UNIVERSITY OF CAMBRIDGE

DEPARTMENT OF EARTH SCIENCES

Cruise Report

R.R.S. DISCOVERY

Cruise 171

Two-ship multichannel seismic profiles with R.V. Conrad in the western Atlantic near the Blake-Spur Fracture Zone

October-November 1987

RRS DISCOVERY 171

Two-ship multichannel seismic profiles with RV Conrad in the western Atlantic near the Blake-Spur Fracture Zone

Barry	depart	23rd October 1987
Bermuda	arrive	9th November 1987
	depart	10th November 1987
Nassau, Bahamas	arrive	27th November 1987

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CONTENTS

1. OBJECTIVES

The objectives of this cruise were to return to an area of the Mesozoic North Atlantic where an earlier reconnaissance multichannel seismic profile had imaged reflectors within the oceanic crust, and to make a detailed seismic survey of the area. In particular, we were to use two-ship expanding spread profiles (ESP's) to determine the velocity structure of the crust and hence to identify the main reflectors seen on normal incidence seismic reflection profiles.

We planned to work across a normal ribbon of oceanic crust and the adjacent small-offset (11 km) Blake-Spur fracture zone so as to investigate the structure of both normal oceanic crust and fracture zone crust. We used two research ships each equipped with multichannel seismic systems, the RRS DISCOVERY and the RV CONRAD. The project was run jointly between Cambridge (R.S. White), Lamont (J. Mutter) and the University of Rhode Island (R.S. Detrick).

2. SUMMARY

This was an extremely successful field program, resulting in acquisition of high quality normal incidence and ESP data from the oceanic crust. All the objectives were met, although slipping ship schedules for both the Conrad and the Discovery meant that we spent much less time working jointly together than planned.

The seismic reflection profiles, recorded primarily from the Conrad, show an abundance of internal crustal reflectors, including crust-cutting faults, lower crustal layering and many strong upper crustal reflectors. Some faults cut down into the upper mantle and there is also layering in the upper mantle beneath the Moho. The main features observed are shown schematically in Figure 1.

We also successfully recorded ESP's along the major seismic reflection profiles. Some results are shown in Figure 2. Besides showing the relationship between the reflection records and seismic velocity structure of normal crust, they show the disruption of structure across the Blake-Spur Fracture Zone (Figure 3). An overview of the results has been published by White et. al. (1990), and by Minshull et al. (in press). Several other papers are in preparation.

Publications (excluding abstracts of talks)

White, R.S., Detrick, R.S., Mutter, J., Buhl, P., Minshull, T.A. & Morris, E. (1990). New seismic images of oceanic crustal structure, *Geology*, 18, 462-465 and foldout.

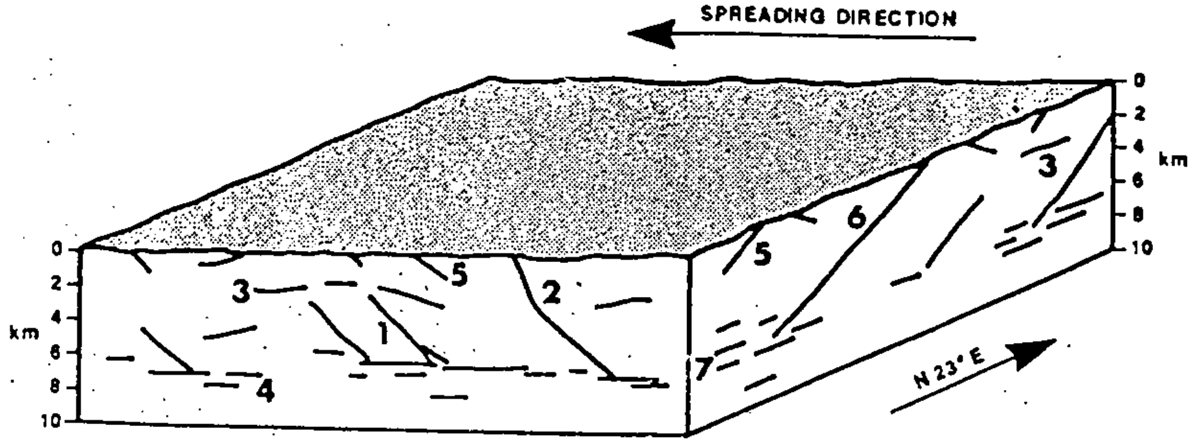
Minshull, T.A., White, R.S., Mutter, J.C., Buhl, P., Detrick, R.S., Williams, C.A. & Morris, E. Crustal structure at the Blake-Spur fracture zone from expanding spread profiles. *Journal of Geophysical Research*, submitted, 1990.

Segmentation of spreading ridges: MCS evidence for structural control, Lamont Newsletter, Fall 1989, pp. 4, 4A.

Minshull, T.A. (1989). Multichannel seismic studies of sediment accretion and anomalous fracture zone crust. Unpublished Ph.D. dissertation, University of Cambridge.

Solomon, S.C. (1990). New images for old faults. Nature, <u>344</u>, 816-817. (A News and Views article commenting on the faulting seen on our profiles).

Other papers describing the seismic results are in preparation.



Schematic block diagram of basement; axes are oriented parallel and perpendicular to ridge spreading direction to illustrate main features observed in seismic profiles across normal oceanic crust in survey area. Numbers refer to features discussed in text. No vertical exaggeration.

GEOLOGY, May 1990

Figure 1. True scale schematic diagram of main reflectors imaged in the western North Atlantic (from White et. al., 1990).

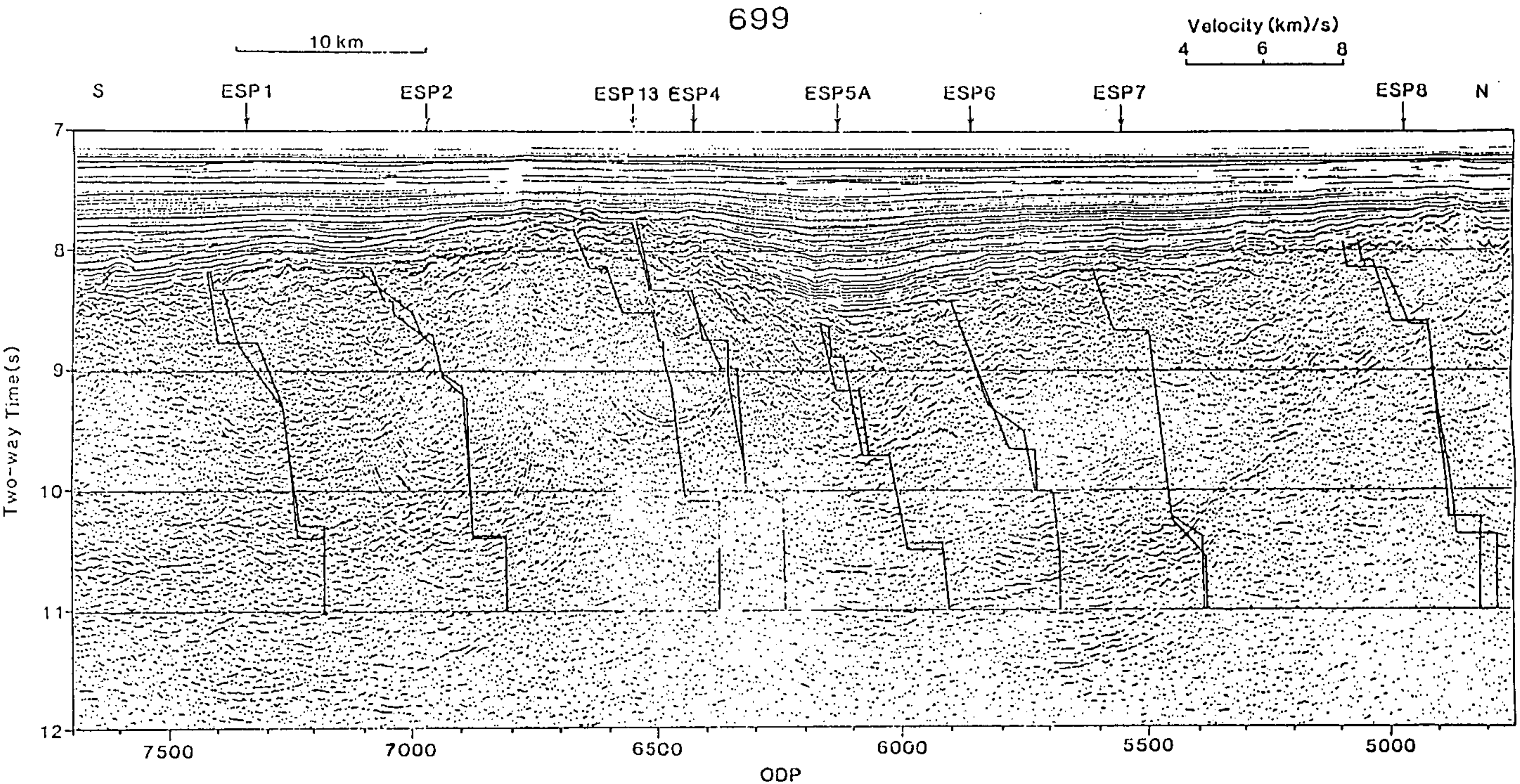


Fig. 2. ESP p-wave velocities superimposed on migrated strike line profiles 699 (for location see Fig. 1). Arrows mark the horizontal position corresponding to a velocity of 6 km/s (from Minshull et al., in press).

