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PRS4 recording of teleseismic data from the Deep-Probe Passive Survey near Grand Junction, Colorado

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PRS4 recording of Teleseismic data from the Deep-Probe Passive Survey near Grand Junction, Colorado

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A ten-day recording of teleseismic earthquakes in a pilot experiment on the Colorado Plateau show that the PRS4 instrument with its standard 2 Hz seismometers triggered successfully on distant earthquakes.

22 February, 1996

Introduction

As part of the Deep-Probe seismic experiment in western U.S. and Canada, researchers from the Rice, Colorado and Oregon universities[1] conducted two pilot earthquake recording experiments on the Colorado Plateau, using PRS4 and REF-TEK instruments. This report is a summary of the PRS4 recording.

The PRS4 instruments have been used successfully in the past in teleseismic studies but with either broad-band seismometers or with 1 Hz seismometers. As neither seismometers were available for this survey, the PRS4's were deployed with their standard 2 Hz 'refraction' seismometers.

Some 18 PRS4 instruments were deployed in an array near Grand Junction , Colorado in August 1995. The instruments have limited recording capacity and were programmed to trigger on teleseismic events and record for a fixed duration after each trigger. The triggering parameters were similar to those selected by the University of British Columbia in their teleseismic studies in Canada.

During the brief 10 days of recording in trigger mode, the PRS4's recorded 10 teleseismic events in the magnitude range of 5.1 to 7.0. The recorded data were written to SEGY_IASPEI files for interpretation. This report explains both the field recording parameters and processing of teleseismic data using the LithoSEIS software package at the Geological Survey of Canada (GSC).

The Earthquakes

During the PRS4 recording period of August 21 to September 1, 1995, some 18 earthquakes in the magnitude range of 5.1-7.0 occurred at teleseismic distances from the PRS4 sites. These events, together with three regional events that occurred in the same time period are listed in Table 1. The teleseismic earthquakes occurred at distances of 600-11000 km from the PRS4 array. Ten of these 18 events triggered 3 or more PRS4 instruments. These 10 events are given an 'Event' number in Table 1. Note from data in this table that the deep-focus earthquakes triggered the PRS4 instruments more successfully than the shallow earthquakes. Maps[2] in figures 1 and 2 show the location of all earthquakes and the PRS4 array.

The Event Table

The GSC's LithoSEIS[3] software package which is used to process the PRS4 data is designed mostly for handling either seismic refraction or microearthquake data. In order to handle teleseismic data, new subroutines had to be created. One such subroutine searched the LithoSEIS catalog for triggered events that occurred within about 15 seconds of each other. These were assumed to have originated from the same teleseismic earthquake.

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1 Levander A., T.J. Henstock, K.D. Dueker, A. F. Sheehan and E.D. Humphreys; The 1995 US Deep Probe Experiment: Natuarl Source Experiments. EOS, Transactions, Americal Geophysical Union, Vol. 76, No. 45, November 1995.

2 Maps in this report are created using GMT; Wessel, P., and W. H. F. Smith, 1995, The Generic Mapping Tools (GMT) version 3.0 Technical Reference & Cookbook, SOEST/NOAA.

3 See, for example, The LithoSEIS User Manual. I. Asudeh, R. Wetmiller and C. Spencer (1993). Geological Survey of Canada Open File Report 2679.

A search of the LithoSEIS catalog identified some 800 distinct events. Most of these were noise bursts and other false triggers and occurred on single sites only. Those triggers that occurred on at least 2 PRS4 sites are listed in Table 2, below. Each trigger set is given an 'Event' number to identify them in LithoSEIS. Note from Table 2 that the largest (magnitude 7.0; event 202) earthquake triggered 15 PRS4 sites (total of 45 components). The smallest (magnitude 5.1; event 204) earthquake only triggered 2 PRS4 sites.

Table 1. Registered earthquakes between August 21 and September 1, 1995. Distance and Azimuth are calculated from epicenters to Grand Junction. The 'Event' field refers to event number in Table 2. The last three events indicated in *italics* are regional events. Table data from T.J. Henstock, personal communication.

Date	Time	Lat.	Long.	Depth	Mb	Distance	Azimuth	Comment	Event
1995/08/21	22:33:25.6	6.2750S	154.0480E	33.0	5.2	11043.0	269.5	?v.weak	
1995/08/22	22:12:00.0	29.0490S	177.5150W	49.0	5.6	10344.4	234.7	?weak	
1995/08/23	07:06:02.6	18.8570N	145.1860E	596.0	**7.0**	10006.0	294.3	great	**202**
1995/08/23	07:57:35.2	19.1060N	144.8440E	567.0	**5.1**	10014.7	294.7		**204**
1995/08/24	01:55:34.6	18.9200N	144.9510E	589.0	**6.2**	10019.9	294.5	good	**242**
1995/08/24	06:28:54.6	18.8770N	145.0070E	600.0	**5.4**	10018.7	294.5		**256**
1995/08/24	07:54:41.7	18.8570N	144.9820E	598.0	**5.3**	10022.1	294.5		**257**
1995/08/24	07:55:25.6	18.8650N	145.0150E	580.0	5.4	10018.9	294.4		
1995/08/25	14:25:25.2	20.2170S	177.9800W	540.0	**5.2**	9706.7	241.4	not great	**330**
1995/08/25	16:51:46.5	18.5910S	175.5430W	224.0	**5.2**	9397.5	240.9		**337**
1995/08/27	17:51:00.2	48.0150S	32.0070E	10.0	**5.1**	16744.5	120.7	not great	**491**
1995/08/28	10:46:12.9	26.1580N	110.3490W	10.0	**6.5**	1429.5	185.5		**554**
1995/08/29	07:25:48.5	47.9890S	99.4530E	10.0	6.4	17523.5	237.1	weak	
1995/08/29	08:51:30.8	20.9230S	174.6050W	18.0	**5.6**	9507.6	238.7	?weak	**613**
1995/08/30	23:04:07.7	19.3060S	173.5530W	33.0	5.8	9303.6	239.1	?weak	
1995/08/31	08:20:55.0	69.3880N	147.0480W	32.0	5.2	4063.2	338.5	weak	
1995/09/01	05:18:04.0	13.6120S	74.8700W	109.0	5.1	6813.7	141.5		
1995/09/01	06:30:37.5	0.0040N	123.2450E	163.0	5.5	13176.0	295.9	pKp	
1995/08/28	*03:16:25.1*	*44.1690N*	*110.2500W*	*5.0*	*4.5*	*583.7*	*350.1*	*good*	
1995/08/28	*05:01:56.2*	*44.1220N*	*110.2890W*	*5.0*	*3.8*	*579.1*	*349.7*	*good*	
1995/08/28	*17:11:09.8*	*44.2340N*	*110.3590W*	*5.0*	*3.1*	*592.4*	*349.4*	*variable*	

Table 2. List of events which triggered at least 2 PRS4 recorders. An event number is allocated to each event. The 'Count' field indicates total number of recorded components. The 'Time' field indicates Julian time for the earliest trigger. Those events for which a SEGY_IASPEI file was created are indicated by 'SEGY' near the event number. Magnitudes are taken from Table 1.

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LithoSEIS Event Table

Date	Time	Span	Count	Event		Mb
Mon 21 Aug 1995	233:19:43:54	0	6	128		
Mon 21 Aug 1995	233:23:12:40	0	12	142	SEGY	
Tue 22 Aug 1995	234:02:02:49	0	6	148		
Tue 22 Aug 1995	234:15:39:40	0	15	165	SEGY	
Tue 22 Aug 1995	234:15:40:04	0	6	166		
Tue 22 Aug 1995	234:19:43:14	0	6	180		
Tue 22 Aug 1995	234:20:09:30	0	21	182	SEGY	
Tue 22 Aug 1995	234:20:09:47	0	9	183	SEGY	
Tue 22 Aug 1995	234:20:32:38	0	6	184		
Tue 22 Aug 1995	234:22:58:18	0	27	192	SEGY	
Tue 22 Aug 1995	234:22:58:36	0	12	193	SEGY	
Wed 23 Aug 1995	235:07:17:30	0	45	202	SEGY	7.0
Wed 23 Aug 1995	235:07:35:03	0	15	203	SEGY	
Wed 23 Aug 1995	235:08:09:09	0	6	204	SEGY	5.1
Wed 23 Aug 1995	235:16:01:05	0	6	211		
Wed 23 Aug 1995	235:21:48:43	0	6	220		
Wed 23 Aug 1995	235:22:05:44	0	6	222		
Thu 24 Aug 1995	236:02:07:03	0	42	242	SEGY	6.2
Thu 24 Aug 1995	236:02:17:10	0	9	243	SEGY	
Thu 24 Aug 1995	236:06:40:25	0	12	256	SEGY	5.4
Thu 24 Aug 1995	236:08:06:11	0	30	257	SEGY	5.3
Fri 25 Aug 1995	237:12:51:34	0	6	323		
Fri 25 Aug 1995	237:14:36:46	0	12	330	SEGY	5.2
Fri 25 Aug 1995	237:16:24:08	0	6	335		
Fri 25 Aug 1995	237:16:24:52	0	18	336	SEGY	
Fri 25 Aug 1995	237:17:03:26	0	21	337	SEGY	5.2
Fri 25 Aug 1995	237:19:26:02	0	6	343		
Sat 26 Aug 1995	238:16:32:23	0	9	397	SEGY	
Sun 27 Aug 1995	239:03:50:13	0	9	455	SEGY	
Sun 27 Aug 1995	239:18:10:37	0	9	491	SEGY	5.1
Sun 27 Aug 1995	239:19:54:53	0	6	506		
Mon 28 Aug 1995	240:03:17:27	0	27	538	SEGY	
Mon 28 Aug 1995	240:05:04:15	0	9	544	SEGY	
Mon 28 Aug 1995	240:10:48:49	0	24	554	SEGY	6.5
Tue 29 Aug 1995	241:09:03:49	0	6	613	SEGY	5.6
Wed 30 Aug 1995	242:15:31:45	0	9	698	SEGY	
Wed 30 Aug 1995	242:19:32:06	0	6	708		
Fri 1 Sep 1995	244:07:11:30	0	24	779	SEGY	
Fri 1 Sep 1995	244:21:26:25	0	6	794		

The Recording History

In order to identify both successful and failed triggers, we first created a history of recording at each site for each event in Table 2. The recording sites are identified with a four-digit SITE-ID and are displayed in Figure 2. As noted from this table, a total of 17 sites were recording for the largest (magnitude 7.0, event 202) earthquake. Two PRS4 instruments (sites 0133 and 0135) did not trigger.

Table 3. List of recording sites which were operational when events listed in Tables 1 and 2 occurred. Sites in which the PRS4 instruments triggered are shown in BOLD. Magnitudes (Mb) and depths (Dpt.) are copied from Table 1. The ratio of the number of triggered sites (Trig.) to the number of recording sites (Rec.) for each event provides a reasonable measure of successful triggering. For the largest event (202), this ratio was 15/17 or about 88 per cent. For one of the smaller events (204), this ratio was 2/17 or 12 per cent.

Event	Mb	Dpt.	Rec.	Trig.	Recording Sites
128:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
142:					0007 0009 0011 0013 **0019** 0023 0025 0034 **0036** 0038 0126 0128 **0131** 0133 0135 **0141** 0143
148:					0007 0009 0011 0013 0019 0023 0025 **0034** 0036 **0038** **0126** 0128 **0131** 0133 0135 0141 0143
165:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
166:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
180:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
182:					0007 0009 0011 0013 0019 0023 0025 **0034** **0036** **0038** **0126** 0128 **0131** 0133 0135 **0141** 0143
183:					**0007** **0009** 0011 0013 0019 0023 0025 0034 0036 0038 0126 **0128** 0131 0133 0135 0141 0143
184:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
192:					0007 0009 0011 0013 0019 **0023** 0025 **0034** **0036** **0038** **0126** **0128** **0131** 0133 0135 **0141** **0143**
193:					**0007** **0009** 0011 **0013** **0019** 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
202:	7.0	596	17	15	**0007** **0009** **0011** **0013** **0019** **0023** **0025** **0034** **0036** **0038** **0126** **0128** **0131** 0133 0135 **0141** **0143**
203:					**0007** **0009** 0011 0013 **0019** 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 **0141** **0143**
204:	5.1	567	17	2	0007 0009 0011 0013 0019 0023 0025 **0034** 0036 0038 **0126** 0128 0131 0133 0135 0141 0143
211:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
220:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
222:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
242:	6.2	589	17	14	**0007** **0009** **0011** **0013** **0019** **0023** 0025 **0034** **0036** 0038 **0126** **0128** **0131** 0133 0135 **0141** **0143**
243:					0007 0009 0011 0013 0019 0023 0025 0034 0036 0038 **0126** **0128** **0131** 0133 0135 0141 0143
256:	5.4	600	17	4	0007 0009 0011 0013 0019 0023 0025 **0034** 0036 0038 **0126** **0128** 0131 0133 **0135** 0141 0143
257:	5.3	598	17	10	**0007** 0009 **0011** **0013** **0019** 0023 0025 **0034** 0036 0038 **0126** **0128** **0131** 0133 **0135** 0141 **0143**
323:					0007 0009 0011 0013 0019 0023 0024 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
330:	5.2	540	18	4	**0007** **0009** **0011** **0013** 0019 0023 0024 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
335:					0007 0009 0011 0013 0019 0024 0025 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
336:					**0007** **0009** **0011** **0013** **0019** **0024** 0034 0036 0038 0126 0128 0131 0133 0135 0141 0143
337:	5.2	224	16	7	**0007** **0009** **0011** **0013** 0019 **0024** 0034 0036 0038 0126 0128 **0131** 0133 **0135** 0141 0143 0151 0152
343:					0007 0009 0011 0013 0019 0024 0034 0126 0128 0131 0133 0135 0141 0143 0151 0152
397:					**0007** 0009 **0011** 0013 0019 0024 0034 **0131** 0133 0135 0141 0143 0151 0152
455:					**0007** 0009 **0011** **0013** 0019 0024 0034 0131 0133 0135 0141 0143 0151 0152
491:	5.1	10	14	3	0007 **0009** 0011 0013 **0019** 0024 0034 0131 **0133** 0135 0141 0143 0151 0152
506:					0007 0009 0011 0013 0019 0024 0034 0131 0133 0135 0141 0143 0151 0152
538:					0007 **0009** **0011** **0013** **0019** **0024** 0034 **0131** **0133** **0135** **0141** 0143 0151 0152
544:					0007 0009 **0011** **0013** **0019** 0024 0034 0131 0133 0135 0141 0143 0151 0152
554:	6.5	10	14	8	**0007** **0009** **0011** **0013** **0019** **0024** 0034 0131 **0133** **0135** 0141 0143 0151 0152
613:	5.6	18	15	2	0007 **0009** **0011** 0013 0019 0023 0024 0025 0034 0133 0135 0141 0143 0151 0152
698:					0007 **0009** **0011** **0013** 0019 0023 0025 0034 0133 0135 0143 0151 0152
708:					0007 0009 0011 0013 0019 0023 0025 0034 0133 0135 0143 0151 0152
779:					0007 **0009** **0011** **0013** **0019** **0023** **0025** 0034 0133 0135 **0143** **0151** 0152
794:					0007 0009 0011 0013 0019 0023 0025 0034 0133 0135 0143 0151 0152

The Trigger History

The Trigger History for all events of Table 2 are summarized in Table 4, below. This table can be used as a quick look-up table to identify recording sites for each event for which triggering occurred.

Table 4. List of recording sites that triggered on larger events of Tables 1 and 2. Magnitudes (Mb) and depths (Dpt.) are copied from Table 1. The ratio of the number of triggered sites (Trig.) to the number of recording sites (Rec.) for each event provides a reasonable measure of successful triggering. A SEGY_IASPEI file was created for each event in this table.

