**NOAA Technical Memorandum NOS OCRM 3**

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# US CRUISE REPORT FOR BIE II

## APRIL 10 - MAY 29, 1992

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## Introduction

The Benthic Impact Experiment (BIE) is designed to simulate the environmental effects of sediment resuspension by deep seabed mining operations and to assess the environmental impact of sediment redeposition on the deep-sea benthos. The ecological effects of sediment redeposition on the deep-sea benthos is hypothesized to be a consequence of sediment burial or food resource dilution. The Benthic Impact Experiment (BIE) attempts to address the effects of these potential environmental problems before commercial mining commences on the abyssal plane.

In this study, a large area of the deep-sea floor is being blanketed with sediment in a manner simulating deep-sea manganese-nodule mining activity. The response of the deep-sea benthic community to different levels of sediment burial will then be monitored both spatially and temporally. The results of this research effort will be used by NOAA to evaluate the terms, conditions and restrictions for commercial permitting by the deep seabed mining consortia so that mining can proceed in a environmentally sound manner.

## Cruise Goals and Objectives

The main goal of the 1992 BIE cruise was to create a sediment redeposition impact on the benthic community at the BIE study site located in the Pacific Ocean at 13° 00′ N and 128° 22′ W. Immediately following sediment redeposition an effort was made to map the extent of the sediment redeposition in the study site. Additionally, samples were taken to assess the short term effects of sediment redeposition on the bacteria and meiofaunal communities. Russian scientists also processed core samples to assess the effects of sediment redeposition on sediment pore water chemistry.

Our primary objectives on the 1992 BIE cruise were as follows:

A) Test the Deep Sea Sediment Resuspension System and newly purchased multicorer at the Patton Escarpment test site off Long Beach, California;

B) Collect four baseline box core samples to fill in gaps in our pre-impact sample coverage;

C) Recover and redeploy two Aanderaa current meters and deploy a sediment-trap array within the study area;

D) Create a large-scale redeposition event by towing the Deep Sea Sediment Resuspension System (DSSRS) through a 400-m-x-2200-m polygon;

E) Map the resedimentation plume using CTD casts, sediment-traps and multicore samples;

F) Collect short-term post-disturbance samples to assess microbiological and meiofaunal impacts using a multicorer;

G) Deploy 8 current meter moorings to obtain more detailed information about the deep ocean currents in the BIE study area.

The remainder of this report details the results of each of these six objectives.

## Cruise Summary

### A. Test Cruise

The ship departed Long Beach, California on schedule at 1930 on 10 April arriving at the Patton Escarpment test site, 31° 30′ N and 128° 14′ W, at 0930 on 11 April. Immediately after arriving at the test site the new multicorer was tested by taking three consecutive samples. All three multicore deployments were successful and the samples collected will be used to supplement data collected last year at this site where a phytodetritus deposition event was observed. The bottom positions of the multicores were determined using the ship's GPS surface position. Immediately after multicoring, testing of the Deep Sea Sediment Resuspension System (DSSRS) commenced on 12 April. From 12 to 13 April we completed two DSSRS tows and encountered a number of problems. The first problem was the failure of both pressure sensors. They appear to have been damaged when the DSSRS was shipped from Seattle to Long Beach. It is not known how the sensors were damaged and since there were no replacement sensors we carried out DSSRS operations on this cruise without them. The second DSSRS problem encountered on the test cruise was the collapse of the new optical backscatter sensor cable under pressure (≈ 1000 m depth). This was subsequently fixed in transit to the BIE study site. Otherwise, all other systems on the DSSRS functioned properly on the test cruise.

### B. Baseline Sampling

In August of 1991 nine 0.25-$m^2$ UNSEL-type box cores were collected serving as baseline samples of the benthic community at the BIE study site. These samples were collected at random from within a 1.6 $nm^2$ area centered in the BIE study area. After looking at the positioning of these samples it was felt that some areas were not adequately sampled. Therefore, on this cruise we collected 4 additional box core samples, two open and two with vegematic inserts, to supplement the nine box core samples collected in August of 1991. The box core samples were collected at night from 17 April to 21 April. The four samples collected on this cruise were chosen at random using the same 1.6 $nm^2$ area as on the 1991 BIE cruise. Ship handling problems resulted in the first box core sample being taken well north of where we had originally planed. The three subsequent box cores were within an acceptable distance from the planned sampling location.

For a more detailed description of the box coring results and methods see Appendix 1.

## C. Pre-disturbance Current Meter Recovery and Sediment Trap Deployment

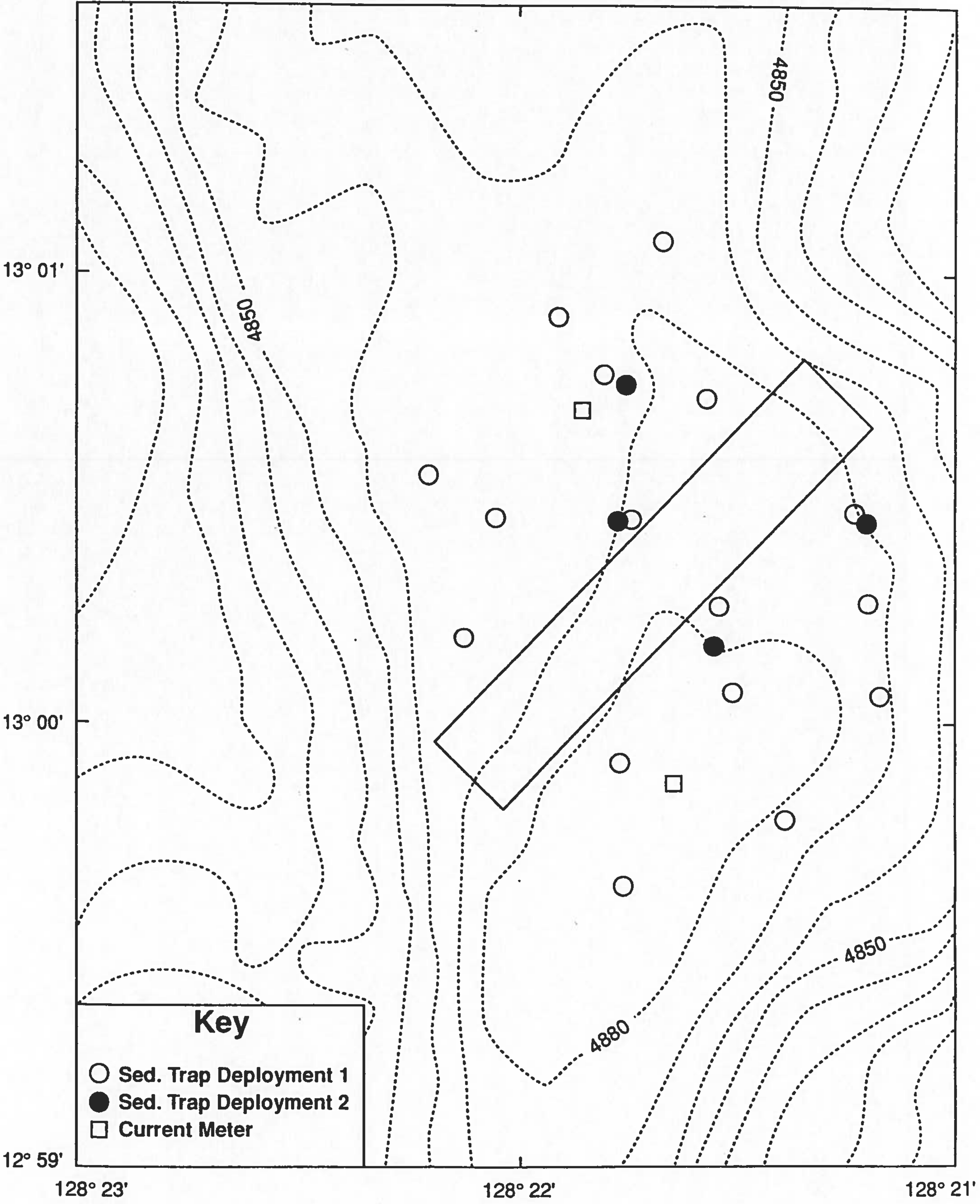
On 18 April we successfully recovered the two Aanderaa current meters we deployed after the 1991 BIE cruise. The current meter data from these two current meters indicated a northwesterly transport of water at speeds averaging ≈ 2 cm/s. Periodically, bursts of near bottom current activity were observed with speeds reaching 8 to 10 cm/s. This current activity may be associated with the lunar cycle. In both October and November of 1991 the current direction changed to a southeasterly flow for periods of approximately 2 weeks, and then resumed its normal northwesterly direction. In March and April of 1992 the current direction was always to the northwest with speeds not in excess of 6 cm/s.

On 19 and 20 April we deployed our sediment trap array in the study site (Fig. 1). The sediment traps were arrayed symmetrically on both sides of the tow area having three parallel rows of traps located on each side of the tow area. Each sediment trap mooring was designed so that the sediment traps were positioned 5 m above the sea floor. The two rows of traps immediately adjacent to the tow area consisted of 3 sediment trap moorings each and were deployed within 100 m to 300 m of the tow area; the traps in the center of each row being the closest to the tow area. Subsequent rows of two and three sediment trap moorings each were deployed at a distance of 500 m and 800 m on each side of the tow area respectively. A total of 16 sediment trap moorings were deployed in the BIE study site with one control sediment trap mooring deployed 6 nm northwest of the study area.

After the sediment trap array was in place, two Aanderaa current meters were deployed, one 500 m north and one 500 m south of the tow area. The northern most current meter had a Sea Tech 25 cm path length transmissometers mounted on it's tail fin. The southern current meter had no transmissometer on it because of an electrical interface problem. Both current meter moorings were designed so that the current meter was positioned 5 m above the sea floor.

For a more detailed description of the sediment trap and current meter deployments see Appendix 2.

Figure 1. Sediment trap and current meter array deployed on the 1992 BIE cruise.



BIE Sediment Trap + Current Meter Array

## D. Creation of the Benthic Resedimentation Environmental Impact

The main goal of the cruise was to create a sediment plume that would blanket a 2 $km^2$ area of the benthos immediately adjacent to the northeasterly oriented 400-m-x-2200-m tow zone. Our goal was to create a deposition area with a monotonic decrease in sediment thickness grading from 10 to 1 mm. Based on last years cruise it was calculated that 60 DSSRS tows should accomplish this task. Therefore, 25 days were scheduled for DSSRS operations in order to achieve our goal of 60 tows.