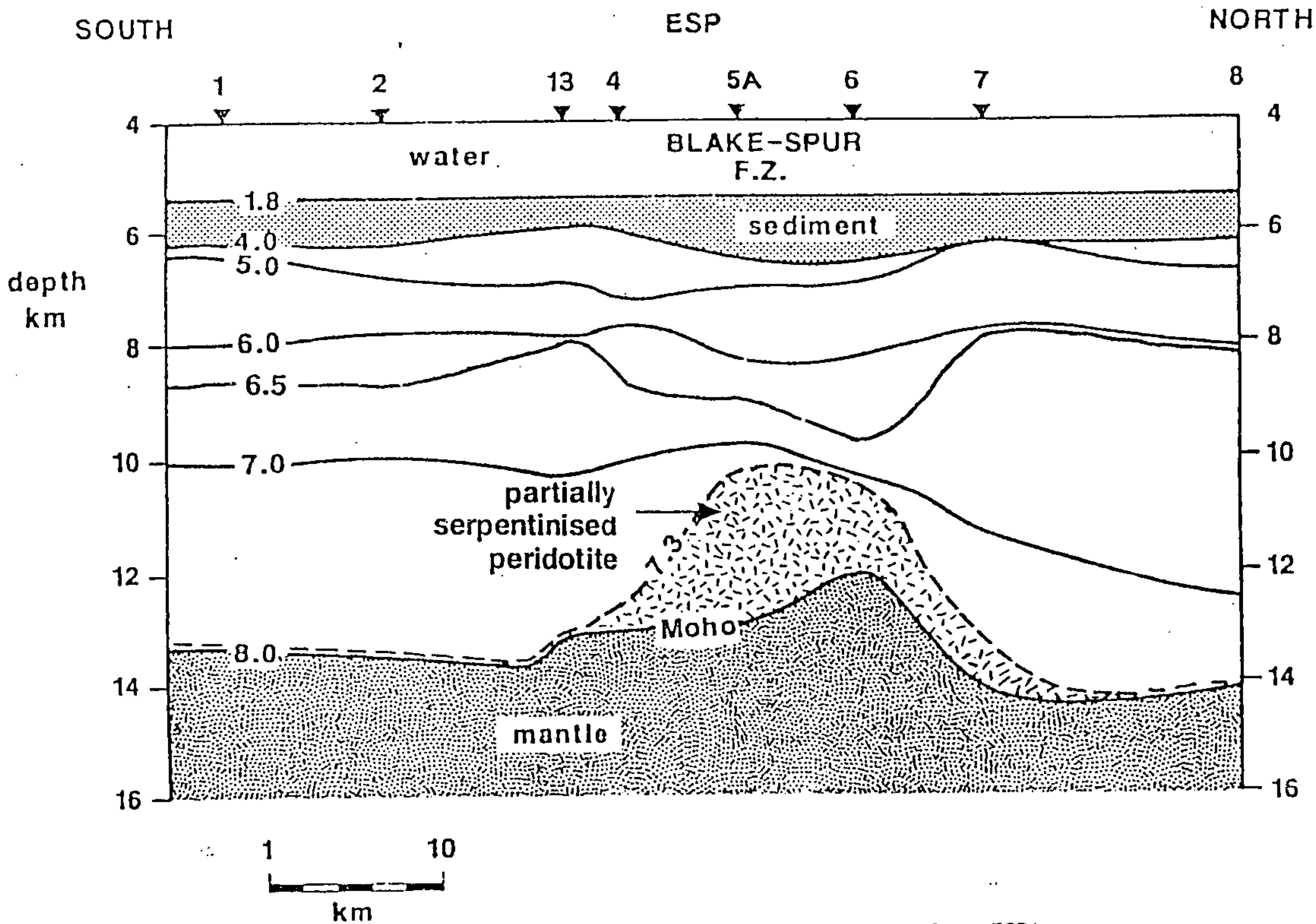


Fig. 3. Velocity-depth structure from ESP's across the Blake-Spur F.Z. in the same location as Fig. 5 (from Minshull et al., in press; White et al., 1990).

3. NARRATIVE

23rd October-9th November 1987   Passage Barry-Bermuda

Very heavy weather during the passage delayed arrival at Bermuda from scheduled 3 Nov to 9 Nov. Tim Minshull and Peter Carter from Cambridge were aboard, with a full complement of RVS technicians. The mcs streamer was deployed several times and balanced roughly. During one deployment the connectors were broken in one of the three front spring sections, so only two serviceable units were left: this may have contributed to noise on the array during the experiment.

The e.t.a. for Conrad kept getting later. It was supposed to sail from New York on 27 Oct, but eventually left on the afternoon of 3 Nov. They only had two days on passage for equipment trials before reaching Bermuda early afternoon on 9 Nov.

While in Bermuda we mounted Raydist and Miniranger slaves on Discovery, Trisponder slaves on Conrad, and calibrated them.

10th November-14th November   Preliminary Survey

Discovery sailed at 1030(1) on 10 Nov, ahead of Conrad which sailed at midday on 11 November. Proceeded direct towards survey area, deploying P.E.S. at 1000(L) on 11 Nov and mcs at 1500 on 11 Nov. Airgun deployment took some time, completed and firing by midnight (L).

Spent 12 Nov tidying up and tuning the system, but weather deteriorated to force 5-6 by evening. Using all four compressors (4 x 35 cu. ft./min), we could fire 700 + 466 + 40 + 40 + 160 = 1406 cu. in. airguns at 1750 psi. But pressure dropped if one compressor failed.

During Friday 13th the weather dropped a little to Force 5, but quite a swell developed which caused heavy rolling on cross-tracks. Guns working well, but streamer sections gradually going open circuit. By the morning, two channels were completely dead and three others down to 24 m groups. By the evening a dozen channels were dead, apparently through failure in the spring section connector.

At 0300(L) on 14 Nov we pulled in the guns and streamer. Spent until 1130(L) mending approx. 50 broken wires in the connectors, eventually fixing all but one channel. Swell dropping. Conrad arrived. On the basis of our preliminary survey we sited the ESP's and single-ship reflection lines. The Blake-Spur F.Z. was some way from where it had been located on earlier regional magnetics profiles.

<u>14th November-20th November</u>   <u>ESP's 1-12</u>

Started first ESP-1 at 70 km range at 1900(L) on 14 Nov. Trisponder held out to 62 km and Raydist to maximum range. Weather force 5 with some sun. Lab radios not working well, so having to use ship's bridge radios for communications with Conrad. Decided to run parallel ESP's northwards to sample crust south of the Blake-Spur F.Z., within the fracture zone, and to the north of it.

Smooth transition from ESP-1 to ESP-2. Double shooting all ESP's (inward from maximum range, then outward). Varied the record lengths during acquisition to keep the water-wave arrival on the digitised record. By midday, weather deteriorating to 24 knot winds and increasing swell. During the morning received a telex from Conrad to say that ESP-3 would start at 1424 (L), so broke off ESP-2 just before the end and headed for start position of ESP-3. At about 1400(L) we received a message from Conrad delaying start of ESP-3 until 1530(L), so we slowed and made a large turn to lose time. Good navigation on ESP-3, with ships finishing at correct range. Weather Force 6, winds 20-25 knots during shooting. Finish ESP-3 at 2230(L).

Coming round to ESP-4 the third mate had difficulty navigating as we came into the weather and had 25 knot winds against us. Another engine was started, but took some time to start up. The result was that we were pushed some way off course and started ESP-4 some 5 nm from the designated start point. Meanwhile (and unbeknown to us), Conrad was experiencing difficulties with the DSS-240 and only started firing 48 min late. The agreed net result was to push the mid-point to the west, and to continue shooting for longer. Weather still deteriorating, force 6, gusting 7, which caused noisy data on both ships.

At the end of ESP-4 we came round to ESP-5. Unfortunately the third mate was not used to towing seismic gear and took the ship up to 8 knots to pull it round the turn. This broke an enormous number of wires in the stretch section, resulting in us losing at least 39 of the 96 groups, open circuit. We continued shooting the inward leg of ESP-5 but broke off at the mid-point (1501L) and pulled the streamer in. Meanwhile Conrad was investigating their continuing memory buffer problems on DSS-240.

We replaced two spring sections, within 1 1/2 hours and planned to restart shooting at 2100(L). Conrad subsequently delayed the start until 0003(L), and we continued with the outward leg of ESP-5. Heavy seas and poor navigation meant that quality was not good and we subsequently re-shot this profile as ESP-5A. Wind was behind us on ESP-5, causing array to be noisy as it picked up and pushed the streamer in the swell. Wind now 35 knots, force 7.

Turned onto ESP-6, starting at 0726(L). Streamer intermittently noisy due to weather, and biggish swell. Conrad briefly lost steering at 1125(L). Otherwise uneventful.

ESP-7 suffered from poor bridge control. Speeds of up to 6.7 knots on the turn broke another 5 wires. At the cross-over, the Master took us 5° to starboard and we never got back on the line. This was one of the least consistent mid-points of all the ESP's.

Coming onto ESP-8, the weather was moderating somewhat. Wind down to 25 knots and swell lower. Agreed with Conrad that they would do the manoeuvering on the cross-over. But on ESP-8 they came too close (320m), and Discovery had to take 30° port avoiding action so as to miss their tail-buoy. It eventually passed us 100-150m off the starboard side. We took about half the outward ESP-8 to get back on course. Slowed down for the last half, as Conrad was apparently making less speed. Wind dropped to 15-20 knots.

ESP-9 through ESP-11 were uneventful. Much quieter, with improved weather, and manoeuvering near mid-point is better with practise. By 19th the weather was beautiful, wind less than 10 knots, force 3-4.

During the last ESP-12, inward leg, the Sercel tape drives stopped working. Continued the inward leg while the drives were stripped (starting at 0500L on 20 Nov). Eventually got one tape drive working shortly after the crossing and shot the outward leg with one drive. By reducing the recording window we maximised the number of shots per tape and minimised the data lost during tape changes. Finished ESP-12 at 1222(L) on 20 Nov. Eventually traced the tape drive problem in the late afternoon to an EOT marker on a bad tape 8' from the beginning. So the recording system was O.K.

<u>20th November-21st November</u> <u>S.A.P. 699 with Conrad</u>

Formed up for the two-ship SAP (line 699) down the mid-points of the ESP's. Weather deteriorated to Force 7 seas with rain. Discovery was lead ship with Conrad maintaining a ship-to-ship range of 5800m. Discovery shooting 700 + 466 + 300 + 160 + 40 guns, alternately with Conrad shooting at 40 sec intervals. Recording 15 sec windows. Conrad shooting 5800 cu in at 2000 psi. Started at 1936(L) on 20 Nov. Wind gusted 8 during the night, but streamer was quiet. Discovery station-keeping not good, with wild speed variations, and current oscillating from 1000 to 1500 amps. At about 1000(L) the engineers shut down the main engine to look at the drive, and continued on the bow-thruster. But this wasn't strong enough to maintain 3 knots against the sea. So we limped on until 1600(L), when we pulled off the line just after crossing the Blake-Spur F.Z. Conrad lost steering temporarily near this point, but then continued. Conrad firing interval increased first to 30 sec, then 20 sec. But they could not maintain 20 sec with 5800 cu in, so changed back to 30 sec for the remainder of the line. On subsequent single-ship profiles they used about 4800 cu in at 20 sec.

