OBSIP Operators Report for Cruise EW-0114 of the R/V *Maurice Ewing*

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Introduction

Cruise EW-0114 (Fremantle, Australia to Hobart, Australia) of the R/V Maurice Ewing (http://www.ldeo.columbia.edu/Ewing/Home.html) took place from December 7, 2001 to January 25, 2002. A primary operational objective of the cruise was the acquisition of seismic refraction data using the multi-element Ewing airgun array as a sound source and Ocean Bottom Hydrophones (OBH) as receivers. For EW-0114, OBH instrumentation and shipboard technical support were provided by Woods Hole Oceanographic Institution (http://obslab.whoi.edu), acting under the auspices of the U.S. National Ocean Bottom Seismograph Instrument Pool (OBSIP) (http://www.obsip.org), a U.S. National Science Foundation funded facility. (As Instrument Contributors to the pool, three institutions — Woods Hole Oceanographic Institution, Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography, and the Lamont-Doherty Earth Observatory at Columbia University — maintain and operate the ocean-bottom seismograph instrumentation and provide complete engineering and technical support for their operation at sea.)

This report describes those aspects of OBH operations and data format necessary for investigators other than the experiment Principal Investigators and their associates to make optimum use of the refraction data set when it becomes available to the general scientific community, two years post-cruise. The overall scientific objectives of EW-0114, the locations of the refraction lines, and a cruise narrative are detailed in the attached cruise report provided by Chief Scientist James Cochran (jrc@ldeo.columbia.edu). A summary of the R/V Maurice Ewing data logging system and the navigation and geophysical data logged during EW-0114 are given in the attached document "R/V Maurice Ewing Data Reduction Summary" provided by the R/V Ewing data reduction technician. In the interest of summarizing in one document all of the necessary information required to utilize the refraction data, there is some repetition between this document and the two aforementioned reports.

EW-0114 Refraction Experiments

Six deployments of 4 OBH each were carried out on EW-0114. These deployments are referred to as SEIR01, SEIR02, SEIR03, SEIR04, SEIR05, and SEIR06. The primary experiment geometry for all deployments was two-dimensional. The refraction lines for the deployments SEIR01-SEIR06 are named OBHL_1, OBHL_2, OBHL_3, OBHL_4, OBHL_5, OBHL_5A, OBHL_7, and OBHL_7A. (There was no line OBHL_6.)

The airgun source array used for all the six refraction lines was the Ewing 20-element array (see "R/V Maurice Ewing Data Reduction Summary", pages 9, 11, and 12). The shot interval was 120 s. Because of damage to the starboard airgun tow points, the airgun array deployed at the beginning of line OBHL_7A consisted of guns 9 – 20 only of the 20-element array (see "R/V Maurice Ewing Data Reduction Summary", page 11). Weather-related tangling of the airgun tow-lines during the shooting of line OBHL_7A resulted in the array being further reduced to guns 9,10,11,12,13,19 and 20. This additional change in the airgun array took place at approximately 2002/01/17 11:00 UTC.

After the completion of each refraction line and prior to OBH recovery, short (~3.5 km) cross lines were shot over each OBH to acquire azimuthally-distributed ranging data in order to better estimate the OBH position on the seafloor. These cross lines were shot with a single 385 in^3 airgun. The cross lines were shot with a 60 s shot interval with the exception of the lines over each OBH on SEIR01 which was shot with a 120 s interval.

Table 1. OBH Drop Positions for Deployment SEIR01

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	100° 50.337′E	47° 24.612′S	2481	2001:12:12 00:58	2001:12:13 09:26
20	100° 28.180′E	47° 13.996′S	2700	2001:12:11 22:08	2001:12:13 02:12
25	100° 40.263′E	47° 20.002′S	2481	2001:12:11 23:43	2001:12:13 05:54
27	101° 03.296′E	47° 30.596′S	2640	2001:12:12 02:25	2001:12:13 12:51

***OBH depth is water depth less 5 meters**

Table 2. OBH Drop Positions for Deployment SEIR02

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	100° 40.456′E	47° 32.977′S	2870	2001:12:13 19:50	2001:12:15 04:48
20	100° 19.170′E	47° 22.538′S	2906	2001:12:13 16:40	2001:12:14 21:44
25	100° 30.033′E	47° 27.961′S	2813	2001:12:13 18:21	2001:12:15 01:00
27	100° 54.747′E	47° 40.321′S	2888	2001:12:13 21:28	2001:12:15 08:39

