124	JC45-16b	MB/SBP/Air Gun	04:34	16.4941	61.8850	3.9	1094	192	192.31	0031	start turn
124	JC45-16b	MB/SBP	04:39	16.4889	61.8889	2.7	1108	2333	232.9	0031	end of turn. Stop shooting. Retrieve airguns.
124	JC45-16b	MB/Boomer	04:54	16.4795	61.9035	4.0	1162	235	237.1	0031	Boomer deployed, speed increased.
124	JC45-16b	MB/Boomer	05:06	16.4749	61.9113	4.0	1193	239	237.6	0031	SBP off.
124	JC45-16b	MB/Boomer	05:24	16.4664	61.9270	4.0	1216	261	261.46	0031	Start of Turn
124	JC45-16b	MB/Boomer	05:30	16.4681	61.9352	3.9	1214	306	306.21	0031	mid turn
124	JC45-17	MB/Boomer	05:38	16.4757	61.9410	3.8	1211	341	342.08	0031	End of turn. Start of profile JC45-17. Waypt 33
124	JC45-17	MB/Boomer	06:00	16.4954	61.9527	4.1	1202	346	345.62	0032	
124	JC45-17	MB/Boomer	06:30	16.5251	61.9703	4.0	1177	344	343.84	0032	
124	JC45-17b	MB/Boomer	06:51	16.5462	61.9831	4.1	1163	342	341.2	0032	Start of turn to port at WPT 35.
124	JC45-17b	MB/Boomer	06:59	16.5514	61.9896	3.9	1164	314	314.49	0032	Startof turn to starboard.
124	JC45-17b	MB/Boomer	07:21	16.5573	61.9781	3.9	1164	176	175.13	0032	Start of turn to Port.
124	JC45-18	MB/Boomer	07:31	16.5509	61.9771	3.9	1166	141	141.1	0032	End of turn to Port. Start of profile JC45-18
124	JC45-18	MB/Boomer	08:00	16.5243	61.9611	3.8	1181	138	138.5	0033	
124	JC45-18	MB/Boomer	08:30	16.4950	61.9433	3.8	1201	138	138.13	0033	
124	JC45-18b	MB/Boomer	08:52	16.4724	61.9325	3.6	1214	179	179.83	0033	Start of turn, waypoint 37
124	JC45-18b	MB/Boomer	09:00	16.4654	61.9365	3.6	1213	220	221.83	0033	
124	JC45-18b	MB/Boomer	09:30	16.4611	61.9664	4.0	1213	320	329.21	0033	
124	JC45-19	MB/Boomer	10:00	16.4841	61.9498	3.9	1207	64	64.78	0034	waypoint 38, on JC45-18
124	JC45-19	MB/Boomer	10:30	16.5014	61.9196	3.0	1162	65	64.44	0034	
124	JC45-19	MB/Boomer	10:56	16.5126	61.9002	3.0	1105	63	62.8	0034	Turn to starboad, end JC45-18
124	JC45-19b	MB/Boomer	11:00	16.5146	61.8966	3.0	1093	69	68.93	0034	On turn
124	JC45-19b	MB/Boomer	11:16	16.5114	61.8852	2.9	1080	151	149.6	0034	Boomer end
124	JC45-19b	MB/SBP	11:30	16.4995	61.8790	2.9	1081	168	168.1	0034	SBP on
124	JC45-19b	MB/SBP	11:45	16.4904	61.8859	3.6	1098	228	228	0035	Airguns in
124	JC45-19b	MB/SBP	12:00	16.4793	61.9049	4.0	1166	237	27.35	0035	
124	JC45-20	MB/SBP/Air Gun	12:30	16.4878	61.9275	4.0	1198	349	348.78	0035	Airguns begin, on JC45-20, past waypt 40
124	JC45-20	MB/SBP/Air Gun	12:55	16.5126	61.9425	4.0	1178	350	350.12	0035	SBP stop-> on
124	JC45-20	MB/SBP/Air Gun	13:00	16.5167	61.9450	3.8	1178	350	348.88	0035	
124	JC45-20	MB/SBP/Air Gun	13:15	16.5315	61.9540	4.0	1171	350	348.5	0035	SBP stop-> on
124	JC45-20	MB/SBP/Air Gun	13:30	16.5456	61.9625	4.0	1166	350	349.9	0035	
124	JC45-20	MB/SBP/Air Gun	13:50	16.5676	61.9757	4.0	1158	350	349.9	0036	EA600 disappeared-> recovered
124	JC45-20	MB/SBP/Air Gun	14:00	16.5753	61.9805	4.2	1155	353	353.32	0036	

124	JC45-20	MB/SBP/Air Gun	14:02	16.5769	61.9814	3.9	1155	355	353.89	0036	SBP restarted
124	JC45-20	MB/SBP/Air Gun	14:18	16.5928	61.9911	3.8	1196	353	353.19	0036	SBP restarted
124	JC45-20	MB/SBP/Air Gun	14:45	16.6181	62.0064	3.9	1131	355	354.96	0036	
124	JC45-20	MB/SBP/Air Gun	15:00	16.6320	62.0148	4.0	1120	355	354.03	0036	
124	JC45-20	MB/SBP/Air Gun	15:30	16.6623	62.0331	4.0	1101	356	354.45	0036	
124	JC45-20	MB/SBP/Air Gun	15:55	16.6898	62.0498	3.8	1067	359	359.1	0037	SBP restarted
124	JC45-20	MB/SBP/Air Gun	16:05	16.6956	62.0533	3.8	1061	359	357.4	0037	
124	JC45-20	MB/SBP/Air Gun	16:30	16.7186	62.0672	4.1	990	354	353.85	0037	one gun leaking slightly
124	JC45-20	MB/SBP/Air Gun	17:00	16.7484	62.0852	3.7	923	353	353.59	0037	
124	JC45-20	MB/SBP	17:19	16.7669	62.0965	2.5	890	357	357.11	0037	End of profile JC45-20. Begin retreiving airguns.
124	-	MB/SBP	17:30	16.7749	62.0986	2.5	870	14	14.29	0037	retreiving air guns
124	-	MB/SBP	17:50	16.7889	62.1011	2.6	827	15	15.02	0038	
124	-	MB/SBP	18:00	16.7933	62.1009	5.4	817	147	146.82	0038	Sharp turn on spot.
124	-	MB/SBP	18:19	16.7553	62.0887	0.3	913	58	57.6	0038	90 degree turn to port on spot.
124	-	MB/SBP	18:30	16.7554	62.0888	0.3	913	60	59.12	0038	Ship almost stationary.
124	-	MB/SBP	18:43	16.7556	62.0872	0.7	916	65	65.12	0038	Begin deployment of P-cable system.
124	-	MB/SBP	19:00	16.7561	62.0826	1.1	914	78	77.33	0038	Continued deployment of P-cable system.
124	-	MB/SBP	19:30	16.7568	62.0744	0.9	910	78	77.8	0038	Continued deployment of P-cable system.
124	-	MB/SBP	19:40	16.7569	62.0722	0.9	909	77	76.77	0038	P-cable deployed (12 streamers)
124	-	MB/SBP	20:00	16.7576	62.0637	1.1	903	75	74.87	0039	Paravane problem
124	-	MB/SBP	20:30	16.7582	62.0561	1.9	894	74	74.26	0039	P-cable testing
124	-	MB/SBP/3D	21:00	16.7594	62.0416	1.0	879	74	74.3	0039	Air gun deployed for P-cable.Soft start.
124	-	MB/SBP/3D	21:30	16.7607	62.0257	2.3	863	75	75.22	0039	On turn to 3D box
124	-	MB/SBP/3D	22:00	16.7497	62.0126	2.7	865	173	172.8	0040	On approach to first line of 3D box 1
124	JC45-3D-01	MB/SBP/3D	22:20	16.7428	62.0256	4.1	900	264	264.4	0040	Start of line 01
124	JC45-3D-01	MB/SBP/3D	22:30	16.7429	62.0364	4.0	912	270	269.8	0040	On line 01
124	JC45-3D-01	MB/SBP/3D	23:00	16.7429	62.0718	3.5	940	270	269.7	0040	On line 01
124	JC45-3D-01	MB/SBP/3D	23:19	16.7429	62.0925	3.8	912	268	267.03	0040	start of turn
124	JC45-3D-01/02	MB/SBP/3D	23:30	16.7363	62.1017	4.0	857	193	192.65	0040	on turn
124	JC45-3D-01/02	MB/SBP/3D	23:45	16.7245	62.0918	3.5	874	88	87.96	0041	End of turn, start line 02
124	JC45-3D-02	MB/SBP/3D	23:53	16.7244	62.0864	2.2	920	90	89.4	0041	Speed drop to 1 knot, paravans down
125	JC45-3D-02	MB/SBP/3D	00:00	16.7245	62.0832	1.0	932	90	89.49	0041	On line 02 of 3D box 1
125	JC45-3D-02	MB/SBP/3D	00:30	16.7245	62.0628	2.5	991	89	88.89	0041	On line 02 of 3D box 1
125	JC45-3D-02	MB/SBP/3D	01:00	16.7245	62.0408	2.5	995	75	74.82	0041	Data logger DPS-116 JC1 error, but no data lost
125	JC45-3D-02	MB/SBP/3D	01:28	16.7244	62.0205	2.5	968	89	88.62	0041	Turn begins/ end of line 2 of box 1
125	JC45-3D-02/03	MB/SBP/3D	01:32	16.7249	62.0174	2.5	960	69	68.14	0041	On turn from line 02 to line 03
125	JC45-3D-02/03	MB/SBP/3D	02:00	16.7412	62.0169	3.1	893	302	300.91	0042	On turn from line 02 to line 03
125	JC45-3D-03	MB/SBP/3D	02:04	16.7424	62.0214	3.6	896	273	271.61	0042	Start of line 3 box 1
125	JC45-3D-03	MB/SBP/3D	02:30	16.7423	62.0506	4.0	932	269	269.09	0042	line 3 box 1
125	JC45-3D-03	MB/SBP/3D	03:00	16.7423	62.0832	3.2	927	280	279.4	0042	line 3 box 1
125	JC45-3D-03	MB/SBP/3D	03:08	16.7423	62.0917	3.5	914	268.5	268.5	0042	end of line 3 box 1
125	JC45-3D-03/04	MB/SBP/3D	03:25	16.7326	62.1021	3.0	848	177	176.17	0042	Box 1 on turn from line 3 to line 4
125	JC45-3D-03/04	MB/SBP/3D	03:42	16.7240	62.0949	2.5	849	80	79.74	0043	Start of line 04 in 3D box 1, slow down to 1 knot
125	JC45-3D-04	MB/SBP/3D	03:57	16.7240	62.0877	1.3	918	80	79.42	0043	Box 1, line 4, speed up requested to 2.5 knots
125	JC45-3D-04	MB/SBP/3D	04:00	16.7239	62.0859	1.7	923	80	79.27	0043	Box 1 line 4
125	JC45-3D-04	MB/SBP/3D	04:33	16.7239	62.0634	2.6	992	79	79.13	0043	Box 1 line 4
125	JC45-3D-04	MB/SBP/3D	05:01	16.7239	62.0427	2.2	1002	88	87.5	0043	Box 1 line 4
125	JC45-3D-04	MB/SBP/3D	05:30	16.7239	62.0219	2.6	975	86	85.4	0043	Box 1 line 4
125	JC45-3D-04	MB/SBP/3D	05:32	16.7239	62.0204	2.8	971	83	82.56	0043	End of Box 1 line 4. Start of Turn
125	JC45-3D-04/05	MB/SBP/3D	05:35	16.0000	62.0000	3.5					increase speed
125	JC45-3D-04/05	MB/SBP/3D	05:40	16.7273	62.0146	2.5	944	36	36.19	0043	reduced to 2.5 kn. Starboard paravane over.
125	JC45-3D-04/05	MB/SBP/3D	05:50	16.7339	62.0128	2.4	913	358	357.84	0043	mid-point of turn
125	JC45-3D-04/05	MB/SBP/3D	06:00	16.7389	62.0141	2.5	897	313	312.11	0044	on turn from L4 to L5
125	JC45-3D-04/05	MB/SBP/3D	06:07	16.7418	62.0199	2.6	896	270	270.02	0044	Start of Box 1 Line 5
125	JC45-3D-05	MB/SBP/3D	06:30	16.7418	62.0444	4.0	920	270	269.52	0044	Box 1 Line 5
125	JC45-3D-05	MB/SBP/3D	07:00	16.7418	62.0803	4.0	938	270	269.51	0044	Box 1 Line 5
125	JC45-3D-05	MB/SBP/3D	07:10	16.7418	62.0919	3.6	900	270	270.51	0044	End of box 1 line 5. start of turn.
125	JC45-3D-05/06	MB/SBP/3D	07:30	16.7292	62.1020	2.6	842	173	173.21	0044	mid-point of turn
125	JC45-3D-06	MB/SBP/3D	07:44	16.7234	62.0998	2.5	840	88	87.18	0045	Start of Line 6
125	JC45-3D-06	MB/SBP/3D	08:07	16.7234	62.0754	2.5	968	80	79.5	0045	Line 6
125	JC45-3D-06	MB/SBP/3D	08:30	16.7234	62.0600	2.5	997	80	79.53	0045	Line 6
125	JC45-3D-06	MB/SBP/3D	09:00	16.7234	62.0396	2.4	998	79	79.17	0045	Line6
125	JC45-3D-06/07	MB/SBP/3D	09:30	16.7236	62.018	2.5	969	66	64.64	0046	On turn

