# D172 878:

## RRS Discovery
## Scotia and Bellingshausen Seas
## Geophysics
## December 1987 - April 1988

B.A.S. Reference Number:

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# BRITISH ANTARCTIC SURVEY

## Cruise Report
## R.R.S. Discovery Cruise D 172
## December 1987 to April 1988

**Marine Geophysics and Marine Geology,**

**Scotia Sea, Weddell Sea and Southeast Pacific**

**December 1988**

Distribution:

**RRS DISCOVERY CRUISE REPORT**

**CRUISE 172**

**DECEMBER 1987 TO APRIL 1988**

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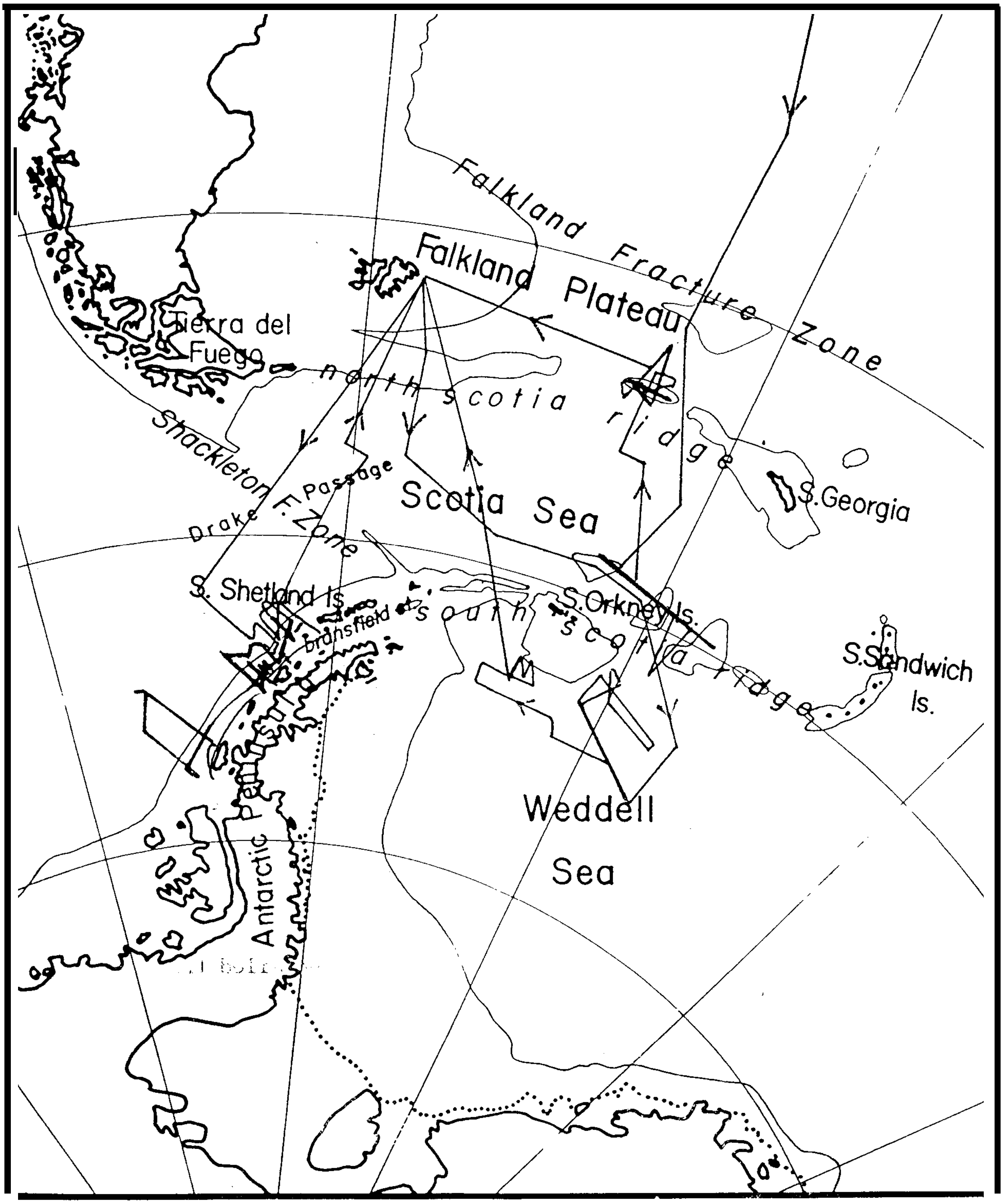
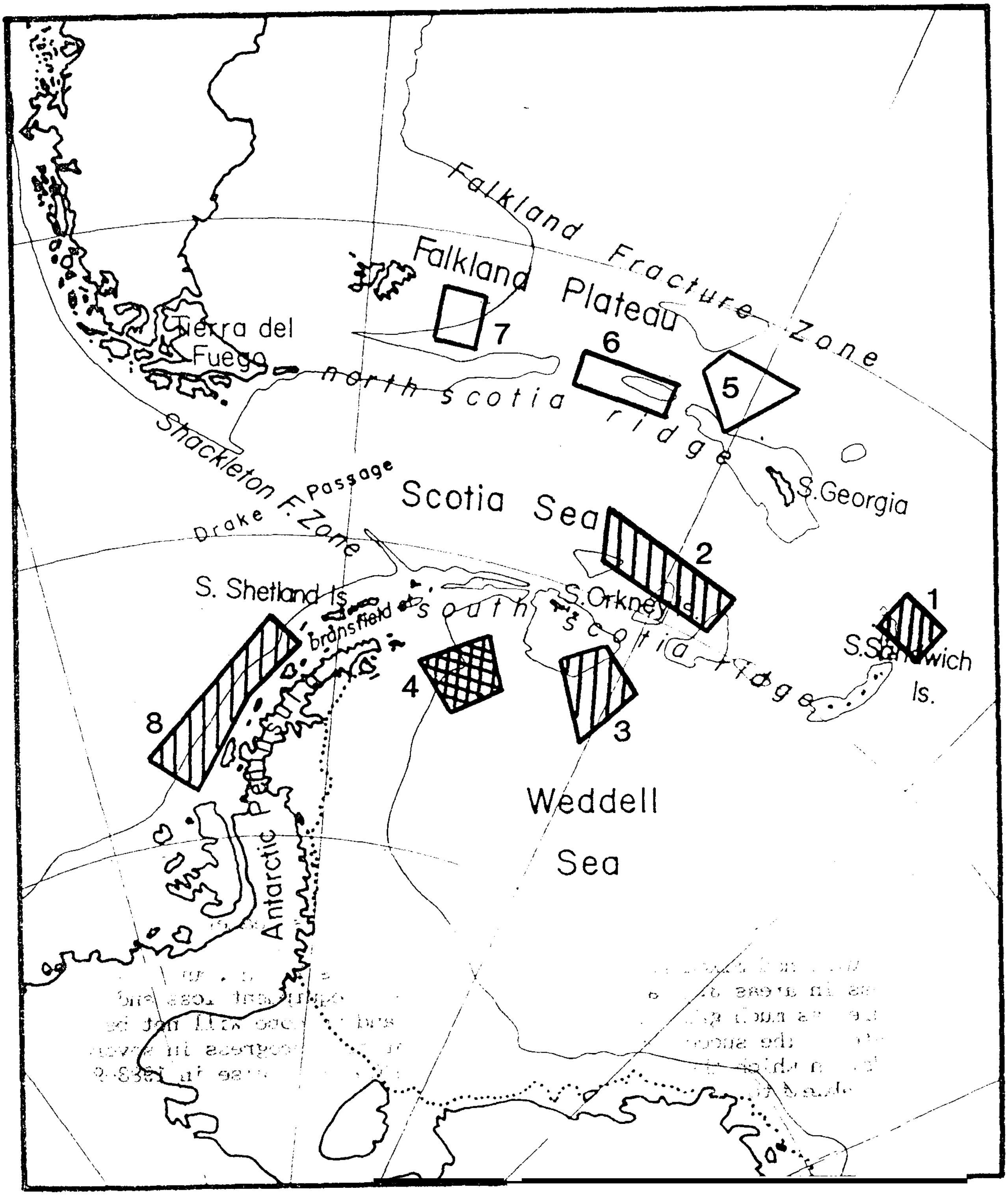



**Figure 1. Track Chart, Discovery Cruise 172, Dec. 1987 to April 1988 (see also folded chart at back)**




Priority 1 areas

Priority 1 but vulnerable to ice

Standby areas

**Figure 2**
**Discovery Cruise 172**

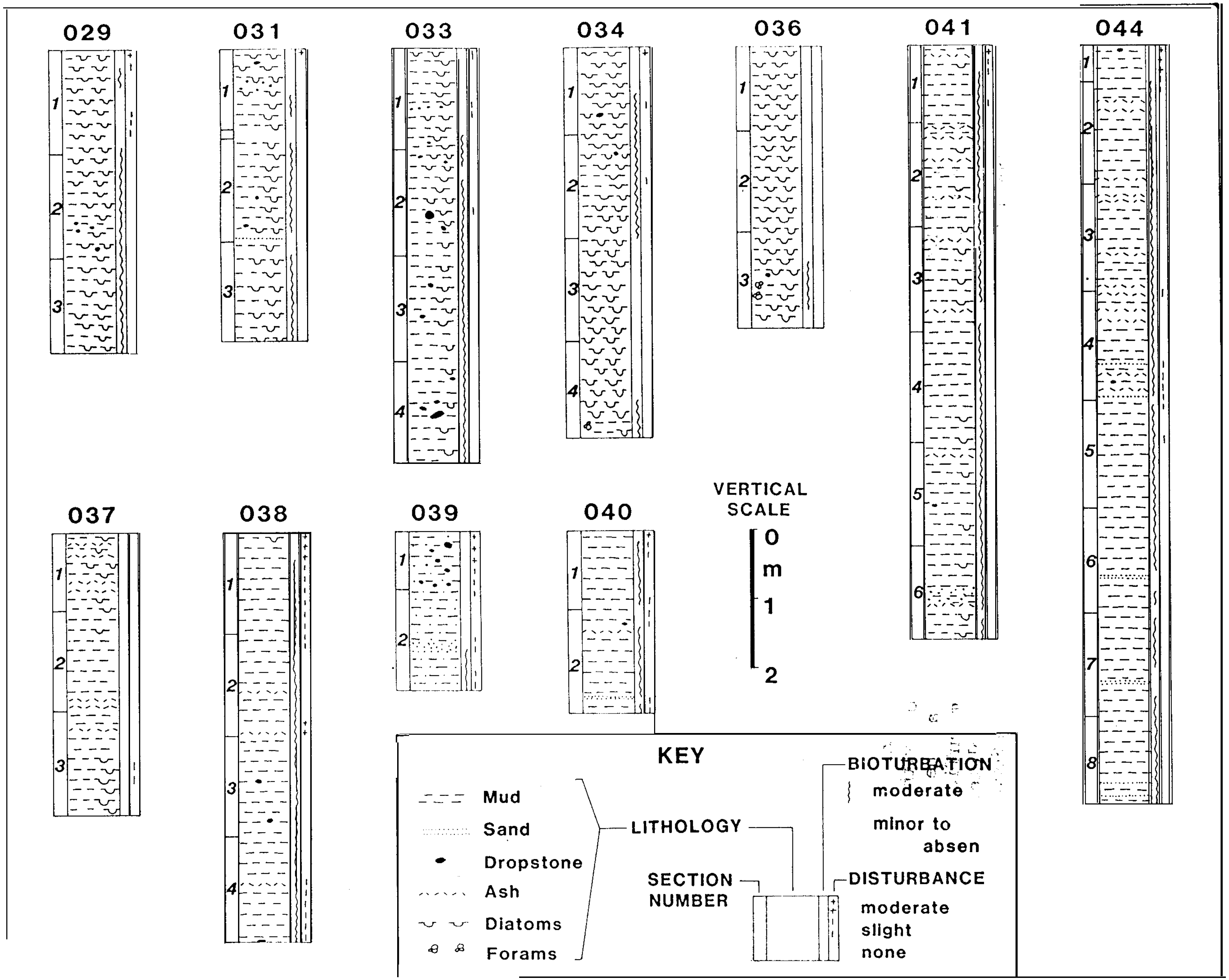



Figure 3 Core summary, Discovery 172 Legs 1 and 2, from shipboard description.

# 1. SUMMARY

Discovery Cruise 172 started from Rio de Janeiro late on 17th December 1987 and ended in Port Stanley early on 30th March, 1988 with two intermediate calls into Port Stanley within the 103 days.

The main field projects attempted during the three legs were

(a) heatflow measurements in 5 Central Scotia Sea basins

(b) a geophysical survey of Aurora Dank on the North Scotia Ridge, to determine its age and evolution

(c) recovery and redeployment of an array of moored current meters in the northern Weddell Sea, looking at the relation between bottom current fluctuations and sedimentation

(d) a survey of the northwest Weddell Sea, south of Powell Basin, to investigate the earliest stage of Scotia Sea development

and

(e) studies of young ridge crest-trench collisions and glacial sedimetary processes along the Pacific margin of the Antarctic Peninsula.

Projects (a) and (d) were unsuccessful, because of equipment failure or loss. The work described in (b), (c) and (e) was successful, despite the effects of equipment loss. The principal disaster was the loss of the multichannel seismic streamer, probably by ice colliding with the tail buoy, in the northwestern Weddell Sea, during Leg 2. A one-third length streamer was constructed from spare sections, and used successfully during Leg 3.

A crude track chart forms Figure 1, while a more detailed track chart may be found at the back of the Report.

## 2. SHIP'S COMPANY R.R.S. DISCOVERY CRUISE 172

### OFFICERS

| | | | |
|---|---|---|---|
| Master | P. MacDermott | Chief Off | D. Coverdale |
| 2nd Off. | P. Evans | 3rd. Off. | M. Attwell |
| Rad. Off. | B. Donaldson | Chief Eng. | P. Jago |
| 2nd Eng. | B. McDonald | 3rd Eng. | C. Melrose |
| 3rd Eng. | B. Gillett | Elec. Eng. | D. Lutey |

### CREW

| | | | |
|---|---|---|---|
| bosun | F. Williams | PO | M. Harrison |
| SlA | S. Hardy | SlA | A. MacLean |
| SIA | A. Marren | SlA | J. Perkins |
| SlA | A. Richards | SlB | G. Crabb |
| M. M. | K. Pratley | C. Stwd. | R. Williams |
| Cook | S. Brown | Stwd. | M. Cross |
| Stwd. | J. Swenson | Stwd. | I. Waite |
| 2nd. Stwd. | P. Acton | | |

### BRITISH ANTARCTIC SURVEY

| | | |
|---|---|---|
| P.S.O. | P. Barker | C. Pudsey |
| | R. Larter | R. Livermore (legs 2 and 3) |
| Doctor | M. Midwinter (leg 3) | |

### UNIVERSITY OF BIRMINGHAM

I. Hamilton
M. Lonsdale
A. Conway (legs 2 and 3)

### UNIVERSITY OF CAMBRIDGE

C. Peirce (leg 1)

### UNIVERSITY OF SOUTHAMPTON

P. O'Brien (legs 1 and 2)

### RESEARCH VESSEL SERVICES

| | |
|---|---|
| P. Booth (legs 1 and 3) | A. Cumming (leg 3) |
| M. Davies (legs 1 and 2) | R. Davies (legs 1 and 2) |
| C. Jackson (legs 1 and 2) | A. Lord (leg 3) |
| C. Paulson (leg 2) | R. Phipps (leg 3) |
| J. Price (leg 1) | K. Smith (leg 3) |
| P. Taylor (leg 2) | C. Washington (leg 2) |
| C. Woodley (legs 1 and 2) | J. Wynar (leg 3) |

### INSTITUTE OF OCEANOGRAPHIC SCIENCES

R. Bonner (legs 1 and 2)
A. Webb (leg 3)

## 3. INTRODUCTION

Discovery Cruise 172 was a joint BAS/Birmingham University enterprise, with contributions from Cambridge and Southampton Universities and supported by RVS and IOS technical staff. It came in the middle of the long transition of Antarctic marine geoscience from Birmingham to BAS, within a few months of the end of the Birmingham contract and with some Birmingham personnel having taken up BAS employment immediately beforehand. This movement did not appear to affect the cruise, but has certainly delayed work on the data acquired, including the production of this Report.

Discovery Cruise 172 was conceived in 1985-6 as mainly a sidescan cruise, involving GLORIA, Seamarc II or possibly the developing TAMU/LDGO system. For various reasons however, after peer review, it became no longer possible to include the sidescan element. The other components of the cruise proposed, involving MCS survey, coring and heatflow, were therefore extended. The revised cruise plan, illustrated in Figure 2, included 5 high-priority study areas (1 to 4 and 8) and 3 stand-by areas, since areas 4 and 3 in particular were vulnerable to unfavourable ice conditions.

The proposed investigations should be seen in the light of the developing BAS long-term strategy. This has major programmes concerned with regional tectonic evolution, subduction-related processes and palaeo-oceanography. Within these lie specific projects to which the field areas in Figure 2 relate.

In area 1 we proposed to dredge the very steep scarp of the northwestern corner of the Sandwich plate, to examine the deep structure of the fore-arc and the history of tectonic erosion, as part of an investigation of the enabling factors for rapid eastward migration of the subduction zone and incipient subduction. This work was abandoned as too time consuming a diversion when Port Stanley replaced South Georgia as the port call at the end of Leg 1.

In area 2 we proposed, with the collaboration of Chris Peirce of Bullard Labs, to measure heatflow in five of the small ocean basins of the Central Scotia Sea, as a way of determining their ages, among the key unknowns in reconstructions of Scotia Sea evolution. In this, as will become clear, we were unsuccessful because of equipment failure.

In area 3 lay an array of moored current meters, deployed from RRS John Biscoe early in 1987, which we intended to recover, service and re-moor. In this we were successful, with 8 of the 12 meters having continously recorded valid data. The moorings were intended to investigate the relationship between modern circulation and sedimentation in the northern Weddell Sea, as a way of informing our understanding of palaeo-circulation from studies of sediment cores. CTD work and further coring were also involved.

bottom water formation. It is however the area least likely to be accessible in a poor to moderate ice year. We were not able to reach the main targets and, while working at the edge of the area during Leg 2, lost the multichannel seismic streamer, probably because of ice.

Area 5 contains some of the oldest surviving ocean floor adjacent to the Falkland Plateau, which may include a magnetic bight in the M-sequence, which would be a valuable datum for reconstructions. Although potentially interesting, the problem was too poorly constrained to have a very high priority, and the area was not visited.

Area 6 covers that section of the North Scotia Ridge which preliminary reconstructions of Scotia Sea evolution suggest could have been the effective deep water passage for the Antarctic Circumpolar Current, directly after Drake Passage opened in the early Miocene. This area was visited, at the end of Leg 1, when ice conditions drove the ship north; the data acquired should go a long way towards establishing the tectonic evolution and (crucially) Miocene palaeo-depth of the ridge section (which we have named Aurora Bank after the Aurora Islands sought fruitlessly in this area by James Weddell in 1820).

Area 7 includes a possible seaward-dipping reflector province on the margin of the Falkland Plateau, which'could have revealed the direction of early South American-Antarctic motion after Gondwana break-up. In the event, we had no time to spend on multichannel survey of this area, as would have been required.

All of Leg 3 was spent in area 8, the Pacific margin of the Antarctic Peninsula, which is becoming a major focus of BAS activity in geophysics and marine geology. The intentions, successfully carried out, were to progress the studies of Cenozoic ridge crest-trench collision and shelf-slope glacial sedimentary processes, begun on Discovery Cruise 154 in 1985. Part of this work was a Z-ship seismic experiment with HMS Endurance, successfully carried out despite appalling weather and the earlier loss of the MCS streamer...,

The cruise had mixed results:- disasters in areas 2 and 4, but much success in areas 3, 6 and 8. The incidence of equipment loss and failure was much greater than in the past, and we hope will not be repeated. The successes, however, represent real progress in several fields, on which the planned Charles Darwin/GLORIA cruise in 1988-9 will be able to build

## 4. SCIENTIFIC NARRATIVE

### LEG 1

leg Discovery sailed from Rio de Janeiro at 1700 on 17 December (day 351), rolling south in a beam sea. Of all the air- and sea-freight due to arrive at Rio, only the p-wave logger (IOSDL Schultheiss) had missed the ship (as it had done at Nassau), and we were well set up for the cruise.

The ship made good time south to 48°S, where routine watchkeeping started on PES, 3.5KHz profiler, magnetometer, gravimeter, navigation and logger at noon on 23 December (day 357). The first real experiment would be a series of heatflow measurements in some of the small, quasi-oceanic basins of the Central Scotia Sea (Figure 2, area 2), to determine their basement age. The first of these was the main basin, and the most promising area was around 57°S: since we would reach there on 25 December, Christmas Day was celebrated a day early.

The heatflow sites were chosen initially from existing single-channel reflection profiles, then revised on the basis of the 3.5KHz profile collected on approach. On station, the ship took a 2- or 3-barrel piston core (to measure sedimentation rate for heatflow corrections) before deploying the heatflow probe.

The fore/aft gyro of the gravimeter platform failed early on day 359, and on the first core (PC029) early on day 360 the coring winch auto-brake came on inappropriately. After a delay while the heatflow railway was made true, the first heatflow deployment was made, using the Bullard Labs (Cambridge Univ) probe. Two penetrations (of a planned 10 or 12) were made with the pinger transmitting cycle indications but no temperature data. The gear was then recovered to see if temperature data were being recorded: they were, and the pinger's reticence was traced to broken conductors in the interconnecting cables, a fault which could be overcome. Meanwhile, the gravimeter gyro had been replaced, but only an approximate alignment was possible at sea, which could lead to a greater than normal degradation of the data quality in bad weather.

