CRUISE REPORT

CHALLENGER 125 leg B

13 February - 3 March 1996

Ardrossan - Southampton

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3 March 1996

1. Introduction

The primary objectives of Challenger 125 leg B were as follows:

(1) Conduct a CTD/bottle sample survey in the SES box on lines S,N,R,P (prefereably twice).

(2) Obtain estimates of respiration rates at selected sites within the SES box.

(3) Deploy settling velocity tubes at selected sites within the SES box.

(4) Deploy a temporary mooring and conduct a 24 hour station on the S-line in the SES box for internal wave measurements.

(5) In the event of evidence of a dense water cascade, to service the 3 cascade moorings laid during leg A

(6) Recover STABLE (Sediment Transport and Boundary Layer Equipment).

(7) Conduct a series of transects south of the SES box using Seasoar/CTD to examine upstream water properties and structure.

As anticipated poor weather conditions hampered some of the work. A total of 200.3 scientific hours were worked, 122 hours were lost to weather, the landing of a scientist ashore took 15 hours and 2.7 hours were lost due to scientific equipment breakdown. However, most of the above objectives where achieved to some degree. Lines S,N and R were thoroughly sampled once each satisfying the objective of surveying the SES box at least once. Objectives (2) and (3) were achieved fully, as was objective (4). There was no evidence that a cascading event had occured in the SES area, hence (5) was not attempted. Objective (6) was achieved with some difficulty. Objective (7) was partly achieved because Seasoar was damaged early in its deployment. However the demands of (7) were met using conventional profiling CTD package. Ironically, it might be argued that consequently the data return under (7) was enhanced because nutrient and other data was obtained to supplement information on along slope variability of water properties.

In addition to the above prescribed objectives, the N300 mooring was recovered when found adrift and 2 current meters and subsurface buoyancy recovered. A limited survey of water properties in the South Minch was also obtained in a contingency work programme undertaken whilst the ship was forced into sheltered inshore waters by adverse weather conditions.

A total of 131 CTD dips were made (132 casts in the scientific log because at station A650 the down and up dips were each designated as separate casts). The regional breakdown of the casts was as follows: 41 in the SES box, 30 at the S400 site in the SES box as part of the internal wave study, 39 casts south of the SES box for the Slope Continuity Study, 1 CTD/thermistor chain calibration cast, 20 casts during the contingency work in the South Minch.

Despite the loss of time due to weather and the unfortunate damage sustained by Seasoar, the cruise scored a success in the discovery of what appears to be a dense water cascade on the UA section some 100 miles south of the SES box. This is likely to prove one of the most important results obtained in the SES project. Moreover, the nature of the cascade in which density is controlled by salinity will force us to re-evaluate the cascade generation mechanism.

2. Narrative of the Scientific Work Programme

The track of RRS Challenger during the course of the scientific work programme described below is shown in Fig. 1.

RRS Challenger sailed from Ardrossan at noon on Tuesday 13 February after scientific equipment had been loaded. Scientific work commenced at 0654 on Wednesday 14 February when the ship arrived at the SES (Shelf Edge Study) CTD grid. The sea was calm with a slight swell. Five shallow CTD stations were worked from east to west on the priority S-line of the SES grid. At S140, in addition to the regular sampling, a set of sea bed photographs was taken. To prepare the Seasoar instrument for readiness and any convenient future opportunity, its faired cable was streamed aft of the vessel on passage to the western end of the S-line. This also had the advantage of enabling the remainder of the S-line to be worked from west to east, with the prevailing sea and swell astern, in worsening weather conditions. After only 3 deep stations, the weather deteriorated significantly and CTD work was abandoned at 2400 on Wednesday 14 February. The ship remained hove-to overnight but at 0842 on Thursday 15 February, in the face of deteriorating weather conditions, the ship headed eastwards for shelter.

A contingency work programme of CTD lines in the South Minch was put into place. This work began at 0036 on Friday 16 February with an east to west section of 5 stations at latitude 57° 10' N (A-section) followed by 3 stations on a west to east section (B-section) at 57° 10' N. Deteriorating weather prevented continuance of even the contingency programme and the ship took shelter in the lee of Eigg in winds gusting at 60-70 knots. Sampling resumed on the B-line at 0935 on 17 February and a west to east line at 56° 45' N was also worked in deteriorating weather conditions, before Challenger took shelter overnight in the lee of Coll. On Sunday 18 February conditions had abated sufficiently to attempt a further CTD line in the Minch but, before the line was reached, 50 knot winds developed and the ship took shelter from the north easterlies in the lee of Rhum.