***OBH depth is water depth less 5 meters**

Table 3. OBH Drop Positions for Deployment SEIR03

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	101° 58.487′E	47° 48.700′S	2832	2001:12:15 14:49	2001:12:17 00:50
20	101° 32.488′E	47° 38.144′S	2822	2001:12:15 11:32	2001:12:16 18:03
25	101° 46.490′E	47° 44.001′S	2732	2001:12:15 13:17	2001:12:16 21:35
27	102° 13.479′E	47° 54.971′S	3007	2001:12:15 16:34	2001:12:17 04:29

***OBH depth is water depth less 5 meters**

Table 4. OBH Drop Positions for Deployment SEIR04

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	101° 50.578′E	47° 58.655′S	2940	2001:12:17 12:32	2001:12:20 10:43
20	101° 26.947′E	47° 49.985′S	2981	2001:12:17 09:03	2001:12:20 15:19
25	101° 36.973′E	47° 53.675′S	2905	2001:12:17 10:45	2001:12:20 13:06
27	102° 04.499′E	48° 03.695′S	2920	2001:12:17 14:21	2001:12:20 08:11

***OBH depth is water depth less 5 meters**

Table 5. OBH Drop Positions for Deployment SEIR05

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	109° 32.677′E	49° 32.986′S	3273	2002:01:06 18:48	2002:01:11 01:58
20	110° 00.192′E	49° 41.418′S	3271	2002:01:06 15:39	2002:01:12 15:27
25	109° 47.031′E	49° 37.495′S	3437	2002:01:06 17:11	2002:01:12 13:00
27	109° 19.993′E	49° 28.988′S	3232	2002:01:06 20:10	2002:01:10 22:19

***OBH depth is water depth less 5 meters**

Table 6. OBH Drop Positions for Deployment SEIR06

OBH	Longitude	Latitude	Water Depth* (m)	Deployment Time (UTC)	Recovery Time (UTC)
16	115° 02.975′E	49° 58.802′S	4120	2002:01:13 10:39	2002:01:18 02:58
20	114° 33.668′E	49° 52.697′S	4308	2002:01:13 07:46	2002:01:17 22:10
25	114° 45.563′E	49° 55.274′S	4274	2002:01:13 09:09	2002:01:18 00:26
27	105° 15.257′E	50° 01.297′S	4168	2002:01:13 11:54	2002:01:18 05:17

***OBH depth is water depth less 5 meters**

Table 7. Correspondence between OBH Deployments and Shooting Line

Deployment #	Shooting Lines
SEIR01	OBHL_1, TEST1
SEIR02	OBHL_2, TEST2
SEIR03	OBHL_3, TEST3
SEIR04	OBHL_4, TEST4
SEIR05	OBHL_5, OBHL_5A, TEST5
SEIR06	OBHL_7, OBHL_7A, TEST7

Table 8. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Line OBHL_1

Trace numbers in SEG-Y Files obh16s1.segy; obh20s1.segy; obh25s1.segy; obh27s1.segy	Ewing Shot Numbers (File ts.n346)
005	005
384	384

Table 9. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Line OBHL_2

Trace Numbers in SEG-Y Files obh16s2.segy; obh20s2.segy; obh25s2.segy; obh27s2.segy	Ewing Shot Numbers (File ts.n348)
008	008
390	390

Table 10. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Line OBHL_3

Trace Number in SEG-Y Files: obh16s3.segy; obh20s3.segy; obh25s3.segy; obh27s3.segy	Ewing Shot Numbers (Files ts.n349; ts.n350)
001	001
450	450

Table 11. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Line OBHL_4

Trace Number in SEG-Y Files: obh16s4.segy; obh20s4.segy; obh25s4.segy; obh27s4.segy	Ewing Shot Numbers (Files ts.n352; ts.n353)
001	001
288	288
289	001
414	126

Table 12. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Lines OBHL_5, OBHL_5A

Trace Number in SEG-Y Files obh16s5.segy; obh20s5.segy; obh25s5.segy; obh27s5.segy	Ewing Shot Numbers (Files ts.n007; ts.n010)
001	001
077	077
078	001
438	361