On recovery of the heatflow probe, the load, cell block inboard of the traction winch had jammed, and had had to be prepaired While waiting for this and the heatflow probe to be repaired, the ship moved southwest to a basin north of Pirie Bank, again using an existing SCS line for initial site location and the 3.5KHz record for the final choice. The piston core attempt recovered only a trigger core (TC030), as the pyro release failed, and a second core (PC031) was taken. Having moved along the line to avoid icebergs, we deployed the heatflow probe for the second time early on 28 December (day 362). The pinger was again only showing the cycle pulses, but we went ahead on the assumption that the probe would be recording internally as before. A suite of 8 seemingly successful penetrations had been achieved when the pinger suddenly dived out of synch. with the PES. While we were recovering the probe, the pinger first revived, then again slipped out. The probe showed signs of having been on its side at some stage, and of contact with the wire.

To give time for the probe to be examined and serviced, we decided to start balancing the MCS hydrophone array, at a site close to Pirie Bank whence we could then either attempt another heatflow station or start a MCS line across 2 of the remaining small basins (there being no existing single-channel data available). The balancing seemed likely to be a protracted operation, involving an average increase in buoyancy of 5 kg per section, partly by adding oil and partly by removing lead: the streamer was last balanced off Bermuda during Leg 171, in surface water temperatures of 27°C Streamer balancing in the Southern Ocean is complicated by a peculiarity of the shallow water mass structure which causes the streamer to be happy to swim shallow, but to start to sink rapidly if taken below about 35 metres (by the tow leader at slow speed for example).

On examination, it became apparent that the clock and logic circuits of the heatflow probe had not functioned after the initial lowering, so that the previous day's work had been in vain. A possible cause was thought to have been that the batteries used (Duracell) had not been able to tolerate the low temperatures of the bottom waters (ca. -0.5°C It was proposed to rig a standby system using Ni-Cd rechargeable batteries, after running the MCS profile across the next 2 basins (between Pirie, Bruce and Discovery Banks).

With the streamer balanced and the airgun system completely deployed (using the new gantry), the MCS line was started around 0600 on 31 December (day 365). After a delay when excessive rolling cut out all ship's auxiliary power, the line restarted at noon.

The line took almost 3 days to shoot, the gear being recovered completely by 0900 on 3rd January (day 003). There were problems with the gun pressure transducer, with inadequate monitoring of gun synchronisation and pressure (cured) and, mostly, with parity and other errors on both tape decks. This last was attributed to the final 300 tapes of the BAS order, which had missed the ship at Barry and been sent by container ship to Rio: while in the container, their stated temperature and humidity limits may have been exceeded.

After recovery of the MCS gear, the ship steamed back at full speed for a core/heatflow site at 60.0°S, 37.8°W.on the first core lowering, the pyro release again failed. Since the weather was reasonable, a hydraulic release was fitted and the corer redeployed this time successfully (core FC033).

After the core, when the heatflow probe was being deployed, the pinger provided a complete suite of information down to 2800 m, but at greater depths gave only the cycle pulse, as before. It was decided to continue, in the hope that the data were being recorded internally. A total of 6 penetrations took until noon on day 004, but on recovery one pressure vessel was found to have flooded, with no data recorded in the sediments. This was the end of the heatflow experiment, which had been disappointing, achieving only 2 successful penetrations instead of the 50 to 60 hoped for. The cause of the flooding appeared to have been faulty potting of or damage to the connecting cabling (possibly related to the connectors lost on the first deployment).

It seemed best to try next the recovery of one or more of the current meter moorings laid last season from RRS John Biscoe in the northern Weddell Sea (Figure 2, area 3). This would allow the RVS current meter specialist (Phil Taylor) who was joining the cruise for the second leg, to start servicing the meters as soon as he joined, instead of having to wait for the ship to return to the area and recover a mooring on Leg 2. At this time we still lacked up to date information on the distribution of pack ice, possibly because of the disruption caused by Christmas and the New Year to the compilation and distribution of the charts. The nearest mooring was at about 63°S, but we were stopped by pack ice about 100 miles to the north, on the morning of 5 January, and had to abandon the attempt.

It was time for a complete reassessment of the aims of the Leg. Of the major projects specified in Figure 2, we had implicitly abandoned (1) as being too far away for a leg which ended at the Falkland Is (but had planned originally to end at South Georgia), and had failed with (2), the heatflow experiment (we had acquired cores and an MCS profile, but these were ancillary to the heatflow measurements and lacked independent purpose, and we had balanced **the** streamer, but had acquired no heatflow measurements themselves). The pack ice would not allow us to start work in the northern Weddell Sea (3), and area (4) was similarly inaccessible. We would be returning to area (3) and probably (4) during Leg 2 and area (8) in Leg 3.

The most important of the "standby" projects was that in area (6). This part of the North Scotia Ridge, according to most recent reconstructions, could have been a crucial barrier to the deep circumpolar circulation in the early Miocene, shortly after the opening of Drake Passage. It was necessary to try to determine its structure and tectonic history, so that its elevation over the period of interest could be more precisely estimated. There was time for a reconnaissance of this feature and, possibly, time also for a brief look at the deep structure of the Falkland Plateau (area 7) on the way to port Stanley.

On the way to area 6 three small projects were attempted. The first was a trial CTD lowering in the Bruce-Discovery Basin, to test the equipment and examine the deep water flow between Jane Basin in the south and the Central Scotia Sea. This was successfully achieved (CTD 878-008) on the morning of 6 January. The second, a core in 1750m water depth on Bruce Bank (PC034), was taken successfully in the afternoon. The third was a dredge station on the curious elongated seamount in the centre of the Pirie-Bruce Basin, as an alternative way (to heatflow) of constraining the age of the basin. On the first attempt, on the east flank, the haul was mostly glacial erratics, so a second attempt was made on the west flank, in worsening weather. On this we sheared the 5-ton weak link and lost the dredge; a further dredge lowering was ruled out by the weather, so the basin age remains unknown.

On arrival at the start of the first planned MCS line across area (6), early on day 009, the weather was still bad, and there was a fault on Sercel tape deck B, so we decided to run some full speed gravity/magnetics profiles, to supplement existing data and find ***some*** dredge sites. After 30 hours the weather had improved, but not the deck. We decided to operate with one tape deck, which would mean the loss of a few records at every tape change (typically 6, with 60 on a tape), until deck B was repaired.

After delays caused by streamer repairs and an engine room problem, the first MCS line (BAS 878-003) started at about 9pm, heading approximately 030°T across the entire Ridge and Falkland Trough onto the Falkland Plateau. Line 004 returned south across the Ridge, Lines 5 and 6 (separated by a gap caused by krill in the ER cooling water intakes) made a SE-NW crossing, and Line 7 crossed the Ridge from west to east. The lines served to define 4 provinces:

1. the young, light but opaque accretionary prism next to the Falkland Trough in the north
2. a magnetic basement ridge running east-west across much of the centre of the Ridge
3. a basin of unbedded and barely transparent sediments south of the basement ridge and
4. a probably oceanic, Drake-Passage-related fracture zone ridge to the south.

The MCS profiles were complete by early on Day 014, and the ship began a programme of dredging, to identify and hope to date the older parts of the structural elements listed above. Dredge D125, on the fracture zone ridge (4) obtained mostly glacial erratics. Dredge 126, on the crest of the main ridge (along strike from (2)) gave a similar result, but with some dateable diatomite, probably pre-Miocene. An attempt to gravity core a small rise, a possible outcrop of (3), was unsuccessful, but Dredge 127, on the backslope of the ridge crest near D126 obtained a suite of indurated sediments which should provide much information on the older part of the accretionary prism (1). In deteriorating weather, the next three dredge stations (D128 to 130) aimed to sample the magnetic basement (4), on the western end of the Ridge: briefly, the first 2 were dominated by glacial erratics, to an extent which will probably prevent identification of an in situ component, but the third obtained mostly altered basalts, from which one might be able to derive an age and mode of origin.

core in the falkland trough near 52.6°S, 46.9°W, the ship broke off at 1430 on Day 016 to"' i?yfor the Falkland Is., running standard underway gear (Pm,s?I?,. !;,: gravimeter, magnetometer) on a track slightly north of any already held. There, was no time remaining for a MCS line, as had originally been intended.

We arrived about 2 hours late at the bunker ship in Berkeley Sound on 18 January, because of head winds, and were alongside at the FIPASS jetty, Port Stanley, by 4.30pm. A gravity tie was made to the station at the BAS Office, via a stanchion of the FIPASS bridge.

LEG 2

Port Stanley saw a partial change of the scientific and technical crew (3 technicians and 1 scientist leaving, 4 technicians and 2 scientists joining). Also, we had been promised some air freight: a newly-purchased Sercel tape deck, the p-wave logger and some smaller but needed items. This had not arrived, the problem being that the RAF flights gave the highest priority to MOD equipment. In the hope that a flight due to arrive late on 22nd would bring them, we sailed at 4pm on 20th January, planning a brief sidescan survey of the very eastern end of Burdwood Bank which would allow us to return to embark the items if word came that they had left UK on the flight, or continue to area 3 (current meter moorings) otherwise. In the event we were told, just before arriving at the survey area, that the air freight had still not left, so we deployed the shallow sidescan for just one line before continuing southeast across the Scotia Sea.

The lack of this air freight was a serious inconvenience. We were left with the prospect of only one working Sercel deck, with consequent loss of data, for an entire leg. Also, the whole purpose of using the IOSDL p-wave logger was to compare before cutting up, pairs of cores taken at the same site for pore-water studies, one of which would have to be frozen unexamined. Those cores were to be taken on <u>this</u> leg, in Jane Basin and on the sediment drift in the northern Weddell Sea.

Ice reports were now showing a north-sough margin to the pack ice down 40 W in the Weddell Sea, south of 61 S, such that the southernmost of the 4 current meter moorings laid last year from RRS John Biscoe was the most accessible. The ship therefore ran a dogleg course to the southeast, filling a gap in our knowledge of Drake Passage and Protector Basin magnetic anomalies, pausing late on Day 024 for a gravity core (GC-037) near 61.1°S, 39.2°W, in about 4000m of water in a small basin directly north of Jane Basin. At this site, the symptoms last seen at core site PC029 on Day 360/87 recurred: an automatic hydraulic brake, designed to stop wire runaway; WAS &plied when the wire was veering under complete control. The problem occurred under high wire tension,,,and ,we had not cored in-such deep water, to produce high: tension ,since, PCO29. On this occasion the core was taken and recovered successfully but it seemed likely that cores in deeper water would be impossible unless the fault was eliminated.

We kept well east of the mapped position of the ice'edge in the Weddell Sea, our only encounter being the collision of the 3.5KHz fish with something shortly before midnight (in good visibility still) on Day 025, which bent the hydraulic ram of the towing boom, removed a few clips from the lower part of the tow cable and cracked the cowling.

At 650S we headed in for the site of current meter mooring no. 4 (CMM 4, see Figure 1). The meter was successfully interrogated, late on Day 026, then a CTS station (CID-009) run about a mile away. The mooring was then called in and recovered without difficulty as darkness fell.

Of the 3 meters on the mooring, the basal (5m) meter had leaked, and recorded no data, and the centre one (50m) had not recorded because the clock had stopped and the battery was flat. The top meter (500m) had recorded a full year's data. A more detailed description of the moorings is'given elsewhere.

After recovery was complete, the ship set off on a gravity/magnetics line for CMM3, offset 30 miles east of the direct line between the 2 moorings to reduce the risk of encountering ice. CMM3 was reached at 1730 on Day 027, and successfully interrogated before a CTD station (010, incorporating a wire test of the CMM4 release) was run about a mile away. This CTD also tested the CMM4 transmissometer, which gave anomalous readings on the downward run.

Because there were pieces of brash ice and bergy bits around, CMM3 was not released until daylight, at about 3am on Day 028. It was recovered with little difficulty, and the results were more cheering: all three meters had written successfully to tape. The WHOI sequential sediment trap, which was expected to have had battery trouble caused by cold bottom water temperatures, had in fact worked properly for most of the year. A separate report contains more detail.

The pack ice distribution being more favourable than predicted by the 19 January chart (we should not have been able to get to CMM3), we headed directly for CMM2. Once there, the same procedure was followed, of initial interrogation, a CTD station (011) nearby, release and recovery, all without difficulty. The middle and upper meters had recorded correctly but the basal meter (again, with the transmissometer input) had clearly leaked while at the sea bed, because the base had blown off during recovery.

Similarly, we next headed directly for CMMl and, once there, followed the same routine, without incident. The two upper meters again had recorded (the middle meter for only a month, however), and the basal meter had failed to record.

The first year's moorings must be counted a success. All four had been recovered, and eight of the twelve meters had recorded good data. This will allow us to examine in detail the phase relation between WSBW and AABW flow, to refine our understanding of the palaeo-environmental significance of Weddell Sea sedimentation It is unfortunate 'that, of the four meters that failed to record (two flooded, two clock/encoder failure), three were at basal (5 'm) sites, and that the transmissometer of the fourth basal meter appears not to have functioned. We therefore still lack knowledge of the connection between currents and sedimentation, and this will have to be the highest priority for the second year's array.

After recovering CMMl we redeployed the 3.5 KHz fish, now refurbished, and undertook a small site survey prior to attempting a 3-barrel piston core (PC-038) close to the mooring site, in the morning of Day 029. At all piston core sites to date, we had been getting less than a full-length core (typically 5 or 6 metres in a 9-m barrel), and suspected that the wire loop attached to the piston was too short. After discussion, we lengthened it for subsequent cores (PC-040 onward).

This core station (PC-038) was the first of a number of smaller tasks undertaken while waiting for the current meters and releases to be serviced and made ready for redeployment. The initial estimate of time required for this was 5 days, but 7 were needed in the event.

After PC-038, we could not get underway immediately because of a foul air-cooling cowl on the main engine. This fixed, we headed northeast along Jane Basin to a point on an existing single channel seismic line (G: King and Barker, 1988) for a Z-barrel gravity core (GC-039) which formed part of a latitude transect, then on to a site near the existing Eltanin core 12-10 for a pair of cores for pore-water studies. The weather got up during the execution of core station DC-040, early on Day 030, and the hydrostatic release allowed the core to pre-trigger in mid-water. Fortunately the core survived and was lowered gently into the seabed, obtaining a trigger core and small "gravity" core in the main barrel.

The worsening weather was caused by two low pressure systems combining and then moving back to the west, a sequence clearly shown ***on*** the satellite weather receiver and forecast by Bracknell (but not believed by us!). Because of it, further coring at that site was abandoned and we started one of two long magnetics and gravity lines, eastward across the 20-MA ridge crest-trench collision zone east of Jane Basin and onto the ocean floor of the northern Weddell Sea, to assist in dating the more recent collisions. These completed, we planned to dredge on the ridge east of Jane Bank, identified as oceanic on the basis of the final magnetic anomaly before collision, but never directly sampled. This was known to be difficult dredging country, as 3 previous attempts had recovered only glacial erratics, but the value of a direct identification of the ridge made a further attempt worthwhile.

The first dredge (D131), on the backslope of the ridge, was run late on day 031, recovering mainly (?entirely) glacial erratics. The second on the main, western slope up from the suture trough, recovered some glacial erratics and hydrothermally-altered pre-middle 'Miocene diatomaceous sediment. This last is entirely compatable with an origin for the ridge as early miocene mid-ocean ridge, but does not demonstrate such an origin, in the way that in <u>situ</u> basalt of the same age would do. Two other dredges (D133 and D134), on the crest and lower backslope of the ridge respectively, were unfortunately no more productive. In all cases, the dredging technique was correct, but the environment unfavourable (probably just enough sediment covering basement to make it inaccessible, but too hard to show on 3.5KHz profiles and too thin to show on seismic profiles).

The next task was a pair of MCS profiles across the same ridge, again in the hope of resolving between a mid-ocean ridge and lower fore-arc origin. The streamer and guns were deployed in Jane Basin on Day 033, after problems with guns sealing and a main generator overload. After about 3 hours of the line, however, the Sercel to a critical current control circuit. The final operation before leaving the North Weddell transect was the re-occupation of two final CTD stations southeast of CMM3.

With CID-012 completed by 2100z/039, the ship headed west along 64.8°S, for Area 4 (Figures 1 and 2). Ice reports had continued to provide only estimates of the position of the pack ice edge, and in view of the value of the work proposed it was thought worth going to see if the area was clear. The studies proposed were

1. Investigation of the structure and tectonic history of the oldest ridge crest-trench collision (63.5 to 65°S, 45 to 51°W), by MCS, gravity and magnetic survey, and

2. Further mapping and study of a sediment drift on the NE margin of the Antarctic Peninsula near 64°S, 53°W (found on Discovery Cruise 154, MCS Line G845-14), by coring and CTD casts, and MCS survey.

Only the magnetometer, 3.5KHz and PES fish were streamed initially, but we slowed the next morning to stream the MCS gear so as to intersect the first track of an existing Birmingham SCS reconnaissance survey near 43°W. At the same time we met a cluster of icebergs, with attendant brash ice and growlers. These eventually became so dense that, with the wind increasing also, the MCS gear had to be recovered after only 1 hour's recording. We headed northward out of the berg area and resumed our westward course along 64.2°S, steadily more quickly through 10 February (Day 041) as the wind moderated.

At 0700z/042, near 49°W, we met a pack-ice stringer which caused us to offset 5 miles north, and 3 hours later at 50°W a more extensive ice field made us offset 30 miles north. These concentrations of pack ice were farther north than the estimated positions of the pack ice edge in the 2 most recent ice reports, and persuaded us that the estimates of the rate of ice edge retreat over the period since.the last firm observation had been too optimistic the next ice report, reaching us on 16 February, confirmed this). At 2100z/042 we gave up trying to head for the Line 14 sediment drift. After further discussion we abandoned also the survey of the oldest RC-T collision zone: we had come through the area on one track without seeing ice between 44°W and 49°W, but could not be sure how much farther south we would be able to go, and could not work as far west as was desirable. We decided instead to work farther north where we could expect much less ice, to try to complete a collaborative study of Powell Basin evolution (BAS marine data and Dr J L LaBrecque's aeromagnetics). This would involve MCS survey of buried transform fault topography in southern Powell Basin near 63°S, 45 to 48°W, and of a postulated extensional margin near 62°S, 53°W.

By 1800z/043 we had reached the start position for the first of a planned series of zigzag tracks across the transform faults. However, the wind was blowing 30 kts and rising, and we-decided not to stream the MCS gear but to run the first 2 or 3 lines as fast as we could using only bathymetry, gravity and magnetics, since in this eastern part much of the topography was probably exposed at the seabed. This was successful, and we made 8 to 9 knots in 30 to 40 kt winds along 3 short lines 60 degrees off the wind. By 16002 on 13 February (Day 044) the wind had moderated and we decided to stream the MCS gear for a 4th line, farther to the west in an area where the topography was much more likely to be buried. By evening we had started the line, heading about 190°T.

Towards the end of the line, near 63.3°S, 46.8°W, we were skirting the eastern edge of an area of small bergs, prior to altering course west for the start of the next line when, at 14502/045, the streamer suddenly went dead. All seismic signal disappeared and the tow cable went slack. There was no prior indication of anything amiss. We slowed and recovered the airguns; the streamer tow lead was around the gun array and the beam was bent. The tow lead was eventually freed and brought inboard on the streamer winch, and the streamer was seen to have parted at the outboard end of the outer of 3 50-m stretch sections, about 250 m astern of the ship (well astern of the gun array). The nylon ropes and conducting wires had broken and the skin had slid cleanly off the end connector, which had gone. The streamer drum had rotated to the limit of the safety strop, allowing the tow cable to move about 1 m farther outboard than it had been set. All these indications (apart from the bent gun beam which remains a mystery) point to a sudden increase in tension farther outboard The most likely cause, although not proved, is a collision of the tail buoy with a bergy bit, growler or large piece of brash ice which had drifted across the path of the streamer since the ship's passing. The tail buoy tows about 20 minutes (1.6 nm [3 km] at 5 kts) astern of the ship, the wind at the time was on the beam and we have experienced surface water currents of 0.5 to 1 kt in this area, under the influence of persistent strong winds: the ship had probably passed within 0.3 nm of more than one piece of ice large enough to have stopped the tailbuoy dead on direct impact.

The ship's position at 14502 had been fixed by GPS. Because of difficulty in disentangling the airgun array and streamer tow lead, and the need to return to the area on bowthrust alone, lest an undetected floating streamer foul a rotating propellor, we only reached this position again at 17502. We were able to search the immediate area and 3-4 miles downwind until nightfall, though hampered by reduced visibility. After dark we commenced dragging for the streamer on the seabed, on a l-km grid down-current (east) from the original position out to 3 nm, using the main warp with pinger, tensiometer and 5-tonne weak link, and with weighted end and 3 ship's grapnels: the water depth was 3200 m and the seabed was sedimented and flat, and the consensus view was that the damaged streamer would have sunk, imploding and towing the tail buoy down with it. We were encouraged by 2 apparent short contacts on different lines in the same area to further attempts with an improved grapnel constructed on board, but to no avail. The search was abandoned at the start of Day 048, in order to meet our schedule for return to Port Stanley. Possible improvements in MCS streamer use are discussed elsewhere.

