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RRS *CHARLES DARWIN* CRUISE 89
19 AUG-13 SEP 1994

Hydrothermal exploration at the Azores Triple Junction: HEAT

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ABSTRACT

The principal objectives of the cruise were to characterise the variations in tectonism and volcanism and their relationship to second-order segmentation of the Mid-Atlantic Ridge, 36°-38°N; to locate and quantify the extent of hydrothermal activity along this section of the neo-volcanic ridge axis; and to investigate the geological and geophysical controls upon the nature of hydrothermal venting in different morphotectonic settings.

Initially, 150 nautical miles of along axis sidescan sonar survey was completed using the IOSDL deep towed instrument, TOBI, 36-38°N. Areas covered included the Menez Gwen and Lucky Strike vent sites (38°N, 37°N) the FAMOUS and AMAR segments (36°-37°N) and the Azores Triple Junction "Overlapper" at ~38°30N. Simultaneously, TOBI transmissometer data identified the presence of particle-rich hydrothermal plumes in all of the "South AMAR", "AMAR Minor", southern and central "AMAR", southern "FAMOUS", "North FAMOUS" and southern "Lucky Strike" segments, providing a minimum estimate of perhaps one vent site every 20 miles along axis.

Subsequent sampling included 7 Dynamic Hydrocast deployments ("Overlapper", "Lucky Strike", "FAMOUS", "AMAR"), yielding >250 samples for shore-based dissolved CH_4, Mn and ^3He analyses. In addition, a total of 22 vertical ZAPS/CTD profiles were occupied for plume sampling and ground-truthing of TOBI plume data. This information was used to direct collection of 20 large-volume plume-particle samples, by *in situ* filtration, for shore based geochemical/microbiological analysis.

Preliminary data from the southern AMAR area indicate the strongest hydrothermal source yet located in the N.Atlantic Ocean. This new site, together with the Lucky Strike and Menez Gwen vent-fields offers an ideal natural laboratory for future hydrothermal process studies.

KEYWORDS

AMAR
AZORES TRIPLE JUNCTION
"*CHARLES DARWIN*"/RRS - cruise(1994)(89)
CTD OBSERVATIONS
FAMOUS
HYDROTHERMAL ACTIVITY
LUCKY STRIKE
MENEZ GWEN
MID-ATLANTIC RIDGE
OVERLAPPER
SEGMENTATION
TECTONICS
TOBI
ZAPS SLED

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ITINERARY

Leg 1:	Departed:	Ponta Delgada, Azores	19 August 1994
	Arrived:	Ponta Delgada, Azores	3 September 1994
Leg 2:	Departed:	Ponta Delgada, Azores	3 September 1994
	Arrived:	Ponta Delgada, Azores	13 September 1994

OBJECTIVES

The objectives of this cruise were three-fold:

(1) To characterise the variations in tectonism and volcanism and their relationship to second-order segmentation of the Mid-Atlantic Ridge, 36°-38°N.

(2) To locate and quantify the extent of hydrothermal activity along this section of the neo-volcanic ridge axis which includes at least five new "active" segments identified between 36°N and 38°N since September 1992.

(3) Combining objectives 1 and 2 above, to investigate the geological and geophysical controls upon the nature of hydrothermal venting in different morphotectonicsettings on the Mid-Atlantic Ridge.

NARRATIVE

Leg 1:

The scientific party for RRS *Charles Darwin* Cruise 89 assembled in Ponta Delgada, Azores between Sun. 14th and Tues. 16th August 1994 to board scientific equipment and prepare laboratory space. The RRS *Charles Darwin* sailed from Ponta Delgada at 0830z on Fri. 19th August, 1994. On clearing port the 3.5kHz and 10kHz fish were deployed, together with the magnetometer, and the shipboard Simrad EM12 swath bathymetry system was activated. Passage was then made to the Mid-Atlantic Ridge at 38°N with a single XBT deployment at 2000z.

We arrived on station at 0900z on Saturday 20th August in an off-set of the Mid-Atlantic Ridge immediately north of the segment containing the Menez Gwen hydrothermal field. The magnetometer was recovered inboard and the RVS sound velocity probe was deployed to provide calibration of the EM12 swath bathymetry. For the remainder of the cruise XBTs were dropped synoptically (1200z and 2400z) to monitor any possible variations in the sound velocity profile of the area. The IOSDL deep-tow instrument, TOBI, was deployed at 1300z and towed south along the axis from 38°N to 37°N, providing a complete single-swath survey of the Menez Gwen, Lucky Strike and North Famous segments and their connecting offsets. TOBI was recovered at 1300z on Tues. 23rd August after 72 hours continuous deployment.

The RRS *Charles Darwin* then proceeded south to the southern end of the FAMOUS segment (36°40'N) where the RVS CTD/nephelometer/transmissometer was deployed at 1600z followed by the IFREMER Dynamic Hydrocast which was deployed at 2000z at 36°32'N. This deployment was aborted and recovered inboard at 0400z on Weds. 24th August due to a lost pinger which rendered safe continuation of the deployment impossible. A second CTD station was then occupied at 36°38'N (0500-0730z) after which the ship proceeded north, back to the northern end of the FAMOUS segment (36°57'N). TOBI was redeployed in the northern portion of the FAMOUS segment at 1057z on Weds. 24th August and towed south along the full length of the FAMOUS segment (36°57'N to 36°33'N) before recovery at 1305z on Thursday 25th August. The Dynamic Hydrocast was then redeployed in the central portion of the FAMOUS segment (36°49'N) and towed south to approximately 36°30'N where the system was recovered at 0556z on Friday 26th August.

TOBI was deployed again at 0759z on Friday 26th August in the southernmost portion of the FAMOUS segment (36°34'N) and towed south as far as 35°47'N, followed by a return tow north, parallel to the original track. This provided a complete double-swath survey of the entire AMAR, AMAR Minor and northern South AMAR segments and their intervening off-sets, including the AMAR/FAMOUS off-set. TOBI was recovered at 0308z on Mon. 29th August at 36°38'N. The Dynamic Hydrocast was redeployed in the central FAMOUS segment (36°44'N) at 0434z on Mon. 29th August and towed toward the northern end of the segment (37°03'N) where it was recovered inboard at 1824z. Passage was then made, due east, to the southern end of the Lucky Strike segment (37°02'N 32°23'W) where TOBI was redeployed at 2152z on Mon 29th August. TOBI was then towed north through the Lucky Strike segment, parallel to the earlier southward tow through this area, completing a double-swath survey of the hydrothermally active zone between 37°02'N and 37°37'N.

TOBI was recovered in-board at 1540z on Tuesday 30th August along with the PES and 3.5kHz fish. The magnetometer was streamed and a swath bathymetry survey was then undertaken (37°25-35'N 31°10-30'W) between 1747z on Tues.30th August and 0557z on Weds.31st August. Passage was then made to the overlapper section of the Azores Triple

Junction at 38°22.2'N 30°34.1'W. TOBI, the PES fish and the 3.5kHz fish were redeployed at 1211z, and TOBI was then towed along a quasi-rectangular course covering both potential "propagaters" of the overlapper system before being recovered at 1140z on Thursday 1st September. The Dynamic Hydrocast was then deployed to the north of the overlapper (38°39'N) at 1414z on Thurs.1st September and towed south to 38°19'N where it was recovered at 0524z on Friday 2nd September.

The PES and 3.5kHz fish were then recovered inboard and a course was followed along 075 to 38°30'N 29°30'W where a swath bathymetry survey was completed across a known area of hydrothermal venting west of Faial (38°30-35'N 29°00-30'W) between 0926z and 1433z on Fri. 2nd September. Passage was then continued along 075 to the NW end of the Sao Jorge channel at 38°47'N 28°32'W where course was altered to 120 and a further swath bathymetry survey of the northern side of this channel was completed between 1747z and 2352z on Fri. 2nd September.

Upon completion of the swath survey, course was made direct to Ponta Delgada, Sao Miguel, Azores, arriving in harbour at 1000z on Sat. 3rd September where TOBI scientific personnel were disembarked via launch and replacement scientists embarked for Leg 2.

Leg 2:

The RRS *Charles Darwin* sailed from Ponta Delgada, Sao Miguel, Azores for Leg 2 of Cruise 89 at 1112z on Sat. 3rd September. Passage was made to the Menez Gwen hydrothermal field, 37°47'N on the Mid-Atlantic Ridge, following a track parallel to - but offset from - that used for the outward passage of Leg 1, thereby maximising swath bathymetric coverage.

The ship arrived on station at 1130z on Sun.4th September and two CTD deployments were completed close to the Menez Gwen hydrothermal field to depths of 950-1000m. The CTD was recovered in-board at 1510z and passage was then made south to the Lucky Strike segment (37°20'N) where the Dynamic Hydrocast was deployed at 1952z. This system was then towed south across the known hydrothermal field as far as 37°00'N before being recovered at 1130z on Mon. 5th September. Passage was then made back to the Lucky Strike hydrothermal field at 37°15'N where two further CTD stations were occupied between 1330z and 1630z to ~1700m depth.

The ship then made passage back to the off-set at the southern end of the Lucky Strike segment where a gravity core was taken between 2000z and 2252z on Mon. 5th September. A series of two CTD stations and one OSU ZAPS sled deployment were then completed across the southern end of the Lucky Strike segment between 0020z and 1200z on Tues. 6th September, after which a stand-alone pumps (SAPs) deployment was carried out in the same location between 1249z and 2124z. A further CTD deployment, including the first deployment of the new Challenger Oceanics Multi-Sampler, was then initiated at the same site. This deployment commenced at 2256z on Tues. 6th September and was completed at 0752z on Weds.7th September.

Passage was then made back to the southern end of the FAMOUS segment where a further Dynamic Hydrocast survey was completed, cross-cutting the earlier N-S survey lines with an E-W line, between 1254z on Weds.7th September and 0355z on Thurs. 8th September. A series of three OSU ZAPS sled deployments were then completed in the southern portion of the FAMOUS segment (36°34-40'N), between 0540z and 1640z, after which a further SAPs station was occupied - still within the southern FAMOUS segment at 36°38'N - between 1740z on Thurs. 8th September and 0100z on Fri. 9th September. Passage was then made to the southern AMAR segment at 36°15'N.

The RRS *Charles Darwin* arrived on station in the southern AMAR segment at 36°15'N at 0400z on Friday 9th September. Two CTD stations were then occupied, at 33°45'W and 33°50'W, to depths of ~2500m before recovery at 0859z. A SAPs mooring was then occupied at the second of these two CTD stations between 0932z and 1524z followed by a series of four OSU ZAPS sled deployments - all within the same area - between 1623z on Fri. 9th September and 0410z on Sat. 10th September. A further SAPs deployment was then completed at the same location as the first SAPs station between 0458z and 1046z. Passage was then made north to 36°30'N where the Dynamic Hydrocast was deployed at 1142z. The Dynamic Hydrocast was then towed south through the southern AMAR segment as far as 36°11'N where it was recovered at 0414z on Sunday 11th September. A further CTD station was then occupied further west at 36°15'N 33°51.5'W between 0545z and 0754z follwed by two further OSU ZAPS sled deployments still within the same area between 0824z and 1249z. A final SAPs deployment was completed in the southern AMAR segment at 33°45'W - the same location as the first CTD station in this segment - between 1312z and 1924z on Sunday 11th September. Passage was then made direct back to Ponta Delgada, Sao Miguel, Azores, where the cruise was completed at 0830z on Tues. 13th September 1994.

The complete ship's track followed by the Charles Darwin during Cruise 89 Legs 1 and 2 is shown in Figure 1. A diary of events for the cruise is given at Appendix A.

CRG

SCIENTIFIC REPORTS

1. TOBI Operations

1.1 TOBI Instrumentation

TOBI (Towed Ocean Bottom Instrument) is IOSDL's deep towed sidescan sonar platform. As well as the 30kHz sidescan sonar the vehicle is equipped with a 7.5kHz seismic profiler, tri-axial fluxgate magnetometer and thermistor temperature sensor. A brief technical description is given at Appendix B. For this particular cruise the vehicle also had fitted a SeaTech 25cm transmissometer and a ZAPS manganese sensor made by Challenger Oceanics/John Wheaton Associates. New for this cruise were an emergency release unit which, under acoustic command, could release the vehicle from the umbilical, and a new deck unit. As this was the first cruise for the release system a series of tests were planned to ensure its integrity prior to full use. TOBI was deployed and recovered a total of five times with runs varying in length from 16.5 hours to 72 hours. The five runs are outlined below:

<u>Run #1</u> Deployed 1300/232. Recovered 1300/235. Length 72 hours. The vehicle was deployed with the emergency release unit cocked but without pyrorelease mechanisms fitted. A safety strop was employed in case of accidental release. An experimental recovery loop attached by velcro was also fitted. After deployment the vehicle was swithed on and all systems were running except the impeller log - for reasons unknown this didn't work during the rest of the cruise. After a short spell of seeming to work the manganese sensor stopped due to pump failure. On recovery a pin prick hole was discovered in the pressure balancing bellows. For subsequent deployments this unit was replaced by a SeaBird unit. On replaying the first data discs it was found that the digital instrument data was not being recorded. The fault was traced to miswiring in the new deck unit and corrected. Digital data was recorded from 1248/234. It was noted that the pressure gauge gave a few false readings. On recovery it was inspected but no major leaks seemed to have occured. The experimental recovery loop fell off despite a safety strop being used. The release mechanism had remained cocked.

<u>Run #2</u> Deployed 1100/236. Recovered 1300/237. Length 26 hours. On deployment the pressure gauge was again giving false readings and it become obvious that it could not be used. Also the manganese sensor was not responding. During this deployment the depth of the vehicle was derived from the surface echo on the starboard sidescan sonar. After recovery it was found that a slight leak had caused the pressure gauge to fail. This was repaired and gave fault free operation for the rest of the cruise. The manganese sensor was eventually got to work by holding one of the data handshake lines high. By this time more information on the unit had been obtained from the manufacturers but it became clear that it would not be able to use the TOBI modem link due to incompatibility with the TOBI vehicle

microcontroller. For subsequent deployments the analogue output was used with the default settings for the instrument.

Run #3 Deployed 0800/238. Recovered 0300/241. Length 67 hours. Good data throughout.

Run #4 Deployed 2230/241. Recovered 1500/242. Length 16.5 hours. Good data throughout.

Run #5 Deployed 1230/243. Recovered 1130/244. Length 23 hours. Good data throughout. During recovery the acoustic part of the emergency release system was tested using the MORS deck unit and the dunking transducer at a range of ~1200m. Upon recovery the puffer indicators showed that the unit had functioned correctly.

During the cruise the TOBI sidescan data was corrected for anamorphic ratio and replayed at a scale of 1:50000 for mosaicing. The TOBI replay computer was networked so that data could be transfered to the ERA-Maptec computer system for further processing. TOBI profiler data was corrected for depth and replayed. TOBI digital data was put onto floppy disks for importation into a spreadsheet for immediate analysis. In total over 200 hours of TOBI data was recorded during the cruise. This represents over 4.3 Gbytes of data.

Despite their complexity all five deployments and recoveries were characterised by a total lack of drama. This is a tribute to the professionalism of the officers and crew of the *Charles Darwin*.

IR, CF

1.2 Image processing

Facilities

During the planning stages of CD89 it was decided to make available interactive digital image processing facilities, both for the existing data for the study area and the newly to be acquired TOBI data. The aim was to have the ability to produce new image maps on-board and to allow the investigation of the spatial relationships between the various data sets. IOSDL provided a Sun Sparcstation 10, with 64 MBytes of RAM, 2 Gbytes of hard disk and a 20" colour monitor (8 bit display graphics). ERA-Maptec provided a Sun Sparcstation 20, with 64 MBytes of RAM, 2 Gbytes of hard disk and a 16" colour monitor (32 bit display graphics). An 8mm Exabyte tape drive provided data backup and exchange facilities. The two Sun computers were incorporated into the ship's ethernet based internet to allow rapid transfer of data to and from other computers, especially the TOBI data acquisition computers. The main software packages used were the WHIPS package for processing the raw TOBI data and ERDAS Imagine (versions 8.02 and 8.1) for general image processing and data integration. For most of the image processing the older version of Imagine (v. 8.02 installed on the IOSDL computer) was not adequate for the tasks in hand. However, the newer version (v. 8.1) installed on the ERA-Maptec computer had a two-user licence allowing sufficent access and more facilities. The Arc/Info GIS software was not brought along on-board, although this might have been useful for the occasional integration of vector data.

