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I.O.S.

RRS DISCOVERY

CRUISE 147

26 APRIL – 17 MAY 1984

BIOGEOCHEMICAL FLUXES IN THE N.E. ATLANTIC (42°N AND 50°N TRANSECTS)

CRUISE REPORT NO. 164
1984

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

WORMLEY

RRS DISCOVERY

Cruise 147

26 April - 17 May 1984

Biogeochemical fluxes in the N.E. Atlantic

(42°N and 50°N transects)

Principal Scientist

W.R. Simpson

CRUISE REPORT NO. 164

1984

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Depart Oporto 26 April 1984
Arrive Falmouth 17 May 1984

SCIENTIFIC PERSONNEL

D.S.M. Billett	I.O.S. (Biology)
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Miss S. Bury	Cambridge University (Earth Sciences)
E. Chapman	I.O.S. (Geochemistry)
Miss J. Clancy	Southampton University (Oceanography)
A.G. Howard	Southampton University (Chemistry)
D.J. Hydes	I.O.S. (Geochemistry)
T.J.P. Gwilliam	I.O.S. (Applied Physics)
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G.A. Lake	I.O.S. (Engineering)
R.J. Lampitt	I.O.S. (Biology)
V.A. Lawford	I.O.S. (Engineering)
A.R. Lewis	R.V.S. (Computing)
D. Lewis	R.V.S. (Computing)
J. Patching	University College, Galway (Observer)
R.D. Peters	I.O.S. (Engineering)
M.G. Sawkins	I.O.S. (Applied Physics)
P.J. Statham	Southampton University (Oceanography)
W.R. Simpson	I.O.S. (Principal Scientist)
J. Watson	S.M.B.A. (Biology)

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S.D. Mayl	Chief Officer
S. Sykes	2nd Officer
A. R. Louch	3rd Officer
D.C. Rowlands	Chief Engineer
I.E. Bennett	2nd Engineer
D. Hornsby	3rd Engineer
T.J. Comley	4th Engineer

K.T. Sullivan	5th Engineer
S.H.A. Thomas	5th Engineer
B.A. Smith	Electrical Engineer
Miss C.A. Langley	Radio Officer
R. Overton	Purser/Catering Officer

PETTY OFFICERS

R. Macdonald	C.P.O. Deck
D. Wiseman	C.P.O. Deck

OBJECTIVES

1. To make the first of four cruises planned to examine biogeochemical fluxes in the N.E. Atlantic working transects in latitude from the shelf to ridge at 5° intervals of longitude. The 42°N and 50°N transects were to be worked on this cruise, sampling to be carried out by in situ filtration (FIDO) and water bottles (CTD - 2.5L Go-Flo rosette).

2. To identify fronts on the 42°N transect by thermosalinograph and XBT records and sample water and particulate material in the fronts.

3. To collect samples of airborne, sea surface and deep water particulate matter in order to determine sources, cycles and fluxes of Pb isotopes.

4. To obtain samples for microbiological (including bacterial) analysis in conjunction with the biogeochemical fluxes studies.

5. To carry out the second of three cruises that comprise the Phytodetritus programme (1984). On this cruise:-

a) To sample superficial sediment and benthic phytodetritus for microbiological, chemical and taxonomic investigation.

b) To examine the effect of recently deposited detritus on chemical fluxes (in particular O_2) across the sediment-water interface by an in situ incubation technique.

c) To quantify the vertical flux of phytodetritus throughout the water column using a sediment trap mooring.

d) To sample the benthic meiofauna.

e) To obtain samples of phytodetritus in midwater for chemical analysis using the FIDO Package.

6. To test the MkIII porewater sampler.

NARRATIVE

The arrival of the party in Oporto coincided with the celebrations of the 10th Anniversary of the 'Bloodless' Revolution. The friendliness and hospitality of the people of Oporto was much appreciated as was the efficiency and helpfulness of the representatives of the Shipping Agents, Rawes Company.

After a few hours delay due to problems with customs clearance of equipment arriving via Spain from the R.R.S. Frederick Russell, we set sail at 1830 on the 26th April, with all in readiness for the first Station. The PES watches were begun at 2000 that evening and Station 11097 commenced at 0400 the following morning. The CTD-rosette was deployed from the midships winch, first to 50m to

rinse the bottles and then to full depth. The 30L Niskin bottles were deployed from the foreward electric winch, the deepest to 800m in order to obtain deep water for filtration. This water was to be retained for subsequent use as the storage medium for filters on which electropheretic mobilities of particles were to be determined at the University of East Anglia. The first of several surface Niskin samples was also taken on this cast relating to the study of atmospheric inputs (Cambridge University). The FIDO cast was aborted due to instrument failure, the fault being subsequently tracked down to a break in the sea cable joint. Station positions are shown on the track chart (Figure 1) and the station log is given in Table 1.

The XBT apparatus was tested during Station 11097 and the 10, 11, 12 and 13° XBT's deployed on passage to the front station. Results from the previous cruise (146) showed a front at 13° to 14°30'W and 20 min deployments of XBT's were run from 13°24'W onwards to aid in the location of the frontal system (see Table 2 and Figure 2c). The data from the thermosalinograph were logged from the evening of day 118 (April 27th), this being a further aid to identifying fronts (Figure 2a and b). Where 12°C water approached 200m and 10°C water first appeared on the XBT records at about 700m, Station 11098 was worked. A single filter was taken and a shallow CTD-rosette cast run. Continuing the XBT run, Station 11099 was worked at the edge of the front on day 120. This was the most intensive station of the cruise where three CTD-rosette casts were made with replicate samples at all depths. Besides the trace elements, rare earth elements are to be determined on these water samples. FIDO was deployed on three occasions, the initial cast being aborted due to a leak in the main electronics tube due to an 'O' ring failure. The WHOI in-line Mn scavengers, designed for the preconcentration of dissolved naturally-occurring radionuclides, were incorporated into the FIDO system. It was essential to fill the holders with seawater prior to deployment to prevent the filters tearing due to air escaping at pressure through the stacks. Eight filter and Mn samples were taken in all. The porewater sampler was deployed aft but only after a burst cooling pipe in the winch room was repaired, the only problem with the winches on the cruise; no sample was obtained by the sampler.

The only bad weather of the cruise was encountered between Stations 11099 and 11100, during which time the ship made about 70nm in 30hrs (see ship's Track Fig. 1 and ship's course in Fig 2f). However, on the approach to the preselected position for Station 11100, the ship passed over an uncharted seamount on the Açores-Biscay Rise, the peak of which was some 2000m below the

surface (see Figure 2d). The mount was surveyed in S-N and E-W directions. Three CTD-rosette casts were made on and close to the seamount.

On this station the second and third serious floods occurred in the main electronics tube on FIDO which prevented the collection of good particle size profiles through to Station 11106 in the mouth of the Seabight (see Fig. 1).

Other leaks were to follow, often due to failure of General Oceanics connectors. Despite these severe problems the electronics team repaired the instrument and good particle samples, water samples and physical data were collected from Station 11101 onwards. The precise record of FIDO difficulties is given in Table 5.

Before the end of Station 11100 permission was granted to use three engines to make up time lost both from bad weather and the delayed start to the cruise.

Station 11101 was occupied on the ridge flank with water samples and filters taken accordingly. The porewater sampler was deployed without success. The last station on the 42°N transect (Station 11102) was worked in the median valley and acted partly as a rehearsal for ridge work to be carried out on a cruise in 1985. From the T-S plots there was evidence of a deep mixed layer in the valley.

Running north along the ridge XBT's were launched every hour to show the movement of fronts across the ridge and this shows up well in the TSG and XBT records (Figure 3a b and c).

There was insufficient time to work the most north-westerly station planned at 50°N 30°W, so as a compromise a station at 48°12' 24°56' was worked (Station 11103) at the eastern end of the Maxwell Fracture Zone. Samples were taken by the CTD-rosette, FIDO, Niskin bottles and Z-boat. The S.M.B.A. multi-corer was deployed as a shakedown for the Porcupine Seabight work; unfortunately the corer came inboard horizontally as a loop of warp had been caught around the frame whilst on the seabed.

On Station 11104 (west flank of the Porcupine Abyssal Plain at 50°N 20°W) three CTD casts were made and the last of the surface Niskin samples taken. FIDO suffered a further leak in a General Oceanics connector. The third drop of the PWS was unsuccessful.

Samples of rainwater were collected at a position close to the Porcupine Sea Bight using equipment located on the wings of the bridge. The pH of subsamples of the rainwater was measured prior to the addition of a small volume of chloroform as a preservative. The samples will be analysed for sulphur species and other dissolved constituents at the University of Virginia, U.S.A. The sampling

described here forms a small part of a programme on acid rain inputs to the Atlantic Ocean.