The passage to the Falkland Is was a straightforward, direct magnetics/gravity/PES/3.5KHz line. We were delayed by dense fog at times on Days 048 and 049, and by strong winds early on Day 051, and reached the fuelling point in Berkeley Sound at about 1730 on 21st February (Day 052). We anchored after fuelling, then picked up anchor later when it seemed likely to drag, and steamed around at the entrance to Berkeley Sound overnight. We anchored in Stanley Harbour at 10am on 22nd, and received our mail, then finally went alongside at about 1630, after waiting for a cargo boat to dock. We had been due to arrive am on the 21st.

Explosives were transferred to Bransfield the same evening (for OSCS, via Rothera), and airfreight taken aboard. This included the spare Sercel tape deck, a spare stainless steel tow cable for the 3.5KHz fish, and the IOSDL p-wave logger, too late to be of any use and after we had asked RVS to stop it coming (maybe we should have done that earlier!)

The RVS and IOS technicians who had been with us for Legs 1 and 2 were all relieved, and Paul O'Brien also flew home. We welcomed Mark Midwinter, ex-Halley FID, as ship's doctor and honorary geophysical watchkeeper.

## LEG 3

Leg 3 was to be spent entirely along the Pacific margin of the Antarctic Peninsula, principally to map and examine the effects on the margin of a series of ridge crest-trench collisions, work started on Discovery Cruise 154 in 1985. The Leg was to be a mixture of magnetic and MCS survey, with dredging, coring and shallow sidescan survey added, and was to include a rendezvous with HMS Endurance for a 2-ship seismic experiment using explosives.

The main concerns for Leg 3 were the availability of a MCS streamer, and the provision of two working Sercel tape decks. From the spare streamer sections held aboard, it seemed possible to make up a 16-channel streamer, with 3 stretch sections (eventually 4) and 2 depth sections. The tailbuoy was a gun buoy, and the tail rope scrounged from Bransfield. Work on filling the sections with oil, and winding them onto the winch, had already started at the end of Leg 2. The arriving RVS technicians brought with them sufficient spares for us to build 2 working birds, and quickly completed filling and winding on the streamer, and setting up the sercel deck.

A streamer of these dimensions would at a pinch fulfil most of our requirements for Leg 3, but would not allow us to carry out as planned the proposed 2-ship expanding spread experiment (ESSEX II) with HMS Endurance. With only a short streamer, the continuous cover needed for tau-P transformation of the recorded data would be impossible without using all of the explosive on only the first of 5 planned lines. We therefore proposed a more radical revision, involving shooting one long reversed dip refraction line, instead of the 5 short strike lines originally intended. We put this to Endurance, and to BAS Cambridge for environmental assessment, and received qualified approval to continue.

We had been scheduled to arrive at Port Stanley early on 21st February and sail late on 23rd. Owing to our late arrival, it seemed reasonable to delay sailing until 24th, but on the 24th a northerly and northwesterly wind kept us pinned to FIPASS. The wind eased overnight and we sailed for the Antarctic Peninsula at 9am on the 25th February (Day 056), running a straight geophysical passage line (magnetics, gravity, PES, 3.5KHz) across Burdwood Bank and Drake Passage, rolling along in response to a west to northwest wind and swell. At 6pm on Day 059 we turned onto a southeasterly track for a magnetics line towards the Peninsula margin, primarily to see if there is an additional collision zone between the 6.5 and 14Ma zones, as had been suspected from ESSEX I data. There is.

On arrival at the shelf edge late on Day 060, we fired 11 explosive charges (6 x 2.5kg, 1 x 5, 10, 25, 50 and 75kg) to determine charge sinking rates and fuse burning rates, for the 2-ship experiment (now renamed SUSSM: - Substitute Under-Sea .....) We then started to balance the short (16-channel) streamer, and by late on Day 061 were on the first of a series of MCS lines (BAS 878-011 to -017). Lines 11 and 12 were short additions to previous lines (AMG 845), and 13/14 (separated by a gun failure late on Day 062) was a long traverse across the shelf and slope, extending well onto ocean floor to see if the marginal magnetic quiet ***zone*** has a distinctive seismic signature.

Also on Day 062, coincident with the airgun failure, the starboard transducer of the shallow sidescan sonar suddenly locked over to port and up, having earlier been unresponsive to inclination commands. It was switched off while advice was sought from ashore.

After Line 14, MCS survey continued with a series of short lines connecting older, isolated lines in deep water and a second shorter traverse of the margin and shelf between lines AMG 845-007 and -008. During this line (BAS 878-015), a 90° rotation of the sidescan stem was noticed, so we slowed and rotated it back, and en passant righted the fault on the starboard plate. Although the plates were still not responding (apparently) to tilt commands, we were getting good records on the continental shelf, so the gear was kept running.

MCS survey continued with Line 16, a traverse northward to the end,of line AMG 845-10, its extension northeastward and then (Day 065) a third traverse (line 17) of the shelf and margin, in the 4Ma collision zone (since AMG 845-005 may not be representative). The MCS gear and sidescan were then recovered so that the line could be continued as one of two fast magnetics lines, to define the extent of the young, non-orthogonal spreading in the 4Ma collision zone.

On our return to the shelf, early on Day 067, we redeployed the sidescan system for an examination of the 25-fathom shoal north of Smith Island, which we believed could be a young outer-shelf volcano related to ridge crest subduction. Only the port side of the sidescan system was working, but we demonstrated that, unfortunately, the shoal was not where the chart puts it. We then headed southwest for a second dredge site, along strike from Smith Island and on a mid-shelf basement high, where two dredges late on

Day 067 recovered metamorphic rocks. Then on to a site on the outer shelf where our own MCS and 3.5KHz data from 1985 suggested strongly that there was a young volcano. The second of two dredges in deteriorating weather on Day 068 recovered fresg basalt.

There was time remaining for a third fast magnetics line in the 4Ma collision zone before our rendezvous with HMS Endurance inside Deception I., to transfer explosives and make the final plans for SUSSEX. We left the dredge site at noon on Day 068 and, although able to make only 6 kts on the outward track, we achieved the magnetics line, and a crossing of the Hero FZ and return across the South Shetland Trench, before entering Deception I at 0700 on Day 070 as arranged.

At a meeting on board Endurance while the explosives were being transferred, we agreed a shooting schedule for SUSSEX, and details of radio communications, pre-line tests, data recording and how any environmental damage would be assessed. When Discovery sailed at 1130am, we left Ian Hamilton on board Endurance to record shot data and Mark Midwinter as environmental assessor.

Discovery took the outside route to the SUSSEX start point, rolling badly overnight in a west to northwest swell and west wind. Endurance left later, taking the inside route, and fired 2 or 3 test shots, for which we tried to record the transmitted shot instant. The next day, Discovery had to go well into Bismarck Strait in order to find sufficiently sheltered water to deploy the MCS streamer, and was therefore late for the rendezvous.

The sea was quite rough at the endpoint, and Endurance suggested that instead of starting the line then, and perhaps only being able to fire the smaller charges, she should return in 3 days' time, when the bad weather and swell should have subsided. This offer was gratefully accepted, since we probably could not have completed the shooting within the original time limits (1200/071 to 1400/074) in those conditions. Endurance visited Rothera and Discovery, after recovering the MCS streamer and listening to further hydrophone transmission tests, went to anchor overnight at Port Lockroy.

The next day (072, 12th March), we headed north for Dallmann Bay, via the Neumayer Channel and Gerlache Strait, running the sidescan sonar (1 side only), hull-mounted PES and gravity. In Dallmann Day we streamed the MCS system (and PES and 3.5KHz fish) for a line (BAS 878-018) which ran southwest along the assumed axis of the inshore basin seen on all processed dip lines, to see how continuous it really is.

At the end of Line 18, there was time before our rendezvous with Endurance to see if we could obtain any useful structural information at intermediate depth from sonobuoys, to assist interpretation of the imminent SUSSEX line. After a trial, to see how far away the sonobuoy signal could be heard in the surviving swell, the gun array was recovered and replaced by a 3-gun rig (1000, 700 and 466 cu.inches) on the same beam. We had enough air to fire this array on a 40-second cycle. We recorded 4 sonobuoy lines, between 10 and 20 km long, the first 2 forming a reversed strike line on the mid-shelf high, the last 2 being shot along the SUSSEX line as we headed for the R/V position, early on Day 074.

The airguns were recovered as we entered Bismarck Strait, the beam coming in bent after the buoy lines had tangled with the streamer tow lead. Despite the poor weather (a 25kt westerly, and the remains of the swell), we decided to go ahead with the first SUSSEX line, starting at 7pm.

[THE NARRATIVE OF THE SUSSEX SHOOTING IS CONTAINED IN A SEPARATE REPORT, WHICH FORMS APPENDIX A.]

By 4pm on Day 076, with SUSSEX complete, our observers and their equipment had been transferred back to RRS Discovery by helicopter. Because the weather remained rough the Captain decided to remain in the comparative shelter of Bismarck Strait overnight. Despite this, the 2 core heads broke loose on the after deck, and damaged the streamer winch electric supply. When the weather abated, late on Day 077, we headed west through the Wilhelm Archipelago and southwest towards southern Adelaide I. We intended to rendevous with RRS Bransfield, leaving Rothera, to transfer the WSR 524 satellite weather receiver borrowed from BAS meteorologists, for her to take on to the Faraday base.

This done late on day 078, we headed northeast again before streaming the MCS gear for a long line (Line 19) out to DSDP Site 325, aiming to correlate shelf and slope seismic sequences with the drilled section.

On the way, first the 300 cu inch gun failed and then, more crucially but very close to the site, the 466 cu inch gun. To ensure a good connection, the guns were recovered and repaired while the ship steamed a loop beyond the site, then the return track (Line 20) was steamed through the site and across the intact part of the outward track.

Line 20 ran first south, across the "A" fracture zone, then southeast onto the Peninsula shelf. Line 21 continued northwest, intersecting line 19 before ending late on Day 082.

We then headed quickly back to the shelf off Anvers I to occupy a coring transect of the shelf, aimed at calibrating the sidescan and 3.5 kHz data collected during Discovery Cruise 154. The transect (4 gravity/trigger core pairs) was completed very quickly on Day 083, and was followed by 2 dredges of the scarp on the inboard side of the mid-shelf high on MCS line 845-03. The next task in this quick round-up of unfinished business was two piston cores in deep water offshore, anticipating future GLORIA mapping of the system of shelf-slope-rise transport of terrigenous sediment from the Peninsula. The final item was 4 CTD dips across the gap between the Hero FZ and the margin, to see if anticlockwise circulation of AABW around Antarctica as a western boundary undercurrent could be detected.

**On the way back to Stanley, two unsuccessful attempts were made to dredge the dead spreading centre in Drake Passage, on Days 087-8. Scientific watchkeeping finished on Burdwood Bank, am on Day 089, and we reached Port Stanley at 0930 on Day 090 (30th March). The ship sailed again late on Day 091 and we all flew home eventually on Day 095.**

## 5. DISCOVERY 172 - CRUISE STATISTICS

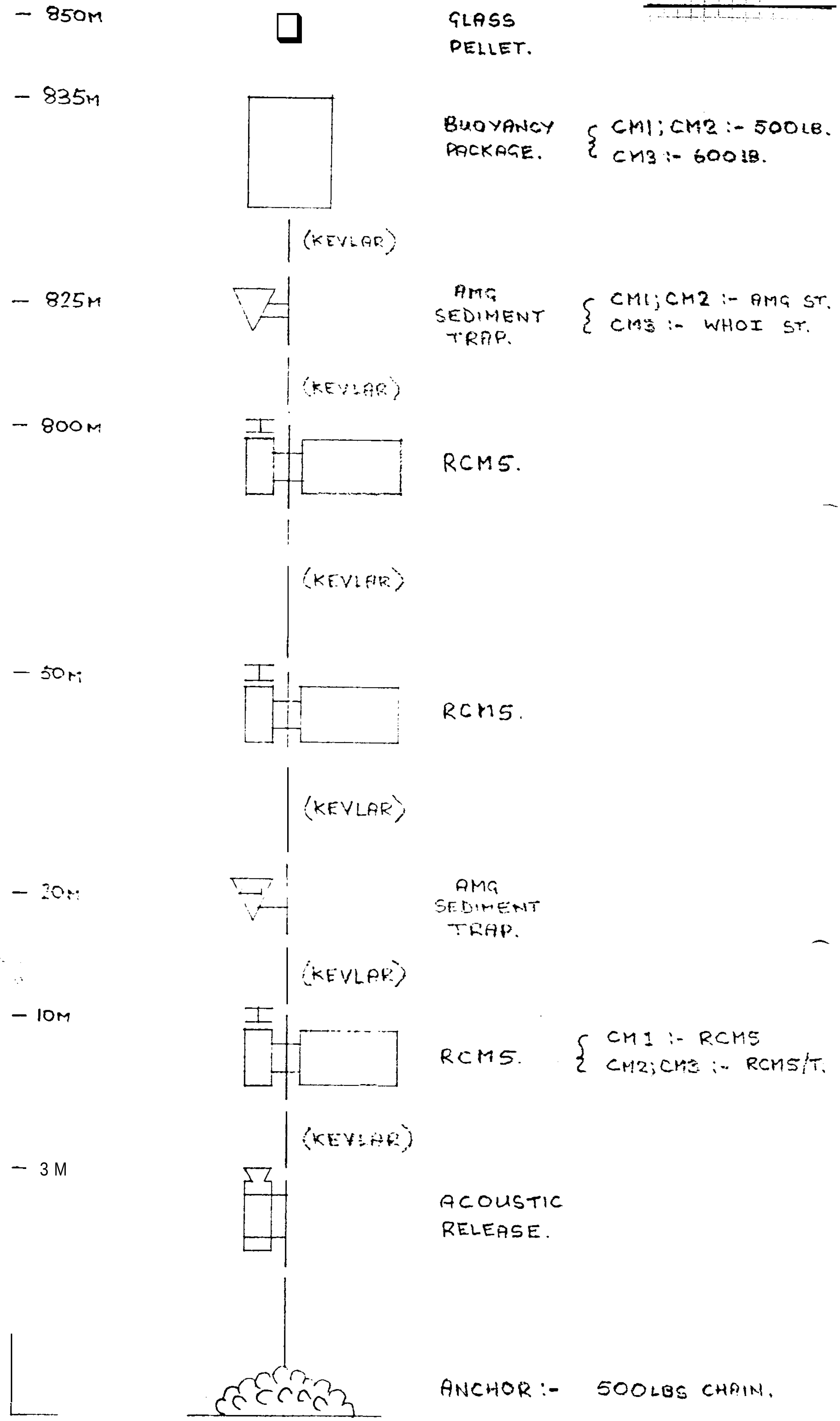
| | | |
|---|---|---|
| 1. Total cruise time, from leaving Rio to arriving Stanley (1800, 17 Dec, 1987 - 0700, 30 Mar, 1988) | | 103.6 days |
| Distance steamed, all cruise | 14350 miles (26595 km) | |
| Calls in Port Stanley and Berkeley Sound | | 6.8 days |
| Passage time (Rio to 48S | | 5.7 days |
| (Return to Stanley) | | 0.9 days |
| 2. Total working time | | 90.2 days |
| Distance steamed, working | 12537 miles (23235 km) | |
| 3. Lost time: at anchor or hove to for weather | | 2.3 days |
| searching for seismic streamer | | 2.6 days |
| Transfer of explosives at Deception Is. | | 0.3 days |
| 4. Total underway time (including time bteween stations) | | 72.3 days |
| Total bathymetry time (PES and 3.5 kHz inc stations) distance 12248 miles (22699 km) | | 81.1 days[b] |
| Total gravity time distance 12148 miles (22515 km) | | 85.9 days[b] |
| Total magnetics time distance 10779 miles (19977 km) | | 57.6 days |
| Total DMCS time distance 1964 miles (3640 km) | | 15.2 days |
| Total sonobuoy time distance 62 miles (115 km) | | 0.5 days |
| Total SUSSEX time distance 118 miles (219 km) | | 1.2 days[a] |
| Total sidescan sonar time distance 1300 miles (2409 km) | | 9.9 days |
| 5. Total station time (not including time between stations) | | 12.7 days |
| 'Coring time | | 3.8 days |
| Dredging time | | 3.6 days |
| CTD time | | 2.5 days |
| Current meter mooring time | | 1.1 days |
| Heatflow time | | 1.7 days |

NOTES

a) Multichannel seismic reflection data were acquired at the same time as the sonobuoy data; however, the shot interval was set at 40 seconds to cope with the increased volume of the airgun array.

b) The gravimeter and PES were usually kept running while on station. **The** greater time spent acquiring gravity data is explained by periods when the PES and 3.5 kHz fish were recovered, such as to visit Deception Is. or anchoring in Port Lockroy, when gravity data continued to be logged. The greater distance over which bathymetric data were acquired is explained by periods underway when the gravimeter failed either through ship power failure or a gravimeter gyro failure; several hours could elapse without gravity data being logged while the gravimeter restabilised.

DISCOVERY 172.



**The** WHO1 sediment trap deployed on CMM3 was successfully recovered. Details of its performance are given separately.

Instrument performance was assessed by quickly translating the recorded data tapes.Feedback from these data also provided useful scaling information which was used when setting up the instruments for redeployment.

Data return from the initial deployment was 61 percent. Good data were recovered from RCM'S 6751, 6749, 3257, 6152, 3258, 8247 and 3259. RCM8250 provided 4 months good data before it leaked. No transmissometer data was recoverable.

Prior to redeployment all instrumentation was thoroughly inspected and overhauled. The command/releases were fitted with new batteries, bench tested, purged with dry gas and resealed. Wire tests were carried out as before and test pyros (puffers) fired at the working depth. To save time, wire tests were combined with CTD operations.

The current meter seals and sealing faces were inspected and cleaned. Suspect conductivity cells were removed and blanking plugs fitted. Rotor bearings were renewed as required. The encoder assembly on RCM3261 was replaced. New batteries were installed, sensor ranges adjusted and test tapes generated. Finally, the instruments were switched on, purged with dry gas and sealed.

The optical windows on transmissometers 75-D and 76-D were cleaned with a mild detergent solution, and the units then powered up on the bench and their calibration values noted. Connectors and cables were also checked. It was decided that 3 moorings would be redeployed on sites CMMl, CMM2 and CMM3. The 4th mooring was omitted because of the lack of suitable replacements on board for the flooded current meters. The moorings were reconfigured to increase the height of the top current meters and the WHOI sediment trap by 300m. They were also modified to allow the addition of 5 new (AMG) sediment traps, supplied by Birmingham University. The extra strops and brackets required to mount these traps were fabricated on board. Fig 2 shows the new mooring configurations for CMMl, CMM2 and CMM3.

The turn around and servicing of the instrumentation and moorings was a time-consuming operation, taking about 7 days in total. During this time the scientific programme continued with the ship occupying CTD coring and dredging stations.

All moorings were deployed as before, anchor first, using a stopping off procedure to insert the instruments into the mooring line. When outboard,the moorings were held until good satellite fixes were obtained and then released (see separate paragraph for problems encountered at CMM3). Each mooring descent was monitored on the PES and the rate recorded. Typical descent rates were about 80 metres per minute. When the moorings were on the sea bed, satellite fixes were again recorded and the ship kept on position until the command/releases had timed out.

Before the release of CMMS, 100lb of excess buoyancy had to be removed because the mooring was too light in the water. It was also noted that strong surface currents had caused the ship to drift off position. An attempt to regain position by towing the mooring failed so the decision was made to release. The mooring failed to submerge and was suspected of having fouled KHz fish. Fortunately, whilst manoeuvring the ship to recover the stray line, which was still visible on the surface, the mooring freed itself. The rest of the deployment went ahead as normal.

Total time for mooring redeployment was 2.5 days.

## 6.2 WOODS HOLE SEDIMENT TRAP

A Parflux Mark IV sediment trap, owned by Woods Hole Oceanographic Institution, was recovered from and redeployed on current meter rig 3. The Woods Hole scientists had experienced battery problems with similar sediment traps which had been deployed in cold Antarctic waters. To ensure against this happening again a larger Controller Unit was installed for the 1988-9 mooring.

### Recovery

The sediment trap was brought aboard RRS Discovery at 0732z on 28/01/88. The carousel had moved during the deployment period so that bottle 9 was located under the funnel. Once on board the bottles were removed, capped and stored at 4°C. The trap was dismantled and each component was washed in warm fresh water and dried. The Controller was opened and the battery voltage showed 26.07 V compared with 26.5 V on deployment. From the data retrieved from the Controller, table 1, an interpretation of events was made. It became apparent that the battery power had faded during the Antarctic winter, but recovered during the summer. Little sediment was collected during the Antarctic winter, but during the summer, sediment was collected, with a maximum of 10% in bottle 9.

