I.O.S.

R.R.S. DISCOVERY
CRUISE 86

7 - 30 September 1977

Meteorological and Oceanographic Observations in the Rockall Trough
(JASIN 1977)

CRUISE REPORT No. 57

1977

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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SCIENTIFIC PERSONNEL

Prof. W.V. Burt	Oregon State Univ.	Moored met. instruments, thermistor chains
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Mr B. Moore	Oregon State Univ.	Moored met. instruments, thermistor chains
Mr B.A. Hughes	IOS Bidston	Moored current meters, tide gauge
Mr J.W. Cherriman	IOS Wormley	Moored current meters
Mr R.F. Wallace	IOS Wormley	Moorings, workshop
Dr R.T. Pollard	IOS Wormley	Batfish, E.M. shear probe, etc.
Mr V.A. Lawford	IOS Wormley	Batfish
Mr J.A. Moorey	IOS Wormley	Salinometer, surface T & S
Mr J. Smithers	IOS Wormley	CTDs
Dr C.H. Clayson	IOS Wormley	E.M. probe, P.R. buoy, VAECM
Mr K.G. Birch	IOS Wormley	E.M. probe, P.R. buoy, VAECM
Dr P.K. Taylor	IOS Wormley	Radiosondes, LO-CATE
Mr A. Osmond	Met. Office	Radiosondes, LO-CATE
Miss T. Colvin	IOS Barry	Computing
Mr P.R. Hartland	IOS Barry	Computing
Mr I. Innes	IOS Barry	Computing
Mr M. Butterfield	U. of Southampton	Float tracking
Mr N.W. Millard	IOS Wormley	Float tracking
Dr P.M. Saunders	IOS Wormley	Float tracking, CTD
Dr J.C. Swallow	IOS Wormley	Float tracking, Pr. Sci.

INTRODUCTION

This cruise was part of JASIN 1977. Its purpose was to continue exploration of the JASIN area (roughly 57°-60°N, 10°-14°W) begun earlier in the year by cruises of "Challenger" and "Tydeman", and to evaluate various instruments and observational methods for possible use in the proposed 1978 experiment.

The main items in the scientific programme were

(1) Setting and recovering four surface moorings carrying meteorological recorders and shallow thermistor chains

(2) Occupying a pattern of CTD stations, in the form of widely spaced small (15 km) triangles, each triangle being occupied twice in a 12½ hour period

(3) Acoustic tracking of near-surface floats, including depth-telemetering floats

(4) Tests of a new batfish and using it for mapping near-surface water structure

(5) Trials of an electromagnetic shear probe

(6) Radiosonde tracking, including use of W-3 LO-CATE equipment

(7) Trials of pitch-roll buoy

(8) Intercomparison of electromagnetic and rotor-vane vector averaging current meters

(9) Recovering six current meter moorings and a tide gauge, set by "Challenger" in July

(10) Surface T and S observations, and bathymetry, on passage when in deep water.

Weather conditions varied, but were mostly good, and work of some kind was always possible. Some progress was made on all the items listed above. All the moorings and the tide gauge were recovered. The e.m. shear probe was lost, but not before some records had been obtained from which its performance could be assessed. More detailed accounts of equipment and observations are given below.

NARRATIVE (see Figs. 1 and 2 for track charts)

'Discovery' sailed from Southampton at 1145/7th September. Three days passage in good weather via the west coast of Ireland brought us to the JASIN area early on the 10th. The first task was to set the four surface moorings, one per day on shallow seamounts, alternating with overnight CTD or batfish work. The first mooring (U3) was set on Anton Dohrn seamount a.m. 10th. On the way to the second mooring position, on the northern slope of Rockall Bank, a triangular pattern of CTD stations to 1200 m was occupied. We had intended to do six stations, repeating the triangle with 6-hour intervals, but troubles with the CTD delayed the start. The second surface mooring (U4) was set in the afternoon of the 11th, after a fruitless search for B1 mooring nearby. Overnight, another triangle of CTD stations was occupied twice and the third surface mooring (U1) was set on George Bligh bank in the afternoon of the 12th. A batfish run was planned from there to the next mooring site, but it soon had to be recovered (noise in its CTD output) and instead several shallow stations were done with the lowered CTD. Subsurface moorings W4 and W1 were interrogated during the overnight run to Rosemary bank. The weather had deteriorated by the time we arrived there, but the fourth surface mooring (U2) was set in a 40 kt wind, p.m. 13th.

A batfish run was made from there to W3 mooring position, near which another triangle of CTD stations was planned. The weather was not fit for CTDs by then, but W3 was interrogated and the batfish run continued on a northwestward course towards moorings W1 and W4, which were thought to be in a suitable region for float tracking and testing other instruments. On the way, during the 14th, the compensating electric winch was tested working from a lowered pressure transducer, and the gyro housing of the electromagnetic shear probe was lowered for a leak test. Overnight, a triangle of CTD stations was occupied twice, near moorings W1 and W4, and an acoustically tracked surface float was launched on the last station. Wire tests of various instruments (e.m. shear probe housing, bottom transponders, remote interrogators) were done alternately with fixing the surface float. A pressure-telemetering float was launched, but an error in loading made it go too deep, and its release did not work, so the float was lost. Two bottom transponders were laid for acoustic navigation whilst fixing floats. Next day (16th) the electromagnetic shear probe was lowered on the electric winch for a test, but after several hours recording the winch cable broke and the probe was lost. A group of four surface floats was then launched and tracked overnight relative to the bottom transponders and a remote interrogator, all of which were recovered in the afternoon of the 17th.

The pitch-roll buoy was then launched, with a float and drogue attached, and the batfish was towed repeatedly round a 5-mile triangle, keeping the pitch-roll buoy at one corner, until a.m. 18th when the batfish and pitch-roll buoy were recovered.

By then it was time to start recovering subsurface moorings; W1 and W4 were recovered that day, followed by a batfish run towards W3 position. Arriving there soon after midnight, the triangle of CTD stations (omitted earlier because of weather) was occupied twice, and W3 mooring recovered p.m. 19th. From there, a zig zag batfish course was set towards moorings B2 and W2, and overnight another series of 5-mile triangles was run with the batfish, relative to a surface float. Moorings B2 and W2 were recovered in daylight on the 20th, and another batfish run was made, north-northwestwards to 59°30'N, 13°W, thence via surface buoys U1 and U4 to the neighbourhood of mooring B1 and the tide gauge on the north slope of Rockall bank. Those two items were recovered in the forenoon of the 21st. In the afternoon, the vector-averaging electromagnetic current meter was compared with a conventional VACM by streaming the two instruments under a surface float from the ship whilst lying to, and a further test was made with the remaining pressure-telemetering float.

