CD37 889:

RRS Charles Darwin
Scotia and Bellingshausen Seas
Geophysics
January 1989 - April 1989

Natural Environment Research Council

British Antarctic Survey

Cruise report

R.R.S. Charles Darwin

Cruise CD 37

January to April 1989

Marine Geophysics, Marine Geology
and Physical Oceanography

Scotia Sea, SW Atlantic and SE Pacific

April 1991

B.A.S. **Reference** No.

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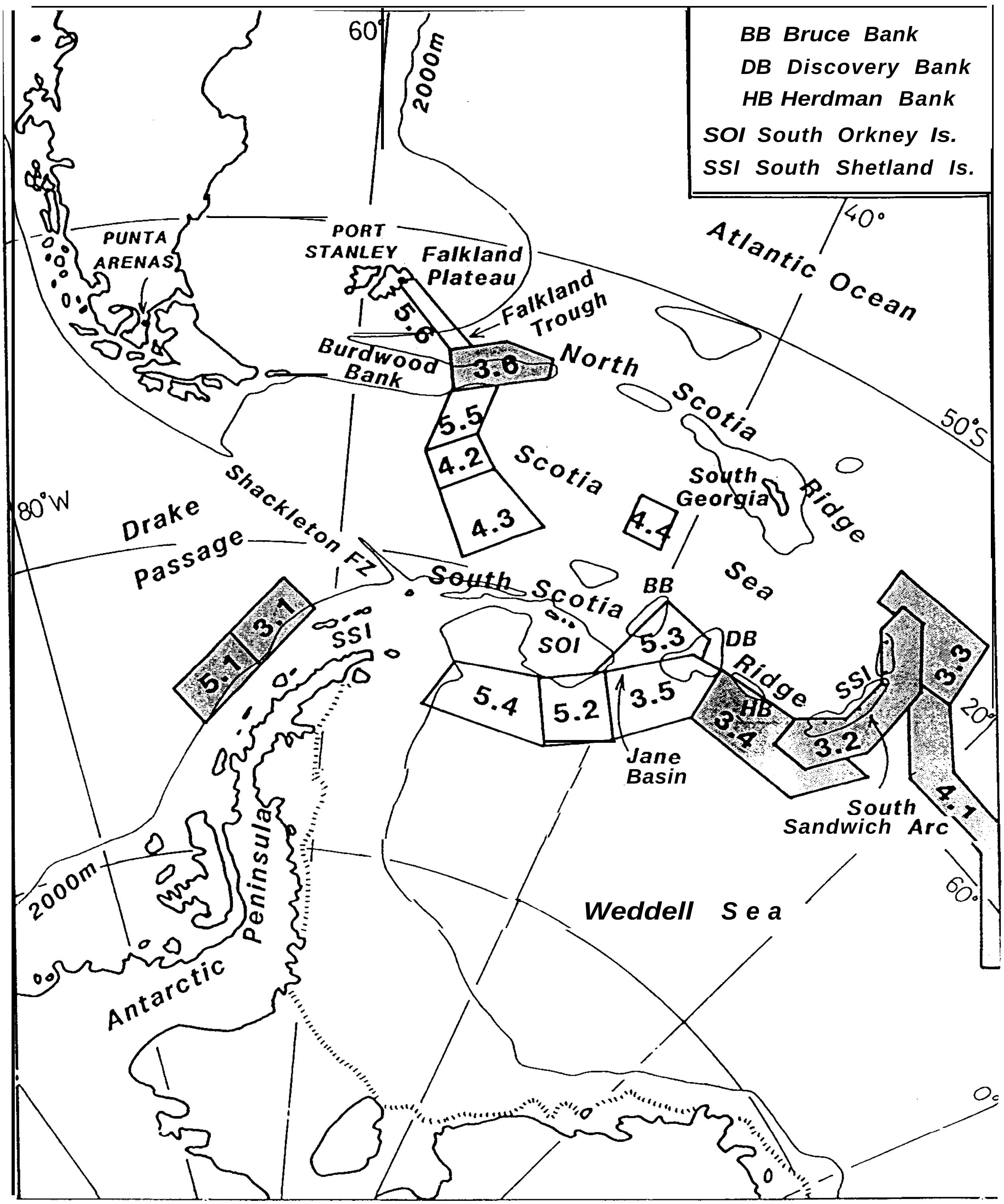


Figure 1. Locations of proposed sidescan sonar surveys

INTRODUCTION

RRS Charles Darwin Cruise 37 was essentially a GLORIA cruise: several efforts had been made during the 1980's to use GLORIA in the far south Atlantic, and a long list of targets had built up. It seemed foolish, given this opportunity, to spend more time than was absolutely necessary on work <u>other</u> than GLORIA survey, during Cruise 37. The only exception, which was unavoidable, was the attempt at recovery and renewal of the array of moored current meters in the northern Weddell Sea.

BAS (earlier Birmingham) marine geoscience interest in the Scotia Sea region can be divided into three fields:

(a) regional tectonic evolution;
(b) subduction-related processes;
(c) palaeo-oceanography and glacial marine sedimentation

The planned GLORIA survey (which included simultaneous single-channel seismic, magnetic, gravity, PES and 3.5 KHz survey) was intended to investigate problems within all three fields. The major surveys planned were:

4.1 South American-Antarctic Ridge: plate motion back to 84 Ma;

3.2, 3.3 tectonic erosion, tearing of the subducting slab, northern South Sandwich trench and fore-arc;

3.2, 3.4 intra-oceanic ridge crest - trench collision, southern S Sandwich area:

3,1, 5.1 ridge crest collision and glacial slope-rise sediment transport, Antarctic Peninsular margin;

3.6 Scotia Sea evolution and Antarctic Circumpolar Current growth, Aurora Bank, North Scotia Ridge.

These surveys are shaded in Figure 1. The other, unshaded areas are those where worthwhile targets of a slightly lower priority were to be found: it was hoped there would be time to examine some of these, if only on passage. They were also standby areas, in case ice cover or other circumstances prevented access to the primary targets.

The current meter moorings were first laid in early 1987 from RRS John Biscoe, and serviced a year later from RRS Discovery. Three moorings at the northern edge of the Weddell gyre (area 5.2 in figure 1) each included current meters at 10, 50 and 800 m off bottom, sediment traps at top and bottom and (on 2) transmissometers within the basal current meter. They are intended to examine the relationship between modern sedimentation and deep circulation, and the coupling between Antarctic Bottom Water and the younger, underlying Weddell Sea Bottom

Water. A suite of CTD and water bottle stations accompany the mooring renewal, for calibration purposes. The first mooring period was planned to be for 2 years, to save the cost of shiptime for renewal in 1989-90. In the event the period when the ship could attempt to recover the moorings became tightly constrained, and in a bad ice year, with a ship not suitable for work in ice, the moorings could not be recovered. The new moorings were laid at sites farther north, following a strategy for examining the relation between AABW and the Antarctic Circumpolar Current, which we had not intended to implement for 2 or 3 years.

In addition, we became aware at a late stage that the acoustic doppler current profile (ADCP) would be available on board (and only later, that the sensor wasn't actually fitted). It seemed worthwhile, given the regular, "passage" nature of GLORIA survey, to run the ADCP throughout the cruise: we would collect up to 6 transects of the ACC axis (Antarctic Convergence or Polar Front) and some indication in each survey area (including the area of the moorings) of the mean and short-term variability of shallow transport. The Hydrographic Department of MoD(N) was able to provide XBT's so that we could clearly identify the water masses whose movement we were observing without interrupting GLORIA survey. During Legs 2 and 3, shallow water samples at each XBT site were filtered for diatoms, to add to constraints on the known association of different species with different water masses and temperatures.

A dark shadow was cast over Cruise 37 by the death of Captain Sam Mayl. Sam became increasingly ill after joining at the start of Leg 2, and the ship returned to Stanley at the end of February, to put him ashore. He was flown home by the RAF, and tests at the Princess Alexandra Hospital, RAF Wroughton diagnosed secondary tumours on the brain. Despite several operations, after transfer to the National Hospital for Nervous Diseases in London he died, peacefully in his sleep, on 4 April, a few days before the end of Leg 3. Sam May1 was a great servant of UK marine science: he was always an enormous pleasure to sail with, and will be sadly missed.

2. NARRATIVE

LEG 1

RRS Charles Darwin arrived at Stanley after passage from Punta Arenas at the end of CD Cruise at 36 0500 on day 365, tying up at FIPASS outside RRS John Biscoe. Preparation for Cruise 37 was restricted to the fitting of the ADCP sensor by members of the HMS Endurance's diving team the next afternoon, all other equipment needed being already in.. place.

RRS Charles Darwin left Port Stanley early on day 003, steaming round to East Cove to fuel. Departing there about 1600, we deployed the PES and 3.5 KHz fish and headed east to the 400 m isobath to stream GLORIA, the single-channel seismic streamer and 3-gun array, and magnetometer. With gravimeter and ADCP, these comprised the standard equipment suite for Leg 1.

All gear was working by 01/004, and the ship headed east down the long slope of the Falkland Plateau. The main surveys planned for Leg 1 all lay far to the east, around the northern South Sandwich arc and trench (3.2 and 3.3) and, even farther east, across the South American-Antarctic Ridge (SAAR, surveys 4.1 of Figure 1). To reach these areas would take several days, and a track was chosen which would examine the deformational front of the accretionary prism of the North Scotia Ridge, running into and then along the Falkland Trough and around the northern slope of the South Georgia block.

Minor equipment problems plagued the first few days: a gravimeter gyro was changed on day 004, and by day 005 all three airguns had failed and the beam on which they were mounted was brought inboard split near the towing point. They were replaced by a single 300 cu inch gun towed over the port quarter. ADCP performance improved when the ship's doppler log was switched off on day 004, and it must be presumed that the two mutually interfere.

We started E-hourly XBT deployments late on day 004, shortening to a 6-hour interval the next day as we approached the Antarctic Convergence. Not all deployments were successful, we think because the wire tangled with one of the 5 lines towed astern, particularly in rougher weather.

The single airgun failed (trigger lead) on day 006, and was replaced by another 300 cu inch gun. At about the same time we met fog and, having crossed the Antarctic Convergence, reduced to a 12 hourly XBT schedule and that night slowed to 6 kts during the hours of darkness, after seeing our first berg.

The weather continued kind, with little or no wind. On day 007, north of South Georgia we had the first of a series of problems with the Carrack digital seismic recording system, in which a suite of curious tape errors pointed at (or caused?) possible corruption of the hard disk, similar to Cruise 36 experience (see equipment report).

By day 008 we were north of South Georgia, having followed the frontal fold of the accretionary prism virtually all the way along the N Scotia Ridge. We proposed to add to at least the western part of this track on our return. Our next area of interest was the East Scotia Sea, the northern end of which presents the-interesting conjunction of back-arc spreading centre and trench. We proposed merely to visit this area briefly on the way east, and add extra lines on the way back westward. This was in fact becoming the general strategy of the leg: the farthest point of survey 4.1 (S American-Antarctic Ridge) was <u>very</u> far east, and could not be left until time was against us.

We encountered a dense concentration of icebergs in the East Scotia Sea, which seriously degraded the quality of the GLORIA record by causing frequent course alterations, and we were essentially driven back north by the futility of attempting survey just then: by the time we returned, the bergs should have moved elsewhere.

The weather remained kind, and on day 010 we were traversing the northern outer wall of the S Sandwich trench at about 5500 m, getting good GLORIA pictures with no clear sign of tearing of the subducting slab at the seabed at its northern end (survey 3.3, Figure 2). This traverse positioned us for the start of survey 4.1, the main business of beg 1.

