WIDE-ANGLE SEISMIC RECORDINGS FROM THE 1998 SEISMIC HAZARDS INVESTIGATION OF PUGET SOUND (SHIPS), WESTERN WASHINGTON AND BRITISH COLUMBIA

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ABSTRACT

This report describes the acquisition and processing of deep-crustal wide-angle seismic reflection and refraction data obtained in the vicinity of Puget Lowland, the Strait of Juan de Fuca, and Georgia Strait, western Washington and southwestern British Columbia, in March 1998 during the Seismic Hazards Investigation of Puget Sound (SHIPS). As part of a larger initiative to better understand lateral variations in crustal structure along the Cascadia margin, SHIPS participants acquired 1000 km of deep-crustal multichannel seismic-reflection profiles and 1300 km of wide-angle airgun shot lines in this region using the **R/V Thompson** and **R/V Tully**. The **Tully** was used to record airgun shots fired by the **Thompson** in two different geometries: (1) expanding spread profiles (ESPs) and (2) constant offset profiles (COPs). Prior to this reflection survey, we deployed 257 Reftek and 15 ocean-bottom seismic recorders to record the airgun signals at far offsets. All data were recorded digitally on large-capacity hard disks. Although most of these stations only recorded the vertical component of motion, 95 of these seismographs recorded signals from an oriented 3-component seismometer. By recording signals generated by the **Thompson's** marine air gun array, operated in two differing geometries having a total volume of 110 and 79 liters (6730 and 4838 cu. in.), respectively, the arrays of wide-angle recorders were designed to (1) image the crustal structure, particularly in the vicinity of crustal faults and Cenozoic sedimentary basins, (2) determine the geometry of the Moho, and (3) image the subducting Gorda and Juan de Fuca plates. Nearly 33,300 air gun shots were recorded along several seismic lines. In this report, we illustrate the expanding spread profiles acquired using the **Thompson** and **Tully**, describe the land and ocean-bottom 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 collected using the Refteks and ocean-bottom seismometers. We also describe the format and content of the archival tapes containing the SEGY-formated, common-receiver gathers for the Reftek data. Data quality is variable but SHIPS appears to have successfully obtained useful data from almost all the stations deployed to record the airgun shots. Several interesting arrivals were observed: including refractions from the sedimentary basin fill in several basins, refractions from basement rocks forming the upper crust, Pg, refractions from the upper mantle, Pn, as well as reflections from within the crust and from the top of the upper mantle, PmP. We separately archived more than 30 local earthquakes recorded by the Reftek array during our deployment.

INTRODUCTION

In the past decade three major seismic hazards to western Washington and British Columbia have been recognized. Large (M~9) magnitude earthquakes along the Cascadia subduction zone megathrust have been proposed and documented in the geological record (Heaton and Kanamori, 1984; Atwater, 1987; Heaton and Hartzell, 1987; Hyndman et al., 1990; Hyndman and Wang, 1993; Atwater, 1996; Atwater and Hempill-Haley, 1997). Earthquakes within the subducting Juan de Fuca plate have been observed since 1940 and thus also represent known seismic hazards (Weaver and Baker, 1988). Finally, the existence of crustal faults capable of large (M~7) magnitude earthquakes within Puget Lowlands has been inferred and mapped using a variety of methods including paleoseismicity, seismicity, seismic reflection, and potential field geophysical data (Atwater and Moore, 1992; Bucknam et al., 1992; Johnson et al., 1994, 1996; Pratt et al., 1997; Wells et al., 1998; Blakely et al., in press; Weaver et al., in press).

A number of important regional seismic reflection and refraction studies have been conducted in western Washington and British Columbia. The subducting Juan de Fuca plate has been imaged beneath Vancouver Island in a number of studies (Clowes et al., 1987a, 1987b, 1995; Calvert, 1996). Onshore offshore studies on the margin of western Washington also image the subducting Juan de Fuca slab, and the geometry of the boundary between the accretionary wedge in the Olympic Mountains and the Siletz volcanics (Luetgert et al., 1992; Flueh et al., 1997; Parsons et al., 1998, in press). Other studies have examined the crustal structure in the foothills of the Cascades (Miller et al., 1997; Symons and Crosson, 1997).

In March 1998 we conducted a multi-institutional, binational seismic investigation of the crustal structure along the western margin of North America in the Puget Sound, Strait of Juan de Fuca, and the Strait of Georgia (Fisher et al., 1999). We recorded more than 33,000 airgun shots using 257 temporary seismic stations (land-based Refteks and ocean-bottom seismometers) at offsets exceeding 370 km. The purpose of the investigation was to obtain new, three-dimensional structural control on the seismogenic structures and Cenozoic basins in western Washington and southwestern British Columbia. A primary goal of this experiment was to provide compressional and shear wave velocity information for the sedimentary basin fill of the Tacoma, Seattle, and Everett Basins and the Fraser River delta to allow better forecasts of earthquake shaking effects in these urban areas (Figure 1). The new 3-D models developed from these data will be used to calculate synthetic seismograms to help understand the lateral variations of strong ground motions in the Puget Lowland urban corridor.

Geologic Setting

Recent interpretation of seismic reflection data and gravity data by Pratt et al. (1997) have led to the recognition of ramp-and-flat structures developed along north-vergent thrust faults. The Tacoma, Seattle, and Everett basins form a series of east-west oriented structural lows associated with the thrust faults (Johnson et al., 1994): Pratt et al. (1997) proposed that on the basis of the ramp-and-flat structures that a north vergent thrust sheet underlies Puget Sound. Existing seismic reflection data did not image the thrust faults beneath the sediment fill-bedrock contact. The observation that these basins coincide with the locations of Quaternary depocenters (Jones, 1994) suggests that the thrust faults remain active (Pratt et al., 1997).

Existing tomographic models for the Puget Lowland were hampered by the low number of seismic stations and relative sparsity of shallow earthquakes (Symons and Crosson, 1997). SHIPS was conducted with the understanding that an improved image of the seismic velocity structure of the crust can result only from additional seismic reflection and refraction profiling in Puget Sound. Existing hydrocarbon test wells do not provide an adequate knowledge of the geometry of the large basins in Puget Lowlands (Johnson, 1993; Johnson et al., 1993; Brocher and Ruebel, 1998).

The Seismic Hazards Investigation of Puget Sound (SHIPS) was conducted in March 1998 to address the need for an improved knowledge of the regional crustal structure in western Washington and southwestern British Columbia.

DATA ACQUISITION

R/V Thompson Instrumentation and Operations

Using the **R/V Thompson**, SHIPS participants acquired several wide-angle seismic lines as well as deep-crustal seismic-reflection profiles in Puget Sound, Strait of Juan de Fuca, and Strait of Georgia (Figures 2 to 4, Tables 1 to 3, Appendix 1). For the first several days of the experiment, Julian Day (JD) 069 to JD 077 (March 10th to 17th), the **Thompson** fired its airgun array 12,963 times without recording the signals on a seismic streamer. These airgun shots were intended solely to be recorded by the wide-angle seismic array described below, as well as by seismic stations in the permanent earthquake monitoring arrays in Washington and British Columbia. Airgun shots were fired at 40 second intervals in order to minimize shot generated noise and to allow the air compressors to recharge the airgun array. By not deploying the streamer for this part of the survey the **Thompson** was able (1) to deploy a larger airgun array consisting of 16 individual airguns (totaling 110.3 liters (6730 cu. in.)), and was also able (2) to survey in constricted waterways such as Hood Canal in which it would have been impossible with the 2.4-km-long multichannel seismic streamer deployed.

The ship started its wide-angle work in Lake Washington (Thompson Line LW1) on JD 069 (March 10th), then crossed into the Puget Sound where it first steamed south then north (Thompson Lines 2-4), and then westward into Hood Canal (Figure 4, Table 3). After completing southward and northward directed transects in Hood Canal on JD 073 (March 13th), the **Thompson** sailed westward in the Strait of Juan de Fuca. After nearly reaching Cape Flattery, the ship turned and returned to the eastern Strait of Juan de Fuca on JD 075 (March 15th), whereupon it sailed northwestward up the Strait of Georgia as far north as Texada Island (Figure 2).

Following completion of the wide-angle shooting on JD 077 (March 17th), the **Thompson** deployed a seismic streamer at the northern end of the survey near Texada Island on JD 078 (Figure 2). Deployment of the 2.4-km-long, 96-channel digital seismic streamer reduced the number of airguns which could be towed by three, yielding a smaller, 13 airgun array with a total airgun volume of 79.3 liters (4838 cu. in.). After deploying the multichannel streamer, the **Thompson** sailed southeastward through the Strait of Georgia collecting Thompson Line SG1 (Table 1), profiled past the San Juan Islands, and sailed westward into the Strait of Juan de Fuca to acquire Thompson Line JDF1. After turning eastward on JD 079 to acquire Line JDF2 the **Thompson** returned to the eastern Strait of Juan de Fuca where she sailed southward into Puget Sound to acquire Line PS1, crossing the Seattle fault (Table 1). After reaching Tacoma, the ship turned back northward acquiring Line PS2, and returned to the eastern Strait of Juan de Fuca, where it finished the survey on JD 083 (March 23rd) after completing a series of short seismic reflection lines across suspected fault zones (Thompson Lines JDF 3 to 6). During the reflection profiling the near-trace of the seismic streamer was 200 m behind the ship, the group interval was 25 m, and the far trace of the streamer was 2575 m behind the ship. The record length for the reflection data was 16 s.

Using two short (300-m) single-channel streamers towed by the **R/V Tully** to record airgun signals from the **Thompson**, 12 expanding spread profiles were acquired along the SHIPS track lines [Chopra et al., 1998; Fisher et al., 1998, 1999]. The expanding spread profiles (ESPs) were acquired as the two ships sailed apart from each other in opposite directions at the same speed, maintaining a common midpoint. Locations of the ESPs acquired using this method are shown in Figure 5 and given in Table 2. The streamers towed by the **Tully** were also used in a common-offset mode, being towed at the same distance behind the **Thompson** to effectively lengthen the recording aperture of the **Thompson's** streamer. Figures 6 to 11 provide maps showing the locations of common-midpoint locations and source-receiver offsets versus shot numbers for the 12 ESPs acquired during SHIPS. These figures show the spread of common-midpoints for each ESP. Figures 12 to 20 show the waveforms of the ESPs acquired during SHIPS.

Air gun firing times on the **Thompson** were determined from the air gun fire command time as measured on a Global Positioning System (GPS) clock. Origin times of the air gun array are believed to be accurate to within a millisecond. Navigation of the **Thompson** was also achieved using a GPS receiver; these coordinates are estimated to be accurate to within 40 m. The air gun array, composed of Bolt air guns, was generally towed at depths between 8 and 10 meters. The airgun shot locations represent locations for the midpoint of the airgun array having been corrected for the offset between the GPS antenna and the airgun array.

Table 1 provides the locations and time for the start and end of the 14 SHIPS lines recorded on the **R/V Thompson**. During our processing of the wide-angle Reftek data into common-receiver gathers we rearranged and reduced the number of airgun shotlines into 11 slightly different seismic lines (Table 3). Table 3 indicates how the airgun shots labeled on the **Thompson** were divided into the new 11 lines. Lines 1, 6, 7, and 8 are the same in both schemes.

In addition to modifying the seismic line numbers we have renumbered the airgun shot Field File Identification Numbers (FFIDs) as well. This renumbering of the airgun shot FFIDs was necessary so that each airgun shot has an unique FFID. Table 4 shows the new FFIDs used for the new lines: shots along each new line have a different unit of 10,000 added to the FFID (line number times 10,000). Appendix 1 provides a table identifying the correspondence between the FFIDs used on the **Thompson** and those used within this report for the wide-angle gathers. Appendix 1 also provides an abbreviated list of the airgun shotpoint locations and times, with information given for shots acquired at 30-minute intervals.

To avoid injury to marine mammals the air gun array was turned off when marine mammals were observed to be within a specified radius of the **Thompson's** airguns. Table 5 provides a list of times when the airgun array was turned off for this and other reasons. After shutting off the airgun array, the airgun volume was built up slowly, over a period of 30 minutes, in order not to inadvertently damage the hearing of any nearby marine mammals. Thus, the quality of airgun signals at wide-angles of incidence could be adversely affected during these airgun "ramp-ups". Table 5 also provides the Reftek FFIDs corresponding to the start of these "ramp-ups", as well as the line number and FFID used on the **Thompson**.

Wide-Angle Recording

The signals generated by the air gun array towed by the **Thompson** were recorded in a wide-angle geometry using 257 Reftek recorders. Many of the Refteks were deployed along the ships tracks to provide quasi two-dimensional lines; typically the curvature of the waterways precluded purely linear profiles.   Many Refteks were also deployed well off-line to provide better three-dimensional coverage of the survey area. Most of recorders were deployed in the Puget Lowland, along the Strait of Juan de Fuca, and along the Strait of Georgia (Figures 2 to 4). Air gun signals were recorded at ranges as close as 1 km and as far as 370 km. Appendix 2 presents the location and elevation of each Reftek station.

The digital Reftek recorders deployed consisted of five major components (PASSCAL, 1991). These components include the (1) Data Acquisition System (DAS), (2) internal or external hard disk drive, (3) internal oscillator and, in most cases, internal or external GPS Clock, (4) 3-component seismometer, and (5) external batteries. For continuous recording for the 18-day length of recording, it was necessary to supplement the small internal Reftek battery with one or two 12-V external (car) batteries. Each Reftek DAS was monitored in the field using either a Palm-Top HP Terminal (Palm-Top) or a Hand Held Terminal (HHT). The Palm-Top Terminals were used to program the DAS of each Reftek prior to their deployment, determining such parameters as the sample rate (100 Hz in our case), mode of recording (continuous in our case), and number of channels to record (1 or 3). The GPS receiver clocks had a duty cycle of 5 minutes per hour. Recording was simply halted when the instrument was retrieved after the end of shooting.

Reftek Instrumentation

Our need for a large number of recorders (257) required us to use all available IRIS/PASSCAL Refteks, of which there were 4 different models (Reftek 06’s, 07’s, 07G’s, and 08’s).   Given the large variety of data storage (hard disk) capacity and clock capabilities between these models, we briefly describe how each model was deployed during SHIPS.

The Reftek 06's were 3-channel recorders with external GPS receiver and antennas, and had relatively small 230 Mbyte internal hard disk drives. For this reason they were programmed to record a single (vertical) component. The relatively small hard drive also required that these models be downloaded at least once during the field experiment. Reftek 06’s lacking an external

GPS receiver needed to be manually pulsed every 2 days. DAS serial numbers for Reftek 06’s had four digits that started with a 6.

The Reftek 07's were 3-channel recorders with either internal or external GPS receivers and antennas, and had a variety of internal hard disk drives of 230, 500, and 540 Mbytes in size. Regardless of the hard drive size, this model was programmed to record a single (vertical) component. Those with 230 Mbyte disk drives also needed to be field downloaded at least once. Those Reftek 07’s lacking external GPS receiver needed to be manually pulsed every 2 days. DAS serial numbers for Reftek 07’s had four digits that started with a 7.

The Reftek 07G's were 3-channel recorders having internal GPS receivers and antennas. All of these models had 1 Gbyte internal hard disk drives, and thus could be programmed to record 3-component data without needing to be downloaded in the field during the experiment.

Finally, the Reftek 08's are 6-channel recorders having external GPS receivers and antennas. This model generally had 1 Gbyte external hard disk drives, and thus was programmed to record 3-components (channels 4-6) without the need for downloading data in the field. Reftek 08’s had three digit DAS serial numbers (e.g., 449).

Nearly all of the geophone sensors used during SHIPS consisted of Mark Products model L-28s, which were 4.5 Hz, 3-component seismometers. At 20 stations we deployed Mark Products model L-22 sensors, which were 2 Hz, 3-component seismometers requiring careful leveling when they are installed. The L-22 sensors were deployed at stations shown as triangles in Figures 3 and 4. The sensors at all stations that recorded 3-component data were oriented with compasses such that the N-S component was directed to **magnetic north**. Stations at which all three geophone-components were recorded are indicated in Appendix 2 and on Figures 2 to 4. Channels 1 or 4 were used for the vertical component, channels 2 and 5 were used for the N-S oriented horizontal components, and channels 3 and 6 were used for the E-W oriented horizontal components.

The power requirements of the Refteks generally required us to deploy two 12-V, 80-Amp/Hr car batteries connected in parallel at each site. Reftek model 06’s without GPS receivers with lower power requirements were deployed with only one battery. In the US, the car batteries were swapped midway through the deployment over a four day period from JD 073 to JD 076 (March 14-17). Each day approximately 50 batteries were replaced by fresh batteries and the 50 depleted batteries were charged overnight and used to replace the next set of 50 batteries the following day. For the 43 units deployed in Canada, brand-new batteries were rented. Fully charged just before deployment, all batteries lasted the full length of the experiment without recharging.

The Hand Held Terminal (HHT)/HP Palm Top Programmers used in the field were programmed by PASSCAL personnel to run a program called **Magic**. Magic allows only certain options of the Field Set-up Controller (**FSC)** program to be run, but is more robust to operator error. One drawback of both the HHTs and Palm Top Terminals is that they fail when wet. In an effort to help keep these field programmers dry, golf umbrellas were distributed to each deployment team.

For Refteks 06's and 07's lacking internal or external GPS clocks, it was necessary to manually pulse time into the Reftek every few days. This pulsing was performed using Master Clocks (which are external GPS clocks), and the Palm Top Terminals.

A new model of Field Fast Data Transfer Units were used for the first time during SHIPS. These functioned reasonably well and field downloading did not add appreciable amounts of time to station visits. To download data in the field, one first pulses time onto the DAS with the master clock. Then one stops data acquisition by the DAS using either **Magic** or **FSC** commands. Next, the internal Reftek drive is forced to spin up using commands in **FSC** (F-5, 4-SCS Power, 1-Set SCSI Pwr On). The SCSI cables are then connected between the Reftek DAS and the Fast Field Data Copy System. Next, power up the Fast Field Data Copy System by connecting its power cable either to a Reftek power port or to a battery. After a couple of minutes the LED screen on the Fast Field Data Copy System will indicate how much disk space is available and asks whether one wants to start the fast copy procedure. After completing the data transfer one disconnects power to the Fast Field Data Copy System and disconnects the SCSI cables to the Reftek DAS. The final step is to reformat the Reftek DASs internal disk to allow more data to be recorded by that station using FSC commands.

As protection from the elements, the equipment was deployed in firm plastic enclosures (Action Packers) at each station to help keep the Reftek DASs, GPS antennas, and batteries dry. The Reftek 08 units did not fit within standard size of enclosures, however, and required the GPS antenna or batteries be deployed outside of the plastic enclosure.

Station Data Acquisition

All Refteks were programmed to record the following parameters: (1) continuous recording with a sample rate of 100 Hz, (2) recording to start at the time of deployment, (3) recording to be halted at the time of retrieval, and (4) the continuously recorded data were divided into 30-minute-long events in the USA (and into 60-minute-long events in Canada). As described earlier, the different Reftek models each had their own program: (1) 06-con (continuous recording of Reftek 06's), (2) 07_con (continuous recording of 07's), (3) 07G540-c (continuous recording of Reftek 07's having 540 Mbyte drives), (4) 07G1_con (continuous recording of Reftek 07G's having 1 Gbyte drives), (5) 08_con (continuous recording of Reftek 08's).

Almost all Reftek recorders were deployed over a four-day period from JD 066 to JD 069 (March 7 to 10th). In the USA the number of Reftek DASs was sufficient so as to not require moving DASs between stations, DASs which failed were replaced by spares. Thus, at 11 USA sites there were more than one DAS unit deployed at a single site (Stations 1007, 1009, 2004, 2012, 4004, 4006, 6010, 7006, 7012, 9012, 9030; Appendix 2). Therefore, the records obtained by the two (or in some cases more than two) DASs at a station needed to be processed to sample all the SHIPS lines. In the USA, only the DAS (#7466) along the Strait of Juan de Fuca at station OR12 (9012) was moved westward to station OR26 (9026) near Cape Flattery (Figure 2).

There were not, however, sufficient DASs available to the Canadian participants to allow them to simultaneously occupy all the desired sites. For this reason, 12 DASs were used to obtain wide-angle data at 21 stations (Table 7). Almost all of the stations along the eastern side of the Georgia Strait (Stations 11030-11033 and 11043-11053) remained at the same station for the entire SHIPS experiment. Of the Canadian DASs that were moved (Table 7), those on southern

Vancouver Island (Figure 2), including Stations 11001-11002 recorded Lines 3-5 only, Station 11003 recorded only Lines 3 to 11, and Stations 11010-11011 and 11013 recorded Lines 4 and 5 only. Along the west side of Georgia Strait, Station 11023 recorded only Lines 1 to 3, and Stations 11024-11029 recorded all lines except Line 4. On the deployment across the Coast Belt (Figure 2), Stations 11033-11037 recorded only Lines 1 to 5, and Lines 11038-11042 recorded Lines 6 to 11. In some cases more than one DAS was used to record data at a station (Table 7), although no DASs recorded data at the same station simultaneously. This mode of operation introduced considerable complexity into the processing flow for these DASs as described below.

The first airgun shots were fired in Lake Washington at 1924 Universal Time (UTC) on JD 069 (March 10th). The last airgun shot was fired in the eastern Strait of Juan de Fuca at 0345 UTC on JD 083 (March 24th). Retrieval of the Refteks started on JD 083 (March 24th) and ended JD 085 (March 26th). The Refteks that had been deployed in the USA and in Canada were separately shipped back to the PASSCAL Instrument Center at Palo Alto.

Station Locations and Elevations

Wide-angle recorders were deployed by teams from the U.S. Geological Survey and the University of Texas El Paso (stations 1001-8014), by Oregon State University (stations 9001-9031 [also referred to as OR01-OR31], there being no station 9020 [OR20]), by the University of Washington (stations 10001-10060 [also referred to as UW01-UW60]), and by several Canadian groups (stations 11001-11053 [also referred to as CA01-CA53]) (Figure 2, Appendix 2). Each team was responsible for deploying and maintaining between 10 and 14 stations. For stations 1001-8014 the station numbers generally increase to the south and to the west, for stations OR01-OR31 (9001-9031) the station numbers increase to the west, for stations 10001-10060 the station numbers increase to the south and east, and for stations 11001-11053 the station numbers increase to the north (Figure 2). The locations of the 9 USGS ocean-bottom seismometers (UOBS1-UOBS9), 6 Canadian ocean-bottom seismometers (COBS1-COBS6), and 13 strong-motion stations deployed in West Seattle by the USGS/Golden are provided at the end of Appendix 2. The data from these 13 strong-motion stations, which consisted of DR200, K2, and Reftek seismic recorders, are not described here.

Almost all Reftek stations had built-in or auxiliary GPS receivers which provided estimates of the station latitude, longitude, and elevation (Appendix 2). Thus the coordinates in Appendix 2 generally represent the average GPS location for the 17 days of GPS data recorded once an hour (providing 408 separate measurements). Estimated average uncertainties (1 standard deviation from the average location) of the latitudes and longitudes are about 50 m. Station elevations for the USA stations (1001 to 10060) were determined from a digital version of USGS topographic maps using GPS coordinates for the latitude and longitude. The agreement was generally within 20 meters: we observed a bias of 18 m caused by differences between the GPS and the USGS datums. Although this difference is small, we used the elevations provided by USGS topographic maps as the station elevation (these are the elevations written in the trace headers). As an additional check on the accuracy of the Reftek GPS locations, the Reftek locations for stations 10001-10060 were checked against preliminary GPS locations made at these stations made using a portable GPS receiver. Because the actual Reftek location sometimes differed from these preliminary sites, the median difference of 119 meters suggests that the Reftek GPS latitudes and longitudes are sufficiently accurate for wide-angle studies.

Only 25 USGS and Oregon State University stations either lacked a GPS receiver or did not obtain a GPS lock and thus provided no GPS coordinates. For these stations the locations and elevations were picked from digital USGS 7 1/2 minute topographic maps on CD-Rom. These stations are indicated on Table 3.

The station coordinates and elevations for the Canadian stations (11001-11053) were determined slightly differently. These coordinates, deemed informally as not-quite differential GPS, relied on single-site GPS, with corrections using precise clocks and orbits. The latitudes and longitudes were checked against those determined using the internal or auxiliary GPS receivers (the median difference of the two different GPS measurements was 43 m). All the elevations for the Canadian stations were determined from not-quite differential GPS measurements. The reference datum used was NA83 (this is almost the same datum as the WGS84 datum used by the GPS units in the Refteks). The original GPS elevation (ellipsoidal height) was corrected to height above sea level by subtracting the geoid height. Geoid heights for our area, determined from a commercial program, varied mainly with latitude, and so corrections were applied assuming the following geoid heights:

Latitude Range	Geoid Height
<49.25	-17 (±2) m
49.25-49.75	-16.6 (±0.4) m
49.75-50.25	-14.8 (±0.5) m
50.25-50.75	-13.4 (±0.2) m
>50.75	-11.8 (±0.3) m

The quoted height error is just the approximate variation in height along the given line of latitude in our area, and should really be added to the RMS-elevation values in Appendix 2. The median difference between these elevations and those provided by the GPS units within the Refteks themselves is -19 m, close to the correction applied from the above table.

Very few (about 3) of the Reftek stations were vandalized and none were stolen. The station at 4013 was vandalized and the geophone cable was severed.

<u>USGS OBS Deployment</u>

To simplify the field logistics, the 9 USGS OBSs (UOBS1 to UOBS9) were deployed only once in Puget Sound, and thus each were used to record at a single site (Figure 4). All USGS OBSs were placed on fine sand and muddy sand bottoms at least 1.5 km from the nearest ferry route or anchoring area and in waters which are believed to have tidal currents of generally less than 0.5 knots. These criteria for selecting OBS locations were used to increase OBS coupling to the seafloor and to reduce water column noise. OBS anchors were fashioned from a perforated flat metal plate 1.02 meters (40") in diameter and weighing 45.4 kgs (100 lbs.).

OBS locations were determined using differential GPS navigation and are believed to be accurate to within 1-2 meters. Depths were determined using available bathymetric maps and are believed to be accurate to within 10 meters. The USGS OBS locations and water depths are provided in Appendix 2.

The OBSs were deployed and retrieved using the **SP Stanley Hayes**, a 12 m vessel owned and operated by NOAA-PMEL in Seattle.   Personnel on the **Hayes** included Gregory Speer (skipper, NOAA-PMEL), Uri ten Brink (scientist, USGS-Woods Hole), Gregory Miller (OBS engineer, USGS-Woods Hole), Michael Taylor (deck hand, USGS-Woods Hole), and Alvin Buchholtz (deck hand, volunteer). The OBSs were deployed with three relocation aides: Strobe, VHF Radio beacon, and acoustic transponder. The OBSs were acoustically released, and have ranging capabilities.

The USGS OBSs were deployed on JD 065 (March 6th) and were programmed to start recording continuous data at 2000 UTC on JD 067 (March 8th). Recording by the OBSs ended upon recovery of the OBSs on JD 084 (March 25th). The OBSs digitally recorded data at 100 samples/second.   All the OBSs were equipped with Seascan clocks with accuracy of $1x10^{-8}$ sec^{-1} or a drift of ~1 msec per day. A linear drift rate was assumed for the duration of the experiment and times were corrected accordingly. Four channels were recorded by the OBSs, including three from a gimbaled, 3-component 4.5 Hz L15B seismometer and one from an OAS E-2S hydrophone.

Two of the USGS OBSs failed upon deployment and two others failed midway through the experiments. OBS7 (A8) failed after writing 680 tracks (226 hours, 9.4 days) due to a disk write failure. OBS4 (C4) failed after writing 170 tracks (56 hours, 2.3 days) due to disk write failure. Data on both were recovered and are usable until the time of OBS failure. OBS6 (D4) did not record valid data due to a failure of the power supply to the sensors at the time of deployment. OBS2 (A3) did not record valid data due to a bad voltage regulator.

Additional specifications about the USGS OBSs are provided in the following tables.

USGS OBS Specifications

Dimensions (meters):	Width	Height	Weight in air (kgs):
on deployment	1.02 (40")	0.97 (38")	170 (375 lbs.)
on recovery	0.69 (27")	0.97 (38")	125 (275 lbs.)

Dynamic range of recording system: 72 dB (A/D converter) + 30 dB (1-step gain range) for each data point.

Data format: Binary with header information for each 1 Megabyte of data

USGS OBS Deployment and Recovery Times (Universal time)

OBS No.	Time of Deployment on JD 065 (March 6) Hr:Min	Time of Recovery on JD 084 (March 25) Hr:Min
A4	17:46	17:21
C1	18:35	18:04

A8	19:07	18:37
D4	19:48	19:16
D1	20:58	19:58
C4	21:34	23:30
A1	22:15	22:56
A3	22:42	22:29
C9	23:19	21:23

The USGS OBS data were converted to SEGY format after retrieval of the OBSs. The FFIDs written to the trace headers of these gathers are for the shot FFIDs used on the **Thompson**, and are not those assigned here to the Reftek data. Record sections from the six successful USGS OBS deployments are shown in Figures 21 to 26.

Dalhousie OBS Deployment

The six Dalhousie University OBSs (COBS1 to COBS2) were deployed in Georgia Strait from the **CGS Vector** on JD 066-067 (March 7-8), by Keith Louden and Bob Iuliucci (Figure 2). Like the USGS OBSs, these OBSs recorded signals from 3 orthogonal geophone components and one hydrophone (see technical specifications below). Coordinates and water depths of the Dalhousie OBSs are provided in Appendix 2. The programmed recording durations were 9 days, starting on 08:00 UTC on JD 073 (March 14th). All 6 OBSs were successfully recovered using the **CCGS Tully** (see table of deployment and recovery times below). However, one OBS (COBS6) failed to record data due to a fault in the cable to the hard disk and one (COBS5) stopped recording before the programmed end time for unknown reasons. Thus, five of the Dalhousie OBSs provided useful data. An example of these OBS data is shown in Figure 27, showing data from COBS1 recorded during Line 6 in the Strait of Georgia. This record section has been plotted with an automatic gain control of 2 seconds in duration. The FFIDs written to the trace headers of these gathers are for the shot FFIDs used on the **Thompson**, and are not those assigned here to the Reftek data.