Having recovered all the subsurface moorings, a start was made next day on the surface moorings, which were recovered in the reverse order. Mooring U2 on Rosemary bank was recovered a.m. 22nd, after an overnight batfish run from near U4. From U2's position, another batfish run was made via 60°N, 11°W to U1 on George Bligh bank. It was recovered a.m. 23rd and, with the prospect of worsening weather, an attempt was made to recover U4 late that afternoon. That had to be abandoned after several tries, resulting only in damaging the meteorological instruments on the buoy. Overnight, surface T and S were recorded along a track returning to U4's position, using the batfish on deck connected to a sea-water hose. Next day (24th) the weather was not fit for mooring recovery. The pressure-telemetering float was launched and recovered several times with different loads, and was tracked overnight until a.m. 25th. Mooring U4 was then recovered in better weather, and the batfish was towed on a track ending near U3 mooring a.m. 26th. Again, the weather was not fit for recovering the mooring (wind 43 knots and heavy swell). The pressure-telemetering float was launched and tracked until late afternoon, when the weather had improved sufficiently for U3 mooring to be recovered. After a further intercomparison of the vector-averaging electromagnetic current meter and a VACM, a batfish run was made ending at the southernmost triangle of CTD stations, which had been occupied only once at the beginning of the cruise. That triangle was worked twice during 27th September, after which 'Discovery' set course for Barry, arriving there via the Irish Sea at 0900/30th September.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the continuing contribution made by the master, Captain M. Harding, and the officers and crew of the R.R.S. 'Discovery', to the success of the scientific work. Particular acknowledgement is due for the efforts of the boat's crew who went out to repair instruments and attach extra recovery lines to the surface buoys, sometimes in poor weather.

J.C. Swallow

NOTES ON EQUIPMENT AND OBSERVATIONS

BATFISH (staff concerned: Lawford, Pollard, Smithers)

The new IOS Batfish was successfully launched and recovered 12 times, completing 126 hours of data collection (Table 4). The normal cycle was from 10 m to 85 m depth, with a period of between 3 min and 5 min, using approximately 160 m of faired cable. Several servo-controlled horizontal runs were made at various depths between 15 m and 90 m. One run was made servoing along the 11.5°C isotherm. The cycling mode tended to be irregular in the depths attained at the top and bottom due to a tendency of the vehicle to shear off to one side or the other of the ship. Cable angles reached 45°, generally to port. It was not found possible to correct this fault during the cruise. Variations in depth during the horizontal tows decreased considerably the deeper the tow, until at 90 m depth variations of less than 2 m peak to peak were obtained. Isothermal towing proved to be a practical proposition as long as the water was reasonably stratified. On three occasions the batfish CTD was run on deck, being supplied with water from the ship's fire main. The hose was connected to a fitting clamped directly to the CTD sensor head. As the fitting was made from perspex it was possible to observe the flow of water about the sensors. No aeration was observed, the water velocity across the sensors being approximately 6 m sec^{-1}. Throughout the cruise a number of fastenings on the vehicle came loose and it was necessary, to mechanically lock as many as possible. On recovering the vehicle after the first run it was found that the towing bridle had become slightly bent downwards; during the last run this bend became considerable, precluding any further use of the vehicle. Two runs had to be aborted due to slight leakage of water into the CTD core and one through loss of a core in the towing cable. The new IOS-built hydraulic unit performed excellently throughout, less than 3 ml of water being found in the outer chamber at any time. Much of the credit for this performance must be due to Mr R.E. Potter who built the unit.

V.A. Lawford

COMPUTING (T. Colvin, P.R. Hartland, I. Innes)

Besides accurate navigation the computer system was used extensively to provide profiles, listings and track charts etc. for the convenience of the main participants of the cruise.

Subjective analysis of the navigational data on a daily basis was made to correct obvious anomalies arising from poor quality fixes. Meteorological, surface salinity and temperature profile data were similarly treated to eliminate known sources of interference. Bathymetric data was logged at six minute intervals.

At all times the prime navigational aid was satellite navigation with Loran-C fixes being calculated for cross reference only. Poor reception of one slave station was experienced throughout and this affected the overall performance of hyperbolic navigation.

Interleaved with the above, which constituted the main bulk of the activity related to the computing facility, user programmes were run as required by the cruise participants. These were in the main related to the calibration of equipment in connection with CTD data and water bottle thermometers. Off-line inputting and processing of data associated with the E.M. shear probe was also carried out.

T. Colvin

CTD WORK (P.M. Saunders, J. Smithers)

42 stations (the first station 9576, the last 9623) were occupied using the Neil Brown CTD during the cruise. Both this instrument and the Hewlett Packard 2100 computer on which the data was logged performed well. A Calcomp plotter normally a peripheral for the ship's IBM 1800 computer was moved into the clean room alongside the HP 2100 and displayed the temperature-salinity data during each cast. The proximity of the plotter to the CTD operator was a great convenience and it is hoped that this move can be repeated in future.

CTD failure occurred only on station 9600 (lowering 1) due to the open circuiting of the main electrical cable to the instrument at 730 m, and on station 9582 whilst being raised due to the failure of the deck unit (because of a short circuit). Both faults were quickly rectified. The first four casts (station 9576 and 9577 lowerings 1-3) were all plagued by erratic behaviour of the conductivity sensor. After it was replaced by a spare, no further major problems were encountered. The multisampler performed extremely reliably providing salinities at 2 to 4 depths and temperatures at 1-3 depths on each cast. The salinity values determined on board yielded estimates of the CTD cell factor which varied during the cruise between 1.0013 and 1.0026. The multisampler thermometer measurements quickly demonstrated large differences from those made with the CTD platinum resistance thermometer: the discrepancy was traced to a change in an amplifier board in the CTD made shortly before departure. An approximate calibration good to $\pm$.01°C was made on the cruise and a more exact determination will be made on return to Wormley.

The observational program for the CTD centred on efforts to measure the mesoscale geostrophic shear at four locations (approximately 57°30'N, 58°30'N and 59°30'N, all close to 12°W, and near 58°30'N, 10°30'W). At each location stations were made to a depth of 1200 m at the vertices of a triangle of side 15 km. In order to reduce the 'noise' due to the semi-diurnal tide each station was occupied twice separated by approximately 6 hours. Pair averages may be expected to contain considerably reduced 'noise' from tides. At the time of writing only the eastern location has yielded geostrophic shear from 200-1100 db in excess of 10 cm/s.

Other CTD observations were as follows:- Lowerings to 120 m were made in the vicinity of each of the four surface moorings 235-238 for intercomparison with thermistor chain data. En route between 59°N, 13°45'W and 59°15'N, 10°W (approximately), 120 m casts were made at 15 km separation. Near 59°30'N and 12°W repeated shallow lowerings were made at 5 minute intervals for a duration of approximately $2\frac{1}{2}$ hours. These latter measurements revealed the complex spatial and temporal variations of the upper ocean probably better described by the Batfish observations.