Station 11105 was used for coring only and marked the start of the biologists' work to examine photodetritus fluxes related to the Porcupine Seabight. 'Fluff' at the sediment sea water interface was found at this depth (4535m). However at station 11106 (3980m) the fluff was absent. FIDO was deployed, again with the Mn scavengers, and seven samples collected in all. Two CTD casts were also run.

A south to north track was then taken through the Seabight with the planned recovery of four moorings en route. However, a sediment trap string would not release and no response was obtained from one tide guage. The transect was primarily for coring (Stations 11107 to 11110 at 2723, 2000, 1336 and 1008m respectively) with detritus in evidence at the latter two depths. It was decided to run the incubation experiment at 1360m (Station 11111) and the PWS took good samples. Southampton University ran water bottle casts aft using Kevlar cable with a view to checking trace metal contamination problems arising with steel warps.

Station 11112 was a reoccupation of Station 11108 and on this occasion fluff was found at the sediment-water interface. It was not feasible to carry out further incubation experiments on the station following requests from R.V.S. and I.O.S. to dock in Falmouth by 0900 on the 17th May thus leaving only 8hrs station time. Particulates were sampled with FIDO using GFF filters for subsequent organic analysis; water samples were taken also.

From Stations 11113 to 11116, an up-slope transect of CTD and particle profiles (FIDO without filters) was made in approximately an easterly direction with the aim of following off-shelf transport and also to gain 'end-member' samples of trace elements in solution. Scientific work was completed at 0236 on the morning of May 16th and Discovery was alongside at Falmouth by 0800 on May 17th.

W.R. Simpson

REPORT OF PROJECTS

ACOUSTICS, MOORINGS AND XBT'S

The standard equipment used on this cruise was the Precision echo-sounder (fish and Mufax), Deck Control Unit MkIII, 10kHz Acoustic Beacon, 35.5kHz Near Bottom Echo-sounder (NBES). All these units performed well during the cruise, maintenance being the only work needed. The fish and Mufax were used for echo-

sounding and in all the operations of other standard equipment. The MkIII Deck Control Unit worked well during the mooring recovery attempts.

The 10kHz Acoustic Beacons were deployed on the S.M.B.A. Corer casts, fifty metres above the corer in order to monitor the height off the sea bed (16 hauls were carried out). The 35.5kHz NBES was used on the CTD and FIDO casts to give high resolution of the height-off-bottom, and worked well during the cruise.

The recovery of four moorings was attempted during the cruise. Three units were Tide Gauges from I.O.S. Bidston, of these two were recovered, of the third there was no sign. The fourth mooring was a string of I.O.S. sediment traps laid in April this year. The mooring used a standard CR200 series release (No. CR2382-230, 280, 098). The release switched on and indicated it had fired, but the mooring refused to surface. Further firing cycles were transmitted but the mooring failed to release.

A total of ninety-seven XBTs were launched and recorded during this cruise. Five XBT's were faulty and were rerun. The positions are given in Table 2 and Figures 2 and 3 show the isotherms so obtained.

M.G. Sawkins
J. Watson

ALUMINIUM DETERMINATIONS

Determinations of aluminium in seawater samples collected by the water column sampling team were made on board ship for the first time on a Discovery cruise. The system, which used a Perkin Elmer LS2 fluorimeter, worked well after a few early problems. Some 300 determinations were made, which gave some interesting results. Aluminium appears to have inputs to seawater from sediments and at the mid-Atlantic ridge. Aluminium is depleted in surface waters presumably due to removal by phytoplankton in the spring bloom.

D.J. Hydes

BIOGEOCHEMICAL PARTICLE FLUXES

a) In situ large volume filtration (FIDO)

Although FIDO had a total of 20 deployments during Cruise 147, data was not collected on all casts.

Inspection of Table 6 shows that one of the causes of data loss was seawater leakage in the main electronics tube. This occurred a total of five

times with varying degrees of damage to the wiring and printed circuit boards. In four cases the leaks were directly attributable to the fracture of the General Oceanic bulkhead connectors. In the fifth case the main end cap 'O' seal failed to "seat" which resulted in flooding. Unfortunately some planned deployments had to be abandoned while repair work was being carried out; but with the combined efforts of all the I.O.S. and R.V.S. engineers these were kept to a minimum.

The pump motors used on FIDO have been, up to date, very successful; however during this cruise the two operational motors and the replacement failed. Two of the motors were damaged due to electrical tracking and arcing between the motor terminals due to carbon build up in the paraffin. The other motor was damaged with overheating on the brush assembly, possibly because of loose fitting.

Apart from connector and motor problems the FIDO equipment behaved very well and perseverence was rewarded with the last 5 deployments giving excellent particle data.

With the problems experienced on this cruise it would appear that a review of the system is required for the purpose of reducing the number of external cables and connectors.

Despite the difficulties, filter samples were taken on most stations (Table 3, Figures 2, 3 and 4). On Stations 11099 and 11106 the Mn-scavengers were used, the radionuclide analysis of these and the corresponding filter sections to be carried out at the C.F.R., Gif-sur-Yvette and W.H.O.I., Mass. All filters were subsampled for particle surface charge determinations (U.E.A.), S.E.M. analysis (Surrey University), major element determinations by I.C.P. and trace element - R.E.E. analysis by I.N.A.A. (C.F.R., Gif-sur-Yvette).

The C.T.D. and particle size profiles at the front Stations (11098 and 11099) and in the Porcupine Seabight were interesting for their complexity, the former for the variation with time and the latter for the variation in space on the E-W transect.

T.J.P. Gwilliam
V.A. Lawford
A.R. Lewis
D. Lewis
W.R. Simpson

b) Lead isotopes

Filters from FIDO were also subsampled for Pb isotope determinations. Bulk samples of surface seawater were taken using 30L Niskin bottles on the electric winch for subsequent filtration (0.4μm Nuclepore) and collection of particulate matter for the Pb isotope work. To check contamination from the ship, surface samples were collected by Z boat at Station 11102, 1km upwind of the ship. Aerosol samples were taken using the Liverpool University sniffer on stations in order to estimate the atmospheric supply of the isotopes to the sea surface. By the combination of atmospheric - sea surface - deep water particle data the sources, fluxes, cycling and fate of the various Pb isotopes will be described.

S. Bury

MICROBIOLOGICAL STUDIES

a) Bacteria

Bacteria are thought to play a significant role in the chemical transformation and the particulate/dissolved exchange of material in the oceans. There is, however, a lack of quantitative data concerning microbial biomass and activity and the association of bacteria with particulate material, especially with respect to deep oceanic waters.

On this cruise, samples were taken and preserved for subsequent study, with the aim of determining the size spectrum and abundance of bacteria in the water column and their degree of association with particulate material. It is also hoped to obtain a relative measure of their rate of division (and hence activity) by the frequency of dividing cells technique.

Two types of samples were taken. Water samples (20ml) were preserved by the addition of particle free 40% formalin (2ml). Such samples have proved adequate for surface oceanic and inshore waters, but in the case of deep oceanic waters, may contain too few bacteria. Larger water samples (1 to 1.5 litre) were filtered on board through black 0.22μ millipore filters. The filters were stored in sealed petri dishes on cellulose pads soaked in dilute formalin (4% in sea water; particle free). Samples were taken from both Rosette and FIDO casts. Due to other demands, only 20ml samples were obtained from the former, but both large and small samples were obtained from each firing of a FIDO bottle. Such firings coincided with the operation of a FIDO filter unit. Table 4 lists the casts which were sampled.

Analysis of the samples is now taking place and should be completed by August. Suitable quantities of water samples are filtered through black 0.22μ millipore filters. The filters are then stained with acridine orange and examined by epifluorescent microscopy. Total counts of bacteria, the proportion attached to particles and the proportion undergoing division are recorded. Photomicroscopy and subsequent measurement is also being used to determine the size spectrum of the microorganisms and in an attempt to obtain an estimate of microbial biomass for samples.

J. Patching

b) Coccolithoporids

All the water bottle filters taken by the hydrographic team are to be analysed for the species diversity of coccolithophorids and the spatial distribution of these organisms. It is hoped to relate the distribution to chemical (primarily nutrients) and physical conditions prevailing at the time of sampling. From previous cruises between the equator and 35°N, coccoliths dominated the particulate material; here we hope to estimate the relative importance of bacteria to coccoliths and siliceous organisms.

W.R. Simpson

NUTRIENT ANALYSIS

Determinations of nitrate, phosphate and silicate were carried out using a continuous flow automated analysis system on 350 samples of seawater and sediment porewater. The analyser (Chemlab) was interfaced to a microcomputer (CBM Pet) for the first time on this cruise, greatly improving the speed of data reduction. The software for this was developed at I.O.S. and debugged during this cruise.

