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ONSHORE-OFFSHORE WIDE-ANGLE SEISMIC RECORDING NEAR CAPE BLANCO, OREGON

Submitted by
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DATA REPORT ON ONSHORE-OFFSHORE WIDE-ANGLE SEISMIC RECORDING NEAR CAPE BLANCO, OREGON

By

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ABSTRACT

This report presents deep-crustal wide-angle seismic reflection and refraction data obtained in the vicinity of Cape Blanco, southern Oregon, in October 1994. As part of a larger U.S. Geological Survey (USGS) initiative to better understand the Cascadia margin, the USGS acquired 760 km of deep-crustal multichannel seismic-reflection profiles on the continental margin of southern Oregon using the **R/V Ewing** from October 3 to October 7, 1994. Prior to this reflection survey, we deployed two temporary, linear arrays of seismic recorders along east-west transects across the Oregon coast range; each array contained 10 matched REFTEK recorders and stretched landward about 80 km from the coast. Each REFTEK recorder contained an oriented 3-component seismometer and recorded digital data on a large capacity hard disk. By recording signals generated by the **Ewing's** marine air gun array, having a total volume of 137.7 liters (8400 cu. in.), the arrays of land recorders were designed to (1) image the lower crustal structure near the coast in the vicinity of Cape Blanco, (2) determine whether any significant differences in crustal structure exist across a postulated major crustal shear zone in the vicinity of Cape Blanco, and (3) image the subducting Gorda and Juan de Fuca plates. Nearly 12,300 air gun shots along 7 reflection lines were recorded by 18 land recorders. Air gun signals were recorded at ranges as close as 5 km and as far as 160 km. In this report, we describe the land recording of the air gun signals, discuss the processing of the land recorder data into common receiver gathers, and illustrate the processed wide-angle seismic data. Data quality is generally high; refractions from the upper mantle, Pn, were observed at almost all recorders at sufficient offsets from the **Ewing**.

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INTRODUCTION

The U.S. Geological Survey (USGS) has recently undertaken an initiative to better understand the crustal structure, tectonics, and earthquake and volcanic hazards in the Pacific Northwest and Cascadia margin (Wells and the Cascadia Working Group, 1993). In this report we describe a deep-crustal onshore-offshore seismic investigation by the USGS in southern Oregon. The USGS acquired approximately 760 km of deep-crustal seismic reflection profiles along seven lines in the vicinity of Cape Blanco, from October 3 to October 7, 1994, using a 20-element air gun array and a 160-channel digital-streamer towed by the **R/V Ewing**. (The **Ewing** is a former seismic industry reflection vessel now operated by the Lamont-Doherty Earth Observatory.) Prior to the start of the **Ewing** cruise, we temporarily deployed two linear east-west trending arrays of 10 REFTEK recorders, each stretching landward about 80 km from the coast. The northern deployment of land recorders was located at latitude 43° 14'N (the latitude of Roseburg), and the other, southern deployment of recorders was centered at latitude 42° 40'N, but angled more southeasterly from Port Orford to Grants Pass (Figure 1). The arrays of land recorders were designed to obtain wide-angle seismic data to allow us to (1) image the crustal structure near the coast in southern Oregon, (2) determine whether significant differences in crustal structure exist across a postulated major crustal shear zone in the vicinity of Cape Blanco, and (3) image the subducting Juan de Fuca and Gorda Plates. Nearly 12,300 air gun signals were recorded by both arrays of seismic recorders.

Geologic Setting

Cape Blanco, in southern Oregon, lies along the Cascadia margin where the Juan de Fuca and Gorda plates subduct beneath the North American continent (Figure 1). Significant differences exist between the forearc structure of the Cascadia subduction zone (CSZ) off central and northern Oregon and that of the southern CSZ off southern Oregon and northern California (Wells and the

Cascadia Working Group, 1993). Cape Blanco lies at the boundary between the northern and southern Cascadia subduction zones.

Off central Oregon the continental margin is aseismic and consists of three parallel, generally north-trending, tectonic elements: (1) an accretionary wedge of offscraped and underplated Eocene to Holocene sediment; (2) the Fulmar terrane, an allochthonous sliver of lower Eocene and older terriginous sediment that has undergone northward translation in the early Tertiary; and (3) the Siletz River Volcanics, a thick monolithic block of Paleogene and lower Eocene oceanic volcanic rocks that may form a backstop for the accretionary complex (Snavely, 1987; Trehu et al., 1994). The continental margin in the northern CSZ has high volcanic productivity. Offshore mapping indicates that the northern CSZ forearc is cut by transcurrent faulting (Goldfinger and others, 1992a, b).

In contrast, the southern CSZ forearc of northern California is seismically active, and it lacks the Siletz River block (Wells and the Cascadia Working Group, 1993). In the southern CSZ, an accretionary wedge of principally Paleogene and younger rocks (Coastal belt of the Franciscan Assemblage) is thrust beneath the Central and Eastern belts of the Franciscan Assemblage, which, in turn, are thrust beneath Mesozoic rocks of the Klamath Mountains. The continental margin of the southern CSZ is characterized by low volcanic productivity. Offshore mapping indicates that the southern CSZ forearc is a single, coherent structural block, uncut by transcurrent faulting (Clarke, 1990; Goldfinger and others, 1992a).

A major E-W trending structural boundary is postulated in the Cape Blanco area, separating the central Oregon forearc from that of the southern Oregon-northern California forearc (Snavely, 1987; Clarke, 1990). This boundary is believed to form the southern terminus of the lower Eocene Siletz River Volcanics, the terrane bounding Fulmar fault, and the aseismic central segment of the Cascadia subduction zone. This structure could potentially represent a major segmentation point limiting rupture along the Cascadia megathrust and thus is of interest from the earthquake hazard perspective.

The wide-angle data acquired at Cape Blanco and described here were meant to fill a gap between an existing deep-crustal seismic survey in central Oregon (Luetgert et al., 1992; Brocher et al., 1993; Trehu et al., 1994), and a larger survey at the Mendocino triple junction (Mendocino 1994 Working Group, 1994). The Cape Blanco vicinity of the Oregon margin is virtually aseismic, although it is widely believed that this portion of Oregon will be subjected to a large (magnitude 8 to 9) earthquake sometime in the future (e.g., Heaton and Kanamori, 1984; Hyndman and Wang, 1993; Dragert et al., 1994; Verdonck, 1995). The dip of the subducting Juan de Fuca oceanic plate is important for estimating the geometry of the locked zone of the Cascadia megathrust which it is believed will produce this large earthquake.

DATA ACQUISITION

Ewing Instrumentation and Operations

Using the R/V **Ewing**, the USGS acquired seven deep-crustal seismic-reflection profiles on the continental shelf of Oregon in the vicinity of Cape Blanco from 42° to 43.5°N (Figure 1, Table 1). Lines 1, 2, 3 and 4 were acquired along-strike on transects either parallel or subparallel to the Oregon coast. Lines 1 and 2 were acquired in water depths of about 100 to 200 m and were designed to cross the Fulmar fault and the postulated E-W trending shear zone, respectively. Line 3 was acquired in water depths of about 250 to 1000 m, and was designed to again cross the postulated E-W trending shear zone. Line 4 was acquired seaward of the deformation front of the Cascadia subduction zone in water about 3100 m deep and was designed to image the subducting oceanic crust. Lines 5, 6, and 7 were acquired along dip-lines perpendicular to the Oregon coast and margin. Lines 5 and 6 were run seaward from the State 3-mile limit to beyond the Cascadia deformation front (Figure 1) to sample the crust north and south of the postulated shear zone; during planning for the experiment the lines were lengthened to enhance the onshore wide-angle recording.