Data Preparation Prior to CD89

Access to detailed bathymetric data was a necessity for cruise planning and essential for accurate location during the cruise. Swath bathymetry for the study area was kindly made available by Dr.D. Needham, IFREMER Centre de Brest. These data were acquired aboard the French ship N/O *l,Atalante* during the "SIGMA" campaign, June-July 1991. The swath bathymetry was supplied as gridded data files and any gaps in the swath bathymetry were filled with interpolated point source SHOM data - although these did not always match the swath bathymetry. Integration of the swath bathymetry and SHOM data was accomplished using ERDAS Imagine. The merged data set was reprojected on to a Mercator projection (standard lat 38°N) using the WGS84 spheroid. Arc/Info was used to contour the swath bathymetry at 25m intervals and the SHOM at 100m intervals. Final bathymetry maps were produced in three series. 13 maps at a scale of 1:100,000 and 21 maps at 1:50,000 were produced, covering the axial portion of the Mid-Atlantic Ridge 40°N-35°30'N, by overlaying the contours on a colour sliced bathymetry background. A series of 1:100,000 maps extended the bathymetric coverage eastwards across the Azores Triple-junction from the Mid-Atlantic Ridge and between the Azores islands. The location of existing known data were assembled and entered in to the Arc/Info software. This mainly consisted of sites of rock cores, dredges and dives. In addition, residual magnetic anomaly maps and processed GLORIA sidescan sonar data for the northern part of the study area (Searle, 1980) were reprojected on to the same map base as the bathymetry and printed at 1:100,000. The maps were used, primarily, to enable efficient cruise planning - in particular to locate the geophysical traverses of the TOBI vehicle. All data were available as A0 working sheets but, in addition, all the digital data files were brought aboard the ship to allow further integration with the new data being acquired during the cruise.

Processing of New TOBI Data

Prior to CD89 all post-acquisition processing of TOBI data was preformed on-shore after the cruise. For CD89, it was planned to process the TOBI on-board soon after acquisition to produce final geocoded images. The Woods Hole Image Processing Software (WHIPS), coupled with customised software developed at IOSDL was to be used for processing the TOBI data. During the CD89 cruise the raw TOBI was recorded on optical disks and then transferred to the Sun workstations via FTP. The raw TOBI data consists of

8000 samples (pixels) across track. This is reduced to 1000 pixels by averaging prior to the main processing. The aim of this data reduction is to remove noise from the data and to make data files more manageable in size. The first stage of the processing involved merging the ship's navigation data with a log with TOBI 'wire-out' data. This caused some initial problems as the file format for the wire-out data is not recorded in the WHIPS/IOSDL software manual. The format was resolved with reference to the program source code and the development of a small re-formatting program. More serious problems arose with the main IOSDL elements of the processing package. Repeated software crashes were eventually traced to problems with the raw data files after sub-sampling to 1000 pixel wide format. It appeared that the time was incorrectly converted during this stage due to a software coding error. The error in the relevant program was fixed on-board. However, this problem took 5 days to solve and resulted in the processing having to restart from scratch.

The TOBI acquisition was not acquired in continously straight lines, but followed the ridge axis. This resulted in many bends along the acquistion track. The processing software has the option of dividing the TOBI imagery into a number of straight line segments. However, using the default settings on the software often broke each map in to as many as 20 segments. This was time consuming, both for the processing and for the time needed to re-join the segments after processing. For these reasons, we chose to use a turn-rate of 360° in one swath line during the processing to eliminate segmentation. In most cases the individual map sheets appeared to register with their neighbours. Problems in joining maps were observed only when map sheets were placed with their boundaries laying across a turn in the TOBI track. This was eliminated by ensuring that one map sheet covered the whole of the turn.

Processing of new SIMRAD MultibeamData.

The RRS *Charles Darwin*'s SIMRAD multibeam system recorded swath bathymetry throughout the cruise which will be incorprated into the bathymetry grids following the cruise. The backscatter information collected during the cruise was also reformatted to be processed using the Imagine software, allowing this cruise the opportunity to directly compare variations in acoustic texture recorded at frequencies of 12 and 30kHz.

Summary

Preliminary interpretative analyses were made of the combined images to guide the sampling programme due to take place during the second leg of the HEAT cruise. As well as compiling syntheses of the full geophysical datasets within the HEAT GIS, shipboard mosaics of the TOBI data were also constructed, largely for archive purposes.

MC, LP

2. Dynamic Hydrocast Operations

Introduction

The normal and traditional way of sampling seawater is to collect samples vertically. This operation is usually conducted by either attaching bottles along a cable at pre-selected depths or by using a CTD-rosette which permits one to record physical parameters of seawater and also to fill sample-bottles at depths selected during the lowering. This punctuated way of sampling can be considered adequate so long as the results of any lowering are representative of an area where the parameters to be measured do not vary significantly in the lateral direction. The study of hydrothermal plumes, either in themselves or as tools for locating hydrothermal sites, do not match these requirements.

It is well demonstrated that hydrothermal exchanges display different characteristics in different contexts and these differences in properties are reflected in hydrothermal plumes. We know of plumes characterised by large methane concentrations (>800 nl/l, seawater background 6 nl/l) with manganese concentrations and particle density almost non-detectable, whereas other plumes can be detected by *in situ* transmissometers or nephelometers. For this reason, both to discover hydrothermal sites and to describe the characteristics of hydrothermal exchanges, it is recommended, if not necessary, to measure several parameters. Although large efforts are being made for *in situ* measurements of hydrothermal tracers in seawater (i.e.: manganese), seawater sampling is still a necessity to get hydrothermal data as classical as methane concentration and helium concentration and isotopic ratio. To overcome the difficulties of punctuated sampling, as mentioned above, the Dynamic Hydrocast system was developed to sample seawater during the study of hydrothermal plumes.

Instead of sampling along a vertical line, the Dynamic Hydrocast samples horizontally or along a line parallel to the bottom. It is composed of four modules attached at selected depths along a non-conductive towing cable (Fig.2). Each module is composed of ten bottles (made of a piston and of a cylinder) and of a modified SeaBird unit. In order not to sample "punctually", each bottle is filled up proportionally to the covered distance thanks to a propeller acting a pump. When a bottle is filled up, the system goes automatically to fill the next one. The distance over which each bottle is filled up can be adjusted by the propeller. The seabird unit records temperature, salinity, depth and the time during which each bottle is filled up. Each measurement made from each Dynamic Hydrocast sample represents the average value over the distance along which the bottle was filled. From each deploymeny an array of data on a vertical cross-section of seawater is obtained with forty "average" measurements distributed along four parallel lines of ten samples each. This data set allows a vertical cross-section of a plume to be constructed for the various elements or compounds whose concentrations are measured in the samples.

Profile selection during CD89.

To prepare for the cruise, several modifications and improvements were made as one of the tasks of the MAST II project MARFLUX/ATJ. Among these were: new data collecting units, new software based on a seabird system, a new detecting system to record the time when bottles are filling up and new adjustments for the propellers. These improvements or modifications needed several tests both in high pressure tanks and at sea.

The locations where the Dynamic Hydrocast system was to be deployed were selected from previous results obtained during the FAZAR cruise (1992), from the DIVA 1 cruise (May 1994; Y.Fouquet Chief Scientist; RV Nadir/Nautile) and from transmissometer (and/or nephelometer) data obtained during CD89 Legs 1 and 2. The work relied on maps obtained during a previous FARA cruise, SIGMA (1991), H.D. Needham being chief scientist on board the R/V l'Atalante and the vertical profiles of methane (J.L.Charlou) obtained from the FAZAR samples were used both as an indication of existing hydrothermal activity and to select the depths were the four modules of the Dynamic Hydrocasts should work. Based on information available before and during HEAT Cruise, the following locations, (from north to south) were chosen to deploy the Dynamic Hydrocasts:

"South of the Azores Triple Junction", DH4, between 38°38'N and 38°20'N. The segments south of the Azores Triple Junction get shallower and shallower as one approaches the area of the Triple Junction. In its southern part an important magmatic production is represented by the shape of the cross section of the axis (no rift valley) and the occurrence of several volcanoes along the axis. A methane signal was detected there during FAZAR.
"The Lucky Strike segment", DH 5. There are two hydrothermal sites already known in the area of interest: Lucky Strike and Menez Guen. Lucky Strike (37°15'N) was discovered in 1992 by a "lucky" dredge during FAZAR, confirmed and studied during the Alvin diving expedition in 1993, (C.Langmuir chief scientist) and during DIVA 1. Menez Guen (38°N) was discovered during DIVA 1. The strategy to select the locations for deploying the Dynamic Hydrocast had to be a compromise between obtaining a better documentation along a segment already known for its hydrothermal activity or collecting new data to discover new sites. The Lucky Strike segment was chosen for the first purpose, but because of meteorological conditions (the direction of the wind being a constraint vis a vis the course of towing Dynamic Hydrocasts) we were able to cover only half of the segment, from the middle of the segment to its southern end. During this tow the lower module did not fill its bottles.

"The FAMOUS segment", DH 1, DH 2, DH 3, DH 6. The FAMOUS segment (36°40'N) was given some priority for two reasons. First, the three vertical profiles in the water column performed along this segment during FAZAR displayed important methane and manganese (when available) anomalies; the southern methane anomaly was the largest recorded in the axial zone during FAZAR. Second, the FAMOUS area is well known from the diving expeditions which were conducted in this area in 1973-74 during the French-American programme FAMOUS. DH 1 had to be abandoned due to pinger loss. DH 2 covered the southern part of the segment (from the "narrow gate" at the centre to the southern end). DH 3 covered the northern part (from the "narrow gate" at the centre to the northern end). DH 6 was deployed in the southern basin to try and locate the sources of the methane anomalies, either from the western wall of the valley, or from the southern wall of the off-set. The decision to conduct this operation was taken after recording transmissometer anomalies during TOBI deployments in this area.
"The AMAR segment", DH 7. Two methane profiles were available from the FAZAR cruise, at 36°33'N (HY 20, northern end of AMAR) and at 36°18'N (HY 19, a complex relay/off-set zone). The methane anomaly at this complex relay zone is almost as important as that of south FAMOUS. In addition, transmissometer (and/or nephelometer) data collected by TOBI, CTD and OSU ZAPS-sled operations revealed the strongest anomaly, over a large area, ever reported in the Atlantic. DH 7 started from south of HY 20 to the HY 19 area, trying to locate two potential hydrothermal structures there.

Mode of operation during HEAT.

The Bridge was told ahead of time of the Deployment Point, Gear point (the point where all modules should be deployed) and Point 1 where the modules, reaching the appropriate depth, should start to work and fill the first bottles. The Bridge, in turn, gave a sign one hour before reaching the deployment point in order that the appropriate orders could be given to the electronic units of the modules to start the work after the deployment. All operations were made by using the stern A-frame and the normal coring/dredging warp (non-conductive cable) of the RRS *Charles Darwin*. For each operation, the four modules were transported from the starboard-side space next to the wet laboratory to the rear deck of the ship. There, buoyancy (two glass spheres) was attached to the base of each module to ensure that each module would stream perpendicular to, and behind, the cable when in the water. A one tonne weight (core bomb), was attached to the very end of the cable with an acoustic pinger attached 10m above this weight. The pinger level was then considered to be the "zero" level", with the depth of each module being referred to this pinger level. The modules were then attached to the cable according to pre-selected working depths.

Navigation of the Dynamic Hydrocast system was conducted by using the pinger information, the swath bathymetric map (which proved to be sufficiently precise, to within

100-200 meters), the shipboard SIMRAD EM12 depth soundings directly beneath the vessel, and the 3.5 kHz echosounder. The 3.5 kHz record was useful for the beginning of the operations to give an idea of possible side-echos which could be met on the pinger record. These various readings and the position of the ship were all recorded every 10 minutes throughout each deployment. After the two first operations (DH1, DH2), since the depth is recorded on each module of the Dynamic Hydrocast, we were able to improve the exploitation of the pinger record during the operation, by correcting the raw depth under the pinger given by the record of both the effect of the distance of the pinger behind the ship and the shape of the cable. The speed over the ground was always between 1.5 and 1.7 knots and the distance covered by each Dynamic Hydrocast deployment was typically about 18 miles. The average distance to fill up each bottle was about 1.8 miles.

Recovery of the equipment was made without major difficulty. We met from time to time, but always for the upper module, a problem which consists of the three cables of the module (attaching the module to the main ship cable) spinning around the main warp. This spinning developed at the end of the operation when wiring in rather than during initial deployment. The buoyancy of the two spheres attached to the back of the module could not maintain the module in its horizontally streamed position during hauling back up to the surface. Hauling created a torque on the attachment gear on the cable which prevented one part of the module, a swivel component, to spin freely around the cable. Consequently, this caused the three cables of the module to spin around the warp instead.

When the four modules were returned to their starboard-side storing area on deck, next to the wet lab, a cable was connected to the recording units of the modules from the main lab. The data recorded on these units, time, depth, temperature, salinity and time when each bottle started to fill up and finished, were transferred onto a computer. The bottles were taken from the modules to the wet lab for sampling for ^{3}He, CH_4, Mn, Si + reference samples. Complete sub-sampling of the Dynamic Hydrocast modules required approximately ten hours for two persons.

From the beginning of the deployment to the recovery on the deck the time to conduct a Dynamic Hydrocast was about 15 to 16 hours. The percentage of recovery for the six Hydrocasts (DH2 to DH7) was 90 %. The linear distance covered during HEAT with the Dynamic Hydrocast was 108 miles. Full details (DH1-7) are given in Appendix C.

Acknowledgments: we particularly appreciated the efforts of Colin Day and Jason Scott who mastered the winch operations, and for the permanent dialog with them when towing our equipments during Dynamic Hydrocast operations. This is nearly as difficult as flying a kite near high tension wires from a moving car. The Bridge was very patient when

we were asking for the wind direction and for 0.01 knot speed adjustments. We thank the crew for help during deployment and recovery. The engines worked so smoothly and silently... We enjoyed our living conditions. Special thanks for kitchen staff for their superb cuisine.

HB, JK, JYL, HP, AD

3. CTD-Nephelometer-Transmissometer Operations

3.1 CTD Operations.

An EG&G Neil Brown MkIIIb CTD interfaced with a Chelsea Instruments Mk2 nephelometer and a 25cm Sea Tech transmissometer was used throughout the cruise. Water samples were provided by a General Oceanics 1015 Rosette multi-bottle array fitted with twelve 10 litre Niskins. Two of the bottles, fitted with SIS reversing thermometers were used to provide calibration check data. Salinity samples were analysed on a Guildline 8400A salinometer. A standard 10kHz beacon was used to monitor near bottom operations. A total of 12 deployments in depths varying from 1000m to 3000m were successfully completed. On one cast (CTD 09) the Challenger Oceanics Multi-sampler was attached below the CTD package. Particle concentrations were monitored using the CTD's nephelometer and transmissometer whilst a series of pre-programmed pump samples were taken. Calibration results showed a temperature offset of +0.002°C and a salinity offset of +0.013PSU.