Dalhousie OBS Technical Specification

Item	Specification
Housing/Platform	Uses existing design of BIO-OBS (6 km maximum water depth). Weight in air: instrument (82 kg); anchor (55 kg) Size: 1.1 m high, 1.2 m long, 0.6 m wide
Release	12.5 kHz Acoustic command and timed backup
Duration of recording	9 days @ 5.7 msec sampling of 4 channels (16 bit) 2 days @ 0.8 msec sampling of 4 channels (12 bit)
Sampling rates/ dynamic range	23/11.5/5.7/2.9/1.4 msec @ 16 bit (AD7716 Sigma-Delta ADC) 1.6/0.8/0.4/0.2 msec @ 12 bit (Tattletale 7 ADC)
Anti-alias filter	Switched-capacitor, software selectable with corner freqs of 12.5, 25, 50, 100, 200, 500, 1000 Hz
Gain	Fixed settings hardware selectable geophones (69-93 dB); hydrophone (46-70 dB)
Max electrical noise	< 125 nVrms on geophone input < 1uVrms on hydrophone input
Clock	Austron 1115 OCXO 5 MHz (drift<1 msec/day)
Data storage	2 Mb RAM stored as separate files on 1 GB Toshiba HD
Sensors	3-component geophone package (oil filled): 4.5 Hz (Mark L-15B or L-28; 380 Ohm coil with 0.7 damping) 100 Hz (Oyo GS-100; 975 Ohm coil with 0.7 damping) hydrophone (OAS E-2SD)
External connectors	4-pin (RS-232 communication and time pulse) 3x1-pin (hydrophone and release)

Batteries	D-cell alkaline (clock), lifetime > 21 days
	D-cell alkaline (analog and digital and data logger)
	acoustic release 9-volt alkaline (electronics)
	9-volt alkaline (pinger and release)
Data transfer rates to PC	TT7 parallel interface to AT-DIO-24 (100 kbyte/s)
Recovery Aids	Strobe and radio beacon (Novatech ST400A, RF700A-1)
	12.5 kHz pinger (ITC 3013 transducer)

Dalhousie OBS Deployment and Recovery

Station	OBS ID	**CCGS Vector** Deployment Time (UTC)	**CCGS Tully** Recovery Time (UTC)	Recording Start Time (UTC)	Recording Stop Time (UTC)
COBS1	A	3/7/98 2035	3/24/98 2300	3/14/98 0800	3/22/98 2255
COBS2	C	2206	2148	3/14/98 0800	3/22/98 2255
COBS3	B	2306	2030	3/14/98 0800	3/22/98 1043
COBS4	D	3/8/98 0006	1910	3/14/98 0800	3/22/98 2255
COBS5	E	0111	1705	3/14/98 0800	3/17/98 1814
COBS6	F	0245	1605	No Recording	

REFTEK DATA REDUCTION

Processing Sequence:

In the following discussion, the names of software programs, scripts, and shells are highlighted in **bold**.

1) DASs that failed in the field and those DASs with small internal disk drives (<230 Mbytes) (for Stations 1001 to 9031) were downloaded in rawrefdump format at the Kitsap County Fairground field headquarters at Silverdale, Washington. These rawrefdump-formatted files were converted into SEGY format using **ref2segy**, were stored on disk, and archived onto multiple DLT tapes.

2) The remaining DASs (stations 1001 to 9031, 10001 to 10060, 11001 to 11054) were trucked back to the PASSCAL Instrument Center at Stanford University between March 26th and 27th.

3) At the PASSCAL Instrument Center at Stanford University, these latter Refteks were downloaded using a special shell created for SHIPS called **download.sh**. This script

downloaded the data from the Refteks and wrote the data in rawrefdump format to several 20-Gbyte disks. In addition, the **download.sh** shell wrote the rawrefdump data to archival DLT and DAT tapes. Files created during this process are named Station#.DAS serial #.Channels.Day1:Day2, where Day1 is the first Julian Day with acquisition, and where Day2 is the end day of acquisition [e.g., B2012.0149.456.068:083]. Logfiles for each downloaded Reftek were generated using the **ref2log** utility. Prior to running the **download.sh**, it was necessary to (1) connect power to the Reftek DAS unit to cause the internal disk to spin up, and then for some DAS models, to (2) use **FSC** on a Palm Top Programmer to force the internal disk to spin up (F5, 4-SCSI Power, 1-SCSI Power On), and then (3) to connect the SCSI cable to the Reftek DAS. The order in which these three steps are performed is important. Typically, the volume of data downloaded at this stage varied from about 100 Mbytes for one-component stations that had been downloaded in the field to 1000 Mbytes for a 3-component station that had not been downloaded in the field. Altogether, nearly 100 Gbytes of rawrefdump-formatted data were acquired during SHIPS.

Several DASs could not be fully downloaded due either to hard disk problems or disk initialization problems. After repair of the disks, data for stations 1011, 1016, 9007, 9008, 9015, 9028, 9030, 10001, 10011, and 10049 could be fully downloaded minus a nearly insignificant loss of data. Data from station 1010, however, could not be read back after JD 077.

Downloading of the SHIPS data at PASSCAL Instrument Center was started using 3 separate workstations on April 1st, 1998 and was completed April 20th, 1998.

4) The logfiles generated at the Kitsap County Fairground field headquarters and at the PASSCAL Instrument Center at Stanford University were collected into a single directory.

5) GPS locks recorded in the logfiles for each station were then averaged to provide GPS estimates of the station location and elevation using the program **position**. Stations for which no GPS location was provided (due to the absence or failure of the GPS receiver), are indicated on Appendix 2.

6) A file containing the station number, DAS number, the station longitude, latitude and elevation was compiled. Refteks that had been moved between stations were noted (Table 7). A set of receiver files was generated that noted when the Refteks were moved. If a Reftek was moved between stations during the acquisition of a seismic line, the shell then generated a separate common receiver gather for each location for that seismic line. Thus, some of these stations have 12 or 13 lines instead of the nominal 11 lines.

7) A script was written (by B.C. Beaudoin) to look for possible clock timing errors in the Reftek logfiles. Flags were set if the number of GPS locks for a Reftek DAS was less than 20, corresponding, on average, to less than one GPS lock per day. In this case, the script then looked for pulses manually pulsed into the Reftek memory during the deployment. If the number of manual pulses was less than 4, corresponding to one pulse every 4 days, then the Reftek was flagged as having potential timing errors. If the number of pulses was greater than 4, then in subsequent processing the timing correction program **refrate** was automatically called. Flags were also raised if the first GPS lock (or pulse) was not on the deployment day or is the last GPS lock (or pulse) was not on the retrieval day. At some stations, the Reftek DAS clock timing is based on both GPS and manual pulses.

During subsequent processing, we visually inspected the clocks in every logfile using **clockview**. Clocks which had more than 20 GPS locks but which lost lock for significant intervals, usually longer than a day, were noted and if the internal clock drift was in excess of 20 msec, **refrate** was run manually. Appendix 3 provides, for each station, a list of whether the clock timing used for the station was based on GPS locks or manual pulses or both, and whether **refrate** was run for the station. The reason why **refrate** was run is also usually given. This appendix also provides a brief description of the quality of the GPS locks (amount of clock drift between time jerks), the quality and quantity of manual pulses, and any other timing (e.g., GPS failure, too few manual pulses) or data acquisition problems noticed for each station during processing.

8) The locations of the rawrefdump-formatted and SEGY-formatted data on all the various hard disks were tabulated in a look-up table.

9) As previously described the >33,000 airgun shots were divided into 11 shot lines based on the locations of the ship. This list of airgun shots is given in Table 4 and Appendix 1.

10) The source-receiver range in integer meters for each airgun shot and every station were calculated and placed in separate files for every DAS and each of the 11 shot lines (by T. Parsons).

11) An interactive shell was written and tested by B.C. Beaudoin and M.G. Alvarez to generate common-receiver, SEGY-formatted, gathers from the rawrefdump-formatted data. Although this shell, named **SegyGather.csh**, could not be fully automated it attempted to maximize the

automation of the data processing. In this shell all processing was referenced to the Reftek DAS serial number. This shell required several steps for each station:

a) The shell first requested a DAS serial number for processing. It then looked for the data on disk for the desired DAS either in rawrefdump format or in SEGY format. It notified the operator if no data were found on disk. In this case the data in rawrefdump format were read from archival tape to disk using **ref2segy -t /dev/rmt/3n** (after positioning the archival tape to the first file of the desired station data using **mt -f /dev/rmt/3n fsf I** where I=0,3,6,9,12, etc.). The program **ref2segy** also converted the data from rawrefdump format to SEGY format and generated logfiles for the data.

b) **SegyGather.csh** then ran **ref2segy** on all rawrefdump-formatted data and placed the converted SEGY data into directories for each Julian Day, e.g., R070.01.

c) The shell determined whether all the logfiles were available on disk or whether any logfiles needed to be imported from /export/home/field/SHIPS98.workingfiles/logfiles. Duplicate logfiles were also identified so that they could be eliminated manually.

d) From the logfiles the shell determined whether **refrate** timing corrections were needed using the logic previously described. This step was verified by the operators by visually examining a plot of the clock logfile using **clockview**. If the GPS clock drifted less than 10 msec between time corrections (time jerks) at intervals less than a day throughout the deployment, then no timing corrections were needed. If not, or if the Reftek was manually pulsed, program **refrate** was run to create Passcal Correction Files (.pcf) from the DAS log files [e.g., **refrate** *.DAS#.log >DAS#.pcf] to correct the timing on the recorded data. Appendix

3 provides documentation of whether **refrate** was run for each station, and usually indicates why.

e) The shell then checked for missing 30-minute-long or 60-minute-long events from the SEGY data for each Julian Day. Links to these data were placed in /tmp/Inputlistn, where n represented the seismic line number (1 to 11). Missing data were flagged for the operator's notice. Usually missing data were located at the beginning and end of the deployment, but were also noted when stations were visited during the deployment.

f) **SegyGather.csh** next created scripts to write SEGY-formatted common-receiver gathers to archival tape using **segygather**. These scripts wrote two identical DLT tapes and one DAT tape for each line recorded by every DAS. The scripts were named writetape0, writetape1, and writetape3 and wrote to the /dev/rmt/0 (DLTA), /dev/rmt/1 (DAT), and /dev/rmt/3 (DLTB). Channel 1 = vertical geophone, Channel 2 = N-S oriented horizontal geophone, and Channel 3 = E-W oriented horizontal geophone. [For the six-channel Reftek 08's, Channel 4 = vertical geophone, Channel 5 = N-S oriented horizontal geophone, and Channel 6 = E-W oriented horizontal geophone.] This script wrote the source and receiver locations and elevations (in meters) for each trace. **Note that the latitudes and longitudes in the trace headers must be divided by 36,000 to yield decimal latitude and longitude in degrees.** Unfortunately, we were not also able to write source and receiver locations in other coordinate systems to the trace headers using this script.

g) At this point the shell provided the operator the opportunity to proceed to write the gathers to tape or to quit the program. This option gave the operator the opportunity to verify (1) that the tape drives were correctly positioned, (2) that links to the SEGY data had been properly made, and (3) to determine that the pathnames in the writetape0, writetape1, and writetape3 scripts were correct. At this stage the operator edited the writetape0, writetape1, and writetape3 scripts so that the pathnames for the source-receiver range tables for the Reftek 08's were correct (the leading zero on these DASs were inadvertently left off of these files).

h) The shell ran the **segyreelmod** program to add the source-receiver offsets to the headers for each trace. Note that only the absolute value of source-receiver offset, in integer meters, was written in the header. No value was assigned for the signed source-receiver offset.

i) The script then ran **segymerge** to make separate traces for earthquakes from a list of 62 local earthquakes and quarry blasts that occurred during our deployment. These earthquakes were stored in SEGY format in the EQ directory for each working directory and then archived to tape using **tar** commands. The earthquakes and blasts archived to tape are listed in Table 6. Events listed in either the University of Washington (UW) or the Pacific Geoscience Centre (PGC) earthquake catalogs were archived. Events 120001 to 120036 are events from the UW catalog. Events 120037 to 120062 are from the PGC catalog. Events 120014 and 120046 represent the same earthquake recorded by the two different arrays, it is a magnitude 2.7, low frequency earthquake located 4.5 km ENE of Mount Baker. This event was the largest local earthquake which occurred during our deployment. Ninety seconds of unreduced data were saved for each event. A separate SEGY trace is saved for each event and each receiver. Thus, for each tape the traces are saved in 62 separate directories, one for each event, with a variable number of traces, representing a separate trace for each component recorded at a station (up to a maximum of about 410). The data values for each trace are preceded by a 240 byte header. The format of the header is given in Appendix 6. All integer values are stored with the most significant byte first. Data values are 16 or 32 bit integers depending upon byte 206 of the header. Tape copies are available from the

IRIS/PASSCAL Data Management Center. Although there is a SEGY trace header for each trace, there is no IBM SEGY tape label header.

j) A script was written (by N.P. Symons), named **catalog_tape**, to verify the contents of each DLT tape and to determine the location on the tape of any zerofiles, discussed below.

Notes on Data Reduction:

1) During the data reformatting data volumes were expanded by a factor of 3.6. The ninety-second records of unreduced data archived for each airgun shot resulted in the following approximate data volumes for each station: (1) 0.6 Gbytes for a single-component Reftek Model 06, (2) 1.2 Gbytes for a single-component Reftek Model 07, (3) 3.6 Gbytes for a three-component Reftek Model 07 or 08.

2) A list was tabulated showing the location of the Reftek station data on the archival tapes (Appendix 5). The three major columns in Appendix 5 show the file numbers written to the two DLT tapes and a DAT tape for each DAS (station). This table is valuable because the processing of stations was not always in numerical order. At first, stations having 12 second jumps were skipped; the table lists where these skipped stations may be found. Also, at some stations the processing was redone when errors were found in the initial processing. For instance, when the program was improperly used the files written to the tape would contain lines without any traces. In Appendix 5 we call these files **zerofiles**, and many commercial software packages can not read them. However, using **mt -f /dev/nrst5 fsf** and **mt -f /dev/nrst5 bsf** commands, it is possible to space through these zerofiles. The zerofiles are more prevalent on the first few tapes written than for the later tapes made. Horizontal component data on Channels 3 and 6 were inadvertently written on the first few tapes instead of vertical component data for

Channels 1 and 4. For this, and many other reasons, data from a station were processed more than once to insure that all the useful data were processed properly.

The most useful data for a station will be that last archived to tape. A short unix program useful for copying all or parts of the SEGY Reftek tapes is provided at the end of Appendix 5.

3) Several stations which did not record all or parts of seismic lines were noted. In the comments columns of Appendix 5 we note any seismic lines for which there are no data for the Reftek DAS. Data generally are lacking due to DAS failure. In addition, a handful of stations produced little or no useful data including: stations 1001, 10006, 10029, and 10041.

4) During processing we noted that 29 Refteks using a particular series of external hard drives experienced 12 second jumps. The affected stations and data are tabulated in Appendix 4. A special shell (**fix12secbug**) was used to correct this problem for each of these stations. In Appendix 3 we indicate whether, when **fix12secbug** was run, there was any problem detected in the logfiles. If not, no further processing was required. If so, then it was necessary to run the scripts generated by **fix12secbug**.

5) The shell described above initially did not successfully process all three components of the 3-component stations. For this reason, we chose to first process the vertical component data for all stations, and then following completion of this task, we processed the horizontal components of the data. Appendix 5 lists where the horizontal components for each of these stations may be located on tape.

6) The Reftek clock at several stations either was not reset from or was inadvertently reset to the default year of **1988** (these stations are identified in Appendix 3). To fix these problems the logfiles of these stations were edited to replace 1988 by 1998 and the event file names were renamed from 1988 to 1998. In addition **segyreelhdr** was run to change 1988 to 1998 in the event files.

7) The complete SHIPS wide-angle dataset reformatted to SEGY common-receiver gathers requires 32 DLT tapes (10 to 20 Gbytes each) and 214 DAT tapes (2 to 4 Gbtyes). All tapes are labeled as indicated on Appendix 5.

8) The processing of the rawrefdump-formatted data into SEGY-formatted common-receiver gathers started on July 20th, 1998 and was completed September 3, 1998 using 2 separate workstations.

Passcal Modified SEGY Trace Format

The common receiver gathers generated from the digital Reftek tapes were written in an unreduced travel time format. Ninety-seconds of data were saved for each trace, starting at the airgun origin time. At a sample rate of 10 ms, there are 9001 samples per trace, for a block length, including header, of either 18242 or 36244 bytes per trace (depending on whether the data are 16 or 32 bit integers, see the next paragraph). The time interval between traces is 40 s for the wide-angle lines (FFIDs 10001-53190) and approximately 20 s for the multichannel seismic reflection lines (FFIDs 60001-112711).

The common receiver gathers were written in SEGY format to DLT and DAT tape by the **segygather** program. SEGY trace header formats described by Barry et al. (1975) were modified slightly, as described in Appendix 6. The modification comes from the fact that we use some of the unspecified header words to store information pertinent to the PASSCAL data. The data values for each trace are preceded by a 240 byte header. The format of the header is given in Appendix 6. All integer values are stored with the most significant byte first. Data values are 16 or 32 bit integers depending upon byte 206 of the header. Tape copies are available from the IRIS/PASSCAL Data Management Center. **Note that the latitudes and longitudes in the trace headers must be divided by 36,000 to yield decimal latitude and longitude in degrees.**

DATA QUALITY

Examples of the Reftek data recorded during SHIPS are provided in Figures 28 to 41. These figures illustrate a very limited subset of the available wide-angle data. Figures 28 and 29 show data recorded along the south shore of the Strait of Juan de Fuca. Figures 30 to 32 show data recorded along the Strait of Georgia. To illustrate the station-to-station variability in data quality, Figures 33 to 39 show data recorded on Whidbey Island at adjacent stations 1011 to 1017. Figures 40 and 41 show data recorded in the southern end of Puget Lowland. Although the quality of the wide-angle data recorded on land ranged from excellent to poor, in Figures 28 to 41 we present the higher quality data. On balance, most stations provided usable data to source-receiver offsets of at least 40 to 50 km, although airgun signals can be observed to much greater ranges at remote bedrock sites. Airgun signals are difficult to detect at some soft soil sites in urban or suburban localities. In some of these locations, very few interpretable data were recorded.

Weather conditions more favorable than might be expected during March were encountered, and this favorable weather undoubtedly contributed to the data quality. There were few extended periods of high winds during the experiment.

DESCRIPTION OF THE DATA

The Reftek and OBS data acquired during the SHIPS experiment show several interesting seismic arrivals. Refractions and direct arrivals from the sedimentary basin fill were well recorded as first and secondary arrivals by both the OBSs and Refteks (e.g. Figures 23, 27, and 40). Refractions from the upper crust, Pg, were routinely recorded (Figures 12 to 41). Many Pg arrivals from shots from the Strait of Juan de Fuca and the Strait of Georgia have apparent velocities close to 6.5 km/s (e.g. Figures 29 to 31), suggesting a relatively high-velocity upper and middle crust. Refractions from the upper mantle, Pn, can be observed (Figure 32, ranges greater than 200 km). Large-amplitude secondary reflected arrivals are prominent on records from shots along the Strait of Juan de Fuca (e.g. Figures 29 and 30). Travel times of arrivals from shots within the Puget Lowland show pronounced delays associated with the Tacoma, Seattle and Everett basins (e.g. Figures 33 to 41). The Seattle fault is associated with a significant travel time delay (e.g., Figure 40 between km 54 and 60).

Three examples of local earthquakes recorded during our Reftek deployment are shown in Figures 42 to 44. In these plots, the traces are ordered from nearest to farthest from the earthquake epicenters. Only data from stations in Puget Sound deployed by the USGS and the University of Washington (1001-8014, 10001-10060) have been plotted in these figures. The plots have been reduced using a velocity of 6.8 km/s and the traces have been shifted down by 5 seconds to illustrate the noise prior to the first arrivals. The events shown in these figures, 120006, 120018, and 120028, are the best recorded earthquakes and produced the largest signal-to-noise ratios observed during our SHIPS Reftek deployment. Shear-wave arrivals are clearly observed on events 120006 and 120018 and are less clear for event 120028.

DATA AVAILABILITY

Tape copies of the Reftek seismic data may be ordered via email from the IRIS/PASSCAL Data Management Center (DMC) in Seattle, Washington. The current email address of the Incorporated Research Institutions for Seismology (IRIS) Consortium is: www.iris.edu. The current general email address for the IRIS DMC is webmaster@iris.washington.edu. The current address of the IRIS DMC is: 1408 NE 45th St., Suite 201, Seattle, WA 98105. telephone (206) 547-0393. Tim Ahern is currently the Program Manger of the IRIS Data Management System at Seattle.

The text of this Open-File Report is available via anonymous ftp. The anonymous ftp address is: andreas.wr.usgs.gov. Change the directory (cd) to /pub/outgoing/puget. The text is in a file named OFR99314.

A short unix program to copy all or part of the SEGY tapes of the Reftek data is provided at the end of Appendix 5. This program copies tapes containing zerofiles.

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TABLE 1. R/V **Thompson** Line Locations and Acquisition Times During 1998 SHIPS

Start of Line UTC JD HR MN	Latitude	Longitude	End of Line UTC JD HR MN	Latitude	Longitude
Line 1 - LW1 - Lake Washington (Wide-angle)					
069 19 24	47.68941	-122.24087	069 22 59	47.69338	-122.24801
Line 2 - WA1 - Western Puget Sound from Seattle to entrance of Carr Inlet					
070 10 03	47.71172	-122.49077	070 17 31	47.21594	-122.59340
Line 3 - WA1 - Carr Inlet to southern end of Possession Sound (Wide-angle)					
070 19 23	47.32157	-122.72075	071 23 42	48.14034	-122.38664
Line 4 - WA1 - Saratoga Passage (Wide-angle)					
072 01 21	48.05701	-122.32777	072 05 59	48.24547	-122.57020
Line 5 - WA1 -Hood Canal, Strait of Juan de Fuca, Strait of Georgia (WA)					
072 14 27	47.82988	-122.39290	077 01 28	49.79598	-124.69054
Line 6 - SG1 - Strait of Georgia southbound (MCS)					
078 00 33	49.69853	-124.71415	079 08 50	48.21493	-123.30816
Line 7 - JDF1 outbound (MCS)					
079 09 02	48.21226	-123.32931	079 21 13	48.53839	-124.64211
Line 8 - JDF2 inbound (MCS)					
079 23 48	48.40921	-124.61268	080 17 59	48.09106	-122.66223
Line 9 - PS1 southbound (MCS)					
080 18 00	48.08977	-122.66191	081 06 19	47.31891	-122.46395
Line 10 - PS2 northbound (MCS)					
081 06 27	47.32112	-122.44772	082 11 28	48.12793	-122.87618
Line 12 - JDF3 (MCS)					
082 11 40	48.11703	-122.89047	082 17 44	48.41048	-123.12624
Line 12 - JDF4 (MCS)					
082 17 44	48.41048	-123.12624	082 22 13	48.18368	-123.26686
Line 13 - JDF5 (MCS)					
082 22 15	48.18513	-123.26546	083 02 22	48.40327	-123.02095
Line 14 - JDF6 (MCS)					

083 02 23	48.40314 -123.01924	083 03 45	48.31285 -123.01163

TABLE 2. Expanding Spread Profiles (ESPs) Locations and Offsets

ESP	Location	Northing (m)	Easting (m)	Min./Max. Offset (m)
1	Hood Canal	5273000±2000	507250±1750	0/60000
2	E. Strait of Juan de Fuca	5337500±4000	513800±2000	2000/48000
3	W. Strait of Juan de Fuca	5358000±300	423900±1250	0/80000
4	Strait of Juan de Fuca	5347900±2000	417500±2500	100/72000
5	Strait of Georgia	5411500±450	494850±1000	0/46000
6	Strait of Georgia	5273000±2000	507200±1750	0/46000
7	Strait of Georgia	5510500±700	397500±500	0/36000
8	Puget Sound	5264000±2500	540500±2500	8000/50000
9	Puget Sound	5270200±2000	543000±2000	2000/60000
11	E. Strait of Juan de Fuca	5347600±800	483500±2500	5000/29000
12	E. Strait of Juan de Fuca	5348200±600	488400±400	0/34000

Note: These UTM coordinates are given for Zone 10.

TABLE 3. Revised Line Numbers and FFIDs for Making SEGY Common-Receiver Gathers

Reftek Line No.	Geographic Location	Thompson Line Number and FFIDS
Line 1	Lake Washington	Line 1 (LW), FFIDs 001-324
Line 2	Puget Sound southbound (western passage)	Line 2, FFIDs 0001-0633
	Carr Inlet	Line 3, FFIDs 0001-0180
	Puget Sound	Line 3, FFIDs 0181-0310
	Lower Puget Sound south bound	Line 3, FFIDs 0311-0580
	Lower Puget Sound north bound	Line 3, FFIDs 0581-0838
	Puget Sound northbound (eastern passage)	Line 3, FFIDs 0839-2403
	Saratoga Passage	Line 4, FFIDs 0001-0419
Line 3	Puget Sound westbound	Line 5 (WA), FFIDs 0001-0223
	Hood Canal southbound	Line 5 (WA), FFIDs 0224-1259
	Hood Canal northbound	Line 5 (WA), FFIDs 1260-2200
	Puget Sound northwestbound	Line 5 (WA), FFIDs 2200-2450
Line 4	Strait of Juan de Fuca west bound	Line 5 (WA), FFIDs 2451-4771
	Strait of Juan de Fuca east bound	Line 5 (WA), FFIDs 4772-6076
Line 5	San Juan Islands	Line 5 (WA), FFIDs 6077-6680
	Strait of Georgia (US Waters)	Line 5 (WA), FFIDs 6681-7603
	Strait of Georgia (Canadian waters, eastern passage)	Line 5 (WA), FFIDs 7604-9512
Line 6	Strait of Georgia (Canadian waters, western passage)	Line 6 (SG1), FFIDs 0001-2690
	Strait of Georgia (US waters)	Line 6 (SG1), FFIDs 2691-3646
	San Juan Islands	Line 6 (SG1), FFIDs 3647-4500
	Eastern Juan de Fuca west bound	Line 6 (SG1), FFIDs 4501-5345
Line 7	Strait of Juan de Fuca west bound	Line 7 (JDF1)
Line 8	Strait of Juan de Fuca east bound	Line 8 (JDF2)
Line 9	Puget Sound south bound	Line 9 (PS1), FFIDs 0001-2111
	Puget Sound north bound	Line 10 (PS2), FFIDs 0001-2511
Line 10	Eastern Strait of Juan de Fuca	Line 10 (PS2), FFIDs 2512-4964
Line 11	Eastern Strait of Juan de Fuca	Lines 11-14 (JDF3-6)

Table 4. List of Reftek Lines, FFIDs, Locations, and Start and Stop Times

Reftek Line No.	Reftek First FFID	Reftek Last FFID	Location	JD:HrMin UTC	JD:HRMin UTC
1	10001	10324	Lake Washington	069:1924	069:2259
2	20001	20633	Puget Sound	070:1003	
2	20634	20813	Carr Inlet		
2	20814	20943	Puget Sound		
2	20944	21213	S. Puget Sound (southbound)		
2	21214	21472	S. Puget Sound		
2	21473	23039	Puget Sound northbound		
2	23040	23458	Saratoga Passage		072:0559
3	30001	30223	NW Puget Sound	072:1427	
3	30224	31259	Hood Canal (southbound)		
3	31260	32200	Hood Canal (northbound)		
3	32201	32391	Puget Sound (northwest bound)		073:1740
4	40001	42320	St. of Juan de Fuca (westbound)	073:1741	
4	42321	43601	St. of Juan de Fuca (eastbound)		075:1002
5	50001	50604	San Juan Islands	075:1003	
5	50605	51527	St. of Georgia (US)		
5	51528	53190	St. of Georgia (Canada)		077:0128
6	60001	62690	St. of Georgia (Canada)	078:0033	
6	62691	63646	St. of Georgia (US)		
6	63647	64500	San Juan Islands		
6	64501	65342	E. St. Juan de Fuca		079:0850
7	70001	72111	St. Juan de Fuca	079:0902	079:2113
8	80001	83092	St. Juan de Fuca	079:2348	080:1759
9	90001	92111	Puget Sound southbound	080:1800	
9	92112	94622	Puget Sound northbound		081:2041

10	100001	102453	E. St. Juan de Fuca	081:2041	082:1128
11	110001	110993	JDF4	082:1140	
11	110994	111727	JDF5		
11	111728	112466	JDF6		
11	112467	112711	JDF7		083:0345

TABLE 5. List Of Airgun Array Ramp-Ups Times

UTC JD HR MN	Latitude	Longitude	Notes	Line (Thompson Line, FFID)	Reftek FFID
070 14 53	47.36998	-122.53110	guns off - seal	WA1 (Line 2, FFID 436)	20436
070 15 21	47.33922	-122.54749	start ramping guns		
071 05 05	47.13800	-122.66895	guns off - fouled	WA1 (Line 3, FFID 874)	21508
071 06 42	47.20268	-122.59590	start ramping guns		
071 23 42	48.14034	-122.38664	guns off	WA1 (Line 4, FFID 240)	23279
072 01 21	48.05701	-122.32777	start ramping guns		
072 18 41	47.86674	-122.61445	guns off, Hood Canal Br.	WA1 (Line 5, FFID 382-415)	30383
072 19 03	47.84647	-122.64186	start ramping guns		
073 12 58	47.84757	-122.63583	guns off, Hood Canal Br.	WA1 (Line 5, FFID 2027-2055)	31996
073 13 17	47.86545	-122.61673	start ramping guns		
073 18 07	48.22383	-122.85925	guns off, mammals	WA1 (Line 5, FFID 2490-2516)	41040
073 18 24	48.24603	-122.88072	start ramping guns		
075 23 50	48.95926	-123.39352	guns off, boat fouled	WA1 (Line 5, FFID 7318-7565)	51242
076 02 37	48.97275	-123.39157	start ramping guns		
076 14 25	49.28288	-124.00117	guns off, mammals	WA1 (Line 5, FFID 8622)	52300
076 15 35	49.33703	-124.08223	start ramping guns		
079 02 01	48.51474	-122.74304	guns off, sea lion	SG1 (Line 6, FFID 4200)	64200
079 02 09	48.50583	-122.74091	start ramping guns		

TABLE 6. Origin Times (UTC), Locations, Depths, and Magnitudes of Earthquakes and Blasts in Western Washington and Southwestern British Columbia, March 7 to 25, 1998[1], written to archive tapes during our processing