As soon as the compressors were switched off on Discovery, the engine problem disappeared. Since we did not intend firing airguns any more and did not need the 200 k.watt generator, we had no further problems. Spent a quiet night waiting for Conrad to finish profiling and re-form to re-shoot two ESP's near the Blake-Spur F.Z.

<u>22nd November-25th November</u> <u>ESP5A, 13-18</u>

Re-shot ESP5A with a mid-point further west, starting at 0140(L) on 22 Nov, completing at 1012(L). Then decided to shoot a new ESP13 between existing ESP3 and ESP4. Near-perfect navigation on ESP-13, staying with 200m of the planned line all the way and with GSP coverage throughout. Navigated this line from the lab., which generally is better than leaving the Bridge to do it as we are more aware of the accuracies of the various navigational systems at any time. Array fairly quiet, despite 15 knot winds.

Remainder of time with Conrad before Discovery had to depart for Nassau was spent in ESP's orientated north-south. Unfortunately the ship scheduling did not leave us together longer than this, although Conrad had another 7 days at sea during which they completed single-ship profiles.

Only the outward leg of ESP-14 was shot, to save time, completing at 1021(L) on 23 Nov. On transit to ESP-15 we recorded XBT's. Surface water temperature is 25°C. ESP-15 completed by 2100(L) on 24 Nov.

On transit to ESP-16 we tried to record wide-angle, constant range arrivals from Conrad, but this was not very successful due to poor navigation and high winds. Navigation on ESP-16 was not very good, as Conrad lost its main engine at 0255(L) on 24 Nov.

During ESP-17 the wind got up to ~25 knots. Ship surging between 4.0 and 4.8 knots, causing the streamer to rise up and down during the line.

After a long 10 hour transit to the north end of ESP-18, we half-shot this final ESP, starting at noon on 25 Nov. Weather getting worse, blowing force 7 by the end of the line.

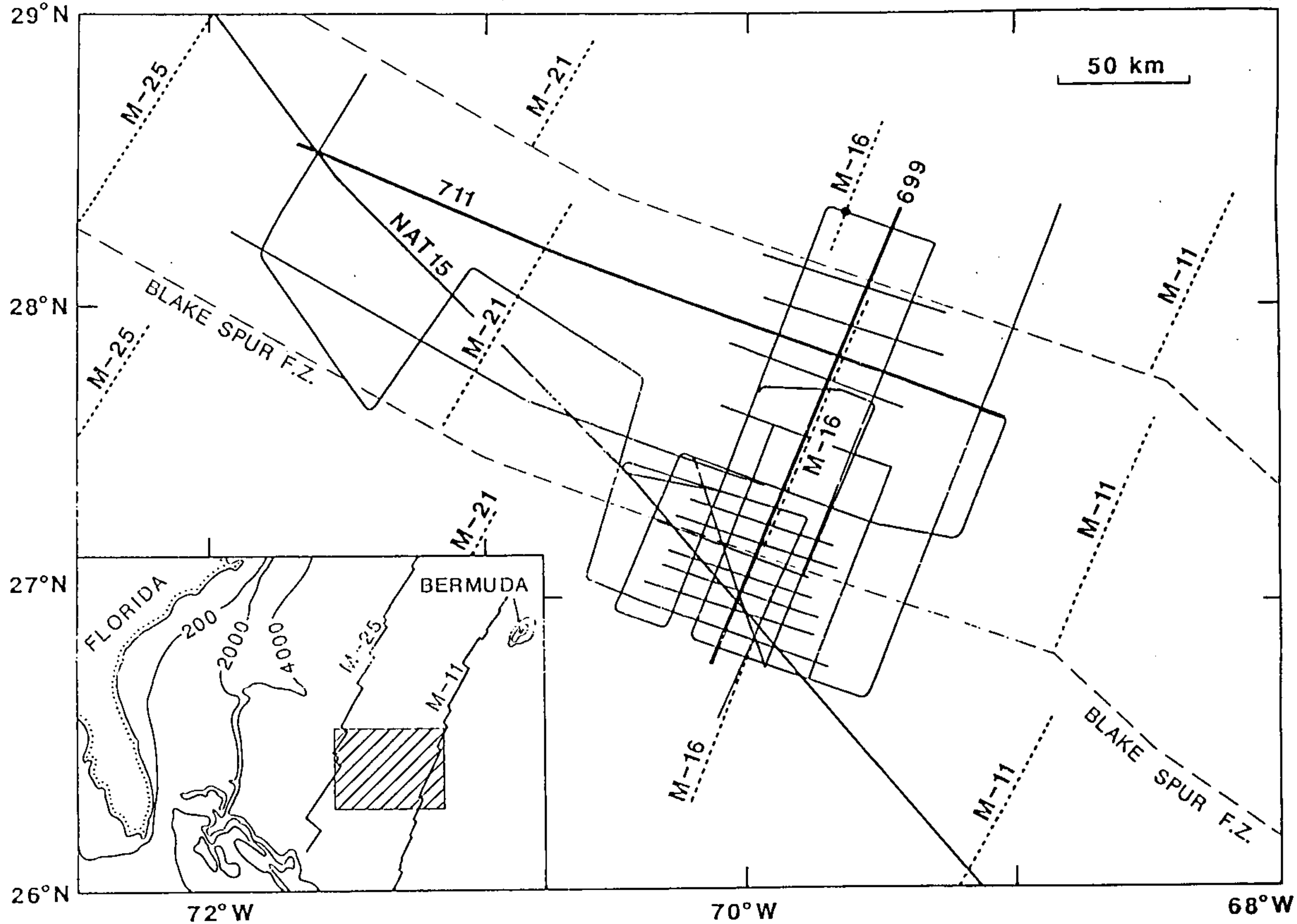
<u>25th November-27th November</u>   <u>Transit to Nassau</u>

At the end of ESP-18 we went head-to-wind and pulled in the mcs streamer and airguns. Completed by 2345(L) on 25 Nov. Stripped off two spring sections en route. Bird 2 found hanging by one collar only.

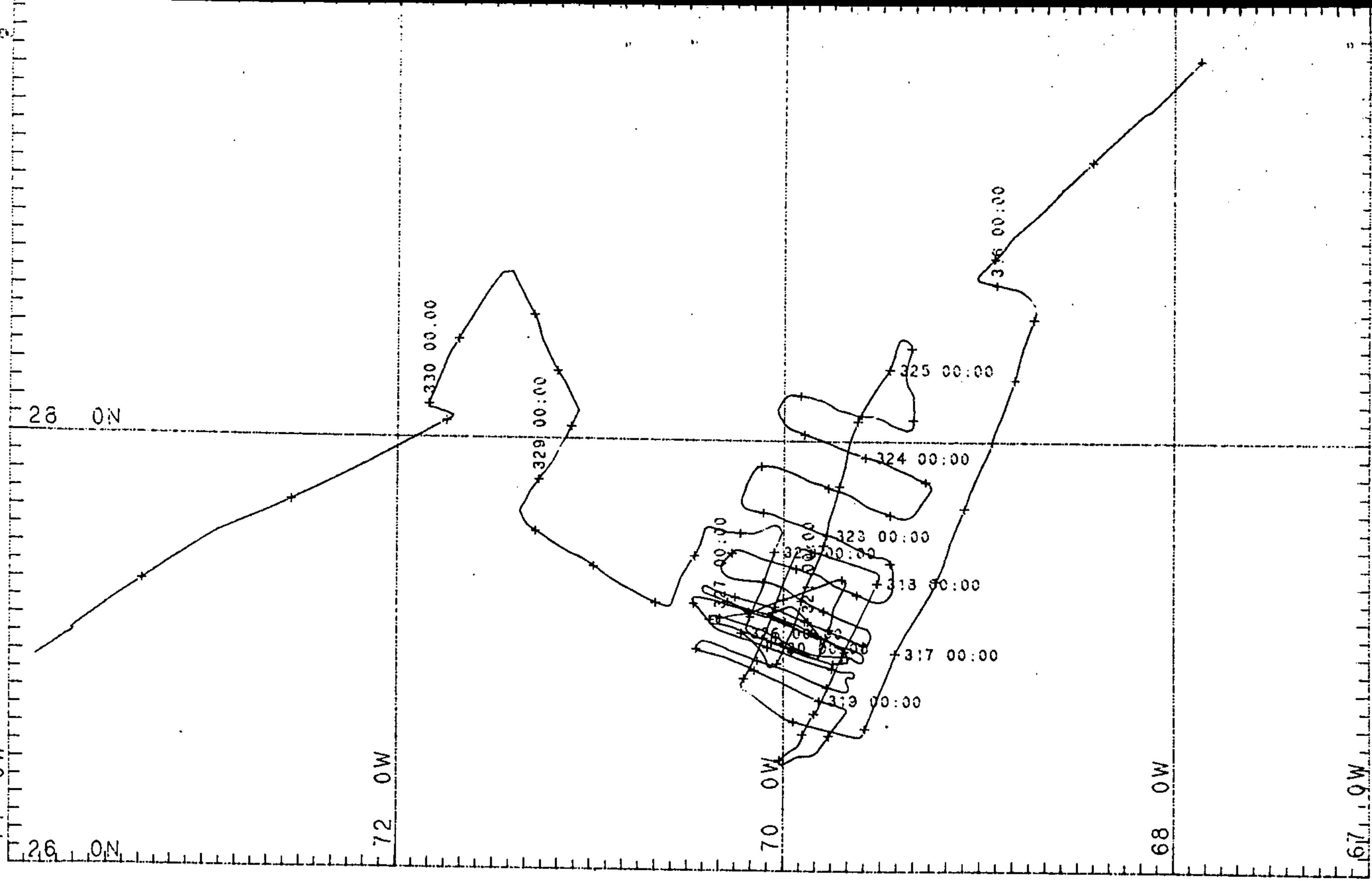
Made good speed to Nassau, 12 1/2 knots on two engines with a following sea. Stripped labs and packed boxes ready for container awaiting us in Nassau.

