CRUISE REPORT

R/V WECOMA W9508A

August 1st.- 5th. 1995

Newport, Or. to Newport, Or.

Microearthquakes on the Endeavour Segment, Juan de Fuca Ridge: OBS Recoveries

W. S. D. Wilcock
University of Washington
Seattle
WA 98195
&
G. M. Purdy
Woods Hole Oceanographic Institution
Woods Hole
Mass 02543

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SUMMARY

We sailed from Newport, Oregon in good weather conditions at 10am Tuesday August 1st bound for the Endeavour segment of the Juan de Fuca Ridge. The single primary objective of the cruise was to recover the fifteen ONR OBS that we had deployed (also from R/V WECOMA) at this location in early June (see Figure 1). We arrived on site to recover the first instrument (#59), a little after Noon on Tuesday, August 2nd. Wind speed was 15-20 knots and there was no swell and insubstantial seas. Recoveries proceeded in a routine way throughout the afternoon and evening, one instrument being recovered every 1.5 hours, approximately. Poor visibility hampered one or two of the recoveries but no real difficulties were experienced. All the instruments were sighted within a minute, at the most, of their expected surface times. All eight of the OBS located off-axis were on board by midnight when operations ended for the day. The seven remaining on-axis instruments could not be recovered until the following day because their programs of data recording did not end until 0815 LT on Wednesday, August 2nd. As soon as possible after recovery of the first OBS the slow process of transcription of the data from the OBS discs onto Exabyte tapes began - it was clear that this operation would have to be carried on continuously if transcription was to be completed before arrival in Newport.

Following a nights sleep the first of the on-axis instruments was released at 830am and the remaining seven OBS were brought on board uneventfully, the last instrument being recovered on board at 1740. The rise time of all the instruments was in the 35-40 minute range and the recovery locations (see Appendix 2) were generally within 0.15nm of the deployment positions. An error was detected in the (lab) recorded position for OBS#53. When the instrument was interrogated before release the horizontal range was seen to be too great - by assuming the planned deployment location was indeed the real position we were able to recover the instrument without difficulty.

The performance of the acoustic transponder/release system was remarkably consistent on this cruise. It was not necessary to transmit a command more than once to any of the OBS - the weather was not rough and we routinely declutched the shaft before every recovery - maybe these are the reasons. Performance of the OBS system overall was reasonable (see Appendices 3 and 4) and data return, at least based on our preliminary assessment, was within acceptable limits - two OBS suffered failures of some part of their power regulator systems resulting in only partial data recovery, and a third had timing problems. Thirteen of the fifteen OBS recorded approximately 1.5 GB of data.

At 1900LT on Thursday August 3rd., having secured all the recovered OBS instruments, we set course for Newport. At 0546LT the following morning we stopped on station to carry out a hydrocast to 2200m using the ship's *Seabird* carousel water sampler, CTD, transmissometer and fluorometer. Three attempts were made to carry out this station but the water sampler failed to operate reliably. At 1415LT a fourth attempt was made to carry out a shallow station. Again the water sampler failed to operate satisfactorily. Further attempts were not judged to be worthwhile and so course was set for Newport at 1530LT.

The vessel came alongside in Newport at 0700 August 5th and unloading began.

Overall the cruise was very successful. All instruments were recovered without difficulty, data return was reasonable, the co-operation we received from all the ships complement was exemplary and the ship handling was excellent (see Appendix 5). The wind never blew more than 20 knots - we were very lucky with the weather.

Plans for meeting our obligations to the Canadian Government are in Appendix 8.

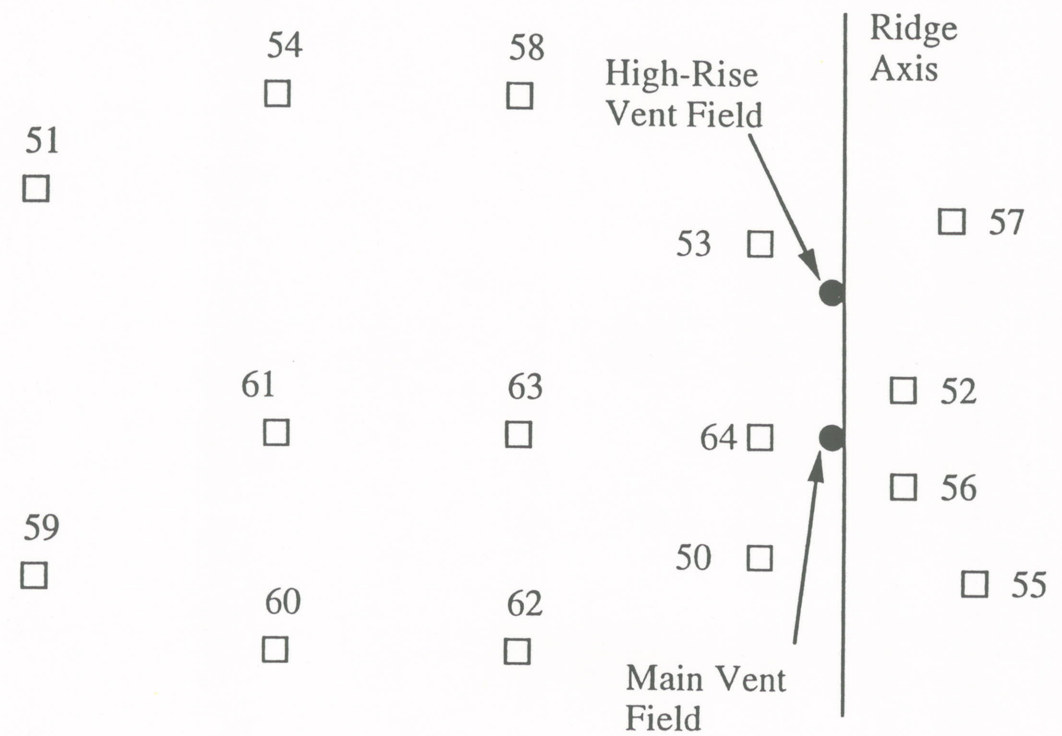


Figure 1. Schematic diagram showing the layout of the OBS network which spans the axial valley and extends about 14 km to the west.

SCIENTIFIC OBJECTIVES

- The overall objective is to study the distribution and characteristics of microearthquake activity across the Endeavour segment of the Juan de Fuca Ridge. The plan is to deploy a network of 15 ONR Ocean Bottom Seismometers (OBSs) for a two month period to span the axial valley in the vicinity of the main vent field and the Western flanks out to crustal ages of 0.5 My (~15km). Although the seismicity in this region has not been well characterized by studies to date, regional T-phase data show that many epicenters lie well off-axis in areas of ridge parallel bathymetry. The Endeavour segment appears to be in a tectonic phase of its evolution and this experiment has specific objectives to:

- Characterize the distribution and nature of off-axis microearthquake activity and to use these data to evaluate and refine existing models of the tectonic evolution of young oceanic crust as it moves off axis.

