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CRUISE REPORT No. 46

RV *PELAGIA* CRUISE 64PE219
05 NOV – 24 NOV 2003

TOBI surveys of Setubal and Nazarre Canyons and
of the MV *Prestige* wreck site, west of Iberia

Principal Scientist
D G Masson

2003

Challenger Division for Seafloor Processes
Southampton Oceanography Centre
University of Southampton
Waterfront Campus
European Way
Southampton
Hants SO14 3ZH
UK

Tel: +44 (0)23 8059 6568
Fax: +44 (0)23 8059 6554
Email: dgm@soc.soton.ac.uk

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ABSTRACT

The main objective of the cruise was to collect TOBI sidescan sonar imagery over three areas of the continental margin west of Iberia, where sediment transport studies are being undertaken as part of the EC funded 'EUROSTRATFORM' project. The three study areas were:

1. The Setubal Canyon, between 38° to 38° 20'N on the continental margin. Here it was planned to image the canyon with a single 6 km-wide swath from the shelf edge near 200m to the abyssal plain at depths exceeding 4800m

2. The Nazarre Canyon, between 39° 30' and 40°N on the continental margin. The survey plan was similar to that for Setubal Canyon, but with two parallel swaths over the lower reaches of the canyon, where it broadens into a 10 km wide channel crossing the continental rise.

3. The *Prestige* tanker wreck site, at 42°N, 12°W, on the west flank of Galicia Bank, off northwest Spain. Here the aim was to investigate the stability of the slope where the tanker was lying. This part of the project was carried out jointly with UTM-CMIMA (CSIC), Barcelona, Spain.

Although some time was lost to bad weather and equipment problems, excellent TOBI images were obtained over all three of the areas studied during *Pelagia* cruise 219. The cruise objectives were fully completed in areas 1 and 3, and about 60% of the expected area was surveyed in area 2, where almost three days were lost to bad weather.

KEYWORDS

continental margin, cruise 64PE219 2003, EUROSTRATFORM, Galicia Bank, Iberia waters, Nazarre Canyon, *Pelagia*, *Prestige*, Setubal Canyon, sidescan sonar, submarine canyons, TOBI, wrecks

ISSUING ORGANISATION

Southampton Oceanography Centre
Empress Dock
European Way
Southampton SO14 3ZH UK

Copies of this report are available from: **National Oceanographic Library, SOC** *PRICE*: £6.00
Tel: +44(0)23 80596116 Fax: +44(0)23 80596115 Email: nol@soc.soton.ac.uk

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SCIENTIFIC PERSONNEL

MASSON, D.G. (Principal Scientist)	Southampton Oceanography Centre, UK
ROUSE, I.P.	Southampton Oceanography Centre, UK
FOWLER, L.	Southampton Oceanography Centre, UK
WHITTLE, S.P.	Southampton Oceanography Centre, UK
HÜHNERBACH, V.	Southampton Oceanography Centre, UK
SORHOUET, S.	Southampton Oceanography Centre, UK
ALVES, T.M.	Instituto Geologico e Mineiro, Portugal
MARIN, M.A.	UTM-CMIMA (CSIC), Spain
GARCIA, M.	UTM-CMIMA (CSIC), Spain

SHIPS PERSONNEL

LEEUW, C.O.	Master

ITINERARY

Departed	Lisbon	5th, November, 2003
Arrived	Southampton	23rd November, 2003

CRUISE OBJECTIVES

The main objective of the cruise was to collect TOBI sidescan sonar imagery over three areas of the continental margin west of Iberia, where sediment transport studies are being undertaken as part of the EC funded 'EUROSTRATFORM' project. The three study areas (Fig. 1) were:

1. The Setubal Canyon, between 38° to 38° 20' N on the continental margin. Here it was planned to image the canyon from the shelf edge near 200 m to the abyssal plain at depths exceeding 4800 m. A single 6 km wide swath was envisaged in the upper reaches of the canyon, with two or more parallel lines covering the abyssal plain region where the canyon broadened to form a fan-like depositional body.
2. The Nazarre Canyon, between 39° 30' and 40° N on the continental margin. The survey plan was similar to that for Setubal Canyon, but with two parallel swaths over the lower reaches of the canyon, where it broadens into a 10 km wide channel crossing the continental rise.
3. The *Prestige* tanker wreck site, at 42°N, 12°W, on the west flank of Galicia Bank, off northwest Spain. Here the aim was to investigate the stability of the slope where the tanker was lying. This part of the project was carried out jointly with UTM-CMIMA (CSIC), Barcelona, Spain.

NARRATIVE

3rd November, 2003.
0900-2000. Began loading TOBI equipment onto the RV *Pelagia*

4th November, 2003.
0800-2000. Completed mobilisation of TOBI onboard *Pelagia*. Despite problems with the logging system, decided not to change planned sailing at 0800 on the 5th.

5th November, 2003.
0800. Sailed from Lisbon.
0800-1200. Passage to first TOBI deployment site at the head of Setubal Canyon (Table 1).
1200-2400. Hove to. TOBI logging system still giving problems. Decided to request that a replacement logging computer be sent from UK.

6th November, 2003.
0800-0900. After discussion with UKORS personnel in Southampton, it was decided that spares for the TOBI logging system should be brought from the UK by an additional engineer (C. Flewellen), with experience of the TOBI logging system.
0900-1200. Proceeded back to anchor off Cascais, at the mouth of the Tagus estuary, to await arrival of engineer from the UK.
1200-2400. At anchor off Cascais. C. Flewellen came aboard at 2000 carrying spares including a replacement logging computer. It quickly became apparent that the logging problem related to a fault in the original logging computer. After some modification of the replacement computer, to ensure compatibility with the rest of the onboard system, it was installed and all logging problems were solved. Tests were completed by 2300 at which time it was decided that we would remain at anchor overnight so that C. Flewellen could go ashore again before we sailed.

7th November, 2003.
0815. C. Flewellen ashore by water taxi.
0815-1300. Passage to start of survey in Setubal Canyon.
1300-1340. Launch TOBI.
1410. Start TOBI logging
1410-2400. TOBI survey of Setubal Canyon, in calm seas with no wind.

8th November, 2003.
0000-2400. TOBI survey of Setubal Canyon. Weather good, with little wind, but moderate swell from the northwest.

