UNIVERSITY of CAMBRIDGE

DEPARTMENT OF EARTH SCIENCES

Cruise Report

DISCOVERY 178/88

Geophysical investigations of the Madeira–Tores Rise

P.J. Barton

CRUISE REPORT

DISCOVERY 178/88

8 November - 7 December 1988

Viana do Castelo - Lisbon - Cascais - Gibraltar

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INTRODUCTION

This cruise and the research grant that supported it started life as a project to investigate the crustal structure of the North Aegean Trough using seismic reflection and refraction and heat flow techniques, as a joint project between the universities of Cardiff and Cambridge. The work was scheduled to take place on cruise Discovery 167 in 1987. Following advice from the FCO, NERC postponed this cruise from early summer 1987 to November 1988, when it was renumbered Discovery 178. The FCO received the Notification from RVS more than six months prior to the start of cruise 178 but did not act in any way for three months. During August 1988 the investigators were requested by the FCO to produce three separate alternative cruise programmes in the North Aegean, none of which the FCO finally felt able to put forward to the foreign governments concerned. At a meeting in Swindon on 14 September 1988 the FCO agreed to pursue a further alternative programme in the Gulf of Corinth on our behalf. We planned on this basis for a further month, but heard on the scientific grapevine on 19 October that permission would be refused by Greece. This rumour was confirmed by FCO on 20 October. At 5pm on Friday 21 October NERC gave the go-ahead for us to use the ship time for an alternative cruise in international waters. Cardiff University no longer wished to participate. Thus one week before our equipment was shipped, two weeks before our departure from the UK and three before sailing, we had the task of designing a completely new project confined to international waters conveniently situated for the ship's scheduled port calls, and using the same personnel and equipment as the original project.

Two separate possible projects were considered:

1) a seismic refraction and heat flow profile of the crustal structure across the southern Rockall continental margin, for comparison with the results obtained during the highly successful two-ship cruise Discovery 155 - Charles Darwin 4/85

2) an investigation of the nature and crustal structure of the Madeira-Tores Rise and other peculiar bathymetric features of the ocean floor in the area of diffuse seismicity between the Azores and Gibraltar

Eventually the Madeira-Tores Rise project was chosen, on the grounds that at this time of year the large number of days spent steaming between Iberia and Rockall would be unlikely to be rewarded by enough time on station to be certain of achieving any useful work. It was clear from stray remarks on joining Discovery that this had been a popular choice.

OBJECTIVES

To investigate the nature and crustal structure of the Madeira-Tores Rise in the vicinity of Josephine Seamount using:

1) a 250 km long wide-angle seismic line recorded on six Cambridge digital ocean-bottom seismometers (DOBS), using closely spaced explosive charges and airgun shots

2) a grid of underway single channel reflection, gravity, magnetic and bathymetry profiles in order to give regional control

3) a test of the DOBS in triggered mode, to monitor micro-earthquake activity on the sea bed

4) heat flow profiles

Work was confined to a small area of international water between Portugal, Madeira and the Azores. Investigations concentrated on the Madeira-Tores Rise, the Horseshoe Abyssal Plain and Ampere Seamount. Work was confined to a box delineated by 38 N 15 W, 39 N 14 W, 35 N 12 W, 34 N 12 W, 34 N 12.5 W, 37 N 16 W and to international waters within this box (Figure 1). The main DOBS/shot firing line ran between 35 37 N 13 17 W and 38 11 N 14 53 W.

NARRATIVE

a) Preparation and loading 5 - 12 Nov 1988
Viana do Castelo and Lisbon

Seven of the team of eight from Cambridge arrived at Discovery moored alongside at Viana do Castelo, north of Oporto, Portugal, late on 5 November 1988. The RVS and IOS participants were already in residence, and we were relieved to see the container of Cambridge equipment on the quayside. The 6th, 7th and 8th were spent unloading our equipment and setting it up in the labs. The remaining two scientists arrived on 7th. At 1400 hrs on 8th set sail for Lisbon to load explosives, arriving there 24 hours later. Our date for loading explosives had by now slipped from 10th November to at least 11th, as the shipment had been delayed in the UK by industrial action. On arriving in Lisbon, RVS computer engineer Rob Lloyd was sent home on medical advice, to be replaced on 11th by Andrew Brook. Due to the unexpected delay, the remainder of 9th, the 10th and 11th November were spent in rather leisurely preparations by the Cambridge party, and a visit to the Geological Survey by those interested. On the 10th we were informed that the explosives should arrive on 12th. On the afternoon of the 11th (a Friday) there was a momentary crisis with the certification of the radio equipment by surveyors at Viana, but the agents at Lisbon defused this somehow.

At 0800 on 12th moved to river berth to load explosive at last.

This operation went very smoothly - the freighter left two containers on the quay (one containing explosive, the other detonators and fuses) and these were unstuffed and craned on board. At 1100 we took on a pilot, arriving at the measured mile at about 1430, after creeping through fog that prevented a compass swing taking place. Just managed four runs of the measured mile (10, 4, 6, 8 knots in both directions) before dark. Left for the work area at 1800, arriving there at 1830 on 13 November.

b) Tests and profiling 13 - 18 Nov (including return to Lisbon for medical reasons)

Overnight on 13th-14th November was spent conducting wire tests (to 2000m) of the acoustic releases. As well as those belonging to RVS there were some from Cambridge and others we had borrowed from the MAFF, as RVS had been unable to fulfill all our requirements. Several of the eight releases were found to be unreliable, and the testing process was slow due to a shortage of puffer vessels. By 0800 on 14th a sufficient number of releases for the DOBS experiment (six) had been coaxed into a satisfactory performance.

The reflection profiling gear was streamed and debugged during the morning of 14th. The purpose of this profile was to survey the main DOBS/explosive line, and to select sites for DOBS deployment. Three guns (300, 160, 300 cu ins fired at 20 second intervals) were deployed using the new gantry system on the starboard stern, a vast improvement over the old system of man-handling the boom. The new umbilical containing firing lines and hoses is also to be commended. Recording started at the northern end of line 1 soon after noon, but stopped again at 1500 when the alternator driving the compressors broke down. We circled to return to the same point by the time that the guns were restarted at 1815 and continued profiling (Figure 2). Profiling continued uninterrupted until 1810 on 15th November when the alternator again crashed. By this time we were in the Horseshoe Abyssal Plain, and it seemed worth continuing using one 300 cu ins gun run from the Gloria alternator. The main alternator was restored at 2145 and the three guns back in action by 2207 on arriving at the end of line 1. Turned onto line 2, steaming northwest, with everything working well. Two sonobuoys were launched on 15th: one at 1700 which was then badly affected by the alternator/compressor problems, and one at 2300. Throughout the day there were mysterious problems with the RVS main clock: it would momentarily flash up a random time every couple of minutes, which, if an integral number of two minutes or of hours, marked the records spuriously. This problem appeared to be fixed, or at least circumvented, by the end of the day. Profiling continued on 16th November, turning onto line 3. During the day it became clear that we should return to port as soon as possible in order to land Richard Smith from Cambridge, so that he could receive medical attention. At 1700 we stopped profiling just over Josephine Seamount, and at 1800 headed back to Lisbon at 13 knots (3 engines!). Arrived off Lisbon at noon on 17th, landed Richard

Smith by boat after a great Customs declaration rigmarole, and sailed at 1400. On departure found ourselves in the midst of a military exercise, alarmingly close to the target. The Master took evasive action and gave them the slip.

c) DOBS experiment 18-26 Nov

Arrived back at the work area at 0730 on Friday 18th November and conducted a PES, magnetometer and gravimeter survey of the valley north of Josephine tentatively identified for a micro-earthquake survey later in the cruise. Informed NATO submarine controller of our intention to fire explosives in the area on 20th and 21st November. The deployment order for the DOBS along the 250 km long line was designed to maximise time on station with GPS coverage. We began deploying DOBS 12 (station 4) at 1615, releasing it at 1740. Arrived at station 5, DOBS 11, at 2145 and released the instrument at 2320 after waiting for GPS. DOBS 10 was deployed at station 6 by 0400 on 19 November, and we then steamed north to deploy at stations 3, 2 and 1. DOBS 13, 14 and 15 were deployed at 1500, 1900 and 2330 respectively. During the afternoon period between DOBS deployments 2750 kg (110 boxes) of explosive was moved from the magazine to the ready-use locker and a tarpaulin-covered stack under the shelter deck.

Shot firing started at noon on Sunday 20th November after a morning meeting and numerous final preparations. The shot firing procedure went very smoothly, but there were a disappointing number of misfires (about 20 %). We were using opencast gelignite as Geophex can no longer be manufactured by ICI, and this alternative had been used with previous success by Bob Whitmarsh. Shot firing ended at 1740, and after steak for supper the stalwarts moved all the explosive for the next day up onto the after deck (a further 158 boxes plus one left over from today). During the night of 20/21 November the weather worsened considerably, but was moderating by breakfast time, and it proved perfectly possible to fire, despite residual large waves. The shot-firing again proceeded well apart from misfires, with a morning and afternoon session separated by a two-hour rest break. The ship had developed a rather sickly air - a combination of flu and tummy upsets.

After shot-firing steamed to southerly end of the line, and at 2130 deployed a 3 gun array to fire into the DOBS for near-surface control. We used 2 x 700 and a 466 gun, fired every minute; although this firing capacity was best using three compressors, it was maintained for a while with two whilst one needed attention. By the morning of 22 November the weather was sunny and the swell had dropped. Continued profiling north along the line, and celebrated the end of the main firing line. The main problem was keeping the ship's speed over the ground down to below 5 knots, as there was a danger of reaching each DOBS before it started recording. During the night of 22/23 November the weather deteriorated again, and the guns and magnetometer were brought in at the end of the profile once it was fully light on 23 November (0815).