On Monday 19 February conditions improved and the ship made for the SES box region. The STABLE rig was successfully interrogated at the S200 site and sampling resumed on the uncompleted S-line. On Tuesday 20 February the second priority N line was worked from west to east as far as station N300. The sampling was broken off here as part of a predetermined plan (in view of forecasts of deteriorating weather) to recover the STABLE rig on Wednesday 21 February.

Wednesday 21 February proved to be a truly remarkable day with occasional bizzare moments. Further details of events can be found in Section 3.3. The vessel arrived at the STABLE site (S200) in the morning. Acoustic release commands on both channels were sent and although STABLE responded that it had released it did not come to the surface. After repeated attempts, it was decided that the only way forward would be to recover the STABLE marker toroid mooring. This would open up several options, enabling us to get closer to STABLE and ultimately allowing us to drag for it if necessary. At 1000 we received an Argos alarm notification that the N300 morring was on the surface and had been adrift for some 24 hours. As we were approaching the STABLE toroid, the N300 subsurface buoy drifted into view and we broke off the approach to recover it. It was recovered succesfully with 2 out of its 3 current meters intact. The third RCM and the acoustic release were missing. After the decks were cleared the STABLE toroid marker was recovered at 1303. The ship then approached the STABLE site once more and obtained an accurate fix on its position using acoustic ranging. After several further attempts to pop up STABLE acoustically, it was decided to drag for the rig with the aim of dislodging STABLE from whatever was holding it fast.

As the grapnel was being towed towards the STABLE site operations were interrupted by a French trawler which was about to steam in a very close approach across the stern. Two French speaking members of the scientific party (first Robin McCandliss then Hilary Wilson) were called upon to communicate with the vessel over the VHF radio with good effect.

After 3 circuits around STABLE, the grapnel was hauled in. At 1758, the complete EMCM spar with a bight of the tow cable around it came up and jammed in the block before the warp parted. The Giffard grapnel, a 25 m length of warp and the EMCM spar were all lost; only the PU coil of one EMCM dropped onto the deck. At 1718 STABLE surfaced and was recovered. There was no indication whatever of why the rig did not pop up normally; all retractor units had fired and there was no evidence of external interference. The rotor stack survived although it lost one savonius rotor. Apart from the total loss of the EMCMs, the associated high-speed thermistors and cables and one sediment cup, the only obvious damage was some heavy scouring on one leg by the main warp.

In the event, despite the loss of the EMCMs, all concerned were greatly relieved at the recovery of STABLE, particularly as all hope of its recovery had seemed lost.

Following the STABLE recovery, Challenger steamed immediately to the N-line to complete the 4 remaining CTD stations. Work then began on the R-line which was designated to be of next highest priority. The rationale for this was that because the high-priority S-line had been sampled in a rather piecemeal fashion owing to weather restrictions, the R-line would provide the next best alternative to quasi-synoptic coverage of the S-line. Work on the R line continued on Thursday 22 February as far as station R1000 in heavy swells and mounting seas. Although the ship reached station R1300, the CTD cast there was not attempted in the face of severe gale force winds and an XBT probe was launched as a substitute.

Weather forcasts initially suggested fairer conditions in sea-area Shannon to the south and it was decided to attempt a passage southward to begin work in that region as part of the Slope Continuity Study component of SES. However, in view of forecasts of deteriorating conditions in Shannon and in heavy seas the southward passage was abandoned after consultation between the Principal Scientist and Master and at 2118 on Thursday 22 February the ship headed for shelter off Islay.

On the morning of Friday 23 February, I was approached by Mr. R. Lloyd (the senior member of the computing support team and the RVS Technical Liason Officer) with a request to be landed ashore on account of a domestic problem. I was told that the Master was prepared to make the landing provided that I agreed. After ensuring that suitable computing cover would be provided, I assented to the request and the ship headed for Ayr to conduct a boat transfer. In view of the fact that the the loss of working time due to bad weather had made the landing of DML personel and their frozen samples at Campbeltown at the end of the cruise an increasingly unlikely prospect, I encouraged Dr. K. Jones to arrange for the accumulated samples to be collected from Ayr and this was duly done.

After landing Mr. Lloyd and the samples, Challenger returned to the Sound of Jura to resume sheltering. By the following morning, Saturday 24 February, conditions had ameliorated sufficiently to head once more for the SES box. The poor weather had, by now, taken its toll on the scientific work schedule and decisions on rationalisation of the programme were required. I decided to attempt to complete all outstanding key elements of the science. Firstly, it was resolved not to recover the cascade moorings as there was no evidence from the SES lines that any such event had occured. Secondly, it was resolved not to complete the SES grid by sampling the P line. This decision was justified on the grounds that the prioriy N and S lines had already been sampled thoroughly. The two outstanding items in our initial set of objectives were the internal wave study and the Slope Continuity Study. It was agreed to conduct the internal wave study next on the grounds that it was the last commitment which tied us to the SES box and, once completed would give maximum scope for an uninterrupted Slope Continuity Study. The CTD data had shown that significant internal wave activity was unlikely. However, the internal wave 24 hour station would also provide valuable information about the variability of all other measured parameters at a single site and hence was judged to have scientific merit beyond the immediate aims of the IW study.