Recent work on existing data from the Southwest Atlantic (Barker and Lawver, 1988) had produced poles and rates of relative motion of the South American and Antarctic plates (SAM-ANT) for the past 50 Ma. Survey 4.1 was aimed at extending that effort back to 84 Ma (Anomaly 34). One of the results of that work was an apparent sharp change in spreading direction at around 20 Ma, causing the formation of the east-west, long-offset transform faults (e.g. South Sandwich, Bullard) which now dominate the plate boundary. Survey 4.1 intended to use GLORIA to help trace a particular fracture zone from A34 on one flank of the plate boundary to A34 on the other, to obtain a precise estimate of plate motion, and also to examine the detail of the 20 Ma episode, if it was accessible. This meant going far to the east on the southern flank, since the north flank equivalents of more-accessible, westerly ridge segments have all been subducted beneath the Scotia Sea.

The ship track was based on best estimates of SAM-ANT motion, calculated around the SAM-AFR-ANT loop using published data. It formed an S-shaped loop from the northern S Sandwich trench to 61°S, 6°E.

All went well for the first 2 days (although the magnetic record was not perfect and sediment obscured some of the basement fabric), but then fog on day 013 (Friday 13th) caused us to recover all of the towed equipment, then re-stream it and again recover it as fog banks came and went. We were able to restream the magnetometer later, but essentially lost a day of GLORIA and SCS cover. By then we were running along the south side of the Bullard FZ, and after redeploying on day 014 obtained spectacular GLORIA images of older small-offset fracture zones anastomosing into the long-offset Bullard. We eventually followed to the southeast one such FZ, chosen on the basis of the estimated plate motion, and reached A34 at 5°E on day 018. Turning onto a parallel track to the east, we then headed back for the Bullard FZ. Apart from additional time spent at only 6 kts because of fog, progress had been good.

Reaching the Bullard FZ on day 021, we crossed onto the N side and traversed the young ocean floor produced since 20 Ma ago. Sight of where that struck off to the NW allowed a reasonably precise check (assuming symmetric spreading) on the true equivalence of the mapped FZs. We headed NW along a synthetic flow line, and finally hit the bad weather we'd successfully avoided hitherto. A short-lived gale on day 022 was followed by a much larger, stronger and longer-lived depression (943 mb) the next day, which lost us 60 hours of science passage time. The gear which had been recovered at 2100(z) on day 023 was not restreamed and working until 0700(z) on day 026.

Late on day 026, having crossed anomaly A34, we turned west off the flow line to begin a survey of the northern corner of the South Sandwich trench and fore-arc (3.3 and part of 3.2). After the negative evidence of our outward track (day 010), it seemed necessary to search the lowest part of the outer wall of the trench for signs of tearing at the northeast corner, but not to work any farther east. No such signs were visible. We therefore concentrated on the fore-arc, and were able to see the folded sediments of the accretionary prism and undeformed volcanigenic sediments covering the upper fore-arc. There appeared to be some limited fore-arc volcanism but little or no sign of serpentinite diapirism (anticipated by comparison with the Marianas fore-arc). The steep east-west slope at the northern end of the arc does appear to truncate all upper fore-arc structures, and represents the true northern edge of the Sandwich plate. The steep slope may be maintained by a species of tectonic erosion.

The weather deteriorated rapidly during the morning of day 029, and GLORIA, magnetometer, gun and streamer were all brought inboard. The fore-arc survey was almost complete and it was not worth waiting for better weather in order to finish it off, so the ship headed slowly west that evening between Zavodovski and Visokoi Is with only the magnetometer streamed, in winds which at times reached 50 kts.

The weather was not suitable for GLORIA redeployment until the next afternoon (day 030), by which time we were virtually at the S Sandwich back-arc spreading centre (56°S, 30°W). In addition to deploying GLORIA and SCS gear, we here restarted the programme of 12 hourly XBT launches, for another crossing of the Antarctic Convergence.

With little time now remaining, above that needed for shortest passage to Stanley, we chose to run directly south of the South Georgia block to join the outbound track near 45°W, just east of Aurora Bank. The intention was then to run a parallel track, 20 miles to the south, to build up a broad swath of GLORIA cover across the North Scotia Ridge, Falkland Trough and Falkland Plateau.

We achieved only about a day of this parallel track, to 48°W. Then, on the morning of day 034, the weather again grew rapidly worse and we decided to recover the gear. In the final stage of recovering GLORIA, a collision with the platform edge dented the nose cone: since a full examination and repair could not be made at sea, that was the last we saw of GLORIA on Leg 1. The next morning we were able to redeploy seismic gear and magnetometer, and chose a shallow zigzag path to Stanley, crossing the outbound GLORIA swath to obtain additional information about the imaged seabed (a problem with the standard survey technique is that the seabed directly beneath the ship, which is examined by seismic, 3.5 KHz, gravity and magnetic survey, is not part of the GLORIA image, and vice versa). All of the geophysical equipment was recovered about 10 miles off C Pembroke, from 0430 on day 037, and we were alongside at FIPASS by 10 am.

Waiting for us were the 2 containers of BAS and RVS equipment which should have reached Port Stanley on 22 December 1988, in good time for Leg 1.

LEG 2

There was much to do in Port Stanley in preparation for Leg 2. The contents of the containers includedparts of the current meter moorings, core liners and dredges, a water gun, microcomputers, plotter and digitiser, sediment traps and water bottles. Current meters, transmissometers, releases, CTD computer and tape decks came by air, as did the long-awaited FAX receiver. The ex-Discovery (BAS) searchlight was mounted on the foremast and the main after crane repaired. The gravimeter gyros were successfully re-aligned but two attempts at a gravity base tie failed because motion of the FIPASS caisson next to the ship was too violent for the Worden to be able to stabilise.

RRS Charles Darwin sailed from Port Stanley at 0830 on day 040 (9 February). A delay in the availability of fuel at a (Russian) tanker in Berkeley Sound presented the opportunity for calibrating the ADCP on the way. A combination of straight and zigzag tracks in shallow water was controlled by GPS fixes, between 12002 and 1630z (1.30 pm). Fuelling took from then until 7 pm, delayed by the need to clean filters frequently, and we were deploying PES, 3.5 KHz and magnetometer by 8 pm. We then headed southeast into deeper water before deploying GLORIA and SCS.

The two main objectives of Leg 2 were a GLORIA survey of the area of a modern, intra-oceanic ridge crest-trench collision (RCTC) south of the South Sandwich island arc, and the recovery and redeployment of an array of moored current meters in the northern Weddell Sea, southeast of the South Orkney block. Reports of sea ice distribution through January had shown fairly dense ice in the western Weddell, to the south and west of a sharp corner at 60°S, with the longitude of the corner steadily migrating westward. By 9 February the corner lay at 60°S, 39°W and there was a re-entrant to the south, so that much of the mooring area (see 5.2, figure 2) was clear. Nevertheless it seemed most likely that the ice situation would improve further over the following fortnight, so we decided to carry out the S Sandwich RCTC zone survey first.

GLORIA, and the single airgun and 2-channel streamer of the SCS system, were streamed by 6 am on day 041, and the ship headed east along the parallel track originally intended as the approach to Port Stanley a few days earlier. The GLORIA data provided a clear image of long parallel folds and faults in the accretionary prism of the North Scotia Ridge. By 8 am on day 043 we had reached 45 W, and altered course to 160° to cross the Scotia Sea. For the previous 2 days we had enjoyed the benefits of a following W to NW wind and sea, but now turned across the swell and began to roll badly. The track crossed area 4.4 (figure 2), identified as somewhere where the history of coupling between the Drake Passage and Central Scotia Sea spreading regimes might be investigated. The GLORIA image of this area strongly resembled that of a large complex fracture zone trough farther north, which would make it clearly part of the Drake Passage system and thus place the boundary farther east. The track was chosen also to help locate a coring transect of the Scotia Sea, part of a hoped-for cruise with a long piston corer aboard the new BAS ship James Clark Ross in 1990-91.

Our intention was to reach 60.7°S, 36.2°W, on Discovery Bank, then head east into the RCTC zone via a small pull-apart basin on the present Scotia-Antarctic plate boundary, where GLORIA survey was expected to show the direction of current and recent plate motion. However, just south of 60°S, in about 37°W on the morning of day 046, we met a dense concentration of icebergs with abundant intervening brash ice, which forced us to recover the towed equipment and head back north. We assumed that the ice we saw had earlier been part of the main pack ice body farther west, until separated from it by the previous few days' strong westerly winds.

To be sure of an uninterrupted passage east, we moved north for 40 miles or so before heading east and re-streaming the complete suite of towed equipment at first light on day 047 (after a night of fog, snow, birdstrikes and searchlight damage). We then headed southeast across an eastward extension of Discovery Bank onto Herdman Bank, having missed all but the farthest NE corner of the basin mentioned. We hoped instead to pass through it on the way west, towards the current meter moorings.

bate on day 047 we began the systematic GLORIA (plus SCS, magnetic, gravity, PES, 3.5 KHZ, ADCP) survey of the area of the most recent ridge crest - trench collision along the S Scotia Ridge. The expected geology of the area dictated that courses should be either 060/240 or 090/270. So, we could run in either direction eastward (anticipated downwind), and would have the choice at the eastern end of either westbound direction, depending on weather, to make the coverage efficient. In the event, after the first track the wind died away and the sea dropped, and all tracks were east-west.

The first line, along 60.3°S, crossed the intact South Sandwich back-arc, arc and trench, onto South American (SAM) ocean floor, to provide a GLORIA character for these tectonic elements which might allow fragments of them to be identified within the collision zone. We then offset 20 miles south for the second line which would lie fully within the collision zone as previously identified (I W Hamilton, 1989).

On the afternoon of day 049, our plans for the further conduct of the survey had to be drastically revised. The medical condition of Cap Mayl, who had not been well since joining, decided our doctor that further tests were needed, which could not wait until the next schedule port call on 12 March. We were given essentially until midnight days 052/3, before the ship would leave for Stanley, intending to arrive on day 057, 2 weeks early. This was about 4 days before we had planned to finish, and would take time from the remainder of the Leg also. We decided to confine the survey in progress to 4 lines, eventually reduce in length to allow us to fill a gap caused by a topographic shadow. This lesser scope would limit our understanding of the regional context of the collision, but would preserve intact the survey of the collision zone itself. Fortunately the weather remained reasonable, and the equipment continued to work well. The GLORIA survey will be of great help in understanding the evolution of this extremely complex area.

After the gear had been recovered, the ship made a direct course for Port Stanley, using direct drive where some speed advantage was to be gained, after obtaining Permission from RVS Barry. The PES, gravimeter and ADCP were kept running, but our request to keep the magnetometer streamed was refused by the Chief Officer, now acting on Capt Mayl's behalf.

The ship was slowed to some extent by fog and head winds on the passage to Port Stanley, and reduced below 6 kts during the hours of darkness while south of the Antarctic Convergence. It averaged 8.94 kts for the passage, arriving alongside at FIPASS at about 2 am on day 058. Capt May1 was taken ashore to Stanley hospital, and Brian Richardson joined as 2nd mate. We heard later that Capt May1 flew to the UK on the following Wednesday (day 060) and was admitted to the Princess Alexandra Hospital, RAF Wroughton.

The ship sailed at 0645 and deployed 3.5 KHz and PES fish at about 8 am off C Pembroke. We then headed southeast to where GLORIA and the magnetometer could be streamed. By 11 am we were headed southeast, in the general direction of the South Orkney Is. We had decided that recovery and replacement of the moored current meter /(transmissometer/sediment trap) array in the northern Weddell Sea was the highest priority task remaining for Leg 2. The array was to examinE the relation between modern sedimentation and circulation, in support of a coring programme aimed at understanding Weddell Sea Bottom Water, started in 1985. The moorings were completing their second year of operation, having been deployed initially from RRS John Biscoe in 1987 and serviced and re-laid from RRS Discovery in 1988.

There was barely enough time remaining in Leg 2 for recovery and replacement of the moorings and the-complementary programme of CTD stations. Thus, although we deployed GLORIA for the passage from the Falkland Is., we did not stream the single-channel seismic gear and were therefore able to travel at 10 kts (except south of the Convergence during darkness). In compensation, we ran tracks close and parallel to existing seismic lines, whenever that was possible without excessive deviation from the direct track.