Despite unpromising weather, we returned to the position of DOBS 15 at the northerly end of the line and recovered it at 1517 on 23rd. We then steamed south to the position of DOBS 12, as DOBS 13 and 14 were unfortunatley not equipped with lights and could not be found at night. DOBS 12 was recovered on a calm moonlit night late on 23rd. Preliminary data plots from DOBS 15 looked encouraging. DOBS 11 was recovered at 0620 on 24th. DOBS 10 however proved to be recalcitrant. Although the acoustic link responded to commands from the surface, and signalled that it had fired its firing pulse, the instrument would not move away from the bottom. After endless tries we decided to drag for it, despite the water depth of 4800 m. The drag operation was designed to coincide with GPS coverage and also to beat the bad weather rapidly coming in from the west. At 1630 on 24th November a Gifford grapnel, 700m of gash wire and 300 kg of weights had been attached to the bottom of the main warp and lowering had begun. A downward pointing pinger 50m from the bottom of the wire was used to give a bottom reflection. Large scale plotting sheets were constructed, and curves calculated for the predicted shape of the pinger response with offset. The plan was to drop the grapnel and weight as close as possible to the DOBS, then to steam a circle slowly around it, sweeping a circle on the seabed using the gash wire. The weather deteriorated badly during the operation, and our initial haste to get started resulted in a poor initial drop, and the attempt was not successful. At 0300 on 25 November the operation was abandoned and the tackle recovered. Feeling rather subdued, we battled north against the weather towards the site of DOBS 14, arriving there at midnight on 25th. Since DOBS 14 did not have a light, decided to spend the night on a sound velocity dip, but this was not successful due to a cable fault. DOBS 14 was recovered at 1030 and DOBS 13 at 1515 on 26th. DOBS 13, deployed in the tectonically active valley earmarked for later micro-earthquake work, came back pitted and discoloured, perhaps by hydrothermal exhalation. Explosion data from DOBS 13 is shown in Figure 3 and airgun records from DOBS 14 in Figure 4.

d) Sound velocity dip 26 - 27 Nov

At 1800 on 26th arrived on station for a second attempt at the sound velocity meter. However the meter continued to produce inconsistent results, and when opened up needed considerable patching up. At midnight all systems were go and the profile began, ending at about 0400 on 27th. The profile was truncated prematurely at 2500 m as the CTD wire was found to be in an appalling state - brittle and rusted with numerous parted strands. The RVS/IOS engineers reckoned that only the conductor wires brought the meter back to the surface.

e) DOBS micro-earthquake experiment: deployment and tests 27 - 28 Nov

During the early part of the 27th, four replenished DOBS were deployed in the valley chosen, on the basis of known activity, for a test of the triggering algorithm for recording micro-earthquakes. Moved off to the west and deployed the large airgun array (700,700,466 cu ins fired at 45 seconds) and the streamer, and began steaming two short lines (lines 4 and 5) over three of the DOBS. This was finished in calm sunny weather at 1020 on 28th November, and the profiling gear was recovered before steaming south for a new rescue attempt on DOBS 10.

f) Second recovery attempt DOBS 10 28 - 29 Nov

Arrived on station at DOBS 10 at 1915 on 28th and found it chirping away as before. Repeated previous strategy (which was successful during CD 18/86) with increased bottom weight and extreme care about initial positioning. Began the procedure at 2220 when GPS came on, and finally abandoned it at 0815 on 29th after a tense but unsuccessful night. DOBS 10 R.I.P..

g) Reflection profiling 29 - 30 Nov

Steamed south across Horseshoe Abyssal Plain to do some reflection profiling across Ampere Seamount. Arrived at start of line 6 at 1500 on 29th and everything was working by 1600. Profiled through the night, arriving at the spectacular (submerged) Ampere Seamount at 0900 on 30th. We crossed this twice, getting back to the monotony of Horseshoe Abyssal Plain in the afternoon, when we deployed two disposable sonobuoys (line 7). During the day the CTD wire, which resembled rusty Shredded Wheat, was wound gingerly off the drum and dumped in lengths. Profiling finished with a survey of the forthcoming heat flow profile, in the centre of the Horseshoe Abyssal Plain. Finished profiling at 2200 on 30 November.

h) Heat flow 1 Dec

Arrived on station for the start of the heat flow profile at 0100, making the first penetration ot 0300, then a succession of pogo-style measurements at 0.5-1 knot. Heat flow profiling continued throughout the day, in a special bid to beat the record number of measurements in a single deployment. After 24 penetrations with the instrument working perfectly, started to recover the probe at 2030 and got it back on deck two hours later.

i) Reflection profiling 2 - 3 Dec

Redeployed the reflection profiling gear in the early hours of 2 December and began line 8 from the Horseshoe Abyssal Plain obliquely across Josephine Bank. Continued profiling along lines 9, 10 and 11 until 1200 on 3rd December, crossing a spectacular submarine crack about 1 km deep, that may mark the position of the Azores fracture zone.

j) DOBS micro-earthquake experiment: calibration and recovery 3 - 4 Dec

On the afternoon of 3rd fired a series of six 25 kg shots at hourly intervals as we approached the DOBS, in order to test their triggering capability for sources of known strength at different ranges. DOBS 12 was recovered by 2000, and we were delighted to find that the test was successful. DOBS 11 was recovered at 2300, by which time it was so calm that the flashing light was visible underwater on its way up. After DOBS 15 was recovered spent the remaining darkness in a small survey in the area until it was light enough to find DOBS 14 without a light on the morning of 4th December. This last recovery was disappointing, as the instrument's clock had become corrupted and the gain values jammed.

k) Survey and passage 4 - 7 Dec

At 1230 on 4th began a gravity, magnetic and bathymetry survey in order to obtain some crossovers, as hitherto most of the profiles have been sub-parallel to each other. This survey was completed at the End of Science at 1800 on 5th December, when the ship reached the edge of Portuguese waters. Passage from 1800/5th until arriving off Gibraltar at 0800 on 7th December, during which time all Cambridge equipment was packed away.

Discovery docked at 0930 on 7th December. The Cambridge container arrived alongside during the morning and was packed during the afternoon.

ACKNOWLEDGEMENTS

First I would like to thank the NERC officers at Swindon and at RVS who allowed this cruise to rise from the ashes as a new project at the eleventh hour, after the Foreign and Commonwealth Office once more failed to act on our behalf. Everybody on cruise Discovery 178 did their utmost to ensure that the experiment was a success, as indeed it was. Technical staff from RVS and IOS worked tirelessly, keeping everything in good running order, and cheerfully tolerating changes of plan or omissions by the PSO. Officers and crew were a pleasure to work with, and special thanks go to Captain Mike Harding for his support and encouragement throughout.