Event No.	JD	Date	Origin Time	Lat.	Long.	Depth (km)	Mag.	Qual.	Comments
120001	066	03/07	05:20:02	47.4	-122.76	22.2	0.7	A	21.5 km SSW of Bremerton, WA
120002	068	03/09	03:15:27	46.65	-121.91	6.5	0.5	B	25.5 km SSW of Mount Rainier
120003	068	03/09	23:48:49	47.16	-121.93	0.0	1.7	A	Blast 4.5 km SE of Enumclaw, WA
120004	069	03/10	11:36:22	47.5	-122.00	15.7	1.1	B	11.2 km WSW of Fall City, WA
120005	069	03/10	17:16:18	46.9	-121.55	8.9	0.3	A	16.8 km ENE of Mount Rainier
120006	069	03/10	22:03:39	46.5	-122.4	16.9	2.8	B	11.7 km WSW of Morton, WA
`120007	070	03/11	06:31:40	46.75	-121.9	9.1	1.0	A	15.4 km SW of Mount Rainier
120008	070	03/11	08:37:23	46.81	-121.95	4.4	0.3	A	15.8 km W of Mount Rainier
120009	070	03/11	14:07:41	47.71	-122.6	0.0	0.0	D	3.1 km ESE of Poulsbo, WA
120010	070	03/11	16:41:41	47.43	-121.61	8.1	1.4	C	13.3 km ESE of North Bend, WA
120011	070	03/11	20:04:23	47.61	-121.95	27.1	1.0	A	4.7 km SW of Carnation, WA
120012	071	03/12	18:05:27	47.68	-121.78	0.0	2.1	C	10.4 km ENE of Carnation, WA
120013	072	03/13	11:11:41	46.71	-121.53	1.5	0.8	B	22.5 km SE of Mount Rainier
120014	072	03/13	20:19:19	48.78	-121.75	22.2	2.7	B	LOWF 4.5 km ENE of Mount Baker
120015	073	03/14	21:47:41	48.3	-122.06	8.3	1.7	B	23.3 km ESE of Mount Vernon, WA
120016	073	03/14	21:50:31	48.3	-122.08	9.8	1.4	A	22.4 km SE of Mount Vernon, WA
`120017	076	03/17	01:58:11	48.48	-121.76	12.9	1.3	A	5.7 km SSW of Concrete, WA
120018	076	03/17	06:27:58	47.53	-122.36	21.1	2.3	A	6.3 km SSW of Seattle, WA
120019	076	03/17	23:05:02	47.73	-122.03	6.9	0.6	B	3.8 km W of Duvall, WA
120020	077	03/18	01:41:06	48.73	-121.5	1.7	1.0	B	23.2 km E of Mount Baker
120021	077	03/18	02:05:04	47.9	-122.58	24.1	1.0	B	20.1 km N of Poulsbo, WA
120022	077	03/18	13:16:30	46.98	-121.95	8.0	0.9	A	20.9 km NW of Mount Rainier
120023	078	03/19	03:35:20	47.68	-122.36	23.0	1.2	B	11.7 km NNW of Seattle, WA
120024	078	03/19	06:27:40	46.53	-121.75	0.7	1.1	A	23.8 km W of Goat Rocks
120025	079	03/20	00:36:07	48.08	-121.91	0.0	1.7	B	Blast 3.3 km E of Granite Falls, WA
120026	079	03/20	10:38:08	47.58	-121.75	6.5	1.3	A	9.8 km N of North Bend, WA
120027	080	03/21	00:33:40	47.88	-122.63	10.9	0.6	B	18.3 km N of Poulsbo, WA
120028	080	03/21	22:21:42	47.58	-122.15	2.8	2.1	A	3.0 km ESE of Bellevue, WA
120029	081	03/22	05:20:43	47.66	-121.81	11.0	1.6	A	7.3 km ENE of Carnation, WA
120030	081	03/22	10:52:23	46.85	-121.95	9.1	0.7	A	15.2 km W of Mount Rainier
120031	081	03/22	17:59:05	46.63	-122.35	18.6	1.3	A	11.5 km NNW of Morton, WA
120032	082	03/23	11:54:36	46.71	-121.85	2.4	2.0	B	16.7 km SSW of Mount Rainier
120033	084	03/25	0:36:09	47.86	-122.7	0.0	1.1	B	16.2 km NNW of Poulsbo, WA
120034	084	03/25	1:15:54	48.08	-121.9	0.0	1.7	B	Blast 5.0 km E of Granite Falls, WA
120035	084	03/25	1:54:55	48.03	-122.25	17.4	1.7	B	7.2 km NNW of Everett, WA
120036	084	03/25	22:21:44	46.76	-122.81	2.0	3.3	A	Blast 12.5 km NE of Centralia, WA
120037	066	03/07	03:29:33	49.79	-123.63	4	1.3		Pacific Geoscience Centre Catalog
120038	067	03/08	05:20:59	49.70	-123.59	4	1.5		

120039	067	03/08	06:04:41	48.76	-128.32	10	
120040	068	03/09	01:44:11	48.92	-123.43	4	0.8
120041	068	03/09	02:05:25	48.92	-123.43	4	1.4
120042	068	03/09	02:16:31	48.92	-123.43	4	0.5
120043	070	03/11	06:17:41	48.92	-123.43	4	0.6
120044	070	03/11	22:31:55	49.79	-123.62	4	1.1
120045	072	03/13	17:36:12	49.51	-129.70	10	
120046	072	03/13	20:19:19	48.81	-121.78	30	3.0
120047	074	03/15	02:31:17	50.23	-129.64	10	
120048	074	03/15	12:54:50	49.73	-126.96	31	1.5
120049	074	03/15	19:36:39	48.88	-123.95	1	0.9
120050	076	03/17	01:18:54	49.35	-121.28	10F	1.7
120051	076	03/17	04:47:54	48.86	-129.18	10	
120052	076	03/17	05:50:24	48.64	-122.99	1	0.7
120053	076	03/17	06:07:41	48.86	-129.18	10	
120054	076	03/17	22:13:07	49.03	-125.57	29	1.0
120055	077	03/18	01:07:49	50.19	-127.74	22	0.5
120056	078	03/19	01:43:37	49.33	-124.63	1	3.0
120057	078	03/19	14:24:09	48.63	-122.99	0F	0.7
120058	078	03/19	16:34:55	49.24	-123.62	3	1.8
120059	079	03/20	06:03:41	48.77	-123.15	59	0.5
120060	083	03/24	19:24:41	50.01	-127.89	24	1.3
120061	083	03/24	20:17:12	49.88	-127.73	25	0.7
120062	084	03/25	15:00:31	48.99	-129.17	10	

[1]http://www.geophys.washington.edu/SEIS/PNSN/CATALOG_SEARCH/cat.search.html
http://www.pgc.nrcan.gc.ca/seismo/recent/swbc.1yr.list.html

Table 7. Reftek Receivers Deployed in Multiple Locations (Times in UTC)

Station No.	DAS No.	Start Time JD:HrMn	End Time JD:HrMn	Reftek Line No.
9012	7466	068:2232	071:2240	1-2
9026	7466	074:0015	083:1721	4-11
11001	7337	073:1729	075:2136	3-5
11002	6116	073:1637	075:2041	3-5
11003	6126	073:1535	083:2006	3-11
11007	7301	069:	071:2304	1-2
11007A	7301	072:0000	084:1857	2-11
11010	6113	073:1907	075:1822	4-5
11011	6058	073:2231	075:1607	4-5
11013	6060	073:2030	075:1608	4-5
11023	7337	069:0040	073:0620	1-3
11025	6126	068:2115	073:0401	1-3
11025	6113	076:0154	084:0158	5-11
11026	6113	068:1930	073:0326	1-3
11026	7337	076:0222	084:0130	5-11
11027	6116	068:1830	073:0235	1-3
11027	6060	076:0304	084:0047	5-11
11028	6058	068:1730	073:0149	1-3
11028	6058	076:0354	083:2350	5-11
11029	6060	068:1650	073:0116	1-3
11029	6116	076:0436	083:1925	5-11
11034	7332	068:1954	077:1550	1-5
11035	7429	068:0146	077:1530	1-5
11036	7351	068:0027	077:0342	1-5
11037	7281	067:2255	077:0419	1-5
11038	7429	077:1819	084:1330	6-11
11039	7332	077:1947	084:0224	6-11
11041	7281	077:1711	083:2156	6-11
11042	7351	077:1815	083:2246	6-11

Appendix 1. Abbreviated list of airgun shotpoint locations, FFID numbers, and shot times

Lat.	Long.	Thompson FFID	REF-TEK FFID	Shottime (JD,hr,mn,sc) UTC	Geo-graphic Location
		Line 1	Line 1		
47.68904	-122.24035	1	10001	69192420000	Lake
47.69218	-122.24487	10	10010	69193020000	Washington
47.71537	-122.27337	55	10055	69200020000	
47.74020	-122.26954	100	10100	69203020000	
47.70795	-122.26742	145	10145	69210020000	
47.68326	-122.23185	190	10190	69213020000	
47.65742	-122.23138	235	10235	69220020000	
47.66335	-122.25640	280	10280	69223020000	
47.69295	-122.24760	324	10324	69225940000	
	WA1	Line 2	Line 2		
47.71222	-122.49091	1	20001	70100300000	Puget Sound
47.68658	-122.48261	42	20042	70103020000	south bound
47.65192	-122.47937	87	20087	70110020000	
47.61397	-122.47465	132	20132	70113020000	
47.57779	-122.46693	177	20177	70120020000	
47.53782	-122.46955	222	20222	70123020000	
47.50203	-122.49168	267	20267	70130020000	
47.46687	-122.51702	312	20312	70133020000	
47.43098	-122.52171	357	20357	70140020000	
47.39766	-122.53941	402	20402	70143020000	
47.37044	-122.53078	436	20436	70145300000	
47.33972	-122.54733	438	20438	70152100000	
47.33171	-122.55186	452	20452	70153020000	
47.31023	-122.55302	497	20497	70160020000	
47.28017	-122.54463	542	20542	70163020000	
47.24955	-122.56683	587	20587	70170020000	
47.21790	-122.59200	632	20632	70173020000	
47.21639	-122.59306	634	20634	70173140000	
	WA1	Line 3	Line 2		
47.32109	-122.72099	1	20635	70192340000	Carr Inlet
47.32550	-122.71229	11	20645	70193020000	
47.29185	-122.71600	56	20690	70200020000	
47.26041	-122.69621	101	20735	70203020000	
47.23218	-122.65662	146	20780	70210020000	
47.20081	-122.63345	191	20825	70213020000	Puget Sound
47.16579	-122.65164	236	20870	70220020000	southbound
47.13103	-122.67446	281	20915	70223020000	(west side)
47.12209	-122.72257	326	20960	70230020000	
47.14783	-122.76150	371	21005	70233020000	
47.17664	-122.79724	416	21050	71000020000	
47.20953	-122.82576	461	21095	71003020000	
47.24566	-122.84677	506	21140	71010020000	
47.28194	-122.85195	551	21185	71013020000	
47.28960	-122.81644	596	21230	71020020000	South Puget
47.25878	-122.85257	641	21275	71023020000	Sound
47.22064	-122.83201	686	21320	71030020000	
47.18473	-122.80392	731	21365	71033020000	
47.14946	-122.77013	776	21410	71040020000	
47.12032	-122.72660	821	21455	71043020000	
47.13220	-122.67324	866	21500	71050020000	Puget Sound
47.13753	-122.66923	874	21508	71050540000	northbound
47.20224	-122.59628	875	21509	71064220000	(east side)
47.22222	-122.58411	902	21536	71070020000	
47.25242	-122.56594	947	21581	71073020000	
47.27933	-122.54335	992	21626	71080020000	
47.30778	-122.55549	1037	21671	71083020000	
47.32764	-122.53837	1082	21716	71090020000	
47.30563	-122.49864	1127	21761	71093020000	
47.28019	-122.45803	1172	21806	71100020000	
47.29649	-122.45046	1217	21851	71103020000	
47.32557	-122.43151	1262	21896	71110020000	
47.34958	-122.38928	1307	21941	71113020000	
47.37396	-122.34941	1352	21986	71120020000	
47.40989	-122.35928	1397	22031	71123020000	
47.44392	-122.38891	1442	22076	71130020000	
47.48291	-122.40236	1487	22121	71133020000	
47.52160	-122.41731	1532	22166	71140020000	
47.56327	-122.43106	1577	22211	71143020000	
47.59947	-122.40720	1622	22256	71150020000	
47.60568	-122.35752	1667	22301	71153020000	
47.62403	-122.40687	1712	22346	71160020000	
47.64980	-122.44314	1757	22391	71163020000	
47.68797	-122.44335	1802	22436	71170020000	
47.72795	-122.43323	1847	22481	71173020000	
47.76892	-122.41902	1892	22526	71180020000	
47.80703	-122.41154	1937	22571	71183020000	
47.84066	-122.39431	1982	22616	71190020000	
47.87473	-122.37766	2027	22661	71193020000	
47.90734	-122.35213	2072	22706	71200020000	
47.94127	-122.32288	2117	22751	71203020000	
47.97325	-122.29385	2162	22796	71210020000	
48.00436	-122.27670	2207	22841	71213020000	
48.03547	-122.30142	2252	22886	71220020000	
48.06584	-122.32637	2297	22931	71223020000	
48.09590	-122.35390	2342	22976	71230020000	
48.12839	-122.37457	2387	23021	71233020000	
48.14016	-122.38592	2405	23039	71234220000	
	WA1	Line 4	Line 2		
48.05750	-122.32801	1	23040	72012100000	Saratoga
48.04813	-122.32935	15	23054	72013020000	Passage
48.04876	-122.37394	60	23099	72020020000	
48.06735	-122.41795	105	23144	72023020000	
48.09031	-122.45460	150	23189	72030019998	
48.10846	-122.49290	195	23234	72033020000	
48.13305	-122.52891	240	23279	72040020000	
48.16262	-122.54650	285	23324	72043020000	
48.19087	-122.555	330	23369	72050020000	
48.22205	-122.55418	375	23414	72053019999	
48.24567	-122.56949	419	23458	72055940000	
	WA1	Line 5	Line 3		
47.83027	-122.3924	1	30001	72142740000	Puget Sound

47.82829	-122.39548	5	30006	72143020000	NW bound
47.84344	-122.42986	50	30051	72150020000	
47.87626	-122.45849	95	30096	72153020000	
47.91467	-122.47634	140	30141	72160020000	
47.94788	-122.52055	185	30186	72163020000	
47.96178	-122.58813	230	30231	72170020000	Hood Canal
47.94548	-122.62999	275	30276	72173020000	south bound
47.91073	-122.62084	320	30321	72180020000	
47.87812	-122.60304	365	30366	72183020000	
47.86718	-122.61405	382	30383	72184140000	
47.84683	-122.64131	415	30384	72190340000	
47.82558	-122.67252	455	30424	72193020000	
47.80243	-122.70523	500	30469	72200020000	
47.77625	-122.72847	545	30514	72203020000	
47.74792	-122.74792	590	30559	72210020000	
47.71616	-122.76095	635	30604	72213020000	
47.68323	-122.76554	680	30649	72220020000	
47.67177	-122.80972	725	30694	72223020000	
47.66141	-122.85136	770	30739	72230020000	
47.6461	-122.8916	815	30784	72233020000	
47.62724	-122.92822	860	30829	73000020000	
47.60368	-122.95592	905	30874	73003020000	
47.57858	-122.98396	950	30919	73010020000	
47.55205	-123.00862	995	30964	73013020000	
47.52512	-123.02966	1040	31009	73020020000	
47.4933	-123.04979	1085	31054	73023020000	
47.46368	-123.08136	1130	31099	73030020000	
47.43147	-123.10732	1175	31144	73033020000	
47.39718	-123.12743	1220	31189	73040020000	
47.37253	-123.12403	1265	31234	73043020000	Hood Canal
47.41092	-123.1182	1310	31279	73050020000	north bound
47.44709	-123.09697	1355	31324	73053020000	
47.48008	-123.06731	1400	31369	73060020000	
47.51329	-123.03921	1445	31414	73063020000	
47.54804	-123.01241	1490	31459	73070020000	
47.58249	-122.98457	1535	31504	73073020000	
47.61167	-122.94987	1580	31549	73080020000	
47.63415	-122.91608	1625	31594	73083020000	
47.65091	-122.87517	1670	31639	73090020000	
47.66685	-122.83324	1715	31684	73093020000	
47.67921	-122.78521	1760	31729	73100020000	
47.70408	-122.75983	1805	31774	73103020000	
47.74027	-122.75201	1850	31819	73110020000	
47.77525	-122.73384	1895	31864	73113020000	
47.80393	-122.70034	1940	31909	73120020000	
47.8268	-122.66788	1985	31954	73123020000	
47.84718	-122.63632	2027	31996	73125820000	
47.86505	-122.61721	2055	31997	73131700000	
47.87739	-122.60295	2075	32017	73133020000	
47.90951	-122.61639	2120	32062	73140020000	
47.94404	-122.6368	2165	32107	73143020000	
47.98383	-122.63406	2210	32152	73150020000	Puget Sound
48.02515	-122.62649	2255	32197	73153020000	NW bound
48.07198	-122.62775	2300	32242	73160020000	

48.11673	-122.6523	2345	32287	73163020000	
48.15843	-122.71269	2390	32332	73170020000	
48.19523	-122.78185	2435	32377	73173020000	
48.20241	-122.80287	2450	32392	73174020000	
	WA1	Line 5	Line 4		
48.20289	-122.80423	2451	40001	73174100000	Juan de
48.21627	-122.84672	2480	40030	73180020000	Fuca
48.25285	-122.8872	2525	40050	73183020000	westbound
48.28254	-122.91308	2567	40092	73190020000	(northern
48.30904	-122.94853	2612	40137	73193020000	side)
48.31071	-123.00722	2657	40182	73200020000	
48.29679	-123.0635	2702	40227	73203020000	
48.28077	-123.11635	2747	40272	73210020000	
48.25869	-123.15963	2792	40317	73213020000	
48.23862	-123.20341	2837	40362	73220020000	
48.21535	-123.24399	2882	40407	73223020000	
48.19239	-123.28168	2927	40452	73230020000	
48.16858	-123.31622	2972	40497	73233020000	
48.15557	-123.34966	3017	40542	74000020000	
48.18008	-123.39074	3062	40587	74003020000	
48.20676	-123.43001	3107	40632	74010020000	
48.22696	-123.47487	3152	40677	74013020000	
48.24704	-123.52186	3197	40722	74020020000	
48.2664	-123.57766	3242	40767	74023020000	
48.2794	-123.63458	3287	40812	74030020000	
48.29166	-123.69842	3332	40857	74033020000	
48.30679	-123.75948	3377	40902	74040020000	
48.31984	-123.81759	3422	40947	74043020000	
48.33184	-123.87048	3467	40992	74050020000	
48.34359	-123.92428	3512	41037	74053020000	
48.35711	-123.97979	3557	41082	74060020000	
48.37169	-124.03528	3602	41127	74063020000	
48.38458	-124.08977	3647	41172	74070020000	
48.3969	-124.14055	3692	41217	74073020000	
48.40863	-124.18868	3737	41262	74080020000	
48.42028	-124.23896	3782	41307	74083020000	
48.43285	-124.28827	3827	41352	74090020000	
48.44522	-124.33812	3872	41397	74093020000	
48.45588	-124.38624	3917	41442	74100020000	
48.46806	-124.43606	3962	41487	74103020000	
48.48125	-124.48536	4007	41532	74110020000	
48.49358	-124.53557	4052	41577	74113020000	
48.50708	-124.58817	4097	41622	74120020000	
48.52131	-124.6415	4142	41667	74123020000	
48.5079	-124.67342	4187	41712	74130020000	
48.46777	-124.6353	4232	41757	74133020000	
48.43403	-124.60583	4277	41802	74140020000	
48.39894	-124.57944	4322	41847	74143020000	
48.38334	-124.52599	4367	41892	74150020000	
48.36743	-124.47547	4412	41937	74153020000	
48.35324	-124.4258	4457	41982	74160020000	
48.33893	-124.37926	4502	42027	74163020000	
48.32198	-124.32938	4547	42072	74170020000	
48.30667	-124.27592	4592	42117	74173020000	

48.29016	-124.22753	4637	42162	74180020000	
48.27474	-124.17865	4682	42207	74183020000	
48.25975	-124.1261	4727	42252	74190020000	
48.24197	-124.07046	4772	42297	74193020000	Juan de
48.22705	-124.02242	4817	42342	74200020000	Fuca
48.21099	-123.97376	4862	42387	74203020000	eastbound
48.20384	-123.91872	4907	42432	74210020000	(southern
48.2042	-123.86409	4952	42477	74213020000	side)
48.20399	-123.80572	4997	42522	74220020000	
48.20186	-123.74982	5042	42567	74223020000	
48.20074	-123.68933	5087	42612	74230020000	
48.20326	-123.6334	5132	42657	74233020000	
48.20156	-123.57594	5177	42702	75000020000	
48.19244	-123.51698	5222	42747	75003020000	
48.17759	-123.46033	5267	42792	75010020000	
48.17866	-123.40798	5312	42837	75013020000	
48.17353	-123.35886	5357	42882	75020020000	
48.15833	-123.30821	5402	42927	75023020000	
48.16416	-123.25453	5447	42972	75030020000	
48.18315	-123.21085	5492	43017	75033020000	
48.19866	-123.16654	5537	43062	75040020000	
48.19767	-123.11379	5582	43107	75043020000	
48.19719	-123.06596	5627	43152	75050020000	
48.16504	-123.04231	5672	43197	75053020000	
48.13483	-123.02457	5717	43242	75060020000	
48.11063	-123.00015	5762	43287	75063020000	
48.10698	-122.95703	5807	43332	75070020000	
48.11145	-122.91489	5851	43376	75072940000	
48.13202	-122.8782	5893	43418	75080020000	
48.15493	-122.84219	5938	43463	75083020000	
48.18294	-122.81961	5983	43508	75090020000	
48.21563	-122.80408	6028	43553	75093020000	
48.24809	-122.79145	6073	43598	75100020000	
48.25055	-122.79037	6076	43601	75100220000	
	WA1	Line 5	Line 5		
48.25137	-122.79005	6077	50001	75100300000	San Juan
48.28309	-122.77901	6118	50042	75103020000	Islands
48.31721	-122.76514	6163	50087	75110020000	
48.35157	-122.74814	6208	50132	75113020000	
48.38655	-122.73352	6253	50177	75120020000	
48.424	-122.72854	6298	50222	75123020000	
48.46648	-122.72977	6343	50267	75130020000	
48.50951	-122.73626	6388	50312	75133020000	
48.55508	-122.74469	6433	50357	75140020000	
48.60092	-122.75427	6478	50402	75143020000	
48.63846	-122.72891	6523	50447	75150020000	
48.67423	-122.70726	6568	50492	75153020000	
48.70557	-122.72797	6613	50537	75160020000	
48.73943	-122.74698	6658	50582	75163020000	
48.76699	-122.77368	6703	50627	75170020000	Strait of
48.77551	-122.82614	6748	50672	75173020000	Georgia
48.79448	-122.8712	6793	50717	75180020000	(USA
48.81237	-122.92049	6838	50762	75183020000	waters)
48.82794	-122.97224	6883	50807	75190020000	

48.8427	-123.02153	6928	50852	75193020000	
48.85718	-123.06998	6973	50897	75200020000	
48.87186	-123.11611	7018	50942	75203020000	
48.88498	-123.16339	7063	50987	75210020000	
48.89801	-123.20779	7108	51032	75213020000	
48.91185	-123.25172	7153	51077	75220020000	
48.92353	-123.29176	7198	51122	75223020000	
48.93575	-123.3322	7243	51167	75230020000	
48.94777	-123.37277	7288	51212	75233020000	
48.95875	-123.39355	7318	51242	75235020000	
48.97225	-123.3917	7565	51243	76023740000	
48.99458	-123.38614	7595	51273	76030020000	
49.02616	-123.3778	7640	51318	76033020000	Strait of
49.06292	-123.36829	7685	51363	76040020000	Georgia
49.09527	-123.3597	7730	51408	76043020000	(Canadian
49.12851	-123.35094	7775	51453	76050020000	waters)
49.16178	-123.34219	7820	51498	76053020000	
49.19614	-123.333	7865	51543	76060020000	
49.23041	-123.32362	7910	51588	76063020000	
49.26603	-123.31448	7955	51633	76070020000	
49.2942	-123.32191	8000	51678	76073020000	
49.28407	-123.3714	8045	51723	76080020000	
49.28143	-123.42142	8090	51768	76083020000	
49.27888	-123.47129	8135	51813	76090020000	
49.2763	-123.52121	8180	51858	76093020000	
49.27364	-123.57261	8225	51903	76100020000	
49.27084	-123.61874	8270	51948	76103020000	
49.2683	-123.66694	8315	51993	76110020000	
49.2653	-123.71831	8360	52038	76113020000	
49.26291	-123.76986	8405	52083	76120020000	
49.26063	-123.8197	8450	52128	76123020000	
49.25698	-123.86712	8495	52173	76130020000	
49.25568	-123.9185	8540	52218	76133020000	
49.26637	-123.96461	8585	52263	76140020000	
49.28265	-124.00047	8622	52300	76142500000	
49.33658	-124.08187	8623	52301	76153540000	
49.365	-124.09016	8660	52338	76160020000	
49.39945	-124.09625	8705	52383	76163020000	
49.43378	-124.10098	8750	52428	76170020000	
49.46658	-124.10226	8795	52473	76173020000	
49.49969	-124.10163	8840	52518	76180020000	
49.53359	-124.1037	8885	52563	76183020000	
49.56453	-124.1276	8930	52608	76190020000	
49.59229	-124.16536	8975	52653	76193020000	
49.62037	-124.20489	9020	52698	76200020000	
49.64602	-124.24275	9065	52743	76203020000	
49.67245	-124.28155	9110	52788	76210020000	
49.69896	-124.32011	9155	52833	76213020000	
49.72608	-124.35786	9200	52878	76220020000	
49.74102	-124.41086	9245	52923	76223020000	
49.75681	-124.46377	9290	52968	76230020000	
49.77584	-124.51346	9335	53013	76233020000	
49.8046	-124.55537	9380	53058	77000020000	
49.83213	-124.59669	9425	53103	77003020000	

49.82284	-124.65441	9470	53148	77010020000	
49.79648	-124.69035	9512	53190	77012820000	
	Line SG1		Line 6		
49.69897	-124.71456	1	60001	78003345235	Strait of
49.66993	-124.68628	77	60077	78010002132	Georgia
49.63956	-124.65377	159	60159	78013011620	(Canadian
49.60904	-124.62278	240	60240	78020004186	waters,
49.57827	-124.5924	321	60321	78023012174	western
49.54721	-124.56141	403	60403	78030008163	passage)
49.51609	-124.5306	485	60485	78033002151	
49.48436	-124.4988	569	60569	78040011765	
49.459	-124.46023	650	60650	78043017160	
49.44485	-124.41096	728	60728	78050014008	
49.4326	-124.35973	807	60807	78053018121	
49.41958	-124.30519	891	60891	78060002454	
49.40627	-124.24938	977	60977	78063021161	
49.39482	-124.20207	1050	61050	78070008462	
49.38246	-124.15009	1130	61130	78073003639	
49.36894	-124.09424	1216	61216	78080008065	
49.35608	-124.04035	1299	61299	78083011053	
49.35562	-123.98378	1381	61381	78090018167	
49.35531	-123.92718	1463	61463	78093003249	
49.35555	-123.86979	1546	61546	78100009721	
49.35271	-123.81306	1626	61626	78103019084	
49.32148	-123.78425	1709	61709	78110018025	
49.28796	-123.76125	1791	61791	78113018920	
49.26146	-123.72389	1871	61871	78120008924	
49.23509	-123.6841	1953	61953	78123014880	
49.20575	-123.65042	2035	62035	78130019869	
49.18329	-123.60854	2114	62114	78133007153	
49.15748	-123.56619	2198	62198	78140019547	
49.13027	-123.52497	2283	62283	78143011941	
49.10441	-123.48563	2364	62364	78150021929	
49.07834	-123.44675	2445	62445	78153022105	
49.05182	-123.40658	2528	62528	78160018921	
49.02407	-123.36412	2614	62614	78163017893	
48.99652	-123.32352	2698	62698	78170017475	Strait of
48.97039	-123.28377	2780	62780	78173008885	Georgia
48.94281	-123.24229	2866	62866	78180010170	(USA
48.9142	-123.20043	2952	62952	78183008862	waters)
48.88731	-123.15728	3039	63039	78190002804	
48.86862	-123.10426	3120	63120	78193017385	
48.84982	-123.05204	3206	63206	78200010186	
48.82986	-122.99946	3295	63295	78203020268	
48.80926	-122.94958	3381	63381	78210007334	
48.79046	-122.89817	3467	63467	78213003963	
48.77112	-122.84652	3551	63551	78220013795	
48.7528	-122.79642	3634	63634	78223003799	San Juan
48.72277	-122.76305	3713	63713	78230002599	Islands
48.68794	-122.73701	3799	63799	78233013775	
48.65355	-122.71707	3882	63882	79000009778	
48.62115	-122.74575	3966	63966	79003014032	
48.58864	-122.75907	4041	64041	79010020739	
48.55334	-122.74905	4121	64121	79013014711	