We began tow operations on 21 April right on schedule. Of the 25 days scheduled for tow operations we were able to successfully tow the DSSRS on 20 days completing a total of 44 tows, averaging 2.5 tows per day. Table 1 provides a summary of the data for each tow. Over 44 tows we pumped a total of 1,621.6 mt of mud, averaging 36.9 mt of mud pumped per tow. This is about half the mud we expected to pump based on the theoretical capabilities of the DSSRS. There are two hypotheses regarding the design of the DSSRS that may explain the lack of mud pumped. The first hypothesis is that there just wasn't enough surface mud to feed the two pumps. There was a great deal of variability in the amount of mud pumped and the position of the DSSRS with in the tow zone. The DSSRS was able to pump more mud when it was kept in the southern third of the tow zone. The farther north we towed in the tow zone, on average the less mud was pumped. Also, we always pumped less mud over the first third of the tow zone and would see an increase in the amount of mud pumped in the northeastern 2/3 of the tow zone (Fig. 2). Additionally, when one of the pumps failed and was being repaired, a plow was placed on the bottom of the sled to feed the one operating pump more mud. This was very effective and doubled the amount of mud pumped by the single pump. This indicates that the pumps were working well but were not being fed enough mud.

A second hypothesis is that the intakes became blocked by sediment piling up in front of them. We experimented with forcing the intakes down and letting them float freely over the sediment surface and found the latter to provide the best mud pumping performance.

After completing 20 tows, we recovered four sediment traps to see how well the DSSRS was dispersing the mud we were pumping. There was very little mud in any of the traps we recovered (Table 2: Traps 5, 7, 10 and 11). This indicated that we were either over-dispersing the sediment or not dispersing the sediment as far as we anticipated. CTD data indicated that a sediment plume was detectable north of the tow zone, but at low concentrations between 1 to 5 mg/l. Given the sediment trap and CTD results and after consulting with the other scientists and engineers, I made the decision to lower the riser hoses from 30 m to 15 m in order to allow the pumps to pump faster and hopefully disperse the sediment more effectively.

There were five days when we were not able to tow due to electrical or mechanical problems with the DSSRS, cable hockling or failure of the large block used for the 25-mm coaxial cable.

Table 1. DSSRS tow summary.

| Date | Tow # | Tow Starts | Tow Ends | Time (Min) | Avg SOG (Nm/h) | Mud Pumped (MT) |
|---|---|---|---|---|---|---|
| 21 April 1992 | 1 | 1243 | 1433 | 110 | 0.83 | 48.7 |
| 21 April 1992 | 2 | 2129 | 2346 | 137 | 0.74 | 53.2 |
| 23 April 1992 | 3 | 0727 | 0842 | 75 | 0.95 | 29.1 |
| 24 April 1992 | 4 | 0508 | 0632 | 84 | 0.97 | 25.8 |
| 24 April 1992 | 5 | 1512 | 1642 | 90 | 0.82 | 54.4 |
| 25 April 1992 | 6 | 0014 | 0155 | 101 | 0.88 | 38.0 |
| 25 April 1992 | 7 | 0855 | 1035 | 100 | 0.80 | 20.6 |
| 25 April 1992 | 8 | 1737 | 1850 | 73 | 0.82 | 25.0 |
| 27 April 1992 | 9 | 0056 | 0227 | 91 | 0.85 | 21.5 |
| 27 April 1992 | 10 | 1002 | 1147 | 105 | 0.74 | 44.1 |
| 27 April 1992 | 11 | 2002 | 2124 | 82 | 0.79 | 26.7 |
| 28 April 1992 | 12 | 0345 | 0505 | 80 | 0.70 | 29.5 |
| 28 April 1992 | 13 | 1158 | 1342 | 104 | 0.75 | 34.6 |
| 28 April 1992 | 14 | 2048 | 2233 | 105 | 0.80 | 56.4 |
| 29 April 1992 | 15 | 0451 | 0618 | 87 | 0.85 | 32.7 |
| 29 April 1992 | 16 | 1231 | 1419 | 108 | 0.73 | 24.7 |
| 29 April 1992 | 17 | 1950 | 2130 | 100 | 0.80 | 51.9 |
| 30 April 1992 | 18 | 0323 | 0505 | 102 | 0.76 | 55.8 |
| 30 April 1992 | 19 | 1139 | 1306 | 87 | 0.88 | 23.0 |
| 30 April 1992 | 20 | 2025 | 2154 | 89 | 0.83 | 49.7 |
| 3 May 1992 | 21 | 1010 | 1140 | 90 | 0.81 | 28.2 |
| 3 May 1992 | 22 | 1801 | 1924 | 83 | 0.96 | 26.7 |
| 4 May 1992 | 23 | 0413 | 0600 | 107 | 0.73 | 51.2 |
| 4 May 1992 | 24 | 1343 | 1550 | 127 | 0.61 | 64.2 |
| 4 May 1992 | 25 | 2249 | 2356 | 67 | 1.04 | 25.4 |
| 5 May 1992 | 26 | 0706 | 0819 | 73 | 0.98 | 27.5 |
| 5 May 1992 | 27 | 2204 | 2321 | 77 | 1.01 | 23.2 |
| 6 May 1992 | 28 | 0500 | 0625 | 85 | 0.89 | 42.2 |
| 6 May 1992 | 29 | 1235 | 1400 | 85 | 0.89 | 38.9 |
| 7 May 1992 | 30 | 1654 | 1800 | 66 | 0.86 | 32.7 |
| 8 May 1992 | 31 | 0223 | 0346 | 83 | 0.95 | 69.5 |
| 8 May 1992 | 32 | 1017 | 1139 | 82 | 0.97 | 51.1 |
| 9 May 1992 | 33 | 2327 | 0041 | 74 | 1.04 | 17.9 |
| 10 May 1992 | 34 | 1132 | 1250 | 78 | 1.08 | 24.4 |
| 10 May 1992 | 35 | 1939 | 2049 | 70 | 0.79 | 22.2 |
| 11 May 1992 | 36 | 0354 | 0530 | 96 | 0.68 | 39.6 |
| 11 May 1992 | 37 | 1211 | 1334 | 83 | 0.94 | 38.3 |
| 13 May 1992 | 38 | 0545 | 0648 | 63 | 0.75 | 29.1 |
| 13 May 1992 | 39 | 1340 | 1503 | 83 | 0.91 | 38.3 |
| 13 May 1992 | 40 | 2203 | 2319 | 76 | 0.92 | 35.1 |
| 14 May 1992 | 41 | 0710 | 0826 | 76 | 1.02 | 35.1 |
| 14 May 1992 | 42 | 1536 | 1704 | 88 | 0.79 | 40.6 |
| 14 May 1992 | 43 | 2300 | 0026 | 86 | 0.81 | 39.7 |
| 15 May 1992 | 44 | 2318 | 0034 | 76 | 0.85 | 35.1 |

Figure 2. The total amount of mud pumped for the first 31 tows by the DSSRS along 8 equal sectors of the polygon.

# Mud Pumped Along 1992 BIE Polygon

## Tows 1 to 31

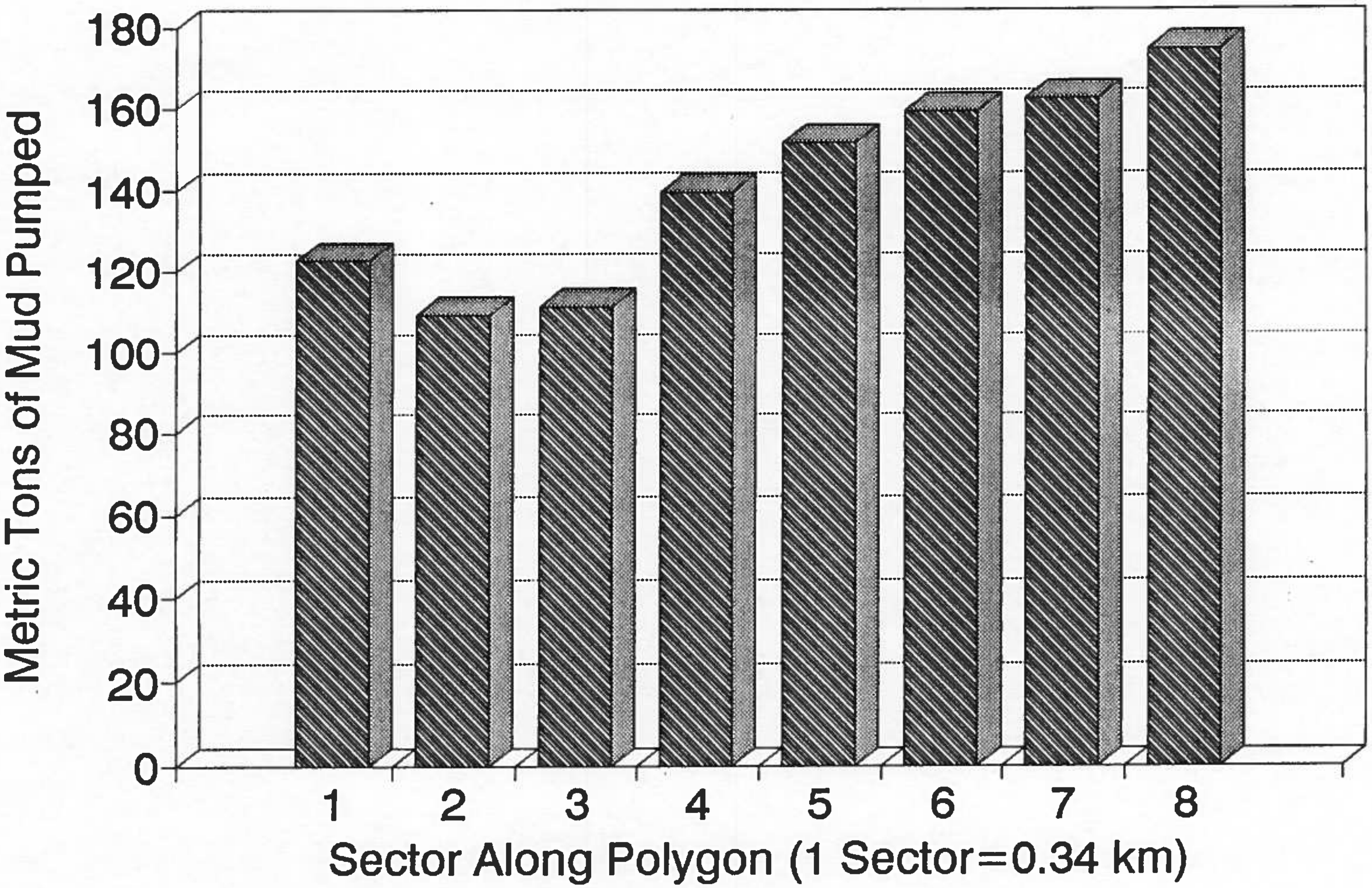


Table 2. Sediment trap results from the optical backscatter probe.