9th November, 2003.
0000-2400. TOBI survey of Setubal Canyon and proximal Tagus Abyssal Plain. Weather deteriorated during the early morning, wind increasing to Force 8 from the west by 0800. Later decreased to 6/7. However, this restricted survey to a continuing single westerly line.

10th November, 2003.
0000-0609. Continue TOBI survey westward across Tagus Abyssal Plain.
0609. End survey line 1. With weather improving, decided to recover TOBI and steam back to lower part of Setubal Canyon to complete survey of canyon mouth area.
0610-1005. Haul in wire and recover TOBI.
1005-1830. Passage to start of survey line 2.
1830-1905. Launch TOBI. Weather now good. Little wind and low northerly swell
1905-2400. TOBI survey of distal Setubal Canyon.

11th November, 2003.
0000-1604. TOBI survey of distal Setubal Canyon. Weather excellent, no wind and little swell.
1604-2005. Haul in wire and recover TOBI.
2005-2400. Passage to Nazarre Canyon survey area.

12th November, 2003.
0000-0820. Passage to Nazarre Canyon survey area. Weather excellent, no wind and little swell.
0820-0850. Launch TOBI
0851-2400. TOBI survey of Nazarre Canyon.

13th November, 2003.
0000-2400. TOBI survey of Nazarre Canyon. Weather excellent, no wind and moderate swell.

14th November, 2003.
0000-1026. TOBI survey of Nazarre Canyon. Weather excellent, no wind and moderate swell.
0830-1020. Increased ship speed to allow all of the TOBI tow cable to be paid out and then rewound under full load. This allowed the cable to spool in a more regular manner than had previously been occurring.
1026. Terminated TOBI survey due to deterioration of the starboard sidescan imagery. This problem had been progressively increasing over a period of about 12 hr, and with bad weather forecast, it seemed prudent to make repairs at this time.
1026-1430. Haul in wire and recover TOBI. from the west and northwest, while carrying out repairs to TOBI. Problem was traced to one element in the sidescan sonar array. This was isolated from the array with only a minimum degradation of the sonar signal.
2200-2235. Launch TOBI.

2235-2400. TOBI survey of the lower part of Nazarre Canyon. Moderate swell but the forecast strong winds had not yet arrived.

15th November, 2003.

0000-1926. TOBI survey of the lower part of Nazarre Canyon. Weather deteriorated throughout the day from westerly force 6 in the morning to northwest force 8/9 by early evening. Survey continued, however, with only a small reduction in data quality due to ship motion being transferred to TOBI. Some noise appeared on the records as the day progressed, suggesting damage to either the umbilical or the swivel due to the severe vessel motion.

1926. Forced to abandon survey as wind increased to 9/10 (gusts up to 28 m s^{-1}). Shortened main cable to 2000 m and altered course into wind.

1926-2400. Heading into wind awaiting improvement in weather.

16th November, 2003.

0000-2400. Heading into wind awaiting improvement in weather. TOBI short hauled on 1500 m cable. Slow improvement from 9/10 to 8/9 during the day but sea still very rough.

17th November, 2003.

0000-2400. Heading into wind awaiting improvement in weather. Wind decreased to force 7 but sea still rough. With forecast for further weather improvement, decided to wait for sea to decrease before recovering TOBI.

18th November, 2003.

0000-0700. Heading into wind awaiting improvement in weather. At first light it could be seen that wind had decreased to force 4/5 and seas were much reduced.

0700-0845. Haul in remaining wire and recover TOBI.

0845-1400. Steam to start of the *Prestige* tanker wreck site while repairing damage to TOBI (no electrical connection through the umbilical) caused by prolonged towing in bad weather.

1400-1654. Launch TOBI and pay out tow wire.

1655. Excessive noise seen on TOBI monitors suggests further umbilical or swivel damage.

1655-2045. Recover TOBI.

2045-2400. Repair TOBI umbilical and change swivel.

19th November, 2003.

0003-0200. Launch TOBI and pay out tow cable.

0200-2400. TOBI survey of *Prestige* site.

20th November, 2003.

0000-1030. TOBI survey of *Prestige* site.

1030-1400. Haul in tow wire and recover TOBI.

1400-2400. Passage to Southampton.

21st November, 2003.

0000-2400. Passage to Southampton.

22nd November, 2003.

0000-2400. Passage to Southampton. Slow progress due to bad weather.

23rd November, 2003.

0000-2000. Passage to Southampton. Slow progress due to bad weather.

2000-2400. In port awaiting demobilisation.

24th November, 2003.
0000-0800. In port awaiting demobilisation.
0800-1300. Demobilisation
1300. Cruise completed. *Pelagia* sailed for Texel.

EQUIPMENT REPORTS
TOBI System Description
TOBI - Towed Ocean Bottom Instrument - is Southampton Oceanography Centre's deep towed vehicle. It is capable of operating in 6000 m of water. The maximum water depth encountered during the TOBI surveys during this cruise was around 5000 m.

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. 30 kHz sidescan sonar with swath bathymetry capability (Built by IOSDL)
2. 8 kHz 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. Gyrocompass (S.G.Brown SGB 1000U)
7. Light backscattering sensor (WET labs LBSS)

A full specification of the TOBI instrumentation is given in Appendix 1.

An Autohelm ST50 GPS receiver provides the TOBI logging system with navigational data. An MPD 1604 9 tonne instrumented sheave provides wire out, load and rate information both to its own instrument box and wire out count signals to the logging system.

The TOBI system uses a two-bodied tow system to provide a highly stable platform for the on-board sonars. The vehicle weighs 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 600 kg depressor weight. This in turn is connected via a conducting swivel to the main armoured coaxial tow cable. All signals and power pass through this single conductor.

For this cruise the SOC TOBI winch system, purchased using European funding, was utilised. This system combines tow, launch and umbilical winches onto one standard 20’ container-sized base plate enabling one winch driver to control all operations. The winch was secured to the aft deck using a custom made base plate that made use of the container fixings on the deck of the *Pelagia*. This fixing method has been used on the three previous occasions that TOBI has been used on *Pelagia* and provides a very strong and secure mount for the 28 tonne winch. During the surveys the winch was controlled from a remote station in the TOBI laboratory.

