Cruise Report

RRS Charles Darwin Cruise 107

20th August - 3rd September, 1997

Principal Scientist

K.S. Black

'……it was of an indefinable translucent blue quite unlike anything I have ever seen in the upper world, and it excited our optic nerves in a most confusing manner …the blueness of the blue…seemed to pass materially through the eye into our very beings..'

WILLIAM BEEBE, *Half Mile Down* (1934)

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Ship’s Company

1. INTRODUCTION

Biogeochemical processes operating at the deep ocean benthic boundary layer represent the interface between the flux of materials carried down through the water column, and their incorporation within the sedimentary record. This zone responds to a variety of physical and biological mechanisms (e.g. benthic storms and boundary currents, seasonal phyto-detritus from plankton blooms) operating over daily to seasonal time scales. Unknown and poorly quantified processes modulate this forcing to produce dramatically different biomass responses over quite small regional areas. The residence time and fate of anthropogenic contaminants to the deep ocean floor is governed by these biogeochemical processes. The BENBO project is a major inter-disciplinary, process-oriented study which will provide a dynamic bio-physico-chemical model that will aid in the assessment of man's impact in the deep-sea. BENBO will achieve this through comparing and contrasting three key sites in the NE Atlantic, with differing water depths, current flows and phyto-detritus inputs.

BENBO is funded by the UK Natural Environment Research Council (NERC) and has a duration of three years from May, 1997. This report details the first of three research cruises to the field study area.

Acknowledgements
The pre-cruise planning stage for CD107 was extremely short and the success of the cruise is a direct result of the hard work of many individuals. The author would like to extend his thanks to all the staff at RVS, including, in particular, all those in the Operations Office and in the Instrumentation Group. Work on board the ship was not always simple or easy, and we had an extended period of extremely rough weather. However, Captain Richard Bourne and his crew did a remarkable job in contributing to the success of our cruise. They also deserve a warm thanks. All the scientific participants must be congratulated on working within such tight time deadlines. Hopefully future cruises will be under considerably less pressure, and perhaps we can hope to achieve even more. Thank you for your patience.

2. ITINERARY

Sailed Fairlie	20th August, 1997
Arrived Southampton	3rd September, 1997

3. OBJECTIVES

At each of the three BENBO sites (denoted A, B and C) the following objectives were established:

1. To map the seabed topography using swath bathymetry.
2. To deploy long moorings comprising sediment traps, transmissometers and current meters.
3. To obtain samples of the seabed using box- and multi-coring techniques
4. To obtain background CTD information.

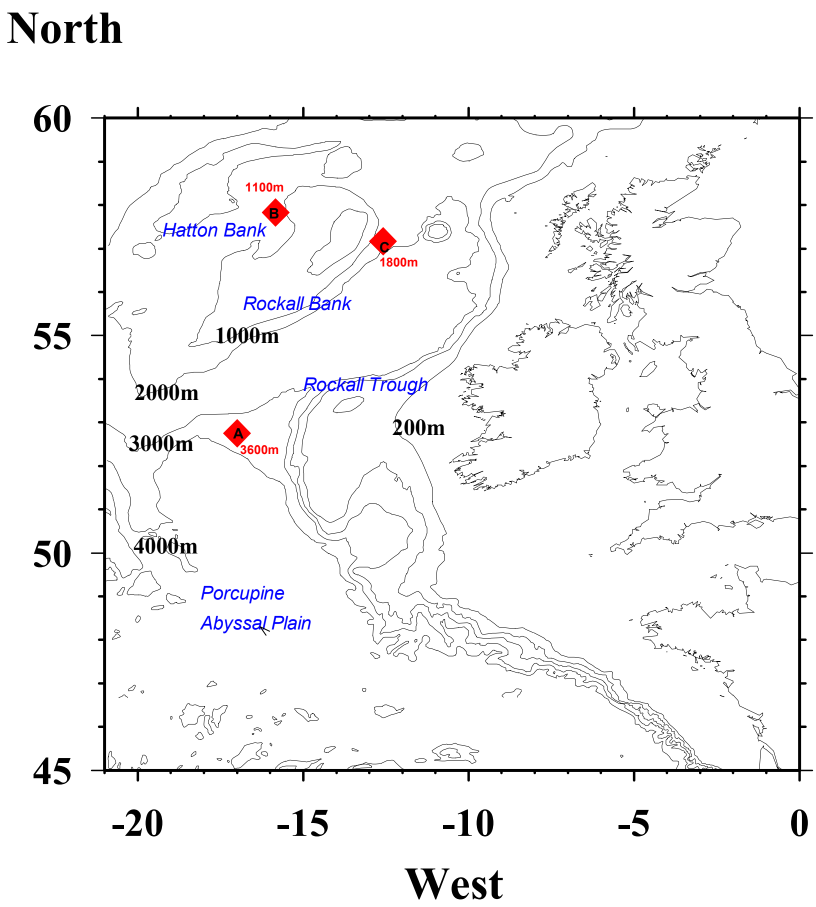
In addition, a bottom mounted ADCP was to be deployed at site B.

