DUNSTAFFNAGE MARINE LABORATORY

and the

SCOTTISH ASSOCIATION for MARINE SCIENCE

OBAN, ARGYLL, SCOTLAND

Rockall Trough time-series

LOIS Shelf-Edge Study pilot programme

EC MAST 2 PROFILE project

CRUISE REPORT

RRS CHALLENGER

CRUISE 103/1993

12 - 24 May 1993

DML, P.O.Box No.3, OBAN, ARGYLL, PA34 4AD, SCOTLAND

RRS CHALLENGER, Cruise 103/1993

Duration:	0845h 12 May - 0900h 24 May 1993 All times GMT
Locality:	Rockall Channel, Scottish continental shelf-edge and Outer Firth of Clyde.
Staff:	D. J. Ellett Dr. J. M. Graham Dr. K. Jones S. M. Harvey B. Grantham C. R. Griffiths Dr. D. Smallman N. MacDougall Ms. J. Sook Park (Pusan Fisheries Laboratory) J. Watson

Aims:

1) To work the CTD stations of the Anton Dohrn Seamount section, between the shelf-edge and Rockall to continue the Rockall Trough time-series as a UK contribution to WOCE Goal 2.

2) To moor a temperature-salinity recorder and thermistor chain at station M of the Anton Dohrn Section.

3) To collect a suite of profiles, samples and cores at the shelf-edge west of Barra to continue DML LOIS Shelf-Edge Study (SES) pilot surveys.

4) To service the DML current meter mooring in the Tiree Passage.

5) To work selected stations of the Malin Head - Rockall CTD section for further investigation of recent water mass changes west of Britain.

6) To work shelf CTD, nutrient and coring stations in the Firth of Clyde as part of the DML/UCNW MAST 2 PROFILE programme.

7) An additional aim was a request received from Professor Simpson just before sailing for the redeployment of a current meter mooring and guard marker in the outer Firth of Clyde.

Narrative:

Scientific staff joined the ship at Campbeltown at 0845h **12 May**, and "Challenger" sailed at 1130h in light and variable winds. Courses were set for the central station of the Malin Head - Rockall section but overnight winds strengthened from the northwest, becoming force 8, northerly by 0515h **13 May**, when the ship hove-to west of the shelf-edge. In the evening, a slight improvement by 2300h allowed course to be set for station MS of the section, but a heavy swell and force 7 winds persisted during the forenoon of **14 May** making CTD tests inadvisable. It was agreed to head for Rockall at 0800h, taking the opportunity to stream the upper 600m of the trawl warps *en route*. Towards evening the northerly winds fell to forces 4-5, and work began at station A of the Anton Dohrn Seamount section at 1925h.

During **15 May** the heavy swell subsided and CTD stations were completed to station K by 1735h. Subsequently "Challenger" proceeded to M, where two successful multicorer lowerings were made between 1930 and 2136h, followed by the CTD profile. During the night station L was worked before the ship returned to M to depth-test glass flotation spheres and acoustic releases from 0525h **16 May** in readiness for the deployment of a temperature-salinity recorder and thermistor chain at this site. The mooring was laid at 1018 to 1054h and the ship continued to station N. At O three further multicorer drops were made between 1703 and 2024h. Northerly winds of force 5 had continued throughout the day with a long swell, but both moderated overnight and the remaining part of the section was completed to S at 0905h **17 May** in quiet weather.

At station S the fluorometer, of 600m depth capability, was attached to the CTD and "Challenger" returned along the line of the section with added intermediate stations to obtain fluorometer profiles and water-bottle samples over the shelf-edge between S and O. The section was temporarily broken off during the afternoon to make two multicorer lowerings at R at 1533 to 1642h and to shoot the Rectangular Midwater Trawl (RMT) at Q between 1833 and 1915h, station O being completed at 0032h, **18 May**.

The ship then steamed to depths of 2000m for a series of vertical plankton net hauls. The southeasterly wind strengthened to force 8 during the working of this station (O1) at 0114 to 0329h, and "Challenger" hove-to throughout the day in winds which veered south-southwesterly and reached forces 9-10 following a rapid barometer rise from 0745h. Winds began to moderate in the late evening, and by 0400h **19 May** the heavy swell had declined sufficiently for the ship to head for the western station of a section crossing the previous one in a SW-NE direction. This station (L1) was begun at 0600h, and the section continued throughout the day except for a break for multicoring at P between 1208 and 1430h. The eastern station, L10, was completed in fine weather at 0103h **20 May**.

With the need to reserve time for the Clyde mooring redeployment in mind, the shelf section beween the shelf-edge and the Sound of Mull was begun at station S at 0219h, and continued eastwards throughout the day. Four multicorer lowerings were made at 14G, but the cores proved too coarse for requirements and a further lowering was made at 10G, in the deep to the east of Barra Head where a good muddy bottom is found. Station 1G off Ardmore Point in the Sound of Mull was completed at 2142h and the ship proceeded to the Tiree Passage current meter mooring site to await the morning low water slack tide.

Recovery of the mooring was effected at 0521-0535h **21 May**, and redeployment took place between 0626 and 0636h, after which "Challenger" set course for the Firth of Clyde via the Firth of Lorne and Sound of Islay. CTD and water-bottle sampling work began at station CS1, on the outer sill of the firth, at 1850h and continued, with Craib corer drops at some stations, overnight to CS6. Here a multicorer lowering was made at 0707h 22 May which recovered an *embarras de riches*, the complete corer having sunk about a metre into soft mud. Following this, course was set for the Menai Bridge mooring, and the instruments and toroid were recovered between 0835 and 0904h. Mr. Watson had in the meantime adapted the Craib corer to provide more suitable samples than the multicorer, and twelve drops were made at station CS7 at 0957-1314 whilst the mooring was being modified for relaying at a shallower depth.

Deployment of the mooring at the new site took place from 1443 to 1452h following a search for suitable depths in the vicinity of the approved position. "Challenger" then returned to the former site to recover the spar guard buoy mooring, and this was re-rigged and relaid at 1649-1653h. CTD and water-bottle work was resumed, with stations worked up to Bute, to Tarbert in Loch Fyne and in Kilbrannan Sound overnight in quiet weather. The final station of the grid, CS16, was completed off Sanda at 1124h **23 May**.

During 22-23 May the consumption of stern tube oil had given rise to concern, and in view of the prospect of several days' passage to Leith, it was decided to anchor and make whatever adjustments were possible. The ship proceeded to Drumadoon Bay, southwest Arran, and anchored from 1303 to 1502h. Temporary repairs being complete, "Challenger" set courses for Oban via the Sound of Islay, berthing at the Railway Pier at 0715h **24 May** to disembark staff and gear, and sailing again for Leith at 0905h.

General results: (see also individual topic reports below)

Aim 1) The Anton Dohrn Seamount CTD section was completed between 1925h 14 May and 0905h 17 May. Figures 2a-c show the preliminary temperature, salinity and density sections from the Sea-Bird CTD. Stratification was mostly well-established, especially over the western half of the section, and upper level salinity values were low by comparison with the previous three years, reaching a maximum of ca. 35.35 psu in the core of the slope current.

Aim 2) A mooring consisting of a Sea-Cat temperature-salinity-depth logger and an Aanderaa thermistor chain was deployed at station M of the section at 1054h 16 May. The logger was mounted immediately below the 50m thermistor chain and a nominal 500m above the sea-bed in 2220m depth with the aim of recording the magnitude of t-s variations in the Labrador Sea water salinity minimum encountered at depths of 1600-1800m.

Aim 3) Two detailed sections intersecting at station R (57°N, 9°W) were obtained across the shelf-edge during 17 - 20 May. The first (Figures 3a-d) ran east-southeast to west-northwest between stations S to O of the Anton Dohrn Seamount

section, with additional intermediate stations, and the second, stations L1, L3 and L5 to 10 (Figure 4a-d), worked two days later after an intervening southerly gale, was from southwest to northeast. Shelf conditions were monitored along the section from the shelf-edge to the Sound of Mull during 20 May (Figure 5a-d).

The first shelf-edge section showed (Figure 3) a higher-salinity, relatively warm core centered over slope depths of 250 to 350m at station Q. A general salinity maximum exceeding 35.34 psu would have covered the slope between 500m at Q1 and intermediate depths to 75m at R1 had it not been split by a well-mixed layer of colder, fresher shelf water occupying the bottom 20m at station R1, but descent of this relatively dense water from the shelf-edge was blocked by the higher-salinity beneath it at this time. However, when the "L" section was worked two days later (Figure 4), the slope current core had moved off-slope, to be centered at depths of 200-300m at L6, whilst the bottom 150m at L7 were occupied by water which was only slightly warmer and more saline than the bottom water previously found at R1. There is a strong suggestion that meandering of the slope current, or perhaps the consequences of the previous days' gale, had allowed shelf water to descend the slope to about 300m depth.

The section running eastwards to the Hebrides (Figure 5) showed cold, dense winter-formed water occupying the bottom 50m at stations G14 to G15 west of Barra Head, with an upper water thermal front between G15 and T. Similar bottom water existed at depth between Barra Head and Coll and a marked, though patchy thermocline was developing in the Sea of the Hebrides.

Aim 4) The Tiree Passage current meter mooring was serviced between 0521 and 0636h 21May. The mooring recovered had been laid on 14 March 1993 and carried two Aanderaa current meters at nominal depths of 27 and 38m in soundings of 49m. Both meters functioned satisfactorily, each returning 68 days' good data.

Aim 5) It had been planned to obtain CTD profiles at a small number of stations on the Malin Head - Rockall section on the outward passage to the start of the Anton Dohrn Seamount section at Rockall. Gales on passage prevented this, and no further opportunity to sample any of these stations arose.

Aim 6) 26 stations were worked around Arran in the Outer Firth of Clyde and in the lower reaches of the Inner Firth and Loch Fyne between 1858h 21 May and 1124h 23 May as part of the joint DML/UCNW PROFILE programme. The main section encircling the Arran Deep, stations CS1 to CS16 is shown in Figures 6a-d. The deep contained cold saline water (ca. 7.5°, 33.4 psu) somewhat denser than that of the North Channel water found outside the plateau front at stations CS1 and CS16. Tentative plans to obtain a North Channel section were pre-empted by the need to attend to the stern tube.

Aim 7) The UCNW mooring to the northeast of Arran had been found, despite full clearances, to be within a former detonator dumping site. The Master of "Prince Madog", through Professor Simpson, had requested the good offices of "Challenger" to redeploy the mooring and its guard buoy. The mooring was raised on 22 May from soundings of 150m and shortened for the depth of 80-90m

expected at the new agreed site. Unfortunately the Aanderaa current meters, though in RCM7 cases, were found upon opening to be of the earlier pattern, logging upon tape. No replacement tapes were available, and in any case the encoders were very dirty and needed attention which we could not give them before redeploying. In view of the planned return of "Prince Madog" within a few weeks, the mooring was therefore moved to soundings of 83m in the vicinity of the new site and redeployed carrying two transmissometers only, the fluorometer having been removed, as requested. The spar guard buoy was subsequently raised, adapted to the new depth and relaid.

Individual topic reports

1) Nutrient sampling

Nutrient measurements were carried out on water samples taken at 23 stations between Rockall and the Sound of Mull, including the LOIS Shelf-Edge Study area, and at 14 stations in the Clyde Sea.

Analyses were made of nitrate (and nitrite), phosphate, silicate and ammonium using an Autoanalyser. Unfortunately the reagents for silicate appeared to be contaminated and satisfactory results could not be obtained. Water samples were therefore frozen for silicate analysis back at the laboratory. All other determinations worked well and full coverage was obtained.

B.E.Grantham

2) Sediment oxygen uptake studies

Principal aim: To determine sediment oxygen uptake rates at selected sites in deep water, on the shelf and across the slope.

Subsidiary aims: To collect sediment samples for particle size analysis, for examination for diatom resting stages (D. Harris, DML) and for possible meio- and microfaunal analysis.