Picked up pilot at 0810(L) on 27 Nov, and berthed by 0900(L). Air-freighted Raydist to New York, and tapes by container to Miami. Tapes were loaded into the rear end of our container, for trans-shipment at Miami. Scientific party left via Miami on 28 Nov.

4. Track Charts



Location of mcs profiles (this survey). Line labelled NAT 15 is earlier North Atlantic Transect mcs profiles. Broken lines show positions of fracture zones; dotted lines show main seafloor spreading magnetic lineations.



MERCATOR PROJECTION

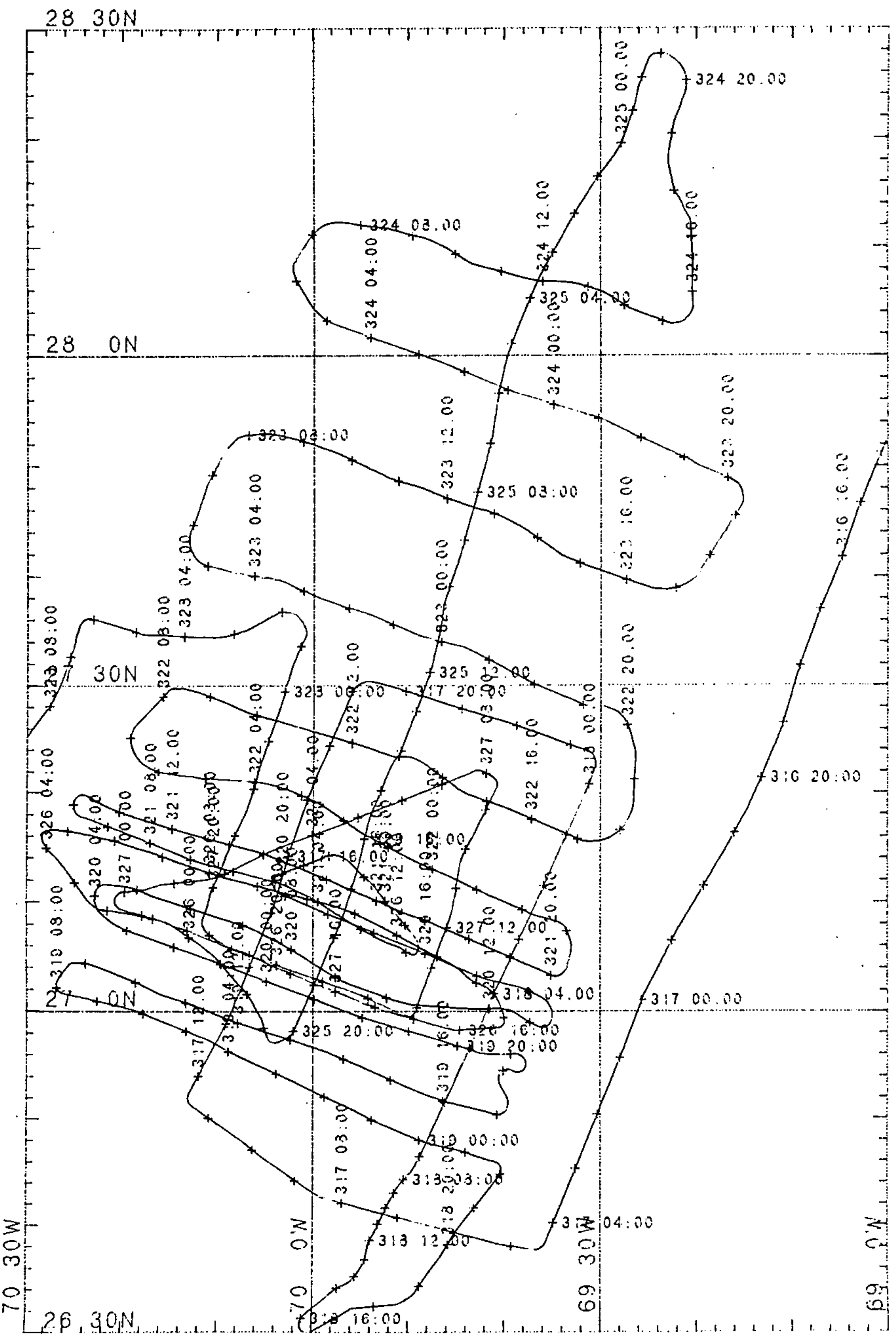
SCALE 1 TO 3000000 (NATURAL SCALE AT LAT. 0)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

GRID NO. 1
TRACK NO. 1

— Track plotted from satnav

Discovery 171 - MCDSAS



MERCATOR PROJECTION

SCALE 1 TO 1000000 (NATURAL SCALE AT LAT. 0)

GRID NO. 1
TRACK NO. 1

Ship RRS DISCOVERY Cruise No 171

Cruise Dates (Inclusive, port to port) Barry - Bermuda - Nassau
24 October - 27 November 1987

It is requested that the following aspects of the cruise may be covered in this report of proceedings for dispatch or delivery to the Director, Research Vessel Base, immediately on return to port.

a) Main objectives of the cruise.
b) Geographical area. Reference stations or points in latitude and longitude.
c) Sea and weather conditions encountered.
d) Conduct of cruise, main problems encountered and success or otherwise of the program
e) Equipment performance.
f) Ship performance.
g) Any recommendations.
h) Signature and date.

Brief comments are preferred but if necessary please continue on another sheet.

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a) Main objectives: to conduct single and two-ship multichannel seismic profiles with R/V CONRAD to investigate the crustal structure of the Blake-Spur Fracture Zone and environs.

b) Area: Western N. Atlantic, 26-29°N, 69-71°W.

c) Weather: mostly force 5-7. Not ideal for seismic profiling, since rough seas can make the records very noisy, but nonetheless we continued work throughout. Predictably, heavy weather on the crossing from Britain to Bermuda caused us to lose about 5 days, representing 25% of our working time.

d) Conduct of cruise and main problems: The cruise was outstandingly successful in achieving all the main objectives. This two-ship seismic dataset is now one of the best, arguably <u>the</u> best in existence anywhere in the world. It is certainly the best seismic dataset of any kind for addressing the crustal structure of a fracture zone and adjacent ribbon of oceanic crust.

The main problems were with wires becoming detached from the connectors in the spring sections of the streamer, as discussed below.

e) Equipment Performance: In general, all the equipment performed well or was quickly repaired or replaced when it failed. The Rubidium clock was outstandingly useful, making the GPS Trimble 4000S receiver highly reliable for real-time navigation for over 12 hours per day, compared with only sporadically useful real-time navigation available without the clock (a full report has been written separately). The airguns, their deployment system and the Riftek control system all worked well. The overhauled Sercel tape drives gave fewer parity errors than I have ever known before. We had only one serious failure of a tape deck, with little loss of data.

The main problems were with the spring sections of the streamer. The wires near the connector apparently had no play in them and they easily pulled off the connectors. There were two major incidents. In the first, the duty officer of the watch took the ship too fast around a turn, exceeding 8 knots, and breaking two-thirds of the connections. We abandoned the line and pulled the streamer in. On the second occasion, a different officer again

/contd...

e) contd.

went too fast, this time reaching 6.7 knots and we lost half a dozen connections. We had to continue for the remainder of the cruise with the degraded streamer. The conditions under which this damage occurred ~~was~~ were fairly severe, with heavy weather causing snatch loads on the streamer and too-high speeds imposed by the bridge, but nevertheless the spring sections should have coped, at least on the second occasion. The internal spring section wires were apparently too tight to allow any play near the connectors.

f) Ship Performance. In general, little time was lost due to engine difficulties. There was some delay caused on the transit to Bermuda when water entered the engine-room, and we unfortunately had to break off our only two-ship wide aperture profile because of high transient currents in the motor loop. Otherwise the ship performance was satisfactory. The Bridge navigation was less precise than I would have liked, but our demands were far higher than most other scientists so the officers were not used to such stringent requirements.

g) Recommendations:

1) If precise real time navigation in deep waters is required, it is essential to use a good frequency standard with the GPS receiver.

2) The spring section wire connections were unsatisfactory in the re-skinned sections, and caused us a lot of trouble. We have not had this trouble before: can they be built with more play in next time?

3) It was worth overhauling the Sercel tape drives. But these are such a crucial and vulnerable part of the mcs system that I cannot understand whey a third tape drive is not purchased for stand-by. Second-hand drives are available relatively cheaply. Fortunately, we only lost a little data through tape drive failure. But it was nerve-racking knowing that there was no back-up.

h) After such a successful cruise it may sound a little churlish to recall that following approval of the NERC grant and seatime the cruise was not initially programmed into the ship schedule. The reason I was given to understand was that the logistics of commissioning the mcs were difficult and the existing airgun array was considered too dangerous to deploy from Discovery. I was very upset, as were our American collaborators on Conrad. Eventually the cruise was re-instated on Discovery but for what was clearly an inadequate period from 25 Oct to 21 Nov. I pointed this out as persistently as I could, and eventually another 7 days were added. If they had not been, we would have had only 7 days on station instead of 14 and we could have done much less than half the two-ship work.

I recall these details partly in order to show that my persistence in obtaining a feasible schedule and the cooperation of those in NERC who took note of it, was indeed justified in the light of events and in the

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outstandingly successful cruise results. If I had accepted the failure to schedule the cruise into the programme, clearly nothing would have been done. If I had accepted the subsequently programmed cruise dates we could still have done rather little two-ship work, which would have been a huge waste of opportunity to say nothing of 3 weeks steaming. But, quite apart from the waste of time in fighting these battles their persistence is battering our morale, and I do not enjoy them. Nor, I presume, do any of the NERC people involved.