4. SURVEY DESIGN

Three areas of seabed, around the Rockall Trough region in the north-east Atlantic, were selected as the field study area (Fig. 1) The locations of these sites are as follows:

		Water depth/m
Site A Mouth of Rockall Trough	52.918°N 16.917°W	3580
Site B Hatton-Rockall Basin	57.425°N 15.683°W	1100
Site C Flank of Feni Drift	57.100° N 12.515°W	1920

Fig. 1. Location of BENBO study sites



The cruise track is given in Figure 2. The overall scheme of operations was to begin survey work at site C, then site B and lastly to site A. However, bad weather on 22nd August precluded the planned work schedule at site C. We consequently steamed to site B to undertake work possible in rough seas, and then returned to site C to complete our work for that site. Subsequently, we travelled direct to site A from site C. We experienced severe weather (wind speed 50-60 knots, wave height 45-50 feet) which delayed out objectives once again on 27-28th August. However, in spite of these poor weather periods, we achieved all our cruise objectives, and in addition sampled the seabed at site C with a 2 m Kasten corer. The cruise track, and data from the swath survey and the CTD dips are available on a compact disc from the Principal Scientist.

Brief synopsis of the physical oceanography of the NE Atlantic from (from LeGall, 1998)

In the North Atlantic the water masses in the top 600 m of the water column are characterised by relatively high temperature and high salinity. These water masses,
named respectively Sub Polar Mode Waters (SPMW) and the Eastern North Atlantic Water (ENAW), are formed by deep winter convection in the Northern Atlantic and in the Bay of Biscay (McCartney & Talley, 1982). In the North East Atlantic, SPMW is entrained North East towards the Norwegian Sea by one branch of the North Atlantic Current. Below SPMW and ENAW, at intermediate depths, two water masses dominate. These are the Sub Arctic Intermediate Water (SAIW) and the Mediterranean Overflow Water (MOW). SAIW is characterised in the NW of the North East Atlantic basin by low temperature and salinity. This water mass originates in the Labrador Current, North of 55°N (Arhan, 1990) and at 48°N it is found around the 800 m depth contour. It is separated from the MOW by a front around 23°W at 48°N (Harvey, 1982). MOW is a mixture of Mediterranean Water and North Atlantic Central Water, which spreads from the Gibraltar Strait at depth of about 1000 m. It is distinguished by relatively high salinity and temperature. This water mass can be seen in a wide area in the North East Atlantic, reaching the Rockall Channel (Ellett *et al*., 1986, Ellett, 1995) and 50°W at 20°N (Broecker & Takahashi, 1980).

The first of the deep waters encountered going down the water column is the Labrador Sea Water (LSW). It is formed by winter convection in the Labrador Sea. It is characterised by a low salinity and a high dissolved oxygen content. It is advected throughout the North Atlantic at depths between 500 and 2000m, occurring as
far south as 40°N in the North East Atlantic (Talley & McCartney, 1982).

Below LSW, a small salinity maximum denotes the presence of North East Atlantic Deep Water (NEADW) at depths around 2700 m (Tsuchyia *et al*., 1992). The benthic water mass has been shown to be of South Atlantic origin (Tsuchyia *et al*., 1992). This water, usually referred to as Antarctic Bottom Water (AABW), actually originates in the Lower Circumpolar Water which has travelled north along the Mid Atlantic Ridge, with North Atlantic Deep

Water, crossed to the East Atlantic through the Vema Fracture Zone, and flowed northward to the Iceland Basin (Tsuchyia *et al.*, 1992, McCartney *et al.*, 1991, Schmitz & McCartney, 1993). AABW is identified by a low salinity, a low temperature and a high silica content.

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Broeker, W.S, & Takahashi, T, 1980, Deep Sea Research, Vol 27A, 591-613.
Ellett, D., 1995, Ocean Challenge, Vol 6, No1, 18-23.
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LeGall, A.C. 1998 http://www.npm.ac.uk/rsdas/omex/atlas/water.html
M^cCartney, M.S., & Talley, L.D., 1982, Journal of Physical Oceanography, Vol 12, 1169- 1188.
M^cCartney, M.S., Bennett, S.L., & Woodgate-Jones, M.E., 1991, Journal of Physical Oceanography, Vol 21, 1089-1121.
Schmitz, W.J. Jr., & M^cCartney, M.S., 1993, Reviews of Geophysics, Vol 31, 29-49.
Tsuchyia, M., Talley, L.D., & M^cCartney, M.S., 1992, Deep Sea Research, Vol 39 No 11/12, 1885-1917.
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5. DIARY OF EVENTS

Collated by R.A. Bourne (Master)

Wednesday 20TH. August '97.
0854 - BST - SBE, Commenced Singling up For'd and Aft.
0900 - Let Go; Vessel leaving Nato Jetty, Fairlie.
0904 - Vessel Clear of Berth and Turning Head to Sea.
0916 - Vessel Passing Hunsterston Ore Terminal.
0942 - Clear of Hunsterston Channel, Full Away on Passage.
Noon Position: Lat: 55 21.2 N. Long: 005 11.8 W. Vessel off Pladda.
Vessel on Passage towards Rockall Work Area.