Event	Mb	Dpt.	Rec.	Trig.	Triggered Sites														
142:			17	4	0019	0036	0131	0141											
165:			17	5	0034	0036	0038	0126	0131										
182:			17	7	0034	0036	0038	0126	0131	0141	0143								
183:			17	3	0007	0009	0128												
192:			17	9	0023	0034	0036	0038	0126	0128	0131	0141	0143						
193:			17	4	0007	0009	0013	0019											
202:	7.0	596	17	15	0007	0009	0011	0013	0019	0023	0025	0034	0036	0038	0126	0128	0131	0141	0143
203:			17	5	0007	0009	0019	0141	0143										
204:	5.1	567	17	2	0034	0126													
242:	6.2	598	17	14	0007	0009	0011	0013	0019	0023	0034	0036	0126	0128	0131	0135	0141	0143	
243:			17	3	0126	0128	0131												
256:	5.4	600	17	4	0034	0126	0128	0135											
257:	5.3	598	17	10	0007	0011	0013	0019	0034	0126	0128	0131	0135	0143					
330:	5.2	540	18	4	0007	0009	0011	0013											
336:			17	6	0007	0009	0011	0013	0019	0024									
337:	5.2	224	16	7	0007	0009	0011	0013	0024	0131	0135								
397:			16	3	0007	0011	0131												
455:			14	3	0007	0011	0013												
491:	5.1	10	14	3	0009	0019	0133												
538:			14	9	0009	0011	0013	0019	0024	0131	0133	0135	0141						
544:			14	3	0011	0013	0019												
554:	6.5	10	14	8	0007	0009	0011	0013	0019	0024	0133	0135							
613:	5.6	18	15	2	0009	0011													
698:			14	3	0009	0011	0013												
779:			14	8	0009	0011	0013	0019	0023	0025	0143	0151							

From data in Tables 3 and 4, we have created Table 5 in which the maximum number of triggers at each PRS4 site is displayed. From this table, it appears that sites to the west of the PRS4 array triggered on earthquakes more frequently than other sites.

Table 5. List of PRS4 recording sites and maximum number of triggers at each site. As seen on figure 2, site numbers increase from west to east. It appears that the sites on the west part of the array triggered on earthquakes more frequently than other sites.

Site:	0007	0009	0011	0013	0019	0023	0024	0025	0034	0036	0038	0126	0128	0131	0133	0135	0141	0143	151	152
Trig.:	12	14	14	13	12	4	4	2	8	5	4	9	7	11	3	6	7	6	1	0

The LithoSEIS deployments

Before we examine the triggering further, we display other important LithoSEIS recording parameters in the next few tables.

Each LithoSEIS deployment identifies a set of recording parameters that are programmed into the PRS4 recorders before they are installed at each recording sites. In 'trigger' mode, the important parameters include a number of 'duration' parameters, short and long-term average parameters and their ratio, and an infinite impulse response filter used for the trigger. Tables 6 and 7, below show the list of parameters for the passive survey.

Table 6. List of deployments used in the survey. Note that all deployments used same duration, short and long term average parameters. The STA/LTA ratio was only slightly changed for deployments 25L and 27L.

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List of LithoSEIS Deployments
With Duration Parameters

Dep Code	Number of PRS Plan	Down	Up	Deployment Start Time jjj:hh:mm:ss	Durations (s) Pre	Post	Mute	Cal.	Now	Warm	Short Term Ave. s	Long Term Ave. s	STA / LTA
19A	151	30	17	231:14:33:00	30	90	120	10	60	15	2.54	102.2	10
19B	19	0	0	231:17:35:00	30	90	120	10	60	15	2.54	102.2	10
23A	149	17	11	235:02:27:00	30	90	120	10	60	15	2.55	102.3	10
25A	0	9	6	237:16:43:00	30	90	120	10	60	15	2.54	102.2	10
25L	0	2	2	237:18:54:00	30	90	120	10	60	15	2.54	102.2	12
27A	0	7	7	239:16:56:00	30	90	120	10	60	15	2.54	102.2	10
27L	0	4	2	239:16:58:00	30	90	120	10	60	15	2.54	102.2	12

The Short Term Average (STA) constant is the time in seconds over which an infinite impulse response (IIR) filter output is averaged to calculate a short term average value.

The Long Term Average (LTA) constant is the time in seconds over which the IIR filter output is averaged to calculate the a long term average value.

The STA/LTA Ratio is the factor by which STA must be greater than LTA for a PRS4 to declare a trigger.

The STA, LTA and their ratio are used together with the IIR filter to declare a trigger. Once a trigger is declared, the PRS4 records data for a number of seconds determined by pre-event and post-event duration's. In this case, the maximum recording duration is 120 seconds.

The IIR filter used for this survey was designed after a successful filter used by the University of British Columbia in teleseismic studies in Saskatchewan[4]. Their IIR filter TF07 was used in the current study. The parameters of this filter are shown in Table 7, below.

4 Investigation of the Properties of the Lithosphere Using Teleseismic Waves, A preliminary report for Energy, Mines and Resources Canada and Cameco Corporation. R.M. Ellis, Z. Hajnal, J. Amor, T. Mulder, N. Dotzev and R.D. Meldrum; January 1992.

Table 7. List of IIR filters. Filter 'GOOD' is a default filter and is not used in the survey. Filter TF07 was used in all deployments listed in Table 6, above.

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IIR Filter Database Standard Report

IIRCOD	Sampl Rate	PRS Mode	Low Pass In Use?	F1 F2 F3	Q1 Q2 Q3	A1 A2 A3	B1 B2 B3	CC1 CC2 CC3	Deci-mation Factor
GOOD	200	S	No	0.0	0.0	0	0	0	1
				50.0	5.0	-1	-41	40	1
				40.0	10.0	35	-52	6	1
TF07	**50**	**S**	**Yes**	**1.1**	**50.0**	**124**	**-61**	**1**	**2**
				0.7	**50.0**	**123**	**-61**	**2**	**1**
				1.9	**20.0**	**107**	**-58**	**3**	**1**

The IIR filter parameters are used to design a combination of three infinite impulse response (IIR) filters which are applied to the signal recorded on the designated trigger channel prior to the calculation of the STA and LTA values in order to determine if a trigger should be declared. This allows the triggering to be carried out on a limited frequency range for which the signal-to-noise ratio of the desired seismic events is optimal. Note that the IIR filtering is only applied for triggering purposes and is not applied to the data stored by the recorder once it triggers.

The IIR filter combination is created in a separate external program in which we specify various combinations of a low pass filter and two band pass filters specified by frequencies (F) and slopes (Q) to achieve the desired result. The performance of the filters specified is displayed in both the frequency and time domains. Figure 3 shows the frequency response and figure 4 the time response of the filters used to create the TF07 filter. Note from figure 3 that the TF07 has a narrow pass-band between 0.7 and 1.5 Hz.

Timing corrections and the LithoSEIS Record

We complete the LithoSEIS listings in Tables 8 and 9 where the recording parameters for all PRS4 recorders for the duration of survey are shown. Note from these tables that the time correction for each recording is the drift of the PRS4 clock for the duration of the recording. Linear interpolation between the download and upload time is used to store a fraction of this drift to the header of each trace stored in the SEGY_IASPEI files. Note that in LithoSEIS processing, the time correction for each trace is ***not*** applied to the data (see Appendix A for details).

Table 8. List of recording parameters of the PRS4 recorders for all deployments of the survey (Table 6). This list is sorted by 'Dep Code' and 'Site ID'.

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List of LithoSEIS Recordings
With Upload and Download Times

Dep Code	Site ID	PRS Ser. Num.	Download Time jjj:hh:mm:ss	Upload Time jjj:hh:mm:ss	Record Span (hr)	Time Corr. (s)	Down Volts	Up Volts	Level One ?
** FSU Code: CLAY									
19A	0007	0258	231:18:44:50	236:15:52:09	117.1	-0.017	11.05	13.70	Done
19A	0009	0271	231:18:49:35	236:16:04:32	117.2	-0.044	11.00	11.30	Done
19A	0011	0307	231:18:45:44	236:15:47:15	117.0	-0.147	11.60	14.30	Done
19A	0013	0049	231:18:59:00	236:15:41:53	116.7	0.052	11.85	11.00	Done
19A	0019	0306	231:19:07:30	237:17:44:36	142.6	0.052	11.65	11.35	Done
19A	0023	0288	231:18:56:29	237:16:20:45	141.4	0.000	11.75	10.10	Done
19A	0025	0308	231:18:54:51	237:16:24:42	141.5	0.006	11.25	10.85	Done
19A	0034	0311	231:18:52:10	239:21:48:52	194.9	0.000	11.65	11.75	Done
19A	0036	0263	231:18:53:08	237:18:52:53	144.0	0.034	11.55	11.00	Done
19A	0038	0309	231:18:53:54	237:17:18:30	142.4	-0.107	11.60	12.35	Done
19A	0126	0067	231:19:08:20	238:01:29:49	150.4	0.003	11.80	10.95	Done
19A	0128	0287	231:18:55:39	238:01:11:06	150.3	0.036	11.10	11.55	Done
19A	0131	0273	231:18:47:38	235:22:41:05	99.9	0.127	11.70	14.00	Done
19A	0133	0305	231:18:48:45	241:18:13:51	239.4	0.124	11.50	14.55	Done
19A	0135	0055	231:18:46:41	235:19:06:45	96.3	0.029	11.85	11.20	Done
19A	0141	0262	231:19:09:05	237:16:28:15	141.3	-0.027	11.70	10.25	Done
19A	0143	0304	231:18:51:19	237:18:21:33	143.5	-0.111	11.75	14.05	Done
23A	0007	0285	235:16:09:12	240:16:20:17	120.2	-0.063	11.75	11.80	Done
23A	0009	0286	235:16:08:23	240:16:53:36	120.8	-0.069	11.95	11.55	Done
23A	0011	0254	235:16:10:52	240:16:31:57	120.4	-0.352	11.70	12.35	Done
23A	0013	0257	235:16:10:03	240:16:43:25	120.6	-0.233	11.60	11.60	Done
23A	0019	0272	236:16:26:49	241:16:27:33	120.0	-0.074	11.55	11.75	Done
23A	0024	0252	236:16:25:45	241:19:04:28	122.6	-0.211	10.70	13.70	Done
23A	0034	0218	236:16:48:05	246:02:06:58	225.3	0.000	12.00	12.55	
23A	0131	0273	235:23:03:12	240:17:05:42	114.0	0.185	14.05	14.05	Done
23A	0135	0055	235:20:14:11	238:01:47:54	53.6	0.015	12.50	11.75	Done
23A	0141	0049	236:16:21:17	241:16:42:49	120.4	0.080	10.65	10.30	Done
23A	0143	0307	236:16:20:16	241:16:22:33	120.0	-0.032	11.50	12.15	Done
25A	0007	0309	239:16:38:28	246:01:24:54	152.8	-0.065	11.35	12.10	Done
25A	0009	0287	239:16:34:36	246:01:12:59	152.6	-0.089	10.85	13.85	Done
25A	0011	0304	239:16:32:55	246:01:29:37	152.9	-0.162	11.25	14.05	Done
25A	0013	0263	239:16:35:23	246:01:34:10	153.0	-0.003	10.85	10.85	Done
25A	0151	0262	237:16:36:33	243:17:24:56	144.8	-0.050	10.25	11.55	Done
25A	0152	0308	237:16:37:19	242:02:50:13	106.2	-0.032	10.85	13.70	Done
25L	0133	0306	237:18:49:51	240:18:24:50	71.6	0.032	11.35	10.80	Done
25L	0135	0288	237:18:48:49	240:17:34:43	70.8	-0.035	10.25	10.30	Done
27A	0019	0035	240:17:27:31	245:23:53:34	126.4	0.000	11.85	10.95	Done
27A	0023	0286	240:17:21:52	245:22:44:55	125.4	0.032	11.35	10.80	Done
27A	0025	0285	240:17:25:22	245:22:49:36	125.4	0.002	11.40	11.80	Done
27A	0143	0257	240:17:24:32	245:23:08:40	125.7	-0.193	11.20	11.00	Done
27A	0151	0272	241:16:41:18	245:22:52:03	102.2	-0.003	11.50	11.10	Done
27A	0152	0307	241:16:40:26	246:00:12:16	103.5	-0.060	11.45	11.35	Done
27L	0133	0055	239:16:50:33	245:21:31:12	148.7	0.032	10.90	11.70	Done
27L	0135	0045	239:16:54:16	245:20:26:53	147.5	-0.394	11.30	10.90	Done

Table 9. List of recording parameters of the PRS4 recorders for all deployments of the survey (Table 6). This list is sorted by 'PRS Serial Number'.

Page No. 1 Deep Probe Passive Survey
95.11.02

List of LithoSEIS Recordings
With Upload and Download Times

Dep Code	Site ID	PRS Ser. Num.	Download Time jjj:hh:mm:ss	Upload Time jjj:hh:mm:ss	Record Span (hr)	Time Corr. (s)	Down Volts	Up Volts	Level One ?
** FSU Code: CLAY									
27A	0019	0035	240:17:27:31	245:23:53:34	126.4	0.000	11.85	10.95	Done
27L	0135	0045	239:16:54:16	245:20:26:53	147.5	-0.394	11.30	10.90	Done
23A	0141	0049	236:16:21:17	241:16:42:49	120.4	0.080	10.65	10.30	Done
19A	0013	0049	231:18:59:00	236:15:41:53	116.7	0.052	11.85	11.00	Done
23A	0135	0055	235:20:14:11	238:01:47:54	53.6	0.015	12.50	11.75	Done
19A	0135	0055	231:18:46:41	235:19:06:45	96.3	0.029	11.85	11.20	Done
27L	0133	0055	239:16:50:33	245:21:31:12	148.7	0.032	10.90	11.70	Done
19A	0126	0067	231:19:08:20	238:01:29:49	150.4	0.003	11.80	10.95	Done
23A	0034	0218	236:16:48:05	246:02:06:58	225.3	0.000	12.00	12.55	
23A	0024	0252	236:16:25:45	241:19:04:28	122.6	-0.211	10.70	13.70	Done
23A	0011	0254	235:16:10:52	240:16:31:57	120.4	-0.352	11.70	12.35	Done
23A	0013	0257	235:16:10:03	240:16:43:25	120.6	-0.233	11.60	11.60	Done
27A	0143	0257	240:17:24:32	245:23:08:40	125.7	-0.193	11.20	11.00	Done
19A	0007	0258	231:18:44:50	236:15:52:09	117.1	-0.017	11.05	13.70	Done
19A	0141	0262	231:19:09:05	237:16:28:15	141.3	-0.027	11.70	10.25	Done
25A	0151	0262	237:16:36:33	243:17:24:56	144.8	-0.050	10.25	11.55	Done
19A	0036	0263	231:18:53:08	237:18:52:53	144.0	0.034	11.55	11.00	Done
25A	0013	0263	239:16:35:23	246:01:34:10	153.0	-0.003	10.85	10.85	Done
19A	0009	0271	231:18:49:35	236:16:04:32	117.2	-0.044	11.00	11.30	Done
23A	0019	0272	236:16:26:49	241:16:27:33	120.0	-0.074	11.55	11.75	Done
27A	0151	0272	241:16:41:18	245:22:52:03	102.2	-0.003	11.50	11.10	Done
23A	0131	0273	235:23:03:12	240:17:05:42	114.0	0.185	14.05	14.05	Done
19A	0131	0273	231:18:47:38	235:22:41:05	99.9	0.127	11.70	14.00	Done
23A	0007	0285	235:16:09:12	240:16:20:17	120.2	-0.063	11.75	11.80	Done
27A	0025	0285	240:17:25:22	245:22:49:36	125.4	0.002	11.40	11.80	Done
23A	0009	0286	235:16:08:23	240:16:53:36	120.8	-0.069	11.95	11.55	Done
27A	0023	0286	240:17:21:52	245:22:44:55	125.4	0.032	11.35	10.80	Done
19A	0128	0287	231:18:55:39	238:01:11:06	150.3	0.036	11.10	11.55	Done
25A	0009	0287	239:16:34:36	246:01:12:59	152.6	-0.089	10.85	13.85	Done
19A	0023	0288	231:18:56:29	237:16:20:45	141.4	0.000	11.75	10.10	Done
25L	0135	0288	237:18:48:49	240:17:34:43	70.8	-0.035	10.25	10.30	Done
19A	0143	0304	231:18:51:19	237:18:21:33	143.5	-0.111	11.75	14.05	Done
25A	0011	0304	239:16:32:55	246:01:29:37	152.9	-0.162	11.25	14.05	Done
19A	0133	0305	231:18:48:45	241:18:13:51	239.4	0.124	11.50	14.55	Done
19A	0019	0306	231:19:07:30	237:17:44:36	142.6	0.052	11.65	11.35	Done
25L	0133	0306	237:18:49:51	240:18:24:50	71.6	0.032	11.35	10.80	Done
23A	0143	0307	236:16:20:16	241:16:22:33	120.0	-0.032	11.50	12.15	Done
19A	0011	0307	231:18:45:44	236:15:47:15	117.0	-0.147	11.60	14.30	Done
27A	0152	0307	241:16:40:26	246:00:12:16	103.5	-0.060	11.45	11.35	Done
19A	0025	0308	231:18:54:51	237:16:24:42	141.5	0.006	11.25	10.85	Done
25A	0152	0308	237:16:37:19	242:02:50:13	106.2	-0.032	10.85	13.70	Done
19A	0038	0309	231:18:53:54	237:17:18:30	142.4	-0.107	11.60	12.35	Done
25A	0007	0309	239:16:38:28	246:01:24:54	152.8	-0.065	11.35	12.10	Done
19A	0034	0311	231:18:52:10	239:21:48:52	194.9	0.000	11.65	11.75	Done

EARTHQUAKE DATA IN SEGY_IASPEI FORMAT

The SEGY_IASPEI format is designed for controlled-source data where seismic traces all originate from same source and, normally, all start at the same time. For earthquake data, the origin time may be used as source time. As the PRS4's do not necessarily trigger at the same time for the same source, the recorded traces do not all share a common start time. This presents a problem when creating the SEGY files. A work-around this problem was to copy trace start time for each trace to shot time. In this way, a 'ghost' shot is defined at each trigger time on each PRS4 record.