I recognise that programming the ships with so many disparate demands and constraints on them is very difficult, but some of these difficulties might be avoided if the Chief Scientists involved had more say in the draft programming before it is finalised. Maybe an all-day session at Swindon with all the Chief Scientists or their representatives present would enable a draft programme to be knocked into shape: at least all those present would then have the opportunity to stand up for constraints which are vital to their work, and to negotiate or allow change to less vital elements. If the people concerned are actually there this could be done in a way that can never be possible by NERC officers telephoning around. Clearly the ultimate responsibility for programming must lie with NERC, but it would be sensible to have the Chief Scientists involved since they alone know what is vital and what is not for the success of their programme.

I reiterate that at the end of the day, and after all the vicissitudes, this was a very successful cruise.

RSWhite

Robert S. White,

Bullard Laboratories,
Madingley Road,
Cambridge CB3 OEZ

6. SERCEL MCS OPERATION

The extended header was inoperable on the Sercel, so only the Sercel header was recorded. In order to provide an unambiguous time base the Cambridge No.1 Clock was recorded continuously on one of the auxiliary channels, providing 1 sec markers with bcd coding for elapsed hours and minutes.

The start of digitisation commenced exactly on an even minute and was derived from the RVS master clock. So during the bulk of the cruise, with 40 sec. firing rate from Conrad, the records commence at

H.M.		SEC
0000	:	00
0000	:	00
0001	:	20
0002	:	00

Very occasionally the Discovery trigger jumped to a different second so the start of digitisation should always be checked by playing out the clock on the auxiliary channel.

When airguns were fired from Discovery, the peak pressure pulse was at 40 msec after the start of digitisation.

During two-ship wide aperture profiles the Discovery and Conrad shots were displayed separately on a split EPC. The Conrad trigger pulse jumped around by a few hundred milliseconds, so the Conrad profile needs timing corrections before it can be processed.

6.2 ESP Recording

At large ranges the water-wave from the previous Conrad shot arrived after the trigger for the next shot. In order to maintain continuous recording of the water-wave we monitored it closely with the camera monitors and adjusted the recording window accordingly. The approximate record windows were as follows, although they were adjusted for each specific line:

Range	Delay	Record Length	Record Window
(km)	(s)	(s)	(s)
>50	0	38	0 - 38
50-45	10	28	10 - 38
45-50	10	25	10 - 35
40-20	6	25	6 - 31
<20	0	25	0 - 25

6.3 Airgun Firing

The airgun array was fired using the Reftek gun synchroniser. This was triggered from the start of digitisation pulse. The peak pressure pulse was set to 40 msec after the start of digitisation.

Five airguns were deployed: four from the new starboard towing beam and the large (700 cu. in.) gun separately. For single ship profiling the array was fixed at 20 sec. intervals using 700 + 466 + 160 + 40 + 20 cu. ins. fired at 1900 psi. For two-ship wide aperture profile we used 40 sec. firing rate with 700 + 466 + 300 + 160 + 40 cu. in. guns fired at 1900 psi.

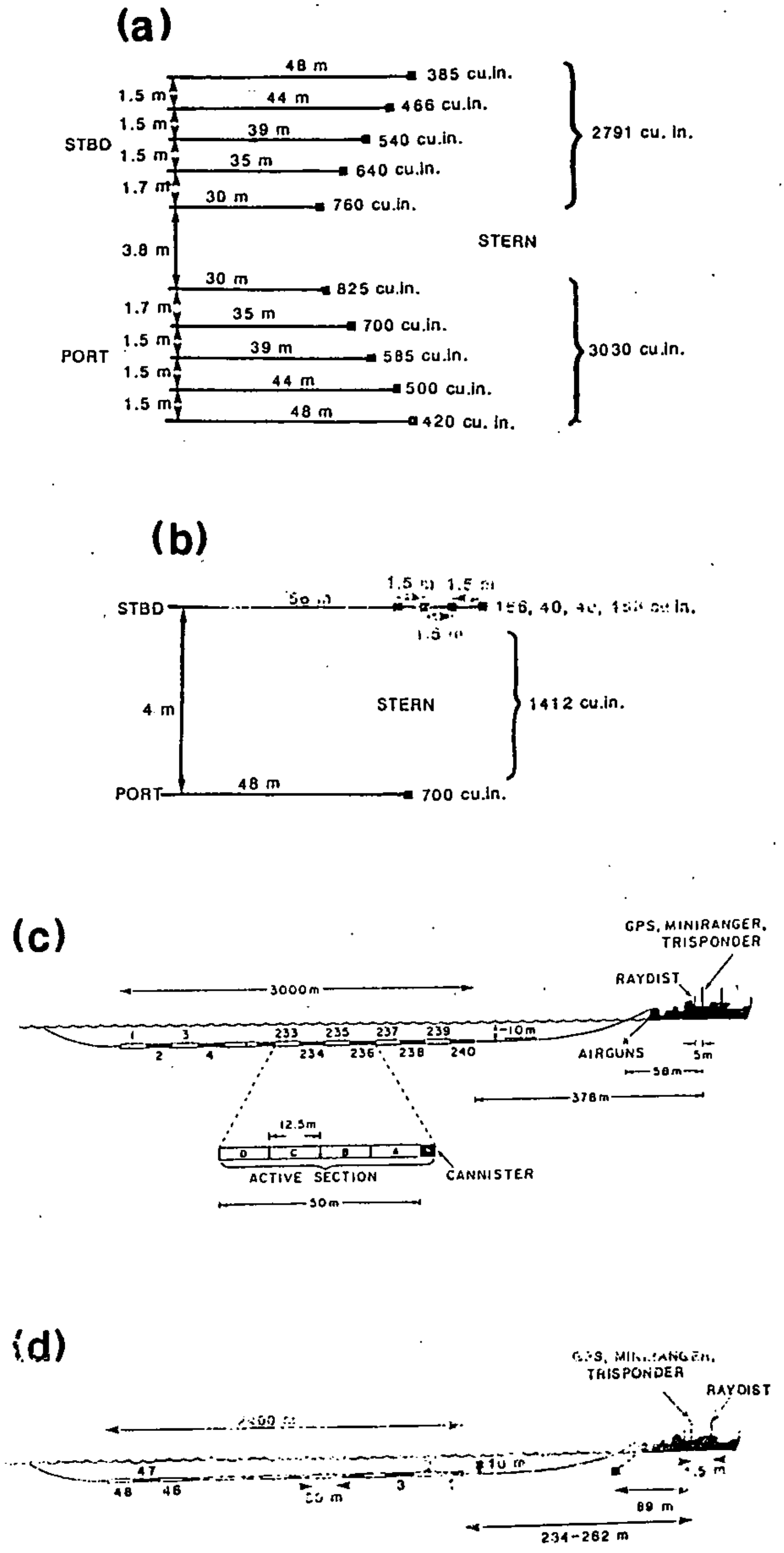
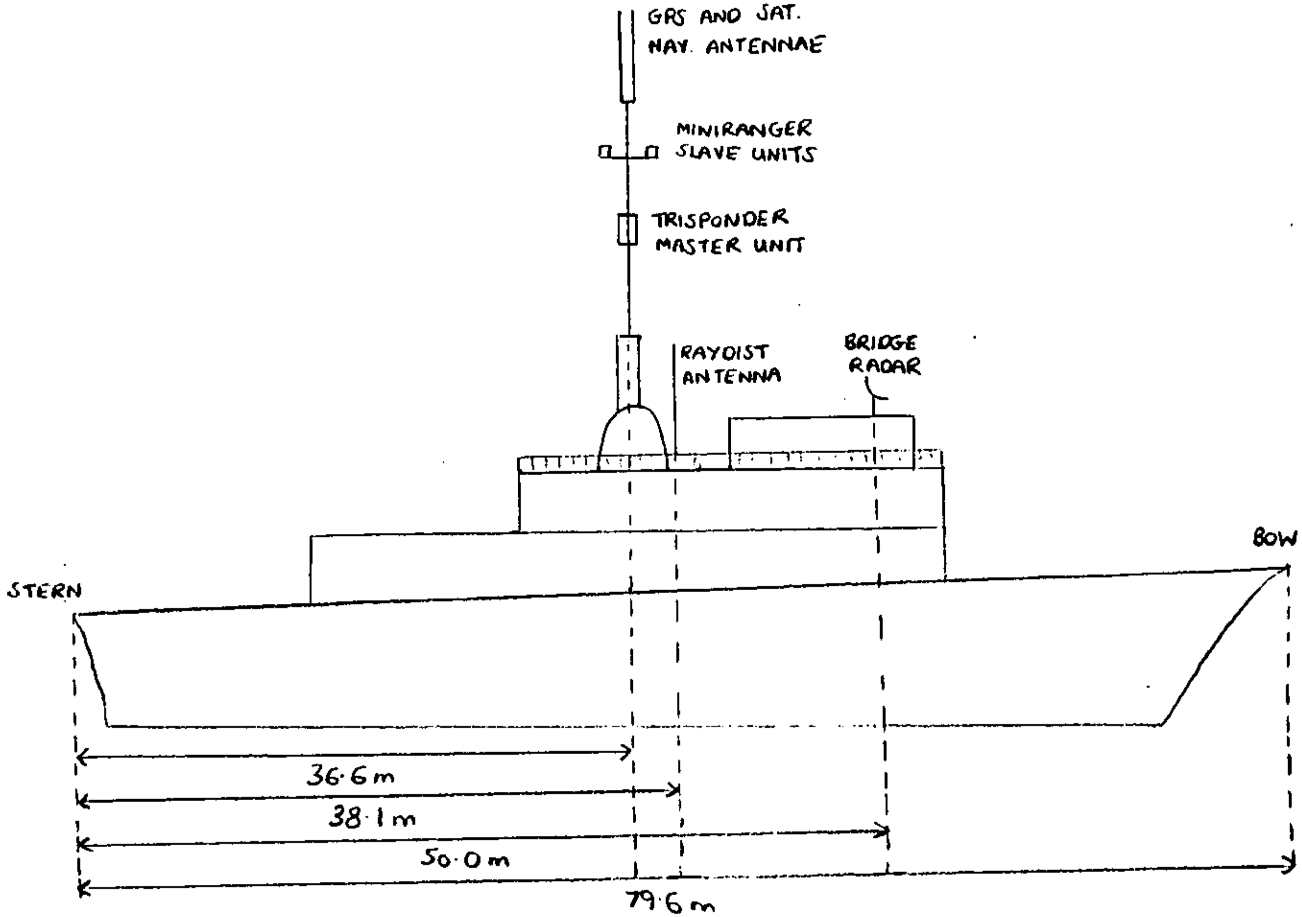


Figure 3.2: (a) Plan view of airgun array towed by R/V Conrad (source for ESP data). (b) Plan view of airgun array towed by RRS Discovery. (c) Multichannel streamer towed by Conrad. (d) Multichannel streamer towed by Discovery (receiver for ESP data) (from T. Minshull, 1989).