### Deployment

The pressure bladder housing the stepper motor was topped up with silicon oil and the carousel assembly was rebuilt. The new Controller was housed in a larger pressure vessel and contained double the battery power. This was opened up and inspected. The circuit boards were found to be adrift from the top of the pressure vessel, but otherwise **appeared to** be undamaged. A d.c. power supply was connected to the Controller to conserve the batteries and a full 15 event test was successfully run. Water was used from a CTD cast at 4000m depth to provide the fill for the bottles. Five litres were mixed with 175 gms NaCl and 16 gms $HgC_2$. Table 2 gives the 28 day cycle which was loaded into the Controller before deployment. No problems were encountered on deployment.

| Event | Date | Time | Clicks | Bottle | Comment |
|---|---|---|---|---|---|
| 1 | 11 Feb | 0900 | 43 | hole | Test on deck to move to open hole |
| 2 | 12 Feb | 1200 | 20 | hole | Carousel must have moved by a small amount during the deployment |
| 3 | 11 Mar | 1200 | 91 | 1 | Moves to bottle 1 |
| 4 | 7 Apr | 1200 | 89 | 2 | Moves to bottle 2 |
| | 4 May | 1200 | 91 | 3 | Moves to bottle 3 |
| 6 | 31 May | 1200 | 88 | 4 | Moves to bottle 4, but fails to open microswitch |
| 7 | 27 June | 1200 | 2 | 4 | Bottle 4 stays under the funnel as microswitch opens |
| a | 24 July | 1200 | 68 | 5 | Moves part way to bottle 5 |
| 9 | 20 Aug | 1200 | 20 | 5 | Moves bottle 5 to almost directly under the funnel, but still fails to open microswitch |
| 10 | 16 Sept | 1200 | 2 | 5 | Bottle 5 still under funnel, microswitch now open |
| 11 | 13 Oct | 1200 | 90 | 6 | Moves to bottle 6 |
| 12 | 9 Nov | 1200 | 90 | 7 | Moves to bottle 7 |
| 13 | 6 Dec | 1200 | 90 | 8 | Moves to bottle 8 |
| 14 | 2 Jan | 1200 | 90 | 9 | Moves to bottle 9 |
| 15 | 29 Jan | 1200 | -- | 9 | Sediment Trap recovered 28 Jan |

Table 1 - Events recovered from the sediment trap deployed in 1987

| Event | Date | Time | Comment |
|---|---|---|---|
| 0 | 06/02/88 | 19:oo | Test on deck, moves to open hole |
| 1 | 07/02/88 | 12:oo | Moves to bottle 1 |
| 2 | 06/03/88 | 12:oo | Moves to bottle 2 |
| 3 | 03/04/88 | 12:oo | Moves to bottle 3 |
| 4 | 31/04/88 | 12:oo | Moves to bottle 4 |
| 5 | 28/05/88 | 12:oo | Moves to bottle 5 |
| 6 | 25/06/88 | 12:oo | Moves to bottle 6 |
| 7 | 23/07/88 | 12:oo | Moves to bottle 7 |
| 8 | 20/08/88 | 12:oo | Moves to bottle 8 |
| 9 | 17/09/88 | 12:oo | Moves to bottle 9 |
| 10 | 15/10/88 | 12:oo | Moves to bottle 10 |
| 11 | 12/11/88 | 12:oo | Moves to bottle 11 |
| 12 | 10/12/88 | 12:oo | Moves to bottle 12 |
| 13 | 07/01/89 | 12:oo | Moves to bottle 13 |
| 14 | 04/02/89 | 12:oo | Moves to bottle 14 |

Table 2 - Schedule loaded into the sediment trap deployed in 1988

## 6.3 MULTI-CHANNEL SEISMIC SYSTEM

At the start of Discovery cruise 172 the multi-channel seismic (MCS) system had been in service with RVS for about three years. In view of this, and the fact that the system had been used extensively on the preceding Discovery cruise, a surprisingly large number of problems had to be overcome at the start of the cruise.

The MCS system has three components:
(a) the Sercel SN358 and peripheral instrumentation,
(b) the streamer and depth control system,
(c) the airguns and compressors.
The performance of each component is discussed below.

### (a) Seismic Recording and Monitoring Instrumentation

#### (i) Sercel SN358

The majority of the SN358 system (power unit, A-D convertors, logic unit, switchover unit) performed well throughout the cruise. However, there were 2 serious tape deck malfunctions and a control panel fault.

#### (ii) Sercel Tape Decks

The most serious problem was the malfunction of tape deck B which occurred midway through leg 1. Even at the start of leg 1 there were several parity errors on most of the tapes recorded on this unit. The fault proved difficult to locate. In order to be sure of having 2 tape decks available for the later part of the cruise, RVS acted swiftly to purchase a second hand one. This was delivered to RAF Brize Norton in good time for it to be flown to Port Stanley for the start of leg 2. Unfortunately, a certain inflexibility on the part of the Ministry of Defence delayed shipment of the new tape deck ('C') until after the port call.

MCS data acquired on the second half of leg 1 and on leg 2 were recorded using only tape deck A (MCS lines BAS-878-03 to BAS-878-10). On average 5 or 6 shots were lost at each tape change. This will create difficulties (and possibly additional expenditure) in processing and will degrade the quality of the processed data.

Tape deck B was eventually repaired by A. Cumming and D. Booth in a period of intensive work at the start of leg 3. The first problem was that the main relay would not energise. This was solved by replacing a faulty transistor in the voltage sense circuit. With power returned, several other problems became apparent:

1) poor response to tape tension test - strain gauge replaced;
2) no remote control - faulty IC replaced;
3) combined local and remote control - faulty IC replaced;
4) no internal write clock - faulty IC replaced.

At this stage the tape deck seemed to be working and was put on test. The first test tape went through without problems, but as testing continued parity errors and eventually H32 inhibits appeared. By monitoring the read outputs it was noticed that track 5 was noisy. The fault was traced to a faulty potentiometer in the write circuit. This was replaced and the deck gave no further problems.

Tape deck C was awaiting collection in Port Stanley at the end of leg 2. When purchased it was configured for 80 inch/s recording. It was reconfigured for 20 inch/s and the tape tension was set up. As there were no spare filter modules, the ones from deck B were used. The new tape deck was tested and to everyone's relief it worked well.

The first MCS data on leg 3 were recorded using tape decks A and C. Deck A started to give an excessive number of parity errors after the first 3 days of MCS work. It was replaced by the newly repaired deck B, which we continued to use until the end of the cruise. The problem with deck A is thought to be one of tape alignment and skew. By altering the postion of the tape guide the number of errors can be reduced, but they cannot be completely eliminated. The deck will require further.investigation at Barry.

(iii) Sercel SN358 Control Panel

After over 3 years use the control panel is showing signs of wear and tear. It was used particularly heavily during legs 1 and 2 of this cruise because each tape change requires several control panel operations when only one tape deck is in use. This may explain the problem which occurred midway through leg 2. The whole Sercel system locked up and would not respond to any input from the control panel. The problem remained after powering down and restarting the system. This forced the abandonment of line BAS-8'78-08 after less than 4 hours recording. The cause was eventually traced to the 'START' key. One of the 2 pairs of contacts behind the key had short circuited, blocking signals from all the other keys. This fault was traced and fixed by C. Woodley within 24 hours.

Recommendation:

Without the control panel the Sercel system is incapable of running diagnostic routines, which is otherwise the design mode of fault tracing. Fcrtunately, a relatively simple repair was possible in this instance once the problem had been traced. A more **serious** or complex problem could have prevented a large part of the cruise program. It seems risky that the system is operated without a spare being carried (as Sercel recommend) for such a vital component. In view of the condition of the present control panel, purchase of a replacement should be given a high priority.

(iv) DSS V

The DSS V performed well throughout the cruise.

(v) BBC Micro and Extended Header Program

The BBC micro and extended header program appear to have performed well throughout the cruise. There was some suspicion of Position Number jumps during leg 1, as on Discovery Cruise 154, but we will not be sure about this until we start processing the data.

(vi) Sercel-Reftek Interface Unit

This unit was designed and built by RVS as a temporary measure to enable the Reftek airgun control system to be used with the Sercel recording system. It is intended that the unit will be replaced by an IBM PC once the appropriate software has been developed.

At the start of the first MCS line of the cruise (BAS 878 01) it was observed that the airguns were firing about 1.6s after the start of recording. This firing delay was traced to the Sercel-Reftek interface unit. The delay was found to consist of 2 components, each of which was precisely measured at the end of the line. 484ms of the delay were caused by an incorrect input and 1120ms were caused by an incorrect switch setting on the interface. An entirely different triggering mechanism, not using this interface, had been employed on Discovery cruise 171.

(vii) SIE Oscillograph (camera)

The camera produced poor records until given a thorough service during leg 3. The automatic camera trigger from the BBC micro was of little value as it was usually too late to display the start of recording. Most camera records were taken manually. During leg 1 the corona element on the camera failed, resulting in blank camera records. The element was replaced within a few hours.

Throughout the cruise the camera showed noise on channels 5 and 15. The noise on channel 15 was regular at about 100Hz, so it must have been generated after the signal had passed through the Sercel anti-alias playback filter. The noise on channel 5 was irregular and intermittent. It was at first thought to be due to leakage of seawater into one of the streamer sections (see section b(iii)). However, this noise continued on leg 3 when the front of the streamer was made up of brand new active sections. The source of the noise on channel 5 could be anywhere from the slip rings on the winch through to the camera itself. We will not know whether the noise seen on the camera records is present on tape until we start processing the data.

Most camera records showed a small deflection on all channels at the arrival time of the seabed reflection on the channel nearest to the ship. Once again, we will not know if these deflections are present on tape until we start processing the data.

(viii) EPC Recorders

2 EPC recorders were used to provide single channel monitor records for all MCS lines. One was used to display the data before it was written to tape and the other was used in read-after-write mode.

No read-before-write EPC record was obtained during the first MCS line of the cruise. This problem was solved by a change of inputs before the next line. On legs 1 and 2 the read-after-write EPC produced no record unless a recording delay was used. This was not a problem at the time because all the MCS lines on legs 1 and 2 were in deep water. For leg 3, where much of the work was on the continental shelf, the problem was solved by taking the EPC trigger from the Sercel-Reftek interface unit (see section a(vi)), instead of from the camera as Cruise 171 had done.

The read-before-write EPC was replaced by a spare EPC on leg 2, following an incident in which a signal from it appeared to have been responsible for multiple triggering of the airguns. This EPC was brought into action again on leg 3 to display sonobuoy records.

(ix) Water-break Recording

The signal from the water-break hydrophone (WBH) was recorded on Sercel auxiliary channel 1 and displayed on camera records during legs 1 and 2. The WBH was lost in the incident on 14th February (see narrative and section b(vii)).

Recommendation:

If the streamer and WBH are to be replaced, consideration should be given to development of an automatic water-break monitoring system. This would measure the time offset between the Sercel key pulse and the time at which the WBH signal exceeds a certain threshold. BCD output could then be made available for display and entry into the BBC extended header.

(x) Data tapes

937 data tapes were recorded on the Sercel on this cruise. 120 of these were Memorex MRX IV tapes which had previously been used as data tapes on Discovery cruise 154. The remainder were all brand new Control Data Storage Master Alpha tapes. Fewer parity errors were encountered when using the Memorex tapes and they seem to have closer length tolerances. The latter is an important factor when 2 tape decks are in use, since the number of records per tape is pre-set and running off the end of a tape can cause considerable difficulties. Some of the Control Data tapes had been transported from Barry to Rio in a non-cooled container. The fact that these tapes had been 'cooked' on arrival in Rio may explain their poorer performance.

About a dozen tapes (some recorded, some blank) were damaged when the tape rack in the wet lab. toppled over in rough weather. The rack was only secured at its base. In future it would be a good idea to secure it at the top as well.

(xi) Air Conditioning

The air conditioning in the Plot is inadequate when the Sercel is in operation. This probably affects the performance of equipment and certainly affects the performance of people. Watchkeepers tend to leave the port windows open when the weather allows. This practice is risky, but is likely to continue until an air conditioning system as effective as the one in the Computer Room is installed in the Plot. This may be expensive, but the expense has to be balanced against the possibility of damage to valuable equipment as a consequence of windows being left open.

## (b) Streamer and Depth Control System

The most important event of the cruise affecting the streamer was the loss of the greater part of it on 14th February (see narrative and section b(vii)). The performance of the streamer prior to this incident is considered first.

### (i) Streamer Balancing

At the end of Discovery cruise 171 the streamer was left balanced for the area around Bermuda. On cruise 172 the first streamer deployment was on 29th December in the Central Scotia Sea. Calculations using the differences in seawater temperature and salinity between these 2 areas, streamer specifications and coefficients of thermal expansion for various components of the system indicated that it would be necessary to add 6 litres of Isopar L per section to restore section shape and remove 3.lkg of lead 'per section to make the streamer suitably buoyant. On the first deployment 6 litres of isopar L were pumped into each active section and 5 litres into each stretch section. Three 2lb sheets of lead were removed from each of the 3 outermost sections (reportedly light on D171) and four 2lb sheets were removed from the others. When all this had been done the streamer was found to be too light. With the streamer being towed at 5kts the birds did not take it down to a reasonable operating depth even when commanded to their maximum depth setting. The streamer was recovered and then redeployed, adding one 21b sheet of lead to each section as it went out. After this deployment the streamer was found to be controllable using the birds and the first seismic line of the cruise was started a few hours later. At this stage the streamer had an average of 9.8 21b sheets of lead on each section, with slightly more lead on the sections further away from the ship than the ones nearer to it.

### (ii) Deployment and Recovery

It was found that if the streamer was fully deployed before slowing to deploy air-guns, it sank quickly to >230ft (the working limit of the depth sections). This occurs because the heavy tow cable drags down the front of the streamer and the rest of it 'follows through'. The structure of the Antarctic water mass is such that temperature decreases sharply with depth in the top lOOm, but without a great increase in density. Once the streamer starts to sink it enters a positive feedback loop: it encounters cooler water which makes it less buoyant, so it sinks further, encounters still cooler water and so on. In an attempt to prevent the steamer sinking during deployment and possible hydrophone damage due to increased pressure, we adopted the practice of retaining most of the tow cable on the winch drum until after the airguns had been deployed and the ship's speed had increased to 5kts. For recovery this procedure was reversed: the tow cable was recovered steaming at 5kts (or as fast as the hydrophone winch could cope with), then the ship was slowed to 2kts for airgun recovery, then the rest of the streamer was recovered.

(iii) Streamer repairs and modifications on legs 1 and 2

A puncture was discovered in the tow cable during the first streamer recovery. This was wound onto the winch drum unrepaired to allow as much seawater as possible to bleed out. The puncture was repaired during the next deployment, about 12 hours later. The tow cable continued to function satisfactorily for the rest of the cruise, but will probably need to be replaced in the near future.

Active section 2 was replaced before line BAS-878-03 because it could be seen to contain bubbles of seawater. On the same deployment the number of stretch sections at the front of the streamer was increased from 2 to 3.

(iv) Amount of Stretch in Stretch Sections

Comparison of the water-break time with the time predicted from the measured geometry of the steamer and aiguns suggests that when 2 stretch sections were being towed ahead of the full streamer at 5.4kts (lOkm/hr) they exceeded their nominal length by approximately 13% (13m in 1OOm). When a third stretch section was inserted the estimated extension decreased to 10% (15m in 150n).

(v) Depth Control and Monitoring Systems

At the start of the cruise 13 depth controllers ('birds') and 8 depth sections were available, providing excellent monitoring and control of the streamer. During leg 1 two birds were damaged by seawater leakage and could not be repaired, on board because the appropriate spares were not carried.

(vi) Magnetometer Deployment During MCS Lines

A magnetometer was towed from the port quarter for the greater part of all MCS lines. On several occasions it was recovered between lines to prevent it from becoming entangled with the streamer.

Recommendation:

It is probably more by luck than judgement that the magnetometer did not wrap itself round the streamer at some stage during this cruise. If the magnetometer cable could be towed from the end of a short boom the probability of such an entanglement would be greatly reduced.

(vii) Streamer Loss

On 14th February the tail buoy is presumed to have collided with floating ice causing the streamer to break at the end of the third stretch section (see narrative). This resulted in the loss of 24 active sections, 11 depth controllers, 8 depth sections, the water-break hydrophone, tail stretch section, end section, tail rope and tail buoy. The third stretch section was damaged beyond repair.

With hindsight, we can see how such a loss can be avoided in future. It is inevitable that, in Antarctic and Arctic waters, research ships towing equipment such as MCS streamers will encounter icebergs, isolated or in groups, with attendant brash ice and growlers which are probably large enough to damage a towed fish or even the ships hull, but too small to appear on radar in all sea conditions. If the only problem is to safeguard the hull, and fish towed close to the ship, then the bridge watchkeeper can steer a safe course through all but the densest aggregations, reducing speed if necessary and either turning away or recovering equipment if conditions become too difficult. However, it is entirely another matter to safeguard an object towed at the surface 3 km astern, whether the danger to it be from ice, driftwood or other shipping. The restrictions that would be placed on survey if a survey ship were to have to keep, say, 0.5 nm away from any other floating object larger than a domestic refrigerator, lest it drift into the path of the tail buoy, are too great to contemplate. In many sea states an object of this size could not be seen at 0.5 nm.

The reputed purpose of a tail buoy on an MCS streamer is to

i. provide stability (through lift and drag) to the after end of the streamer, to minimise acoustic noise,

ii. provide sufficient buoyancy that if (as it did) the streamer parts farther forward, it will not sink,

iii. mark the position of the end of the streamer, under way and if it becomes detached, for the benefit of the seismic ship and other shipping.

These functions need further qualification. The first could be provided solely by a rope if necessary. The third contains a self-imposed legal requirement: the buoy provides an indication to the seismic ship of where the end of the streamer is, but then the tailbuoy itself is a surface-towed object, and legally should therefore have a (flashing?) light and radar reflector for the protection of other shipping. However, most seismic ships take care to warn passing ships on VHF of the length of their streamer underway, for the streamer's own protection and to persuade noisy ships' engines away from it: the light and radar reflector are not usually in themselves powerful enough to attract attention. We do the same, if the need arises. To provide a lamp sufficiently powerful to attract attention unaided, and a radar <u>transponder</u> for the same purpose, would require an altogether bigger tailbuoy, to carry the battery pack necessary for prolonged operation.

The second function, to provide buoyancy, contains a half-truth. The streamer sections (active and spring) are made slightly positively buoyant. The tow cable is massively heavy, in order to sink the front of the remainder of the streamer to the typical 9 m underway depth. The "birds" which are used to control streamer depth are made as small as possible, consistent with their ability to compensate for the effects of changes in sea water temperature and salinity and ship speed, and errors in initial balancing, because they themselves create drag and acoustic noise. They are made negatively buoyant to ensure stable operation. The optimal solution, minimising the seismic noise created by streamer plus birds, is to try to make the positive buoyancy of the streamer only about half the negative buoyancy of the birds. The complete rig, discounting the tow cable, is therefore slightly negatively buoyant. If there is an accident to the streamer, it usually becomes even more negatively buoyant; the light streamer oil escapes from any puncture of the skin, and if the streamer sinks into cooler water, the very high temperature coefficient of expansion of most streamer oils ensures that it loses further buoyancy. The buoyancy of the tail buoy is intended to counteract this weight, and if it does then the streamer ends up hanging from the tail buoy, which marks its position. This is all very well on the shallow continental shelf, where almost all commercial seismic exploration takes place: dumping the streamer on the seabed in, say, 100 m may even protect it, by moving it out of the way of other shipping. If the streamer parts in deep water however, with a typical rope length of 300 m and a 50 m after stretch section, all the streamer hydrophones will come to rest below their 300 m quoted maximum operational depth. Also, the much larger effects on streamer buoyancy of deep-water temperatures and pressures apply a much greater weight to the tail buoy than would a continental shelf resting place, and the tail buoy may well sink too. In these circumstances, the tail buoy has not performed its function of safeguarding the streamer: in our particular case, it achieved its loss instead.

We suggest the following modifications.

1. The tailbuoy should be redesigned as more cigar-shaped, to provide more buoyancy but less drag and to improve its chances of glancing off objects which collide with it.

2. Notwithstanding this change, the tailbuoy tow rope should be provided with a weak link, as weak as possible consistent with its ability to survive the normal stresses from forward drag and vertical motion in a rough sea, and support the weight of a sunken cable. It is ridiculous that a collision at the very after end of a streamer should have caused it to break at the front.

3. Some means of checking that the tailbuoy is still connected should be available, if a weak link is introduced: wire tension may be enough (see below), or a radar transponder. On Discovery, the buoy tows within the shadow zone of the Bridge radar, and its radar reflector cannot usually be seen.

4. Consideration should be given to incorporating one or more strain gauges in the streamer, to learn more about the ambient stresses and allow some kind of warning of unusual cable stress.

5. If the improvements to streamer safety suggested above cannot be achieved then, notwithstanding the greater seismic noise resulting, the streamer should be made sufficiently positively buoyant that it can support also the weight of the birds, if it is to be used in water depths exceeding 300m. The methods of ascertaining streamer buoyancy (metering and measuring the temperature of oil as it is filled, weighing after repair, keeping a comprehensive log of all changes)

should be reviewed, so that the buoyancy is at all times reasonably well known.

(viii) Leg 3 Short Streamer

For leg 3 a short streamer was constructed from the spare sections on board. These numbered 8 in all, including one which had previously been taken out of the streamer because seawater had leaked into it (see section b(iii)). 2 spare stretch sections were available, and 2 of the original stretch sections remained usable. Initially 2 stretch sections were used in front of the short array and 1 after it. A third stretch section was inserted in front of the array before the SUSSEX refraction work.

2 spare depth sections and a spare tail section were on board. Swift action by RVS secured spare parts for the 2 damaged birds (see section b(v)) in time for the start of leg 3.

The short array was first deployed on 1st March. Each active section was weighted with nine 21b sheets of lead. This was approximately the same as the amount of lead which had been on the front 8 sections of the original streamer before its loss (see section b(i)). The short streamer performed excellently and over 2000km of 16 channel data were acquired during leg 3. Thanks are due to all the RVS personnel who helped salvage what at first looked like a hopeless situation.

