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Rockall Trough Time Series
LOIS Shelf Edge Study Pilot Programme
EC MAST 2 PROFILE Project

Cruise Report
R.R.S. Challenger Cruise 101/93
Leg 1 : Barry to Oban : 1993 March 6 to 13
Leg 2 : Oban to Ardrossan : 1993 March 13 to 20

Anton Edwards (DML) & John Gage (SAMS)
September 1993

Leg 1: 6th March to 13th March 1993; Barry to Oban

Leg 2: 13th March to 20th March 1993; Oban to Ardrossan.

Leg 1: 6th March to 13th March 1993; Barry to Oban.

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Narrative

"Challenger" sailed from Barry at 0630 hrs 6 March 1993 and after brief trials with the ship's echo sounder landed her pilot and steamed west into the Bristol Channel in calm conditions. The excellent sea conditions persisted across the Celtic Sea and "Challenger" rounded Mizzen Head the next morning (Sunday 7 March) at 0900 hrs in a light but freshening southerly breeze. Helped by the southerly seas, "Challenger" made good progress to the first station in the southern Rockall Trough, heading across the Porcupine Bank over the shelf edge into deep water. The wind had increased to force 6 from the SSE, with a building sea. During the night of 7/8 March the wind had swung round to the north and increased to force 6/7, but by the time "Challenger" arrived on the SMBA Permanent Station (54°30' N, 12°16' W) at 0700 hrs the following morning (Monday 8 March) it had eased to force 5/6. "Challenger" hove to for the first epibenthic haul (fitted with 300-micron mesh net) on the main wire, launching at 0737 hrs 9 March. "Challenger" steamed slowly almost due north at 1.5 to 2 knots until we were sure the sled had bottomed with 6000 metres of wire out, and was then towed at about a knot for an hour before starting to haul it slowly. The epibenthic sled was recovered at 1247 hrs with a satisfactory catch (sample ES 445 - see Table 1), one-third filling the extension bag. The muddy sample was washed using the elutriating bin system and a 300-micron sieve using the filtered sea water from the ship's fire hose supply. An aliquot of the sample was examined under the microscope and found to contain sufficient numbers of the macrofaunal species required by SAMS Academic Research Project 2. In addition, 46 specimens of the bivalve *Ledella pustulosa* were transferred individually by Dr Hazel Kennedy to vials and held in a flask of liquid nitrogen for molecular genetics studies in conjunction with Dr Alex Rogers at MBA.

While the epibenthic sled was readied for another haul, "Challenger" steamed back to the starting position of the previous haul for another one on the Permanent Station; this time with the sled fitted with a 500-micron mesh main bag. The gear was launched at 1445 hrs and finally recovered after another 1-hour haul over the bottom in 2900 m depth, at 2003 hrs. Although this time the sled recovered a smaller volume of material than previously, the sample (ES 446) contained several hundred small, transparent gelatinous elasipod holothurians (*Kolga hyalina*).

With "Challenger" hove to near the Permanent Station, the new Mk II Multicorer (Bowers & Connelly 1991 design) was then deployed at 2014 hrs on the main wire to obtain undisturbed core samples of the sediment at the Permanent Station. The gear was monitored using a IOSDL 'H'-type 10 kHz pinger and the newly fitted Simrad precision depth recorder in the ship's control room. The gear bottomed at 2132 hrs after lowering at about 50 $m.min^{-1}$, was winched in at 60/70 $m.min^{-1}$, arriving on deck at 2225 hrs 8 March with closed core tubes but no samples.

With all deck gear secured, course was set for Station "M" (57° 14' N, 10° 27' N), roughly 160 miles to the NNE, between the Anton Dohrn seamount and the adjacent Barra Fan on the Hebridean slope. The wind by now was NE force 6 with a moderate to rough sea. From the morning of 9th March surface water samples were taken (using the ship's non-toxic supply) at regular intervals for Mr David Ellett, DML, between 56° and 58° N. This continued to the end of the programme on the upper continental slope on 12th March. Large samples of oceanic sea water were also taken for Ocean Scientific International (Wormley).

"Challenger" arrived in the vicinity of station "M" at 1600 hrs 9th March 1993 for another epibenthic sled haul. The wind was now ENE 5/6. The sled was deployed with a 500-micron mesh main bag at 1626 hrs and recovered, after a 1-hr haul over the ground, with 5000 m of wire out, at 2126 hrs, but with only a small, washed sample filling the end pot. The sample was washed through a 420-micron sieve and an aliquot examined microscopically. This showed that the sample was quite rich in material, and 40 individuals of *Ledella pustulosa* were picked off and frozen individually for the genetics work mentioned above. The sample also contained the ophiuroid *Ophiura ljungmani* and the asteroid *Hymenaster membranaceus*.

The 3-m wide RVS Agassiz trawl was next readied while "Challenger" steamed south back to the starting position for the haul required on Station "M". The Agassiz was put over the side at 2302 hrs 9 March and recovered at 0600 hrs the following day (10 March 1993) after a one-hour haul on the ground with 5.5 kilometres of wire out. The small catch (AT 448) contained the usual faunal elements previously caught from this station, including the echinoid *Echinus affinis*, the sea stars *Plutonaster bifrons*, *Hymenaster membranaceous*, the brittle star *Ophiomusium lymani*, the gorgonian *Acanella arbuscula*, the stone crab *Neolithodes grimaldi*, and various gastropods and sponges.

Following this successful trawl, the multicorer was readied for another attempt to obtain undisturbed sediment cores. The gear was put over the side at 0614 hrs and recovered after a clear indication of bottoming from both the pinger and the wire tension, at 0729 hrs with the same result as previously.

"Challenger" then steamed a little way eastwards into soundings of 2000 m in the vicinity of DML Hydrographic Station "N" where it was decided to repeat the Agassiz trawl in the hope of obtaining a larger catch for the on-board experiments. The trawl was launched at 0916 hrs and later recovered, after paying out 4500 m of wire and towing for one hour over the bottom, at 1413 hrs 10th March. The catch (AT 449) was small but in exceptionally good condition, with all the species present in the Station "M" haul present in addition to the sea stars *Bathybiaster vexillifer*, *Pseudarchaster parelli* and *Plutonaster bifrons* present in numbers, arms of brissingid sea stars, and the brittle stars *Ophiura ljungmani* and *Ophiacantha bidentata*. In a stiffening sea, we undertook one more Agassiz trawl a little further east between hydrographic stations "O" and "P" in about 1750 m depth on the middle to lower continental slope. As previously, 4000 m were put out and the trawl towed for one hour. The catch (AT 450) was recovered at 2015 hrs on 10 March and sorted immediately. It consisted of a fair catch featuring mainly echinoderms, with many of the echinoids *Echinus affinis* and *Phormosoma placenta*, various sea stars including those caught at the previous station, various crustaceans, anemones, corals and gastropods.

Because of the marginal conditions, "Challenger" then hove to for the night, but by morning on 11th March the wind was Southerly force 6, with a moderate to rough sea. "Challenger" positioned herself in soundings of about 750 m on the upper slope The multicorer was again deployed at 0614 hrs with some slight modifications to try and bottom the gear before it pre-fired. The multicorer was recovered again at 0847 hrs 11th March with the cores closed but with no evidence of their having contained sediment, although there was clear evidence from sediment smearing that the corer framework had bottomed.

The Agassiz was next deployed in about 1000 m depth on the upper slope. The trawl was shot at 0916 and 2500 m, of wire put out with the ship making just under a knot over the ground. By 1100 hrs 11th March it seemed to have become fast on the bottom. "Challenger" immediately was allowed to drift off wind and the winch started with the ship beam on, and then steamed at right angles to the fishing course to winch the net clear. However, tension increased slowly to 2 tonnes, then suddenly dropped away. The Agassiz was eventually recovered at 1152 hrs, intact and with some polishing but little other damage apart from a parted weak link, but with no catch. The multicorer was again deployed on this position at 1219 hrs, and recovered on deck after a clear indication of bottoming but nothing in the cores, immediately sent down again, and finally recovered after another bottoming, at 1351 hrs. As previously, the core tubes were closed but contained only clear water, yet the frame work showed clear evidence of the gear having bottomed.