Results: Short cores were collected using the SMBA multicorer (M) or modified Craib corer (C) as follows:

Stn.	Date	Time (GMT)	Corer	No. of drops	No. of cores
M	15/5	1948-2140	M	2	8
O	16/5	1710-2030	M	3	8
R	17/5	1535-1640	M	2	failed
P	19/5	1210-1445	M	3	8
14G	20/5	0835-1030	M	4	2
CS6	22/5	0707-0716	M	1	failed
CS7	22/5	1000-1222	C	7	6

Failure at station M was due to the ground being too coarse, resulting in two of the core tubes being broken, and at station CS6 it was due to the ground being too soft, resulting in the core tubes being completely filled.

At the deeper stations (M, O and P) the top 1cm section of one core was transferred to a jar and refrigerated for examination for diatom resting stages back

at the laboratory, another core was sectioned into 0-1, 1-2 and 2-3cm sections. These were transferred into jars containing buffered formalin and rose bengal for faunal analysis. The top 1cm section of one of the cores used for oxygen uptake analysis was also transferred to a jar for particle size analysis.

All the remaining cores, and all the cores collected from the other sites were transferred to a tank of aerated seawater in the constant temperature room maintained approximately at bottom water temperature. They were left in darkness for 6-12 hours to minimize coring effects. After this time the core tubes were sealed and stirred for 2-4 hours. At the beginning and end of this period water samples were removed from the tubes, fixed and titrated to determine their dissolved oxygen content. Samples of bottom water were sealed in bottles and treated similarly to determine the overlying water oxygen content.

Sediment oxygen uptake rates at the sampled sites were found to be as follows:

Station	**n**	**O_2 uptake rate ($\mu M/m^2/day$)**
M	6	9.3 +/- 1.4
O	6	4.8 +/- 2.6
P	6	7.9 +/- 1.5
14G	2	13.5
CS7	6	32.8 +/- 11.5

The site in the Arran Deep (CS7) shows a markedly higher oxygen uptake rate than the other sites. The anticipated reason for this is the greater amount of organic material present in the sediment. The large variation about the mean value at this site is due to fact that the ship was drifting markedly between successive drops of the corer, over an area of rapidly changing bottom topography. (Note that the Craib corer was used at this site, so that each of the six cores is from a different drop.) It was noted that two of the deployments of the corer yielded cores showing a much more well-developed anaerobic layer than the remaining four. The measured oxygen uptake of these two cores was found to be approximately twice that of the others.

S.M.Harvey

3) Multiple long-core samples

Multiple long-core samples were taken at three stations across the outer slope. A total of eight cores at each of the stations M (2200m depth), O (2018m) and P (1400m) were utilized in the study. Two cores at each station were sectioned in layers at 0-1, 1-3, 3-5, 5-7, 7-9 and 9-11cm. These were subject to further processing for the determination of porosity, carbon and nitrogen analysis, and for bacterial biomass (phospholipid levels). Three cores were each sectioned into 0-2 and 2-4cm sections and were each immersed in formalin, mercuric chloride and glutaraldehyde repectively, for preservation and subsequent microscopic examination. One core was maintained at 4°C, the overlying water to be utilized for the extraction of DNA, after filtering on a 0.22μm cellulose nitrate filter, for PCR with primers for nitrifying bacteria. The two remaining cores were frozen and extruded for storage.

Two cores were obtained with the deep-sea Craib corer at each of a number of selected sites on the outer shelf, the Sea of the Hebrides and in the Clyde Sea area. Stations included 14G, 10G, CS6, CL1, CS4 and CS7. The cores were sectioned to a depth of 11cm, as previously, for porosity and CN analysis.

D.J.Smallman

4) Phytoplankton biomass and relative production

Objectives and methods: The main objective of the work was to investigate relationships between the distribution of phytoplankton biomass and density stratification and watermass distribution across the Hebridean shelf and Rockall Trough. Particular attention was paid to the shelf-edge region between 56°40' to 57°20'N and 8°30' to 9°30'W, the proposed site for the LOIS Shelf Edge Study. Phytoplankton biomass was determined as extracted chlorophyll-*a* in hydrocast samples taken from the Rockall Channel and by vertical-profiling *in situ* fluorometry at the shelf-edge and shelf stations. Near-surface fluorescence and temperature measurements, from sensors mounted in the ships non-toxic seawater supply, were continuously logged along the ships track using a data logger, developed at DML, interfaced with a GPS positioning system. Relative primary production potential of phytoplankton communities along the transect lines were made using a 3-(3,4-dichlorophenyl)-1,1-dimethylurea (DCMU)-enhanced fluorescence method similar to that described by Figueras and Pazos (1991, J. Plankton Res., **13**, 589-608).

As a secondary objective a survey of phytoplankton biomass and nutrient distributions was carried out in the Clyde Sea as part of the EC MAST 2 Project, PROFILE which is concerned with modelling the physics and micobialproduction in coastal regions influenced by freshwater run-off.

Preliminary Results: *In situ* fluorescence measurements indicated enhanced phytoplankton biomass on the outer shelf about 10nm inshore of the shelf break and extending to 30nm seaward of the shelf break (Figures 3d and 4d). Fluorescence maxima were found at a depth of about 50 m and appeared to occur in association with intensification of density stratification related to the presence of cool, dense water at the bottom at outer shelf stations and apparent uplift of cool water further offshore at the seaward extremity of the slope current feature. Nutrient concentrations at the shelf edge appeared to be relatively high. The enhanced phytoplankton biomass observed therefore may result from the recent onset of the Spring phytoplankton increase in this region.

Further inshore high fluorescence was observed associated with a thermal front east of Barra Head (Figure 5d).

In the Clyde Sea fluorescence maxima were observed on the plateau inshore of the salinity front at the boundary with the North Channel and in Inchmarnock Water (Figure 6d).

K.J.Jones

5) Plankton sampling

Plankton samples were collected by three methods, as follows;

1) A neuston net drifting astern of the ship when stopped on station. This was a rectangular net of $1m^2$ opening with a 2mm mesh. Nine hauls were taken over the deep-water or at the shelf-edge, three over the shelf and two in the Firth of Clyde.

2) Two stratified tows were made with a small Rectangular Mid-water Trawl (RMT 1), one over the slope-zone in a depth of 350m at station Q, and the second over the shelf at station 14G in a depth of 130m. The RMT 1 had a $1m^2$ opening and a 300μm mesh. Immediately above the RMT 1 during both hauls a 2-metre diameter Stramin net with 400μm mesh was mounted to collect mesoplankton. The first haul was made during the evening and the second in the morning. Night hauls were not possible due to the crew's overtime arrangements.

3) Three sets of vertical hauls were made at night with a ½m diameter tow net with 400μm mesh upon the hydrowire. Hauls were made consecutively from 400, 300, 200 and 100m depths in the deep water at stations M and O1, and from 100m at station L9 close to the shelf-edge.

J.Sook Park

Acknowledgements

We thank Captain Maw, his officers and crew for their efforts in making this a very successful cruise in which all the major aims, plus an extra last-minute addition, were achieved. Dr. Graham ensured the smooth accquisition of the CTD and fluorometer data upon which much of the work depended, Mr. Griffiths' near-real time PC sections helped to decide strategy, Mr. Watson's *rapport* with the corers produced solid (!) results and Mr. MacDougall, as usual, made the mooring work look easy.

D.J.Ellett

9 June 1993

Table 1. RRS "Challenger" Cruise 103/1993 : Station List

Date 1993	Start GMT	Stn.	Lat. N. ° '	Long. W. ° '	Sdg. (m)	CTD Dip no.	w/bs	coring	plankton haul
			Anton Dohrn Seamount section						
14 May	1925	A	57 35.0	13 38.2	110	001	-	-	neuston
	2054	B	57 34.0	13 20.1	185	002	-	-	-
	2230	C	57 33.1	13 00.0	300	003	-	-	-
	2333	D	57 32.6	12 51.8	1125	004	-	-	neuston
15 May	0156	E	57 31.9	12 38.2	1630	005	-	-	-
	0450	F	57 30.4	12 14.8	1816	006	-	-	-
	0748	G	57 29.6	11 51.0	1800	007	-	-	-
	1056	H	57 28.6	11 32.0	2025	008	-	-	neuston
	1337	I	57 28.0	11 19.0	758	009	-	-	-
	1519	J	57 26.9	11 05.0	595	010	-	-	neuston
	1650	K	57 24.1	10 52.0	795	011	-	-	-
	1930	M	57 17.9	10 22.0	2200	-	-	Mx2	-
	2324	M	57 18.0	10 23.0	2220	012	-	-	vertical
16 May	0242	L	57 22.0	10 40.2	2045	013	-	-	-
	1054	M	57 18.0	10 23.2	2220	temp-salinity recorder mooring laid			
	1213	N	57 14.0	10 02.8	2113	014	-	-	-
	1419	N	57 13.7	09 59.3	2113	-	10	-	-
	1703	O	57 08.6	09 42.4	2018	-	-	Mx3	-
	2048	O	57 09.0	09 42.1	1950	015	-	-	-
	2251	O	57 09.2	09 42.1	1948	-	10	-	neuston
17 May	0152	P	57 05.8	09 24.8	1350	016	-	-	-
	0415	P	57 05.7	09 23.6	1350	-	9	-	-
	0505	Q	57 02.7	09 13.3	372	-	7	-	-
	0534	Q	57 02.3	09 13.3	375	017	-	-	neuston
	0702	R	57 00.0	09 00.1	138	-	-	-	-
	0718	R	57 00.0	09 00.2	138	-	6	-	-
			Shelf-edge CTD, fluorometer and nutrient section (to 500m depth)						
17 May	0836	S	56 57.0	08 47.1	129	-	5	-	-
	0853	S	56 57.1	08 47.2	125	019	-	-	-
	1004	R	57 00.0	09 00.0	135	020	-	-	-
	1049	R1	57 01.7	09 06.4	155	021	-	-	-
	1108	R1	57 01.9	09 06.5	151	-	6	-	-
	1156	Q	57 03.0	09 13.3	343	022	-	-	-
	1251	Q1	57 04.5	09 19.1	800	023	-	-	neuston
	1327	Q1	57 04.4	09 19.7	800	-	9	-	-
	1533	R	57 00.0	09 00.1	135	-	-	Mx2	-
	1833	Q	57 03.4	09 12.8	350	-	-	-	RMT shot
	1915	Q	57 04.6	09 13.8	350	-	-	-	RMT hauled
	2018	P	57 05.9	09 25.0	1050	024	-	-	-
	2129	P1	57 07.5	09 33.7	1375	025	-	-	-
	2206	P1	57 07.8	09 33.7	1375	-	9	-	-
18 May	0001	O	57 09.0	09 41.9	1640	026	-	-	-
	0120	O1	57 04.9	09 47.0	2000	-	-	-	vertical

w/bs = no. of water-bottles Mx3 = 3 multicorer lowerings RMT = rectangular midwater trawl