## 6.4 CORING EQUIPMENT CTD AND SIDESCAN

1) Piston/Gravity Corer

1.1. Core cutters and catchers

These performed well, only one of each being damaged while coring sediments containing large dropstones.

1.2. Core barrels and collars

Three barrels were slightly bent while coring stiff sediments. One more barrel became very tight in the collars (elliptical cross-section?). The straightening machine was not used. Two barrels and two sleeves were lost at station PC055 because the Allen screws in the sleeves had not been tightened: the barrels fell off as the corer was being swung down from the rail.

"When Richie went coring one night,
His Allen screws weren't very tight.
He was heard to say Bother!
As they lowered the bucket,
And the barrels disappeared out of sight."

1.3. Liners and end-caps

Polycarbonate liners again performed well. During longitudinal splitting of the liners (see 3.2) the material was found to be quite heterogeneous: many sections were easy to saw, but some tended to bind on the saw blade until it seized. In effect the plastic was trying to close up into a smaller tube. Only about 10% of the liners gave trouble and there was no visible difference between these and the majority.

Red flanged end-caps are a very tight fit on the liners: they are satisfactory on complete sections, but fall off half-sections. The ends of split cores were therefore sealed with tape.

1.4. Trigger corer

The modified trigger corer, with 0.5m of pipe above the weight, was a great success: the extra height preserved the core top even when the trigger core re-penetrated on pull-out.

Normally the liner full of mud was removed with the corer suspended vertically from the Hiab crane, thus avoiding disturbance of the recovered sediment. Repenetration occurred at most sites but was easy to detect using changes in lithology. At the shallow sites cored on Leg 3 the trigger corer was lowered on its own to obtain a surface sample, followed by a gravity corer. Because each wire trip was short this was faster than rigging a piston corer.

1.5. Release Mechanisms

On Leg 1 we had no up-to-date pyros, and two stations had to be repeated because the pyro failed to fire at the first lowering. For most of the stations on Leg 2 and both piston core stations on Leg 3 the sea was calm and a hydrostatic release was used. This worked perfectly. During one station (PC040) a swell built up rapidly and the corer pre-triggered half-way down. A gravity core was nevertheless obtained. New pyros were supplied for Leg 2 but only one was used. We noted that each pyro took about 8 minutes to fire after the acoustic command was sent.

1.6. Pingers

A pinger was attached 50m above the core head at all sites except the shallow shelf sites. No failures occurred.

2) Deck Handling

The core bucket hydraulics worked well throughout, as did the Schat davit and Hiab crane. The small davits previously used for raising and lowering the core barrels from the rail had been removed to make way for the airgun boom and A-frame. The core barrels were instead raised and lowered on a wire from the deckhead winch, led through a block on the airgun A-frame or on the ship's aft crane, depending upon length of corer. This was an unsatisfactory procedure because when raising the barrels the chain sling jerked forward along them, endangering the limbs of anyone standing by and often causing the wire to slip off the deckhead winch. There is plenty of deck space forward of the airgun boom for one small davit. Access to the corer was severely restricted by the airgun boom assembly. Coring was about 300% easier at the end of Leg 3 when the guns and boom had been removed.

3) Core Laboratory

The following operations were done in the lab:

3.1. Sawing core liners to 1.5m sections, taping ends

3.2. Splitting liners lengthways with circular saw, splitting core with cheese-wire

3.3. Cleaning sediment surface with electro-osmotic knife or glass slide
3.4. Description - macroscopic and microscopic
3.5. Colour photography, using a camera on a tripod lashed to the deckhead. No film processing was done on board.
3.6. Sampling for palaeomagnetic measurements
3.7. Each core section was covered in cling-film and heat-sealed inside lay-flat polythene tubing, prior to storage in the scientific cold room. Corrugated plastic sheeting supported on wooden battens was used to separate layers of cores.
3.8. Two long cores were taken for oxygen isotope measurements on pore water. Each was sawn into 0.5m sections and slices of mud 5cm thick were extruded using the Robbie Davies Special Extruder (patent applied for).

Each slice of mud was wrapped in cling-film and heat-sealed inside lay-flat tubing, excluding as much air as possible to minimise evaporation. These samples were frozen in one of the chest freezers.

TRACTION WINCH

Problems were experienced with the Traction Winch in veer mode on a few occasions, in the first instance with more than 3300M wire out and loads in excess of 4.5 ton. Each ships heave accellerated the Traction Winch Drums, causing temporary run away, The problem was temporarily eliminated by increasing the bias adjustment on the auto back pressure circuit for the hydraulic motors. When the problem occurred again during a deeper core stn, with higher loads, the bias adjustment was again reset.

It was found that the setting of this bias is quite critical, as too little allows the winch to run away, and too much causes one Traction Winch Drum to stop turning, making the wire lose traction and allowing it to skid and run away. It is assumed that the lock nut holding the bias adjusting screw had worked loose through vibration and allowed the adjustment to lower from its original setting:

CTD REPORT

1. Instrumentation

All of the sensors on the CTD worked well except for the transmissometer, which was noisy. A transmissometer from one of the moorings was substituted but with no improvement. A reversing thermometer was used at CTD stations 009 to 020 and the bottom temperature agreed to within 0.02 deg. C with that measured by the CTD temperature sensor.

2. Water bottles

On average one bottle out of 12 on the rosette failed to close properly, so new lanyards and latex closure bands were made up as required. Two petcocks were also replaced.

Water bottles were removed from the CTD as soon as it was on deck, and stored in racks in the bio. lab (the wet lab being full of magnetic tapes). The water was suction-filtered through glass-fibre filters and a 200 ml sample from each bottle kept for salinity calibration and oxygen isotope measurements. The filters were also saved for study of suspended particulate matter.

3. Logging

Data from each CTD cast were logged independently on the BBC micro and on the ABC computer system. Initial problems with negative temperatures and pressures were solved by modifying the programs on board. The modifications made by John Price (BBC) and Chris Jackson (ABC) had already been done by Andy Lord on a previous cruise, but the standard software had not been updated. We are concerned about the waste of time involved in such repetition.

SIDE SCAN

The sidescan was re-installed specially for this cruise, for use during Leg 3 along the Pacific margin of the Antarctic Peninsula. The first deployment went smoothly but after a few hours we lost control of the tilt angle of the starboard transducer. The control signal was traced as far as the port ASDIC junction box , the last point before the control signal goes down to the fish. Also, hydraulic pressure to the pod was normal, with no sign of leakage. The fault was therefore within the pod, and inaccessible. When control was switched from lab to ASDIC the starboard transducer spun round to 180 degrees opposite its intended setting and stuck there.

When the pod was retracted, control to the transducers was regained. When it was next deployed the transducers could only be controlled from the ASDIC position. Again the system worked for a few hours before control was lost on the starboard side; we still had an error signal and a control signal on the port junction box. The sidescan was left running with only the port side functioning and the port tilt angle stuck at 25 degrees.

It was also noticed that, from the beginning, the port electronics had to be set up with much more gain than the starboard side. There was very little decay on the transmitted envelope compared with the starboard output pulse. This suggests that the port side transmitting circuit is poorly matched to the transducer.

Towards the end of Leg 3 the sidescan pod was left down while the ship worked in deep water, but the lab electronics were turned off. Some time later it was noticed that the azimuth indicator had moved: the pod was now oriented 20 degrees from fore-and-aft, rather than athwartships. We could not drive the pod back to its correct position even with the ship stopped, but had to retract the pod and re-orient it manually.

In summary, the sidescan provided much less useful image than we had hoped, being either faulty (l-sided at best) or out of action completely for almost all of Leg 3.

## 6.5 NAVIGATION, DATA LOGGING AND PROCESSING

### DATA LEGGING

#### Description of data logging system

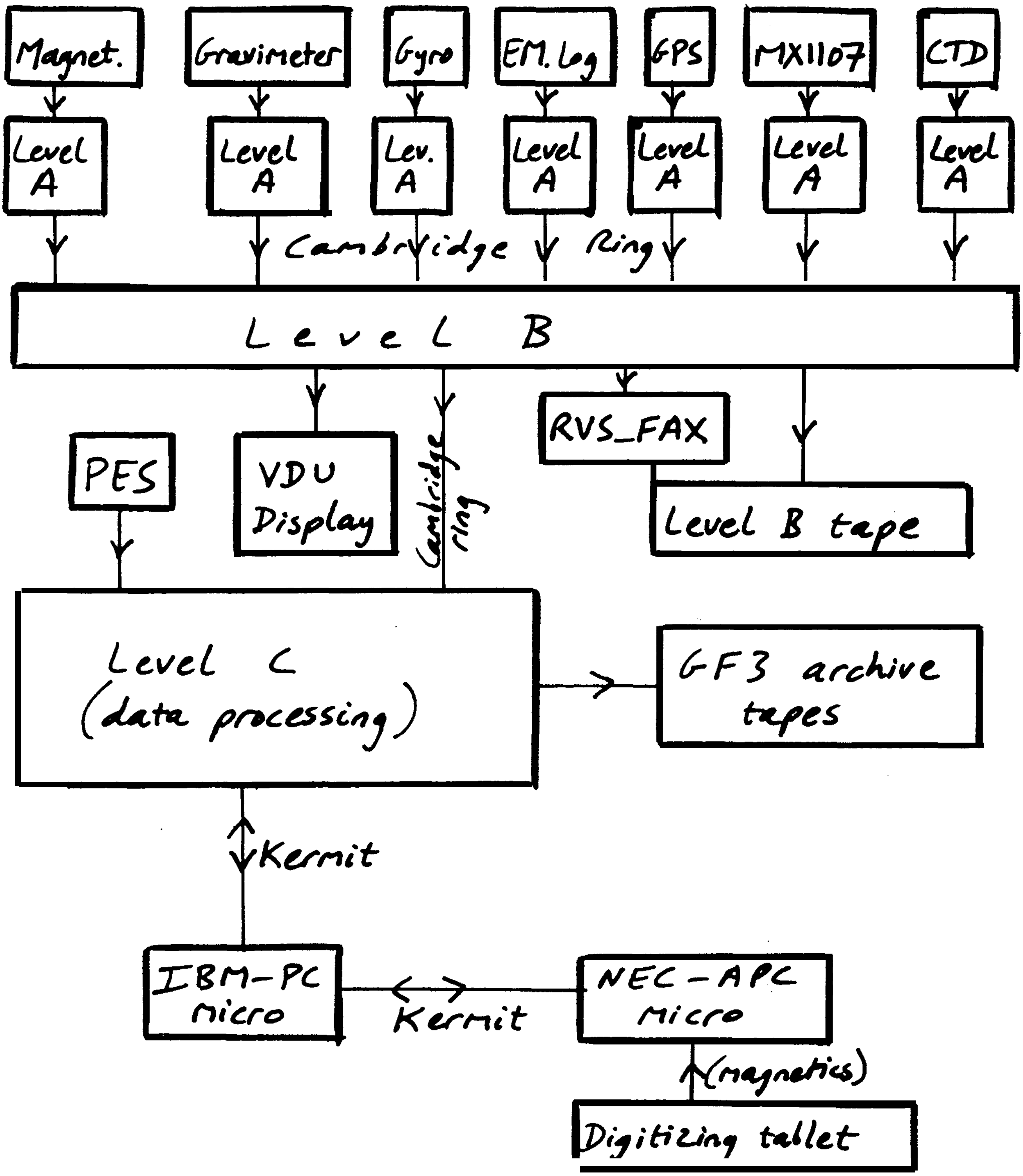
The data logging was done by the RVS "ABC" system which consists of three "levels": level A, level B and level C, connected to each other by a Cambridge ring. See diagram 1. Each device (magnetometer, gravimeter, gyro, EM log, GPS, MX1107 sat-nav,CTD) has its own level A. The level A takes data from the device and converts to a standard digital code which is passed to the level B. Level B collects data from all the level As, passes them to level C and also writes immediately to a level B tape. A VDU display allows the status of various aspects of the level B to be monitored - this is the primary means of checking that the logging system is running properly. In level C the raw data are written to disk files ("streams") which are updated as and when new data comes in. Data processing and archiving are done on level C. Water depths, which are read manually from the PES are input manually direct to level C using a program called mandep.

#### Performance of the data logging system

The data logging system caused a good deal of trouble although in the end relatively few data were lost. One problem was caused by the design of the system not catering for our requirements, the other problems were caused by various parts of the system not working properly.

At the start of the cruise we had hoped to archive all the raw data - including all the gyro and EM log readings (every 1 second). The processing'capacity and disk space were inadequate to cope with this and eventually we reverted to the usual RVS system of archiving one-minute averaged EM log and gyro data (relmov) plus all the other raw data. We wanted to archive all the EM log and gyro data because detailed records of ship's speed and course could possibly be used to improve the accuracy of GPS navigation. The full potential of GPS for precise navigation has not yet been realized. At present we are content to accept that GPS navigation is more accurate than transit sat-nav/DR, and continue to plan surveys in a frame of mind that assumes that the navigation may not be terribly accurate. However, in the foreseeable future people will want to squeeze the maximum accuracy out of GPS navigation for precision surveys - e.g. Sea-Beam surveys. At that stage it will be worth thinking of ways to combine finely sampled speed and course with GPS fixes to produce improved navigation. It may also be worth reprocessing navigation from previous cruises. Hence we think

Diagram 1 - Data logging system



that the data logging system should be capable of archiving 1 second EM log and gyro data in an accessible form.

There were several failures and persistent problems with the data logging system. These will be described below. Most of these problems are apparently unique to Discovery and may be related to old wiring and high ambient levels of electromagnetic noise. Although relatively few data were lost, the quality of the final processed data was often degraded and considerable computer technician and scientist time was soaked up.

## Level A

Most of the level As failed at one time or another. The magnetometer level A broke down completely during leg 1. It was eventually repaired after seven days, during which time the magnetic data were manually digitized from chart recorder rolls using the University of Birmingham micro and digitizing tablet. The gyro and EM log level As output constant speed and course values for several short periods during leg 2 - this may have been related to ship's power failures. The MX1107 level A persistently failed to log a few (0 to 6) satellite fixes each day throughout legs 2 and 3. It is not known what caused this. Occasionally an MX1107 level A failure caused the level C to crash. These MX1107 level A failures required vigilance from the watchkeepers because, once a failure occurred, no fixes would be logged until the level A was reset. It was difficult and time-consuming to insert missed fixes into the level C data files.

## Clock

During legs 1 and 2 backward running times often appeared in the data files. These were caused by jumps of the master clock. The data processing software does not accept backward running times so these had to be corrected each day before data could be processed; a difficult and time-consuming procedure. Anew clock was installed for leg 3 and no further problems caused by clock jumps were experienced.

## Level B

During leg 2 and especially leg 3 the level B frequently (about three times per day) crashed. The reason for these crashes was not established. A level B crash is a serious failure of the data logging system - EM log and gyro data are irretrievably lost and other data can only be recovered by manual digitization of chart rolls (gravity, magnetics) or by typing it in (GPS and MX1107 fixes). Following a level B crash, data logging would only be resumed if the level B was reset, a simple matter of turning a key. Unfortunately it sometimes took the watchkeeper more than an hour to notice that the level B had crashed. The system gives inadequate signal of a level B crash, a yellow flashing box in the corner of the VDU display stopping flashing is the only indication that the level B is not working. A level B failure is serious, should be rectified immediately by the watchkeeper and should therefore be signalled by a loud distinctive audible alarm.

It was usually possible to repair the effects of a level B crash by manual digitization of chart rolls, manual entry of satellite fixes and by making reasonable assumptions about the ship's speed and heading. This was difficult and time-consuming since the level C files are intentionally hard to alter.

## CTD

The logging system was unable to cope with negative temperatures, so some modifications to the software had to be made. This problem had apparantly been encountered and solved on a previous Charles Darwin cruise but the software modifications had not found their way to Discovery.

## NAVIGATION

### Description

Navigational data were obtained from:

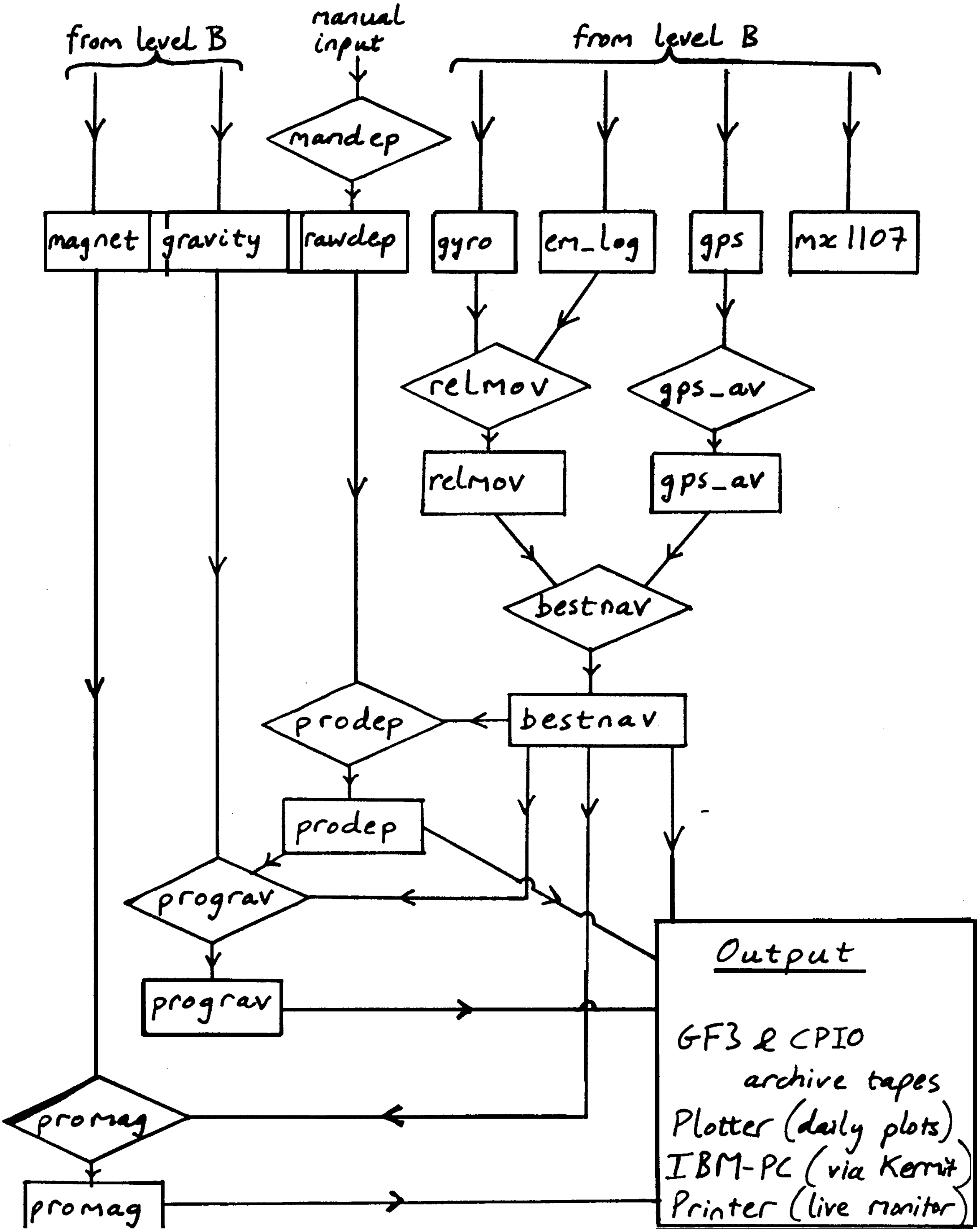
Trimble 4000 GPS locator
Magnavox MX1107 dual-channel transit sat-nav
EM log
Gyro

These devices were logged by the "ABC" system as described above. Navigation processing was done by a suite of programs on level C. For periods when GPS was available (GPS windows totalled about 8 hours pre day on average) GPS fixes alone were used to provide final navigation; transit satellite fixes and DR were ignored. At other times the traditional method of DR relaxed between satellite fixes was used. The interleaving of GPS derived navigation and sat-nav/DR data was achieved by a program called bestnav which was developed by Chris Jackson during leg 1. Diagram '2 illustrates the sequence of navigational data processing.

GPS fixes occur about every 70 seconds during a GPS window, and the positions produced are rather noisy. GPS data were smoothed and converted to one-minute samples by a program called gps_av which was also developed by Chris Jackson during leg 1. Gps_av obtains its results by taking a weighted least-squares average of the latitudes and longitudes of the GPS fixes within a specified time window. Various parameters can be varied in order to achieve sensible results: length of the time window, types of weighting to be used, and relative weights of each type of weighting. In the early stages of the cruise we experimented with various combinations of these parameters and decided that the following parameter settings gave satisfactory results:

5 minute time window
Weighting according to:
"Centre smoothing" (weight proportional to closeness to centre of time window)

# Diagram 2 - Level C data processing



"Fix quality" (weight inversely proportional to PDOP)
Equal weight given to each of the weighting methods.

## Performance of the navigation system

### EM log and gyro

Performed well throughout the cruise. The EM log appeared to be well calibrated. The port EM log retraction/deployment motor failed during leg 2 and was replaced in Stanley at the end of the leg.

### Magnavox MX1107

Performed well throughout the cruise, the only problem being the persistent level A failures discussed above.