The Agassiz was then deployed again at 1420 hrs for a haul at 750 m. Pay-out was to 2500 m and the ship's speed was increased to 1.5 knots for the tow over the bottom on a heading of 150°. A

sudden tension drop was noticed at 1613 hrs at 542 m depth. It was suspected that a weak link had sheared after the trawl had snagged something, so a slow winching in was started. Tension slowly increased to 2 tonnes, when a procedure similar to that instigated previously was undertaken in an effort to free the gear. However tension increased to 7 tonnes and then suddenly dropped away with 2286 m of wire out. The virtually slack wire was then winched in and the gear found to have been lost completely along with about 300 metres of the main warp with the bare end being recovered, broken and stranded, at 1734 hrs 11th March.

The broken end of the main warp was remade and the second Agassiz trawl was bent on. This gear was shot at 2030 hrs 11th March, recovering at 2350 hrs with a good mixed haul (AT 451) of megafauna. This contained the usual upper slope sea stars such as *Zoroaster fulgens* along with the echinoids *Echinus acutus*, *Porocidaris purpurata*, *Phormosoma placenta* and *Sperosoma grimaldii*, and the holothurian *Benthogone rosea* and *Laetmogone violacea*, and the ophiuroids *Ophiactis abyssicola* and *Ophiopleura inermis*. Other invertebrates included scleractinian corals, including a large samples of the species *Fungiacyathus marenzelleri*, *Caryophyllia seguenzae* and *Stephanocyathus mosleyanus*, to be presented to Dr John Thomson, IOSDL for radiometric dating (as part of a current MAST 2 contract), anemones and the gorgonian *Acanella arbuscula* with its epizoic anemone *Amphianthus inornata*.

The epibenthic sled was deployed at 0030 hrs 12 March. After a half-hour tow on the bottom at almost 1000 m the sled was winched in, recovering a fair muddy sample at 0315 hrs. A large grenadier (*Coryphaenoides rupestris*) was caught in the bag, and this probably contributed to the rather small sample. However, the material proved rich in species, with many megafauna present including the echinoids (*Echinus acutus* and *Phormosoma placenta*), zooanthids on hermit crabs and synaphobranchid eels.

"Challenger" then moved about 7 miles to the northeast to shoot another Agassiz trawl in about 1500 m depth. By now the wind was Southerly force 6, with a forecast increase to 8. With 4500 m of warp out, the trawl again came fast. "Challenger" slowly reversed course and steamed back towards the trawl, recovering the wire as she did so. Fortunately, the trawl came free and was recovered intact at 1054 hrs, with a fair sample (AT 453) of megafauna, including assorted sea stars (including *Plutonaster bifrons* and brissingids), various holothurians, assorted gastropods and scaphopods, scleractinian corals and various other invertebrates. This successful haul was then followed in steadily worsening sea conditions by another attempt at an epibenthic sled haul in about 1000 m depth. The sled was launched at 1226 hrs 12 March,, paying out a little more than 2000 m of warp, and was recovered after a half-hour tow over the bottom at 1504 hrs with a satisfactory sample (ES 454). This completed the scientific work, and gear was secured and "Challenger" set course for Oban at full speed. The ship was stopped for a short plankton tow during the evening. "Challenger" berthed at Oban at 0815 hrs 13th March to change personnel and equipment for leg 2.

John D. Gage

Results

Aim 1) Seasonal time series sampling

Satisfactory samples were obtained of macrobenthos using the epibenthic sled from the SMBA (SAMS) Permanent Station. Samples were obtained using both the 300- and 500-micron nets. Preliminary examination showed the samples to contain adequate numbers of the species currently under investigation. A good epibenthic sled sample was also obtained from the secondary station "M". The latter station is maintained chiefly for megabenthos sampling, and the Agassiz trawl samples obtained for this purpose were good. Coiled brown tubes from AT 453 (1500 m) were found to be densely packed with egg capsules. The tubes have been maintained at 60 C since the cruise and after 90 days viable embryos can still be found along with undeveloped eggs. Each egg capsule contains two embryos, but the highly motile larvae have not been observed to settle and develop further. The tubes may be made by a turbellarian worm. *P.A.Lamont & Hazel F.Kennedy*

Aim 2) Molecular genetics

a) *Ledella* study: Adequate samples were obtained of the two depth-zoned morphotypes of the protobranch bivalve *Ledella pustulosa*. They were picked directly from the fresh sample and transferred in separate vials that were stored in a liquid nitrogen flask. At the end of the cruise they were transferred to a larger cryogenic flask prior to transportation to Plymouth in April for protein electrophoresis by Dr Rogers (MBA). *J.D.Gage*

b) Molecular genetics of echinoderms: Samples of deep-sea echinoids and other fauna were collected for studies of molecular genetics with the University of New Hampshire, USA. The following species were collected and shipped frozen to the U.S for Dr R.Olson and Miss Medieros: *Ophiura jungmani*, *Ophiomusium lymani* and *Ophiocten gracilis*. *Dorothy Medieros-Bergen*

c) Molecular phylogeny of echnoderms: Samples of deep-sea ophiuroids were taken for a study of molecular phylogeny by the Station Biologique,Villefranche, and the Natural History Museum (Dr A.B.Smith). Material of the following species was collected: *Hymenaster membranaceous and Ophiomusium lymani* (2200 m); *Ophiomusium lymani*, *Ophiura ljungmani*, *Ophiacantha bidentata*, *Ophiopleura inermis*, *Phormosoma placenta* (2000 m); *Ophiopleura inermis*, *Phormosoma placenta* (1700 m); *Benthogone rosea*, *Laetmogone violacea*, *Ophiacantha abyssicola*, *Amphilepis ingolfiana*, *Ophiactis abyssicola*, *Ophiocten gracilis*, *Ophiopleura inermis* (ca 1000 m).

Scientific Background to the molecular genetics work

Over the last twenty years, molecular phylogeny analyses have become important for the study of evolution. At the molecular level, evolution is characterised by the accumulation of punctual mutations through time. Comparison of molecular sequences shows similarities or differences that can exist between sequences of the same molecule in different organisms. It is then possible to compute these differences so as to find the polarity of evolution and build the phylogeny of the organisms. As in classical evolution, studies are based on similarities, and homology is the first requirement for comparison of molecules: homologous molecules should possess the same function and structure in all organisms under study. Molecules are treated as a suite of characters (the different positions in the molecule sequences) which can show different states (the four nucleotides for nucleic acids or the twenty amino-acids for proteins). The phylogeny reconstruction can be computed using methods based on evolution models; they are divided into distances matrix and discrete character methods: the first type (Fitch, Neighbor-Joining for instance) transforms the aligned sequences into distances which quantify the dissimilarities between each pair of sequences; the second type (maximum parsimony, maximum likelihood) considers each position of the aligned sequences one by one and evaluates the change polarity for this position.

However, despite the understanding of molecular evolution and the development of phylogeny reconstruction algorithms, ambiguities remain in the interpretation of resultant phylogenies. The abundance of methods is an indication that none is infallible and that there is a real need for calibration and verification of results. To test the power of molecular phylogeny analysis, we started a phylogenetic study of a well-described phylum: the echinoderms. This is collaborative work with Dr A.B.Smith of the Natural History Museum, London (Department of Palaeontology). The first part concerned the echinoid class with a relatively good fossil record over the past 250 million years: molecular data were then compared to morphological and palaeontological data. For this work, the 5' end of the 28S ribosomal RNA (rRNA) was used. Ribosomal RNA is a commonly employed molecule to study phylogeny. It is a constituent of the ribosomes involved in cellular protein synthesis, found in all cells of all organisms, and presenting a conserved function through the whole living world. The 5' end of the 28S rRNA was selected because this region appears to have a rate of evolution appropriate for divergences over a time span of 250-500 million years, corresponding to the divergence period of echinoid families. The analysis led us to develop a polarised parsimony approach using a hypothetical ancestral sequence built by comparing outgroup sequences (four other echinoderm classes) to echinoid sequences. We then decided to test the molecular techniques in study of deeper branchings in the phylum Echinodermata, at the class level (time span 250-500 million years) by the construction of hypothetical ancestral sequence of each echinoderm classes. The class Asteroidea was first studied and a similar ophiuroid class analysis is in progress in collaboration with Dr G.L.J.Paterson (Natural History Museum of London, Department of Zoology). For the last year, ophiuroids have been collected, first in Villefranche (*Ophioderma longicauda*, *Amphipholis squamata*, *Ophiothrix fragilis*) and then at the Roscoff marine station in France (*Ophiura albida*), the Millport marine station in Scotland (*Ophiopholis aculeata*) and from the north-west coast of Spain (*Ophiura ophiura*).