| Trap Number | Total Sediment in Trap A (mg) | Total Sediment in Trap B (mg) | Total Sediment (mg) Avg of Replicates |
|---|---|---|---|
| 1 | 89.90 | 73.88 | 81.89 |
| 2 | 137.96 | 77.44 | 107.70 |
| 3 | 321.30 | 173.56 | 247.43 |
| 4 | 107.70 | 72.10 | 89.90 |
| 5 | 134.40 | 84.56 | 109.48 |
| 6 | 259.00 | 289.26 | 274.13 |
| 7 | 114.82 | 116.60 | 115.71 |
| 8 | 143.30 | 275.02 | 209.16 |
| 9 | 289.26 | 324.86 | 307.06 |
| 10 | 102.36 | ND | 51.18 |
| 11 | 36.50 | 57.86 | 47.18 |
| 12 | 56.08 | 50.74 | 53.41 |
| 13 | 59.64 | 79.22 | 69.43 |
| 14 | 27.60 | 207.38 | 117.49 |
| 15 | 168.22 | 27.60 | 97.91 |
| 16 | 91.68 | 29.38 | 60.53 |
| 17 | 360.46 | 171.78 | 266.12 |
| 20 | 95.24 | 64.98 | 80.11 |
| 21 | 202.04 | 95.24 | 148.64 |
| 22 | 43.62 | 50.74 | 47.18 |
| 23 | 18.70 | 15.14 | 16.92 |

| Trap Number | Sed Deposition Trap A (mm) | Sed Deposition Trap B (mm) | Sed Deposition (mm) Avg of Replicates |
|---|---|---|---|
| 1 | 0.06 | 0.05 | 0.05 |
| 2 | 0.09 | 0.05 | 0.07 |
| 3 | 0.21 | 0.12 | 0.16 |
| 4 | 0.07 | 0.05 | 0.06 |
| 5 | 0.09 | 0.06 | 0.07 |
| 6 | 0.17 | 0.19 | 0.18 |
| 7 | 0.08 | 0.08 | 0.08 |
| 8 | 0.10 | 0.18 | 0.14 |
| 9 | 0.19 | 0.22 | 0.20 |
| 10 | 0.07 | ND | 0.03 |
| 11 | 0.02 | 0.04 | 0.03 |
| 12 | 0.04 | 0.03 | 0.04 |
| 13 | 0.04 | 0.05 | 0.05 |
| 14 | 0.02 | 0.14 | 0.08 |
| 15 | 0.11 | 0.02 | 0.07 |
| 16 | 0.06 | 0.02 | 0.04 |
| 17 | 0.24 | 0.11 | 0.18 |
| 20 | 0.06 | 0.04 | 0.05 |
| 21 | 0.13 | 0.06 | 0.10 |
| 22 | 0.03 | 0.03 | 0.03 |
| 23 | 0.01 | 0.01 | 0.01 |

DSSRS electrical problems ranged from simple electrical shorts on the sled, including the failure of both optical backscatter sensors after 30 tows, to failure of the generator on board the ship. All these problems were able to be fixed, but usually always required between 8 to 12 h to repair. The main mechanical problem we encountered with the DSSRS was the failure of the port motor. We were able to replace it with a spare motor, but due to a poor cable splice, this took almost 36 h.

The 26-mm coaxial cable worked well until the very end of the cruise. We almost always had to reterminate the cable when the DSSRS was brought on deck for maintenance because of cable hockles. The hockles always occurred between the depressor and the sled and were not really a operational hinderance as long as the DSSRS was deployed. However, due to the weight of the DSSRS in air, it was necessary to cut the hockles out of the cable before the sled was redeployed. This was at least a 6 h operation and usually took 8 h. We also had major problems with the large block used to deploy the DSSRS from the 26-mm coaxial cable. The block had no thrust bearings and after tow 8 and tow 32, respectively, it failed.

Overall I believe the DSSRS tow operations were a limited success. We were able to pump sediment and disperse at least some of it into the far field area of the BIE study site, however the amount of sediment resuspended was much less than anticipated.

For a more detailed description of the DSSRS operations see Appendix 3.

### E. Mapping the Redeposition Sediment Plume

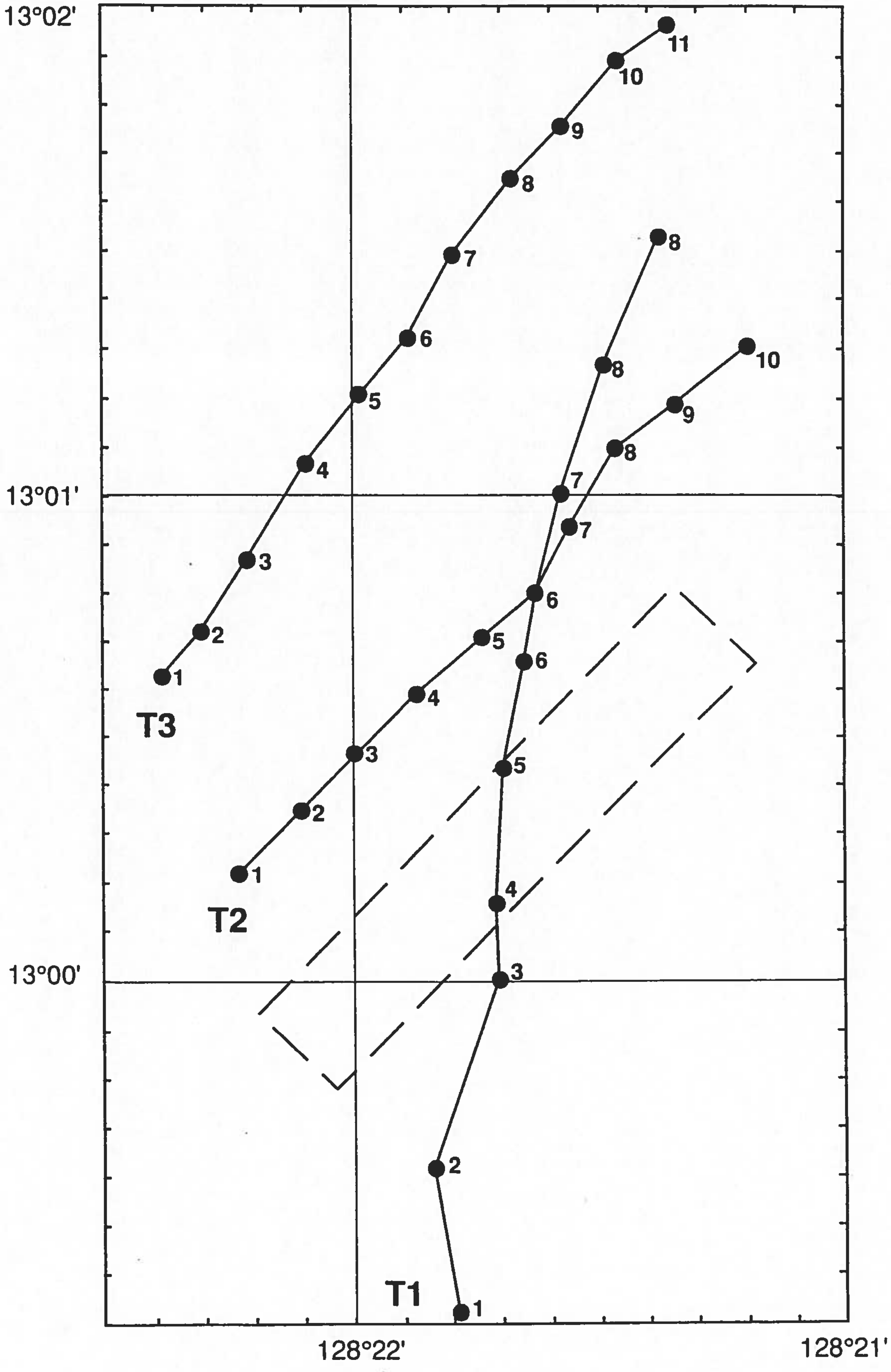
Four techniques were used to map the sediment plume created by the DSSRS: CTD casts, sediment traps, and radionuclide and x-ray analysis of sediment cores. The CTD casts were done by the Russian scientists with one south-to-north transect made after tow 20 and two east-to-west transects made to the north of the tow zone after tow 37 (Fig. 3). All three CTD transects indicated that the sediment plume was being transported north of the tow zone with water column plume concentrations ranging between 1 and 10 mg/l.

Between 16 and 22 May we recovered all 17 sediment trap moorings. The amount of sediment recovered in the traps ranged from 50 to 307 mg of sediment as determined by optical backscatter (OBS) analysis (Table 2). This translates into a sediment deposition of between 0.03 to 0.21 mm which is much lower than anticipated. There is a trend of higher sedimentation north of the tow zone, but since the control trap had the second highest OBS readings, further conclusions can not be drawn until the gravimetric analysis of the sediments from the traps is completed. It may be that rust from fixtures on the sediment traps has caused spurious OBS results in some of the traps. For a more detailed description of the OBS protocol see Appendix 4.

X-ray analysis of the sediment cores collected between 16 and 24 May indicates a very heterogenous redeposition environment. The character of the sediment deposited by the DSSRS ranged from very thin lenses of sediment (0.4 to 2 mm in thickness), to sediment

Figure 3. CTD tow paths made through the BIE study area.

# Location of CTD Transects



cores having very large clumps of sediment (8 to 12 mm in size) on their surface. Based on these results it was decided that it would be necessary to take multicore samples within the tow zone from between the tow tracks to obtain a high sedimentation treatment effect.

Results from the radionuclide analyses will not be available until the end of the summer when a more detailed map of the deposition environment at the BIE study site will be made.

## F. Post-disturbance Microbiological and Meiofaunal Sampling

Sediment samples were collected from 16 multicores to assess the short-term effect of sediment redeposition on the microbiological and meiofaunal communities (Fig. 4). The results of these analyses will not be available for another year. For sampling methodology details, please refer to the 1991 BIE I cruise report (NOAA Technical Memorandum NOS OCRM 2).

For a more detailed description of the DSSRS operations see Appendix 5.

## G. Post-impact Current Meter Deployments

From 20 to 23 May we deployed current meter moorings in the immediate vicinity surrounding the BIE study site in order to get a better assessment of the deep ocean current regime in this area. Seven Russian and seven US current meters were deployed on eight moorings (Table 3). Current meters were deployed on the eight moorings so that the current regime from 5 m to 300 m above the bottom could be characterized. These moorings will be deployed for approximately 3.5 months and their data will be used to model the flow over the topography in the BIE study site.

## Conclusions

Overall the 1992 BIE cruise was a success. We were able to generate a sediment redeposition impact in the BIE study site using the DSSRS, although it is not as thick and uniform as we originally envisioned. The box coring, multicoring, sediment trap and current meter deployments/recoveries were all successful and will provide insightful data regarding the environmental impacts of sediment redeposition from deep seabed mining. I have nothing but the highest regard for the US and Russian crews. Everyone worked at a consistently hard and professional level even when things did not go according to plan.

Figure 4. Multicore sample positions at the BIE study site.