Table 1 (continued). RRS "Challenger" Cruise 103/1993 : Station List

Date 1993	Start GMT	Stn.	Lat. N. ° '	Long. W. ° '	Sdg. (m)	CTD Dip no.	w/bs	coring	plankton haul
			SW-NE shelf-edge section (to 500m depth)						
19 May	0600	L1	56 42.0	09 48.0	1820	-	8	-	-
	0645	L1	56 41.8	09 47.9	1810	027	-	-	-
	0843	L3	56 48.0	09 31.8	1720	028	-	-	-
	0915	L3	56 47.9	09 31.5	1720	-	8	-	-
	1208	P	57 06.1	09 24.9	1400	-	-	Mx3	neuston
	1605	L5	56 54.0	09 15.6	1286	-	8	-	-
	1646	L5	56 53.8	09 14.6	1286	029	-	-	neuston
	1734	L6	56 55.5	09 12.7	1039	030	-	-	-
	1804	L6	56 55.5	09 12.0	960	-	8	-	-
	1912	L7	56 56.9	09 07.9	370	-	8	-	-
	1934	L7	56 56.8	09 07.5	343	031	-	-	-
	2033	L8	56 58.5	09 03.8	145	032	-	-	-
	2048	L8	56 58.4	09 03.7	147	-	8	-	-
	2139	R	56 59.8	09 00.1	136	033	-	-	-
	2235	L9	57 02.6	08 52.4	143	034	-	-	-
	2252	L9	57 02.4	08 52.6	143	-	8	-	-
	2324	L9	57 02.4	08 52.6	135	-	-	-	vertical
20 May	0026	L10	57 05.0	08 45.3	135	035	-	-	-
	0041	L10	57 05.2	08 45.0	135	-	8	-	-
			Shelf-edge - Sound of Mull section						
20 May	0219	S	56 57.0	08 46.7	130	036	-	-	neuston
	0347	15G	56 52.9	08 29.7	132	037	-	-	-
	0405	15G	56 52.7	08 28.7	130	-	9	-	-
	0506	T	56 50.2	08 19.8	138	038	-	-	-
	0600	14G	56 48.7	08 10.1	131	039	-	-	neuston
	0615	14G	56 48.7	08 10.1	131	-	8	-	-
	0720	14G	56 47.6	08 08.6	130	-	-	-	RMT shot
	0737	14G	56 47.2	08 08.2	130	-	-	-	RMT hauled
	0833	14G	56 48.5	08 10.3	133	-	-	Mx4	-
	1015	13G	56 47.0	07 59.9	123	040	-	-	-
	1103	12G	56 45.5	07 50.0	-	surface salinity sample only			
	1146	11G	56 43.9	07 40.0	59	041	-	-	-
	1158	11G	56 43.9	07 40.0	59	-	5	-	-
	1254	10G	56 43.8	07 29.9	216	-	-	Mx1	-
	1307	10G	56 43.8	07 29.8	220	042	-	-	-
	1327	10G	56 43.7	07 29.5	220	-	8	-	-
	1427	9G	56 44.0	07 19.8	159	-	9	-	-
	1449	9G	56 44.1	07 19.0	159	043	-	-	-
	1532	8G	56 44.3	07 09.9	-	surface salinity sample only			
	1606	7G	56 44.1	06 59.7	142	044	-	-	neuston
	1621	7G	56 44.3	06 59.0	140	-	9	-	-

w/bs = no. of water-bottles Mx3 = 3 multicorer lowerings RMT = rectangular midwater trawl

Table 1 (continued). RRS "Challenger" Cruise 103/1993 : Station List

Date 1993	Start GMT	Stn.	Lat. N. ° '	Long. W. ° '	Sdg. (m)	CTD Dip no.	w/bs	coring	plankton haul
			Shelf-edge - Sound of Mull section (continued)						
	1730	6G	56 43.9	06 44.7	49	045	-	-	-
	1815	5G	56 44.9	06 36.0	-	surface salinity sample only			
	1850	4G	56 44.0	06 27.0	88	046	-	-	-
	1904	4G	56 44.0	06 26.5	86	-	5	-	-
	1936	3G	56 42.5	06 22.0	-	surface salinity sample only			
	2013	2G	56 40.9	06 16.8	37	-	3	-	-
	2020	2G	56 40.9	06 16.7	35	-	2 Cs	-	-
	2028	2G	56 40.8	06 16.4	34	047	-	-	-
	2118	1G	56 40.0	06 07.9	155	048	-	-	-
	2232	1G	56 40.1	06 08.0	120	-	2 Cs	-	-
			Tiree Passage current meter mooring						
21 May	0521	Y	56 37.6	06 24.0	49	previous mooring recovered			
	0632	Y	56 37.7	06 23.8	51	current meter anchor laid			
	0635	Y	56 37.8	06 23.8	56	spar buoy anchor laid			
			Outer Firth of Clyde stations						
21 May	1850	CS1	55 09.2	05 22.0	68	-	5	-	-
	1904	CS1	55 08.9	05 21.7	69	049	-	-	-
	1958	CS2	55 13.9	05 14.6	50	050	-	-	-
	2006	CS2	55 13.8	05 14.3	50	-	4	-	-
	2047	CL1	55 17.1	05 17.2	50	-	-	Cx2	-
	2107	CL1	55 17.1	05 17.0	50	051	-	-	-
	2141	CS3	55 18.0	05 10.9	53	052	-	-	-
	2150	CS3	55 18.0	05 10.8	53	-	4	-	-
	2242	CS4	55 21.8	05 04.5	63	-	-	Cx2	-
	2302	CS4	55 21.7	05 06.1	64	-	5	-	-
	2316	CS4	55 21.6	05 03.8	65	053	-	-	-
22 May	0013	AD5	55 23.6	04 51.7	61	054	-	-	-
	0058	CL15	55 26.5	04 54.2	60	-	-	Cx2	neuston
	0135	AD4	55 25.3	04 57.0	71	055	-	-	-
	0209	CL15	55 26.5	04 54.2	60	-	-	Cx1	-
	0255	CS5	55 26.7	05 01.3	123	056	-	-	-
	0307	CS5	55 26.8	05 01.9	125	-	8	-	-
	0413	CS6	55 32.0	04 58.8	107	-	7	-	-
	0427	CS6	55 32.0	04 58.8	110	057	-	-	-
	0511	AD2	55 31/5	04 52.8	82	058	-	-	-
	0707	CS6	55 32.0	04 59.1	110	-	-	Mx1	-
	0835	-	55 37.9	05 01.0	155	Menai Bridge mooring recovered			
	0957	CS7	55 38.5	05 01.6	182	-	-	Cx4	-
	1031	CS7	55 38.7	05 01.3	135	-	-	Cx3	-
	1109	CS7	55 38.2	05 02.0	157	-	9	-	-

w/bs = no. of water-bottles Mx3 = 3 multicorer lowerings RMT = rectangular midwater trawl
2 Cs = 2 large-volume samples for radiocaesium Cx3 = 3 Craib corer lowerings

Table 1 (continued). RRS "Challenger" Cruise 103/1993 : Station List

Date 1993	Start GMT	Stn.	Lat. N. o '	Long. W. o '	Sdg. (m)	CTD Dip no.	w/bs	coring	plankton haul
			Outer Firth of Clyde stations (continued)						
22 May	1126	CS7	55 38.3	05 01.9	172	059	-	-	-
	1148	CS7	55 38.4	05 01.5	172	-	-	Cx5	-
	1447	-	55 33.3	04 55.8	83	Menai instrument mooring laid			
	1450	-	55 33.4	04 55.8	86	Toroid marker buoy anchor			
	1536	-	55 37.9	05 00.7	173	guard spar buoy recovered			
	1653	-	55 33.3	04 55.8	80	guard spar buoy redeployed			
	1835	CE2	55 46.6	04 58.6	84	-	6	-	-
	1846	CE2	55 46.6	04 58.6	87	060	-	-	-
	1921	AB35	55 49.5	04 58.8	66	061	-	-	-
	2048	CS8	55 41.8	05 08.9	163	062	-	-	-
	2103	CS8	55 42.0	05 09.1	163	-	9	-	-
	2156	CS9	55 46.2	05 15.1	138	-	8	-	-
	2209	CS9	55 46.2	05 15.3	151	063	-	-	-
	2303	LF2	55 50.6	05 20.0	175	064	-	-	-
	2347	LF3	55 53.4	05 23.0	171	065	-	-	-
23 May	0004	LF3	55 53.5	05 23.0	171	-	9	-	neuston
	0212	CS10	55 42.8	05 20.4	112	-	7	-	-
	0237	CS10	55 42.6	05 20.3	124	066	-	-	-
	0340	CS11	55 40.2	05 25.1	126	067	-	-	-
	0350	CS11	55 40.2	05 25.1	126	-	8	-	-
	0455	CSE	55 34.4	05 25.4	80	-	6	-	-
	0503	CSE	55 34.4	05 25.4	81	068	-	-	-
	0544	CS12	55 30.1	05 26.3	84	069	-	-	-
	0550	CS12	55 30.1	05 26.3	84	-	6	-	-
	0645	CS13	55 26.1	05 28.7	54	-	5	-	-
	0749	CS13	55 25.9	05 28.9	60	070	-	-	-
	0849	CS14	55 22.6	05 18.6	55	071	-	-	-
	0900	CS14	55 22.7	05 18.5	55	-	4	-	-
	1005	CS15	55 17.0	05 27.6	44	-	4	-	-
	1012	CS15	55 17.2	05 27.4	46	072	-	-	-
	1100	CS16	55 14.6	05 33.1	81	073	-	-	-
	1114	CS16	55 14.6	05 32.7	81	-	6	-	-

w/bs = no. of water-bottles Cx3 = 3 Craib corer lowerings

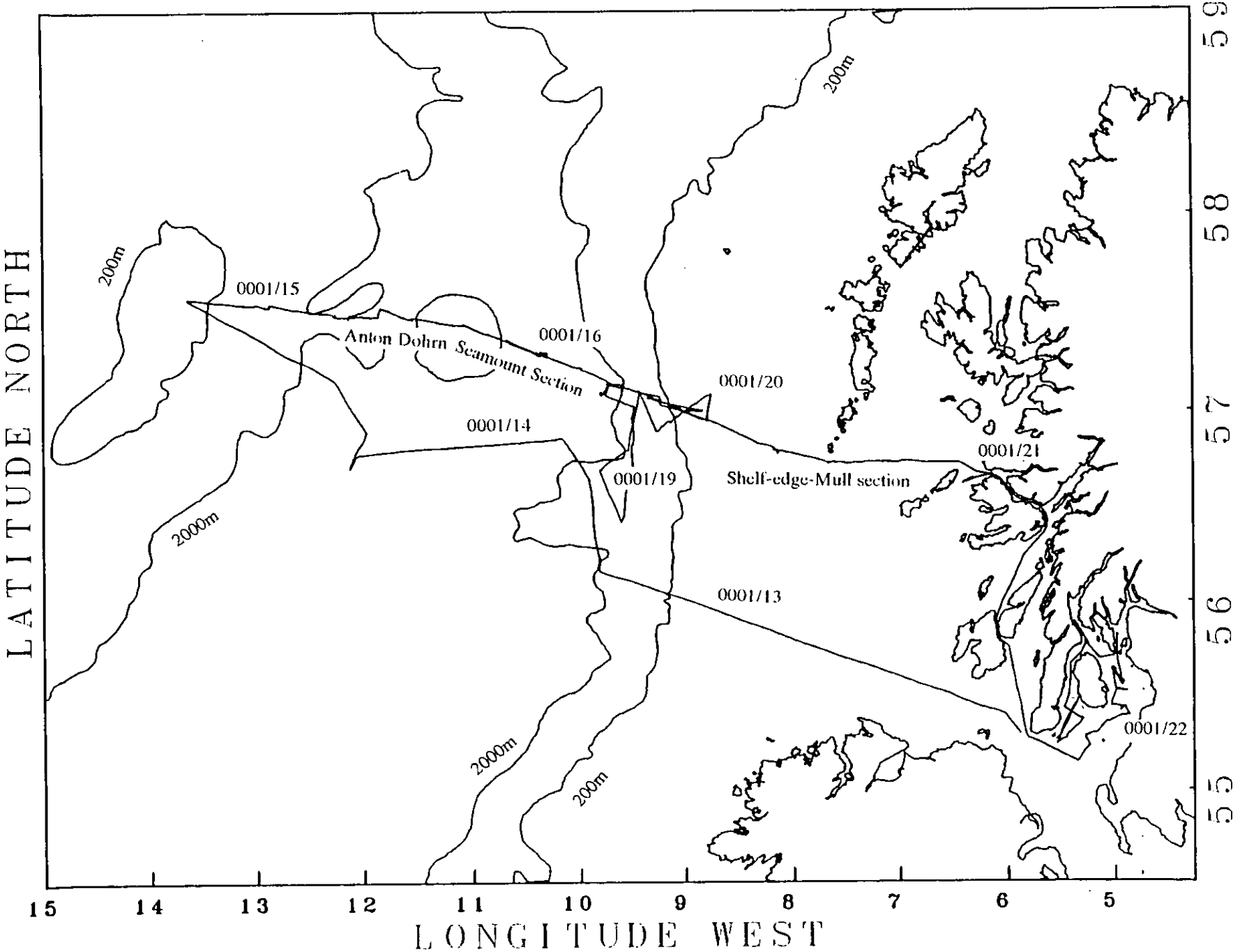

Figure 1. RRS "Challenger", Cruise 103/1993. Ship's track, 12 - 23 May 1993.