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125	JC45-3D-06/07	MB/SBP/3D	10:00	16.7405	62.0168	2.6	896	285	284.05	0046	On turn
125	JC45-3D-07	MB/SBP/3D	10:12	16.7412	62.0286	3.8	910	260	259.7	0046	Start of line 7
125	JC45-3D-07	MB/SBP/3D	10:30	16.7412	62.0485	4.0	926	280	279.84	0046	
125	JC45-3D-07	MB/SBP/3D	11:00	16.7496	62.0834	3.3	928	281	279.88	0046	
125	JC45-3D-07/08	MB/SBP/3D	11:11	16.7412	62.0926	3.0	901	270	269.36	0046	On turn
125	JC45-3D-07/08	MB/SBP/3D	11:30	16.7314	62.0854	2.5	846	178	117.9	0046	On turn
125	JC45-3D-08	MB/SBP/3D	11:50	16.7229	62.0939	2.3	867	88	88.46	0047	Sart of line 8
125	JC45-3D-08	MB/SBP/3D	12:01	16.7228	62.0853	2.5	924	84	84.08	0047	Box 1, on line 08
125	JC45-3D-08	MB/SBP/3D	12:30	16.7228	62.0649	2.5	988	85	84.63	0047	Box 1, on line 08
125	JC45-3D-08	MB/SBP/3D	13:00	16.7228	62.0433	2.4	1011	84	84.06	0047	Box 1, on line 08
125	JC45-3D-08	MB/SBP/3D	13:30	16.7228	62.0210	2.6	985	90	89.39	0047	Box 1,end of line 08
125	JC45-3D-08/09	MB/SBP/3D	13:51	16.7325	62.0128	2.4	918	11	11.22	0048	Box1, turn from line 08 to line 09
125	JC45-3D-08/09	MB/SBP/3D	14:00	16.7386	62.0155	3.0	900	326	323.6	0048	Box1, turn from line 08 to line 09
125	JC45-3D-08/09	MB/SBP/3D	14:08	16.7407	62.0232	3.3	904	286	279.41	0048	Box1, start of line 09
125	JC45-3D-09	MB/SBP/3D	14:30	16.7407	62.0441	3.3	922	280	279.62	0048	Box 1, line 09
125	JC45-3D-09	MB/SBP/3D	15:00	16.7407	62.0740	3.5	939	280	279.59	0048	Box 1, line 09
125	JC45-3D-09	MB/SBP/3D	15:19	16.7406	62.0941	3.4	903	267	266.22	0048	Box 1, line 09 ends
125	JC45-3D-09/10	MB/SBP/3D	15:33	16.7309	62.1021	2.4	844	176	174.51	0048	Box 1, turn from line 09 to line 10
125	JC45-3D-10	MB/SBP/3D	15:55	16.7223	62.0922	2.5	876	80	79.68	0049	Box 1, start of line 10
125	JC45-3D-10	MB/SBP/3D	16:31	16.7223	62.0661	2.3	987	80	79.62	0049	Box 1, line 10
125	JC45-3D-10	MB/SBP/3D	17:00			2.4	1028	79	79.09	0049	Box 1, line 10
125	JC45-3D-10	MB/SBP/3D	17:30	16.7223	62.0236	2.3	984	84	83.94	0049	Box 1, line 10
125	JC45-3D-10/11	MB/SBP/3D	17:35	16.7223	62.0204	2.4	980	89	89.25	0049	End of Line 10, Start of turn.
125	JC45-3D-10/11	MB/SBP/3D	18:01	16.7367	62.0138	2.8	905	328	327.19	0050	mid turn
125	JC45-3D-11	MB/SBP/3D	18:12	16.7374	62.0219	3.7	903	270	269.65	0050	End of turn. Start of line 11.
125	JC45-3D-11	MB/SBP/3D	18:32	16.7401	62.0446	4.0	924	269	268.79	0050	Box 1, line 11
125	JC45-3D-11	MB/SBP/3D	19:02	16.7401	62.0785	4.0	932	270	269.17	0050	Box 1, line 11
125	JC45-3D-11	MB/SBP/3D	19:10	16.7401	62.0890	3.2	917	270	270.07	0050	Tail buoy missing
125	JC45-3D-11/12	MB/SBP/3D	19:15	16.7401	62.0925	3.0	908	270	269.61	0050	End of box 1, line 11, start turn
125	JC45-3D-11/12	MB/SBP/3D	19:30	16.7313	62.1021	2.8	846	180	178.97	0050	Mid turn
125	JC45-3D-12	MB/SBP/3D	19:48	16.7218	62.0952	2.5	862	81	80.07	0051	Start of box 1, line 12
125	JC45-3D-12	MB/SBP/3D	20:00	16.7217	62.0865	2.4	918	72	79.3	0051	Box1, Line12
125	JC45-3D-12	MB/SBP/3D	20:30	16.7217	62.0644	2.4	989	79	79.1	0051	Box1, Line12
125	JC45-3D-12	MB/SBP/3D	20:35	16.7217	62.0585	2.5	1004	80	79.3	0051	Stop air gun, prepare to attach new Pcable float
125	JC45-3D-12	MB/SBP/3D	21:00	16.7218	62.0465	0.8	1028	84	84.35	0051	Stop air gun, prepare to attach new Pcable float
125	JC45-3D-12	MB/SBP/3D	21:38	16.7217	62.0376	0.4	1019	89	89.48	0052	Stop air gun, prepare to attach new Pcable float
125	JC45-3D-12	MB/SBP/3D	23:10	16.7217	62.0215	1.9	987	88	87.88	0052	Deployment 3D
125	JC45-3D-12	MB/SBP/3D	23:30	16.7218	62.0083	1.9	964	89	88.87	0052	Deployment 3D
125	JC45-3D-12	MB/SBP/3D	23:32	16.7218	62.0083	2.5	962	89	88.57	0052	Airgun in water
125	JC45-3D-12/13	MB/SBP/3D	23:58	16.7241	61.9901	2.5	983	269	269.42	0053	Turning from line 12 to line 13, wide loop
126	JC45-3D-12/13	MB/SBP/3D	00:26	16.7396	62.0006	3.3	871	269	269.42	0053	Approaching line 13
126	JC45-3D-13	MB/SBP/3D	00:39	16.7395	62.0148	3.8	894	270	269.49	0053	Box 1, start of line 13
126	JC45-3D-13	MB/SBP/3D	01:03	16.7396	62.0398	3.9	928	269	268.69	0053	Box 1, start of line 13
126	JC45-3D-13	MB/SBP/3D	01:30	16.7396	62.0695	3.6	951	270	269.3	0053	Box 1, start of line 13
126	JC45-3D-13/14	MB/SBP/3D	01:50	16.7396	62.0918	3.7	910	269	268.73	0054	End of line 13, turn to line 14
126	JC45-3D-13/14	MB/SBP/3D	02:04	16.7294	62.1021	2.5	841	179	178.57	0054	mid turn
126	JC45-3D-14	MB/SBP/3D	02:25	16.7212	62.0943	2.5	870	84	83.31	0054	Start of line 14
126	JC45-3D-14	MB/SBP/3D	02:30	16.7212	62.0902	2.4	899	84	83.38	0054	Box1, Line14
126	JC45-3D-14	MB/SBP/3D	03:00	16.7212	62.0688	2.4	979	84	84.08	0054	Box1, Line14
126	JC45-3D-14	MB/SBP/3D	03:30	16.7212	62.0470	2.4	1029	85	84.8	0054	Box1, Line14
126	JC45-3D-14	MB/SBP/3D	04:00	16.7212	62.0256	2.5	995	86	85.15	0055	Box1, Line14
126	JC45-3D-14/15	MB/SBP/3D	04:07	16.7212	62.0203	2.5	989	88	88.68	0055	End of Line 14. Start of turn.
126	JC45-3D-14/15	MB/SBP/3D	04:30	16.7332	62.0130	3.2	916	351	350.13	0055	Mid point of turn. Increase speed to 4 kn.
126	JC45-3D-15	MB/SBP/3D	04:42	16.7391	62.0217	4.0	908	278	277.59	0055	End of turn. Start of Line 15.
126	JC45-3D-15	MB/SBP/3D	05:00	16.7391	62.0421	4.3	931	274	273.32	0055	Box 1 Line 15
126	JC45-3D-15	MB/SBP/3D	05:11	16.7391	62.0575	4.0	945	274	274.21	0055	Noticed SBP had stopped at 04:23. Restarted.
126	JC45-3D-15	MB/SBP/3D	05:14	16.7391	62.0595	3.5	944	275	275.02	0055	Slow to 3.5 kn due to GPS feed loss
126	JC45-3D-15	MB/SBP/3D	05:24	16.7391	62.0775	4.0	946	275	274.11	0055	GPS feeds back up.
126	JC45-3D-15	MB/SBP/3D	05:32	16.7391	62.0784	4.0	947	275	274.65	0055	Box 1 line 15
126	JC45-3D-15/16	MB/SBP/3D	05:43	16.7391	62.0932	4.0	908	270	269.45	0056	End of Line 15. Start of turn to line 16
126	JC45-3D-15/16	MB/SBP/3D	06:00	16.7308	62.1019	2.5	845	180	179.5	0056	Mid point of turn. Decrease speed to 2.5 kn.
126	JC45-3D-16	MB/SBP/3D	06:19	16.7207	62.095	2.5	861	82	81.28	0056	End of turn. Start of Line 16