Ice reports showed that the northeast corner of the pack-ice area had indeed receded southward since the beginning of beg 2, perhaps justifying our decision to go to the South Sandwich area first. However, the strong westerlies which had swept the area for the past week or so seemed likely to have driven stringers of pack eastward from the pack ice edge. We therefore thought it most prudent to give the northeast corner a wide berth, and approach the moorings from the east, as we had done successfully in 1988. Despite this wide sweep, we met a stringer of bergs and intervening brash ice at 60.7°S, 39°W, at noon on day 062. Rather than seek a way through and probably meet other stringers behind it (we had still over 150 miles to the nearest mooring) we steered ENE in hopes of rounding the stringer zone. A day later however, we still had not found the end, the weather was deteriorating and a new ice report (estimated, not analysed but still presumably based on some information) showed the moorings covered by the main body of the pack, blown eastward by the persistent west wind. We decided to abandon the attempt to recover the moorings; and decide if and where the new moorings should be laid.

The original intention had been that only 2 of the 3 existing moorings should be relaid, and a new site for the 3rd mooring had been chosen in the northern part of Jane Basin. This would be the start of a northward extension of the survey of present-day deep circulation, towards the axis of the Antarctic Circumpolar Current (ACC). In a subsequent season, moorings would be laid farther north still, in the basin between Bruce and Discovery Banks and in the trough north of the South Orkney block. Since the Jane Basin site was also inaccessible, we decided to advance the date of these more northerly moorings. We would then seek time in the 1989-90 season, initially aboard John Biscoe, to recover the older moorings, possibly adjust the newer moorings (although they have a 2-year capability) and probably re-lay at the reference site (Mooring III).

Time was short, so we began immediately, early on day 063, recovering GLORIA, the seismic gear and magnetometer. A site for Mooring V was chosen in the southern Bruce-Discovery basin and, after repairs to the CTD winch control and bow thrust, 2 CTD casts were made on site, to check the assumed water mass structure and as a wire test of the acoustic releases to be used. By early on day 064, Mooring V had been released, and we occupied CTD stations 11 miles west and 17 miles east, for an independent, geostrophic measurement of current speed. This and the passage to Mooring VI took longer than hoped because bad visibility reduced ship speed. However, we had laid Mooring VI by noon on day 065 and by early on day 066 (slow passage again) had run 3 more CTD stations (on site and, as with Mooring V, to east and west).

At this Point we had to decide if sufficient time could be allowed for deployment of Mooring VII, in the South Orkney trough. It would t a useful complement to Moorings V and VI, measuring the flow of AABW west into Drake Passage (and ultimately, along the Antarctic margin). However, it was 180 miles to the WSW and was a deep site, so would take at least 42 hours to complete, even with more favourable weather than had been having. After consideration of the remainder of the cruise programme (to Valparaiso), and since the fog had cleared completely, we decided to do it. GLORIA was streamed and we headed WSW at 10 kts, arriving on site early on day 067.

Sediment traps were added to top and bottom of Mooring VII, thanks to the efforts of RVS staff in completing their assembly and manufacturing brackets: the parts had been brought down essentially as spares for those on Moorings I to III, not recovered. A site was chosen in the middle of a sediment pond at 5500 m, and by late morning Mooring VII had been released and had timed out. As the CTD was going down, a mile away from the mooring, distinctly bad values were noticed, first for conductivity and then for temperature: on recovery a leak was found into the terminal compartment of the recorder. There was no time for repairs and testing, so a shallow bottle cast and XBT to 900 m gave the possibility of characterising the shallow water mass structure and local biogenic productivity.

We left the site of Mooring VII at about 4 pm on day 067 for Port Stanley via some kind of dogleg to the north, depending on the weather Head winds initially meant we could not exceed 8 kts, and darkness was imminent, so the seismic gear was streamed as well as GLORIA and the magnetometer, since it would not slow us down. The next morning, a continued head wind and poor visibility similarly allowed us to leave the seismic gear out. It was early on day 069, after our last night south of the Antarctic Convergence, before we could hope to gain time recovering the seismic gear. By then it was clear that we would be sensible to think in terms of an early 13 March arrival at Stanley, which could be accomplished at 7.7 kts, compatible with leaving the gear streamed.

This schedule slipped unfortunately, because of strong westerlies on day 070, after we had turned west along the North Scotia Ridge. For all that day we were forced to tack, in essence, to maintain GLORIA speed, so did not add a near parallel swath to the 2 GLORIA lines previously run. By day 071 the wind had slackened and we could make better time and more precise tracks, but had lost several hours. The seismic gear, which was by now running at low gun pressure because of the leak, was recovered late on day 071, and GLORIA and the remainder of the towed gear came inboard after breakfast the next morning. We arrived alongside at FIPASS that afternoon.

Resides the prime achievements of Leg 2, the south Scotia Ridge RCTC survey and laying the moorings, we had also built a very interesting North Scotia Ridge mosaic, had learnt a few interesting things about Scotia Sea basement and sediments from single GLORIA passes, and acquired 4 more ADCP crossings of the ACC, calibrated by XBT casts. At each XBT and CTD site, filtrates of shallow water samples should provide additional information on the link between diatom species and modern water masses, useful in interpreting the fossil record.

LEG 3

Charles Darwin sailed from FIPASS in the afternoon of March 15th (day 074)and loaded 150 tons of fuel in Berkeley Sound, leaving there at 7.00 pm. The PSE and 3.5 kHz fish and magnetometer were deployed and we made a fast passage SSW across Burdwood Bank. The ADCP was calibrated again in the shallow water on the Falkland Plateau and Burdwood Bank. GLORIA was deployed in 600m water depth at 54° 50'S., 60° 10'W. There was a fresh to strong westerly wind and conditions were marginal for launching the vehicle, but the weather was forecast to improve. Once on our course of 210° across the Scotia Sea the ship was comfortable at 10 kts and GLORIA record quality was excellent. XBT's were launched every 6 hours (7th crossing of the Convergence).

Between Burdwood Bank and the Shackleton Fracture Zone our track was across ocean floor 15-22 Ma old, with a sediment cover so thick that only a few basement ridges showed through. A widely-spaced spreading fabric trending 035° was seen in the 60 miles north of the SFZ. The fracture zone itself did not show any evidence of convergence between the Scotia and Antarctic plates, as hypothesized by some workers. South of the SFZ we obtained clear images of a closely-spaced (< 1 mile) spreading fabric on 9-12 Ma old ocean floor, again trending 035°, with isolated circular volcanoes 2-3 miles across. Two small-offset fracture zones were also seen clearly in this area. The ocean floor here is swept clean of sediment by the ACC.

We had hoped to continue to the survey area via an inactive spreading ridge segment, but deteriorating weather wiped out the plan. Heavy rolling on the afternoon of day 076 had affected the GLORIA record and the gravimeter beam was clamped for 6 hours. On the morning of day 077, after several violent rolls, the captain ordered a change of course. The wind was now NW force 9-10 with a swell estimated at 40ft. The gravimeter beam was clamped at noon. On a westerly course the best speed we could make was 4-5 kts. At such a low speed the GLORIA vehicle towed very deep, as well as yawing and pitching so that record quality was very poor: finally at 17.30 the cable failed and we lost the 15v supply direction and depth sensors. The magnetometer had failed a few minutes earlier. Conditions on the after deck were too dangerous to attempt gear recovery so we continued slowly west all night.

By 08.00 the sea had moderated, so we recovered the magnetometer and GLORIA vehicle safely, and ran for shelter in the South Shetlands. The spare magnetometer was streamed to obtain a magnetic profile just NE of the Hero Fracture Zone. The gravimeter was restarted and 6-hourly XBT launches recommenced. The fault in the first magnetometer was traced to water in a connector and was quickly remedied. The GLORIA cable failure was at the outboard end and the cable had flooded, necessitating replacement.

The vessel entered Boyd Strait at lunch-time on day 079 and hove to about 4 miles SE of Smith Island in calm water. Replacement of the GLORIA cable took all day; meanwhile the 700 cu. in. airgun and 80 cu. in. watergun were prepared for use. The workers on the afterdeck were treated to a stunning view of Smith I. in the sunshine. By late evening we were again able to deploy GLORIA, the magnetometer, seismic streamer and airgun and head out across the shelf to begin the survey of the Antarctic Peninsula Margin.

The principal fabric directions were predicted to be NW-SE (fracture zones and deep-sea channels) and NE-SW (spreading fabric and along-slope features). GLORIA'S insensitivity to fabrics perpendicular to the track reduced the choice of survey line orientations to N-S or E-W. As one part of the survey area was thought to contain E-W trending spreading fabric, we decided to run E-W lines.

The original plan had been to start at the northern end of the survey area and step southward on successive lines, then to finish the survey with a long line from SW to NE near the base of the continental slope. However, as we were now starting from Smith I. it was more efficient to start on the nearest E-W line. We then worked southwards as planned, leaving the northern part of the survey to be completed after the base-of-slope line. Six E-W lines were run, with a track spacing of 21 miles. The eastern end of each line was at 1000-1500m depth on the continental slope. The survey was generally uneventful with light to moderate winds; there was fog for about 15% of the time. No icebergs were seen in the survey area. One radar target thought to have been floating ice was observed at about 62° 45'S 62° 15'W (outside the main survey area) on day 080. Survey speed was 8 to 8½ kts in daylight and 5½ to 6 kts in darkness and fog. Winds of force 6 or more forced recovery of the gear (GLORIA, SCS and magnetometer) for 12 hours on day 081 and 7½ hours on day 084. We also had to get the gear in briefly late on day 081 while the engines were shut down and a seawater isolating valve was replaced (lost time 2½ hours). During the survey ten XBT's were launched to give two onshore-offshore transects.

The southernmost E-W line was finished early on day 087; we continued SW along the slope to 65°S, turned and ran a base-of-slope line at 2750-3000m depth. Three more E-W lines were planned for the area N of Smith I. followed by a passage across the inactive spreading ridge we had failed to survey earlier. The weather continued fine, though intermittently foggy, until late on day 091 by which time we were half way along the last line. We had to recover the gear at midnight before the end of the line, with the wind increasing from NE and a rapidly falling barometer. The sea built up quickly and a second GLORIA cable was damaged during recovery, though luckily no harm was done to the vehicle itself. The magnetometer was re-deployed, the PES and 3.5 kHz fish left out and the ship headed slowly NW with the wind now on the starboard quarter. Several hours later the sanitary seawater system flooded part of the forecastle deck-and the ship hove to for repairs. In the early afternoon we were able to set course NW and increase to full speed. The magnetometer, PES and 3.5kHz fish were recovered at 1430 on day 093 and the ship proceeded to Valparaiso. The ADCP was left running, and 12-hourly XBT launches continued, until day 098. Strong headwinds slowed the ship considerably until April 8th; thereafter the engines were put into direct drive and we arrived only a few hours late, at 1400 on day 100 (April 10th).

3. EQUIPMENT REPORT

3.1. NAVIGATION

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 elsewhere. Navigation processing was done by a suite of programs on level C. For periods when GPS was available, 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 Discovery cruise 172.

The Magnavox, EM log and gyro performed well throughout the cruise except for a brief gyro failure on the evening of day 100. This year the GPS system included a rubidium clock, which was connected by Pete Mason during Leg 2. GPS coverage was thus increased from 6 hours per day (3 satellites required for a position fix) to 11 hours per day (only 2 satellites required). Coverage increased to 18 hours per day for one week during Leg 3, when GPS satellite 14 was temporarily operational.

Ideally, 'parallel' GLORIA survey tracks should be great circles distant from their common pole. Straight lines on the Lambert Conformal Conic projection used for the GLORIA mosaics closely approximate-great circles. Real ships are affected by currents and have to avoid icebergs, so many of our survey lines are not straight. In addition, lines which are straight on the Mercator projection (always used for plotting on ships) are curved on the Lambert projection. This effect was particularly marked on Leg 3 because we were working further South than during the previous legs. On the long E-W lines on this leg we picked way points at 60 mile intervals from straight lines drawn on the LCC projection.