Thursday 21st. August '97.
Times now in UTC, for Scientific Purposes.
1136 - Lat: 56 59.9 N. Long: 012 29.3 W. Vessel on Site; Comm. Calibrating Instruments.
1252 - 1447 - Lat: 56 59.8 N. Long: 012 30.3 W. CTD Deployed to 1826 metres.
1610 - Lat: 56 58.9 N. Long: 012 32.6 W. PES Fish Deployed.
1658 - Lat: 57 00.5 N. Long: 012 30.8 W. Commenced Swath Survey of Site `C'.

Friday 22nd. August '97.
0040 - Lat: 57 05.0 N. Long: 012 39.3 W. Complete Swath Survey of Site `C'.
0142 - Lat: 57 05.2 N. Long: 012 50.1 W. PES Fish Recovered.
0246 - 0410 - Lat: 57 04.7 N. Long: 012 30.5 W. CTD Deployed to 1935 metres.
0455 - Adverse Weather precludes Coring Activites at Site `C'; Set Course for Site `B'.
2100 - Lat: 57 22.0 N. Long: 015 44.9 W. Vessel Hove To at Site `B'.
2129 - 2227 - Lat: 57 21.9 N. Long: 015 45.2 W. CTD Deployed to 1095 metres.
2320 - Lat: 57 22.4 N. Long: 015 45.4 W. Commenced Swath Survey of Site `B'.

Saturday 23rd. August '97.
0637 - Lat: 57 28.7 N. Long: 015 36.9 W. Complete Swath Survey of Site `B'.
0724 - 0823 - Lat: 57 25.6 N. Long: 015 41.0 W. CTD Deployed to 1082 metres.
0922 - 1019 - Lat: 57 25.6 N. Long: 015 41.0 W. Multicorer Deployed in 1100 metres of water.
1111 - 1203 - Lat: 57 25.6 N. Long: 015 41.0 W. Multicorer Deployed in 1100 metres of water.
1225 - 1250 - Lat: 57 25.5 N. Long: 015 42.0 W. Plankton Nets Deployed Astern.
1338 - Lat: 57 25.6 N. Long: 015 41.0 W. Commenced Deploying Mooring.

1439 - Lat: 57 25.77 N. Long: 015 42.14 W. Long-Term Sediment-Trap/Current-Meter Mooring Deployed in
1536 - Lat: 57 25.81 N. Long: 015 41.97 W. Long-Term,Sea-Bed Mounted, ADCP Mooring Deployed.
1620 - 1714 - Lat: 57 25.5 N. Long: 015 41.0 W. Multicorer Deployed in 1100 metres of water.
1759 - 1855 - Lat: 57 25.6 N. Long: 015 41.1 W. Box-Corer Deployed in 1100 metres of water.
2000 - Lat: 57 25.6 N. Long: 015 40.9 W. Water Sample Taken over Bow. Complete Site `B'.
Set Return Course for Site `C'.

Sunday 24th. August '97.
0535 - Lat: 57 06.0 N. Long: 012 31.0 W. Vessel Hove To at Site `C'.
0605 - 0730 - Lat: 57 06.1 N. Long: 012 31.0 W. Box-Corer Deployed in 1925 metres of water.
0920 - Lat: 57 07.1 n. Long: 012 29.8 W. Commenced Deploying Mooring.
1013 - Lat: 57 06.35 N. Long: 012 30.12 W. Long-Term Current Meter Mooring
Deployed in 1925 metres of water; Upper Buoyancy 1590 metres below Sea Surface.
1105 - 1232 - Lat: 57 06.0 N. Long: 012 30.8 W. Multicorer Deployed in 1925 metres of water. 1307 -
1426
Lat: 57
06.0 N. Long: 012 31.1 W. Multicorer Deployed in 1925 metres of water.
1500 - 1620 - Lat: 57 05.9 N. Long: 012 31.3 W. Multicorer Deployed in 1925 metres of water.
1700 - Lat: 57 05.9 N. Long: 012 31.4 W. All Secure; complete Site`C', Set Course 211 T.

Monday 25th. August '97.
0857 - Lat: 55 19.2 N. Long: 014 23.0 W. Water Sample Taken.
1358 - Lat: 54 45.1 N. Long: 014 58.7 W. Water Sample Taken.
1800 - Lat: 54 17.6 N. Long: 015 28.1 W. Water Sample Taken.

Tuesday 26th. August '97.
0550 - Lat: 52 45.1 N. Long: 017 00.1 W. Vessel Hove To at Site `A'.
0826 - 1100 - Lat: 52 45.2 N. Long: 016 59.4 W. CTD Deployed to 3596 metres.
1211 - Lat: 52 47.3 N. Long: 017 00.7 W. Commenced Swath Survey.
1908 - Lat: 53 00.3 N. Long: 017 01.6 W. Completed Swath Survey.
2000 - Lat: 53 00.5 N. Long: 017 01.6 W. Vessel Steaming Downwind of Work Area, to await daylight
and weather improvement. Wind 340 True: 30 Kts: Baro: 998.2 mb.
2300 - Lat: 52 45.6 N. Long: 016 50.6 W. Wind 330 True. 25 Knots. Baro: 991.0 mb.

Wednesday 27th. August '97.