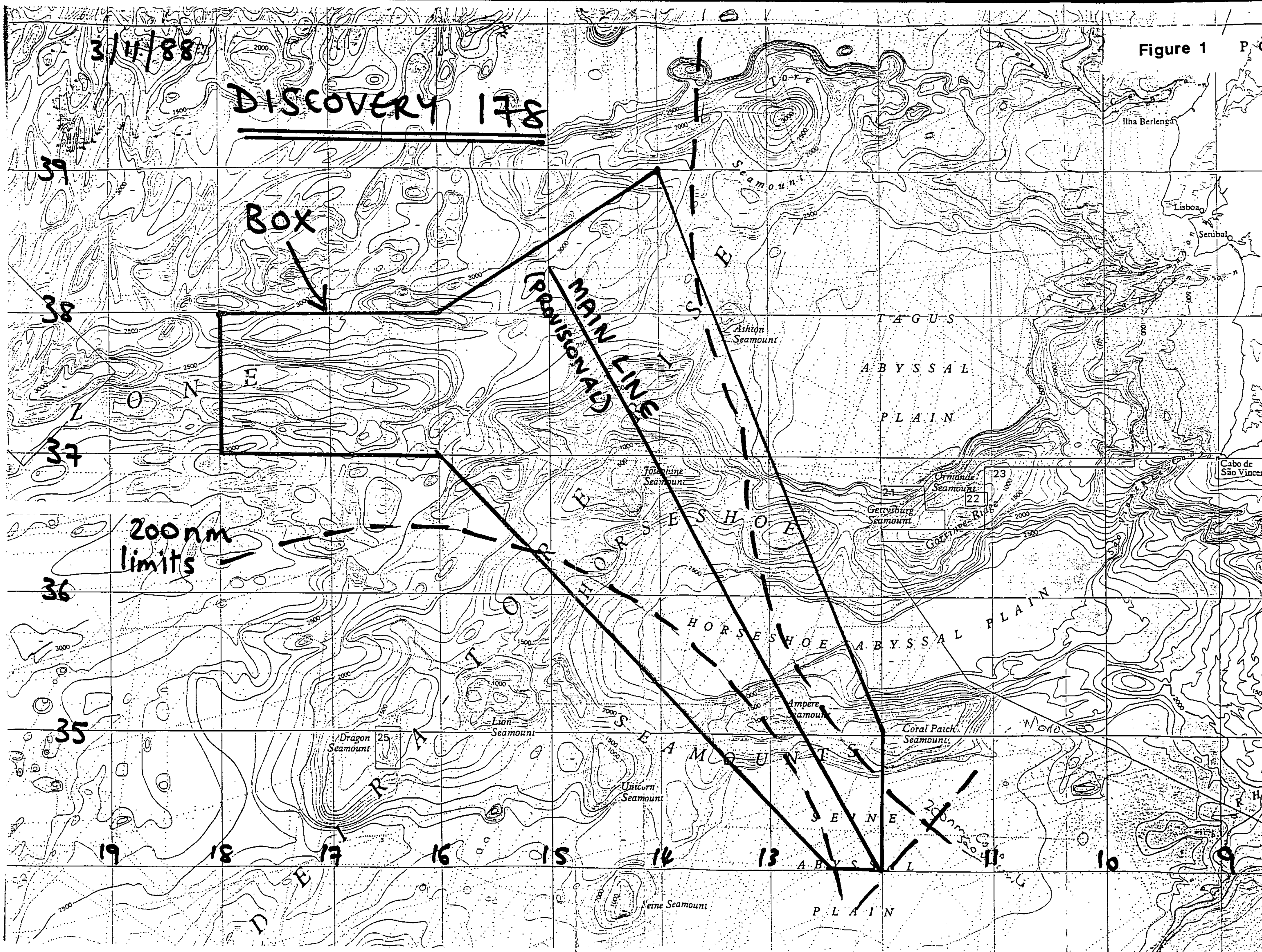
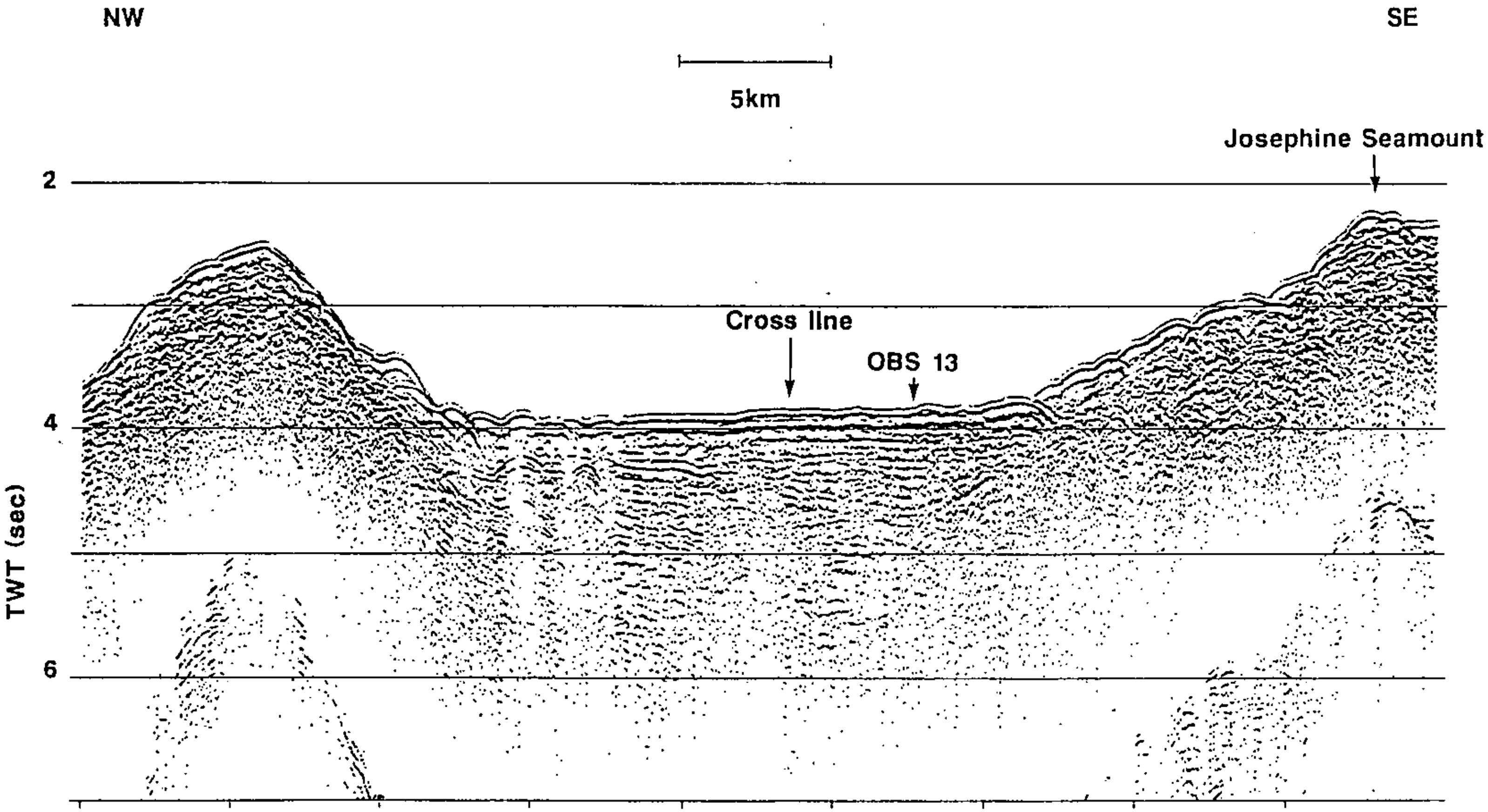

3/11/88
DISCOVERY 178
BOX
MAIN LINE (PROVISIONAL)
200nm limits
200nm limit
39
38
37
36
35
19
18
17
16
15
14
13
11
10
9
Ilha Berlenga
Lisboa
Setubal
Cabo de São Vicente
TAGUS ABYSSAL PLAIN
HORSESHOE ABYSSAL PLAIN
HORSESHOE SEAMOUNTS
SEINE ABYSSAL PLAIN
Ashton Seamount
Josephine Seamount
Gettysburg Seamount
Ormonde Seamount
Gorringe Ridge
Ampere Seamount
Coral Patch Seamount
Lion Seamount
Dragon Seamount
Unicorn Seamount
Seine Seamount
ZONE
21
22
23
25

Figure 1

Single channel reflection profile - Josephine refraction line



Processing:

Deconvolution:- 1500ms window, 1000ms operator, 80ms predictive lag

Filter:- 5-24Hz

Figure 2

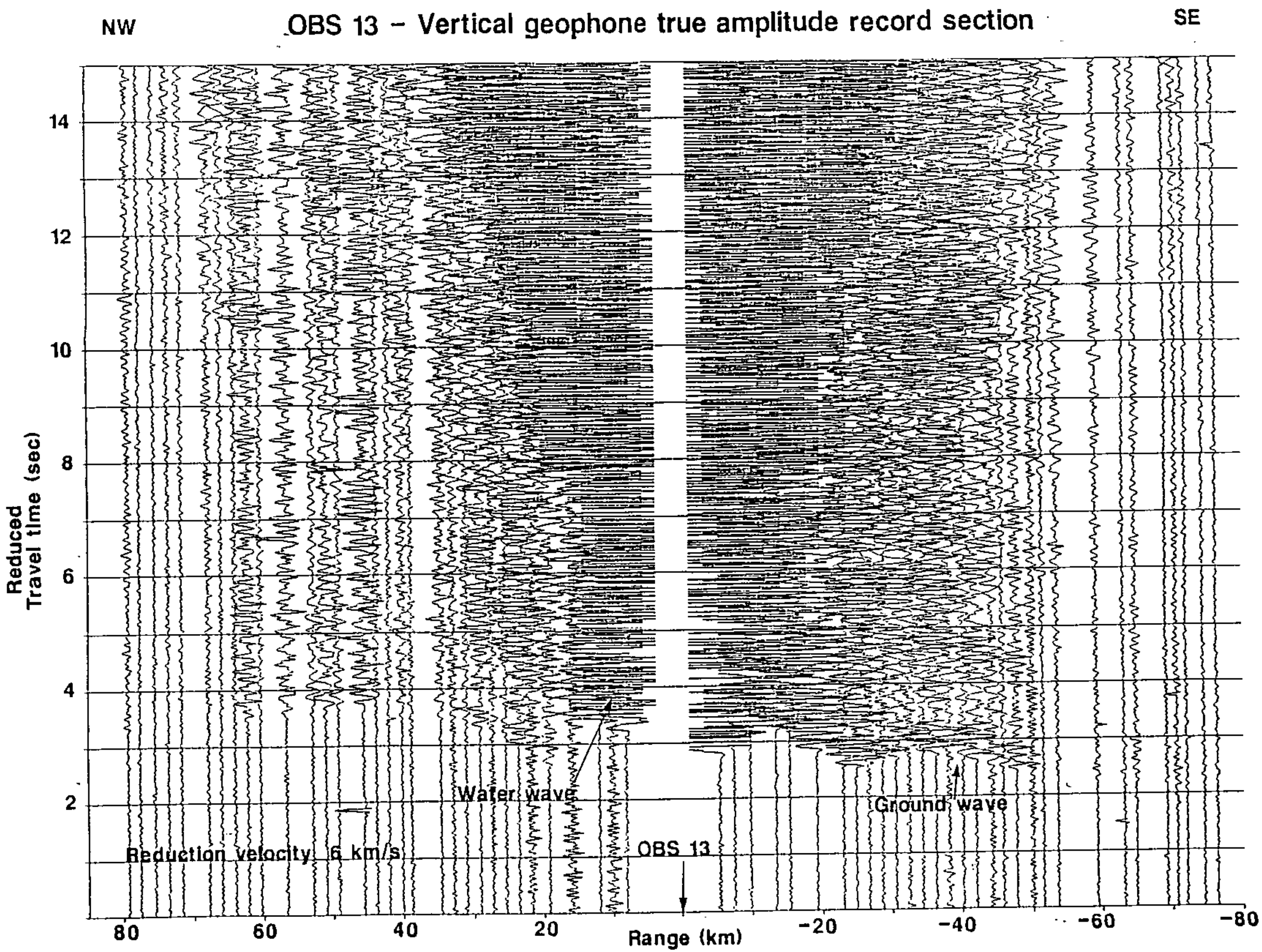

NW
OBS 13 - Vertical geophone true amplitude record section
SE
Reduced Travel time (sec)
14
12
10
8
6
4
2
Water wave
Ground wave
Reduction velocity 6 km/s
OBS 13
80
60
40
20
Range (km)
-20
-40
-60
-80