A second problem with using the SEGY_IASPEI format for earthquake data is that since no controlled-source 'shots' are defined, the SEGY trace headers lack their SHOT identifiers. A work-around this problem was to assign an 'event' number to each group of triggers that occurred within a few tens of seconds of each other. This 'unique' event number was then copied to SHOT_ID in the SEGY_IASPEI headers. These event numbers are shown in Tables 1-4, above.

With the ***trigger-times copied to shot-times and event numbers copied to shot names***, we proceeded to create the SEGY_IASPEI files for all PRS4 data that triggered at least two sites.

All SEGY_IASPEI files were created in TAPE IMAGE, in I*2 format and from the first data sample to the last data sample (normally about 120 seconds) and in non-reduced format. See Appendices A and B for more details about the SEGY_IASPEI files.

The Exabyte tape

SEGY_IASPEI, log[5] and flat[6] files were created for each event in Table 4. All the SEGY_IASPEI files and their log and flat files were written to an exabyte tape. Listing of a shell script used for taping data and listing of a shell script for restoring data from the Exabyte tape follows.

Table 10 Example of Unix shell script used to tape the data.

```
#!/bin/csh -f
# Script to create an Exabyte tape on remote node juandefuca
rsh juandefuca mt -f /dev/nrst4 rew
rsh juandefuca mt -f /dev/nrst4 status
cd /bear2/asudeh/passive/segy
tar cvfb - 20 *.sgy | rsh juandefuca dd of=/dev/nrst4 obs=20b
rsh juandefuca mt -f /dev/nrst4 status
tar cvfb - 20 *.log | rsh juandefuca dd of=/dev/nrst4 obs=20b
rsh juandefuca mt -f /dev/nrst4 status
tar cvfb - 20 *.flt | rsh juandefuca dd of=/dev/nrst4 obs=20b
rsh juandefuca mt -f /dev/nrst4 status
```

5 Log files and flat are created by MAKESEGY program in LithoSEIS. Useful information about SEGY_IASPEI files are found in log files.
6 Flat files are ASCCI image of a LithoSEIS database and contain all SEGY_IASPEI trace header information for each SEGYfile.

Table 11. Example of Unix shell scripts for restoring data from the Exabyte tape.

```
#!/bin/csh -f
# Script to restore data from exabyte tape on node lamb
#
# make sure we are at start of tape:
#
rsh lamb mt -f /dev/nrst4 rew
#
# display tape stats
#
rsh lamb mt -f /dev/nrst4 status
#
# get all .sgy files, they are first on tape
#
rsh -n lamb dd if=/dev/nrst4 bs=20b | tar xvBfb - 20
#
# Now, get all .log files, they are on next tar volume
#
rsh -n lamb dd if=/dev/nrst4 bs=20b | tar xvBfb - 20
#
# Finally, get all .flt files, they are on last tar volume.
#
rsh -n lamb dd if=/dev/nrst4 bs=20b | tar xvBfb - 20
```

Example of a log file

For each event in Table 4, the LithoSEIS MAKESEGY program creates a log file. The log file for event 142 is listed below with further explanations in the footnotes.

```
            * MAKESEGY *************************  Version 5.0 *
            *                 1995.10.31 09:26                  *
            ***************************************************
Error log                    P:\SEGY\MAKESEGY.ERR
Log file                     P:\SEGY\142.LOG
TRACE file directory         P:\STORE\
Input FLAT file name         P:\SEGY\TRACE.FLT
Output FLAT file name        P:\SEGY\142.FLT
REEL FLAT file name          P:\SEGY\REEL.FLT
Ascii Header file name       P:\SEGY\142.AHD
Segy output file name        P:\SEGY\142.SGY
Reduction velocity (km/s)       0.000000E+00
Output start time               0.000000E+00
Output end time                   120.000000
Dummy trace 1 distance              1.000000[7]
Dummy Offset between traces         1.000000
Output format                          3
Disk/Tape switch T=DISK      T
Calculate distances ?        F
Output type for disk SEGYS   TAPE
SEGY include version number         300
Debug flag                   F
Creating a disk file for TAPE format ...

Flat file Validation.
         Data format code                                3
         No of samples for output                     6001
         Number of bytes per trace                   12242
This is fine for disk output.

Reel Header Information From Flat file:
     JOBID                              27
     LINENO                              0
     REELNO                              0
     NTRACE                             12
     VERSION found on read             300
     VERSION in reel header            300


---------------------------------------------------------------------------
---------------------------------------------------------------------------
Trace TSNT_ ISI___ SHOT REC_ Shot Time__ Rec Time___ Dist___   Byte1 Good
---------------------------------------------------------------------------
    1     1  20000 142  0019 23:12:49.00 23:12:49.00[8]    0       1[9] TT1[10]
    2     2  20000 142  0019 23:12:49.00 23:12:49.00       0          1 TT2
    3     3  20000 142  0019 23:12:49.00 23:12:49.00       0          1 TT3
    4     4  20000 142  0036 23:12:49.00 23:12:49.00       0          1 TT1
    5     5  20000 142  0036 23:12:49.00 23:12:49.00       0          1 TT2
    6     6  20000 142  0036 23:12:49.00 23:12:49.00       0          1 TT3
    7     7  20000 142  0131 23:12:40.00 23:12:40.00       0          1 TT1
    8     8  20000 142  0131 23:12:40.00 23:12:40.00       0          1 TT2
    9     9  20000 142  0131 23:12:40.00 23:12:40.00       0          1 TT3
   10    10  20000 142  0141 23:12:47.00 23:12:47.00       0          1 TT1
   11    11  20000 142  0141 23:12:47.00 23:12:47.00       0          1 TT2
   12    12  20000 142  0141 23:12:47.00 23:12:47.00       0          1 TT3
---------------------------------------------------------------------------
```

7 Dummy distances used.
8 Shot and record (i.e.trigger) times are identical.
9 All data are stored from first sample of each trace.
10 TT1 means vertical-component. TT2 is north-south, TT3 is east-west.

Typical data sections and triggering

The VISTA[11] software package was used to display the SEGY_IASPEI files in sections similar to those used for controlled-source data. Data are normally shown from the first triggered sample and are sorted from smallest SITE_ID to the largest. Location of sites are shown in Figure 2. Some sections display three-component data, others display vertical-component only. When the three-component data are shown, they are displayed in the order 'vertical, north-south and east-west' for each site. In some cases, data are RMS scaled first. Only the first 50 to 60 seconds of data are displayed. For each seismic section, amplitude spectra are calculated and displayed.

Figures 5 to 12 show seismic sections and amplitude spectra for typical events in Table 4. Figures 5 and 6 show three-component and vertical-component data for event 202 (magnitude 7.0) in Table 4. Both figures show good signal to noise ratio on all sites indicating that this event is suitable for teleseismic wave-form and travel-time residual analysis. Using VISTA, we have displayed the amplitude spectrum for the vertical-component data of Figure 6 in Figure 7. Most of the signal energy is below 4 Hz with peaks near 1, 1.5 and 2 Hz as displayed in the lower frame in Figure 7. Event 202 triggered PRS4's at 15 sites from the total 17 sites that were recording when the event occurred.

It is not clear why event 204 of Table 4 (magnitude 5.1) triggered only 2 sites as displayed in Figure 8. The amplitude response of this event is similar but not identical to those of event 202 of Figure 7. The two events occurred within one hour of each other and examination of data on all sites show that the noise levels were similar for the two sites that triggered for event 204 and all sites of event 202. What we need to learn is how to improve the IIR trigger filter such that all sites, under similar conditions, trigger for all events greater than magnitude, say 5.0. It is difficult to achieve this goal without 'training' the trigger filter at each site. It is also difficult to obtain information from the current data about failed triggers, as, necessarily, the recorded data are all result of successful triggers.

Figures 9 and 10 display waveform data and an amplitude spectrum for event 242 (magnitude 6.2) of Table 4. The signal energy is similar to that of event 202 shown in Figure 7. Event 242 exhibits some higher frequency energy at sites 36, 126 and 128 as seen in Figure 10. Both events originated from similar depths of about 600 km.

Event 554 of Table 4 with a shallow focus and reported magnitude of 6.5 triggered only 8 sites from the maximum possible 14. The signal-to-noise ratio was good as seen in Figure 11. In this case, the signal energy is more concentrated near lower frequencies as seen in the lower frame in Figure 12. Certain sites like 11, 24, and 133 exhibit higher frequency noise on the amplitude spectrum in the upper frame in Figure 12.

In general, it appears from the small sample at hand that deep-focus earthquakes triggered the PRS4 sites more successfully than the shallow-focus events of similar magnitude. The IIR filter was used at all sites had a band-pass near 1 Hz. Comparison of the lower frame of Figure 12 for a shallow event to the lower frame of Figures 7 and 10 for deep events shows that the latter had a wider spectrum with more peaks below 4 Hz than the former. Could this have resulted in more triggers?

By far the best way to study the triggering is to 'train' each site in the first few days of recording and design an IIR filter that best triggers. This was not possible in the current study. An alternative IIR filter to the one used in the current study is given in Figure 13. The filter is designed near the center frequency of .815 Hz with smooth slopes and the lower-frequency slope falling less rapidly than the higher-frequency one. The response of this filter to a sweep of signals from 0-10 Hz is shown in Figure 14. The peak amplitude is well above the sweep signal at frequencies below 4 Hz, but falls rapidly at frequencies above 4 Hz. This response is consistent with amplitude spectra of the successful triggers shown in Figures 7, 8, 10 and 12. Use of this IIR filter with STA and LTA constants similar to those of the current study (shown in Table 6, above) but with a higher STA/LTA ratio could have increased the frequency of triggering in general. In particular, since the shape of the filter favours events with

11 VISTA 7.00, Seismic Image Software Ltd., Calgary.

signal energies below 4 Hz, teleseismic events of lower magnitude would have triggered at a larger number of sites with this filter.

A different view of the trigger problem is shown in Figure 15 in which data for the same site for event 204 (magnitude 5.1) with only 2 successful triggers is compared to event 202 (magnitude 7.0) with 15 triggers. The amplitude spectra plotted on the right side of this figure indicate that the smaller event did not produce as much low frequency energy as the large event. If this is true, the response of the IIR filters shown in Figures 3, 4, 13 and 14 must be re-shaped and peak amplitude moved slightly in the direction of higher frequencies. These views can only be tested in field deployments where the IIR filters at each sites can be 'trained' for maximum performance.

Appendix A: General notes on SEGY-IASPEI files

The PRS recorder's clock drifts are NOT applied to the waveform data. The drifts are stored in bytes 217-218 of each trace header, for each trace (see Appendix B). Depending on the style of merging, you must either apply these corrections at the time of merging or store and apply them at the time of reading and picking the arrival times.

Clock corrections for controlled-source shots are applied to the shot times.

Both the single and three component data for each shot are stored in the same SEGY file.

For the 3-component PRS4 recorders, the horizontal components follow the vertical immediately in the SEGY files. The 3-component data are indicated by the 'trace identification code (tic)' variable, bytes 29-30 of SEGY-IASPEI trace headers. For vertical component of a three component set, tic is 11, for North-South component, tic it is 12, and for East-West component it is 13 (see Appendix B). For the single component data, tic is 1.