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126	JC45-3D-16	MB/SBP/3D	06:30	16.7207	62.0876	2.5	912	79	78.84	0056	Box 1 Line 16.
126	JC45-3D-16	MB/SBP/3D	07:02	16.7207	62.0638	2.5	968	79	78.46	0056	Box 1 Line 16.
126	JC45-3D-16	MB/SBP/3D	07:39	16.7207	62.0378	2.5	1018	80	79.07	0056	Box 1 Line 16.
126	JC45-3D-16	MB/SBP/3D	08:00	16.7206	62.0224	2.5	994	90	89.4	0057	Box 1 Line 16.
126	JC45-3D-16/17	MB/SBP/3D	08:07	16.7218	62.0317	2.5	976	63	62.76	0057	On turn, end of line 16.
126	JC45-3D-16/17	MB/SBP/3D	08:30	16.7373	62.0175	3.4	908	298	296.8	0057	On turn
126	JC45-3D-17	MB/SBP/3D	08:40	16.7385	62.0286	3.8	921	270	269.56	0057	End of turn, Box 1 Line 17
126	JC45-3D-17	MB/SBP/3D	09:00	16.7385	62.0503	3.9	965	270	269.51	0057	Box 1 Line 17
126	JC45-3D-17	MB/SBP/3D	09:30	16.7385	62.0850	3.9	929	270	269.37	0057	Box 1 Line 17
126	JC45-3D-17/18	MB/SBP/3D	09:40	16.7380	62.0957	3.3	889	250	249.1	0058	End of box 1, line 17, start of turn
126	JC45-3D-17/18	MB/SBP/3D	10:00	16.7250	62.1018	2.4	820	160	159.7	0058	On turn
126	JC45-3D-18	MB/SBP/3D	10:13	16.7201	62.0947	2.5	862	88	88.08	0058	End of turn, start of box 1, line 18
126	JC45-3D-18	MB/SBP/3D	10:30	16.7201	62.0821	2.4	941	89	89.07	0058	Box 1, line 18
126	JC45-3D-18	MB/SBP/3D	11:00	16.7201	62.0597	2.5	999	85	84.46	0058	Box 1, line 18
126	JC45-3D-18	MB/SBP/3D	11:30	16.7201	62.0388	2.5	1016	84	84.06	0058	Box 1, Line 18 (SBP lost 15 mins, restarted 11.35)
126	JC45-3D-18	MB/SBP/3D	11:55	16.7201	62.0198	2.3	991	82	81.68	0059	Box 1, end of line 18
126	JC45-3D-18/19	MB/SBP/3D	12:00	16.7208	62.0168	2.4	979	57	55.97	0059	Mid turn
126	JC45-3D-18/19	MB/SBP/3D	12:30	16.7379	62.0211	3.3	911	283	282.45	0059	Mid turn
126	JC45-3D-19	MB/SBP/3D	12:32	16.7380	62.0230	3.4	914	272	271.85	0059	Box1, start of line 19
126	JC45-3D-19	MB/SBP/3D	13:00	16.7380	62.0535	3.7	969	270	269.63	0059	Box1, line 19
126	JC45-3D-19	MB/SBP/3D	13:30	16.7380	62.0863	3.9	925	270	269.82	0059	Box1, line 19
126	JC45-3D-19	MB/SBP/3D	13:37	16.7379	62.0943	3.4	904	256	255.58	0059	Box1, end of line 19
126	JC45-3D-19/20	MB/SBP/3D	14:00	16.7225	62.1007	2.3	824	142	141.46	0060	Box 1, mid way turn from line 19 to line 20
126	JC45-3D-20	MB/SBP/3D	14:11	16.7196	62.0945	2.6	862	84	83.92	0060	Box1, start of line 20
126	JC45-3D-20	MB/SBP/3D	14:30	16.7196	62.0778	3.0	951	84	84.34	0060	Box 1, line 20
126	JC45-3D-20	MB/SBP/3D	15:01	16.7196	62.0503	2.9	966	84	83.79	0060	Box 1, line 20
126	JC45-3D-20	MB/SBP/3D	15:32	16.7196	62.0247	2.6	1028	79	78.46	0060	Box 1, line 20
126	JC45-3D-20	MB/SBP/3D	15:39	16.7196	62.0209	2.8	1033	78	77.11	0060	Box 1, end of line 20
126	JC45-3D-20/21	MB/SBP/3D	15:58	16.7320	62.0134	3.1	923	340	338.77	0061	Box 1, midway on turn
126	JC45-3D-21	MB/SBP/3D	16:09	16.7375	62.0225	4.0	915	270	269.7	0061	End of turn. Start of Line 21.
126	JC45-3D-21	MB/SBP/3D	16:34	16.7375	62.0516	4.1	977	269	269.67	0061	Box 1 Line 21.
126	JC45-3D-21	MB/SBP/3D	17:00	16.7374	62.0820	3.6	932	270	265.59	0061	Box 1 Line 21.
126	JC45-3D-21/22	MB/SBP/3D	17:15	16.0000	62.0000						End of Line 21.Start turn to Line 22.
126	JC45-3D-21/22	MB/SBP/3D	17:30	16.7245	62.1016	3.0	821	157	156.06	0061	Turn to Line 22.
126	JC45-3D-22	MB/SBP/3D	17:43	16.7191	62.0927	3.0	867	79	78.8	0062	Start Line 22
126	JC45-3D-22	MB/SBP/3D	18:00	16.7190	62.0772	3.0	953	80	79.63	0062	Box 1 Line 22.
126	JC45-3D-22	MB/SBP/3D	18:30	16.7190	62.0521	3.1	955	88	87.83	0062	Box 1 Line 22.
126	JC45-3D-22	MB/SBP/3D	19:00	16.7190	62.0261	2.7	1029	89	89.05	0062	Box 1 Line 22.
126	JC45-3D-22/23	MB/SBP/3D	19:04	16.7190	62.0224	2.8	1008	89	88.5	0062	End of Line 22. Start of Turn to 23
126	JC45-3D-23	MB/SBP/3D	19:37	16.7369	62.0217	3.5	917	271	270.66	0062	End of turn, start of line 23
126	JC45-3D-23	MB/SBP/3D	20:00	16.7369	62.0474	4.0	941	270	269.81	0063	Box 1 Line 23
126	JC45-3D-23	MB/SBP/3D	20:30	16.7368	62.0828	3.9	929	270	269.86	0063	Box 1 Line 23
126	JC45-3D-23/24	MB/SBP/3D	20:43	16.7361	62.0966	3.4	980	242	240.7	0063	End of line 23, turning
126	JC45-3D-23/24	MB/SBP/3D	21:00	16.7235	62.1014	2.8	816	158	157.06	0063	Turn
126	JC45-3D-24	MB/SBP/3D	21:11	16.7185	62.0930	3.0	864	158	157.06	0063	Start of line 24
126	JC45-3D-24	MB/SBP/3D	21:30	16.7185	62.0771	2.9	959	89	88.79	0063	Box 1 Line 24
126	JC45-3D-24	MB/SBP/3D	22:00	16.7185	62.0513	2.9	964	85	84.89	0064	Box 1 Line 24
126	JC45-3D-24	MB/SBP/3D	22:30	16.7185	62.0257	3.0	1029	84	84.13	0064	Box 1 Line 24
126	JC45-3D-24/25	MB/SBP/3D	22:39	16.7193	62.0176	3.0	990	55	54.65	0064	On turn, end of line 24
126	JC45-3D-24/25	MB/SBP/3D	23:00	16.7350	62.0172	3.4	917	300	299.48	0064	On turn
126	JC45-3D-25	MB/SBP/3D	23:05							0064	End of turn, start Box 1,Line 25
126	JC45-3D-25	MB/SBP/3D	23:30	16.7363	62.0495	4.0	981	270	269.74	0064	Box 1 line 25
126	JC45-3D-25	MB/SBP/3D	23:58	16.7364	62.0832	3.9	931	270	269.41	0064	Box1 line 25
127	JC45-3D-25/26	MB/SBP/3D	00:24	16.7265	62.1021	2.9	824	178	177.53	0065	Box 1, midway on turn
127	JC45-3D-25/26	MB/SBP/3D	00:30	16.7217	62.1007	2.9	818	144	143.65	0065	Box1, turn from line 25 to line 26
127	JC45-3D-26	MB/SBP/3D	00:40	16.7180	62.0929	3.0	875	90	89.15	0065	Box 1, start of line 26
127	JC45-3D-26	MB/SBP/3D	00:58	16.7179	62.0767	2.9	966	90	90.25	0065	Box 1, line 26
127	JC45-3D-26	MB/SBP/3D	01:30	16.7179	62.0497	3.0	1014	90	89.39	0065	Box1, line 26
127	JC45-3D-26	MB/SBP/3D	02:00	16.7180	62.0234	2.9	1035	90	89.23	0066	Box1, line 26
127	JC45-3D-26	MB/SBP/3D	02:03	16.7180	62.0204	2.8	1005	83	81.99	0066	Box 1, end of line 26, start of turn to line 27
127	JC45-3D-26/27	MB/SBP/3D	02:30	16.7349	62.0180	3.3	918	29.5	294.44	0066	Box1, on turn
127	JC45-3D-27	MB/SBP/3D	02:35	16.7358	62.0226	4.0	923	270	269.61	0066	Box1, start of line 27