48.51704	-122.74337	4200	64200	79020003714	
48.48269	-122.74446	4277	64277	79023004734	
48.44796	-122.76452	4358	64358	79030021221	
48.41695	-122.78703	4435	64435	79033010693	
48.39785	-122.83232	4516	64516	79040005000	Eastern
48.37993	-122.88337	4602	64602	79043011001	Strait of
48.3615	-122.93136	4688	64688	79050016973	Juan de
48.34244	-122.98072	4773	64773	79053001977	Fuca
48.32356	-123.02999	4859	64859	79060007950	(westbound)
48.3042	-123.07933	4945	64945	79063013942	
48.28547	-123.12752	5031	65031	79070019910	
48.26619	-123.17716	5116	65116	79073004883	
48.24725	-123.22574	5201	65201	79080005828	
48.22829	-123.27377	5287	65287	79083011811	
48.21519	-123.30749	5345	65345	79085029792	
	Line JDF1		Line 7		
48.21218	-123.32856	1	70001	79090223781	Strait of
48.22217	-123.37826	80	70080	79093002771	Juan de
48.23353	-123.43237	166	70166	79100008742	Fuca
48.24436	-123.4873	252	70252	79103014723	(westbound,
48.25625	-123.54207	338	70338	79110020688	northern
48.27302	-123.59358	423	70423	79113005659	side)
48.28835	-123.64639	509	70509	79120013615	
48.30211	-123.6987	595	70595	79123019603	
48.31515	-123.74953	680	70680	79130004576	
48.32751	-123.80084	766	70766	79133010562	
48.33989	-123.85539	852	70852	79140016534	
48.35192	-123.90788	937	70937	79143001511	
48.36387	-123.9606	1023	71023	79150007479	
48.37623	-124.01563	1109	71109	79153013450	
48.3886	-124.07012	1195	71195	79160019437	
48.40152	-124.12293	1280	71280	79163004409	
48.41522	-124.17764	1366	71366	79170010402	
48.42858	-124.23385	1452	71452	79173016384	
48.44213	-124.2872	1537	71537	79180001356	
48.45621	-124.341	1623	71623	79183007328	
48.47172	-124.39753	1712	71712	79190013549	
48.48688	-124.45313	1802	71802	79193014943	
48.50208	-124.50866	1892	71892	79200016321	
48.51707	-124.56338	1982	71982	79203017700	
48.53132	-124.61676	2072	72072	79210019078	
48.53818	-124.6414	2113	72113	79211359706	
	Line JDF2		Line 8		
48.40946	-124.61335	1	80001	79234845607	Strait of
48.40401	-124.59885	34	80034	80000018597	Juan de
48.39004	-124.55512	119	80119	80003003600	Fuca
48.37432	-124.50563	205	80205	80010009607	(eastbound,
48.35715	-124.45151	291	80291	80013015614	southern
48.33997	-124.39753	376	80376	80020000620	side)
48.322	-124.34106	462	80462	80023006627	
48.30342	-124.28305	548	80548	80030012634	
48.28444	-124.22375	634	80634	80033018640	
48.26588	-124.16536	719	80719	80040003647	
48.24723	-124.10773	805	80805	80043009654	

48.22889	-124.05032	891	80891	80050015662	
48.21202	-123.99793	976	80976	80053000669	
48.20505	-123.94173	1062	81062	80060006676	
48.2001	-123.88153	1148	81148	80063012683	
48.19573	-123.82568	1234	81234	80070018690	
48.19143	-123.77096	1319	81319	80073003697	
48.18705	-123.71686	1380	81380	80080009704	
48.18293	-123.66461	1466	81466	80083015711	
48.17892	-123.61749	1551	81551	80090000719	
48.17994	-123.56923	1637	81637	80093006726	
48.18201	-123.51496	1723	81723	80100012734	
48.18354	-123.46204	1809	81809	80103018741	
48.18506	-123.41554	1894	81894	80110003749	
48.18677	-123.36898	1980	81980	80113009756	
48.18825	-123.32304	2066	82066	80120015763	
48.19032	-123.26798	2151	82151	80123000771	
48.19218	-123.21052	2237	82237	80130006778	
48.19435	-123.15092	2323	82323	80133012786	
48.19678	-123.09075	2409	82409	80140018794	
48.19607	-123.03402	2494	82494	80143003801	
48.19256	-122.97729	2580	82580	80150009809	
48.18994	-122.91767	2666	82666	80153015817	
48.18569	-122.85292	2751	82751	80160000824	
48.17175	-122.78869	2837	82837	80163006832	
48.14889	-122.73802	2923	82923	80170012839	
48.12239	-122.6919	3009	83009	80173018846	
48.09156	-122.66237	3092	83092	80175921853	
	Line PS 1		Line 9		
48.09027	-122.66204	1	90001	80180024853	Puget Sound
48.05277	-122.65234	86	90086	80183009860	southbound
48.01788	-122.6351	172	90172	80190015867	
47.98568	-122.61515	257	90257	80193000874	
47.95667	-122.59349	343	90343	80200006880	
47.9397	-122.55818	429	90429	80203012887	
47.92408	-122.52354	515	90515	80210018893	
47.90297	-122.49819	600	90600	80213003900	
47.8715	-122.48772	686	90686	80220009906	
47.83811	-122.47725	772	90772	80223015912	
47.80502	-122.46549	857	90857	80230000919	
47.76928	-122.45537	943	90943	80233006925	
47.73223	-122.45583	1029	91029	81000012932	
47.6968	-122.47002	1115	91115	81003018938	
47.66246	-122.4768	1200	91200	81010003945	
47.62528	-122.47355	1286	91286	81013009951	
47.58587	-122.46218	1372	91372	81020015958	
47.54601	-122.46021	1457	91457	81023000965	
47.50949	-122.48625	1543	91543	81030006972	
47.47511	-122.51051	1629	91629	81033012979	
47.43845	-122.52242	1715	91715	81040018985	
47.40402	-122.53633	1800	91800	81043003992	
47.36718	-122.53167	1886	91886	81050009999	
47.32924	-122.54335	1972	91972	81053016005	
47.31697	-122.50246	2057	92057	81060001012	
47.31883	-122.4647	2112	92112	81061916016	

	Line PS2		Line 9		
47.321	-122.44845	1	92113	81062739999	Puget Sound
47.32172	-122.44436	8	92120	81062959999	northbound
47.34076	-122.39783	97	92209	81065959999	
47.37068	-122.36923	186	92298	81072959999	
47.40828	-122.35632	276	92388	81075959999	
47.44228	-122.38638	366	92478	81082959999	
47.47731	-122.40373	455	92567	81085959999	
47.51519	-122.41567	545	92657	81092959999	
47.55329	-122.42664	634	92746	81095959999	
47.59066	-122.44134	724	92836	81102959999	
47.62969	-122.44772	814	92926	81110000000	
47.66911	-122.45049	904	93016	81112959999	
47.70628	-122.43835	994	93106	81115959999	
47.74302	-122.42768	1082	93194	81122959999	
47.7804	-122.42822	1172	93284	81125959999	
47.81778	-122.44127	1261	93373	81132959999	
47.85523	-122.45349	1351	93463	81135959999	
47.89253	-122.46686	1440	93552	81142959999	
47.92939	-122.48171	1530	93642	81145959999	
47.9497	-122.52324	1620	93732	81152959999	
47.96743	-122.57235	1710	93822	81155959999	
48.00206	-122.59995	1800	93912	81163000000	
48.03536	-122.62463	1886	93998	81170006007	
48.07321	-122.63461	1968	94080	81173004014	
48.11112	-122.64659	2051	94163	81180017021	
48.1377	-122.68359	2136	94248	81183002028	
48.16215	-122.72993	2222	94334	81190008035	
48.18597	-122.77823	2308	94420	81193014041	
48.20797	-122.82487	2394	94506	81200020048	
48.23784	-122.85981	2479	94591	81203005055	
48.24980	-122.87169	2511	94623	81204117058	
	Line PS2		Line 10		
48.25017	-122.87205	2512	100001	81204138058	Eastern
48.27028	-122.88999	2565	100054	81210011062	Strait of
48.30302	-122.91952	2651	100140	81213017069	Juan de
48.3353	-122.94925	2736	100225	81220002076	Fuca
48.36746	-122.97909	2822	100311	81223008083	
48.40095	-123.00857	2908	100397	81230014090	
48.42964	-123.046	2994	100483	81233020097	
48.45494	-123.08387	3079	100568	82000005104	
48.47879	-123.118	3165	100654	82003011111	
48.4958	-123.14487	3250	100739	82010017118	
48.51316	-123.17028	3332	100821	82013021125	
48.52884	-123.19905	3413	100902	82020003132	
48.51262	-123.24835	3495	100984	82023007139	
48.47556	-123.24219	3577	101066	82030011146	
48.44617	-123.21397	3659	101148	82033015153	
48.41667	-123.18044	3741	101230	82040019160	
48.3887	-123.15224	3822	101311	82043001167	
48.36955	-123.11131	3904	101393	82050005174	
48.38443	-123.05923	3986	101475	82053009181	
48.38864	-123.00281	4068	101557	82060013187	
48.38942	-122.94863	4150	101639	82063017193	

48.39038	-122.88877	4232	101721	82070021199	
48.39128	-122.83249	4313	101802	82073003206	
48.37194	-122.79001	4395	101884	82080007212	
48.33486	-122.78346	4477	101966	82083011219	
48.29662	-122.78993	4559	102048	82090015225	
48.25876	-122.79524	4641	102130	82093019232	
48.22229	-122.80178	4722	102211	82100001239	
48.1854	-122.80819	4804	102293	82103005245	
48.15559	-122.84388	4886	102375	82110009252	
48.1283	-122.87567	4964	102453	82112845258	
	Line JDF3		Line 11		
48.11738	-122.88991	1	110001	82114029261	Eastern
48.10782	-122.92378	55	110055	82120017265	Strait of
48.10797	-122.98325	137	110137	82123021271	Juan de
48.13083	-123.02447	218	110218	82130003277	Fuca
48.17046	-123.01927	300	110300	82133007283	
48.21218	-123.01341	382	110382	82140011290	
48.25156	-123.01347	464	110464	82143015296	
48.29023	-123.01429	546	110546	82150019302	
48.32838	-123.01485	627	110627	82153001309	
48.36713	-123.01599	709	110709	82160005315	
48.40532	-123.01664	791	110791	82163009323	
48.43284	-123.05157	873	110873	82170013330	
48.42344	-123.10721	955	110955	82173017336	
48.41168	-123.12512	993	110993	82174413339	
	Line JDF4		Line 11		
48.41092	-123.12584	1	110994	82174457339	Eastern
48.39457	-123.141	43	111036	82180021342	Strait of

48.36316	-123.17122	124	111117	82183003349	Juan de
48.33041	-123.20312	206	111199	82190007354	Fuca
48.29741	-123.2352	288	111281	82193011361	
48.26637	-123.26501	370	111363	82200015368	
48.23533	-123.29484	452	111445	82203019375	
48.20888	-123.33272	533	111526	82210001382	
48.17495	-123.332	615	111608	82213004388	
48.17277	-123.28117	697	111690	82220009395	
48.18325	-123.26725	734	111727	82221343398	
	Line JDF5		Line 11		
48.1847	-123.26588	1	111728	82221520000	Eastern
48.19664	-123.25258	44	111771	82222959999	Strait of
48.22286	-123.22574	133	111860	82225959999	Juan de
48.24763	-123.20072	222	111949	82232959999	Fuca
48.27288	-123.17409	312	112039	82235959999	
48.30184	-123.14575	400	112127	83002959999	
48.33187	-123.11669	490	112217	83005959999	
48.36074	-123.08878	580	112307	83012959999	
48.3914	-123.05858	670	112397	83015959999	
48.40332	-123.02171	739	112466	83022259999	
	Line JDF6		Line 11		
48.40321	-123.02	1	112467	83022359999	Eastern
48.40102	-123.01051	19	112485	83022959999	Strait of
48.36713	-123.00369	107	112573	83025959999	Juan de
48.33267	-123.01115	197	112663	83032959999	Fuca
48.31337	-123.01163	245	112711	83034559999	

Appendix 2. Reftek and OBS station locations and elevations

Station Name	DAS No.	Reftek GPS Latitude	Reftek GPS Longitude	Topo map elev (m)
1002	6095	48.90531	-122.76530	7
1003	6041	48.82119	-122.68182	54
•1004	7278	48.74074	-122.70870	66
1005	7447	48.68605	-122.64225	64
1006	6035	48.65071	-122.49103	44
1007	7111	48.57740	-122.55620	10
1007	6097	48.57740	-122.55620	10
•1008	550	48.51381	-122.59857	53
1009	7097	48.46125	-122.62924	210
1009	6062	48.46125	-122.62924	210
Δ1010	7059	48.39422	-122.62177	72
•Δ1011	7602	48.32825	-122.61927	30
Δ1012	6056	48.27197	-122.68263	39
Δ1013	6121	48.21907	-122.63097	11
•1014	7298	48.17365	-122.60353	94
Δ1015	6086	48.12120	-122.57480	111
Δ1016	7069	48.06512	-122.57518	134
•1017	7285	48.01509	-122.55997	61
Δ1018	7083	47.96957	-122.43875	30
•1019	7289	47.92208	-122.41042	41
•1020	7286	48.66294	-122.94756	42
1021	7357	48.55026	-122.87657	23
1022	7345	48.43231	-122.86050	12
•2001	153	47.90831	-122.53122	6
2002	6032	47.87833	-122.60722	112
Δ2003	6021	47.84944	-122.53889	90
2004	7593	47.81583	-122.53806	41
2004	6091	47.81583	-122.53806	41
•2004	6088	47.81583	-122.53806	41
Δ2005	6047	47.79280	-122.53995	27
•2006	7300	47.75610	-122.47481	0
Δ2007	6122	47.74722	-122.56194	13
Δ2008	6093	47.71722	-122.54983	39
2009	6031	47.79516	-122.66198	104
2010	6087	47.66626	-122.62344	87
•2011	359	47.67500	-122.54159	23
•2012	149	47.63114	-122.53383	32
2012	6064	47.63114	-122.53383	32
•2013	340	47.61271	-122.60715	96
2014	6071	47.70000	-122.68056	58
3001	6057	47.58250	-122.55615	30
•3002	529	47.54794	-122.59029	92
3003	6081	47.54934	-122.55049	68
3004	6125	47.51598	-122.53207	67
Δ3005	7044	47.49750	-122.51250	77
•3006	880	47.47698	-122.54888	128
Δ3007	7064	47.44733	-122.58167	38
Δ3008	7058	47.41483	-122.55367	73
•3009	348	47.39031	-122.56419	91
Δ3010	7081	47.36250	-122.57717	27
3011	6045	47.31861	-122.59753	81
•3012	7283	47.29096	-122.62180	58
•3013	7362	47.25799	-122.63843	36
•3014	7597	47.22738	-122.60925	99
•4001	898	47.75100	-122.70327	99
4002	7066	47.69337	-122.73305	102
•4003	7288	47.64841	-122.78774	56
4004	7078	47.61771	-122.89439	94
4004	6066	47.61771	-122.89439	94
4005	7100	47.58407	-122.93298	101
4006	7112	47.55660	-122.88785	159
4006	6120	47.55660	-122.88785	159
•4007	7282	47.55361	-122.97433	136
4008	7063	47.59469	-122.75805	137
4009	7110	47.48830	-122.90544	110
4010	6020	47.48582	-123.01287	70
4011	6108	47.43981	-123.05902	125
4012	6037	47.42026	-122.95088	137
4013	6085	47.42113	-123.08682	147
Δ5001	7107	47.36717	-122.85033	71
•5002	895	47.31109	-122.92594	55
•5003	395	47.47459	-122.73159	122
5004	6025	47.38922	-122.73923	73
Δ5005	7077	47.25733	-122.74800	23
Δ5006	7039	47.22700	-122.75200	12

•5007	877	47.24915	-122.82293	72
•5008	369	47.17546	-122.75692	57
•5009	656	47.39099	-122.39513	122
•6001	7291	47.90120	-122.67049	158
∆6002	6084	47.92200	-122.81750	120
6003	6080	47.88639	-123.02847	925
•6004	7595	47.84326	-122.71887	134
∆6005	6051	47.80250	-122.77167	126
∆6006	6098	47.75183	-122.78683	121
6007	7448	47.73744	-123.16681	492
6008	7444	47.73958	-123.07108	185
•6009	7605	47.73029	-123.12343	377
6010	6003	47.72260	-122.99782	116
6010	6114	47.72260	-122.99782	116
•6011	7615	47.71146	-122.92585	154
•6012	7594	47.70990	-122.82293	52
∆6013	6019	47.69350	-122.77867	85
∆6014	6067	47.68833	-122.90317	2
7001	7056	47.50570	-123.31528	242
7002	7604	47.49454	-123.24184	275
7003	7052	47.45156	-123.20860	295
7004	7306	47.40793	-123.15837	54
7005	6090	47.35248	-123.08809	72
7006	7070	47.34062	-123.02668	154
7006	6102	47.34062	-123.02668	154
7007	6042	47.31966	-123.12363	125
7008	7292	47.28107	-123.15098	84
•7009	381	47.23547	-123.20967	76
•7010	7316	47.23655	-122.99754	60
7011	7085	47.21057	-123.24407	70
7012	7592	47.09431	-123.04005	44
7012	6107	47.09431	-123.04005	44
8001	6092	47.17125	-122.82019	32
8002	6040	47.12037	-122.87655	37
•8003	7614	47.10356	-122.73843	33
8004	6101	47.08301	-122.77955	81
8005	6118	47.02664	-122.78467	48
•8006	7303	46.96839	-122.85793	57
8007	6065	46.92920	-122.96770	55
8008	7330	46.88895	-123.00933	52
•8009	7630	46.82657	-123.06417	48
8010	7320	46.78954	-123.13044	114
8011	7460	46.73608	-123.20089	73

•8012	7295	46.69334	-123.21161	108
8013	7462	46.63818	-123.27519	98
8014	7440	46.58854	-123.29948	159
9001	7104	48.10256	-122.69603	37
9002	7046	48.02084	-122.69337	35
9003	6028	48.13702	-122.76747	50
9004	7099	48.08057	-122.87965	102
9004	6018	48.08057	-122.87965	102
9005	6046	48.01858	-122.80665	92
•9006	7598	48.06772	-122.95655	76
9007	7092	48.02455	-123.07024	526
•9008	7072	48.11804	-123.08073	9
9009	7116	48.04403	-123.22399	338
•9010	7038	48.07383	-123.43074	318
•9011	7428	48.01442	-123.37468	783
9012	7466	48.04549	-123.58785	157
•9012	227	48.04541	-123.58761	157
9012	6069	48.04541	-123.58761	157
9012	6030	48.04541	-123.58761	157
9013	7324	47.98313	-123.62507	537
•9014	7296	48.15068	-123.66639	277
9015	7098	48.08301	-123.69480	397
9016	7061	48.10898	-123.79098	291
9017	7452	48.15132	-123.88121	178
•9018	7302	48.09739	-123.95508	721
9019	7454	48.17031	-124.11473	151
9021	7352	48.23669	-124.23487	187
9022	7435	48.26467	-124.36379	161
•9023	338	48.31059	-124.47501	241
9024	7317	48.35624	-124.55875	72
9025	7089	48.37861	-124.59513	12
9026	7466	48.35312	-124.66331	138
9027	7339	48.10491	-124.22802	511
9028	7073	48.03434	-123.97658	619
•9029	771	47.98776	-123.94732	577
9030	7075	47.95154	-123.07359	726
9030	6029	47.95154	-123.07359	726
9031	6026	47.78516	-122.95995	488
10001	7041	48.13589	-122.28318	127
10002	7114	48.14494	-122.03767	47
10003	7334	48.13327	-121.84234	564
•10004	7627	48.05236	-122.23341	89
10005	7074	48.04871	-122.03270	67
•10006	556	48.04495	-121.84704	529

10007	7364	48.06790	-121.61598	418
10008	7047	47.94643	-122.27877	113
10009	7040	47.94969	-122.10789	98
•10010	7629	47.95012	-121.88737	139
10011	7043	47.94859	-121.67681	500
•10012	7591	47.87189	-122.29232	165
10013	7082	47.86871	-122.09487	58
•10014	7341	47.87789	-121.90167	96
10015	7091	47.86693	-121.69991	51
10016	7093	47.83102	-122.29529	139
10017	7068	47.78986	-122.38863	40
•10018	391	47.77521	-122.27981	142
10019	7050	47.77621	-122.10849	104
10020	7088	47.80087	-121.89000	354
10021	7094	47.73244	-122.25730	108
10022	7096	47.71570	-122.12720	27
•10023	7438	47.72196	-121.89069	114
•10024	7279	47.65700	-122.40850	93
10025	7622	47.65810	-122.27400	31
•10026	7600	47.64620	-122.16626	149
•10027	192	47.74043	-121.97816	79
•10028	7611	47.63958	-122.00745	46
•10029	7624	47.63200	-121.88080	53
10030	7095	47.65570	-121.79087	439
•10031	878	47.64414	-121.69344	412
•10032	7294	47.46592	-121.98399	267
10033	7071	47.58260	-122.28907	1
•10034	7297	47.56334	-122.12078	219
10035	7053	47.56550	-121.91008	29
10036	7350	47.54175	-121.72909	315
10037	7101	47.51189	-122.38010	119
10038	7108	47.54042	-122.27766	37
•10039	7601	47.45223	-122.28156	148
•10040	7619	47.47111	-122.11353	114
10041	7062	47.39524	-122.19449	143
10042	7113	47.37181	-122.30889	68
10043	7109	47.36834	-122.08693	119
10044	7054	47.40784	-121.95686	213
10045	7467	47.44480	-121.72298	210
10046	7076	47.31839	-122.38262	83
10047	7103	47.31361	-122.19441	104
10048	7342	47.31293	-121.90073	262
10049	7086	47.25644	-122.08354	169

10050	7346	47.22514	-122.41480	89
10051	7087	47.21838	-122.27387	136
10052	7084	47.19603	-122.53663	67
•10053	384	47.14730	-122.59277	102
10054	7065	47.14832	-122.08552	189
10055	7328	47.10271	-122.51340	88
10056	7060	47.11840	-122.25942	181
•10057	875	47.19489	-121.95976	244
10058	7090	47.11481	-122.41840	107
•10059	553	47.03820	-122.38978	143
•10060	7609	46.95748	-122.22510	226
11001	7337	48.52200	-124.37238	141
11002	6116	48.46436	-124.20221	147
11003	6126	48.43786	-124.04447	212
11004	6110	48.37991	-123.82990	78
11005	6119	48.33655	-123.63596	42
11006	6039	48.43170	-123.46930	31
•11007	7301	48.48839	-123.32809	44
•1107A	7301	48.47805	-123.34097	64
•11008	7287	48.53711	-123.42348	109
•11009	7606	48.69453	-123.44014	97
11010	6113	48.59210	-124.20870	145
11011	6058	48.52766	-123.94405	472
11012	6111	48.44856	-123.73988	140
11013	6060	48.71879	-124.13007	280
11014	7344	48.67678	-123.90354	530
11015	6109	48.57412	-123.65498	200
11016	7343	48.67360	-123.70840	284
•11017	7599	48.79884	-123.15541	186
•11018	7280	48.85273	-123.28708	83
•11019	7625	48.91217	-123.41275	91
•11020	7299	49.00126	-123.58513	40
•11021	7610	49.13327	-123.70140	15
11022	7331	49.18940	-123.84224	66
11023	7337	49.24688	-124.13186	102
11024	7456	49.28920	-124.26460	98
11025	6126	49.36021	-124.55196	98
11025	6113	49.36021	-124.55196	98
11026	6113	49.44801	-124.71729	80
11026	7337	49.44801	-124.71729	80
11027	6116	49.57209	-124.91459	115
11027	6060	49.57209	-124.91459	115
11028	6058	49.74435	-124.96417	78

11029	6060	49.84638	-125.15021	79
11029	6116	49.84638	-125.15021	79
•11030	7277	48.99948	-123.08761	46
•11031	7623	49.09759	-123.16613	3
•11032	7284	49.20780	-123.20110	5
•11033	7628	49.37259	-123.35300	151
11034	7332	49.51485	-123.26071	75
11035	7429	49.69002	-123.14189	14
11036	7351	49.84851	-123.14893	362
11037	7281	50.01199	-123.12417	417
11038	7429	50.13873	-122.97090	639
11039	7332	50.29668	-122.81987	251
11041	7281	50.76848	-122.79745	1148
11042	7351	50.91822	-122.77316	852
11043	7431	49.43293	-123.62201	168
11044	7445	49.46926	-123.78085	26
11045	7360	49.54428	-123.96990	56
11046	7348	49.64117	-124.06438	32
11047	7446	49.78119	-124.18988	30
11048	7430	49.78960	-124.44199	72
11049	7449	49.89324	-124.58886	64
11050	7333	49.99049	-124.77668	32
11051	7322	49.75872	-124.61613	114
11052	7433	49.65440	-124.40199	236
11053	7612	49.56184	-124.20385	397
•COBS1		49.02985	-123.37678	-256
•COBS2		49.16065	-123.34257	-188
•COBS3		49.28722	-123.30885	-106
•COBS4		49.27663	-123.51692	-284
•COBS5		49.26493	-123.72753	-423
•COBS6		49.35255	-124.03270	-334
•UOBS1	c9	47.88630	-122.48005	-200
•UOBS2	a3	47.82007	-122.44609	-185
•UOBS3	a1	47.77423	-122.44812	-210
•UOBS4	c4	47.70578	-122.44392	-197
•UOBS5	d1	47.64988	-122.45830	-220
•UOBS6	d4	47.55924	-122.46157	-195
•UOBS7	a8	47.49326	-122.41073	-193
•UOBS8	c1	47.43661	-122.38993	-225
•UOBS9	a4	47.35736	-122.35752	-171
•ALD	DR200	47.57492	-122.41781	3
•BG1	Reftek	47.59706	-122.30694	42
•CHR	DR200	47.57089	-122.38875	114
•CLL	DR200	47.58325	-122.38854	96
•DAK	DR200	47.56728	-122.38889	114
•EAK	K2	47.57375	-122.38202	120
•HAN	K2	47.57442	-122.38872	107
•HOL	DR200	47.58691	-122.38834	90
•KD1	Reftek	47.59521	-122.33337	4
•LAN	DR200	47.57889	-122.38865	104
•SQ1	Reftek	47.54968	-122.25038	10
•WEK	K2	47.57453	-122.38403	119
•WIN	K2	47.57475	-122.38200	119

• 3-component site

Δ Location from topographic map

Appendix 3. List of timing used for Reftek stations (Times in UTC)

Station Name	DAS No.		Timing used in **segygather.csh**
1001	642		**No timing and no data**, and no logfile!
1001	7347		**No timing and no data**, and no logfile!
1002	6095		GPS and Pulsed (Manual refrate), GPS never locked, no GPS locks or pulses after JD 076:0031
1003	6041		GPS (okay), 13 msec sawteeth, fix12secbug, ran scripts
1004	7278		GPS (excellent) <1 msec errors
1005	7447		GPS (okay), <5 msec errors, two 7 msec spikes
1006	6035		GPS (excellent) <1 msec errors, fix12secbug, no problem
1007	7111		Pulsed (Auto refrate)
1007	6097		Pulsed (Manual refrate) - timing only from JD 073 to JD 075
1008	550		GPS (okay), with 14 msec sawteeth, last GPS lock JD 083:2056
1009	7097		Pulsed (Manual refrate) - Only one pulse, no GPS!!
1009	6062		GPS (excellent), <1 msec errors, edit logfile only on first pass
1010	7059		Pulsed (Auto refrate), data from JD 069 to JD 078 only, 1st pulse JD 068:1947
1011	7602		GPS (excellent), <1 msec errors
1012	6056		Pulsed (Auto refrate), deleted out peaks and duplicate times, 1st pulse JD 068:2032
1013	6121		Pulsed (Auto refrate), deleted out peaks and duplicate times
1014	7298		GPS (Manual refrate), 2 1-2 hour spikes in GPS time
1015	6086		Pulsed (Auto refrate), 1st pulse JD 068:2312
1016	7069		Pulsed (Auto refrate)
1017	7285		GPS (excellent), <2 msec errors
1018	7083		Pulsed (Auto refrate)
1019	7289		GPS (excellent), <1 msec errors, lost header values
1020	7286		GPS (excellent), <1 msec errors
1021	7357		GPS (excellent), <1 msec errors
1022	7345		GPS (excellent), <2 msec errors
2001	153		GPS (excellent), <1 msec errors
2002	6032		Pulsed (Auto refrate), 2nd pass edited .pcf to change 1988 to 1998, segymod year, event file names changed also
2003	6021		Pulsed (Auto refrate), 2nd pass edited to remove 1988, segymod year, event file names changed also
2004	7593		GPS (okay), 12-13 msec sawteeth
2004	6091		GPS (Manual refrate), 3 pulses, all JD 075:2232, recorded only 4 hrs of line 5
2004	6088		Pulsed (Auto refrate), recorded lines 8-11
2005	6047		Pulsed and GPS (Auto refrate), 2nd pass edited to remove 1988, segymod year, event file names changed also
2006	7300		GPS (very good)
2007	6122		Pulsed (Auto refrate), 2nd pass edited to remove 1988, segymod year, event file names changed also

2008	6093		Pulsed (Auto refrate), 2nd pass edited to remove 1988, segymod year, event file names changed also, last pulse 083:2010
2009	6031		Pulsed and GPS (Manual refrate), 1st pulse JD 068:2006, last pulse JD 083:1756
2010	6087		Pulsed and GPS (Manual refrate), 2nd pass edited to remove 1988, segymod year, event file names changed also, fix12secbug, no problem, 1st pulse 068:1807, last pulse 083:1656
2011	359		GPS (very good)
2012	149		GPS (very good)
2012	6064		GPS (excellent), 14 GPS locks in 4 hours
2013	340		GPS (excellent)
2014	6071		Pulsed (Manual refrate), not edited, ran fix12secbug, no problem; 1st pulse JD 068:2117, last pulse JD 083:1722
3001	6057		GPS (Manual refrate), pulsed JD 068:0144; ran fix12secbug, ran script, refrate with corrected log files
3002	529		GPS (okay), duplicate entries, not edited
3003	6081		GPS (Manual refrate), a few short spikes were not edited, 1st pulse JD 068:0020
3004	6125		GPS (Manual refrate), no GPS locks before JD 070, 1st pulse JD 067:2327
3005	7044		Pulsed (Auto refrate)
3006	880		GPS (Manual refrate), numerous short spikes
3007	7064		Pulsed (Auto refrate), deleted first line
3008	7058		Pulsed (Auto refrate), deleted first line
3009	348		GPS (excellent), < 1 msec errors
3010	7081		Pulsed (Auto refrate), duplicate entries in .pcf deleted on 2nd pass
3011	6045		GPS (excellent), < 2 msec errors
3012	7283		GPS (okay), 13 msec sawteeth errors
3013	7362		GPS (okay), < 8 msec errors
3014	7597		GPS (excellent)
4001	898		GPS (Manual refrate), last pulse JD 084:0051
4002	7066		Pulsed (Manual refrate), 1st pulse JD 071:1651
4003	7288		GPS (okay), 11 msec sawteeth
4004	7078		Pulsed (Auto refrate), deleted 1st 2 lines in .pcf file
4004	6066		Pulsed (Auto refrate) 1st pulse JD 075:1843 at start of data acquisition
4005	7100		GPS and pulsed (Manual refrate), 1st pulse JD 067:2315, last pulse JD 083:1810
4006	7112		Pulsed (Auto refrate), not timed on start day
4006	6120		Pulsed (Manual refrate), lines 7-11, deleted 1st 2 lines in .pcf file, 1st pulse JD 079:2242 at start of acquisition
4007	7282		GPS (good to excellent), generally < 2 msec errors, 8 msec sawtooth near end
4008	7063		GPS and pulsed (Manual refrate), 1st pulse JD 068:2208
4009	7110		GPS and pulsed (Manual refrate), 1st pulse JD 067:1857
4010	6020		GPS and pulsed (Manual refrate), 1st pulse JD 067:2218
4011	6108		GPS (Manual refrate), no GPS lock on last day, last pulse JD 083:2350
4012	6037		Pulsed (Manual refrate), 2nd pass ran fix12secbug, script, last pulse JD 083:2248
4013	6085		Pulsed (Manual refrate), 2nd pass deleted duplicates in .pcf file, last pulse JD 081:1926
5001	7107		Pulsed (Auto refrate)