All seven deep-crustal seismic reflection lines were acquired using a 20-element, 137.7 liters (8400 cu. in.) air gun array deployed on two large booms and a 4.2-km-long, 160-channel digital streamer (Figure 2). Air gun firing times on the **Ewing** were determined from the air gun fire command time as measured on a Global Positioning System (GPS) Clock. The GPS clock was stabilized using a Rubidium clock accurate to within 1 nannosecond. Origin times of the air gun array are believed to be accurate to within a millisecond. Navigation of the **Ewing** was achieved using a Global Positioning System (GPS) receiver; these coordinates are estimated to be accurate to within 20 m. Files containing smoothed navigation and shot times were transmitted daily from the **Ewing** via e-mail.

The geometry of the air gun deployment from the **R/V Ewing** is presented in Figures 2 and 3. The air gun array, composed of Bolt air guns, was generally towed at depths between 8 and 10 meters. As shown in Figure 2, 8 guns were towed on each side of the ship from large retractable booms that were swung out abeam of the ship. The remaining four air guns were deployed from an A-frame on the stern of the ship. The ship-to-gun distance was staggered to minimize fouling the air guns and to optimally separate the air bubbles created by the individual air guns: the center of the air gun array was towed approximately 39.6 m behind the stern of the ship at a depth between 8 and 12 meters (Figure 2). The width of the air gun array across the beam of the ship was roughly 33.8 m (111 feet) (see Figure 3). The Magnavox GPS receiver for the ship was located above the ship's bridge about 47.8 m forward of the stern of the ship, roughly 87.4 m forward of the center of the air gun array. (The data shown here and on tape have not been corrected for this slight offset.) The sizes of the air gun chambers varied from 145 cu. in. (2.4 liters) to 875 cu. in. (14.2 liters) to provide a tuned outgoing source wavelet (Figure 3).

The **Ewing** sailed from port at Coos Bay, Oregon, at 1715 UTC on JD 276 (1015L on 4 October 1994). Almost immediately upon reaching the open ocean the crew began to deploy the streamer as well as the air gun array. The first air gun shot fired by the **Ewing** was at 0243 UTC on JD 277 and the last air gun shot was fired at 1523 UTC on JD 280. Table 1 summarizes the 9 reflection line segments acquired using the **Ewing**, showing the start and end times and locations of each line. In order to acquire lines 5 and 6 as soon into the cruise as possible, to enhance the chances for successful wide-angle recording of these lines, most of the reflection lines were acquired out of numerical order. For example, the track line geometry required Line 4, the most seaward of the strike lines, to be acquired in two pieces, Line 4 and 4S. Appendix 1 presents a more detailed listing of the **Ewing** air gun shot times, locations, and field file ID (FFID) numbers, giving these values at 30 minute intervals along the track line. The air guns generally were not fired while the **Ewing** was turning from the end of one line to the start point of another line. A total of 12,283 air gun shots were fired during this 3 1/2 day interval.

Finally, scientists on the **Ewing** acquired a number of ancillary data, including several sonobuoys, during the cruise. These sonobuoys were expendable military hydrophones which self-scuttle after 8 hours. The goal of recording these sonobuoys was to obtain control of crustal velocities along the **Ewing** ship tracks necessary to constrain velocities of the offshore regions of the survey area. Table 5 provides a summary of the locations and times the sonobuoys were deployed. Other geophysical data acquired during the cruise included gravity, magnetic, and 3.5 kHz bathymetry data. Weather data were also recorded on the **Ewing**.

TABLE 1. R/V **Ewing** Airgun Firing Times and Locations

UCT Yr Day:HR:MIN:SEC	FFID	Lat. (N) Deg. Minute	Long. (W) Deg. Minute	Line No.	Tape FFID
94+277:02:43:13.596	00103	43 27.6102	124 21.9956	cb01	00001
94+277:07:15:10.487	00876	43 11.1202	124 38.9450	cb01	00774
94+277:10:08:51.208	00104	43 13.3858	124 29.2266	cb05	00775
94+277:20:12:42.245	01854	43 09.6455	125 32.4822	cb05	02525
94+277:20:31:56.944	00102	43 08.1771	125 32.4372	cb04	02526
94+278:00:58:15.485	00864	42 47.8815	125 32.0572	cb04	03288
94-278:01:44:40.833	00101	42 48.9993	125 33.4243	cb06	03289
94+278:12:11:16.762	01746	42 42.5987	124 34.2138	cb06	04934
94+278:13:10:51.908	00103	42 40.4444	124 32.9880	cb06T	04935
94-278:16:53:13.019	00755	42 30.7248	124 52.5357	cb06T	05587
94+278:18:49:43.119	00104	42 31.1803	124 55.0315	cb03	05588
94+279:07:11:22.543	01985	43 17.7285	124 46.7986	cb03	07469
94-279:09:45:57.807	00101	43 13.1471	124 36.9358	cb02	07470
94+279:23:00:06.358	02353	42 13.4499	124 37.1967	cb02	09744
94+280:00:33:10.079	00102	42 14.9724	124 37.2126	cb07	09745
94+280:07:46:42.418	01362	42 17.8625	125 22.4321	cb07	11005
94+280:08:02:23.945	00106	42 18.5793	125 23.6212	cb04s	11006
94+280:15:23:54.110	01380	42 51.7775	125 32.8437	cb04s	12280

Wide-Angle Recording

In addition to serving as the sound source for the deep-crustal seismic reflection lines, signals generated by the air gun array on the **Ewing** were recorded in a wide-angle geometry along two temporary deployments of REFTEK recorders. Each deployment consisted of 10 REFTEKs spaced about 9 km apart beginning at the Oregon coast. The northern deployment stretched 76 km from Seven Devils State Park eastwards to Melrose (just west of Roseburg, Figure 1). This deployment was primarily designed to record reflection line 5, an 86-km-long line trending east-west from just south of Cape Arago. The southern deployment, which trended more NW-SE, ran a total of 94 km from Port Orford to Hugo, north of to Grants Pass (Figure 1). This deployment was designed primarily to project offshore to reflection line 6, an 81-km-long line trending WNW-ESE from Port Orford. Air gun signals were recorded at ranges as close as 8 km and as far as 160 km along both deployments. Air gun signals from lines 1, 2, 3, 4 and 7 were recorded in a fan geometry by the REFTEK recorders.