Table 13. Correspondence Between SEG-Y Trace Numbers and R/V Ewing Shot Numbers for Lines OBHL_7, OBHL_7A

Trace Number in SEG-Y Files: obh16s6.segy; obh20s6.segy; obh25s6.segy; obh27s6.segy	Ewing Shot Numbers (Files ts.n016; ts.n017)
001	001
248	248
249	001
506	258

OBH Data Format

The archived refraction data are in two formats: the PASSCAL SEGY format (Appendix 1 and http://www.passcal.nmt.edu/NMT_pages/Software/segy.shtml) and the Society of Exploration Geophysicists Y format (SEG-Y) [*Barry et al.*, 1975]. The choice of name for the former format is unfortunate because it does not conform to the SEG-Y standard. (The PASSCAL SEGY format was developed at the PASSCAL Instrument Center as a format for temporary files generated in the process of converting raw data logger files to SEED and/or SEG-Y format.)

PASSCAL SEGY Data

All of the data acquired with the OBH are archived in PASSCAL SEGY format. PASSCAL provide a number of tools to analyze and reformat PASSCAL SEGY data. The program "segyhdr" lists the contents of the PASSCAl SEGY header. The program "pql" (PASSCAL Quick Look) plots PASSCAL SEGY data. The program "clockcor" applies clock corrections to PASSCAL SEGY files. The program "segygather" merges and cuts PASSCAL SEGY files and generates a SEG-Y file (i.e. a file conforming to the format described by Barry et al.).

The time of the first sample in each of the archived PASSCAL SEGY files has been corrected assuming a linear clock drift. The clock rating files that were used to generate the clock corrections are included in the archived data set. After application of scale and gain values included in the trace header, the data values represent voltages at the output of the hydrophone pre-amplifier (see Appendix 2).

SEG-Y Data

The archived data also includes 24 SEG-Y files, one file for each OBH for each deployment. These files contain the common-receiver gathers for the 6 refraction lines. These files have the following characteristics.

Number of Samples per Trace:	12,000
Sample Interval (ms):	5
Sample Rate (Hz):	200
Delay (s):	0
Trace Units:	volts normalized to the high-gain channel (see Appendix 2)
Shot Interval	120 s

- The source-to-receiver horizontal ranges listed in the SEG-Y trace headers were calculated under the assumption that the drop position of the OBH was its true position. (The drop position may be offset from the actual seafloor location by 10's-100's of meters.) Consequently, these ranges, while useful for initial data assessment, are incorrect. The travel times of a modest number times of azimuthally-distributed shots, together with the ship's position at the time the shots were fired, can be used to invert for the true position of the OBH [*Creager and Dorman*, 1982]. Note that in accordance with OBSIP policy (http://www.obsip.org), the estimation of the seafloor positions of the OBH and the archiving of these positions with the IRIS DMC is the responsibility of the Principal Investigator and not the OBSIP operator.

- The source-to-receiver ranges listed in the SEG-Y trace headers use the mid-point of the airgun array as the shot position.

- The OBH depths listed in the binary portion (bytes 3200-3600) of the SEG-Y reel header assume that the water depth at the OBH drop position is the water depth at the true location of the OBH. The calculation of the OBH depth takes into account the known height of the OBH above the seafloor (i.e. the length of the OBH anchor line, 5 meters)

- The time-tagging of the OBH data has been corrected for clock drift. Measured drift rates are given in Table 14. (Note the sometimes large experiment-to-experiment variation in clock drift rates for the same receiver reflects the fact that the same clock was not always used for each experiment.)

Table 14. OBH Clock Drift Rates for SEIR Experiment (Cruise EW-0114)

Expt. # / OBH #	OBH 16	OBH 20	OBH 25	OBH 27
SEIR01	+1.12e-07	-1.20e-07	-2.99e-08	-5.43e-08
SEIR02	-7.15e-08	+6.60e-09	-2.96e-08	-1.28e-07
SEIR03	+8.43e-09	-7.26e-08	-3.00e-08	-5.47e-08
SEIR04	+3.77e-09	-1.30e-07	-3.06e-08	-7.24e-08
SEIR05	+1.62e-09	-1.32e-07	-2.81e-08	-5.73e-08
SEIR06	-1.73e-09	-1.31e-07	-6.95e-08	-5.87e-08