Charles Darwin's autopilot is one designed for big ships on long passages, and in its normal adaptive mode is not always suitable for scientific surveys. Particularly in a quartering sea, the amount of yaw permitted is too much for a yaw-sensitive instrument like GLORIA, and record quality is poor. We found it better to run the autopilot in back-up mode, as the ship steers much straighter (although using a little more fuel and presumably incurring more wear to the steering gear). Fig. 2 illustrates the contrast between the two autopilot modes.

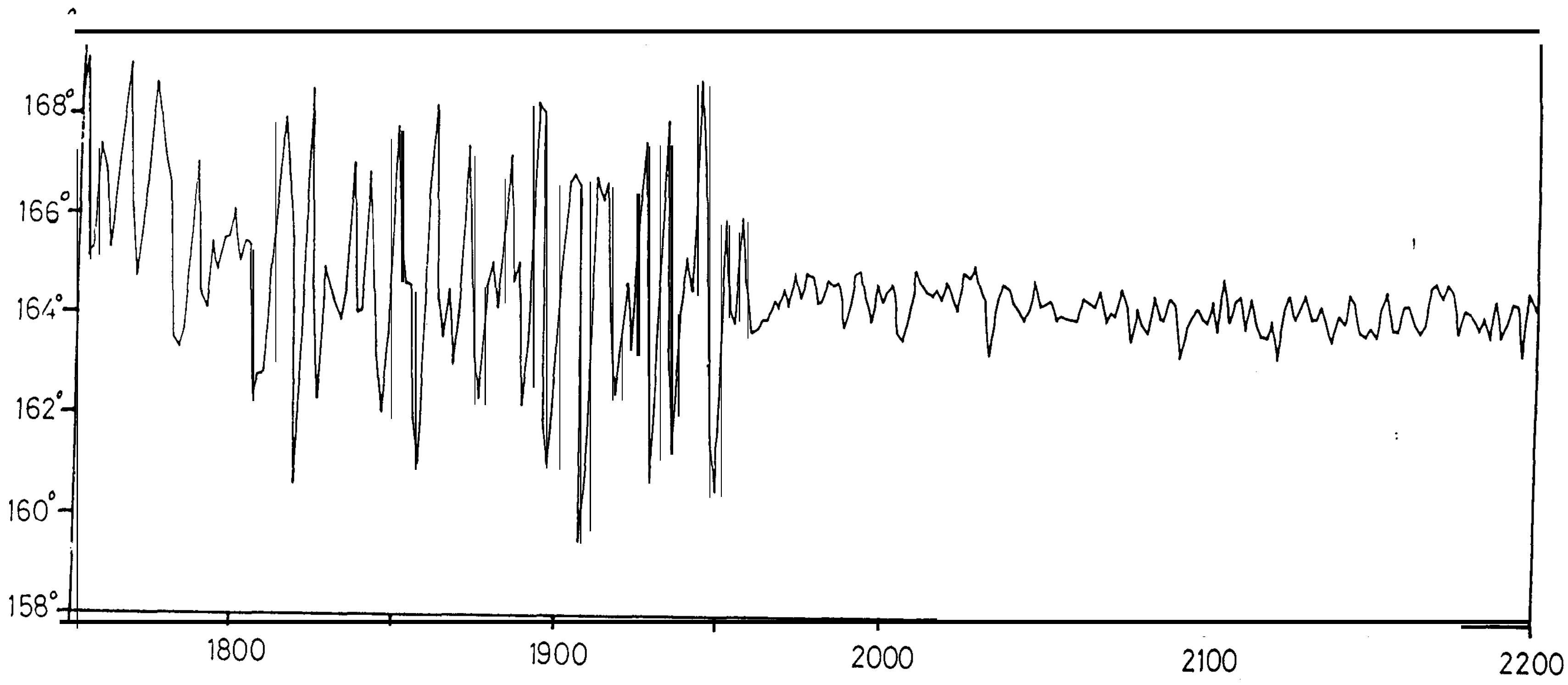


Figure 2 Ship's course record (1-minute gyro values), showing contrast between autopilot in adaptive mode (1730 to 1930) and backup mode (1930 to 2200) Ship speed 10 kts, course 164°: wind speed 25 kts, on starboard quarter. Autopilot settings in backup mode: weather = 0, counter rudder = 3.3, rudder = 2.0, rudder limit = 20°.

3.2. GLORIA

Leg 1

Preparation and testing of all system components was carried out as far as possible without the vehicle in the water prior to sailing and during the bunkering at Mare Harbour. The vehicle was launched at 2100 on day 003 1989, but no transmissions were made until the ship was settled on her course with all other gear deployed and working.

Some sound ray plots were made with data provided by BAS for various stations within or close to the work areas. These showed the presence of a weak sound channel at 40-50m depth, just about the vehicle working depth. This channel was expected to have two effects, which turned out to be one too few. First with the abundance of biological mass in the upper layers in this region, it was expected that the channel would cause excess reverberation, and second it was expected that icebergs would be particularly visible on the GLORIA records. In the event both effects were visible, with the icebergs being more obvious, but neither was critical. The ice also had another effect which might have been foreseen. The icebergs, particularly in rough weather, generate a great deal of noise which shows up as bands of noise in the far range, that in the near range being suppressed by the TVG.

There were some early problems getting sufficient contrast on the photographic replays, owing in part to the early use of a bottle of developer which had been started on the previous cruise. After a careful review of techniques and a small adjustment to the laser drive no further problems were encountered in this direction.

The onboard GLORIA replay system allows for image processing in form, inter alia, of range (i.e. time) dependent shading. The required shading function should be independent of geology but not of depth. The technique was refined a little on this leg, and three shading files have now been compiled for shallow, mid and deep water regions, using the statistics from extensive volumes of data.

Weather and ice conditions had a significant effect on the data set over the course of the leg. The need to alter course for ice caused frequent direction changes, making it impossible to lay up a continuous mosaic, and the occurrence of fog and bad weather caused an unscheduled vehicle recovery to be made on five occasions (twice on day 013). On the last occasion, on day 034, caused by bad and rapidly worsening weather the vehicle sustained extensive damage to the fibreglass nose dome, which prevented any further attempts to use the system on this leg. The total loss of potential GLORIA time amounted to approximately 5 days, though whether the final loss of 54 hours is ascribable to weather or equipment failure is a moot point.

Apart from this damage, the system was very nearly free of problems. On day 027 there was a problem with one of the port power amplifiers, which subsequently turned out to be a minor mis-adjustment. The system ran for several hours on a spare amplifier, during which time the occurrence of some acoustic artefacts on the port side caused doubt:

to be raised about the phasing of the new amplifier. These were resolved fairly quickly, though the artefact, a doublet structure of varying separation, rcontinued to recur intermittently and remains a mystery. All reasonable equipment malfunctions have been eliminated, but it has so far been impossible to postulate acoustic conditions which could produce the effect exclusively on the port side.

Owing to the late arrival of the BAS container at Port Stanley the Ship was short of 9 track magnetic tape, so instead of the usual three copies of GLORIA data, only two were made. Of these one will remain aboard to be shipped home by BAS and the other will be carried back to the UK by hand. Once there a new copy will be made and sent to BAS, while the other remains in the IOSDL GLORIA data archive. Public use of these data will not be made without the approval and cooperation of BAS.

Leg 3

The GLORIA system which had been originally installed on board Charles Darwin at Mombasa in February '87 was run throughout the entire cruise, the only breaks in the data logging being due to the necessity of recovering the vehicle for rough weather and a ship's engine repair. The system performed well in spite of not having had a major overhaul since February '87 and the only unscheduled break in operation occurred when electrical conductors parted in the vehicle tow cable while the vehicle was being towed in very rough weather conditions.

The quality of the data was up to the standard expected of the system. However, it was noticed that on some courses, particularly those with a following sea, the vehicle yaw compensation was not always able to make the necessary corrections for the vehicle's motion. This caused a temporary reduction in signal level. On the evidence available, it was thought that this was due to the over-damping of the vehicle's compass caused by the low seawater temperature increasing the viscosity of the damping fluid in the compass.

At times there was evidence of multiple path interference of the acoustic propagation. As this was particularly prevalent along the western margin of the Antarctic Peninsula, data have been collected to make a more thorough study of the interference at this shelf break. Occasionally a doublet appeared at the first backscatter return on the port side acoustic array. This occurred when there was strong backscatter from a smooth seabed. In the absence of any doublets in the main beam, this is attributed to the presence of a weak sidelobe on the beam pattern of the port array. The absence of a doublet on the starboard side could be due to the different sidelobe pattern created by the lower operational frequency of the starboard array.

The data logging and replay systems performed faultlessly throughout the cruise, but a fault on one of the tape cartridges (Tape 42 Pass 231) prevented data from the cartridge being transferred to either the 9 track tape or film. To overcome this problem the cartridge is being returned to the IOS Deacon Laboratory where a program will be compiled to enable the data to be transferred.

The periods of rough weather, supported by somewhat misleading weather forecasts, resulted in the GLORIA vehicle being towed and recovered in adverse weather conditions. This had the inevitable effect of damaging the vehicle, gantry and tow cables. The damage sustained by the vehicle and gantry was superficial and has since been repaired. However, the first cable to be damaged had also flooded rendering it irreparable. Fortunately the second cable, that failed during the final recovery of the vehicle, can be reterminated and used again. Overall the damage sustained during the cruise is considered to be above average but to be expected in this survey area.

3.2a. Gloria photographic processing

Monochrome digital image representations of the sidescan data in the LASP (anamorphicallyand slant-range corrected) and SHADED (amplitudes adjusted according to an empirically determined scaling factor-offset function) files were written to technical pan film using the GLORIA replay system laserwriter. The exposed films were then developed and printed in the conventional manner for monochrome prints.

The films were immersed in the developing solution (precisely 20°C) for approximately 11 minutes and 45 seconds. Subsequently, the films were immersed in a fixing solution (20 + 0.5°C) for 10 minutes. The digital images were printed at a scale of 1:375000 using a Lambert's Conformal Conic projection with standard parallels at 57°S and 63°s. The individual pass lengths were measured from the daily navigation plots. The exposure times for the prints were varied to produce a consistent contrast across the mosaic with exposure times generally 9 to 23 seconds. Details of the equipment and chemicals used are given in Table 1.

There were relatively few problems during the course of the photographic processing. However, it was found that the developer concentrate deteriorates after opening, causing a persistent lightening of the negatives with time. The deterioration is caused by oxidation of the concentrate and the developer should be discarded if it shows any discoloration. The useful life of the developer can be prolonged by storage of the concentrate in resealable plastic bottles which allow the exclusion of air.

For some of the longer GLORIA passes it was found difficult to obtain an even illumination from the enlarger. This caused the prints to lighten towards the beginning and end of the pass.

Shortly after the beginning of Leg 2, the processing was interrupted by the shorting of the motor in the Inter 145 printing machine. This resulted from a spillage of printing chemicals in the machine troughs. The Agfa processor which was used as a replacement is designed such that the motor is well isolated from the troughs making it an easier machine to work with in rough weather.

Table 1

Film: Kodak technical pan film TP135-36

Developing

Equipment: Paterson Super System 4 developing tank

Chemicals: Paterson Acutec-developer, Kodak Unifix fixer, kodak photofile.

Printing

Equipment Ilford Ilfoprint YR 2.1P Paper, Varicon de Vere SO4 Enlarger, Inter 146 processor, Agfa processor 942°/100.

Chemicals: Ilford Ilfoprint IS-21 Stabilizer
Ilford Ilfoprint IA-11 Activator

RW/AC/JT 1989

3.3. SEISMIC REFLECTION PROFILING SYSTEM

Overall, the seismic reflection profiling (SRP) system performed well, and continuous profiles were obtained along the majority of GLORIA survey tracks. On a few passage lines the decision was taken to forego SRP data so that GLORIA could be towed at 10kts.

The new SSI Model S80 was used for the first time on leg 3 with encouraging results.

The SRP system has three components:
(a) the Carrack SAQl system and peripheral instrumentation,
(b) the Geomechanique hydrophone streamer,
(c) the air guns, water gun and compressors. The performance of each component is discussed below.