Appendix B: The SEGY_IASPEI Format

```
c- Start of FINAL segy.inc version 3.00 (IASPEI), January 25, 1993 ----
c
c Isa Asudeh, Geological Survey of Canada
c             1 Observatory Crescent
c             Ottawa, Ontario
c             Canada K1A 0Y3
c             Tel. 613-996-5757
c             Fax. 613-992-8836
c             e.mail asudeh@cg.emr.ca
c
c This file is an implicit definition of the SEGY format with additions
c for refraction work. It is based on the SEGY standard of Barry et al,
c Geophysics (1975) with extensions labelled SEGY_IASPEI
c for refraction work. This version has been checked and verified by
c the U.S. Geological Survey and the IRIS/PASSCAL Consortium and will
c be used for data exchange in North America.
c
c This format is primarily for the EXCHANGE of data between processing
c centers. All information that we consider to be  essential for the
c successful exchange of data are marked with a "R" in column 70:     R
c Items considered desirable are marked with a "D" in column 70:      D
c
c Some items have been added to facilitate disk
c storage in a SEGY type file.
c Items purely for tape use are labelled TAPE                  TAPE
c in column 62 items purely for disk user are
c labelled DISK, otherwise this field                          DISK
c is left blank.
c
c-Units:
c  Refraction ground velocities are
c  in nanometers/sec. We adopt the convention:
c    (tape data word)*(10**gc) = nanometers/sec;
c  where tape data word is the value in the trace
c  data block and gc is a two byte gain constant word
c  beginning in byte 121 of the trace header.
c
c-Dimensions:
c These may vary from system to system.
c SEGY allows no more than 32767
c samples per trace. Maximum number of bytes needed to
c hold a single trace and its header is:
c 131308 = (32767 samples)*(4 bytes per sample) + 240 bytes header.
c For TAPE we recommend that
```

```
c no more than 32767 bytes per trace be used (including
c 240 bytes for a header). This leaves space for
c 16728 two byte samples or 8139 4 byte samples per trace.

c
c start of Declarations:
c
c Parameter Statements:
c

c      maximum number of bytes per trace
       integer MAXLEN
       parameter (MAXLEN = 131308)

c      maximum number of samples per trace
       integer MAXSAM
       parameter (MAXSAM = 32767)

c      EBCDIC/ASCIIR header length (bytes)
       integer EBCDIC
       parameter (EBCDIC = 3200)

c      Reel Header Length (bytes)
       integer RHLEN
       parameter (RHLEN = 400)

c      Trace Header Length (bytes)
       integer THLEN
       parameter (THLEN = 240)
c
c Dimension Statements:
c

c      SEGY reel identification header part 1
       character*1  segy1a(EBCDIC)

c      SEGY reel identification header part 2
       character*1  segy1b(RHLEN)

c      SEGY trace data block
       character*1  segydb(MAXLEN)

c      SEGY trace header
       character*1 thead(THLEN)
       equivalence (segydb(1),thead(1))

c      real and integer data arrays
       integer*2    idata(MAXSAM)
       real*4       rdata(MAXSAM)
       equivalence (segydb(241),idata(1),rdata(1))
c
c end of Declarations.
c

c
c-------------------------------------------------------------------+
c Reel Identification Header (total 400 bytes)    Starts here       |
c-------------------------------------------------------------------+
c

c Job identification number                     SEGY_STANDARD
       integer*4    jobid
       equivalence  (segy1b(1),jobid)

c Line number                                   SEGY_STANDARD         R
       integer*4    lineno
       equivalence  (segy1b(5),lineno)
```

```
c Reel number                                     SEGY_STANDARD   TAPE   R
       integer*4     reelno
       equivalence   (segy1b(9),reelno)

c Number of data traces per record                SEGY_STANDARD          R
c By "record" we mean gather
       integer*2     ntrace
       equivalence   (segy1b(13),ntrace)

c Number of auxilliary traces per record          SEGY_STANDARD          R
       integer*2     nauxt
       equivalence   (segy1b(15),nauxt)

c Sample interval in microseconds (this data),   SEGY_STANDARD          R
c See override for this value (sinto, bytes 117-120) for
c more precise presentation.
       integer*2     sint
       equivalence   (segy1b(17),sint)

c Sample interval in microseconds (in field)      SEGY_STANDARD
c See override for this value (sint2o, bytes 121-124) for
c more precise presentation.
      integer*2     sint2
      equivalence   (segy1b(19),sint2)

c No of samples per trace this data               SEGY_STANDARD          R
c The total number of samples per trace is also
c stored with each trace, so this word is not
c essential. It can be used to calculate
c record length for disk files.
c If number of sample per trace varies
c from trace to trace leave this as 0.
      integer*2     nsam
      equivalence   (segy1b(21),nsam)

c No of samples per trace in the field            SEGY_STANDARD
      integer*2 nsamf
      equivalence   (segy1b(23),nsamf)

c Data sample format code                         SEGY_STANDARD          R
c  1   IBM 370 floating point (4 bytes)           SEGY_STANDARD          R
c  2   Fixed point            (4 bytes)           SEGY_STANDARD          R
c  3   Fixed point            (2 bytes)           SEGY_STANDARD          R
c  4   Fixed point with gain  (4 bytes)           SEGY_STANDARD          R
c
       integer*2     icode
       equivalence   (segy1b(25),icode)

c No of traces per  CDP ensemble                  SEGY_STANDARD
       integer*2     ncdp
       equivalence   (segy1b(27),ncdp)

c Trace sorting code                              SEGY_STANDARD          R
c      itsort=1     Shot Gathers                  SEGY_STANDARD
c      itsort=2     CDP ensemble                  SEGY_STANDARD
c      itsort=3     Single fold continuous        SEGY_STANDARD
c      itsort=4     Horizontal stack              SEGY_STANDARD
c      itsort=5     Receiver Gather               SEGY_IASPEI
c      itsort=6     Gathers Sorted By Distance    SEGY_IASPEI
c      itsort=7     Gathers Sorted By Azimuth     SEGY_IASPEI
c      itsort=0     No sort.                      SEGY_IASPEI
       integer*2     itsort
       equivalence   (segy1b(29),itsort)

c  Vertical sum code                              SEGY_STANDARD
c  vcode = n sum on n traces                      SEGY_STANDARD
```

```
      integer*2    vcode
      equivalence  (segy1b(31),vcode)

c Start sweep frequency (HZ)                      SEGY_STANDARD
      integer*2    ssweep
      equivalence  (segy1b(33),ssweep)

c End sweep frequency (HZ)                        SEGY_STANDARD
      integer*2    esweep
      equivalence  (segy1b(35),esweep)

c Sweep length in milliseconds                    SEGY_STANDARD
      integer*2    sleng
      equivalence  (segy1b(37),sleng)

c Sweep type                                      SEGY_STANDARD
c     stype=1  linear                             SEGY_STANDARD
c     stype=2  parabolic                          SEGY_STANDARD
c     stype=3  exponential                        SEGY_STANDARD
c     stype=4  other                              SEGY_STANDARD
c     stype=5  borehole explosive source          SEGY_IASPEI
c     stype=6  water explosive source             SEGY_IASPEI
c     stype=7  airgun source                      SEGY_IASPEI
c     stype=8  earthquake                         SEGY_IASPEI
c     stype=9  quarry_blast                       SEGY_IASPEI
      integer*2    stype
      equivalence  (segy1b(39),stype)

c Trace no of sweep channel                       SEGY_STANDARD
      integer*2    nts
      equivalence  (segy1b(41),nts)

c Sweep trace taper in milliseconds at start      SEGY_STANDARD
      integer*2    stts
      equivalence  (segy1b(43),stts)

c Sweep trace taper  in milliseconds at end       SEGY_STANDARD
      integer*2    stte
      equivalence  (segy1b(45),stte)

c Taper type                                      SEGY_STANDARD
c     ttype=1 linrst                              SEGY_STANDARD
c     ttype=2 cos**2                              SEGY_STANDARD
c     ttype=3 other                               SEGY_STANDARD
      integer*2    ttype
      equivalence  (segy1b(47),ttype)

c Correlated data traces                          SEGY_STANDARD
c     cort=1 no, 2=yes
      integer*2    cort
      equivalence  (segy1b(49),cort)

c Binary Gain recovered                           SEGY_STANDARD
c     bgr=1 yes, 2=no
      integer*2    bgr
      equivalence  (segy1b(51),bgr)

c Amplitude recovery methods                      SEGY_STANDARD
c     arm=1 none, 2=spherical, 3=AGC, 4=other
      integer*2    arm
      equivalence  (segy1b(53),arm)

c Measurement system                              SEGY_STANDARD          R
c     1=meters, 2=feet                            SEGY_STANDARD
      integer*2    isys
      equivalence  (segy1b(55),isys)
```

```
c Polarity                                          SEGY_STANDARD
c   ipol=1 upward case movement gives negative      SEGY_STANDARD
c   ipol=2 upward case movement gives positive      SEGY_STANDARD
      integer*2     ipol
      equivalence   (segy1b(57),ipol)

c Vibrator polarity code                            SEGY_STANDARD
      integer*2     vpc
      equivalence   (segy1b(59),vpc)

c     number of traces in the tape/file             SEGY_IASPEI
      integer*2 notif
      equivalence (segy1b(61),notif)

c attribute information
c attri=0    velocity data nanometers/s             SEGY_IASPEI
c attri=1    instantaneous velocity nanometers/sSEGY_IASPEI
c attri=2    instantaneous frequency milliHz        SEGY_IASPEI
c attri=3    instantaneous phase  degrees           SEGY_IASPEI
c attri=4    slowness (m/ms)                        SEGY_IASPEI
c attri=5    semblance (0-1000)                     SEGY_IASPEI
c attri=6    displacement nanometers                SEGY_IASPEI
      integer*2 attri
      equivalence (segy1b(63),attri)

c Mean amplitude of all samples in all              SEGY_IASPEI
c     traces in the file.
      real*4 meanas
      equivalence (segy1b(65),meanas)

c Domain of data                                    SEGY_IASPEI
c       domain=0 time/distance
c             =1 fk
c             =2 tau-p
      integer*2 domain
      equivalence (segy1b(69),domain)

c Not in use from version 3.00.
c Set to 1 for compatibility.
      integer*2 msexp
      equivalence (segy1b(71),msexp)


c Reduction velocity in meter(feet)/sec             SEGY_IASPEI           R
      integer*4   vred
      equivalence (segy1b(73),vred)

c Seconds of window start time                      SEGY_IASPEI           R
      real*4 wstart
      equivalence (segy1b(77),wstart)

c Seconds of window end time                        SEGY_IASPEI           R
      real*4 wend
      equivalence (segy1b(81),wend)

c Minimum of all samples in the file.               SEGY_IASPEI
      real*4    minass
      equivalence (segy1b(85),minass)

c Maximum of all traces in the file                 SEGY_IASPEI
      real*4     maxass
      equivalence (segy1b(89),maxass)

c Recording instrument type                         SEGY_IASPEI           R
c If instrument types in reel header and trace
c header are different, then the trace header value
c must be used.
```

```
c
c       =0 Not specified.
c       =1 EDA (Scintrex) PRS1
c       =2 USGS cassette
c       =3 GEOS
c       =4 Springnether
c       =5 Teledyne
c       =6 Kinemetrics
c       =7 SGR
c       =8 TERATEK
c       =9 EDA (Scintrex) PRS4
c       =10 MARS 88
c       =11 MARS 66
c       =12 PCM 5800
c       =13 REFTEK
c       =14 GEOSTORE
c       =100 Mixed data
      integer*2 iinstr
      equivalence(segy1b(93),iinstr)

c File creation date - Year                   SEGY_IASPEI             R
      integer*2 cryear
      equivalence(segy1b(95),cryear)

c File creation date - Month                  SEGY_IASPEI             R
      integer*2 crmnth
      equivalence(segy1b(97),crmnth)

c File creation date - Day                    SEGY_IASPEI             R
      integer*2 crday
      equivalence(segy1b(99),crday)

c Disk File format                                          DISK
c   pad first header record past 3600 to data length
c   =0 Reel Header is 3600 bytes, data has
c      variable length records.
c   =1 Reel Header is 3600 bytes,
c      data is padded to nnb bytes.
c   =2 Reel Header and data are padded to nnb bytes.
c      All data have the same length.
      integer*2 padtyp
      equivalence (segy1b(101),padtyp)

c Character code. Must use EBCDIC for tape exchange.
c        =1 EBCDIC                            SEGY_IASPEI   TAPE    R
c        =2 ASCIIR                                      DISK
      integer*2 ccode
      equivalence(segy1b(103),ccode)

c File record length in bytes,                              DISK
c    data are padded to nnb bytes.
c  if padtyp=1,
c       then nnb should be >= trhlen+data length in bytes)
c  if padtyp=2, t
c       then nnb should be >= max(3600,trhlen+data length in bytes)
      integer*4 nnb
      equivalence (segy1b(105),nnb)

c Byte order within words                                   DISK
c     1   ='00 01'x Most  Signicant Byte first.
c     2   ='02 00'x Least Significant Byte first.
c Default for tape is MSB. Default for disk depends on machine.
      integer*2 bord
      equivalence(segy1b(109),bord)

c Trace header length                                       DISK
c   traces on disk are stored with header length
```

```
      integer*2 trhlen
      equivalence(segy1b(111),trhlen)

c Max number of channels per seismograph        SEGY_IASPEI           D
      integer*2 nchps
      equivalence(segy1b(113),nchps)
c
c n.b. bytes 115-116 of Binary Reel ID are empty.
c

c Override for sample interval(this data; sint) SEGY_IASPEI           D
c This variable is related to variable sint bytes (17-18).
c If this variable is set to non-zero, it holds a more
c precise value than sint.
c
c This is the status table for the value of this variable:
c      Variable Name  Overrides  Value       Result
c      sinto          sint       0           No action
c      sinto          sint       < 0         Sample rate in samples per second
c      sinto          sint       > 0         Sample interval in Nanoseconds
c
      integer*4 sinto
      equivalence(segy1b(117),sinto)

c Override for sample interval(in field; sint2) SEGY_IASPEI           D
c This variable is related to variable sint2 bytes (19-20).
c If this variable is set to non-zero, it holds a more
c precise value than sint2
c
c This is the status table for the value of this variable:
c      Variable Name  Overrides  Value       Result
c      sint2o         sint2      0           No action
c      sint2o         sint2      < 0         Sample rate in samples per second
c      sint2o         sint2      > 0         Sample interval in Nanoseconds
c
      integer*4 sint2o
      equivalence(segy1b(121),sint2o)

c     Distance-Azimuth Calculation Algorithm    SEGY_IASPEI
c     0 = Not specified
c     1 = Sodano algorithm. The program utilizes the
c         Sodano and Robinson (1963) direct solution
c         of geodesics (Army Map Service, Tech Rep #7,
c         section IV).
      integer*2 daca
      equivalence(segy1b(125),daca)

c     Earth Dimension Code                      SEGY_IASPEI
c     0 = Not specified
c     1 = Fisher 1960
c     2 = Clark 1866
c     3 = Ref ellipsoid 1967
c     4 = Hayford Internationl 1910
c     5 = World Geodetic Survey 1972
c     6 = Bessel 1841
c     7 = Everest 1841
c     8 = Airy 1936
c     9 = Hough 1960
c     10= Fischer 1968
c     11= Clarke 1880
      integer*2 edc
      equivalence(segy1b(127),edc)

c
c n.b. bytes 129-398 of Binary Reel ID are empty.
c
```

```
c Format version number times 100              SEGY_IASPEI          R
c         =99 Version .99
c         =100 Version 1.0
c         =200 version 2.0
c         =300 version 3.0
      integer*2 fvn
      equivalence (segy1b(399),fvn)

c
c-------------------------------------------------------------------+
c Reel Identification Header (total 400 bytes)    Ends here         |
c-------------------------------------------------------------------+
c

c
c-------------------------------------------------------------------+
c Trace Identification Header (total of 240 bytes) Starts here      |
c-------------------------------------------------------------------+
c

c Trace sequence number within line            SEGY_STANDARD        R
      integer*4 tsnl
      equivalence (thead(1),tsnl)

c Trace sequence number within tape            SEGY_STANDARD        R
      integer*4 tsnt
      equivalence (thead(5),tsnt)

c Original field record number                 SEGY_STANDARD        D
c Sequential Shot Number                       SEGY_IASPEI
      integer*4 ofrn
      equivalence (thead(9),ofrn)

c Trace number withint original field record    SEGY_STANDARD        R
c Receiver Site Number                         SEGY_IASPEI
      integer*4 tnofr
      equivalence (thead(13),tnofr)

c Energy source point number                   SEGY_STANDARD        R
c Shot Site Number                             SEGY_IASPEI
      integer*4 espn
      equivalence (thead(17),espn)

c CDP number                                   SEGY_STANDARD
      integer*4 cdp
      equivalence (thead(21),cdp)

c Trace number within CDP                      SEGY_STANDARD        R
      integer*4 tncdp
      equivalence (thead(25),tncdp)

c Trace identifications code                   SEGY_STANDARD        R
c     tic=1 seismic data                       SEGY_STANDARD
c     tic=2 dead                               SEGY_STANDARD
c     tic=3 dummy                              SEGY_STANDARD
c     tic=4 time break                         SEGY_STANDARD
c     tic=5 uphole                             SEGY_STANDARD
c     tic=6 sweep                              SEGY_STANDARD
c     tic=7 timing                             SEGY_STANDARD
c     tic=8 water break                        SEGY_STANDARD
c     tic=11 --> tic=20 component number + 10
c                     for multi-compnent data  SEGY_IASPEI
c     e.g. tic=11 (vertical component, horizontals following);
c          tic=12 (North-South component of 3 component);
c          tic=13 (East-West component of 3 component).
c     tic=100 calibration pulse                SEGY_IASPEI
c     tic=101 calibration Frequency            SEGY_IASPEI
```

```
c               /Amplitude/Phase triplets
c
       integer*2 tic
       equivalence (thead(29),tic)

c Number of vertically summed traces           SEGY_STANDARD
c yeilding this trace
       integer*2 nvs
       equivalence (thead(31),nvs)

c Number of horizontally stacked traces        SEGY_STANDARD
c  yeilding this trace
       integer*2 nhs
       equivalence (thead(33),nhs)

c Data use   (1=productions, 2=test)           SEGY_STANDARD
       integer*2 duse
       equivalence (thead(35),duse)

c Distance from source to receiver (meters)    SEGY_STANDARD
       integer*4 idist
       equivalence (thead(37),idist)

c Receiver group elevation                     SEGY_STANDARD
       integer*4 irel
       equivalence (thead(41),irel)

c Surface elevation of source                  SEGY_STANDARD
       integer*4 ishe
       equivalence (thead(45),ishe)

c Source depth                                 SEGY_STANDARD
       integer*4 ishd
       equivalence (thead(49),ishd)

c Datum elevation at receiver                  SEGY_STANDARD
       integer*4 delr
       equivalence (thead(53),delr)

c Datum elevation at source                    SEGY_STANDARD
       integer*4 dels
       equivalence (thead(57),dels)

c Water depth at source                        SEGY_STANDARD
       integer*4 wds
       equivalence (thead(61),wds)

c Water depth at receiver                      SEGY_STANDARD
       integer*4 wdr
       equivalence (thead(65),wdr)

c Scalar multiplier/divisor(+/-)for bytes 41-68 SEGY_STANDARD
       integer*2 smul1
       equivalence (thead(69),smul1)

c Scalar multiplier/diviso(+/-)for bytes 73-88  SEGY_STANDARD
       integer*2 smul2
       equivalence (thead(71),smul2)

c Source coordinate X or Longitude
c (East positive)                              SEGY_STANDARD
       integer*4 ishlo
       equivalence (thead(73),ishlo)

c Source coordinate Y or Latitude
c (North positive)                             SEGY_STANDARD
       integer*4 ishla
```

```
      equivalence (thead(77),ishla)

c Group coordinate X or Longitude
c (East positive)                            SEGY_STANDARD
      integer*4 irlo
      equivalence (thead(81),irlo)

c Group coordinate Y or Latitude
c (North positive)                           SEGY_STANDARD
      integer*4 irla
      equivalence (thead(85),irla)

c Ccoordinate units (1 : meters/feet,        SEGY_STANDARD
c                    2 : seconds of arc
c                       (smul2 holds multiplier)
c                   -N : mod 100 = TX UTM zone
c                        div 100 = RX UTM zone
      integer*2 cunits
      equivalence (thead(89),cunits)

c Weathering velocity (meters(feet)/sec)     SEGY_STANDARD
      integer*2 wvel
      equivalence (thead(91),wvel)

c Subweathering velocity (meters(feet)/sec)  SEGY_STANDARD
      integer*2 swvel
      equivalence (thead(93),swvel)

c Uphole time at source                      SEGY_STANDARD
      integer*2 utimes
      equivalence (thead(95),utimes)

c Uphole time at group                       SEGY_STANDARD
      integer*2 utimeg
      equivalence (thead(97),utimeg)

c Source static correction                   SEGY_STANDARD
      integer*2 sstati
      equivalence (thead(99),sstati)

c Group static                               SEGY_STANDARD
      integer*2 gstati
      equivalence (thead(101),gstati)

c Total static                               SEGY_STANDARD
      integer*2 tstati
      equivalence (thead(103),tstati)

c Lag time A                                 SEGY_STANDARD
      integer*2 istime
      equivalence (thead(105),istime)

c Lag time B                                 SEGY_STANDARD
      integer*2 ibtime
      equivalence (thead(107),ibtime)

c Delay recording time                       SEGY_STANDARD
      integer*2 ictime
      equivalence (thead(109),ictime)

c The above times as defined for SEGY are not
c adequate for refraction data because they
c are limited to 32s. Use cor and tstart later on.

c Mute time start                            SEGY_STANDARD
      integer*2 mtimes
      equivalence (thead(111),mtimes)
```

```
c Mute time end                                   SEGY_STANDARD
        integer*2 mtimee
        equivalence (thead(113),mtimee)

c No of samples in this trace                      SEGY_STANDARD        R
        integer*2 length
        equivalence (thead(115),length)

c Sample interval in microseconds                  SEGY_STANDARD        R
c See override for this value (isin, bytes 201-204) for
c more precise presentation.
        integer*2 isi
        equivalence (thead(117),isi)

c Gain type  (1=fixed, 2=binary, 3=floating)       SEGY_STANDARD
        integer*2 gaint
        equivalence (thead(119),gaint)

c Gain constant                                    SEGY_STANDARD        D
c data in nanometers/sec = (tape data)*(10**gc)    SEGY_IASPEI
        integer*2  gc
        equivalence (thead(121),gc)

c Instrument or initial gain in dB                 SEGY_STANDARD
        integer*2 gidb
        equivalence (thead(123),gidb)

c Correlated 1=no, 2=yes                           SEGY_STANDARD
        integer*2  tcorr
        equivalence (thead(125),tcorr)

c Start sweep frequency (HZ)                       SEGY_STANDARD
        integer*2    tsswee
        equivalence  (thead(127),tsswee)

c End sweep frequency (HZ)                         SEGY_STANDARD
        integer*2    teswee
        equivalence  (thead(129),teswee)

c Sweep Length in milliseconds                     SEGY_STANDARD
        integer*2    tsleng
        equivalence  (thead(131),tsleng)

c Sweep type                                       SEGY_STANDARD        D
c     tstype=1  linear                             SEGY_STANDARD
c     tstype=2  parabolic                          SEGY_STANDARD
c     tstype=3  exponential                        SEGY_STANDARD
c     tstype=4  other                              SEGY_STANDARD
c     tstype=5  borehole source                    SEGY_IASPEI
c     tstype=6  water explosive source             SEGY_IASPEI
c     tstype=7  airgun source                      SEGY_IASPEI
c     tstype=8  earthquake                         SEGY_IASPEI
c     tstype=9  quarry-blast                       SEGY_IASPEI
c
        integer*2    tstype
        equivalence  (thead(133),tstype)

c Sweep trace taper in milliseconds at start       SEGY_STANDARD
        integer*2    tstts
        equivalence  (thead(135),tstts)
c
c Sweep trace taper in milliseconds at end         SEGY_STANDARD
        integer*2    tstte
        equivalence  (thead(137),tstte)

c Taper type                                       SEGY_STANDARD
```

```
c     ttype=1 linear
c     ttype=2 cos**2
c     ttype=3 other
       integer*2    tttype
       equivalence  (thead(139),tttype)

c Anti alias filter frequency                    SEGY_STANDARD
       integer*2    aif
       equivalence  (thead(141),aif)

c Alias filter slope                             SEGY_STANDARD
       integer*2    ais
       equivalence  (thead(143),ais)

c Notch filter frequency                         SEGY_STANDARD
       integer*2  nif
       equivalence (thead(145),nif)

c Notch filter slope                             SEGY_STANDARD
       integer*2    nis
       equivalence  (thead(147),nis)

c Low cut frequncy                               SEGY_STANDARD
       integer*2    flc
       equivalence  (thead(149),flc)

c High cut frequncy                              SEGY_STANDARD
       integer*2    fhc
       equivalence  (thead(151),fhc)

c Low cut slope                                  SEGY_STANDARD
       integer*2    slc
       equivalence  (thead(153),slc)

c High cut slope                                 SEGY_STANDARD
       integer*2    shc
       equivalence  (thead(155),shc)

c Year of start of trace                         SEGY_STANDARD         R
       integer*2    tyear
       equivalence  (thead(157),tyear)

c Julian day of start of trace                   SEGY_STANDARD         R
       integer*2    tday
       equivalence  (thead(159),tday)

c Hour of start of trace                         SEGY_STANDARD         R
       integer*2    thour
       equivalence  (thead(161),thour)

c Minute of start of trace                       SEGY_STANDARD         R
       integer*2    tmin
       equivalence  (thead(163),tmin)

c Second of start of trace                       SEGY_STANDARD         R
       integer*2    tsec
       equivalence  (thead(165),tsec)

c Time basis code  1=local, 2=gmt                SEGY_STANDARD         R
       integer*2    tbcode
       equivalence  (thead(167),tbcode)

c Trace weighting factor                         SEGY_STANDARD
       integer*2    twf
       equivalence  (thead(169),twf)

c Geophone group no on roll switch               SEGY_STANDARD
```

```
c first position
       integer*2     ggrp1
       equivalence   (thead(171),ggrp1)

c Geophone group no trace position 1 on rec     SEGY_STANDARD
       integer*2     ggtp
       equivalence   (thead(173),ggtp)

c Geophone group no on last trace of filed rec  SEGY_STANDARD
c      Or institution use
       integer*2     gglp
       equivalence   (thead(175),gglp)

c Gap size                                      SEGY_STANDARD
c      Or institution use
       integer*2     gapsz
       equivalence   (thead(177),gapsz)

c Field LINE number                             SEGY_IASPEI          D
       integer*2     overt
       equivalence   (thead(179),overt)

c Microseconds of trace start time              SEGY_IASPEI          R
       integer*4   mst
       equivalence (thead(181),mst)

c Charge size in kg or airgun size in litres    SEGY_IASPEI          R
       integer*2   charge
       equivalence (thead (185),charge)

c Shot or triger time - year                    SEGY_IASPEI          R
       integer*2 syear
       equivalence (thead(187),syear)

c Shot or triger time - Julian day              SEGY_IASPEI          R
       integer*2 sday
       equivalence (thead(189),sday)

c Shot or triger time - hour                    SEGY_IASPEI          R
       integer*2 shour
       equivalence (thead(191),shour)

c Shot or triger time - minute                  SEGY_IASPEI          R
      integer*2 smin
      equivalence (thead(193),smin)

c Shot or triger time - second                  SEGY_IASPEI          R
       integer*2 sseco
       equivalence (thead(195),sseco)

c Shot or triger time - microsecond             SEGY_IASPEI          R
       integer*4 ssmic
       equivalence (thead(197),ssmic)

c Override for sample interval.                 SEGY_IASPEI          D
c This variable is related to variable isi bytes (117-118).
c If this variable is set to non-zero, it holds a more
c precise value than isi.
c
c This is the status table for the value of this variable:
c      Variable Name  Overrides  Value       Result
c      isin           isi        0           No action
c      isin           isi        < 0         Sample rate in samples per second
c      isin           isi        > 0         Sample interval in Nanoseconds
c
       integer*4 isin
       equivalence (thead(201),isin)
```

```
c Azimuth of geophone orientation axis with     SEGY_IASPEI             D
c respect to true north in minutes of arc
      integer*2 geoazi
      equivalence (thead(205),geoazi)

c Angle between geophone orientation axis and   SEGY_IASPEI             D
c vertical in minutes of arc
      integer*2 geover
      equivalence (thead(207),geover)

c Static correction                             SEGY_IASPEI             D
c time to be added to recorded trace time to
c get actual trace start
c time. To be used when data has been reduced
      integer*4  ttrace
      equivalence (thead (209),ttrace)

c Flag to signal that ttrace has been used to   SEGY_IASPEI             D
c modify trace start time
c  tapply=0   static ttrace has been used to
c             reduce the data
c             and trace start time updated
c  tapply=1   static ttrace has beed has been
c             used to reduce the data but trace
c             start time has not been corrected
c
      integer*2  tapply
      equivalence (thead(213),tapply)

c Recording instrument type                     SEGY_IASPEI             R
c If instrument types in reel header and trace
c header are different, then the trace header value
c must be used.
c
c       =0 Not specified.
c       =1 EDA (Scintrex) PRS1
c       =2 USGS cassette
c       =3 GEOS
c       =4 Springnether
c       =5 Teledyne
c       =6 Kinemetrics
c       =7 SGR
c       =8 TERATEK
c       =9 EDA (Scintrex) PRS4
c       =10 MARS 88
c       =11 MARS 66
c       =12 PCM 5800
c       =13 REFTEK
c       =14 GEOSTORE
      integer*2 instru
      equivalence(thead(215),instru)

c Millisecond of timing correction              SEGY_IASPEI             R
c to be added to reported times to get true
c local or gmt times.
c This should be the sum of all timing
c corrections such as master clock and
c seismograph drifts.
      integer*2  cor
      equivalence (thead(217),cor)

c Azimuth of receiver                           SEGY_IASPEI             D
c from shot in minutes of arc
      integer*2 azimut
      equivalence (thead(219),azimut)
```

```
c
c----------------------------------------------------------------------+
c Binary part of Trace Identification Header Ends here                 |
c----------------------------------------------------------------------+

c Character information.

c Recording instrument name
      character*4   scrs
      equivalence (thead (221),scrs)

c Shotpoint name
      character*4 spname
      equivalence (thead(225),spname)

c Receiver site name
      character*4 rstnam
      equivalence (thead(229),rstnam)

c Shot site name
      character*4 shotid
      equivalence (thead(233),shotid)

c Geophone mnemonic
c for example L4-Z, L4-N
c use reel header to explain the mnemonics
c used on a tape.
      character*4 geopin
      equivalence (thead (237),geopin)
c
c----------------------------------------------------------------------+
c Trace Identification Header (total of 240 bytes) Ends   here         |
c----------------------------------------------------------------------+
c
c- End   of FINAL segy.inc version 3.00 (IASPEI), January 25, 1993 ----
```