The digital REFTEK recorders deployed, primarily models 07G, consist of five major components (PASSCAL, 1991). These components include the (1) Data Acquisition System (DAS), (2) internal hard disk drive, (3) internal oscillator and external GPS Clock, and (4) 3-component 4.5-Hz seismometers. For continuous recording it was necessary to supplement a small internal battery with an 12-V external battery. Each REFTEK DAS is controlled by a Hand Held Terminal (HHT), which is used to program the DAS, determining such parameters as the start and end times of recording, the sample rate (125 Hz in our case), mode of recording (continuous in our case), and number of channels to record (3 in our case). The GPS receiver clocks had a duty cycle of 5 minutes per hour. For our brief deployment, it was not necessary to program a time to stop recording. Recording was simply halted when the instrument was retrieved.

The REFTEK recorders were deployed along existing access roads on October 1-2 (JD 274 and 275). All were programmed to record 3-geophone components continuously at a sample rate of 125 Hz beginning at JD 276 0000 UTC. Three of the REFTEKs (model 07) had only 340

MByte hard-disks and were programmed to record two-components continuously at 125 Hz beginning at JD 276 at 0700 UTC. The start time for the REFTEK recording was chosen to insure recording of a shot window for a 20,000 lb (9090 kg) explosive charge to be fired offshore Portugal at 0830 UTC on JD 276. [Due to problems in obtaining permission to fire the shot this shot was indefinitely delayed]. All the REFTEKs used 4.5 Hz, 3-component seismometers and were connected to 80 Amp-Hour truck batteries, sufficient to provide continuous recording for 8 days (based on a maximum power consumption of 10 Amphour/day).

Latitudes and longitudes of the REFTEK recorders was determined from either the built-in or auxilliary GPS receivers of the REFTEKs, and represent the average GPS location for the 5.5 days of GPS data recorded at 24 different times a day. Estimated average uncertainties of the latitudes and longitudes are about 50 m. Elevations of the recorders were taken from USGS topographic maps using the initial map coordinates.

The percentage of successful data recovery for the experiment was roughly 88% (not including data lost due to the tampering of N-2). Due to instrument malfunction, Stations N-5 and S-10 failed to record any useful data during the experiment. Station N-2 was tampered with sometime after JD 277 and before its retrieval on JD 280, when it was found with its seismometers pulled out of the ground. Station N-3 failed to start recording until it was visited on JD 277, and failed to record Line 1 and virtually all of Line 5 (successful 79%). Station S1 failed to lock to GPS during the experiment, resulting in a free-running, uncorrected, internal clock and no GPS location fix. Fortunately, and most unusually, the station recorded an air wave arrival with a velocity of 0.334 km/s during Line 6 to a maximum offset of about 22 km. This air wave arrival allowed us to determine the amount of drift which had occurred prior to the acquisition of Line 6, and thus infer the drift rate of the low precision internal clock (about 175 ms/day). Station S7 obtained only one GPS lock during the experiment, when it was first deployed. REFTEKs run on low precision clocks until its predetermined "wake-up" time. After waking up the REFTEKs run on a higher precision clock (drift rate typically <10 ms/day), and is ideally periodically synchronized with GPS time. For this reason we assume the drift of the higher precision internal clock at Station S7 was negligible during the 4 days of data recording.

Fair weather prevailed for the majority of the survey, with generally clear or partly cloudy skies and winds picking up in the evening. No rain was experienced during the experiment. During our experiment, 7 small earthquakes occured in the Basin and Range province in Northern California, to the south and east of our arrays (Table 3). The local magnitudes of these events varied from between 0.6 and 1.8. The nearest of these earthquakes was approximately 108 km from the southeastern station of our array.

TABLE 2. REFTEK Station GPS Locations and Elevations

Station No.	Station Name	Latitude (N) Degrees	Longitude (W) Degrees	Elevation (m)
N1	Seven Devils	43.234016	124.386360	10
N2	Coos Co. Forest	43.235151	124.346661	128
N3	Beaver Hill	43.230861	124.267648	42
N4	Noble Creek	43.244370	124.175407	42
N5	Coquille River	43.241188	124.059451	60
N6	Middle Creek	43.245236	123.956843	103
N7	Tioga	43.252014	123.831544	230
N8	Williams River	43.250026	123.708675	285
N9	Long Ridge	43.247500	123.576947	750
N10	Melrose School	43.241766	123.444512	160
S1	Port Orford*	42.737500	124.508333	79
S2	Elk River	42.711690	124.375358	61
S3	Panther Creek	42.698689	124.296421	491
S4	Panther Mtn.	42.687346	124.191169	712
S5	Agness Pass	42.679279	124.092266	788
S6	Rogue River	42.654769	123.969733	667
S7	Bear Camp	42.644503	123.860547	1309
S8	Howard Creek	42.601130	123.754598	909
S9	Golden Wedge Mine	42.602454	123.624577	848
S10	Quartz Creek	42.477815	123.410125	679

*Map location, no GPS lock.

Table 3. Local Earthquakes Reported by the University of Washington During the Reftek Deployment

Date	Time Hr:Mn:Sec	Lat Deg.Min	Lon Deg.Min	Depth, km	Mag	Nst	Azi. Gap	Clo-sest	RMS, sec.	???
1994/10/03	16:32 23.51	42N16.37	121W57.93	10.73	0.6	5/006	166	7	0.07	0.5
1994/10/04	02:36 36.26	42N17.26	121W58.84	10.11	1.1	5/008	149	6	0.03	0.2
1994/10/04	13:01 54.80	42N16.06	121W54.70	00.04	1.8	6/007	170	8	0.12	0.1
1994/10/05	02:44 59.42	42N15.73	121W57.82	10.97	1.3	6/007	178	8	0.03	0.2
1994/10/06	03:36 27.10	42N21.28	122W02.43	05.83	1.3	6/009	142	7	0.10	0.9
1994/10/06	07:24 30.95	42N18.23	121W59.93	09.31	0.9	5/007	127	5	0.05	0.3
1994/10/06	22:41 22.37	42N22.75	122W04.12	04.31	0.9	6/008	154	10	0.11	0.8

DATA QUALITY

The data quality obtained during our experiment was generally high. Higher ambient noise near the coasts of each deployment line was observed, and is attributed to wind and wave action localized to the coast. Station N10 was deployed near Interstate Freeway 5, near Roseburg, and experienced higher than average ambient cultural noise. Spectra indicated that the air gun signal was peaked at about 8 Hz, so we typically used a band-pass filter ramped up between 3 and 5 Hz, flat between 5 and 10 Hz, and ramped down between 10 and 12 Hz.