The species collected to date are shallow-water animals and do not represent the whole class. The "Challenger" cruise offered the opportunity to collect deep-sea species, in order to get a broader representation of this class and pursue the study of echinoderm phylogeny by molecular techniques.

Bénédicte LaFay

Aim 3) Pressure effects on early development

Large samples of the echinoid *Echinus affinis* were obtained to continue pressure chamber studies started on a "Challenger" cruise in February 1991. The major goal was to define better the embryonic pressure tolerances. Specifically, we wanted to determine if this species has a maximum pressure threshold for embryonic development. Although some 120 individuals were injected with 0.55M KCl to induce spawning, the few gametes obtained did not develop, as the majority of the population had apparently spawned earlier in the season. Although frustrating this lent great support

to the seasonal cycle in this species, previously documented from histological study of the gonad. Some success was achieved with the upper abyssal sea star *Plutonaster bifrons*. This species has also been described from histological study to show a seasonal gametogenic cycle, with the gonad ripening in February and March. Successful fertilisations and embryonic cultures to the 32-cell stage were achieved with this species. Embryos developed most rapidly and with fewest abnormalities at pressures near to those at which the adults live. Lower and higher pressures caused more aborted divisions in the early cleavage stages. Gonads from a number of echinothuriid sea urchins (*Phormosoma placenta*) were removed and frozen for later allozyme comparisons with conspecifics in the Bahamas and the Caribbean. Gametes from a variety of sea stars were characterised with respect to egg size and buoyancy for a comparative study on starfish reproductive patterns throughout the North Atlantic. A brief experiment on the pressure effects on development of a tube-brooding turbellarian worm was conducted in conjunction with Mr Peter Lamont who has maintained the embryos in culture in the laboratory up until the time of writing. *C.M.Young & P.A.Tyler*

Aim 4) Reproductive cycles and organic carbon transfer in deep-sea echinoderms

a) Organic carbon transfer studies: The Agassiz trawls taken from 2200 - 1000 m depth provided a wealth of material for use in NERC Grant GR3/8243 (Dr P.A Tyler, Southampton).Samples of the asteroids *Bathybiaster vexillifer*, *Plutonaster bifrons*, and *Persephonaster patagiatus* were taken and the gonad, pyloric caecum, stomach and stomach contents separated and frozen individually. One piece of the gonad and the pyloric caecum were fixed in 5% seawater formalin or Bouin's solution for the determination of development and for histochemistry. All other dissected material was frozen for analysis in Southampton by GCMS, biochemistry or bomb calorimetry. Other species dissected included *Pseudarchaster parelli* and *Plinanthaster dentatus* as part of a survey of the rarer asteroids taken in the N.E. Atlantic. Good samples of the echinoids *Echinus affinis*, *Phormosoma placenta* and *Sperosoma grimaldii* were also taken in the Agassiz trawls. These were dissected as soon as possible after dissection into gut, gut contents and gonad and the tissue frozen. As for the asteroids, pieces of tissue were fixed for histology and histochemistry. In addition a single specimen of *Porocidaris purpurata* was dissected. *C.Bishop & P.A.Tyler*

b) Reproduction in deep-sea anthozoans: Samples of a variety of anthozoans were taken in the Agassiz trawls. These included *Acanella arbuscula* and its epizoite anemone *Amphianthus inornata*. Individuals of the anemone were removed from each bush of the gorgonian and frozen separately. These will be analysed by enzyme electrophoresis to see if all the individuals on one bush are clones or whether they represent distinct genetically individuals. Frozen material will also be used for biochemical and calorific analysis. Other anthozoans taken include *Phelliactis robusta*, other, as yet unidentified anemones, and the pennatulid *Pennatula aculeata*. These samples were either frozen or fixed for later analysis. *Sarah K.Bronsdon & P.A.Tyler*

Acknowledgements

It is my pleasure again to acknowledge the skill and courtesy of the master Captain Maw and his officers and men, and the helpful and cooperative spirit shown by the crew to the scientists and their work which contributed so much to the success of the cruise in these marginal sea conditions, despite the loss of one of the Agassiz trawls.

As pointed out by Captain Maw in his report, some problems were experienced with the main gantry centre block, which made a lot of noise and then seized up completely early in the cruise - despite its major service before the cruise. However, it was no trouble to operate the main wire through one of the two other blocks. Another problem was that the electronic SEAMETRIX wire metering system controlling the main winch would not re-set, despite 'phone calls from the ship to the makers for help. *J.D.Gage*

CHALLENGER CRUISE SAMPLES

SPECIES	DEPTH	TRAWL	STARTING POSITION	ENDING POSITION	DATE
Asteroidea					
Hymenaster membranaceus	2200	AT	57°14'03"N, 10°25'91"W	57°17'25"N, 10°13'60"W	9.3.93
Echinoidea					
Phormosoma placenta	1700	AT	57°07'85"N, 09°31'98"W	57°06'01"N, 09°20'32"W	10.3.93
Holothuroidea					
Laetmogone violaceum	1000	AT	57°06'09"N, 09°21'12"W	57°05'12"N, 09°19'45"W	11.3.93
Bentogone rosea	1000	AT	57°06'09"N, 09°21'12"W	57°05'12"N, 09°19'45"W	11.3.93
Ophiuroidea					
Ophiacantha bidentata	2000	AT	57°12'15"N, 09°55'58"W	57°10'48"N, 09°43'46"W	10.3.93
Ophiactis aphidicola	2000	AT	57°12'15"N, 09°55'58"W	57°10'48"N, 09°43'46"W	10.3.93
	1000	ES(0.5)	56°39'83"N, 09°11'27"W	56°38'26"N, 09°12'05"W	12.3.93
Ophiochiton tenuispinus	1000	AT	57°06'09"N, 09°21'12"W	57°05'12"N, 09°19'45"W	11.3.93
	1500	AT	56°44'94"N, 09°24'90"W	56°47'05"N, 09°23'46"W	12.3.93
Ophiocten gracilis	1000	ES(0.5)	56°39'83"N, 09°11'27"W	56°38'26"N, 09°12'05"W	12.3.93
Ophiomusium lymani	2200	AT	57°14'03"N, 10°25'91"W	57°17'25"N, 10°13'60"W	9.3.93
Ophiopleura inermis	1000	AT	57°06'09"N, 09°21'12"W	57°05'12"N, 09°19'45"W	11.3.93
Ophiura carnea	1000	ES(0.5)	56°39'83"N, 09°11'27"W	56°38'26"N, 09°12'05"W	12.3.93
Ophiura ljungmani	2000	AT	57°12'15"N, 09°55'58"W	57°10'48"N, 09°43'46"W	10.3.93

Leg 2: 13th March to 20th March 1993; Oban to Ardrossan.

Staff

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C. R. Griffiths		DML
B. E. Grantham		DML
K.J.Jones		DML
N. MacDougall		DML
D. J. Smallman		DML
L. Campos		University of East Anglia
I. P. Wade		University of East Anglia
J. Pates		Scottish Universities Research Reactor Centre
C. L. Unsworth		University College of North Wales

Aims

1) To collect water samples for radiocaesium studies and for nutrient and phytoplanktonic analysis at standard positions between the Sound of Mull and the shelf edge West of Barra: to make Conductivity - Temperature - Depth (CTD) profiles on this line.
2) To maintain the DML current meter mooring in the Tiree Passage.
3) To work the CTD stations of the Anton Dohrn seamount section between the shelf-edge and Rockall and to collect nutrient and phytoplankton samples.
4) To maintain the DML/WOCE temperature-salinity mooring at station M in the Rockall Trough.
5) To work shelf CTD sections in the Sea of the Hebrides and the Clyde Sea area.
6) To collect sediment cores and grab samples from the Clyde Sea and Hebridean shelf.