PT

3.2 Optical Sensor (Nephelometer/Transmissometer) Data

A total of twelve CTD stations were occupied during CD89. All stations were chosen either to coincide with known sites of hydrothermal venting (Menez Gwen, Lucky Strike) or to investigate those areas which had yielded the strongest TOBI transmissometer anomalies. Deep water light-scattering signals, interpreteted to be characteristic of particle-rich hydrothermal discharge, were observed at nine of these stations. CTDs 01 and 02 were occupied in the southern FAMOUS area at 36°36-40'N. Slight light-scattering anomalies were observed at approximately 2200-2300m and also at approximately 2500m. CTDs 03 and 04 were occupied close to the Menez Gwen hydrothermal field at 37°47-50'N. No light-scattering anomalies were observed at these stations. CTD stations 05 and 06 were occupied at the Lucky Strike hydrothermal vent-field at 37°17'N. Strong light-scattering anomalies were observed close to the seabed at these stations (06 was within the Lucky Strike "caldera") between 1500 and 1700m water depth. CTD stations 07-09 were occupied at the southern end of the Lucky Strike segment. At CTD station 07, in the Lucky Strike/North Famous off-set (37°03'N 32°32'W), no light-scattering anomalies were observed. By contrast, at CTD station 08, located just a few miles to the east within the southern end of the Lucky Strike segment (37°03'N 32°25'W) a strong light-scattering anomaly was observed which was approximately 20% more pronounced than the central Lucky Strike anomalies (CTDs 05, 06) and occurred approximately 200m deeper in the water column (1700-1900m). A similar, albeit less pronounced, light scattering anomaly centered at approximately 1800m was also observed at CTD station 09, which was located approximately midway between CTD 08 and CTDs 05 and 06. CTDs 10-12 were all occupied in the southern portion of the AMAR segment close to the AMAR/AMAR Minor transition. CTD station 10 was occupied at 36°16'N 33°46'W and yielded extremely strong light-scattering anomalies between 1600m and 2500m. Maximum anomalies were observed at ~2075m. More focussed features were observed at CTD station 11 (36°15'N 33°50'W), occupied a few miles west of CTD 10, where light scattering anomalies were observed between just 1750 and 2250m and exhibited slightly greater maximum anomalies at a marginally shallower depth of 2050m. The final station, CTD12, occupied NW of station CTD11 at 36°16'N 33°51'W exhibited similar magnitude light-scattering anomalies to those obsereved at CTD 10 and were similarly broader than at CTD 11, extending over a depth range between 1600m and 2300m. In total, the AMAR stations (CTD10-12) exhibited a strong hydrothermal plume signal extending over a lateral dimension of 5 miles or more. This indicated the presence of a strong hydrothermal field in the vicinity, comparable to the TAG hydrothermal field at 26°N - previously recognised to be the strongest known hydrothermal site in the Atlantic Ocean.

CG

3.3 Water column sampling (chemistry)

One of the objectives of the cruise was to document the vertical extent of hydrothermal plumes in the target areas of the Azores domain. When found, these plumes could be sampled for a suite of hydrothermal plume tracers using the Niskin bottles mounted on the CTD rosette. For this study, hydrothermal tracers that were sampled for included total dissolvable manganese (TDMn) and the dissolved gases methane and helium. In addition, aliquots for silicate analyses were taken to identify samples collected with possibly improperly closed Niskin bottles. During the first leg of the cruise (station CTD 01), the Niskin bottles were fitted with stainless steel springs which were inadequate for contamination-free TDMn sampling. At the beginning of the second leg, these springs were replaced with silicone rubber springs and the bottles were cleaned with detergent (all subsequent CD89 hydrocasts). Manganese samples were not collected at CTD station 03 because the bottles had been cocked and left opened on the deck for 12 hours prior to the cast. The following number of samples were acquired during the cruise for shore-based analyses:

CTD No	Latitude N	Latitude W	Methane	Helium	Manganese	Silicate
01	36°16.0	33°51.4	8	10		11
03	37°47.3	31°31.7	10	10		10
06	37°17.5	32°16.7	11	11	11	11
09	37°02.7	32°25.0	12	12	12	12
10	36°16.4	33°45.7	10	10	10	10
12	36°16.0	33°51.4	12	12	12	12

Helium, then methane, manganese, and silicate samples were collected within 30 minutes of the CTD/rosette arriving on deck. Samples were not analyzed on board but stored as follows. Helium samples (6mL) were stored in crimped copper tubing, methane samples (125mL) were poisoned with sodium azide and kept in glass bulbs closed with Teflon stopcocks. Manganese samples (125mL) were acidified with hydrochloric acid while silicate samples were not treated; they were stored in high-density polyethylene (HDPE) bottles.

JK, AD

3.4 Water column sampling (microbiology)

Water column samples were taken from 5 CTD drops (03, 06, 07, 09 and10) for the following purposes: (i) To carry out shipboard measurements of microbial process rates (section 7, below); (ii) Total count samples (TC) for subsequent enumeration and sizing of bacteria by epifluorescent optical microscopy; (iii)Samples preserved for subsequent examination by electron microscopy (EM) and dispersive X-ray analysis to investigate bacterial/metal associations; (iv) Samples for subsequent extraction of nucleic acids (NA) with the objective of examining microbial community structure (cf section 5.4, below). Details of CTD sampling for microbiological studies were as follows: CTD 03; TC samples at all depths, NA samples at 1100,1000,900, 700m. CTD 06; TC samples at all depths, NA samples at 1654 and 900m, water from 1654m for shipboard experiments 1-3. CTD 07; TC and NA samples at all depths. CTD 09; TC and EM samples at 1835m (corresponds with filter 2, MS#1), water for shipboard experiments 4-6. CTD 10; TC at all depths. EM and NA samples at 2000 and 1200m. Water for shipboard experiments 7-9 (1200m) and 10-12 (2000m).

JP, DE

4. ZAPS Sled Operations.

Introduction

Venting of hot, chemically-rich, buoyant fluids from mid-ocean ridge spreading centres produces hydrothermal plumes with thermal, physical, and chemical signatures quite different from background sea water. These plumes rise several hundred meters above the sea floor where they reach neutral buoyancy and begin to spread laterally. The marine geochemistry group at Oregon State University has designed and constructed an instrument package, the ZAPS Sled, that carries state-of-the-art, in situ sensors capable of detecting such plumes and tracing them back to the source of venting. During Cruise 89 the ZAPS system was used to study plumes in the Lucky Strike, FAMOUS and AMAR segments of the Mid-Atlantic Ridge.

The ZAPS Sled Frame

The ZAPS Sled vehicle is an open framework of 5 cm Type 316 SS pipe. The ZAPS Sled stands 90 cm wide, 90 cm tall, and is 270 cm long with a tapered bow 42 cm wide. This frame hangs from a standard conducting cable by an adjustable 3-point chain bridle to ensure that the sled attains a forward facing, level attitude in the water. The two vertical sides of the sled aft section have 0.95 cm thick polycarbonate panels attached to serve as rudder vanes and give structural hydrodynamic stability. The weight of the frame in air is about 350 kg. The ZAPS Sled can be used for tow-yowing at 1-2 knots as well as for vertical profiling.

ZAPS Sled Instrumentation

The central instrument on board the ZAPS Sled is a Sea-Bird 9/11 plus CTD sampling at 24 Hz and fitted with modular temperature and conductivity sensors and a Paroscientific Digiquartz Pressure Sensor. Four analog instruments are interfaced through the Sea-Bird underwater unit. These include: (i) SeaTech Transmissometer to measure 660 nm wavelength beam transmission through a 25 cm path length; (ii) Chelsea Aquatracka Mk III Fluorometer operating as a nephelometer at a wavelength of 420 nm to measure scattered light at 90 degrees to the incident light beam; (iii) Zero Angle Photon Spectrophotometer (ZAPS) that uses solid-state chemistry with analog fluorescence to measure the concentration of dissolved manganese; (iv) SIMRAD Mesotech Systems Model 807 Echo Sounder/Altimeter to determine the height of the sled off the bottom within a 500 meter range. The ZAPS Sled also carried a General Oceanics Rosette array interfaced to the CTD which held six 2-liter Niskin sample bottles for collecting sea water samples for laboratory measurements of manganese for ground-truthing data from the ZAPS probe. The bottles are tripped by signals from the CTD deck unit at any time without interrupting the data steam. In addition the sled can be fitted with an acoustic transponder that is interrogated with a transducer at the surface to determine the direct slant range and computed horizontal range to the sled. During Cruise 89 a pinger was fit to the sled to aid in near bottom surveys as the altimeter proved to be unreliable.

ZAPS Sled Power

A custom power delivery system was used to supply power to all the underwater instruments, including the CTD. The power delivery system in the SeaBird CTD was bypassed. This custom power delivery system can provide more than 10 times as much power as the system in the CTD, which had proven to be insufficient in the past. The Simrad altimeter, Chelsea nephelometer, and ZAPS probe consume large amounts of current in pulses. The SeaBird CTD, its pump, and the ZAPS pump consume substantial power as well. The total power consumption of all the underwater instruments was approximately 60W, more than double the rated 27 W capacity of the SeaBird CTD system. By providing the capability to deliver more than 200 W, our improved power delivery system ensures that these power hungry instruments do not interfere with each other or the other instruments in the system.

CTD Data Acquisition and SLED Navigational System

The ZAPS Sled is powered through a purpose-built deck unit that also receives frequencies from the underwater unit and sends converted data via an RS232 port to a Silicon Valley 486 computer that supports an Introl optical disk. Raw CTD data files are stored on the optical disk and echoed to a second, identical computer. This second, navigational computer also receives ship positions from a Garmin MRN 100 GPS Satellite Receiver and imports this data into a proprietary SLED navigation program developed at Oregon State University. This navigation program plots in real-time the ship's position and trackline and the computed horizontal range and position of the instrument package as projected onto the trackline of the ship. This "nav" program also shows a diagrammatic cross-sectional view of the ship, the towed vehicle, and a calculated "bottom depth" derived from the sum of the CTD pressure data and the concurrent altimeter data (height above bottom) from the package. This calculated bottom depth can then be compared to the depth records and/or bathymetric maps of the area to help locate the package with respect to bottom features or obstacles.

A full duplex modem channel was used to communicate with the ZAPS probe and fire the GO rosette to collect water samples. The modem channel was also intended to activate a stand-alone pump, which was not deployed when its batteries failed to recharge. The modem channel, which operated well at 9600 baud on a standard UNOLS conducting cable, did not operate as well on the *Charles Darwin* CTD cable. However the modem managed to maintain a connection when the speed was reduced to 300 baud. Even at this reduced transmission rate, noise caused erroneous characters to be received periodically. Despite the noise, commands and parameters could be sent to the rosette interface and ZAPS instrument. The rosette was fired successfully on every attempt without interrupting the data stream from the CTD or other sensors. Communication with ZAPS allowed it's parameters to be adjusted once it was deployed.

ZAPS Deployments

The ZAPS Sled was involved in 10 operations during Cruise 89 of the RRS *Charles Darwin*. These operations are summarized in the following table.

Table of ZAPS Sled Operations on HEAT

Stataion No.	Date	Location	Operation Type
SL01	6 Sept.	Lucky Strike	Vertical
SL02	8 Sept.	FAMOUS	Vertical
SL03	8 Sept.	FAMOUS	Vertical
SL04	8 Sept.	FAMOUS	Vertical
SL05	9 Sept.	AMAR	Vertical
SL06	9 Sept.	AMAR	Vertical & Tow
SL07	9 Sept.	AMAR	Vertical
SL08	9 Sept.	AMAR	Vertical
SL09	11 Sept.	AMAR	Vertical
SL10	11 Sept.	AMAR	Vertical

ZAPS Results

SL01: (Lucky Strike at 37°07'N, 32°23'W) This vertical lowering was carried out in the SW corner of the Lucky Strike segment near the offset. Small anomalies in ZAPS Mn, nephels, and light transmission were observed in the bottom 1200 m of water column. There seemed to be two small plume maxima, 1600 and 1800 m. These results are totally consistent with work carried out during the FARA cruise, FAZAR. The Lucky Strike vent field in the middle of the segment is the center of a broad area of widely dispersed but small hydrothermal plumes that seem to fill the axial valley of this segment. Two small maxima were observed during FAZAR at these same depths.

SL02: (FAMOUS at 36°39'N, 33°18'W) This was the first of three ZAPS Sled vertical lowerings in the FAMOUS segment. The first part of this deployment involved a series of profiles down to 200 m. These profiles through the mixed layer were used to diagnose the response of the ZAPS sensor. As we learned later the ZAPS magnetic pump became decoupled after leaving the mixed layer making it impossible to produce a Mn profile. The nephelometer and transmissometer traces showed that there was possibly a hydrothermal plume at this location but the anomalies were very small and restricted to the bottom 200 m (2300-2500m).

SL03: (FAMOUS at 36°36'N, 33°24'W) The water at this site was 150 m deeper than at the previous station and the small near-bottom plume again began at about 2300 m and extended into the bottom. This gave us added confidence that this plume was hydrothermal, but unfortunately we continued to have problems with the ZAPS pump and the Mn profile was inconclusive.

SL04: (FAMOUS at 36°34'N, 33°24'W) The water depth at this, our last FAMOUS station, was again about 2600 m but the near-bottom anomaly here extended up to 1800 m and was larger in amplitude. Fortunately the ZAPS pump was working during this lowering and we were able to record a positive anomaly in dissolved Mn (Fig.3) that coincides with the anomalies in nephels and light transmission. This is an important data set because it is the first time that we have been able to produce conclusive evidence of hydrothermal activity in the FAMOUS segment with this package of instruments. These results were consistent with the CH_4 results of J-L. Charlou from the FARA Program that also indicated this segment to be hydrothermally active.

SL05: (AMAR at 36°15'N, 33°50'W) Work in the AMAR segment during this leg began with CTD10 and CTD11 carried out in the SW offset corner (Section 3.2 above). Both of these CTD casts encountered very large hydrothermal plumes that seemed to be related to substantial plumes to the north first encountered during the FARA Program and also detected by the transmissometer on TOBI during the first part of HEAT. In fact the area covered by CTD 10 and 11 was selected using the distribution of transmissometer anomalies from TOBI surveys of the segment. SL05 was a re-occupation of CTD11. The maximum of nearly 0.14 FTU detected on this lowering is the largest nephel anomaly ever recorded with this nephelometer. It is approximately twice as large as the largest anomaly recorded at TAG and 6-7 times larger than the maximum found at Broken Spur. This nephel anomaly was associated with a negative anomaly in light transmission and a positive anomaly in dissolved Mn (Fig.4).

SL06: (AMAR at 36°12'N, 33°47'W) This operation was the first of three back-to-back ZAPS deployments around the nodal deep associated with CTD10 and CTD11. The ZAPS pump was "decoupled" during this lowering and no useful Mn data was obtained for this station, but plume maxima were detected between 2000 and 2400 in light transmission and nephels. The nephel maximum here was 0.06 FTU; significantly smaller than at the CTD11/SL05 site but still a large plume.

SL07: (AMAR at 36°13'N, 33°44'W) This station was located on the eastern side of the deep. The nephel maximum here was similar to that at SL06 but the plumes were spread out more in the water column (1700-2300 m). In general plume structure here was flatter and more complex than at the previous site suggesting that this site is farther removed from the source of venting. Again the ZAPS pump seemed to be having problems and no useful Mn data were recorded for this station.

<u>SL08: (AMAR at 36°17'N, 33°48'W)</u> This station was positioned on a small ridge NE of the CTD11 site. Modest plumes were found between 1700 and 2200 m. The broad nephel maximum reached 0.03 FTU but small maxima of another 0.01 FTU were superimposed on this broad peak. These superimposed peaks were located at approximately 2070 and 2140 m, which seems to indicate that the plumes at this site originate at the same source as the plumes at CTD10 and CTD11. Nevertheless, the overall shape of the plume at this site suggests that the plumes here are advected. The gear pump for ZAPS behaved erratically during the two previous lowerings. In order to give us more time to work on this problem, the ZAPS pump and Mn cartridges were removed before SL08. This gave us the opportunity to try to detect natural fluorescence in the plume. The Mn filters were left in the instrument so the water column was irradiated at 250 nm and monitored at wavelengths above 320 nm. This arrangement produced the profile shown in Fig.5. As can be seen in this illustration, an anomaly in ambient fluorescence was detected at plume depths. This result holds promise for future work. This is especially true when one considers two facts. First, the plumes here were on the small side for this area and apparently advected. One would expect the population of the most fluorescent organic matter, that associated with methanogens, to be in low abundance at such a site. Second, and more importantly, the excitation wavelength used by ZAPS in this preliminary work was not optimized to detect methanogenic fluorescence, which one would expect to occur at about 400 nm.