Figure 3

OBS 14 - Vertical geophone and airgun shots

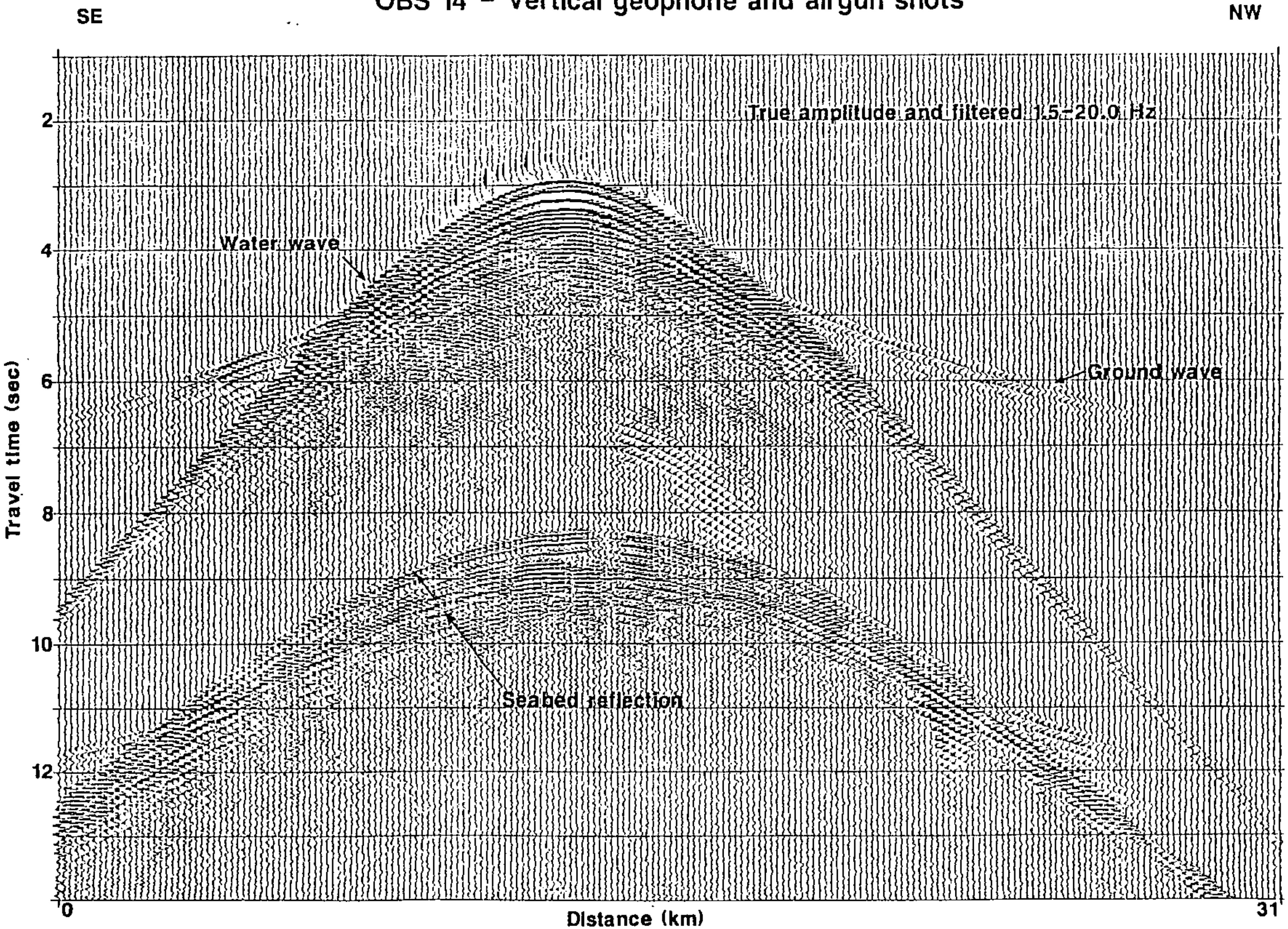


Figure 4

SUMMARY OF DATA COLLECTED

1) Wide angle seismic profile between 35 37 N, 13 17 W and 38 11 N, 14 53 W, using six DOBS (of which only five were recovered), 110 explosive shots, and an airgun array. See Figures 3 and 4 for examples of data.

2) Seismic reflection profiles along the wide-angle line and as a regional survey of the area, covering the Madeira-Tores Rise around Josephine Seamount, the Horseshoe Abyssal Plain and the Ampere Seamount. Single channel data recorded analogue and subsequently digitised at Bullard Labs. See Figure 2.

3) Two short DOBS/airgun profiles recorded as crosslines north of the Josephine Seamount.

4) Deployment of four DOBS for five days just north of Josephine to test triggered recording in response to micro-earthquakes. Three of the four recorded successfully, detecting several events as well as the series of charges (6 x 25 kg) used to calibrate them.

5) A heat flow profile consisting of 24 closely spaced measurements in the Horseshoe Abyssal Plain.

6) Bathymetry, gravity and magnetic profiles along most of the ship's tracks.

7) XBT measurements at the DOBS positions, a sound velocity meter dip and several disposable sonobuoys (Horseshoe Abyssal Plain).

CHARTS OF TRACKS

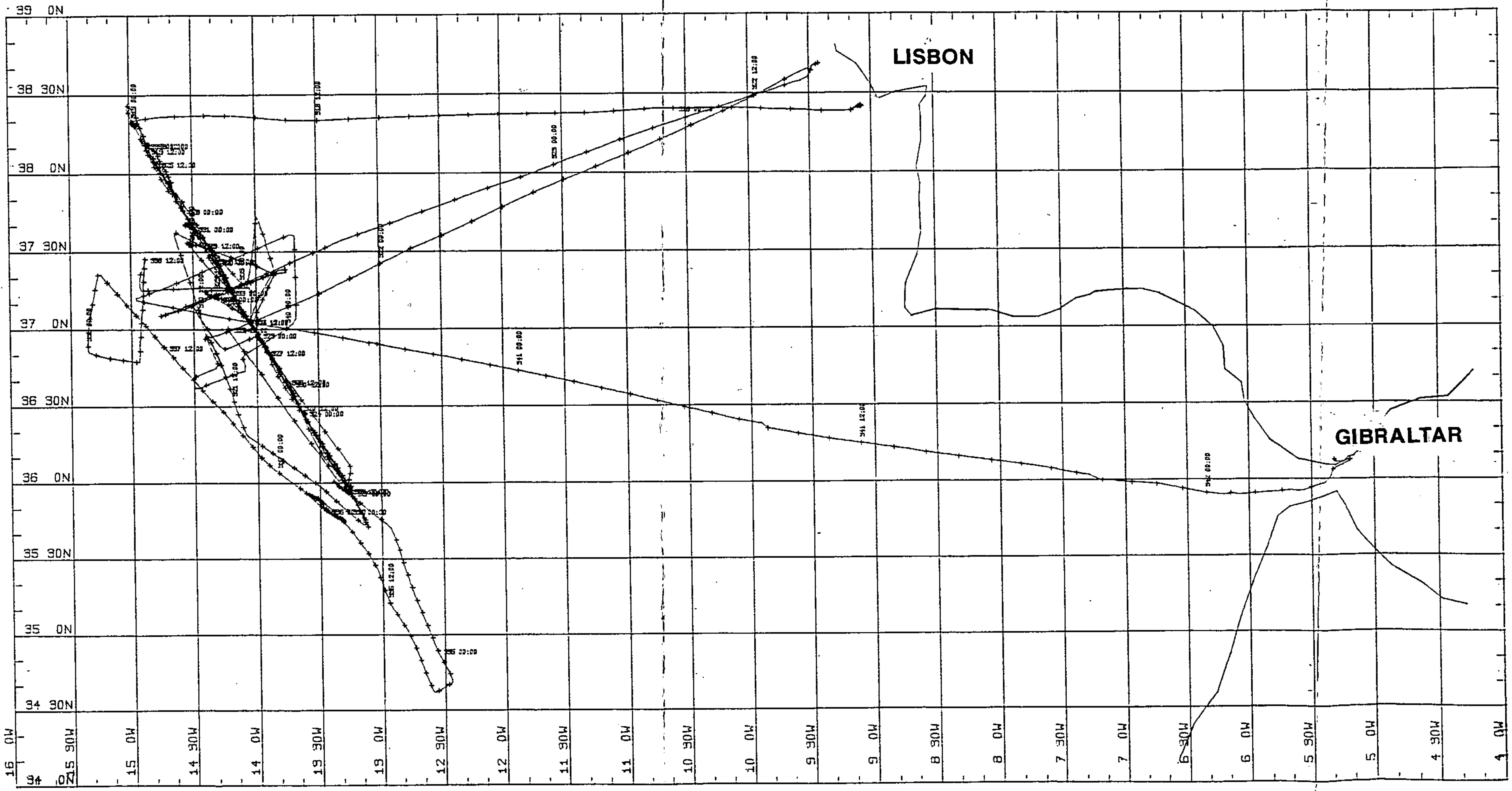
1) Complete track chart for cruise Discovery 178