5002	895		GPS (Manual refrate), no GPS in middle of recording window
5003	395		GPS (good)
5004	6025		GPS (very good), 2nd pass ran fix12secbug, script
5005	7077		Pulsed (Auto refrate)
5006	7039		Pulsed (Auto refrate), deleted 1st 2 lines
5007	877		GPS (no data lines 4-11)
5008	369		GPS (excellent)
5009	656		GPS (very good), 2nd pass ran fix12secbug, script
6001	7291		GPS (very good)
6002	6084		Pulsed (Auto refrate), deleted 1st 3 lines
6003	6080		GPS (excellent)
6004	7595		GPS (good)
6005	6051		Pulsed (Auto refrate)
6006	6098		Pulsed (Auto refrate), deleted entries for 1998:001
6007	7448		GPS (good)
6008	7444		GPS (excellent)
6009	7605		GPS (okay), 10 msec sawtooth pattern
6010	6114		GPS (excellent), no data before first lock JD 072:0115 (after lines 1-2)
6010	6003		**No data!** Not processed!
6011	7615		GPS (okay), <10 msec errors
6012	7594		GPS (excellent) <1 msec errors
6013	6019		Pulsed (Auto refrate)
6014	6067		Pulsed (Auto refrate)
7001	7056		GPS (Manual refrate), 100 msec sawteeth of GPS clock, 1st lock JD 070:0700
7002	7604		GPS (excellent)
7003	7052		GPS (okay), 10 msec sawteeth, 40 msec peak at JD 083 ignored
7004	7306		GPS (excellent) < 1 msec error
7005	6090		GPS (excellent) < 2 to 3 msec errors
7006	7070		GPS failed (Manual refrate), partial line 2 only, no timing (GPS or pulse) for line 2
7006	6102		GPS (good, 1 drift of ~5msec)
7007	6042		GPS (excellent), fix12secbug was run, no problems, NO LINE 1
7008	7292		GPS (excellent)
7009	381		GPS (Manual refrate), JD 069-075 no GPS locks (but low drift rate ~50 msec), fix12secbug, script, refrate with segyshift
7010	7316		GPS (excellent) < 1 msec errors
7011	7085		GPS (excellent) < 3 msec errors
7012	7592		**No data**
7012	6107		GPS (manual refrate), 1st lock JD 076:0020 at start of acquisition, JD 078:1100-1500 250 msec peak with no locks, last lock JD 080:2000 at end of acquisition
8001	6092		GPS (excellent) < 1 msec errors
8002	6040		GPS (okay), 10 msec sawteeth
8003	7614		GPS (generally <2 msec errors, one 10 msec peak)
8004	6101		GPS (excellent) < 1 msec errors, ran fix12secbug no problems, last lock JD 084:0000
8005	6118		GPS (okay), <6 msec errors, ran fix12secbug no problems, last lock JD 084:0000

8006	7303		GPS (good), out of sequence event at battery swap no problem
8007	6065		GPS (okay), 12 msec sawteeth, fix12secbug, ran script, no refrate
8008	7330		GPS (excellent), < 1 msec errors
8009	7630		GPS (good), < 5 msec errors
8010	7320		GPS (excellent), < 1 msec errors
8011	7460		GPS (excellent), < 3 msec errors
8012	7295		GPS (excellent), < 1 msec errors
8013	7462		GPS (good), < 7 msec errors
8014	7440		GPS (good), ignored a couple of time jerks
9001	7104		GPS (good)
9002	7046		GPS (good)
9003	6028		Pulsed (Auto refrate), edited to remove duplicate
9004	7099		Pulsed (Auto refrate), no data lines 6-11 (after JD 077)
9004	6018		Pulsed (Auto refrate), duplicate logs warning, not found in .pcf file
9005	6046		Pulsed (Auto refrate), deleted 1st line
9006	7598		GPS (good)
9007	7092		GPS (okay), 5 msec half-step in middle
9008	7072		GPS (okay), 10 msec sawteeth, ran fix12secbug, ran script
9009	7116		GPS (Manual refrate), edited .pcf file
9010	7038		GPS (okay), < 10 msec errors
9011	7428		GPS (Auto refrate), not edited to remove 26 msec pulses
9012	227		GPS (excellent), < 3 msec errors
9012	6030		GPS (very good)
9012	6069		GPS (Manual refrate), bad GPS clock!!
9012	7466		GPS (Manual? refrate)
9013	7324		GPS (good)
9014	7296		GPS (excellent), < 1 msec errors
9015	7098		GPS (looks good)
9016	7061		GPS (okay), 12 msec sawteeth (4 day cycle)
9017	7452		GPS (Manual refrate), 15 msec offsets
9018	7302		GPS (good!)
9019	7454		GPS (good)
9021	7352		GPS (excellent)
9022	7435		GPS (Manual refrate)
9023	338		GPS (good), ran fix12secbug, no problem
9024	7317		GPS (okay), 10 msec sawteeth
9025	7089		GPS (excellent)
9026	7466		GPS (Manual? Refrate)
9027	7339		GPS (okay), 6 msec sawteeth
9028	7073		GPS (Manual refrate), 32 msec spikes
9029	771		GPS (Manual refrate), 400 msec errors, GPS has large driftrate and offsets, 1st lock JD 066:2338, last lock JD 083:1700
9030	7075		GPS (okay)
9030	6029		Pulsed (Auto refrate)

9031	6026		Pulsed (Auto refrate)
10001	7041		GPS (okay), 11 msec sawteeth
10002	7114		GPS, no data JD 075 to JD 077
10003	7334		GPS (Manual? refrate)
10004	7627		GPS (Manual refrate), pulsed at end of acquisition, deleted one out of sequence event from .pcf file
10005	7074		GPS (excellent), < 1 msec errors
10006	556		GPS, **no data**, GPS locks only on JD 075 and 076
10007	7364		GPS (okay), up to 18 msec sawteeth
10008	7047		GPS (excellent), < 1 msec errors
10009	7040		GPS (excellent), < 1 msec errors
10010	7629		GPS (excellent), generally < 2 msec errors, deleted one out of sequence data event
10011	7043		GPS (okay), 11 msec sawteeth
10012	7591		GPS (excellent), < 1 msec errors, ignored one short spike
10013	7082		GPS (excellent), < 1 msec errors
10014	7341		GPS (good), < 5 msec errors
10015	7091		GPS (okay), <10 msec errors
10016	7093		GPS (good), < 5 msec errors
10017	7068		GPS, generally < 10 msec errors, up to 30 msec spikes
10018	391		GPS (okay) <10 msec errors, several short 18 msec errors during JD 069-070 ignored
10019	7050		GPS (okay), generally < 5 msec errors with 13 msec sawteeth
10020	7088		GPS (excellent), < 1 msec errors
10021	7094		GPS (okay), 13 msec sawteeth
10022	7096		Pulsed (Auto refrate), 1st pulse JD 069:1927
10023	7438		GPS (excellent), <2 msec errors, no data before JD 076:1950 (no lines 1-4)
10024	7279		Pulsed (Auto refrate), not pulsed on start day, 1st pulse JD 068
10025	7609		GPS (good), generally < 2 msec errors, 423 msec spike on JD 068
10025	7622		Pulsed (Auto refrate), lst pulse 069:1927
10026	7600		GPS (excellent), < 3 msec errors
10027	192		GPS (good), < 5 msec errors
10028	7611		GPS (excellent) <1 msec error for 069:1542 to 083:2246
10029	7624		**Recorded only 4 events**, 075:1630 to 075:1830, no locks or pulses
10030	7095		GPS (good) < 7 msec errors
10031	878		GPS (excellent), <1 msec error
10032	7294		GPS (excellent), <1 msec error
10033	7071		GPS (excellent), <5 msec error
10034	7297		GPS (good), ignored one time jerk
10035	7053		GPS (Manual refrate), fix12secbug, then script, no duplicates found, last lock JD 083:2000
10036	7350		GPS (excellent), <1 msec error, last lock JD 083:1300
10037	7101		GPS (good) <10 msec error
10038	7108		GPS (excellent), <2 msec error
10039	7601		GPS (excellent), <3 msec errors
10040	7619		GPS (ignored a 24 hr 46 msec peak on JD 070)

10041	7062		**No data**
10042	7113		GPS (excellent), one 10 msec spike, ran fix12secbug, ran script
10043	7109		GPS (excellent), <1 msec error, ran fix12secbug, ran script
10044	7054		GPS (excellent), <4 msec errors, ran fix12secbug, no problem
10045	7467		GPS (excellent), <1 msec error
10046	7076		GPS (Manual refrate), no GPS between 072:2000 and 083, deleted 4 lines at end of pcf file, ran fix12secbug, no problem
10047	7103		GPS (excellent), <2 msec error - forgot to run fix12secbug, has 2 events
10048	7342		GPS (excellent), <2 msec error, ignore 3 daily peaks up to 26 msec JD 081-083
10049	7086		GPS (excellent), <2 msec error, ran fix12secbug, ran script
10050	7346		GPS (excellent), <1 msec error
10051	7087		GPS (excellent), <1 msec error, ran fix12secbug, ran script
10052	7084		GPS (good), ran fix12secbug, no problem
10053	384		GPS (excellent), <1 msec error
10054	7065		GPS (excellent), <1 msec error, ran fix12secbug, no problem
10055	7328		GPS (okay), 10 msec sawteeth
10056	7060		GPS (excellent), <1 msec error, ran fix12secbug, ran script
10057	875		GPS (excellent), <3 msec errors
10058	7090		GPS (excellent), <1 msec error
10059	553		GPS (Manual refrate), up to 50 msec sawteeth
10060	7609		GPS (excellent), <1 msec error
11001	7337		GPS, removed JD 013 entry from near JD 073:0200 in logfile
11002	6116		GPS, only 2 GPS locks (46 msec drift)
11003	6126		GPS (Manual refrate), Poor timing because there are only 17 GPS locks
11004	6110		GPS (good), <10 msec errors
11005	6119		GPS (okay), 17-25 msec sawteeth ignored
11006	6039		Pulsed (Auto refrate) deleted 1st 2 lines in .pcf file
11007	7301		GPS (excellent) <1 msec error, 1st lock JD 070:0000
1107A	7301		GPS (excellent) <1 msec error, 1st lock JD 070:0000
11008	7287		GPS (Manual refrate), 62 msec sawtooth peaks
11009	7606		GPS (good), < 2.5 msec errors
11010	6113		GPS (Manual refrate), JD 069-074 few GPS locks, 100 msec sawteeth
11011	6058		GPS (excellent), generally <1 msec error
11012	6111		GPS (Manual refrate), no GPS locks JD 070 to JD 074 and from JD 079 to JD 084
11013	6060		GPS (excellent), <1 msec error
11014	7344		GPS (Manual refrate), GPS missing JD 070:2358 to JD 079:0225
11015	6109		Pulsed (Auto refrate), deleted before JD 069:2300 in .pcf file
11016	7343		GPS (okay), 10 msec sawtooth pattern
11017	7599		GPS and pulsed (Manual refrate), last lock JD 080:1200, last pulse JD 085:1752
11018	7280		GPS (good)
11019	7625		GPS (excellent), <1 msec errors
11020	7299		GPS (excellent), <1 msec errors
11021	7610		GPS (okay), up to 8 msec errors
11022	7331		GPS (excellent), <1msec error, last lock JD 083:2348

11023	7337		GPS, edited logfile to remove JD 013 event from near JD 073:0200 in logfile
11024	7456		Pulsed (Auto refrate), infrequently pulsed, deleted out of sequence events
11025	6113		GPS (Manual refrate), few GPS locks from JD 069 to JD 074, 100 msec sawteeth
11025	6126		GPS (Manual refrate), Poor timing because there are only 17 GPS locks
11026	6113		GPS (Manual refrate), few GPS locks from JD 069 to JD 074, 100 msec sawteeth
11026	7337		GPS, edited logfile to remove JD 013 event from near JD 073:0200 in logfile
11027	6060		GPS (excellent), <1 msec error
11027	6116		GPS (excellent)
11028	6058		GPS (excellent), generally <1 msec error
11029	6060		GPS (excellent), <1 msec error
11029	6116		GPS (excellent)
11030	7277		GPS (excellent), <1 msec error
11031	7623		GPS (excellent), <3 msec error
11032	7284		GPS (excellent), <1 msec error
11033	7628		GPS (excellent), <1 msec error
11034	7332		GPS (excellent)
11035	7429		GPS (excellent)
11036	7351		GPS (excellent), <3 msec errors, edited to remove 1988, segymod year, event file names changed also
11037	7281		GPS (good)
11038	7429		GPS (excellent)
11039	7332		GPS (excellent)
11041	7281		GPS (good)
11042	7351		GPS (excellent), <3 msec errors
11043	7431		GPS and pulsed (Manual refrate), no GPS locks after >JD 073:0000, high GPS driftrates, no locks JD 072-082, pulsed JD 082:0055 and JD 083:1634
11044	7445		GPS (good)
11045	7360		GPS (generally good), one 40 msec spike at JD 070:0000 was ignored
11046	7348		GPS (Manual refrate), 100 msec errors
11047	7446		GPS (good), 29 msec spike late JD 069, ignored), lst lock JD 069:2142, 2 locks prior
11048	7430		GPS (good)
11049	7449		GPS (Manual refrate), 70 msec error on JD 073), 1st lock before JD 068
11050	7333		GPS (Manual refrate), JD 080 large errors
11051	7322		GPS (good)
11052	7433		GPS (okay), <10 msec errors
11053	7612		GPS (excellent), JD 070 to JD 084
Tully	7356		GPS (okay), 6 msec sawteeth

Appendix 4. List of stations having problems with spurious 12-second shifts

Station Name	DAS No.		Effected Lines, JD:UTC (HrMn), and No. of 30-min-long Events
1003	6041		Lines 4 and 9, 074:0045, 081:0104-0334, 6 events
3001	6057		Lines 4 and 9, 074:0013, 081:0030-0130, 3 events total
3002	529		Line 4, Ch. 4-6, 074:0014, 1 event
4005	7100		Line 9, 081:0043-0143, 3 events
4011	6108		Line 4, 074:0017, 1 event
4012	6037		Line 9, 081:0112-0142, 2 events
5004	6025		Line 9, 081:0023-0323, 6 events
5009	656		Line 9, Ch. 4-6, 081:0012, 1 event
6003	6080		Before shooting started, JD 067:2225, 1 spike, removed
7009	381		Line 9, 081:0053-0423, 8 events
8007	6065		Line 9, 081:0043-0313, 6 events
9001	7104		Lines 4 and 9, 074:0015-0045, 081:0052-0322, 7 events
9008	7072		Lines 4 and 9, 074:0101, 081:0039-0339, 12 events
9009	7116		Line 9, 081:0027-0427, 8 events
9012	6030		Line 9, 081:0022-0222, 4 events
9015	7098		Line 9, 081:0016-0316, 6 events
10008	7047		Line 4, 074:0016, 1 event
10009	7040		Lines 4 and 9, 074:0047-0117 , 081:0037-0337 , 9 events
10011	7043		Line 9, 081:0041-0341, 6 events
10013	7082		Lines 4 and 9, 081:0103-0233, 4 events
10016	7093		Line 4, 074:0022, 1 event
10020	7088		Line 9, 081:0028-0328, 6 events
10035	7053		Line 9, 081:0109-0839, 16 events
10037	7101		Line 9, 081:0043, 1 event
10042	7113		Line 9, 081:0104-0134, 2 events
10043	7109		Line 4, 074:0043, 2 events
10047	7103		Lines 4 and 9, 074:0043, 081:0043, 2 events total
10049	7086		Line 9, 081:0048-0318, 6 events
10051	7087		Line 4, 074:0052-0122, 2 events
10056	7060		Line 9, 081:0104-0134, 2 events

Appendix 5. List of location of Reftek station data on archival tapes

Station Name	DAS No.	Tape Name	File No.	Comments	Tape Name	File No.	Comments	Tape Name	File No.	Comments
1002	6095	USGS DLT1A	1-11	Ch. 1	USGS DLT1B	1-11	Ch. 1	USGS DAT1	1-11	Ch. 1
1004	7278	copy of	12-22	All zero files		12-22	All zero files		12-22	All zero files
1004	7278	USGS DLT1B	23-33	Ch. 3		23-33	Ch. 3		23-33	Ch. 3
1005	7447		34-44	Ch. 1		34-44	Ch. 1	USGS DAT2	1-11	Ch. 1
1006	6035		45-55	Ch. 1		45-55	Ch. 1		12-22	Ch. 1
1007	7111		56-66	Ch. 1		56-66	zerofiles 60-66, no lines 5-11		23-33	zerofiles 26-33, no lines 5-11
1007	6097		67-77	Ch. 1		67-77	All zero files		34-44	All zero files
1008	550		78-88	All zero files		78-88	All zero files	USGS DAT3	1-11	All zero files
1008	550		89-99	All zero files		89-99	All zero files		12-22	All zero files
1008	550		100-110	All zero files		100-110	All zero files		23-33	All zero files
1008	550		111-121	All zero files		111-121	All zero files		34-44	All zero files
1008	550		122-132	All zero files		122-132	All zero files		45-55	All zero files
1009	6062		133-143	All zero files		133-143	All zero files	USGS DAT4	1-11	All zero files
1010	7059		144-154	Ch. 1		144-154	zerofiles 149-154, no lines 6-11		11-22	zerofiles 17-22 no lines 6-11
1012	6056		155-165	Ch. 1		155-165	zerofiles 155-158, no lines 1-4		23-33	zerofiles 23-26 no lines 1-4
1013	6121		166-176	Ch. 1		166-176	zerofiles 166-169, no lines 1-4		34-44	zerofiles 34-37 no lines 1-4
1014	7298		177-187	Ch. 3		177-187	Ch. 3	USGS DAT5	1-11	Ch. 3
1015	6086		188-198	Ch. 1		188-198	zerofiles 188-191, no lines 1-4	USGS DAT6	1-11	zerofiles 1-4, no lines 1-4
1016	7069		199-209	Ch. 1		199-209	Ch. 1		12-22	Ch. 1
1017	7285		210-220	Ch. 3		210-220	Ch. 3	USGS DAT7	1-11	Ch. 3
1018	7083	USGS DLT2A	1-11	Ch. 1	USGS DLT2B	1-11	zero file 1, no line 1	USGS DAT8	1-11	zero file 1, no line 1
1019	7289		12-22	Ch. 3		12-22	Ch. 3	USGS DAT9	1-11	Ch. 3
1020	7286		23-33	Ch. 3		23-33	Ch. 3	USGS DAT10	1-11	Ch. 3
1021	7357		34-44	zero files 35-44, no lines 2-11		34-44	zero files 35-44, no lines 2-11		12-22	zero files 13-22 no lines 2-11
1021	7357		45-55	Ch. 1		45-55	Use this version		23-33	Use this version
1022	7345		56-66	zero file 56, no line 1		56-66	zero file 56, no line 1		34-44	zero file 34, no line 1
2001	153		67-77	All zero files		67-77	All zero files	USGS DAT11	1-11	All zero files
2002	6032		78-88	Ch. 1		78-88	Ch. 1		12-22	Ch. 1
2003	6021		89-99	Ch. 1		89-99	Ch. 1		23-33	Ch. 1

2004	7593		100-110	All zero files		100-110	All zero files		34-44	All zero files
2005	6047		111-121	Ch. 1		111-121	Ch. 1		45-55	Ch. 1
2006	7300		122-132	Ch. 1		122-132	Ch. 1		56-66	Ch. 1
2007	6122		133-143	Ch. 1		133-143	Ch. 1		67-77	Ch. 1
2008	6093		144-154	Ch. 1		144-154	Ch. 1	USGS DAT12	1-11	Ch. 1
2009	6031		155-165	Ch. 1		155-165	Ch. 1		12-22	Ch. 1
2010	6087		166-176	Ch. 1		166-176	Ch. 1		23-33	Ch. 1
2011	359		177-187	Ch. 4		177-187	Ch. 4		34-44	Ch. 4
2012	149		188-198	Ch. 4		188-198	Ch. 4	USGS DAT13	1-11	Ch. 4
2013	340	USGS DLT3A	1-11	Ch. 4	USGS DLT3B	1-11	Ch. 4	USGS DAT14	1-11	Ch. 4
2014	6071	copy of	12-22	Ch. 1		12-22	Ch. 1		12-22	Ch. 1
3001	6057	USGS DLT3B	23-33	Ch. 1		23-33	Ch. 1		23-33	Ch. 1
3002	529		34-44	zerofile 44, no line 11, Ch. 4		34-44	zerofile 44, no line 11		34-44	zerofile 44, no line 11
3003	6081		45-55	Ch. 1		45-55	Ch. 1	USGS DAT15	1-11	Ch. 1
3004	6125		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
3005	7044		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
3006	880		78-88	Ch. 4		78-88	Ch. 4		34-44	Ch. 4
3008	7058		89-99	Ch. 1		89-99	Ch. 1	USGS DAT16	1-11	Ch. 1
3007	7064		100-110	Ch. 1		100-110	Ch. 1		12-22	Ch. 1
3009	348		111-121	Ch. 4		111-121	Ch. 4	USGS DAT17	1-11	Ch. 4
3010	7081		122-132	on DLT3A		122-132	on DLT3A		12-22	on DLT3A
3011	6045		133-143	Ch. 1		133-143	Ch. 1		23-33	Ch. 1
3012	7283		144-154	Ch. 1		144-154	Ch. 1	USGS DAT18	1-11	Ch. 1
3013	7362		155-165	Ch. 1		155-165	Ch. 1	USGS DAT19	1-11	Ch. 1
3014	7597		166-176	Ch. 1		166-176	Ch. 1		12-22	Ch. 1
4001	898		177-187	Ch. 4		177-187	Ch. 4	USGS DAT20	1-11	Ch. 4
4002	7066	USGS DLT4A	1-11	Ch. 1	USGS DLT4B	1-11	Ch. 1		12-22	Ch. 1
4003	7288		12-22	Ch. 1		12-22	Ch. 1		23-33	Ch. 1
4004	6066		23-33	zero files 23-25, no lines 1-3		23-33	zero files 23-25, no lines 1-3	USGS DAT21	1-11	zero files 1-3, no lines 1-3
4006	7112		34-44	zero files 41-44, no lines 8-11		34-44	zero files 41-44, no lines 8-11		12-22	zero files 19-22, no lines 8-11
4007	7282		45-55	Ch. 1		45-55	Ch. 1		23-33	Ch. 1
4008	7063		56-66	Ch. 1		56-66	Ch. 1	USGS DAT22A	1-11	Ch. 1
4009	7110		67-77	Ch. 1		67-77	Ch. 1		12-22	Ch. 1
4010	6020		78-88	Ch. 1		78-88	Ch. 1		23-33	Ch. 1
4011	6108		89-99	Ch. 1		89-99	Ch. 1		34-44	Ch. 1
4013	6085		100-110	zero files 100-102, no line 1-3		100-110	zero files 100-102, no line 1-3	USGS DAT22B	1-11	zerofiles 1-3, no lines 1-3
5001	7107		111-121	zero file 113, missed line 1-5 data		111-121	zero file 113, missed line 1-5 data		12-22	Ch. 1, missed line 1-5 data

5002	895		122-132	Ch. 4		122-132	Ch. 4		23-33	Ch. 1
5003	395		133-143	Ch. 4		133-143	Ch. 4	USGS DAT23	1-11	Ch. 1
5004	6025		144-154	zero files 144-146, missed line 1-5 data		144-154	zero files 144-146, missed line 1-5 data		12-22	Ch. 1, zerofiles 12-14,
5005	7077		155-165	Ch. 1		155-165	Ch. 1	USGS DAT24	1-11	Ch. 1
5001	7107		166-176	Use this gather!		166-176	Use this gather! - ch. 1		12-22	Use this gather! Ch. 1
5004	6025		177-187	Use this gather!		177-187	Use this gather! - Ch. 1		23-33	Use this gather! Ch. 1
5006	7039	USGS DLT5A	1-11	Ch. 1	USGS DLT5B	1-11	Ch. 1	USGS DAT25	1-11	Ch. 1
5007	877		12-22	All zero files		12-22	All zero files		12-22	All zero files
5007	877		23-33	zero files 27-33, no lines 5-11, Ch. 4		23-33	zero files 27-33, no lines 5-11		23-33	zero files 27-33, no lines 5-11
5008	369		34-44	Ch. 4		34-44	Ch. 4		34-44	Ch. 1
5009	656		45-55	All zero files		45-55	All zero files	USGS DAT26	1-11	All zero files
5009	656		56-66	Ch. 4		56-66	Ch. 4		12-22	Ch. 1
6001	7291		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
6002	6084		78-88	Ch. 1		78-88	Ch. 1		34-44	Ch. 1
6003	6080		89-99	Ch. 1		89-99	Ch. 1		45-55	Ch. 1
6004	7595		100-110	Ch. 1		100-110	Ch. 1	USGS DAT27	1-11	Ch. 1
6005	6051		111-121	Ch. 1		111-121	Ch. 1		12-22	Ch. 1
6006	6098		122-132	Ch. 1		122-132	Ch. 1		23-33	Ch. 1
6007	7448		133-143	Ch. 1		133-143	Ch. 1		34-44	Ch. 1
6008	7444		144-154	Ch. 1		144-154	Ch. 1	USGS DAT28	1-11	Ch. 1
6009	7605		155-165	Ch. 1		155-165	Ch. 1		12-22	Ch. 1
6010	6114		166-176	zero file 166, no line 1		166-176	zero file 166, no line 1		23-33	Ch. 1, zerofile 23, no line 1
6011	7615		177-187	Ch. 1		177-187	Ch. 1	USGS DAT29	1-11	Ch. 1

6012	7594		188-198	Ch. 1		188-198	Ch. 1		12-22	Ch. 1
6013	6019		199-209	Ch. 1		199-209	Ch. 1		23-33	Ch. 1
6014	6067		210-220	Ch. 1		210-220	Ch. 1		34-44	Ch. 1
1004	7278	USGS DLT6A	1-11	Ch. 1	USGS DLT6B	1-11	Ch. 1	USGS DAT30	1-11	Ch. 1
1007	6097		12-22	All Zero files		12-22	All Zero files		12-22	All Zero files
1009	6062		23-33	zero files 23-24, no lines 1-2		23-33	zero files 23-24, no lines 1-2		23-33	zero files 23-24, no lines 1-2
1007	6097		34-44	zero files 34-35, no lines 1-2		34-44	zero files 34-35, no lines 1-2		34-44	zero files 34-35, no lines 1-2
1011	7602		45-55	Ch. 1		45-55	Ch. 1	USGS DAT31	1-11	Ch. 1
1012	6056		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
1013	6121		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
1014	7298		78-88	Ch. 1		78-88	Ch. 1		34-44	Ch. 1
1015	6086		89-99	Ch. 1		89-99	Ch. 1	USGS DAT32	1-11	Ch. 1
1017	7285		100-110	Ch. 1		100-110	Ch. 1		12-22	Ch. 1
1019	7289		111-121	Ch. 1		111-121	Ch. 1		23-33	Ch. 1
1020	7286		122-132	Ch. 1		122-132	Ch. 1	USGS DAT33	1-11	Ch. 1
2001	153		133-143	Ch. 4		133-143	Ch. 4		12-22	Ch. 1
2002	6032		144-154	Ch. 1		144-154	Ch. 1		23-33	Ch. 1
2003	6021		155-165	Ch. 1		155-165	Ch. 1		34-44	Ch. 1
2004	7593		166-176	zero files 169, 174-176, no line 4, 9-11		166-176	zero files 169, 174-176, no line 4, 9-11	USGS DAT34	1-11	Ch. 1, zerofiles 4, 9-11, no lines 4, 9-11
2004	6091		177-187	zero files 177-179, 182-187, partial line 5 only		177-187	zero files 177-179, 182-187, partial line 5 only		12-22	Ch. 1, zerofiles 12-14, 17-22,
2004	6088		188-198	zero flles 188-192, no lines 1-5		188-198	zero flles 188-192, no lines 1-5		23-33	Ch. 1, zerofiles 23-27, no lines 1-5
2005	6047		199-209	Ch. 1		199-209	Ch. 1	USGS DAT35	1-11	Ch. 1
2007	6122		210-220	Ch. 1		210-220	Ch. 1		12-22	Ch. 1
2008	6093		221-231	Ch. 1		221-231	Ch. 1		23-33	Ch. 1
2010	6087		232-242	Ch. 1		232-242	Ch. 1		34-44	Ch. 1
2012	6064		243-253	zero files 243-244, 249-250, no lines 1-2, 7-8		243-253	zero files 243-244, 249-250, no lines 1-2, 7-8		45-55	Ch. 1, zerofiles 45-46, 51-52
3010	7081	USGS DLT7A	1-11	Ch. 1	USGS DLT7B	1-11	Ch. 1	USGS DAT36	1-11	Ch. 1
4004	7078		12-22	zero files 16-22, no lines 5-11		12-22	zero files 16-22, no lines 5-11	USGS DAT37	1-11	Ch. 1, zerofiles 5-11, no lines 5-11
4006	6120		23-33	zero files 23-27, no lines 1-5		23-33	zero files 23-27, no lines 1-5		12-22	Ch. 1, zerofiles 12-16, no lines 1-5
4011	6108		34-44	Ch. 1		34-44	Ch. 1	USGS DAT38	1-11	Ch. 1
4012	6037		45-55	Ch. 1		45-55	Ch. 1	USGS DAT39	1-11	Ch. 1
4013	6085		56-66	zero files 56-58, no lines 1-3		56-66	zero files 56-58, no lines 1-3	USGS DAT40	1-11	Ch. 1, zerofiles 1-3, no lines 1-3
5005	6025		67-77	Ch. 1		67-77	Ch. 1	USGS DAT41	1-11	Ch. 1