<u>SL09 : (AMAR at 36°16'N, 33°50'W)</u> This lowering was carried out NE of the CTD11 site, on the eastern flank of the south offset high. This station was positioned on a feature that appeared to be a ridge in TOBI images. The ZAPS pump decoupled once again, although this problem was resolved before the upcast by using modem commands. The plume anomalies in light transmission and nephels were small, broad, and complex at this location. A broad nephel peak extended from 1700 to 2300 m with maximum readings of about 0.03 FTU. These plumes appear to be far-field.

<u>SL10: (AMAR at 36°16'N, 33°46'W)</u> The last ZAPS deployment was a vertical lowering positioned north of CTD 10, on the western flank of a small ridge. Small anomalies were detected in light transmission, nephels, and dissolved Mn . These plumes extended from 1600 to 2500 m. Although rather broad, a maximum nephelometer response of about 0.04 FTU occurred between 2030 and 2100 m. These depths are consistent with plumes originating at the same source as those producing the anomalies at CTD10 and CTD11, although the plumes here are much smaller and appear to be advected.

GK, PS

5. In Situ Filtration Operations

5.1 Challenger Oceanics Multi-Sampler.

This newly developed unit consists of a single pump unit with an eight-port valve-block connected to eight 142mm diameter filter housings each with their own 700 mL water bottle. The system is powered by battery packs within their own pressure case. Eight flow meters show the amount of water passed through each filter and water bottle assembly. A microprocessor-based control system allows on/off pump control and port selection. This can be done remotely via a pre-programmed menu downloaded to memory or under the control of a personal computer connected to the serial port of the instrument. This enables the unit to be wire deployed or attached to a deep tow instrument. The system was demonstrated in the acoustic test tank at IOSDL Wormley just before being shipped for the cruise, but was not available for pressure testing prior to sailing.

The multisampler was assembled and tested during the cruise. Motor control and port selection were demonstrated under direct personal computer control. A test task was devised, entered in the spread sheet program and downloaded to the multisampler. The task was monitored during operation and ran as programmed. The system was then pre-programmed, rigged and slung below the RVS CTD unit (CTD 09). This would enable particle rich water to be detected using the nephelometer and transmissometer mounted with the CTD. The cast was halted at various depths until pump samples were completed. Details of the deployment are tabulated below. Deployment and recovery of the CTD and multisampler assembly went smoothly under excellent weather conditions.

<u>CTD09/MS01</u> <u>7/9/94</u>

Port	Pump on	Pump off	Depth
1	01.00	01.30	1825m.
2	01.42	02.12	1825m.
3	02.30	03.00	1775m.
4	03.12	03.42	1775m.
5	04.00	04.30	1725m.
6	04.42	05.12	1725m.
7	05.42	06.12	1000m.
	06.24	06.54	1000m.

Readings taken from the flow meters at recovery showed that only three of the ports had pumped water. Interrogation of the program indicated that it had completed execution of its task. Battery volts were measured under load and found to be well within specification. Port operation was next checked under terminal control. Although the software indicated that the valve selector had completed its task it was found to be in the wrong position.

Further testing, by letting water flow from pump to port, indicated that the valve selector was not operating properly. Sometimes the unit would not step on command and at other times it did. This seemed to localise the problem to the oil filled motor/valve unit. More mechanical details were requested from the manufacturers of the assembly before attempts were made to dismantle the unit and valve system to rectify the problem. As there were several other instrument systems aboard it was decided that the unit should not be used again during this cruise but that it should be prepared for the following instrument trials cruise.

RK

5.2 Stand Alone Pump Operations

During Cruise 89, the stand alone pumps (SAPs) were deployed five times, each time clamped to the dredging warp from the stern gantry. A typical rig comprised a 1 tonne core bomb lowered to 50m above seabed with an acoustic pinger clamped to the cable 50m above the bomb. Pump samplers were clamped to the cable at required depths above the pinger to encounter hydrothermal plumes (as deduced from previously acquired nephelometer/transmissometer data). It was found that a 2 hour delay was sufficient to deploy the rig, in the calm weather we enjoyed, and lower the instruments to their operating depths (water depth nominally 3,000m). On recovery, the pumps could be turned around in less than 4 hours, taking only about three hours to recharge the battery pack after a 2-hour pumping "on-time". No problems were encountered in the SAPs operations and they were found to be reliable and easy to maintain.

JW

5.3 SAP Filter Samples (Geochemistry)

A total of 20 filters were collected during 5 SAPS deployments. Fourteen of these were for trace metal analysis and 2 MnO_2 cartridges were used in each of these pumps for corresponding measurements of dissolved Th-230 in the filtered seawater. Sample stations were chosen with reference to CTD data collected during Cruise 89. Particulates from the neutrally buoyant plume were collected on 293mm diameter, 1μm Nucleopore® filters for chemical analysis and processing was carried out in a trace metal clean laminar-flow bench. The filters were washed in sub boiling water, dryed under suction and frozen until transfer to the lab for digestion. Four samples were collected from the southern end of the Lucky Strike segment, two from the south of the FAMOUS segment and eight from the newly discovered area of hydrothermal activity at South AMAR. Details of all deployments are tabulated in Appendix D.

EL, CG

5.4 SAP Filter Samples (Microbiology)

The objective of studies to be carried out on material obtained on SAPs filters is to investigate the structure of microbial communities associated with hydrothermal plumes by means of nucleic acid (non-culture) based methods. Filters were preserved in alcohol. Following the return of this material to Galway, nucleic acids will be extracted. PCR using kingdom-specific primers will be carried out so as to obtain banks of sequences. Subcloning will be carried out so as to produce phylogenetic libraries. Significant components of these libraries will be sequenced. Probes based on these sequences will be prepared and used to examine their proportion in vent-associated communities. When assessing the performance of SAPS and the multisampler, it should be noted that the filters used for microbiological purposes have a smaller pore size (0.2μm) than those used for geochemistry (1μm) and, thus, exhibit a lower mean flow rate. Filters were obtained from one lowering of the multisampler (MS01/CTD09) and two drops of the SAPs arrays (SAPs 02 & 04):

MS 01 — One filter was obtained (Filter 2). 18.4L (30 min. pumping) were filtered at a depth of 1835m. This depth corresponded to a turbidity maximum.

SAPS 02 — Two filters were collected. 330L (2 hr. pumping) were filtered at a depth of 2275m (Filter 2). This depth corresponded to an area of increased turbidity. 376L (2 hr. pumping) were filtered at a depth of 1500m (Filter 4). This depth was above the turbid region and was sampled to provide a control for subsequent studies.

SAPS 04 — Four filters were collected. The depths and location corresponded to those for SAPS 03 which obtained material for chemical analysis (Section 5.3, above). 140L (2 hr. pumping) were filtered at a depth of 2100m (Filter 1). This filter was found to be split, but this had apparently occurred during recovery, since the filter still carried a significant load. 323L (2 hr. pumping) were filtered at a depth of 2050m (Filter 2). 1088L (2 hr. pumping) were filtered at a depth of 2000m (Filter 3). The high volume pumped would suggest either a mismounted filter or a leaky filter connector. The filter carried a significant load, however. 459L (2 hr. pumping) were filtered at a depth of 1500m (Filter 4).

JP, DE

6. Sediment Coring

One sediment core was collected using a 1m gravity core at the southern end of the Lucky Strike segment (Station CD89-46; location 37°02.98'N 32° 31.71'W). The core penetrated beyond the top of the core-bomb indicating that the sediment-water interface was definitely not recovered. Approximately 1m of dark tan carbonate ooze was collected in the core barrel with rock fragments included at the top of the core. Full details are given in Appendix E. The core was packed, stored upright and returned to the core store at IOSDL at 4°C.

CG

7. Shipboard Microbiology Experiments

Bacterial activity was investigated by observing the incorporation of radiolabelled compounds by samples incubated at both surface and *in situ* pressures. All incubations were carried out at 4°C (near *in situ* temperature) for intervals between 16 and 21 hrs. Bacterial DNA production was followed by the incorporation of [methyl-^{3}H] thymidine and protein production by the incorporation of L-[4,5 -^{3}H] leucine. Carbon dioxide (as ^{14}C-labelled bicarbonate) incorporation was used mainly to monitor autotrophic activity, since some autotrophs do not incorporate thymidine. Incorporated radioactivity was counted on board by means of the Ryan Institute's scintillation counter. Unfortunately this counter developed a normalisation fault rendering onboard counts unreliable. All material will be recounted onshore. Water column activity was measured on samples from the following hauls:

Haul	Sample depth	Comment
CTD 06	1654m	In Plume, Lucky Strike
CTD 09	1835m	In Plume, FAMOUS
CTD 10	1200m	Above Plume, AMAR
CTD 10	2000m	In Plume, AMAR

All samples apparently showed measurable incorporation of all three compounds. For comparison, previous studies by us in the Porcupine Abyssal Plain area (N Atlantic, but away from the mid oceanic ridge) showed no measurable activity in water from 1000m to 10m above bottom. The Lucky Strike sample showed the highest level of activity per litre. Bacteria at this site appeared to be adapted to *in situ* pressures (barophilic). Actvities at all other sites appeared to be relatively low. At the AMAR site, activity within and outside the plume did not appear to differ significantly.

As has already been mentioned, these results must be reassessed by scintillation counting onshore. Rates obtained on board are calculated per unit volume of sample, and expression of these results in the more meaningful biomass-specific form must await the onshore determination of bacterial numbers and bio-volumes.

JP, DE

8. XBT Deployments

A total of 31 XBT deployments were made during the cruise. The primary purpose of these deployments was to monitor variability in sound velocity profiles beneath the ship throughout the survey area, to ensure that the swath bathymetry calibrations established from our initial sound velocity profile station (Station CD89-03) remained valid. All data were recorded on board ship by RVS personnel and copied to The Hydrographic Office, Royal Navy, upon completion of the cruise. The majority of stations were occupied synoptically at 0000z and 1200z using a combination of T-05 and T-07. Full details of all 31 stations are given below:

XBT No.	Date	Time	Latitude	Longitude	Type
1	94 231	19:44:00	37 47.26N	27 59.89W	T-05
2	94 232	09:11:00	38 00.13N	31 00.61W	T-05
3	94 232	23:55:00	37 59.93N	31 21.40W	T-07
4	94 233	12:07:00	37 44.23N	31 33.80W	T-05
5	94 233	23:42:00	37 33.96N	32 02.14W	T-07
6	94 234	12:14:00	37 14.40N	32 15.89W	T-05
7	94 234	23:49:00	37 03.11N	32 36.22W	T-07
8	94 235	11:48:00	36 57.40N	33 02.25W	T-05
9	94 235	23:42:00	36 36.96N	33 21.03W	T-07
10	94 236	23:45:00	36 52.88N	33 13.85W	T-07
11	94 237	11:57:00	36 31.94N	33 20.24W	T-05
12	94 237	23:48:00	36 36.83N	33 20.81W	T-07
13	94 238	12:11:00	36 34.14N	33 27.73W	T-05
14	94 238	23:58:00	36 15.33N	33 48.08W	T-07
15	94 239	12:20:00	35 56.06N	34 12.12W	T-07
16	94 239	12:30:00	35 55.62N	34 12.15W	T-07
17	94 240	00:44:00	36 05.22N	34 04.73W	T-07
18	94 240	11:44:00	36 23.74N	33 43.04W	T-05
19	94 241	00:12:00	36 37.12N	33 18.86W	T-07
20	94 241	11:47:00	36 53.84N	33 13.56W	T-05
21	94 242	00:15:00	37 05.27N	32 21.20W	T-07
22	94 242	11:40:00	37 29.47N	32 13.55W	T-05
23	94 243	00:09:00	37 30.57N	31 26.11W	T-07
24	94 243	11:55:00	38 21.84N	30 39.65W	T-07
25	94 244	00:07:00	38 32.43N	30 15.68W	T-07
26	94 244	11:53:00	38 24.04N	30 37.32W	T-05
27	94 245	11:49:00	38 29.98N	29 05.86W	T-05
28	94 248	12:11:00	37 04.82N	32 21.86W	T-05
29	94 250	11:45:00	36 42.85N	33 15.13W	T-07
30	94 253	11:39:00	36 19.61N	33 45.32W	T-05
31	94 255	11:41:00	36 55.15N	30 07.73W	T-07

JW, DT, RP

9. Simrad EM12 Swath Bathymetry

The EM12s-120 system on board RRS *Charles Darwin* comprises a single multibeam echosounder generating 81 stabilized beams, providing a coverage up to 120° in water depths of 100 to 11,000 meters. Acoustic frequencies used are 12.66, 13.00, and 13.33 kHz. Transmission transducers are installed in 24 modules each containing 16 elements mounted alongships, slightly to starboard and flush with the keel. Receiving transducers are installed in 14 modules each containing 15 elements mounted athwartships just forward of the transmitting array. The system is continually provided with surface sound velocity, clock, gyro and GPS navigation data. A vertical referencing unit mounted close to the centre of the ship provides roll, pitch and heave information.

The EM12 system was logged continually during Cruise 89, generating nearly 3 Gbytes of raw bathymetric and 'side scan' data. Raw multibeam data, logged by the 'Mermaid' swath logging system, was routinely archived to exabyte cartridge and converted to Simrad 'Survey Format' files for use with the 'Neptune' swath data processing system.

Due to the irregular nature of the survey undertaken during the cruise, it became apparent that it would be essential to maintain the complete data set within the work area on the Neptune processing system. To gain the required data storage it became necessary to 'borrow' one of the large data disks from the ship's ABC system and install it as a second data disk on Neptune. With the second disk installed it was possible to statistically clean and prepare data for gridding as work was completed within particular areas or survey blocks. Data added during Cruise 90 was to be treated in much the same fashion, thus enabling the final tape/printed 'products' to contain all of the data collected within the area.

During routine cleaning and preparation it was noted that anomalies were occurring in the swath data in areas which had been identified as having high levels of hydrothermal activity. The anomalies had a very distinctive signature and could easily be identified and 'removed' from the data set by reducing their status values. The correlation of these anomalies with the presence of plumes has yet to be established but if proven could lead to an interesting new detection method.

AF, RP

10. Shipboard Computing

The RVS 'ABC' computing system was used to log and process data from a variety of scientific and navigational instruments. A total of 400 Mbytes of data was collected during both legs of the cruise. Scientific sources included a gravity meter, a magnetometer, an acoustic depth sounder, an Acoustic Doppler Current Profiler (ADCP) and a CTD system. Navigational sources included two GPS receivers (Trimble and Decca), a 'Transit' satellite receiver, a ship's gyro and a ship's log. Navigation data was processed to provide a 'best position' data record every ten seconds. GPS coverage was generally good throughout the trip (at least 98% over a twenty four cycle), though there were two isolated incidents where both receivers output a series of erroneous fixes. The processed navigation data was in turn used to process depth sounder, gravity, magnetics, TOBI and swath bathymetry data. CTD data was processed using calibrations from the previous cruise (CD88), these values were checked and confirmed during the second leg of the cruise.

RP, AF

11. Scientific Engineering

The RVS Engineering Division provided technical support for the following scientific operations during cruise CD89/94:

11.1 CTD (deployments)
11.2 TOBI (deployments/towing operations)
11.3 Dynamic hydrocast system (deployments/towing operations)
11.4 Multi sampler (rigging/deployment)
11.5 SAPs (installation/deployments)
11.6 ZAPS (deployments)
11.7 Gravity coring (rigging/deployment)

11.1 CTD

All CTD operations were carried out successfully during Legs 1 and 2 of the cruise, the only point of concern being the external condition of the cable. Excessive surface rust deposits on the wire may cause problems for science operations working in the trace metal field.