### GPS

This was only the second NERC cruise on which GPS was available so some comments may be useful. The Trimble 4000 GPS locator worked well throughout the cruise - only one problem occurred: an "error 13" message was diplayed and the system could only be reset by switching it off and on again. GPS fixes were available for about 8 hours per day and provided accurate live navigation. The GPS data are more convenient to process than transit sat-nav/DR, being independent of unknown water currents and a lot more accurate than transit sat-nav/DR derived data. It would be very worthwhile for RVS to obtain a rubidium clock if this would extend GPS coverage.

An inconvenient aspect of the GPS locator is that it requires a reference position (within about 30 miles of the true position) at the start of each GPS window. This must be input manually before the start of a GPS window, unless the ship has not moved far since the last GPS window. If the GPS locator does not have a correct reference position it will not produce sensible results. It was impossible to enter a reference position during a GPS window - i.e. if you forget to enter a reference position before the start of a GPS window you effectively lose the whole of that window.

The GPS locator produces a measure of fix accuracy termed PDOP (Possible Dilution Of Position, low PDOP = high accuracy). According to the Trimble manual, fixes with a PDOP of greater than 7 should be rejected. Nominally fixes with a PDOP of less than 7.0 should be accurate to within 70m. Fixes will be produced if three or more satellites are in view. However, if only three satellites are in view the system assumes that the ship sits on a reference geoid. If sea-level differs from this reference geoid then an error is introduced into the fix position. It was found that constellation changes ("constellation" = group of satellites in view) produced slight shifts in GPS fix positions, especially for changes from 3 to 4 and 4 to 3 satellites in view. It was noticed that the PDOP given for fixes with 3 satellites in view tended to be lower than that given for fixes with 4

In the gravity processing the eotvos correction (calculated at one minute intervals from one-minute navigation) should be smoothed before being applied to gravity data which is smoothed by hardware filter with a four minute time constant.

The design of the data processing system, particularly the file structures, made it difficult and time-consuming to repair the effects of level A and B crashes. While accepting the logic in safeguarding the data files by making them hard to alter, it seems that either you have to be sure that the level As and level B will not fail or it should be easier to insert data into the data files. Too much computer operator and scientist time was spent struggling to put data into files after level B crashes.

RVS_FAX
-------

This system was installed on the ship throughout the cruise, with displays in the bio-lab, the plot and on the bridge. It was intended primarily as an information display system. In the event it was not used very much, partly because those people who had useful information to disseminate did not learn how to use it. The only useful service the RVS_FAX provided was transmitting GPS fixes to the bridge (where degrees and minutes would have been appreciated more than decimal degrees!). It is hard to see what the advantages of this system are over the traditional method of bits of paper stuck to doors. It did provide a homely chiming clock sound in the computer room.

## 6.6 GRAVITY

lacoste-Romberg gravimeter no. S84, which had been installed on board Discovery in Barry on 15th/16th October 1987, was run through the entire cruise. It performed well most of the time and caused few problems. Our Christmas present from the gravimeter was a gyro failure on X1.12.87; the gyro was replaced at sea and the gravimeter resumed normal operation. There were several power failures during the cruise (at least three); the gravimeter was restarted with no problems after each of these.

The gravity data appeared noisier than expected sometimes when the ship was rolling heavily. Very high amplitude (50 mgal) noise with about a five minute periodicity was observed in these instances. This particularly high amplitude noise: a) did not occur very often, b) did not necessarily occur when the ship's motion was at it's worst. Maybe the gravimeter reacted badly to some particular mode of ship's motion.

Base station ties and gravimeter drift
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The base-station ties are listed in table 1 and brief details of the IGSN 71 base-stations used are given in table 2. The Rio base-station which was used (083.42) is noted to be suspect in the MOD Geophysics Section MS6/MS7 reference, however it is unlikely to be wrong by more than 0.2 mgal because: a) only one of the two ties used to establish this station is suspect, b) all the other base-stations in the vicinity have similar gravity values.

The ties at Port Stanley will not be very accurate because the ship was moored to a floating dock (at FIPASS) about 200m away from the nearest firm ground for which an IGSN 71 gravity value could be established (see below for details of the base-station established here). For the Stanley base-station ties and drifts in tables 1 and 3 only the height difference between the base-station and the ship has been taken into account. Other factors (Bouguer correction, terrain correction, horizontal field gradient) are likely to cause less than 1 mgal total difference between the base-station and the ship's meter, i.e. base-station ties at Stanley could be in error by up to 1 mgal.

Gravimeter drift (see table 3) has been calculated for each leg of the ship's voyage since leaving Barry (22.10.87) and for the whole cruise up to the end of each leg. The drifts for individual legs are moderately high and rather variable (-0.218 to +0.366 mgal/day). A lower and more uniform drift would be calculated if the Rio tie was ignored. However, as noted above, the Port Stanley ties are more suspect than the Rio tie. Furthermore the likely errors in the Rio and Stanley ties would make little difference to the calculated drift rates. It seems most likely that the gravimeter has drifted, apparently consistently negatively at about -0.2 mgal/day since Rio.

## Addendum for gravity section of D172 cruise report

A base station tie at Harry on 9.5.88 after the ship's return to the UK indicates a high drift rate of +0.2 mgal/day for Stanley-Harry and a low drift rate of -0.02 mgal/day for the whole round trip (ZOO days) - see tables 1 and 3. These drift values cast doubts on the Rio and the Stanley base ties. Is it just coincidence that the apparently high drift rates for the individual legs happen to cancel out and produce a very low net drift rate for the whole cruise? A study of cross-overs will be necessary to answer this.

## Base Station established at FIPASS, Stanley Harbour

### Falkland Islands

### Description

At the landward end of the bridge giving access to the FIPASS floating dock. A low concrete pillar, to the west of the roadway, forming part of the abutment of the bridge. Marked by a chiselled cross.

In the gravity processing the eotvos correction (calculated at one minute intervals from one-minute navigation) should be smoothed before being applied to gravity data which is smoothed by hardware filter with a four minute time constant.

The design of the data processing system, particularly the file structures, made it difficult and time-consuming to repair the effects of level A and B crashes. While accepting the logic in safeguarding the data files by making them hard to alter, it seems that either you have to be sure that the level As and level B will not fail or it should be easier to insert data into the data files. Too much computer operator and scientist time was spent struggling to put data into files after level B crashes.

## RVS_FAX

This system was installed on the ship throughout the cruise, with displays in the bio-lab, the plot and on the bridge. It was intended primarily as an information display system. In the event it was not used very much, partly because those people who had useful information to disseminate did not learn how to use it. The only useful service the RVS_FAX provided was transmitting GPS fixes to the bridge (where degrees and minutes would have been appreciated more than decimal degrees!). It is hard to see what the advantages of this system are over the traditional method of bits of paper stuck to doors. It did provide a homely chiming clock sound in the computer room.

## 6.6 GRAVITY

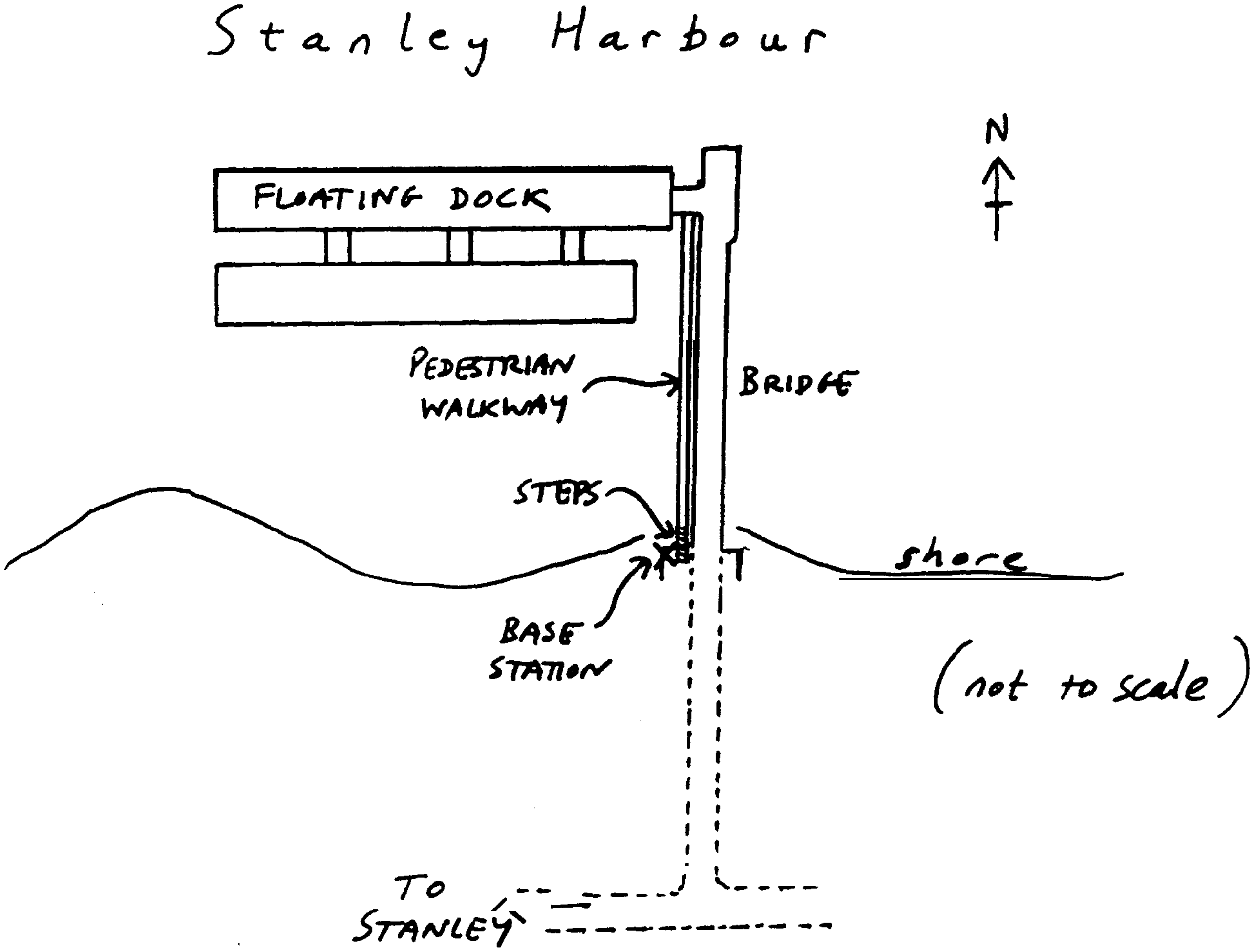
lacoste-Romberg gravimeter no. S84, which had been installed on board Discovery in Barry on 15th/16th October 1987, was run through the entire cruise. It performed well most of the time and caused few problems. Our Christmas present from the gravimeter was a gyro failure on 25.12.87; the gyro was replaced at sea and the gravimeter resumed normal operation. There were several power failures during the cruise (at least three); the gravimeter was restarted with no problems after each of these.

The gravity data appeared noisier than expected sometimes when the ship was rolling heavily. Very high amplitude (50 mgal) noise with about a five minute periodicity was observed in these instances. This particularly high amplitude noise: a) did not occur very often, b) did not necessarily occur when the ship's motion was at it's worst. Maybe the gravimeter reacted badly to some particular mode of ship's motion.

### Base station ties and gravimeter drift

The base-station ties are listed in table 1 and brief details of the IGSN 71 base-stations used are given in table 2. The Rio base-station which was used (083.42) is noted to be suspect in the MOD Geophysics Section MS6/MS7 reference, however it is unlikely to be wrong by more than 0.2 mgal because: a) only one of the two ties used

## Location of gravity base station at FIPASS



Observations

| Date | Instrument | Reference - station | value | dg | Type of tie |
|---|---|---|---|---|---|
| 17.1.88 | Worden (RVS 676) | Stanley - BAS office 080.01 | 981226.77 | +0.88 | ABA |
| 23.2.88 | " | " | " | +0.84 | ABA |

IGSN 71 g - 981227.63 mgal (+/- 0.05mgal assuming 080.01 is accurate)

Observed by C.Paulson, I.Hamilton, J.Wynar.

Worden gravimeter drift less than 0.15 mgal over the time of each tie.

Table 1 - Gravity base-station ties, Discovery cruise 172

Gravimeter S84, calibration constant = 0.9967

| Date | Place | g at meter (transferred from IGSN 71 base-station) | Meter reading (meter units) |
|---|---|---|---|
| 22.10.87 | Harry | 981190.63 | 12429.0 |
| 9.11.87 | Bermuda | 979845.56 | 11077.5 |
| 27.11.87 | Nassau | 979013.113 | 10243.6 |
| 15.12.87 | Rio de J. | 978793.22 | 10029.6 |
| 17. 1.88 | Stanley (I) | 981228.39 | 12465.5 |
| 23. 2.88 | Stanley (II) | 981227.84 | 12459.5 |
| 30. 3.88 | Stanley(III) | 981227.99 | 12454.6 |
| 9. 5.88 | Barry | 981191.27 | 12425.8 |

Table 2 - Details of base-stations used, Discovery cruise 172.

Barry

? Lamp post near Research Vessel Base.
NGRN 73
g = 981190.27 [NGRN 731

Bermuda

5th bollard from N. end of quay, near grain silos.
Reference - MS6 Hydrographic Navy 115.05 NAVOCEANO
g = 979845.0 [IGSN 71]

Nassau

Reference - NAVO 0083.02 Station no. 101.02
g = 979013.36 [IGSN 71]

Rio

10m N. of 3rd bollard, E. side of Praca Maua
Reference - Geophysics Section MS7 (MOD) 083.42
g = 978792.73 [IGSN 71]

Stanley

Porch of BAS office, near public jetty.
Reference - Geophysics Section MS6 5/1982 080.01
Other reference - ACIC 4721-1
g = 981226.77 [IGSN 71]

Stanley (FIPASS)

Concrete pillar, west side of bridge abutment at shore end of bridge.
Reference - this report.
g = 981227.63 [IGSN 71]

Table 3 - Gravimeter drifts, Discovery cruise 172.

| Drift beween: | dg(mga1) | dm(meter units) | dm(mga1) | total drift | no. days | drift per day |
|---|---|---|---|---|---|---|
| Barry-Bermuda | -1345.07 | -1351.5 | -1347.04 | -1.97 | 18 | -0.1094 |
| Barry-Nassau | -2177.52 | -2185.4 | -2178.19 | -0.668 | 36 | -0.0186 |
| Bermuda-Nassau | -832.45 | -833.9 | -831.15 | 1.30 | 18 | +0.072 |
| Barry-Rio | -2397.41 | -2399.4 | -2391.48 | 5.928 | 54 | +0.1098 |
| Nassau-Rio | -219.89 | -214.0 | -213.29 | 6.596 | 18 | +0.3665 |
| Barry-Stanley(I) | 37.76 | 36.5 | 36.38 | -1.380 | 87 | -0.0159 |
| Rio-Stanley(I) | 2435.17 | 2435.9 | 2427.86 | -7.308 | 33 | -0.2215 |
| Barry-Stanley(II) | 37.21 | 30.5 | 30.40 | -6.811 | 124 | -0.0549 |
| Stanley(I)-(II) | -0.55 | -6.0 | -5.98 | -5.430 | 37 | -0.1468 |
| Barry-Stanley(II1) | 37.36 | 25.6 | 25.52 | -11.844 | 160 | -0.0740 |
| Stanley(II)-(III) | 0.15 | -4.9 | -4.88 | -5.034 | 36 | -0.1398 |
| Barry-Barry | +0.64 | -3.2 | -3.19 | -3.829 | 200 | -0.0191 |
| Stanley (III)-Barry | -36.72 | -28.8 | -28.71 | +8.015 | 40 | +0.2004 |

Notes:
Negative drift indicates that gravimeter at end of leg is reading lower than it should.
dg(mga1) and dm(meter units) are obtained from Table 1.
dm(mga1) = (dm(meter units))*0.9967
total drift = dm - dg

## 7. ACKNOWLEDGEMENTS

We wish to thank all those on board RRS Discovery who retained their dedication and sense of humour during what **were** trying times. We are particularly grateful for those on board and back at Barry who helped create a seismic streamer from spare parts for Leg 3, after loss of the primary streamer during Leg 2.

We were impressed by and grateful for HMS Endurance's determination to carry the 2- ship seismic programme through to a successful conclusion despite appalling weather.

Myriam Booth again struggled bravely and usually effectively with the difficulties of providing major port facilities in Port Stanley. We are grateful also to Dawn Cheetham at BAS for coping with Fax and Telex traffic to and from the ship, and to Jon Shanklin for organising the loan to us of a weather satellite receiver en route to Faraday.

# APPENDIXA

## REPORT ON 2-SHIP SEISMIC EXPERIMENT - SUSSEX - MARCH 1988

### 1. Introduction.

Early in 1985, HMS Endurance and RRS Discovery took part in the first Expanding Spread Seismic Experiment (ESSEX I), on the Pacific margin of the Antarctic Peninsula near Anvers Island. The experiment was aimed at understanding the crustal structure and evolution of the margin by measuring the variation of seismic velocity with depth in the crust. Two lines were shot, parallel to the margin, out to 63 and 48 km range (ESSEX 1 and 2, figure Al). For each line, the two ships steamed in opposite directions at 5 knots from a common mid-point, with Endurance firing explosive charges of increasing size at 2.lkm intervals and Discovery towing a 2.4km-long seismic streamer to record the reflected and refracted seismic energy.

This method proved extremely useful, since the large number of seismic records acquired provided a very detailed and precise indication of the velocity-depth structure. The understanding we gained needed to be extended to adjacent areas and to greater depth by means of additional lines, hence the planning of a second ESSEX for the 1987-8 season. This consisted of 5 lines (Figure Al and below), which were submitted for environmental impact assessment before the start of the season.

| Line | Lat. of midpoint | Long. of midpoint | Line Orientation | Maximum Range(km) |
|---|---|---|---|---|
| 3 | 65°14'S | 64°48'W | 031/211 | 48 |
| 4 | 64°30'S | 66°07'W | 043/223 | 75 |
| 5 | 66°52'S | 69°04'W | 024/204 | 75 |
| 6 | 64°56'S | 65°35'W | 041/221 | 75 |
| 7 | 64°15'S | 66°42'W | 055/235 | 48 |

The assessment recommended the abandonment of Line 3, and the shooting of Lines 5 and 6 in such a way that the shots were as far as possible away from penguin rookeries on Anvers I and southern Adelaide I. These restrictions would have been complied with.

### 2. Explosives and ESSEX Shooting Plan

The following amounts of explosive were available:

| | | | |
|---|---|---|---|
| (0081 11D) | Cpencast gelignite (25 kg bulk) | 202 cases | 5050 kg |
| (0081 11D) | Cpencast gelignite (2.5kg stick) | 9 cases | 220 kg |
| (0065 11D) | Cordtex 250 m lengths | | ca. 980 m |
| (0029 1lD) | Fuse-fired detonators (2-m fuses) | | 288 |

These represented the original order from ICI Nobel Division, carried south aboard Discovery, minus 12 x 2.5 kg sticks, 6 x 25kg bulk cases, ca. 20m Cordtex and 12 detonators used aboard Discovery to determine charge sinking rates (see below), but including 200 detonators carried south aboard Endurance.

On an expanding spread profile, the two ships steam in opposite directions from a common mid-point, with one (Endurance)

2i

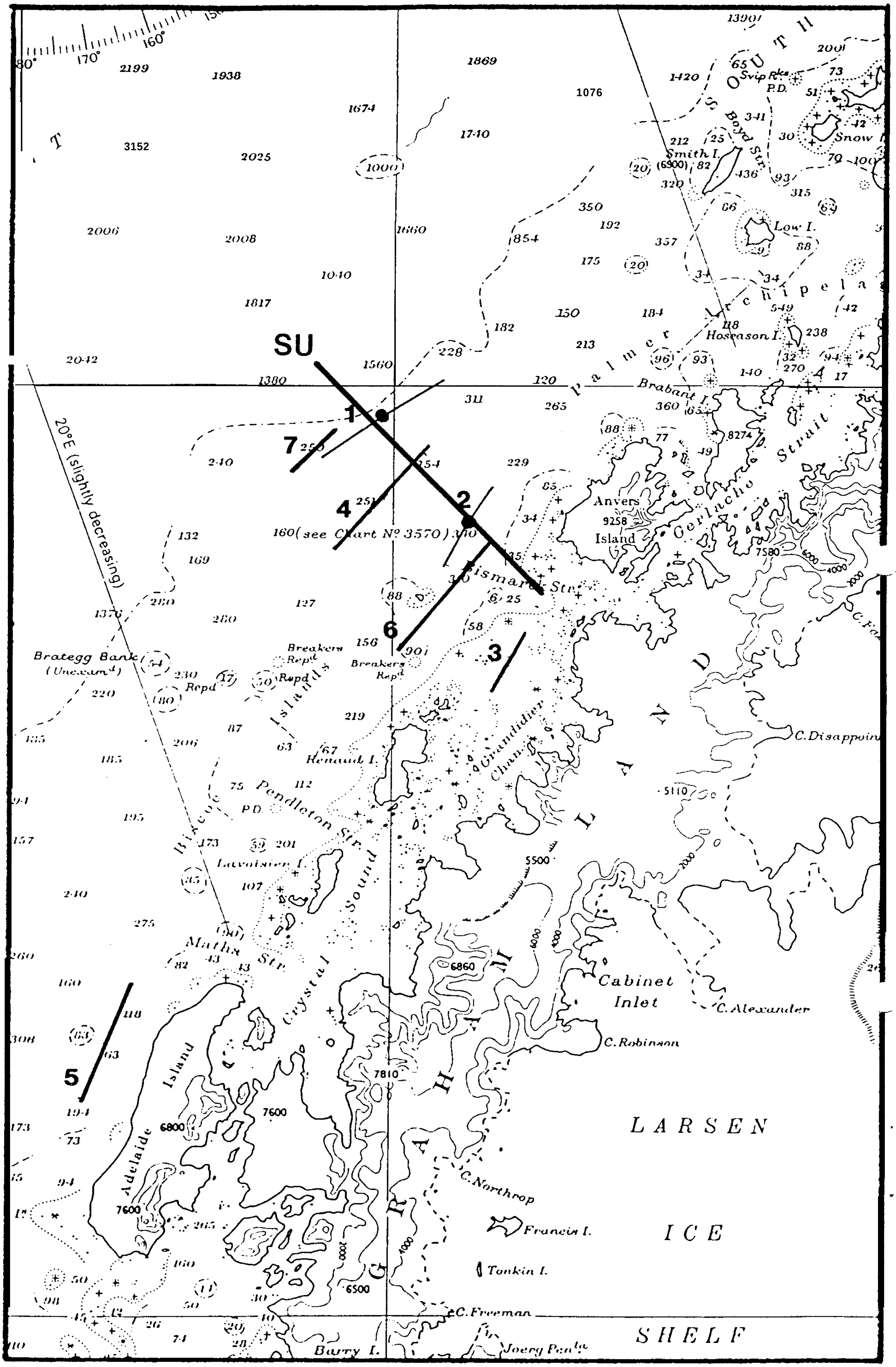



**Figure Al** Existing (1985) seismic lines ESSEX 1 and 2, proposed ESSEX 3 to 7, and SUSSM reversed refraction line actually shot.

shooting and the other (Discovery) recording. At 5 kt speeds, shots at 7 minute (1.1 km) intervals provide continuous cover with a 2.4km-long streamer. Charge sizes need to increase with increasing range; for example, a 75-km long line would shoot 3 x 2.5kg, 3 x 5kg, 3 x l0kg, 6 x 25kg, 6 x 50kg and 12 x 75kg. The charges came in 2.5kg cartridges and 25kg cardboard boxes. For the larger charges it would be necessary to strap charges together, using tape or the banding machine provided.