- Estimate the depth of the brittle-ductile transition from the maximum depth of seismicity as a function of distance from the ridge axis, and to relate the results to models of hydrothermal circulation and crustal cooling.

- Two auxiliary objectives will be to provide an opportunity to assess the errors in epicentral locations determined from regional US Navy acoustic arrays (SOSUS arrays) and, secondly, to provide high quality recordings of axial microearthquake swarms.

- A secondary oceanographic objective was to confirm the presence of a sedimentary denitrification signal in Washington coastal waters via the collection of samples for high precision gas ratio and gas isotopic analyses.

OPERATIONAL OBJECTIVES

- Recover a network of 15 ONR OBS that had been recording microearthquake activity on the Endeavour segment of the Juan de Fuca Ridge for ~2 months.

- As an auxiliary program, for participating UW graduate student Jay Brandes, carry out two hydrocasts, one deep one shallow, using the OSU *Seabird* carousel water sampler with CTD, transmissometer and fluorometer.

LOG BOOK

Sunday July 30th., 1995

Arrive in Newport around 3pm. Load some essential gear on board and check operation of Sun and OBS PC computers and the master GPS clock.

Monday July 31st., 1995

Complete loading of gear and checkout of computer systems

Tuesday August 1st., 1995

1535 UT (0835LT) Preparing to sail - weather excellent
1700 UT (1000LT) Depart Newport, heading for OBS #59 position.
1800 UT (1100LT) Complete F&B drill - dense fog, but reasonably calm seas. Proceeding at full speed

Wednesday August 2nd., 1995

0100UT (1800LT) Proceeding at full speed, visibility clear. Wind speed 15knots. ETA at OBS site late morning tomorrow
1500UT (0800LT) Proceeding at full speed, wind speed 20 knots, reasonable visibility but some cloud in sight. ETA at first OBS site (#59) is around 1115 LT this morning. The plan is to recover eight instruments (i.e. all the off-axis instruments) today in the following order: #59, #51 (the one-year instrument), #54, #61, #60, #62, #63, and finally #58. If all goes well then we will recover the remaining seven on-axis instruments tomorrow.
1745UT (1045LT) Discovered that Bridge was not heading for the OBS#59 position, but rather for some generic location in the center of the network. Passed the #59 position to the Bridge and a small course change was made. The ETA now is around 1210LT. Weather conditions are excellent - if anything improving, although there remain a few rain showers in sight.
1917UT (1217LT) **OBS #59 Confirmed release**. Predicted surface time 1257LT
1959UT (1259LT) **OBS #59 sighted on surface** about 0.5 nm on the beam
2009UT (1309LT) **OBS #59 Instrument alongside** Position:
47° 58.51'N 129° 16.69'W
2013UT (1313LT) **OBS #59 on board.** One flasher flooded, radio OK.
2022UT (1322LT) Getting underway to OBS#51 position. This is the one year instrument.

2059UT (1359LT) **OBS #51 Confirmed release.** Predicted surface time 1440LT
2141UT (1441LT) **OBS #51 Surface**
2152UT (1452LT) **OBS #51 Alongside** Position:
48° 01.16'N 129° 14.84'W
2200UT (1500LT) Underway to OBS #54 position

2229UT (1509LT) **OBS #54 Confirmed release**. Predicted surface time 1609LT
2310UT (1610LT) **OBS #54 Surface**
2320UT (1620LT) **OBS #54 Alongside** Position:
48° 01.00'N 129° 11.14'W
2323UT (1623LT) **OBS #54 on board**
2328UT (1628LT) Underway to OBS #61 position.

Thursday August 3rd., 1995

0008UT (1708LT) **OBS #61 Confirmed release**. Predicted surface time 1750LT
0050UT (1750LT) **OBS#61 Surface**
0056UT (1756LT) **OBS#61 Alongside** Position
47° 58.80'N 129° 12.42'W
0059UT (1759LT) **OBS #61 On Board**
0106UT (1806LT) Underway to OBS#60 position

0136UT (1836LT) **OBS#60 Confirmed release**. Predicted surface time 1918LT
0218UT (1918LT) **OBS#60 Surface**
0227UT (1927LT) **OBS#60 Alongside** Position:
47° 56.77'N 129° 13.87'W
0230UT (1930LT) **OBS#60 On Board**
0233UT (1933LT) Underway to OBS#62 position

0312UT (2012LT) **OBS#62 Confirmed release.** Predicted surface time 2050LT
0350UT (2050LT) **OBS#62 Surface -** very low visibility, not easily sighted
0358UT (2058LT) **OBS#62 Alongside.** Position:
47° 55.98'N 129° 10.61'W
0403UT (2103LT) **OBS#62 On Board**
0405UT (2105LT) Underway to OBS#63 position - patchy fog, visibility low and variable

0438UT (2138LT) **OBS#63 Confirmed release**. Predicted surface time 2216LT
0516UT (2216LT) **OBS#63 Surface** - patchy fog, but clear for this pickup.
0526UT (2226LT) **OBS#63 Alongside**. Position:
47° 57.91'N 129° 09.49'W
0530UT (2230LT) **OBS#63 On Board**
0535UT (2235LT) Underway to OBS #58 position for the last pickup of the night - approach to the position slowed by traffic in the area.

0614UT (2314LT) **OBS#58 Confirmed release.** Predicted surface time 2352LT
0654UT (2354LT) **OBS#58 Surface**
0706UT (0006LT) **OBS#58 Alongside**. Position:
47° 59.9'N 129° 07.81'W
0708UT (0008LT) **OBS#58 On Board.** Heave to overnight.
0800UT (0100LT) Secure for the night - transcribing operations continuing, albeit slowly.
1400UT (0700LT) Standing-by for the first recovery (OBS#50) - weather remains very good though rain showers are visible.

1533UT (0833LT) **OBS#50 Confirmed release**. Predicted surface time 0908LT. Acoustic range to OBS was about 60m less than supposed instrument depth - so depth from Seabeam map must be in error.
1607UT (0907LT) **OBS#50 Surface** The tactic of holding off 0.3nm from the deployment position, keeping the OBS position on the bow seems to work very well.
1616UT (0916LT) **OBS#50 Alongside.** Position:
47° 56.27'N 129° 06.84'W
1621UT (0921LT) **OBS#50 on board**
1624 UT (0924LT) Underway to OBS#64 position.

1654UT (0954LT) **OBS#64 Confirmed release**. Predicted surface time 1028LT.