R.R.S. DISCOVERY

7. (a) Table of Line Numbers and Corresponding Field Tapes From RRS DISCOVERY

Suffix A or B refers to the tape deck on which the tape was recorded

Line number	Experiment Location	Start-time (GMT)	End-time (GMT)	Tape Numbers
CAM 31	Line 101	0345/316	0417/317	1A-51B
CAM 32	Line 106	0544/317	1241/317	52A-68A
CAM 33	Line 104	1242/317	1912/317	69B-86A
CAM 34	(between ESP 8 and ESP 9)	1912/317	2353/317	87B-98A
CAM 35	Line 102	2354/317	0702/318	99B-117B
CAM 36	ESP 1	2300/318	0720/319	118A-152A
CAM 37	ESP 2	0916/319	1656/319	153B-182A
CAM 38	ESP 3	1928/319	0306/320	183A-215A
CAM 39	ESP 4	0432/320 (CONRAD start firing 1518/320)	1148/320	216A-244A
CAM 40	ESP 5	1440/320	1859/320	245B-262A
CAM 41	ESP 5	0405-321	0758/321	263A-280A
CAM 42	ESP 6	1130/321	1934/321	281A-315A
CAM 43	ESP 7	2226/321	00532/322	316A-375B (1st shot)
CAM 44	ESP 8	0900/322	1700/322	375B-380A
CAM 45	ESP 9	2058/322	0508/323	381A-416B
CAM 46	ESP 10	0900/323	1631/323	417A-451A
CAM 47	ESP 11	2052/323	0477/324	452A-486A

CAM 48	ESP 12	0829/324	1457/324	487B-495A
CAM 49	SAP 1	2330/324	2012/325	496A-557B
CAM 50	ESP 5A	0600/326	1407/326	558A-593B
CAM 51	ESP 13	1700/326	2336/326	594A-619B
CAM 52	ESP 14	0846/327	1407/327	620A-642A
CAM 53	ESP 15	1656/327	0000/328	643B-664A
CAM 54		0320/328	0610/328	665B-669B
CAM 55	ESP 16	0632/328	1058/328	670A-686A
CAM 56	ESP 17	2145/328	0507/329	687B-718A
CAM 57	ESP 18	1556/329	0009/330	719A-752B

b)

Tape numbers from RV CONRAD

RC 28-10
CDP and WACDP PROFILES

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
103	683	2130Z 13 Nov 87	26°35.600'N 70°05.654'W	0700Z 14 Nov 87	27°17.044'N 69°46.276'W	2-23	2
109	684	0701Z 14 Nov 87	27°15.097'N 69°46.635'W	1437Z 14 Nov 87	27°28.752'N 70°26.571'W	24-42	2
110	685	1556Z 14 Nov 87	27°23.845'N 70°29.530'W	1920Z 14 Nov 87	27°07.050'N 70°35.723'W	43-51	2
ESP 1	686	2300Z 14 Nov 87	26°59.836'N 70°23.421'W	0732Z 15 Nov 87	26°46.121'N 69°42.033'W	52-78	4
ESP 2	687	0930Z 15 Nov 87	26°52.116'N 69°44.473'W	1800Z 15 Nov 87	27°03.611'N 70°22.285'W	79-93	4
ESP 3	688	1937Z 15 Nov 87	27°07.345'N 70°18.312'W	0301Z 16 Nov 87	26°55.307'N 69°42.584'W	95-112	4
ESP 4	689	0518Z 16 Nov 87	27°00.032'N 69°45.664'W	1144Z 16 Nov 87	27°10.150'N 70°16.501'W	113-126	4/5
ESP 5 INBOUND	690	1442Z 16 Nov 87	27°14.108'N 70°15.494'W	1901Z 16 Nov 87	27°07.544'N 69°59.967'W	127-136	5
ESP 5 OUTBOUND	691	0403Z 17 Nov 87	27°08.406'N 69°58.083'W	0821Z 17 Nov 87	27°01.393'W 69°38.522'W	136-146	5
ESP 6	692	1126Z 17 Nov 87	27°06.003'N 69°39.357'W	1919Z 17 Nov 87	27°17.214'N 70°15.770'W	147-165	5
ESP 7	693	2248Z 17 Nov 87	27°20.754'N 70°12.646'W	0532Z 18 Nov 87	27°10.901'N 69°40.248'W	166-180	6
ESP 8	694	0902Z 18 Nov 87	27°16.447'N 69°33.506'W	1700Z 18 Nov 87	27°30.215'N 70°13.787'W	181-198	6
ESP 9	695	2100Z 18 Nov 87	27°39.927'N 70°06.201'W	0516Z 19 Nov 87	27°27.357'N 69°26.981'W	199-217	7
ESP 10	696	0900Z 19 Nov 87	27°39.496'N 69°25.306'W	1632Z 19 Nov 87	27°52.810'N 70°03.894'W	218-235	7/8
ESP 11	697	2100Z 19 Nov 87	28°02.011'N 69°56.405'W	0442Z 20 Nov 87	27°50.113'N 69°16.783'W	236-253	8/9

(Cont'd)

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
ESP 12	698	0810Z 20 Nov 87	27°58.874'N 69°15.976'W	1622Z 20 Nov 87	28°10.693'N 69°56.594'W	254-271	9
WACDP 1	699	2336Z 20 Nov 87	28°24.348'N 69°26.375'W	2303Z 21 Nov 87	26°47.433'N 70°06.970'W	272-370	9
ESP 5A	700	0551Z 22 Nov 87	27°04.050'N 69°45.930W	1412Z 22 Nov 87	27°16.474N 70°25.392'W	371-388	9
ESP 13	701	1600Z 22 Nov 87	27°11.983N 70°23.630'W	0029Z 23 Nov 87	26°59.188'N 69°48.746'W	389-404	-
ESP 14	702	0533Z 23 Nov 87	27°03.236'N 69°47.843'W	1421 23 Nov 87	27°39.283'N 69°31.834'W	405-424	10
111	703	1600Z 23 Nov 87	27°43.190'N 69°38.534'W	2001Z 23 Nov 87	27°43.549'N 69°57.170'W	425-436	10
ESP 15 INBOUND	704	2006Z 23 Nov 87	27°43.757'N 69°57.067'W	0100Z 24 Nov 87	27°24.565'N 70°04.927'W	437-448	11
112	705	0326Z 24 Nov 87	27°24.082'N 70°16.147'W	0612Z 24 Nov 87	27°26.673'N 70°28.770'W	449-453	11
ESP 16 OUTBOUND	706	0630Z 24 Nov 87	27°27.734'N 70°29.070'W	1100Z 24 Nov 87	27°44.605'N 70°23.629'W	454-460	11
113	707	1108Z 24 Nov 87	27°45.797'N 70°24.106'W	2051Z 24 Nov 87	28°08.490'N 71°02.017'W	461-484	11
ESP 17	708	2054Z 24 Nov 87	28°08.195'N 71°02.323'W	0450Z 25 Nov 87	27°40.365'N 71°23.975'W	485-498	11
114	709	0530Z 25 Nov 87	27°40.640'N 71°26.724'W	1350Z 25 Nov 87	28°10.338'N 71°49.351'W	499-517	11
ESP 18	710	1617Z 25 Nov 87	28°19.140'N 71°45.136'W	0002Z 26 Nov 87	28°48.555'N 71°26.615'W	518-534	11
115	711	1554Z 26 Nov 87	28°37.104'N 71°40.185'W	0520Z 28 Nov 87	27°37.159'N 69°02.348'W	535-654	11-13
116	712	0527Z 28 Nov 87	27°36.814'N 69°02.669'W	1100Z 28 Nov 87	27°13.164'N 69°12.796'W	655-672	13
117	713	1111Z 28 Nov 87	27°12.941'N 69°13.847'W	1300Z 28 Nov 87	27°14.713'N 69°23.371'W	673-678	13

(Cont'd)

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
117A	714	1516Z 28 Nov 87	27°16.205'N 69°32.301'W	0134Z 29 Nov 87	27°29.692'N 70°14.851'W	679-711	13
118	715	0138Z 29 Nov 87	27°29.483'N 70°14.944'W	1026Z 29 Nov 87	26°57.171'N 70°29.551'W	712-739	13
119	716	1339Z 29 Nov 87	26°54.600'N 70°27.200'W	0732Z 30 Nov 87	28°20.906'N 69°42.877'W	740-802	13
120	717	0854Z 30 Nov 87	28°18.923'N 69°36.345'W	1250Z 30 Nov 87	28°12.927'N 69°18.154'W	803-815	13
121	718	1254Z 30 Nov 87	28°12.927'N 69°18.154'W	1541Z 30 Nov 87	28°02.249'N 69°23.421'W	816-824	13-14
121A	719	1830Z 30 Nov 87	28°02.574'N 69°23.830'W	1420Z 01 Dec 87	26°45.422'N 69°55.830'W	825-894	15
122	720	1723Z 01 Dec 87	26°59.920'N 70°01.573'W	2235Z 01 Dec 87	27°28.830'N 70°11.833'W	895-916	15
123	721	2343Z 01 Dec 87	27°29.237'N 70°12.292'W	2309Z 02 Dec 87	28°26.178'N 71°56.131'W	917-999	15

8. PRECISION TIMING

The following clocks were run continuously and intercalibrated about four times daily.

a) GOES satellite clock

b) RVS master clock (DMW)

c) Cambridge no. 1 clock

d) Cambridge no. 2 clock

e) Radio Moscow (RWM), when available

The timing for sercel firing was taken from the RVS master clock. The GOES satellite clock and Cambridge no. 1 clock were recorded continuously on two auxiliary channels. On the transit from the UK to Bermuda the Cambridge clock crystals were adjusted to keep time with the Rubidium frequency standard and calibrated against the RVS master clock and Radio Moscow, corrected for propagation delays.