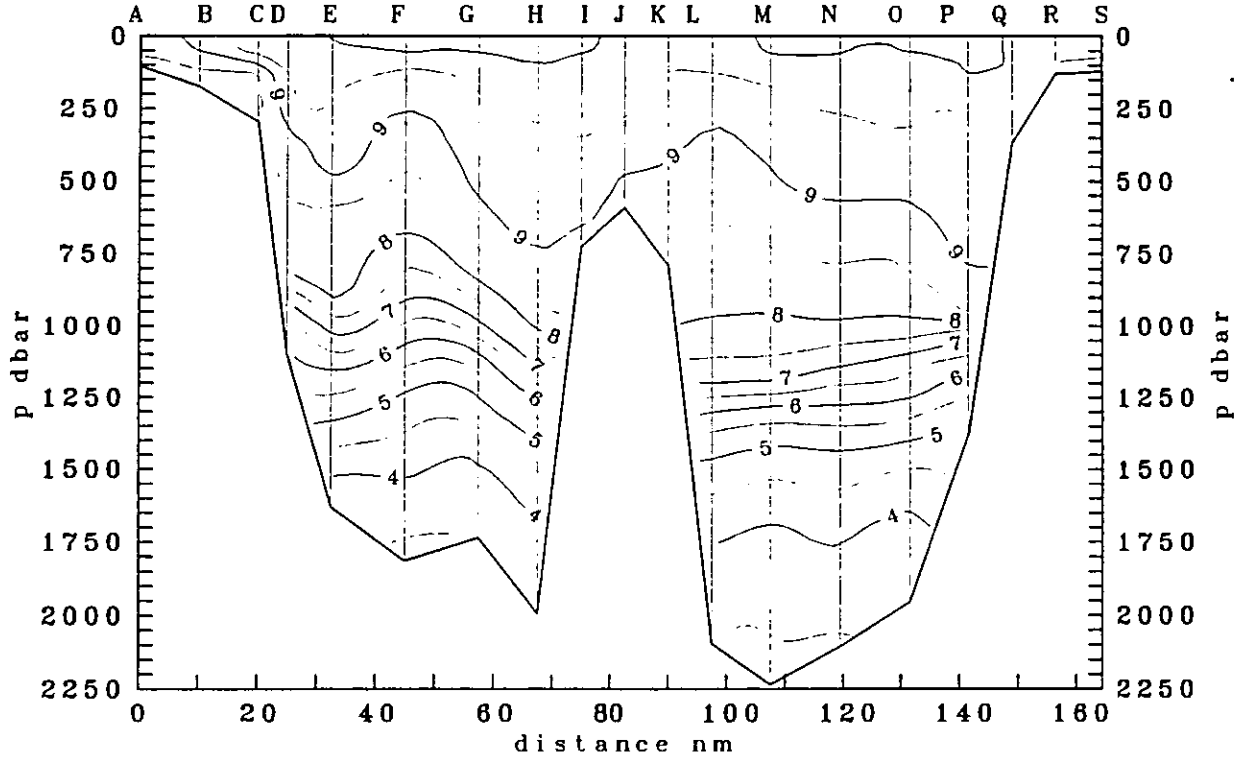

Figure 2a. Anton Dohrn Seamount section, 14 - 17 May 1993. Temperature.

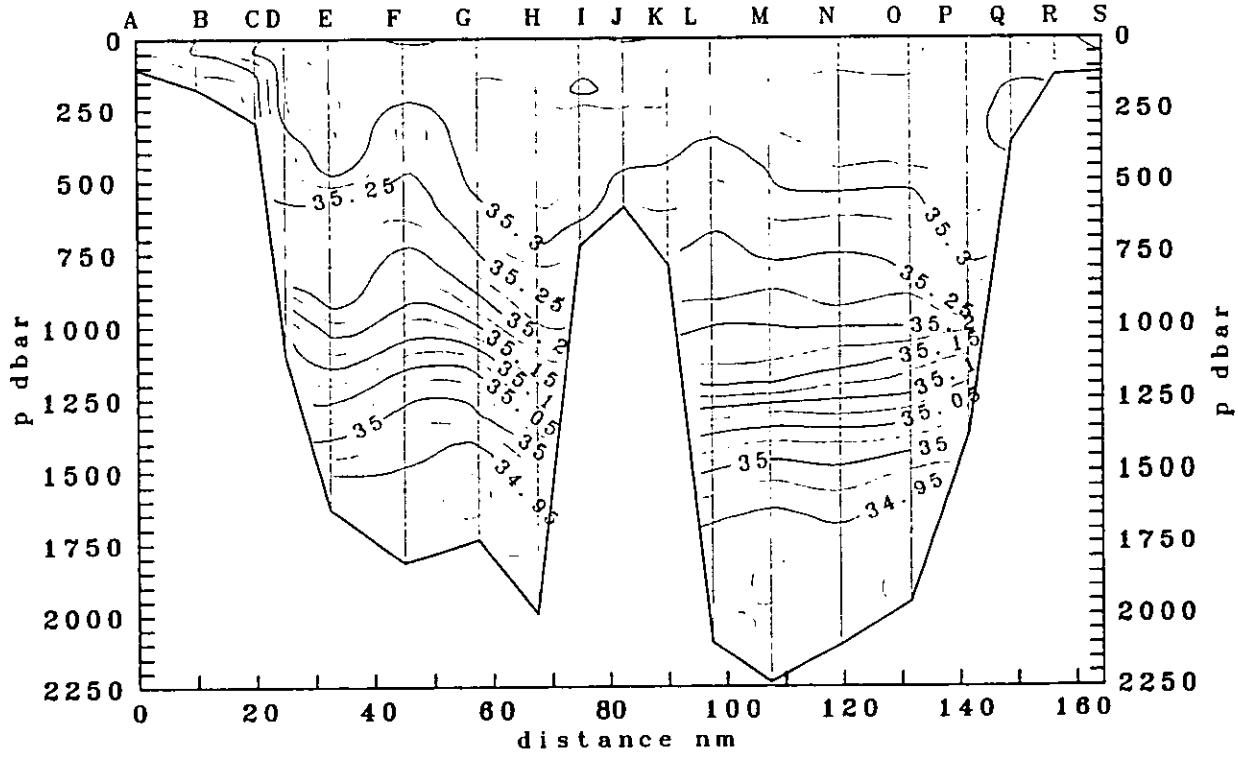

Figure 2b. Anton Dohrn Seamount section, 14 - 17 May 1993. Salinity.

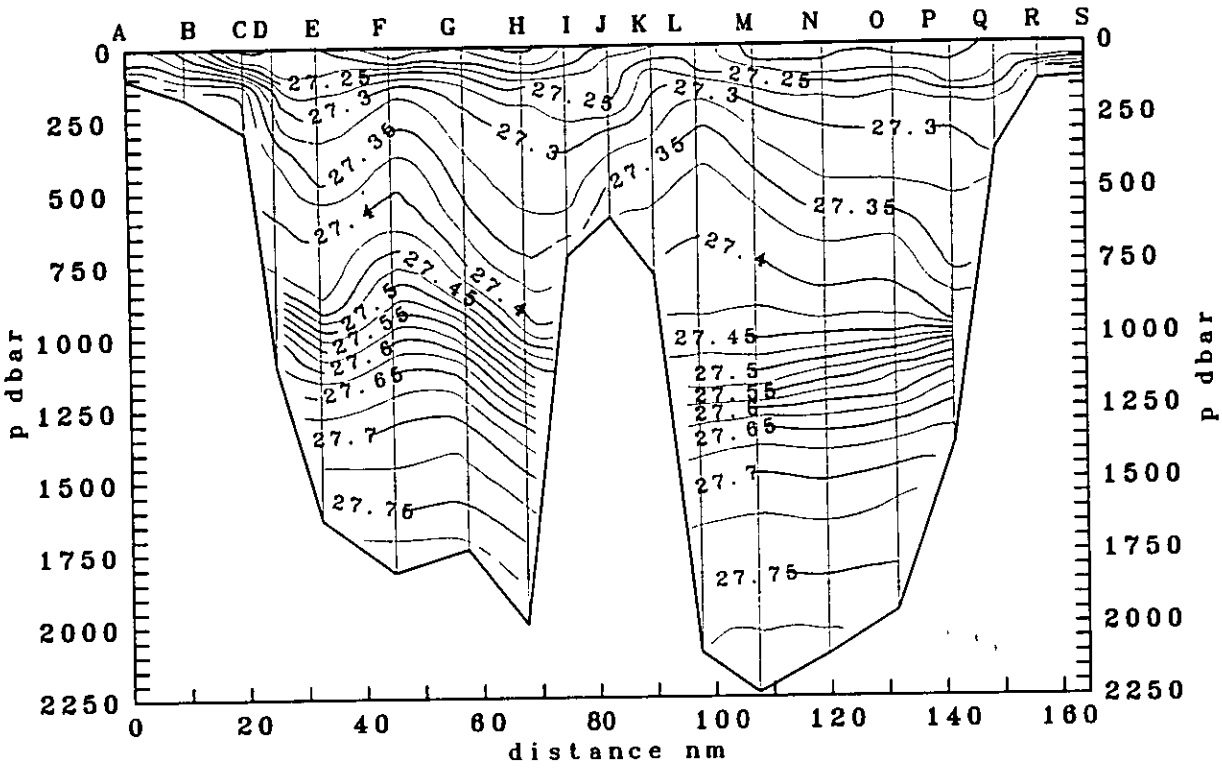

Figure 2c. Anton Dohrn Seamount section, 14 - 17 May 1993. Density (sigma-t).

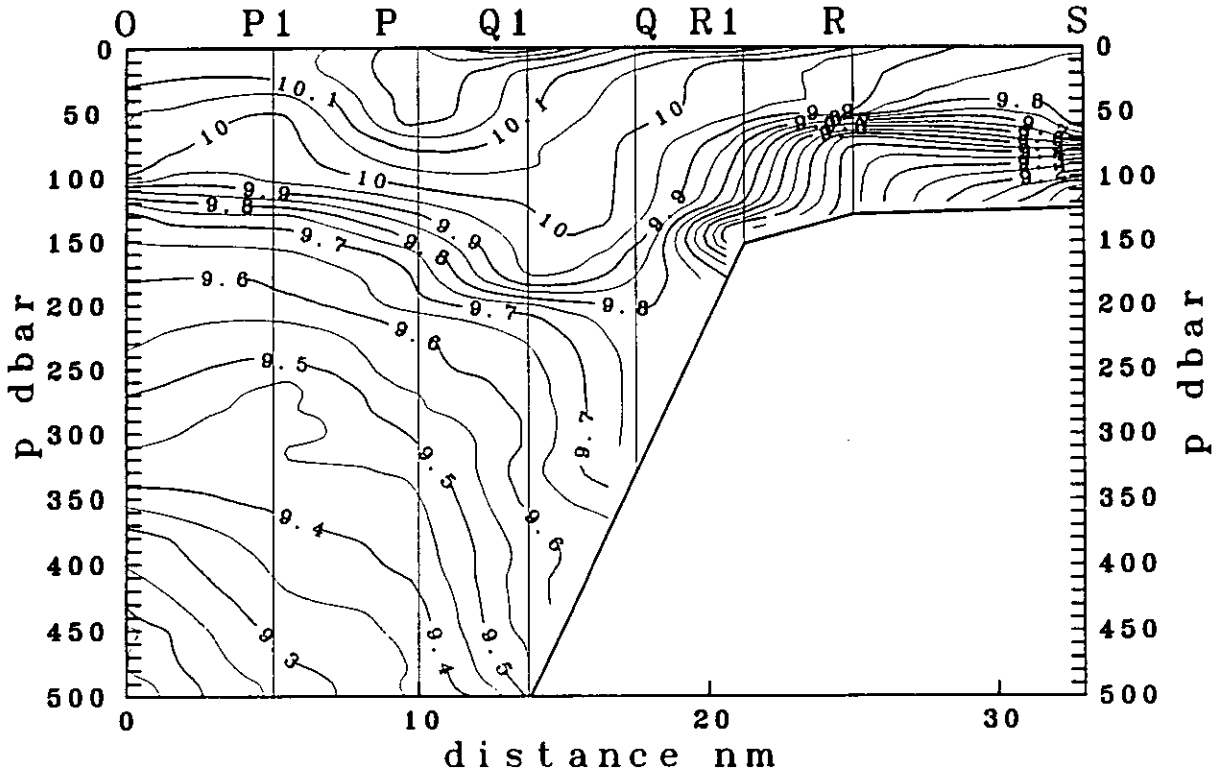

Figure 3a. Shelf-edge section, 17 - 18 May 1993. Temperature.