The deck electronic systems and the logging and monitoring systems were set up in the small laboratory on the starboard side of the ship. The TOBI replay computer was mounted in the chemistry laboratory just forward of the TOBI laboratory. As TOBI has been used previously on the ship, mobilisation of the major components was easily accomplished in less than 12 hours.

TOBI Deployments
The *Pelagia* is equipped with a wide stern mounted hydraulic 'A' frame that allows TOBI to be deployed and recovered in an athwartships position. This gives good control of the vehicle during these operations. The main sheave was used for deploying and recovering the depressor weight and

the TOBI vehicle. The main sheave was used for towing during the survey. No problems were encountered during any of the launch or recovery operations, which is a very great credit to the deck crews involved.

TOBI was launched and recovered a total of 6 times during the cruise. The times are listed below along with relevant comments:

Deployment	Start time/day	End time/day	Comments
1	14:08/311	06:10/314	Gyro not locking in.
2	19:42/314	17:21/315	Gyro disconnected.
3	08:51/316	14:23/318	Low signal on starboard sidescan.
4	22:34/318	20:08/319	Break off due to weather.
5a	14:27/322	19:03/322	Run curtailed due to noise on sidescan
5b	00:03/323	11:48/324	Galicia bank area.

The M-O disks used and their relevant numbers, files and times are listed in Appendix 2.

TOBI Watchkeeping

TOBI watchkeeping was split into three, four-hour watches repeating every 12 hours. Watchkeepers kept the TOBI vehicle flying at a height of ideally 350 to 400 m above the seabed by varying wire out and/or ship speed. Ship speed was usually kept at 2.5 knots over the ground with fine adjustments carried out by using the winch. As well as flying the vehicle and monitoring the instruments watchkeepers also kept track of disk changes and course alterations.

The bathymetry charts of the work area were found to be quite accurate which helped immensely when flying the vehicle. The ship's ORETECH profiler was used with a new design of SOC profiler display and control system mounted in the TOBI lab to give the watchkeepers a read out of water depth.

TOBI Instrument Performance

Vehicle

For the first four runs the vehicle performed well. During the fourth run noise became apparent on the sidescan and profiler records. Due to the poor weather conditions the vehicle could not be recovered for over two days. On recovery damage to the conducting cable in the umbilical was found. After unsuccessfully trying to repair the damage it was decided to swap the umbilical for the spare. The vehicle was launched for run five but at a depth of around 2500 m noise reoccurred on the sonar records and the depressor was recovered to swap the swivel – the most likely cause of the noise. On powering up the vehicle after this operation an intermittent open circuit was found. By measuring the capacitance of the umbilical the fault was found to be close to the depressor end of the umbilical. The vehicle was recovered and the damaged part of the umbilical cut off and a new termination made. This umbilical successfully completed the cruise.

Profiler

For recent cruises the profiler had been fine tuned to give best results over soft sediment areas. For the terrain covered during this cruise the receiver gain had to be increased from 2 to 5 to enable tracking by the logging computer. Between runs 3 and 4 a check was made of the resistance of each of the ceramic ring elements. The lowest resistance ring was found to be 1 Mohm; this element was isolated for the remainder of the cruise.

Sidescan

During run 3 it was observed that the starboard sidescan signal was getting weaker. On recovery of the vehicle the array cable harness was found to be perished at one place and one transducer element measured low resistance. Replacing the harness and isolating the transducer element affected a cure. Apart from this the sidescan gave excellent records throughout the cruise.

Magnetometer

The unit worked well throughout the cruise. An incorrect reading of the x value was observed in the logged data every 12 s, which may be explained by the asynchronous nature of the A/D converter for the unit leading to readings during a sonar transmission. No calibration of the magnetometer in the vehicle was undertaken although there should be enough data within the survey to carry one out post cruise.

Gyro

During the first run it was noted that the gyro did not settle to give a heading value. Testing on deck before run 2 gave large swings in current. It was felt that this could damage other parts of the system so the gyro was disconnected for subsequent runs.

CTD

For the majority of the cruise the CTD worked perfectly. From the second run onwards intermittent incorrect readings were observed from the pressure sensor when the unit was at a depth of less than 1000 m. As the majority of the runs were at greater depths this was not a problem. The incorrect readings could be linked to the disconnection of the gyro as they share a common interface or it may just be an error in the CTD itself. The CTD data is used to give derived local sound speed and salinity.

Pitch/Roll

This unit performed admirably for the whole cruise.

LSS

The light scattering sensor was used throughout the cruise. No obviously significant targets were observed although a more thorough examination of the data may reveal more.

Swath bathymetry

This cruise built on the work done previously to enhance the swath system. The problem previously encountered with the swath processor card has now been fixed. On this cruise a problem of duplicate signals being repeated sent to the deck unit was found. This could be caused by conflicting interrupts on the processor card or the processor not receiving the trigger signal. With little time between deployments investigation could not be carried out. From the results of this cruise it could be seen that there is a good 1.5 km range for the starboard swath with approximately 1km for the port side. The port side seemed to suffer from periods where the far range was washed out by a strong, non-acoustic signal. The port side seemed to have a poorer beam pattern also. These observations will be investigated at SOC.

Deck Unit

The system proved very reliable in operation throughout the cruise. A voltage of 350 V was used to power the vehicle with a current of approximately 300 mA.

Instrumented Sheave

The sheave performed mechanically very well throughout the cruise. The wire out meter proved extremely accurate, being less than 5 m out at the end of each survey run.

Winch

The winch was reliable throughout the cruise. In order to correctly tension the tow cable after it was wound on prior to the cruise the cable was paid out to the last lay and rewound onto the winch.

This operation was conducted on run 3 in approximately 5000 m of water, speeding up the ship to around 2.5 knots to stream the cable safely away from the sea floor. The cable was washed with fresh water during the final runs to prevent corrosion due to salt. The winch could benefit from a calibration of the valve control electronics in order to give a more linear control. This could be done at SOC.

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 GPS receiver and wire out from the sheave. Data was recorded using TOBI programme LOG.

As well as recording sidescan and digital telemetry data LOG displays real-time slant range corrected sidescan and logging system data, and outputs the sidescan to a Raytheon TDU850 thermal recorder. PROFDISP displays the chirp profiler signals and outputs them to a Raytheon TDU850. 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 on board image processing system. On M-O disk 886 the wrong date was recorded. This was corrected using programme DAYFIX prior to copying onto CD-ROM.