Figure 1: Registered earthquakes between August 21 and September 1, 1995 are shown as solid circles. Recording stations were located in the area shown by a small solid box in the centre of the map and in figure 2. This map is created by GMT, the projection is Azimuthal Equidistant centered at 39.0N, 108.0W. For a list of these earthquakes, see Table 1.

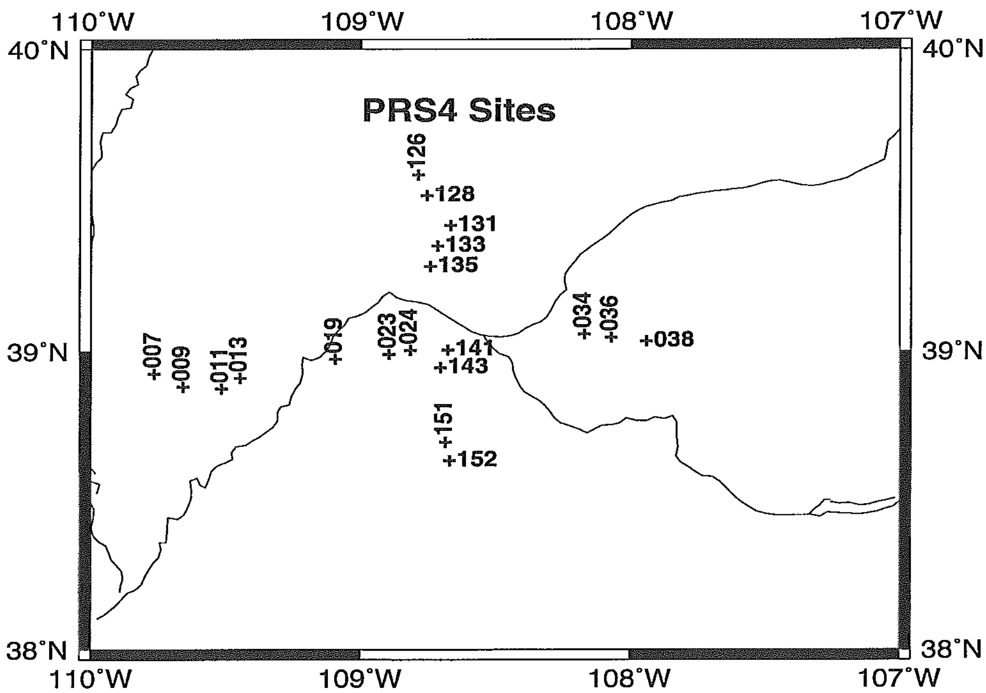

Figure 2: Location of PRS4 recording sites as also indicated by the small solid box in Figure 1.

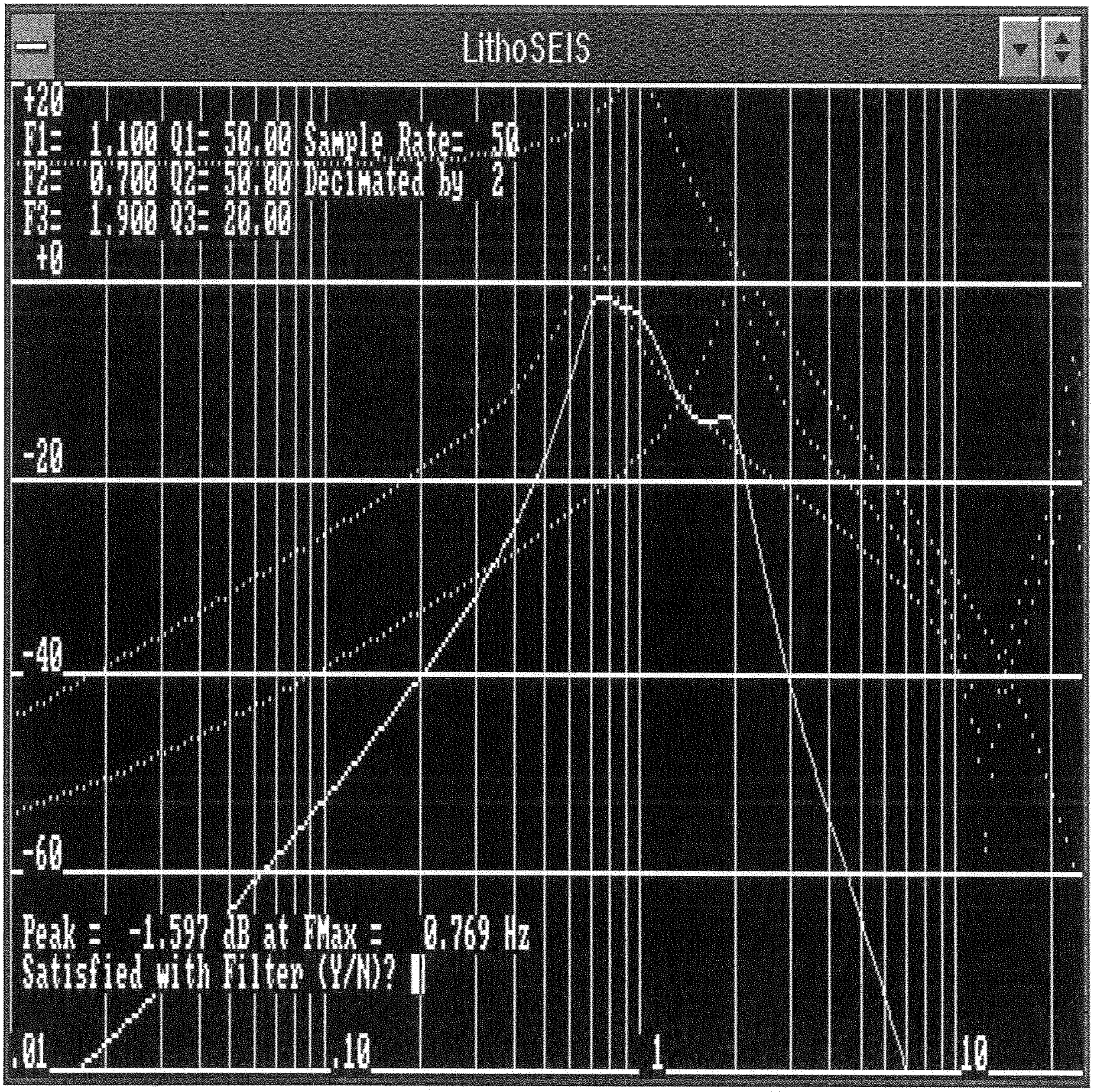

Figure 3: Frequency response of three infinite impule response (IIR) filters which were applied to the signal prior to the calculation of the STA and LTA values in order to determine if a trigger should be declared on a PRS4. The combination of the three filters F1, F2 and F3 creates a filter set (shown in solid; named TF07) with a narrow passband and peak of 0.769 Hz. Details of these filters is given in Table 7.