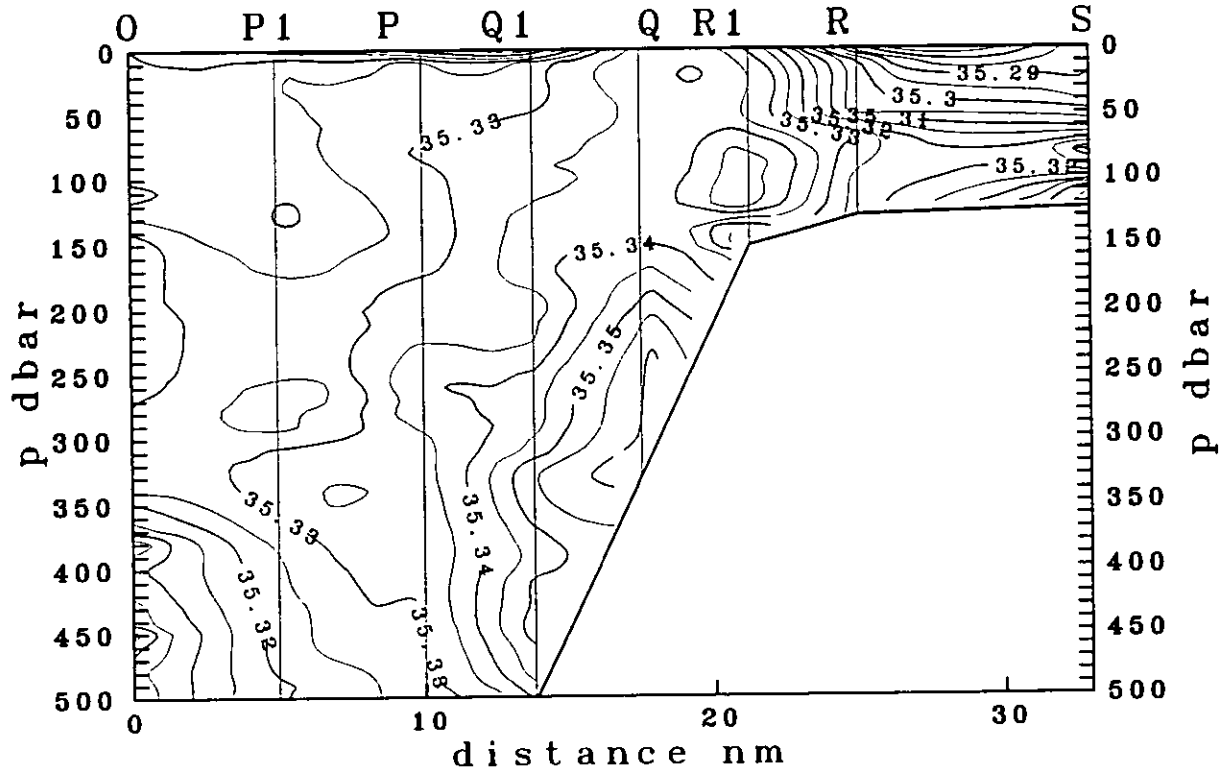

Figure 3b. Shelf-edge section, 17 - 18 May 1993. Salinity.

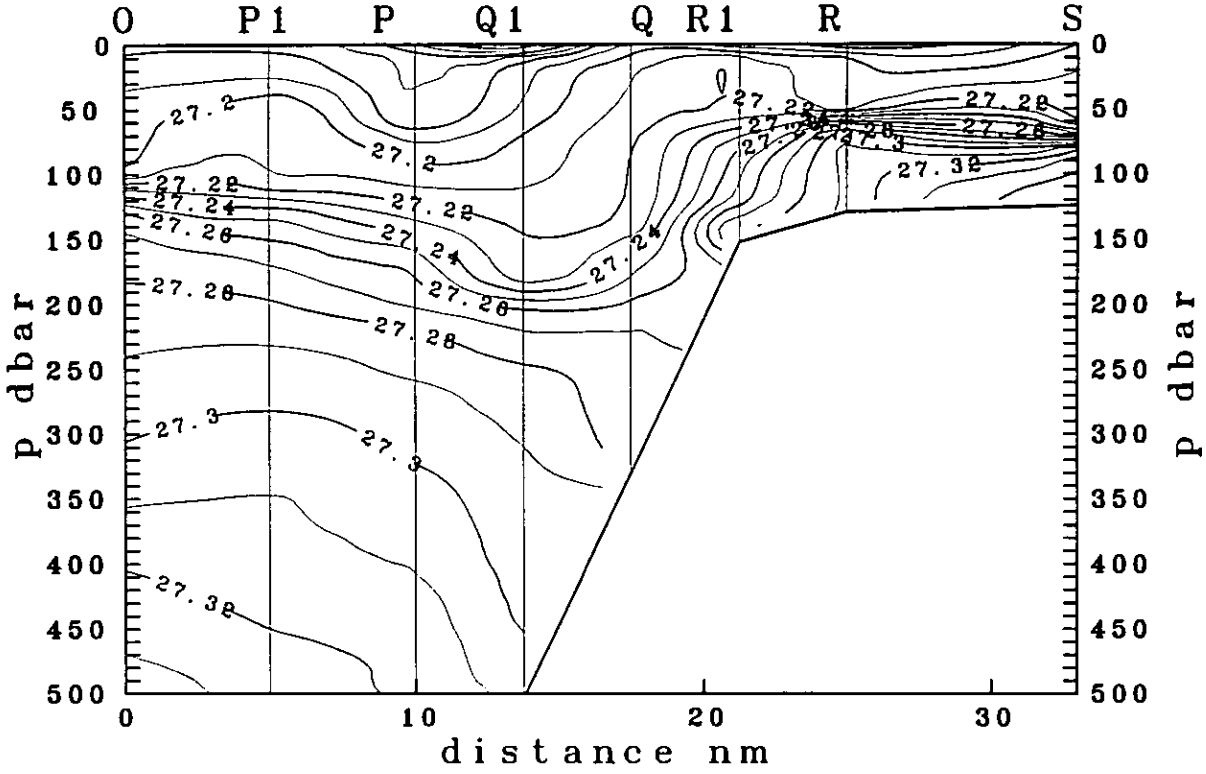

Figure 3c. Shelf-edge section, 17 - 18 May 1993. Density (sigma-t).

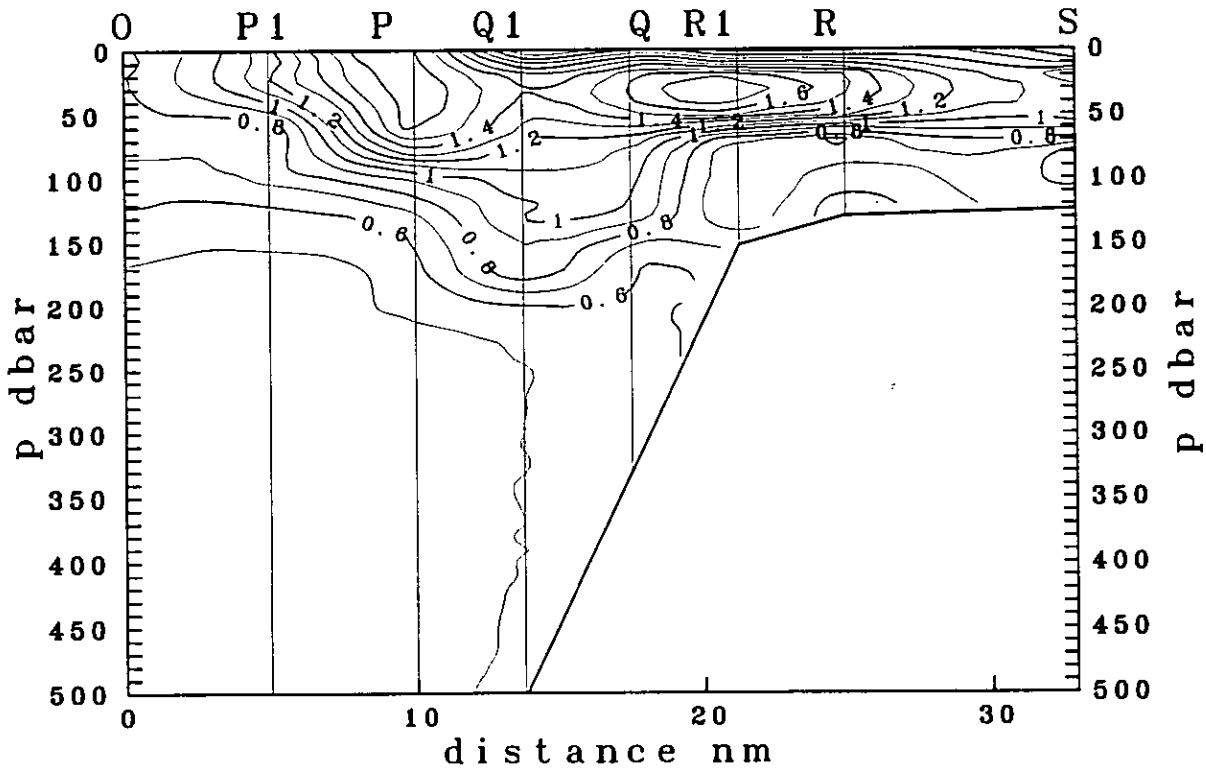

Figure 3d. Shelf-edge section, 17 - 18 May 1993. Fluorescence.