DATA REDUCTION

REFTEKs digitally recorded the wide-angle seismic data using 1 Gbyte hard-disks in compressed format. After retrieving the REFTEKs from the field, we downloaded the digital seismic data onto DAT tapes in refdump format using both a Sun workstation and a PASSCAL field DAT drive. The procedure followed for the field DAT drive consisted of the following. A power supply or battery and a hand-held terminal (HHT) were connected to each DAS unit, and SCSI cables were connected from the DAS to the field DAT drive. The field DAT drive was also connected to a power supply. For each station a new DAT tape was inserted into the field DAT drive. Using the HHT the DAT tape was then formated by the following steps: press F5 (Data

Menu), press 5 (SCSI Format), press 1 (Format Tape), and press F10 (Start Procedure). With the HHT and power supply still connected to the DAS, and the SCSI cable still connected to the DAT drive, the REFTEK data on the DAS was then written to DAT tape using the following steps: F5 (Data Menu), press 2 (Copy Data), press 8 (Copy Disk to Tape), and press F10 (Start Procedure). Repeating this procedure resulted in 20 DAT tapes, one each for stations N1-N10 and S1-S10. We attempted to repeat this procedure twice for each station, one using the field DAT drive and the other using the Sun workstation. For some DAS units, however, it was possible to download the data using the field DAT drive. If using a Sun workstation, type **refdump -d /dev/sd5c /dev/rst1.**

The seismic data were then converted to SEG-Y format using a PASSCAL program called ref2segy (see Appendix 2). Finally, we converted these SEG-Y data into SEG-Y-formated, common receiver gathers using PASSCAL program segygather (Appendix 2). Common receiver gathers were plotted using ProMAX, after trace equalization, bandpass filter, and linear moveout to a velocity of 8 km/s.

SEG-Y Tape Format

The common receiver gathers generated from the digital REFTEK tapes are stored in a unreduced travel time format. Sixty seconds of data were saved for each trace in the common receiver gather (7501 data samples per trace). The sample interval is 8 msec. All the air gun shots for all the reflection lines (12,283 traces) were saved for each common receiver gather. The common receiver gathers obtained were written in SEG-Y format to an Exabyte tape by the segygather program. Data from all three geophone components were converted to SEG-Y format and saved to tape. SEG-Y trace header formats described by Barry and others (1975) were modfied slightly, as described in Appendix 3. The header is in EBCDIC format, and the data are in IBM floating point format. Appendix 4 describes how we processed the data using ProMAX. Data for each reflection line can be identifed on tape via the tape FFID numbers shown on the right-hand side of Table 1.

DESCRIPTION OF THE DATA

We next describe the REFTEK data for the two major E-W trending lines acquired during the Cape Blanco, Oregon experiment in the order the lines were collected. Figures 5 to 21 present data recorded inline to Lines 5 and 6, linearly reduced to 8 km/s. Figures 22 to 39 present data recorded in a fan geometry for Lines 5 and 6. In these plots we show data recorded by northern stations for Line 6, to the south, and data recorded by the southern stations for Line 5, to the north. Figures 22 to 39 are plotted linearly with regard to FFID, but nonlinear ranges are provided. Figures 40 and 41 show data recorded at two stations for Lines 1 and 2, which trended north-south.

Data quality obtained during the experiment for both Lines 5 and 6 was significantly superior to that obtained in a similar experiment in central Oregon [Brocher and others, 1993], in that coherent arrivals could be traced to ranges as much as 170 km, whereas in central Oregon arrivals could seldom be traced beyond 100 to 120 km. In the vicinity of Cape Blanco Pg arrivals from the crust can be traced to source-receiver offsets as much as 100? km. Weak but coherent refractions having apparent velocities of 9.5 km/s, inferred to be refractions from the upper mantle, Pn, can be traced on many of the profiles for distances up to 30 km. The distance to the cross over between Pg and Pn is about 60 km for stations near the coast, and progressively increases to distances of 100 km as the station location was moved landward.

Strong shear wave arrivals were recorded by stations along the northern REFTEK deployment. These arrivals have apparent velocities between 1.8 and 3.0 km/s, and were best observed by stations nearest the coast. No shear waves were recorded by stations along the southern REFTEK deployment.

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TABLE 4. REFTEK Deployment Information

Station No.	Station Name	REFTEK Number	Deployment Time (JD 274) hh:mm (UTC)	Pickup Time (JD 280) hh:mm (UTC)	Comments
N1	Seven Devils	7279	1600	1600	
N2	Coos Co. Forest	7322	1630	1630	Seismometer tampered with
N3	Beaver Hill	7355	1710	1712	PLN when deployed
N4	Noble Creek	7300	1800	1600	
N5	Coquille River	7278	1915	1806	Sample Rate 80 ms
N6	Middle Creek	7316	2015	1900	
N7	Tioga	7282	2100	1940	
N8	Williams River	7321	2210	2045	
N9	Long Ridge	7294	2310	2115	
N10	Melrose School	7364	2200	2156	
S1	Port Orford	7317	1626	1620	GPS No Lock
S2	Elk River	7100	1729	1707	Two channels (V,H1)
S3	Panther Creek	7301	1820	1750	
S4	Panther Mtn.	7289	2005	1840	
S5	Agness Pass	7277	2055	1935	
S6	Rogue River	7296	2304	2136	
S7	Bear Camp	7101	2354	2230	Only one GPS Lock Two channels (V,H1)
S8	Howard Creek	7302	0100 JD 275	2309	
S9	Golden Wedge Mine	7281	1908 JD 275	0010 JD 281	
S10	Quartz Creek	7103	1700 JD 275	0150 JD 281	Failed to record Two channels (V,H1)

TABLE 5. Sonobuoy Launch Times and Locations

Sonobuoy No.	Line, FFID*	Launch Time JD:Hr:Mn:Second	Latitude (N) Deg. Minute	Longitude (W) Deg. Minute
46	1A, 2754	220:23:05:53.027	60 02.6129	169 14.6611
47	1C, 280	221:06:56:10.223	60 25.5245	169 08.9543
48	1C, 1331	221:12:29:12.483	60 53.4262	169 02.1449
49	1D, 155	221:18:04:29.205	61 23.3408	168 54.3576