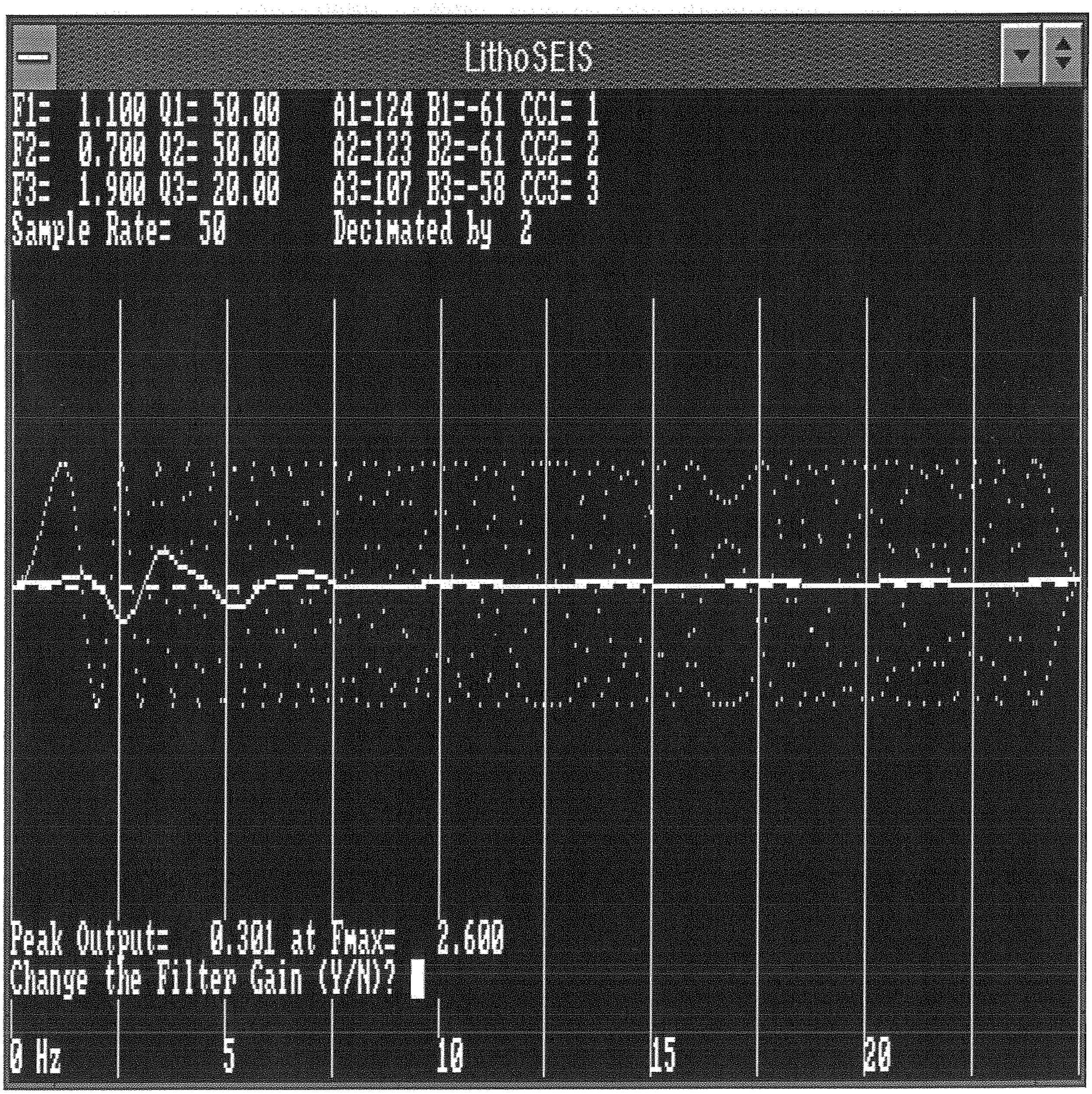

Figure 4: Amplitude response of a sweep of signals between 0-25 HZ to the combination filter (shown in solid in figure 3).

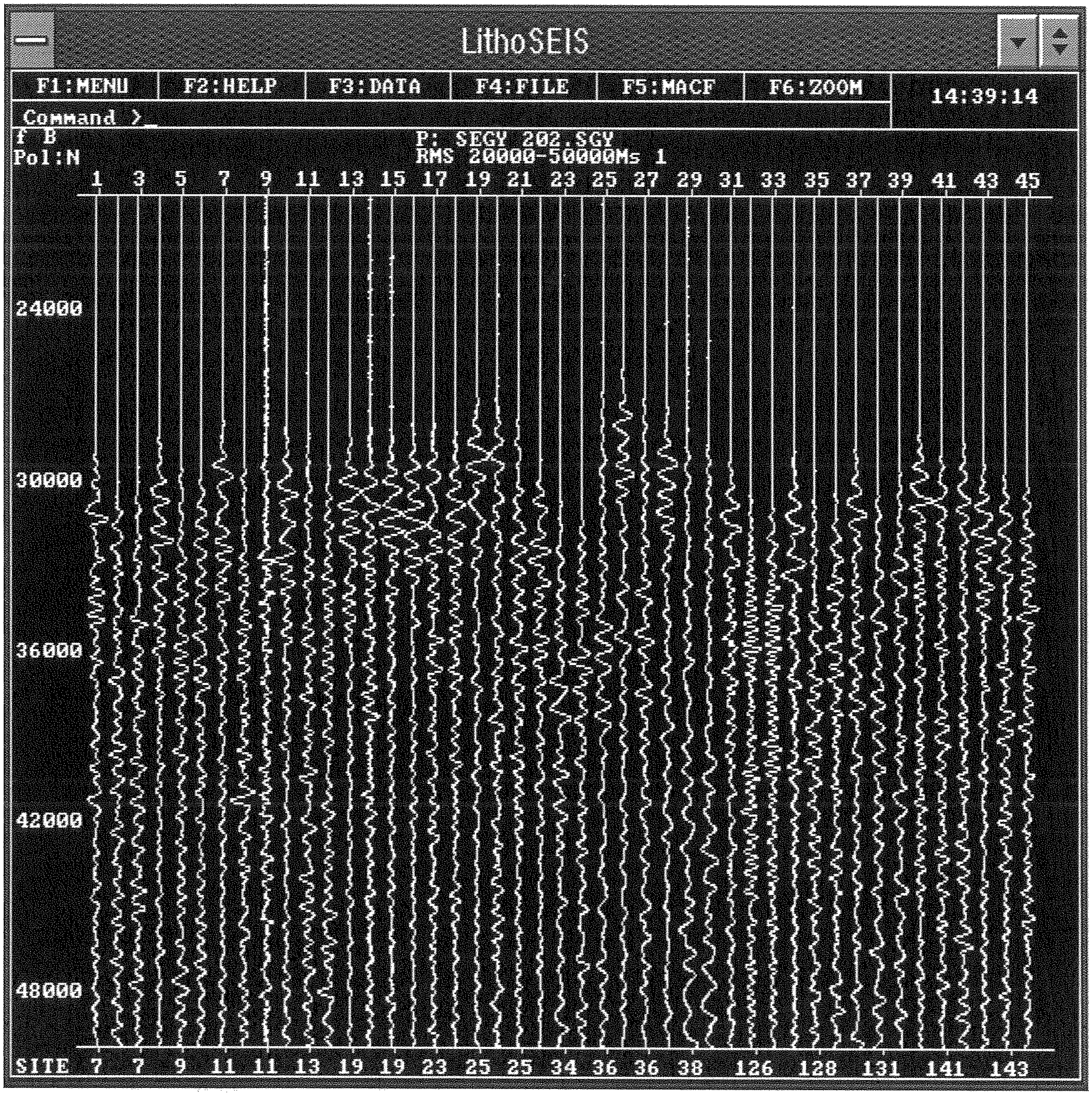

Figure 5: Three-Component seismic data for event 202 (magnitude 7.0; see Tables 1-4 for details). Data are sorted from smallest Site-ID to the largest. Location of sites are shown in Figure 2. For each site, three-component data are shown in the order: vertical, north-south and east-west. Only 30 seconds of the data are shown after RMS filter. Seismic sections in this and other figures were created using Vista software package.

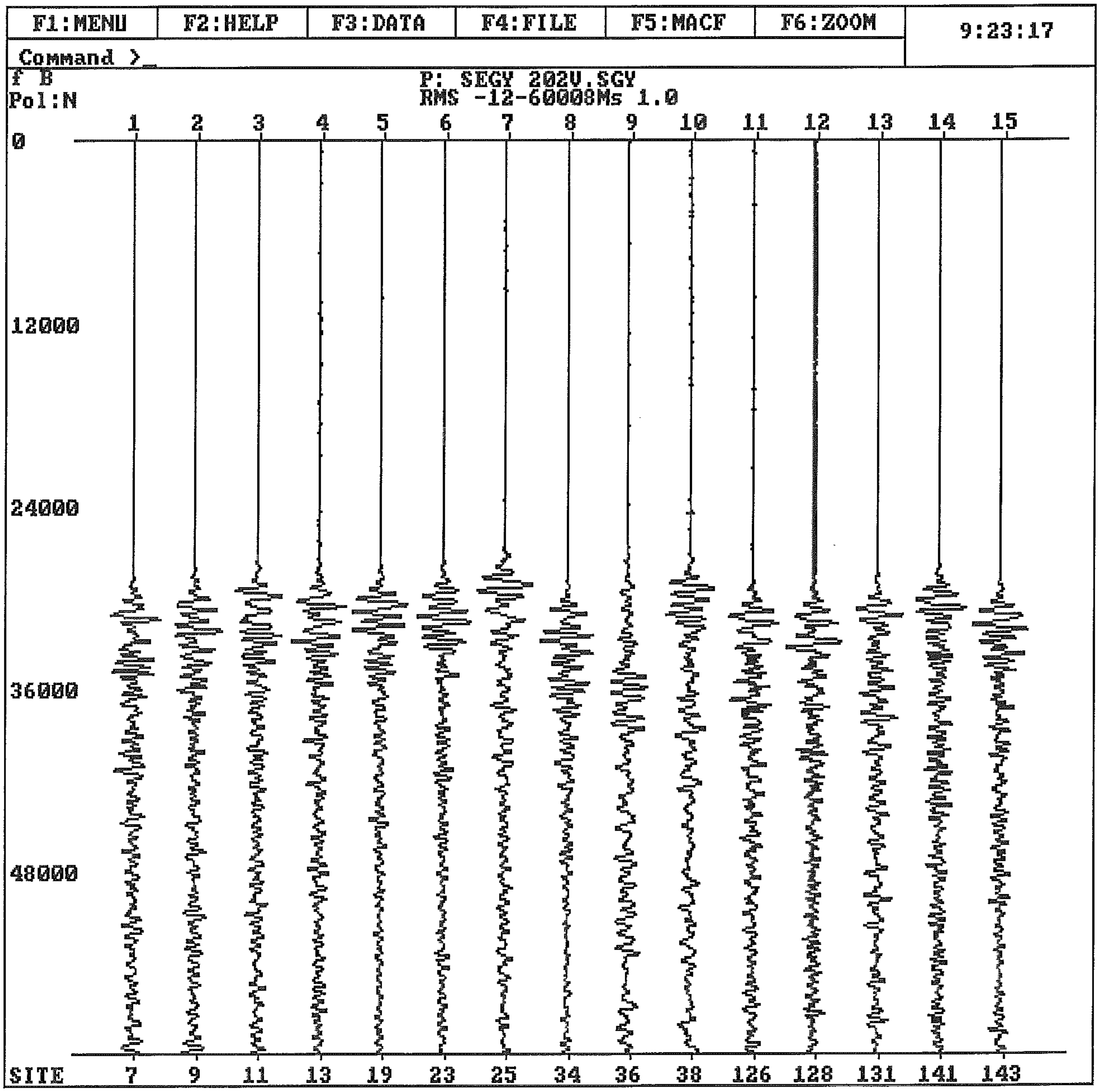

Figure 6: Vertical-Component seismic data for event 202 (magnitude 7.0; see Tables 1-4 for details). Data are sorted from smallest Site-ID to the largest. Location of sites are shown in Figure 2. Only 60 seconds of the data are shown after RMS filter.

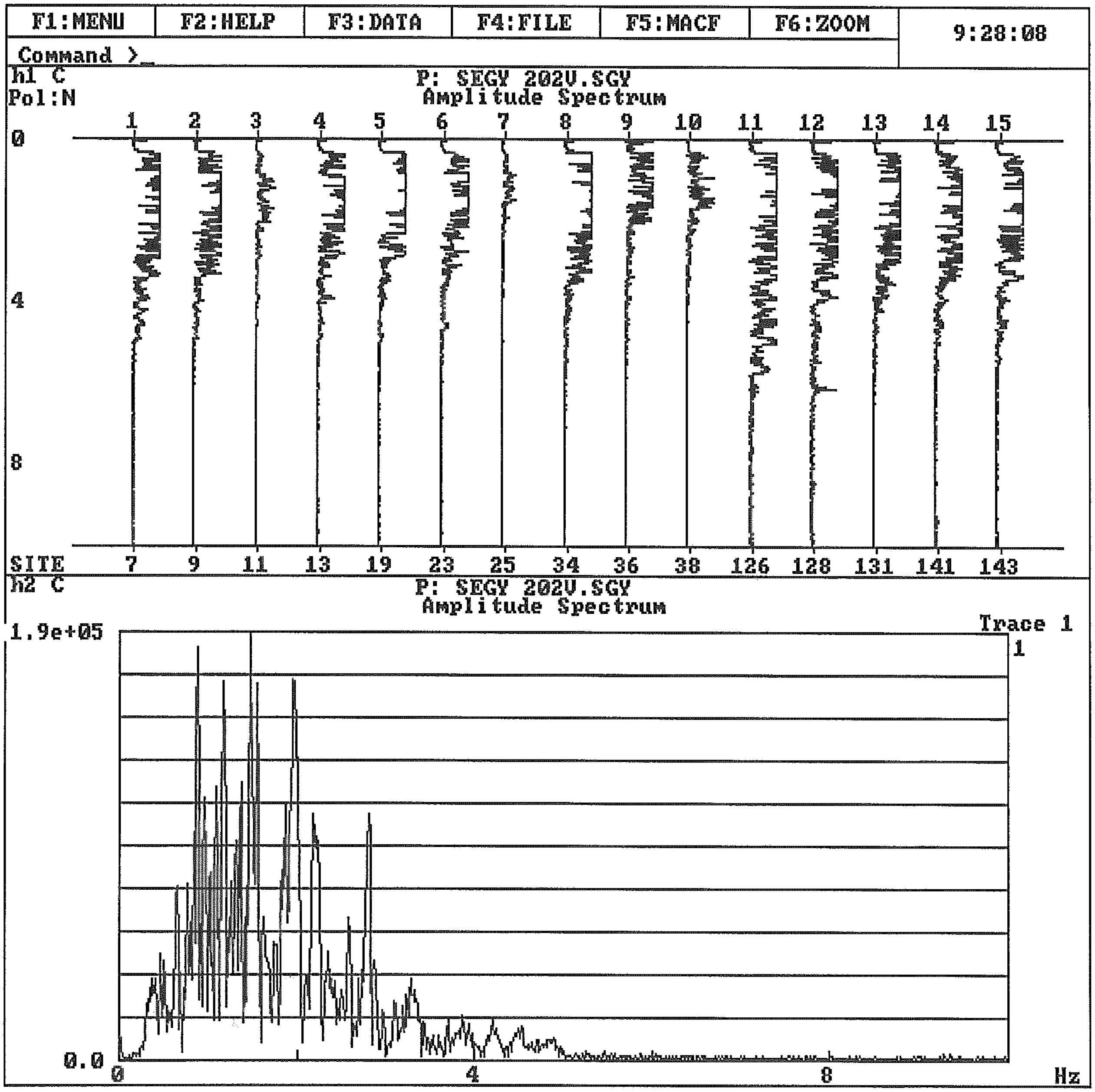

Figure 7: Amplitude spectrum of data in Figure 6. Spectrum for trace one is amplified in the lower frame of the figure. Note that most of signal energy is below 4 Hz with peaks beween 1-2 Hz. Note that the peak signal energy is close to the IIR filter peak (see Figure 3).