The cable was reterminated during the cruise due to kinks in the wire, which resulted in a loss of electrical signal. After retermination no further problems were noted.

11.2 TOBI

TOBI operations were successfully carried out during Leg 1. The vehicle was towed via the stern "A" frame at an average speed of 1.5 knots over the ground for between 1 to 3 day periods. All mechanical handling equipment required for operations during this cruise functioned satisfactorily. The Port side Effer crane was used to move the vehicle around the deck as a fault was detected with the starboard side crane, temporarily reducing its load bearing capacity.

11.3 Dynamic Hydrocast System (DHC)

DHC operations were completed satisfactorily during Legs 1 and 2 despite the initial lack of familiarity with the French equipment and working practices. Deployments were via the stern "A" frame using the 3/19 core wire. During the first towing operation the pinger was lost requiring the termination of the operation. It is thought the wire is subject to significant vibration due to the dynamic characteristics of the equipment. For subsequent deployments, additional measures were taken to secure the pinger to its mounting bracket thus preventing any potential reccurrence.

11.4 Multisampler

One deployment was carried out during Leg 2. The sampler was suspended underneath the CTD frame and deployed via the starboard "A" frame. This proved a suitable method of deployment, also providing a saving in wire time as both CTD and sampler were operated simultaneously.

11.5 ZAPS Sled

All operations were carried out via the starboard "A" frame using the CTD wire. The instrument weighs approximately 0.5T in air so excessive movement of the package in air must be avoided. In adverse weather conditions additional measures would have to be adopted to ensure safe and effective deployments.

11.6 SAPs

SAPs operations were carried out over the stern "A" frame using the 3/19 core wire. A 1T core weight was used as the ballast weight, this ensured sufficient wire tension at the shallower depths for a suitable wire speed, and aided a closer to vertical wire profile.

Conclusions/Recommendations

In general all overside operations were carried out by the various interdisciplinary teams satisfactorily providing a good overall operational performance. It is important that in the future an adequate level of experienced manpower is maintained by the RVS technical and Marine deck departments on a 24 hour basis. This will ensure continuation of the high standard of overside operations required for the safe and effective execution of cruise programmes.

CD, JS

SUMMARY

Between August 19th and September 13th 1994, a detailed investigation of the location and tectonic setting of hydrothermal activity was completed along the Mid Atlantic Ridge, between 36 and 38 degrees North, close to the Azores Triple Junction. During Leg 1, a regional survey was completed using the IOSDL deep towed instrument, TOBI, and IFREMER's towed water column sampling equipment, the Dynamic Hydrocast.

TOBI provided along axis sidescan sonar coverage of a 6km wide swath along the entire ridge section between 36 and 38 degrees North, including the Menez Gwen vent site discovered by the French submersible "Nautile" in May 1994 and the FAMOUS segment at approximately 36 30N - 37 00N. In areas of particular interest, double swath coverage was collected. This was the case for the entire section between the southern end of FAMOUS and the South AMAR segment (35 30 to 36 30 N) and through the Lucky Strike segment. A fifth and final TOBI deployment during Leg 1 successfully intercepted and identified the most volcanically and tectonically active region of the Azores Triple Junction Overlapper at approximately 38 30N.

In addition to its sidescan sonar coverage, TOBI also provided real time transmissometer data which was used to identify potential "targets" for follow up hydrothermal studies. Because high temperature black smoker hydrothermal plumes are typically characterised by high concentrations of suspended particulate matter, it had been proposed that a drop in recorded light transmission on the TOBI transmissometer, flying 300-500m above the seabed, might be able to indicate the presence of any hydrothermal plumes serendiptitiously intercepted by the TOBI vehicle during routine operations. Over a total cruise track of 150 nautical miles, significant transmissometer anomalies were recorded from the TOBI vehicle on at least seven occasions, in the South AMAR, AMAR Minor, southern and central AMAR, southern FAMOUS, North FAMOUS and southern Lucky

Strike segments. These signals were in addition to the already known hydrothermal fields in the cenral Lucky Strike and Menez Gwen areas at 37 15N and 38N respectively. Thus, our preliminary (Leg 1) survey indicated the presence of at least one site of hydrothermal activity in each of the seven offset ridge segments studied. Because TOBI would not necessarily have been flying at the appropriate height to intercept any particular hydrothermal plume at any time, this frequency of occurrence must be considered to be a minimum estimate. Nevertheless, at a frequency of 7 potential sites in 150 miles we calculate an average of perhaps one vent site every 20 miles, representing an almost order of magnitude increase over previous estimates.

Continuing operations during both Legs 1 and 2 involved underway water column sampling through areas of interest, using the Dynamic Hydrocast (IFREMER), for shore based dissolved methane, manganese and helium 3 analyses. All three tracers are characteristic of hydrothermal activity and, thus, will provide information about along axis DISSOLVED hydrothermal tracer distributions to complement our real time transmissometer particle distribution data. Dynamic Hydrocast deployments were completed on 7 occasions in particular areas of interest at: the Azores Triple Junction overlapper, Lucky Strike, FAMOUS and AMAR. In total over 250 water column samples were taken, each for triplicate analysis at IFREMER and in associated laboratories (UBO-Brest and CEA-Saclay, France).

In addition to Dynamic Hydrocast deployments, vertical CTD profiles were also occupied at Menez Gwen and Lucky Strike for hydrothermal plume sampling, along with a series of ground-truthing CTD/nephelometer/ transmissometer deployments and ZAPS sled deployments to verify the presence of hydrothermal activity in new areas indicated by the transmissometer mounted on TOBI. CTD profiles at the southern end of the Lucky Strike segment and a combination of CTD and SLED profiles in the southern FAMOUS segments confirmed the presence of relatively weak hydrothermal plumes in both areas. This information was used to direct *in situ* filtration operations in both areas for combined shore based geochemical and microbiological analyses between IOSDL/U.Bristol and University College, Galway. At a third site of interest, an extremely strong hydrothermal plume signal was obtained in the southern portion of the AMAR segment, approximately 36 15N. Here, hydrothermal plume signals have been detected over a range of 4 to 5 miles which measure more than double those recorded previously by our same equipment at the TAG hydrothermal field, 26N MAR, in 1993 (CD77) and some 5 to 6 times greater than the Broken Spur and Snakepit plumes, 29 and 23N MAR (CD76, CD77).

Although we were not able to identify the exact source(s) of the southern AMAR venting during our preliminary 60 hours on station, a series of ten CTD/SLED lowerings have begun to demarcate where the plume does and does not flow. This data, combined with a completed 40 bottle Dynamic Hydrocast and three deployments each of 4 stand alone pump filtrations systems (each yielding 500-1000 litres worth of filtered hydrothermal plume particulates) should provide a valuable initial data set from which the true importance of this vent field can be established.

Because this newly discovered Southern AMAR site is located in a relatively hospitable region of the N.Atlantic, only 36 hours steaming from a convenient port (Ponta Delgada, Azores) it also offers - in combination with the shallower, less conventional hydrothermal fields at Lucky Strike and Menez Gwen - a strategically important site for future hydrothermal process studies.

CG

ACKNOWLEDGEMENTS

It is a great pleasure, on behalf of the entire scientific party, to express my thanks to Captain R. Bourne, the officers and crew of RRS *Charles Darwin* Cruise 89. We were indeed fortunate to sail with such an enthusiastic, helpful and resourceful team ... and the food was excellent too!

I would also like to pay particular tribute to the scientific support staff from RVS Barry who, as always, provided the excellent shipboard service which can too easily be taken for granted, but which fundamentally underpins all marine science.

RRS *Charles Darwin* Cruise 89 (HEAT) was supported by the NERC Community Research Programme "BRIDGE" and EC MAST-II Programme "MARFLUX/ATJ" (Contract No. MAST-MAS2 CT93 0070)

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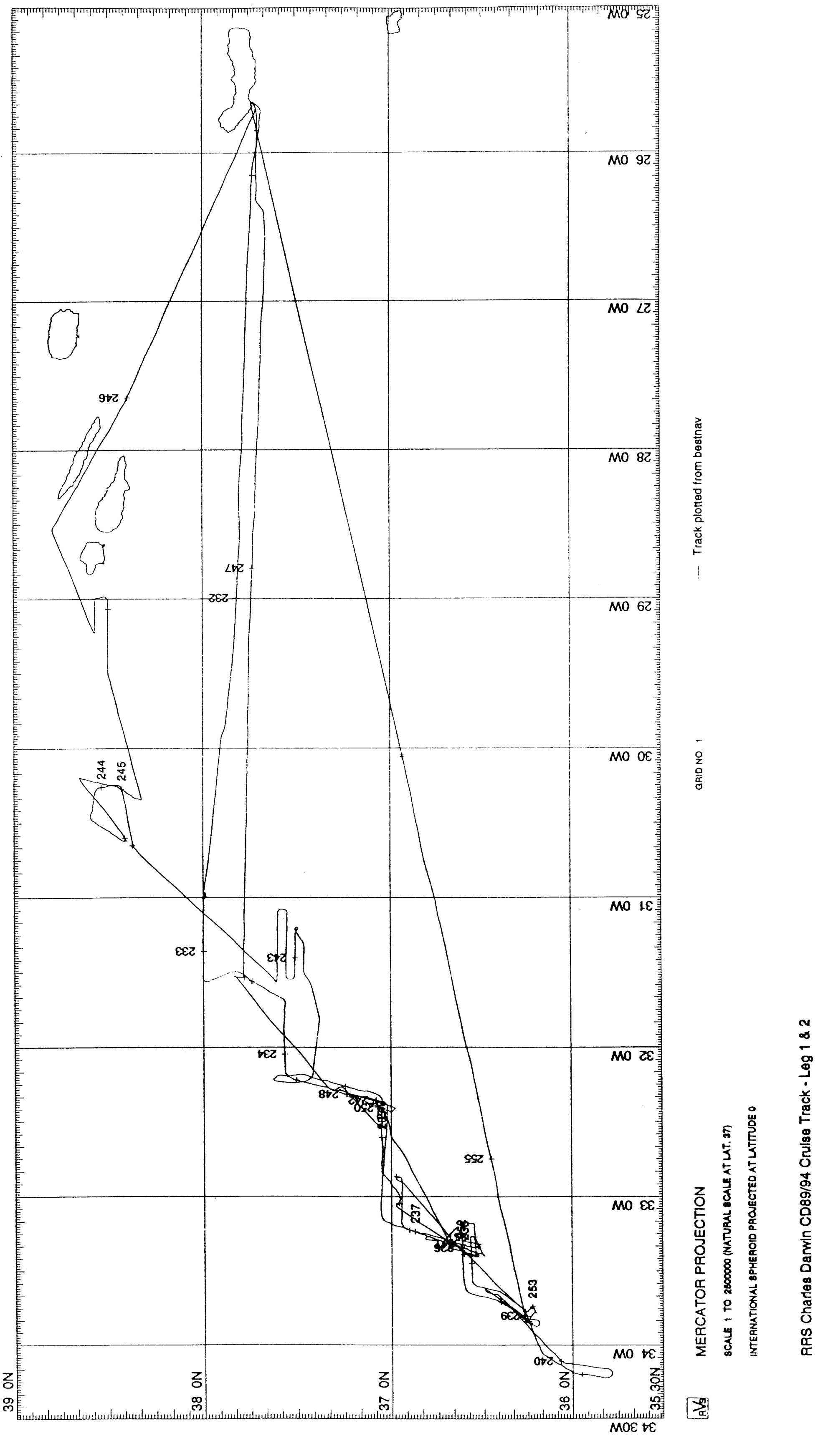

Fig.1: Track chart for RRS *Charles Darwin* Cruise 89, Leg 1&2, 19 Aug-13 Sep 1994. Principal work areas were along the Mid-Atlantic Ridge, 36-38°N. Julian days are numbered along track.

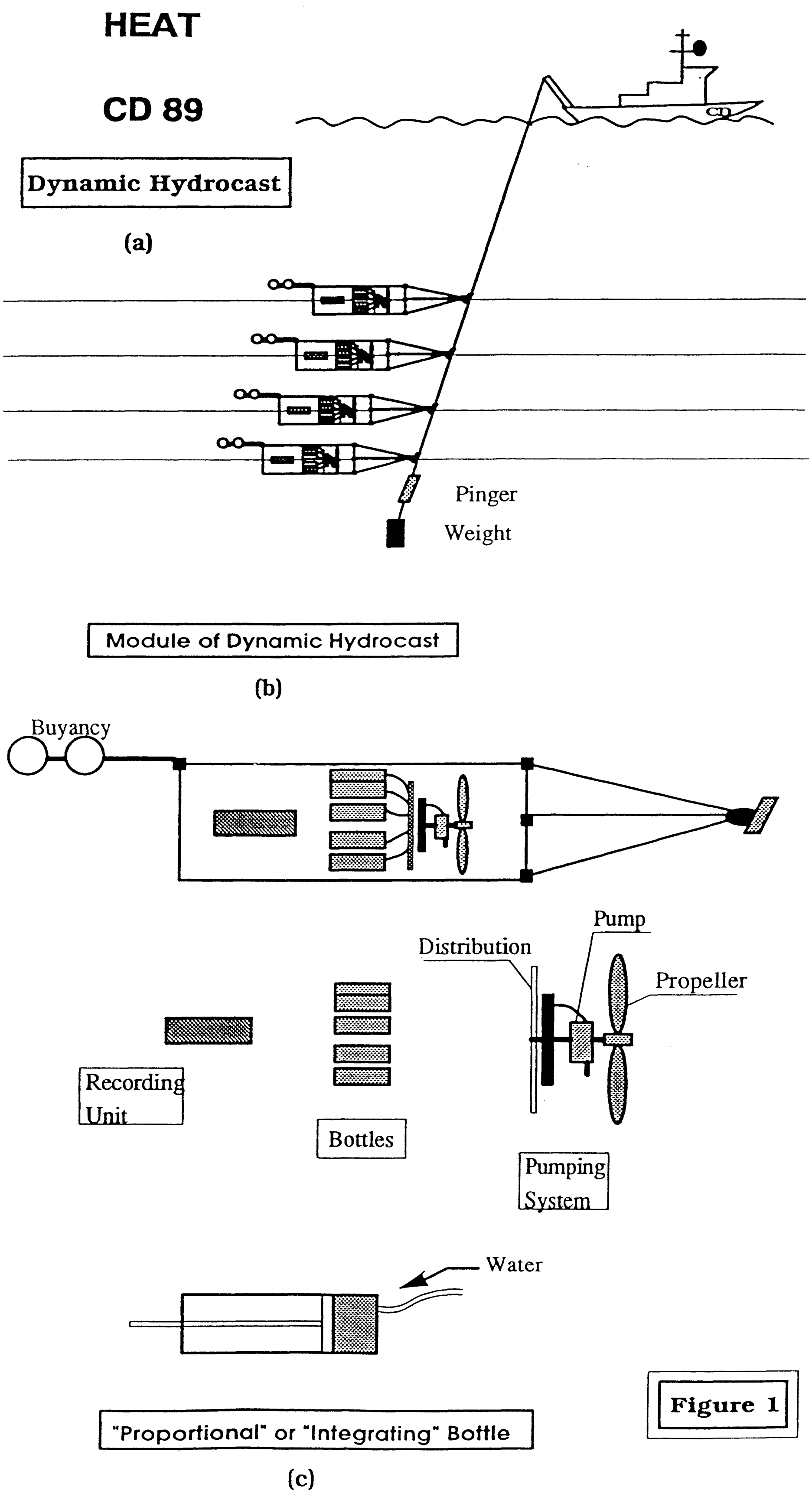

Fig.2: (IFREMER Figure 1) Schematic representation of the IFREMER Dynamic Hydrocast as deployed during RRS *Charles Darwin* Cruise 89: (a) full system; (b) individual module (detail); (c) individual "proportional/integrating" bottle (detail).