APPENDIX 1. R/V **Ewing** Air Gun Firing Times and Locations

UCT Day:HR:MN:SEC	FFID	Lat. (N) Deg. Min.	Long. (W) Deg. Minute
Line CB01			
277:02:43:13.596	00103	43 27.6102	124 21.9956
277:03:00:15.566	00147	43 26.6286	124 23.0631
277:03:30:18.175	00235	43 24.7091	124 24.9628
277:04:00:18.977	00321	43 22.9125	124 26.8377
277:04:30:07.990	00404	43 21.1732	124 28.7690
277:05:00:18.699	00491	43 19.3270	124 30.8129
277:05:30:00.880	00576	43 17.4726	124 32.4988
277:06:00:18.078	00665	43 15.5757	124 34.4907
277:06:30:05.631	00750	43 13.8356	124 36.4291
277:07:00:03.592	00834	43 12.0172	124 38.2633
277:07:15:10.487	00876	43 11.1202	124 38.9450
Line CB05			
277:10:08:51.208	00104	43 13.3858	124 29.2266
277:10:30:11.146	00169	43 13.3141	124 31.6216
277:11:00:00.757	00264	43 13.2408	124 35.1000
277:11:30:10.008	00350	43 13.0798	124 38.1078
277:12:00:08.401	00434	43 12.9212	124 41.1892
277:12:30:11.582	00518	43 12.8632	124 44.2584
277:13:00:04.155	00602	43 12.6749	124 47.3269
277:13:30:14.432	00689	43 12.3434	124 50.5072
277:14:00:02.892	00776	43 12.1146	124 53.6157
277:14:30:06.004	00857	43 12.0605	124 56.5089
277:15:00:14.142	00939	43 12.1069	124 59.5744
277:15:30:06.734	01025	43 11.9852	125 02.7398
277:16:00:07.224	01113	43 11.7551	125 05.9386
277:16:30:20.275	01199	43 11.6308	125 09.0631
277:17:00:06.458	01285	43 11.4920	125 12.2315
277:17:30:08.167	01376	43 11.2694	125 15.5296
277:18:00:10.037	01463	43 10.9922	125 18.6518
277:18:30:53.413	01553	43 10.8393	125 21.9516
277:19:00:08.122	01639	43 10.7501	125 25.0634
277:19:30:00.645	01726	43 10.5856	125 28.2297
277:20:00:07.042	01816	43 10.3533	125 31.5579
277:20:12:42.245	01854	43 09.6455	125 32.4822
Line CB04			
277:20:31:56.944	00102	43 08.1771	125 32.4372
277:21:00:11.683	00185	43 05.9924	125 32.3669
277:21:30:08.914	00270	43 03.7431	125 32.3543
277:22:00:05.240	00355	43 01.4881	125 32.2956
277:22:30:16.176	00439	42 59.2314	125 32.2493
277:23:00:01.338	00523	42 56.9896	125 32.2143
277:23:30:16.228	00610	42 54.6327	125 32.3245
278:00:00:12.370	00699	42 52.2554	125 32.3412
278:00:30:11.163	00784	42 50.0200	125 32.2821
278:00:58:15.485	00864	42 47.8815	125 32.0572
Line CB06			
278:01:44:40.833	00101	42 48.9993	125 33.4243
278:02:00:12.160	00139	42 48.8671	125 31.8780
278:02:30:27.213	00208	42 48.6396	125 29.5865
278:03:00:08.517	00268	42 48.3660	125 27.4584
278:03:30:27.395	00333	42 48.2197	125 25.0874
278:04:00:17.689	00397	42 47.9021	125 22.7299
278:04:30:04.848	00470	42 47.6075	125 20.0321
278:05:00:06.626	00550	42 47.3850	125 17.0958
278:05:30:10.208	00634	42 46.9381	125 14.0705
278:06:00:18.320	00725	42 46.5435	125 10.7236
278:06:30:15.090	00814	42 46.1930	125 07.6280

278:07:00:14.933	00901	42 45.8403	125 04.5469
278:07:30:08.651	00986	42 45.4446	125 01.4656
278:08:00:03.935	01072	42 45.0810	124 58.4216
278:08:30:05.283	01156	42 44.7900	124 55.4299
278:09:00:00.694	01237	42 44.4861	124 52.5584
278:09:30:21.544	01316	42 44.1720	124 49.7533
278:10:00:16.047	01391	42 43.7901	124 47.1304
278:10:30:14.836	01467	42 43.4004	124 44.3405
278:11:00:01.500	01547	42 43.1629	124 41.4369
278:11:30:00.271	01628	42 43.0515	124 38.4949
278:12:00:10.818	01714	42 42.7398	124 35.3837
278:12:11:16.762	01746	42 42.5987	124 34.2138

Line CB06T

278:13:10:51.908	00103	42 40.4444	124 32.9880
278:13:30:14.931	00158	42 39.4920	124 34.5781
278:14:00:13.184	00246	42 38.0653	124 37.0754
278:14:30:04.174	00331	42 36.8819	124 39.6899
278:15:00:09.626	00420	42 35.6390	124 42.4644
278:15:30:12.243	00510	42 34.2098	124 45.0989
278:16:00:16.314	00600	42 32.9656	124 47.8788
278:16:30:13.376	00689	42 31.7122	124 50.5590
278:16:53:13.019	00755	42 30.7248	124 52.5357

Line CB03

278:18:49:43.119	00104	42 31.1803	124 55.0315
278:18:59:46.803	00129	42 31.8823	124 54.9045
278:19:32:29.279	00130	42 31.0777	124 56.3565
278:20:00:18.258	00156	42 29.2992	124 55.8522
278:20:30:08.454	00239	42 31.2082	124 55.1669
278:21:00:18.603	00321	42 33.3984	124 54.6102
278:21:30:13.463	00406	42 35.6386	124 54.0681
278:22:00:00.818	00491	42 37.9020	124 53.6506
278:22:30:13.504	00578	42 40.1765	124 53.3134
278:23:00:01.480	00658	42 42.3030	124 52.8964
278:23:30:13.238	00740	42 44.4693	124 52.4517
279:00:00:19.986	00824	42 46.6787	124 52.1748
279:00:30:14.002	00905	42 48.8454	124 52.1269
279:01:00:05.791	00988	42 51.0158	124 51.4521
279:01:30:21.260	01070	42 53.1612	124 51.0483
279:02:00:12.243	01149	42 55.2633	124 50.8578
279:02:30:18.362	01231	42 57.4629	124 50.2631
279:03:00:15.864	01317	42 59.7057	124 49.7535
279:03:30:12.776	01405	43 02.0308	124 49.6356
279:04:00:04.726	01485	43 04.0894	124 49.1819
279:04:30:10.487	01555	43 05.8180	124 48.8018
279:05:00:10.529	01624	43 07.7633	124 48.4863
279:05:30:10.329	01706	43 09.9824	124 48.0267
279:06:00:19.840	01781	43 12.2963	124 47.5731
279:06:30:13.529	01868	43 14.6090	124 47.2059
279:07:00:06.204	01953	43 16.8831	124 46.8656
279:07:11:22.543	01985	43 17.7285	124 46.7986

Line CB02

279:09:45:57.807	00101	43 13.1471	124 36.9358
279:10:00:20.087	00141	43 12.0812	124 37.1116
279:10:30:11.217	00226	43 09.8227	124 37.7771
279:11:00:09.029	00311	43 07.5358	124 38.2413
279:11:30:01.200	00401	43 05.1594	124 38.6903
279:12:00:08.101	00489	43 02.8680	124 39.1879
279:12:30:04.160	00575	43 00.6100	124 39.6234
279:13:00:14.134	00661	42 58.3128	124 40.0178
279:13:30:18.031	00743	42 56.1869	124 40.3676
279:14:00:16.521	00828	42 53.8947	124 40.9234
279:14:30:12.978	00917	42 51.5633	124 41.5231
279:15:00:11.474	01001	42 49.4349	124 41.8500
279:15:30:15.135	01078	42 47.3216	124 41.9611
279:16:00:05.417	01160	42 45.1420	124 42.1691
279:16:30:04.179	01247	42 42.7627	124 41.9473
279:17:00:15.140	01337	42 40.3828	124 41.6480
279:17:30:05.426	01424	42 38.1048	124 41.2165
279:18:00:00.950	01509	42 35.8531	124 40.7938
279:18:30:15.174	01594	42 33.6278	124 40.3745
279:19:00:13.493	01680	42 31.3320	124 39.9767
279:19:30:01.823	01760	42 29.2963	124 39.4817
279:20:00:13.494	01839	42 27.1675	124 39.2205
279:20:30:11.804	01921	42 24.9708	124 38.9345
279:21:00:13.714	02005	42 22.7542	124 38.5564
279:21:30:07.956	02089	42 20.4900	124 38.3073
279:22:00:13.486	02175	42 18.2168	124 37.7613
279:22:30:17.657	02263	42 15.8486	124 37.4274
279:23:00:06.358	02353	42 13.4499	124 37.1967
279:23:07:59.436	02377	42 12.8352	124 37.0884