5009	656		78-88	Ch. 4		78-88	Ch. 4	USGS DAT42	1-11	Ch. 1
7001	7056		89-99	Ch. 1		89-99	Ch. 1	USGS DAT43	1-11	Ch. 1
7002	7604		100-110	Ch. 1		100-110	Ch. 1	USGS DAT44	1-11	Ch. 1
7003	7052		111-121	Ch. 1		111-121	Ch. 1	USGS DAT45	1-11	Ch. 1
7004	7306		122-132	Ch. 1		122-132	Ch. 1	USGS DAT46	1-11	Ch. 1
7005	6090		133-143	Ch. 1		133-143	Ch. 1	USGS DAT47	1-11	Ch. 1
7006	7070		144-154	zero files 144, 146-154, have only line 2		144-154	zero files 144, 146-154, have only line 2		12-22	Ch. 1, zerofile 12, 14-22, have only line 2
7006	6102		155-165	zero file 155, no line 1		155-165	zero file 155, no line 1		23-33	Ch. 1, zerofile 23, no line 1
7007	6042		166-176	zero file 166, no line 1		166-176	zero file 166, no line 1	USGS DAT48	1-11	Ch. 1, zerofile 1, no line 1
7008	7292		177-187	Ch. 1		177-187	Ch. 1		12-22	Ch. 1
7009	381		188-198	Ch. 4		188-198	Ch. 4	USGS DAT49	1-11	Ch. 1
7010	7316		199-209	Ch. 1		199-209	Ch. 1	USGS DAT50	1-11	Ch. 1
7011	7085	USGS DLT8A	1-11	Ch. 1	USGS DLT8B	1-11	Ch. 1	USGS DAT51	1-11	Ch. 1
8001	6092		12-22	Ch. 1		12-22	Ch. 1	USGS DAT52	1-11	Ch. 1
8003	7614		23-33	Ch. 1		23-33	Ch. 1	USGS DAT53	1-11	Ch. 1
7012	6107		34-44	zero files 34-37, 43, no lines 1-4, 10		34-44	zero files 34-37, 43, no lines 1-4, 10		12-22	Ch. 1, zerofiles 12-15, 21, no lines 1-4
8002	6040		45-55	Ch. 1		45-55	Ch. 1	USGS DAT54	1-11	Ch. 1
8004	6101		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
8005	6118		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
8006	7303		78-88	Ch. 1		78-88	Ch. 1	USGS DAT55	1-11	Ch. 1
8007	6065		89-99	Ch. 1		89-99	Ch. 1		12-22	Ch. 1
8008	7330		100-110	Ch. 1		100-110	Ch. 1	USGS DAT56	1-11	Ch. 1
8009	7630		111-121	Ch. 1		111-121	Ch. 1	USGS DAT57	1-11	Ch. 1
8010	7320		122-132	Ch. 1		122-132	Ch. 1	USGS DAT58	1-11	Ch. 1
8011	7460		133-143	Ch. 1		133-143	Ch. 1	USGS DAT59	1-11	Ch. 1
8012	7295		144-154	Ch. 1		144-154	Ch. 1	USGS DAT60	1-11	Ch. 1
8013	7462		155-165	Ch. 1		155-165	Ch. 1	USGS DAT61	1-11	Ch. 1
8014	7440		166-176	Ch. 1		166-176	Ch. 1	USGS DAT62	1-11	Ch. 1
4003	7288	USGS DLT9A	1-11	Ch. 2	USGS DLT9B	1-11	Ch. 2	USGS DAT63	1-11	Ch. 2
4003	7288		12-22	Ch. 3		12-22	Ch. 3		12-22	Ch. 3
4007	7282		23-33	Ch. 2		23-33	Ch. 2		23-33	Ch. 2
4007	7282		34-44	Ch. 3		34-44	Ch. 3	USGS DAT64	1-11	Ch. 3
5002	895		45-66	Ch. 5 and 6		45-66	Ch. 5 and 6		12-33	Ch. 5 and 6
5003	395		67-88	Ch. 5 and 6		67-88	Ch. 5 and 6	USGS DAT65	1-22	Ch. 5 and 6
5007	877	Ch. 5 and 6	89-110	zerofiles 97-110, no lines 5-11, Ch. 5 and 6		89-110	zerofiles 97-110, no lines 5-11, Ch. 5 and 6		23-44	zerofiles 31-44 no lines 5-11, Ch. 5 and 6
5008	369		111-132	Ch. 5 and 6		111-132	Ch. 5 and 6	USGS DAT66	1-22	Ch. 5 and 6
5009	656		133-154	Ch. 5 and 6		133-154	Ch. 5 and 6	USGS DAT67	1-22	Ch. 5 and 6
6001	7291		155-176	Ch. 2 and 3		155-176	Ch. 2 and 3	USGS DAT68	1-22	Ch. 2 and 3
6004	7595	USGS DLT10A	1-22	Ch. 2 and 3	USGS DLT10B	1-22	Ch. 2 and 3	USGS DAT69	1-22	Ch. 2 and 3

6009	7605		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	USGS DAT70	1-22	Ch. 2 and 3
6011	7615		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	USGS DAT71	1-22	Ch. 2 and 3
6012	7594		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	USGS DAT72	1-22	Ch. 2 and 3
7002	7604		89-110	Ch. 2 and 3		89-110	Ch. 2 and 3	USGS DAT73	1-22	Ch. 2 and 3
7004	7306		111-132	Ch. 2 and 3		111-132	Ch. 2 and 3	USGS DAT74	1-22	Ch. 2 and 3
7009	381		133-154	Ch. 5 and 6		133-154	Ch. 5 and 6	USGS DAT75	1-22	Ch. 5 and 6
7010	7316		155-176	Ch. 2 and 3		155-176	Ch. 2 and 3	USGS DAT76	1-22	Ch. 2 and 3
8003	7614	USGS DLT11A	1-22	Ch. 2 and 3	USGS DLT11B	1-22	Ch. 2 and 3	USGS DAT77	1-22	Ch. 2 and 3
8006	7303		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	USGS DAT78	1-22	Ch. 2 and 3
8009	7630		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	USGS DAT79	1-22	Ch. 2 and 3
8012	7295		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	USGS DAT80	1-22	Ch. 2 and 3
1004	7278		89-110	Ch. 2 and 3		89-110	Ch. 2 and 3	USGS DAT81	1-22	Ch. 2 and 3
1008	550		111-143	Ch. 4, 5, 6		111-143	Ch. 4, 5, 6	USGS DAT82	1-33	Ch. 4, 5, 6
1011	7602		144-165	Ch. 2 and 3		144-165	Ch. 2 and 3	USGS DAT83	1-22	Ch. 2 and 3
1014	7298	USGS DLT12A	1-22	Ch. 2 and 3	USGS DLT12B	1-22	Ch. 2 and 3	USGS DAT84	1-22	Ch. 2 and 3
1017	7285		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	USGS DAT85	1-22	Ch. 2 and 3
1019	7289		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	USGS DAT86	1-22	Ch. 2 and 3
1020	7286		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	USGS DAT87	1-22	Ch. 2 and 3
2001	153		89-110	Ch. 5 and 6		89-110	Ch. 5 and 6	USGS DAT88	1-22	Ch. 5 and 6
2004	7593		111-132	zerofiles 117-118, 127-132, Ch. 2 and 3		111-132	zerofiles 117-118, 127-132, Ch. 2 and 3	USGS DAT89	1-22	zerofiles 117-118, 127-132, Ch. 2 and 3
2006	7300		133-154	Ch. 2 and 3		133-154	Ch. 2 and 3	USGS DAT90	1-22	Ch. 2 and 3
2011	359		155-176	Ch. 5 and 6		155-176	Ch. 5 and 6	USGS DAT91	1-22	Ch. 5 and 6
2012	149	USGS DLT13A	1-22	Ch. 5 and 6	USGS DLT13B	1-22	Ch. 5 and 6	USGS DAT92	1-22	Ch. 5 and 6
2013	340		23-44	Ch. 5 and 6		23-44	Ch. 5 and 6	USGS DAT93	1-22	Ch. 5 and 6
3002	529		45-77	Ch. 4, 5, 6		45-77	Ch. 4, 5, 6 l	USGS DAT94	1-33	Ch. 4, 5, 6
3006	880		78-110	zerofiles 75-77, Ch. 4-6		78-110	zerofiles 75-77, Ch. 4-6	USGS DAT95	1-33	zerofiles 1-3, Ch. 4-6
3009	348		111-132	Ch. 2 and 3		111-132	Ch. 2 and 3	USGS DAT96	1-22	Ch. 2 and 3
3012	7283		133-154	Ch. 2 and 3		133-154	Ch. 2 and 3	USGS DAT97	1-22	Ch. 2 and 3
3014	7597		155-176	Ch. 2 and 3		155-176	Ch. 2 and 3	USGS DAT98	1-22	Ch. 2 and 3
4001	898	USGS DLT14A	1-33	Ch. 5 and 6	USGS DLT14B	1-33	Ch. 5 and 6	USGS DAT99	1-22	Ch. 5 and 6
1003	6041		34-44	Ch. 1 -		34-44	Ch. 1 - fix12secbug	USGS DAT100	1-11	Ch. 1 - fix12secbug
2002	6032		45-55	Ch. 1 - fix 1988		45-55	Ch. 1 - fix 1988		12-22	Ch. 1 - fix 1988
2003	6021		56-66	Ch. 1 - fix 1988		56-66	Ch. 1 - fix 1988		23-33	Ch. 1 - fix 1988
2005	6047		67-77	Ch. 1 - fix 1988		67-77	Ch. 1 - fix 1988		34-44	Ch. 1 - fix 1988
3001	6057		78-88	Ch. 1 - manual refrate		78-88	Ch. 1 - manual refrate, fix12secbug		45-55	Ch. 1 - manual refrate, fix12secbug
3003	6081		89-99	Ch. 1 - manual refrate		89-99	Ch. 1 - manual refrate		56-66	Ch. 1 - manual refrate
3004	6125		100-110	Ch. 1 - manual refrate		100-110	Ch. 1 - manual refrate	USGS DAT101	1-11	Ch. 1 - manual refrate
4005	7100		111-121	Ch. 1		111-121	Ch. 1		12-22	Ch. 1
4011	6108		122-132	Ch. 1		122-132	Ch. 1	USGS DAT104		Ch. 1
6003	6080		133-143	Ch. 1		133-143	Ch. 1			Ch. 1

1003	6041		144-145	Lines 4 and 9		144-145	Lines 4 and 9	USGS DAT103	1-2	Lines 4 and 9
3001	6057		146-147	Lines 4 and 9		146-147	Lines 4 and 9		3-4	Lines 4 and 9
3002	529		148-150	Line 4, Ch. 4-6		148-150	Line 4, Ch. 4-6		5-7	Line 4, Ch. 4-6
4012	6037		151	Line 9		151	Line 9		8	Line 9
5004	6025		152	Line 9		152	Line 9		9	Line 9
5009	656		153-155	Zerofiles		153-155	Zerofiles		10-12	Zerofiles
5009	656		156-158	Line 9, Ch. 4-6		156-158	Line 9, Ch. 4-6		13-15	Line 9, Ch. 4-6
7009	381	OSU DLT4A	98-100	Line 9	OSU DLT4B	98-100	Line 9	USGS DAT104	1-3	Line 9
8007	6065		101	Line 9		101	Line 9		4	Line 9
9001	7104	OSU DLT1A	1-11	Ch. 1	OSU DLT1B	1-11	Ch. 1	OSU DAT1	1-11	Ch. 1
9003	6028		12-22	Ch. 1		12-22	Ch. 1		12-22	Ch. 1
9002	7046		23-33	Ch. 1		23-33	Ch. 1	OSU DAT2	1-11	Ch. 1
9004	7099		34-44	zero files 39-44, no lines 6-11		34-44	zero files 39-44, no lines 6-11		12-22	zero files 17-22 no lines 6-11
9005	6046		45-55	Ch. 1		45-55	Ch. 1	OSU DAT3	1-11	Ch. 1
9006	7598		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
9007	7092		67-77	Ch. 1		67-77	Ch. 1	OSU DAT4	1-11	Ch. 1
9008	7072		78-88	Ch. 1		78-88	Ch. 1		12-22	Ch. 1
9009	7116		89-99	Ch. 1		89-99	Ch. 1	OSU DAT5	1-11	Ch. 1
9010	7038		100-110	Ch. 1		100-110	Ch. 1		12-22	Ch. 1
9011	7428		111-121	Ch. 1		111-121	Ch. 1	OSU DAT6	1-11	Ch. 1
9012	7466		122-133	Ch. 1		122-133	Ch. 1		12-23	Ch. 1
9012	227		134-144	zero files 134, 139-144, no lines 1, 6-11		134-144	zero files 134, 139-144, no lines 1, 6-11	OSU DAT7	1-11	zero files 1, 6-11, no lines 1, 6-11
9012	6030		145-155	zero files 145-151, no lines 1-7		145-155	zero files 145-151, no lines 1-7		12-22	zero files 12-18, no lines 1-7
9013	7324		156-166	Ch. 1		156-166	Ch. 1	OSU DAT8	1-11	Ch. 1
9014	7296		167-177	Ch. 1		167-177	Ch. 1	OSU DAT9	1-11	Ch. 1
9015	7098		178-188	Ch. 1		178-188	Ch. 1	OSU DAT10	1-11	Ch. 1
9016	7061	OSU DLT2A	1-11	Ch. 1	OSU DLT2B	1-11	Ch. 1	OSU DAT11	1-11	Ch. 1
9017	7452		12-22	Ch. 1		12-22	Ch. 1	OSU DAT12	1-11	Ch. 1
9018	7302		23-33	Ch. 1		23-33	Ch. 1	OSU DAT13	1-11	Ch. 1
9019	7454		34-44	Ch. 1		34-44	Ch. 1	OSU DAT14	1-11	Ch. 1
9021	7352		45-55	Ch. 1		45-55	Ch. 1	OSU DAT15	1-11	Ch. 1
9022	7435		56-66	Ch. 1		56-66	Ch. 1	OSU DAT16	1-11	Ch. 1
9023	338		67-77	All Zero files		67-77	All Zero files			
9023	338		78-88	Ch. 4		78-88	Ch. 4	OSU DAT17	1-11	Ch. 4
						89-91	All Zero files			
9024	7317		89-99	Ch. 1		92-102	Ch. 1	OSU DAT18	1-11	Ch. 1
9025	7089		100-110	zero file 100, no line 1		103-113	zero file 100, no line 1	OSU DAT19	1-11	zero file 1, no line 1
9027	7339		111-121	Ch. 1		114-124	Ch. 1	OSU DAT20	1-11	Ch. 1
9028	7073		122-132	Ch. 1		125-135	Ch. 1	OSU DAT21	1-11	Ch. 1

9029	771		133-143	Ch. 4		136-146	Ch. 4	OSU DAT22	1-11	Ch. 4
9030	6029		144-154	zero files 144-148, no lines 1-5		147-157	zero files 147-151, no lines 1-5	OSU DAT23	1-11	zero files 1-5, no lines 1-5
9031	6026		155-165	zero file 155, no line 1		158-168	zero file 158, no line 1	OSU DAT24	1-11	zero file 1, no line 1
9004	6018		166-176	zero files 166-169, no lines 1-4		169-179	zero files 169-172, no lines 1-4	OSU DAT25	1-11	zero files 1-4, no lines 1-4
9012	6069		177-187	zero files 177-181, 187, no lines 1-5, 11		180-190	zero files 180-184, 190, no lines 1-5, 11	OSU DAT26	1-11	zero files 1-5, 11, no lines 1-5, 11
9030	7075	OSU DLT3A	1-11	zero files 7-11, no lines 7-11	OSU DLT3B	1-11	zero files 7-11, no lines 7-11	OSU DAT27	1-11	zero files 7-11, no lines 7-11
9006	7598	CAN DLT4A	89-110	Ch. 2 and 3	CAN DLT4B	89-110	Ch. 2 and 3	OSU DAT28	1-22	Ch. 2 and 3
9018	7302		111-132	Ch. 2 and 3		111-132	Ch. 2 and 3	OSU DAT29	1-22	Ch. 2 and 3
9023	338		133-154	Ch. 5 and 6		133-154	Ch. 5 and 6	OSU DAT30	1-22	Ch. 5 and 6
9008	7072		155-187	Zerofiles 156-157, 159-160, 162-163, 165-166, 168-169, Ch. 1, 2, 3		155-187	Zerofiles 156-157, 159-160, 162-163, 165-166, 168-169, Ch. 1, 2, 3	OSU DAT31	1-22	Zerofiles 2-3, 5-6, 8-9, 11-12, 14-15, Ch. 1, 2, 3
9010	7038	OSU DLT4A	1-22	Ch. 2 and 3, Zerofiles 1-8, no lines 1-4	OSU DLT4B	1-22	Ch. 2 and 3, Zerofiles 1-8, no lines 1-4	OSU DAT32	1-22	Ch. 2 and 3 Zerofiles 1-8, no lines 1-4
9011	7428		23-44	Ch. 2 and 3, Zerofiles 23-30, no lines 1-4		23-44	Ch. 2 and 3, Zerofiles 23-30, no lines 1-4	OSU DAT33	1-22	Ch. 2 and 3 Zerofiles 1-8, no lines 1-4
9012	227		45-66	Ch. 5 and 6, Zerofiles 45-46, 55-66, no lines 1, 6-11		45-66	Ch. 5 and 6, Zerofiles 45-46, 55-66, no lines 1, 6-11	OSU DAT34	1-22	Ch. 2 and 3 Zerofiles 1-2, 23-30, no lines 1, 6-11
9014	7296		67-88	Ch. 2 and 3, Zerofiles 67-74, no lines 1-4		67-88	Ch. 2 and 3, Zerofiles 67-74, no lines 1-4		23-44	Zerofiles 23-30, no lines 1-4
9001	7104		89-90	Lines 4 and 9		89-90	Lines 4 and 9	OSU DAT35	1-2	Lines 4 and 9
9008	7072		91-94	Line 4 Ch. 1, Line 9 Ch. 1-3		91-94	Line 4 Ch. 1, Line 9 Ch. 1-3		3-6	Line 4 Ch. 1, Line 9 Ch. 1-3
9009	7116		95	Line 9		95	Line 9		7	Line 9
9012	6030		96	Line 9		96	Line 9		8	Line 9
9015	7098		97	Line 9		97	Line 9		9	Line 9
7009	381	OSU DLT4A	98-100	Line 9	OSU DLT4B	98-100	Line 9	USGS DAT104	1-3	Line 9
8007	6065		101	Line 9		101	Line 9		4	Line 9
10008	7047	OSU DLT4A	102	Line 4	OSU DLT4B	102	Line 4	UW DAT48	1	Line 4
10009	7040		103-104	Lines 4 and 9		103-104	Lines 4 and 9		2-3	Lines 4 and 9
10011	7043		105	Line 9		105	Line 9		4	Line 9
10013	7082		106-107	Lines 4 and 9		106-107	Lines 4 and 9		5-6	Lines 4 and 9
10016	7093		108	Line 4		108	Line 4		7	Line 4
10020	7088		109	Line 9		109	Line 9		8	Line 9
10035	7053		110	Line 9		110	Line 9		9	Line 9
10037	7101		111	Line 9		111	Line 9		10	Line 9
10042	7113		112	Line 9		112	Line 9		11	Line 9

10043	7109		113	Line 4		113	Line 4		12	Line 4
10047	7103		114-115	Lines 4 and 9		114-115	Lines 4 and 9		13-14	Lines 4 and 9
10049	7086		116	Line 9		116	Line 9		15	Line 9
10051	7087		117	Line 4		117	Line 4		16	Line 4
10056	7060		118	Line 9		118	Line 9		17	Line 9
10001	7041	UW DLT1A	1-11	Ch. 1	UW DLT1B	1-11	Ch. 1	UW DAT1	1-11	Ch. 1
10002	7114		12-22	Ch. 1		12-22	Ch. 1		12-22	Ch. 1
10003	7334		23-33	Ch. 1		23-33	Ch. 1		23-33	Ch. 1
10004	7627		34-44	Ch. 3		34-44	Ch. 3	UW DAT2	1-11	Ch. 3
10005	7074		45-55	Ch. 1		45-55	Ch. 1	UW DAT3	1-11	Ch. 1
10006	556		56-66	All Zero files		56-66	All Zero files		12-22	All Zero files
10007	7364		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
10008	7047		78-88	zerofiles 84-88, no lines 7-11		78-88	zerofiles 84-88, no lines 7-11		34-44	zerofiles 40-44, no lines 7-11
10010	7629		89-99	Ch. 3		89-99	Ch. 3	UW DAT4	1-11	Ch. 3
10011	7043	UW DLT2A	1-11	Ch. 1	UW DLT2B	1-11	Ch. 1	UW DAT5	1-11	Ch. 1
10013	7082		12-22	Ch. 1		12-22	Ch. 1		12-22	Ch. 1
10014	7341		23-33	Ch. 1		23-33	Ch. 1		23-33	Ch. 1
10012	7591		34-44	Ch. 3		34-44	Ch. 3	UW DAT6	1-11	Ch. 3
10015	7091		45-55	Ch. 1		45-55	Ch. 1	UW DAT7	1-11	Ch. 1
10016	7093		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
10017	7068		67-77	zerofiles 74-76, no lines 9-11		67-77	zerofiles 75-77, no lines 9-11		23-33	zerofiles 31-33, no lines 9-11
10019	7050		78-88	Ch. 1		78-88	Ch. 1		34-44	Ch. 1
10021	7094		89-99	Ch. 1		89-99	Ch. 1	UW DAT8	1-11	Ch. 1
10022	7096		100-110	Ch. 1		100-110	Ch. 1		12-22	Ch. 1
10020	7088	UW DLT3A	1-11	Ch. 1	UW DLT3B	1-11	Ch. 1	UW DAT9	1-11	Ch. 1
10021	7094		12-12	Line 1		12-12	Line 1		12-12	Line 1
10023	7438		13-23	zerofiles 13-16, no lines 1-4		13-23	zerofiles 13-16, no lines 1-4		13-23	zerofiles 13-16, no lines 1-4
10024	7279		24-34	Ch. 1		24-34	Ch. 1		24-34	Ch. 1
10025	7622		35-45	Ch. 1		35-45	Ch. 1	UW DAT10	1-11	Ch. 1
10026	7600		46-56	Ch. 1		46-56	Ch. 1		12-22	Ch. 1
10027	192		57-67	Ch. 4		57-67	Ch. 4		23-33	Ch. 4
10004	7627		68-78	Ch. 1		68-78	Ch. 1	UW DAT11	1-11	Ch. 1
10010	7629		79-89	Ch. 1		79-89	Ch. 1		12-22	Ch. 1
10012	7591	UW DLT4A	1-11	Ch. 1	UW DLT4B	1-11	Ch. 1		23-33	Ch. 1
10018	391		12-22	Ch. 4		12-22	Ch. 1	UW DAT12	1-11	Ch. 1
10004	7627		23-55	Ch. 2 and 3		23-55	Ch. 2 and 3	UW DAT40	1-22	Ch. 2 and 3
10006	556		56-77	Ch. 2 and 3, zerofiles 56-61, 66-77		56-77	Ch. 2 and 3, zerofiles 56-61, 66-77	UW DAT41	1-22	Ch. 2 and 3, zerofiles 1-6, 11-22
10010	7629		78-99	Ch. 2 and 3		78-99	Ch. 2 and 3		23-44	Ch. 2 and 3

10028	7611	UW DLT5A	1-11	Ch. 1	UW DLT5B	1-11	Ch. 1	UW DAT13	1-11	Ch. 1
10030	7095		12-22	Ch. 1		12-22	Ch. 1		12-22	Ch. 1
10031	878		23-33	Ch. 4		23-33	Ch. 4		23-33	Ch. 1
10032	7294		34-44	Ch. 1		34-44	Ch. 1	UW DAT14	1-11	Ch. 1
10033	7071		45-55	Ch. 1		45-55	Ch. 1		12-22	Ch. 1
10034	7297		56-66	Ch. 1		56-66	Ch. 1		23-33	Ch. 1
10035	7053		67-77	Ch. 1		67-77	Ch. 1	UW DAT15	1-11	Ch. 1
10036	7350		78-88	Ch. 1		78-88	Ch. 1		12-22	Ch. 1
10037	7101		89-99	Ch. 1		89-99	Ch. 1		23-33	Ch. 1
10038	7108		100-110	Ch. 1		100-110	Ch. 1	UW DAT 16	1-11	Ch. 1
10039	7601		111-121	Ch. 1		111-121	Ch. 1		12-22	Ch. 1
10040	7619		122-132	Ch. 1		122-132	Ch. 1		23-33	Ch. 1
10042	7113		133-143	Ch. 1		133-143	Ch. 1	UW DAT17	1-11	Ch. 1
10043	7109		144-154	Ch. 1		144-154	Ch. 1		12-22	Ch. 1
10044	7054		155-165	Ch. 1		155-165	Ch. 1		23-33	Ch. 1
10045	7467	UW DLT6A	1-11	Ch. 1	UW DLT6B	1-11	Ch. 1	UW DAT18	1-11	Ch. 1
10046	7076		12-22	Ch. 1		12-22	Ch. 1	UW DAT19	1-11	Ch. 1
10047	7103		23-33	Ch. 1		23-33	Ch. 1	UW DAT20	1-11	Ch. 1
10048	7342		34-44	Ch. 1		34-44	Ch. 1	UW DAT21	1-11	Ch. 1
10049	7086		45-55	Ch. 1		45-55	Ch. 1		12-22	Ch. 1
10050	7346		56-66	Ch. 1		56-66	Ch. 1	UW DAT22	1-11	Ch. 1
10051	7087		67-77	Ch. 1		67-77	Ch. 1	UW DAT23	1-11	Ch. 1
10052	7084		78-88	Ch. 1		78-88	Ch. 1	UW DAT24	1-11	Ch. 1
10053	384		89-99	Ch. 4		89-99	Ch. 4	UW DAT25	1-11	Ch. 1
10054	7065		100-110	Ch. 1		100-110	Ch. 1	UW DAT26	1-11	Ch. 1
10055	7328		111-121	Ch. 1		111-121	Ch. 1		12-22	Ch. 1
10056	7060		122-132	Ch. 1		122-132	Ch. 1		23-33	Ch. 1
10057	875		133-143	Ch. 4		133-143	Ch. 4	UW DAT27	1-11	Ch. 1
10058	7090		144-154	Ch. 1		144-154	Ch. 1	UW DAT28	1-11	Ch. 1
10059	553		155-165	Ch. 4		155-165	Ch. 4	UW DAT29	1-11	Ch. 1
10060	7609	UW DLT7A	1-33	Ch. 1-3	UW DLT7B	1-33	Ch. 1-3	UW DAT30	1-33	Ch. 1-3
10028	7611		34-55	Ch. 2 and 3		34-55	Ch. 2 and 3	UW DAT31	1-22	Ch. 2 and 3
10031	878		56-77	Ch. 5 and 6		56-77	Ch. 5 and 6	UW DAT32	1-22	Ch. 5 and 6
10032	7294	UW DLT8A	1-22	Ch. 2 and 3	UW DLT8B	1-22	Ch. 2 and 3	UW DAT33	1-22	Ch. 2 and 3
10034	7297		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	UW DAT34	1-22	Ch. 2 and 3
10039	7601		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	UW DAT35	1-22	Ch. 2 and 3
10040	7619		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	UW DAT36	1-22	Ch. 2 and 3
10053	384	UW DLT9A	1-22	Ch. 5 and 6	UW DLT9B	1-22	Ch. 5 and 6	UW DAT37	1-22	Ch. 5 and 6
10057	875		23-44	Ch. 5 and 6		23-44	Ch. 5 and 6	UW DAT38	1-22	Ch. 5 and 6
10059	553		45-66	Ch. 5 and 6		45-66	Ch. 5 and 6	UW DAT39	1-22	Ch. 5 and 6
10012	7591	UW DLT10A	1-22	Ch. 2 and 3	UW DLT10B	1-22	Ch. 2 and 3	UW DAT42	1-22	Ch. 2 and 3
10018	391		23-44	Ch. 5 and 6		23-44	Ch. 5 and 6	UW DAT43	1-22	Ch. 5 and 6

10023	7438		45-66	Ch. 2 and 3, Zerofiles 45-52, no lines 1-4		45-66	Ch. 2 and 3, Zerofiles 45-52, no lines 1-4	UW DAT44	1-22	Ch. 2 and 3, Zerofiles 1-8, no lines 1-4
10024	7279		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	UW DAT45	1-22	Ch. 2 and 3
10026	7600		89-110	Ch. 2 and 3		89-110	Ch. 2 and 3	UW DAT46	1-22	Ch. 2 and 3
10027	192		111-132	Ch. 5 and 6		111-132	Ch. 5 and 6	UW DAT47	1-22	Ch. 5 and 6
10008	7047	OSU DLT4A	102	Line 4	OSU DLT4B	102	Line 4	UW DAT48	1	Line 4
10009	7040		103-104	Lines 4 and 9		103-104	Lines 4 and 9		2-3	Lines 4 and 9
10011	7043		105	Line 9		105	Line 9		4	Line 9
10013	7082		106-107	Lines 4 and 9		106-107	Lines 4 and 9		5-6	Lines 4 and 9
10016	7093		108	Line 4		108	Line 4		7	Line 4
10020	7088		109	Line 9		109	Line 9		8	Line 9
10035	7053		110	Line 9		110	Line 9		9	Line 9
10037	7101		111	Line 9		111	Line 9		10	Line 9
10042	7113		112	Line 9		112	Line 9		11	Line 9
10043	7109		113	Line 4		113	Line 4		12	Line 4
10047	7103		114-115	Lines 4 and 9		114-115	Lines 4 and 9		13-14	Lines 4 and 9
10049	7086		116	Line 9		116	Line 9		15	Line 9
10051	7087		117	Line 4		117	Line 4		16	Line 4
10056	7060		118	Line 9		118	Line 9		17	Line 9
9030	7075	OSU DLT3A	1-11	zero files 7-11, no lines 7-11	OSU DLT3B	1-11	zero files 7-11, no lines 7-11	OSU DAT27	1-11	zero files 7-11, no lines 7-11
11001	7337		12-24	CA23, CA01,CA26 - Ch. 1		12-24	CA23, CA01,CA26 - Ch. 1	CAN DAT1	1-13	CA23, CA01,CA26 - Ch. 1
11008	7287		25-35	Ch. 1		25-35	Ch. 1		14-24	Ch. 1
11009	7606		36-46	Ch. 1		36-46	Ch. 1		25-35	Ch. 1
11014	7344		47-57	Ch. 1		47-57	Ch. 1	CAN DAT2	1-11	Ch. 1
11016	7343		58-68	Ch. 1		58-68	Ch. 1		12-22	Ch. 1
11017	7599		69-79	Ch. 1		69-79	Ch. 1		23-33	Ch. 1
11018	7280		80-90	Ch. 1		80-90	Ch. 1	CAN DAT3	1-11	Ch. 1
11019	7625		91-101	Ch. 1		91-101	Ch. 1		12-22	Ch. 1
11020	7299		102-112	Ch. 1		102-112	Ch. 1		23-33	Ch. 1
11034	7332		113-123	CA34, CA39 - Ch. 1		113-123	CA34, CA39 - Ch. 1	CAN DAT4	1-11	CA34, CA39 - Ch. 1
11035	7429		124-134	CA35, CA38 - Ch. 1		124-134	CA35, CA38 - Ch. 1		12-22	CA35, CA38 - Ch. 1
11036	7351		135-145	CA36, CA42 - All Zero files	zero files	135-145	CA36, CA42 - All Zero files	zero files	23-33	CA36, CA42 - All Zero files
11037	7281		146-156	CA37, CA41 - Ch. 1		146-156	CA37, CA41 - Ch. 1		34-44	CA37, CA41 - Ch. 1
11044	7445		157-167	Ch. 1		157-167	Ch. 1	CAN DAT5	1-11	Ch. 1
11045	7360		168-178	Ch. 1		168-178	Ch. 1		12-22	Ch. 1
11046	7348	CAN DLT1A	1-11	Ch. 1	CAN DLT1B	1-11	Ch. 1		23-33	Ch. 1
11047	7446		12-22	Ch. 1		12-22	Ch. 1	CAN DAT6	1-11	Ch. 1
11048	7430		23-33	Ch. 1		23-33	Ch. 1		12-22	Ch. 1
11049	7449		34-44	Ch. 1		34-44	Ch. 1		23-33	Ch. 1