Chlorophylls were determined fluorimetrically after acetone extraction using a Turner spectrophotometer and dissolved oxygen was determined photometrically by a modified Winkler technique after Bryan, Riley and Williams (1976). Salinity measurements were made using a Guildline salinometer unit.

D.S.M. Billet
E. Chapman
D.J. Hydes
R.J. Lampitt

PHYTODETRITUS STUDIES

Data collected on the R.R.S. Frederick Russell Cruise 519 suggested that the spring phytoplankton bloom became nutrient deficient this year on about 15th April and it was therefore expected that detritus would have reached the seabed and over the whole of the seabight down to 4000m and possibly to 4500m by May 10, the day sampling began in the area. Incubation experiments had been successfully carried out on the Russell cruise at 2000m depths prior to the arrival of detritus and they were to have been repeated at the same station soon after the arrival of detritus (this cruise) and when it had substantially degraded in late August (Challenger 6/84). The following was the outcome of the objectives sought on this cruise.

a) During the transect leading north (10th to 13th May), detritus was collected from the tops of cores from Station 11105 (4535m), St. 11109 (1336m) and St. 11110 (1008m), but not from St. 11106 (3980m), St. 11107 (2723m) or St. 11108 (2000m). This was very surprising and was possibly due to spatial variations in surface primary productivity.

By 15th May, detritus was present on core tops from 2030m (St. 11112) providing a unique opportunity to collect very recently deposited material. Unfortunately due to a shortage of ship time and a coring problem on the second deployment, only one set of good samples was obtained. This was all the more disappointing as a Bathysnap unit was photographing the seafloor every 8 hours only a few kilometres away. A similar coring problem at St. 11114 (1610m) on the east side of the Seabight precluded collection of material from this station.

Several good samples of phytodetritus were taken, notably at Sts. 11105, 11109 and 11112. Material was preserved in formalin for taxonomic and microbiological studies, extracted in $ChCl_3$/methanol for lipid analysis, and frozen onto GFF's for chloropigment and other chemical analyses.

b) No phytodetritus was present on the seabed at the 2000m repeat stations when the incubation experiment was planned (12th May); by the time it had arrived (15th May) there was insufficient ship time for an experiment. The experiment was therefore carried out at 1360m where detritus was present. This proved to be disastrous as far as oxygen consumption measurements were concerned owing to high spatial and/or temporal gradients in oxygen concentration at this depth leading to meaningless results.

c) The sediment trap was to have been in operation at the 2000m repeat station during 4 separate periods in the year (each period about 40 days long). An

attempt was made to recover the mooring deployed on 10 April; although still on location and upright, it would not release (see Acoustics section). The opportunity to collect material of this kind throughout the year at regular intervals will not be available again for several years.

d) Samples of sediment were successfully collected for microfaunal analyses from most of the coring stations within the seabight.

e) Samples of particulate material in the water column were taken using GFF's on the FIDO package of Station 11112 (2030m). This station was in the area of greatest interest to the phytodetritus programme and was close to a Bathysnap unit due to be retrieved in August 1984.

D.S.M. Billett
R.J. Lampitt
J. Patching
J. Watson

PORE WATER SAMPLING

Pore water samples were collected by two methods during this cruise. Firstly this was a trials cruise for the I.O.S. MkIII in situ pore water sample prior to more intensive use on Cruise 149. Four lowerings were made in all, only the final deployment being successful. Problems arose with the operation of the valves used on the instrument to control its lowering into the sediment and to initiate sampling. Improvements were made in priming of hydraulic lines, construction of the filters, and operation of the camera. Secondly, pore water samples were also obtained, by centrifuging sections of cores obtained using the S.M.B.A. corer. This work was aimed at assessing how successfully a centrifuge could be operated at sea, and how well a sufficiently oxygen-free environment could be maintained around samples to enable iron determinations to be made on the extracted pore waters. Both aims were achieved successfully, and the results indicated that the continental shelf edge in the Porcupine Seabight would probably be a rewarding area for further studies of the mobility of trace metals in sediments and into the overlying water column.

E. Chapman
D.J. Hydes
G.A. Lake

SHIPBOARD COMPUTING REPORT

The 'S1' system was configured to log dead-reckoning, met and thermosalinograph (TSG) data routinely, and CTD and FIDO rigs when on station. The 'Usersystem' was likewise configured to accept all routine data (including TSG) from the S1 system, and after one or two initial configuration problems on both systems (see full software report, R.V.S./S.C.G. internal document) everything worked very smoothly for the whole cruise.

On the first attempt at transferring data from machine to machine via the HDLC link, the now well-known transmission error (repeated block(s)) occurred immediately. Cancelling one of the two time-scheduled system tasks for the duration of the transfer apparently cured the problem and all the data were routinely transferred via this link, some 750 Kbytes per day, for the remainder of the cruise. Only one reentry was necessary and that during a CTD dip when the system is at its peak activity. The root problem has not yet been satisfactorily solved however - see full software report for a fuller discussion.

The station work (CTD and FIDO) again went very well, although almost continuous software intervention was necessary during FIDO casts as various different parts of the sensor rig failed in different combinations and with different levels of effect. ½-second values of over 100 different variables are derived from this piece of equipment, and much use was made of the HP flatbed plotter's automatic paper-advance and cut facility for display of the data. This facility has been incorporated into a new 'batch' plotting program, which allows any number of standard plot-description files to be stacked into a 'plotlist' and globally edited via single commands to provide uniform plot dimensions, stat/stop time, independent variables, etc. The 'plot' command then initiates plotting of each file in turn, including paper advance and cut between each plot. Over 1000 plots were produced in this way in the 21 days at sea, and the consequent saving of man-hours therefore enormous.

Other new programs added are a) a general-purpose data-break detector (although the main raison d'etre is for automatic listing of bottle firing stations during CTD casts), b) a dot-plotting program (rather than line-drawing - usefal for widely scattered data), and c) two programs to force the FACIT line-printer to use either the top or the bottom of the ribbon (the ribbons are double sided but not manually invertible). Improvements were also made to the profiling program PROFI, which now not only calculates the height of the plot correctly, but will also profile ANY named variables from the 'final' data file, as well as the

'standard' geophysical data. This facility was used to produce full-cruise profiles of sea-temperature, salinity and corrected depth against distance along track as in Figures 2 and 3. (For full descriptions of these programs and other modifications see the full software report).

Few problems were experienced with the hardware. Two previously existing ones persisted, both of which caused inconvenience rather than hardship. One was on a magnetic tape transport, which made it unreliable and hence unusable for archiving purposes. The other was on the CALCOMP drum plotter, and restricted it to working at about half its normal speed.

The pen assembly on the Hewlett-Packard flatbed plotter needed adjustment before it would work satisfactorily with the roller paper used with the automatic advance facility, as did the paper-sensing microswitches. These problems are discussed in more detail in the full hardware report (S.C.G./R.V.S. internal document).

A.R. Lewis
D. Lewis

TRACE ELEMENTS IN SOLUTION

Hydrographic work was performed at the 14 stations indicated in Tables 1 and 3. Most sea water samples were taken using 2.5L Go-Flo bottles mounted on a General Oceanics rosette. Real time data on variations in salinity and temperature with depth were provided by a Neil-Brown CTD probe located below the rosette. As on Cruise 125, 129 and 135, this system allowed the most suitable choice of sampling depths to be made in relation to the structure of the water column. The Marine Physics group at I.O.S. is thanked for the loan of the rosette and CTD. The sampling system was deployed 23 times during the cruise; there were only 10 occasions when a bottle did not close correctly (96% success rate). The fault with one bottle, which was collecting water from the wrong part of the water column as indicated by oxygen and nutrient data, was traced to a flattened section of the nylon lanyard which was able to pull past the firing pin on the rosette prior to reaching the depth. Sub-samples of unfiltered water were taken from the bottles for analyses of nutrient, salinity, dissolved oxygen, aluminium, chlorophyll and dissolved organic carbon. Water remaining in the bottles was pressure filtered through in-line 0.4μm filters for dissolved trace metal studies and either processed onboard ship, or preserved by freezing (As, Sb, Se) or acidification for subsequent shore-based analysis.

A new 'non-metallic' system for taking sea water samples for trace metal studies was tested at Station 11111. A 6mm diameter Kevlar line, fitted with a polyester coated lead bottom weight, was deployed over the stern using the auxilliary winch and the main winch crane. Four 2.5L Go-Flo bottles were attached to the Kevlar at set intervals by using the 5m markings on the line to measure the separation between samplers. Once the bottles had been lowered to the appropriate depths, they were closed using PTFE Messengers. The system functioned well, and 12 samples from the top 330m of the water column were obtained from 3 casts. It is anticipated that this system will be able to generate 'clean' samples for subsequent analysis of elements such as Fe and Zn, where contamination problems are particularly acute. At Station 11102, additional samples for dissolved trace metal studies were obtained both at the 1km upwind position and adjacent to the ship using the inflatable; a comparison of trace metal concentrations at the two locations will provide some indication of whether or not the research vessel represents a significant source of contamination.