127	JC45-3D-27	MB/SBP/3D	03:00	16.7358	62.0514	4.0	983	270	269.69	0066	Box1, line 27
127	JC45-3D-27/28	MB/SBP/3D	03:35	16.7358	62.0925	3.4	897	268	267.63	0066	Box1, end of line 27, start of turn to line 28
127	JC45-3D-27/28	MB/SBP/3D	04:00	16.7195	62.0991	3.1	832	129	129.92	0067	On turn to Line 28
127	JC45-3D-28	MB/SBP/3D	04:08	16.7174	62.0933	2.7	882	89	88.8	0067	Start line 28
127	JC45-3D-28	MB/SBP/3D	04:30	16.7174	62.0733	2.9	972	85	84.72	0067	Line 28
127	JC45-3D-28	MB/SBP/3D	05:00	16.7174	62.0489	2.8	1032	85	84.69	0067	Line 28
127	JC45-3D-28/29	MB/SBP/3D	05:30	16.7174	62.0221	2.9	1036	89	88.49	0067	End of line 28. Start of turn to Line 29.
127	JC45-3D-29	MB/SBP/3D	06:02	16.7352	62.0208	3.3	921	279	279.27	0068	End of turn. Start of line 29.
127	JC45-3D-29	MB/SBP/3D	06:26	16.7353	62.0489	2.9	985	270	269.91	0068	Slowed to 3.0 kn due to yacht
127	JC45-3D-29	MB/SBP/3D	06:31	16.7353	62.0529	3.0	976	270	269.65	0068	Line 29
127	JC45-3D-29	MB/SBP/3D	06:45	16.7353	62.0651	4.0	973	270	269.81	0068	Line 29. Back up to 4.0 Yacht out of way.
127	JC45-3D-29	MB/SBP/3D	07:00	16.7353	62.0799	4.0	940	270	270.03	0068	Box 1 Line 29.
127	JC45-3D-29/30	MB/SBP/3D	07:07	16.7353	62.0916	3.4	903	271	270.38	0068	End of Line 29. Start turn to Line 30.
127	JC45-3D-29/30	MB/SBP/3D	07:30	16.7210	62.1009	3.0	819	148	147.38	0068	Turn to 30.
127	JC45-3D-30	MB/SBP/3D	07:41	16.7169	62.0934	3.0	884	86	85.38	0068	End turn. Start Line 30.
127	JC45-3D-30	MB/SBP/3D	08:00	16.7169	62.0769	3.0	949	85	84.89	0069	line 30
127	JC45-3D-30	MB/SBP/3D	08:30	16.7169	62.0509	2.9	1033	85	84.59	0069	line 30
127	JC45-3D-30	MB/SBP/3D	09:00	16.7002	62.0248	2.9	1027	89	88.93	0069	line 30
127	JC45-3D-30/31	MB/SBP/3D	09:05	16.7169	62.0204	2.7	1014	83	82.79	0069	End of line 30. Start to turn to line 31
127	JC45-3D-30/31	MB/SBP/3D	09:30	16.7339	62.0182	3.5	923	294	293.49	0069	on turn
127	JC45-3D-31	MB/SBP/3D	09:34	16.6847	62.0225	3.3	926	270	269.51	0069	start of line 31
127	JC45-3D-31	MB/SBP/3D	10:00	16.7347	62.0520	3.8	983	270	269.81	0070	line 31
127	JC45-3D-31	MB/SBP/3D	10:30	16.7347	62.0861	3.5	924	270	270	0070	line 31
127	JC45-3D-31/32	MB/SBP/3D	10:50	16.7263	62.1021	3.0	824	181	181.26	0070	At the middle of the turn to line 32
127	JC45-3D-31/32	MB/SBP/3D	11:00	16.7192	62.1001	3.0	826	137	137.36	0070	on turn to line 32
127	JC45-3D-32	MB/SBP/3D	11:08	16.7163	62.0932	3.0	886	90	89.55	0070	start line 32
127	JC45-3D-32	MB/SBP/3D	11:30	16.7163	62.0748	2.9	964	90	89.9	0070	line 32
127	JC45-3D-32	MB/SBP/3D	12:00	16.7164	62.0497	2.9	1032	89	89.03	0071	Box 1 line 32
127	JC45-3D-32	MB/SBP/3D	12:31	16.7163	62.0213	3.0	1039	87	86.41	0071	Box 1, end of line 32
127	JC45-3D-32/33	MB/SBP/3D	13:00	16.7333	62.0183	3.4	925	293	292.81	0071	Box 1, turn from line 32 to line 33
127	JC45-3D-33	MB/SBP/3D	13:05	16.7341	62.0249	3.7	933	269	269.11	0071	Box 1, start of line 33
127	JC45-3D-33	MB/SBP/3D	13:30	16.7342	62.0534	4.2	977	271	270.37	0071	Box 1, line 33
127	JC45-3D-33	MB/SBP/3D	14:00	16.7342	62.0869	3.9	919	270	270	0072	Box 1, line 33
127	JC45-3D-33	MB/SBP/3D	14:04	16.7342	62.0917	3.4	902	270	270.13	0072	Box 1, end of line 33
127	JC45-3D-33/34	MB/SBP/3D	14:30	16.7178	62.0991	2.9	839	128	128.43	0072	Box1, turn from line 33 to line 34
127	JC45-3D-34	MB/SBP/3D	14:38	16.7158	62.0922	2.9	892	89	88.85	0072	Box1, start of line 34
127	JC45-3D-34	MB/SBP/3D	15:00	16.7158	62.0734	2.8	979	84	84.1	0072	Box1, line 34
127	JC45-3D-34	MB/SBP/3D	15:30	16.7158	62.0474	2.8	1030	84	83.79	0072	Box1, line 34
127	JC45-3D-34	MB/SBP/3D	16:00	16.7157	62.0217	3.0	1041	89	88.65	0073	Box1, end of line 34
127	JC45-3D-35	MB/SBP/3D	16:30	16.7336	62.0218	4.0	930	272	271.34	0073	Box 1, start of line 35.
127	JC45-3D-35	MB/SBP/3D	17:00	16.7336	62.0632	4.0	978	270	269.53	0073	Box 1, line 35
127	JC45-3D-35	MB/SBP/3D	17:30	16.7337	62.0914	4.0	908	275	274.06	0073	End of line 35. Start turn to 36.
127	JC45-3D-36	MB/SBP/3D	18:03	16.7153	62.0940	3.0	887	85	84.36	0074	End of Turn. Start Box 1 line 36.
127	JC45-3D-36	MB/SBP/3D	18:21	16.7153	62.0780	4.0	951	84	84.27	0074	Increase in speed to avoid small yacht
127	JC45-3D-36	MB/SBP/3D	18:30	16.7152	62.0665	3.8	998	84	84.34	0074	Box I Line 36
127	JC45-3D-36	MB/SBP/3D	18:56	16.7152	62.0392	3.0	1029	85	84.25	0074	Decrease speed to 3kn, yacht changed course
127	JC45-3D-36	MB/SBP/3D	19:00	16.7152	62.0363	3.0	1027	84	83.46	0074	Box 1 Line 36
127	JC45-3D-36/37	MB/SBP/3D	19:16	16.7153	62.0220	3.0	1034	84	84.31	0074	End of Line 36. Start turn to Line 37
127	JC45-3D-36/37	MB/SBP/3D	19:30	16.7207	62.0133	3.0	971	11	10.37	0074	mid turn to line 37
127	JC45-3D-37	MB/SBP/3D	19:51	16.7332	62.0263	3.6	941	275	275.07	0075	start line 37
127	JC45-3D-37	MB/SBP/3D	20:00	16.7330	62.0332	4.0	980	268	268.2	0075	line 37
127	JC45-3D-37	MB/SBP/3D	20:30	16.7330	62.0672	4.0	971	270	269.8	0075	line 37
127	JC45-3D-37/38	MB/SBP/3D	20:53	16.7330	62.0943	3.4	885	258	258.5	0075	start to turn to line 38
127	JC45-3D-37/38	MB/SBP/3D	21:00	16.7300	62.0996	3.3	856	220	220.56	0075	on turn
127	JC45-3D-38	MB/SBP/3D	21:24	16.7147	62.0937	2.9	889	89	88.24	0075	line 38
127	JC45-3D-38	MB/SBP/3D	21:30	16.7147	62.0883	3.0	912	89	88.63	0075	line 38
127	JC45-3D-38	MB/SBP/3D	22:00	16.7147	62.0619	2.9	1012	84	83.99	0076	line 38
127	JC45-3D-38	MB/SBP/3D	22:30	16.7147	62.0367	2.9	1029	85	84.55	0076	line 38
127	JC45-3D-38/39	MB/SBP/3D	22:48	16.7147	62.0208	2.9	1036	80	79.43	0076	End of line 38, start turn
127	JC45-3D-38/39	MB/SBP/3D	23:00	16.7198	62.0135	2.9	975	13	12.56	0076	On turn
127	JC45-3D-39	MB/SBP/3D	23:18	16.7325	62.0212	3.3	934	274	273.08	0076	Start of line 39
127	JC45-3D-39	MB/SBP/3D	23:30	16.7326	62.0333	3.7	975	270	269.7	0076	Line 39