3.3a. Seismic recording and monitoring instrumentation

(i) Carrack SAQl

This was only the third cruise on which the SAQl system has been used. On CD36 a hard disk problem had developed on the Elonex PC within the first few days, forcing a return to analog recording. During mobilisation for CD37 a new hard disk and controller were installed. However, after the first few days of recording there was a recurrence of the problems experienced on CD36. Eventually it was decided to substitute an IBM PC-AT (on board as a spare for the ADCP) for the Elonex, and no further problems were encountered.

The input to the SAQ1 was unfiltered. Anti-alias filtering (125Hz corner frequency for 2ms sampling) takes place within the system itself.

The system requires a 2 second interval after the end of recording of each shot before it is ready to receive the trigger for the next one. If the sum of recording delay and record length does not allow for this the system only records alternate shots. This mistake was made on two occasions while profiling across deep-sea trenches, and in each case escaped notice for several hours.

Recommendation: the cycle time should be included as a configuration parameter. The system should check that this is at least 2s greater than the sum of recording delay and record length, and issue a warning if there is a danger of shots being missed.

The SAQl system uses the clock on the PC to provide times for shot headers. Unless care is taken to synchronise this clock with the master scientific clock before starting recording, a time offset may be introduced into the seismic data. To adjust the PC clock it is necessary to exit from the recording software package. Like most PC clocks, the one in the PC used with this system showed a marked drift, which became significant whenever recording continued over several days.

Recommendation: the feasibility of adapting the system to take an RS232 input from the master clock should be investigated.

The present system does not include any auxiliary channels for recording (for example) a gun hydrophone, far-field hydrophone or water-break hydrophone signal. A modern seismic recording system should have such a facility. With the acquisition of the water gun, there will be recurrent requests for gun hydrophone recording, since the far-field signature of a water gun can be easily and accurately derived from the near-field signature and gun depth.

Recommendation: as the software for the present system is designed to handle four channel recording, and only two seismic channels are used while towing GLORIA, the feasibility of using the other two channels to record auxiliary signals should be investigated. As the hardware is capable of recording 16 channels, the next software update should allow some of the excess channels to be used for recording auxiliary signals. The feasibility of taking BCD coded input of gun depths and writing them to trace headers should also be investigated.

At present record length can only be changed in the 'configuration' menu. If a change of record length is required while recording is in progress this is most inconvenient.

Recommendation: the next software update should enable record length to be changed from the 'go' menu.

These minor problems aside, the SAQl system represents a major advance over previous arrangements for recording a small number of channels of SRP data. It is anticipated that its use with GLORIA will become standard procedure. In some other cases it may be used (in combination with the Geomechanique streamer) in preference to the NERC multi-channel system on account of its ease of use, low tape usage, and because it enables reasonable quality, digital SRP data to be acquired at speeds up to 8kts.

(ii) Pertec tape deck

The tape deck generally performed well except that, very occasionally, it spontaneously stopped recording, showing tape error 30 ('tape not tight') or 63 ('tape door open'). The former error condition was usually rectified by opening the tape door, tensioning the tape manually, closing the tape door and restarting recording. The cause of the latter error condition is a mystery (the tape door was clearly not open). It was sometimes possible to escape from this situation by pressing the 'reset' button on the tape drive, then restarting recording, but on other occasions the tape was rewound and a new tape loaded.

At present the system includes only one tape deck, and it is necessary to rewind a tape before the next one can be loaded. Tape changes take a minimum of 5 minutes. For many applications, 8 hours of continuous recording (see below) would be more than adequate. However, where the intention is to obtain continuous profiles over several days these gaps in the recorded data are annoying.

Recommendation: addition of a second tape drive and instant switch-over facility to the system should be given a high priority.

(iii) Tape usage

On CD37 the SAQl system was normally configured to record 2 channels with an 8s record length and 2ms sampling interval. Using a 15s cycle time it was found that one nine track, 2400ft tape recorded at 1600bpi could store data from over 2000 shots, thus lasting over 8 hours. A total of 159 tapes was recorded.

(iv) Sequencer and delay unit

These systems performed well throughout the cruise, proving themselves versatile and easy to use. The sequencer was set to a 15s cycle for all SRP acquisition, and was used to control the SAQl system, the Waverley and EPC recorders and the gun triggers. It was programmed to activate one of the channels only on alternate cycles, to provide the water gun trigger (see section c(ii). The delay unit was used to delay the start of display on the Waverley and EPC recorders, and to delay the air gun trigger while the water gun was in use, usually by 2s.

(v) Waverley and EPC recorders

The Waverley and EPC recorders performed well throughout the cruise. The ability of the Waverley to store a signal and repeat it on several scans enables single trace monitor records to be displayed at a much lower vertical exaggeration than is possible on EPCs. For display of the air gun record the Waverley was usually set up with a 10-80HZ filter on the input, an 8s sweep and a paper speed of 2mm/min. At 8kts this resulted in a vertical exaggeration on the seabed return of about 6:l. The storage capability of the Waverley was particularly useful for display of the water gun record. As the water gun was used on a 30s cycle, display on an EPC would have resulted in appalling vertical exaggeration. After some initial trial and error, the water gun was displayed using a 20-150Hz filter on the input, a 3s sweep and a paper speed of 2mm/min. These parameters still resulted in a fairly large vertical exaggeration (17:l on the seabed return at 8kts), but a longer sweep time would have allowed too few pixels per second to display adequately the high frequency components of the water gun signal, and a faster paper speed would have made the pixels very elongate.

During water gun recording the trigger for the Waverley recorder was taken from the same delay unit output channel as the water gun trigger, to give a 30s cycle time. As a result, it was not possible to use the delay unit to delay the start of the Waverley display. This was achieved instead by using the delay facility on the Waverley recorder itself.

3.3b. Geomechanique Hydrophone streamer

The streamer configuration was as follows:

200m tow cable (147m beyond stern)
50m stretch section
25m weight section
50m stretch section
1.5m depth section
5Omactive section
5Omactive section
5Om passive section
tail rope

This arrangement produced surprisingly low levels of towing noise when towed at speeds of up to 8kts. However, the loss of high frequency content in the signal when the ship slowed down at night suggests that at slower speeds (<6kts) the streamer, the air gun, or quite probably both, towed too deep. Unfortunately, it is not possible to be more precise about this because the depth section in the streamer was not calibrated, and its output is known to drift. There was no depth measurement system available for use with the guns.

Recommendation: the depth of the active sections and of the seismic source are important acquisition parameters. Provision of accurate and reliable systems for monitoring both streamer depth and gun depth should be given a high priority. Such systems should produce BCD output, which should be directed to the recording system and recorded in trace headers.

At 8kts, channel 1 (the nearest to the ship) was noisier than channel 2. This may have been due to ship noise, but if so, such a noticeable difference between 300m and 350m distance from the stern is surprising.

3.3c. Guns and compressors

(i) Air guns

The water gun was not available for leg 1, so initially it was decided to try using a variety of air guns on the 5m beam. The beam was deployed for the first (and last) time on 4th January. Three air guns with chamber sizes of 300, 160 and 40 cu. ins were used. A waveshape kit was fitted in the 40 cu. in. gun as it was intended to be used to provide a separate, high resolution record by firing it 2s before the larger guns. However, after deployment it could not be made to fire, and the decision was taken to start the line without it. During the next day and a half the shot phones and air hoses to the other two guns failed one by one, presumably due to abrasion against other guns and the underside of the beam as a consequence of the high towing speed. When recovered the beam was found to be cracked and bent, and clearly could not be used again.

In the light of this experience, and in the interests of minimum disruption to the GLORIA survey, it was decided to revert to a simple single air gun source. As a compromise between resolution and penetration a 300 cu. in. gun was towed during the remainder of leg 1 and during the 15 days on which we acquired seismic data on leg 2. During leg 3 an air gun with a 700 cu. in. chamber was used for part of the time; with the water gun in use there was no longer any need to compromise on air gun capacity in the interests of resolution. However, as it was not possible to tow the water gun in all conditions (see following section), an air gun with a 300 cu. in. chamber was deployed on day 084. Once deployed it worked continuously without problems, so we continued using it until the end of the survey on day 090. All through the cruise there were virtually no problems with air hoses or trigger leads while towing a single air gun. Several deployments lasted for over a week, and even then recovery was usually because of bad weather or an impending port call rather than gun problems. This is in marked contrast to air gun performance on this and previous cruises when the beam method of deployment has been used: then air hoses, trigger leads and shot phone cables seem to fail with monotonous regularity.

(ii) Water Pun

The recently acquired SSI Model S80 water gun was first deployed on day 080. Previous attempts to use water guns with GLORIA have revealed that they can cause interference in the GLORIA data. A brief experiment showed that this gun is no exception. A 1.5s wide band of noise appeared on the GLORIA line scan recorder at about the position in the cycle that the water gun was being fired. It has been suggested that it is the exhaust 'whistle' from water guns which produces this interference. An alternative possibility is that this noise results from the action of the GLORIA correlator on the main implosive spike of the water gun source signature. Whatever the cause of the interference, it was clear that the only way the water gun could be used with GLORIA was to synchronise firing with the GLORIA transmission. This was done, and despite the fact that the sequencer unit and GLORIA use different clocks they stayed in synchronisation for several days at a time.

The water gun was used to provide a separate, high resolution seismic profile. This was achieved by delaying the air gun trigger relative to the water gun trigger, usually by 2s. The water gun was used for a cumulative total of over 7 days during leg 3. While in use it effectively bridged the gap in information provided by the air gun and 3.5kHz records, giving better resolution of sediment reflectors than the former, and much greater penetration than the latter.

The principal operational problem with the water gun was the lack of a suitable towing point. It was towed from the port quarter, less than 3m away from the GLORIA cable. On its first deployment it was recovered after only 6 hours use (8 hours before the rest of the gear) because of concern that the swell on the port beam might cause it to foul the GLORIA cable. Similar concerns delayed its redeployment by 20 hours on days 081-2 and by 27 hours on days 084-5.

<u>Recommendation:</u> these problems with water gun deployment illustrate the need for booms as towing points for guns, to keep them away from other towed equipment.

On day 087 March the water gun started misfiring intermittently. It was recovered and the problem was attributed to partial seizure of the solenoid armature. It was also noticed that the cable impedance was down, and water was found in the inboard connector. The connector was remade, the solenoid cleaned and the gun was redeployed. After this it worked normally for a few hours, but then started misfiring again. However, the deterioration in record quality was not enough to force recovery. It stopped firing altogether on day 089, and was recovered again. The solenoid was again suspected, and was found to be holding residual magnetism around the coil core. By use of a Variac this was removed through reducing hysteresis cycles. The gun was then deployed but failed to seal. On retreival the gun was fully stripped down and seizure marks were found on the free piston rod, probably due to the newness of the device. These were removed, all parts were cleaned and the gun rebuilt. Some of the seals were also renewed. After being redeployed on day 090, the gun worked normally for the last day and a half of the survey.

A lack of facilities for gun servicing is the main deficiency of the Charles Darwin for seismic work. It should not be necessary to use part of the Main Lab. for this kind of work.

<u>Recommendation:</u> the Darwin desperately needs a Rough Lab. for air gun and water gun servicing on seismic cruises. This need is going to

intensify with the planned increase in number of air guns to be used on multi-channel cruises. Perhaps Rough Lab. facilities could be containerised. On cruises on which the Wet Lab. is not being used for other purposes it could provide a space for gun servicing.

(iii) Compressors

Generally the compressors performed well throughout the cruise. Number 1 compressor required some attention during leg 3. The fourth stage valve was changed because high pressure air was leaking over a defective side valve seat and causing the third stage relief valve to lift. Data acquisition was unaffected. The defective valve has been overhauled by hand lapping.

R.D.Larter, with contributions from
J.Davies, H.Rvans and C.Woodley

3.4. GRAVITY

3.4a. Lacoste & Romberg Gravity meter S40

An intermittent fault occurred at intervals during the cruise, the problem showing up as a drop in the measured gravity value of approximately 200 mgal and a simultaneous shift of the long axis. The offset is equivalent to an error in the platform angle of about 1 degree.