2) Chart showing DOBS postions and explosives runs on main wide-angle line

3) Tracks of single channel reflection profiles

4) Detailed track of heat flow profile

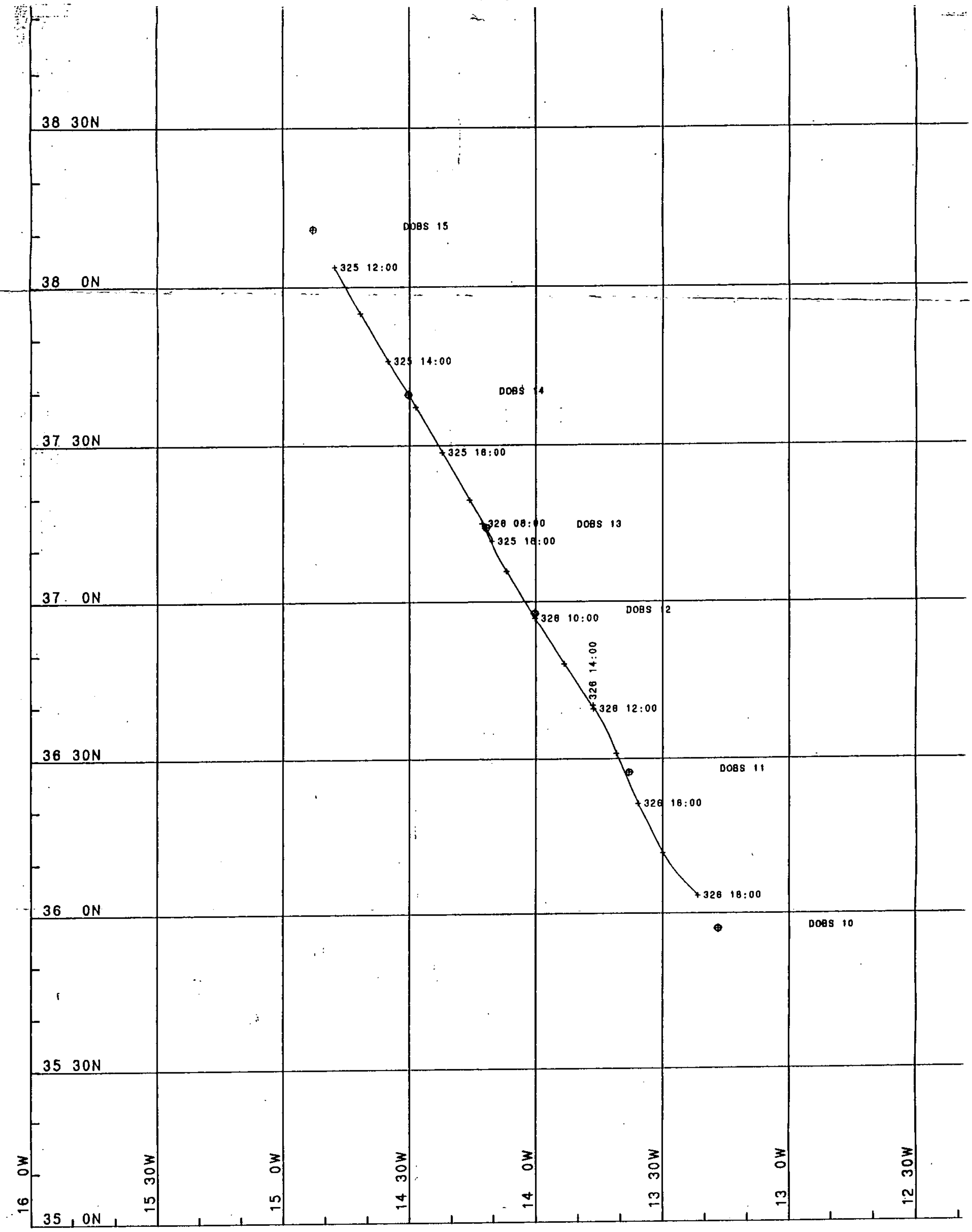
Chart 1



MERCATOR PROJECTION

R.R.S Discovery 178 Dr P Barton Full Cruise Track

Chart 2



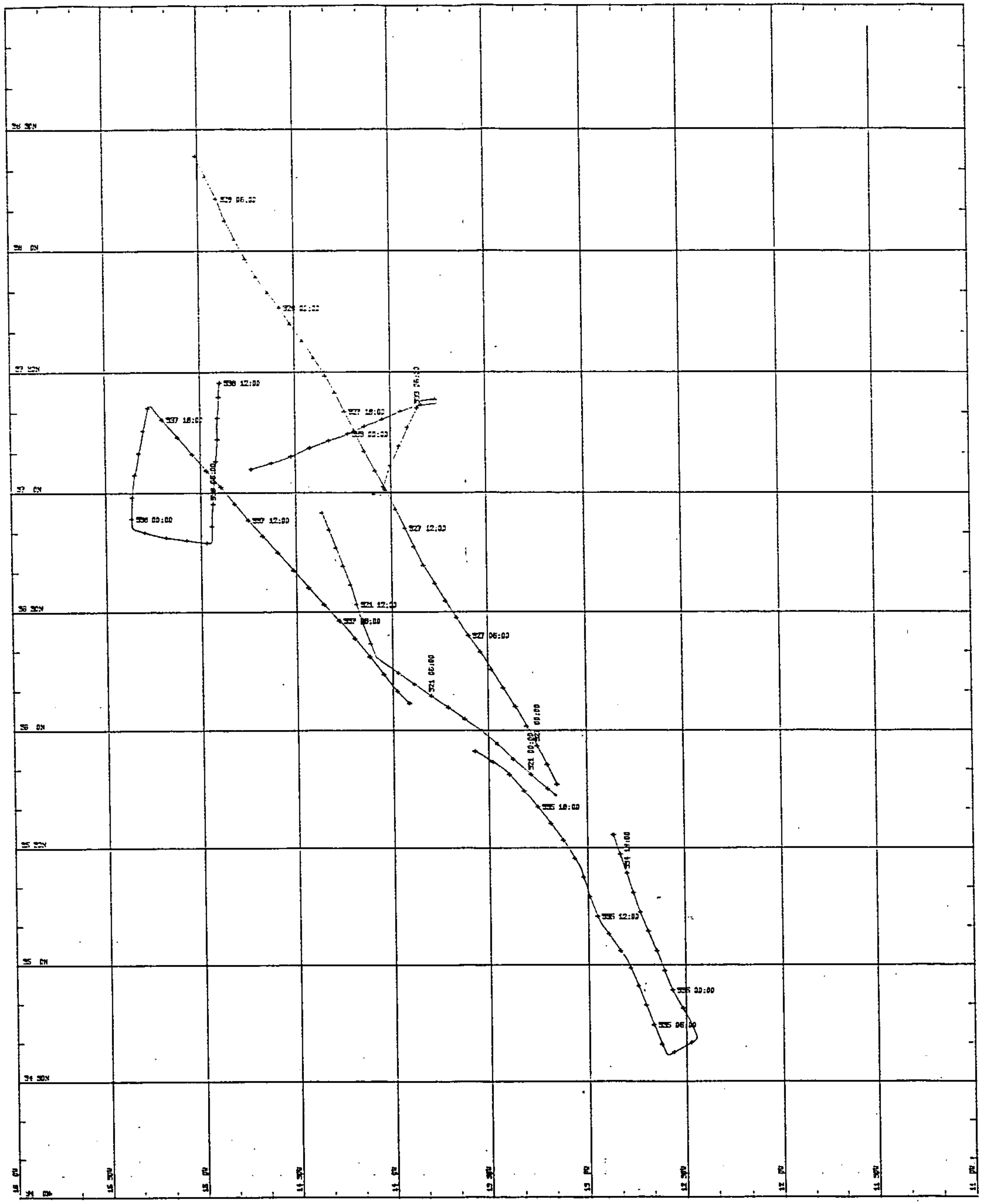
MERCATOR PROJECTION
SCALE 1 TO 1000000 (NATURAL SCALE AT LAT. 46)
INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 46

GRID NO. 4
TRACK NO. 4

— Track plotted from bestnav

R.R.S Discovery 178 Dr P Barton Explosives Runs

Chart 3



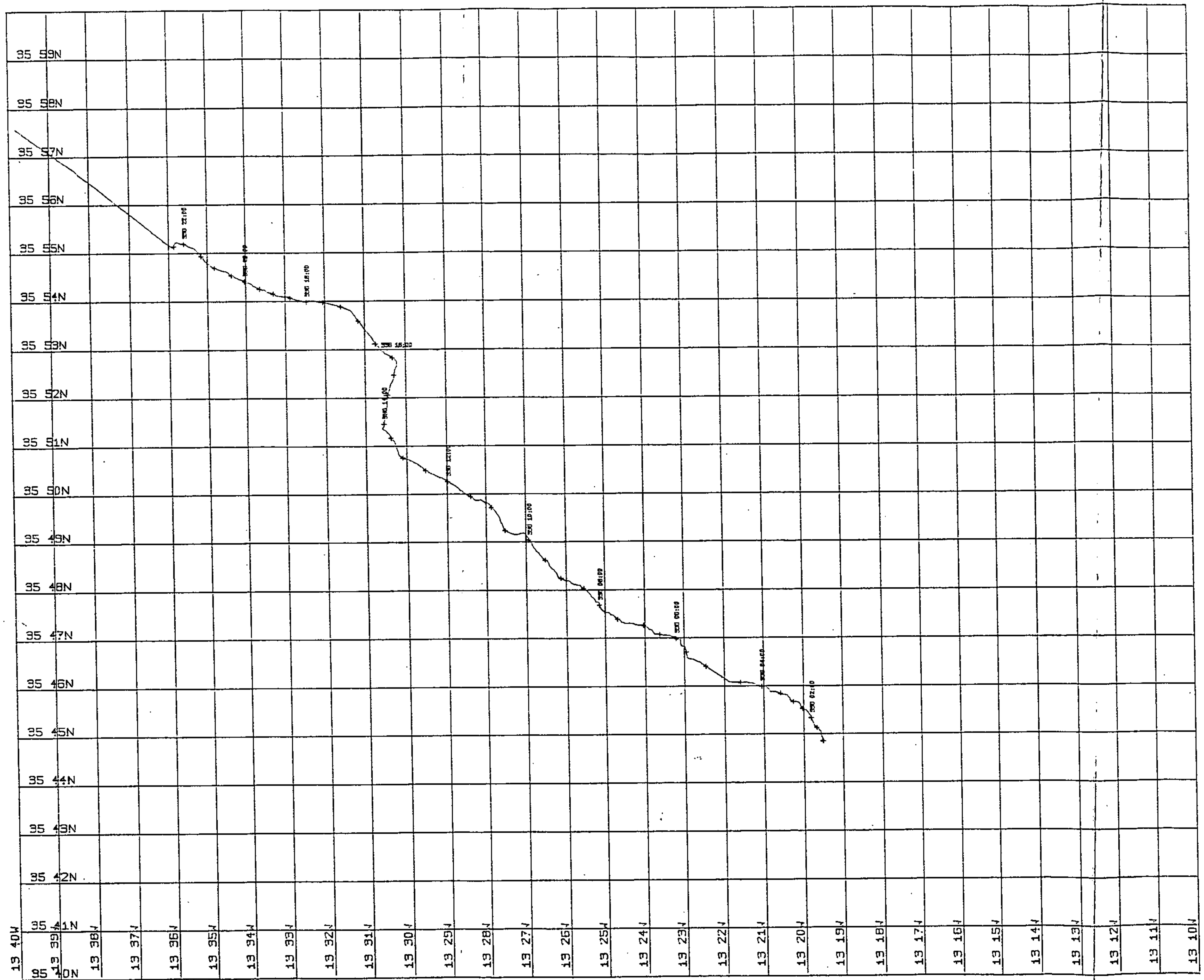
MERCATOR PROJECTION
SCALE 1 TO 1000000 (NATURAL SCALE AT LAT. 40)
INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 40