11050	7333		45-55	Ch. 1		45-55	Ch. 1	CAN DAT7	1-11	Ch. 1
11051	7322		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
11052	7433		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
11053	7612		78-88	Ch. 1		78-88	Ch. 1	CAN DAT8	1-11	Ch. 1
Tully	7356		89-99	zero files 89-93, no lines 1-5		89-99	zero files 89-93, no lines 1-5		12-22	zero files 12-16, no lines 1-5
11002	6116		100-112	CA27, CA02, CA29 - Ch. 1		100-112	CA27, CA02, CA29 - Ch. 1	CAN DAT9	1-13	CA27, CA02, CA29 - Ch. 1
11003	6126		113-124	CA25, CA03 - Ch. 1		113-124	CA25, CA03 - Ch. 1		14-25	CA25, CA03 - Ch. 1
11004	6110		125-135	Ch. 1		125-135	Ch. 1	CAN DAT10	1-11	Ch. 1
11005	6119		136-146	Ch. 1		136-146	Ch. 1		12-22	Ch. 1
11006	6039		147-157	Ch. 1		147-157	Ch. 1		23-33	Ch. 1
11007	7301		158-169	CA07, CA07A, zerofile 158, no line 1		158-169	CA07, CA07A, zerofile 158, no line 1		34-45	CA07, CA07A, zerofile 34, no line 1
11010	6113		170-182	CA26, CA10, CA25 - Ch. 1		170-182	CA26, CA10, CA25 - Ch. 1		46-58	CA26,CA10,CA25 - Ch. 1
11012	6111		183-193	Ch. 1		183-193	Ch. 1	CAN DAT11	1-11	Ch. 1
11013	6060		194-206	CA29, CA13, CA27 - Ch. 1		194-206	CA29, CA13, CA27 - Ch. 1		12-24	CA29, CA13, CA27 - Ch. 1
11015	6109		207-217	Ch. 1		207-217	Ch. 1		25-35	Ch. 1
11011	6058		218-230	CA28, CA11, CA28 - Ch. 1		218-230	CA28, CA11, CA28 - Ch. 1		36-48	CA28, CA11, CA28 - Ch. 1
11036	7351	CAN DLT2A	1-11	CA36, CA42 - Ch. 1	CAN DLT2B	1-11	CA36, CA42 - Ch. 1	CAN DAT12	1-11	CA36, CA42 - Ch. 1
11021	7610	copy of	12-22	Ch. 1		12-22	Ch. 1	CAN DAT13	1-11	Ch. 1
11022	7331	CAN DLT2B	23-33	Ch. 1		23-33	Ch. 1		12-22	Ch. 1
11024	7456		34-44	Ch. 1		34-44	Ch. 1		23-33	Ch. 1
11030	7277		45-55	Ch. 1		45-55	Ch. 1	CAN DAT14	1-11	Ch. 1
11031	7623		56-66	Ch. 1		56-66	Ch. 1		12-22	Ch. 1
11032	7284		67-77	Ch. 1		67-77	Ch. 1		23-33	Ch. 1
11033	7628		78-88	Ch. 1		78-88	Ch. 1	CAN DAT15	1-11	Ch. 1
11043	7431		89-99	Ch. 1		89-99	Ch. 1		12-22	Ch. 1
11021	7610	CAN DLT3A	1-22	Ch. 2 and 3	CAN DLT3A	1-22	Ch. 2 and 3	CAN DAT16	1-22	Ch. 2 and 3
11030	7277		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	CAN DAT17	1-22	Ch. 2 and 3
11031	7623		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	CAN DAT18	1-22	Ch. 2 and 3
11032	7284		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	CAN DAT19	1-22	Ch. 2 and 3
11033	7628		89-110	Ch. 2 and 3		89-110	Ch. 2 and 3	CAN DAT20	1-22	Ch. 2 and 3
11007	7301		111-134	Ch. 2 and 3		111-134	Ch. 2 and 3	CAN DAT21	1-22	Ch. 2 and 3
				zerofiles 111-112, no line 1			zerofiles 111-112, no line 1			zerofiles 1-2, no line 1
11017	7599		135-156	Ch. 2 and 3		135-156	Ch. 2 and 3	CAN DAT22	1-22	Ch. 2 and 3
11018	7280		157-178	Ch. 2 and 3		157-178	Ch. 2 and 3	CAN DAT23	1-22	Ch. 2 and 3
11019	7625	CAN DLT4A	1-22	Ch. 2 and 3	CAN DLT4B	1-22	Ch. 2 and 3	CAN DAT24	1-22	Ch. 2 and 3

11020	7299		23-44	Ch. 2 and 3		23-44	Ch. 2 and 3	CAN DAT25	1-22	Ch. 2 and 3
11008	7287		45-66	Ch. 2 and 3		45-66	Ch. 2 and 3	CAN DAT26	1-22	Ch. 2 and 3
11009	7606		67-88	Ch. 2 and 3		67-88	Ch. 2 and 3	CAN DAT27	1-22	Ch. 2 and 3
11007	7301							CAN DAT28	1-30	Ch. 1-3, Lines 2-11
9006	7598		89-110	Ch. 2 and 3		89-110	Ch. 2 and 3	OSU DAT28	1-22	Ch. 2 and 3
9018	7302		111-132	Ch. 2 and 3		111-132	Ch. 2 and 3	OSU DAT29	1-22	Ch. 2 and 3
9023	338		133-154	Ch. 5 and 6		133-154	Ch. 5 and 6	OSU DAT30	1-22	Ch. 5 and 6
9008	7072		155-187	Zerofiles 156-157, 159-160, 162-163, 165-166, 168-169 Ch. 1-3		155-187	Zerofiles 156-157, 159-160, 162-163, 165-166, 168-169, Ch. 1-3	OSU DAT31	1-33	Ch. 1-3

copy_segy_tape (need number of the first file to copy, the number of the last file to copy, and path names of the tape drive of tape to be copied (in_device) and of the tape drive to copy the tape onto (out_device)

```
#! /bin/sh
# Program to do a tape to tape copy with segy files
#  assumes the existence of an mt asf command
#  assumes tcopy returns 0 on successfull completion
#  non-zero on failure

if test $# -lt 4
then
        echo "Need 4 args; start, stop, in_device, out_device"
        exit
fi

STARTNUM=$1
ENDNUM=$2
INTAPE=$3
OUTTAPE=$4

mt -f $INTAPE asf `expr $STARTNUM - 1`
mt -f $OUTTAPE asf `expr $STARTNUM - 1`

CURRNUM=$STARTNUM
while test $CURRNUM -le $ENDNUM
do
```

```
	echo "Copying record $CURRNUM"

	RETURNVAL=`tcopy $INTAPE $OUTTAPE | grep "record 2"`
	if test -n "$RETURNVAL"
	then
		echo "Successful Record $CURRNUM"
	else
		echo "Un-successful $CURRNUM; rewinding tapes"
		mt -f $INTAPE asf $CURRNUM
		mt -f $OUTTAPE asf $CURRNUM
	fi
	CURRNUM=`expr $CURRNUM + 1`
done
```

APPENDIX 6. 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 = 1 or 4 for the vertical component, 2 or 5 for the N-S horizontal component, 3 or 6 for the E-W horizontal component
|	
29 - 30	Trace identification code = 1 for seismic data
|	
69 - 70	Elevation constant = 1
71 - 72	Coordinate constant = 1
|	
89 - 90	Coordinate units = 2 for Lat/Long
|	
103 - 104	Low 2 bytes of the total shift in milliseconds
|	
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*	Milliseconds 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

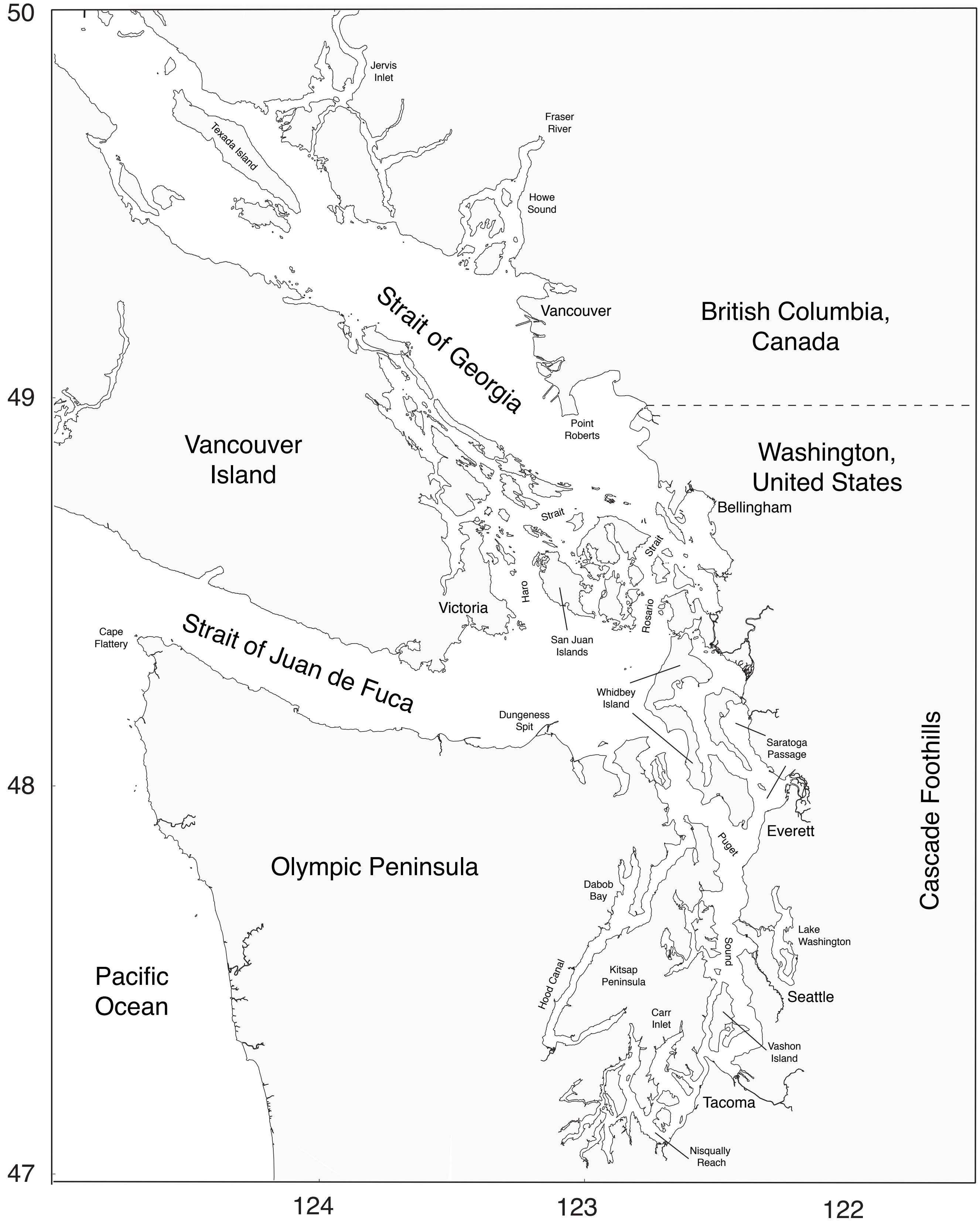


Figure 1. Map of study area showing major sedimentary basins and cities

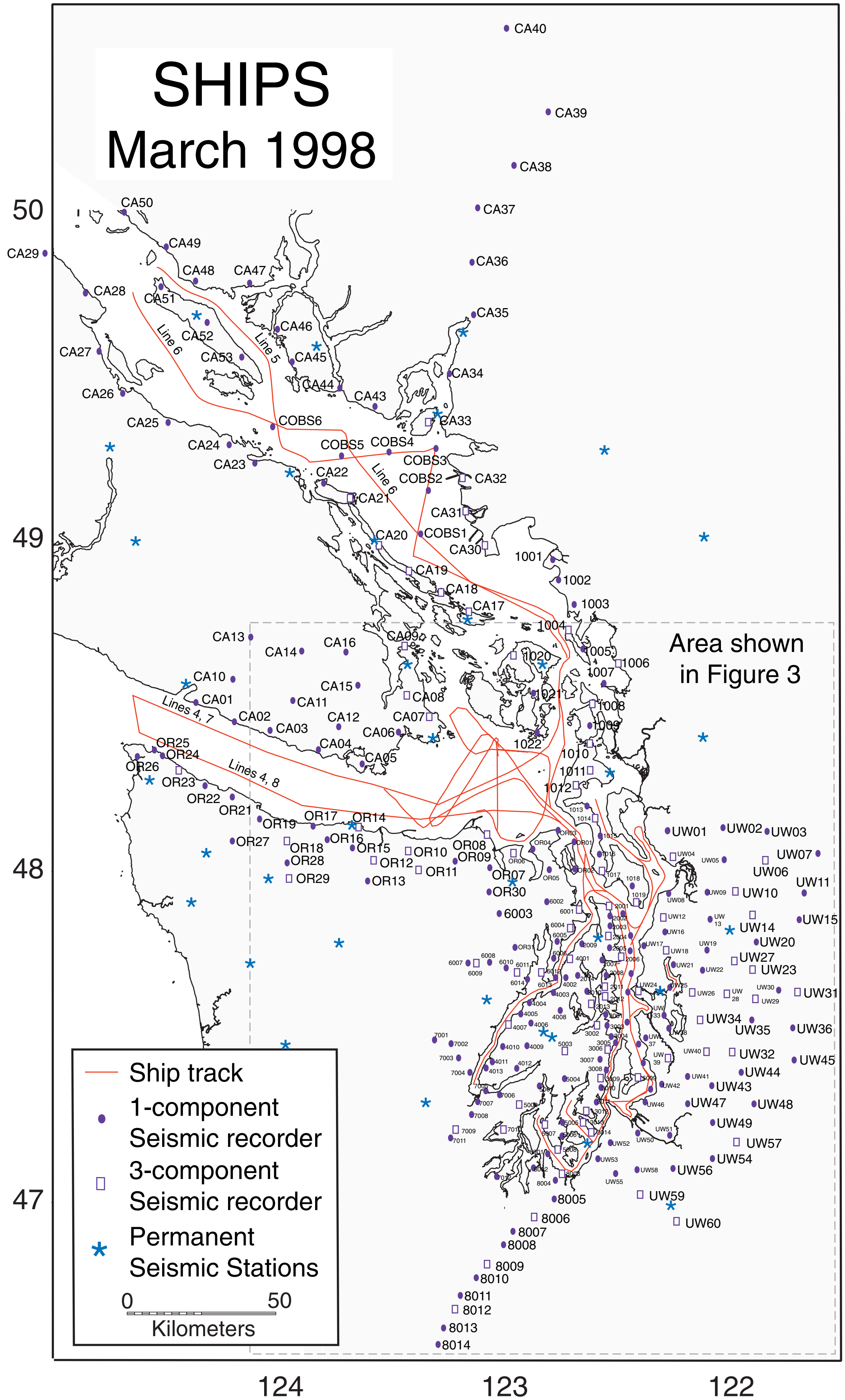


Figure 2. Map of study area showing locations of SHIPS seismic lines and recorders.

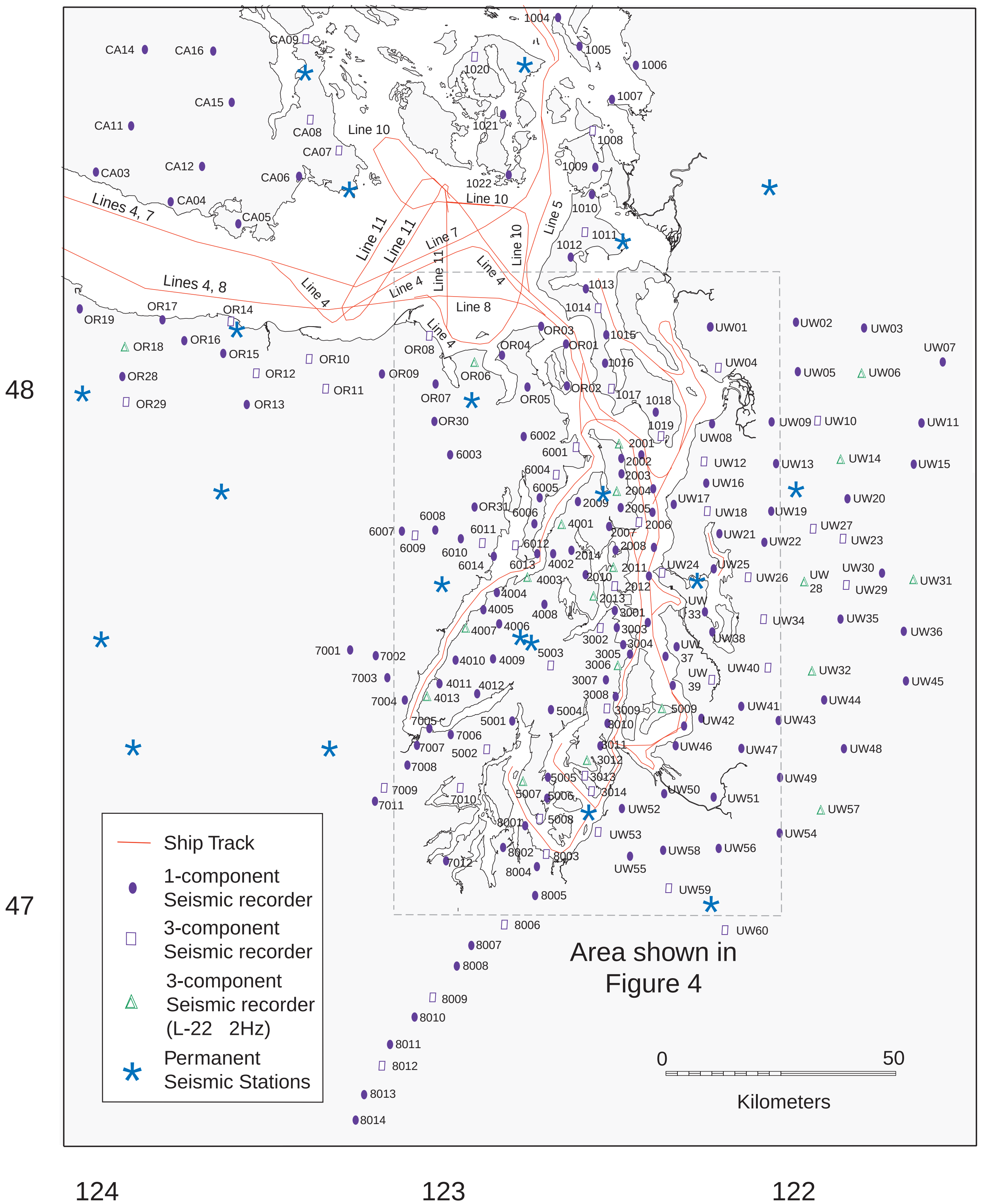


Figure 3. Detail of map showing locations of SHIPS seismic lines and recorders.

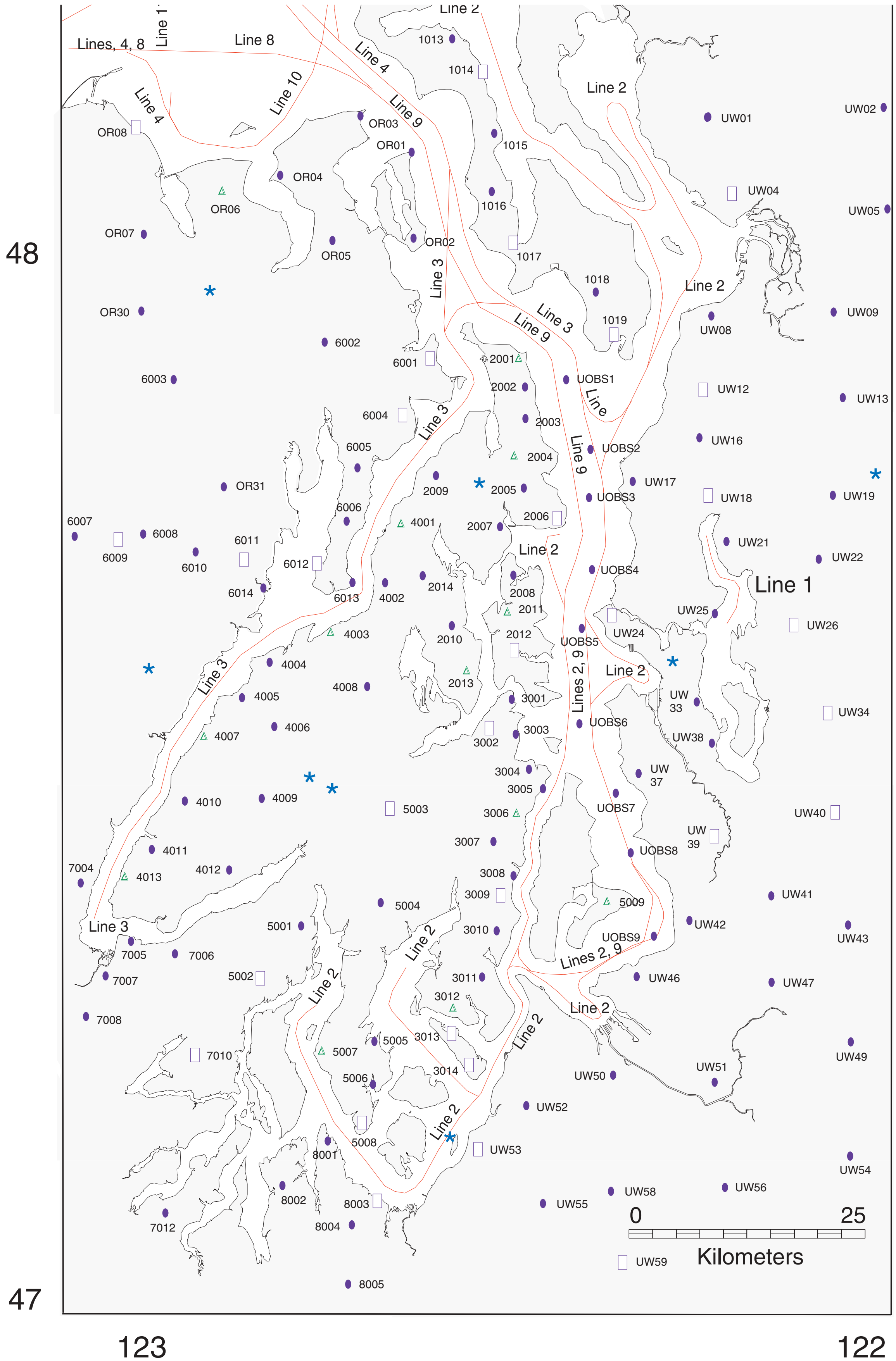


Figure 4. Map showing locations of SHIP seismic lines and recorders in the Puget Lowland.

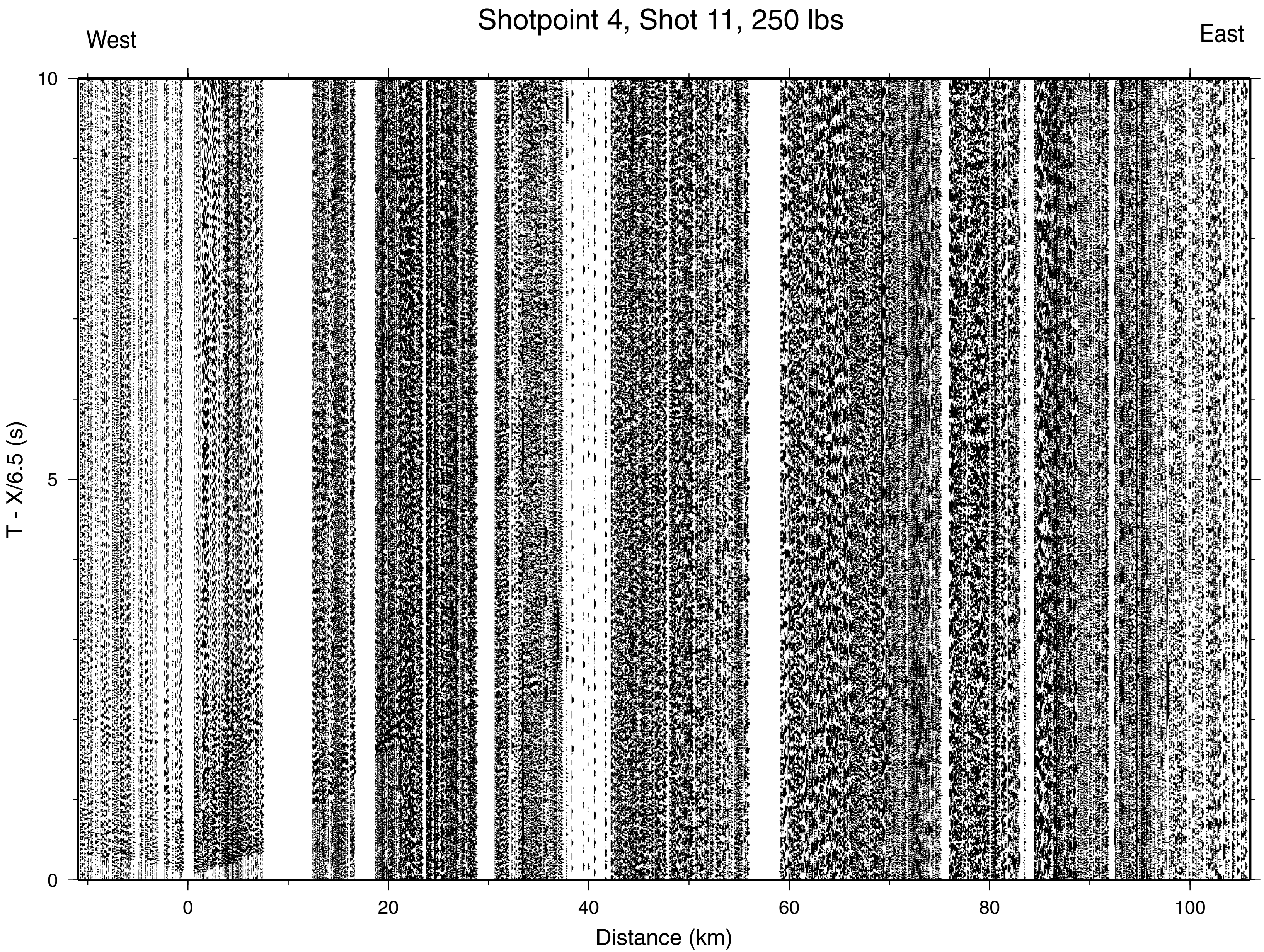


Figure 5. Reduced record section for Shotpoint 4, vertical component only, for Lines 1 and 2.

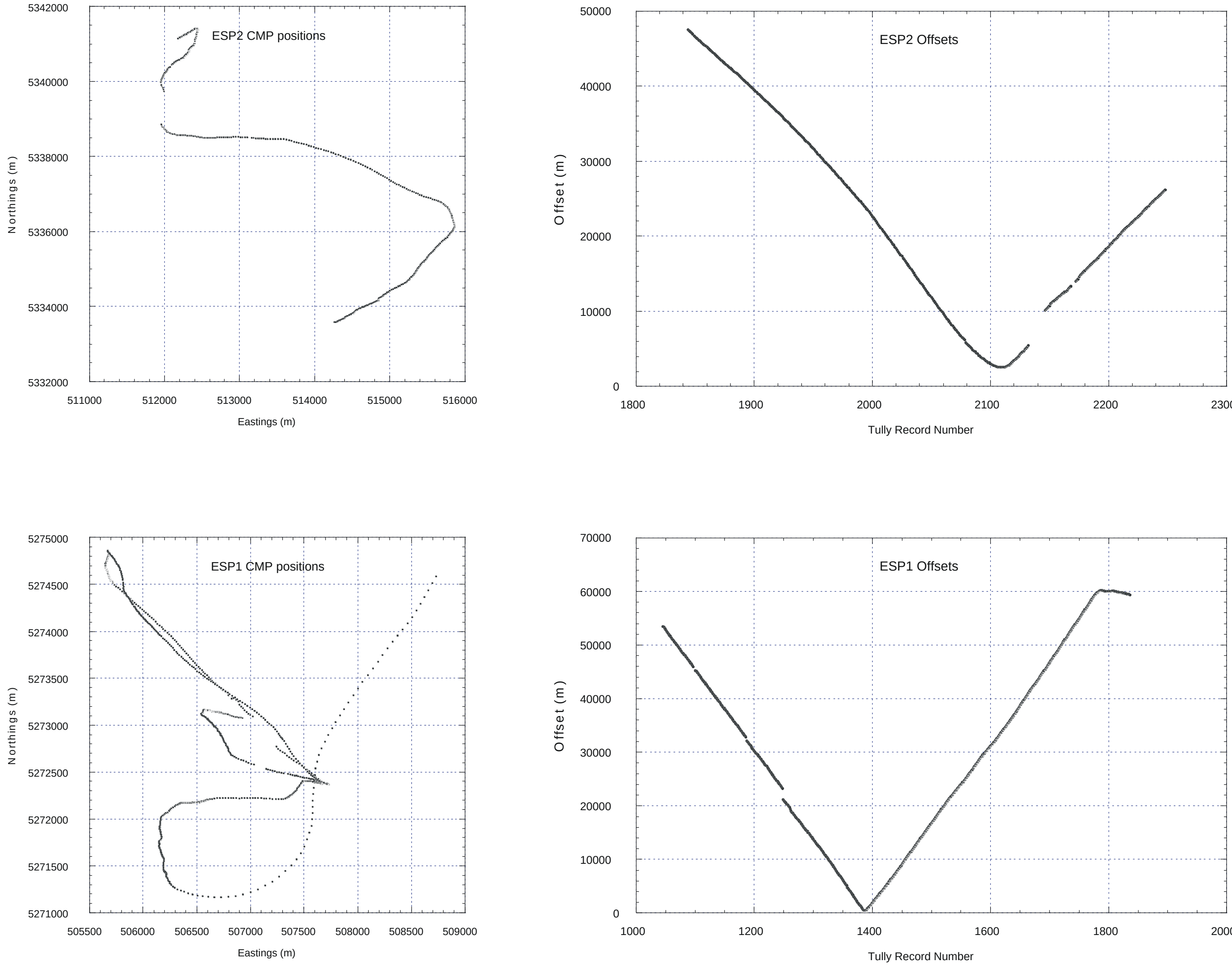


Figure 6. Maps showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESPs 2 and 1.