128	JC45-3D-39	MB/SBP/3D	00:00	16.7326	62.0673	3.9	970	270	269.3	0077	Line 39
128	JC45-3D-39	MB/SBP/3D	00:20	16.7325	62.0918	3.6	896	270	269.8	0077	End of line 39
128	JC45-3D-39	MB/SBP/3D	00:30	16.7301	62.0991	3.5	860	225	224.57	0077	on turn to line 40
128	JC45-3D-39/40	MB/SBP/3D	00:55	16.7142	62.0929	2.9	889	89	89.22	0077	Start of Line 40
128	JC45-3D-40	MB/SBP/3D	01:00	16.7141	62.0887	2.9	910	90	89.57	0077	Line 40
128	JC45-3D-40	MB/SBP/3D	01:30	16.7142	62.0626	2.9	1011	85	85.07	0077	Line 40
128	JC45-3D-40	MB/SBP/3D	02:00	16.7142	62.0366	2.7	1030	86	85.37	0078	Line 40
128	JC45-3D-40	MB/SBP/3D	02:16	16.7141	62.0219	3.0	1025	90	89.29	0078	End of Line 40
128	JC45-3D-40/41	MB/SBP/3D	02:30	16.7200	62.0132	2.9	975	13	12.58	0078	on turn to line 41
128	JC45-3D-41	MB/SBP/3D	02:50	16.7320	62.0233	3.4	939	269	269.08	0078	Start of Line 41
128	JC45-3D-41	MB/SBP/3D	03:00	16.7320	62.0348	3.9	962	280	279.31	0078	Line 41
128	JC45-3D-41	MB/SBP/3D	03:30	16.7320	62.0699	3.9	966	274	273.83	0078	Line 41
128	JC45-3D-41/42	MB/SBP/3D	03:49	16.7321	62.0917	3.6	896	269	269.2	0079	End of Line 41. Start of turn to Line 42
128	JC45-3D-41/42	MB/SBP/3D	04:00	16.7270	62.1011	3.5	843	211	210.56	0079	Turn to Line 42
128	JC45-3D-42	MB/SBP/3D	04:22	16.7136	62.0933	3.0	897	84	83.83	0079	End of turn.Start Line 42
128	JC45-3D-42	MB/SBP/3D	04:30	16.7136	62.0855	3.0	930	85	84.72	0079	Box 1 Line 42
128	JC45-3D-42	MB/SBP/3D	05:00	16.7136	62.0588	2.9	1025	84	84.19	0079	Box 1 Line 42
128	JC45-3D-42	MB/SBP/3D	05:31	16.7136	62.0330	3.0	1030	85	84.75	0079	Box 1 line 42
128	JC45-3D-42/43	MB/SBP/3D	05:44	16.7136	62.0219	2.9	1026	90	89.74	0080	End of Line 42.Start turn to Line 43.
128	JC45-3D-42/43	MB/SBP/3D	06:00	16.7215	62.0128	2.9	966	358	357.35	0080	Turn to Line 43.
128	JC45-3D-43	MB/SBP/3D	06:16	16.7315	62.0221	3.5	939	266	265.94	0080	End of Turn. Start of Line 43.
128	JC45-3D-43	MB/SBP/3D	06:30	16.7315	62.0392	3.9	957	270	269.51	0080	Box 1 Line 43
128	JC45-3D-43	MB/SBP/3D	07:00	16.7315	62.0706	3.9	966	269	269.24	0080	Box 1 Line 43
128	JC45-3D-43/44	MB/SBP/3D	07:15	16.7315	62.0924	4.0	900	269	268.86	0080	End of Line 43. Turn to Line 44.
128	JC45-3D-43/44	MB/SBP/3D	07:30	16.7230	62.1021	3.5	810	182	181.65	0080	Turn to Line 44.
128	JC45-3D-44	MB/SBP/3D	07:47	16.7131	62.0924	2.9	900	84	84.14	0081	End of turn. Start line 44
128	JC-45-3D-44	MB/SBP/3D	08:00	16.7131	62.0828	3.0	943	84	83.87	0081	Line 44
128	JC-45-3D-44	MB/SBP/3D	08:30	16.7131	62.0562	2.9	1024	85	85.1	0081	line 44
128	JC-45-3D-44	MB/SBP/3D	09:00	16.7131	62.0305	3.0	1031	84	83.94	0081	line 44
128	JC-45-3D-44/45	MB/SBP/3D	09:08	16.7131	62.0234	2.9	1029	85	84.39	0081	End of line 44/Start to turn to line 45
128	JC-45-3D-44/45	MB/SBP/3D	09:30	16.7251	62.0134	3.4	952	334	333.38	0081	on turn to line 45
128	JC-45-3D-45	MB/SBP/3D	09:40	16.7309	62.0215	3.3	941	269	268.28	0082	start line 45
128	JC-45-3D-45	MB/SBP/3D	10:00	16.7310	62.0438	4.0	969	269	268.87	0082	line 45
128	JC-45-3D-45	MB/SBP/3D	10:30	16.7309	62.0789	4.1	942	270	269.56	0082	line 45
128	JC-45-3D-45/46	MB/SBP/3D	10:43	16.7309	62.0935	3.2	893	263	262.49	0082	end of line 45/ start to turn to line 46
128	JC-45-3D-45/46	MB/SBP/3D	11:00	16.7202	62.1021	3.0	811	173	172.01	0082	on turn to line 46
128	JC-45-3D-46	MB/SBP/3D	11:17	16.7125	62.0959	2.8	908	89	88.86	0082	start line 46
128	JC-45-3D-46	MB/SBP/3D	11:30	16.7125	62.0804	3.0	948	89	88.86	0082	line 46
128	JC-45-3D-46	MB/SBP/3D	12:00	16.7126	62.0544	2.9	1027	89	89.11	83	line 46
128	JC-45-3D-46	MB/SBP/3D	12:37	16.7125	62.0213	2.9	1029	88	87.35	0083	Box 1, end of line 46
128	JC-45-3D-46/47	MB/SBP/3D	12:55	16.7226	62.0128	2.9	963	355	354.58	0083	Box 1, on turn from line 46 to line 47
128	JC-45-3D-47	MB/SBP/3D	13:05	16.7305	62.0231	3.5	945	269	269.6	0083	SOL47
128	JC-45-3D-47	MB/SBP/3D	13:31	16.7304	62.0460	3.8	980	270	269.2	0083	line 47
128	JC-45-3D-47/48	MB/SBP/3D	14:11	16.7304	62.0924	3.6	898	268	268.3	0084	end line 47, start turn onto 48
128	JC-45-3D-47/48	MB/SBP/3D	14:30	16.7184	62.1019	3.0	823	164	163.5	0084	turn between lines 47 and 48
128	JC-45-3D-48	MB/SBP/3D	14:43	16.7120	62.0933	2.9	901	89	89.3	0084	SOL48
128	JC-45-3D-48	MB/SBP/3D	16:00	16.7120	62.0260	3.1	1034	89	89.08	0085	Box 1 Line 48
128	JC45-3D-48/49	MB/SBP/3D	16:07	16.7120	62.0219	2.9	1032	90	89.94	0085	End of Line 48. Start turn to 49.
128	JC45-3D-48/49	MB/SBP/3D	16:30	16.7293	62.0190	3.5	943	287	286.33	0085	Turn to line 49
128	JC45-3D-49	MB/SBP/3D	16:38	16.7298	62.0222	4.0	946	271	270.76	0085	End of turn.Start of Line 49.
128	JC45-3D-49	MB/SBP/3D	17:00	16.7298	62.0473	3.9	984	269	269.4	0085	Box 1 Line 49
128	JC45-3D-49	MB/SBP/3D	17:30	16.7298	62.0831	4.0	929	270	269.7	0085	Box 1 Line 49
128	JC45-3D-49/50	MB/SBP/3D	17:38	16.7299	62.0918	3.4	900	270	269.77	0085	End of Line 49. Start of turn to Line 50.
128	JC45-3D-49/50	MB/SBP/3D	18:00	16.7147	62.0997	3.5	859	137	136.9	0086	Turn to Line 50
128	JC45-3D-50	MB/SBP/3D	18:09	16.7145	62.0921	3.0	906	89	89.07	0086	End of Turn. Start of Line 50
128	JC45-3D-50	MB/SBP/3D	18:30	16.7114	62.0749	3.1	979	84	84.52	0086	Box 1 Line 50
128	JC45-3D-50	MB/SBP/3D	19:00	16.7114	62.0503	2.9	1034	84	84.01	0086	Box 1 Line 50
128	JC45-3D-50/51	MB/SBP/3D	19:30	16.7114	62.0220	2.9	1033	90	89.47	0086	End of Line 50. Start turn to Line 51.
128	JC45-3D-50/51	MB/SBP/3D	20:00	16.7284	62.0179	3.6	943	300	299.37	0087	Turn to Line 51
128	JC45-3D-51	MB/SBP/3D	20:05	16.7293	62.0253	3.6	953	275	274.57	0087	Start of line 51
128	JC45-3D-51	MB/SBP/3D	20:30	16.7293	62.0523	3.9	1001	269	269	0087	Line 51
128	JC45-3D-51	MB/SBP/3D	21:00	16.7293	62.0877	3.7	918	269	269.32	0087	Line 51