Sea water samples were processed according to the requirements of the individual groups, as indicated below.

Much of the sample processing was performed as on R.R.S. Discovery Cruises 125, 129 and 135. Water from the Go-Flo bottles was filtered directly into acid cleaned polyethylene bottles. Up to about 1000ml of the filtrate was preserved by acidification with sub-boiling distilled nitric acid, and stored at ambient temperature for subsequent processing at Southampton. In total, 277 sea water samples were stored for later analytical work. Smaller aliquots of filtrate were frozen for later analysis of As, Sb and Se species. A further 64 samples of filtered sea water were processed onboard using one of two different techniques to separate and concentrate a range of trace metals in a stabilized form suitable for transport to, and analysis at, the shore laboratory. In the first technique, which was applied to samples from Stations 11099 and 11104, dissolved Ag and other metals were complexed by a mixed dithiocarbamate reagent and extracted into chloroform. The metals were back extracted into a final small volume of dilute nitric acid. The method was calibrated for Co, Cu, Ni, Cd, Pb and Zn in addition to Ag. At Station 11102 the second technique, which has been applied during previous cruises, was used. Here, dissolved Mn, Cd and other elements were complexed with a mixed dithiocarbamate reagent, extracted into Freon TF, and then finally back extracted into a dilute nitric acid solution. With both the above techniques, the acidic concentrates were transported to the shore laboratory

for the determination of the trace metals by graphite furnace atomic absorption spectrophotometry.

The only reliable silver data currently available are derived from a few determinations on Pacific Ocean waters. The measurements made on this cruise should significantly increase our knowledge of the water column geochemistry of this element. Manganese and cadmium measurements will increase the coverage of data for the North Atlantic, and additionally dissolved Mn measurements over the ridge should indicate whether or not there are significant hydro-thermal inputs in this area. Arsenic, Sb and Se are of interest because of their aqueous redox chemistry and/or their ability to form organic species. Reliable data on the concentrations, forms, and water column distributions of these elements are scarce, and the current work should significantly increase our knowledge about them.

The chlorophyll data, which has not been available on previous cruises, will be very useful when interpreting the surface trace element data, in terms of indicating areas in the water column where biota-metal interactions may be occurring. At Station 11099, 18 samples from the water column were taken for subsequent rare earth element analysis at Cambridge by mass spectrometric methods. Samples were pressure filtered through o.4µm Nuclepore filters, and then 1L aliquots of the filtrates were stabilized by acidification with sub-boiling distilled HCl.

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TABLES AND FIGURES

Table 1 STATION LOG

Series	Lat Deg Min	Long Deg Min	Time G.M.T.	Gear	P.E.S. Depth	Wire out Depth	Remarks
Day 117			1830				Sailed from Oporto (April 26th 1984).
Day 118	Station 11097						Slope station
1	42 00.3	10 00.5	0430	CTD	2535	2576	15m off bottom
2	42 00.7	10 03.8	0816	NISKIN		800	Deep water for sample storage
3	42 01.3	10 02.3	1016	FIDO		-	Cable-connector problems aborted
4	42 00.4	10 00.8	1205	CTD		2200	
			1536	END			Heading 270°
Day 119	Station 11098						Front Station (XBT and TSG)
1	42 02.7	14 14.6	1548	FIDO	5280	2000	One sample. Filters connected incorrectly
2	42 02.9	14 14.6	1940	CTD		2000	
			2120	END			Heading 270°
Day 120	Station 11099						Iberian Abyssal Plain/Front
1	41 58.0	14 51.8	0252	FIDO	5278	5285	10m off bottom. Socket 'O' ring u/s. Flood. One sample
2	42 00.4	14 51.1	0818	CTD	5260	5319	13m off bottom. Duplicate sampling.
3	42 00.4	14 42.2	1134	NISKIN		20	
4	42 01.6	14 52.3	1430	PWS	5270	5485	No sample. Water cooling pipe in winch room burst
5	42 02.4	14 53.9	1918	CTD		400	
6	42 02.0	14 54.8	2126	FIDO		800	Two burst filter (air from Mn Scavengers). Repeat for top samples
Day 121							
7	42 03.4	14 55.9	0210	CTD		2100	
8	42 04.3	14 55.7	0417	FIDO		4500	Three filters. No particle data.
			1012	END			Heading 270°. (Bad weather).
Day 123	Station 11100						Acores - Biscay Rise (New seamount)
1	42 00.1	20 00.0	1514	NISKIN		20	
2	41 59.9	19 59.5	1600	FIDO		2455	'O' ring u/s. Flood in main tube.

3	41 59.9	20 01.6	1929	NISKIN		20	
4	41 59.9	20 02.6	2136	CTD	3412	3418	10m off bottom
					2000		Return to seamount - S - N crossing
Day 124							
5	41 59.8	19 59.9	0126	CTD	2200	2216	10m off bottom.
6	42 00.1	20 03.2	0358	FIDO	-	-	Test.
7	42 00.4	20 03.4	0444	CTD		400	
			0536	END			Heading 270° (Three engines)
Day 125 Station 11101							Ridge Flank
1	41 59.7	24 59.8	0248	CTD	3260	3278	16m off bottom
2	41 58.6	24 58.6	0515	PWS	3250	3455	No sample.
3	41 58.0	24 57.6	0758	NISKIN		20	
4	41 57.8	24 57.4	0822	CTD		1750	
5	41 57.8	24 56.7	0923	FIDO	3240	3271	Hit bottom
			1600	END			Heading 280°
Day 126 Station 11102							Ridge Median Valley
1	42 35.1	29 21.5	1053	CTD	3270	3309	20m off bottom
2	42 35.6	29 20.8	1304	NISKIN		20	
3	42 35.8	29 20.6	1400	FIDO	3053	3083	10m off bottom. Z boat surface sampling
4	42 36.9	29 23.4	1950	CTD		1500	
			2100				Heading 018°. XBT run.
Day 128 Station 11103							Maxwell Fracture zone (East).
1	48 12.4	24 57.3	0934	FIDO		3600	Two filters. Valve rotation problem.
2	48 12.1	24 56.3	1206	CTD	3465	3516	10m off bottom. Z-boat for surface samples.
3	48 12.1	24 56.4	1416	CORER	3445	3685	Coil around corer - inboard horizontal.
4	48 12.1	24 56.0	1548	NISKIN		20	
5	48 12.3	24 55.4	1709	FIDO	3762	3780	5m off bottom. Leak via connector.
			2400	END			Heading 059°

Day 130	Station 11104						Porcupine Abyssal Plain (West Flank)
1	50 00.1	19 59.7	0004	CTD	4364	4435	10m off bottom
2	50 00.8	20 02.7	0300	FIDO		1200	Leak in tube via connector. Wire tested tube.
3	50 01.6	20 03.7	0505	PWS		4515	
4	50 01.0	20 04.8	0907	CTD		2250	
5	50 01.3	20 05.2	1107	NISKIN		20	
6	50 01.3	19 59.8	1346	CTD		1500	
			1524	END			Heading 103° (Two engines)
Day 131	Station 11105						Porcupine Abyssal Plain (East Flank)
1	49 07.0	14 09.1	1540	CORER	4535	4720	
2	49 07.5	14 09.6	1818	CORER	4520	4697	
			2100	END			Heading 003°
Day 132	Station 11106						Mouth of the Porcupine Seabight
1	49 50.1	14 05.0	0126	CORER	3980	4131	
2	49 49.9	14 03.0	0357	CTD	3960	3750	
3	49 51.0	14 02.2	0632	FIDO		1500	Mn scavengers
4	49 50.2	14 04.3	1300	CTD		800	
5	49 50.2	14 03.2	1354	CORER	3975	4118	
6	49 50.2	14 02.7	1600	FIDO	3960	3973	10m off bottom. Mn scavengers
			2400	END			Heading 038°
Day 133	Station 11107						Porcupine Seabight
1	50 17.9	13 23.9	0437	CORER	2723	2829	
			0620	END			Heading 020° to moorings. Tide guage 1 and 3 recovered. Sediment traps and T.G.2 would not release.
Day 133	Station 11108						Biology '2000m' station.
1	51 03.5	12 57.9	1826	CORER	2000	2094	
2	51 03.7	12 56.7	2008	CORER	2010	2116	
				END			Heading 344°