	Wind Direction:	Wind Speed:	Baro:	Wave Height:
0300 - Lat: 52 45.8 N. Long: 016 50.9 W.	325 True.	35 Knots.	988.7 mb.	
0700 - Lat: 52 51.0 N. Long: 016 56.2 W.	320 True.	40 Knots.	989.2 mb.	
1100 - Lat: 52 57.5 N. Long: 017 03.6 W.	320 True.	45/50 Knots.	989.8 mb.	45/50 Ft.
1500 - Lat: 53 03.3 N. Long: 017 07.9 W.	310 True.	45/50 Knots.	990.2 mb.	45/50 Ft.
1900 - Lat: 53 09.9 N. Long: 017 14.0 W.	320 True.	50 Knots.	992.4 mb.	45/50 Ft.
2300 - Lat: 53 15.8 N. Long: 017 21.2 W.	320 True.	50/60 Knots.	996.0 mb.	45/50 Ft.

Thursday 28th. August '97.
0300 - Lat: 53 25.7 N. Long: 017 27.8 W.   315 True.   50 Knots.   996.7 mb. 45/50 Ft.
0700 - Lat: 53 31.6 N. Long: 017 43.0 W.   310 True.   40 Knots.   999.0 mb.
0914 - Lat: 53 34.3 N. Long: 017 49.4 W. Weather Moderated sufficiently to reverse Course back towards
Work Site.
1100 - Lat: 53 21.4 N. Long: 017 34.0 W.   305 True.   34 Knots.   1002.0 mb.
1500 - Lat: 52 54.7 N. Long: 016 54.6 W.   315 True.   35 Knots.   1003.3 mb.
1900 - Lat: 52 58.2 N. Long: 017 01.2 W.   290 True.   30 Knots.   1003.8 mb.

Friday 29th. August '97.
0000 - Lat: 52 53.3 N. Long: 016 51.2 W. Swell Moderating.
0332 - 0547 - Lat: 52 55.1 N. Long: 016 55.0 W. Multicorer Deployed in 3569 metres of water.
0610 - 0826 - Lat: 52 55.1 N. Long: 016 54.9 W. Multicorer Deployed in 3569 metres of water.
0849 - 0856 - Lat: 52 55.2 N. Long: 016 54.6 W. Plankton Net Deployed to 50 metres.
1031 - 1245 - Lat: 52 55.1 N. Long: 016 55.1 W. Multicorer Deployed in 3569 metres of water.
1316 - Lat: 52 54.2 N. Long: 016 54.3 W. Commenced Deploying Mooring.

1427 - Lat: 52 54.94 N. Long: 016 56.40 W. Long-Term Sediment-Trap/Current-Meter Mooring Deployed in 3572 metres of water; Upper Buoyancy 2565 metres below Sea Surface.
1445 - Lat: 52 55.04 N. Long: 016 56.70 W. Water Sample Taken at Bow.
1601 - 1826 - Lat: 52 55.3 N. Long: 016 55.0 W. Box Corer Deployed; Failed to Sample. 1942 - Lat: 52 55.0 N. Long: 016 54.9 W. CTD Deployed to 3570 mtrs; Recovered to 1000 mtrs.
2227 - CTD Veered to 3360 metres to resolve scrolling problem.
2319 - Lat: 52 55.0 N. Long: 016 55.0 W. CTD Recovered.
2340 - Lat: 52 54.9 N. Long: 016 55.2 W. CTD Deployed to 256 metres.

Saturday 30th. August '97.
0003 - Lat: 52 54.9 N. Long: 016 55.2 W. CTD Recovered.
0741 - 1012 - Lat: 52 55.1 N. Long: 016 54.8 W. Box Corer Deployed in 3569 metres of water.
1155 - 1354 - Lat: 52 55.0 N. Long: 016 54.8 W. Kasten Corer Deployed.
1414 - 1424 - Lat: 52 55.0 N. Long: 016 54.8 W. Plankton Net Deployed to 50 metres.
1430 UTC - Lat: 52 55.1 N. Long: 016 55.0 W. Science Completed; Set Course 115 True.

Sunday 31st. August '97.
Times Now in BST.
Noon Position: Lat: 51 12.7 N. Long: 011 27.2 W.

Monday 1st. September '97.
0615 - Vessel Entering Scilly Isles Eastbound Traffic Separation Scheme.
Noon Position: Lat: 49 50.7 N. Long: 005 08.3 W.

Tuesday 2nd. September '97.
0610 - Engine Tested Astern, Steering, Bow Thrust etc., Tested.
0618 - SBE, End of Passage.
0638 - Vessel Entering Needles Channel.
0745 - Pilot Boards off East Lepe Buoy.
0851 - Vessel entering Empress Dock.
0903 - First Lines Ashore.
0918 - Vessel Securely Moored, Starb'd Side To, SOC. FWE.

6. SAMPLING PROTOCOL

6.1 Seabed coring

The Watson-Barnett SMBA multi-corer and the RVS NIOZ-type box corer were deployed to recover seabed sediments. The multi-corer is able to sample simultaneously using eight cyclindrical core tubes (internal diameter 62 mm). The presence of intact 'fluff' in the cores indicates that the samples are relatively undisturbed. Entry velocity was 15 m/min and 10 m of over-run was used. The corer achieved almost 100% success apart from one misfire due to the cocking arm being unable to release the sealing caps (a fault traced to a missing pin). The core tubes were carefully detached from the rig and provided to scientists for various purposes.