128	JC45-3D-51/52	MB/SBP/3D	21:13	16.7271	62.0988	3.3	858	227	227.47	0087	On turn, after end of line 51
128	JC45-3D-51/52	MB/SBP/3D	21:30	16.7130	62.0991	3.1	874	127	126.84	0087	On turn
128	JC45-3D-52	MB/SBP/3D	21:37	16.7109	62.0935	2.9	907	89	88.52	0087	Start of line 52
128	JC45-3D-52	MB/SBP/3D	22:00	16.7071	62.0711	2.9	983	84	84.03	0088	Line 52
128	JC45-3D-52	MB/SBP/3D	22:30	16.7109	62.0470	3.0	1037	85	84.53	0088	Line 52
128	JC45-3D-52	MB/SBP/3D	23:00	16.7109	62.0222	3.0	1035	84	84.18	0088	Line 52
128	JC45-3D-52/53	MB/SBP/3D	23:30	16.7286	62.0201	3.5	948	276	273.44	0088	Turn
128	JC45-3D-53	MB/SBP/3D	23:32	16.7287	62.0231	3.4	953	264	263.86	0088	Start Line 53
129	JC45-3D-53	MB/SBP/3D	00:00	16.7288	62.0530	3.9	1004	269	269.55	0089	Line 53
129	JC45-3D-53	MB/SBP/3D	00:28	16.7287	62.0874	3.9	921	270	269.36	0089	Box 1, line 53
129	JC45-3D-53/54	MB/SBP/3D	00:33	16.7288	62.0923	3.7	898	270	269.42	0089	Box 1, end of line 53
129	JC45-3D-53/54	MB/SBP/3D	01:00	16.7119	62.0985	2.9	884	122	121.28	0089	Box 1, turn from line 53to line 54
129	JC45-3D-54	MB/SBP/3D	01:06	16.7104	62.0926	3.4	914	88	88.15	0089	Box 1, start of line 54
129	JC45-3D-54	MB/SBP/3D	01:31	16.7104	62.0713	3.0	984	84	83.49	0089	Box 1, line 54
129	JC45-3D-54	MB/SBP/3D	01:51	16.7104	62.0532	3.0	1030	84	83.96	0090	Box 1, line 54, SBP restarted
129	JC45-3D-54	MB/SBP/3D	02:00	16.7104	62.0463	3.0	1038	84	83.69	0090	Box 1, line 54
129	JC45-3D-54/55	MB/SBP/3D	02:30	16.7104	62.0209	3.0	1036	82	81.31	0090	Box1, end of line 54
129	JC45-3D-54/55	MB/SBP/3D	03:00	16.7281	62.0209	3.3	952	276	275.1	0090	Box1, turn from line 54 to line 55
129	JC45-3D-55	MB/SBP/3D	03:02	16.7282	62.0228	3.6	954	270	269.59	0090	Box1, start of line 55
129	JC45-3D-55	MB/SBP/3D	03:30	16.7116	62.0573	4.2	998	270	269.66	0090	Box1, line 55
129	JC45-3D-55	MB/SBP/3D	04:00	16.7116	62.0902	3.4	898	270	269.05	0091	Box1, line 55
129	JC45-3D-55/56	MB/SBP/3D	04:02	16.7116	62.0922	3.3	898	270	269.97	0091	Box1, end of line 55
129	JC45-3D-55/56	MB/SBP/3D	04:30	16.7099	62.0947	3.0	915	94	92.78	0091	Turn onto line 56
129	JC45-3D-56	MB/SBP/3D	04:35	16.7098	62.0919	3.0	917	84	83.5	0091	Start of Line 56
129	JC45-3D-56	MB/SBP/3D	05:00	16.7098	62.0700	3.0	971	84	84.6	0091	Box 1 Line 56
129	JC45-3D-56	MB/SBP/3D	05:38	16.7098	62.0368	3.0	1043	80	80.1	0091	Box 1 Line 56
129	JC45-3D-56/57	MB/SBP/3D	05:57	16.7099	62.0213	2.7	1037	86	86.1	0092	End of line 56. Start turn to Line 57.
129	JC45-3D-56/57	MB/SBP/3D	06:29	16.7277	62.0221	3.8	956	270	269.62	0092	End of turn. Start Line 57.
129	JC45-3D-57	MB/SBP/3D	07:00	16.7277	62.0577	4.0	999	275	274.75	0092	Box 1, Line 57.
129	JC45-3D-57	MB/SBP/3D	07:20	16.7277	62.0815	2.5				0092	Slowed to 2.5 knots to avoid yacht
129	JC45-3D-57	MB/SBP/3D	07:28	16.7277	62.0888	3.5	888	274	274.98	0092	Back up to speed
129	JC45-3D-57/58	MB/SBP/3D	07:35	16.7277	62.0931	3.4	884	271	269.74	0092	End of line 57, turning onto line 58
129	JC45-3D-57/58	MB/SBP/3D	08:00	16.7098	62.0965	2.8	901	101	100.69	0093	turn
129	JC45-3D-58	MB/SBP/3D	08:05	16.7093	62.0922	2.9	919	84	83.49	0093	Start Line 58
129	JC45-3D-58	MB/SBP/3D	08:30	16.7093	62.0706	3.0	993	85	84.91	0093	line 58
129	JC45-3D-58	MB/SBP/3D	09:00	16.7093	62.0445	2.9	1040	85	84.93	0093	line 58
129	JC45-3D-58/59	MB/SBP/3D	09:24	16.7093	62.0235	3.0	1040	84	83.77	0093	End of line 58, start to turn
129	JC45-3D-58/59	MB/SBP/3D	09:30	16.7097	62.0186	2.9	1034	63	62.9	0093	Turn
129	JC45-3D-59	MB/SBP/3D	09:56	16.7271	62.0220	3.6	957	270	269.82	0094	Start Line 59
129	JC45-3D-59	MB/SBP/3D	10:00	16.7271	62.0257	3.9	963	269	269.26	0094	Line 59
129	JC45-3D-59	MB/SBP/3D	10:30	16.7271	62.0605	4.0	993	276	275.16	0094	line 59
129	JC45-3D-59/60	MB/SBP/3D	10:56	16.7271	62.0915	3.9	892	276	275.23	0094	end of line 59/ start to turn to line 60
129	JC45-3D-59/60	MB/SBP/3D	11:00	16.7268	62.0951	3.8	867	258	257.9	0094	on turn to line 60
129	JC45-3D-60	MB/SBP/3D	11:26	16.7255	62.0934	3.0	923	89	88.6	0094	start of line 60
129	JC45-3D-60	MB/SBP/3D	11:30	16.7087	62.0905	3.0	921	89	89.1	0094	line 60
129	JC45-3D-60	MB/SBP/3D	12:00	16.7087	62.0648	3.0	1008	84	84.28	0095	line 60
129	JC45-3D-60	MB/SBP/3D	12:30	16.7087	62.0387	2.9	1045	84	84.15	0095	Box 1, line 60
129	JC45-3D-60/61	MB/SBP/3D	13:00	16.7116	62.0148	2.9	1040	38	37.18	0095	Box 1, end of line 60, turn to line 61
129	JC45-3D-60/61	MB/SBP/3D	13:30	16.7266	62.0245	3.6	965	270	269.49	0095	Box 1, end of turn, start of line 61
129	JC45-3D-61	MB/SBP/3D	14:00	16.7266	62.0648	4.2	986	275	274.67	0096	Box 1, line 61
129	JC45-3D-61	MB/SBP/3D	14:24	16.7266	62.0923	3.5	890	270	269.12	0096	Box1, end of line 61
129	JC45-3D-61/62	MB/SBP/3D	14:30	16.7249	62.0983	3.4	847	233	232.2	0096	Box1, on turn
129	JC45-3D-62	MB/SBP/3D	14:57	16.7082	62.0922	2.9	930	88	88.58	0096	Box1, start of line 62
129	JC45-3D-62	MB/SBP/3D	15:00	16.7082	62.0899	3.0	930	87	86.21	0096	Box1, line 62
129	JC45-3D-62	MB/SBP/3D	15:30	16.7082	62.0634	3.2	1020	84	4.28	0096	Box1, line 62
129	JC45-3D-62	MB/SBP/3D	16:00	16.7082	62.0375	2.9	1047	85	84.91	0097	Box1, line 62
129	JC45-3D-62/63	MB/SBP/3D	16:16	16.7082	62.0220	2.9	1043	85	84.75	0097	End of Line 62.Start of turn to line 63.
129	JC45-3D-62/63	MB/SBP/3D	16:30	16.7118	62.0142	2.9	1042	26	25.28	0097	Turn onto line 63
129	JC45-3D-63	MB/SBP/3D	16:50	16.7261	62.0226	4.0	964	276	275.02	0097	Start of Line 63
129	JC45-3D-63	MB/SBP/3D	17:00	16.7261	62.0331	4.0	985	270	269.98	0097	Box 1, Line 63.
129	JC45-3D-63	MB/SBP/3D	17:30	16.7260	62.0716	3.9	975	270	269.36	0097	Box 1, Line 63.
129	JC45-3D-63/64	MB/SBP/3D	17:50	16.7261	62.0921	3.4	888	270	269.65	0098	End of Line 63. Start of turn Line 64.

129	JC45-3D-63/64	MB/SBP/3D	18:00	16.7205	62.1014	3.3	815	200	199.55	0098	Turning onto line 64
129	JC45-3D-64	MB/SBP/3D	18:23	16.7099	62.0933	2.9	927	84	84.04	0098	Start of Line 64
129	JC45-3D-64	MB/SBP/3D	18:30	16.7076	62.0868	3.0	940	84	84.19	0098	Box 1, Line 64.
129	JC45-3D-64	MB/SBP/3D	19:00	16.7077	62.0609	3.0	1035	89	89.02	0098	Box 1, Line 64.
129	JC45-3D-64	MB/SBP/3D	19:30	16.7076	62.0328	2.9	1051	89	88.48	0098	Box 1, Line 64.
129	JC45-3D-64/65	MB/SBP/3D	19:46	16.7077	62.0206	3.0	1042	83	82.18	0099	End of Line 64. Turn to Line 65.
129	JC45-3D-64/65	MB/SBP/3D	20:00	16.7155	62.0128	2.8	998	360	359.24	0099	on turn
129	JC45-3D-65	MB/SBP/3D	20:17	16.7255	62.0256	3.7	966	272	271.41	0099	start new line 65
129	JC45-3D-65	MB/SBP/3D	20:30	16.7255	62.0359	4.0	985	270	269.43	0099	line 65
129	JC45-3D-65	MB/SBP/3D	21:00	16.7256	62.0707	4.0	980	270	269.52	0099	line 65
129	JC45-3D-65/66	MB/SBP/3D	21:25	16.7235	62.0985	3.5	828	230.1	231	0099	End of line 65/Start to turn to line 66
129	JC45-3D-65/66	MB/SBP/3D	21:30	16.7197	62.1014	3.4	818	200	199.13	0099	Turn
129	JC45-3D-66	MB/SBP/3D	21:52	16.7071	62.0935	3.0	927	86	85.43	0100	Start of line 66
129	JC45-3D-66	MB/SBP/3D	22:00	16.7072	62.0866	2.8	938	85	84.97	0100	Line 66
129	JC45-3D-66	MB/SBP/3D	22:30	16.7071	62.0601	2.9	1031	85	84.45	0100	line 66
129	JC45-3D-66	MB/SBP/3D	23:00	16.7071	62.0340	3.0	1051	85	84.62	0100	line 66
129	JC45-3D-66/67	MB/SBP/3D	23:15	16.7071	62.0209	2.8	1043	80	79.07	0100	End of line 66 - Turn
129	JC45-3D-66/67	MB/SBP/3D	23:30	16.7155	62.0128	3.0	1000	355	354.22	0100	on turn
129	JC45-3D-67	MB/SBP/3D	23:44	16.7249	62.0215	3.4	969	268	267.64	0101	start of line 67
130	JC45-3D-67	MB/SBP/3D	00:00	16.7250	62.0368	3.9	986	270	269.72	0101	Line 67
130	JC45-3D-67	MB/SBP/3D	00:30	16.7249	62.0718	4.0	967	270	269.81	0101	Line 67
130	JC45-3D-67	MB/SBP/3D	00:49	16.7249	62.0950	3.9	865	270	269.44	0101	End of line 67
130	JC45-3D-67/68	MB/SBP/3D	01:00	16.7285	62.1054	3.9	816	318	318.14	0101	on turn
130	JC45-3D-67/68	MB/SBP/3D	01:30	16.7181	62.1205	3.5	682	136	134.95	0101	on turn
130	JC45-3D-68	MB/SBP/3D	02:00	16.7217	62.0981	2.9	834	90	88.94	0102	Start of Line 68
130	JC45-3D-68	MB/SBP/3D	02:30	16.7218	62.0718	2.9	975	85	84.48	0102	Line 68
130	JC45-3D-68	MB/SBP/3D	03:00	16.7218	62.0458	3.0	1028	84	84.08	0102	Line 68
130	JC45-3D-68	MB/SBP/3D	03:28	16.7217	62.0212	3.0	985	82	82.07	0102	End of line 68
130	JC45-3D-69	MB/SBP/3D	03:30	16.7219	62.0195	3.0	983	73	72.49	0102	On turn
130	JC45-3D-69	MB/SBP/3D	04:00	16.7413	62.0197	3.3	898	285	284.85	0103	On turn
130	JC45-3D-69	MB/SBP/3D	04:30	16.7426	62.0559	3.9	933	272	272.27	0103	Line 69
130	JC45-3D-69	MB/SBP/3D	05:00	16.7417	62.0913	3.4	920	269	268.61	0103	Line 69.
130	-	MB/SBP/2D	07:00	16.7238	62.0665	2.6	990	90	89.74	0104	air guns and streamer in water.
130	-	MB/SBP/2D	07:30	16.7383	62.0514	3.3	973	313	312.5	0104	Turning. On way to beginning of Profile 21.
130	JC45-21a	MB/SBP/2D	07:38	16.7401	62.0594	3.4	941	270	269.49	0104	Air guns to full pressure.
130	JC45-21a	MB/SBP/2D	08:00	16.7401	62.0812	4.0	933	270	269.38	0105	On short straight line approaching JC45-21
130	JC45-21a	MB/SBP/2D	08:18	16.7402	62.1016	3.9	870	264	262.96	0105	Start turn to port, approach to JC45-21
130	JC45-21a	MB/SBP/2D	08:30	16.7288	62.1075	3.9	802	177	176.6	0105	turn
130	JC45-21	MB/SBP/2D	08:32	16.7261	62.1068	3.8	801	155	154.34	0105	start line JC45-21
130	JC45-21	MB/SBP/2D	09:00	16.6999	62.0912	4.0	969	139	138.6	0105	Line JC45-21
130	JC45-21	MB/SBP/2D	09:30	16.6705	62.0735	3.9	1072	139	138.97	0105	Line JC45-21
130	JC45-21	MB/SBP/2D	10:00	16.6421	62.0564	3.9	1115	140	139.95	0106	Line JC45-21
130	JC-45-21	MB/SBP/2D	10:30	16.6133	62.0390	4.0	1132	139	138.28	-106	Line JC45-21
130	JC-45-21	MB/SBP/2D	11:00	16.5847	62.0209	3.9	1148	107	105.09	0106	Line JC45-21 to JC45-22 turn
130	JC-45-22	MB/SBP/2D	11:16	16.5929	62.0136	3.8	1146	343	343.44	0106	start of line JC45-22
130	JC-45-22	MB/SBP/2D	11:30	16.6088	62.0232	3.9	1125	340	338.04	0106	line JC45-22
130	JC-45-22	MB/SBP/2D	12:00	16.6376	62.0390	4.0	1128	341	340.22	0107	line JC45-22
130	JC-45-22	MB/SBP/2D	12:30	16.6659	62.0577	3.8	1090	341	340.96	0107	line JC45-22
130	JC-45-22	MB/SBP/2D	13:00	16.6949	62.0752	3.9	1017	344	343.77	0107	line JC45-22
130	JC-45-22	MB/SBP/2D	13:30	16.7243	62.0931	3.9	864	344	344.01	0107	line JC45-22
130	JC-45-22	MB/SBP/2D	13:37	16.7301	62.0966	2.9	876	329	331.51	0108	End of line JC45-22, start to turn
130	JC-45-23	MB/SBP/2D	13:53	16.7345	62.0896	3.6	913	148	145.81	0108	Start of line JC45-23
130	JC-45-23	MB/SBP/2D	14:00	16.7283	62.0858	3.6	944	134	133.17	0108	Line JC45-23
130	JC-45-23	MB/SBP/2D	14:30	16.7004	62.0691	3.8	1020	135	134.97	0110	2D line JC45-23
130	JC-45-23	MB/SBP/2D	15:00	16.6735	62.0529	3.7	1074	134	134.36	0110	2D line JC45-23
130	JC-45-23	MB/SBP/2D	15:25	16.6502	62.0390	3.8	1104	129	129.26	0110	2D line JC45-23
130	JC-45-23	MB/SBP/2D	16:00	16.6190	62.0203	3.6	1127	129	128.64	111	2D line JC45-23
130	JC-45-23	MB/SBP/2D	16:27	16.5926	62.0044	3.8	1149	134	133.9	0111	End of 2D line JC45-23
130	JC-45-24	MB/SBP/2D	16:56	16.6053	61.9835	3.7	1141	330	329.89	0111	Start of Profile JC45-24.
130	JC-45-24	MB/SBP/2D	17:30	16.6360	62.0020	3.8	1117	339	338.75	0111	Line 24.
130	JC-45-24	MB/SBP/2D	18:00	16.6635	62.0186	3.6	1100	340	339.51	0112	Line 24.
130	JC-45-24	MB/SBP/2D	18:32	16.6934	62.0368	3.7	1070	339	339.19	0112	Line 24.