At the start of the cruise a problem with the logging computer lead to a spare system having to be flown out from SOC. This seriously delayed the start of data gathering part of the cruise and is a sign that the TOBI computers are getting near to the end of their useful life – they are 8.5 years old now. Replacements need to be sought along with perhaps a rethink on the rest of the computer hardware.

Summary

The system performed well overall and produced some excellent sidescan imagery. It is clear that some of the system components are nearing the end of their useful life and a review of the TOBI deck computer requirements is probably overdue. New umbilical cables need to be procured in good time for future cruises.

TOBI technical reference:

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

e-mail: ianr@soc.soton.ac.uk   url: http://www.soc.soton.ac.uk

3.5 kHz Profiler

In order to fly TOBI effectively and safely it is essential to provide a read out of the water depth in the TOBI laboratory. For this cruise the ship's ORETECH profiler was used with a new prototype design of SOC profiler display and control system.

The SOC display and control system is a PC running Microsoft Windows 2000 with a hardware interface box and a Raytheon TDU850 thermal line printer. Trigger signals are generated by the system and fed to the Oretech transceiver in the ship's computer room using a BNC cable. Likewise received signals are sent from the transceiver to the SOC display system.

In operation the display and control system proved easy to use and suffered no programme crashes in over 14 days of use. The system is based on a 1 second cycle. Each cycle may be edge trigger, centre trigger, receive or gate. Combinations of these cycles provide a 750 m receive window for each depth range from 0 to 5600 m. Some programming bugs were evident in certain depth range combinations giving rise to striped images and virtual seafloor reflections. These did not seriously compromise the systems performance and will be easy to fix for future use of the system. The hardware interface was modified after the first TOBI run to incorporate an amplifier and true RMS detector stages. Before the fourth TOBI deployment a modification to the software provided half hour time marks to the PC monitor and the Raytheon printer.

The Oretech transceiver is shared with the ship’s bridge echo sounder monitor for deep-water work. Unfortunately the bridge monitor is not compatible with the SOC system so had to be turned off when the SOC unit was in operation. This did not interfere with the ship’s operation as in shallower, more hazardous water a separate, higher frequency echo sounder is used for the bridge monitor.

Over rugged terrain in deep water the Oretech’s wide beam pattern gave multiple returns from the sea floor. This made determining the correct depth difficult although comparison to the bathymetry charts usually resolved any ambiguity.

In summary, the new SOC profiler logging and display system is easy to use and reliable in operation. With the addition of logging and record annotation it will provide an excellent basis for many platforms to use.

TOBI Image Processing

Onboard processing equipment during this cruise consisted of a PC notebook with 40 Gigabyte of disk space. Preliminary maps containing side-scan sonar imagery were plotted on an A0 plotter. All raw data were also archived on CD-ROM.

Good navigation data is essential for processing, because the vehicle position and hence the sidescan image position is calculated from it. The ship's navigation was recorded online – in approximately 10 seconds intervals - on a Unix server of the ship. Due to software problems it was not possible to extract the ship’s navigation on a daily basis while at sea. The entire navigation of the cruise was taken off the server after arrival in Southampton. It was noted during the cruise that the DGPS positions were not recorded with associated GPS times. Instead, the time from the internal clock of the Unix server storing the positions was recorded. This required correction to ‘real’ time because the Unix times were adrift by approximately 63 minutes. Often the navigation file revealed gaps of up to 7 minutes during which no GPS position nor any other ship’s data was logged. A cause is yet unknown. Preliminary processing was done using GPS data from the TOBI backup system, stored in the sonar header data.

The winch data (wireout) were also recorded online and stored in the sidescan raw data. The winch data were tested for abnormal wireout values mainly caused by cable counter resets, of which none occurred.

The TOBI imagery was downloaded from the CD-ROMs using a subsample and average factor of 8. This gave a pixel resolution of ca. 6 m and an almost 3-fold improvement of the signal-to-noise ratio. The TOBI raw data was also checked for vehicle errors, and if necessary corrected. During the operations the gyrocompass had to be disconnected due to technical reasons (see TOBI Instrument performance, above). For the preliminary processing of the sonar data aboard, vehicle positioning and heading was calculated from the GPS data provided by the TOBI backup system.

The survey was divided into three main areas – the Setubal Canyon, the Nazarre Canyon and the

Prestige wreck site. The first two areas consist of 10 and 7 blocks respectively (processed at 38°10' standard latitude in order to match the imagery with Multibeam bathymetry from the Setubal area). The third area west of Galicia was divided into 4 blocks, processed at 40° standard latitude. The approximate size of the blocks was 0.20 by 0.30° for all areas. As each survey in an area was completed the imagery was processed using the PRISM (v4.0) and ERDAS Imagine (v8.5) software suites to produce geographically registered imagery, which could then be composed onto a series of map sheets. These were mainly produced at a scale of 1:50000, and printed on the A0 plotter.

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

```
suppress_tobi -i %1 -o %0
tobtvg -i %1 -o %0 -a
mrgnav_inertia -i %1 -o %0 -t -u 236 -n navfile.veh_nav
tobtvg -i %1 -o %0 -h -l 50
tobslr -i %1 -o %0 -r 6.0 , 6.0
edge16 -i %1 -o %0 –m
drpout -i %1 -o %0 -u -f -p -k 201
drpout -i %1 -o %0 -u -f -p -k 51
shade_tobi -i %1 -o %0 -t1,4095
```

To explain this in sonar terms (in order):