1727UT (1927LT) **OBS#64 Surface**
1736UT (1036LT) **OBS#64 Alongside**. Position:
47° 57.08'N 129° 06.20'W
1740UT (1040LT) **OBS#64 on board**
1745UT (1045LT) Underway to OBS#53 position

1815UT (1115LT) **OBS#53 Confirmed release**. Predicted surface time 1151LT. Acoustic ranges to instrument were unusually high. Upon comparing lab and bridge GPS positions for this instrument a 0.5' descrepancy in latitude was detected. Strongly suspect lab position is in error. Decided to carry out recovery under assumption that bridge position was correct. This proved to be a valid assumption. Believe lab latitude should be 47° 58.38'N and NOT 58.88'N. Basic error of reading a 3 for an 8.
1851UT (1151LT) **OBS#53 Surface**
1858UT (1158LT) **OBS#53 Alongside.** Position:
47° 58.31'N 129° 05.64'W
1902UT (1202LT) **OBS#53 on board**
1906UT (1206LT) Underway to OBS#57 position

1933UT (1233LT) **OBS#57 Confirmed release.** Predicted surface time 1307LT.
2007UT (1307LT) **OBS#57 Surface**
2017UT (1317LT) **OBS#57 Alongside.** Position:
47° 58.03'N 129° 04.40'W
2021UT (1321LT) **OBS# 57 on board.**
2024UT (1324LT) Underway to OBS#52 position

2055UT (1355LT) **OBS#52 Confirmed release**. Predicted surface time 1431LT
2132UT (1431LT) **OBS#52 Surface**
2144UT (1444LT) **OBS#52 Alongside**. Position:
47° 57.24'N 129° 05.39'W
2149UT (1449LT) **OBS#52 on board.**
2155UT (1455LT) Underway to OBS#56 position

2220UT (1520LT) **OBS#56 Confirmed release**. Predicted surface time 1556LT.
2256UT (1556LT) **OBS#56 Surface**
2314UT (1614LT) **OBS#56 Alongside.** Position:
47° 56.67'N 129° 05.77'W
2317UT (1617LT) **OBS#56 on board**
2320UT (1620LY) Underway to OBS#55 position - the last OBS.

2347UT (1647LT) **OBS#55 Confirmed release**. Predicted surface time 1721LT

Friday August 4th., 1995

0022UT (1722LT) **OBS#55 Surface**
0034UT (1734LT) **OBS#55 Alongside. Position**:
47° 55.55'N 129° 05.55'W
0040UT (1740LT) **OBS#55 On board**. Heave to, to secure all OBS gear. Complete plans for the remainder of the trip will carry out two hydrocasts, but still get in to Newport on Saturday morning.

0200UT (1900LT) All secure - getting underway at full speed for the first hydrocast station at 46° 30'N 127° 00'W
1230UT (0530LT) Heave to, to carry out first hydrocast

1246UT (0546LT) Commence lowering using *Seabird* carousel sampler - down to 2200m

Position: 46° 29.94'N 127° 00.07'W
Water depth: 2687 corr.m
Will take 10 samples between 1150-2200m.

1515UT (0815LT) Water sampler over the side to repeat the hydrocast - the first time it did not work. Only 14 hours from Newport so this will have no impact on our arrival time. Recorder package #32 was dropped on the deck yesterday as it was being loaded onto its rack in the main lab. When this package was opened this morning to have its disc removed it was determined that several of the screws holding the internal frame to the end cap had been sheared off by the impact. Weather conditions continue to be good, though cloudy. Multiple satellite phone calls made in an effort to organise shipping of our vans out of Eugene on Monday instead of Wednesday.

1705UT (1005LT) *Seabird* carousel sampler on board - and again it had not worked - i.e. the bottles had not closed. Remain on station for a while to see if any explanation for the failures can be determined.

1855UT (1155LT) *Seabird* carousel sampler overside for third attempt at the hydrocast station.

2015UT (1315LT) Water sampler recovered - a few samples recovered this time - intermittent operation.

2120UT (1420LT) Water sampler overside again to try for a shallow cast (1000m). Will fire two bottles at each depth to increase the chances of getting something......

2220UT (1520LT) Water sampler on board - only one bottle operated. End of science operations - steaming for Newport. Received message from WHOI that the truck to transport our gear back home had been arranged for Monday afternoon.

Saturday August 5th., 1995

1400UT (0700LT) Alongside in Newport - unloading begins.

DATA AND RESULTS

The short length of the cruise did not allow sufficient time for useful evaluation of the data quality. All data processing efforts were directed towards producing two Exabyte copies of each OBS' data and making a basic log of the events that each OBS had recorded (see Appendices 6 and 7). One copy of the tapes will archived at WHOI, the other will serve as the working copy to be held at UW where the interpretation of these results will be carried out. These logs had not been completed at the time of writing of this report. Suffice it to say that, as detailed in Appendix 4, 13 of the 15 OBS recorded approximately 1.5Gb of data each, and that this volume of data corresponds to the recording of more than 1000 events per instrument (in addition to the substantial blocks of continuously recorded data). Therefore it seems probable that a large and powerful set of data have been recorded.

The primary problem with the data undoubtedly will be caused by the large number of instruments that suffered severely tilted sensor packages (again see Appendix 4).

An initial event count was made following the logging of the Exabyte tapes immediately following their transcription from the OBS discs (see Appendix 6). The table "on axis events" (overleaf) lists how many triggered events were recorded on each day of the experiment, and the total number of triggers over the entire 42 day of event detect recording deployment, for each of the seven OBSs arranged along the ridge axis. The table "off axis events" (on the following page) lists the same information, but for the eight OBSs which lie off to the west of the ridge axis. Two OBSs (54 and 62) failed to record to the end of the experiment. The periods of continuous recording are not included in these tables. The largest number of triggers in any day was 763 events recorded on OBS 52 on Julian day 175, while the minimum number of triggers was zero. The total number of triggers recorded over the deployment varied by over two orders of magnitude, from 64 triggers on OBS 58 to 13585 triggers on OBS 52. The large number of triggers on many OBSs almost certainly include many non-seismic events since the event-detect trigger ratios were deliberately set low. The small number of triggers on OBS 58 may be due an unusually high background noise level or to an instrumentation problem. One of the first tasks of the data analysis will be to separate the seismic and non-seismic events, a formidable task!