130	JC-45-24	MB/SBP/2D	19:00	16.7184	62.0519	3.9	959	339	339.47	0112	Line 24.
130	JC-45-24	MB/SBP/2D	19:30	16.7480	62.0697	3.8	920	345	344.46	0112	Line 24.
130	JC-45-24	MB/SBP/2D	20:00	16.7730	62.0849	3.7	913	345	344.45	0113	Line 24.
130	JC-45-24	MB/SBP/2D	20:03	16.7761	62.0868	3.9	913	348	348.78	0113	Line 24 - Bend in line
130	JC-45-24	MB/SBP/2D	20:30	16.8038	62.0927	3.8	805	4	3.99	0113	Line 24
130	JC-45-24/25	MB/SBP/2D	20:35	16.8091	62.0938	3.9	800	8	8.08	0113	End of Line 24 - Start of turn
130	JC-45-25	MB/SBP/2D	20:58	16.8122	62.0762	3.6	827	168	166.93	0113	Start of Line 25
130	JC-45-25	MB/SBP/2D	21:00	16.8096	62.0756	3.8	832	158	157.41	0113	Line 25
130	JC-45-25	MB/SBP/2D	21:30	16.7796	62.0692	3.8	895	156	154.37	0113	Line 25
130	JC-45-25	MB/SBP/2D	22:00	16.7500	62.0515	3.9	906	131	130.57	0114	Line 25
130	JC-45-25	MB/SBP/2D	22:30	16.7222	62.0380	3.9	1004	131	131.14	0114	Line 25
130	JC-45-25	MB/SBP/2D	23:00	16.6934	62.0172	3.6	1066	131	130.93	0114	Line 25
130	JC-45-25	MB/SBP/2D	23:30	16.6656	62.0005	3.9	1087	126	125.7	0114	Line 25
131	JC-45-25	MB/SBP/2D	00:00	16.6348	61.9817	3.8	1043	127	126.58	0115	line 25
131	JC-45-25	MB/SBP/2D	00:08	16.6298	61.9787	4.0	975	114	112.53	0115	End of line 25, start to turn
131	JC-45-26	MB/SBP/2D	00:25	16.6369	61.9669	3.8	692	342	342.78	0115	Start of line 26
131	JC-45-26	MB/SBP/2D	00:30	16.6414	61.9695	3.4	797	345	344.29	0115	line 26
131	JC-45-26	MB/SBP/2D	01:00	16.6700	61.9870	4.0	1086	343	343.58	0115	line 26
131	JC-45-26	MB/SBP/2D	01:30	16.6999	62.0049	3.9	1073	344	343.62	0115	line 26
131	JC-45-26	MB/SBP/2D	02:00	16.7284	62.0222	3.9	950	345	344.21	0116	line 26
131	JC-45-26	MB/SBP/2D	02:30	16.7568	62.0395	3.8	880	352	350.35	0116	line 26
131	JC-45-26/27	MB/SBP/2D	02:58	16.7841	62.0561	3.7	874	324	322.95	0116	Start turn from line 26 to 27
131	JC-45-26/27	MB/SBP/2D	03:06	16.7861	62.0644	4.0	879	239	239.5	0116	End turn from line 26 to 27
131	JC-45-27	MB/SBP/2D	03:30	16.7724	62.0872	3.9	914	233	232.51	0116	line 27
131	JC-45-27	MB/SBP/2D	04:00	16.7547	62.1166	3.4	681	233	233.28	0118	line 27
131	JC-45-27/28	MB/SBP/2D	04:06	16.7511	62.1218	3.4	576	214	212.88	0117	End of line 27, start of turn to line 28
131	TURNING	MB/SBP/2D	04:07	16.7456	62.1221	3.4	576	158	157.94	0117	turning
131	TURNING	MB/SBP/2D	04:30	16.7794	62.1159	3.6	733	152	152.31	0117	turning
131	TURNING	MB/SBP/2D	04:41	16.7193	62.1119	3.4	753	143	140.55	0117	turning
131	JC-45-28	MB/SBP/2D	04:50	16.7176	62.1045	3.3	866	57	56.74	0117	start of line 28
131	JC-45-28	MB/SBP/2D	05:00	16.7231	62.0952	3.4	848	57	56.36	0117	line 28
131	JC-45-28	MB/SBP/2D	05:32	16.7392	62.0685	3.5	951	58	57.48	0117	line 28
131	JC-45-28	MB/SBP/2D	06:00	16.7545	62.0433	3.5	887	58	57.73	0118	line 28
131	JC-45-28	MB/SBP/2D	06:30	16.7699	62.0178	3.4	847	63	61.45	0118	line 28
131	JC-45-28	MB/SBP/2D	06:33	16.7708	62.0162	3.4	845	63	63	0118	end of line 28
131	TURNING	MB/SBP/2D	07:00	16.7535	61.9976	3.4	828	148	149.55	0118	turning
131	JC-45-29	MB/SBP/2D	07:08	16.7478	61.9997	3.3	843	222	224	0118	start of line 29
131	JC-45-29	MB/SBP/2D	07:30	16.7361	62.0189	3.4	917	238	237.37	0118	line 29
131	JC-45-29	MB/SBP/2D	08:00	16.7215	62.0430	3.5	1020	237	236.79	0119	Line 29
131	JC-45-29	MB/SBP/2D	08:30	16.7036	62.0725	3.9	1012	237	237.04	0119	line 29
131	JC-45-29	MB/SBP/2D	09:00	16.6864	62.1010	3.8	995	237	237.31	0119	line 29
131	JC-45-29/30	MB/SBP/2D	09:17	16.6770	62.1164	3.3	832	238	237.7	0119	End of Line 29. Start turn to Line 30.
131	JC-45-29/30	MB/SBP/2D	09:30	16.6674	62.1172	3.4	910	150	149.5	0119	turn line 29 to line 30
131	JC-45-30	MB/SBP/2D	09:44	16.6597	62.1056	4.0	1028	55	54.81	0119	Start of Line 30
131	JC-45-30	MB/SBP/2D	10:00	16.6695	62.0916	4.2	1062	54	52.75	0120	Line 30
131	JC-45-30	MB/SBP/2D	10:30	16.6875	62.0598	4.0	1059	57	57.32	0120	Line 30
131	JC-45-30	MB/SBP/2D	11:00	16.7040	62.0325	3.9	1059	66	66.43	0120	Line 30
131	JC-45-30	MB/SBP/2D	11:30	16.7213	62.0038	3.9	963	63	62.86	0120	Line 30
131	JC-45-30	MB/SBP/2D	11:38	16.7268	61.9946	3.8	948	63	62.12	0120	Line 30 (start to turn)
131	JC-45-30/31	MB/SBP/2D	12:00	16.7162	61.9787	3.5	987	154	153.55	0121	on turn
131	JC-45-31	MB/SBP/2D	12:14	16.7055	61.9784	3.4	802	241	241.3	0121	Start of line 31
131	JC-45-31	MB/SBP/2D	12:30	16.6960	61.9942	3.8	1060	233	232.55	0121	line 31
131	JC-45-31	MB/SBP/2D	13:00	16.6783	62.0237	4.0	1084	233	232.64	0121	line 31
131	JC-45-31	MB/SBP/2D	13:30	16.6607	62.0528	3.8	1093	234	232.98	0121	line 31
131	JC-45-31	MB/SBP/2D	14:00	16.6429	62.0822	3.8	1076	233	233.39	0122	line 31
131	JC-45-31/32	MB/SBP/2D	14:11	16.6365	62.0932	3.8	1048	246	246.5	0122	turn from line 31 to line 32
131	JC-45-32	MB/SBP/2D	14:30	16.6384	62.1159	4.0	1003	288	287.4	0122	line 32
131	JC-45-32	MB/SBP/2D	15:00	16.6428	62.1498	3.8	832	287	287.28	0122	line 32
131	JC-45-32	MB/SBP/2D	15:30	16.6475	62.1855	3.9	720	288	287.32	0122	line 32
131	JC-45-32	MB/SBP/2D	16:00	16.6517	62.2184	3.9	685	288	287.56	0123	line32
131	JC-45-32	MB/SBP/2D	16:30	16.6394	62.2345	3.5	757	108	108.35	0123	Approaching start of line 33.
131	JC-45-33	MB/SBP/2D	17:00	16.6339	62.2002	4.0	780	94	92.74	0123	Line 33.
131	JC-45-33	MB/SBP/2D	18:00	16.6243	62.1287	3.9	972	88	87.87	1024	Line 33.
131	JC-45-33	MB/SBP/2D	18:30	16.6199	62.0957	4.1	1046	86	86.17	0124	Line 33.