P.M. Saunders

E.M. SPAR (K.G. Birch, C.H. Clayson, R.T. Pollard)

A newly developed version of the E.M. spar was used to make measurements of vertical and horizontal flow. This version incorporated a vertical gyroscope to measure the orientation of the sensors. Two of the current meter heads were of the recently developed open construction which is not subject to the stalling problem experienced with the solid heads at high flow angles. A number of records were made to compare the performance of the open and solid heads. A pressure sensor was also included in the new configuration with the objects of monitoring and controlling the vertical motion of the spar relative to the water particle motion, by applying feedback to the servo-controlled electric winch. This pressure feedback system had been tested earlier in the cruise with only the pressure sensor and a weight on the end of the wire. After adjustment to stabilise the system, about a 90% reduction of the pressure fluctuations measured by the transducer was achieved in conditions in which the ship's heave was above 3 m. When the pressure feedback was tried again with the sensor on the spar, the high drag of the sphere on the spar resulted in slack wire when the compensation was not perfect. Unfortunately a turn of wire was caught up on the winch under these conditions with the result that the wire broke and the spar was lost. Since the pressure housing was only adequate for 200 m and the water depth was over 1 km, dragging was not attempted.

The hard work put into the construction of this instrument by both the IOS workshop (R.F. Wallace) and instrument laboratory (A.C. Braithwaite, S.K. Willis) is gratefully acknowledged.

Preliminary analysis showed vertical velocities due to ship motion of up to 1.5 m/sec. Severe stalling on one closed head was induced. Pitch and roll angles were less than 3°, but were nevertheless clearly correlated with "horizontal" velocities uncorrected for tilt showing the gyroscope to be necessary if horizontal currents and current-shear are to be determined.

C.H. Clayson, R.T. Pollard

FLOAT TRACKING (M. Butterfield, N.W. Millard, P.M. Saunders, J.C. Swallow)

Our objectives were to assess the feasibility of acoustic tracking of near-surface floats in the JASIN area, to track a group of closely spaced floats (tens of metres apart) relative to bottom transponders, and to test a pressure-telemetering float loaded to stay in the mixed layer and fitted with extra drag against vertical relative motion.

It was found possible to detect a surface float (transducer at 4 m depth) at ranges up to 10 km with the ship moving at speeds up to 8 knots. For accurate range measurement (.01 sec travel time or better) 5 km range and 3 knots speed are more realistic limits. Four surface floats were released simultaneously, spaced approximately 10 m apart across wind, and were tracked relative to bottom transponders and a remote interrogator for 21 hours. Problems were encountered, with one bottom transponder moving significantly during the experiment, and frequently arrivals via acoustic paths involving the remote interrogator could not be detected. But, although the full accuracy of the intended tracking method could not be achieved, it was possible to observe the dispersion of the group of floats, and a short test using a free-floating remote interrogator at the surface gave promising results.

The first test of a pressure-telemetering float was disastrous. A gross error in loading (the buoyancy of the extra drag plate had been counted twice in calculating the load) made it sink quickly beyond the intended depth, and several attempts to release it had no effect. It went to the bottom and thereafter gave us a lower-limit measure of mean near-bottom current, averaged over 67 hours. The second pressure-telemetering float behaved more satisfactorily. After two adjustments to its calculated load it was possible to place it in or near the bottom of the mixed layer, and some striking changes of pressure were observed with it in winds of 30-40 knots during 26th September.

Starting and end times and provisional positions for float tracks are listed in Table 5.

J.C. Swallow

MOORINGS (W.V. Burt, J.W. Cherriman, F. Evans, B.A. Hughes, B. Moore, R.F. Wallace, J.C. Swallow)

Four surface moorings were set and recovered during the cruise, and six subsurface moorings set by 'Challenger' in July were recovered. A tide gauge, set by 'Challenger' in July, was also recovered.

Recovery of the subsurface moorings and tide gauge was straightforward, except that some concern was felt that during interrogations earlier in the cruise it was not possible to switch the command pinger on, and with the shallowest mooring (B1, in 220 m depth) some time had to be spent searching for the mooring before recovery. These observations suggest that the transducers on the command (and release) pingers look upwards into a relatively narrow cone, necessitating a very close approach (a few hundred metres) before a shallow pinger can be switched successfully.

With the less familiar surface moorings, several lessons were learned. Launching the moorings went satisfactorily, but on attempting recovery in all four cases the recovery lines had become tangled round the lower part of the buoy framework, necessitating boat trips to disentangle the lines or to fit extra ones. In future it would be better to have recovery lines leading up from the attachment points on the lower framework, to suitable points on the upper instrument ring and thence hanging down to water level attached to a trawl float and short stray line. A heavy lifting strop should also be fitted, running from the upper end of the mooring wire below the buoy to some convenient point on the upper instrument ring, so that the weight of the mooring can easily be taken on the trawl winch as soon as possible after the buoy has been lifted by the crane. Loosening of seized shackles caused part of the chain and sinkers to be lost on two moorings, and might have caused more serious losses if the buoys had been left out much longer; shackles secured with nuts and split pins would be much preferable.

Times, positions, types and depths of instruments and some preliminary notes on their performance are listed in Table 2. For further details about the results, consult Professor W.V. Burt (O.S.U.) regarding meteorological and thermistor chain records, Dr R.T. Pollard (IOS Wormley) about current meter records, Dr D.E. Cartwright (IOS Bidston) about the tide gauge record.

J.C. Swallow

PITCH-ROLL BUOY (K.G. Birch, C.H. Clayson)

Two trials of a self contained version of the pitch-roll buoy were carried out. In the first of these the buoy was tethered to a drogue and to a transponder and allowed to drift free overnight during a series of triangular runs made with the Batfish. In the second, the buoy was launched so as to record during the first of the VACM intercomparisons referred to above.

C.H. Clayson

RADIOSONDES (P.K. Taylor, A. Osmond)

The radiosonde work during this cruise was in preparation for the JASIN 1978 experiment. It included instrument trials, and the evaluation of Loran-C tracking capabilities in the proposed JASIN area. It had also been hoped to obtain a series of radiosonde flights through a secondary front during a cold air outbreak, a weather situation amenable to study from a single ship. Although such an event did not occur, on several occasions radiosonde soundings from an array of ships, as planned for 1978, would have been of interest.

The major instrument trial was the evaluation of the LO-CATE W3 radiosonde tracking system when used with Loran-C. This system, which provides computer-compatible logging of data from the fast sampling VIZ 1223 radiosonde, is considered the primary choice for 1978. Delay in obtaining necessary repairs had resulted in the set being put on the ship in a partially working condition and changes to the electronics were necessary before and during the cruise. In particular the set was operated on a temporary reference oscillator constructed at IOS by Mr John Bunting. VIZ 1223 sondes were tracked to give chart recorder and magnetic tape logging of pressure, temperature and relative humidity and both the 1223 and the slow sampling 1205 sondes, were tracked to give wind data. However interference between the 'meteorological' and the wind data caused sudden loss of tracking during all flights for which logging of both types of data was attempted. A low 40 MHz clock signal was considered the probable reason for this but correction at sea did not prove possible.