Navigation, Bathymetry, and Shot Data

The time and latitude and longitude of every shot, and the water depth beneath the ship as a function of time and position are listed in the data files provided by the R/V Ewing data reduction technician. These data are described in the document "R/V Maurice Ewing Data Reduction Summary". Note that the shot position is actually the position of the Tasmon GPS receiver, and not the position of the mid-point of the airgun array (see Cruise Report, page 23). Likewise, the water depths are the values directly beneath the ship (not the airgun array) as a function of smoothed position and time (rounded to the nearest minute). The multibeam swath-bathymetry data acquired by R/V Ewing are archived at the Lamont-Doherty Earth Observatory at Columbia University.

References

Barry, K.M., D.A. Cavers, and C.W. Kneale, Report on recommended standards for digital tape formats, *Geophysics*, *40*, 344-352, 1975.

Creager, K.C. and L.M. Dorman, Location of instruments on the seafloor by joint adjustment of instrument and ship positions, *J. Geophys. Res.*, *87*, 8379-8388, 1982.

Acknowledgments

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Appendix 1
PASSCAL SEGY Format

SEG Y FORMAT

SEG Y format was originally established by the Society of Exploration Geophysicists as an exchange format for demultiplexed seismic data on 9-track tape. The SEG document Recommended Standards for Digital Tape Formats contains the complete description of the SEG Y revision 0 format standard currently in use. The revision 1 draft standard, also maintained by SEG, describes the next proposed SEG Y revision.

Standard SEG Y

A tape reel is divided into a tape identification header followed by multiple trace data blocks. The reel header is in turn subdivided into a 3200-byte EBCDIC block followed and a 400-byte binary block. Seismic trace blocks include a 240-byte trace header followed by the trace samples in either 32-bit floating point, 32-bit integer, 16-bit integer or integer with gain code formats (big-endian, twos-compliment).

Although SEG Y is a tape standard, much SEG Y data now resides on disk and, therefore, the reel identification header is omitted. The SEG Y standard defines the first 180 bytes of the trace header, leaving bytes 181-240 uassigned for optional use. Because of this, the trace header will be described first below, followed by the reel identification header.

The difference between standard and non-standard SEG Y formats is in the use of bytes 181-240. Nonstandard formats assign and use these bytes and their definition varies across nonstandard formats.

PASSCAL SEG Y

Each PASSCAL SEG Y file contains one trace (data block). The PASSCAL SEG Y trace format is a modified form of the standard SEG Y traceformat; we use some of the unspecified trace header words to store information pertinent to the PASSCAL data. The format of the header is given below. All integer values are stored with the most significant byte first. Data values are 16 or 32 bit integers depending upon byte 206 of the header.

SEG Y Trace Header

Byte Number	Type	Standard SEG Y	PASSCAL SEG Y
1 - 4	Integer	Trace sequence number within line	Trace sequence number within data stream
5 - 8	Integer	Trace sequence number within reel	Trace sequence number within reel (same as bytes 1-4)
9 - 12	Integer	Original field record number	Event number
13 - 16	Integer	Trace number within field record	Channel number
17 - 20	Integer	Source point number	Not used
21 - 24	Integer	CDP number	Not used
25 - 28	Integer	CDP sequece number	Not used
29 - 30	Flag	Trace identification code: 1 = seismic 4 = time break 7 = timing 2 = dead 5 = uphole 8 = water break 3 = dummy 6 = sweep 9 = option use	Trace identification code = 1 for seismic data
31 - 32	Integer	Number of vertically summed traces	Not used
33 - 34	Integer	Number of horizontally summed traces (fold)	Not used
35 - 36	Flag	Data use: 1 = production; 2 = test	Not used
37 - 40	Float	Source-receiver offset in feet or meters	Not used
41 - 44	Float	Receiver group elevation in feet or meters; positive above sea level	Not used
45 - 48	Float	Surface elevation at source (feet or meters)	Not used
49 - 52	Float	Source depth below surface (>0)	Not used
53 - 56	Float	Datum elevation at receiver group	Not used
57 - 60	Float	Datum elevation at source	Not used
61 - 64	Float	Water depth at source	Not used
65 - 68	Float	Water depth at receiver group	Not used
69 - 70	Integer	Elevation multiplication scalar for bytes 41-68 = 1, 10, 100, 1000 or 10,000 positive indicates multiplication; negative, division	Elevation constant = 1
71 - 72	Integer	Coordinate multiplication scalar for bytes 73-88 (see bytes 69-70)	Coordinate constant = 1
73 - 76	Float	Source X (feet or meters) or longitude (seconds of arc; + is E, - is W)	Not used
77 - 80	Float	Source Y (feet or meters) or latitude (seconds of arc; + is N, - is S)	Not used
81 - 84	Float	Receiver X (feet or meters) or longitude (seconds of arc; + is E, - is W)	Not used
85 - 88	Float	Receiver Y (feet or meters) or latitude (seconds of arc; + is N, - is S)	Not used
89 - 90	Flag	Coordinate units 1 = feet or meters; 2 = seconds of arc	Coordinate units = 2 for Lat/Long