Shortly after midnight on Sunday 25 February a temporary internal wave mooring was deployed at S400 and a cycle of CTD casts at that station each hour, on the hour, was begun. This work finished when the temporary mooring was recovered at 0840 on Monday 26 February. Shortly afterwards a CTD cast was performed with the mooring thermistor chain strapped to the CTD frame to calibrate the thermistor chain.

The outstanding item of scientific work was now the Slope Continuity Study. Challenger was directed to proceed westwards along the S-line into deep (>1000 m) water whilst Seasoar was prepared for deployment. The instrument was deployed at 1233 on Monday 26 February and 200m of cable payed out. There were light winds and low swells. The instrument was undulated and towed onto the shelf where the ship turned and began to tow Seasoar on an outward leg across the shelf break. At 1506 the instrument struck the bottom in 149 m of water at 56° 15.74' N , 009° 00.33' W and all data signals were lost. The instrument was recovered immediately. The Seasoar vehicle had lost both tail fins, the rudder, the lower casing, the bomb weight and the nose cone was damaged. The fluorometer and clamps were also lost but the CTD was intact and undamaged. The circumstances of the incident are discussed further in section 5.

Scientific work resumed immediately and 4 CTD lines crossing the shelf edge south of the SES box were designated. CTD profiling resumed at 1942 on Monday 26 February. Lines UA, UB and UC were located upstream (south) of the SES box at approximately 50 mile intervals and were worked from 26-28 February. As the CTD was being recovered on the last station on the UC line at 0610 on Wednesday 28 February one of the scientific party, Dr. Mark Inall, sustained a hand crush injury as the CTD was landed. He was attended to by the Chief Officer and a member of the scientific party, Robin McCandliss, who is a trained nurse. An accident report form was completed. The final upstream section extended across the entire Porcupine Bank system at latitude 53° 15' N. This section was intended to provide a picture of the upstream conditions on the Porcupine slope as well as sampling inshore waters which are also potentially source waters for the Hebridean slope egion. Moreover, the Porcupine Bank/slope region is also a potential cascade site. Work on the PB line finished at 1406 on Thursday 29 February, from where the ship made passage to Southampton.

The slope continuity survey using the CTD provided what is probably the most important scientific result of the cruise in that clear evidence for cascading was found on the UB section at about 55° N. Contrary to expectations the cascade water was slightly warmer than slope waters and its higher salinity was the source of its negative buoyancy.

Cast 150 – 157
154 especially.

3. Summary of Scientific Work.

3.1 Sampling in the SES grid

Sampling on the SES grid followed the pattern of previous cruises and is not discussed further in detail here. I was, however, surprised to discover before the cruise that there was no definitive list of station positions even though cruise 125 is the fifth in the cruise series. Even on the bridge track plotter there were frequently two positions marked for the same nominal station.

I also decided to extend the SES grid by the addition of stations S6 (56° 27' N , 08° 30' W) and S7 (56° 27' N , 08° 45' W) to the S line and stations N6 (56° 30' N , 08° 30' W) and N7 (56° 33.45' N , 08° 45' W) to the N line. The rationale for this is that the existing lines did not extend far enough onto the shelf to be able to distinguish between true shelf water and slope current water that may have made an incursion onto the shelf. Due to the position of these stations they also serve as shelf extensions of the R and P lines. I recommend that the remaining SES surveys also include these shelf extensions.

3.2 The Slope Continuity Study

The slope continuity study was conducted on 3 'upstream' sections UA, UB and UC separated along-slope by a distance of about 50 miles. The fourth upstream section was located across the Porcupine Bank/slope system. As referred to previously, clear evidence for a cascade of dense, saline, warm, high fluorescence, low transmission water was observed on section UB. There was no evidence of cascading on the SES lines or on UA.

3.3 STABLE recovery (J. Humphery, Proudman Oceanographic Laboratory)

POP-UP STABLE II was deployed during leg A of Challenger cruise 125, in position 56deg 27.60'N, 09deg 02.78'W. It was to be recovered during leg B, after it had had time to record a meaningful amount of data. It was fitted with sensors to record high-speed 3D turbulent currents, pressures and temperatures; tidal currents, directions and pressures, heading, pitch and roll and integrated temperatures were all measured more slowly. It was also fitted with four simple integrating sediment traps.