The WL-2 LO-CATE system, used on previous cruises, was operated with an IOS constructed data logging system and performed reliably. This set is considered the back-up system for the 1978 experiment. To compare their performance the WL-2 and W3 sets were used simultaneously both to track radiosonde flights, and to measure the ship's velocity using signals from a 1223 sonde fixed to the aft mast.

The radiosonde flights were normally single balloon flights to a chosen pressure level at which the sonde was released and descended by parachute. Two release types were used, each being essentially a box, the parts of which were kept together provided a pressure difference existed between the outside and inside. The IOS release performed reliably to the required 500 mb level. The Max-Planck-Institut für Meteorologie, Hamburg, release required a modification to reach 500 mb but then performed reliably. It is cheaper and easier to set than the IOS release and is recommended for the 1978 experiment. Two radiosonde parachute designs were used, one provided by the Meteorological Office and one by the Deutscher Wetterdienst Seewetteramt, Hamburg. Since both types are normally used in a different manner from that required in JASIN, evaluation trials were necessary. The Meteorological Office parachute proved the more reliable and gave an acceptable rate of descent. The accuracy of this parachute in sensing the mean wind will be evaluated from the flight data.

The VIZ 1223 radiosondes for use with the W3 equipment proved unreliable. All ten sondes showed oscillation of the Loran-C receiver, a similar failure to that experienced with VIZ 1220 radiosondes during JASIN 1972. Although a simple remedy was devised and tested both time and data had already been lost.

Loran-C signal quality in the JASIN area was monitored during the cruise. The SL3W (Sylt) signal was very low in amplitude and manual locking of the W3 set was sometimes necessary. However preliminary inspection of the ship velocity comparisons suggested that the W3 one minute winds should be of the required accuracy (better than $\pm$0.3 m/s) although the quarter minute winds were not. The W3 appeared less susceptible to propagation errors than the WL2 although night time tracking errors of about 1 m/s in one minute 'winds' were observed.

The radiosonde flights are summarized in Table 3.

P.K. Taylor

UNDERWAY OBSERVATIONS AND NAVIGATION

The echo-sounder was operated and logged manually at 6 min intervals whenever the ship was underway in deep water (100 fm). By convention, Matthews' table for Area 9 was used for correcting soundings all over the JASIN area.

At the beginning of the cruise, Loran-C fixes were logged by the computer in addition to satellite fixes (the primary navigation aid) but the weakness of one Loran-C signal (Sylt) and consequent frequent loss of lock caused them to be abandoned after a few days.

J.C. Swallow

The S-T profiler was towed almost continuously throughout the cruise, giving analogue records of near-surface temperature and salinity and being logged simultaneously by the computer. It suffered some shifts of calibration, and frequent checks were made against bucket observations. An intercomparison of various sensors including the S-T profiler was made on two CTD stations, as described below.

(1) S-T Profiler   When hove to on station the fish sinks to about 7 m, during these comparisons the fish was first at 7 m and

then raised to about 1 m. Water temperature and salinity appeared to be well mixed between these two limits.

(2) R.A.S.T.U.S. sea surface sensor mounted on the hull, temperature is a digital visual readout.

(3) Hull temperature, an IOS sensor mounted on the hull, 10 minute temperature values are printed on the 1053 printer.

(4) S-T Profiler bucket, an ordinary rubber bucket with a line attached, the temperature is measured using two IOS surface thermometers. Salinity samples were taken from the bucket on the Autolab.

(5) Crawford bucket, this has a mercury in glass thermometer permanently fitted.

(6) The CTD was held at 10 m and two water bottles fired (there were no reversing thermometers on these bottles), the salinity samples were measured on the Autolab. Results of these inter-comparisons are listed in Table 6.

J. Moorey

VECTOR-AVERAGING ELECTROMAGNETIC CURRENT METER (J.W. Cherriman, C.H. Clayson)

Two trials of a prototype VAECM, recently constructed at IOS, Wormley by T.J.P. Gwilliam, were carried out. The performance of the new current meter was compared with that of an AMF VACM with both current meters suspended from a cluster of surface floats which were tethered to the ship by 100 m of polypropylene rope. The ship lay to during the measurements so that the current meters were towed at between $\frac{3}{4}$ and $1\frac{1}{2}$ knots. The current meters were at 30 m depth with their sensors vertically separated by 1 m: current shear should have been small as the mixed layer depth was about 70 m. The second trial was carried out in seas of about 4 m wave height and was, thus, a severe test of the instruments' response.