Event Counts for On-Axis Instruments

	A	B	C	D	E	F	G	H
1	OBS	50	64	53	57	52	56	55
2	Julian Day							
3								
4	159		95			88	21	98
5	160	255	262	69	93	320	125	196
6	161	23	12	16	32	39	9	14
7								
8	Continuous							
9								
10	162	370	29	45	173	291	16	23
11	163	94	108	58	111	362	24	44
12	164	119	133	182	490	492	70	115
13	165	373	26	144	662	672	30	48
14	166	476	146	68	438	443	46	342
15	167	309	382	136	130	451	59	185
16	168	75	162	289	76	551	70	62
17	169	299	48	61	48	308	289	51
18	170	91	30	76	31	318	172	165
19	171	273	18	67	22	281	24	57
20	172	123	26	77	30	270	93	97
21	173	60	12	70	25	195	21	45
22	174	300	28	64	23	415	21	84
23	175	85	15	53	26	763	21	85
24	176	100	136	75	47	419	35	100
25	177	107	68	98	95	302	72	193
26	178	79	28	219	80	431	43	123
27	179	119	76	167	86	470	34	339
28	180	114	98	103	64	387	43	113
29	181	235	160	322	175	626	134	145
30	182	68	25	88	44	310	36	176
31	183	75	19	36	39	203	19	160
32	184	175	104	64	89	303	40	116
33	185	140	76	58	20	223	20	75
34	186	130	71	112	68	299	34	123
35	187	57	12	39	27	146	7	48
36	188	43	22	68	19	106	12	48
37	189	114	34	70	55	301	50	120
38	190	100	17	42	38	221	19	104
39	191	64	14	22	12	250	13	120
40	192	67	15	21	16	194	9	111
41	193	324	117	236	198	505	127	462
42	194	67	23	51	56	260	21	282
43	195	90	17	53	68	210	21	257
44	196	99	69	119	92	405	39	201
45	197	39	30	19	74	143	14	292
46	198	71	34	37	41	201	35	174
47	199	32	12	20	26	203	15	71
48	200	37	35	24	29	206	8	108
49	201				1	2	1	1
50								
51	Continuous							
52								
53	TOTAL	5871	2844	3638	3969	13585	2012	5773

Event Counts for Off-Axis Instruments

	A	B	C	D	E	F	G	H	I
1	OBS	59	51	54	61	60	62	63	58
2	Julian Day								
3									
4	159				6		122		
5	160	242	142	188	23	228	175	252	9
6	161	2	17		2	17	13	42	3
7									
8	Continuous								
9									
10	162	44	39	94	11	32	15	155	
11	163	45	68	94	21	32	24	134	
12	164	85	54	76	19	64	42	198	10
13	165	74	57	54	23	47	50	139	
14	166	54	48		20	46	52	196	2
15	167	82	59		14	34	127	219	2
16	168	120	59		47	92	54	218	6
17	169	74	47		34	49	119	152	
18	170	82	49		23	56	183	189	1
19	171	101	49		13	49	94	241	3
20	172	78	64		13	35	64	135	2
21	173	49	51		10	24	26	124	3
22	174	78	40		9	46	18	318	
23	175	63	44		9	45	23	162	2
24	176	43	26		5	23		155	
25	177	64	22		21	23		199	1
26	178	75	25		21	35		274	2
27	179	60	25		29	21		213	
28	180	49	27		40	24		151	
29	181	84	47		12	35		232	6
30	182	36	17		12	11		104	2
31	183	7	17		27	8		47	2
32	184	32	20		21	23		92	
33	185	36	31		35	31		86	
34	186	136	131		13	103		153	
35	187	72	32		26	51		110	
36	188	56	53		21	45		74	1
37	189	49	59		11	41		112	2
38	190	42	74		20	28		103	
39	191	45	64		25	20		79	
40	192	32	46		21	26		54	
41	193	145	136		39	119		257	2
42	194	38	51		44	25		92	
43	195	31	47		23	37		86	
44	196	37	34		30	29		123	
45	197	32	45		43	20		63	
46	198	75	82		54	46		103	
47	199	21	30		86	13		50	3
48	200	18	35		24	12		38	
49	201		1		1				
50									
51	Continuous								
52									
53	TOTAL	2588	2064	506	1001	1745	1201	5924	64

APPENDICES

Appendix 1: Personnel

Science Complement

W.S.D. Wilcock	Chief Scientist, University of Washington
S. Archer	Graduate Student, University of Washington
J. Bailey	Technician, WHOI
L. Bachelor	Undergraduate Student, OSU
J. Brandes	Graduate Student, University of Washington
D. DuBois	Technician, WHOI
J. Hallinan	Engineer, WHOI
R. Handy	Technician, WHOI
G. M. Purdy	Co-Chief Scientist, WHOI
M. Willis	OSU Marine technician
R. Bower	OSU Electrical Technician

Officers and Crew

D. J. Arnsdorf	Master
P. A. Smith	Chief Mate
M. Jenkins	2nd Mate
J.R.Keiper	Bos'n
R. Torgeson	A/B
R. E. Guillory	A/B
M.D.Estey	A/B
R. F. Ashley	Chief Engineer
E. S. Beavers	Assistant Engineer
J. D. Walters	Assistant Engineer
R. L. Searls	Cook/Steward
R. G. Schroeder	Messman

Appendix 2: OBS Recovery Table

OBS #	Date/Time Alongside	Position when alongside Latitude	Longitude	Observed Rise Rate m/min
#59	8/2/2009UT	47° 58.51'N	129° 16.69'W	59
#51	8/2/2152UT	48° 01.16'N	129° 14.84'W	60
#54	8/2/2320UT	48° 01.00'N	129° 11.14'W	60
#61	8/3/0056UT	47° 58.80'N	129° 12.42'W	61
#60	8/3/0227UT	47° 56.77'N	129° 13.87'W	62
#62	8/3/0358UT	47° 55.98'N	129° 10.61'W	61
#63	8/3/0526UT	47° 57.91'N	129° 09.49'W	61
#58	8/3/0706UT	47° 59.90'N	129° 07.81'W	59
#50	8/3/1616UT	47° 56.27'N	129° 06.84'W	63
#64	8/3/1736UT	47° 57.08'N	129° 06.20'W	64
#53	8/3/1858UT	47° 58.31'N	129° 05.64'W	58
#57	8/3/2017UT	47° 58.03'N	129° 04.40'W	62
#52	8/3/2144UT	47° 57.24'N	129° 05.39'W	60
#56	8/3/2314UT	47° 56.67'N	129° 05.77'W	62
#55	8/4/0034UT	47° 55.55'N	129° 05.55'W	61

Appendix 3: OBS System Performance - Hardware and Operations

The EG&G acoustic release system operated exceptionally well. In every case the transponders replied to the first command - at no time was it necessary to transmit a command twice! Because of concerns about spurious replies from instrumentation deployed in this busy region we routinely sent out interrogate commands before beginning the release procedure. In two cases this proved to be a worthwhile precaution - in each case we simply switched to the second release unit.

The rise rate was well established to be 61m/min, on average, a substantial increase of approximately 20 m/min resulting from the addition of two balls to the frame.

The primary disappointment with regards to the data was the large number of sensor packages that were tilted greater than 15° while on the seafloor:

Overview of Sensor Package Tilts

In Range of Gimbals:	**OBS#**	**51,54,58,59,61,63**
Near 15° Tilt:	**OBS#**	**52,53,60**
Clearly > 15° Tilt:	**OBS#**	**50,55,56,57,62,64**

While this cruise reaffirmed the importance of the RSLI (rust spot level indicators) that show us the magnitude and direction of the sensor tilt, it suggested also that some redesign of the sensor package base may be required to improve performance in rough terrains.