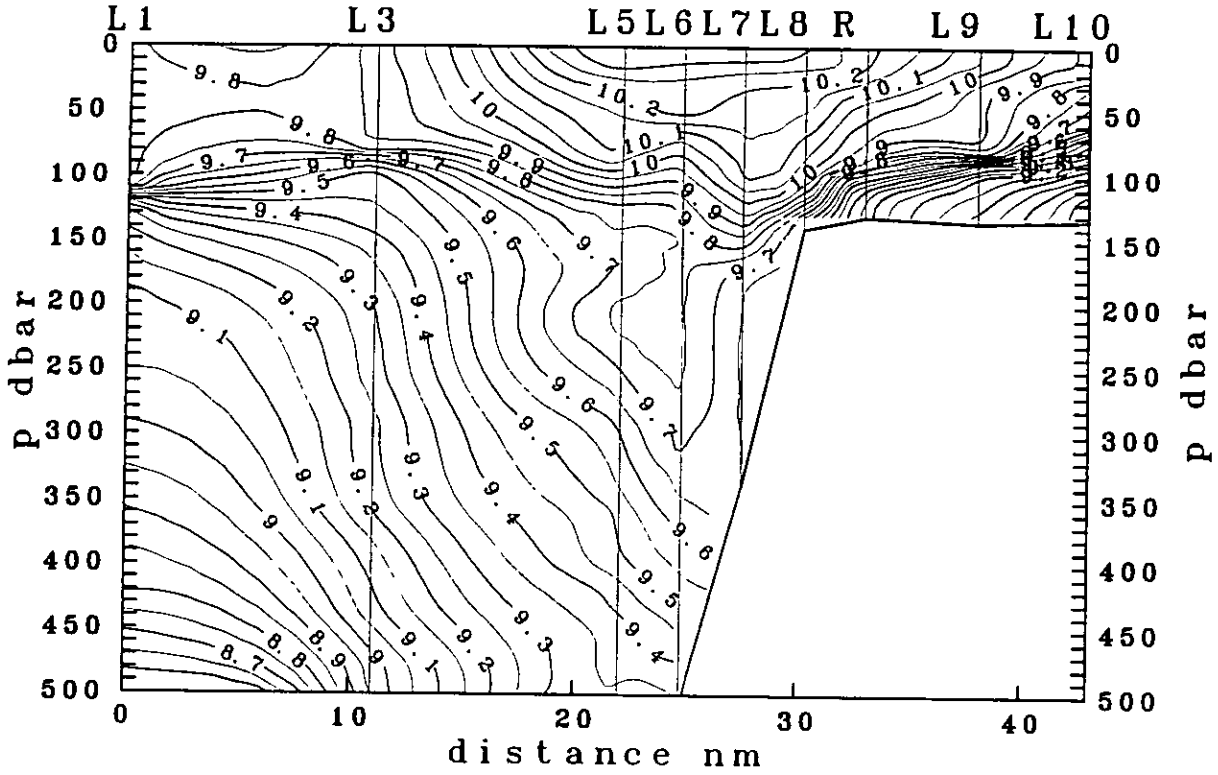

Figure 4a. Section "L", shelf-edge, 19 - 20 May 1993. Temperature.

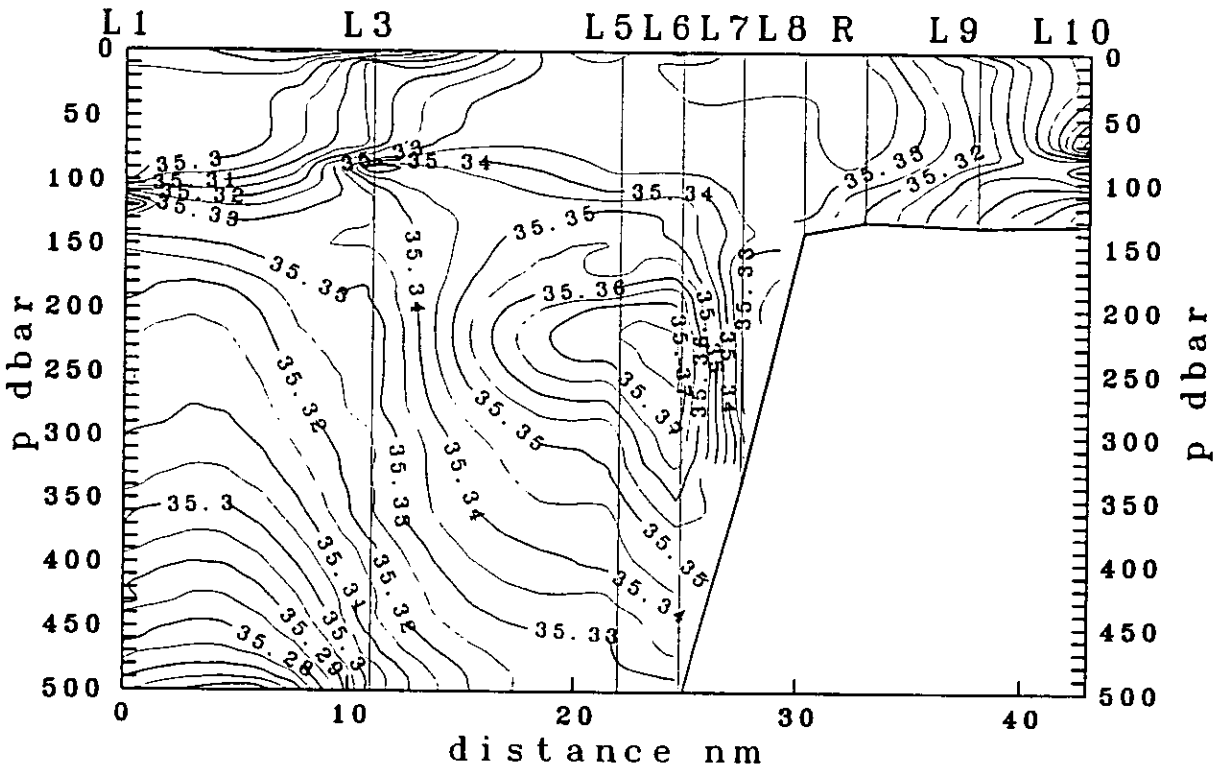

Figure 4b. Section "L", shelf-edge, 19 - 20 May 1993. Salinity.

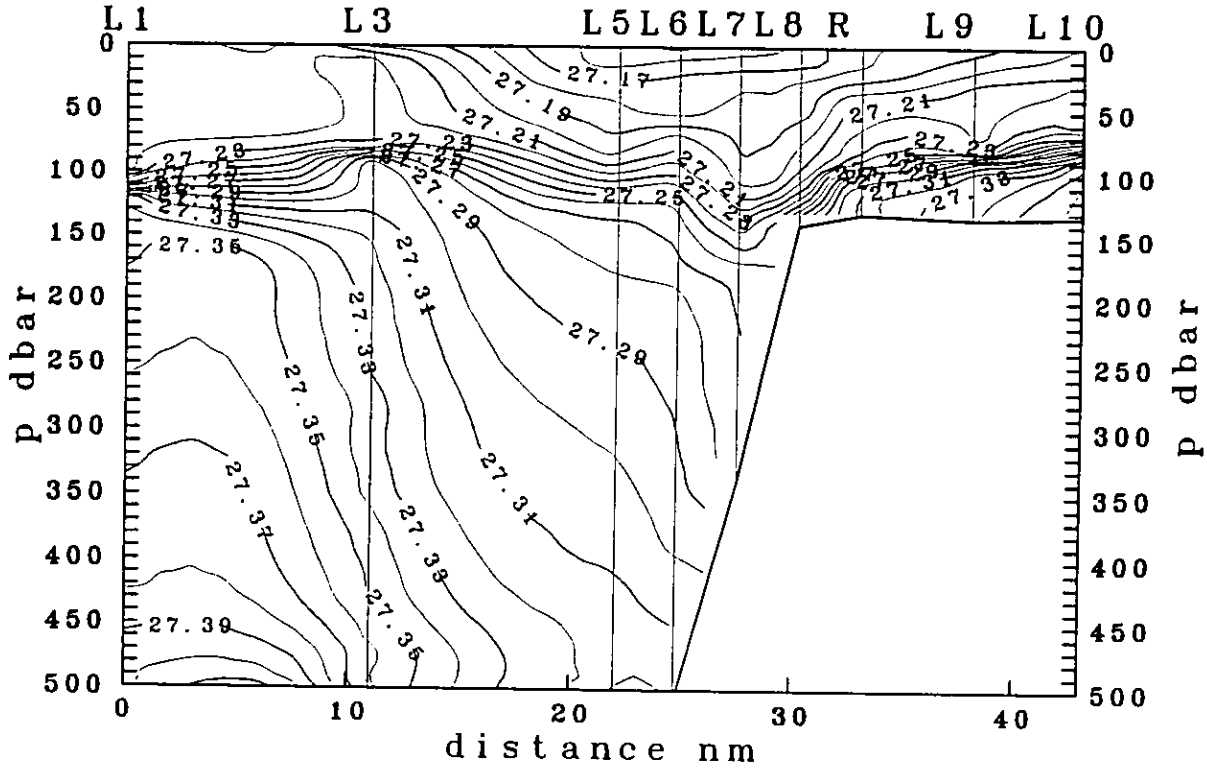

Figure 4c. Section "L", shelf-edge, 19 - 20 May 1993. Density (sigma-t).

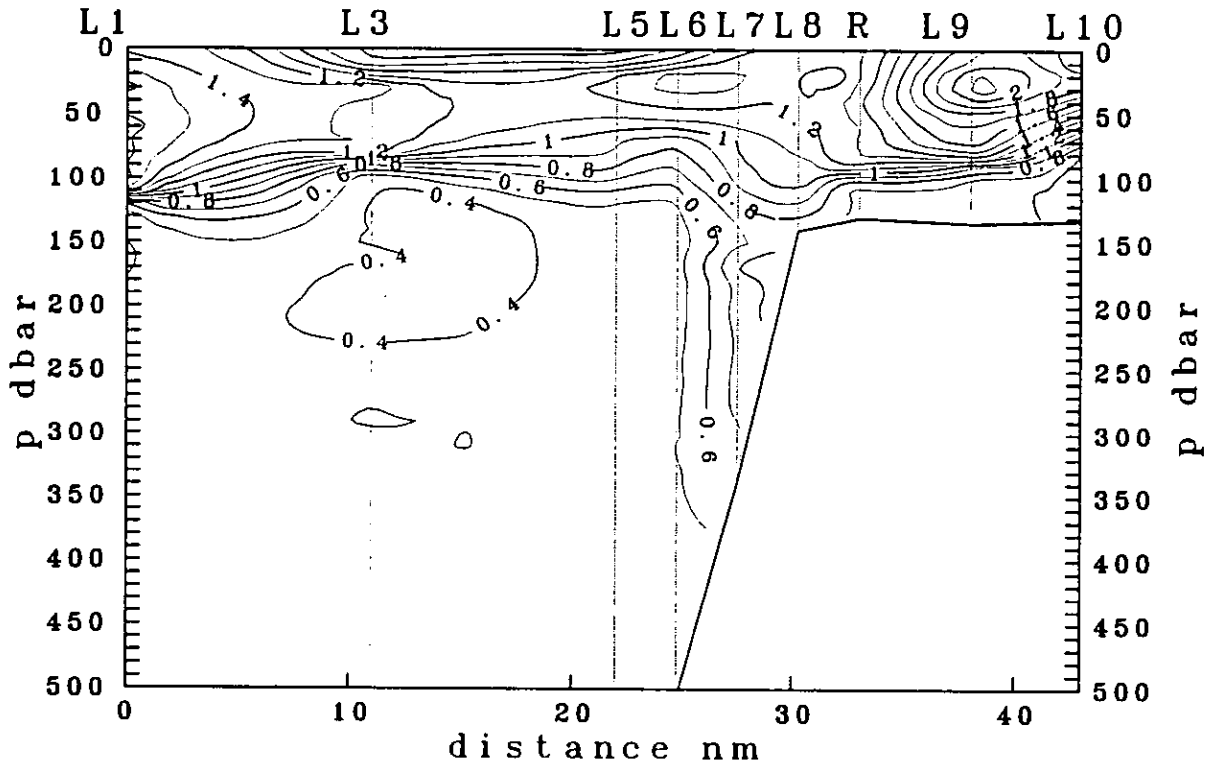

Figure 4d. Section "L", shelf-edge, 19 - 20 May 1993. Fluorescence.