Narrative

"Challenger" sailed from Oban Railway Pier in a brisk breeze at 1400Z on the 13th March and headed for the mooring in the Tiree Passage via the Sound of Mull. The mooring was grappled soon after 1800Z but could not be relaid because of the combination of gathering darkness and wind increasing to 30 knots. The ship then steamed to station 1G to start the programme of CTD dips, water sample collection and coring. The day finished with a slight moderation of the southeasterly wind as the ship arrived at C2. Stations C2 and C3 were worked during the night and the ship returned in the morning light of the 14th to relay the Tiree passage mooring. We returned then to the line of stations running past Barra Head towards the shelf edge, reaching T around midnight. No coring was done here because of ##the problems of premature surface triggering of the multi-corer.

After CTD and water sampling at station P in the morning of the 15th, it was decided to take advantage of remaining good weather before forecast southwesterly gales to head to station M and recover the WOCE mooring of SEACAT logger and thermistor chain. A core planned at P was abandoned so as to hasten to M in time for ample light. The mooring was released at 1322Z and recovered by 1503Z. The mooring line had been damaged, perhaps by fish bite, over a short section around 900 metres deep. In view of this and the rising swell that increased the probability of entanglement, we decided not to relay the mooring on this cruise. The ship sailed for station L, with a view to working east to station P before the forecasted approaching depression. Stations L and M were worked before abandoning overside work because of increasing wind and swell. With a gale blowing, the ship steamed through the night to a position in the Minch, arriving in the shelter of Barra around midday on the 16th March. During the afternoon, with further prolonged gales 6-8/9 forecast for the Rockall and Hebrides area, it was decided to head for the Clyde Sea *via* the Sounds of Mull and Islay.

The morning of the 17th dawned with a continuing gale as we made slow passage southward in the Firth of Lorne towards the Sound of Islay. There were calmer conditions to the south of the sound

and station CL1 on the Great Plateau in the Clyde Sea was reached about 1730Z. After some difficulties in getting power to the winch and a remake of the CTD connector tail, water bottle and CTD stations started about 2000Z. Stations CL1 to CL14 were worked in ameliorating conditions during the night and the morning of the 18th and multiple cores were then collected at stations CL12 and CL10. By the end of the afternoon, winds were increasing once more from the Southwest and reaching gale force at times. A quasi-synoptic survey of the surface water of the waters east of Arran was made from 1730Z through the night until 0700Z on the 19th, when the vessel steamed for stations CL15, CL14 and CL1 for multiple coring. During the 19th, westerly winds of 30-35 knots developed. A second synoptic survey followed from the Mull of Kintyre to the northern end of Arran, finishing at station CL10. The ship docked at Ardrossan around 0900Z on the 20th March.

Equipment: Ship's Gear

Most but not all gear worked satisfactorily throughout the cruise. Two particular items deserve attention from NERC's Research Vessel Services (RVS) at Barry:

1). This comment was made at the end of cruises 86/91 and 87/92. It as relevant now as it was on those occasions: It is inconvenient that the Simrad Echo sounder cannot be triggered with a selectable delay relative to a standard clock. Could this be done, it would be easier to find the trace of pingers used to monitor the approach of equipment to the sea-bed.

2). It was extremely inconvenient both to crew and scientists that the metering gear on the hydrographic winch was unreliable during water sampling bottle deployment and also could not be set to read zero when the equipment was at the surface. According to hearsay, this fault has been known for several cruises. I recorded a similar complaint at the end of cruise 87/92 regarding the CTD wire metering, but no problems with this occurred on the present cruise. On the 17th, following a repair to the winch, it became possible to reset the hydrographic wire to zero once more, but the metering device is clearly not reliable and needs attention.

To leave these matters unattended impairs both safe working and scientific accuracy.

Results

The results are summarised in figures 1 to 5 and tables 2 to 4:

1) The track of the WOCE and shelf section is shown in figure 1a. Because of actual and forecast bad weather and the short duration of this cruise, the remainder of the section could not be attempted and had to be abandoned in favour of coastal work in the Clyde Sea area.

The (uncalibrated) oceanographic sections of temperature, salinity and density resulting from these measurements are shown in figures 2 and 3. Many samples were taken at discrete depths with NIO water bottles. These samples were analysed for nutrients, chlorophyll, photosynthetic activity after inhibition of photosystem II with DCMU, and for iodide and iodate concentrations.

2) All required large volume water samples at the standard positions between the Sound of Mull and the shelf edge West of Barra were obtained for radiocaesium studies.

3) The DML current meter mooring in the Tiree Passage was recovered and relaid successfully.

4) The DML/WOCE temperature-salinity mooring at station M in the Rockall Trough was successfully recovered but not relaid. The preliminary temperature, salinity and pressure record from the mooring is shown in figure 5.

5) A section was worked around Arran in the Clyde Sea and was complemented by a quasi-synoptic survey of surface conditions. The tracks of the ship are shown in figure 1b. The (uncalibrated) oceanographic sections of temperature, salinity and density resulting from these measurements are shown in figure 4.

Many samples were taken at discrete depths with NIO water bottles. These samples were analysed for nutrients, chlorophyll, photosynthetic activity after inhibition of photosystem II with DCMU, and for iodide and iodate concentrations.

6) Sediment samples in the Clyde Sea and the shelf are summarised in table 4.

Moorings

Tiree Passage Mooring Details

The mooring was recovered at 1807Z on the 13th March with tapes in good condition, and relaid at 56° 37.6'N 6° 24.1'W at 0922Z on the 14th March 1993 with two Aanderaa meters recording at 30 minute intervals: No. 74211 (RCM7) at 22m over bottom; and No. 7229 (RCM4S) at 11m over bottom. The depth at this position was 49m.

Mooring at M details

The instrumentation on the mooring at M comprised a 50m thermistor chain and SEACAT logger at a depth of about 400m in a water depth of 2236m. The acoustic release was released at 1332Z on 15th March and all gear was inboard at 1503Z. Fish bite damage from to the Paraline rope was seen from 1500m depth to 700m, being worst at about 1000m. Both thermistor logger and SEACAT temperature-salinity recorder seemed to have recorded satisfactorily since deployment.

Acknowledgements

The cooperation of the captain, Peter Maw, the officers and crew of the Challenger was very much appreciated. This cruise was supported by the Ministry of Agriculture, Fisheries and Food and by the Natural Environment Research Council as part the WOCE and LOIS programmes.

Table 2: "Challenger" Cruise 101/93 Leg 2. CTD and Water Samples Station List

Notes:

The CTD depth shown is derived from the sounding and pinger height over the bottom or wire out indicator.

SS denotes a surface salinity only was taken.

* a sample for iodine analysis (UEA) was taken.

\# a surface sample for 234Thorium analysis (SURRC) was taken.

Depth Photosynthesis in samples at these depths was investigated with the DCMU technique.

Station	Disc /Dip	Lat. °.'N	Long. °.'W	Date/ Time Z	Depth,m	CTD depth	Samples Depth Cs	Nutrient+ Chl'phyll *(+DCMU)* *Iodine
C1/1G	1/001	56.40	6.08	**13/3** 2100	200	180	0 65 160	
C2/2G	1/002	56.41	6.17	**14/3** 0012	036	030	0 15 30	
/3G	SS	56.42	6.22	0047	-	-	-	
C3/4G	1/003	56.44	6.27	0127	73	67	0 40 80	***5 10 25*** *0 45 65
/5G	SS	56.44	6.36	1035	-	-	-	
C4/6G	1/004	56.44	6.45	1150	60	47	0 43	00 ***05 10*** 20 ***30***
C5/7G	1/005	56.44	7.00	1300	142	140	0 65 130	
/8G	SS	56.44	7.10	1438	-	-	-	
C6/9G #	1/006	56.44	7.20	1702	162	155	0 75 155	***5 10 20*** 40 80 120 155
10G	SS	56.44	7.30	1800	-	-	-	
C7/11G#	1/007	56.44	7.40	1849	63	55	0 30 55	***5 10 20*** 40 55
/12G	SS	56.45	7.50	2029	-	-	-	
C8/13G	1/008	56.47	8.00	2300	120	110	0 60 110	***5 15 35*** 75 115
/14G	SS	56.48	8.10	2350 **15/3**	-	-	-	
T	SS	56.50	8.20	0031	-	-	-	
C9/15G	1/009	56.53	8.30	0125	130	120	0 60 120	***5 10 20*** 40 60 80 120 *0 *5 *10 *20 *40 *80 *120 *155
S	SS	56.57	8.47	0404	-	-	-	
C10 /16G/R	1/010	57.00	9.00	0630	137	130	0 70 130	5 10 20 40 60 80 120 130
Q #	1/011	57.03	9.13	0738	340	328		***10 20 40*** 80 150 300 *10 *20 *40 *80*150*300