# BIE Post Impact Multicore Samples

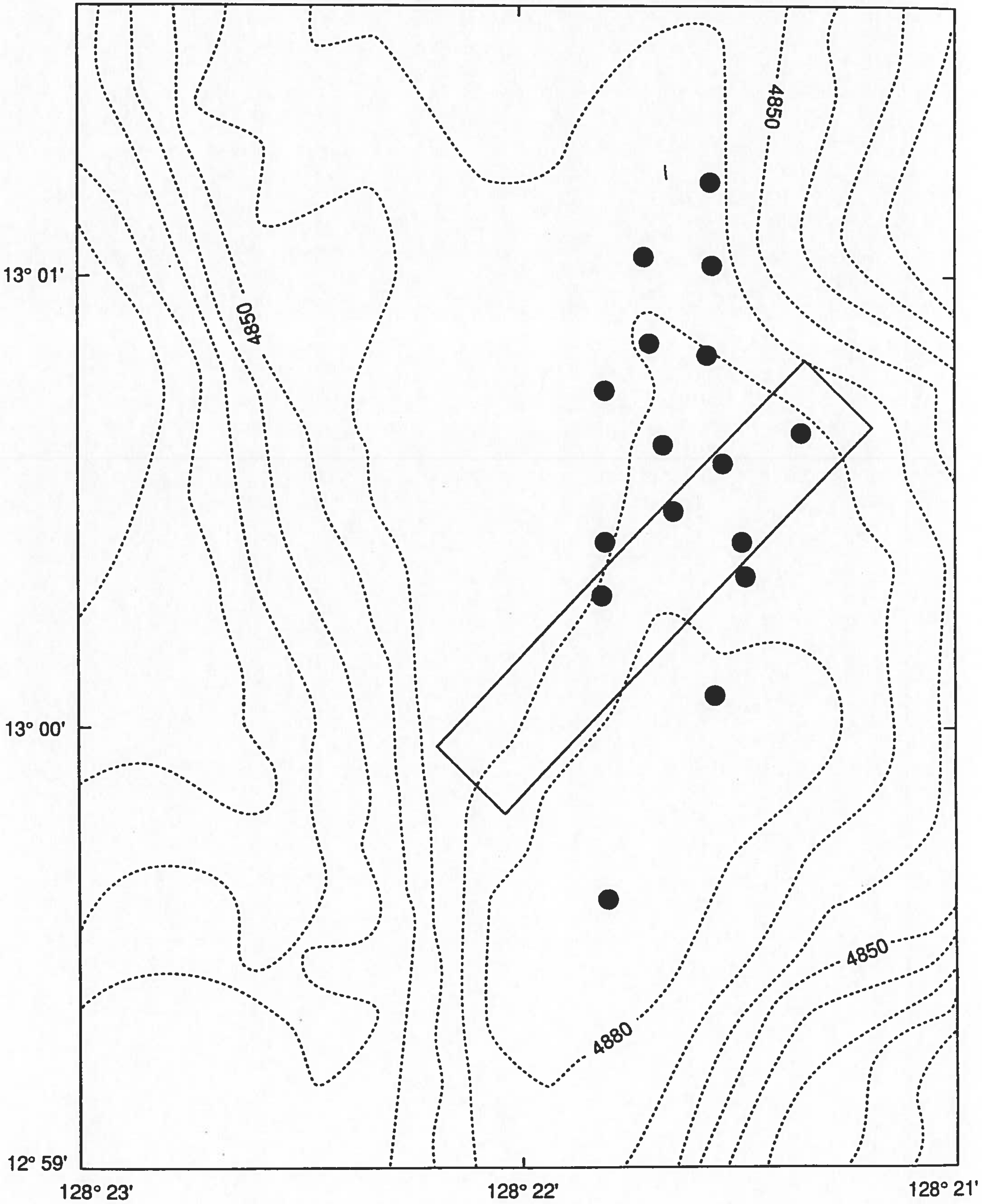


Table 3. BIE current meter deployment scheme.

| Mooring # | Lat (N) | Long (W) | Water Depth (m) | Height Above Bottom (m) | Meter Depth (m) | Meter Source |
|---|---|---|---|---|---|---|
| 1 | 12°58.3′ | 128°23.7′ | 4760 | 60 | 4700 | FSU[1] |
| 2 | 12°58.3′ | 128°23.3′ | 4820 | 5<br>120 | 4815<br>4700 | R[2]<br>R |
| 3 | 12°58.5′ | 128°20.0′ | 4790 | 5<br>90 | 4785<br>4700 | R<br>R |
| 4 | 12°58.5′ | 128°20.6′ | 4760 | 60 | 4700 | FSU |
| 5 | 12°59.7′ | 128°21.7′ | 4880 | 5<br>300 | 4875<br>4580 | R<br>OME[3] |
| 6 | 13°01.4′ | 128°23.4′ | 4760 | 60 | 4700 | FSU |
| 7 | 13°01.1′ | 128°21.9′ | 4860 | 5<br>160 | 4855<br>4700 | R<br>OME |
| 8 | 13°01.2′ | 128°20.3′ | 4720 | 20<br>140 | 4700<br>4580 | FSU<br>R |

[1] Florida State University, Geodyne meters
[2] Russian meters, Rotock-2, Vector averaging
[3] Ocean Minerals and Energy Division, NOAA, Aanderaa meters

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[1] Florida State University, Geodyne meters

[2] Russian meters (Rotock-2, Vector Averaging)

[3] Ocean Minerals and Energy Division, NOAA, Aanderaa meters

# Appendix 1

## BOX CORE AND MULTICORE SAMPLING

Susan P. Garner

The BIE 2 cruise of April/May 1992 was composed of two phases. The first phase, the "Test Cruise", was to the Patton Escarpment at approximately 31 North and 120 West, and the second was to the BIE site at approximately 13 North and 128 West. The purpose of the test cruise phase was to test the Disturber Sled and to test the new Multicorer delivered from Germany just prior to the cruise. Gerd Shriever came from Hamburg for the test cruise to show us how to correctly assemble the Multicorer and to guarantee that it worked properly.

## PATTON ESCARPMENT

At the Patton Escarpment site, three Multicore samples were taken, all successfully. The sample locations occupied were determined by samples collected last year on BIE 1 at this site, in which very interesting deposits of a probable phytodetritus pulse were observed in the cores. We hoped to sample at the same locations to determine if the phytodetritus was still present. From visual observation of these three multicore samples taken on this present test cruise, phytodetritus does not appear to be evident. However, further laboratory work will be performed at the University of Hawaii and other institutions. All of the core tubes from each Multicore drop were photographed and described prior to being distributed for further processing. The core tubes were distributed for the following investigations : radionuclides (Db and inventory), x-ray, microbiology, pigments/CHN, macrofauna/meiofauna, and geochemistry.

The mud from the tubes used for x-ray analysis will also be utilized for meiofauna population studies. The cores were sliced into fractions of 0-1 cm, 1-2 cm, 2-5 cm, and 5-10 cm. The mud was not sieved but placed directly into plastic sample jars and fixed with 10% buffered formalin. The mud from the cores saved for Macrofauna were treated in the same manner as the x-ray cores.

## BIE SITE

At the BIE site there were two stages to the biological sampling efforts. The first stage, prior to the Disturber runs, was to further characterize the background fauna by collecting additional baseline samples with the Box Core, concentrating on the area south of the Disturber track site. The second stage was to try to determine the extent of redeposition of the Disturber plume by collecting 16 Multicorer samples at various locations north and south of the Disturber track and in the track. The drop sites were determined by results from the current meter, sediment trap, and CTD data.

## BOX CORES

The Box Core used for the BIE 2 cruise was the same as the one used for the BIE 1 cruise (0.25 $m^2$ Hessler Box Core from Scripps Institution of Oceanography), and set up in the same configuration (Russian pinger at 18 m above Box Core and 2 Russian transponders at 100 m above Box Core) as BIE 1.

Four Box Core samples were collected at the BIE site before the Disturber commenced its runs through the track. BC 3 (CRS 98) was a vegematic sample collected about 280 m off the NE end of the track. The remaining three box cores were collected south of the track. BC 4 (CRS 98) at 1400 m south, BC 5 (CRS 99) at 1200 m south, and BC 6 (CRS 100) 900 m due south of the SW end of the track. BC 6 was also a vegematic box core, while BC 4 and BC 5 were open box cores.

The Box Core was lowered at a speed of 0.8 mps to an altitude of 100 m off the bottom. At that time the winch speed was lowered to 0.5 mps into the bottom. Three extra meters of wire was deployed, the winch stopped, reversed, and then slowly the speed was increased to 0.25 mps to 100 m altitude, after which it was recovered at 0.8 mps.

The vegematic box core contained 22 10-x-10-cm subcores and two meiostecher cores for x-rays mounted in the V2,3,4 position. After the top water was drained off the whole box core and saved in a jar, photos were taken and a description made of the surface of the samples. Next the remaining top water was siphoned off each individual subcore and saved before any subcores were removed for further processing. Each vegematic subcore was sliced into 0-1cm, 1-5cm, and 5-10-cm fractions. The 0-1 cm fraction was placed directly into jars without washing and fixed in 10% buffered formalin. The lower two fractions were carefully washed on a 0.297-mm screen and the material retained on the screen was fixed in 10% buffered formalin.

The open box cores contained one 10-x-10-cm subcore mounted in the center of the box core in the V13 position. After the top water was drained off the whole box core and photos taken and a description made of the surface, any water remaining on the surface of the core was siphoned off and placed directly into a jar without sieving and labeled aspirator water. Afterwards the mud in the open box core was divided into the same fractions as the vegematic box cores : 0-1 cm, 1-5 cm, and 5-10 cm. As in the vegematic samples, the 0-1cm fraction was not sieved prior to being fixed in 10% formalin, and the deeper fractions were washed on a 0.297-mm screen. The subcore mounted in the center was processed separately but otherwise treated the same as the rest of the sample.

After a minimum of three days, all of the box core samples were gently washed with fresh water to remove the mud and formalin and transferred to 80% ethanol.

Any nodules found in the box cores were double-bagged, without rinsing, in Ziploc or Whirlpak type plastic bags and fixed in 10% buffered formalin. These bags were placed in plastic jars and will be shipped to Dr. Lauren Mulllineaux at Woods Hole Oceanographic Institution for studies of the fauna inhabiting the nodules.

An interesting observation of these four box cores was that the three southern samples (BC 4, BC 5, BC 6) were composed of mud of a much softer consistency than was observed at the more northern location (BC 3) and softer than samples taken last year in BIE 1. This observation was later corroborated in a Multicore sample (MC 21/CRS 118) extremely full of very soft mud taken in the same general location as these three box cores.

The first two attempts to collect box cores were unsuccessful, partly due to the fact that the sea conditions were less than optimal, and on a smaller, less stable ship, would most likely not have been attempted. The first drop, BC 1 (CRS 95), did not trip at all and probably should have had more wire let out. The second attempt, BC 2 (CRS 96), was unsuccessful due to a problem with transponders and navigation, which consequently resulted in a lack of time to complete the station before current meter recovery in the morning.