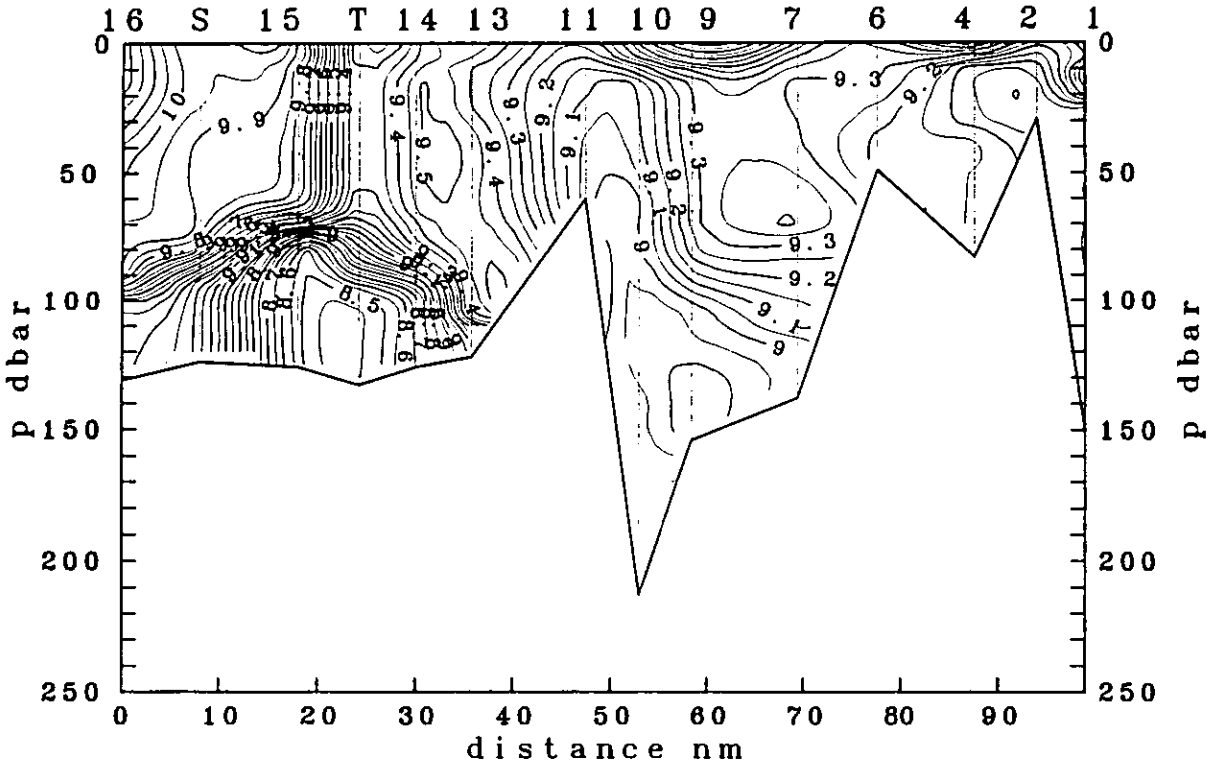

Figure 5a. Shelf-edge - Sound of Mull, 20 May 1993. Temperature.

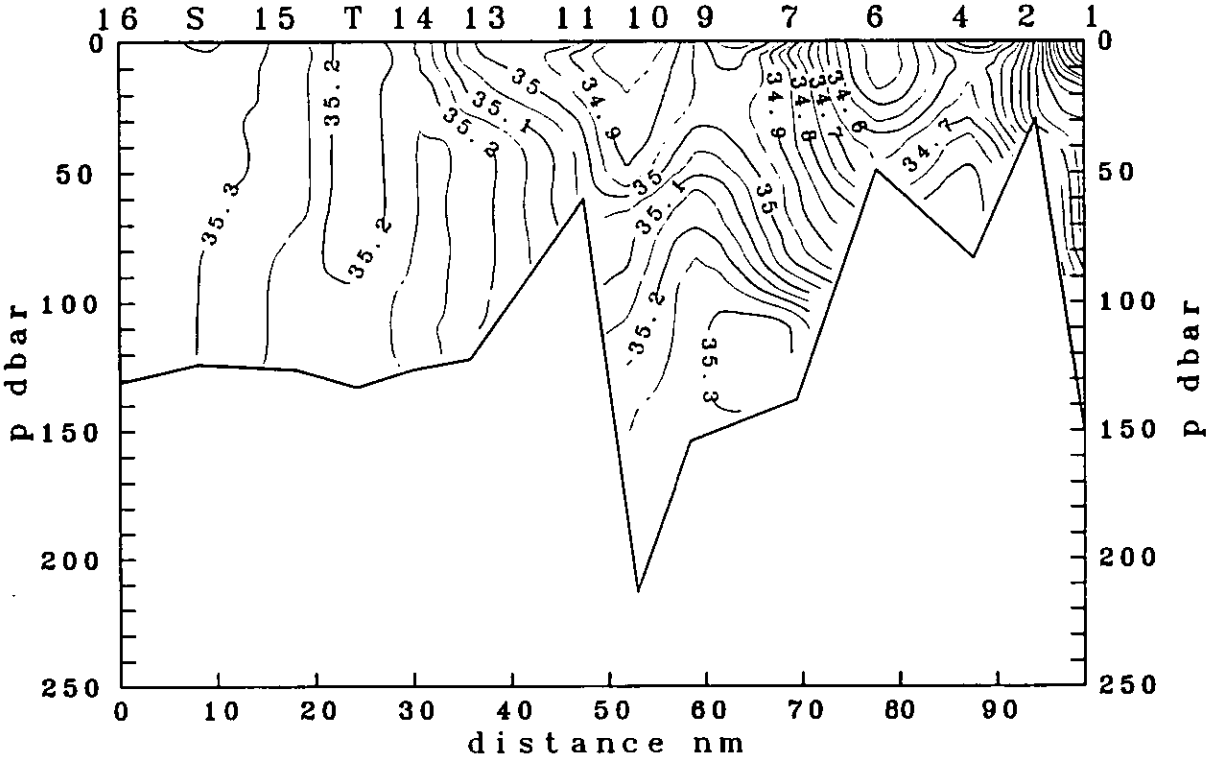

Figure 5b. Shelf-edge - Sound of Mull, 20 May 1993. Salinity.

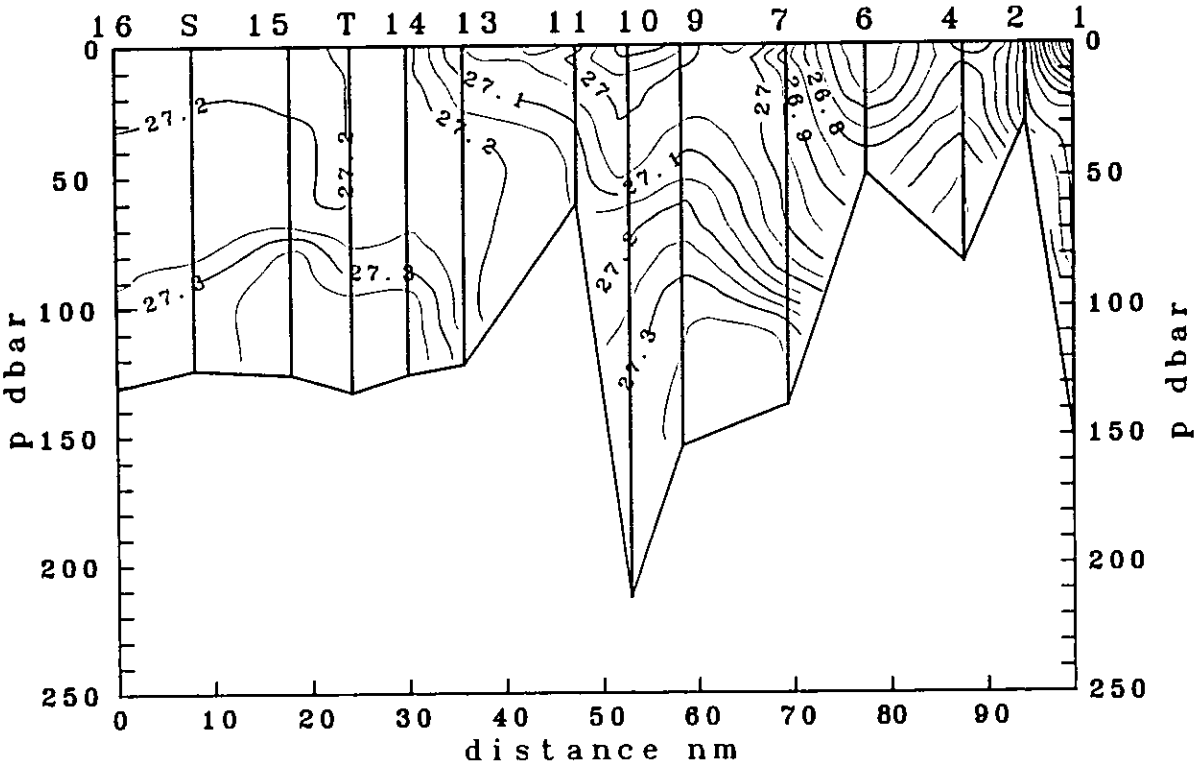

Figure 5c. Shelf-edge - Sound of Mull, 20 May 1993. Density (sigma-t).

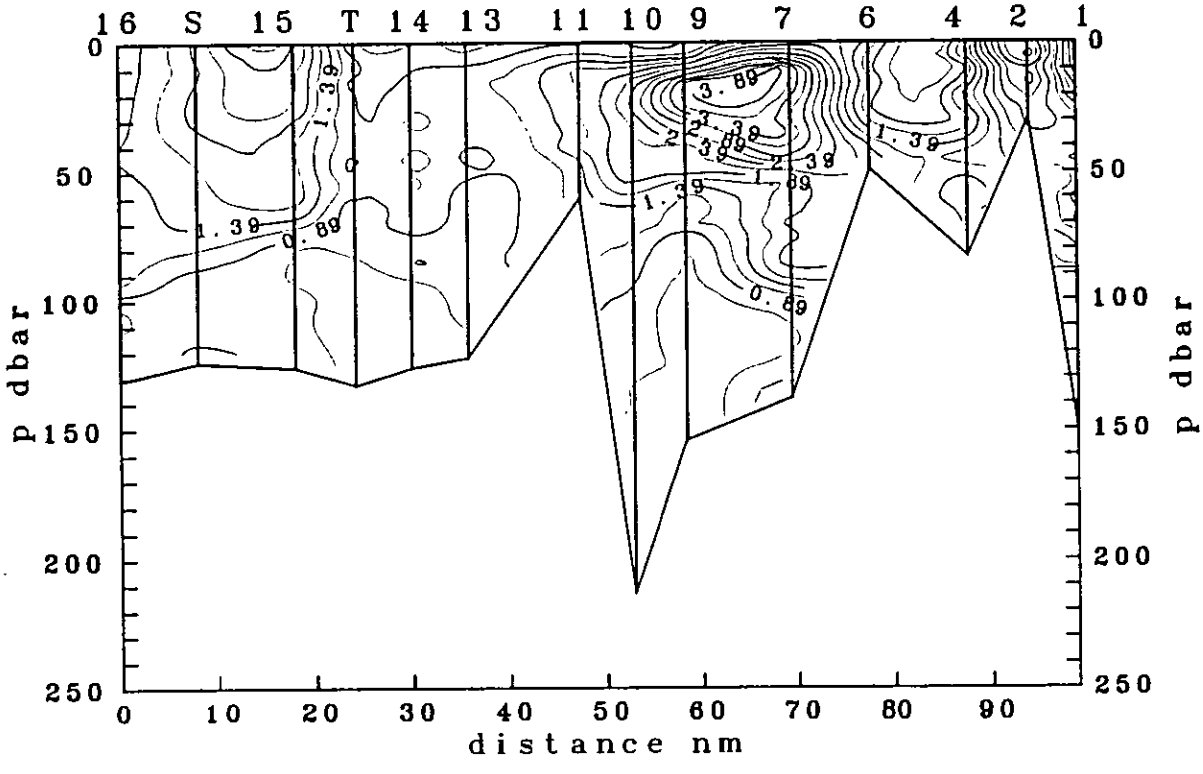

Figure 5d. Shelf-edge - Sound of Mull, 20 May 1993. Fluorescence.