The STABLE site was approached at 0814GMT on the morning of 21st February, 1996. After first ranging onto the instrument, a signal to actuate the recovery system was transmitted. The transponder replied with the acknowledgement-signal, but STABLE did not surface. The second recovery system was actuated, but again, without success. The process was repeated several times until the ship was immediately above STABLE, but the instrument did not surface.

At 1015GMT, a sub-surface sphere was spotted floating by; on investigation, it proved to be the N300 mooring which was deployed during leg A. The sphere was recovered, together with a submersible Argos transmitter, two current meters and two in-line Benthos glass-sphere buoyancy packages. The remains of a third current meter clearly demonstrated that the mooring had been trawled.

The buoy marking the STABLE site was recovered because it was limiting ship-manoeuverability. After sending more release-commands without success, dragging-operations were started. After interruption by a French trawler, the ship moved round STABLE three times in a tight circle; the wire was then pulled in. The current meter spar from STABLE was caught in the wire and jammed in the A-frame sheave; the main warp parted and the grapnel, spar and all current meters were lost overboard.

The STABLE flashing lights were spotted on the surface at 1817GMT, when it was dusk. Despite the poor conditions, the ship was positioned and the strayline grappled. STABLE was recovered on deck at 1844GMT; it was complete and undamaged apart from the current meter spar and associated instrumentation

3.4. SPM measurements (R. Mc Candliss, University of Wales, Bangor)

The overall project objectives, which extend over all six cruises, include:

a) Measurement of variation in concentration of suspended particulate matter (SPM) at the shelf edge over a range of spatial and temporal scales using moored and CTD-mounted optical beam transmissometers.
b) Determination of SPM composition, size and settling velocity by analysis of water samples.
c) Modelling of SPM dynamics over short term and seasonal time scales using coupled physical/biogeochemical numerical models.
d) Assimilating model output with measurements to esimate along- and across- slope fluxes of constituents of SPM.

1) Calibration of CTD-mounted transmissometer

A total of 140 samples were collected from Niskin bottles during CTD surveys and filtered through pre-weighed 47mm GF/C filters. Between 8 and 10 litres of water were filtered for each sample. These samples will be used to convert optical beam attenuation measured by the CTD-mounted transmissometer into total SPM concentration.

2) Particle size/shape distribution

It was not possible to perform any analysis of particle size because the laser component of the instrument was broken and not repairable before sailing. The camera and video components were functioning, however and 91 2 litre water samples from various depths and locations throughout the cruise were videoed for shape analysis at a later date.

3) Particle settling velocity

The UWB Settling Velocity Tubes were deployed successfully 5 times during the cruise when time and weather conditions permitted.The tubes, after deployment, were set upright on a stand and subsamples were withdrawn from the base of the tube at 1, 10, 20, 40, 80, 160, 320, 440 and 600 minutes. Subsamples were filtered through pre-weighed Cyclopore 0.4 micron polycarbonate membrane filters for determination of settling velocity distribution of SPM.

3.5. Oxygen Sensor calibration and Respiration Measurements

H. Wilson (University of Wales, Bangor)

The work undertaken consisted of calibrating the CTD-mounted oxygen sensor and taking samples for estimating microplankton and bacterial respiration.

The oxygen pump had been examined on leg A of this cruise and found to have been mounted upside down, causing some of the problems encountered on previous cruises. It was repositioned correctly, and subsequently performed better during CH125B. There are still questions regarding the performance of the pump.

1. Oxygen sensor calibration

The calibration equation obtained by regressing the sensor current against O/S* (O=measured dissolved oxygen concentration, S*=corrected oxygen saturation) for CH125B is:

$$y = 8.1623e\text{-}3 + 0.44872x$$

The dissolved oxygen concentration values obtained from the sensor correlated well with measurements from water samples (r^2=0.974, n=34).

2. Respiration measurements

Samples were taken at five different stations at depths representing the bottom boundary layer, the mixed layer and surface coastal waters. Some shallow coastal samples were lost.

Respiration measurement - SES5 CH125B

Date	Station	Cast	Depth (m)	MP resp. (μM/d)	SE diff	Bact. resp. (μM/d)	SE diff
14/2/96	S140	50	5	0.008	0.196	-0.79	1.057
19/2/96	S300	77	20	0.563	0.116	0.875	0.264
20/2/96	N1500	86	1499	0.131	0.139	-1.590	0.708
20/2/96	N1150	90	1142	0.445	0.498	-0.106	0.608
27/2/96	UBS2	156	60	0.448	0.293	0.862	0.687

The only samples which showed some activity were S300 and UBS2 at 20m and 60m. The error does not allow us to comment on which size-fraction was consuming oxygen. It will be of interest to see if it corresponded to a slightly increased biomass or some slight chlorophyll enhancement.