Line CB07

280:00:33:10.079	00102	42 14.9724	124 37.2126
280:01:00:05.263	00177	42 15.2143	124 39.9594
280:01:30:01.085	00265	42 15.5166	124 43.0562
280:02:00:10.015	00350	42 15.5076	124 46.0712
280:02:30:18.414	00433	42 15.7040	124 49.1072
280:03:00:10.135	00518	42 15.9797	124 52.1320
280:03:30:07.329	00603	42 16.0909	124 55.1472
280:04:00:16.776	00690	42 16.1584	124 58.3059
280:04:30:02.992	00776	42 16.4413	125 01.3843
280:05:00:10.803	00863	42 16.7079	125 04.5059
280:05:30:20.490	00951	42 16.8271	125 07.6324
280:06:00:07.729	01038	42 16.9263	125 10.7886
280:06:30:18.089	01126	42 17.1299	125 13.9259
280:07:00:18.420	01217	42 17.4725	125 17.2581
280:07:30:11.981	01309	42 17.7558	125 20.5571
280:07:46:42.418	01362	42 17.8625	125 22.4321

Line CB04s

280:08:02:23.945	00106	42 18.5793	125 23.6212
280:08:30:11.951	00181	42 20.5553	125 24.0540
280:09:00:04.508	00267	42 22.8538	125 24.4219
280:09:30:03.188	00356	42 25.2168	125 25.0514
280:10:00:03.608	00448	42 27.6620	125 25.6255
280:10:30:13.885	00541	42 30.0764	125 26.4417
280:11:00:13.265	00632	42 32.4303	125 27.0421
280:11:30:04.940	00722	42 34.7959	125 27.6391
280:12:00:09.478	00815	42 37.2562	125 28.4700
280:12:30:18.221	00909	42 39.6638	125 29.2628
280:13:00:04.440	00999	42 42.0079	125 29.9014
280:13:30:12.742	01086	42 44.1726	125 30.7297
280:14:00:13.317	01166	42 46.2625	125 31.1849
280:14:30:02.804	01243	42 48.2557	125 31.7983
280:15:00:14.798	01319	42 50.1818	125 32.5497
280:15:23:54.110	01380	42 51.7775	125 32.8437

APPENDIX 2: CONVERTING REFTEK FORMAT DATA TO RECEIVER GATHERS

Below is a step by step description of the processes necessary to convert the continuously recorded REFTEK data into SEG-Y format common receiver gathers. The bulk of this reduction was carried out by the Stanford PASSCAL Instrument facility, however it was necessary for us to make/re-make several receiver gathers (where?). To cut 1 day of data with a 100 Hz sample rate and 20 s air gun repetition rate requires about 20 minutes of wall clock time. For more detail, please consult the online manual page for segygather.

1. Download data from REFTEKs compressed hard drives as described in text.

2. Convert REFTEK formatted data tapes to SEG-Y formatted tapes

   use **tar xvf /dev/nrst1** to read the refdump file from tape and write it to disk

   Type:

   ```
   mkdir XXXX          (where XXXX is the station number)
   cd XXXX
   mt -f /dev/rstY/ rewind
   ref2segy -t /dev/rstY        (where Y is the tape device number)
   ```

   If prompted, enter the sampling rate and gains in dB for each channel

3. Check REFTEK functioning and obtain station coordinates

   These checks were made using the logview program to view the information contained in the REFTEK log file. A plot of the GPS coordinates obtained every hour can be obtained using the GPS tool. The average of these positions is used for the station location. Clock performance can also be assessed via plots of clock phase locking.

   First, type **logview filename** where filename is a REFTEK logfile e.g. **94:231.7300.log**

   Second, click on **GPS: Clock** window in **logview.** A plot of all GPS coordinates and statistics on these locations will be provided.

4. Generate shot times file

   This file should be in the format:

   ```
   shot time lat lon
   1 94:277:02:43:13.596 43.460171 -124.366592
   2 94:277:02:43:38.730 43.459801 -124.367004
   ```

Note that shot time format is (yr:jd:hr:min:sec). This information is obtained from the shotfile generated on board the **EWING** (for shotfiles lon is negative in the western hemisphere). A detailed example of how to do this is given below:

First, combine all shot information into one big file: e.g. **big.shot.**

Second, edit **(vi) timeflt.awk** to select needed dates for shottimes.

Third, type **awk -f timefilt.awk big.shot >tmp**. Puts output into tmp.

Fourth, type **awk -f degmin2degdec.awk tmp >277_280.shotfile** where **277_280.shotfile** is an example of a shotfile name

Fifth, type **head 277_280.shotfile** to look at first few lines of shotfile

Sixth, type **tail 277_280.shotfile** to look at last few lines of shotfile

Seventh, **vi 277_280.shotfile** to delete s.ts.n220: from files
vi 277_280.shotfile to change "94-" to "94:"
vi 277_280.shotfile to change "94+" to "94:"
vi 277_280.shotfile to header line "shot time lat lon" in lower case

e.g. :%s/94+/894:/g in **vi**

Eighth, **awk '{print $1, $2}' 220_228.shotfile >220_228.starttime**

5. Generate Receiver File (RCVR file)

This file should be in the format:

number	DAS/C	lon	lat	elevation
1	7317/1	42.737500	-124.508333	79
2	7317/2	42.737500	-124.508333	79
3	7317/3	42.737500	-124.508333	79

number = arbitrary sequential station number
DAS = REFTEK unit number
C = Channel (1=vertical, 2=N-S Horizontal, 3=E-W Horizontal)
lon = negative in the western hemisphere
elevation = elevation in meters

6. Write cshell to produce start times list and cut data.

e.g. cut.csh

The same cshell can be used for both operations. First a start times list must be created. This list was created by appending the lists produced for each day in step 2. Secondly the continuous data was cut using segygather. The format is:

segygather -i ../starttimes -s ../shottimes -g

```
../rcvrfile -d device -n record_length -o
output_device
```

An example c-script for Cape Blanco is:

```
#! /bin/cshls

$1/R277.01/*.1>/breck/data1/CB/lst/$1.1.lstls
$1/R278.01/*.1>>/breck/data1/CB/lst/$1.1.lstls
$1/R279.01/*.1>>/breck/data1/CB/lst/$1.1.lstls
$1/R280.01/*.1>>/breck/data1/CB/lst/$1.1.lstls
$1/R277.01/*.2>/breck/data1/CB/lst/$1.2.lstls
$1/R278.01/*.2>>/breck/data1/CB/lst/$1.2.lstls
$1/R279.01/*.2>>/breck/data1/CB/lst/$1.2.lstls
$1/R280.01/*.2>>/breck/data1/CB/lst/$1.2.lstls
$1/R277.01/*.3>/breck/data1/CB/lst/$1.3.lstls
$1/R278.01/*.3>>/breck/data1/CB/lst/$1.3.lstls
$1/R279.01/*.3>>/breck/data1/CB/lst/$1.3.lstls
$1/R280.01/*.3>>/breck/data1/CB/lst/$1.3.lst

/breck/data1/CB/segygather -i /breck/data1/CB/lst/$1.1.lst -o /dev/nrst$2 -s
/breck/data1/CB/shot_times -d $1/1 -g /breck/data1/CB/receivers -n 60
/breck/data1/CB/segygather -i /breck/data1/CB/lst/$1.2.lst -o /dev/nrst$2 -s
/breck/data1/CB/shot_times -d $1/2 -g /breck/data1/CB/receivers -n 60
/breck/data1/CB/segygather -i /breck/data1/CB/lst/$1.3.lst -o /dev/rst$2 -s
/breck/data1/CB/shot_times -d $1/3 -g /breck/data1/CB/receivers -n 60
```

where $1/RZZZ.01/*.N defines the year, julian day and REFTEK channel number where /breck/data1/CB defines the data directory