Stat -ion	**Disc** /Dip	Lat. °.'N	Long. °.'W	**Date/** Time Z	Dep- th,m	CTD depth	Samples Depth Cs	Nutrient+ Chl'phyll *(+DCMU)* *Iodine
P	SS	57.06	9.25	0925	-	-		
O	SS	57.09	9.42	1022	-	-		
N #	SS	57.14	10.03	1120	-	-		
M	SS	57.18	10.23	1400	-	-		
L	**2**/012	57.22	10.40	1824	1986	1970		***0*** 5 ***10 20*** 40 80 150 300 600 900 1950
M	**2**/013	57.18	10.23	2113	2220	2090		
CL1	**2**/014	55.17	5.17	**17/3** 1833	49	45		***5 10 20*** 44 *0
CL2	**2**/015	55.21	5.22	2025	46	40		***5 10 20*** 40 *0
CL3	**2**/016	55.26	5.26	2140	41	32		***10 20 40*** *0
CL4	**2**/017	55.31	5.26	2239	77	65		***5 10 20*** 40 60 70 *0
CL5	**2**/018	55.35	5.25	**18/3** 0019	124	115		***5 10 50*** 70 ***115***
CL6	**2**/019	55.39	5.26	0112	145	140		***5 10 20*** 40 60 80 120 140
CL7	**2**/020	55.43	5.19	0252	99	95		***5 10 20*** 40 60 80 95
CL8	**2**/021	55.48	5.15	0355	165	160		***5 10 20*** 40 60 80 120 140 160
CL9	**3**/022	55.44	5.11	0529	175	170		***5 10 20*** 40 60 80 120 140 165
CL10 #	**3**/023	55.40	5.04	0633	157	150		***5 10 20*** 40 60 80 141 *100
CL11	**3**/024	55.36	4.59	0820	102	90		***5 10 20*** 40 60 80 90
CL12 #	**3**/025	55.31	4.59	0912	105	95		***5 10 20*** 40 60 80 100
CL13	**3**/026	55.26	5.02	1055	123	115		***5 10 20*** 40 60 80 115
CL14 #	**3**/027	55.21	5.04	1146	56	50		***5 10 20*** 40 47

Table 3: Synoptic Surveys in the Clyde Sea

Synoptic Survey: Continuous Lines AB,BC, 18-19/3 : East of Arran
Temperature, Salinity, Chlorophyll, Hourly Iodine in line

Line End	Lat °N	Long °W	Time	
A	55.41	5.05	1745	
B			1800	
C #	55.49	4.58	1900	1900 (55.50, 4.58)
D	55 42	5.00	1952	2000 (55.42, 4.58)
F	55.41	4.55	2015	2100 (55.37, 5.03)
G	55.35	5.07	2122	2200 (55.35, 4.58)
H	55.35	4.45	2252	
I	55.30	5.02	0023	2300 (55.35, 4.46)
				0000 (55.32, 4.58)
J	55.26	4.47	0136	0100 (55.28, 4.54)
				0200 (55.25, 4.51)
K	55.25	5.05	0310	0300 (55.26, 5.03)
				0400 (55.21, 4.55)
L	55.20	4.52	0417	0500 (55.19, 5.00)
				0600 (55.18, 5.11)
M	55.18	5.12	0609	
CL13	55.26	5.02	0720	

Synoptic Survey: Continuous Lines LM,MN, 19-20/3 West of Arran
Temperature, Salinity, Chlorophyll,

Line End	Lat °N	Long °W	Time
L	55.14	5.29	1237
M	55.19	5.32	1313
N	55.23	5.29	1452
O	55.24	5.31	1638
P	55.27	5.19	1720
Q	55.28	5.31	1802
R	55.26	5.22	1840
S	55.30	5.29	1912
T	55.31	5.22	1940
U	55.32	5.28	2004
V	55.33	5.22	2028
CL5	55.35	5.25	2048
CL6	55.39	5.26	2115
CL7	55.43	5.19	2154
CL8	55.48	5.15	2231
CL9	55.44	5.11	2307
CL10	55.40	5.04	2340

Table 4: Sediment Samples in the Clyde Sea and the Hebridean Shelf:

Stat -ion	Sample Type	Lat. °.'N	Long. °.'W	Date/ Time Z	Dep- th,m	
C4/6G	Day Grab	56.44	6.45	13/1145	63	Sandy mud
C5/7G	Day Grab	56.44	7.00	14/1350	148	Sandy mud, no macrofauna, good corring area
C6/9G	Day Grab	56.44	7.20	14/1537	160	Rock bottom no sample
C8/13G	Day Grab	56.47	8.00	14/2250	121	Little mud muddy sand good coring
C9/15G	Day Grab	56.53	8.30	15/0158	130	Sand, medium, very little mud
C10/16G	Day Grab	57.00	9.00	15/0700	137	Rocky bottom much granite
CL12	Multicore	55.31	4.59	18/1425	105	4 long cores very soft mud
CL10	Multicore	55.40	5.04	18/1540	153	7 short cores soft mud
CL15	Multicore	55.26	4.0	19/0830	72	2 cores on 3 attempts: dragged
CL14	Multicore	55.21	5.04	19/1030	53	5 short cores 3 attempts
CL1	Multicore	55.17	5.17	19/1300	46	