GRID NO. 18
TRACK NO. 10

— Track plotted from bouncer

R.R.S Discovery 170 Reflection Profile lines

Chart 4



MERCATOR PROJECTION

SCALE 1 TO 100000 (NATURAL SCALE AT LAT. 46)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 46

GRID NO. 12

TRACK NO. 12

— Track plotted from bestnav

R.R.S Discovery 178 Heat Flow Positions

APPENDIX A

Report of Proceedings

DISCOVERY CRUISE 178

8/11/88 Viana do Castelo - 7/12/88 Gibraltar
(Lisbon 9 - 12/11, Cascais 17/11)

Background

This cruise started life as Discovery 167 to the North Aegean, as a joint project between the universities of Cardiff and Cambridge. Following advice from the FCO, NERC postponed this cruise from early summer 1987 to November 1988 (Discovery 178). The FCO received the Notification from RVS more than six months prior to the start of cruise 178 but did not act in any way for three months. During August 1988 we were requested by the FCO to produce three separate alternative cruise programmes in the North Aegean, none of which they finally felt able to put forward to the foreign governments concerned. At a meeting in Swindon on 14 September the FCO agreed to pursue a further alternative programme in the Gulf of Corinth on our behalf. We planned on this basis for a further month, but heard on the scientific grapevine on 19 October that permission would be refused by Greece. This rumour was confirmed by FCO on 20 October. At 5pm on Friday 21 October NERC gave the go-ahead for us to use the ship time for an alternative cruise in international waters. Cardiff University no longer wished to participate. Thus one week before our equipment was shipped, two weeks before our departure from the UK and three before sailing, we had the task of designing a completely new project confined to international waters conveniently situated for the ship's existing programme, and using the same personnel and equipment as the original project.

Objectives of cruise

To investigate the crustal structure of the Madeira-Tores Rise near Josephine Seamount, using seismic reflection and refraction, heat flow, and underway bathymetry, gravity and magnetic measurements. To test triggered mode earthquake recording in the Cambridge Digital Ocean Bottom Seismometers (DOBS).

Geographical area

The cruise took place in a small area of international water between Portugal, Madeira and the Azores. Investigations concentrated on the Madeira-Tores Rise, the Horseshoe Abyssal Plain and Ampere Seamount. Work was confined to a box delineated by 38 N 15 W, 39 N 14 W, 35 N 12 W, 34 N 12 W, 34 N 12.5 W, 37 N

16 W and to international waters within this box. The main DOBS/shot firing line ran between 35 37 N 13 17 W and 38 11 N 14 53 W.

Sea and weather conditions encountered

Generally working conditions were good or excellent. The weather was mild and dry and the sea fairly calm, although there was usually a slow swell. One period of bad weather 24/25 November (force 7-8) slowed a steaming leg considerably, and the conditions for the second day of shot firing the main line (21 November) were uncomfortable in the early morning.

Conduct of cruise

Scientifically the cruise was extremely successful. Various misfortunes near the beginning caused a significant loss of scientific time: we were two days late sailing from Lisbon at the start of the cruise waiting for the explosives shipment, which was delayed by civil service industrial action, and had to return to Lisbon 16/17 November to land a sick scientist, losing a further 39 hours.

All equipment worked satisfactorily and we acheived significant reflection, bathymetry, magnetics and gravity coverage, a major (250 km) wide-angle seismic line, and successfully recorded a number of small earthquakes. 6850 kg of ICI Opencast Gelignite were fired with an unusual number of misfires (26 misfires out of 142 shots): it is not clear whether fuses or explosive were to blame.

Equipment performance

Cambridge equipment

A total of ten deployments were made of the DOBS: six on the main wide-angle seismic line and four on the subsequent micro-earthquake test deployment. One of the instruments on the main line failed to release when signalled and was declared lost after two attempts to drag it up. Data from the other five insruments were excellent. One pressure case returned pitted by corrosion and was considered unfit for further use. The remaining four instruments underwent a six-day deployment to record earthquakes and experimental shots in a known seismically active area: three of these produced good data, the fourth had become corrupted.

The heat flow probe was used for one pogo-profile in the Horseshoe Abyssal Plain. The probe worked in an exemplarary fashion, and a total of twenty-four separate measurements were made.

RVS Equipment

Underway measurements of bathymetry, gravity and magnetics worked routinely. Seismic reflection results were as good as they could be given the archaic sensing and recording equipment supplied. The Geomechanique array never had more than two active sections in action, and was reduced to one by the end of the cruise. Data was displayed on EPC recorders and recorded analogue on a Store-4. Guns were synchronised using a storage scope. It is regrettable that the single channel digital system and Reftek airgun synchronisation system could not be supplied as requested. The gun array (used with 2 x 300 + 160 cu ins and 2 x 700 + 466 cu ins guns) was impressively trouble free, and worked non-stop whenever it was required, partly due to judicious swapping around between the four compressors. The new airgun deployment boom is a great improvement over the old system.

The XBT system and sonobuoys worked as required. The sound velocity meter required a major overhaul to get it going - difficult for the technicians involved as there were no manuals on board.

The winch systems performed well, but the CTD wire was in such an appalling state in the middle section (from about 2500m wire out onward) that it was necessary to dump it. The state of the wire (its outside appearance was that of Shredded Wheat) was discovered during the sound velocity dip (27 November), cutting this dip short and preventing further use of the CTD wire. The wire had also been used at the beginning of the cruise to 2000 m for the testing of acoustic releases; fortunately we did not test these at greater depths, as the weight of a couple of releases might have parted the wire, bringing all our DOBS activities to an abrupt halt.

The DMW clock developed a peculiar and irritating fault: it went through periods of flashing up a completely different time on its display then instantly reverting (no loss of time base was detected). The effect of this fault was to trigger spurious time marks on the PES and EPC records, if the flashed up time coincided with a potential time mark. The fault was circumvented, but not eliminated.

Computer support was efficient and flexible.

The lost DOBS (see above) incorporated an acoustic release minus pressure tube, three 18" Benthos spheres, and a pair of gas retractors all belonging to RVS. All items were thoroughly tested and appeared to be functioning properly: it is not known why the instrument failed to release.

I have already mentioned the lack of SVM manuals. There were several instances where the effectiveness of RVS support was diminished by factors completely outside the control of those on board: items were requested for the cruise and appear on the equipment allocation list but did not turn up on board (the full number of acoustic releases, flashing lights and Benthos spheres were not supplied), or could not be located until well into the cruise (pinger test boxes and test transducer). Both shortcomings resulted in wasted ship time and could have jeopardised the whole experiment.

Ship performance

The ship performed exactly as required. Officers and crew alike were a pleasure to work with. Everyone was comfortable and well-fed. A number of problems with the main alternator (known as Fred) only caused one 20 minute break in data collection as at other times its function was taken over by the Gloria alternator.

Recommendations

The problems of obtaining diplomatic clearance for research cruises show no signs of improvement (see report for Darwin cruise 18/86 for example). More of this elsewhere. We are extremely grateful to the NERC for allowing us to go ahead with this new cruise plan at such short notice: we have become fascinated by the problems of this area during this cruise and are already planning further work.

The RVS/IOS on-board support for the cruise was as always tireless and tolerant. However the supply of equipment from RVS seems to be reaching crisis point. In most cases the technicians on board seemed not to have been involved in preparing and packing the gear which put them at a disadvantage despite their good intentions. Anticipating problems with RVS supplying lights, releases and Benthos spheres, I repeatedly telephoned Barry throughout the summer, to be assured that I would be notified of any shortfall in good time. In fact no mention was made of a lack of lights and spheres until we had sailed, and we ended up with one fewer releases than the reduced number that I had been notified of by telex. Fortunately we had been able to borrow two releases from the MAFF at short notice (why couldn't RVS borrow from the MAFF?) and thereby had just enough on board.

There is no excuse for working wires to be in the state of that CTD wire. It is fortunate that it was discovered on a cruise where the CTD wire did not form a key facility.

P.J. Barton
6/11/88

Table A.6 Josephine Seamount Shot Data

Shot No.	Location Latitude N	Longitude W	Shot Inst. h m s	Water Depth m	Charge Weight kg	Det. Depth m
1	38°03.81'	14°47.73'	12 01 50.960	5263	25	109
4	38°01.23'	14°45.93'	12 19 37.089	5241	25	100
5	38°00.35'	14°45.29'	12 25 37.987	5135	25	103
6	37°59.46'	14°44.65'	12 31 54.477	5060	100	108
7	37°58.58'	14°44.02'	12 37 35.247	4973	25	97
10	37°55.95'	14°42.19'	12 55 28.732	5025	25	94
11	37°55.09'	14°41.58'	13 01 27.984	4993	25	93
12	37°54.22'	14°40.96'	13 07 54.133	4929	100	164
13	37°53.35'	14°40.35'	13 13 27.803	4873	25	101
15	37°51.31'	14°39.06'	13 25 59.082	4713	100	173
16	37°50.44'	14°38.45'	13 31 29.790	4625	25	92
17	37°49.56'	14°37.85'	13 37 30.798	4553	25	103
18	37°48.70'	14°37.23'	13 44 00.021	4515	100	176
19	37°47.81'	14°36.59'	13 49 31.348	4488	25	95
21	37°46.09'	14°35.34'	14 01 59.594	4393	100	171
22	37°44.92'	14°34.31'	14 07 29.814	4363	25	96
23	37°44.07'	14°33.66'	14 13 28.740	4350	25	104
24	37°43.22'	14°32.97'	14 20 02.108	4303	100	176
25	37°42.37'	14°32.30'	14 25 28.442	4235	25	93
27	37°40.64'	14°30.86'	14 37 54.911	4110	100	164
28	37°39.77'	14°30.23'	14 43 32.321	4033	25	106
29	37°38.89'	14°29.59'	14 49 33.708	3970	25	97
30	37°38.01'	14°28.96'	14 55 54.664	3893	100	148
31	37°37.07'	14°28.30'	15 01 31.238	3805	25	105
33	37°35.40'	14°27.04'	15 14 01.560	3625	100	178
34	37°34.56'	14°26.43'	15 19 28.285	3552	25	99
35	37°33.69'	14°25.80'	15 25 30.542	3498	25	96
36	37°32.82'	14°25.18'	15 31 59.282	3448	100	168
37	37°31.94'	14°24.56'	15 37 33 719	3445	25	120
39	37°30.25'	14°23.35'	15 49 57.516	3328	100	168

cont.