The first twelve lines produce a list of all the start times for days 277 to 280 (the period of the **EWING** cruise). The 1s are for component 1, 2s for component 2, and 3s for component 3. Segygather is then run using the start times list generated ($1.lst), the shot file (shot_times), and the receiver file (receivers). The data was cut to 60 sec, this means that a 60 sec slice of the continuous data was cut for each shot. The shots were separated by 20 to 30 sec resulting in more than one shot being recorded on each trace. The cut traces are then downloaded to tape.

When finished editing, type **chmod +x cut.csh** to make it executable

Put a new, labeled Exabyte tape in the Exabyte tape drive.

Run program by typing **cut.csh XXXX Y** where XXXX is the station number and Y is the tape device number.

7. Load into PROMAX

The data is now in a format suitable to be loaded into PROMAX. Appendix 2 lists the necessary input parameters. Read tape using ProMAX software and make screen display to verify **segygather** worked properly.

APPENDIX 3. PASSCAL SEGY TRACE HEADER FORMAT

Byte #	Description
1 - 4	Trace sequence number within data stream
5 - 8	Trace sequence number within reel (same as above)
9 - 12	Event number
13 - 16	Channel number
|	
29 - 30	Trace identification code = 1 for seismic data
|	
69 - 70	Elevation constant = 1
|	
115 - 116	Number of samples in this trace (note if equal 32767 see bytes 229 - 232)
117 - 118	Sample interval in microsecs for this trace (note if equal 1 see bytes 201 - 204)
119 - 120	Fixed gain flag = 1
121 - 122	Gain of amplifier
|	
157 - 158	Year data recorded
159 - 160	Day of year
161 - 162	Hour of day (24 hour clock)
163 - 164	Minute of hour
165 - 166	Second of minute
167 - 168	Time basis code: 1=local 2=GMT 3=other
|	
174 - 174	Stake number index
|	
181 - 186*	Station Name code (5 chars + 1 for termination)
187 - 194*	Sensor Serial code (7 chars + 1 for termination)
195 - 198*	Channel Name code(3 chars +1 for termination)
199 - 200*	Extra bytes (2 chars)
201 - 204*	Sample interval in microsecs as a 32 bit integer
205 - 206*	Data format flag: 0=16 bit integer 1=32 bit integer
207 - 208*	Miliseconds of second for first sample
209 - 210*	Trigger time year
211 - 212*	Trigger time julian day
213 - 214*	Trigger time hour
215 - 216*	Trigger time minutes
217 - 218*	Trigger time seconds
219 - 220*	Trigger time milliseconds
221 - 224*	Scale factor (IEEE 32 bit float) (true amplitude = (data value)*(scale factor)/gain
225 - 226*	Instrument Serial Number
229 - 232*	Number of Samples as a 32 bit integer
233 - 236*	Max value in counts.
237 - 240*	Min value in counts.

* Header values not specified in the standard SEGY format

APPENDIX 4. PROMAX INPUT AND PROCESSING PARAMETERS

This appendix contains all the information necessary to load the Cape Blanco, Oregon wide-angle seismic data into ProMAX, manipulate the ProMAX database, filter the data, produce plots and pick arrivals. The appendix is divided into four sections. The first describes the structure of the flows used, the second then lists the input parameters for all the ProMAX tools used the the flows. The third describes how to pick and export arrival times.

1.0 FLOWS

1.1 INPUT FROM TAPE TO DISK

SEG-Y Input
Disk Data Output

1.2 PROCESS AND PLOT ADJACENT SHOTS

This flow was used to realise our first objective, to simply plot the data for a 'first look'. Thus no velocity reduction was applied and all traces were plotted with equal spacing.

Disk Data Input
Trace DC Removal
Bandpass Filter
Automatic Gain Control
Spiking/Predictive Decon
Create CGM+ Plotfile
Plot CGM+ Plotfile ZGS

1.3 GEOMETRY

Non-standard geometry is difficult in ProMAX. Rather than do the geometry inside ProMAX the necessary parameters were calculated outside ProMAX and then imported to ProMAX. It was necessary, however, to initialise the geometry first which was achieved as follows.

Geometry Installation*

The * indicates it is a standalone tool which does not need Disk Data Input.

1.4 PROCESSING AND PLOTTING AS A FUNCTION OF RANGE

This flow was used once the shot-receiver ranges had been imported into the ProMAX database. On each occasion the flow is run the range information must be read from the database, it is not stored permanently as a header value.

Disk Data Input
Trace DC Removal
Bandpass Filter
Database/Header Transfer
Trace Header Math
Trace Header Math
Linear Moveout Correction

Automatic Gain Control
Spiking/Predictive Deconvolution
Trace Mixing
Trace Header Math
Create CGM+ Plotfile
Plot CGM+ Plotfile ZGS

The two Trace Header Math tools after the Database/Header Transfer load the range and the absolute range into OFFSET and AOFFSET respectively. This transfer allows the velocity tool to be used on the screen display. The trick to plotting as a function of range is to pretend the range is a CDP. To do this the integer value of the range is loaded into the CDP header prior to plotting. The plot is then created in the CDP spatial domain. The conversion to an integer means it is necessary to calculate the range in meters otherwise all shots within 1 km would be collapsed together.

2.0 ProMAX TOOL PARAMETERS

Below are lists of the critical input parameters for the tools used, note that this is not a complete list.

2.1 SEG-Y INPUT

Type of storage	Tape
Input multiple files from tape(s)	Yes
Multiple file selection	Select
Specify input files list	1/
IBM standard label?	No
Input data's sample rate	8.0
Maximum time to input	60000.0
Get channel number from trace headers	Yes
Input trace format	Get from header
Is this stacked data?	No
Maximum traces per ensemble	12283
Primary sort header word	SHOT
Input primary selection choice	Input ALL
Input secondary selection choice	None
Enter primary tape drive device path name	/dev/rmt/1

Notes: When selecting which file to load it is only possible to indicate one file at a time. To view more than one channel, first execute the flow, and then change the 1/ to a 2/ and execute again. When ProMAX gets to the end of the file it states 'Run out of data'. This phrase simply means 'at the end of the file' so select 'stop'.