Components involved in the control loop for the long axis were tested and eliminated from the investigation, and further long term measurements on the control signals suggested that the fault was in the wiring to the table. Removing and cleaning the plug to the platform (on the end of the flexible cable around the servometer) seems to have cured the problem.

The gyro on the cross axis failed and was replaced. A spare was ordered for the next port call.

These tests and adjustments have involved moving the position of the gyros. Their sensitive axes have to be carefully aligned so that they cannot "see" accelerations at right-angles to the direction of the axis. Adjustments can only be made when the platform is perfectly stable, a condition that may not always be obtained at Port Stanley.

The cross-axis gyro failed on day 087 causing the platform to jolt violently from side to side in the cross-axis direction. The gyro was replaced and the gravity meter was again being logged within two hours. However, within 7 hours the platform appeared to be "sticking" off level in the long axis with resultant loss of sensible gravity output. Exhaustive monitoring of the gyro signals both within the electronic consoles and at the platform did not indicate any problem with the gyro/platform servo loop. However, testing the free motion of the platform with the torque amplifiers turned off showed that the platform appeared to be only free to move within 50% of total travel in the long direction. Removing and dismantling the long-axis torque motor revealed a seized bearing assembly. Unsealing, freeing and greasing the assembly greatly improved the platform travel and subsequently the meter operated with no further problems.

<u>Cross-over errors</u>:-

Analysis of ten cross-overs obtained in variable weather conditions during Leg 3 revealed a mean mis-tie of 2.9 milligals.

<u>Drift Errors</u>

Analysis of ties at Valparaiso, Punto Arenas and FIPASS jetty, Port Stanley (3 times) indicate less than 2 milligals total drift for cruise 37.

3.4b. Gravity ties for CD 37

The instrumental drift of the gravimeter S40 was monitored using a series of gravity base ties at Valparaiso and Port Stanley. Details of the gravity ties and the IGSN71 base stations used are given in tables 2 and 3.

The gravity ties at FIPASS, Port Stanley, suffered from an additional source of error because the FIPASS berth is a floating structure on which a Worden gravimeter cannot be used. The nearest base station on land, set up during the Discovery Cruise 172 in 1988, is situated some 200m or so south of the berth. Estimates of the gravity at the ship's meter derived from the base station value have been calculated using the latitude and free air elevation corrections only. For the elevation correction, the ship's meter has been assumed to be approximately 0.61m (2') above sea level. The error generated by this assumption should be negligible. In estimating the value of the gravity field at the ship's meter at FIPASS, no allowance has been made for additional factors such as the Bouguer correction, terrain corrections, and any anomalous free air gradient,. It has been suggested that the error in the gravity ties at FIPASS may be as much as 1 mGa1 (Discovery Cruise 172 Report).

Drift values for each leg and for the entire cruise are given in Table 4. The drift values are generally very small, but the value for leg 1 is noticeably greater than those for the other legs. The overall drift rate for the cruise is -0.011 mGal/day which produces a total drift of -1.62 mGa1. The drift rates for the individual legs of the cruise suggest that the observed drift rate for the entire cruise is an average of a series of generally more substantial drift rates of shorter duration. Therefore, the drift rates for the individual legs are of greater importance than the drift rate for the entire cruise.
This is because the instrumental drift is too rarely measured to provide a comprehensive record and other methods such as the examination of track cross-over errors should be used to determine the reliability of the gravity data.

3.5. MAGNETICS

Varian V75 Magnetometer

The aft magnetometer bottle failed during heavy weather on day 077. The spare magnetometer was deployed during calmer weather the following day with good results. Tests on the failed magnetometer revealed water ingress in the plug connector, which was quickly repaired.

Table 2

Day	Estimated gravity at ship's meter	Meter reading
323/88	979621.95	7950.6
003/89	981228.11	9570.0
037/89	981228.26	9568.5
058/89	981228.23	9568.8
074/89	981228.20	9568.5
101/89	979620.99	7948.0

Table 3 Gravity base stations

Valparaiso

Ref: UW:WH 1020, EPB:9592-67

The station is located at Valparaiso harbour at the base of the 20th pillar from the dock entrance.

g = 979620.87 + 0.044 mGa1.

Port Stanley (FIPASS)

Concrete pillar, west side of bridge abutment at shore end of bridge.
Ref: See Discovery Cruise 172 Report.

g = 981227.63 mGa1.

Table 4 Drift

	dg (mgal)	dm (mu)	dm (mgal)	total	days	Drift per day
Valparaiso/Stanley (005)	1606.16	1619.4	1605.96	-0.2	45	-0.011
Stanley (003)/Stanley (037)	0.15	-1.5	-1.487	-1.637	34	-0.048
Stanley (037)/Stanley (058)	-0.03	0.3	0.2975	0.33	21	0.016
Stanley (058)/Stanley (074)	-0.03	-0.3	-0.2975	-0.2675	16	-0.017
Stanley (074) /Valparaiso (101)	-1607.21	-1620.5	-1607.05	0.16	27	0.006
Valparaiso (323)/Valparaiso (101)	-0.96	-2.6	-2.578	-1.62	143	-0.011

mu = meter units
dm (mgal) = dm (mu) * 0.9917

Latitude Correction for FIPASS

N-S gradient = .812 sin2 (lat.) Lat. 51° 38.098' Grad = 0.79 mGal/km

3.6. CTD

The sensors on the CTD frame were pressure, conductivity, temperature and transmissivity. All worked perfectly for the first six casts. At about 450m on the seventh cast (no 031) water started to leak into the instrument package via a connector: this was immediately obvious from the anomalous salinity and temperature values and so the CTD was recovered. With the ship still on station, the CTD package was removed from the frame and a water bottle cast was made to 900m depth, simultaneously with an XBT launch. Water samples from this cast were analysed on the Autosal, so a shortened salinity-temperature-depth profile was obtained.

Nine 1.71 water bottles were available for the rosette. Bottle 1 had a persistent leak so bottle 2 was always taken at the same depth as 1. There were only 2 other bottle failures during the seven casts. Water sample depths are given in Table 5. The samples were filtered through nuclepore or glass-fibre filters for studies of phytoplankton or suspended sediment. Salinity samples were also taken for calibration on an Autosal. The calculated CTD salinities were apparently high by as much as .23°/oo (see Table 6). A pair of reversing thermometers attached to bottle 1 measured in-situ temperatures consistently 0.008° and 0.014°C lower than the CTD temperature sensor.

Data from each CTD cast were logged and plotted independently on the BBC micro and on the ship's ABC computer system. No problems were encountered.

Table 5 CTD water-bottle samples

CTD 025	026	027	028	029	030	031
1 (+8)	1 (+10)		1 (+10)*	1 (+10)		
2 (+50)*	4 (+200)	1 (+6)	3 (+50)*	2 (50)*	1 (+10)*	7 (-120)
			4 (+200)*			
			5 (t 500)*			
4 (+200)*	5 (+500)	3 (+50)*	6 (+800)*	3 (+200)	3 (+50)*	8 (-55)
	6 (+800)*					
5 (+500)*	7 (-1500)*	4 (+200)	7 (-1500)*	4 (+200)	4 (+200)*	9 (-25)
6 (+800)*	8 (-	(+500)	8 (-130)	5 (+500)	5 (+500)	
					6 (+800)*	
7 (-1500)*	9 (-43)	6 (+800)*	9 (-20)	7 (-1500)*	7 (-1500)*	
8 (-100)	8	(-58)		8 (-85)	8 (-108)	
9 (-30)	9	(-25)		9 (-20)	9 (-15)	

Most of these samples were filtered and the filter retained.
* indicates that a water sample was also retained.
1 to 9 are bottle numbers.
Numbers in brackets are depths: positive numbers are metres off bottom (measured by pinger-bottom echo separation, negative numbers are metres below surface (measured by wire-out meter).

Table 6 Salinity measurements by Autosal

Sample	CTD calculated value	Autosal value
889 CTD 025-7	34.793 °/oo	34.775°/oo
" 026-1	34.767	34.663
" 026-9	34.010	33.760
" 027-3	34.765	34.638
" 027-7	34.788	34.660
" 028-1	34.769	34.650
" 028-9	33.813	33.605
" 030-8	34.353	34.121

3.7. CURRENT METERS

Three single point current meter moorings were deployed on sites V, VI and VII. Fig. 3 shows a detailed breakdown of a mooring indicating materials used. 400 lb of sub-surface buoyancy was provided by eight 17" diameter glass spheres manufactured by Benthos Inc, USA. The mooringlinewas a 7mm braided kevlar rope manufactured by H.T. Marlowe Ltd, UK. Release mechanisms were the standard 10 KHz IOS CR200 series fitted with lithium batteries and pyrotechnics. Two releases were connected in series because of the 2 year deployment requirement, one serving as a backup unit.

Each mooring supported three Aanderaa recording current meters, fitted in a standard configuration. Table 7 details instrument parameters, ranges and positions. The bottom current meter in each case was interfaced to a Sea Tech 25cm transmissometer. Mooring VII, in addition to the current meters, supported two BAS sediment traps. Six of the current meters deployed were Aanderaa RCM8 vector averaging instruments fitted with lithium batteries and extended data storage units (DSU's), capable of recording data for 2-3 years. The three bottom instruments were Aanderaa RCM5 meters. These were necessitated by the requirement to interface transmissometers. (It is not possible at present to interface a Sea Tech transmissometer to an Aanderaa RCM8). Unfortunately the limited tape capacity of the RCM5 restricts its data recording period to 15 months.

All instrumentation was thoroughly bench tested before deployment: Wire tests were carried out on the releases and test pyros (buffers) were fired at the working depth. To save time wire tests were combined with CTD operations. Some minor problems were encountered with releases but these were rectified.

The moorings were deployed as in previous cruises, anchor first using a stopping off procedure to insert the instruments into the mooring line. When outboard, the moorings were held until a good position fix was obtained and then released. Each mooring descent was monitored on the PES and the rate recorded. Typical descent rates were 90m/min. When the moorings were on the seabed satellite fixes were again recorded and the ship kept on position until the command/releases had timed out. Total time for mooring deployment, wire tests and CTD stations was 5 days.