3.6. Dissolved Nutrients and Dissolved Organic Carbon (DOC), Nitrogen (DON) and Phosphorus (DOP) (K. Jones and J. Leftley, Dunstaffnage Marine Laboratory)

Samples from 104 CTD casts from the Hebridean shelf and shelf edge region and the western Irish shelf edge were analysed on board ship for nitrate (+ nitrite), ammonium, phosphate and silicate using a Lachat QuikChem 2000 flow injection analyzer. At selected sections along the S and N line transects within the SES box additional samples were taken, filtered and stored for analysis for DOC and DON (Miller) at PML and DON and DOP (Grantham) at DML at a later date.

Preliminary analysis of dissolved inorganic nutrient data within the SES area suggests that vertical nutrient distributions were uniform over the shelf and to a depth of 200m beyond the shelf break. Shelf waters contained slightly less nitrate (5.5-6.0 μM l^{-1}) and phosphate (0.3-0.4 μM l^{-1}) than surface waters at the shelf break (7.0-8.0μM l^{-1} and 0.5-0.6 μM l^{-1} repectively).Silicate concentrations were similar in the upper water column throughout the area (3.9-4.1 μM l^{-1}). Below 200 m, seaward of the shelf break, nutrient concentrations steadily increased with depth. Bottom water concentrations of phosphate, nitrate and silicate were c.1.1 μM l⁻¹, 12.2 μM l⁻¹ and 13.1 μM l⁻¹ respectively. It is interesting to note that the relative rate of increase in concentration of silicate with depth was apparently faster than that of nitrate, resulting in near bottom water at S1500 having a silicate:nitrate ratio (c. 1.0) almost twice that in the overlying surface waters (c.0.55).The high silicate concentrations in deep water at S1500 might be explained by mixing of this water with the silicate-rich deep watermass which had been observed to occupy the deep (>2000 m) of the Rockall Trough during Challenger 123B.

3.7 Chlorophyll (K. Jones and J. Leftley, Dunstaffnage Marine Laboratory)
Water samples from the upper 100 m at each station were filtered through GF/F glass fibre filters and the filters stored frozen for later analysis for chlorophyll a at DML. Samples were also taken at each station from the non-toxic seawater supply and treated in a similar manner. Results of chlorophyll analyses will be used to calibrate the CTD fluorometer and the deck-tank fluorometer monitoring near-surface chlorophyll concentrations.

Fluorescence profiles in the SES region show higher fluorescence over the shelf and lower fluorescence offshore with a strong gradient in fluorescence at the shelf break. Confirmation of whether this represents a real difference in chlorophyll standing crop or simply a variation in optical properties of the suspended particulate material between the two domains awaits calibration of the CTD fluorescence sensor.

Similar differences between shelf and offshore fluorescence were seen in transects across the shelf break south of the SES area. In particular along the UB transect fluorescence is a particulary effective tracer of shelf water cascading down the slope.

3.8. Dissolved Iodine Species (K. Jones and J. Leftley, Dunstaffnage Marine Laboratory)
Water samples were taken from the non-toxic supply for later analysis for iodide and iodate (Truesdale, Brookes University).

3.9. Internal Wave Observations (M. Inall, University of Wales, Bangor)
A light weight mooring with an S4 current meter and a 76 m thermistor chain was deployed for a period of 30 hours near station S400 in 425 m of water. This water depth allowed for the upper 30 m of the pycnocline to be sampled by the moored instruments and the ADCP to sample the full depth of the water column. The 400 m contour also coincided approximately with the position of the density front between the shelf waters and slope water. During the deployment full depth CTD casts were made every hour, and water samples taken for nutrients, chlorophyll and SPM analysis. The mooring was successfully recovered and data retrieved. It is not yet clear how well the internal M2 tide was sampled, nor how much higher frequency internal wave activity was present.

4. Performance of Scientific Equipment

4.1 Underway recording and sampling
The surface instruments , including transmissometer # 104D, fluorometer # 246 , thermosalinograph # TSG103 and ADCP all worked well without any major faults. However it was discovered that a step function was imposed on the TSG temperature trace

by a coffee machine which was being used on the clean supply.