91 - 92	Integer	Weathering velocity	Not used
93 - 94	Integer	Sub-weathering velocity	Not used
95 - 96	Integer	Uphole time at source (milliseconds)	Not used
97 - 98	Integer	Uphole time at group (milliseconds)	Not used
99 - 100	Integer	Souce static correction (milliseconds)	Not used
101 - 102	Integer	Receiver static correction (milliseconds)	Not used
103 - 104	Integer	Total static applied	Low 2 bytes of the total static (milliseconds) (note: if >= 32767 see bytes 199 - 200)
105 - 106	Integer	Lag time A between trace header time and time break (milliseconds)	Not used
107 - 108	Integer	Lag time B between time break and source time (milliseconds)	Not used
109 - 110	Integer	Delay time between source and recording time (milliseconds)	Not used
111 - 112	Integer	Brute start time (milliseconds)	Not used
113 - 114	Integer	Mute end time (milliseconds)	Not used
115 - 116	Integer	Number of samples in this trace	Number of samples in this trace (note if >= 32767 see bytes 229 - 232)
117 - 118	Integer	Sample interval (microseconds)	Sample interval (microseconds) (note if equal 1 see bytes 201 - 204)
119 - 120	Flag	Gain type: 1 = fixed; 2 = binary 3 = floating point; 4 = optional use	Fixed gain flag = 1
121 - 122	Integer	Instrument Gain Constant	Gain of amplifier
123 - 124	Integer	Instrument early or initial gain	Not used
125 - 126	Flag	Correlated; 1 = yes, 2 = no	Not used
127 - 128	Integer	Sweep frequency at start (Hz)	Not used
129 - 130	Integer	Sweep frequency at end (Hz)	Not used
131 - 132	Integer	Sweep length (milliseconds)	Not used
133 - 134	Flag	Sweep type: 1 = linear; 2 = parabolic 3 = exponential; 4 = other	Not used
135 - 136	Integer	Sweep taper length at start (milliseconds)	Not used
137 - 138	Integer	Sweep taper length at end (milliseconds)	Not used
139 - 140	Flag	Sweep taper type: 1 = linear 2 = cosine squared; 3 = other	Not used
141 - 142	Integer	Alias filter frequency (Hz), if used	Not used
143 - 144	Integer	Alias filter slope (dB/octave)	Not used
145 - 146	Integer	Notch filter frequency (Hz), if used	Not used
147 - 148	Integer	Notch filter slope (dB/octave)	Not used
149 - 150	Integer	Low-cut frequency (Hz), if used	Not used
151 - 152	Integer	High-cut frequency (Hz), if used	Not used
153 - 154	Integer	Low-cut filter slope (dB/octave)	Not used
155 - 156	Integer	High-cut filter slope (dB/octave)	Not used
157 - 158	Integer	Year data recorded	Year data recorded
159 - 160	Integer	Day of year	Day of year
161 - 162	Integer	Hour of day (24 hour clock)	Hour of day (24 hour clock)
163 - 164	Integer	Minute of hour	Minute of hour
165 - 166	Integer	Second of minute (for trace start)	Second of minute
167 - 168	Flag	Time basis code: 1=local 2=GMT 3=other	Time basis code: 1=local 2=GMT 3=other
169 - 170	Integer	Trace weighting factor: 2*N volts for least significant bit where N = 0,1,...,32.767	Not used
169 - 170	Integer	Trace weighting factor: 2*N volts for least significant bit where N = 0,1,...,32.767	Not used
171 - 172	Integer	Receiver group number at roll switch position 1	Not used
173 - 174	Integer	Receiver group number for first trace in field record	Not used
175 - 176	Integer	Receiver group number for last trace in field record	Not used
177 - 178	Integer	Gap size (number of receiver groups dropped)	Not used
179 - 180	Integer	Overtravel associated with taper at start or end of line: 1 = down (or behind), 2 = up (or ahead)	Not used