## MULTICORES

At the BIE site, 17 multicore samples were collected, out of a total of 24 attempts. This number includes one sample (MC 4 / CRS 101) taken about half way through the Disturbing. The failures were due to several different reasons, including lack of ship maneuverability sometimes coupled with weather problems (MC 5 / CRS 102; MC 6 / CRS 104; MC 7 / CRS 105; MC 27 / CRS 124), problems with the pinger (MC 16 / CRS 113; MC 17 / CRS 114), and a mechanical problem with the multicore (MC 24 / CRS 121). The sample locations of the successful drops ranged from 900 m south of the Disturber track to 1100 m north of the track, with five samples actually in the Disturber track itself.

The Russian pinger was mounted on the wire at 48 m above the multicore, and the Russian transponders were mounted at 100 m above. With some trial and error, the lowering method that seemed to work best to optimize the chances of sampling as near a target location as possible, was as follows. The multicorer was lowered at a speed of 1.2 mps to an altitude of 200 m above the bottom, where the winch was stopped until the ship had maneuvered into position near the target location. Wire was then let out again until the multicorer was 50 m above the bottom, where it was stopped for 1 minute to 2 minutes to allow the apparatus to hang more vertically, the amount of time depending on nearness to the target. Afterwards the multicorer was lowered into the bottom at 1.2 mps, for a total of 1 minute on the bottom, which included an additional 30 m of wire being let out after the touchdown. The multicorer was then brought back up to the surface at 1.2 mps.

After each of the multicore tubes was photographed and described, they were distributed for further processing for the following investigations : (in descending priority) radionuclides and x-rays, microbiology, meiofauna, geochemistry, and macrofauna. The x-ray and macrofauna samples were sliced into 0-1 cm, 1-5 cm, and 5-10 cm fractions and placed directly into jars without sieving, and fixed in 10% buffered formalin.

Many (9) of the Multicore samples showed evidence of what we presume to be redeposition from the Disturber. One sample was fairly far north (700 m) of the track, and one was south of the track (60 m) and these two especially will benefit from the radionuclide and x-ray studies that hopefully will answer the redeposition question.

One of the samples collected in the track, MC 23/CRS 120, was obviously taken right in a Disturber run, due to the fact that the mud level was lower by 8-10 cm than all the other samples and that some of the tubes had piles of sediment that looked like physical displacement by the Disturber Sled itself. Another sample, MC 14/CRS 111, 460 m north of the track, had large disturbed piles of sediment that appeared to be naturally created by some animal, possibly an Echiuran, reworking the sediment into a mound.

This BIE site seems to be heavily burrowed, since 56% of the tubes had burrows in them, some with just one small one, others riddled with burrow holes and passages. One of the box core samples (BC 6/CRS 100) was also heavily burrowed, and in fact, the animal responsible for the burrow was recovered in that sample, an Enteropneust. Almost all of the tubes have a mottled section in the sediment starting about 16 cm below the surface of the mud, and running about 18 cm thick. This mottled sediment appears to be old filled burrows, so in the past this area has also been favorable for fairly large burrowing organisms.

From the biological standpoint, this cruise has been very successful, and the continuing investigations into the various samples collected on this BIE 2 cruise should yield some fascinating information over the ensuing years.

## Appendix 2

# Preliminary BIE-92 Cruise Report

by Meredith H. Sessions

Aboard the R/V Yuzhmorgeologiya we departed Long Beach, California on April 10, 1992 for a short test of the disturber in 3700 meters off San Diego before continuing to the BIE site. Concluding an initial check of disturber and the new multicorer after several days, we discharged a number of passengers and departed for the BIE site at 13.00 north and 128-20 west. We arrived at the test site on 18 April and immediately called up the long term current meter moorings deployed at the end of the BIE-91 cruise (11 August 1991). Both current meters were recovered and yielded good data records collected over the intervening eight months. They showed coherent records with a prevailing bottom current transport (3 meters above sea floor) toward the north for approximately one month prior to their recovery.

Following a careful examination of the recovered current meter records we started installation of the array of near bottom sediment traps positioned both north and south of the northeasterly oriented disturber tow track. The sediment traps were arrayed in a symmetrical pattern parallel to the tow track with three rows of traps located on each side of the track. The first rows were spaced as close to the track as possible and successive rows were spaced several hundred meters farther afield. One trap was placed about six miles northwest of the experiment site. This entire array of traps were installed over a period of two days prior to the commencement of disturber towing.

With the sediment trap array in place, the Aanderaa current meters were then modified by the addition of Sea Tech 25 cm path length transmissometers mounted in a special tail fins. During the modification of the second current meter (s/n 10173) it was discovered that the combination of the transmissometer (s/n 159D) and interface circuit board loaded down the current meter electronics and disabled current meter operation. Due to this problem the transmissometer was deleted from the south current meter. The current meters were installed on their original Oregon State University moorings one and two days after the sediment trap array was in place. Their sampling interval was set to 10 minutes to yield higher frequency resolution by taking advantage of the expected shorter recording time required during disturber towing.

At the completion of 20 tows, four sediment traps were recovered in order to determine the efficacy of sediment resuspension and verify our assumption that transport would be to the north as shown in the earlier current meter record. Results from these traps were inconclusive as they showed very low dispersion of sediment both north and south of the tow track. A

CTD profile was conducted across the tow track and clearly showed the effects of a plume to the north, by use of its transmissometer. The preliminary values of the maximum plume concentration as determined by transmissometer readings were in the range of 1-2 mg/l of sediment. Water samples were taken near the bottom in the plume region using the rosette sampler equipped with 10 liter bottles. Unfortunately the CTD was connected to the large Finland winch which, due to a combination of small diameter of wire spool and slow speed, produced very slow lowering and raising speeds of the CTD. This winch also produced loud grinding noises from its gear box which is cause for concern, particularly after considering its history on our last cruise. After studying all available information it was decided to cut the length of the disturber hoses to half their original height to concentrate the sediment to the area close to the track in order to provide a sufficiently thick deposition layer.

After 44 disturber tows were completed the 25-mm electomechanical cable shorted electrically. Since we were within two days of the scheduled time for finishing the towing, it was decided to commence recovering sediment traps, current meters and begin multicoring. Most sediment traps and current meters were recovered during daylight hours over three days from 15-17 May. Several sediment traps and one current meter failed to respond to their acoustic commands to release or enable transponder operation. Subsequently it was discovered that the ASMOD tow fish was transmitting very low acoustic pressure even though the electrical input was high. After repair of the tow fish all the remaining sediment traps and current meters were recovered without significant difficulty.

Of the current meters deployed during the BIE disturber towing only one yielded useful data. The north current meter (#19) with transmissometer attached failed near the time it reached the bottom. It recorded no data until approximately the time it returned to the surface when it again began to record data. It is presumed that the transmissometer and interface somehow loaded down the current meter electronics and prevented normal operation. This could be either a temperature or pressure problem, but since this entire system has never been together in a laboratory situation, it has not been possible to perform suitable tests to verify satisfactory performance under actual field conditions. We observed similar symptoms during the deployment last year, but attributed that failure to a drop of water found on the current meter circuit board. Current meter #19 was also the one which was difficult to release due to acoustic tow fish problems noted earlier, and upon release was seen to ascend very slowly. When reaching the surface (after four hours) we discovered that one of the 17 inch diameter glass balls had imploded at depth, reducing the reserve buoyancy to a near critical level. After restoring this current meter to its original configuration it checked out well and was installed in one of the moorings mentioned below. The second current meter (#18) recorded good data and showed that the flow was always in the northerly direction during the disturber towing. The question as to why very low sediment was observed in the north traps after 20 tows seems to be answered by the fact that during the time when the first 20 tows were performed very low currents were in recorded. With a current threshold of 2.0 cm/sec specified for the Aanderaa meters and the rotation to speed calibration curve used, they report 1.1 cm/sec when zero rotations are recorded during the 10 minute averaging time interval. Many of the 20 tows occurred during times when data reported this value, indicating very low transport (if not zero). Later (after 20 tows) currents were stronger toward the northwest during the towing period and better transport can be expected.

Concluding recovery of sediment traps and current meters, all our acoustic releases and current meters were reworked to be used for subsequent current meter moorings. We then installed eight current meter moorings over a period of three days, (May 20-23) using seven Russian Potok current meters, four Florida State University vector averaging current meters and the two Aanderaa RCM-8 current meters. The eight moorings, containing 13 current meters, were anchored in a box around the BIE-92 site within two miles of the tow track. Four meters were place at a height of five meters and one at 20 meters above the sea floor. Seven current meters were placed at a depth of 4700 meters. The remaining current meter was placed near the center of the test site at a depth of 300 meters above the bottom (4580 M).

During the course of the experiment two of the ASMOD acoustic transponders failed. Both were 12.25 KHZ units. One unit died and the other failed by changing frequency and transmitting first on 11.25 KHZ and later on 10.75 KHZ. Both of these units were replaced with new ASMOD transponders in locations optimized for later sampling. Near the end of the experiment (23 May) we installed a Benthos transponder (s/n 45155) which was repaired and reset to 13.0 KHZ. This frequency was selected for best use of the available frequencies with all the current meter mooring installed (which use 16 transponding releases). Great care in selecting frequencies is still necessary due to the large number of units deployed in a small area. During the last multicore attempt Yevgeniy reported that the received signal level from the Benthos transponder was low and that he had difficulty receiving it at significant ranges. The modifications of the ASMOD navigation provided additional frequencies on the underwater unit including an altimeter and acoustic depth output which was used extensively during both disturber towing and multicoring. The system is now capable of calibrating multiple units simultaneously and this feature was used to save substantial time during sediment trap calibration. The complete acoustic navigation system worked very well during the entire cruise even though it was necessary to lower the tow fish to depths greater than 250 meters on occasions.

In summary, all operations went very well, with primarily only the normal or expected difficulties encountered. One unexpected problem encountered was the repeated failure of the large diameter block used for towing with the 25-mm wire. The failure resulted from a combination of heavy towing loads and large side loads placed on the sheave by turning of the ship sharply during towing. The design of this block does not provide thrust bearings for the side loads which were encountered while turning. A modification, designed by Oleg Lyaskovskiy, provided better bearing retainers which also performed the function of thrust washers and this configuration continued to operate during the remainder of the cruise. Weather at the site was excellent during the entire experiment and caused no lost days. One difficulty that continues, is ship handling and maneuvering through the chain from deck to navigation to the bridge. Frequently during critical operations the navigation, located away from the source of action or control, cannot know or understand the nature of what is need to accomplish a given task. Also this additional link in the chain between deck operations and ship control slows down response time when quick action is required. This problem could be easily remedied by placing the navigation function on the bridge where they have an excellent view of deck operations and can quickly respond to changing situations. With modern computer navigation and plotting equipment this presents no problem and is in fact how all U.S. research vessels operate. The SAS winch performed superbly during all cycles. The 25-mm wire continued to break strands during operations and was repaired by the deck crew on numerous occasions. By the time of its electrical failure it had about 15 breaks in the outer armor strands.