2.2 DISK DATA OUTPUT

Record length to output	0.0
Compress the data	Yes
Pre-geometry database initialization	No

Note: The 0.0 outputs all the data.

2.3 DISK DATA INPUT

Trace read option	Sort
Select primary trace header entry	Recording channel number
Select secondary trace header entry	Field file ID number
Select tertiary trace header entry	None
Sort order for dataset	1:3289-4934(1)/

Notes: In some flows it is necessary to indicate all traces for a process in which case it is useful to have the primary trace header entry something that is the same for all traces. In the case of the Chukchi data, channel number is such a field. The secondary trace header entry is actually the one that picks out the required traces.

2.4 BANDPASS FILTER

Type of filter	Single filter
Type of filter specification	Ormsby bandpass
Phase of filter	Zero
Domain of filter	Frequency
Frequency values	3-5,10-12

Note: The phase of the filter (zero or minimum) may be used depending on the processors preference.

2.5 TRACE HEADER MATHS

Select mode	Fixed equation mode
Define trace header equation	aoffset=abs(range)

Notes: This tool simply sets the aoffset attribute to the absolute value of the range for each trace. It is useful to put the calculated range in offset and aoffset as this allows the velocity tool to be used on screen.

2.6 LINEAR MOVEOUT CORRECTION

Type of LMO application	Forward
Header entry used to specify distance	aoffset
Select primary header entry	None
Specify velocity parameters	8000:
Additional Time Shift	-2000

Notes: The distance used must be positive otherwise the timeshift applied will be in the wrong direction for the negative ranges.

2.7 SCREEN DISPLAY

2.7.1 CONSTANT TRACE SPACING

Number of traces per screen	500
Maximum number of ensembles per screen	500
Do you wish to use variable trace spacing?	No
Select trace display mode	WT/VA
Primary trace labelling header entry	FFID
Mode of primary trace annotation	Incremental

Increment for primary trace annotation	50
Secondary trace labelling header entry	None
Trace scaling mode	Conventional

Notes: An ensemble is the group of traces indicated by a single value of the 'primary trace header entry' specified in 'Disk Data Input'. If FFID is specified as the primary entry then the maximum number of ensembles will have to be the same as the number of traces as there is only one trace per ensemble. The best solution is to specify a large number.

2.7.2 VARIABLE TRACE SPACING

Number of traces per screen	0
Maximum number of ensembles per screen	1
Do you wish to use variable trace spacing	Yes
Header entry for trace spacing	range
Secondary trace labelling header entry	range
Mode of annotation	Incremental
Increment	50

Notes: It is only possible to display the data on the screen with variable trace spacing if all the data is displayed on one screen. The user must then zoom in and out to have a closer look if necessary. The 'traces per screen option' must be either 0, for automatic mode, or a number greater than twice the total number of traces. Ideally the 'primary trace header entry, specified in the 'Input from Disk' should be something that specifies all traces (channel number for the Cape Blanco data), in which case we can enter one here. Otherwise the 'maximum numberof ensembles' must be greater than twice the number of traces. If the maximum number of ensembles specified is not 1 the automatic mode for number of traces does not work in which case both numbers must be greater than twice the total number of traces. Twice the number of traces must be specified because ProMAX will only display half the number given. A problem occurs if the number of traces is greater than 499 as the largest number that can be entered in either of these options is 9999.

2.8 CREATE CGM+ PLOTFILE

2.8.1 CONSTANT TRACE SPACING

Plot file name	cgmplot
Plotting units	cm
Spatial domain of plot	Input trace order
CDP increment	1

Submenu to view Traces/Plots/Posts/Graphs

Components list Post>Header>FFID

Posting method	Value
Select header values to post	3289-4934(400)
Include label	Yes
Label text	FFID

Components list >primary trace data<

Trace space (traces/plot unit)	80
Time scale (plot units/sec)	2
Start time	0

End time	40
Timing lines	2000 5000
Timing annotation increment	5000
Timing annotation format	Decimal seconds
Trace plot mode	Variable area
Section gain	0.5
Clip limit	2

Submenu to view Title box text

Minimum height of side label -1

Submenu to view Processing sequence text Processing sequence options Fully Automatic

Notes: Problems were encountered when the file name was changed from the default. The user must specify the actual numbers to be posted in the 'select header values to post'. The maximum number of traces it is possible to plot was about 80 per cm, to do so it must be a variable area only plot. Specifying '-1' in the 'minimum height of side label' results in no label, specifying the default of 0 generates the label automatically. If a label is generated then specifying a 'fully automatic processing sequence' prevents the user entering a generating tool which causes unnecessary complications.

2.8.2 VARIABLE TRACE SPACING

Before the create plot tool the user must insert a Trace Header Math tool specifying the following:

Select mode Fixed equation mode Define trace header equation cdp=int(range)

The critical parameters in Create CGM+ Plotfile are:

Spatial domain of plot	CDP Leftmost CDP	250 000
	Rightmost CDP	250 000
CDP increment	1	

Submenu to view Traces/Plots/Posts/Graphs Components list >PRIMARY TRACE DATA<

Trace space (traces/plot units) 10 000

Notes: The plot will cover the range specified here however there will only be data if the input traces specified in 'Input From Disk' are in this CDP/range interval. The 'Trace space' is now CDPs per plot unit.

3.0 PICKING ARRIVALS

The first and some secondary arrivals were picked in ProMAX. A pick file can then be exported and imported into modelling packages. This picking is achieved by picking a 'Top Mute'. Care must be taken using the "snap" icon as ProMAX may interpolate and pick incorrectly. The picks are exported using the Trace Muting tool as described in the step by step instructions below. The format of the exported file is shown in the comment lines at the beginning of the code reduction3. It is important to note that the exported times will be the reduced times if the picks were made on a reduced time plot.

Insert the 'Trace Muting' tool at end of flow but leave is inactive (MB3).

Run a flow to display the data on the screen. It is preferable to display all the data on one screen and then zoom in to pick, if the data is split across several screens then it is impossible to check the continuity of the picks. If stacking/trace mixing is used, it may be necessary to moveout section 5 of the line at different velocities, and later (after unreducing the times), splice the picks together.

Zoom in to where you want to start picking.

Click on the pick (hammer) and 'Pick top mute'.

Choose between creating a new file of picks or modifying an old one.

Choose a secondary key. The pick file generated will contain the 'primary trace header entry' specified in the 'Input from Disk' tool (Section $$) and the secondary key specified here. Clearly we choose range or offset.

Enter a name which ProMAX uses to refer to this set of picks.

Pick away. MB1 adds picks either individually or by holding it down and drawing a line. MB3 deletes picks. Snap icon enables the nearest peak, trough, or zero crossing to be found. We used the nearest peak (black). Use this tool with care!

Once finished click on the 'Stop' icon and 'Save work to database before quitting'.

Once back in the flow click with MB2 on the inactive Trace Muting tool. Then click with MB1 on the 'Select mute parameter file' which should read 'INVALID'.

The file containing the picks should now appear. Click on 'Export' from the menu bar, and then the pick file. Type the path and file name where you would like the file to be saved and press Return. The file has now been saved and may be manipulated to be input to a modelling package.

Move the mouse to the top of the screen to reenter the flow.