181 - 186	UNIX String (PASSCAL SEG Y)	Unassigned	Station Name code
187 - 194	UNIX String (PASSCAL SEG Y)	Unassigned	Sensor Serial code
195 - 198	UNIX String (PASSCAL SEG Y)	Unassigned	Channel Name code
199 - 200	Integer (PASSCAL SEG Y)	Unassigned	High 2 bytes of the total static shift in milliseconds
201 - 204	Integer (PASSCAL SEG Y)	Unassigned	Sample interval in microsecs
205 - 206	Flag (PASSCAL SEG Y)	Unassigned	Data format flag: 0=16 bit integer, 1=32 bit integer
207 - 208	Integer (PASSCAL SEG Y)	Unassigned	Milliseconds of second for first sample
209 - 210	Integer (PASSCAL SEG Y)	Unassigned	Trigger time year
211 - 212	Integer (PASSCAL SEG Y)	Unassigned	Trigger time julian day
213 - 214	Integer (PASSCAL SEG Y)	Unassigned	Trigger time hour
215 - 216	Integer (PASSCAL SEG Y)	Unassigned	Trigger time minutes
217 - 218	Integer (PASSCAL SEG Y)	Unassigned	Trigger time seconds
219 - 220	Integer (PASSCAL SEG Y)	Unassigned	Trigger time milliseconds
221 - 224	IEEE Float PASSCAL SEG Y	Unassigned	Scale factor (true amplitude = (data value)*(scale factor)/gain
225 - 226	Integer (PASSCAL SEG Y)	Unassigned	Instrument Serial Number
227 - 228		Unassigned	Not used
229 - 232	Integer (PASSCAL SEG Y)	Unassigned	Number of Samples
233 - 236	Integer (PASSCAL SEG Y)	Unassigned	Max value in counts
237 - 240	Integer (PASSCAL SEG Y)	Undefined	Min value in counts

SEG Y Reel Identification Header (EBCDIC block)

The EBCDIC block of the reel identification header is composed of 40 cards (80 bytes per card) that describe data from a line of shot points. Each card should begin with the character "C"; bytes 29-39 are unassigned for optional use. Unused cards are EBCDIC blank.

SEG Y Reel Identification Header (Binary block)

Byte Number	Type	Description
3201 - 3204	Integer	Job Identification Number
3205 - 3208	Integer	Line number (1 line per reel)
3209 - 3212	Integer	Reel number
3213 - 3214	Integer	Number of data traces per record
3215 - 3216	Integer	Number of auxillary tracer per record
3217 - 3218	Integer	Sample interval for this reel (microseconds)
3219 - 3220	Integer	Sample interval for original field recording (microseconds)
3221 - 3222	Integer	Number of samples per data trace for this reel
3223 - 3224	Integer	Number of samples per data trace (original field recording)
3225 - 3226	Flag	Data sample format code: 1 = 32-bit float; 2 = 32-bit integer 3 = 16-bit integer; 4 = integer with gain code
3227 - 3228	Integer	Nominal CDP fold
3229 - 3230	Flag	Trace sorting code: 1 = as recorded (no sorting) 2 = CDP ensemble; 3 = single fold continuous profile 4 = horizontally stacked
3231 - 3232	Integer	Number of vertically summed traces
3233 - 3234	Integer	Sweep frequency at start (Hz)
3235 - 3236	Integer	Sweep frequency at end (Hz)
3237 - 3238	Integer	Sweep length (milliseconds)
3239 - 3240	Flag	Sweep type: 1 = linear; 2 = parabolic 3 = exponential; 4 = other
3241 - 3242	Integer	Trace number of sweep channel
3243 - 3244	Integer	Sweep taper length at start (milliseconds)
3245 - 3246	Integer	Sweep taper length at end (milliseconds)
3247 - 3248	Flag	Taper type: 1 = linear 2 = cosine squared; 3 = other
3249 - 3250	Flag	Correlated data traces: 1 = yes, 2 = no
3251 - 3252/td>	Flag	Binary gain recovered: 1 = yes, 2 = no
3253 - 3254	Flag	Amplitude recovery method: 1 = none 2 = spherical divergence; 3 = AGC; 4 = none
3255 - 3256	Flag	Measurement system: 1 = feet, 2 = meters
3257 - 3258	Flag	Impulse signal: 1 = negative amplitude means increased pressure or upward movement; 2 = positive amplitude means increased pressure or upward movement
3259 - 3260	Flag	Vibratory polarity code (seismic signal lags pilot trace by): 1 = 337.5 to 22.5 degrees, 2 = 22.5 to 67.5 degrees 3 = 67.5 to 112.5 degrees, 4 = 112.5 to 157.5 degrees 5 = 157.5 to 202.5 degrees, 6 = 202.5 to 247.5 degrees 7 = 247.5 to 292.5 degrees, 8 = 292.5 to 337.5 degrees
3261 - 3600		Unassigned