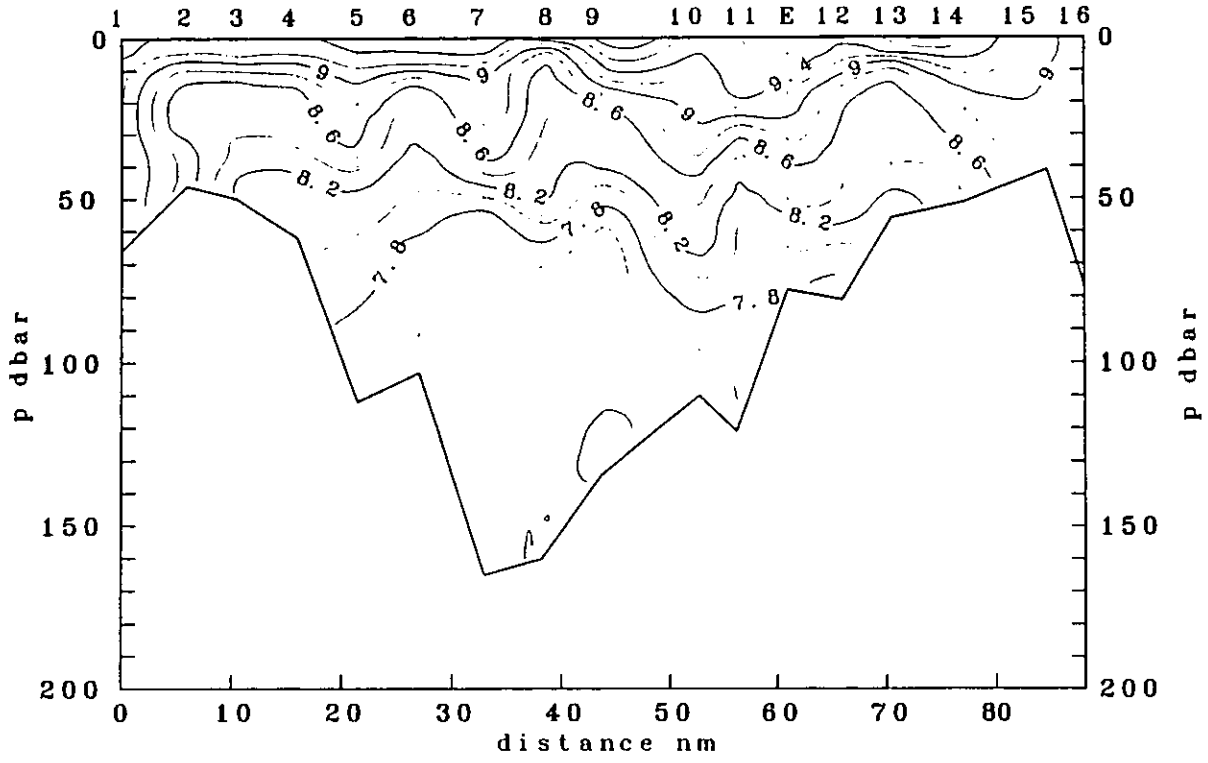

Figure 6a. Section anticlockwise around Arran, 21 - 22 May 1993. Temperature.

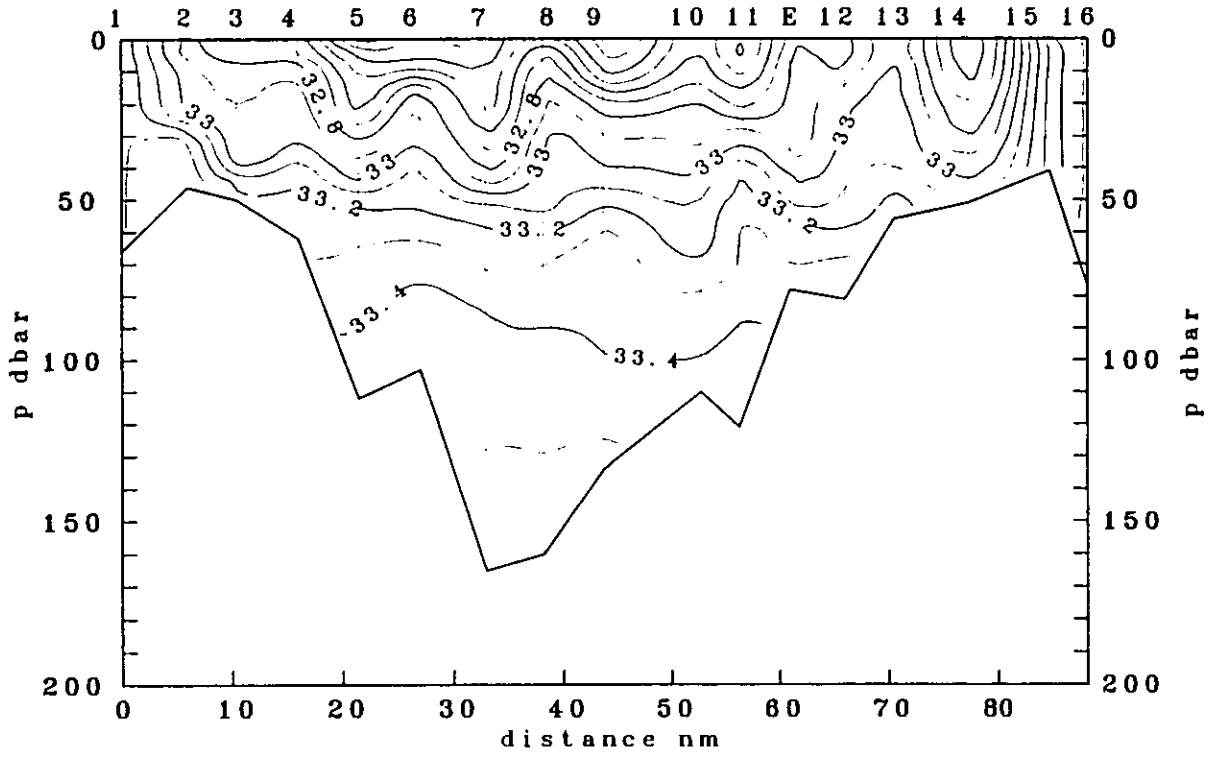

Figure 6b. Section anticlockwise around Arran, 21 - 22 May 1993. Salinity.

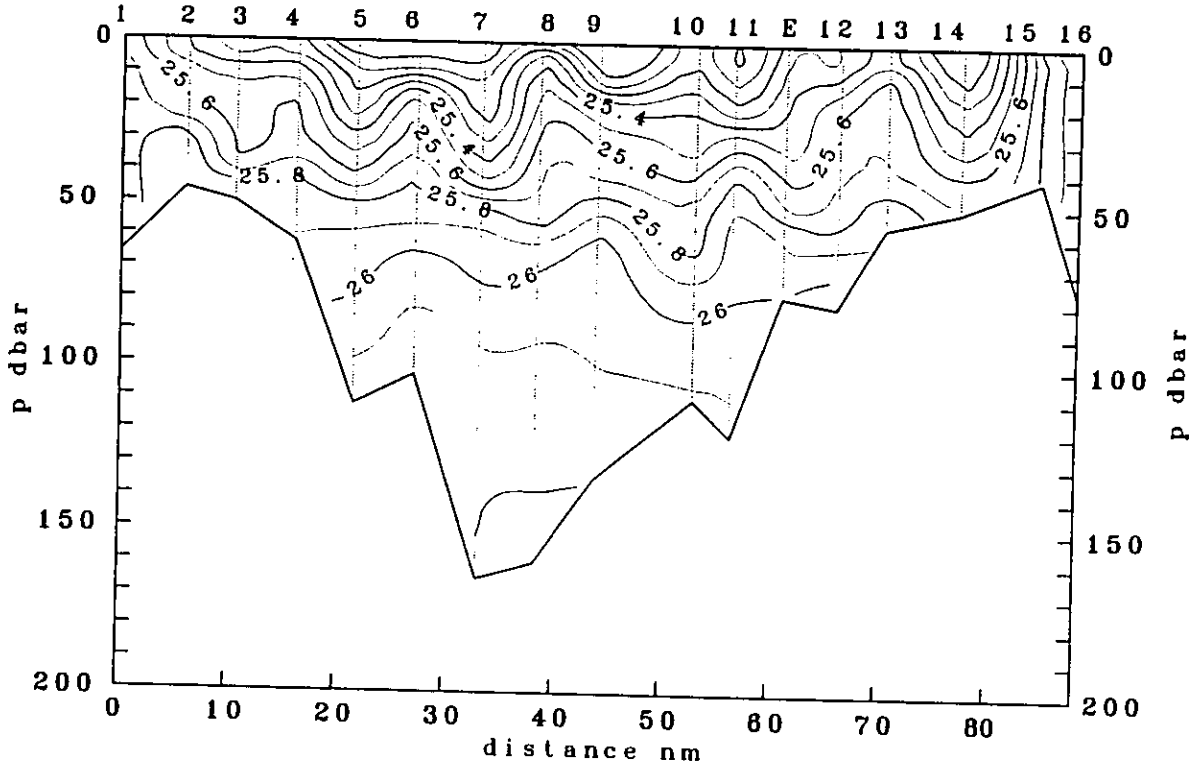

Figure 6c. Section anticlockwise around Arran, 21-22 May 1993. Density (sigma-t).

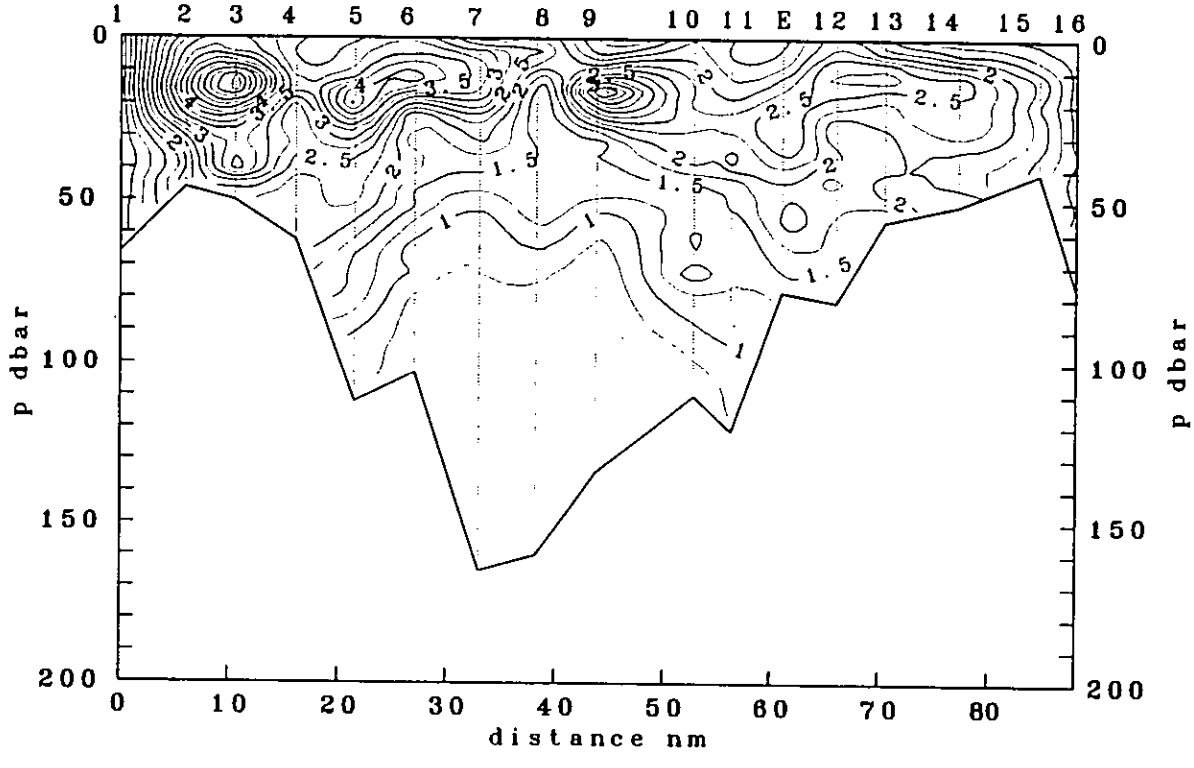

Figure 6d. Section anticlockwise around Arran, 21 - 22 May 1993. Fluorescence.