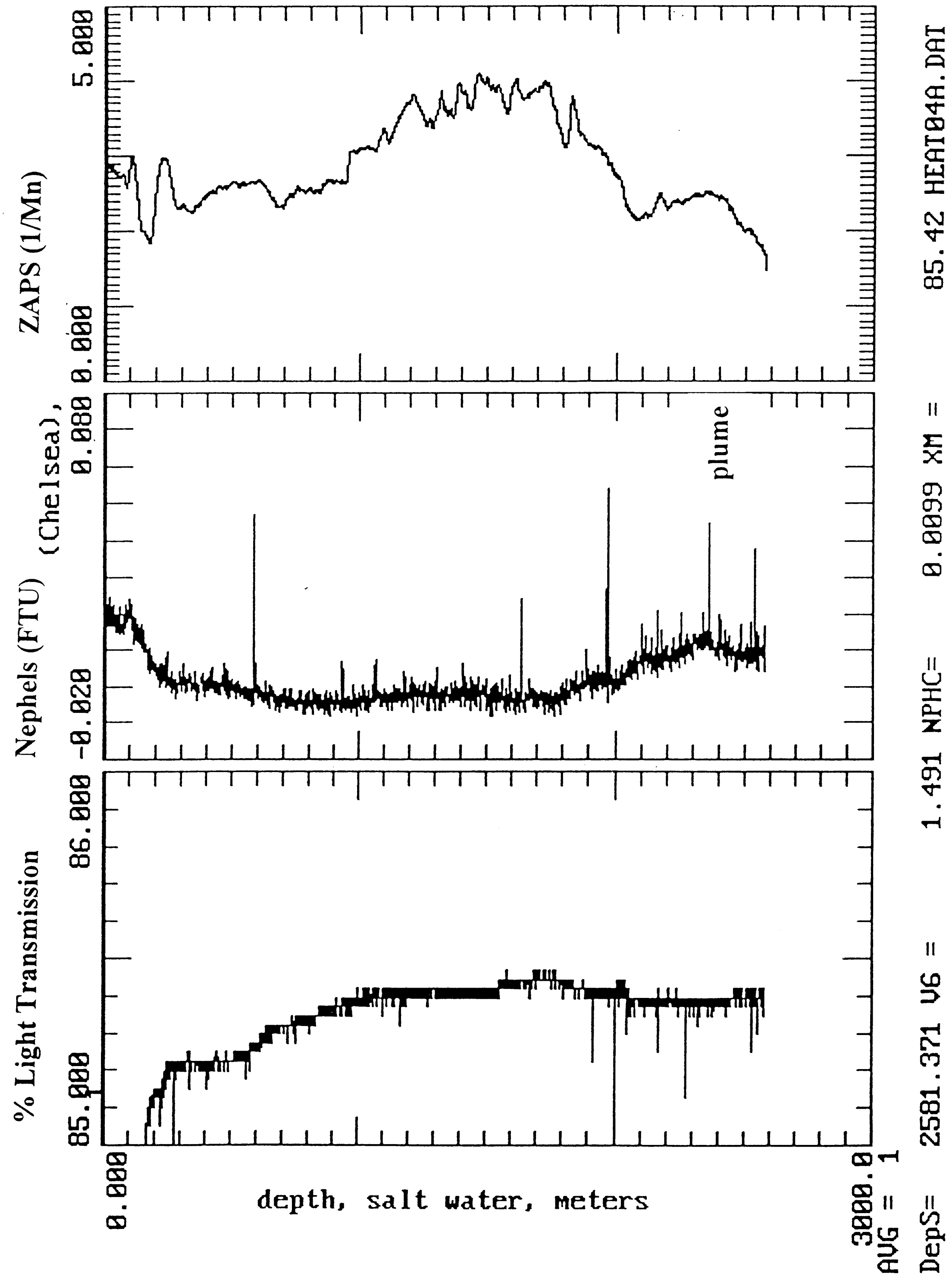

Fig.3: (ZAPS Fig.1) Vertical profiles of transmissometer, nephelometer and ZAPS Mn anomalies at ZAPS Sled station SL04: (FAMOUS at 36°34'N, 33°24'W).

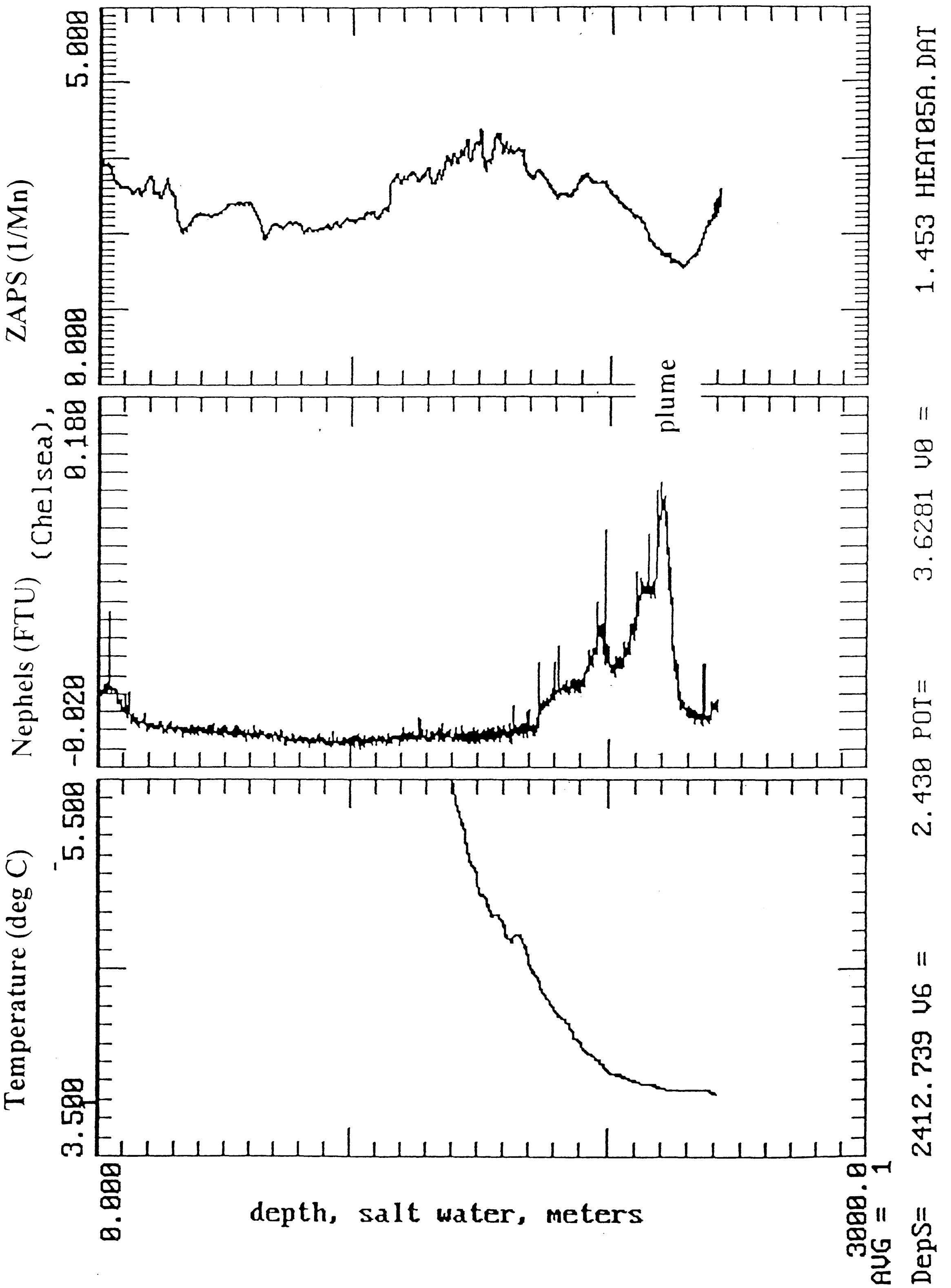

Fig.4: (ZAPS Fig.2) Vertical temperature, nephelometer and ZAPS Mn profiles at ZAPS Sled station SL05: (AMAR at 36°15'N, 33°50'W). Note change of scale (Nephels) from Fig.3 (ZAPS Fig.1).

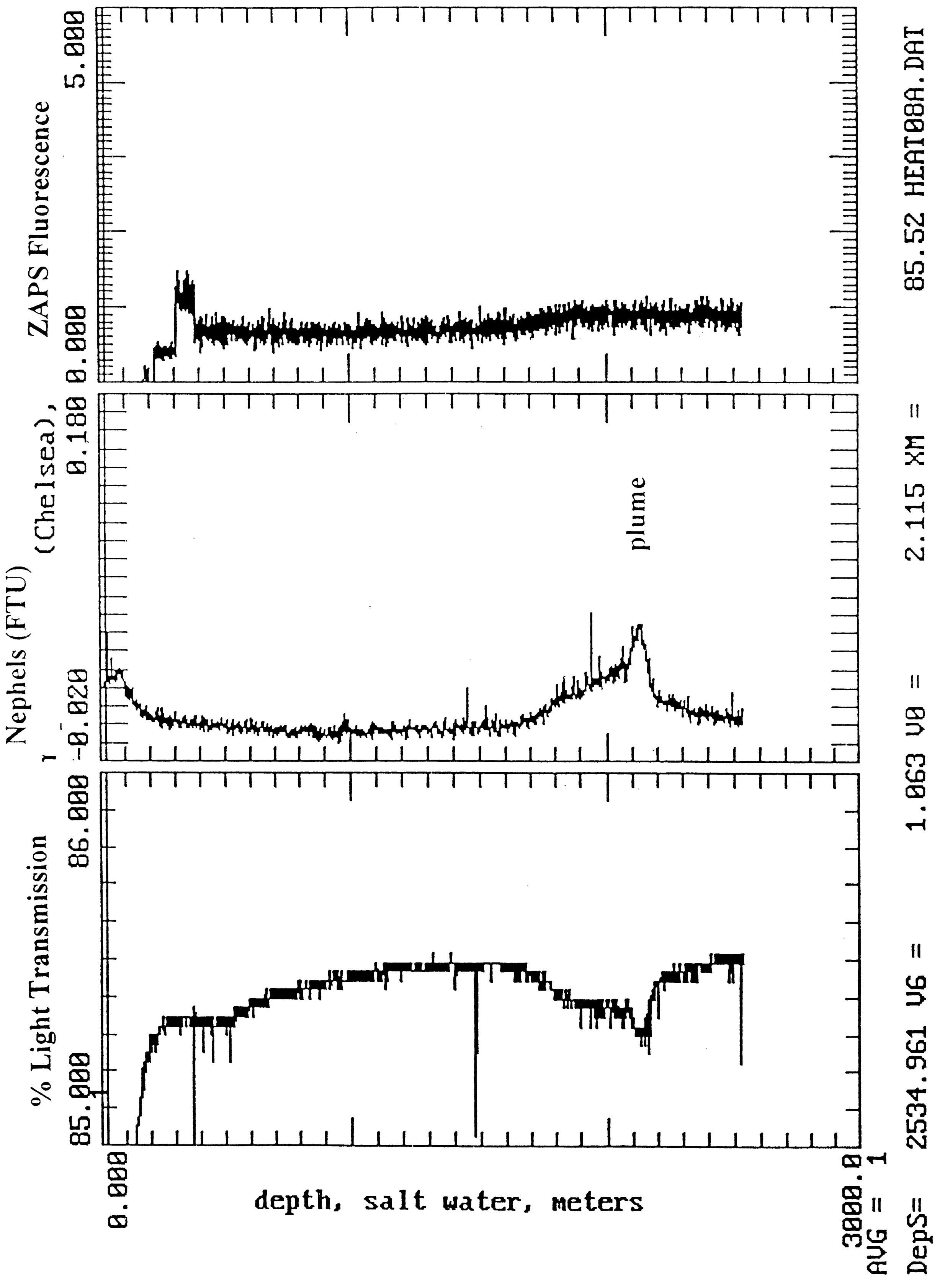

Fig.5: (ZAPS Fig.3) Vertical profiles of transmissometer, nephelometer and ZAPS Fluoresence anomalies at ZAPS Sled station SL08: (AMAR at 36°17'N, 33°48'W).

APPENDIX A

RRS CHARLES DARWIN: CRUISE 89 - DIARY OF EVENTS.

Leg 1

Friday 19th. August '94.
0830 - Pilot Onboard.
0831 - SBE, Commenced Singling up.
0833 - All Gone and Clear For'd and Aft.
0836 - Vessel Clear of Berth.
0838 - Pilot Disembarked.
0840 - Vessel Clear of Breakwater.
0854 - Full Away on Passage from Ponta Delgada, Sao Miguel, Azores.
0950 - 3.5 Khz. Fish Deployed.
1015 - 10 Khz. Fish Deployed.
1030 - Magnetometer Deployed (89-01).
1200 - Position Lat: 37 43.8 N. Long: 26 09.1 W.
2000 - Lat: 37 47.6 N. Long: 28 03.8 W. XBT No.1 Deployed (89-02).

Saturday 20th. August '94.
0854 - Lat: 38 00.1 N. Long: 31 00.3 W. Magnetometer Recovered.
0905 - Sound Velocity Probe Cast Deployed (89-03).
0918 - Lat: 38 00.1 N. Long: 31 00.6 W. XBT No.2 Deployed, (89-04).
1115 - Sound Velocity Probe Inboard.
1200 - Position Lat: 37 59.5 N. Long: 30 59.6 W.
1250 - Commenced Deploying TOBI.
1325 - Depressor Weight Connected, Commenced Streaming Cable.
1511 - TOBI Fully Deployed, Commencing TOBI Run No.1 (89-05).
2400 - Lat: 37 59.9 N. Long: 31 21.6 W. XBT No.3 Deployed (89-06).

Sunday 21st. August '94.
1200 - Position Lat: 37 44.5 N. Long: 31 33.5 W.
1210 - Lat: 37 44.1 N. Long: 31 33.9 W. XBT No.4 Deployed (89-07).
2348 - Lat: 37 34.0 N. Long: 32 02.3 W. XBT No.5 Deployed (89-08).

Monday 22nd. August '94.
1200 - Position Lat: 37 14.8 N. Long: 32 15.8 W.
1210 - Lat: 37 14.6 N. Long: 32 15.9 W. XBT No.6 Deployed (89-09).
2353 - Lat: 37 03.1 N. Long: 32 36.3 W. XBT No.7 Deployed (89-10).

Tuesday 23rd. August '94.
1036 - Lat: 36 57.4 N. Long: 32 59.6 W. Commenced Recovering TOBI.
1152 - Lat: 36 57.4 N. Long: 33 02.3 W. XBT No.8 Deployed (89-11).
1200 - Position Lat: 36 57.5 N. Long: 33 02.8 W.
1230 - Depressor Weight Onboard.
1254 - TOBI Onboard, Fully Recovered.
1601 - Lat: 36 40.4 N. Long: 33 19.0 W. CTD to 2700 m. (89-12).
1824 - Lat: 36 40.4 N. Long: 33 19.0 W. CTD inboard.
1946 - Lat: 36 31.8 N. Long: 33 23.4 W. Comm. Deploying Dynamic Hydrocast.
Piston Core Bomb, Pinger, and 4 Sampling Modules at 200 metre intervals on Main Coring Warp) (89-13).
2030 - Lat: 36 32.1 N. Long: 33 23.0 W. Complete Deployment, Comm Veering.
2353 - Lat: 36 37.3 N. Long: 33 20.8 W. XBT No. 9 Deployed (89-14).

Wednesday 24th. August '94.
0212 - Pinger Trace Lost on Dynamic Hydrocast; Commenced Hauling Cable.
0249 - Commenced Recovering Hydrocast Modules.
0334 - All Modules and Bomb Weight Inboard. Pinger Lost from Clamps.
0408 - Lat: 36 39.4 N. Long: 33 19.1 W. All Secure. Set Course 205 True.
0502 - CTD Deployed (89-15).
0621 - Lat: 36 38.1 N. Long: 33 20.5 W. CTD Deployed to 2934 metres.