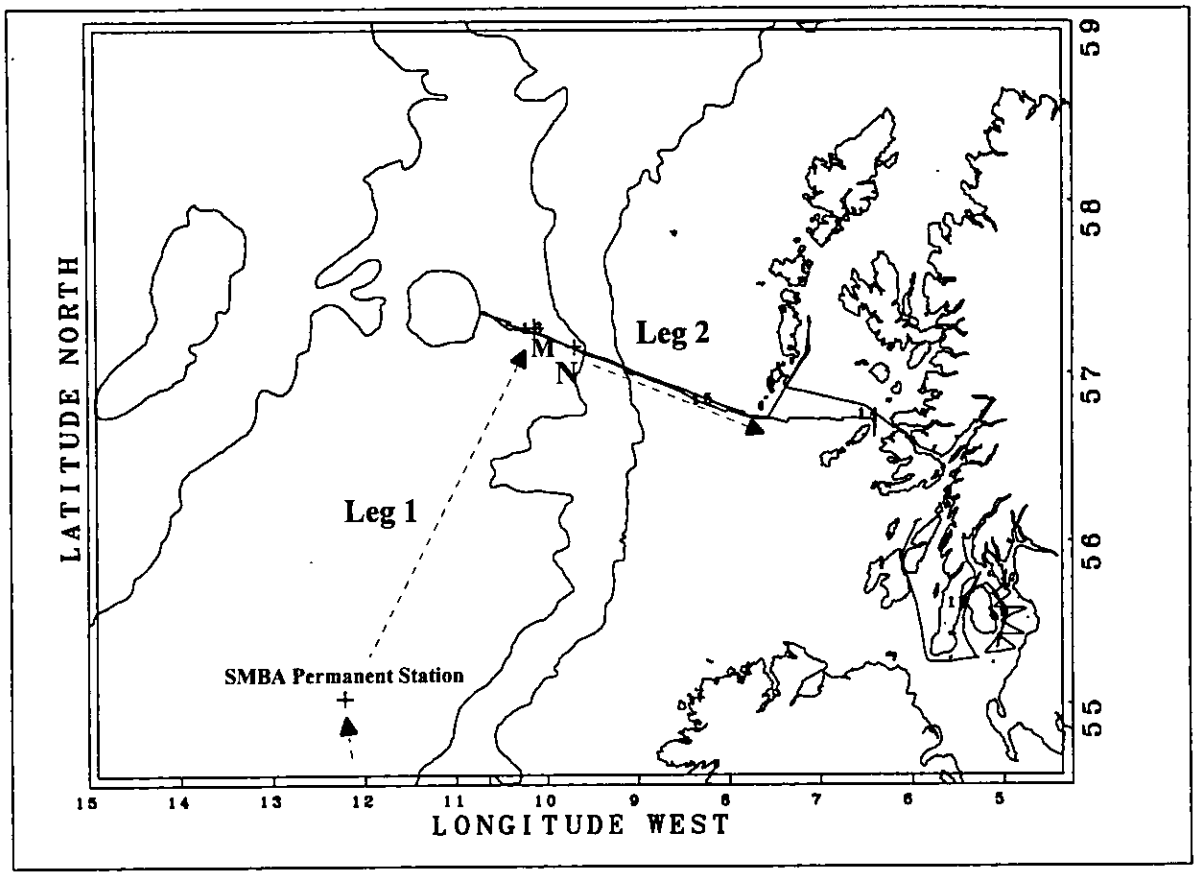


Figure 1a: Cruise tracks in the Rockall Trough

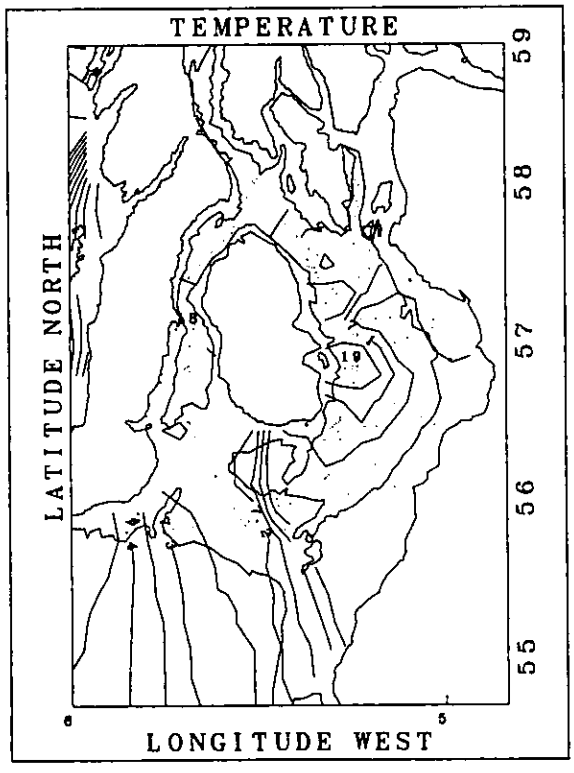


Figure 1b: Cruise Tracks and temperature in the Clyde Sea, 18 to 20 3/1993.

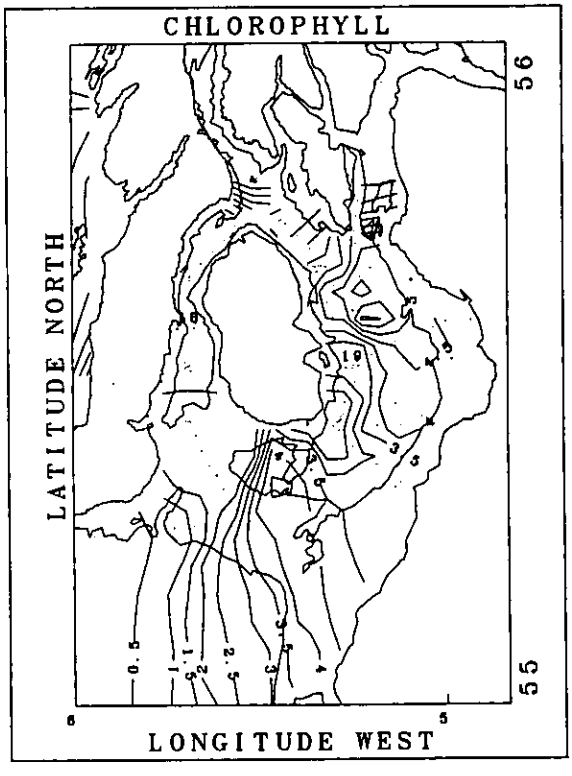


Figure 1c: Cruise Tracks and Chlorophyll in the Clyde Sea, 18 to 20 3/1993.

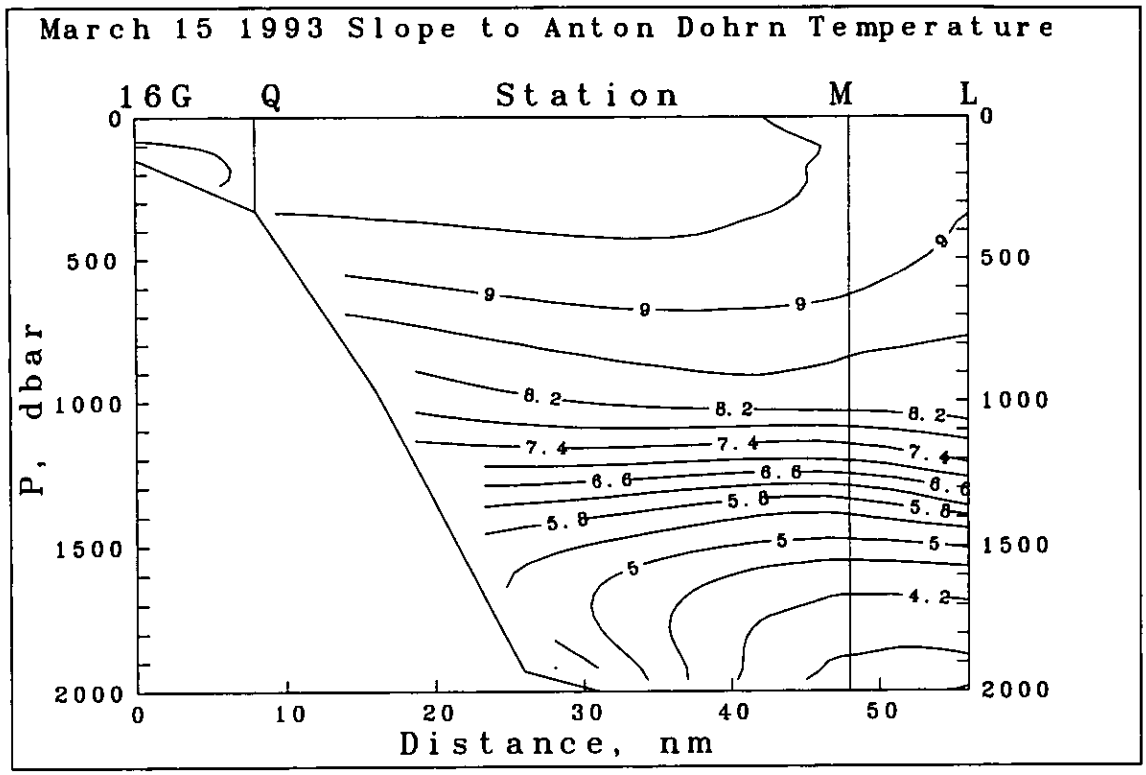


Figure 2a ***Temperature distribution over the continental slope (uncalibrated data)***