C.H. Clayson

TABLE 1. STATION LIST

Station No.	Date	Time Start (all times GMT)	Time End	Position Lat.N. ° '	Position Long.W. ° '	Gear Used, Comments	
9575	10	1024	1200	57 23.1	11 10.3	Mooring 235	(U3) set
9576		1252	1257	57 23.3	11 10.2	CTD 1	(100m)
9577	11	0012	0052	57 27.3	11 56.6	CTD 2	(1200m)
9578		0204	0259	57 22.1	12 09.5	CTD 3	(1200m)
9579		0406	0453	57 29.4	12 09.7	CTD 4	(1200m)
9580		1311	1420	58 04.3	13 49.2	Mooring 236	(U4) set
9581		1436	1442	58 04.1	13 49.5	CTD 5	(110m)
9582		2142	2238	58 34.9	12 12.5	CTD 6	(1200m)
9583	12	0102	0148	58 38.2	12 01.5	CTD 7	(1200m)
9584		0254	0354	58 42.7	12 12.2	CTD 8	(1200m)
9585		0454	0556	58 35.8	12 14.7	CTD 9	(1200m)
9586		0705	0803	58 39.9	12 01.4	CTD 10	(1200m)
9587		0945	1036	58 44.4	12 16.4	CTD 11	(1200m)
9588		1614	1705	58 58.0	13 42.6	Mooring 237	(U1) set
9589		1719	1729	58 57.6	13 43.3	CTD 12	(110m)
9590		2139	2147	59 02.6	13 16.2	CTD 13	(110m)
9591		2318	2324	59 08.8	12 52.3	CTD 14	(110m)
9592	13	0058	0106	59 13.7	12 25.3	CTD 15	(110m)
9593		0238	0248	59 23.6	12 12.6	CTD 16	(130m)
9594		0451	0502	59 26.0	11 49.3	CTD 17	(130m)
9595		0645	0655	59 21.9	11 22.1	CTD 18	(130m)
9596		0842	0850	59 18.2	10 51.5	CTD 19	(150m)
9597		1017	1023	59 15.4	10 25.8	CTD 20	(130m)
9598		1353	1510	59 14.1	10 12.4	Mooring 238	(U2) set
9599		1520	1533	59 14.0	10 12.6	CTD 21	(130m)
9600	14	2147	2234	59 25.6	12 14.0	CTD 22	(1200m)
9601	14-15	2344	0034	59 33.6	12 14.6	CTD 23	(1200m)
9602	15	0137	0228	59 29.6	12 02.0	CTD 24	(1200m)
9603		0332	0423	59 26.7	12 16.3	CTD 25	(1200m)
9604		0555	0643	59 34.1	12 14.6	CTD 26	(1200m)
9605		0755	0843	59 29.3	12 01.0	CTD 27	(1200m)
9606		1253	1256	59 27.9	12 03.5	CTD 28	(1200m)
9607		1311	1336	59 28.0	12 03.8	CTD 28/1	(5 dips, 30-100m)
9608		1436		59 27.6	12 04.8	CTD 28/2	(19 dips, mostly
			1551	59 27.6	12 05.1		50-110m)
9609		2208		59 27.1	12 04.2	CTD 29	(6 dips, 10-120m)
			2300	59 26.8	12 04.2		
9610	16	1027	1041	59 27.2	12 04.2	CTD 30	(120m)
9611		1108	1540	59 25.5	12 04.3	E.M. shear spar	
9612	19	0047	0137	58 23.0	10 36.2	CTD 31	(1200m)
9613		0236	0327	58 19.4	10 24.6	CTD 32	(1200m)
9614		0432	0529	58 15.4	10 38.3	CTD 33	(1200m)
9615		0642	0752	58 24.4	10 36.9	CTD 34	(1200m)
9616		0904	0942	58 19.6	10 23.4	CTD 35	(1200m)
9617		1050	1134	58 15.3	10 37.5	CTD 36	(1200m)
9618	27	0750	0841	57 30.4	12 09.1	CTD 37	(1200m)
9619		0958	1043	57 22.0	12 08.7	CTD 38	(1200m)
9620		1140	1230	57 27.8	11 58.3	CTD 39	(1200m)
9621		1330	1412	57 29.7	12 09.3	CTD 40	(1200m)
9622		1523	1616	57 22.6	12 05.0	CTD 41	(1200m)
9623		1728	1808	57 27.6	11 57.1	CTD 42	(1200m)

TABLE 2. MOORING LIST

Notes:

(1) For subsurface moorings (W,B...) the listed recovery time is the time that the acoustic release was fired. For surface moorings (u...) it is the time that the crane was hooked on, to start lifting the surface buoy.

(2) Abbreviations: ACM - Aanderaa current meter
MDL - Meteorological data logger
TL/TC - Thermistor logger/thermistor chain
VACM - Vector-averaging current meter.

The meteorological data loggers, thermistor loggers and thermistor chains were also manufactured by Aanderaa.

(3) Meteorological and other sensors on the surface buoys, recorded by the meteorological data logger, comprised the following:

1. wind speed (cup anemometer)
2. wind direction (relative to buoy)
3. air pressure (static head + quartz sensor)
4. buoy orientation (magnetic compass)
5. wet bulb air temperature
6. dry bulb air temperature
7. solarimeter

8 and 9. thermistors at 0.5m and 2m depth.

Mooring No. 229 (W3), set 1702Z 14.7.77, 58°15.7'N, 10°42.8'W, 1970m.
recovered 1218Z 19.9.77, 58°16.0 N, 10°42.7'W.

VACM	ser.no. V0130,	depth 19m,	record no. 22901	
TL/TC	T178	20,21(5)66	02	
ACM	940	66	03	
ACM	302	185	04	short record (leaked)
ACM	2106	490	05	
ACM	423	1000	06	

Mooring No. 230 (W1), set 1414Z 15.7.77, 59°29.1'N, 12°11.5'W, 1426m.
recovered 1124Z 18.9.77, 59°28.9'N, 12°11.2'W.

VACM	ser.no. V0159,	depth 27m,	record no. 23001	
TL/TC	T245	28,30(5)75	02	
ACM	469	75	03	
ACM	2109	197	04	
ACM	420	504	05	rotor stuck after 12 days.
ACM	2449	1017	06	

Mooring No. 231 (W4), set 2145Z 15.7.77, 59°18.1'N, 12°15.3'W, 1519m.
recovered 1413Z 18.9.77, 59°18.1'N, 12°15.2'W.

VACM	ser.no. V0156,	depth 36m,	record no. 23101	
TL/TC	T44	37,38(5)83	02	
ACM	1620	83	03	no data, flat battery.
ACM	2110	205	04	
ACM	794	510	05	no rotor
ACM	2450	1019	06	

Mooring No. 232 (W2), set 1540Z, 16.7.77, 58°38.3'N, 12°21.4'W, 1647m.
recovered 1201Z, 20.9.77, 58°38.6'N, 12°21.4'W.

VACM	ser.no. V0132,	depth 39m,	record no. 23201
TL/TC	T206	40,42(5)87	02
ACM	1623	87	03
ACM	468	208	04
ACM	1622	311	05

Mooring No. 233 (B2), set 1457Z, 18.7.77, 58°34.6'N, 12°22.8'W, 1639m.
recovered 1015Z, 20.9.77, 58°34.6'N, 12°22.5'W.

ACM	ser.no. 1867,	depth 297m,	record no. 23301
ACM	2575	501	02
ACM	1506	754	03
ACM	1746	959	04
ACM	1750	1217	05
ACM	2573	1475	06

Mooring No. 234 (B1), set 0857Z, 19.7.77, 58°06.0'N, 13°49.2'W, 228m.
recovered 0926Z, 21.9.77, 58°05.9'N, 13°49.5'W.

ACM	ser.no. 570,	depth 88m,	record no. 23401
	2576	194	02

Mooring No. 235 (U3), set 1200Z, 10.9.77, 57°23.1'N, 11°10.3'W, 639m
recovered 1825Z, 26.9.77, 57°24.6'N, 11°09.8'W.

MDL	ser.no. D221	(surface)	record no. 23500	wind dir. failed, (time unknown).
VACM	V0155,	depth 10m	01	
TL/TC	T265/290	11(3)41	02	
TL/TC	TC9/76	46(5)91	03	

Mooring No. 236 (U4), set 1420Z, 11.9.77, 58°04.3'N, 13°49.2'W, 222m.
recovered 0938Z, 25.9.77, 58°04.3'N, 13°49.1'W.

MDL	ser.no. D222	(surface)	record no. 23600*	
TL/TC	T269/291	11(3)41m	01	
TL/TC	TC6/77	46(5)91	02	battery leaked

*Most meteorological sensors damaged in recovery attempts 1650-1755Z 23.9.77.

Mooring No. 237 (U1), set 1705Z, 12.9.77, 58°58.0'N, 13°42.6'W, 461m.
recovered 0840Z, 23.9.77, 58°57.6'N, 13°43.7'W.