Day 134	Station 11109						Biology '1370m' station
1	51 34.9	13 00.3	0114	CORER	1336	1360	
			0228	END			Heading 002°
Day 134	Station 11110						
1	51 50.0	13 00.0	0416	CORER	1008	1074	
			0553	END			Heading 180°
Day 134	Station 11111						Biology '1370m' Station
1	51 34.9	12 59.7	0722	CORER	1360	1421	Incubation experiment held 70m off bottom
Day 134							
2	51 30.9	13 05.6	0240	CTD	1343	1347	10m off bottom
3	51 30.7	13 05.6	0353	PWS		1415	
4	51 30.7	13 06.5	0515	FIDO	1314	1340	5m off bottom.
5	51 29.4	13 09.1	0848	KEVLAR		20	
6	51 29.6	13 08.6	1020	FIDO	1290		Aborted. Main engine room switchboard problem.
7	51 28.8	13 09.3	1444	KEVLAR		50	
8	51 30.9	13 09.9	1607	CORER	1360	1418	
9	51 30.5	13 09.4	1717	CORER	1360	1402	
10	51 30.5	13 10.0	1824	KEVLAR		100	
			1915	END			Heading 164°
Day 135	Station 11112						Biology '2000m' station
1	51 03.0	12 58.1	2228	CTD	2010	2053	10m off bottom
2	51 02.4	12 58.2	2349	CORER	2030	2149	
Day 136							
3	51 02.6	12 54.2	0110	FIDO	2039	2042	10m off bottom. GFC Filters
4	51 03.9	12 50.3	0624	CORER	2027	2128	
			0755	END			Heading 108°

Day 136	Station 11113						Up slope Transect
1	50 50.5	11 59.8	1205	CTD	2000	2019	
			1342	END			Heading 110°
Day 136	Station 1114						
1	50 45.3	11 33.5	1612	CORER	1610	1690	
2	50 45.0	11 32.3	1736	CTD	1605	1602	12m off bottom
3	50 45.0	11 32.6	1900	FIDO	1640	1643	10m off bottom. Particle profiles only.
			2000	END			Heading 110°
Day 136	Station 1115						
1	50 36.7	11 06.0	2216	FIDO	589	594	5m off bottom. Particle profiles only
2	50 36.4	11 06.3	2303	CTD	535	550	10m off bottom
			2338	END			Heading 109°
Day 137	STation 1116						
1	50 32.3	10 45.8	0130	FIDO	190	190	2m off bottom. Particle profiles only
2	50 32.2	10 46.0	0205	CTD	177	170	10m off bottom.
			0236	END			Heading 109°
Day 138			0748				Docked at Falmouth (17th May 1984). 11 days station time. 10.5 days steaming over 2350nm (9.3 knots average).

Table 2 XBT LOG

Day	Time	Lat	Long.	Ref		Remarks
118	1052	42 01.5	10 02.4	1		
	1108	42 01.5	10 02.5	2		
	2112	42 00.8	11 00.1	3		
	-	-	-	4		
119	0227	42 00.2	12 01.1	5		One degree XBT's
	0725	41 58.3	13 00.3	6		
	0920	41 58.7	13 24.5	7		Twenty minute XBT's:-
	0941	41 59.0	13 29.2	8		Hunt the front
	1000	41 59.3	13 33.3	9		
	1020	41 59.6	13 37.8	10		
	1040	41 59.8	13 41.9	11		
	1100	42 00.1	13 46.3	12		
	1120	42 00.1	13 50.6	13		
	1140	42 00.2	13 54.4	14		
	1200	42 00.3	13 58.6	15	)	(Included in one degree)
	1220	42 00.1	14 02.4	16	)	
	1240	42 00.0	14 06.7	17		
	1300	41 59.9	14 10.8	18		
	1320	42 01.2	14 15.7	19		
	1340	42 01.7	14 18.6	20		Front located
	1400	42 01.6	14 22.6	21		
	1420	42 02.0	14 24.8	22		
	1440	42 01.8	14 21.4	23		Station 11098
	1500	42 01.5	14 18.2	24		
	1520	42 01.3	14 15.6	25		
	2120	-	-	26		Leaving Station 11098
	2140	42 02.8	14 17.8	27		
	2200	42 02.6	14 21.7	28		
	2221	42 02.3	14 25.8	29		
	2243	42 02.1	14 30.3	30		
	2300	42 01.9	14 33.6	31		
	2322	42 01.7	14 38.1	32		
	2340	41 59.9	14 42.2	33		
120	0001	41 59.8	14 46.5	34		
	0020	41 59.6	14 50.1	35		
	0040	41 59.6	14 54.0	36		
	0100	41 59.4	14 57.1	37		
	0120	41 59.4	14 53.1	38		
	0156					On station 11099

121	1040	42 92,3	14 59.8	39	(Included in one degree)
	1100	42 02.9	15 02.6	40	
	1120	42 02.2	15 06.3	41	
	1140	42 01.7	15 09.8	42	
	1200	42 01.6	15 12.9	43	
	1220	42 01.5	15 16.2	44	
	1240	42 01.3	15 19.2	45	
	1300	42 00.7	15 22.3	46	End of 20 min run for front.
	1730	42 59.2	16 02.7	47	One degree run recommences
	2400	42 01.3	16 59.9	48	
122	1351	41 55.4	18 00.2	49	Heavy weather
123	0814	42 10.8	19 00.3	50	
	1428	42 00.5	19 58.5	51	
124	1051	42 00.3	21 06.2	52	
	1425	42 00.1	22 00.6	53	
	1816	42 00.4	23 00.4	54	
	2208	42 00.8	24 00.0	55/56	
125	0204	42 00.6	24 56.7	57	
	2050	42 07.1	26 00.9	58	
126	0048	42 14.8	27 00.8	59	
	0453	42 21.1	28 02.1	60	
	0848	42 28.1	28 59.9	61	
					End of E-W Transect Station 11102
					Ridge Transect 1 hourly run
	2200	42 45	29 19.0	62	
	2300	42 59.3	29 15.0	63	
	2400	43 10.4	29 10.5	64	
127	0100	43 21.6	29 06.0	65	
	0200	43 33.3	29 01.2	66	
	0300	43 44.1	28 55.5	67	
	0400	43 55.2	28 50.0	68	
	0500	44 06.4	28 44.7	69	
	0600	44 17.6	28 39.5	70	
	0700	44 29.2	28 34.1	71	
	0800	44 40.1	28 28.6	72	
	0900	44 51.1	28 23.6	73	
	1000	45 01.8	28 17.6	74	
	1100	45 12.8	28 12.0	75	
	1200	45 23.1	28 07.1	76	
	1300	45 32.0	28 02.8	77	
	1400	45 45.6	27 55.8	78	

127	1500	45 55.7	27 50.3	79	
	1600	46 03.2	27 46.9	80	
	1700	46 09.5	27 44.4	81	
	1800	46 20.9	27 36.8	82	
	1900	46 32.3	27 32.7	83	
	2000	46 44.3	27 28.3	84	
	2100	46 55.8	27 23.8	85	
	2200	47 07.9	27 18.6	86	
	2300	47 19.5	27 13.4	87	
	2400	47 25.2	27 09.4	88	
128	0100	47 29.9	26 57.7	89	
	0200	47 36.1	26 43.1	90	
	0300	41 41.7	26 27.2	91	
	0400	47 47.4	22 11.6	92	
	0500	47 53.2	25 56.0	93	
	0600	47 57.0	25 41.1	94	
	0700	48 02.0	25 25.8	95	
	0858	48 12.7	24 57.5	96	
	0900	48 12.7	24 57.5	97	Station 11103 End of XBT run.

Table 3 WATER FILTER SAMPLES AT WIRE-OUT DEPTHS

11097	11098	11099	11100	11101	11102	11103	11104
10	7	7	7	7	7	7	7
25	15	20	15	20	20	25	20
60	20	F25 (67)	20	F25 (107)	F25 (168)	F25 (79)	50
100	F24 (168)	F44 (181)	25	30	40	40	75
200	25	50	30	50	100	55	100
300	30	100	50	75	200	100	150
400	50	F150(818)	75	100*	300*	200	200
480	75*	200	100	150*	550*	350	250
650	100	400	150	200	810	440	300
750	150	650	200	300	F880(1054)	F440(585)	400+
825	200	800	300	400	1000	550	500
880*	300	F800(1123)	400	500	1200	F564(853)	600
999	400	950	500	F500(1076)	1350	2000	700
1200	(shallow	1200	750	750	1500	F2000(1162)	850
1500	only)	1650	1000	1000	1650	3476	1000
1800		2100	1250	F1082(1032)	1800	3516	1250+
2200		2500	1500	1150	1950	F3645(1087)	1500
2556		3500	1750	1300	F2000(1091)	F3162(1163)	1750
2576		F3500(1077)	2000	F1300(1133)	2100		2000
		4500	2300	1500	2250		2250
		F4500(900)	2600	1750	2400		
		5100	3000	2000*	2550*		
		F5245(1009)	3368	2300	2700		
		5319	3418	2600	2850		
				3000	3000		
				3258	F3033(1202)		
					3279		
					3309		

*Rejected sample
F(x) = FIDO Filters (Volume filtered in litres)
+ Replicate samples for REE determinations
11111K Kevlar cable cast.