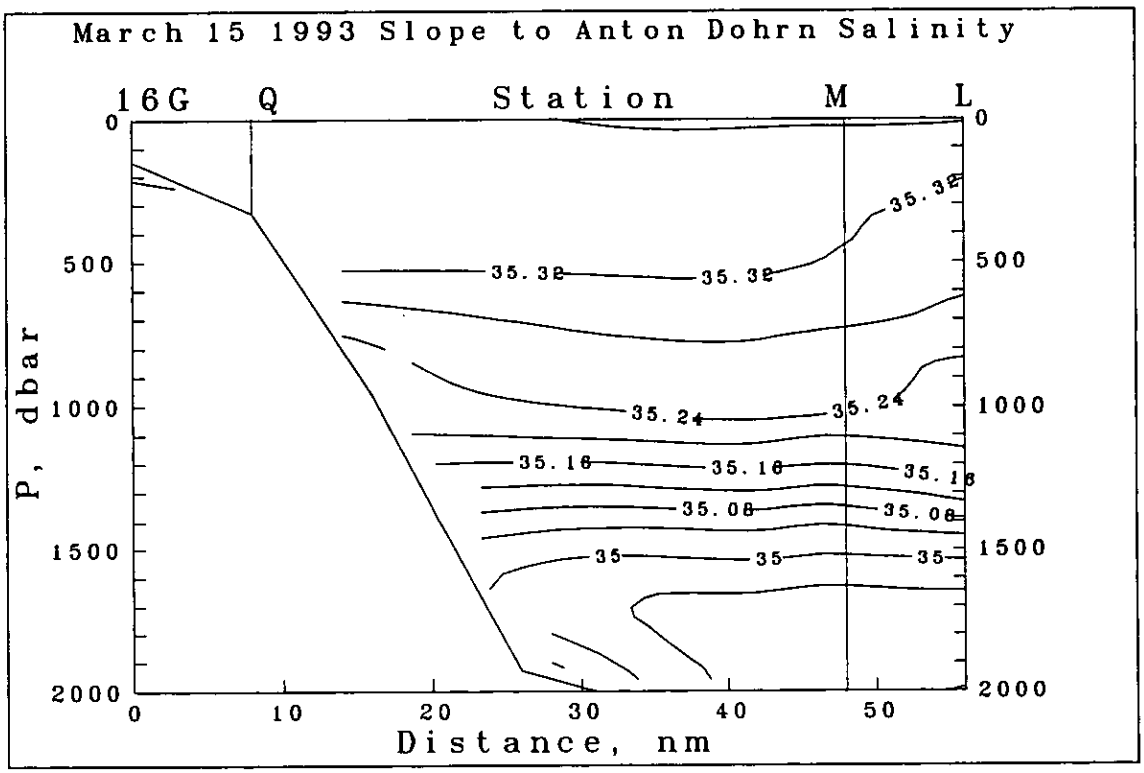


Figure 2b ***Salinity distribution over the continental slope (uncalibrated data)***

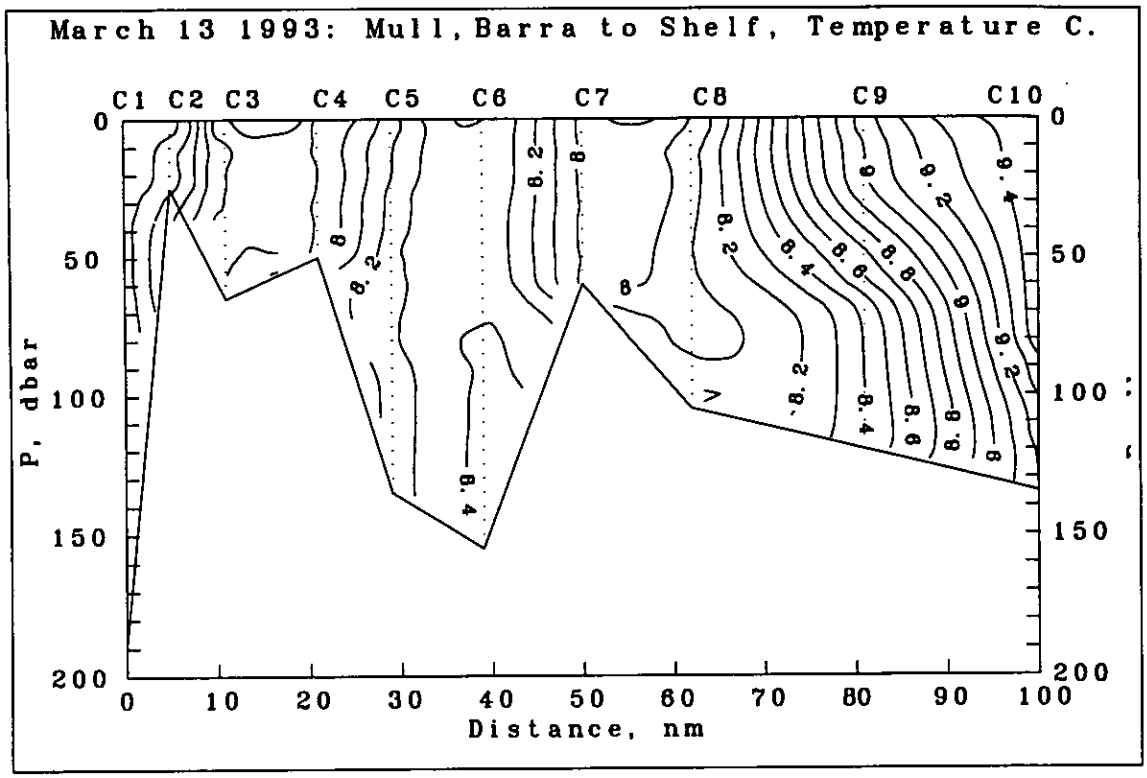


Figure 3a *Temperature distribution over the continental shelf (uncalibrated data)*

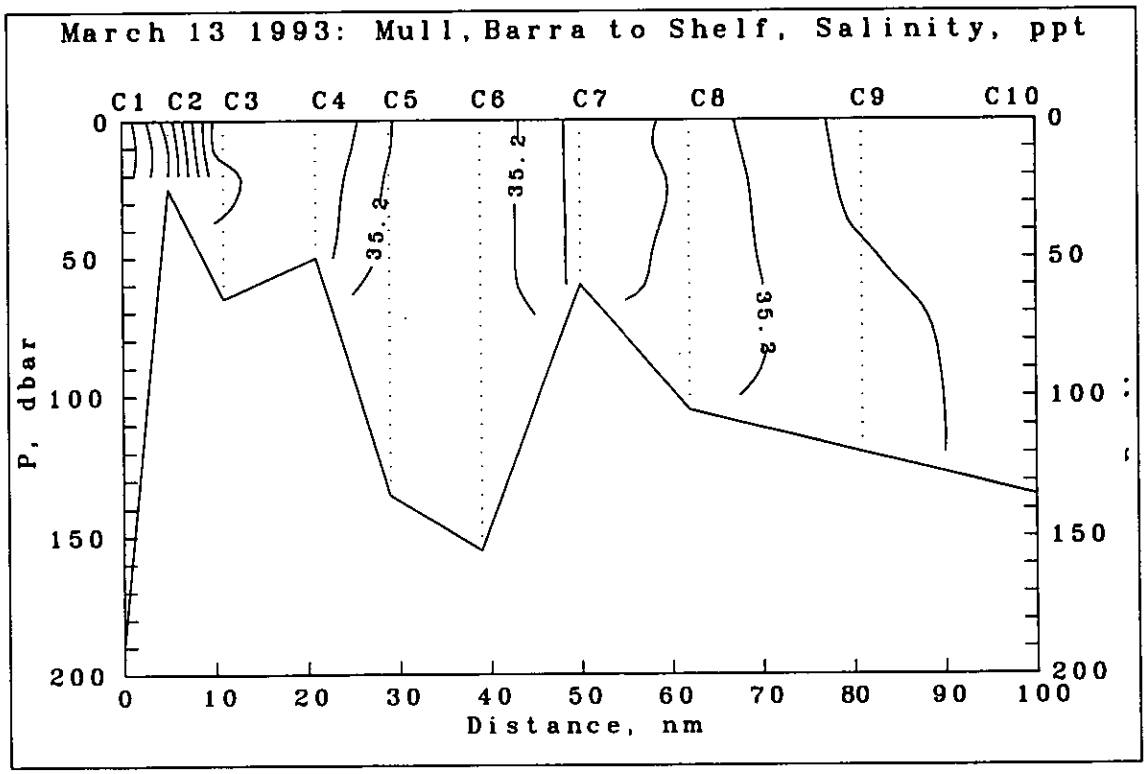


Figure 3b *Salinity distribution over the continental shelf uncalibrated data)*

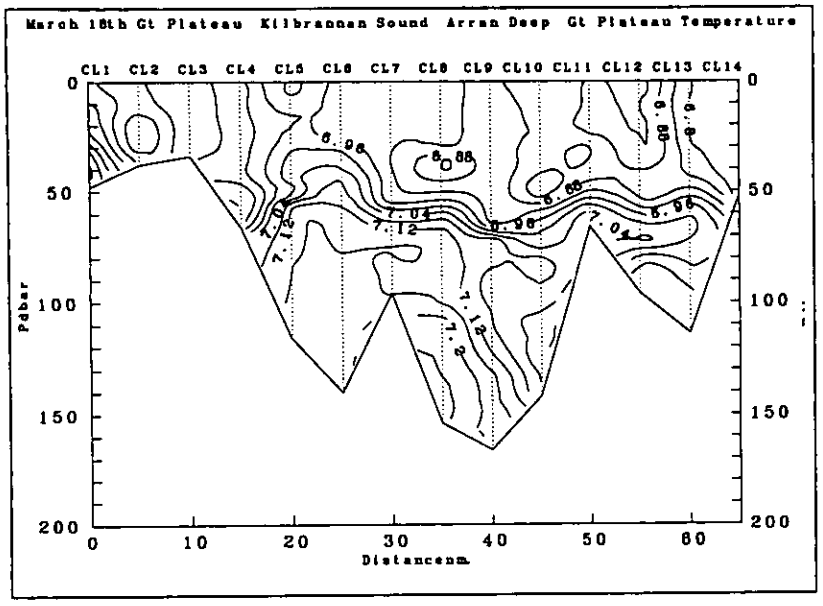


Figure 4a

Temperature distribution around Arran (uncalibrated data)