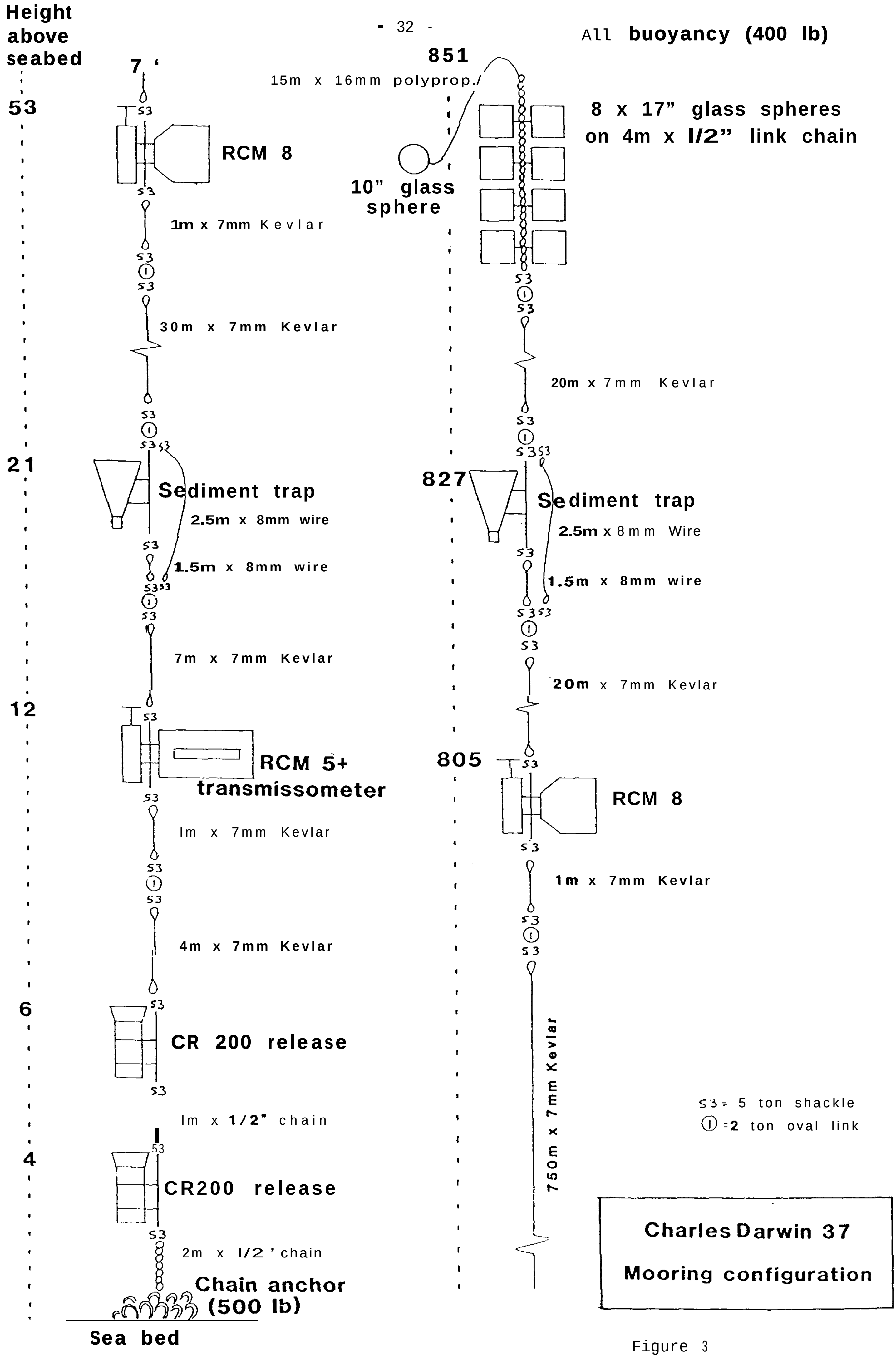

Height above seabed
All buoyancy (400 lb)
851
15m x 16mm polyprop.
8 x 17" glass spheres on 4m x 1/2" link chain
53
RCM 8
10" glass sphere
1m x 7mm Kevlar
30m x 7mm Kevlar
20m x 7mm Kevlar
21
Sediment trap
2.5m x 8mm wire
1.5m x 8mm wire
827
Sediment trap
2.5m x 8mm Wire
1.5m x 8mm wire
7m x 7mm Kevlar
20m x 7mm Kevlar
12
RCM 5+ transmissometer
805
RCM 8
1m x 7mm Kevlar
1m x 7mm Kevlar
4m x 7mm Kevlar
6
CR 200 release
750m x 7mm Kevlar
S3 = 5 ton shackle
① = 2 ton oval link
1m x 1/2" chain
4
CR200 release
2m x 1/2' chain
Chain anchor (500 lb)
Sea bed
Charles Darwin 37
Mooring configuration

Figure 3

Table 7

Moorings V,VI,VII

Height above seabed	Mooring V	Mooring VI	Mooring VII
826 m	.		Sediment trap
804 m	RCM8 (9441) P (0 to 9000) HRT (-1.4 to t1.4) V 1st record 2300/046	RCM8 (9440) P (0 to 9000) HRT (-1.4 to t1.4) V 1st record 2000/046	RCM8 (9439) P (0 to 9000) HRT (-1.4 to t1.4) V 1st record 2100/046
52 m	RCM8 (9423) C (25 to 72) HRT (-1.4 to t1.4) V 1st record 1800/046	RCM8 (9422) C (25 to 72) HRT (-1.4 to t1.4) V 1st record 1600/046	RCM8 (9421) C (25 to 72) HRT (-1.4 to t1.4) V 1st record 2300/046
21 m			Sediment trap
12 m	RCM5T (8250; 74D) T (-2 to 21) TR (0 to 100) V 1st record 1700/047	RCM5T (7063; 79D) T (-2 to 21) TR (0 to 100) V 1st record 1400/048	RCM5T.(6750; 73D) T (-2 to 21) TR (0 to 100) V 1st record 1300/048
6 m	CR 200 (2496) (320; 460; 1.16; 64)	CR200 (2495) (320; 240; 1.04; 40)	CR200 (2467) (320; 260; 1.02; 30)
4 m	CR 200 (2492) (320; 380; 1.12; 35)	CR 200 (2493) (320; 280; 1.16; 65)	CR200 (2494) (320; 420; 1.10; 30)
	Deployed 1107/064	Deployed 1440/065	Deployed 1306/067

All instruments have a sample interval of 60 minutes. All moorings have 400 lb of buoyancy.

RCM8 = Aanderaa vector-averaging current meter
RCM5T = Aanderaa current meter with Seatech transmissometer
CR200 = IOS 10 kHz command release
T = standard temperature
HRT = high-resolution temperature
P = pressure
c = conductivity
TR = transmission
v = velocity

3.8. EXPENDABLE BATHYTHERMOGRAPHS (XBT'S)

Type T7 probes were launched on all three legs of the cruise at various locations (see Table A3), although concentrating on the region of the Antarctic Convergence. The launcher was connected to a Bathy Systems Model SA 810 XBT Controller and a Hewlett Packard 85B microcomputer. The latter was used for the initial processing of the data and for profile plotting. The profiles were then coded and in conjunction with the meteorological observations (carried out by the ship's officers) were sent to the Met. Office at Bracknell. The XBT data were then transferred to the ship's computer (see section on Data Processing and bogging for further information).

3.9. SURFACE WATER SAMPLING

On legs 2 and 3 water samples were taken to coincide with most XBT launches, using the ship's non-toxic seawater supply. The tap in the Wet Lab was run for approximately 15 minutes to allow the system to be flushed through and 'fresh' seawater to be drawn up to the tap. Approximately 11 of seawater was collected in a 21 plastic screwtop bottle. Using a filter pump, the sample water was drawn through a Nuclepore polycarbonate filter (47mm diameter, 0.4μm porosity) attached to a nuclepore filter holder. The filter was rinsed in fresh water to prevent the residual salt from recrystallising on drying. The filter was then placed in a Petrislide storage holder and allowed to air dry.

The filters will be analysed for phytoplankton using scanning electron microscopy.

3.10. DATA lOGGING AND PROCESSING

Description of the data logging system

Logging of all navigation, magnetics, gravity and CTD data was done by the RVS 'ABC' system. This consists of three 'levels': level A, level B and level C, connected to each other by a Cambridge ring. 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 it to a standard digital code which is passed to the level B. bevel 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. In level C the raw data are written to disk files ('streams') which are updated as and when new data come 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'. XBT data were transferred to the level B from the Hewlett Packard 85B in the XBT system, via an RS232 link. This was done using a program called 'XBT8C', written on the HP85B by D. Beasley during Leg 2.

Performance of the data logging system

Generally, the logging system performed well throughout the cruise.

There were 2 level B stoppages on each leg. The cause of these stoppages is not known, but in every case the alarm quickly alerted the watchkeeper and the level B was reset in a matter of minutes. The only level A which gave problems was the one on the CTD system. The CPU board in this level A was replaced and there were no further problems.

The level B logged all GPS and transit satellite fixes. EM log and gyro data were logged by the level B at 1 second intervals, and gravity and magnetic data were logged at 6 second intervals. Water depths were sampled manually from the PES at 4 minute intervals while underway, and at longer time intervals while on station or hove-to. The CTD level A received data at a rate of 16 samples per second and produced one second averaged values which it sent to the level B.

Data Processing

Data processing was done by a suite of programs on the level C. EM log and gyro data were combined by program 'relmov' to produce 1 minute averaged values of velocity north and velocity east. GPS data were smoothed and converted to one minute samples by program 'gps_av', then interleaved with transit satellite/DR data by program 'bestnav', which produces an output file with a position for every minute that data acquisition was in progress. A fuller description of the function of these navigation data processing programs is contained in the RRS Discovery Cruise 172 Cruise Report.

Carter Corrections (Carter, D.J.T., 1980. Echo Sounding Correction Tables, third edition. Hydrographic Dept, Ministry of Defence, Taunton) were applied to all water depths entered into the level C by program 'prodep'. Program 'promag' was used to subtract the IFGRF85 from the 1 minute averaged raw magnetics data. Gravity data were referenced to IGSN71 using the base tie made at Valparaiso at the start of CD36 (day 323/88). No drift corrections were made on board because of uncertainty about the validity of the Port Stanley base ties (see gravity report). Program 'prograv' was used to carry latitude corrections (using the Gravity Formula 1967) and Eotvos corrections (using the output from 'bestnav') on one-minute averaged raw gravity data. On legs 1 and 2 the Eotvos corrections calculated from 'bestnav' output were applied directly to the gravity data. On leg 3 Eotvos corrections were smoothed using a 9 minute running average before being applied to the data. The justification for this is that the navigation data contain a relatively high frequency noise component which would otherwise be transferred into the gravity corrections.

Files of 1 minute sampled processed data ('bestnav' output, corrected depth, IGRF85 corrected total magnetic field and free-air anomaly) were created using program 'mutli' and transferred to a BAS IBM PC using the 'kermit' communications package. data were transferred to the IBM PC in the same way, after being transferred from the XBT system to the level B and from the level B to the level C.

Subsequent examination of the magnetic anomaly reduction procedure at BAS HQ, Cambridge, indicated that the software used by RVS to calculate the value of the geomagnetic reference field at a specified point on the spheroid was not as accurate as similar software developed by the British Geological Survey (BGS).

This was considered to be caused by two factors:-

1. the RVS software uses only 80 of the 120 specified spherical harmonic coefficients of the IGRF;

2. and the software uses a reduced number of Schmidt quasi-normal coefficients (45 as compared to 66).

As a result of these investigations, all of the magnetic anomaly data for the cruise were reduced a second time using the more accurate software from the Geological Survey.

R.D.Larter, with advice from
D.Lewis, R.Pearce, C.Paulson and R W Woollett, and
using extracts from the Data Logging, Navigation and Processing Report
written by I.W.Hamilton for the RRS Discovery Cruise 1'72 Cruise Report.

4. Charles Darwin Cruise 37 - Statistics

1)	Total cruise time from leaving Stanley to arriving Valparaiso (3/l/89 - 10/4/89)	= 97 days
	Distance steamed all cruise	= 15.139 miles
	Calls in Port Stanley and Berekley Sound	= 6.2 days
	Passage time (61°S to Valparaiso)	= 8.6 days
2)	Total working time	= 82.2 days
	Distance steamed working	= 13810 miles
3)	Lost time due to bad weather, returning to Stanley beg 2 and repairing the GLORIA cable at Smith Island	= 12.1 days
4)	Total underway time (including time between stations)	= 68.7 days
5)	Total station time (CTD and wire testing)	= 1.4 days
	Total PES time distance 14230 miles (26372 km)	= 84.7 days
	Total gravity time distance 12785 miles (23694 km)	= 76.1 days
	Total magnetics time distance 11827 miles (21920 km)	= 70.4 days
	Total single channel seismic time distance 8938 miles (16564 km)	= 53.2 days
	Total GLORIA time distance 10080 miles (18682 km)	= 60.0 days
	Total 3.5 kHz profiling time distance 12970 miles (24037 km)	= 77.2 days
	Total ADCP time distance 14431 miles (26746 km)	= 85.9 days

NB Distances are expressed in nautical miles and have been calculated assuming an average speed of 7 knots.