The performance of the Finland winch used for CTD profiles limited the speed which these profiles could be conducted and hence the number which could be accomplished within the time available for this work. CTD's should be taken using one of the other more suitable winches located on the ship. We considered changing winches during our cruise, but could not afford the time this would consume. Future use of the Finland winch for side scan sonar and camera profiles should be carefully considered due to the noises generated by its gear box under only small loads imposed by CTD profiles. The major limitation of the ship for towing, launch and recovery operations and precision positioning of cores and CTD's remains the lack of a powerful bow thruster. Considerable towing time could have been saved and much better success with coring and CTD profiles could be obtained with the addition of this equipment. It would also improve side scan sonar, camera and television profiles, and most wire over the side operations. In this connection, Scripps Institution of Oceanography and Woods Hole Oceanographic Institution have recently modified their ships R/V Melville and Knorr by changing engines, propulsion units and lengthening the hulls by 10 meters. These ships are now about 85 meters in length (2500 tons) and have two steerable stern propellers and one retractable bow thruster of 900 horsepower.

Model tests in wind and wave tanks predict capability to hold position in 15 meters per second winds and seas. Actual at sea tests on the real ships remain to be conducted, but preliminary experience seems to confirm these expectations. In my opinion, the installation of a retractable, steerable bow thruster on the R/V Yuzhmorgeologiya would greatly improve its capability for a wide range of ocean science programs and substantially increase its marketability.

# Appendix 3

## BIE 92 DEEP SEA SEDIMENT RESUSPENSION SYSTEM TEST REPORT

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Prepared on site (13N, 128W)
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David Wilson

## SUMMARY

A total of 44 bottom tows were completed with the DSSRS sled during the BIE 92 operations and an estimated 1600 tonnes of mud pumped. During the bottom tows, pump discharge concentrations were dependent upon the section of the BIE track over which the sled was being towed. Towing operations where begun on 21 April and lasted through 16 May. Operations where terminated by a short in the tow cable of the coax shield to the inner armor wires in a section of the cable already damaged from use. Insufficient time remained for switching over to the spare tow cable.

The towing operations where hindered by component failures of DSSRS components, ship's equipment, and ancillary support equipment. Through a combination of available spare parts and resourcefulness on the part of the ship's crew and DSSRS team the system was kept running. Component failures aside, the towing operations went smoothly, due in large part too improved communications the familiarity of key people with the operation.

## 1.0 INTRODUCTION

The following report summarizes the operation of the DSSRS sled during the BIE 92 tests. Comments are also included on events and equipment which although not directly under the control or responsibility of the DSSRS team did have some impact on the operation of the DSSRS sled. A detailed discussion of the performance of the sled on each tow is not included as this data was logged on disk. A table at the end of the report summarizes the events of the cruise that relates to DSSRS operations. This report was prepared on site.

Williamson and Associates function during BIE 92 was a continuation of its roll in the 91 operations, that is the operation and maintenance of the DSSRS for purposes of resuspending seafloor sediments in water depths of 4800 meters. BIE 91 operations proved the viability of the DSSRS sled, and only minor modifications where made to the sled for the 92 operations. These modifications included: strengthening the oversize material rejection bars on the pump intakes, installing additional OBS and differential pressure sensors, repairing housing mounts, repair and remounting of the altimeter, modifications to the data display, and statistical calculations on the concentration data logged from the OBS sensors.

## 2.0 LONG BEACH OPERATIONS

The test cruise off Long Beach revealed two problems. A faulty output signal from the differential pressure transducers, and a depth induced failure on the OBS (Optical Back Scatter) sensor cable splice which caused a communications failure at 1500 meters depth. The pressure transducers where not field repairable and were not used during the rest of the cruise. Although the manufacture stated that they could make repairs in one day, the delay of the ship was not acceptable. The cable splice problem was repaired, and two bottom tows completed. The sled performed as expected, even to the extent of ingesting several wads of sonabouy wire as occurred in 91.

Had the test cruise been conducted at the alternative location in 1000 meters of water, the cable splice problem may have never appeared until at the BIE site. Although adequate materials were on hand to repair a cable splice failure if one did occur during the BIE site operations, the conducting of test cruises in conditions as similar to those in which the system will be operated is advisable for future operations.

It should be noted that an inadequate amount of preparation time was available to prepare for the BIE 92 operations due to the lateness with which the contract for this project was let. The test off Long Beach was the first time since the 91 tests that the system was tested in its entirety as parts for the system where still being acquired two days before departure. Manufacturers of specialty components have long lead times. Some component tests where made in Seattle before shipping the system and those functions tested appeared to be working. Components of an instrumentation-telemetry system may be working at the component level, but when connected together as a system may reveal a new set of problems. Time is needed for the ordering of parts, testing of the system in its entirety, and repair or replacement of any components that might fail. Had the contract been in place sooner, the long hours preparation required while on site and the loss of the differential pressure transducers may have been avoided. As it was, with out the pressure sensors to verify the pump flow rates, the integrity of the riser hoses, and the validity of the OBS sensors, the output from pumps and the OBS sensors readings came under question during many of the upcoming BIE tows. The loss of the sensors also limited the maximum time deemed acceptable between sled inspections to three days.

## 3.0 BIE DSSRS OPERATIONS

### 3.1 Sediment Output

Based on the output of the OBS sensors, the sediment resuspension rate of the DSSRS at the BIE 92 site appeared to be dependent on section of the BIE tow area that the sled was being towed through. Resuspension outputs where generally high during the first few minutes of the tow, would then drop as low as 15 to 40 g/l and would recover to moderate to high levels (60 to 120 g/l+) during the later half of the tow. Tows down the right side of the test area generally yielded higher outputs than tows down the left side. The repeat performance of a tow was not often possible, although trends in output along the length of the track where more repeatable than across track trends i.e. left or right side of the track.

This evidence lead to the speculation of different bottom types within the BIE test area. Higher outputs generally obtainable from the right side of the tow area occurred less frequently during the later tows. Although the possibility seems remote, the sled may have been set down in its previous tracks on several occasions.

In an attempt to increase the output over the length of the BIE area, modifications where made to the sled. These included; a modification of the pump intake's suspension, and the addition of baffles to the front of the sled to direct more material towards the pump intakes. From tow 3 onward, the intakes where changed from a forced deployment using the discharge pressure of the pumps to a more responsive means of suspension that relied on their own weight to keep them in contact with the seafloor. The reason for the change was the appearance of very stiff sediment high up on the upper portions of the intakes, approximately ---- cm above the bottom of the sled's runners. An indication that the intakes might have been plowing or pushing a mound of sediment in front of them because of their inability to readily accommodate fluctuations in bottom topography or changes in depth to which the sled would sink with changes in seafloor bearing strength. If the intakes where pushing a wave of sediment in front of them, it was conjectured that this might be limiting the amount of loose sediment that was available for them to ingest. During the nodule mining tests of 77 and 78, this plowing effect was observed to occur on the nodule collectors whenever their intakes where set too low, the result was a low output. For tows 9 and above, baffles where added to the front of the sled to direct more material towards the pump intakes. With the variability in the performance of the sled over different sections of the site, the effect of these modifications was difficult to access.

The pump intakes where inspected after each recovery. None of the inspections revealed any evidence that would indicate that the intakes to the pumps was being blocked. Stiff clay and nodules where often found packed in the section of the oversize bars where they are bolted to the intakes, ahead and above the actual intake area itself. The bar area extending over the intake area was always free of sediment and would contain only a few nodules wedged in between the bars. These where easily dislodged and their numbers appeared to be independent of the number of bottom tows completed between inspections. An indication that the pump intakes where self clearing over the length of the tow.

### 3.2 OBS Sensors

The OBS sensors where the only means available for monitoring the real time discharge concentration of the pumps. For the majority of the tows, the readings from the OBS sensors looked realistic. A post test calibration of these sensors is recommended and if possible should be done under pressure. The OBS sensor head is constructed from materials with different coefficients of elasticity, so failure after a number of cycles (raising and lowering) is not surprising.

After tow 26, the starboard OBS sensor output a steady 0 g/l reading. For tow 27 the sensor was replace with a spare. However, because of the mounting orientation of the sensor, the maximum reading of the sensor was approximately 250 g/l. After the failure of the port pump at the completion of tow 29, this spare sensor was mounted on the inoperable port pump discharge and the new sensor acquired for BIE 92 was switched to the starboard pump.

### 3.3 Pumps

The port pump was inoperable for tows 30 through 32. Inspection of the pump after tows 22, 26, and 29 revealed a loose impeller. Because the impeller mounting bolt was sheared after tow 29, the impeller could not be remounted. During the towing operations, this manifested itself as a rise in amperage at the end of the tow as the DSSRS was being lifted off the seafloor. Due to a bad cable splice on the spare pump, and the need to build a replacement for the port pump starting capacitor, which had also failed, the spare pump was not installed until to tow 33.

The disturber's pumps were left on between bottom tows. Starting the pumps at depth (4000 m) proved to be impossible unless a restart command was given within seconds after a shut down. It was possible to restart the pumps with the system at 200 meters depth. Standard procedure was to start the pumps on deck just before the sled entered the water and leave them on for the duration of that launch cycle. Repeated starting of the pumps was felt to be harder on the entire system, pumps, starting circuits, connectors, and cables. The Starboard pump operated in a normal manner throughout the tests, with a total running time of 360 hours.

## 3.4 Riser Hoses and Discharge Rates

A nominal discharge height of the risers is approximately 20 meters. The discharge height was measure during the BIE 91 operations by using an acoustic altimeter mounted on the flotation frame which supports the riser hoses. The discharge height measured at that time was _____ meters with a forward speed of 0.6 knots. At higher tow speeds used for BIE 92 (i.e. 0.8 to 1.5 knots) the discharge height of the riser would decrease due to the increase in drag. Using the data gathered in BIE 91, this decrease in height could be more accurately calculated for changes in speed, but as yet has not been done. After the height measurement taken during BIE 91, the altimeter was placed on the DSSRS sled for bottom detection prior to landing.

For tows 27 and above, the length of the riser was shortened by 10 meters at the request of the chief scientist. As the discharge rate of the pumps is determined by the back pressure on the pumps created by the length of the riser and the specific gravity of the fluid being pumped, the following discharge rates where calculated.