3. Revision of Plans - SUSSEX

On 14th February, in Powell Basin towards the end of Leg 2, RRS Discovery lost the 2.4~km streamer, probably by collision of the tailbuoy with a bergy bit or growler. By putting together all of the spare sections on board, we were able to make up a streamer with an active length of 800m, which would suffice for most of our objectives on Leg 3. However, the continuous common-depth-point cover intended for the expanding-spread profiles of ESSEX II would be acquired only by shooting virtually all of the explosive on one line: without continuous cover, the precise and detailed velocity-depth data which can be derived from tau-P transformation would be unavailable.

Rather than shoot only one short expanding-spread line, we decided to re-organise the shooting into a long, reversed dip refraction line, stretching from the ocean floor in the northwest to Bismarck Strait in the southeast. In a refraction experiment, the shooting ship fires a series of charges of increasing size at the same point, while the receiving ship as before steams away at constant speed. The line is reversed by the shooting ship going to the other end and repeating the firing sequence, while the recording ship steams back along the line. We could achieve a line 160km long, with shots at 4km intervals, by firing every 25 minutes and steaming at 5.2kts.

A refraction line would give us less precise information than an expanding spread line, but would achieve the regional cover of the original ESSEX II proposal. An unfortunate characteristic of refraction shooting is that deep information is not obtained about the shotpoint itself, from shooting there. This meant we could not locate the inboard shotpoint far offshore in the area of immediate interest, but had instead to move it inshore, closer to known penguin rookeries on Anvers I. Also, the particular line chosen (with shotpoints at 64° 57'S, 64° 31'W and 63° 58'S, 66° 42'W) was optimal, as it overlay an existing MCS reflection profile (AMG 845-003) of better quality than we were likely to obtain with only a 16-channel streamer, and intersected ESSEX lines 1 and 2 close to their mid-points.

BAS Cambridge and HMS Endurance both agreed to the proposed revision of the 2-ship programme (SUSSEX: - Substitute Under-Sea.......), and when the 2 ships met inside Deception I. on 10th March to transfer explosives, the details were arranged. The shooting schedule (4km/25minute intervals) was 1 x 2.5kg, 2 x 5kg, 2 x l0kg, 4 x 25kg, 9 x 50kg, 13 x 75kg, 9 x l00kg, subject to adjustment as suggested by the data being acquired.

4. Charge Sinking Rate Trials

For each charge size there is an optimal depth of detonation, which maximises the amount of useful seismic energy entering the sea bed. To arrange for the charges to fire at this depth, one must (a) determine the burning rate for each charge, bearing in mind that fuse burns faster at depth, (b) determine the sinking rate for each charge size and (c) check that the shooting ship can move the required distance away from the charge before it detonates.

Earlier during the season we carried out aboard RRS Discovery a limited trial of burning and sinking rates for the explosives to be used. Six 2.5kg charges were fired on a range of fuse lengths from 12 to 60 inches. Then, one each of 5, 10, 25, 50 and 75kg charges were fired using a 45 inch fuse length. The results are plotted on the accompanying graph of burn time against fuse length (Figure S2). Each shot is represented by a bar joining the ignite-to-bang and the splash-to-bang times: the bar length is 2.5 to 3 seconds, the time taken for the charge to be pushed overboard and hit the water, after ignition.

The 6 2.5kg shot times fall on a smooth curve: the larger shots fall below it. The curve reflects the increased burning rate of fuse with depth, for a constant sinking rate. The larger charges fall below the curve because they sink faster, so the fuse burns faster. Charge sinking rates are determined from the time difference between the direct arrival and the seabed reflection. Although there is some scatter in the measurements, it is clear that the larger charges sink faster, and there is a clear distinction between those made from 2.5kg bottles and those made from 25kg bulk packs. The following table shows our estimated sinking rates (V metres/sec) and optimal depths of detonation (Z metres), with minimum recommended ship speed (knots), horizontal (X) and slant (R) ranges from detonation to ship (metres) at that speed, sinking time (T secs), fuse length (L) in inches and Safety Factor (S), for. each charge size (kg).

| KG | V | Z | KTS | X | R | T | L | S |
|---|---|---|---|---|---|---|---|---|
| 2.5 | 0.6 | 43 | 8 | 287 | 290 | 72 | 35 | 0.0014 |
| 5 | 0.7 | 49 | 8 | 280 | 284 | 70 | 35 | 0.0021 |
| 10 | 0.8 | 56 | 8 | 280 | 286 | 70 | 35 | 0.0030 |
| 25 | 1.4 | 67 | 10 | 239 | 249 | 48 | 23 | 0.0059 |
| 50 | 1.5 | 77 | 10 | 257 | 268 | 50 | 24 | 0.0078 |
| 75 | 1.6 | a3 | 10 | 259 | 272 | 52 | 25 | 0.0095 |
| 100 | 1.7 | 88 | 11 | 285 | 298 | 52 | 25 | 0.0100 |

The Safety Factor formula is one used throughout NERC ships, and has its origin in USN practice. It is:

$$S = 0.23 \frac{(1 \text{ t } \sin A)}{R} W$$

where W is charge size in kg and A is the angle of approach of the shock wave below the horizontal. Shooting is constrained so that S does not rise above 0.01. The Safety Factor can be reduced further by increasing ship speed above that shown. The fuse lengths assume a time between ignition and splash of 2.5 to 3 seconds. If this were to be regularly exceeded, then a further 1 inch would be added for each extra 2.5 seconds.

5. Charge Preparation.

The 2.5kg "sticks" were actually orange plastic bottles. A det-sized hole was poked in each (with non-ferrous tool) and the detonator secured using tape. For 5kg and 10kg shots, the bottles were taped together. The 25kg bulk explosive was contained in 2 black plastic bags inside a stiff cardboard case. The det. was pushed into a hole poked in the side and secured using tape. It was essential to poke other holes in the case, or sufficient air could be trapped to prevent the case from sinking. Cases were tightly banded together to produce 50, 75 and 100kg charges, using the banding machine put aboard Endurance in Portsmouth.

There is always the chance that only a part of a composite charge will explode. To reduce this chance we suggested that about 3 turns of Cordtex were wrapped around the banded charge and the free end taped to the detonator before insertion.

6. Scare Charges.

The original ESSEX II experiment included the firing of a small (unspecified) charge 30 seconds or 1 minute before the larger (or all) charges, to deter anything mobile and with an aural sense of direction from approaching the ship. With Endurance now firing all the shots at only 2 sites this approach seemed counter-productive. It was decided to fire a RN-issue 1 lb (454gm) scare charge at each site about 20 minutes before the first charge proper, but no other scare charges.

7. Shot Instant Recording and Transmission.

Ian Hamilton's prime responsibilities aboard Endurance were to ensure that a seismic record of each shot was recorded, and transmitted back to the shooting ship, and that records of ship's position and water depth were also retained. We put aboard a Store4 tape deck, two towed hydrophones (an EG&G 265 and a single Hall Sears MP3) and a geophone (to be fixed on the hull), and a precision clock previously calibrated against Discovery's clock. Thus, the arrival at the shooting ship of the direct and bottom-reflected signal from each explosion could be recorded against a known time and, knowing the splash-to-bang time (stopwatches at the after end) and ship speed, the depth and time of detonation could be calculated. In addition, the towed hydrophone signal was transmitted to the recording ship, alternating with voice transmission of the countdown etc. We used 3.6MHz for transmission from HMS Endurance, and 3.8MHz for Discovery's response. We were not allowed by the ship's RO to use Discovery's main transmitter, but had the use of a RVS Yaesu receiver and an amateur radio transmitter. If radio communication failed, the calibrated clocks would allow shooting to continue on a fixed 25-minute schedule.

8. Environmental Impact

BAS had prepared and distributed an environmental impact assessment for the original ESSEX II experiment. The late stage revision of shooting plans necessitated by loss of the long streamer gave no chance for the preparation and re-circulation of a revised EIA, so we had to consider the likely impact, and how it might be reduced, in an *ad hoc* manner. Firstly, shooting at the outboard end seemed likely to raise no problems, since it was farther from nesting sites than all of the ESSEX lines. The inboard shotpoint was quite near Anvers I. and other inshore nesting sites however, nearer even than line 3, which was disapproved of. Against this, the criteria used to assess impact assumed that the ship moved through a static biomass. On this assumption, since all the SUSSEX charges would be fired in one spot, their impact would be much less. In fact, the biomass moves, so that each shot would in part affect a different population. However, it was clear that anything with binaural hearing and an ounce of intelligence would not stray far into the shooting area after the first one or two shots in the same place.

If the shooting was to go ahead as planned, the best course would be to ensure that it was effectively monitored, so that any such experiments in future could be more precisely assessed in advance. Accordingly, we put an observer aboard Endurance for the duration of the shooting. Mark Midwinter's task was to search for signs of penguin and other mortality in the shot area, with the help of other Bridge watchkeepers, and curate any corpses recovered. Besides the watch kept while shooting was in progress, Endurance was asked if her helicopter would fly a reconnaissance of the area around the shotpoint after shooting had finished. Corpses were to be deep frozen for return to the UK and subsequent examination.

9. Narrative

Discovery took the outside route from Deception I to the SUSSM start point on 10th March, rolling badly overnight in a west to northwest swell and west wind. Endurance left later, taking the inside route, and fired 2 or 3 test shots, for which we tried to record the transmitted shot instant. The next day, Discovery had to go well into Bismarck Strait in ***order*** to find sufficiently sheltered water to deploy the MCS streamer, and was therefore late for the rendezvous.

The sea was quite rough at the endpoint, and the forecast unfavourable. Endurance suggested that instead of starting the line then, and perhaps only being able to fire the smaller charges, she should return in 3 days' time, when the bad weather and swell should have subsided. This offer was gratefully accepted, since we probably could not have completed the shooting within the original time limits (1200/071 to 1400/074) in those conditions. Endurance visited Rothera and Discovery, after recovering the MCS streamer and listening to further hydrophone transmission tests, went to anchor overnight at Port Lockroy. Over the next 2 days, as the wind and swell eased, we shot a long MCS reflection line and 4 short sonobuoy lines in the central part of the SUSSEX line, for control on upper layer velocities and thicknesses. Late on the 14th March we were back in Bismarck Strait.

Despite the poor weather (a 25kt westerly, and the remains of the swell), we decided to go ahead with the first SUSSEX line, starting at 7pm. The endpoint of the line had been moved about 1 mile south, to avoid loss of direct water wave at extreme range: the track skirted a quite shallow-water area at 20km range, and on a practice shot fired as Endurance approached from the southwest, travelling across similarly shallow water, we had received no water wave arrival.

The first 5 shots were fired as planned. However, the amplitude of refracted and reflected arrivals was low, and we became concerned about the prospects for the remainder of the line. The endpoint was located in the 1100-m trough of Bismarck Strait, for reasons already explained. However, the possibility occurred to us that, perhaps because the trough itself was structurally controlled, the seismic energy may be being dispersed in an unfavourable way. To guard against this unnecessary hazard, the endpoint for the remainder of the inboard shooting was moved to the position of the 4th shot (at 64°51.8'S, 64°46.0'W), some 16km along the line. The shooting schedule was modified so that the 6th shot (on the position of the 5th) was the first of 2 10Kg shots, to be followed by the larger charges as scheduled.

The line proceeded on schedule, but with only low amplitudes of arriving ground waves. In an attempt to improve the arrivals from the final shot, with the recording ship at the position of the shot-point of the reverse line, a 200-kg charge was detonated. This final shot was fired at llam on the 15 March (Day 075), and Discovery then investigated the region of the western endpoint for several hours, in rapidly worsening weather, while Endurance made her way there.

By 6pm on Day 075, the wind was blowing 40 to 50kts from the ENE, and the barometer dropping rapidly. Conditions for shooting a seismic refraction line were highly unsatisfactory. However, time was now running out, and this would be our only chance of reversing the line. We considered that the required course for the recording ship, to make about 135°T, would be feasible in those conditions, and that by travelling slower than 4.5kts we could tow the streamer sufficiently deep (20 to 30 metres) to decouple it from sea surface and ship noise. As the sea built however, conditions for the shooting ship would be much worse, since she would have to loop repeatedly through the sea, and fire while running downwind in order to make sufficient distance from the charge before it detonated. We were therefore particularly grateful when Endurance agreed to start the line. We agreed a revised shooting schedule, which amounted to a reversal of the outer two-thirds of the line, shooting at 20-minute intervals and going on to the larger charge sizes earlier than originally planned, in order to combat the greatly increased amount of wind- and swell-generated acoustic noise at the sea surface.

This plan proved successful, and excellent seismic arrivals were recorded from all shots, even when the wind reached 60 to 75kts at 8pm. Endurance continued to fire even the larger charges, up to lOOkg, despite the conditions, and the final shot was fired at 7am on Day 076. In all, 75 charges had been launched, including 3 misfires.

After shooting had finished, both ships headed for Bismarck Strait. By 3pm, Discovery had recovered the hydrophone streamer in sheltered water and cleared the after deck: at 4pm, Endurance's Wasp helicopter had returned Ian Hamilton, Mark Midwinter and our equipment.

10, Results

It is too soon to provide a crustal interpretation of the SUSSEX data, even one of a preliminary nature. For one thing, the data on the first line will need careful processing to extract true first arrivals, since the general level of seismic energy was so low. Secondly, despite all attempts, the satisfactory radio transmission to Discovery of the signal from the hydrophone towed by Endurance was never really achieved. This was probably a result of impedance and signal level mismatching between the hydrophone and the transmitter input, and of breakthrough of other signals onto the cables carrying the signal through the ship. It creates no serious long-term problem, since we have all of the required data on tape, but it prevented a "quick-look" interpretation of the data aboard Discovery as they were acquired, as we had hoped to achieve. At the end of the shooting, we were overjoyed merely to have collected data of such excellent quality (on the second line) in such atrocious conditions. We must have set a record for the worst weather in which a successful seismic line has been shot, and we are grateful to all those, particularly the demolition and WE teams on Endurance, whose efforts made it all possible.

11. Environmental Impact. (M Midwinter, MD)

The first charges to be fired were a few trial charges (mostly 2.5Kg) to test the recording equipment and launching system. These were however dropped while on passage, so the ship was too far away to assess their impact. On the endpoints of the seismic line proper, charges were dropped at 25-minute and shorter intervals, which involved the ship steaming in a loop or undertaking a "Williamson" turn. It was decided not to drop 'scare' charges during these manoeuvres away from the drop site, as this was felt as likely to drive any animals towards the drop site as away.

Approximately 30 minutes before the commencement of the experiment, about a dozen penguins (Chinstraps) and six seals were sighted at the drop site. They stayed visible for 10 minutes then disappeared. During daylight hours of the charge dropping I stayed on the bridge and so was able to view the drop site as we approached and assess the impact of the previous charge. Endurance commenced the experiment at the in-board end of the line and started dropping charges in the late afternoon, in good visibility and calm seas.

After the second shot (first 5 kg charge) some skuas were seen feeding on the surface. Although it was not possible to identify the material on which they were feeding it was thought likely to be fish. At no other time during shooting from the inshore end was any biological debris seen, despite excellent conditions for spotting. Also present on the bridge were the officer of the watch and a member of the ship's company as watchkeeper. They also kindly kept a watch for evidence of biological damage but saw nothing. After the last charge fired, an extra circuit was steered to pass through the drop area for a final check. Nothing was seen. Immediately afterwards, Endurance's helicopters were airborne, for aerial survey of nearby islands rather than in connection with SUSSM, but nothing large was seen.

The extreme weather conditions that were experienced during shooting at the outboard end of the line made observations for biological debris a hopeless task (although initially attempted).

To summarize, there was no evidence of any significant environmental impact on the animals that might inhabit the waters at the site of the experiment apart from possibly a few fish.

Other Observations:

(i) Discovery steamed through the main inboard shotpoint about 25 hours after shooting there had finished. A concentrated watch for 3 miles either side saw only one live seal. Endurance did likewise, without result.

(ii) Enquiry of Discovery's Bridge watchkeepers revealed that off the Antarctic Peninsula over the previous 3 weeks they had usually seen some penguins, typically in small groups and up to 2 dozen in a 4-hour watch, at all distances offshore, certainly up to 150 miles (we never went farther). Whales (1 to 3 at a time) and dolphins were also seen occasionally.

12. Comment:

The discernible environmental impact of SUSSEX was very small. What does this mean? Was the observation adequate? Did the initial EIA make reasonable assumptions? Can similar explosion seismology experiments be performed in future without the need for an EIA, and/or without the need for environmental monitoring?

12.1 Monitoring. The environmental monitoring of the SUSSEX experiment was less than perfect, in that some charges were fired in the dark (there are about 10 hours of darkness in mid-March), Endurance did not undertake a thorough helicopter search of the area after the lines were completed, and the second line was shot in such bad weather that effective monitoring was impossible. Nevertheless, many of the shots on the first line (thought to be environmentally the more sensitive) were shot in daylight, in good weather and visibility, and a thorough watch was kept. The effective range of such a watch is probably 100 to 200 metres either side of the ship, which was also the probable uncertainty in precise location of successive shots, so the area directly above each shot was being monitored. The range ofmanoeuvre of the ship between shots was probably about 2 km either side of the shotpoint, so an area of that radius was swept. The shots were strung out over a period of 18 hours, so any delayed results of damage should have *been* visible also. This is a much higher level of environmental monitoring than normally is feasible, since modern seismic experiments (as ESSEX) usually involve shooting successive charges at different locations, so that immediate and repeated return over the shotpoint is impossible. With so little having been seen from shipboard, I sympathise with the decision of Endurance's Captain not to expend helicopter time on a further search.

12.2 EIA Assumptions. Almost all of the assumptions made in trying to estimate in advance the damage (of ESSM remember, not SUSSEX) were worst case. All penguins were assumed to swim at 100m depth: much shallower is much more likely, and much more favourable to their survival. Penguins from the known rookeries were assumed to range no farther offshore than the ESSEX lines, whereas observation suggests they are more thinly spread. Penguins were treated physiologically as mammals, whereas-as diving birds they are probably more robust. The ESSEX shots were to be strung out along a line, so were assumed to encounter'eash a new static population: SUSSEX shots largely overlap, and so affect the same biomass, except to the extent that it is mobile. Penguins and large mammals, though mobile, are probably sufficiently intelligent to head away from a fixed point of hazard rather than randomly around or towards it.

The cumulative effect of all these worst-case assumptions is likely to be an over-estimate of damage of at least 100 times. The assumption of deep swimming alone probably accounts for more than a factor of 10. Against this, the level of damage chosen for assessment is too slight to be observed: observable damage (essentially mortality) occurs within a smaller radius of the explosion, and the numbers which would have been predicted (had this level of damage been used) would have been very small. Essentially, there was no major contradiction between prediction and observation. The concern appears to have arisen because worst case assumptions were made, and labelled as such, without the enormous difference between "worst-case" and "most likely", and between "safe level" and observable damage being stated. It may not be in the long term interest of accurate environmental assessment to combine worst-case assumptions in this way. SUSSEX probably killed few or no penguins, as was predictable.

12.3 Future Experiments No explosion seismological experiment should be undertaken in Antarctic waters without an EIA (now a "Comprehensive Environmental Evaluation"), because it is possible to pick entirely the wrong location or time of year, or unwittingly create some other hazard which only specialist scientists could anticipate. However, the future for such experiments seems bright, should no other development in theory or practice send them out of fashion. They are not a priori environmental disasters.