The ADCP heading output was found to be incorrect at the start of the cruise , the fault was found to be in the synchro card and it was changed for the spare card; data were gathered using the RDI Transect software. After this problem was dealt with, the ADCP functioned satisfactorily throughout the cruise. Its standard setting throughout the cruise was with 8m bin depth and ensemble averaging interval of 5 minutes. During the Internal Wave study on 25-26 February it was reset with bin depth 8m and averaging interval 2 minutes. It should be noted that the ADCP Transect software was not equipped to deal with leap years so 29 February was recorded as 1 March and all subsequent dates were affected. Notes to this effect were entered in the scientific log.

4.2 CTD

The profiling instrumentation comprised Neil Brown Mk 111 CTD #1195 , fluorometer # 229 transmissometer # 103D .In total 132 casts were carried out on leg B CH125.

Faults occurring during the cruise were as follows:-

1. The power connector on the CAD unit leaked causing tracking and burning of terminals , therefore causing loss of power to CAD.
2. An intermittent data loss occurred .On investigation this was found to be due to a loose component in the underwater unit.
3. The termination on the CTD failed once and this was remade.

During various casts, 3 10L Niskin bottles were damaged and 1 SIS Reversing thermometer was broken. On deep stations, the requirement for 10-11 bottles made the operation vulnerable to further bottle losses. It is recommended that the stock of 10 litre bottles be replenished to enable spares to be carried.

5. Damage to Seasoar

The damage to Seasoar on this cruise is regrettable. The deployment of Seasoar at the Hebridean shelf was always going to be a high-risk operation and the Principal Scientist and Seasoar operaters were apprehensive about it. Several discussions between Seasoar operators and the Principal Scientist were held in advance of the deployment which were concerned with the strategy for its use. The original intention had been to deploy it on 500-700m of cable in deep water and tow in oblique zig-zags across the shelf edge. In response to increasing anxiety, this strategy was abandoned in favour of a more cautious approach. It was agreed that Seasoar would be deployed in deep water on 200 m of cable and undulated onto the shelf where a slow turn of 10 degrees per minute would be made. On the oblique off-shelf course, cable would be paid out and Seasoar undulated over the shelf edge. In deep water, the Seasoar cable would then be hauled in to 200m length and the ship would set a course onto the shelf again. This towing cycle would then be repeated to incorporate 5 off-shelf transects. Primary data collection would thus be confined to the out-legs over the slope to minimise risks of bottoming the instrument. In the event, despite this more cautious strategy, the instrument struck the bottom on the shelf over a relatively flat sea bed terrain.

After the incident, the Principal Scientist instituted an immediate inquiry and obtained the necessary plots of flight path and bathymetry from the ship's on-board computer. As a result of this information and discussions with the operators, it was concluded that there was no single cause for the accident but that several factors had acted in combination.

(a) The operators had difficulty flying the instrument and, in particular, the bias control was very sensitive to adjustment. Operating the dial locking control was itself liable to upset the chosen setting. Operators were unable to find any setting where the fish would fly in a level position for more than a few seconds. Apart from the settings in the CI handbook, which did not relate to the type and length of cable in use , there were no other guidelines to follow regarding dial settings for the deck unit. Settings were left as found except for small adjustments to try and improve the flight path of the fish.

(b) The CTD depth read -4.0 metres at the surface which meant that the fish flew 4 metres deeper than indicated by the pressure readings. It was intended to correct both the Neil Brown and Labview Calibration files to minimise this error but lack of familiarity with the Labview software meant that this was not done. The positive offset to the pressure reading could have lead to some confusion which inevitably reduced the margin of safety when the fish was near the bottom.

(c) The operators aimed to undulate the instrument to within 7-10 metres off the bed which with hindsight, even without the potential confusion over the pressure offset, was probably too close. However, given the difficulties experienced in flying the fish, the setting of a more conservative depth margin may have had little practical effect.

At the time of the incident the Seasoar was being flown by Nigel Mathers, the most experieced Seasoar operator on board. Neither he nor John Wynar nor Andy Jones can be held at fault for the incident. As Principal Scientist, I take full responsibility for any deficiencies in the operational strategy which may have contributed to the incident. In particular, I take responsibility for not having insisted that the pressure correction be implemented and for not ensuring that the operators fully understood the implications of the offset. Moreover, I take responsibility for not having formally specified a minimum height off the bottom for the undulation path. Both these factors could have improved the safety margin, perhaps averting the bottom impact that occurred.

In retrospect, however, I am of the view that in its present form, with the existing control mechanism and vehicle design, Seasoar is unsuited to operation in regions of steeply varying terrain. Although variable topgraphy did not contribute to this particular incident, my opinion is that, given the difficulties experienced in flying the instrument, we were likely to have experienced severe problems later in the flight when undulating over the shelf edge and slope. Indeed the diagnostic plots indicated a near miss at the shelf break on the initial on-shelf part of the tow.