The cylindrical NIOZ box corer was used to recover large volumes of seabed sediment. Entry velocity was 20 m/min and 10 m of over-run was used. The box core inevitably disturbs the sediment-water interface as it is brought back to the surface.

On deck, the circular drum was removed and the surficial water was siphoned off, and up to six 11 cm diameter bevelled acetate tubes were inserted to the base of the box (see Section **6.6**). Following description and labelling, intact sub-cores were stored at 4^{o}C for later geochemical analysis. Some *in situ* freezing using liquid nitrogen was performed for the analysis of sediment micro-structure (see Section **6.5**). A 100% success rate was achieved with the NIOZ box corer. Arrival at the seafloor of both coring devices was guided through use of a pinger 50 m above bottom

The multi-corer was deployed three times and the box corer was deployed once at each of the sites. Table I below summarises the Southampton Oceanography Centre coding for these deployments.

Table I. SOC coding for the multi-box core deployments

	Site A	**Site B**	**Site C**
Multicore 1	54203#1	54201#1	54202#1
Multicore 2	54203#2	54201#2	54202#2
Multicore 3	54203#3	54201#3	54202#3
Box core 1	54203#4	54201#4	54202#4

The RVS Kasten corer with a 2 m barrel 30 m/min entry velocity was deployed once at Site A. This was successful and 2 m of mud was logged and sub-sampled using longitudinally split piston core liner. The sub-samples were stored at 4^{o}C. All analyses will be carried out on return to the laboratory.

6.2 Multi-beam bathymetry

The shipboard multi-beam swath bathymetry system was used to map the seabed topography accurately at each of our sites. The premise of this was to define flat areas of seabed onto which we will deploy benthic lander instruments on subsequent cruises.

A survey box of approximately 12x14 km was defined for each of the sites. Each box was nominally anchored at the southwestern corner to the provisional mooring position, and oriented to allow the vessel to be steered along courses most appropriate to the weather and sea conditions. The survey lines were planned to allow a generous overlap of 20-30%. The extreme degree of overlap would allow the outer beam data to be discarded if the associated noise was too severe.

Single sound velocity probe (SVP) dips were done prior to each survey. The Neptune processing application *Binstat* was used to remove spikes and erroneous soundings from the swath data before it was processed using *Irap* software to produce gridded bathymetry. The very flat nature of the seabed required a post-collection correction to the raw roll data of +0.3°. Gridding intervals for sites A, B and C were 100 m, 50 m and 80 m, respectively. Bathymetric plots for each of the Sites are shown in Figure 3.

6.3 Water column properties

6.3.1 Moorings

A mooring array comprising current meters, transmissometers, sediment traps, weights and buoyancy was deployed at each of the sites. A sediment trap was not included on the mooring for site C. The moorings were designed to operate until mid-April, 1998, when they will be turned around. The precise locations of each of the moorings is given below. Drawings of each of the moorings may be found in Appendix I.

Site A	52 55.07N, 16 56.96W
Site B	57 42.88N 15 71.23W
Site C	56 59.92N 12 30.10W

A vertical, single point mooring comprising two McClane 21 bottle sediment traps, two Sea Tech 20 cm transmissometers, two UMI-2SB7 marine loggers, two S4 current meters, and associated buoyancy, was deployed at Site B. The rig was also fitted with an SMM 500 Argos location beacon. The mooring was approximately 300 m long in a water depth of 1122 m. A mooring of similar design to that deployed on site B was deployed at Site C except that no sediment traps were incorporated and

RCM 8 current meters were used instead of the S4 type. Also, a Seimac 3721 Argos location beacon was used. The mooring was approximately 325 m long in a water depth of 1881m.

The configuration of the mooring at site A was similar to B with the exception of using an RCM8 and an S4D in place of the two S4s (because of the greater depth), and the omission of a logger/transmissometer combination due to technical problems. The mooring was approximately 1000 m in length in a water depth of 3572m. During the period before the deployment at site A, the opportunity was taken for more rigorous testing of the new UMI-2SB7 Marine Monitors and Sea Tech transmissometers. Time for this had not been available beforehand either at SOC (as they were only delivered the day before they were due to be dispatched to the ship) or on board. The tests revealed problems with the two remaining instruments unable to log data to memory, or to operate with the transmissometers. Internal inspection of the loggers revealed differences in the settings of their DIP switches.

On contacting the manufacturers, they suggested that the switches be set to the factory default shown in the handbook and re-booting the loggers into the default mode. This enabled one of the monitors to log to memory, but both instruments still refused to read data in from the transmissometers. It was found that the working logger would read data from an old-type Sea Tech transmissometer. It was decided to deploy the working logger with this transmissometer.

All the moorings used Oceano RT661 releases except for the SC-ADCP which used an RT361. They had all been tested by attaching them to the CTD in a water depth comparable to that in which they would be used prior to deployment. The bottom-most instrument (the transmissometers) at Sites A, B and C were 46 m, 48 m and 48 m above the seabed, respectively.

6.3.2 Bottom-mounted ADCP

A 150kHz frame-mounted SC-ADCP, fitted with a Seimac 3721 free floating Argos beacon was emplaced on the seabed in 1100 m of water at Site B. The instrument was setup to utilise 30 bins of 8m length and to record data every 30 mins. The data is an average of 120 pings over approximately two minutes.