Note: missing shot numbers correspond to misfires

Table A.6 cont. Josephine Seamount Shot Data cont.

Shot No.	Location Latitude N	Longitude W	Shot Inst. h m s	Water Depth m	Charge Weight kg	Det. Depth m
40	37°29.37'	14°22.73'	15 55 31.747	3237	25	94
41	37°28.51'	14°22.13'	16 01 28.881	3133	25	99
42	37°27.63'	14°21.49'	16 07 58.777	2957	100	179
43	37°26.75'	14°20.85'	16 13 31.496	2799	25	100
44	37°25.88'	14°20.22'	16 19 34.118	2590	25	99
45	37°25.00'	14°19.58'	16 25 57.070	2258	100	164
46	37°24.10'	14°18.93'	16 31 29.933	1978	25	107
48	37°22.25'	14°17.58'	16 43 57.222	1935	100	160
49	37°21.37'	14°16.95'	16 49 30.906	2333	25	124
51	37°19.54'	14°15.63'	17 01 54.782	2796	100	179
52	37°18.63'	14°14.98'	17 07 33.932	2830	25	104
53	37°17.72'	14°14.33'	17 13 31.066	2862	25	97
55	37°15.90'	14°13.04'	17 25 31.836	2850	25	100
57	37°14.09'	14°11.74'	17 37 57.156	2824	100	170
58	37°15.32'	14°12.45'	08 01 28.876	2850	25	105
59	37°14.38'	14°11.84'	08 07 32.720	2838	25	100
60	37°13.47'	14°11.23'	08 13 58.993	2819	100	168
61	37°12.52'	14°10.67'	08 19 25.892	2808	25	99
62	37°11.57'	14°10.12'	08 25 31.856	2803	25	103
63	37°10.42'	14°09.97'	08 31 54.165	2790	100	170
64	37°09.43'	14°09.43'	08 37 29.853	2720	25	91
66	37°07.53'	14°08.26'	08 50 07.461	2390	100	159
67	37°06.58'	14°07.63'	08 55 34.172	2209	25	97
69	37°04.76'	14°06.36'	09 07 56.496	1843	100	107
71	37°02.93'	14°05.09'	09 19 31.304	1615	25	179
72	37°02.02'	14°04.43'	09 25 57.029	1604	100	104
73	37°01.11'	14°03.81'	09 31 28.218	1698	25	98
74	37°00.17'	14°03.15'	09 37 28.890	1754	25	159
75	36°59.34'	14°02.04'	09 43 56.980	1794	100	96
76	36°58.39'	14°01.35'	09 49 32.286	1830	25	99

cont.

Table A.6 cont. Josephine Seamount Shot Data cont.

Shot No.	Location Latitude N	Longitude W	Shot Inst. h m s	Water Depth m	Charge Weight kg	Det. Depth m
77	36°57.47'	14°00.62'	09 55 33.413	1830	25	163
78	36°56.54'	13°59.87'	10 01 59.049	1834	100	163
79	36°55.66'	13°59.17'	10 07 31.587	1834	25	103
80	36°54.80'	13°58.47'	10 13 25.302	1831	25	91
81	36°53.89'	13°57.76'	10 19 49.272	1806	100	143
82	36°52.98'	13°57.05'	10 25 26.149	1799	25	98
83	36°52.12'	13°56.41'	10 31 35.752	1755	25	107
84	36°51.22'	13°55.71'	10 37 49.258	1908	100	167
85	36°50.27'	13°54.98'	10 43 29.010	2083	25	91
86	36°49.40'	13°54.32'	10 49 26.819	2278	25	89
87	36°48.44'	13°53.58'	10 56 11.703	2550	100	161
90	36°45.78'	13°51.49'	11 13 57.899	2530	100	169
92	36°43.93'	13°50.06'	11 25 28.969	2777	25	95
93	36°43.04'	13°49.37'	11 32 02.163	2873	100	174
95	36°41.95'	13°48.15'	11 43 28.619	3083	25	93
96	36°41.09'	13°47.47'	11 49 55.484	3243	100	160
98	36°39.37'	13°46.16'	12 01 31.810	3430	25	101
99	36°40.24'	13°46.68'	14 02 09.893	3353	100	173
101	36°30.41'	13°45.35'	14 13 30.869	3555	25	100
102	36°37.51'	13°44.67'	14 20 06.915	3708	100	171
103	36°36.60'	13°43.99'	14 25 32.841	3808	25	99
104	36°35.69'	13°43.40'	14 31 30.100	3950	25	91
105	36°34.75'	13°42.77'	14 38 14.472	4109	100	166
106	36°33.92'	13°42.19'	14 43 28.644	4164	25	102
107	36°33.01'	13°41.62'	14 49 26.986	4238	25	104
108	36°32.06'	13°41.03'	14 56 06.001	4304	100	149
109	36°31.14'	13°40.46'	15 01 18.274	4355	25	93
110	36°30.21'	13°39.89'	15 07 27.596	4395	25	89
111	36°29.29'	13°39.32'	15 13 58.684	4422	100	136
113	36°27.43'	13°38.18'	15 25 31.333	4455	25	101

cont.

Table A.6 cont. Josephine Seamount Shot Data cont.

Shot No.	Location Latitude N	Longitude W	Shot Inst. h m s	Water Depth m	Charge Weight kg	Det. Depth m
114	36°26.52'	13°37.62'	15 31 57.668	4459	100	158
115	36°25.59'	13°37.05'	15 37 33.138	4462	25	103
116	36°24.65'	13°36.47'	15 43 24.281	4436	25	96
117	36°23.73'	13°35.91'	15 49 51.676	4413	100	150
118	36°22.80'	13°35.27'	15 55 36.150	4424	25	111
119	36°21.89'	13°34.62'	16 01 37.216	4443	25	104
120	36°20.19'	13°34.98'	16 07 56.475	4305	100	154
122	36°18.30'	13°33.76'	16 19 24.709	4459	25	80
123	36°17.37'	13°33.16'	16 26 03.970	4448	100	170
125	36°15.52'	13°31.99'	16 37 26.909	4320	25	104
126	36°14.58'	13°31.38'	16 44 00.932	4245	100	160
127	36°13.64'	13°30.78'	16 49 31.176	4335	25	103
128	36°12.69'	13°30.17'	16 55 36.036	4483	25	108
129	36°11.64'	13°29.59'	17 02 13.789	4515	100	177
130	36°10.73'	13°28.93'	17 07 32.831	4453	25	107
132	36°08.90'	13°27.49'	17 20 09.460	4617	100	177
133	36°08.06'	13°26.69'	17 25 23.360	4710	25	87
134	36°07.24'	13°25.86'	17 31 30.656	4770	25	100
135	36°06.44'	13°24.97'	17 37 58.975	4794	100	155
136	36°05.65'	13°24.06'	17 43 28.089	4802	25	98

Shots to test DOBS triggering

Day 338/88

Shot no	Size kg	Det'n time (at ship)	Position Lat	Long
1	25	13 46 40	37 14.99	14 55.38
2	25	14 46 43	37 15.90	14 42.66
3	25	15 46 42	37 16.08	14 30.37
4	25	16 46 43	37 16.12	14 17.10
5	25	17 16 44	37 16.11	14 10.61
6	25	17 46 40	37 15.95	14 03.93

Table A.3 Josephine Seamount Instrument Positions and Depths

Instrument No.	Location Latitude N	Longitude W	Depth m
11	36°27.30'	13°37.91'	4490
12	36°57.70'	14°00.14'	1844
13	37°14.32'	14°11.73'	2844
14	37°39.59'	14°30.21'	4061
15	38°11.02'	14°52.97'	5459

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF CAMBRIDGE

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BULLARD LABORATORIES
MADINGLEY ROAD
CAMBRIDGE CB3 0EZ

1 February 1989

Mr. Downes
Quality Assurance Manager
ICI Nobels
Nobel House
Stevenston
Ayrshire KA20 3LN

Dear Mr. Downes,

University College Cardiff Order No.63/7170 for
200 oceanographic capped fuses and 6850 kg explosives

The performance of the items supplied against the above order was extremely disappointing, and I am writing to ask whether you can offer any explanation or advice.

Although the order originated from Professor M. Brooks, University College Cardiff, for various complicated reasons I was finally responsible for the use of this explosive at sea on a UK research ship in November 1988. The order changed a number of times, both in delivery date and materials, but we finally settled on 6850 kg of bulkpack opencast gelignite and 200 oceanographic capped fuses (2m and 3m) to be delivered to Lisbon for loading onto RRS DISCOVERY in early November. In the event the shipment was delayed by the civil service dispute and we finally transferred the explosive to DISCOVERY on 12 November 1988. In the past we have always used Geophex explosive for firing at sea but you were unable to supply Geophex, and experience of Dr. Whitmarsh of the Institute of Oceanographic Sciences suggested that the gelignite would provide a satis-factory alternative, provided that it was not stored for a long period or immersed for a significant amount of time before firing.