MDL	ser.no. D225	(surface)	record no. 23700 bad tape, cause unknown.
VACM	V0430,	depth 10m	01
TL/TC	T264/289	11(3)41	02
TL/TC	TC8/78	46(5)91	03

Mooring No. 238 (U2), set 1510Z, 13.9.77, 59°14.1'N, 10°12.4'W, 468m.
recovered 0858Z, 22.9.77, 59°14.5'N, 10°10.8'W.

MDL	ser.no. D226	(surface)	record no. 23800
VACM	V0429	depth 10m	01
TL/TC	T268/288	11(3)41	02
TL/TC	T230/292	46(5)91	03

Tide Gauge (Mk 4) set 1339Z, 1.7.77, 58°16.1'N, 13°50.9'W, 388 m.
recovered 1120Z, 21.9.77, 58°15.9'N, 13°51.8'W.

TABLE 3. SUMMARY OF RADIOSONDE FLIGHTS

Flight No.	Sonde 1205	1223	Tracking WL2	W3	Ascent Rate m/s.	Release IOS	MPI	Set	Released	Parachute DWD	MO	Rate m/s.	Comments
D8601	x		x		4.6	x		507	519		x	4.6	
D8602	x		x		-			-	-				Temp. only
D8603	x		x		6.3	x		524	523	x		9.4	
D8604		x		x	-			-	-		x	3.3	Only partly tracked
D8605		x		x	5.7			-	-		x	4.3	
D8606	x		x		5.7	x		480	485	x		23.0	Parachute failed
D8607	x		x		5.5	x		481	461		x	6.7	
D8608	x		x		5.6	x		481	490		x	5.0	
D8609	x		x		5.6	x		481	730	x		18.5	Parachute failed
D8610	x		x		5.9	x		434	481		x	4.4	
D8611	x		x		5.5	x		531	584		x	5.2	
D8612		x		x	-			-	-		x	-	No pressures
D8613	x		x		5.8		x	488	333		x	4.8	
D8614	x		x		6.0		x	533	475	x		9.7	
D8615	x		x		6.7		x	?	390	x		17.9	Parachute failed
D8616		x		x	6.6			-	-		x	4.2	
D8617		x		x	5.9		x	533	489		x	3.4	
D8618	x		x	x	5.5		x	533	517		x	4.1	
D8619	x		x	x	6.7		x	534	572		x	3.9	
D8620	x		x		5.2		x	484	480		x	4.2	
D8621	x		x	x	5.4	x		452	445		x	4.9	
D8622	x		x		5.8	x		472	450		x	5.2	
D8623	x		x	x	5.3	x		476	454		x	5.4	
D8624	x		x	x	-	x		470	-		x	-	Temp. only
D8625	x		x	x	5.8	x		470	550		x	4.6	
D8626	x		x	x	6.0	x		463	450		x	5.7	
D8627	x		x	x	3.2		x	440	(484)		x	2.2	Balloon leaked
D8628	x		x	x	5.6		x	496	450		x	4.0	
D8629	x		x	x	5.6		x	496	455		x	15.9	Parachute failed
D8630	x		x	x	5.4		x	486	470		x	5.7	

Release performance

Mean difference between setting and actual release height (neglecting one worst case for each type):

IOS -10mb (range -80 to + 22 mb)
MPI +23mb (range -38 to + 58 mb)

where a negative sign means a release nearer the surface.

Parachute performance (includes tests with water ballast only).

D.W.D. 6 flights, 4 failures
Mean successful descent rate 9.6 m/s.

M.O. 25 flights, 1 failure
Mean descent rate 4.9 $\pm$ 0.2 m/s (1205 sonde)
3.8 $\pm$ 0.3 m/s (1223 sonde).

TABLE 4. BATFISH TOWS

Run	(Sept) Date	Start Time(Z)	Stop Time(Z)	MODE	TRACK	COMMENTS
1	12	2001	2007	Yoyo 10-70m	Near George Bligh Bank	Aborted, water in CTD
2-6	13 14	1616	 0244	Yoyo 10-80m	From mooring U2 (Rosemary Bank) to mooring W3	Force 9, ships speed 4-6 kts, batfish response marginal.
7-8	14	0255	0907	Horizontal 20m ± 10m	From W3 to W1	No hydraulic control, due to cable failure.
9-15	17 18	1929	 0851	Yoyo 10-90m	Seven runs round triangle 5 miles on a side near moorings W1 and W4. Each triangle began near drogued drifting Pitch Roll buoy	On two occasions, buoy was located by navigating on mixed layer temperature structure.
16 17	18 18	1621 2000	1751 2400	Yoyo 0-90m	From W4 to W3	CTD fault caused break between runs 16 and 17.
18	19	1450	1716	Yoyo 10-90m	Course 247° from W3	Terminated by CTD deck unit failure.
19-23	19 20	2308	 0907	Yoyo 10-90m	Five runs round triangle 5 miles on a side near moorings W2 and B2. Each triangle began near surface Swallow float.	Float drifted to west at 10-15 cm/sec.
24-33	20 21	1354	 0716	Yoyo 10-90m	From B2 via 59°30'N, 13°W and U1 to B1.	
34-40	21 22	1931	 0705	Yoyo 5-90m	Course 065° from B1 to U2	

TABLE 4. BATFISH TOWS continued...

Run	(Sept) Date	Start Time(Z)	Stop Time(Z)	MODE	TRACK	COMMENTS
41-51	22 23	1030	 0553	Yoyo 10-90m	From U2 via 60^{o}N,11^{o}W to U1	
52	23 24	1915	 0710	On deck, with pumped flow.	From U4 course 053^{o} until 0100/24th, then 240^{o} to re-return to U4.	Too rough to launch
53-60	25 26	1117	 0213	Yoyo 5-90m.	From U4 course 090^{o} to 11^{o}8'W then 180^{o} to U3.	
61-62	26	0512		Yoyos and level tows at 30, 50 and 70m.	Two runs round 4 mile tri-angle near U3.	Aborted, water in CTD
63	26 27	2311	 0133	Yoyo 10-90m and level tows at 15, 90 and 70m.	Yoyo course 000^{o} from U3, 15m tow on 180^{o} reverse course, 90 and 70m tows on 000^{o} again.	
64-65	27	0138	0643	Yoyo 10-90m, tow on 11.5^{o}C isotherm, yoyo, level tows at 10, 90 and 60m.	Yoyo course 270^{o}, 11.5^{o}C tow on 090^{o} and 270^{o}, rest of run approx. west to 57^{o}30'N, 12^{o}7'W.	