For a 20 meter discharge height
    Pump output with clear water        xx l/s @ xx bar
    Pump output with slurry of 1.15 sg        xx l/s @ xx bar
    (1.15 sg is approx xx g/l discharge concentration)
For a 10 meter reduction in discharge height
    Pump output with clear water        xx l/s @ xx bar
    Pump output with slurry of 1.15 sg        xx l/s @ xx bar

These estimates of discharge rate where based on manufacturers pump curves and standard formulas and assumptions for calculating head loss. The above numbers have not been verified by any other means, i.e. flow tests.

## 3.4 Miscellaneous Component Status Comments

The DSSRS's telemetry system performed without any problems throughout the duration of the cruise. The only communication failure to the sled that can be attributed to the telemetry system occurred during the Long Beach tests, and that was due to a faulty cable splice. Other communication failures occurred but where due to loss of power to the system, i.e. blown fuses, shorts, etc.

No problems were encountered with the pitch, roll, compass, depth, or altimeter sensors. As noted, the differential pressure sensors never worked and could not be repaired, and one OBS sensor failed and was replaced with a spare. The point at which the magnetic switches used to sense the position of the pump intakes failed is not certain.

A failure of a high voltage cable connector occurred during a prelaunch deck test prior to tow 33. This connector is one of 4 on the sled, and had never been disconnected since shipping the system from Seattle. It may have been contaminated from seawater intrusion during recovery, or damaged by the hydrostatic cycling from 200 meters to 4850 meters that occurred between each tow.

### 3.5 Future Modifications

God forbid that an attempt to make 60 to 80 tows with the disturber (DSSRS) should ever occur again, but if it should, the following is a list of modifications that should be taken into account. The intent of these modifications is to increase the discharge rate of sediment from the disturber and the reliability of the system, thereby reducing the number of tows, and time at sea, necessary to blanket an area with sediment.

Depending upon the bottom type, more permanent baffles or modifications to the sled runners could be made to increase the amount of material fed to the pumps. Care must be taken that this is not taken to excess such that the pumps become overloaded and the riser plugged. Along with this modification, the capability for real time adjustment of the position of the pump intakes relative to the seafloor should be made.

Along with the OBS and differential pressure sensors from which concentration and flow rate can be inferred, a means for directly measuring the flow velocities in the riser would be very useful for confirming the sediment discharge rates from the pumps.

Visual confirmation is needed of bottom type and of the interaction of the disturber with the seafloor. Ideally this could be accomplished with a real time video display to the operator, or post test video or photographs from cameras mounted on the sled. As an aside, a camera mounted on the multicore frame would also yield a lot of information about the seafloor.

A modem-satellite communication system so that Richard and Dave can direct the operations of the disturber from the comfort of their homes and not have to suffer the whims of disturbed scientists at sea for 50 days.

## 4.0 ANCILLARY EQUIPMENT

### 4.1 Tow Cable

The electrical characteristics of the coax tow cables used in the BIE tests is excellent. It is much better than the 0.68 in. coax cables used by the UNOLS fleet. Mechanically it did suffer from breaks of the outer armor wire, which required frequent pauses in the operation to secure the loose wire ends. This breakage is not totally unexpected, in fact hand tools where fabricated before hand to help the Russian's repair the cable. The loads on the cable where approaching almost half the breaking strength of the cable. Traction winches are also notoriously hard on cables because of the number of flexure cycles that the cable must endure on each lowering. A total of twenty bends for each deployment and recovery of the system.

The cable was reterminated five times to remove cable hockles. Since a retermination was not required after each recovery, the presence of cable hockles was attributed to operating procedures, i.e. maintaining adequate ship speed.

The disturber towing operations were terminated after tow 44, as the system was being lowered for tow 45. The electrical failure of the cable occurred at a spot where a significant number of outer armor wires had been removed because of breakage. Within a few centimeters of the failed spot, the inner armor wire was deeply imbedded into the inner jacket of the cable. Probably as a result of the inner wires having to carry more tension. The failure was a shorting of the coax shield to the inner armor wires, which blew a hole in the jacket of the cable and severed 4 or 5 of the inner armor wires. Just prior to the electrical failure of the cable, concern was expressed by the disturber team over the mechanical integrity of the cable.

### 4.2 Tow Sheave

The tow sheave experienced two failures of its bearings. The ship's crew did a remarkable job of repairing and rebuilding the sheaves in a relatively short amount of time.

### 4.3 Slip Rings

Two electrical failures occurred at the slip ring. Both were initiated outside the slipring body and inside the winch drum in the section of cable that splices onto the tow cable. The first failure resulted in a blown fuse, and the splice was readily repaired. The second failure caused a meltdown of the slipring's internals and required a rebuild of the slipring from spare parts.

### 4.4 Winch

The winch for BIE 92 performed quite well. Minor concerns were raised early in the cruise by metal shavings from the gears, but these proved to be a minor wear in problem.

### 4.5 Generator

At the most inappropriate times the generator became a problem. Most prevalent was due to the dirty fuel taken on in Long Beach. Even the ship's main engines where having a problem with the fuel. The problem was solved by replacing the fuel filter on the generator and by installing an additional fuel filter borrowed from the ship.

Least expected was a failure of the generator's voltage regulator. Since the regulator was a sealed unit, nothing could be done to repair it and no spares where brought. The regulator was bypassed by using the spare power supply for the DSSRS' instrumentation system to obtain an adjustable 12 volt excitation signal for the alternator.

# 5.0 OPERATIONS

## 5.1 Launch and Recovery

The launch and recovery operations went quite well, aided by two significant factors, the same deck crew as last year, and good weather.

## 5.2 Towing

The tow configuration of the system was the same as for BIE 91. The ship's depressor frame was placed 200 meters up the cable from the sled. A very useful addition to the system was the addition of an altimeter to the depressor frame, with the information on depressor altitude being displayed on the acoustic navigation screen.

The elliptical tow pattern that was used in BIE 91 was again used in the BIE 92 operations. With refinements in ship's speed, and winch rates, it was possible to obtain 3 tows per day. For the majority of the tows, the wind and surface current conditions were such that the relative speed of the ship through the water was sufficient so that adequate steerage could be maintained for running a tow. For the days that light wind conditions prevailed, a bow thruster probably would have been useful. Fortunately we did not have any heavy weather days.

A prevailing problem during the tows was the determination of ship speed over ground. Update rates from the acoustic navigation system were not very frequent and not very accurate for areas outside the tow area, i.e. on the approach. Although the ship's GPS system had faster update rates, its fluctuations at 1 knot where significant. Low speeds decrease the tension in the tow cable during bottom tows and create a hockling problem in the tow cable.

The smoothness with which the towing operations were performed was in large part due to the better communications between ship's navigation, acoustic navigation, the disturber operators, the bridge, and winch control room. Communications was enhanced by having the first three groups all in the same room, and by setting up a remote monitor to display disturber status in the winch room. With this arrangement, all parties could stay informed without having to resort to a message relay network. The watch standers had ready access to the information needed, allowing them to anticipate what was about to occur which got them more actively involved in the operations. This arrangement also lessened the extent to which the scientific team needed to be involved in the shipboard operations, allowing the ship's crew to do their job.

### 5.3 Disturber Watches

The 4 hour rotating watches staffed by the scientific team for monitoring the DSSRS sled worked well when the sled was in a normal operating mode. This minimized the amount of time required of the disturber team, allowing them to be available for critical periods for bottom landing and disturber maintenance. Unfortunately, due to component failures, there where too many periods when an overtime effort on the part of the disturber team was required to get the system back in operation. When operating one-of-a-kind specialized equipment, there is probably no way around this other than adequate up-front contingency planning to allow for these repair periods.

### 5.4 Personnel

The return of many of the ship's crew members to this years operations was a great asset. Particularly Oleg and his team on the back deck who took care of the launch and recovery of the system at any time of day. Yevgeniy and his wife who headed up the acoustic navigation, and members of the electrical and mechanical departments on the ship who lent a hand when needed. The presence of Katrina as a translator whenever any new or different portion an operation was about to be undertaken was also a great asset.

## 6.0 SIGNIFICANT EVENTS AFFECTING DISTURBER OPERATIONS

| Date | Launch/ Recovery | Tow no. | System status/significant events |
|---|---|---|---|
| 07 Apr | | | Long Beach Mobilization. |
| 10 Apr | | | Depart for test site. |
| 12 Apr | L1 | 0 | Differential pressure transducers inoperable. |
| | R1 | | Telemetry failure at 1500 m. |
| | L2 | 0 | No depressor.<br>OBS cable harness disconnected. |

| Date | Launch/ Recovery | Tow no. | System status/significant events |
|---|---|---|---|
| | R2 | | Tested successfully to 3000 m. |
| | L3 | 1,2 | Single cable to Port side OBS.<br>Depressor installed. |
| 13 Apr | R3 | | No hockles in tow cable.<br>Sonabouy wire caught in pumps.<br>Depart for BIE site. |
| ****** | | *** | BIE TOWING OPERATIONS |
| 21 Apr | L4 | 1,2 | System configuration as tested off Long Beach. |
| 22 Apr | R4 | | Short in subsurface tow cable termination on sled.<br>Hockle in tow cable. |
| | L5 | 3 | Pump intakes modified to deploy via own weight. |
| | R5 | | Failure of slipring splice on winch. |
| 23 Apr | L6 | 4-8 | No changes to sled. Generator fuel problems. |
| 25 Apr | R6 | | System recovered to repair tow sheave bearings. |
| | L7 | 9-20 | Cable reterminated to remove hockle.<br>Conc. baffles added to sled.<br>Port pump intake limited to max deployment depth of 1" above bottom of sled runner. Both intakes deploy via own weight. |
| 1 May | R7 | | Recovery initiated for sediment trap recovery and CTD profiles. |
| 3 May | L8 | 21,22 | Port pump intake set same as STBD, deploys to bottom of sled runner.<br>Riser hose brackets repaired from shackle wear. |
| | R8 | | Surge in amps required shut down of Port pump at end of tow 22. Pump impeller found loose, STBD pump OK. |
| 4 May | L9 | 23-26 | Port impeller bolt tightened. |

| Date | Launch/ Recovery | Tow no. | System status/significant events |
|---|---|---|---|
| 4 May | R9 | | Initiated to shorten riser hose.<br>Port impeller loose.<br>STBD OBS reading erratically on tow 26. |
| 5 May | L10 | 27-29 | Hose shortened by 10 meters.<br>Spare OBS installed on STBD side, max reading of approx. 250 g/l. |
| 6 May | R10 | | Port pump shut down because of excessive amperage draw. |
| 7 May | L11 | 30-32 | Stbd pump only. Spare pump not installed because of bad cable splice and blown start capacitor.<br>Conc. baffle added to direct more sediment toward Stbd pump.<br>Good OBS sensor swapped to Stbd side. |
| 8 May | R11 | | Bearings in tow sheave failed. |
| 9 May | L12 | 33-37 | Port pump and starting capacitor replaced.<br>Single conc. baffle removed and dual baffles remounted.<br>Spare OBS left on Port pump, Stbd sensor face appears to be delaminating.<br>Sheave rebuilt by ship's crew.<br>Tow cable reterminated to remove hockle.<br>High voltage connector replaced after failure during pre-launch test. |
| 11 May | R12 | | Voltage regulator on generator fails.<br>System recovered for CTD ops while gen. repairs attempted. |
| 13 May | L13 | 38-43 | Spare power supply used to bypass generator voltage controller. |
| 15 May | R13 | | Slip ring failure. Sled recovered for inspection.<br>Current meter recovered.<br>Transponder deployed. |

| Date | Launch/ Recovery | Tow no. | System status/significant events |
|---|---|---|---|
| 15 May | L14 | 44 | Slip ring rebuilt.<br>Tow cable reterminated to remove hockle. Both pumps and all sensors except diff pressure working. |
| 16 May | R14 | | Electro/mechanical failure of tow cable. |

# **Appendix 4**

## Sediment Trap Processing and OBS Protocol

by

Dr. Dwight D. Trueblood
NOAA, Ocean Minerals and Energy Division

After each sediment trap was brought on board, the samples were taken to the lab and secured in an upright position. The top plastic caps, which were placed on top of the traps before they were recovered to avoid sample loss, and the baffles were removed and the traps let stand for 30 min.