5. SHIP'S COMPANY R.R.S. CHARLES DARWIN CRUISE 37

	Leg 1	Leg 2a	Leg 2b	Leg 3
Master	P.H.P. Maw	S.D. May1	K.O. Avery	
Chief Officer	S.Jackson	K.O. Avery	A.R. Louch	
2nd Officer	R.J. Chamberlain	A.R. Louch	B.M. Richardson	
3rd Officer	G. Proctor		J.L. Clarke	
Radio Officer	J.G.L. Baker		C.R. Brown	
Chief Engineer	G.M. Batten		D. Anderson	
2nd Engineer	G.A. Robertson		G. Gimber	
3rd Engineer	V.E.D. Love11		B. McDonald	
Electrician	P.G. Parker		P.E. Edge11	
Doctor	A.T. Leanord		R. Butler	
Bosun	D.C. Wiseman		M. Trevaskis	
A.B.		A. Marren		
A.B.		M.J. Drayton		
A.B.		W.M. Dowie		
A.B.		M.J. Robinson		
A.B.		R.T. Cove		
Chief cook	Kevin Peters		G.H. Wood	
Cook		L.C. Alcott		
2nd steward		R.M. Stephen		
Steward		G.M. Cairns		
Steward		R. Pope		
Motorman	K.J.H. Pratley	D.J. Hanlon		-
P.S.O.		P.F. Barker		*C J. Pudsey
Scientist		R.D. Larter		*R D. Larter
Scientist		C.J. Pudsey		
Scientist		R.A. Liver-more		
Scientist		R.W. Jordan		
Scientist		J.S. Tomlinson		
Scientist		A.P. Cunningham		
Scientist			R. Woollett	
Technician (IOS)	M.L. Somers	E. Darlington		M.J. Harris
Technician (RVS)	K.E. Potter	P. Mason		D. Lewis
Technician (RVS)	M.G. Sampson		J. Davies	
Technician (RVS)	J.D. Price		C.H. Woodley	
Technician (RVS)		G.R. White		C.J. Paulson
Technician (RVS)		R.A. Phipps		G.H. Evans
Technician (RVS)		D. Beasley		R.O. Pearce
Technician (RVS)		P. Taylor		

* Co-Chief Scientists for Leg 3.

6. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the willing and effective help, throughout Cruise 37, of RVS personnel, whether ship's company, engineering support or staff onshore. The contribution also of IOS(DL) engineers in support of the GLORIA operation was crucial.

We are once again grateful for the part played by Miriam Booth of BAS Stanley Office in acting as ship's agents during-4 separate visits in the middle of a busy season. BAS personnel in Cambridge also kindly digitised and transmitted weather maps to the ship during Leg 1 in the absence of a promised FAX machine.

Carol J. Pudsey

Table A1

Mooring sites

Mooring	Time of release	Position of ship		Water depth
V	1107/064/89	60°11.2'S	38°09.6'W	2980 m
VI	1440/065/89	59°08.5'S	37°57.9'W	2880 m
VII	1306/067/89	60°19.3'S	43°35.8'W	5500 m

Table A2

CTD positions

Station	Lat. S	Long. W	Time on	Time off	Depth	Comments
889CTD025	60°10.9'	38°09.4'	2301/063	0232/064	2980 m	Mooring V
889CTD026	60°05.5'	38°29.4'	1322/064	1640/064	2835 m	
889CTD027	60°19.9'	37°41.5'	1924/064	2207/064	2995 m	
889CTD028	59°09.2'	37°55.8'	1547/065	1835/065	2880 m	Mooring VI
889CTD029	59°03.3'	37°19.8'	2222/065	0116/066	2898 m	
889CTD030	59°13.8'	38°35.4'	0850/066	1133/066	2898 m	
889CTD031	60°19.6'	43°35.2	1436/067	1743/067	900 m	Mooring VII (sensor failed)

Table A3

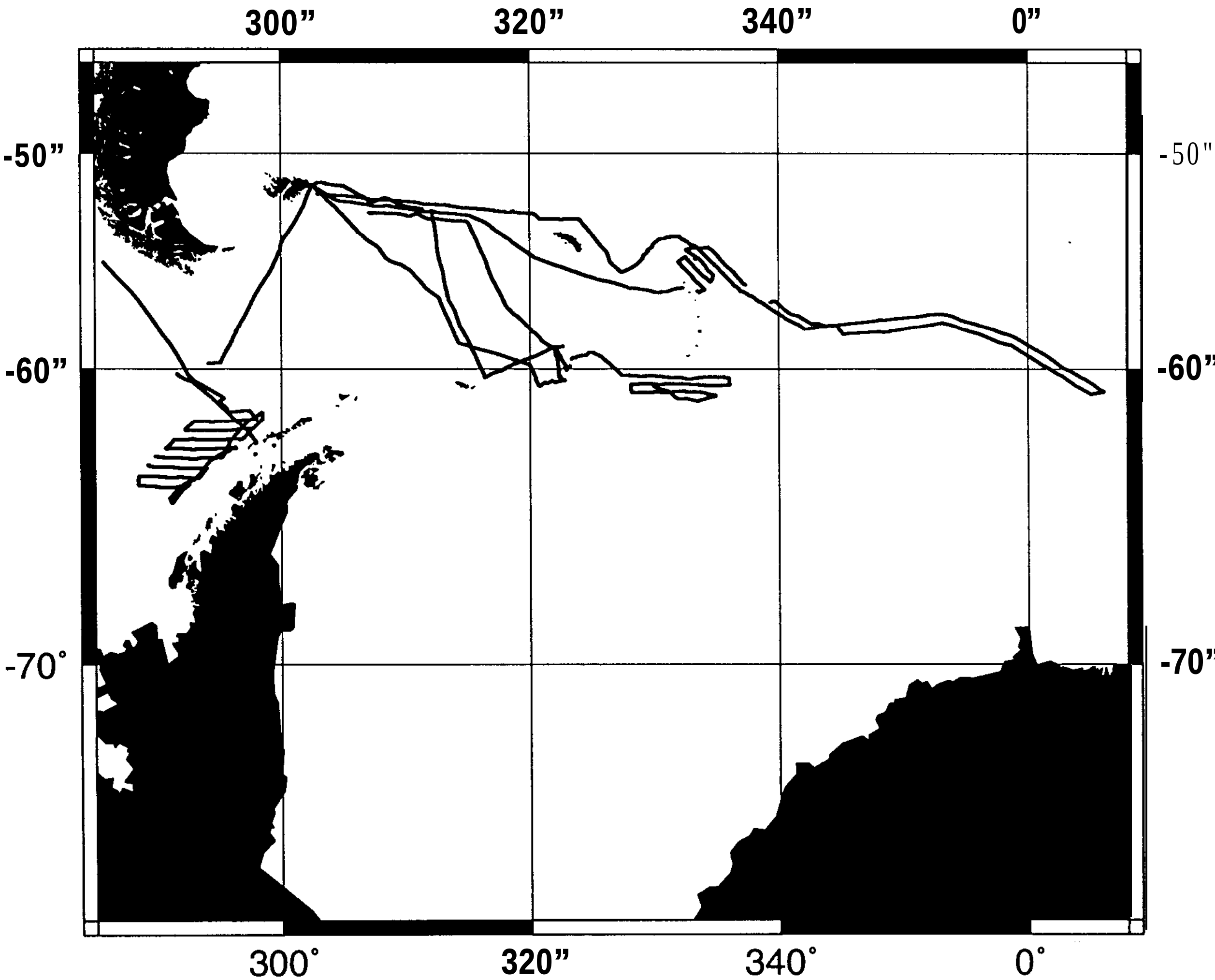
XBT STATION LIST

XBT NO.	DATE/TIME (GMT)	LAT(S) (° ')	LONG(W) (° ')	MAX DEPTH (metres)
2	004 2309	52 20	52 40	380
3	005 1100	52 26	50 08	840
5	005 1655	52 29	49 01	600
7	005 2314	52 36	47 45	900
8	006 0455	52 38	46 40	900
9	006 1120	52 46	45 17	900
10	006 1652	52 48	44 08	900
13	006 2301	52 54	42 53	670
14	007 1055	53 01	40 28	900
15	007 2244	53 19	38 10	900
16	008 1049	53 23	35 55	900
17	008 2313	54 35	34 17	900
18	009 1122	55 36	33 03	900
19	009 2308	55 13	30 54	900
20	010 1128	54 18	29 38	900
21	010 2301	54 25	27 18	900
22	018 1535	60 21	04 22	900 (E. Long)*
23	031 1131	56 14	33 47	900 *
24	032 2317	54 33	41 06	900
25	033 1134	53 46	42 59	150
27	033 2324	53 07	45 10	600
28	034 1129	52 57	47 45	160
29	035 1126	52 45	49 14	900
30	035 2330	52 15	51 40	900
31	036 1133	52 05	53 52	250
32	041 1902	52 35	53 10	400
33	042 0528	52 42	51 02	250
34	042 1731	52 36	48 27	300
35	042 2324	53 16	47 44	610
36	043 0538	53 22	46 43	480
37	043 1117	53 25	45 40	630
38	043 1728	53 45	44 45	900
39	043 2318	54 25	44 14	900
40	044 0517	55 00	43 46	800
41	044 1122	55 42	43 20	880
42	044 1721	56 25	42 45	610
43	044 2318	57 05	42 07	900
44	045 0520	57 32	41 34	140
45	045 1722	58 36	39 23	900
46	046 0515	59 26	37 34	900
47	047 0541	59 19	34 56	900
48	047 1724	60 13	32 39	900
49	048 0529	60 17	30 01	900
50	048 1716	60 23	27 02	230
51	049 0529	60 21	24 19	900
53	049 1804	60 38	26 19	880

54	050 0520	60 36	28 39	900
55	052 1723	61 08	28 16	900
56	054 1136	58 18	38 11	900
57	055 1125	56 31	43 11	870
58	056 0537	55 25	46 47	900
59	056 1718	54 21	50 00	900
60	059 0312	53 21	54 41	500
61	059 1128	54 16	53 13	900
61B(62)	059 1718	54 50	51 52	220
64	060 0528	55 54	49 22	510
66	060 1132	56 34	48 19	880
67	060 1716	57 10	47 11	490
68	061 0534	58 35	46 04	900
69	061 1718	59 17	43 40	220
70	062 0548	59 42	40 45	900
71	062 1714	60 34	38 54	900
72	064 0218	60 11	38 10	900
73	066 2312	59 56	41 55	900
75	067 1711	60 20	43 36	900
76	068 0520	59 25	44 26	900
77	068 1714	58 10	45 41	500
78	069 0521	57 00	46 35	900
79	069 1206	56 15	46 54	900
82	069 1736	55 26	47 11	550
83	070 0516	53 57	47 37	610
84	075 1305	53 30	58 56	900
85	075 2354	54 54	60 11	870
86	076 0528	55 43	60 49	60*
87	076 1114	56 28	61 42	860
88	076 1718	57 21	62 36	890
89	076 2313	58 13	63 27	390
90	077 0531	59 08	64 18	148*
91	077 0549	59 09	64 19	900
92	078 1244	60 13	68 22	900
93	078 1719	60 41	66 49	290
94	078 2311	61 27	64 59	530
96	079 1126	62 19	62 57	870
97	082 0212	62 44	68 30	900
98	083 0445	63 04	63 46	850
99	084 1016	63 22	70 22	900
100	084 2014	63 45	69 40	58*
101	084 2020	63 45	69 39	104
102	085 2311	64 07	69 01	350
103	087 0215	64 26	68 16	400
104	087 0942	64 33	68 00	380
105	089 1530	62 15	62 08	900
106	091 1126	62 01	63 30	270
107	092 0208	61 42	64 04	400
108	092 2323	60 31	66 52	900
109	093 1527	59 00	68 55	330
110	094 0206	57 26	71 01	870
111	094 1551	55 35	73 59	900


CHARLES DARWIN 37
TRACK CHART
British Antarctic Survey cruise 1989
KEY
Position at 0000 (z) Julian day 094
Magnetic, gravity, bathymetric, 3.5 kHz and ADCP data
Single-channel seismic reflection profile
GLORIA swath coverage
Current meter mooring
CTD station
XBT station
Falkland Is
Aurora Bank
South Georgia
South Sandwich Is
South Orkney Is
South Shetland Is
Smith I
Antarctic Peninsula
Larsen Ice Shelf
Shackleton Fracture Zone
TO VALPARAISO
SEE INSET
INSET
50°S
70°W
60°
50°
40°
30°
55°
65°
60 S
20°W
10°
0°
2000m
6000m

Cd37_magnetics



Cd_37_gravity