TABLE 5. FLOAT TRACKS (Provisional Data)

Track No	Nominal Depth (m)	Start Date (Sept 77)	Start Time GMT	Start Lat.N. ° '	Start Long.W. ° '	End Date (Sept 77)	End Time GMT	End Lat.N. ° '	End Long.W. ° '	Mean cm/sec	Velocity °T	
380	0	15	0805	59 29.4	12 00.9	16	0948	59 25.6	12 07.2	10.0	220	
381	50	15	1301	59 27.9	12 03.7	18	0820	59 22.1	12 09.5	5.0	208	Sank, would not release.
										(Minimum mean near-bottom current)		
382	0	16	1721	59 29.2	12 04.6	17	1450	59 27.2	12 02.9	5.2	157	
383	0	16	1721	"	"	17	1450	"	"			
384	0	16	1721	"	"	17	1450	"	"			
385	0	16	1721	"	"	17	1450	"	"			
386	0	19	2110	58 35.0	12 12.7	20	0948	58 35.1	12 18.0	11.3	272	Marker for batfish ran.
387	50	24	0929	58 03.9	13 48.8	24	1148	58 03.8	13 49.2			Pressure telemeter trial.
388	50	24	1445	58 04.2	13 48.9	24	1645	58 05.1	13 50.8			" "
389	50	24	1757	58 04.5	13 50.1	25	0850	58 08.9	13 54.0	16.8	335	At surface from 2010/24
390	50	26	0832	57 22.6	11 07.8	26	1644	57 24.2	11 10.8	14.2	315	Various depths 10-70m.

TABLE 6. INTERCOMPARISON OF SURFACE SENSORS

Station 9619 Time	S-T Profiler T Chart	T 1053	S Chart	S 1053	RASTUS	HULL	Crawford bkt.	S-T	Bucket	W/B 10m	CTD T	CTD S
1000	12.74	12.75	35.58	35.56		12.3						
1010	12.74	12.75	35.57	35.54	12.1/12.2	12.3		12.25	35.277	35.263	11.911	35.262
1020	12.74	12.75	35.57	35.56		12.3						
Station 9621												
1330	12.22	11.93	35.53	35.54	11.9	12.0						
1340	12.25	12.25	35.53	35.53	11.8	12.0	11.9	11.8	35.237	35.226	11.455	35.220
1350	12.27	12.27	35.54	35.53		12.0						

Note: "Chart" : analogue record of S-T profiler

"1053" : computer printout of S-T profiler

"RASTUS": Bridge monitor for sea surface temperature.

These temperatures are all raw readings without any correction. The correction to be applied to the CTD temperatures, (as shown by several previous comparisons with reversing thermometer, not used this time) was + 0.35°C.

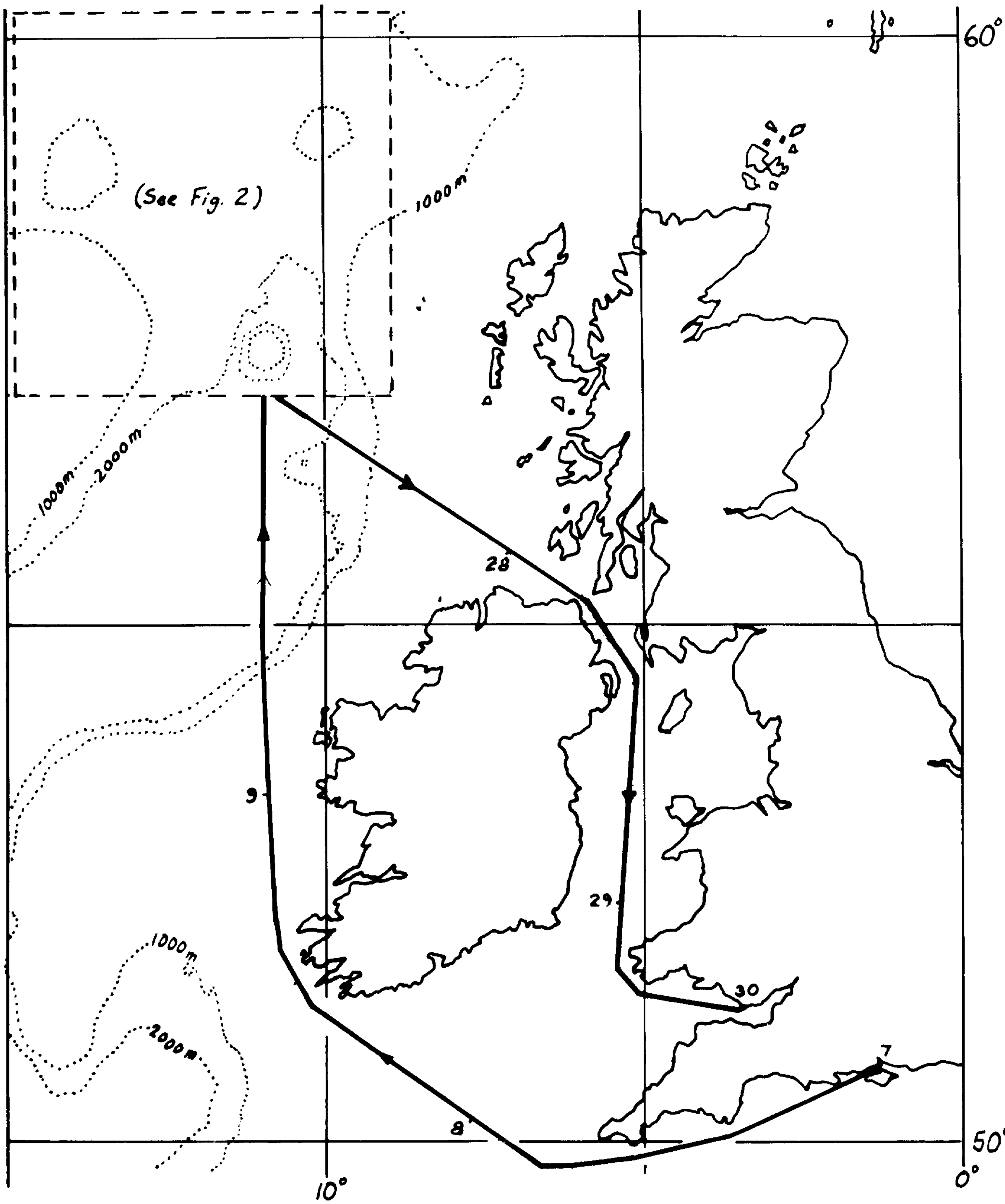

Fig. 1. Discovery Cruise 86 - General Track Chart.