- Removal of any surface reflection (i.e. from vehicle to the sea surface and back) – generally only a problem in water depths <3000 m, where a bright stripe or line is seen semi-parallel to the ship's track. Removal is only done when the imagery is unambiguous, i.e. when it the line is true artefact and not an actual seafloor feature. The result can sometimes be seen on the final imagery as a faint dark line.
- Smoothing of the altitude of the vehicle above the seafloor. The altimeter sometimes cannot locate the seafloor, possibly due to weak returns from very soft sediment 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 the first return and altitude value differ. Generally first return values are used, as these values will be used in the slant-range correction too.
- Merging of ship navigation and cable data with the imagery and calculation of the TOBI position using an inertial navigation algorithm. The 'navfile.veh_nav' file contains ship position and cable values and an umbilical length of 200 m is assumed (default) plus an additional 36 m for the distance between the GPS receiver and the point where the cable enters the water. The recorded cable values in the TOBI data are used. Various assumptions are applied: the cable is assumed to be straight, the cable value is assumed to be correct, and zero cable is set when the depressor enters the water.
- Replaces the TOBI compass heading with track heading. A smoothing filter of 50 pings is applied. The heading values are used in the geographic registration process to angle each ping relative to the TOBI position.
- Slant-range correction assuming a flat bottom. This is a simple Pythagoras calculation assuming that the seafloor is horizontal across-track and sound velocity is 1500 m s^{-1}. Each pixel is 8 ms (giving 6 m resolution) and any pixel gaps on the output file are filled by pixel replication.
- Median filter to remove any high or bright speckle noise. A threshold is defined for the

maximum deviation for adjoining pixels over a small area above which the pixel is replaced by a median value.

- Dropout removal for large imagery dropouts. When the vehicle yaws excessively, it is possible for the 'transmit' and 'receive' phase of each ping to be angled apart. If this exceeds the beam sensitivity value (0.8º) little or no signal is received, creating a dark line on the imagery. The program detects the dropout lines and interpolates new pixel values. If more than 7 dropouts are present concurrently (28 s) no interpolation is done.
- More dropout removal but for smaller, partial line dropouts. If more than 7 partial dropouts are present concurrently (28 s) 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, attenuation of sound in the water, and differences in seafloor backscatter response in terms of angle of incidence. The result of this is to amplify the near and far-range pixels by about 1.5 and reduce the mid-range pixels by 0.8.

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

The second phase (of mosaicing) allows the user to view all the ‘layers’ of data for an area. The software used is a commercial package named ERDAS Imagine (v8.5). Within this software the different layers can be displayed in different colours to distinguish the layers with data that will overlap with 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. Matching Multibeam data from the Setubal area allowed contour lines to be placed on top of the sonar imagery, as well as viewing the seafloor in 3-D.

SUMMARY OF RESULTS

Excellent TOBI images were obtained over all three of the areas studied during *Pelagia* cruise 219. Despite problems with both weather and equipment breakdowns, the cruise objectives were fully completed in areas 1 and 3 (Table 4). About 60% of the expected area was surveyed in area 2, where almost three days were lost to one extended period of bad weather followed by repair of equipment damaged by the weather (Table 4).

Cruise tracks and the TOBI survey areas are shown in Figs 2-4.

TABLES

Line	Way point number	Latitude	Longitude
1	1	38° 17.8’ N	08° 53.0’ W
1	2	38° 16.2’ N	08° 56.4’ W
1	3	38° 17.2’ N	09° 03.3’ W
1	4	38° 16.8’ N	09° 10.0’ W
1	5	38° 17.9’ N	09· 20.0’ W
1	6	38° 14.2’ N	09° 25.0’ W
1	7	38° 13.5’ N	09° 27.4’ W
1	8	38° 11.7’ N	09° 30.5’ W
1	9	38° 09.8’ N	09° 32.5’ W
1	10	38° 07.7’ N	09° 39.4’ W
1	11	38° 04.1’ N	09° 43.0’ W
1	12	38° 03.9’ N	09° 45.5’ W
1	13	38° 06.0’ N	09° 54.8’ W
1	14	38° 06.0’ N	10° 02.5’ W
1	15	38° 05.0’ N	10°10.0’ W
1	16	38° 15.9’ N	11° 28.1’ W
2	17	38° 05.5’ N	09° 55.0’ W
2	18	38° 10.4’ N	10° 30.0’ W
2	19	37° 56.5’ N	10° 30.0’ W

Table 1. Waypoints for TOBI survey of Setubal Canyon

Line	Way point number	Latitude	Longitude
3	20	39° 38.0’ N	09° 13.4’ W
3	21	39° 35.0’ N	09° 25.5’ W
3	22	39° 31.8’ N	09° 29.3’ W
3	23	39° 31.8’ N	09° 33.9’ W
3	24	39° 30.2’ N	09° 37.8’ W
3	25	39° 29.0’ N	09° 43.3’ W
3	26	39° 31.4’ N	09° 47.8’ W
3	27	39° 30.6’ N	09° 56.6’ W
3	28	39° 31.5’ N	10° 06.8’ W
3	29	39° 36.5’ N	10° 32.8’ W
3	30	39° 45.5’ N	10° 40.7’ W
3	31	30° 52.5’ N	11° 03.0’ W
3	32	39° 53.6’ N	11° 10.0’ W
4	33	39° 32.8’ N	09° 59.0’ W
4	34	39° 38.8° N	10° 30.4’ W
4	35	39° 47.5’ N	10° 38.0’ W
4	36	39° 49.0’ N	10° 44.0’ W

Table 2. Waypoints for TOBI survey of Nazarre Canyon

Line	Way point number	Latitude	Longitude
5	37	41° 57.00’ N	11° 58.80’ W
5	38	42° 19.44’ N	12° 06.10’ W
5	39	42° 20.00’ N	12° 03.25’ W
5	40	42° 03.40’ N	11° 57.90’ W
5	41	42° 02.20’ N	12° 04.27’ W
5	42	42° 18.80’ N	12° 09.62’ W

Table 3. Waypoints for TOBI survey of *Prestige* tanker wreck site

Date	Mobilisation (hr)	TOBI survey (hr)	Weather downtime (hr)	Repairs (hr)	Passage (hr)
3 Nov	15				
4 Nov	24				
5 Nov	8			12	4
6 Nov				23	
7 Nov		11		8	5
8 Nov		24			
9 Nov		24			
10 Nov		15.5	8.5		
11 Nov		20			4
12 Nov		16			8
13 Nov		24			
14 Nov		16.5		7.5	
15 Nov		19.5	4.5		
16 Nov			24		
17 Nov			24		
18 Nov		5	7	7	5
19 Nov		24			
20 Nov		10			14
21 Nov					24
22 Nov					24
23 Nov	4				20
24 Nov	13				
Totals (days)	**64 (2.7)**	**209.5 hr (8.7)**	**68 hr (2.8)**	**57.5 hr (2.4)**	**108 (4.5)**

Table 4. Summary of cruise activities

APPENDIX 1. TOBI SPECIFICATION

TOBI: Brief Technical Specification.