131	JC-45-33	MB/SBP/2D	18:45	16.6176	62.0789	3.8	1074	79	78.5	0124	Turn to Port in Line 33.
131	JC-45-33	MB/SBP/2D	19:00	16.6244	62.0648	4.1	1101	53	52.92	0124	Line 33.
131	JC-45-33	MB/SBP/2D	19:30	16.6434	62.0333	3.9	1112	57	56.45	0124	Line 33.
131	JC-45-33	MB/SBP/2D	20:00	16.6604	62.0055	4.0	1098	63	62.67	0125	line 33
131	JC-45-33/34	MB/SBP/2D	20:26	16.6758	62.9798	4.0	930	65	64.11	0125	End of line 33, start to turn
131	JC-45-33/34	MB/SBP/2D	20:30	16.6769	62.9746	3.3	834	116	117.06	0125	On turn
131	JC-45-34	MB/SBP/2D	20:47	16.6587	62.9689	4.1	969	232	232.01	0125	Start line 34
131	JC-45-34	MB/SBP/2D	21:02	16.6533	62.9780	4.0	1074	239	238.64	0125	Line 34
131	JC-45-34	MB/SBP/2D	21:30	16.6374	62.0042	3.9	1117	228	227.2	0125	line 34
131	JC-45-34	MB/SBP/2D	22:00	16.6174	62.0374	4.5	1131	232	232.3	0126	line 34
131	JC-45-34	MB/SBP/2D	22:30	16.5987	62.0693	4.1	1085	253	256.1	0126	Line 34, after bend in line
131	JC-45-34	MB/SBP/2D	23:01	16.6044	62.1110	4.3	1012	285	284.7	0126	Line 34
131	JC-45-34	MB/SBP/2D	23:30	16.6098	62.1475	4.6	933	286	285	0126	Line 34

APPENDIX 3

TOBI: Technical Specification.

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

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Mechanical	
Towing method	Two bodied tow system using neutrally buoyant vehicle and 600kg depressor weight.
Size	4.5m x 1.5m x 1.1m (lxhxw).
Weight	2500kg in air.
Tow cable	Up to 10km armoured coax.
Umbilical	200m long x 50mm diameter, slightly buoyant.
Tow speed	1.5 to 3 knots (dependent on tow length).
Sonar Systems	
Sidescan Sonar	
Frequency	30.37kHz (starboard) 32.15kHz (port).
Pulse Length	2.8ms.
Ouput Power	600W each side.
Range	3000m each side.
Beam Pattern	0.8 x 45 degree fan.
Profiler Sonar	
Frequency	6 to 10kHz Chirp.
Pulse Length	26ms.
Output Power	1000W.
Range	>50ms penetration over soft sediment.
Resolution	0.25ms
Beam Pattern	25 degree cone.
Standard Instrumentation	
Magnetometer	Ultra Electronics Magnetics Division MB5L.
Range	+/- 100,000nT on each axis.
Resolution	0.2nT.
Noise	+/- 0.4nT.
CTD	Falmouth Scientific Instruments, Micro CTD.
Conductivity:	
Range	0 to 65 mmho/cm.
Resolution	0.0002 mmho/cm.
Accuracy	+/- 0.005 mmho/cm.
Temperature:	
Range	-2 to 32° Celcius.
Resolution	0.0001° C.
Accuracy	+/- 0.005° C.
Depth:	
Range	0 to 7000 dbar.
Resolution	0.02 dbar.

Accuracy	+/-0.12% F.S.
Heading	S.G. Brown SGB 1000U gyrocompass.
Resolution	0.1 degrees.
Accuracy	Better than 1°, latitude < 70°.
Pitch/Roll	Dual Axis Electrolytic Inclinometer.
Range	+/- 20 degrees.
Resolution	0.2 degrees.
Altitude	Taken from profiler sonar.
Range	1000m.
Resolution	1m.

Additional Instrumentation

Light back-scattering sensor	WET labs LBSS
Source	2 x 880nm LEDs
Detector	Solar-blind silicon light detector
Range	~10mg/l
Resolution	0.01% F.S., ~1ug/l

APPENDIX 4
TOBI image processing

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

```
suppress_tobi -i %1 -o %0 –s9
widealt -i %1 -o %0 -r 3.0 -w2,25,5,4 –p
mrgnav_inertia -i %1 -o %0 -u 147 -n navfile.veh_nav
tobtvg -i %1 -o %0 -l 100
tobslr -i %1 -o %0 -r 3.0 , res
edge16 -i %1 -o %0 -m
drpout -i %1 -o %0 -u -f -p -k 401
drpout -i %1 -o %0 -u -f -p -k 101
shade_tobi -i %1 -o %0 -t1,4095 –n 1000
increm –i %1 –o %0
```

To explain this in sonar terms (in order):

- Removal of any surface reflection (i.e. from vehicle to the sea surface and back) – generally only a problem in shallower water depths, where a bright stripe or line is seen semi-parallel to the ship's track. Removal is only done when the imagery is unambiguous, whether the line is true artefact and not an actual seafloor feature. The result can sometimes be seen on the final imagery as a faint dark line. The width of the artefact correction is 9 pixels.
- Smoothing of the altitude of the vehicle above the seafloor. The altimeter sometimes cannot locate the seafloor, possibly due to very soft sediment thus reducing the return profiler signal. Smoothing is done by a median filter of the given values, comparing this with the first return seen on the port and starboard sides, and applying a maximum threshold for altitude change if first return and altitude value differ. Generally first return values are used, as these values will be used in the slant-range correction too.
- Merging of ship navigation and cable data with the imagery and calculation of the TOBI position using an inertial navigation algorithm. The 'navfile.veh_nav' file contains ship position and cable values and an umbilical length of 100metres plus an additional 47 metres for the distance between the GPS receiver and the approximate point where the cable enters the water. The cable values from the shipboard winch system were used in the TOBI cable file. Various assumptions are applied: the cable is assumed to be straight, the cable value is assumed to be correct, and zero cable is set when the depressor enters the water.
- Uses the TOBI compass heading. A smoothing filter of 100 pings is applied. The heading values are used in the geographic registration process to angle each ping relative to the TOBI position.

- Slant-range correction assuming a flat bottom. This is a simple Pythagoras calculation assuming that the seafloor is horizontal across-track and sound velocity is $1500ms^{-1}$. Each pixel is 8ms and generally equates to 6 metre pixel size (here a pixel size of 3 metres is used); any pixel gaps on the output file are filled by pixel replication.
- A median filter to remove any high or bright speckle noise. A threshold is defined for the maximum deviation for adjoining pixels over a small area above which the pixel is replaced by a median value.
- Dropout removal for large imagery dropouts. When the vehicle yaws excessively, it is possible for the 'transmit' and 'receive' phase of each ping to be angled apart. If this exceeds the beam sensitivity value (0.8º) little or no signal is received, creating a dark line on the imagery. The program detects the dropout lines and interpolates new pixel values. If more than 7 dropouts are present concurrently (28 seconds) no interpolation is done.
- More dropout removal but for smaller, partial line dropouts. If more than 7 partial dropouts are present concurrently (28 seconds) no interpolation is done.
- Across-track equalisation of illumination on an equal range basis. This assumes that the backscatter from a particular range should average a given amount for each piece of data. The near-range pixels and far-range pixels are generally darker than mid-range pixels. This is due to the transducer’s beam pattern and differences in seafloor backscatter response in terms of angle of incidence. The result of this is to amplify the near and far-range pixels by about 1.5 and reduce the mid-range pixels by 0.8.
- Adds a pixel value of 1 to each pixels to avoid zero pixel values that would appear white on a transparent or white background, e.g. when printing maps.

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

The second phase (of mosaicing) allows the user to view all the ‘layers’ of data for an area. The software used is a commercial package named ERDAS Imagine (v9.3). Within this software the different layers can be displayed in different colours to distinguish the layers with data that will overlap data from another layer. In order to merge the different layers and their data together, polygons (Areas of Interest –or AOI) are drawn by the user to define the join lines between layers and then applied to create a single layer final image map. This procedure can also be used to remove shadow zones and areas of no data. The program that merges all data within selected AOIs into the final single layer image is called ‘addstencil’. Several of these final images can then be mosaiced together into a big image from which maps can be created in different projections and spheroids, including scales, co-ordinates and text. Also annotation such as ship's track, vehicle track and dates and times can be added to the map. The map can then be plotted on the A0 plotter and/or converted into other format e.g. TIFF, JPEG, generic postscript etc. to be used for further analysis on PC, Macintosh or UNIX workstations.