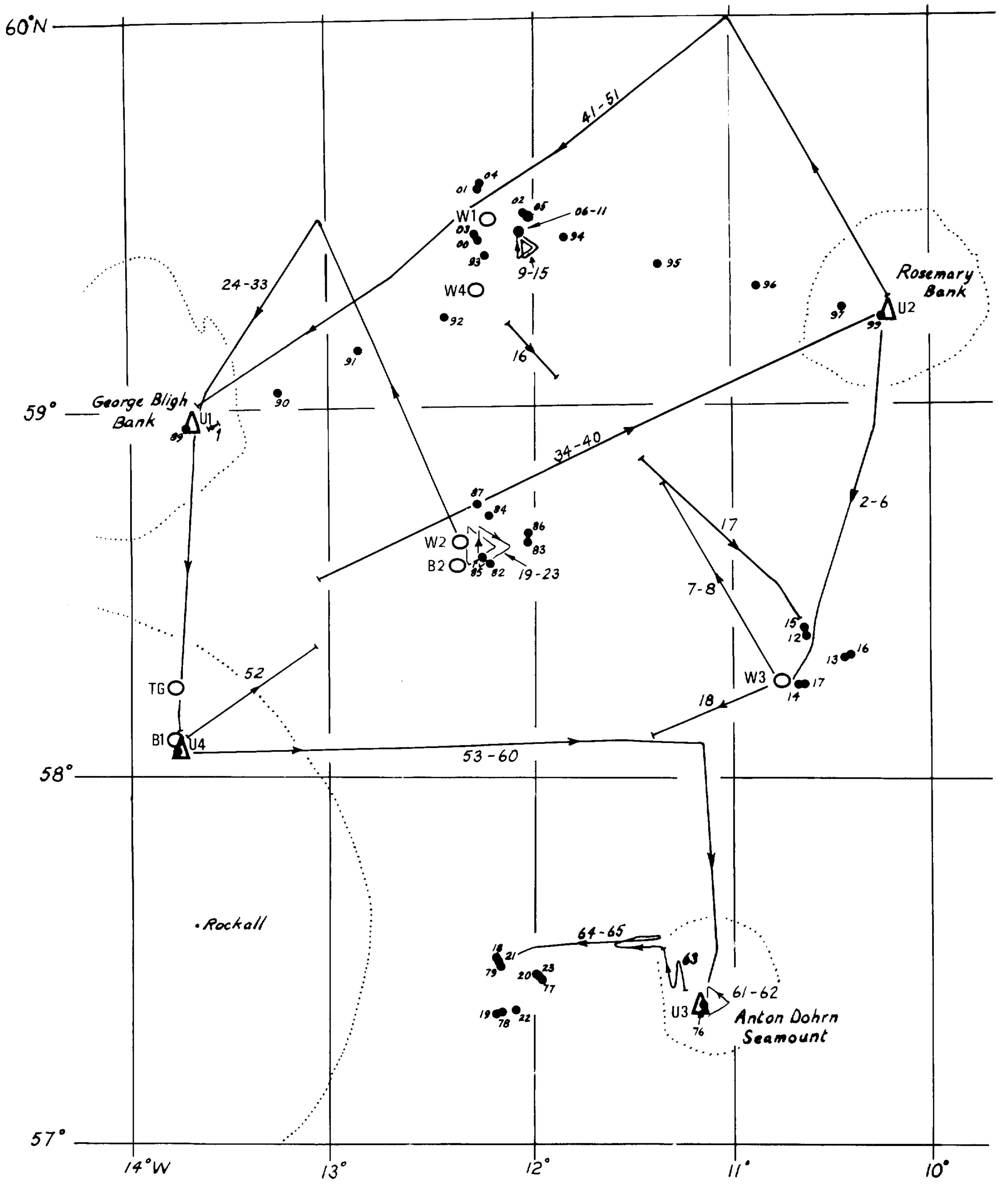

Fig. 2. Discovery Cruise 86 - JASIN Area.
Open triangles: surface moorings. Open circles: subsurface moorings.
Small solid circles: station positions. Numbered sections of track are batfish runs. Dotted lines are 1000 m bathymetric contours.

CRUISE REPORTS

CRUISE No. and/or SALE REPORT No.

D.E. "VICKERS VOYAGER" AND "PISCES 111"

	June - July 1973	IOS CR 1

R.R.S. "DISCOVERY"

1	(International)	
2	(Indian Ocean)	
3	(Expedition)	
		NIO CR[1]
4	February - March 1965	4
37	November - December 1970	37
38	January - April 1971	41
39	April - June 1971	40
40	June - July 1971	48
41	August - September 1971	45
42	September 1971	49
43	October - November 1971	47
44	December 1971	46
45	February - April 1972	50
46	April - May 1972	55
47	June - July 1972	52
48	July - August 1972	53
49	August - October 1972	57
50	October 1972	56
51	November - December 1972	54
52	February - March 1973	59
53	April - June 1973	58
		IOS CR[2]
54	June - August 1973	2
55	September - October 1973	5
56	October - November 1973	4
57	November - December 1973	6
58	December 1973	4
59	February 1974	14
60	February - March 1974	8
61	March - May 1974	10
62	May - June 1974	11
63	June - July 1974	12
64	July - August 1974	13
65	August 1974	17
66	August - September 1974	20
68	November - December 1974	16
69	January - March 1975	51
73	July - August 1975	34
74	Leg 2 Sept. Oct. 1975	33
74	Leg 1 & 3	
75	October - November 1975	43
77	July - August 1976	46
78	September - October 1976	52
79	October - November 1976	54

[1] NIO CR National Institute of Oceanography, Cruise Report
[2] IOS CR Institute of Oceanographic Sciences, Cruise Report

CRUISE REPORTS

CRUISE No. and/or DATE	REPORT No.
R.R.S. "CHALLENGER"	
August - September 1974	IOS CR 22
March - April 1976	IOS CR 47
R.V. "EDWARD FORBES"	
October 1974	IOS CR 15*
January - February 1975	IOS CR 19
April 1975	IOS CR 23
May 1975	IOS CR 32
May - June 1975	IOS CR 28
July 1975	IOS CR 31
July - August 1975	IOS CR 36
August - September 1975	IOS CR 41
August - September 1976	IOS CR 44
February - April 1976	IOS CR 48
April - June 1976	IOS CR 50
May 1976	IOS CR 53
R.R.S. "JOHN MURRAY"	
April - May 1972	NIO CR 51
September 1973	IOS CR 7
March - April 1974	IOS CR 9
October - November & December 1974	IOS CR 21
April - May 1975	IOS CR 25
April 1975	IOS CR 39
October - November 1975	IOS CR 40
August - October 1975	IOS CR 42
N.C. "MARCEL BAYARD"	
February - April 1971	NIO CR 44
M.V. "RESEARCHER"	
August - September 1972	NIO CR 60
R.V. "SARSIA"	
May - June 1975	IOS CR 30
August - September 1975	IOS CR 38
March - April 1976	IOS CR 44
R.R.S. "SHACKLETON"	
August - September 1973	IOS CR 3
January - February 1975	IOS CR 18
March - May 1975	IOS CR 24
February - March 1975	IOS CR 29
July - August 1975	IOS CR 37
June - July 1976	IOS CR 45
October - November 1976	IOS CR 49
M.V. "SURVEYOR"	
February - April 1971	NIO CR 38
June 1971	NIO CR 39*
August 1971	NIO CR 42*

*not distributed