6.3.3 CTD casts

CTD measurements were made at each site to broadly characterise the NE Atlantic water masses and to provide samples of suspended particulate matter to calibrate the fluorimeter. The timing of the dips varied but usually measurements were made immediately upon arriving on site, and then just before we left after all other work was completed. Three dips were made altogether on the deep Site A owing to wire scrolling problems on CTD#6. Details of the CTD dips are given below.

Table II. ***Charles Darwin 107*** **CTD Log**

	#	*Date*	*Time (GMT)*	*Depth (m)*	*Co-ord-inates (N/W)*
Site A	CTD#5	26/08/97	8:27	3588 m	52.752 16.999
	CTD#6	29/08/97	19.42	3576 m	52.517 16.915
	CTD#7	29/08/97	23.40	3574 m	52.517 16.915
Site B	CTD#3	22/08/97	21.29	1115 m	57.366 12.450
	CTD#4	23/08/97	07:26	1100 m	57.407 12.261
Site C	CTD#1	21/08/97	13:02	2040 m	56.998 12.502
	CTD#2	22/08/97	02:47	1950 m	57.289 12.512

The information gained from the CTD paired dips were highly consistent. Example data from the first of the two deployments for each site is given in Figure 4.

Sampling of suspended particulate material for fluorimeter calibration

Twelve 0.5 litre samples for chlorophyll analysis were taken from the CTD rosette at depths indicated in Table III. The bottom nepheloid layer (determined from an optical backscatter instrument on the CTD) was sampled with three bottles in order to test for the presence of phyto-detritus. The samples were filtered through Whatman GF/F filters by pressure filtration and stored at -20^{o}C. Usually, only the upper 20-40 m of the water column displayed any noticeable pigment on the filter papers. These samples will be analysed at DML by HPLC/fluorimetry and the results used to provide a suitable calibration for the CTD fluorimeter.

Table III Water depths (m) for chlorophyll analysis (all 0.5 *l*)

Site A *CTD #5, #7*	**Site B** *CTD #4, #3*	**Site C** *CTD #1, #2*
5	6	5
15	16	15
25	25	25
35	35	36
45	45	45
60	60	60
80	80	80
100	100	100
125	125	125
150	150	154
200	203	204
250	252	300
200	25	400
300	60	500
400	100	750
500	200	1000
1000	300	1494
1500	400	1990
2000	600	2046
2500	798	2055
3016	995	2065
3555	1068	
3530	1078	
3570	1088	

Deployment of sediment traps

A total of four 21 cup, McLane 7G-21 (area=0.5 m^2) sediment traps were deployed. It was decided to deploy two on the mooring at Site A (52° 55.07 N, 16° 56.96 W), at depths of 1000 mab (S/N 10699-2/23218) and 100 mab (S/N 10699-3/23213) and two on the mooring at Site B (57° 42.88 N, 15° 71.23 W), at depths of 300 mab (S/N 10452-1/1515) and 100mab (S/N 10699-1/23217). Traps were each programmed with 22 sampling periods (Table IV). Sampling intervals varied from 7 to 28 days.

Table IV CD107 Sediment Trap Sampling Schedule ***N.B: 'mab' refers to metres above bottom.

Event No.	Date.	Time(GMT)	Interval(Days)
1	31/08/97	12:00:00	7
2	07/09/97	12:00:00	7
3	14/09/97	12:00:00	7
4	21/09/97	12:00:00	7
5	28/09/97	12:00:00	14
6	12/10/97	12:00:00	14
7	26/10/97	12:00:00	14
8	09/11/97	12:00:00	14
9	23/11/97	12:00:00	21
10	14/12/97	12:00:00	28
11	11/01/98	12:00:00	21
12	01/02/98	12:00:00	14
13	15/02/98	12:00:00	14
14	01/03/98	12:00:00	7
15	08/03/98	12:00:00	7
16	15/03/98	12:00:00	7
17	22/03/98	12:00:00	7
18	29/03/98	12:00:00	7
19	05/04/98	12:00:00	7
20	12/04/98	12:00:00	7
21	19/04/98	12:00:00	7
22	26/04/98	12:00:00	close

Both deployments were successful. It is anticipated that traps will be recovered and turned around on CD111 between April 1998 and May 1998. Samples will be removed from traps, chemically preserved and then returned to SOC where they will be split and distributed amongst collaborating BENBO partners.

6.3.4. Plankton Collection

Plankton samples were collected by two methods: (1) A 100 µm mesh sieve was used to filter the non-toxic seawater supply for approximately 12 hours per sample, and (2) a plankton net was deployed on three occasions. The first plankton deployment, towing a small net of 63 μm mesh size astern at low speed, failed when the net ripped. The subsequent deployments were performed by lowering a larger net of 200 μm mesh size from the CTD winch to a depth of 50 m and proved successful. The details of the samples collected are as follows.