Mechanical

Towing method	Two bodied tow system using neutrally buoyant vehicle and 600 kg depressor weight.
Size	4.5 m x 1.5 m x 1.1 m.
Weight	2500 kg in air.
Tow cable	Up to 10 km armoured coax.
Umbilical	200 m long x 50 mm diameter, slightly buoyant.
Tow speed	1.5 to 3 knots (dependent on tow length).

Sonar Systems

<u>Sidescan Sonar</u>

Frequency	30.37 kHz (starboard) 32.15 kHz (port).
Pulse Length	2.8 ms.
Output Power	600 W each side.
Range	3000 m each side.
Beam Pattern	0.8 x 45° fan.

<u>Bathymetry Sonar</u>

Transmitter	Uses sidescan sonar.
Receiver	6 hydrophone arrays in 2 housings for each side.
Detection	Single and multi-phase.
Range	Up to 3000 m each side.

<u>Profiler Sonar</u>

Frequency	6 to 10 kHz Chirp.
Pulse Length	26 ms.
Output Power	1000 W.
Range	>50 ms penetration over soft sediment.
Resolution	0.25 ms
Beam Pattern	25° cone.

Standard Instrumentation

Magnetometer	Ultra Electronics Magnetics Division MB5L.
Range	+/- 100,000 nT on each axis.
Resolution	0.2 nT.
Noise	+/- 0.4 nT.

CTD	Falmouth Scientific Instruments, Micro CTD.

<u>Conductivity</u>

Range	0 to 65 mmho/cm.
Resolution	0.0002 mmho/cm.
Accuracy	+/- 0.005 mmho/cm.

<u>Temperature</u>

Range	-2 to 32° C.
Resolution	0.0001° C.

Accuracy	+/- 0.005° C.
Depth	
Range	0 to 7000 dbar.
Resolution	0.02 dbar.
Accuracy	+/-0.12% F.S.
Extra Depth Sensor	AML Pressure Smart Sensor
Range	0 to 6000 dbar.
Resolution	0.1 dbar.
Accuracy	+/-0.05% F.S.
Heading	S.G. Brown SGB 1000U gyrocompass.
Resolution	0.1°.
Accuracy	Better than 1°, latitude < 70°.
Pitch/Roll	Dual Axis Electrolytic Inclinometer.
Range	+/- 20°.
Resolution	0.2°.
Altitude	Taken from profiler sonar.
Range	1000 m.
Resolution	1 m.

Additional Instrumentation

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

APPENDIX 2. Summary of *Pelagia* 219 TOBI Magneto-Optical disks

M-O Number	File Name	Time/ Day START	Time/ Day STOP	Comments / Run numbers	Profiler Roll
875	TOBI.DAT	1408/311	0617/312	Start of run 1	1
876	TOBI.DAT	0618/312	2227/312		2
877	TOBI.DAT	2227/312	1436/313		3
878	TOBI.DAT	1436/313	0610/314	End of run 1	4
879	TOBI.DAT	1942/314	1151/315	Start of run 2	5
880	TOBI.DAT	1151/315	1721/315	End of run 2	6
881	TOBI.DAT	0851/316	0100/317	Start of run 3	7
882	TOBI.DAT	0100/317	1709/317		8
883	TOBI.DAT	1709/317	0918/318		9
884	TOBI.DAT TOBIa.DAT	0918/318 2234/318	1423/318 0941/319	End of run 3 Start of run 4	10
885	TOBI.DAT	0941/319	2008/319	End of run 4	11
886	TOBI.DAT TOBIa.DAT TOBIb.DAT	1427/322 0003/323 0429/323	1903/322 0428/323 1137/323	Run 5 a Run 5 b Day correction	12
887	TOBI.DAT	11:37/323	03:44/324		13
888	TOBI.DAT	03:44/324	11:48/324	End of run 5	14