The GOES satellite clock repeatedly lost lock, so should not be used without checking. The clock was restarted by powering down and up again, and took about half an hour to resynchronise with the satellite. It did not use an external frequency standard.

The RVS master clock display on two occasions jumped forward one minute. This was a problem with the output logic rather than the time base. The RVS clock was used to trigger the recording system, with recording commencing exactly on the even minute and at 40 second intervals (two ship work) or 20 second intervals (single ship work). On a few occasions, for short intervals the start of recording drifted up to several seconds, due to problems with the trigger delay unit. When airguns were being fired, the peak pressure pulse was set at 40 msec after the start of digitisation.

The following three pages are extracted from Tim Minshull's Ph.D. dissertation (pp. 72-74).

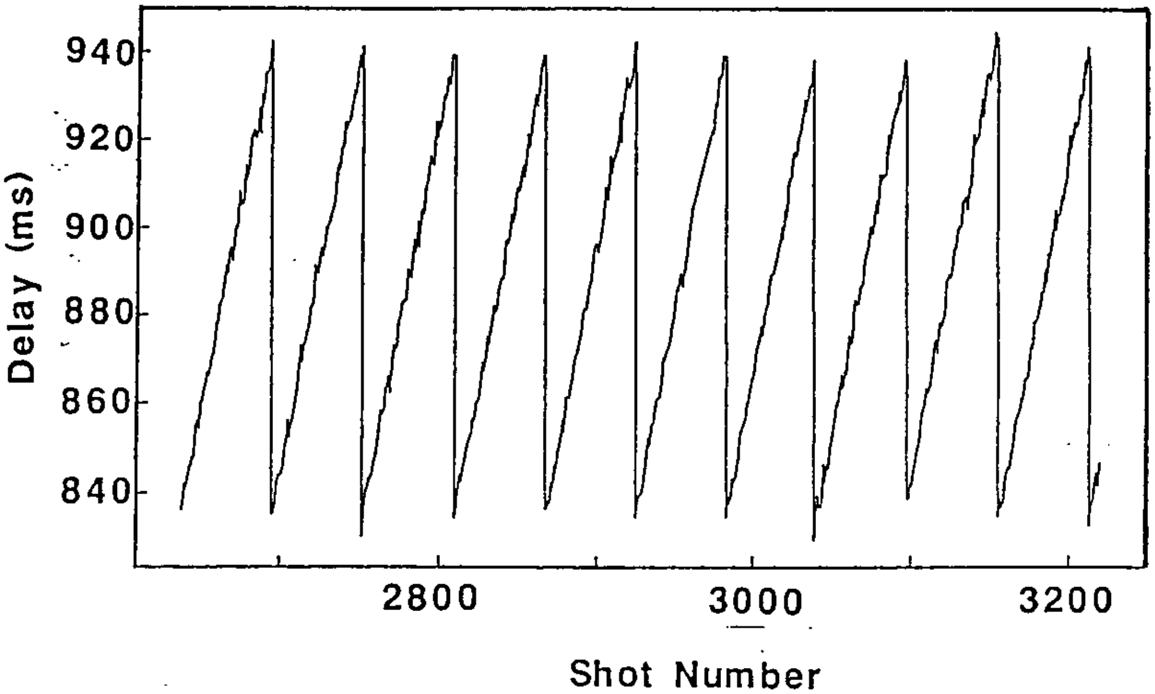


Figure 3.6: Start-up time of Conrad's seismic acquisition system. The time plotted is the delay between the trigger from the GOES clock and the time of the airgun blast.

3.3.1 Timing

Accurate timing is of crucial importance for two-ship work, so considerable attention was paid to this during cruise planning. Both ships were equipped with a GOES clock receiver. The clock is located in a geostationary satellite above the western Atlantic, and transmits times as a coded 1 kHz signal. The signal is subject to propagation delays, but the delay may be assumed to be identical for both ships at the ranges involved in an ESP.

Shots were fired at 40 s intervals. On the Conrad, the GOES clock signal triggered the startup of the seismic acquisition system on the 40 s mark, and the clock was read at the trigger time for the airgun array. Subsequent analysis showed that the acquisition system start-up time was 100–200 ms, with a periodic saw-tooth variation (Figure 3.6). Superimposed on this pattern is a jitter of amplitude ~ 2 ms. Examination of seismic data recorded on Discovery during the wide aperture profile suggested that this jitter was

Table 3.1: ESP recording windows

Range (km)	Recording Delay (s)	Record Length (s)
< 20	0	25
20–40	6	25
40–45	10	25
45–50	10	28
> 50	0	38

due to the logging system on Conrad and did not reflect a true variation in airgun blast times [P. Buhl, pers. comm., 1988]. However, since the amplitude is less than the 4 ms sample interval, no attempt was made to remove the jitter from the data. There was a further delay between the clock reading and the airgun blast. This was measured as 760±3 ms by comparison on an oscilloscope of the trigger pulse and the signal from a near field "blast phone" [J. C. Mutter and P. Buhl, pers. comm., 1988], and checked by looking at the direct water wave recorded on Discovery.

The Sercel acquisition system on Discovery was triggered by the ship's DMW master clock. The recording window was chosen to include both ground waves and reflected water waves, and was adjusted according to range (Table 3.1). At long range, the reflected water wave appeared at the beginning of the next shot record, so zero delay was used. A 1 Hz square wave signal from the GOES clock, and a coded 1 Hz square wave from a "Cambridge clock", were recorded on auxiliary channels, so that a measure of absolute time was available on the field tapes. The relative drifts of the DMW and GOES clocks, the Cambridge clocks, and a Radio Moscow clock signal, were monitored by comparison of the signals 3–4 times a day The Cambridge clocks had drifts of around 2 ms per day, while the DMW clock was consistently 16 ms ahead of the GOES clock throughout the cruise.

From the GOES clock reading and the various delays detailed above, a precise delay between the airgun blast and the first sample recorded by the Sercel was calculated for each shot. Occasional timing problems occurred on both ships. These were detected by plotting out a "single fold monitor" for each ESP consisting of four traces from each shot. Steps in the reflected water wave indicated timing errors. Two types of errors occurred:

1. Errors due to the recording system were eliminated by using the auxiliary clock channels. For small time shifts, the number of whole seconds was deduced from the reflected wave step and the precise fraction of a second from the clock channel square wave. Occasionally (e.g. during ESPs 1 and 6), there were shifts of 10–20 s, so that the ground waves remained within the recording window but the water waves did not. It was then necessary to search for the minute marks in the Cambridge clock signal and deduce the shot time from these.

2. Errors in the shooting system were eliminated by iterative adjustment of the time entered into the trace headers until the reflected water wave was aligned on a plot reduced at the appropriate velocity.

There were also periods when no shot time was recorded on Conrad. During these periods the saw-tooth pattern was interpolated, and the resulting times checked by plotting the reflected water wave.

9. INTER-SHIP RANGING

We used three real-time inter-ship ranging devices: a trisponder with two channels and the master readout on Discovery; a Raydist with the master on Conrad; and a miniranger with the master on Conrad.

The trisponder used an omnidirectional master (on Discovery) and one forward-looking and one rearward looking slave (on Conrad). Ranges of up to 70 km were achieved, but the recording unit locks at the last good value until it is updated by a new, good value. The greatest ranges were achieved

when the ships were receding from each other. Occasionally a channel is updated by spurious readings. Trisponder ranges were logged once every 2 sec from both channels, and the logger tape edited to remove all times when both channels read zero.

See the figure in section 6 for the spacing of the navigation antennae with respect to the airguns and streamers. See Tim Minshull's Ph.D. dissertation, pp. 74-77, for further information on the ranges devices and the criteria used to select ranges for seismic processing.

10. GPS NAVIGATION

GPS navigation used a Trimble 4000S with a rubidium clock to increase coverage available when only two satellites were visible. Good periods during the cruise were approximately 1300-1930 Z and 2050-2340 Z. Satellites 04 and 08 were permanently disabled.

Remainder of navigation was from dead-reckoning using E-M log and gyro compass, with Transit satellite fixes.

11. GRAVITY LOGGING

a) Base Station at RVS Barry. Gravity = 981190.63

(IGSN 71, ref. 115.05 Navoceans)

Meter reading at RVS Barry Meter = 12429.0 units

Meter calibration constant = 0.9967

RVS Meter Number S84

b) Base Station at Bermuda Gravity = 979845.56

Meter = 11078.0 units

(Ireland Island Naval Dockyard, 5th Bollard from North end)

Drift, Barry to Bermuda is 0.077 mgal/day

To get true reading, subtract 0.077 x no. of days from the gravity calculated from the meter.

(Values on data tape are not corrected for drift, but are adjusted to the base station value at Barry. It would be worth checking base stations from subsequent cruises to confirm the overall drift rate during the second part of the cruise).

12. BATHYMETRY AND MAGNETICS

The PES fish was deployed from the mid-ships port side at a depth of 8 m (recording unit was set to 8 m depth also). Assumed sound of speed 1500 m/sec. Depths were hand digitised once every 4 mins and manually punched into the data logger.

The magnetometer recording head was towed 700 ft. astern. Values were recorded on an analogue chart recorder and automatically input into the data logger via a level A interface.

On the data-logger tape the depths have also been converted to 'real' depths using Carter's Tables.