Samples from the non-toxic supply

Sample Number	Start/End	Day	Time	Lat N	Long W
PNT 1	s	232	13:20	55 17.70	5 53.05
	e	232	22:15	56 02.30	8 41.16
PNT 2	s	233	11:00	56 57.50	12 20.13
	e	234	22:00	57 21.87	15 45.18
PNT 3	s	234	22:00	57 21.87	15 45.18
	e	235	15:00	57 25.70	15 42.86
PNT 4	s	235	15:00	57 25.70	15 42.86
	e	236	20:20	56 49.30	12 46.72
PNT 5	s	236	20:20	56 49.30	12 46.72
	e	237	18:00	54 17.85	15 27.39
PNT 6	s	237	18:00	54 17.85	15 27.39
	e	239	12:00	52 59.15	17 4.87
PNT 7	s	239	12:00	52 29.15	17 4.87
	e	241	14:00	52 54.82	16 55.68

Samples from the plankton net (J. days 241 & 242)

PPN 1	14:00	52 54.82	16 55.68
PPN 2	14:14	52 55.03	16 54.79

The samples will be used for the separation and analysis of planktonic foraminifera for Cd/Ca and carbon isotopes.

Surface seawater samples

A series of surface seawater samples were collected from the ship's bow at low speed using a 1 litre trace metal cleaned weighted bottle. After collection a sub-sample was treated with mercuric chloride and stored for subsequent phosphate analysis. The remainder was filtered through a 0.4 μm nuclepore polycarbonate filter and sub-samples taken for Cd/Ca (acidified to pH 1 with nitric acid) and carbon isotopes (treated with mercuric chloride and sealed in a nitrogen purged ampule). Samples collected are as follows:

Surface Seawater samples

Sample Number	Day	Time	Lat N	Long W
SSW 1	233	11:30	56 59.49	12 27.84
SSW 2	235	20:00	57 25.63	15 40.79
SSW 3	236	16:30	57 5.94	12 31.19
SSW 4	237	09:00	55 19.08	14 23.24
SSW 5	237	14:00	54 45.04	14 58.86
SSW 6	237	18:10	54 17.40	15 28.52
SSW 7	238	11:30	52 45.61	16 59.95
SSW 8	241	14:00	52 54.82	16 55.68
SSW 9	243	15:00	50 51.03	10 20.18
SSW 10	244	08:00	49 42.36	09 55.32

The samples will be used to investigate the relationship between water nutrients and foraminiferal chemistry in the surface water regime.

Other seawater samples

Some deep seawater samples were collected either from the deepest firings of a CTD cast or siphoned from the tops of the multi-core tubes. The samples were sub-sampled as outlined above for further analysis of Cd/Ca, carbon isotopes and phosphate. The samples collected were as follows:

Deep water samples

Sample Number	Day	Time	Lat N	Long W	Depth of sample /m
DSW 1*	233	12:50	56 59.49	12 27.84	2025
DSW 2*	233	12:50	56 59.49	12 27.84	2020
DSW 3**	235	09:22	57 25.70	15 42.86	*c.*1100
DSW 4**	236	11:05	57 5.94	12 31.19	*c.* 2040
DSW 5*	238	11.12	52 45.30	16 59.43	*c.* 3570

* CTD sample
** Multi-core sample

6.4 Microbiology and enzymatic activity in deep sea sediments

Much of the material which sinks to the deep-sea sediment is utilized by benthic organisms leaving only a small amount being preserved in the sediment record. Bacteria may be very important agents in the decomposition of this material in the sediment surface. They achieve this by producing enzymes extra-cellularly which break up polymeric compounds so they can pass through the bacterial cell wall. These enzymes may be attached to the cell wall or be free. The bacteria use these compounds for their growth and cell maintenance, synthesising new DNA and protein to do so. The aim for this first BENBO cruise was to clarify and test aspects of the enzymatic and microbial production methods in the deep-sea sediment environment. Table V provides a summary of the experiments carried out.

Site B. Measurements were conducted to establish the substrate saturation concentration needed to measure the maximum possible rate of substrate hydrolysis (V_{max}) for each of our substrates used. V_{max} was determined for aminopeptidase, α- and β- glucosidase and lipase. In addition, experiments were conducted using ^{3}H-thymidine and ^{3}H-leucine to establish which concentration to add to achieve saturation and therefore estimate bacterial DNA and protein synthesis, respectively. Both of these can be used to estimate bacterial production but as yet have rarely been applied to deep-sea sediments. Extensive time course experiment were also performed in order to establish optimum incubation times for linear hydrolysis/production rates. This information permits the incubation conditions for samples from other sites and other cruises to be set.

Site C. Site C was characterised by a substantial layer of phyto-detritus or fluff overlying the sediment surface. Enzyme hydrolysis rates and rates of bacterial protein and DNA synthesis were consequently measured for both the sediment and the fluff.

Site A. A ‘heterogeneity experiment’, investigating the variability in the activity of the 4 enzymes, bacterial protein and DNA synthesis and bacterial numbers in the upper 1 cm sediment from eight separate cores from the same multi-core deployment, was conducted at Site A. In addition, pore water extractions were filtered through a 0.2 μm pore size filter, and the enzyme activity in the pore waters measured in order to compare with that on the sediment. This permits evaluation of enzymes as either free or bound.

At all sites, interface water from the multi-core tubes was siphoned off, and investigated for enzyme activity and bacterial protein and DNA synthesis for comparison with the sediment measurements.

6.5 Cryogenic sampling

Sediment samples were retrieved from each of the three sites using a box core and a multi-core. These were rapidly frozen and stored at -20°C for subsequent analysis using low temperature scanning electron microscopy.