0728 - CTD Inboard; Set Course 050 True.
1036 - Lat: 36 57.0 N. Long: 32 54.0 W.Commenced Deploying TOBI (89-16).
1048 - TOBI Recovered for adjustment.
1057 - TOBI Redeployed.
1124 - Depressor Weight Deployed, Commenced Veering Cable.
1200 - Position Lat: 36 58.4 N. Long: 32 52.0 W.
2352 - Lat: 36 52.5 N. Long: 33 14.0 W. XBT No. 10 Deployed (89-17).

Thursday 25th. August '94.
1110 - Lat: 36 33.1 N. Long: 33 20.7 W. Commenced Recovery of TOBI.
1200 - Position Lat: 36 31.9 N. Long: 33 20.1 W.
1209 - Lat: 36 31.5 N. Long: 33 19.8 W. XBT No. 11 Deployed (89-18).
1245 - TOBI Depressor Weight Inboard.
1305 - TOBI Vehicle fully Recovered.
1322 - All Secure; Set Course 007 True.
1512 - Lat: 36 48.8 N. Long: 33 16.4 W. Commenced Deploying Hydrocast.
1548 - Dynamic Hydrocast Fully Deployed (89-19).
1658 - Lat: 36 47.0 N. Long: 33 16.5 W. Commenced Run, 200 True, 2 Knots.
2350 - Lat: 36 36.8 N. Long: 33 20.9 W. XBT No. 12 Deployed (89-20).

Friday 26th. August '94.
0412 - Lat: 36 30.5 N. Long: 33 23.2 W. Comm. Hauling; Reduce to 0.5 K.
0513 - First Module Recovered.
0556 - Dynamic Hydrocast Fully Recovered.
0609 - Lat: 36 29.8 N. Long: 33 24.1 W. All Secure; Set Course 054 True.
0726 - Lat: 36 34.5 N. Long: 33 16.6 W. Comm. TOBI Deployment (89-21).
0759 - Depressor Weight Deployed; Commenced Veering Cable.
1200 - Position Lat: 36 34.2 N. Long: 33 27.1 W.
1222 - Lat: 36 34.1 N. Long: 33 28.4 W. XBT No. 13 Deployed (89-22).
2400 - Lat: 36 15.3 N. Long: 33 48.2 W. XBT No. 14 Deployed (89-23).

Saturday 27th. August '94.
1200 - Position Lat: 35 56.9 N. Long: 34 12.1 W. Continue TOBI Run.
1210 - Lat: 35 56.4 N. Long: 34 12.1 W. XBT No. 15 Deployed (Failed).
1220 - Lat: 35 55.9 N. Long: 34 12.1 W. XBT No. 16 Deployed (89-24).
1802 - Lat: 35 50.3 N. Long: 34 09.5 W. Two Oceanographic Surface Moorings Sighted; CPA 1.2 Miles to East.
2400 - Lat: 36 03.9 N. Long: 34 06.6 W. Course 046 True.

Sunday 28th. August '94.
0045 - Lat: 36 05.3 N. Long: 34 04.7 W. XBT No. 17 Deployed (89-25).
1150 - Lat: 36 23.8 N. Long: 33 43.0 W. XBT No. 18 Deployed (89-26).
1200 - Position Lat: 36 24.3 N. Long: 33 42.7 W.
2400 - Lat: 36 37.1 N. Long: 33 19.3 W. Towing TOBI Throughout.

Monday 29th. August '94.
0015 - Lat: 36 37.1 N. Long: 33 18.5 W. XBT No. 19 Deployed (89-27).
0040 - Commenced Hauling TOBI Cable.
0249 - Depressor Weight Inboard.
0308 - Lat: 36 38.1 N. Long: 33 12.6 W. TOBI Vehicle Recovered.
0330 - All Secure; Set Course 319 True.
0434 - Lat: 36 44.0 N. Long: 33 18.0 W. Hydrocast Weight Deployed.
0517 - Completed Deploying Hydrocast Modules (89-28), Veering Cable.
0552 - Lat: 36 45.2 N. Long: 33 17.3 W. Point 1, Course 020, Speed.1.5 k.
1150 - Lat: 36 53.9 N. Long: 33 13.5 W. XBT No. 20 Deployed (89-29).
1200 - Position Lat: 36 54.1 N. Long: 33 13.4 W.
1626 - Lat: 37 01.0 N. Long: 33 10.3 W. Last Waypoint, Commenced Hauling.
1725 - First Module Inboard.
1804 - Bomb Weight Inboard, Complete Recovery.
1824 - Lat: 37 03.2 N. Long: 33 07.8 W. All Secure, Set Co. 086, Full Speed.
2152 - Lat: 37 01.7 N. Long: 32 22.7 W. Comm. TOBI Deployment. (89-30).
2224 - Depressor Weight Deployed, Commenced Veering Cable.

2400 - Lat: 37 05.0 N. Long: 32 21.4 W.

Tuesday 30th. August '94.
0016 - Lat: 37 05.3 N. Long: 32 21.2 W. XBT No. 21 Deployed (89-31).
1145 - Lat: 37 29.7 N. Long: 32 13.5 W. XBT No. 22 Deployed (89-32).
1200 - Position Lat: 37 30.3 N. Long: 32 13.2 W.
1400 - Commenced Hauling Cable.
1524 - Depressor Weight Inboard.
1540 - Lat: 37 37.0 N. Long: 32 12.4 W. TOBI Inboard.
1608 - P.E.S. & 3.5 Khz. Fish Inboard; Commenced Deploying Magnetometer.
1619 - Magnetometer Streamed.
1747 - Lat: 37 24.9 N. Long: 32 10.0 W. Comm. Swath Bathymetry Survey.
2400 - Lat: 37 30.5 N. Long: 31 24.4 W.

Wednesday 31st. August '94.
0017 - Lat: 37 30.6 N. Long: 31 28.0 W. XBT No. 23 Deployed (89-33).
0557 - Lat: 37 36.4 N. Long: 31 33.8 W. Complete Swath Survey at 10 Kts. Alter Course 043 True, Full Speed.
1125 - Lat: 38 20.4 N. Long: 30 41.9 W. Commence Magnetometer Recovery.
1136 - Magnetometer Inboard.
1145 - P.E.S. and 3.5 Khz. Fish Deployed.
1157 - Lat: 38 22.2 N. Long: 30 39.2 W. XBT No. 24 Deployed (89-34).
1200 - Position Lat: 38 22.4 N. Long: 30 34.1 W. Vessel Hove To.
1211 - TOBI Vehicle Deployed (89-35).
1233 - Depressor Weight Deployed, Commenced Veering Cable.
1415 - Lat: 38 22.5 N. Long: 30 35.9 W. Waypoint A, Alter Course 079 T.

Thursday 1st. September '94.
0000 - Lat: 38 32.2 N. Long: 30 15.6 W. XBT No. 25 Deployed (89-36).
0004 - Lat: 38 32.4 N. Long: 30 15.7 W.
1000 - Lat: 38 26.3 N. Long: 30 36.4 W. Comm. Hauling TOBI Cable.
1121 - Lat: 38 24.2 N. Long: 30 37.3 W. Depressor Weight Inboard.
1140 - Lat: 38 23.9 N. Long: 30 37.3 W. TOBI Vehicle Recovered.
1155 - Lat: 38 24.1 N. Long: 30 37.6 W. All Secure, Set Course 054 True.
1156 - Lat: 38 24.3 N. Long: 30 36.9 W. XBT No. 26 Deployed (89-37).
1200 - Position Lat: 38 24.7 N. Long: 30 35.9 W.
1414 - Lat: 38 38.9 N. Long: 30 11.5 W. Commenced Deploying Hydrocast.
1450 - French Dynamic Hydrocast fully Deployed (89-38).
1530 - Lat: 38 37.5 N. Long: 30 12.2 W. Vessel Passing Waypoint 1.
2400 - Lat: 38 25.7 N. Long: 30 16.3 W.

Friday 2nd. September '94.
0345 - Lat: 38 21.2 N. Long: 30 20.2 W. WP 3, Commenced Hauling Cable.
0524 - Lat: 38 19.4 N. Long: 30 20.7 W. Complete Hydrocast Recovery.
0534 - 3.5 Khz. Fish Recovered.
0542 - P.E.S. Fish Recovered, Set Course 075 True, Full Speed.
0809 - Stop. Lub Oil Pump failed on Starboard ESL.
0845 - Full Speed, Resumed Passage.
0926 - Lat: 38 30.0 N. Long: 29 30.0 W. 8 Knots for Swath Survey.
1155 - Lat: 38 30.0 N. Long: 29 04.5 W. XBT Deployed, (Failed).
1200 - Lat: 38.30.0 N. Long: 29 04.0 W. XBT No.27 Deployed, (89-39).
1433 - Lat: 38 34.0 N. Long: 29 13.6 W. Increase to Full Speed.
1747 - Lat: 38 47.4 N. Long: 28 31.6 W. Alter Course 120 True, and Reduce to 8 Knots; Simrad Survey Sao Jorge Channel.
2000 - Lat: 38 38.9 N. Long: 28 13.4 W. Morro Grande Brg.011 x 1.73 m.
2352 - Lat: 38 24.1 N. Long: 27 40.2 W. Alter Course 114 True, and Increase to Full Speed, Simrad Survey Completed.

Saturday 3rd. September '94.
0900 - SBE, Approaching Ponta Delgada.
0909 - Engine Tested Astern, Bow Thrust Tested.
0922 - Pilot Embarked. 0931 - Vessel Entering Harbour.

0940 - Let go Starboard anchor in Ponta Delgada Harbour.
1000 - Launch Alongside with new personnel.
1050 - Complete transfering personnel and loading provisions.
1056 - Anchor Aweigh. 1101 - Pilot Disembarked.
1112 - Full Away on Passage for Second Leg of Cruise CD89/94.
1200 - Position Lat: 37 42.2 N. Long: 25 51.2 W.
1500 - Lat: 37 39.5 N. Long: 26 34.2 W. Course 272 True, Running Parallel Track to Outward Track of CD 89/94, Leg 1.
2400 - Lat: 37 44.0 N. Long: 28 47.7 W.

Sunday 4th. September '94.
1130 - Lat: 37 47.2 N. Long: 31 31.8 W. P.E.S. and 3.5 Khz. Deployed.
1136 - 1243 - Lat: 37 47.1 N. Long: 31 31.8 W. CTD Deployed,(89-40).
1342 - 1440 - 37 50.4 N. 31 31.4 W. CTD Deployed to 975 m., (89-41).
1502 - 1510 - CTD Deployed, Faulty, Re-terminating Conducting Cable.
1952 - Lat: 37 19.5 N. Long: 32 17.0 W. Commenced Deploying Hydrocast.
2034 - French Dynamic Hydrocast Fully Deployed, (89-42).
2400 - Lat: 37 14.3 N. Long: 32 19.0 W.

Monday 5th. September '94.
0900 - Lat: 37 01.6 N. Long: 32 25.3 W. Commence Recovering Hydrocast.
1026 - Lat: 36 59.8 N. Long: 32 26.2 W. Upper Module on Deck.
1112 - Lat: 36 59.2 N. Long: 32 25.2 W. Hydrocast Fully Recovered.
1128 - Aft Deck Secure; Set Course 018 True.
1200 - Position Lat: 37 02.8 N. Long: 32 22.6 W.
1213 - Lat: 37 05.2 N. Long: 32 21.7 W. XBT No. 28 Deployed, (89-43).
1333 - 1450 - Lat: 37 17.2 N. Long: 32 16.5 W. CTD Deployed, (89-44). 1511 - 1628 - Lat: 37 17.5 N. Long: 32 16.7 W. CTD Deployed, (89-45).
2007 - Lat: 37 02.9 N. Long: 32 31.9 W. Gravity Corer Deployed,(89-46).
2144 - Lat: 37 03.0 N. Long: 32 31.0 W. Pull-out at 3058 metres.
2252 - Lat: 37 03.0 N. Long: 32 30.4 W. Gravity Corer Recovered.
2400 - Lat: 37 03.3 N. Long: 32 32.7 W.

Tuesday 6th. September '94.
0020 - 0234 - Lat: 37 03.0 N. Long: 32 31.7 W. CTD Deployed to 2974 metres (89-47).
0330 - 0534 - Lat: 37 02.7 N. Long: 32 25.0 W. CTD Deployed to 2821 metres (89-48).
0731 - Lat: 37 06.8 N. Long: 32 22.5 W. ZAP Sledge Deployed, (89-49).
1008 - Lat: 37 06.8 N. Long: 32 22.5 W. ZAP Sledge at 2900 metres.
1139 - Lat: 37 06.4 N. Long: 32 22.3 W. ZAP Sledge Inboard.
1200 - Position Lat: 37 05.7 N. Long: 32 22.5 W.
1249 - Lat: 37 02.7 N. Long: 32 24.4 W. Comm. Deploying SAPS, (89-50).
1300 - 1342 - Suspend Deployment, Winch Failure.
1500 - Lat: 37 03.0 N. Long: 32 24.6 W. 4th. SAPs Pump Deployed.
1715 - Lat: 37 02.96 N. Long: 32 24.69 W. Pumping Commences.
1915 - Lat: 37 02.93 N. Long: 32 24.61 W. Pumping Ceases.
1925 - Lat: 37 03.0 N. Long: 32 24.9 W. Commenced Hauling.
2039 - Lat: 37 02.4 N. Long: 32 26.4 W. SAP No.4 Inboard.
2124 - Lat: 37 02.1 N. Long: 32 26.8 W. Complete SAPs Recovery.
2256 - Lat: 37 03.0 N. Long: 32 24.7 W. Commenced Deploying CTD plus Multisampler, (89-51).
2400 - Lat: 37 03.0 N. Long: 32 24.5 W.

Wednesday 7th. September '94.
0110 - Lat: 37 02.8 N. Long: 32 25.0 W. Vessel Re-Positioned.
0730 - Lat: 37 02.6 N. Long: 32 25.1 W. CTD/Multisampler Inboard.
0752 - Lat: 37 02.3 N. Long: 32 26.2 W. All Secure, Set Course 244 True.
1148 - Lat: 36 42.6 N. Long: 33 15.9 W. XBT No. 29 Deployed, (89-52).
1200 - Position Lat: 36 41.6 N. Long: 33 18.3 W.
1216 - Lat: 36 41.0 N. Long: 33 19.6 W. Commenced Deploying Hydrocast.
1254 - French Dynamic Hydrocast Fully Deployed, (89-53).

1341 - Lat: 36 40.2 N. Long: 33 21.1 W. Vessel Passing Point 1.
2400 - Lat: 36 33.0 N. Long: 33 16.3 W.

Thursday 8th. September '94.
0150 - Lat: 36 33.1 N. Long: 33 12.5 W. Vessel at final WayPoint.
0321 - Lat: 36 34.7 N. Long: 33 10.8 W. First Module Inboard.
0355 - Lat: 36 35.8 N. Long: 33 10.6 W. Complete Recovering Hydrocast.
0433 - All Secure, Set Course 297 True, at Full Speed.
0526 - Lat: 36 39.5 N. Long: 33 18.1 W. Vessel Hove To on Station.
0540 - Lat: 36 39.5 N. Long: 33 18.1 W. ZAP Sledge Deployed, (89-54).
0815 - Lat: 36 39.5 N. Long: 33 18.2 W. 2500 metres, Commenced Hauling.
0911 - Lat: 36 39.4 N. Long: 33 18.5 W. ZAP Sledge Inboard.
1007 - Lat: 36 36.4 N. Long: 33 23.1 W. Vessel Hove To on Station.
1010 - Lat: 36 36.4 N. Long: 33 23.1 W. ZAP Sledge Deployed, (89-55).
1200 - Position Lat: 36 36.6 N. Long: 33 23.4 W.
1316 - Lat: 36 36.5 N. Long: 33 23.6 W. ZAP Sledge InBoard.
1357 - Lat: 36 33.9 N. Long: 33 24.4 W. ZAP Sledge Deployed, (89-56).
1640 - Lat: 36 34.0 N. Long: 33 24.2 W. ZAP Sledge Inboard.
1734 - Lat: 36 38.0 N. Long: 33 20.5 W. Vessel Hove To on Station.
1740 - Core Bomb Weight Deployed, Commenced Deploying Stand-Alone-Pumps.
1845 - Lat: 36 38.1 N. Long: 33 20.6 W. 4th. SAP Outboard, (89-57).
1940 - Ceased Veering Cable at 2850 metres.
2045 - Lat: 36 37.99 N. Long: 33 20.50 W. Commenced Pumping.
2251 - Lat: 36 37.96 N. Long: 33 20.27 W. Completed Pumping, Comm. Haul.
2346 - Lat: 36 37.7 N. Long: 33 20.3 W. SAP No.4 Inboard.