11106	11111	11111K	11112	11113	11114	11115	11116
7	7	2	F606(1232)	7	7	7	3
20	20	7	F1656(1374)	20	20	20	7
F40(199)	50	20	F2039(1145)	50	50	35	15
50	75	30	(GFC filters CTD profile)	75	75	50	20
75	100	40		100	100	75	35
100	200	50		200	150	100	50
F180(681)	400	60		500	200	200	100
319	F651(555)	80		1110	800	300	125
F319(537)	800*	90		1400	1100	400	140
430	1000	100		1700	1400	510	155
540	F1039(751)	110		2019	1602	550	170
654	1200				(FIDO profiles)		
F654(1026)	F1291(755)						
700	1347						
800							
962							
1000							
1250							
2000							
2300							
F2400(1096)							
2600							
2900							
3200							
3500							
3750							
F3860(1069)							
F3960(1053)							

Table 4 - STATIONS AND CASTS SAMPLED FOR MICROBIOLOGICAL ANALYSIS
(R = ROSETTE; F = FIDO; N = NISKIN BOTTLE - SURFACE SAMPLE)

Station	Cast	Apparatus
11097	1	R
	2	N
	4	R
11098	1	F
	2	R
11099	6	F
	8	F
11100	4	R
11101	1	R
	4	R
	5	F
11102	1	R
	3	F
	4	R
11103	1	F
	2	R
	5	F
11104	4	R
	6	R
11106	2	R
	3	F
	4	R
	6	F
11111	2	R
	4	F

Table 5 - CORING DEPTHS

Station	Uncorrected m	Corrected m
11103#	3445	3451
05#1	4535	4561
05#2	4520	4546
06#1	3980	3994
06#5	3975	3989
07#1	2723	2722
08#1	2000	1998
08#2	2010	2008
09#1	1336	1336
10#1	1008	1009
11#1	1360	1360
11#9	1360	1360
11#10	1360	1360
12#2	2030	2028
12#4	2027	2025
14#1	1610	1609

TABLE 6 - DETAILED FIDO LOG

Station No.	Depth (m)	Filters	Water Bottles	Temp/Press Sensors	Transmiss-ometer	Particle Cell	Remarks/ Duration
11097#2	-	-	-	-	-	-	Aborted - fault in sea cable joint.
11098#1	2000	1	3	O.K.	O.K.	Fault	Low flow rates through part cell, indications of pump blockage . 3 hours 14m.
11099#1	5277	1	1	O.K. till failure		Profile down O.K.	Lack of control after filter 1 completed. Water leak due to failure of 'O' ring seal . 3hrs 33m.
11099#6	800	4	3	O.K.	O.K.	O.K.	4hrs 9m.
11109#8	4500	3	3	O.K.	O.K.	Profile down to 2266m O.K.	Loss of PC flow due to battery pack failure 5hrs 36m.
11100#2	2200	-	FAULT	-			Water in electronics tube. Crack in G.O. Bulk-head connector. 1hr 33m.
11100#6	-	-	FAULT	-			Water leak - main Piston 'O' ring not seated.
11101#5	3260	4	3	Damaged pressure sensor	O.K.	Fault	P.C. motor u/s. Pressure sensor damaged on bottom. 5hrs 37m.
11102#3	3028	4	3	O.K.	O.K.	Fault	Interference on PC data from "fizzing" filter battery harness. 5hrs 27m.
11103#1	3600	2	3	O.K.	O.K.	(Profile)	7hrs. Valve rotation problem.
11103#5	3760	4	3	O.K. down to seabed.			Water leak - G.O. connector failed (not 'O' ring) 7hrs.
11104#2	1200	-	FAULT	-			Water leak - G.O. connector failed (not 'O' ring) 1½hrs.
11106#3	1500	4	3	O.K.	O.K.	(Profile)	Problem with P.C. flow data. 6hrs 14m.
11106#6	3960	3	3	O.K.	O.K.	Profile O.K.	6hrs.
11111#4	1314	3	3	O.K.	O.K.	Profile O.K.	Temporary loss of data due to previous water damage 3hrs 20m.
11111#6	1300	-	N.A.	O.K.	Noisy	Profile O.K. to 1000m.	Filter motor u/s 2 hrs.
11112#3	2037	3	N.A.	O.K.	O.K.	O.K.	5hrs.
11114#4	1600	N.A.	N.A.	O.K.	O.K.	O.K.	1hr. } Particle profiles
11115#1	600	N.A.	N.A.	O.K.	O.K.	O.K.	35mins. } only because of time
11116#1	179	N.A.	N.A.	O.K.	O.K.	O.K.	15mins. } limitation.