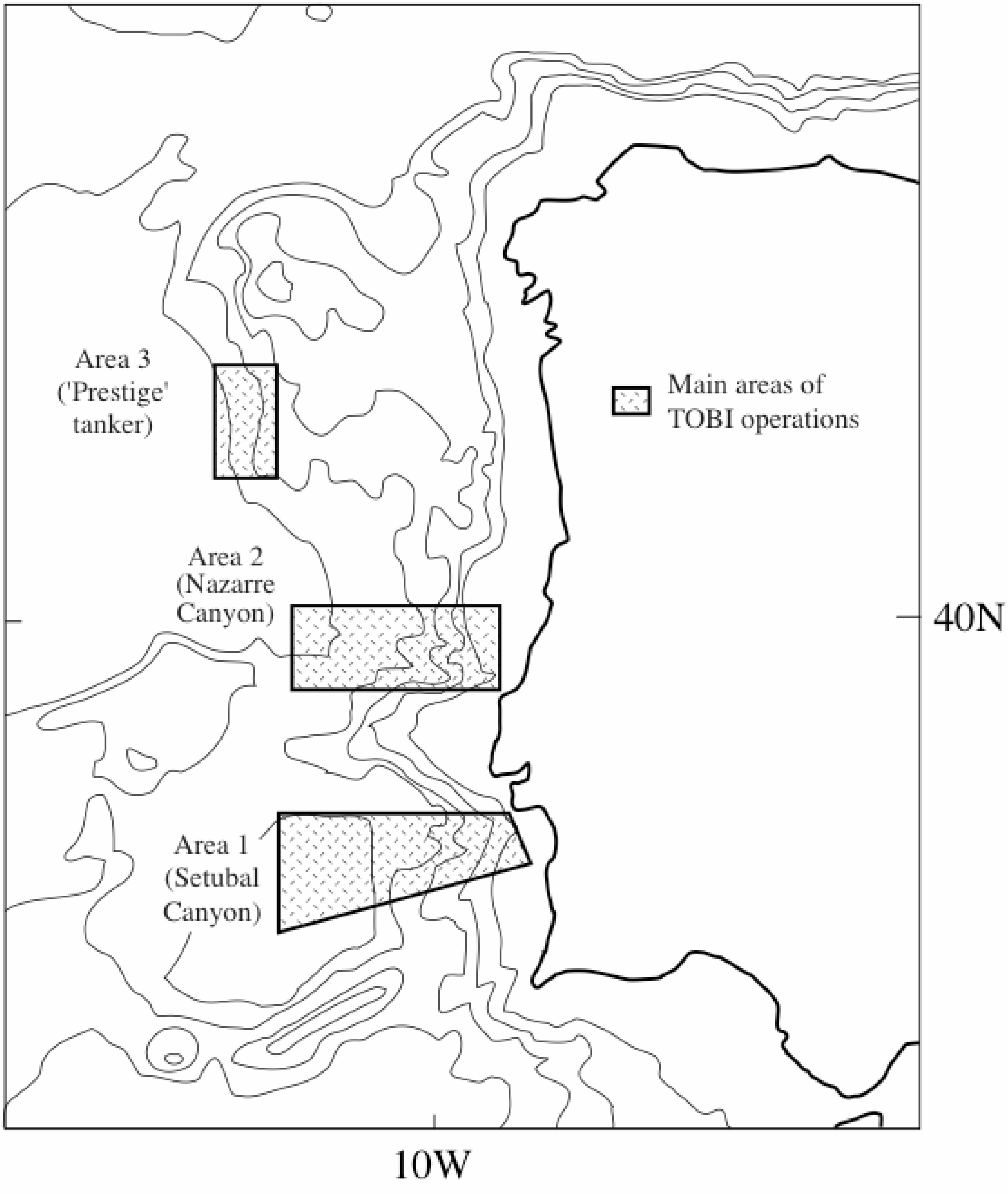

Figure 1. Location of three study areas west of Portugal and Spain.

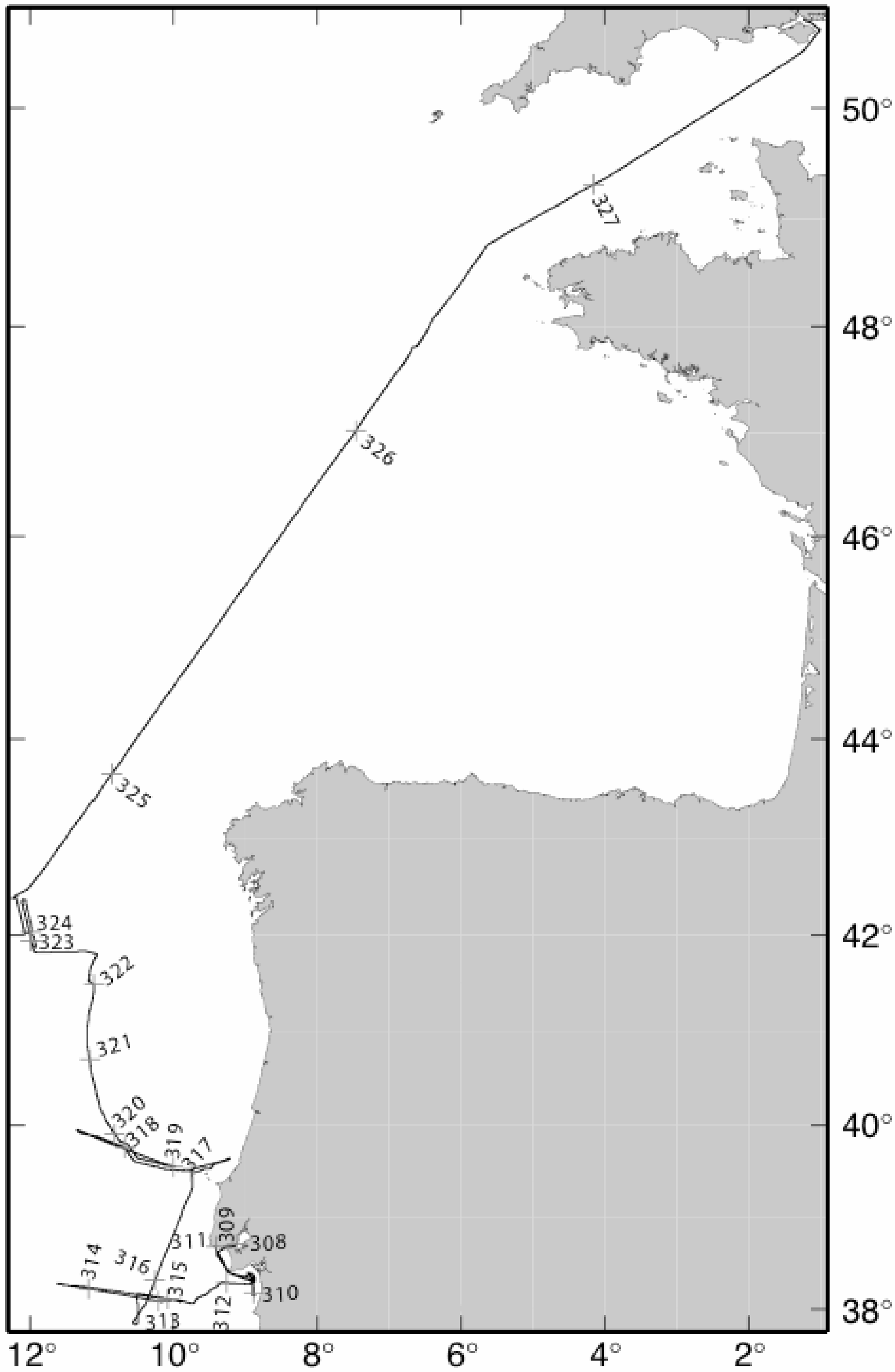

Figure 2. Summary track chart for *Pelagia* cruise 219. Numbers are Julian days (at 0000 hr).