A number of suggestions for improving Seasor in the light of the difficulties experienced are suggested:

(i) It would be an advantage if future operators of the Seasoar could have details of previous cruise deck unit settings with comments regarding ship's towing speed, amount of cable out and details of any problems encountered during deployment or recovery.

(ii) Regarding the deck unit, action is required to reduce the sensitivity of the bias control so that it can be set with confidence and locked in position. It would also be useful to incorporate a readout from the Simrad into a digital display on the deck unit front panel so that the operator can concentrate on one unit at a time especially when working in shelving or shallow water as we were.

(iii) A preset control for getting the fish down from the surface would be useful to avoid having to keep altering the emergency climb override control.

(iv) A serious defect in the control system is that in the event of power being lost to the deck unit, the current to the Moog valve disappears. Presently, if the fish is climbing, it will eventually come to the surface but if it is diving it will continue to do so. It is suggested that a small box capable of withstanding the maximum pressure that the seasoar experiences should go in line with the leads to the CTD and Moog valve. Inside there would be a 9v battery, with suitable dropping resistor to feed current to the Moog valve. The current would pass through a small low voltage relay. When power is on to the CTD, the relay coil, fed via a suitable filter to prevent loss of data signals would be energised and allow the valve current to flow from the deck unit to the Moog valve. If the deck unit fails then the CTD could be switched off and the relay would become de-energised and apply current from the battery to cause the Moog valve to drive the wings to a climb position and bring the fish to the surface.

(v) The incorporation of a small Altimeter in the fish might assist in avoiding collision with the seabed.

6. Support Services

6.1 RVS Scientific Instruments Group

As usual I found an excellent level of support from SIG. Both Andy Jones and John Wynar were very competent and helpful at all times. I suspect at times they may have had an excessive workload, particularly as on their watches they took charge of both CTD control and deck operations, clearly out of their sense of responsibility for RVS equipment.

The damage to Seasoar was clearly a grave dissapointment to the SIG staff. I also feel that both I and the RVS staff could have benefited from the services of a Technical Liason Oficer and the departure of Mr. Lloyd without suitable cover in this field was regrettable in the circumstances.

6.2 RVS Computing

The loss of Mr R. Lloyd partway through the cruise clearly increased the workload of the remaining member of the computing group. My main concern with computing support during this cruise was the slow turn around time for the production of section plots. My view is that the primary difficulty here rests, not with the computing staff aboard the ship, but the computer system itself. Modern oceanography demands near-real time access to data and failure to deliver this is a serious problem.

My central requirement as a customer-scientist is quick access to contoured plots of CTD sections. Ideally I would like to have a contunious access to contoured data of the major parameters as the section evolves station by station. Whilst working in the Minch (in shallow water), this was achieved by demanding 2-second averaged listings of data and updating, station by station, a hand drawn section plot on A4 graph paper. I was was doing this 15 years ago and it seems that, despite the advances in computer technology, I still have to resort to this technique to get what I want, when I want it ! The importance to the scientific operation of near-real time evolving section data is immense and is used to (i) quality control data (ii) provide information enabling operational changes to sampling strategy to be made as data is being collected. This includes, for example, changes to station separation or extension of sampling lines. Given the high cost of ship time, it is essential that sampling be conducted optimally and quick availability of data, presented in a suitable form, is central to this.

The present RVS ship board computing system is well suited to data logging and archiving but is far from ideal in presentation of near real-time evolving section plots. There are PC based packages, however, which perform much better than the RVS system and which I have seen in operation on other, much smaller, though less well-equipped vessels. My requirements in this respect are not unusual and they are currently satisfied by pencil and paper. After so many years, it is about time the RVS computing section dealt seriously with this requirement. I expect that by the time I sail on a NERC ship again I can leave my graph pad behind.