P F Barker
BAS Geophysics Division
1 April 1988

cc Captain HMS Endurance (4)
Captain RRS Bransfield
Captain RRS Discovery
W N Bonner, BAS
J Bawden, BAS
D Jones, BAS

## APPEND B STATION LISTS

TABLE Bl. RRS DISCOVERY CRUISE 172 DREDGE STATIONS

| STN | START LATITUDE SOUTH | START LONGITUDE WEST | END LATITUDE SOUTH | END LONGITUDE WEST | DEPTHS START | DEPTHS END | YR/DAY/HR |
|---|---|---|---|---|---|---|---|
| 123 | 59 23.40 | 42 27.00 | 59 23.16 | 42 28.80 | 2900 | 2300 | 8800710 |
| 124 | 59 23.16 | 42 35.46 | 59 23.16 | 42 31.26 | 3000 | 1740 | 8800716 |
| 125 | 53 41.04 | 45 57.96 | 53 40.56 | 45 58.56 | 3340 | 3100 | 8801414 |
| 126 | 53 5.22 | 46 13.44 | 53 5.64 | 46 12.66 | 1450 | 1200 | 8801423 |
| 127 | 53 1.50 | 46 12.48 | 53 0.90 | 46 12.72 | 1850 | 1810 | 8801508 |
| 128 | 53 9.78 | 46 59.28 | 53 9.66 | 47 0.42 | 1500 | 1310 | 8801518 |
| 129 | 53 10.38 | 47 30.84 | 53 10.32 | 47 32.16 | 2180 | 2040 | 8801601 |
| 130 | 53 9.96 | 47 30.06 | 53 9.84 | 47 30.48 | 2280 | 2100 | 8801605 |
| 131 | 62 47.58 | 39 47.70 | 62 47.34 | 39 43.14 | 4100 | 3520 | 8803206 |
| 132 | 62 39.12 | 39 36.18 | 62 39.84 | 39 33.84 | 3500 | 3000 | 8803215 |
| 133 | 62 39.30 | 39 25.56 | 62 39.36 | 39 24.90 | 2680 | 2645 | 8803223 |
| 134 | 62 40.56 | 39 21.90 | 62 40.44 | 39 23.10 | 3500 | 2840 | 8803304 |
| 135 | 63 24.54 | 63 25.26 | 63 24.72 | 63 25.32 | 550 | 340 | 8806801 |
| 136 | 63 25.14 | 63 27.72 | 63 25.02 | 63 27.42 | 500 | 400 | 8806805 |
| 137 | 63 25.32 | 64 2.34 | 63 24.36 | 64 2.22 | 215 | 200 | 8806811 |
| 138 | 63 23.04 | 64 5.70 | 63 22.92 | 64 7.02 | 280 | 125 | 8806813 |
| 139 | 64 24.48 | 65 46.44 | 64 24.42 | 65 47.34 | 500 | 415 | 8808407 |
| 140 | 64 23.88 | 65 46.20 | 64 23.52 | 65 46.20 | 480 | 396 | 8808410 |
| 141 | 58 34.08 | 61 13.74 | 58 35.40 | 61 9.90 | 2700 | 1960 | 8808715 |
| 142 | 57 29.10 | 58 53.46 | 57 28.38 | 58 54.54 | 3000 | 2550 | 8808808 |

TABLE B2 DISCOVERY 172: CORE STATIONS, DEPTHS IN CORRECTED METERS

| Station No. | Lat degS | Lon degW | Depth | Time On | Time Off | Recovery Tc | Recovery PC/GC |
|---|---|---|---|---|---|---|---|
| 878 PC 029 | 56 25.3 | 41 09.9 | 3369 | 235035987 | 063036087 | 1.59 | 4.39 |
| 878 PC 030 | 58 05.7 | 44 17.2 | 2730 | 214536187 | 012036287 | 1.40 | |
| 878 PC 031 | 58 02.7 | 44 20.0 | 2745 | 015536287 | 055036287 | 1.23 | 4.24 |
| 878 PC 032 | 6000.1 | 37 47.2 | 2915 | 195000388 | 000000488 | 1.08 | |
| 878 PC 033 | 60 00.8 | 37 47.3 | 2913 | 000000488 | 040000488 | | 5.97 |
| 878 PC 034 | 59 47.3 | 39 35.8 | 1652 | 172500688 | 202000688 | 0.73 | 5.73 |
| 878 GC 035 | 53 10.8 | 46 24.9 | 1445 | 034001588 | 053001588 | | 0.05 |
| 878 PC 036 | 52 36.2 | 46 52.7 | 3552 | 134001688 | 172001688 | 1.34 | 4.12 |
| 878 GC 037 | 61 06.3 | 39 10.7 | 4025 | 233002488 | 033002588 | | 4.07 |
| 878 PC 038 | 63 10.1 | 42 43.4 | 3802 | 091002988 | 130002988 | 1.55 | 5.98 |
| 878 GC 039 | 62 39.2 | 41 34.7 | 3616 | 205002988 | 235002988 | | 2.31 |
| 878 PC 040 | 62 19.8 | 41 26.3 | 3456 | 023003088 | 070003088 | 1.51 | 2.65 |
| 878 PC 041 | 62 03.9 | 40 35.2 | 3310 | 003003588 | 044503588 | 1.40 | 8.59 |
| 878 PC 042 | 62 04.2 | 40 35.6 | 3305 | 092503588 | 134503588 | 1.40 | 8.60 |
| 878 GC 043 | 62 09.6 | 38 38.0 | 5180 | 190003588 | 012003688 | Winch | fails |
| 878 PC 044 | 63 56.8 | 40 55.9 | 4548 | 063003888 | 113503888 | 1.48 | 11.04 |
| 878 PC 045 | 6357.0 | 40 56.7 | 4547 | 144503888 | 191503888 | 1.50 | 10.89 |
| 878 TC 046 | 64 36.0 | 64 48.0 | 518 | 142008388 | 152008388 | 1.10 | |
| 878 GC 047 | 64 35.3 | 64 48.3 | 536 | 152008388 | 164008388 | | 3.80 |
| 878 TC 048 | 64 26.6 | 65 08.9 | 547 | 183008388 | 193008388 | 0.80 | |
| 878 GC 049 | 64 26.6 | 65 08.9 | 547 | 193008388 | 203008388 | | 4.02 |
| 878 TC 050 | 64 18.8 | 65 26.8 | 575 | 231508388 | 001508488 | 0.10 | |
| 878 GC 051 | 64 18.8 | 65 27.0 | 575 | 001508488 | 012008488 | | 4.37 |
| 878 TC 052 | 64 08.4 | 65 46.0 | 493 | 031008488 | 041008488 | 0.01 | |
| 878 GC 053 | 64 08.2 | 65 46.5 | 495 | 041008488 | 051508488 | | 0.40 |
| 878 PC 054 | 64 02.5 | 67 15.3 | 2766 | 173008488 | 210008488 | 1.52 | 5.40 |
| 878 PC 055 | 63 50.0 | 67 47.9 | 3155 | 013008588 | 051008588 | 1.67 | 7.68 |

TABLE B3 DISCOVERY 172: CTD STATIONS, DEPTHS IN CORRECTED

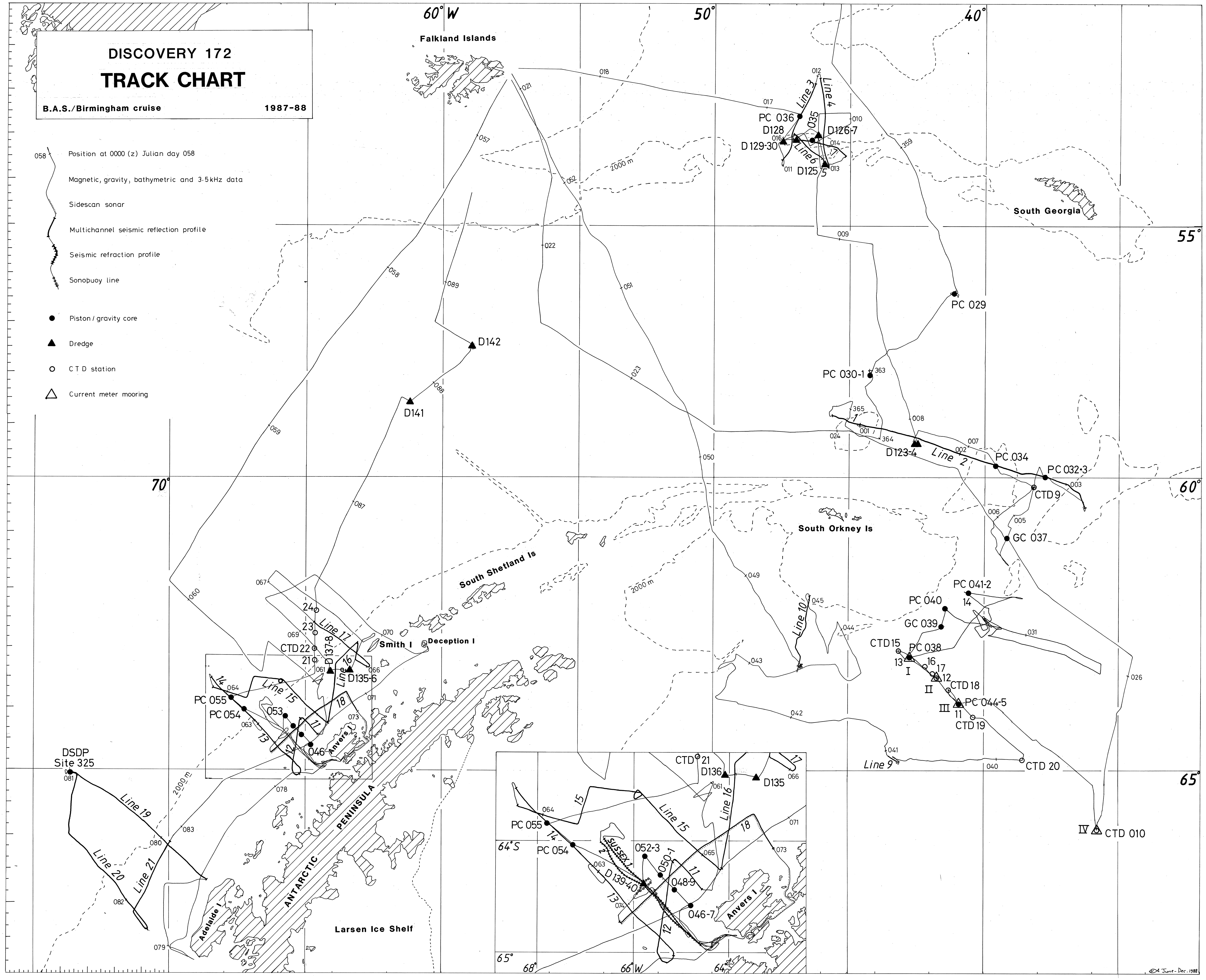
| Station No. | Lat degS | Lon degW | Depth | Time On | Time Off | Comments |
|---|---|---|---|---|---|---|
| 878 CTD 009 | 60 11.2 | 38 09.0 | 3006 | 064000788 | 110000788 | Practice |
| 878 CTD 010 | 65 54.5 | 35 49.5 | 4746 | 171002688 | 211002688 | Rig 4 |
| 878 CTD 011 | 63 56.1 | 40 53.2 | 4560 | 210002788 | 023002888 | Rig 3 |
| 878 CTD 012 | 63 30.3 | 41 43.3 | 4526 | 121502888 | 153002888 | Rig 2 |
| 878 CTD 013 | 63 09.9 | 42 45.3 | 3788 | 220002888 | 012502988 | Rig 1 |
| 878 CTD 014 | 62 03.8 | 40 36.9 | 3300 | 051003588 | 090003588 | Cores 41,2 |
| 878 CTD 015 | 63 04.0 | 43 08.6 | 3662 | 212003688 | 004003788 | Rpt of 001 |
| 878 CTD 016 | 63 20.0 | 42 10.6 | 3810 | 055503788 | 091003788 | " " 002 |
| 878 CTD 017 | 63 27.2 | 41 53.9 | 4760 | 155003788 | 202003788 | " " 003 |
| 878 CTD 018 | 63 42.6 | 41 17.8 | 4537 | 220003888 | 013003988 | close 004 |
| 878 CTD 019 | 64 08.7 | 40 24.5 | 4675 | 073003988 | 112003988 | Rpt of 005 |
| 878 CTD 020 | 64 49.6 | 38 34.2 | 4820 | 182503988 | 213003988 | close 006 |
| 878 CTD 021 | 63 13.3 | 64 40.5 | 2756 | 180008588 | 212008588 | |
| 878 CTD 022 | 63 02.1 | 64 40.1 | 3105 | 231008588 | 014508688 | |
| 878 CTD 023 | 62 45.6 | 64 40.5 | 3290 | 035508688 | 063008688 | |
| 878 CTD 024 | 62 23.4 | 64 37.7 | 3657 | 090008688 | 121008688 | |

TABLE B4 MULTICHANNEL SEISMIC LINE STATISTICS

| Line | Start time | End time | Duration (hours) | Distance km | Course | Last record no. |
|---|---|---|---|---|---|---|
| LEG 1 | | | | | | |
| 1 | 1402/365 | 2155/365 | 7.9 | 79 | 110 | 1501 |
| 2 | 0131/001 | 0720/003 | 53.8 | 538 | 107/135 | 10090 |
| Total 2 tape deck, 48 channel: | | | 61.7 | 617 | | |
| 3 | 0131/011 | 2144/011 | 20.2 | 202 | 020 | 3308 |
| 4 | 0117/012 | 0027/013 | 23.2 | 232 | 180 | 4093 |
| 5 | 0207/013 | 0314/013 | 1.1 | 11 | 316 | 205 |
| 6 | 0400/013 | 1212/013 | 8.2 | 82 | 316 | 1448 |
| 7 | 1406/013 | 0521/014 | 15.3 | 153 | 100/136 | 2704 |
| Total 1 tape deck, 48 channel: | | | 68.0 | 680 | | |
| Leg 1 overall totals | | | 129.7 | 1297 | | |
| LEG 2 | | | | | | |
| 8 | 2038/033 | 0003/034 | 3.4 | 34 | 130 | 618 |
| 9 | 1927/040 | 2108/040 | 1.7 | 17 | 290 | 308 |
| 10 | 2335/044 | 1450/045 | 15.3 | 153 | 190 | 2668 |
| Leg 2 totals (all 1 tape deck, 48 channel) | | | 20.4 | 204 | | |
| LEG 3 | | | | | | |
| 11 | 1954/061 | 0001/062 | 4.1 | 41 | 320 | 824 |
| 12 | 0001/062 | 1119/062 | 11.3 | 113 | 190 | 3068 |
| 13 | 1119/062 | 2227/062 | 11.1 | 111 | 315 | 5280 |
| 14 | 0410/063 | 1706/063 | 12.9 | 129 | 315 | 2523 |
| 15 | 2113/063 | 0244/065 | 29.5 | 295 | 105/015/ 100/135 | 5872 |
| 16 | 0244/065 | 1852/065 | 16.1 | 161 | 005/045 | 9093 |
| 17 | 1852/065 | 1502/066 | 20.2 | 202 | 190/128/ 308 | 13112 |
| 18 | 0006/073 | 2138/073 | 21.5 | 215 | 330/230 | 4298 |
| 19 | 1435/079 | 1852/080 | 28.3 | 283 | 315/295 | 5720 |
| 20 | 2151/080 | 0532/082 | 31.7 | 317 | 180/135 | 6323 |
| 21 | 0532/082 | 2058/082 | 15.4 | 154 | 330/026 | 9798 |
| SB1-4 | 0135/074 | 1305/074 | 11.5 | 115 | 028/235/ 135 | 1153 |
| Leg 3 totals (all 2 tape decks, 16 channel) | | | 213.6 | 2136 | | |
| Cruise totals | | | 363.7 | 3637 | | |

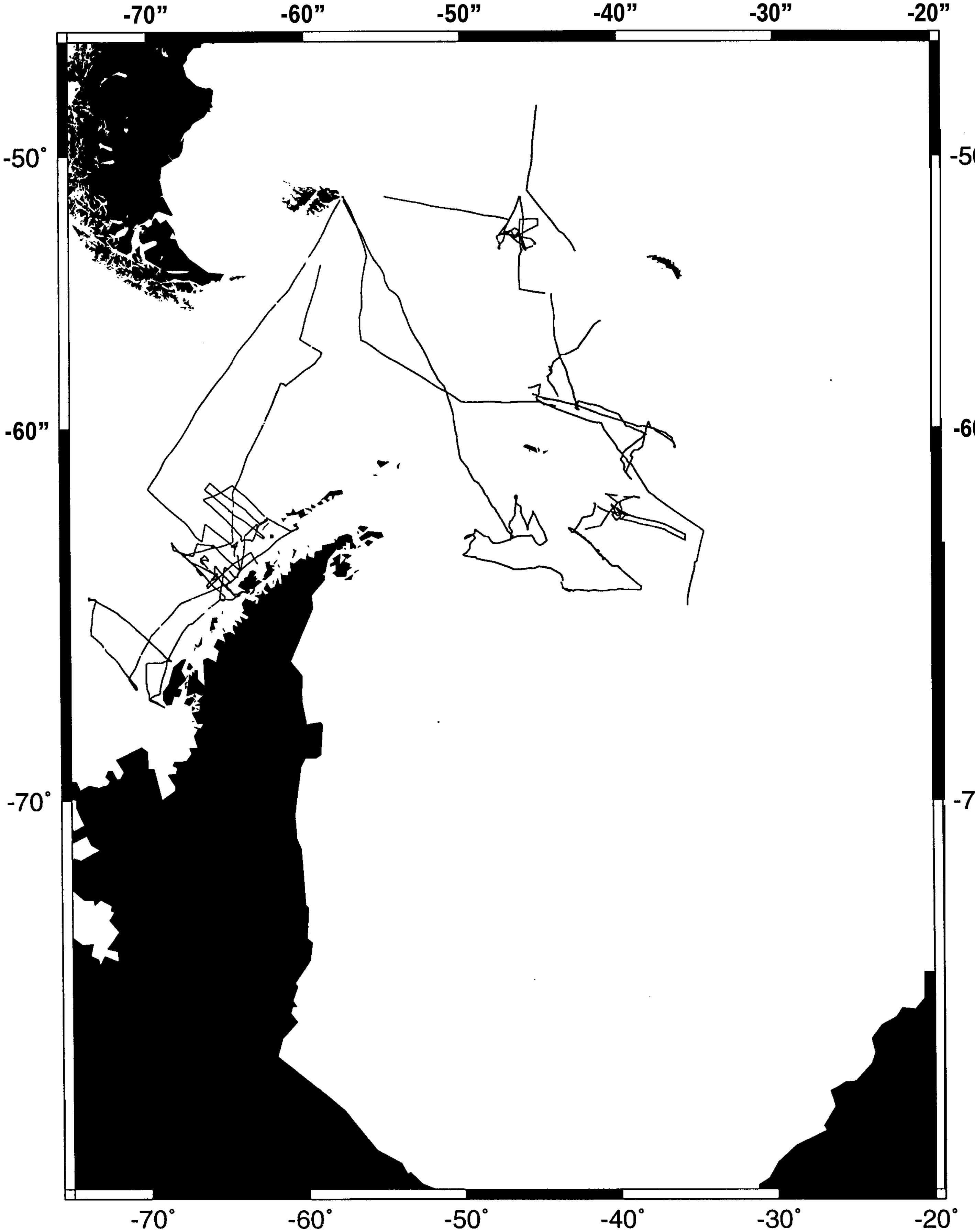
Notes:

1) Distances have been calculated assuming an average ground speed of 10km/hr (=5.4kts).
2) Recording was continuous from the start of line (SOL) 11 to the end of line (EOL) 13, so record no. was not reset at SOL 12 or SOL 13. Similarly, recording was continuous from SOL 15 to EOL 17 and from SOL 20 to EOL 21, and record no. was not reset at SOL 16, SOL 17 or SOL 21.
3) The full identifier of MCS lines referred to above as line no. NN is BAS-878~NN.



DISCOVERY 172
TRACK CHART
B.A.S./Birmingham cruise
1987-88
Position at 0000 (z) Julian day 058
Magnetic, gravity, bathymetric and 3·5kHz data
Sidescan sonar
Multichannel seismic reflection profile
Seismic refraction profile
Sonobuoy line
Piston / gravity core
Dredge
C T D station
Current meter mooring
60° W
50°
40°
55°
60°
65°
70°
Falkland Islands
South Georgia
South Orkney Is
South Shetland Is
Smith I
Deception I
Anvers
ANTARCTIC PENINSULA
Adelaide I
Larsen Ice Shelf
DSDP Site 325
2000 m
Line 2
Line 3
Line 4
Line 6
Line 9
Line 10
Line 15
Line 16
Line 17
Line 19
Line 20
Line 21
PC 036
PC 029
PC 030-1
PC 034
PC 032-3
GC 037
PC 040
PC 041-2
GC 039
PC 038
PC 044-5
PC 055
PC 054
D128
D126-7
D129-30
D125
D142
D141
D123-4
D137-8
D135-6
D136
D135
D139-40
CTD 9
CTD15
CTD 18
CTD 19
CTD 20
CTD 010
CTD22
CTD 21
052-3
050-1
048-9
046-7
053
046
SUSSEX 1
64° S
65°
68°
66° W
64°

# D172_878 gravity



# D172_878 magnetics