We fired the explosive as 142 shots in four sessions over three days, on 20 November, 21 November and 3 December 1988. Two sizes of charge were used; 25 kg and 100 kg, composed of four 25 kg boxes securely banded together. The charges were made up and lit by a qualified and experienced shot firer (Mr. S. Jones, RVS Barry) and a number of experienced assistants, in a manner that we have used on numerous occasions before. The nominal fuse burn times for 25 kg shots was 90 seconds and for 100 kg shots, 120 seconds. 25 kg shots were mostly single fused, 100 kg shots mostly double fused. Charges were free sinking, pushed off the back of the moving ship and would have detonated at about 130 m (25 kg) and 175 m (100 kg) water depth.

Thus the different explosive type was the only deviation from a firing procedure that we have used a number of times before, and yet we had an unacceptable level of misfires. Normally we would expect perhaps one or two misfires in 142 shots, and would certainly worry if we had more than three:

contd...

Mr. Downes 1 February 1989

on this trip we had a total of 26 (i.e. 18% of the number of shots). The distribution of misfires is shown on the attached graph, and you can see immediately that they almost all occurred on the single fused 25 kg shots: only one multiple fused shot misfired.

Both explosive and fuses were examined carefully, and whilst nothing untoward was noted in the appearance of the explosive, the interior of the fuses seemed to have a far less uniform structure than usual and were sometimes difficult to light.

Two theories emerged on board ship:

1) That perhaps the gelignite needs more to detonate it than the Geophex we are accustomed to, explaining why multiple-fused charges seemed more reliable than single-fused.

2) That the fuses were faulty. Statistically it is unlikely that two faulty fuses would end up on one charge, which would explain why only one double-fused charge misfired. Also there was some evidence of variation amongst batches of fuses (fuses are kept in batches as delivered until the last minute, whilst explosive boxes will have been thoroughly mixed by the time they are fired).

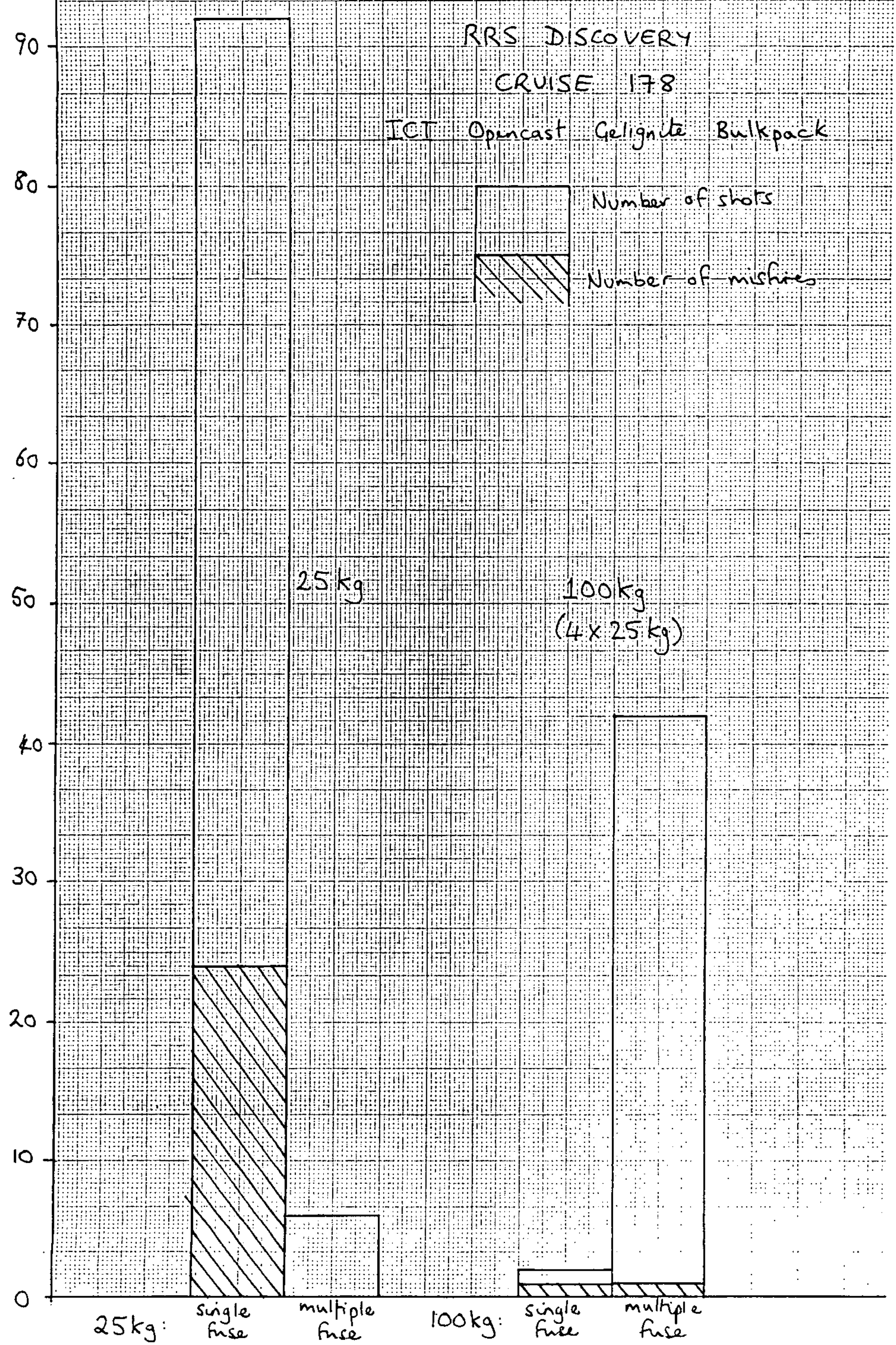
Our shot firer favoured the former explanation, whilst I prefer the latter. On a more positive note, the gelignite gave a very good bang when it did detonate.

It would be very interesting to know whether you could trace any irregularity in your fuse manufacture, or whether you have any views on our various theories. Obviously this experience will make us very wary of using the gelignite again unless it can be positively eliminated from suspicion, as the scientific loss from misfires is enormously greater than simply the cost of the explosive itself.

Yours sincerely,

P.J. Barton (Dr.)
Principal Scientist, cruise Discovery 178

cc: Dr. R. Whitmarsh, Secretary, Explosion Seismology Working Group, IOSDL
Mr. C. Adams, Operations Office, Research Vessel Services, Barry
Mr. S. Jones, Shot Firer, Research Vessel Services, Barry


RRS DISCOVERY
CRUISE 178
ICT Opencast Gelignite Bulkpack
Number of shots
Number of misfires
90
80
70
60
50
40
30
20
10
0
25kg
100kg
(4 x 25kg)
25kg:
single fuse
multiple fuse
100kg:
single fuse
multiple fuse

I received no written reply from ICI to my letter of 1 Feb 89, but Mr Jones, ICI Southern Region Technical Engineer (0443-224904), telephoned. His view was:

1) the detonator crimps were not suitable for use in that depth of water;

2) the opencast gelignite was not suitable for use at that pressure;

3) there should be no problem with the fuses as they are military spec;

4) he recommends sealing around the dets with silicone sealant;

5) ICI no longer supply Geophex. They now have a much safer emulsion explosive micro-encapsulated in wax spheres.

APPENDIX D

PARTICIPANTS
DISCOVERY 178

SCIENTIFIC

Principal Scientist	P.J. Barton
University of Cambridge	T.R.E. Owen
	C. Peirce
	J.R. Leonard
	P.W. Carter
	R. Evans
	S.P. Watson
	R.S. Smith (until 17/11/88)
IOSDL / Portugal	L.F. Pinheiro
RVS	S.J. Jones
	W.K. Smith
	C.H. Woodley
	R.A. Phipps
	R.B. Lloyd (until 9/11/88)
	A.J. Brook (from 10/11/88)
IOSDL	A.W. Gray
	R.E. Dyer

SHIP'S PERSONNEL

Master	M.A. Harding
Officers	P.J. Macdermott
	P.T. Oldfield
	M.A. Atwell
Radio Officer	B. Donaldson
Chief Engineer	P.E. Jago
Engineers	P.J. Byrne
	A. Greenhorn
	S.F. Green
Electrical Eng	W.D. Lutey
Bosun	F.S. Williams
Assistant Bosun	M.A. Harrison
Deck crew	M. Trevaskis
	D.W. Bevan
	S.C. Cook
	C.K.J. Cole
	S.E. Evans
	A.E. Olds
Motorman	I.W. Gibbs
Cook steward	R.L. Williams
Cook	G.A. Welch
2nd steward	P.C.H. Acton
Steward	J.T. Coleman
	D.E. Jenkins
	A.E. Philp

Table of Julian day numbers APPENDIX E

DISCOVERY cruise 178, 1988

Sat	5	Nov	310
Sun	6	Nov	311
Mon	7	Nov	312
Tue	8	Nov	313
Wed	9	Nov	314
Thu	10	Nov	315
Fri	11	Nov	316
Sat	12	Nov	317
Sun	13	Nov	318
Mon	14	Nov	319
Tue	15	Nov	320
Wed	16	Nov	321
Thu	17	Nov	322
Fri	18	Nov	323
Sat	19	Nov	324
Sun	20	Nov	325
Mon	21	Nov	326
Tue	22	Nov	327
Wed	23	Nov	328
Thu	24	Nov	329
Fri	25	Nov	330
Sat	26	Nov	331
Sun	27	Nov	332
Mon	28	Nov	333
Tue	29	Nov	334
Wed	30	Nov	335
Thu	1	Dec	336
Fri	2	Dec	337
Sat	3	Dec	338
Sun	4	Dec	339
Mon	5	Dec	340
Tue	6	Dec	341
Wed	7	Dec	342