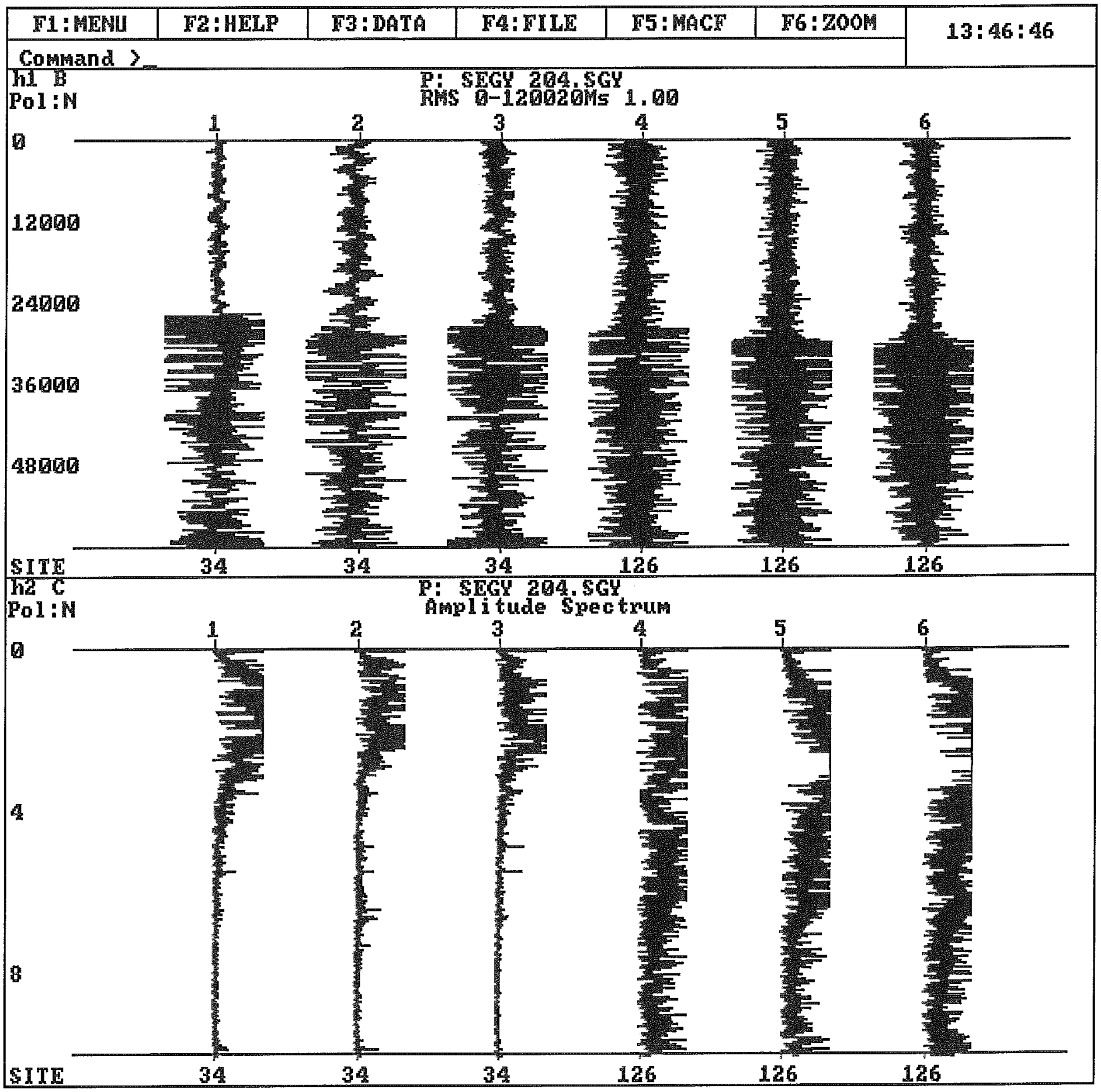

Figure 8: Three-Component seismic data and their amplitude spectra for event 204 (magnitude 5.1; see Tables 1-4). Only two sites triggered for this event and show significant signal energy in the range of 0-4 Hz (similar to those of Figure 7). It is not clear why more sites did not trigger on this event.

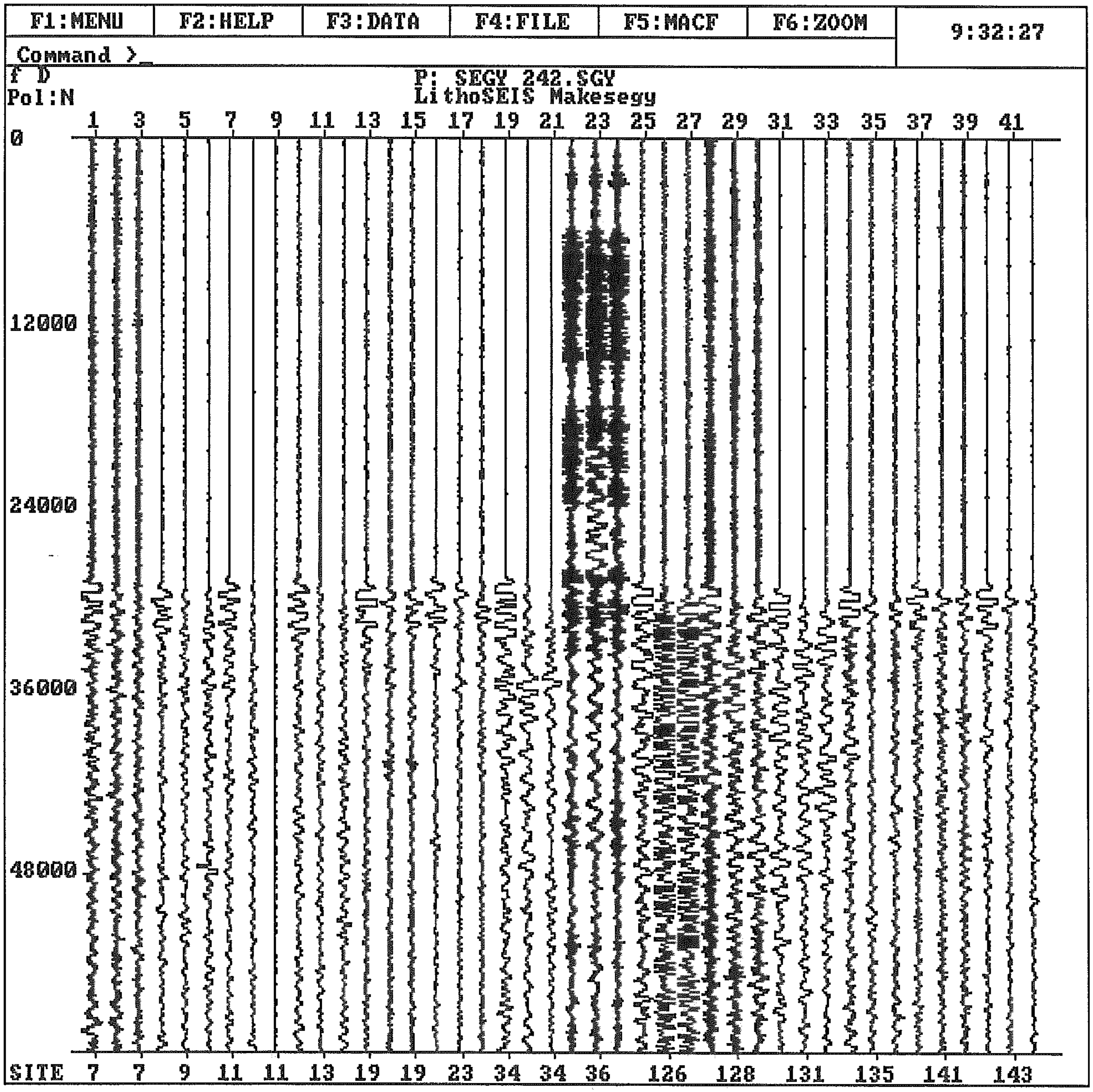

Figure 9: Three-Component seismic data for event 242 (magnitude 6.2; see Tables 1-4 for details). Data are sorted from smallest Site-ID to the largest. Location of sites are shown in Figure 2. For each site, three-component data are shown in the order vertical, north-south and east-west. Only 60 seconds of the data are shown after normalized scaling.

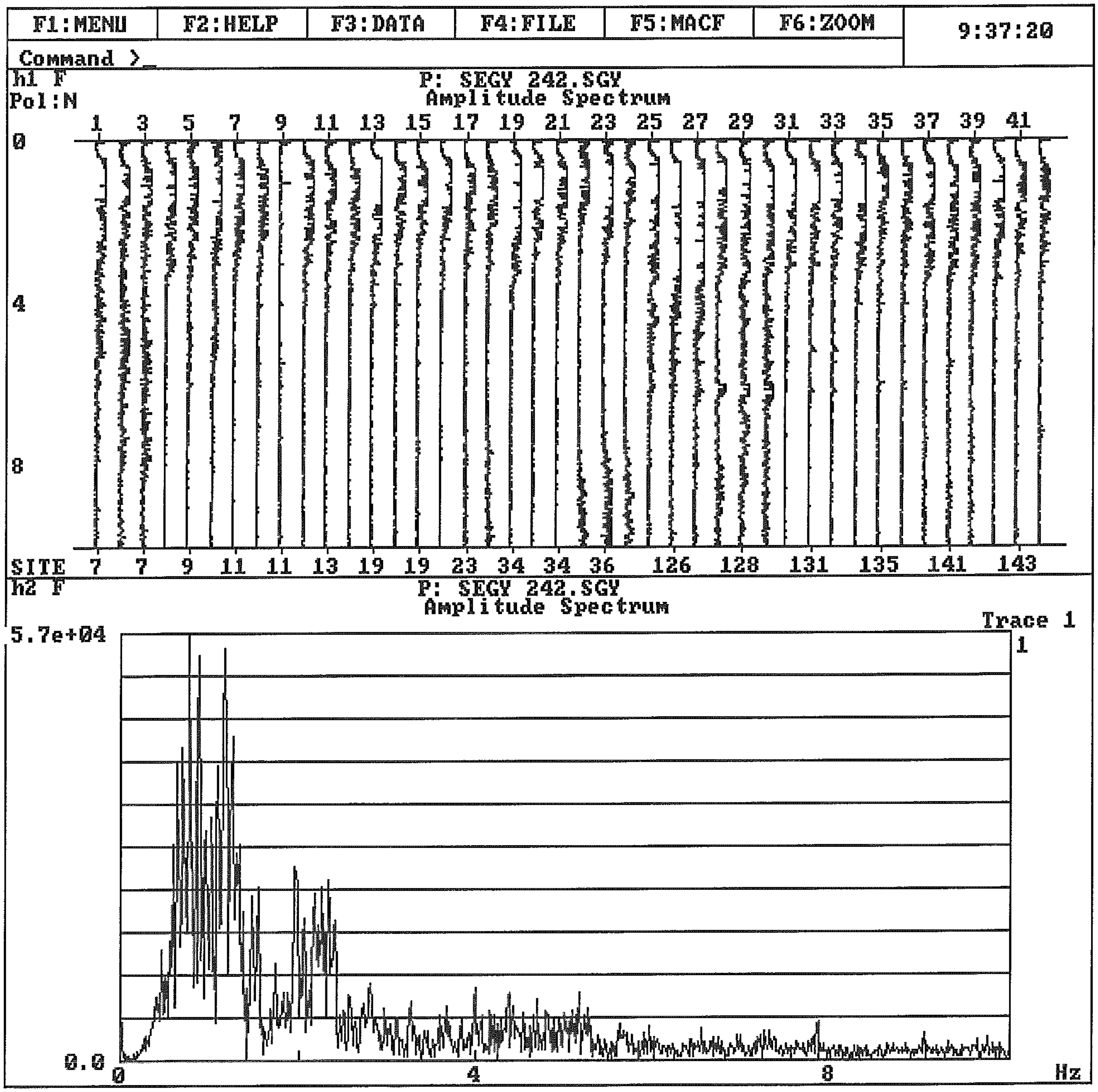

Figure 10: Amplitude spectrum of data in Figure 9. Spectrum for trace one is amplified in the lower frame of the figure. Note that most of signal energy is below 4 Hz with peak beween 1-2 Hz. Note that the peak signal energy is close to the IIR filter peak (see Figure 3). Sites 7, 36, 126 and 128 show noises beyond the 4 Hz window.

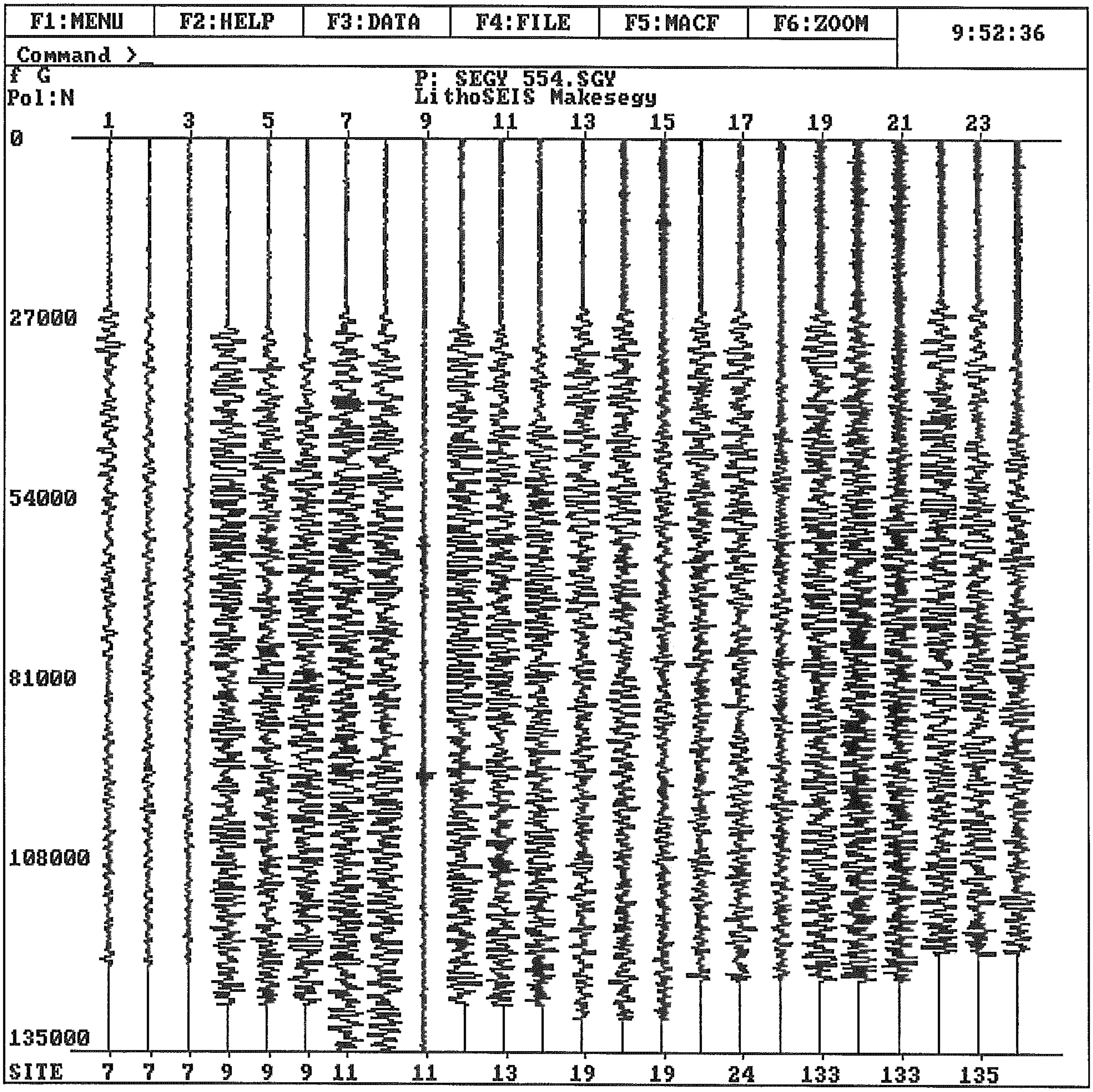

Figure 11: Three-Component seismic data for event 554 (magnitude 6.5; see Tables 1-4 for details). Data are sorted from smallest Site-ID to the largest. Location of sites are shown in Figure 2. For each site, three-component data are shown in the order vertical, north-south and east-west. All 135 seconds of the data are shown after normalized scaling.