Sampling

Collection of samples for scanning electron microscopy

Samples were retrieved from each of the three sites using the box and multi-corer. Samples from the former were obtained by first carefully removing the overlying seawater and then extruding the sediment until it was flush with the top of the core tube. Frozen sections were then obtained from the exposed surface. Sub-surface sections were similarly sampled after the core had been sectioned using a slicer to the relevant datum.

Frozen sections were sampled directly on the surface of box-cored sediment. Table VI provides details of the sampling programme.

Table VI. Summary of cryogenic sampling protocol

	Total Number of Samples	
	Multi-core	*Box core*
Site A	3	1
Site B	2	1
Site C	4	1

Specific details of individual samples at each site are as follows.

Site A	LTSEM #1	sediment-water interface
	LTSEM #2	Holocene-older clay horizon
	LTSEM #3	Deep, glacial clays; sheared upper surface
	LTSEM #4	sediment-water interface
Site B	LTSEM #1	surficial fluff
	LTSEM #2	surficial fluff
	LTSEM #2	surficial fluff
Site C `	LTSEM #1	sediment-water interface
	LTSEM #2	exposed surface @2cm
	LTSEM #3	oxic/anoxic boundary (@12cm)
	LTSEM #4	exposed faecal pellets (@12-14cm)
	LTSEM #2	surficial fluff

Sectioning a core for particle size analysis

In addition to the above samples,a single core from Site A was sectioned at intervals for particle size analysis. Samples were bagged every cm over the interval 0-5 cm, and thereafter every two cm to a depth of 29 cm.

6.6 Sub-sampling of box cores for radio-isotope determination of sedimentation rate

Box cores were required on this cruise to give a longer sediment section from which recent sediment accumulation rates and bioturbation parameters could be estimated. The large RVS-NIOZ box core was used rigged with a cylindrical barrel 50 cm in diameter and 57 cm in length. Cores were recovered at site B on 23rd August in 1098 m water depth, at Site C on 24th August in 1925 m, and at Site A on 30 August in 3570 m. An attempt to core at Site A on 29th August failed due to swell conditions at the time of coring.

In all cases the sediment recovered was 40-50 cm, and all cores were sampled by insertion of 6x11 cm diameter clear polyacrylate plastic tubes. These were capped and preserved for later sampling and archiving ashore. Surface scraped and samples of surficial biology were also taken after the insertion of the sub-cores.

At Sites B and C, the entire cores were carbonate and foram rich, and were inferred to be entirely Holocene. There was also a distinct colour contrast at 10-15cm which is thought to be related to the penetration of oxygen, with brown manganese-rich sediment above and grey sediment below.

At Site A, a grey carbonate-rich layer (0-15 cm) overlay a dark brown clay. From previous accumulation rates determined in this area, it is inferred that perhaps 25-50 cm of the lower Holocene is missing in this core, and that the brown clay is glacial sediment.

Kasten coring

A single Kasten core was taken on this trip at Site A (3580 m, 30th August). This was undertaken because the shorter cores at Site A had indicated that sediment deposition had been interrupted at this site. The RVS corer with a piston core bomb and a rectangular 2 m barrel 15x15 cm in cross-section was employed. The barrel design had 2 plates on the side opposing the lid, so that the entire core could be extruded length-ways. The core completely filled the barrel. Two sub-cores of sediment were taken from archive in piston core lines split lengthways. The entire section was photographed.

The following preliminary interpretation was made on board, but it is stressed that this requires verification by micropalaeontological methods and dating. A section of lower Holocene (stage 1) sediment is completely missing, so that late Holocene carbonated ooze overlies the glacial clays of stage 2 with some mixing by bioturbation. In turn, the glacial clay is undertaken by a single turbidite with a coarse base and a fine upper body. The upper part of the fine-grained body has been oxidised after deposition, so that this part of the turbidite is in two shades of grey, lighter above and darker below the sharp relict oxidation interface. The upper reaches of the turbidite have been intensely mixed by bioturbation with the overlying glacial clay, but narrow horizontal chemical lamination of Fe–enriched sediment are present in the mixed zone. The course base of the turbidite consists of black sand with many larger stones of different lithologies (originally re-rafter to this site?).

The sediments below the turbidite appear to be grey and white carbonate cores from stage 5, which implies that

a) sediments from stages 4 and 3 are missing

b) that the turbidite is likely to be associated with re-deposition of sediment at the end of the slump event which removed the sediments of stages 3 and 4,

c) that the slump event occurred during stage 2 time, by brown glacial clay (stage 6?) with a very dry brown clay at the transition. The stage 6 (?) sediments are undertaken by, and bioturbated into, a white carbonate ooze (stage 7?) which is at the base of the core.

7. CONCLUSION

In spite of considerable pressure during both the early planning stages of the BENBO Thematic programme and during pre-cruise logistical operations, CD 107 was a total success with the completion of all cruise objectives. This is a tribute to the hard work of all individuals from the scientific community as well as the support from RVS and NERC. We discovered substantial fluff at the seabed which has even now yielded some very interesting biogeochemical data. The data collected now forms a cornerstone from which BENBO can conduct further experimental work both aboard ship and using the new free-fall lander instrument during 1998.

Appendix I.

MOORING DRAWINGS