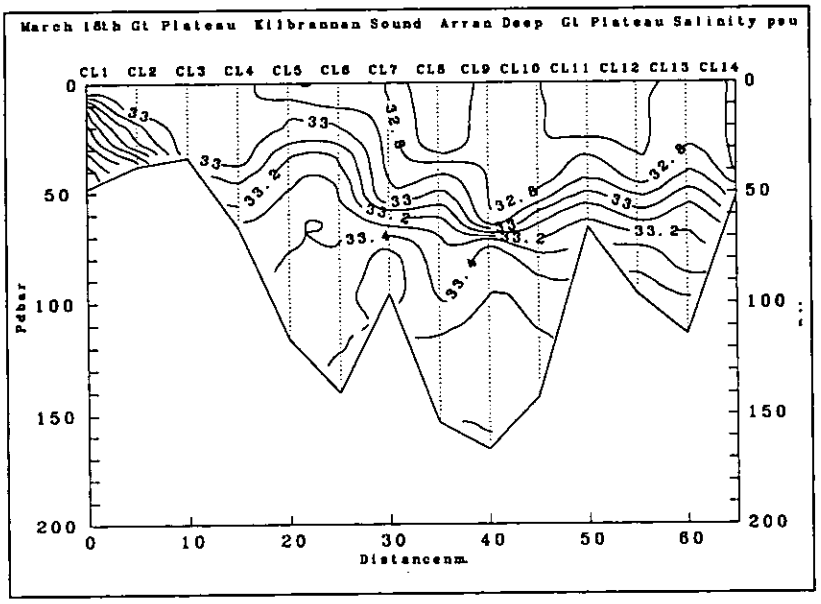


Figure 4b

Salinity distribution around Arran (uncalibrated data)

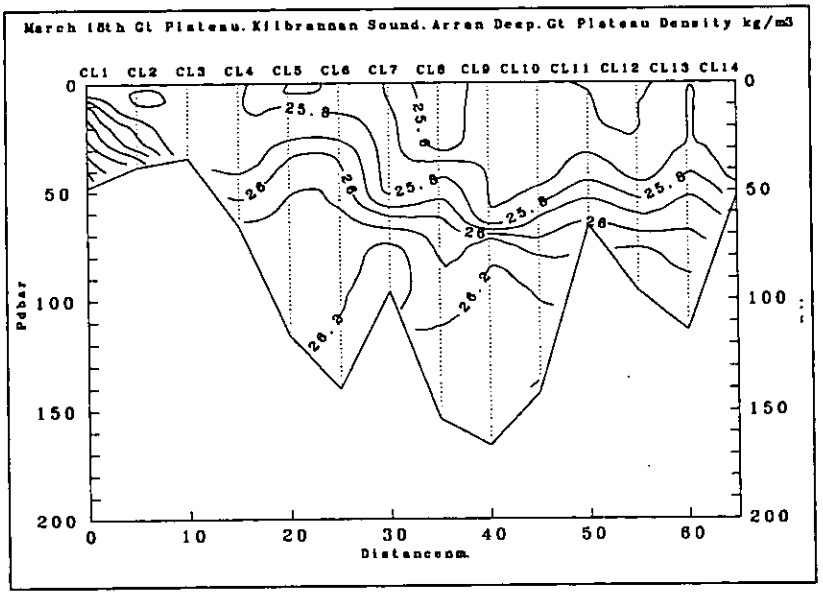
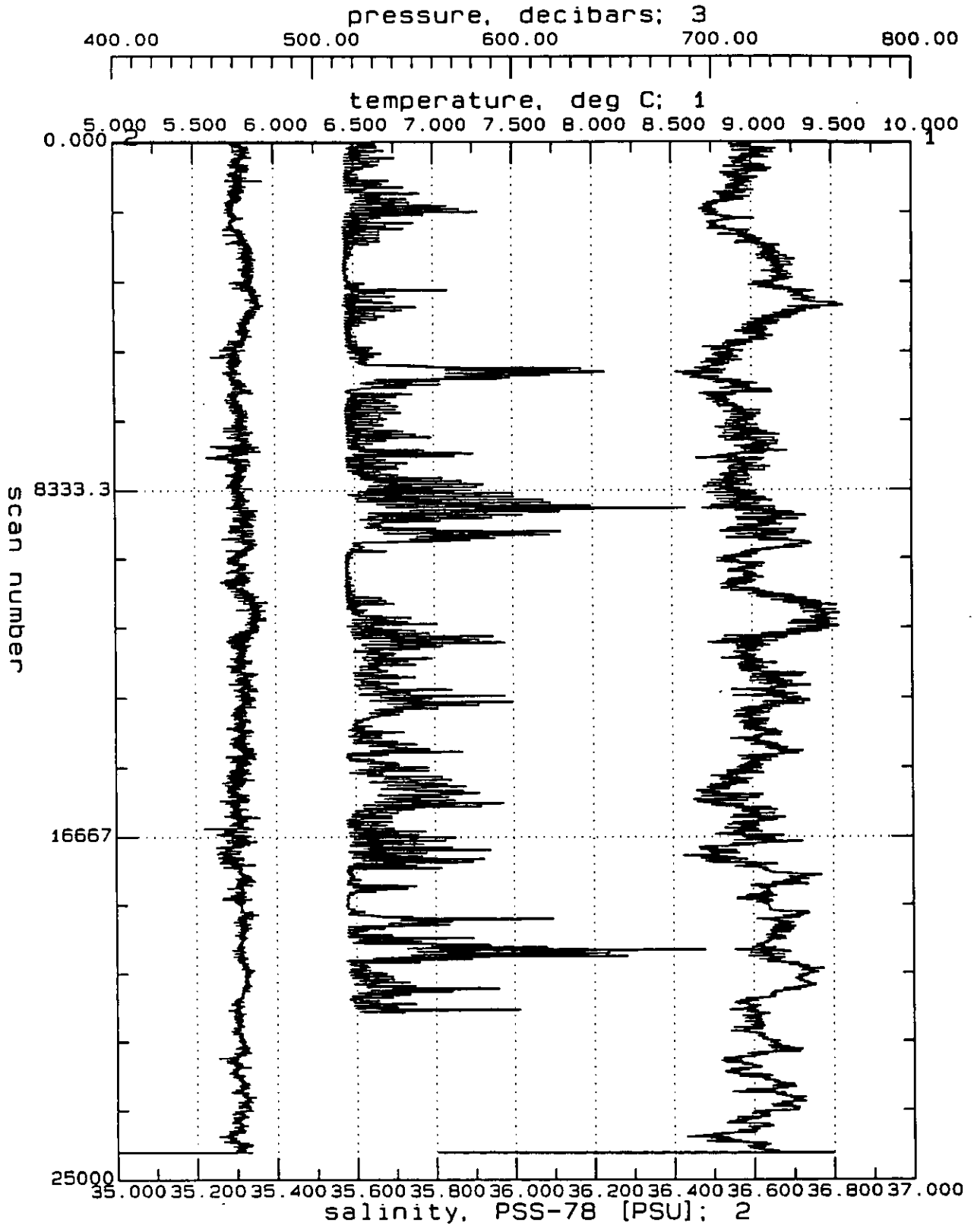


Figure 4c

Density distribution around Arran as Sigma-t (from uncalibrated data)



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Challenger 101/93 Figure 5