The Sauter compasses seemed to work fine although reading them is a tedious operation. One was lost - only the string came back!

Two Novatech flashers failed, both due to water leaks. This did not cause a problem on this cruise, but if both units had, by chance, been on one OBS that was to be recovered at night, then the situation would have been less than optimum. We suffered no radio failures - the radios remain very important as a signal that an instrument has surfaced - certainly in one instance an instrument surfaced at a time when visibility was down to 2-300yds and the confirmation provided by the radio was important. It did not prove necessary, at any time, to use the radio beacon to determine bearing.

In the current conditions at Juan de Fuca the instruments were surfacing within 0.15nm of their drop locations. The procedure adopted by the bridge for pickups was to approach the deployment position upwind and aim to be ~0.3nm away at the time of surfacing. This proved a good compromise between being close enough for reliable visual contact and far enough away to provide maneuvering room for the vessel. Importantly it practically guaranteed that the OBS would surface ahead of the vessel.

Appendix 4: OBS System Performance: Electrical

Seascan and Bigtime Clock Drifts for Juan De Fuca

The convention to calculate the change in time during deployment established in the first deployment of FARA and modified slightly during 504B is maintained. To review:

First the SAIL Vs Instrument Bigtime number: The Delta (both recovery and deployment) is formed by subtracting the Bigtime from the SAIL time.

Second the SAIL Vs Seascan time: The Delta (both recovery and deployment) is formed by subtracting the Seascan time from the SAIL time.

The modification made on 504B and maintained here was to zero the SAIL clock relative to the GPS clock prior to reading all clocks. Therefore no corrections are necessary for the SAIL clock.

The latest specification for Seascan drift is put at 300 milliseconds per year or 0.82 msecs per day. Any clock with a change of greater than 46.849 msecs during the deployment has failed to meet this specification. Clocks failing this specification are:

TABLE A4.1 DRIFTING CLOCKS

Seascan Clock #	OBS #
37	54
20	57
28	59
18	61

TABLE A4.2 CLOCK PERFORMANCE

OBS#		Deployment	Recovery	Bigtime change in msecs	Seascan change in msecs
	SAIL	0159 21:04:44.985107	215 16:32:36.973041		
	@ Bigt	802645485	807467557		
50	Delta	-14.893	-26.959	-12.066	
	SAIL @	0159 21:05:33.999495	215 16:35:03.987433		
	Seascan 46	0159 21 05 34	215 16 35 04		
	Delta	-0.505	-12.567		-12.062
	SAIL	0159 17:09:54.984914	214 22:10:27.948912		
	@ Bigt	802631395	807401428		
51	Delta	-15.086	-51.088	-36.002	
	SAIL @	0159 17:10:53.999545	214 22:11:29.963538		
	Seascan 39	0159 17 10 54	214 22 11 30		
	Delta	-0.455	-36.462		-36.007
	SAIL	0158 21:55:41.985157	215 21:58:31.986911		
	@ Bigt	802562142	807487112		
52	Delta	-14.843	-13.089	+1.754	
	SAIL @	0158 21:56:55.999820	215 21:59:42.001576		
	Seascan 31	0158 21 56 56	215 21 59 42		
	Delta	-0.180	+1.576		+1.756

	SAIL	0159 20:25:59.986349	215 19:10:00.994515		
	@ Bigt	802643160	807477001		
53	Delta	-13.651	-5.485	+8.166	
	SAIL @	0159 20:27:06.001009	215 19:11:20.009175		
	Seascan 27	0159 20 27 06	215 19 11 20		
	Delta	+1.009	+9.175		+8.166
	SAIL	159 20: 001:03.984371	214 23:40:01.934024		
	@ Bigt	802641664	807406802		
54	Delta	-15.629	-65.976	-50.347	
	SAIL @	0159 20:02:03.998998	214 23:40:34.948656		
	Seascan 37	0159 20 02 04	214 23 40 35		
	Delta	-1.002	-51.344		-50.342
	SAIL	0159 01:28:16.985182	216 01:07:46.942836		
	@ Bigt	802574897	807498467		
55	Delta	-14.818	-57.164	-42.346	
	SAIL @	0159 01:29:12.999815	216 01:08:42.957465		
	Seascan 17	0159 01 29 13	216 01 08 43		
	Delta	-0.185	-42.535		-42.350
	SAIL	0158 22:23:58.985533	215 23:22:24.976341		
	@ Bigt	802563839	807492145		
56	Delta	-14.467	-23.659	-9.192	
	SAIL @	0158 22:25:02.999887	215 23:22:59.990704		
	Seascan 32	0158 22 25 03	215 23 23 00		
	Delta	-0.113	-9.296		-9.183
	SAIL	0159 20:46:17.983574	215 20:35:41.915381		
	@ Bigt	802644378	807482142		
57	Delta	-16.426	-84.619	-68.193	
	SAIL @	0159 20:47:08.998214	215 20:36:06.930023		
	Seascan 20	0159 20 47 09	215 20 36 07		
	Delta	-1.786	-69.997		-68.191
	SAIL	0158 18:49:57.981408	215 07:19:05.934872		
	@ Bigt	802550997	807434345		
	Delta	+981.408	+934.872	-46.536	
58	SAIL @	0158 18:51:25.999940	215 07:19:42.953409		
	Seascan 34	0158 18 51 26	215 07 19 43		
	Delta	-0.060	-46.591		-46.531
	SAIL	0159 19:27:36.980740	214 20:35:10.897640		
	@ Bigt	802639657	807395711		
59	Delta	-19.260	-102.360	-83.100	
	SAIL @	0159 19:28:30.999285	214 20:35:58.916194		
	Seascan 28	0159 19 28 31	214 20 35 59		
	Delta	-0.715	-83.806		-83.091
	SAIL	0159 18:40:28.984893	215 02:43:37.974548		
	@ Bigt	802636829	807417818		
60	Delta	-15.107	-25.452	-10.345	
	SAIL @	0159 18:41:28.999520	215 02:44:03.989183		
	Seascan 30	0159 18 41 29	215 02 44 04		
	Delta	-0.480	-10.817		-10.337