FIGURE 1. SHIP'S TRACK AND STATION POSITIONS

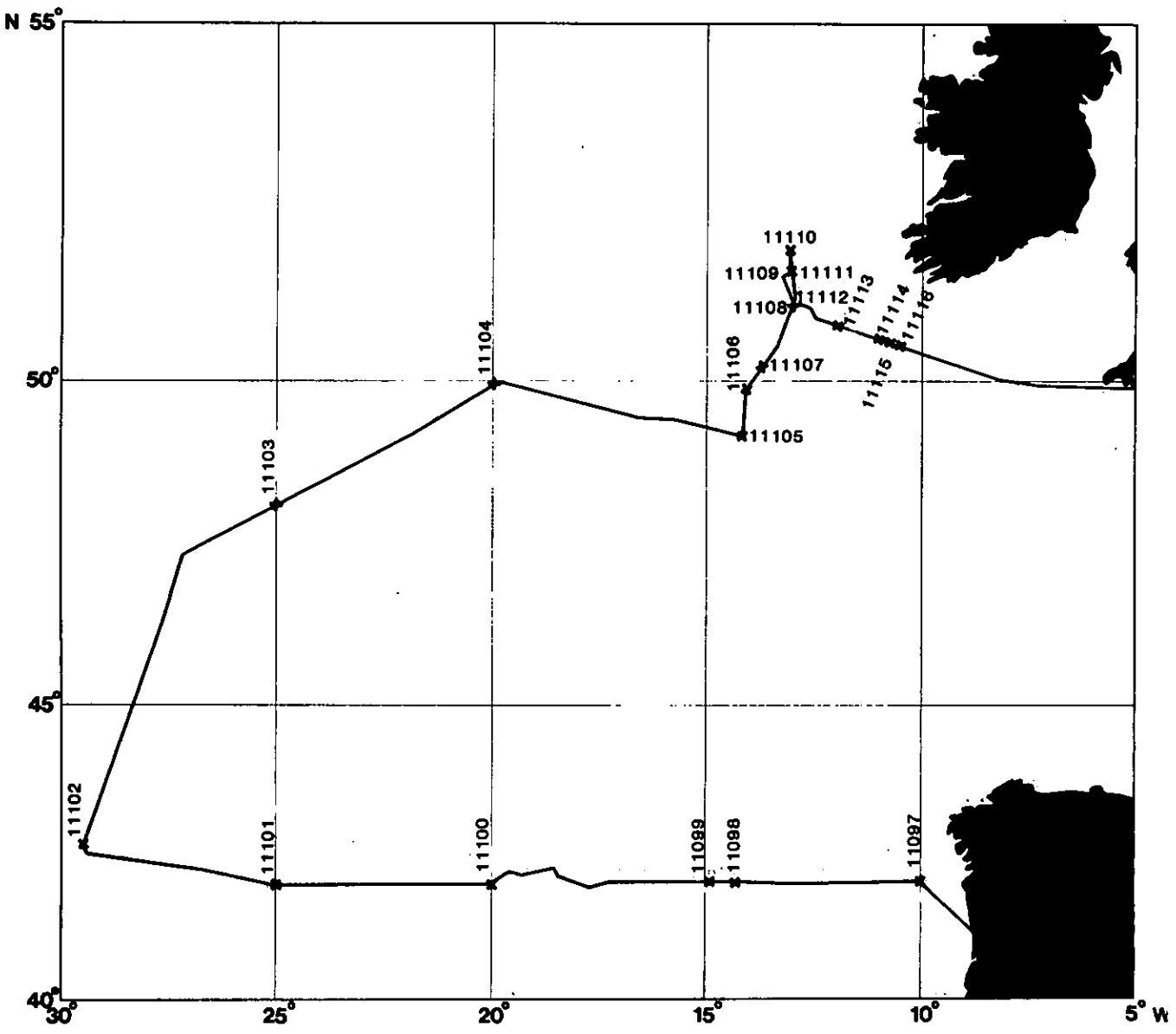
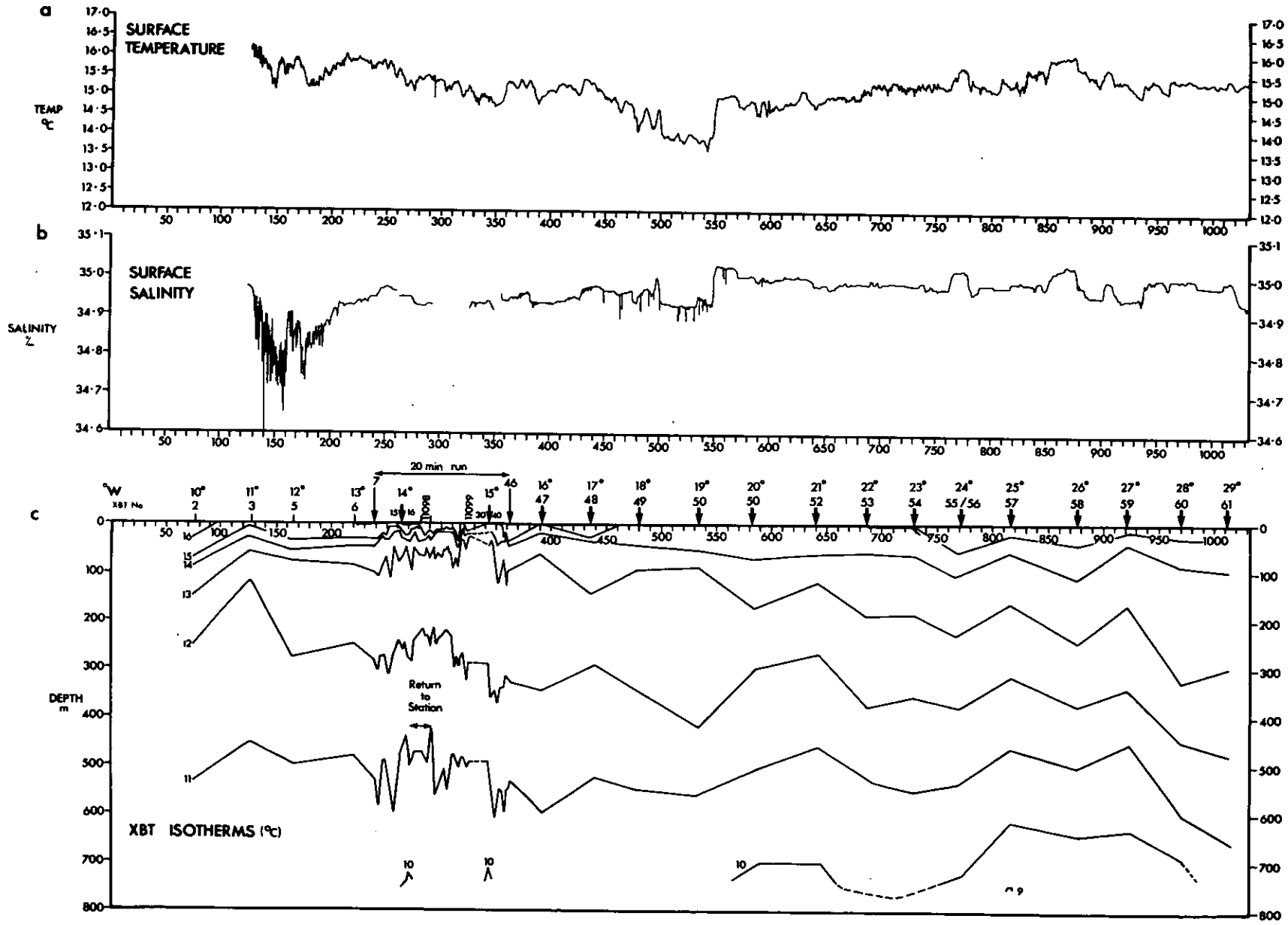
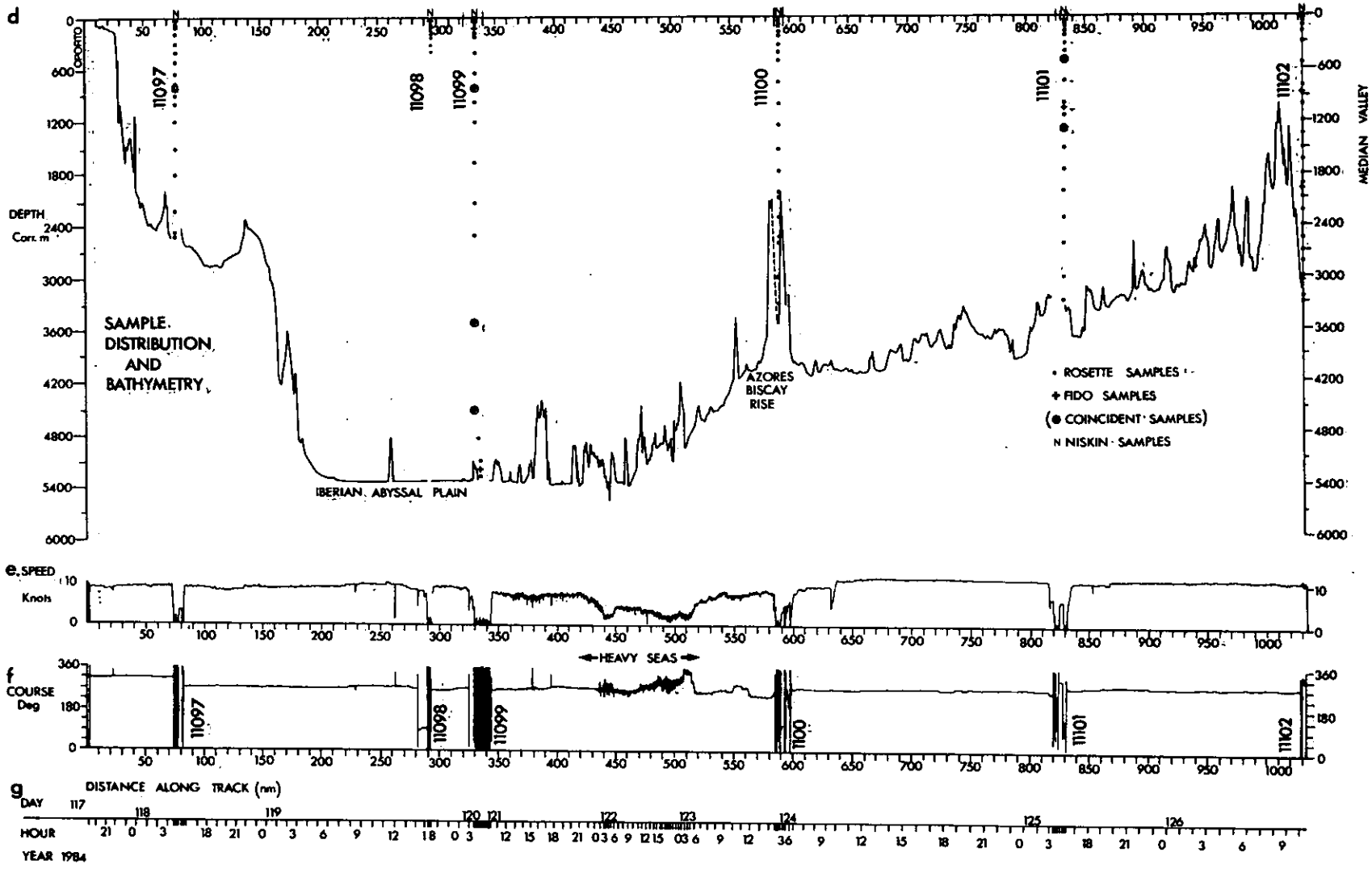


Fig.2 THE 42° N TRANSECT.