6.3 Marine Staff

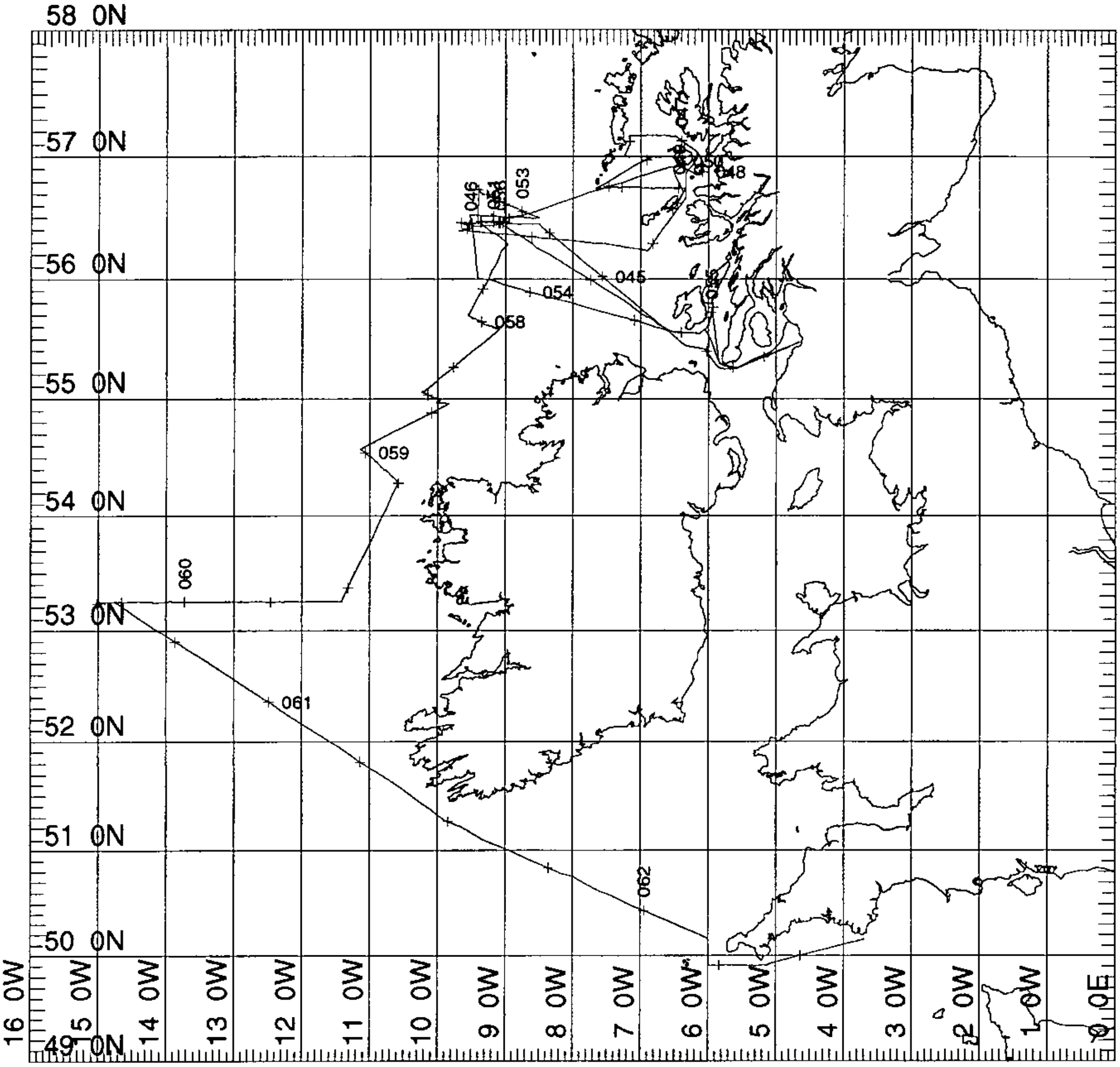
The services provided by the marine staff were excellent in all respects. I found Captain Harding approachable and most helpful throughout the cruise. The other officers and crew were also most cooperative and helpful at all times. Particular mention is given to the Chief Officer, Roger Chamberlain for his assistance in deck operations. His keen interest in the scientific work and his good humour in dealing with the scientists is a great credit to RVS Marine. The catering staff also deserve particular praise for the service they provided throughout the cruise, often in heavy seas. The vegetarians in the scientific party were most impressed by the meals prepared for them.

6.4. Scientific Staff

I am grateful to all my scientific and technical colleagues for their hard work and patience during this cruise. I single out John Humphery (POL) for particular mention because, in addition to his normal duties, he acted at rather short notice to log cruise events on behalf of BODC. His painstaking care in this regard has made an important contribution to the work.

7. Conclusions

Challenger 125 (B) was a demanding cruise with a number of disappointing setbacks including loss of time due to bad weather, damage to STABLE during a difficult recovery and damage to Seasoar. Nevertheless despite these problems all key ingredient of the initial scientific objectives were achieved. The identification of a probable dense water cascade on the Hebridean shelf is an achievement of cruise 125 that I trust will be remembered long after the problems have been forgotten.



MERCATOR PROJECTION

GRID NO. 1

SCALE 1 TO 6500000 (NATURAL SCALE AT LAT. 53)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 53

RRS Challenger Cruise 125 Leg B - Cruise Track