13. SONOBUOYS

Disposable AW/SSQ sonobuoys were deployed off both ships. On Discovery they were recorded on one auxiliary channel of the Sercel and continuously on an analogue STORE 4DS tape recorder. They were monitored on the Cambridge jet pen. Locations for the sonobuoys are not listed below, as the post-processing positions will be better than the dead reckoning estimate at the time of deployment. Listed below are the sonobuoys deployed from Discovery:

Sonobuoy No.	Time Z	Hydrophone depth ft.
1	1702/317	60
2	2017/317	60
3	0102/319	60
4	1207/319	60
5	2204/319	60
6	0749/320	400
7	1357/321	400
8	0048/322	400
9	1145/322	400
10	2255/322	400
11	1119/323	400
13	1033/324	400
14	1329/325	400
15	1355/325	400
16	0833/326	400
17	1859/326	400
18	0346/328	400
19	2300/328	400
20	1737/329	400

Sonobuoy data from RV CONRAD Cruise Report

RC 28-10
Sonobuoys

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
3D	26°50.200'N 69°54.400'W	ESP 1	0102Z 15 Nov 87		58,
4D	26°58.600'N 70°07.700'W	ESP 2	1207Z 15 Nov 87	1800Z 15 Nov 87	83,93
5C	27°04.800'N 70°12.000'N	ESP 3	2100Z 15 Nov 87	0300Z 16 Nov 87	97,112
6D	26°59.500'N 69°55.100'W	ESP 3	2204Z 15 Nov 87	0300Z 16 Nov 87	99,112
7C	27°02.338'N 69°53.171'W	ESP 4	0644Z 16 Nov 87	1144Z 16 Nov 87	116,126
8D	27°06.200'N 70°03.100'W	ESP 4	0749Z 16 Nov 87	1144Z 16 Nov 87	116,126
9C	27°06.800'N 69°53.200'W	ESP 5	0510Z 17 Nov 87	0821Z 17 Nov 87	139,146
10C	27°08.400'N 69°46.900'W	ESP 6	1303Z 17 Nov 87	1433Z 17 Nov 87	151,155
11D		ESP 6	1405Z 17 Nov 87	1919Z 17 Nov 87	154,165
12C	27°11.500'N 69°55.200'W	ESP 6	1444Z 17 Nov 87	1700Z 17 Nov 87	156,160
13C	27°19.200'N 70°04.900'W	ESP 7	0132Z 18 Nov 87	0532Z 18 Nov 87	168,180
14D		ESP 7	0050Z 18 Nov 87	0532Z 18 Nov 87	170,180
15D	27°24.200'N 69°57.300'W	ESP 8	1145Z 18 Nov 87	1700Z 18 Nov 87	186,198
16C	27°21.600'N 69°49.100'W	ESP 8	1203Z 18 Nov 87	1700Z 18 Nov 87	187,198
17C	27°37.800'N 69°57.500'W	ESP 9	2234Z 18 Nov 87	0516Z 19 Nov 87	202,217
18D	27°32.100'N 69°42.100'W	ESP 9	2245Z 18 Nov 87	0516Z 19 Nov 87	203,217

(cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
19C	27°41.900'N 69°32.200'W	ESP 10	1023Z 19 Nov 87	1632Z 19 Nov 87	221,235
20D		ESP 10	1120Z 19 Nov 87	1632Z 19 Nov 87	223,235
21D		ESP 11	2226Z 19 Nov 87	0442Z 20 Nov 87	239,253
22C	27°59.400'N 69°47.300'W	ESP 11	2244Z 19 Nov 87	0442Z 20 Nov 87	239,253
23C	28°01.546'N 69°23.100'W	ESP 12	0942Z 20 Nov 87	1622Z 20 Nov 87	257,271
24D	28°08.000'N 69°42.600'W	ESP 12	1033Z 20 Nov 87	1622Z 20 Nov 87	259,271
25D (No Good)		WACDP 1	1330Z 21 Nov 87	1350Z 21 Nov 87	333,334
26D		WACDP 1	1356Z 21 Nov 87	2303Z 21 Nov 87	335,370
27C	27°06.600'N 69°53.200'W	ESP 5A	0730Z 22 Nov 87	1412Z 22 Nov 87	374,388
28D	27°11.800'N 70°08.100'W	ESP 5A	0833Z 22 Nov 87	1412Z 22 Nov 87	376,388
29C	27°08.200'N 70°15.800'W	ESP 13	1834Z 22 Nov 87	0029Z 23 Nov 87	392,404
30D	27°02.800'N 69°54.800'W	ESP 13	1859Z 22 Nov 87	0029Z 23 Nov 87	393,404
31C	27°07.600'N 69°46.300'W	ESP 14	0200 23 Nov 87	1421Z 23 Nov 87	408,424
32C	27°43.800'N 69°41.700'W	111	1629Z 23 Nov 87	1908Z 23 Nov 87	426,433
33C	27°37.800'N 70°00.800'W	ESP 15	2139Z 23 Nov 87	0100Z 24 Nov 87	440,448
34C	27°56.600'N 70°42.800'W	113	1547Z 24 Nov 87	2042Z 24 Nov 87	None (Paper Record)
35C	28°02.300'N 71°06.200'W	ESP 17	2236Z 24 Nov 87	0450Z 25 Nov 87	None (Paper Record)

(cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
36D	27°44.900'N 71°18.900'W	ESP 17	2300Z 24 Nov 87 2300Z 24 Nov 87	No end time (Not Recorded)	
37C	28°24.900'N 71°41.000'W	ESP 18	1740Z 25 Nov 87	0002Z 26 Nov 87	None (Paper Record)
38C	28°32.000'N 71°39.800'W	115	1836Z 26 Nov 87	0000Z? 27 Nov 87	None (Paper Record)
39C	28°26.700'N 70°55.900'W	115	0331Z 27 Nov 87	0711Z 27 Nov 87	None (Paper Record)
40C	28°07.600'N 70°33.600'W	115	0802Z 27 Nov 87	1453Z 27 Nov 87	None (Paper Record)
41C	27°52.900'N 69°42.000'W	115	1957Z 27 Nov 87	0030Z 28 Nov 87	None (Paper Record)
42C	27°26.900'N 70°16.100'W	118	0226Z 29 Nov 87	0604Z 29 Nov 87	None (Paper Record)
43C	26°57.900'N 70°16.200'W	119	1418Z 29 Nov 87	1822Z 29 Nov 87	None (Paper Record)
44C	27°19.300'N 70°07.800'W	119	1830Z 29 Nov 87	2228Z 29 Nov 87	None (Paper Record)
45C	27°40.900'N 69°57.800'W	119	2312Z 29 Nov 87	2352Z 29 Nov 87	Bad After 30 mins
46C	27°44.600'N 69°56.300'W	119	0000Z 30 Nov 87	0700Z 30 Nov 87	None (Paper Record)
47C	28°18.700'N 69°36.700'W	120	0903Z 30 Nov 87	1300Z 30 Nov 87	None (Paper Record)
48C	28°05.200'N 69°21.800'W	121A Off 2545Z & back on 1807Z (see log)	1451Z 30 Nov 87	2201Z 30 Nov 87	None (Paper Record)
49C	27°47.200'N 69°29.100'W	121A	2204Z 30 Nov 87	0324Z 01 Dec 87	None (Paper Record)
50C	27°27.300'N 69°37.700'W	121A	0329Z 01 Dec 87	0857Z 01 Dec 87	None (Paper Record)

TABLE 3 (cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
51C	27°06.800'N 69°46.700'W	121A	0858Z 01 Dec 87	1352Z 01 Dec 87	None (Paper Record)
52C	27°29.800'N 70°14.500'W	123	0015Z 02 Dec 87	0454Z 02 Dec 87	None (Paper Record)
53C	27°36.500'N 70°36.500'W	123	0456Z 02 Dec 87	0838Z 02 Dec 87	None (Paper Record)
54C	27°43.200'N 70°54.000'W	123	0843Z 02 Dec 87	1309Z 02 Dec 87	None (Paper Record)
55C	27°57.100'N 71°13.000'W	123	1313Z 02 Dec 87	1714Z 02 Dec 87	None (Paper Record)
56C	28°02.300'N 71°31.400'W	123	1718Z 02 Dec 87	2045Z 02 Dec 87	None (Paper Record)
57C	28°09.800'N 71°46.100'W	123	2047Z 02 Dec 87	2120Z 02 Dec 87	None (Paper Record)

14. TABLE OF JULIAN DAY NUMBERS

Julian Day No.	Date
	November 1987
313	9
314	10
315	11
316	12
317	13
318	14
319	15
320	16
321	17
322	18
323	19
324	20
325	21
326	22
327	23
328	24
329	25
330	26
331	27

Scientific watchstanding was all recorded in G.M.T. The local time zone throughout the second part of the cruise (Bermuda-Nassau) was four hours ahead of G.M.T.

15. Cruise Participants on DISCOVERY

Dr. R.S. White	Principal Scientist	
Dr. C.A. Williams	Scientist	
Dr. C. Powell	"	
Mr. T. Minshull	"	
Ms. J. Collier	"	
Mr. H. Upshall	"	
Dr. P. Buhl	"	
Mr. P. Carter	Technician,	Cambridge
Mr. R. Wallace	"	I.O.S.
Mr. J. Davies	"	R.V.S.
Mr. S. Smith	"	"
Mr. S. Jones	"	"
Mr. D. Booth	"	"
Mr. R. Davies	"	"
Mr. A. Robinson	"	"
Mr. G. Long	Master	
Mr. B. Richardson	1st Mate	
Mr. P. Oldfield	2nd Mate	
Mr. R. Ginger	3rd Mate	
Mr. B. Donaldson	Radio Officer	
Mr. I. Bennett	Chief Engineer	
Mr. S. Moss	2nd "	
Mr. C. Phillips	3rd "	
Mr. P. March	3rd "	
Mr. B. Smith	Electrician	
Mr. F. Williams	C.P.O. (Deck)	
Mr. M. Harrison	P O. (Deck)	
Mr. R. Williams	Cook/Steward	
Mr. S. Hardy	Seaman	
Mr. A. McLean	"	
Mr. A. Marren	"	
Mr. J. Perkins	"	
Mr. A. Richards	"	
Mr. G. Crabb	"	
Mr. K. Pratley	"	
Mr. S. Brown	Cook	
Mr. L. Brown	Steward	
Mr. M. Cross	"	
Mr. J. Swenson	"	
Mr. I. Waite	"	