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Appendix 2
WHOI OBH System Response

WHOI Ocean Bottom Hydrophone Response

The Woods Hole Oceanographic Institution (WHOI) Ocean Bottom Hydrophone (OBH) used on Cruise EW-0114 of the R/V Ewing records the digitized output of a single hydrophone sensor [*Peal et al.*, 1993]. The OBH is equipped with a Tattletale Model 6 single-board computer manufactured by Onset Computer Corporation (Pocasset, MA, USA). The Tattletale Model 6 includes a 12-bit analog-to-digital converter (A/D), a processor, and a hard disk recorder. A dynamic range of 98 dB is achieved by connecting the output of the hydrophone pre-amplifier (+20 dB gain) to two analog channels with different gains (+35 dB and +9 dB). Both channels are digitized and the higher gain channel stored if the voltage is less than a specified percentage of full scale; otherwise the low-gain channel is used. Assuming a hydrophone sensitivity of 4.467e-4 V/Pa, the resolution of the system at high- and low-gains is 0.022 Pa/count and 0.44 Pa/count, respectively.

Hydrophone Type: Models E-2SD and E2-PD, Ocean and Atmosphere Science, Inc.,145 Palisade Street, Dobbs Ferry, New York 10522.
Hydrophone Frequency Response: Flat (± 1 dB) 0 – 5 kHz
Directionality: Omnidirectional (0 – 5 kHz)
Pressure Sensitivity: None (hydrophones are pressure compensated)

Table 4. Hydrophone Sensitivities (V/Pa) for SEIR Experiment (Cruise EW-0114)

Expt. / OBH #	OBH 16	OBH 20	OBH 25	OBH 27
SEIR01	2.512e-04	2.512e-04	4.467e-04	2.512e-04
SEIR02	2.512e-04	2.512e-04	4.467e-04	2.512e-04
SEIR03	2.512e-04	2.512e-04	4.467e-04	2.512e-04
SEIR04	2.512e-04	2.512e-04	4.467e-04	2.512e-04
SEIR05	2.512e-04	2.512e-04	4.467e-04	2.512e-04
SEIR06	2.512e-04	2.512e-04	4.467e-04	2.512e-04

Response Type: Theoretical
Gain (high-gain channel): 3.0392e+02
Normalization Factor: 6.6310e+14

All poles and zeros are in units of radians/sec

9 Poles (complex):
(-4.273574e+00, 0.000000e+00)
(-1.999755e-01, 0.000000e+00)
(-8.981651e+01, 1.314392e+02)
(-8.981651e+01, -1.314392e+02)
(-6.446954e+01, 3.661337e+02)
(-6.446954e+01, -3.661337e+02)
(-2.369668e+01, 4.831257e+02)

(-2.369668e+01, -4.831257e+02)
(-1.000000e+01, 0.000000e+00)

3 Zeros (complex):
(0.000000e+00, 0.000000e+00)
(-2.005000e-01, 0.000000e+00)
(0.000000e+00, 0.000000e+00)

Consequently, the transfer function for the OBH is:

$$T(s) = \text{Gain} \bullet \text{A0} \bullet \frac{\prod_{n=1}^{n=3} (s - z_n)}{\prod_{n=1}^{n=9} (s - p_n)}$$

where s = i*ω = i*2*π*f; i = $\sqrt{-1}$, f = frequency (Hz), p_n and z_n are the values of the poles and zeros, respectively in units of angular frequency.