	SAIL	0158 20:19:47.980877	215 01:12:12.926544		
	@ Bigt	802556388	807412333		
61	Delta	-19.123	-73.456	-54.333	
	SAIL @	0158 20:20:50.999402	215 01:12:45.945073		
	Seascan 18	0158 20 20 51	215 01 12 46		
	Delta	-0.598	-54.927		-54.329
	SAIL	0158 21:23:26.981474			
	@ Bigt	802560207	No Bigtime		
62	Delta	-18.526			
	SAIL @	0158 21:24:56.999994	215 04:23:25.967710		
	Seascan 41	0158 21 24 57	215 04 23 26		
	Delta	-0.006	-32.290		-32.284
	SAIL	0159 18:04:02.984485	215 05:39:38.958450		
	@ Bigt	802634643	807428379		
63	Delta	-15.515	-41.550	-26.035	
	SAIL @	0159 18:04:59.999113	215 05:42:23.973076		
	Seascan 51	0159 18 05 00	215 05 42 24		
	Delta	-0.887	-26.924		-26.037
	SAIL	0158 23:02:43.981360	215 17:50:40.951391		
	@ Bigt	802566164	807472241		
64	Delta	-18.640	-48.609	-29.969	
	SAIL @	0158 23:03:43.999893	215 17:51:21.969928		
	Seascan 29	0158 23 03 44	215 17 51 22		
	Delta	-0.107	-30.072		-29.965

TABLE A4.3 PRELIMINARY OBS PERFORMANCE ASSESSMENT

OBS #	Data bytes disk1	Data bytes disk2	Data Total	Clock drift (msecs)	Error Codes	Comments
50	1,054,514,176	661,846,528	1,716,360,704	-12.066	None	Voltages OK Excessive sensor tilt.
51	1,056,106,496	493,786,624	1,549,893,120	-36.007	None	Voltages OK Sensor tilt OK
52	1,056,568,832	985,631,232	2,042,200,064	+1.756	None	Voltages OK Sensor tilt marginal
53	1,054,107,648	567,888,896	1,621,996,544	+8.166	None	Voltages OK Sensor tilt marginal
54	157,900,288	0	157,900,288	-50.342	ecomseq	24 @ 3.06V. Recorder draws >> 3 amps of shore current. Excessive clock drift Sensor tilt OK
55	1,054,055,936	658,165,760	1,712,221,696	-42.350	None	Dropped recorder after post recovery debriefing Excessive sensor tilt.
56	1,055,160,832	499,873,280	1,555,034,112	-9.183	None	Voltages OK Excessive sensor tilt.
57	1,056,073,216	580,859,904	1,636,933,120	-68.191	None	Voltages OK Excessive clock drift Excessive sensor tilt
58	1,056,073,216	327,648,256	1,383,721,472	-46.531	None	Voltages OK Sensor tilt OK
59	1,053,716,480	519,071,232	1,572,787,712	-83.091	None	Voltages OK Excessive clock drift Sensor tilt OK
60	1,055,344,640	456,490,496	1,511,835,136	-10.337	None	Voltages OK Sensor tilt marginal
61	1,053,031,936	401,272,320	1,454,304,256	-54.329	None	Voltages OK Excessive clock drift sensor tilt OK
62	288,678,912	0	288,678,912	-32.284	Not available	24 V and +12 V drained. Unable to talk to unit. Disk draws >> 3 amps of shore current. Excessive sensor tilt.
63	1,054,295,040	746,250,752	1,800,545,792	-26.969	None	Voltages OK Sensor tilt OK
64	1.055,496,192	533,004,288	1,588,500,480	-29.965	None	Voltages OK Excessive sensor tilt.

OBS 54 and 62

OBS 54: The debriefing of OBS 54 indicated that the +24 Volts had been drained and the disks could not be turned on. There was one error code "ecomseq" indicating there was a problem in the command sequence to disk. The shore power supplies were turned on in attempt to examine the disks but the current draw from the supplies was excessive (>>3 amps). Upon opening the pressure housing the disks were moved to another recorder and powered up. They seem to work fine. Disk number one went through the transcription process with no problem. The disks were reinstalled in OBS 54. The battery was removed from the recorder and examined with no apparent anomalies. The recorder was powered up under shore power and the disks seem to work. Disk number one went through the transcription process with no problem. A new battery was installed and shore power was applied. The current draw was not excessive. There are two scenarios. One is that the CPU got hung up after the disk had been turned on draining the battery and the other is that a short somewhere drained the battery. Visual inspection did not find a short.

OBS 62: The debriefing of OBS 62 indicated that the +24 Volts and the +12 Volts had been drained. The instrument had lost all error codes and bigtime was not running. The disks could not be turned on. The shore power supplies were turned on in attempt to examine the disks but the +24 Volt current draw from the supplies was excessive (>>3 amps). Upon opening the pressure housing the disks were moved to another recorder and powered up. They seem to work fine. The battery was removed from the recorder and examined with no apparent anomalies. Disk number one went through the transcription process with no problem. There are two scenarios. One is that the CPU got hung up after the disk had been turned on draining the battery and the other is that a short somewhere drained the battery. Visual inspection did not find a short.

Appendix 5: R/V WECOMA

As previously it was a pleasure to sail on the highly capable vessel R/V WECOMA. We suffered absolutely no delays and the fact we were able to complete all our recoveries in two days was due to skill concerned with every aspect of the vessel's operations. We received excellent co-operation from the ships officers and crew and all the ships systems operated faultlessly for us. The small articulated crane on the fantail had been repaired since our last trip in June and it was used for all the recoveries without difficulty.

One quantitative measure of the efficiency of the ship operations and, in particular, the skillful ship handling of the Captain and mates, is that the time (averaged over all fifteen recoveries) between the surfacing of an OBS and the time it was hooked onto the ship's crane was 10.2 minutes.

The Marine Technician, Mark Willis, could not have been more helpful. And everyone enjoyed the excellent food from the galley.

Someone who deserves special mention is nightwatchman at the Newport Marine Facility, Bob Bechtel. We arrived at the vessel late on a Sunday afternoon and desperately needed the services of a fork lift operator to help us get a couple of loads of gear on the ship - it was essential to get two of our main computer systems powered up so that if there were problems we had chance on Monday to obtain outside help before we sailed. Bob readily offered his assistance and did not complain when access to the equipment we needed required the moving of multiple vehicles in the storage area. He provided substantive assistance at a time when we really needed it, and we are extremely grateful.

The only flaw in the near perfect record of performance was the repeated failure of the *Seabird* water sampling system. On three deep lowerings only three samples were recovered, and on the one shallow lowering, only one. It seemed little return for Jay Brandes' five days at sea.

Appendix 6: Data Transcription

For W9508A, the Juan de Fuca pickup cruise, a computer subnet consisting of indigo - a SPARC 1+, jade - a SPARC ELC, and pumori - a networked H-P LaserJet printer was formed to transcribe the large volume of OBS data. Indigo had as its peripherals a Unison 3-slot box containing two external disk drives and an Exabyte 8mm cartridge tape drive. Attachedto a second SCSI bus was an ADS 2-slot disk garage for use in transcribing the OBS data. When initially unpacked, the contents of the 3-slot box were found slid toward the back of the unit. There were no screws holding the disk and cartridge drives to the base of the unit. After having problems with one of the disks during the indigo bootup sequence, a power connector was exchanged and allother connectors were reseated. This enabled the bootup sequence to proceed without error.Screws were also put in place to keep the contents of the 3-slot box from shifting.