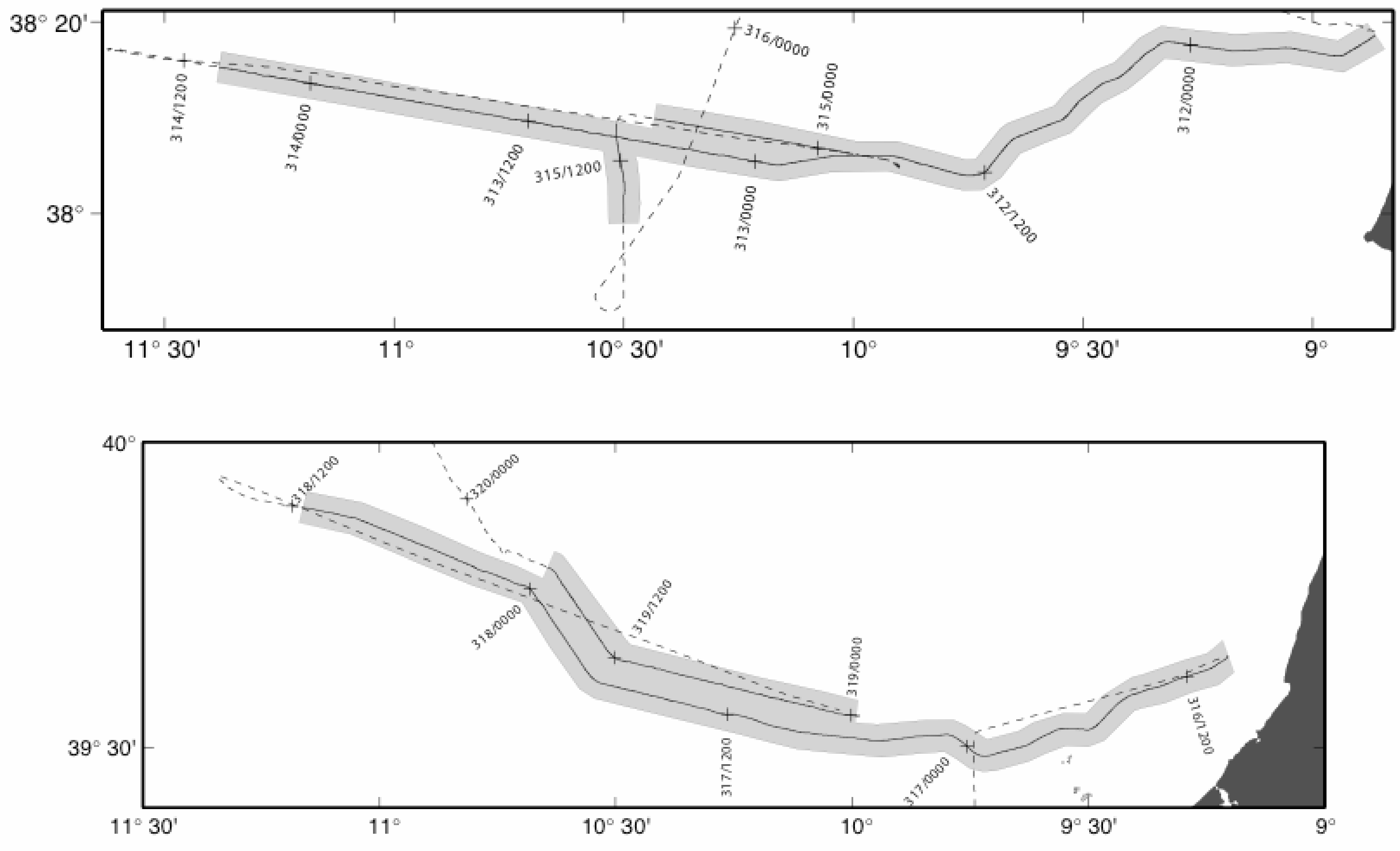

Figure 3. Track charts and TOBI sidescan sonar coverage (shaded) for the Setubal (upper) and Nazarre Canyon (lower) study areas. Solid track lines are those along which sidescan data was acquired, dotted lines are passage tracks.

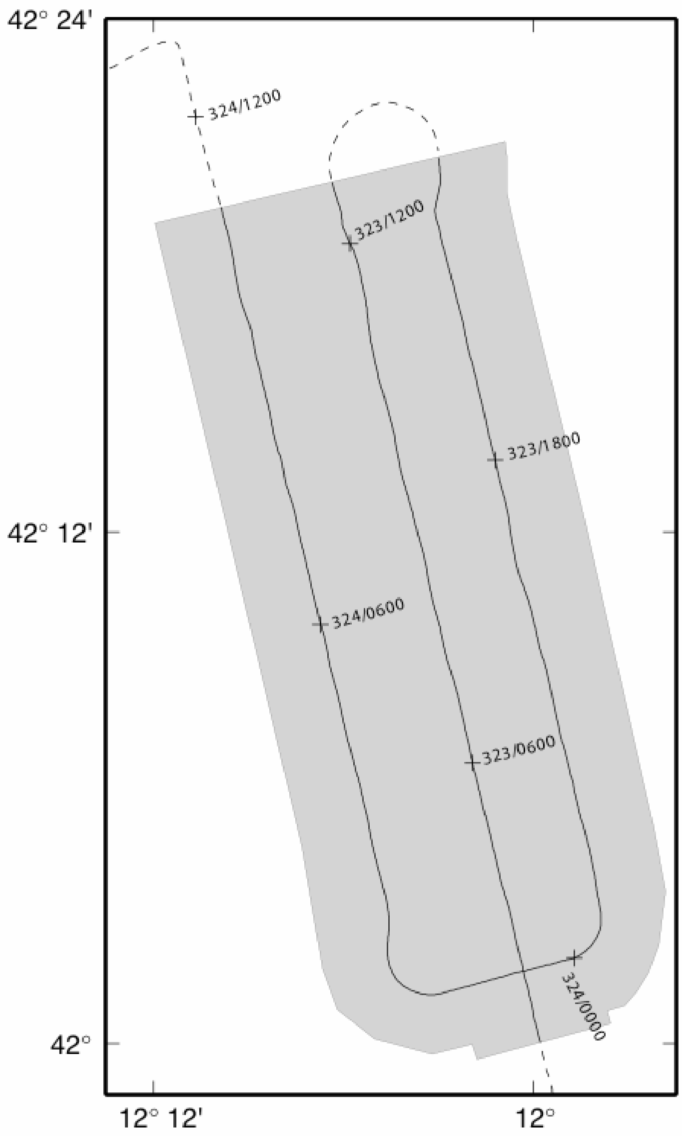

Figure 4. Track chart and TOBI sidescan sonar coverage (shaded) for the *Prestige* study area. Solid track lines are those along which sidescan data was acquired, dotted lines are passage tracks.