Friday 9th. September '94.
0043 - Lat: 36 37.6 N. Long: 33 20.6 W. Core Bomb Weight Inboard.
0102 - All Secure, Set Course 223 True, Full Speed.
0345 - Lat: 36 16.5 N. Long: 33 45.5 W. Vessel Hove To on Station.
0410 - Lat: 36 16.4 N. Long: 33 45.6 W. CTD Deployed, (89-58).
0457 - Lat: 36 16.4 N. Long: 33 45.6 W. CTD Veered to 2518 metres.
0557 - Lat: 36 16.5 N. Long: 33 45.6 W. CTD Inboard.
0602 - All Secure, Set Course 245 True, Full Speed.
0647 - Lat: 36 14.7 N. Long: 33 50.4 W. Vessel Hove To on Station.
0704 - Lat: 36 14.7 N. Long: 33 50.3 W. CTD Deployed, (89-59).
0758 - Lat: 36 14.7 N. Long: 33 50.3 W. CTD Veered to 2496 metres.
0859 - Lat: 36 14.7 N. Long: 33 50.3 W. CTD Inboard.
0932 - Core Bomb Weight Deployed, Commenced Deploying Stand-Alone-Pumps.
1026 - Lat: 36 14.8 N. Long: 33 50.3 W. 4th. SAP Outboard, (89-60).
1121 - Ceased Veering Cable at 2450 metres.
1130 - Lat: 36 14.7 N. Long: 33 50.2 W. Commenced Pumping.
1330 - Lat: 36 14.6 N. Long: 33 50.9 W. Completed Pumping, Comm. Haul.
1441 - Lat: 36 14.3 N. Long: 33 50.9 W. SAP No.4 Inboard.
1524 - Lat: 36 13.9 N. Long: 33 51.6 W. Core Bomb Weight Inboard.
1534 - All Secure, Set Course 057 True, Full Speed.
1623 - Lat: 36 14.5 N. Long: 33 50.3 W. ZAP Sledge Deployed, (89-61).
1742 - Lat: 36 14.7 N. Long: 33 50.2 W. ZAP Sledge Veered to 2442 metres.
1748 - Lat: 36 14.8 N. Long: 33 50.4 W. Commenced Co. 331 True at 1 Knot.
1834 - Lat: 36 15.1 N. Long: 33 50.7 W. Station Aborted, Commenced Hauling.
1934 - Lat: 36 15.4 N. Long: 33 50.5 W. ZAP Sledge Inboard.
1940 - All Secure, Set Course 138 True, Full Speed.
2028 - Lat: 36 12.3 N. Long: 33 46.8 W. Vessel Hove to on Station.
2035 - Lat: 36 12.2 N. Long: 33 46.8 W. ZAP Sledge Deployed, (89-62).
2148 - Lat: 36 12.2 N. Long: 33 46.8 W. ZAP Sledge Veered to 2540 metres.
2235 - Lat: 36 12.1 N. Long: 33 46.7 W. ZAP Sledge Inboard.
2245 - All Secure, Set Course 060 True, Full Speed.
2327 - Lat: 36 13.4 N. Long: 33 44.4 W. ZAP Sledge Deployed, (89-63).

Saturday 10th. September '94.
0049 - Lat: 36 13.4 N. Long: 33 44.4 W. Zap Sledge Veered to 2480 metres.
0137 - Lat: 36 13.4 N. Long: 33 44.3 W. ZAP Sledge Inboard. Set Course 318 True, Full Speed for Next Station.

0223 - Lat: 36 17.3 N. Long: 33 48.4 W. ZAP Sledge Deployed, (89-64).
0320 - Lat: 36 17.3 N. Long: 33 48.6 W ZAP Sledge Veered to 2550 metres.
0410 - Lat: 36 17.4 N. Long: 33 48.7 W. ZAP Sledge Inboard.
0424 - All Secure, Set Course 204 True.
0455 - Lat: 36 14.9 N. Long: 33 49.9 W. Vessel Hove To on Station.
0458 - Core Bomb Weight Deployed, Commenced Deploying Stand-Alone-Pumps.
0544 - Lat: 36 14.7 N. Long: 33 50.2 W. 4th. SAP Deployed, (89-65).
0630 - Lat: 36 14.7 N. Long: 33 50.3 W. Cable Veered to 2450 metres.
0700 - Lat: 36 14.7 N. Long: 33 50.3 W. Commenced Pumping.
0900 - Lat: 36 14.7 N. Long: 33 50.2 W. Ceased Pumping.
0907 - Lat: 36 14.7 N. Long: 33 50.3 W. Commenced Hauling.
1000 - Lat: 36 14.6 N. Long: 33 50.4 W. SAP No.4 Inboard.
1046 - Lat: 36 14.6 N. Long: 33 49.9 W. Core Bomb Weight Inboard.
1056 - All Secure, Set Course 033 True, Full Speed.
1142 - Lat: 36 20.2 N. Long: 33 44.9 W. XBT No. 30 Deployed, (89-66).
1200 - Position Lat: 36 23.2 N. Long: 33 42.8 W.
1247 - Lat: 36 29.4 N. Long: 33 37.9 W. Commenced Deploying Hydrocast.
1318 - French Dynamic Hydrocast Fully Deployed, (89-67).
1446 - Lat: 36 27.6 N. Long: 33 39.2 W. Vessel at Point 1.
2400 - Lat: 36 16.0 N. Long: 33 49.4 W. Course 180 True, Speed 1.5 Knots.

Sunday 11th. September '94.
0231 - Lat: 36 12.0 N. Long: 33 49.6 W. Complete Lines, Commenced Recovery.
0344 - Lat: 36 11.1 N. Long: 33 51.2 W. Module No. 4 Inboard.
0414 - Lat: 36 11.3 N. Long: 33 52.0 W. Complete Hydrocast Recovery.
0447 - All Secure, Set Course 010 True, Full Speed.
0527 - Lat: 36 16.0 N. Long: 33 51.4 W. Vessel Hove To on Station.
0545 - Lat: 36 16.0 N. Long: 33 51.4 W. CTD Deployed, (89-68).
0643 - Lat: 36 16.0 N. Long: 33 51.5 W. CTD Veered to 2492 metres.
0651 - Lat: 36 16.0 N. Long: 33 51.5 W. CTD Veered to 2483 metres.
0754 - Lat: 36 15.9 N. Long: 33 51.4 W. CTD Inboard. Set Course 102 True.
0822 - Lat: 36 15.8 N. Long: 33 50.3 W. Vessel Hove To on Station.
0824 - Lat: 36 15.8 N. Long: 33 50.4 W. ZAP Sledge Deployed, (89-69).
0926 - Lat: 36 15.8 N. Long: 33 50.5 W. ZAP Sledge Veered to 2450 metres.
1012 - Lat: 36 15.8 N. Long: 33 50.5 W. ZAP Sledge Inboard.
1016 - All Secure, Set Course 090 True, Full Speed.
1100 - Lat: 36 15.7 N. Long: 33 46.2 W. Vessel Hove To on Station.
1102 - Lat: 36 15.7 N. Long: 33 46.2 W. ZAP Sledge Deployed, (89-70).
1200 - Lat: 36 15.8 N. Long: 33 46.2 W. ZAP Sledge Veered to 2608 metres.
1249 - Lat: 36 15.8 N. Long: 33 46.2 W. ZAP Sledge Inboard, Set Co. 038.T.
1307 - Lat: 36 16.4 N. Long: 33 45.3 W. Vessel Hove To on Station.
1312 - Core Bomb Weight Deployed, Commenced Deploying Stand-Alone-Pumps.
1351 - Lat: 36 16.4 N. Long: 33 45.6 W. Complete Deploying SAPS,(89-71).
1515 - Lat: 36 16.4 N. Long: 33 45.6 W. Commenced Pumping.
1715 - Lat: 36 16.4 N. Long: 33 45.6 W. Ceased Pumping.
1823 - Lat: 36 16.5 N. Long: 33 46.2 W. 4th. SAP Inboard.
1852 - Lat: 36 16.7 N. Long: 33 46.3 W. Complete Recovering SAPS.
1924 - All Secure, Set Course 078 True, Full Speed, for Ponta Delgada.

Monday 12th. September '94.
1142 - Lat: 36 55.2 N. Long: 30 07.7 W. XBT No. 31 Deployed, (89-72).
1200 - Position Lat: 36 56.0 N. Long: 30 03.0 W.

Tuesday 13th. September '94.
0748 - EOP, Approaching Ponta Delgada.
0800 - Pilot Boarded. 0808 - Vessel Rounding Breakwater.
0824 - First Lines Ashore. 0826 - Vessel in Position Alongside.
0830 - FWE. 0833 - Vessel Securely Moored, 4 + 2, Stb'd. Side To.

End of Cruise

(R.A.Bourne. Master.)

APPENDIX B

TOBI: Brief Technical Specification.

Mechanical

Towing method	Two bodied tow system using neutrally buoyant vehicle and 600kg depressor weight.
Size	4.5m x 1.5m x 1.5m (lxhxw).
Weight	2000kg in air.

Sonar Systems

Sidescan Sonar	
Frequency	30.37kHz (starboard) 32.15kHz (port).
Pulse Length	2.8ms.
Ouput Power	600W each side.
Range	3000km each side.
Beam Pattern	0.8 x 45 degree fan.
Profiler Sonar	
Frequency	7.5kHz.
Pulse Length	0.26ms.
Output Power	500W.
Range	Up to 70m penetration over soft sediment.
Beam Pattern	25 degree cone.

Instrumentation

Magnetometer	Tri-axial fluxgate magnetometer.
Resolution	X and Y axes10nT. Z axis 15nT.
Temperature	Thermistor sensor.
Range	1 - 22 degrees Celcius.
Heading	Magnetic card compass.
Resolution	0.3 degrees.
Transmissometer	25cm path length 670nm transmissometer.
Pitch/Roll	Dual Axis Inclinometer.
Range	+/- 20 degrees.
Resolution	0.2 degrees.
Speed	Impeller log.
Depth	Strain gauge pressure transducer.
Range	0 - 6000m.
Resolution	1m.
Accuracy	1% of reading.

HEAT cruise
CD 89
Aug. 19 th - Sept. 13th 1994

Appendix C - Dynamic Hydrocasts

	starts		ends		Gear Point		Point1		Point 2		Point 3		Point 4	
DH #	date	time	date	time	Lat	Long	Lat	Long	Lat	Long	Lat	Long	Lat	Long
DH 1 South FAMOUS	23/8/94	19:44	24/8/94	3:34			36°33.5	33°22.2	36°41.0	33°19.35	36°47.0	33°16.60		
DH 2 South FAMOUS	25/8/94	15:08	26/8/94	5:55	36°48.15	33°16.1	36°47.0	33°16.60	36°41.0	33°19.35	33°33.5	33°22.2		
DH 3 North FAMOUS	29/8/94	4:37	29/8/94	17:55	36°44.3	33°17.8	36°45.2	33°17.4	37°01.0	33°10.4				
DH 4 South ATJ	1/9/94	14:10	2/9/94	5:18	38°38.20	30°12.10	38°37.55	33°17.4	38°26.65	30°15.50	38°21.20	30°20.30		
DH 5 South Lucky Strike	4/9/94	19:50	5/9/94	11:05	37°18.90	32°17.30	37°19.50	32°17.48	37°12.75	32°19.50	37°01.90	32°25.22		
DH 6 Basin South FAMOUS	7/9/94	12:16	8/9/94	3:49	36°41.02	33°20.72	36°40.20	33°21.00	36°32.40	33°23.97	36°32.78	33°15.30	36°33.10	33°12.50
DH 7 AMAR	10/9/94	12:47	11/9/94	4:47	36°28.70	33°38.90	36°27.55	33°39.20	36°25.15	33°39.20	36°16.15	33°49.50	36°12.00	33°49.50

** Gear Point: the four modules deployed*

Charles Darwin-CD 89 Date 6/9/94 Station No. 89-50

Water Depth 2830M Lat 37°02.98'N Long 32°24.69'W

Weak plume @1900m-1650m Max @~1875m

	SAPS 1 Bottom	SAPS 2	SAPS 3	SAPS 4 Top
Ave pump depth	1880M	1830M	1780M	1730M
Vol Pumped	1137L	993L	1228L	979L

Neph Data: CD89-48 CTD08
Pump 1: V pale, light covering of brown dust
Pump 2: V pale, light cover of v small visible black brown part.
Pump 3: Biege, ~20 visible black/brown part, light cover of v small brown part.
Pump 4: V pale, ~20 visible black/brown part.

Charles Darwin-CD 89 Date 8/9/94 Station No. 89-57

Water Depth 3047M Lat 36°37.99'N Long 33°20.42'W

V weak plume @2440m-1950mm Max @~2300m

	SAPS 1 Bottom	SAPS 2	SAPS 3	SAPS 4 Top
Ave pump depth	2567M		2267M	
Vol Pumped	1019L		1214L	

Neph Data: CD89 CTD02
Pump 1&3 for Th & TM
Pump 2&4 cellulose filters for microbiology
Pump 1: Beige, covering of brown dust, v few visible black particles
Pump 3: Pale beige, light covering of brown dust, few visible black particles

Charles Darwin-CD 89 Date 9/9/94 Station No. 89-60

Water Depth 2591M Lat 36°14.72'N Long 33°50.30'W

V strong plume @2250m-1700m Max @~2050m

	SAPS 1 Bottom	SAPS 2	SAPS 3	SAPS 4 Top
Ave pump depth	2120M	2070M	2020M	1520M
Vol Pumped	850L	669L	705L	1186L

Neph Data: CD89 CTD11
Pump 1:Beige, covering of brown dust, no visible particles
Pump 2:Beige, covering of brown dust, no visible particles
Pump 3: Biege, covering of brown/red dust, v few v small grey/black particles
Pump 4: V pale(B/G), few visible grey/brown particles
NB.Filter 3 had 1x5mm black particle

Charles Darwin-CD 89 Date 11/9/94 Station No. 89-71

Water Depth 3559M Lat 36°16.42'N Long 33°45.56'W

Strong plume @2525m-1600mm Max @~2100m

	SAPS 1 Bottom	SAPS 2	SAPS 3	SAPS 4 Top
Ave pump depth	2024M	1974M	1924M	1874M
Vol Pumped	727L	731L	1142L	934L

Neph Data: CD89 CTD10
Pump 1: Beige, v light covering of grey/black dust, 1 visible black particle
Pump 2: V pale beige, no visible particles
Pump 3: Pale beige, no visible particles
Pump 4: Pale beige, v few visible grey/brown particles

Appendix E - Core GC01

Station No:	89-46
Core No:	GC 1
Date:	5/9/94
Water Depth:	2957

		Ships Position	
	Time	Long (°N)	Lat (°W)
Core On Bottom	1:22	37° 2.98'	32° 31.71'

Wire In At: 35m/min

Extra Pay-Out: 25m

Sample Description:

Approximately 1m of dark tan carbonate ooze.

Top 4cm in liner disturbed (Colin Day's packing!!!)

Core bomb entered sediment too - definitely no core-top recovered.

Rocky fragments recovered from top of core barrel (not bomb).

Sediment right up out of top of core-bomb, no guess of true core-top position.