(Plots Versus Distance Along Track)




d
OPORTO
11097
11098
11099
11100
11101
11102
MEDIAN VALLEY
DEPTH
Corr. m
SAMPLE
DISTRIBUTION
AND
BATHYMETRY
IBERIAN ABYSSAL PLAIN
AZORES
BISCAY
RISE
• ROSETTE SAMPLES
+ FIDO SAMPLES
(● COINCIDENT SAMPLES)
N NISKIN SAMPLES
e SPEED
Knots
HEAVY SEAS
f
COURSE
Deg
g
DISTANCE ALONG TRACK (nm)
DAY
HOUR
YEAR 1984

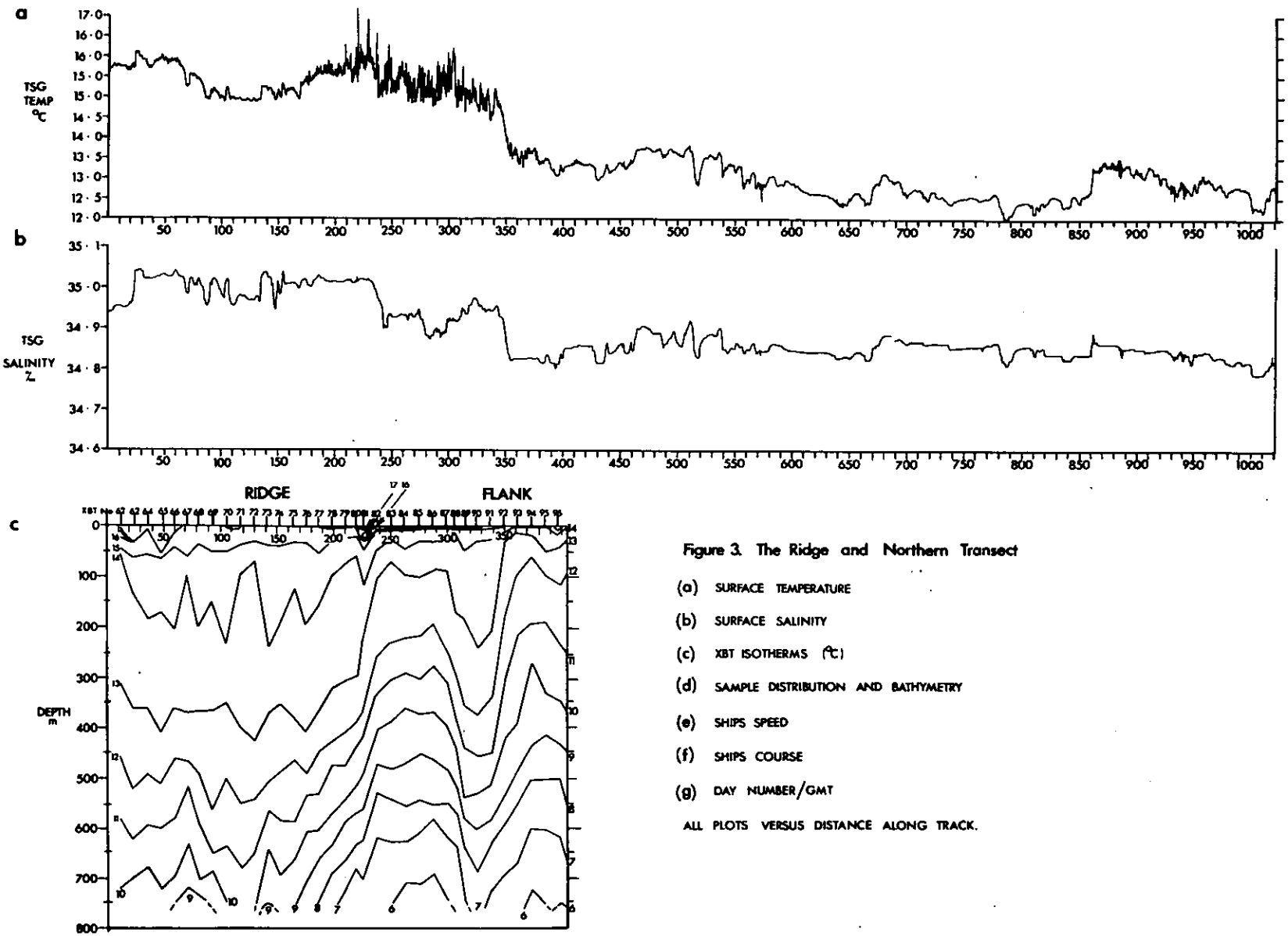


Figure 3. The Ridge and Northern Transect

(a) SURFACE TEMPERATURE

(b) SURFACE SALINITY

(c) XBT ISOTHERMS (°C)

(d) SAMPLE DISTRIBUTION AND BATHYMETRY

(e) SHIPS SPEED

(f) SHIPS COURSE

(g) DAY NUMBER/GMT

ALL PLOTS VERSUS DISTANCE ALONG TRACK.

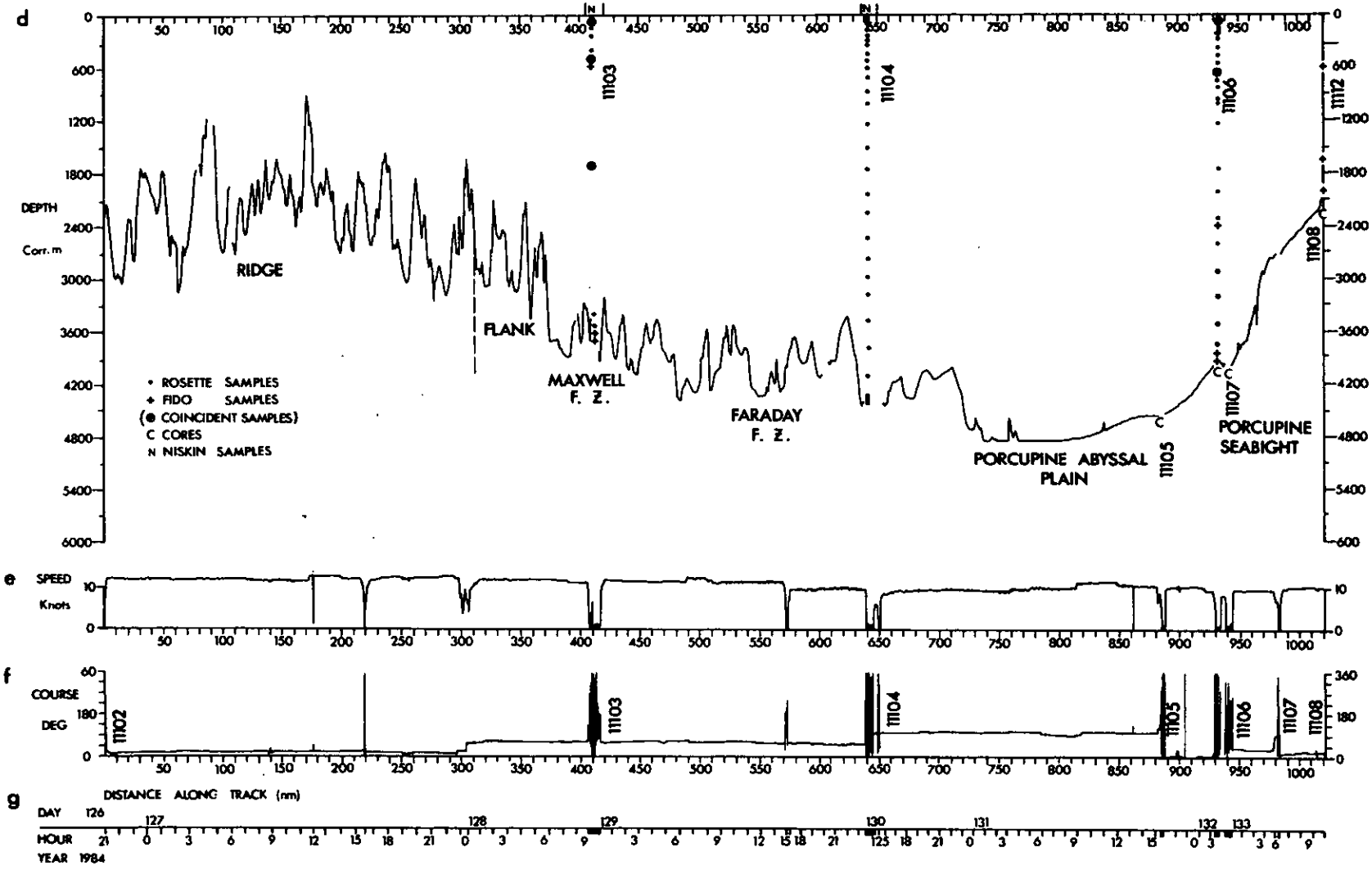

d
DEPTH
Corr. m
RIDGE
FLANK
MAXWELL
F. Z.
FARADAY
F. Z.
PORCUPINE ABYSSAL
PLAIN
PORCUPINE
SEABIGHT
• ROSETTE SAMPLES
+ FIDO SAMPLES
(● COINCIDENT SAMPLES)
C CORES
N NISKIN SAMPLES
11102
11103
11104
11105
11106
11107
11108
11112
e
SPEED
Knots
f
COURSE
DEG
g
DISTANCE ALONG TRACK (nm)
DAY 126 127 128 129 130 131 132 133
HOUR 21 0 3 6 9 12 15 18 21 0 3 6 9 3 6 9 12 15 18 21 0 3 6 9 12 15 0 3 3 6 9
YEAR 1984

FIGURE. 4. SAMPLE DISTRIBUTION IN THE PORCUPINE SEABIGHT