Connected to jade was an external Exabyte, an external disk drive, an ADS 2-slot boxcontaining two Micropolis 2210 disk drives formatted with filesystems that were also mounted onindigo, and a second 2-slot ADS disk garage (model AD5L-C) borrowed from Ken Peal for use intranscribing OBS disks. The latter formed part of a trio of lost luggage and was not connected tojade until after 4pm on 1 Aug.; the afternoon before sailing! Pumori was not only networked withthe Sun computers. A parallel PC connection and an AppleTalk connection broadened printeraccess. An extra Micropolis 2210 drive was configured at WHOI as a spare system disk whichcould be swapped in for either jade or indigo in the event of a system crash.

The primary data processing activity on the pickup cruise involved production of two byte-for-byte 8mm tape copies of each of the OBS disks containing data. The existence of two transcription systems which could be run in parallel and around the clock greatly speeded up the transcription process. Each full OBS disk took approximately 2 hours to transcribe to tape.

Jim Dolan modified the existing transcription program **obs_transcribe** to accept two input disk device names. Thus both OBS disks could be slotted into the 2-slot ADS garages and transcription could proceed without operator intervention. The only command line argument to the program was a parameter file containing: the two input disk device names, the output tape device name, the transcription log filename, and the start (2) and end (LBA+1) logical blocks (in decimal notation) to be transcribed. At this stage, the transcription program calculates the number of megabytes of data to transcribe to tape from the start and end LBAs given in the parameter file for the first disk and the results of transcription from the second disk are written to a file called obs.log.test.

So, the procedure followed on either system, differing mainly in the input disk device names was (for example using OBS 50):

1) login to the jdf cruise account.

2) cd /jdf1/recov ; a filesystem mounted on both machines.

3) create obs50 directory, move there, and edit a obs50_transcribe.par parameter file.

4) disable scrolling in the command tool window used. There was one case of a window disappearing and program termination which might have been due to an exceeded window resource.

5) put a data tape in the Exabyte drive and start the program:

obs_transcribe obs50_transcribe.par

6) when the program finishes rename the log files

mv obs50_transcribe.log obs50_transcribe.log1

mv obs.log.test obs.log.test1

7) change tapes, label and write protect the finished tape.

8) when the second copy is finished, do a **diff** on the log files to compare them. Assuming no differences other than date/time groups, concatenate the copy 2 log files and delete the copy 1 log files.

A check sheet was devised to keep track of recorder package warmup times, the copy-by-copy progress of transcription, quantities of data written to disk, and any other data quality indicators and comments of note.

After the first OBS (#59) was transcribed, one of the archive tapes was logged with a modified version of **obsed** called **lognobs** to be sure that what was on tape was the contents of both disks and that the transition between disks was not flawed.

dd if=/dev/rst1 bs=1048576 | lognobs

One unexplained glitch occured during the transcription of the first two instruments on indigo. A segmentation fault occured immediately after starting the program **obs_transcribe**. The **format** program could see the disk in the top slot (sd5) but declared it 'unknown'. To solve the problem for OBS #51, the target id for the top slot was changed to 0 (sd7 for SCSI bus esp1). For the next OBS (#61) and all subsequent transcription, the target id was returned to 1 (sd5).

During the Newport transit, **lognobs** was run on the copy 1 tapes (WHOI archive copies).

N.B. The next time the Exabyte drives are to be worked so hard bring a cleaning tape. Loss of just one drive would have added many hours to the transcription and logging process.

Appendix 7: Data Processing

To process to raw data into a more meaningful format, several programs have been written, as well as some previously written programs which are used. First, to convert the raw data into the segy format, the program Obsed has been used. Obsed takes the raw data piped in from an exobyte tape, and setting the file format to 'segy', produces a subdirectory for every julian day there is data. Within these subdirectories, each events of that day for that obs are stored in segy format, each with the standard 240 byte header. Obsed also makes a log of all the triggers and an additional log of detailing each event, including continuous ones, it found.

After this is done for each obs, the segy files must be corrected for clock discrepancies using the program Time_corr. For each obs, Time_corr takes the starting and ending times (in big time) of the data and the clock error at the start and end, and corrects the header of each segy file for this error, by calculating an absolute error all the files are off by, from the clock error at the start and a relative error based on the difference in the errors at the start and at the end (This program is still being written). The time given in the header of each event is then corrected by the absolute error of that obs and by the relative error times the difference of the event's time and the starting time of the obs.

To analyze the triggered events, the segy files for each obs for each day are concatinated by using the program Concat. This program takes all the segy files from each obs in the directory for that julian day, and concatinates them into a master segy file for each obs named 'obs'obs##_day (ie the file for obs 50 for day 166 is called obs50_166). This program must be run for each day, but will handle all the obs' active that day. The program Makelog takes all of the master segy files in the julian day directory and creates a matrix of the obs number, the byte in the master segy file the event starts with, the starting time of the event trace, and the end time of the event trace (both in big time) for each triggered event. The byte number and the times are determined from the headers of the events in the master segy file. Also the length of each trace is given in the header so that Makelog can find every event by skipping from header to header. This matrix is sorted by the starting time and then saved as 'trig_log_'day.

From the trigger log, a master event file can be created in two ways. First, using Makeevent, an event driven master event file is produced by settimg a minimum number of obs' that must be recording simultaneously to be worthwhile. Makeevent loops through the trigger log and looks for events which either start or end during the course of another event. If multiple traces meet this criteria from a particular obs, the first trace is used. A matrix is formed of the number of obs' recording, the big time, and the byte of the master segy file the event occurs for each active obs or zero for the obs' which don't record at that time. This matrix is then sorted by the number of obs' recording and saved as 'event_log_'day. To prevent the same event from being multiply listed, an array the length of the trigger log called 'flag' is used to denote traces which are already listed and thus are ineligible to be used as new events. This must be done for each day separately.

The other method of generating a master event file is by using a program called Choosetime takes an array of big times (such as the shot times) and then finds which obs' are recording at those times. A matrix is formed with the same information as is in the matrix created by Makeevent, except that this matrix is sorted in the order of the array of times given as input, and is then saved as 'time_log_'day. This must be done for each day individually.

Once a master event file has been generated, the program Pick_event is run. The day, the event number from the master event file, the channels (vertical, horizontal 1,

horizontal 2, and hydrophone) to be looked at, the obs' to be looked at, which master event file to be used, and the velocity model and other control parameters are used to plot the seismograms for that event. On this plot, a number of functions can be used. The p-wave and s-wave arrival time picks can be made or removed from the plot. The picks can be saved or old picks can be reloaded and replotted. The current picks are automatically saved when one is finished with that event.