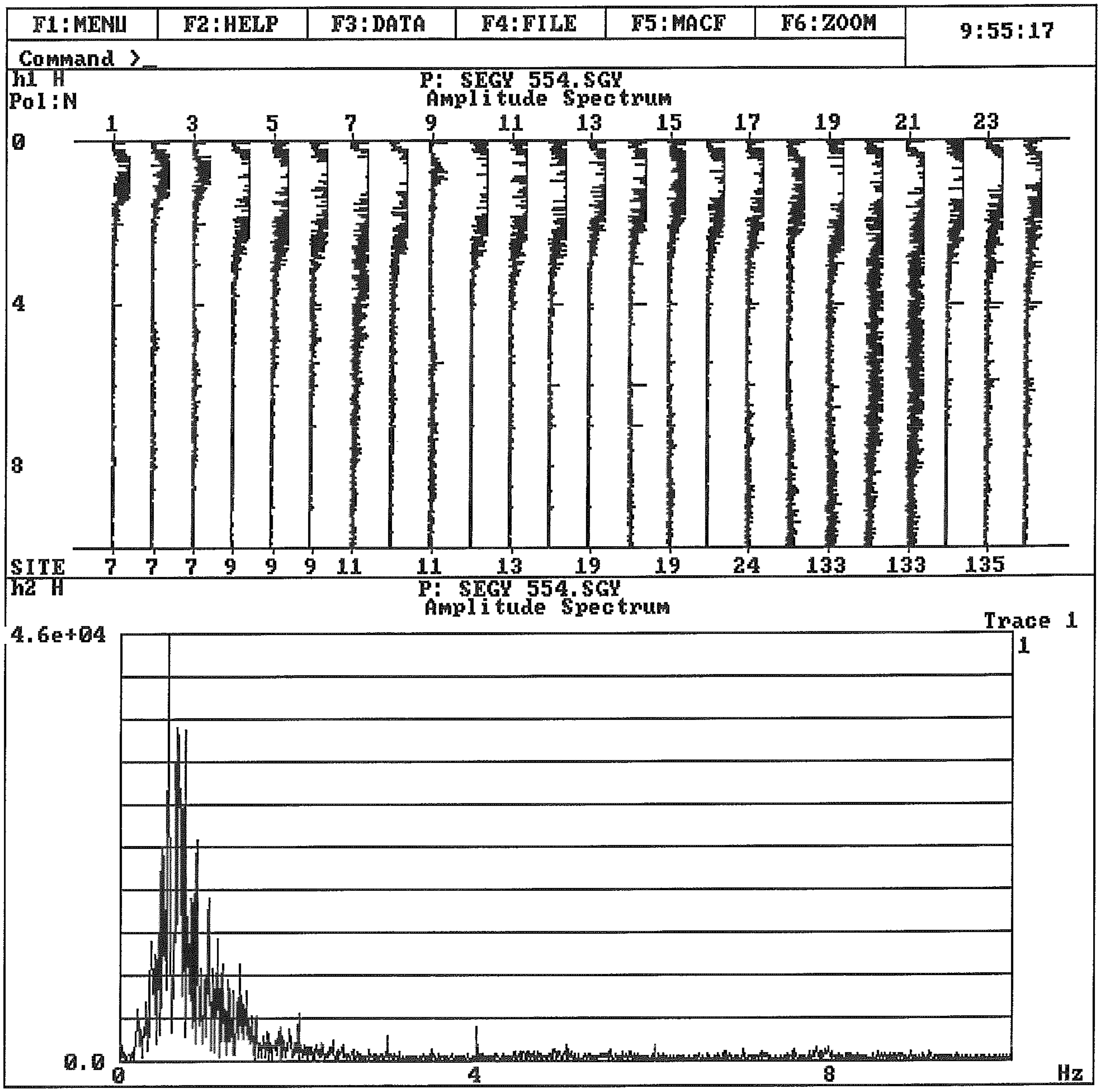

Figure 12: Amplitude spectrum of data in Figure 11. Spectrum for trace one is amplified in the lower frame of the figure. Note that most of signal energy is below 4 Hz. Sites 7, 11 and 128 show noise beyond the 4 Hz window.

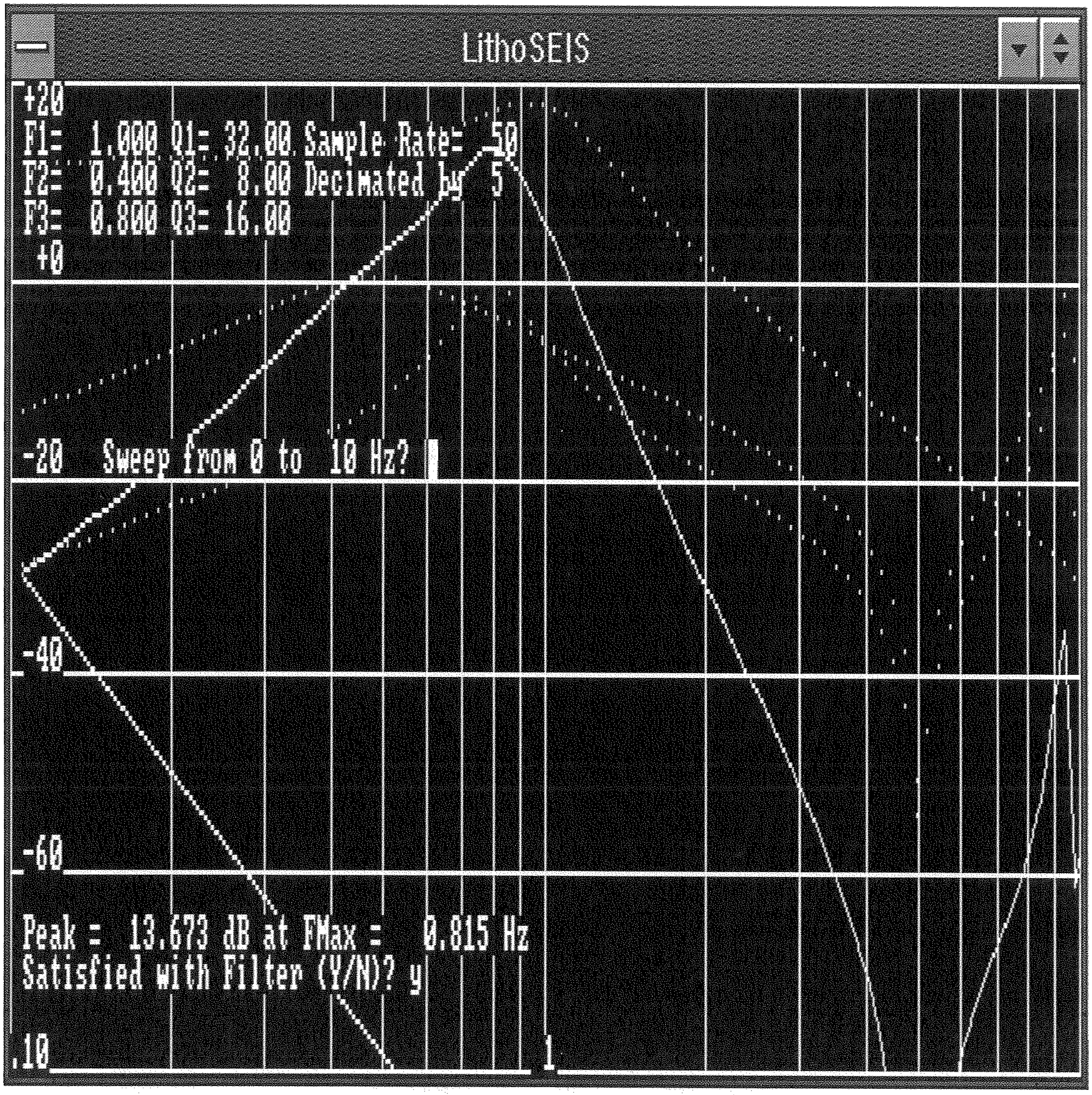

Figure 13: Frequency response of three infinite impule response (IIR) filters which could have been applied to the signal prior to the calculation of the STA and LTA values in order to improve on successful triggers. The combination of the three filters F1, F2 and F3 creates a filter (shown in solid) with a narrow passband and peak of 0.815 Hz.

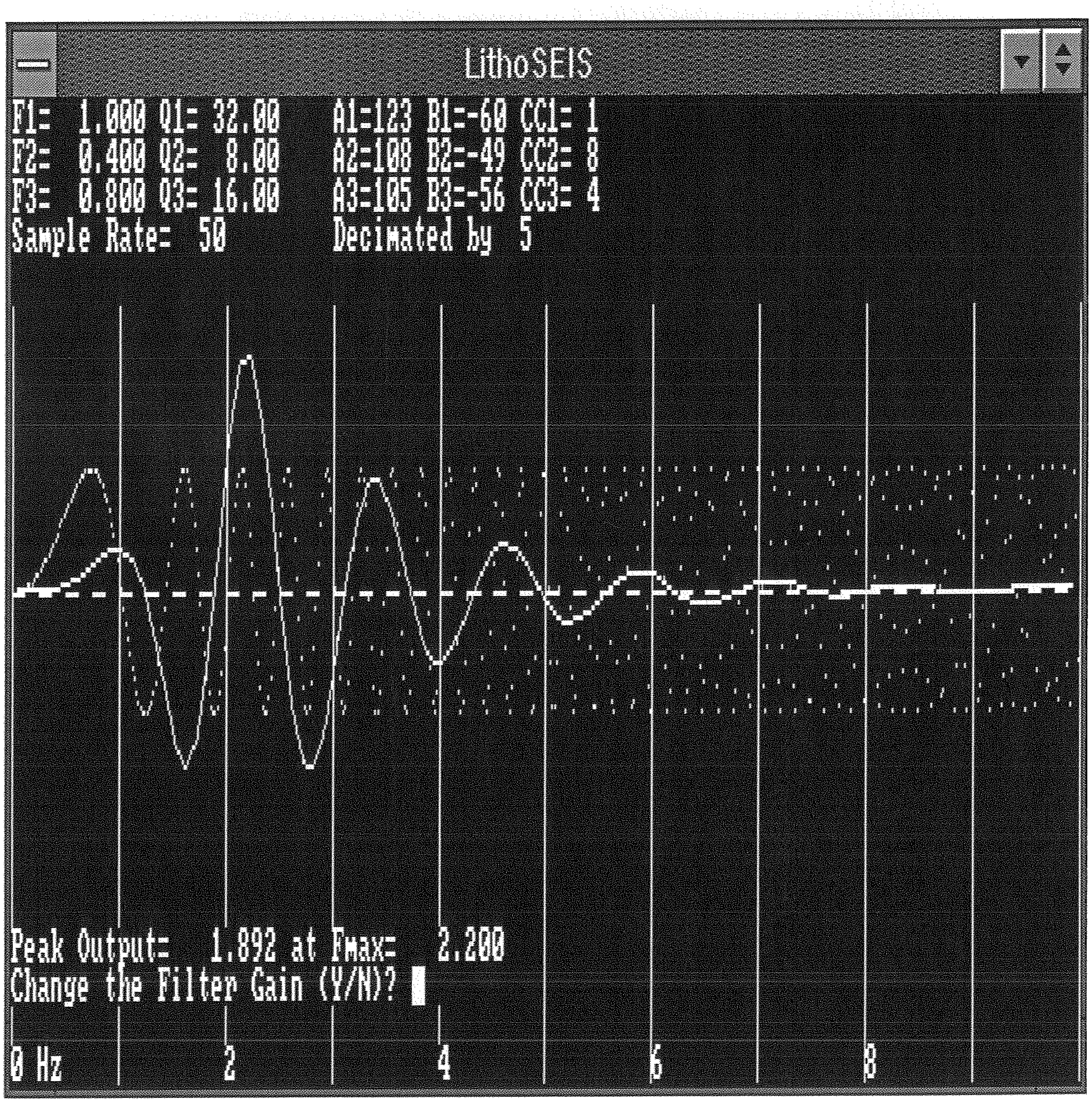

Figure 14: Amplitude response of a sweep of signals between 0-5 HZ to the combination filter (shown in solid in figure 13).

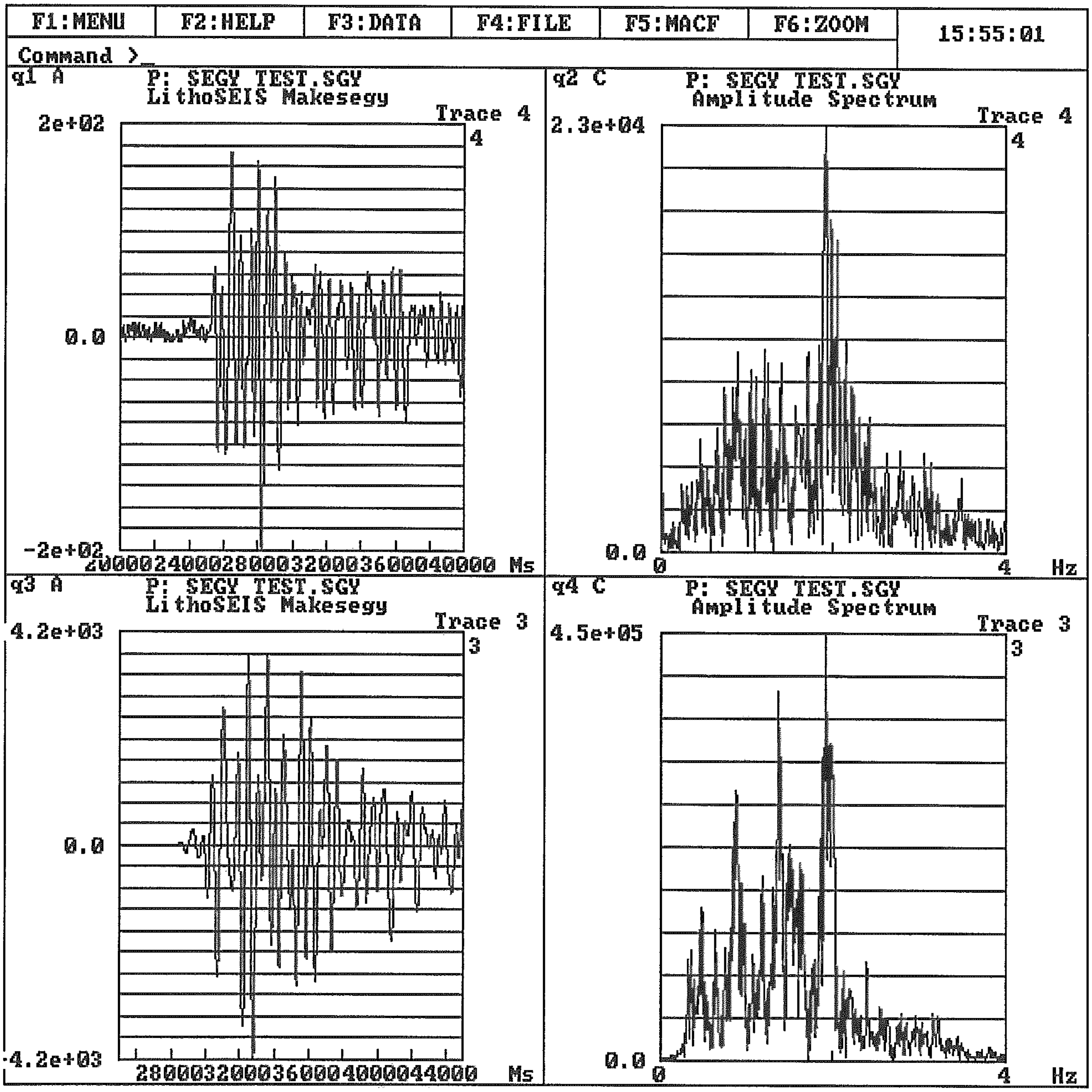

Figure 15: Comparison of of a magnitude 5.1 event (204, Tables 1-4) and a magnitude 7.0 event (202, Tables 1-4) at site 0034. The larger magnitude event (plotted in q3 and q4) shows stronger signal and spectrum than the smaller event (plotted in q1 and q2). The amplitude spectrum may indicate that the smaller event did not produce as much low frequency signal as the large event to trigger all sites.