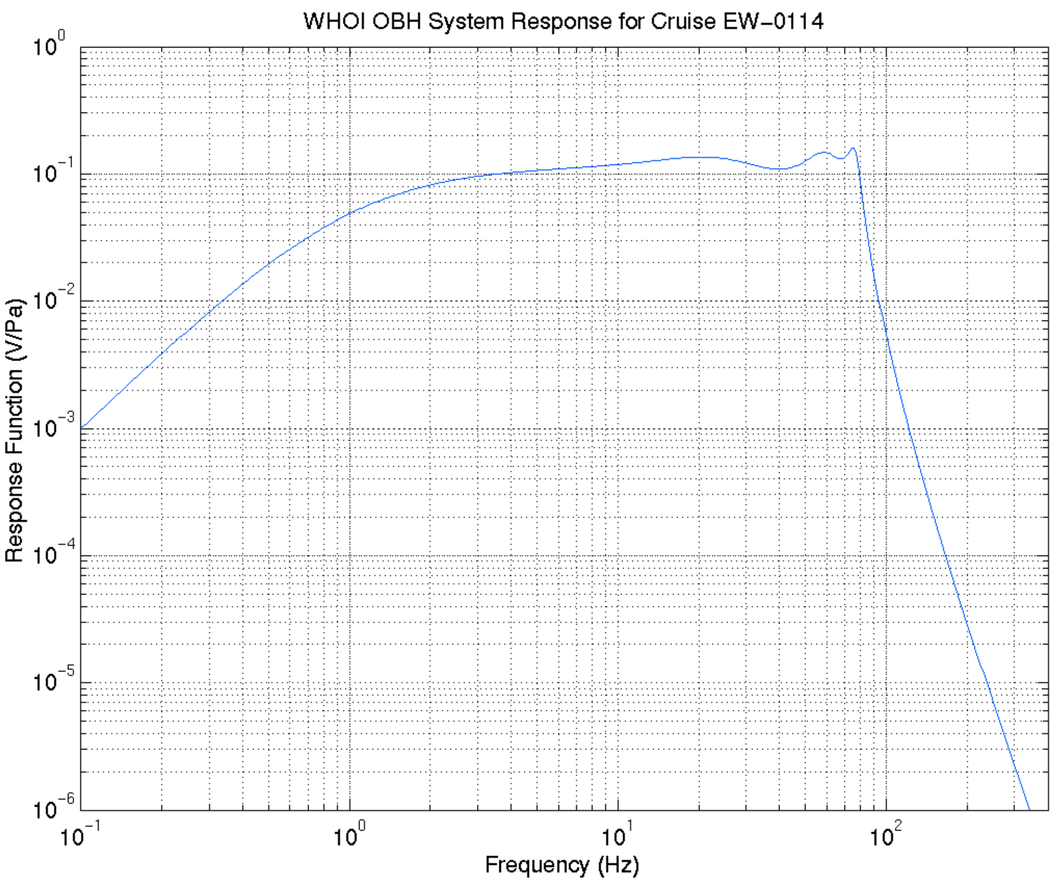

Figure 1. Response of WHOI OBH high-gain channel when OBH is equipped with a hydrophone of sensitivity of 4.467e-04 V/Pa.

The trace values of the PASSCAL SEGY data are normalized to volts at the pre-amplifier output as follows:

*Amplitude (volts at pre-amplifier output) = trace value * (scale/gain)*

where the "scale" and "gain" factors are stored in bytes 221-224 and bytes 121-122, respectively. These scaled data are converted to passcals (Pa) by first multiplying by the value 25 (35-7 dB) and then applying the above system response.

The SEG-Y data values are in units of volts normalized to the high-gain channel. These data are converted to passcals (Pa) with the above system response.

References

Peal, K.R., G.M. Purdy, D.E. Koelsch, and F.B. Wooding, A Simple Ocean Bottom Hydrophone with 200 Megabyte Data Capacity, Woods Hole Oceanographic Institution, 1993.