The plot can be zoomed in, to show a section of the plot in greater detail, or can be zoomed out once, to the last size of the plot, or twice, to show the full trace. A yet to be implimented funtion is to be able to choose a 15 second portion of the full trace which would be saved as the full plot to avoid the run time needed to manipulate 120+ second traces. The amplitude of the seismograms can be altered for greater clarity. The channels shown in the plot can be altered if one wishes to view only certain ones. Another feature to be implimented would allow the obs' shown in the plot to be changed as well so that an obs which had only noise could be removed, also decreasing the run time.

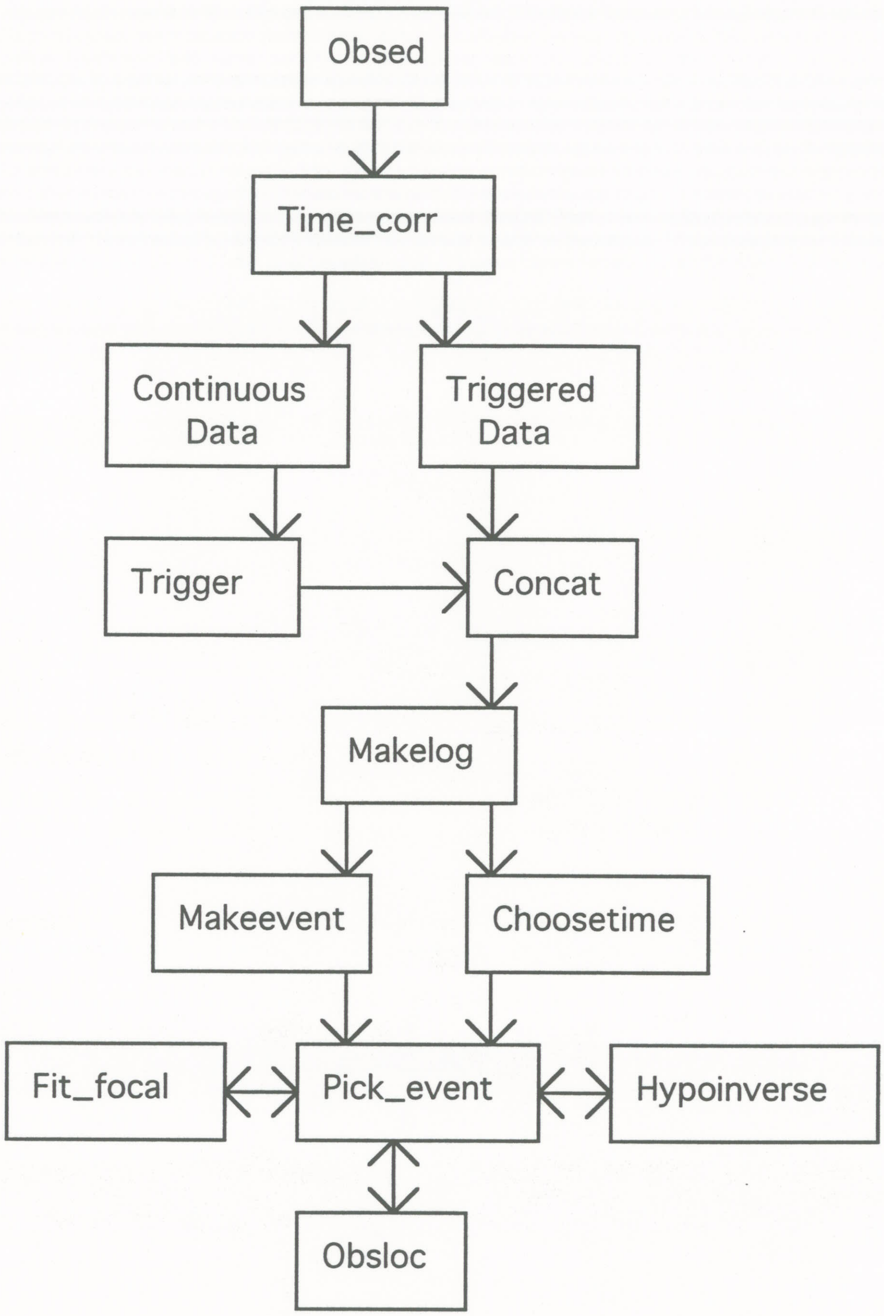
From the p-wave and s-wave arrival picks, the velocity model and the obs locations determined by Obsloc, the program Hypoinverse can be called from within Pick_event to locate the source of the event as long as a minimum number of picks have been made. After the event is located, the predicted arrival times are plotted on the seismogram for comparison to the picks which were made. The p-wave and s-wave arrival picks as well as the event location information are all saved as outputs, and can also be used as inputs if an event is being looked at a second (or more) time, so that the picks used to locate the event don't have to be redetermined. A hard-copy print out of the seismogram can be made, though a feature to plot the event locations and obs locations onto a topographic map is still to be written.

Also still to be written is a function to pick first motions of the seismic traces, be they up, down, nodal, or no pick, and then to use the program Fit_focal to determine the focal mechanism of the event. These first motion picks would be saved as output, and like the event locations could be used as input when reviewing an event. Functions to align the traces by p-wave arrival time rather than by real time and to sort the traces by distance from the event's location are also to be written.

The positions of each obs on the seafloor can be found using the program Obsloc. This program uses the shot-obs travel times, the tenative locations of the shots and the obs, the shot times, the shot depths, a velocity model, and a host of other inputs to determine the obs's location using the Creager-Dorman method and the uncertainty of the locations.

Once an event has been looked at, another event can be plotted using the next event function, the previous event function, or the change event function. As their names imply these functions plot either the next or previous event, or an event whose number is asked for. Before the new event is plotted the p-wave, s-wave, and event location (and eventually the first motions) are saved and the current plot is closed. The new event is then plotted at the default scale, with the full trace (or the modified full trace) shown. If this event has been looked at before, the old p-wave and s-wave picks are plotted.

To process continuously recorded data, the program Trigger is used. This program, which is still to be written, takes a given short term to long term amplitude ratio and uses that ratio to trigger the data similarly to how the triggered data was recorded. These triggered events would then be processed in the same manner as described above for the events which were triggered in the obs'.



Data Processing and Analysis Flow Diagram

Appendix 8: Schedule for Meeting Obligations to Canadian Government.

The approval of the Government of Canada to operate in their waters requires that we provide a schedule for the provision of the full data results to the Canadian Government.

The analysis and processing procedures to be applied to these seismic data are described in Appendix 7. It is anticipated that this analysis will be completed by June 1998. This is the termination date of the NSF grant that has supported this research project. At this time all data results will be forwarded to the Government of Canada.