Each trap was then viewed with the aid of a flash light. If the bottom of the trap was totally covered with sediment, the trap was used for $Th^{234}$ analysis. If not, the top water was siphoned off using a piece of latex tubing. All water, except for the final 500 ml was siphoned off into a 10 gal cubitainer. The remaining water and sediment was swished around and poured into a 1 l Nalgene beaker. The bottom of the trap was then washed again with 20 ml of seawater to remove any remaining particles.

Since siphoning water didn't always remove all but 500 ml of water, the water-sediment suspension was adjusted to 500 ml vol either by adding water from the samples cubitainer or pouring water off the sample into the cubitainer. The water was then transferred into a 600 ml nalgene beaker and agitated using a stir plate set at setting number 5. The OBS probe was then placed into the sample and a voltage reading taken using the 2.5 V scale on the voltage meter. The sample was then measured quantitatively for its total water volume. and then transferred into a cubitainer for transport to shore. This procedure was repeated for each replicate trap.

After returning to shore each sample will be shaken up in its cubitainer and 1 l filtered onto a 0.45 μm, preweighed Nucleopore filter. The filters will then be placed in individual vials and later dried and weighed to obtain the particulate weight per unit volume.

## Appendix 5

# MICROBIOLOGICAL SAMPLING ON THE BIE 2 CRUISE

by Dr. Fred Dobbs

Samples were collected from the Patton Escarpment and the BIE site. At both areas, sediment was sampled to quantify microbial biomass (lipids and ATP), characterize microbial community structure (lipids), and estimate concentrations of labile protein. Microbial biomass and labile protein represent potential food resources for deposit-feeding macrofauna, the dominant trophic group of the deep-sea benthos. With respect to the Benthic Impact Experiment, information on the amount and vertical distribution of food for deposit feeders, and comparison of samples taken before and after disturbance, will provide insight into the potential effects of deep-sea mining of manganese nodules. At the Patton Escarpment phytodetritus site, additional samples were collected for analysis of pigments and sedimentary carbon and nitrogen. Details about the sampling at each area are provided below.

## PATTON ESCARPMENT:

Three multicores were collected and from each, one tube was sampled for microbiology (lipids and protein) and another tube for pigments and CHN (carbon, hydrogen, and nitrogen) (Table 1). From each tube, a total of fifteen sediment horizons were collected in the ship's microbiology laboratory: 0.5-cm intervals from the sediment-water interface down to 5.0 cm, then 1.0-cm intervals down to 10 cm. Samples for lipids, protein, pigments, and CHN were quickly frozen in liquid nitrogen and transferred to the ship's freezer (-16 degrees C). Samples for ATP were collected from the "microbiology" core and from only the uppermost three horizons (0.0-0.5, 0.5-1.0, and 1.0-1.5 cm). ATP samples were plunged into cold 0.5 N sulfuric acid ($H_2SO_4$) and refrigerated.

## BIE SITE:

Samples were collected from fifteen multicores taken after the disturber's operation (Table 2). From each multicore, one tube was sectioned in the ship's microbiology laboratory as described above. Immediately after a horizon was collected, sediment for analysis of lipids and protein was frozen (see paragraph below for details) and later transferred to the ship's freezer. So-called "clumps" of sediment were also sampled on the several occasions when they were distinctly positioned on the otherwise level sediment-water interface. Samples for ATP were processed as described above.

The freezing protocol calls for quick freezing in liquid nitrogen. However, my tank of liquid nitrogen degassed at an extraordinary rate, with the result that I had none left at the time when post-disturbance sampling began. I experimented with alcohol baths and ice, but the easiest and (surprisingly) quickest freeze was simply to place the samples on the freezer shelf of the laboratory refrigerator. I plan to assess the effects of slow freezing on my analyses, and probably will perform the comparative experiment, i.e., freezer shelf vs. liquid nitrogen, next September on BIE cruise # 3.

All samples will be transported to my laboratory at the University of Hawaii for further processing.

Table 1. Patton Escarpment: List of multicores from which samples were collected for analyses. The numbers in the two right-most columns correspond to the tube number within the multicorer assembly.

| CRS | MC | Microbiology | Pigments and CHN |
|---|---|---|---|
| 92 | 1 | 5 | 8 |
| 93 | 2 | 8 | 7 |
| 94 | 3 | 7 | 6 |

Table 2. BIE Site: List of multicores from which samples were collected for microbiological analysis.

| CRS | MC | Tube number |
|---|---|---|
| 105 | 8 | 5 |
| 106 | 9 | 5 |
| 107 | 10 | 1 |
| 108 | 11 | 5 |
| 109 | 12 | 3 |
| 110 | 13 | 2 |
| 111 | 14 | 2 |
| 112 | 15 | 4 |
| 115 | 18 | 5 |
| 116 | 19 | 5 |
| 117 | 20 | 5 |
| 119 | 22 | 8 |
| 120 | 23 | 2 |
| 122 | 25 | 4 |
| 123 | 26 | 4 |

## MEIOFAUNAL SAMPLING ON THE BIE 2 CRUISE

N.B. All samples for meiofaunal analysis were collected at the BIE site. Susan Schell processed the samples under my (FCD) supervision.

MEIOFAUNAL LIPID RESERVES: Samples for meiofaunal lipids were collected from fifteen multicores taken after the disturber's operation (Table 1). From each multicore, one tube was sectioned in the ship's microbiology laboratory as follows: 0.0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0, 2.0-2.5, and 2.5-3.0 cm. So-called "clumps" of sediment were also sampled on the several occasions when they were distinctly positioned on the otherwise level sediment-water interface. Immediately after a 0.5-cm horizon was collected, it was frozen (see following paragraph for details) and later transferred to the ship's freezer. The samples will be shipped frozen to Prof. David Thistle, The Florida State University, Tallahassee, Florida, 96822, USA. He will pick out the harpacticoid copepods from the sample and quantify their lipid content. Comparison of these pre-disturbance samples with post-disturbance samples will suggest the copepods' level of nutritional stress caused by redeposition of sediment. If the vertical distribution and lipid content of the copepods does not change following disturbance, then redeposition will be considered to have little effect. If lipid content decreases, then starvation will be indicated.

The freezing protocol calls for quick freezing in liquid nitrogen . However, my tank of liquid nitrogen degassed at an extraordinary rate, with the result that I had none left at the time when post-disturbance sampling began. I experimented with alcohol baths and ice, but the easiest and (surprisingly) quickest freeze was simply to place the samples on the freezer shelf of the laboratory refrigerator. I have alerted Prof. Thistle to this variation in procedure, and he will assess the effects of slow freezing on his analyses.

MEIOFAUNAL COMMUNITY STRUCTURE: Samples for meiofaunal community structure were collected from ten multicores taken after the disturber's operation (Table 1). From each multicore, one tube was sectioned in the ship's microbiology laboratory as described above. One tube (CRS 117, MC 20, Tube 7) was mistakenly processed on deck for macrofauna and the sample effectively lost for meiofaunal analysis. In another tube (CRS 112, MC 15, Tube 8), a "clump" of sediment was sampled separately. Each horizon was fixed in formalin (10%) and will be sent to and analyzed by Prof. David Thistle (address above). Comparison of these post-disturbance samples with pre-disturbance samples taken last year will indicate the degree of disruption to the meiofaunal community caused by redeposition of sediment.

Table 1. List of multicores from which meiofaunal samples were collected. The numbers in the two right-most columns correspond to the tube number within the multicorer assembly. A "-" signifies that no samples were collected.

| CRS | MC | Lipids | Community structure |
|---|---|---|---|
| 105 | 8 | 8 | 7 |
| 106 | 9 | 8 | 7 |
| 107 | 10 | 3 | 8 |
| 108 | 11 | 8 | 1 |
| 109 | 12 | 5 | - |
| 110 | 13 | 1 | - |
| 111 | 14 | 6 | 5 |
| 112 | 15 | 7 | 8 |
| 115 | 18 | 3 | 7 |
| 116 | 19 | 8 | 4 |
| 117 | 20 | 1 | 7* |
| 119 | 22 | 5 | 1 |
| 120 | 23 | 6 | - |
| 122 | 25 | 2 | - |
| 123 | 26 | 7 | - |

*This tube was selected for meiofauna, but accidentally processed for macrofauna.

## **Appendix 6**

### USA Scientific Party

| Chief Scientist | Affiliation |
|---|---|
| Dr. Dwight D. Trueblood | NOAA/ Ocean Minerals and Energy |

**Scientific Team**

| | |
|---|---|
| Dr. Erdogan Ozturgut[1] | NOAA/ Ocean Minerals and Energy |
| Mr. Craig Baily | NOAA Corps |
| Ms. Svetlana Andreeva | NOAA Corps |
| Mr. Dick Greenwald[1] | Ocean Mining Associates |
| Mr. Richard Petters | Williamson & Associates, Seattle |
| Mr. David Wilson | Williamson & Associates, Seattle |
| Mr. Meredith Sessions | Scripps Institute of Oceanography |
| Dr. Craig Smith[1] | University of Hawaii |
| Dr. Fred Dobbs | University of Hawaii |
| Ms. Susan Garner | University of Hawaii |
| Ms. Susan Schell | University of Hawaii |
| Mr. Shawn Doan[1] | University of Hawaii |
| Ms. Victoria Rectenwald | Texas A & M University |
| Dr. Gerd Schriver[1] | University of Hamburg, Germany |
| Mr. Lu Lin | Third Institute of Oceanography, China |
| Mr. Peter Schlicht[1] | Ocean Instruments |
| Mr. Tim Marrs[1] | Ocean Instruments |

1 - Participated only in test cruise operations off of Long Beach, CA.