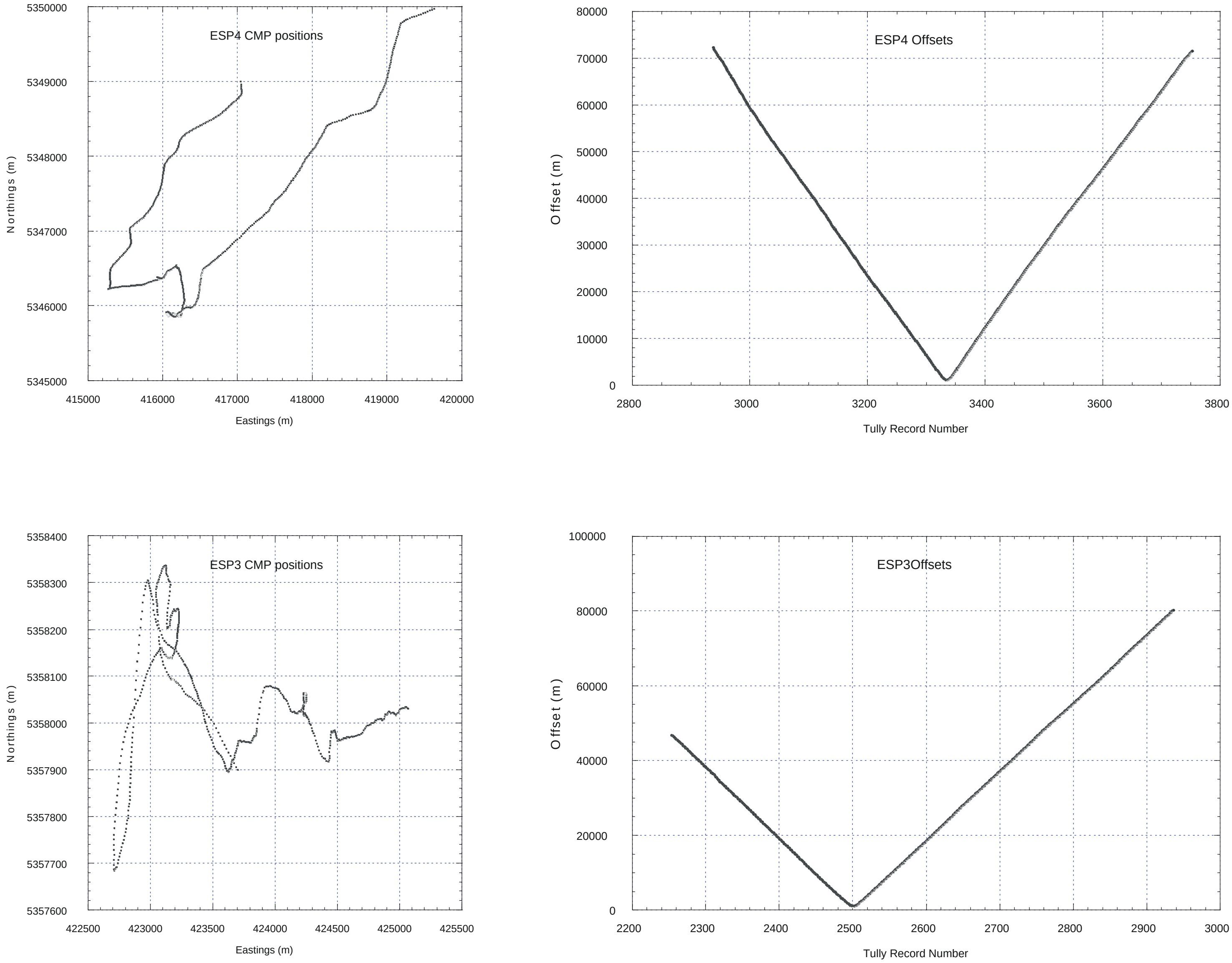


Figure 7. Maps showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESPs 4 and 3.

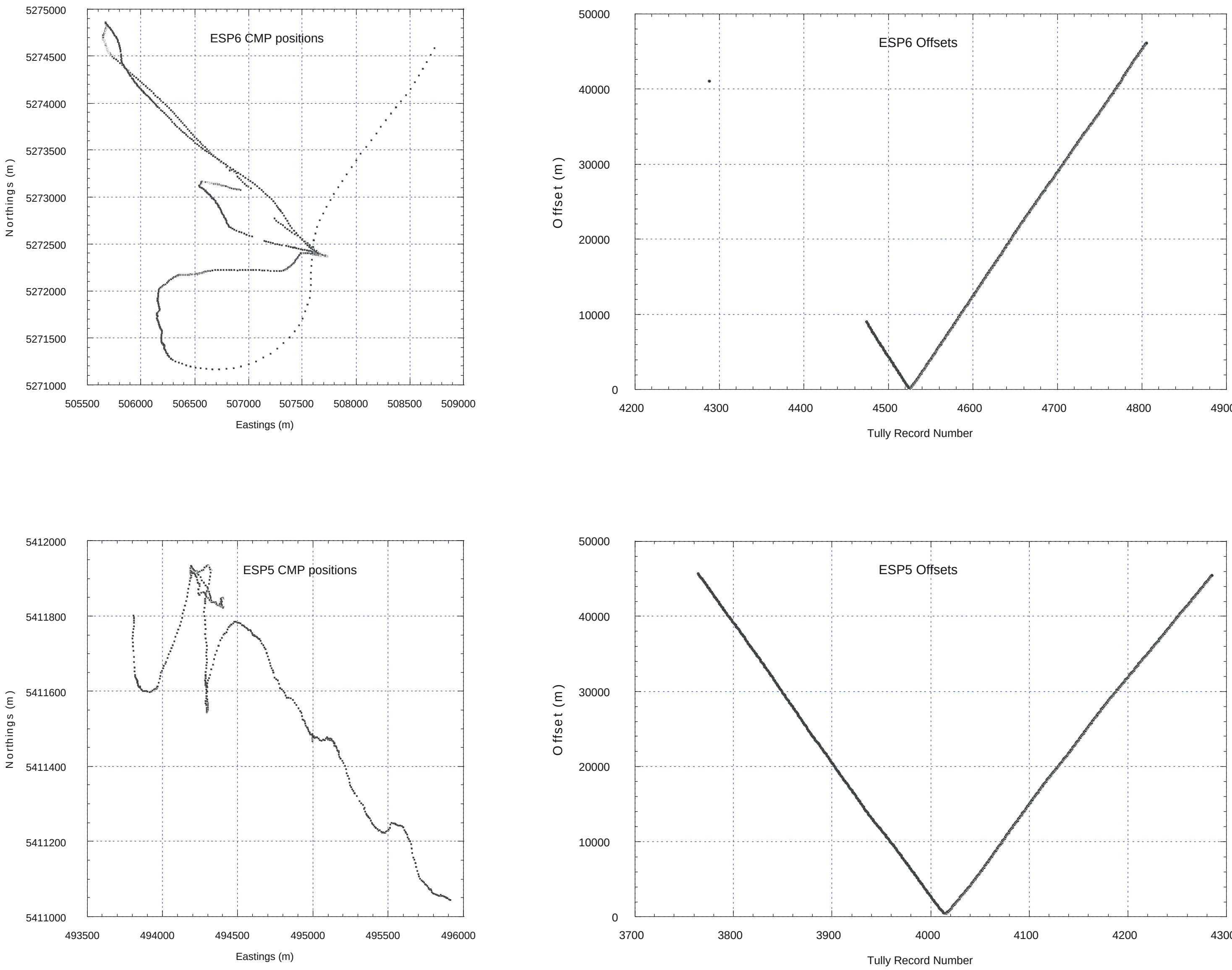


Figure 8. Maps showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESPs 6 and 5.

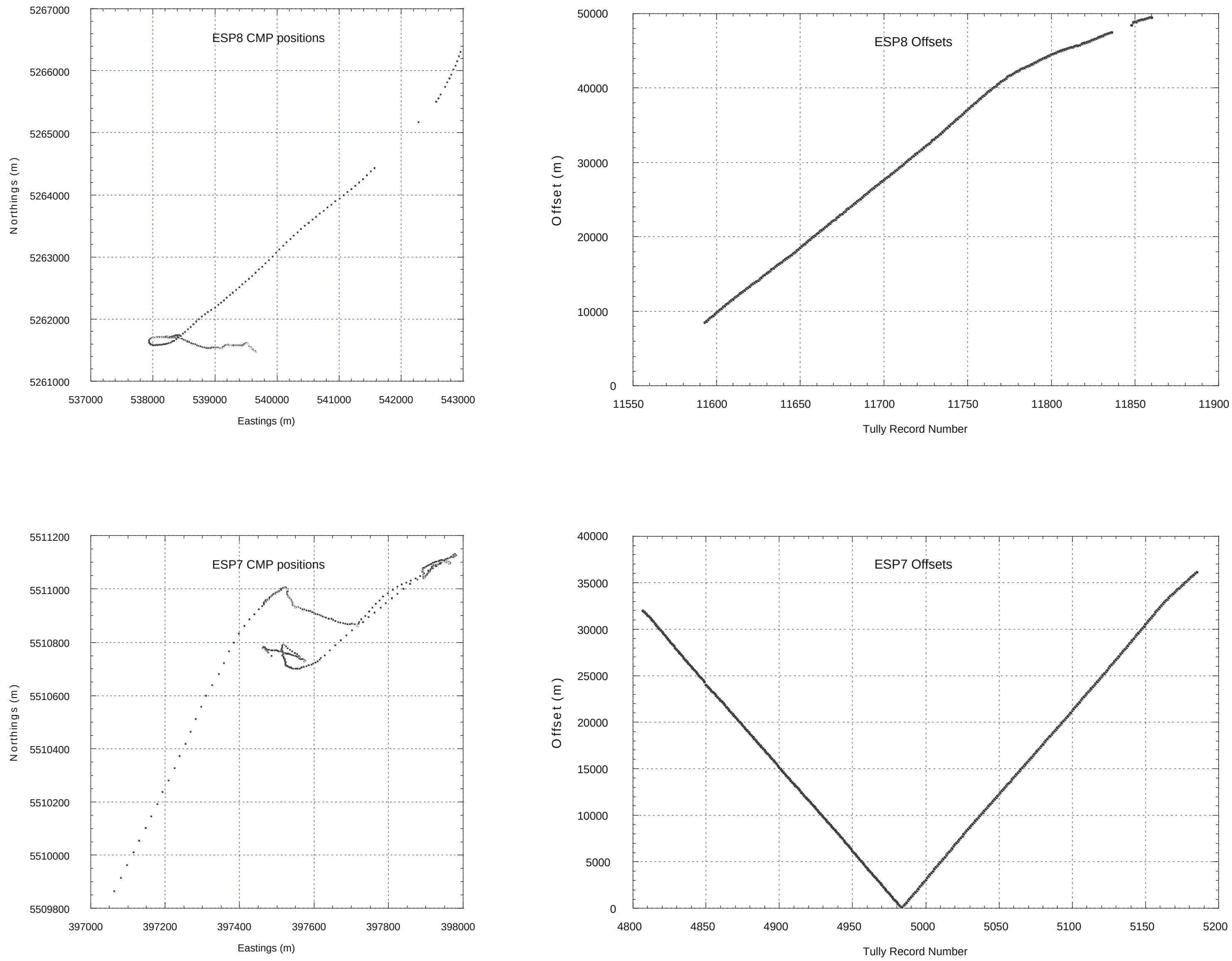


Figure 9. Maps showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESPs 8 and 7.

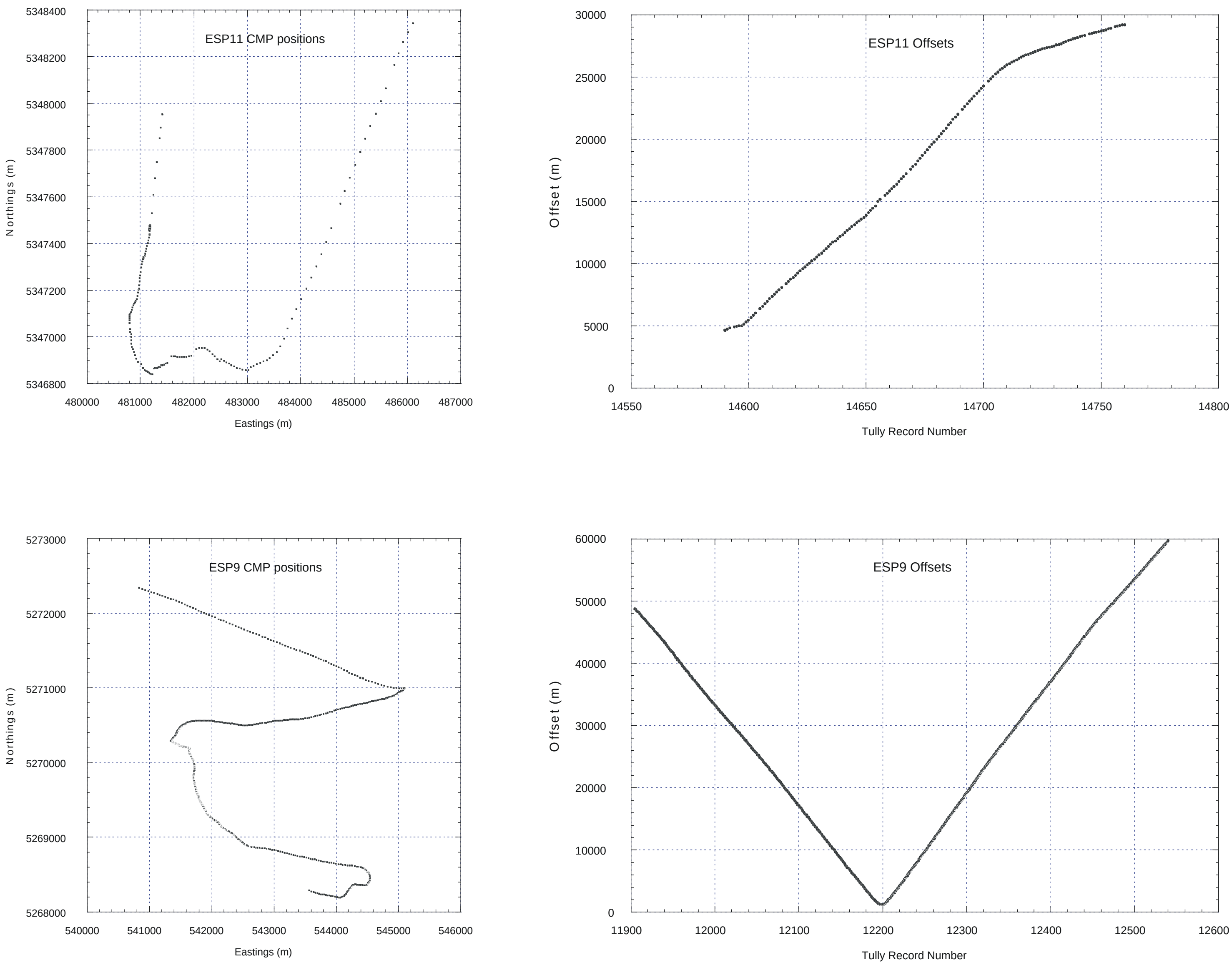
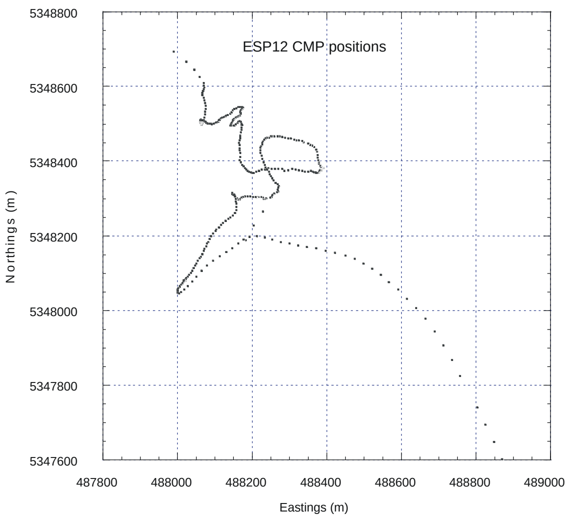


Figure 10. Maps showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESPs 10 and 9.



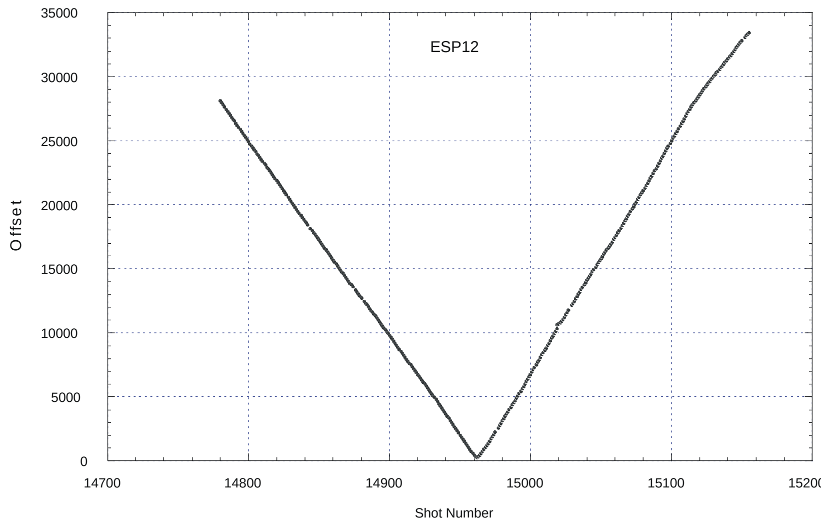


Figure 11. Map showing distribution of common midpoints (left) and receiver offsets as a function of R/V Tully record number (right) for ESP 12.

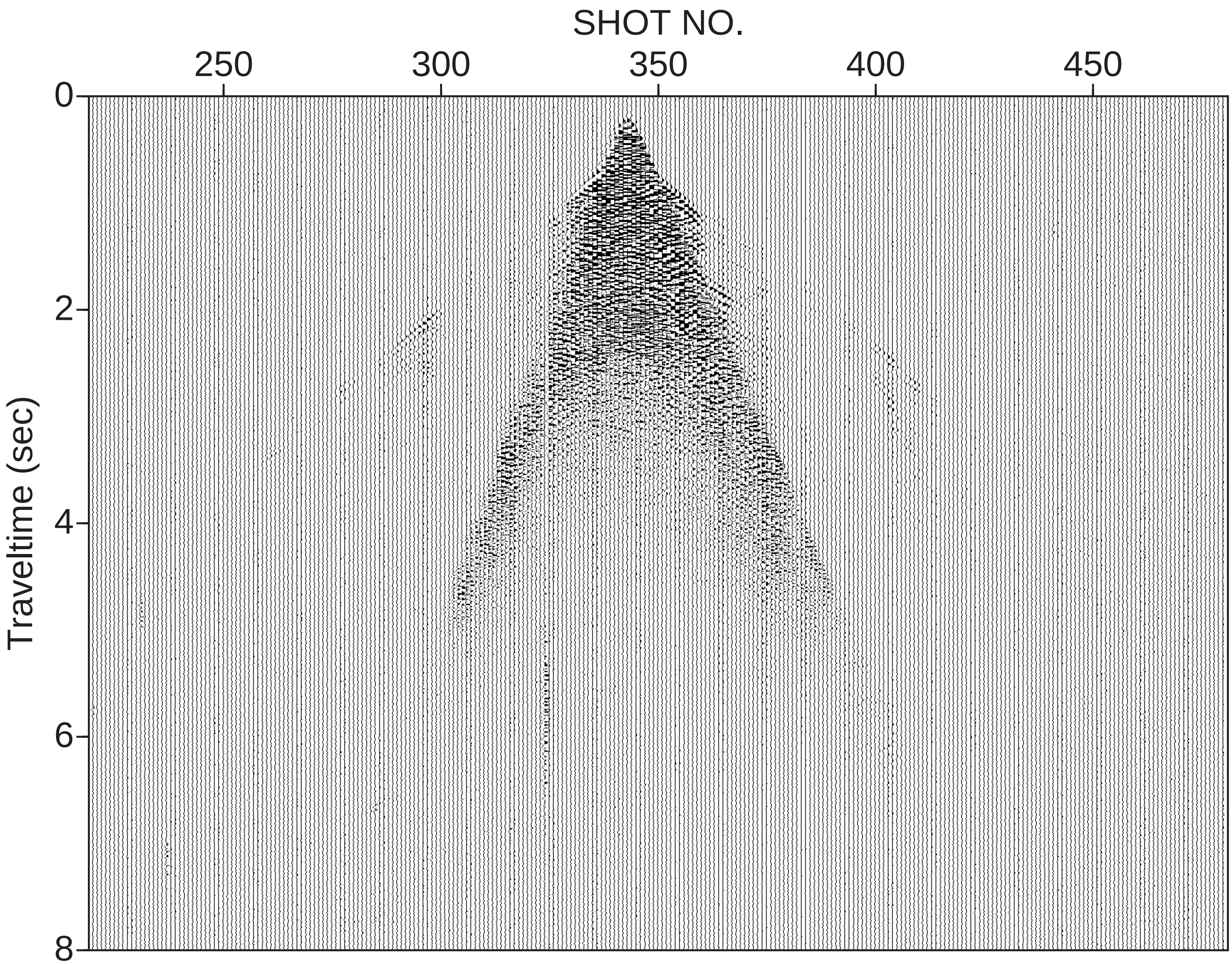


Figure 12. Record section for ESP 1 in Hood Canal.

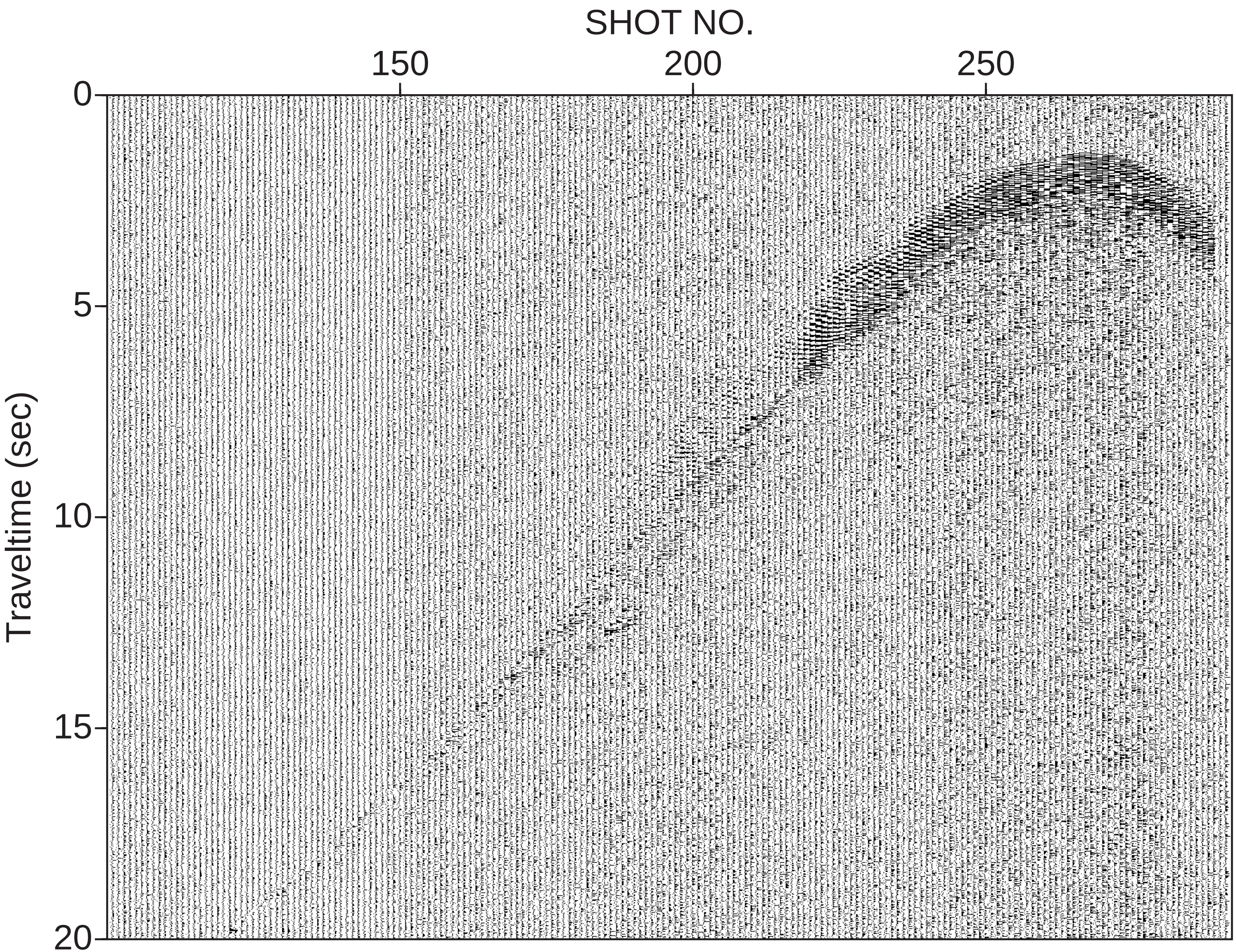


Figure 13. Record section for ESP 2 in the eastern Strait of Juan de Fuca.

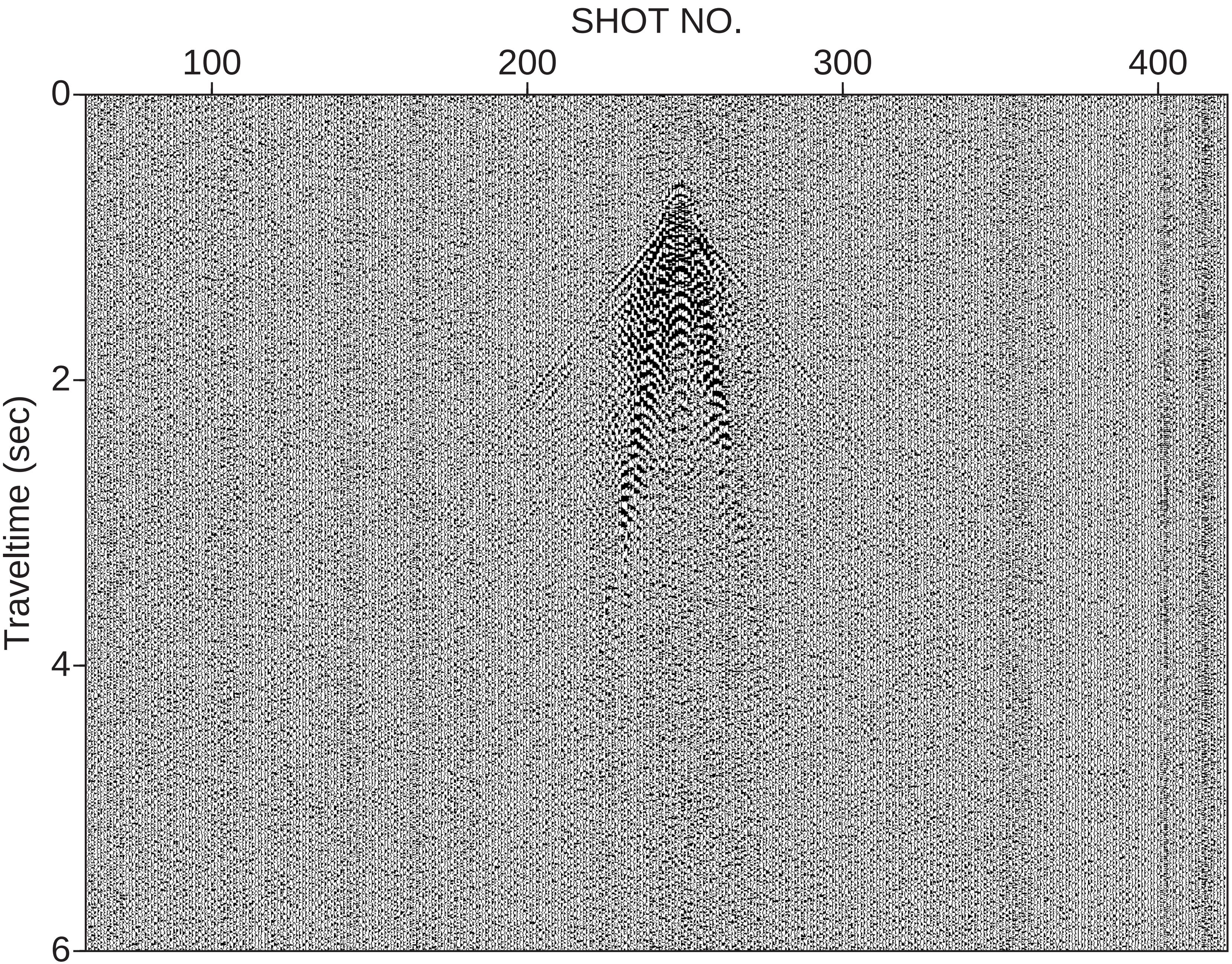


Figure 14. Record section for ESP 3 in the western Strait of Juan de Fuca.

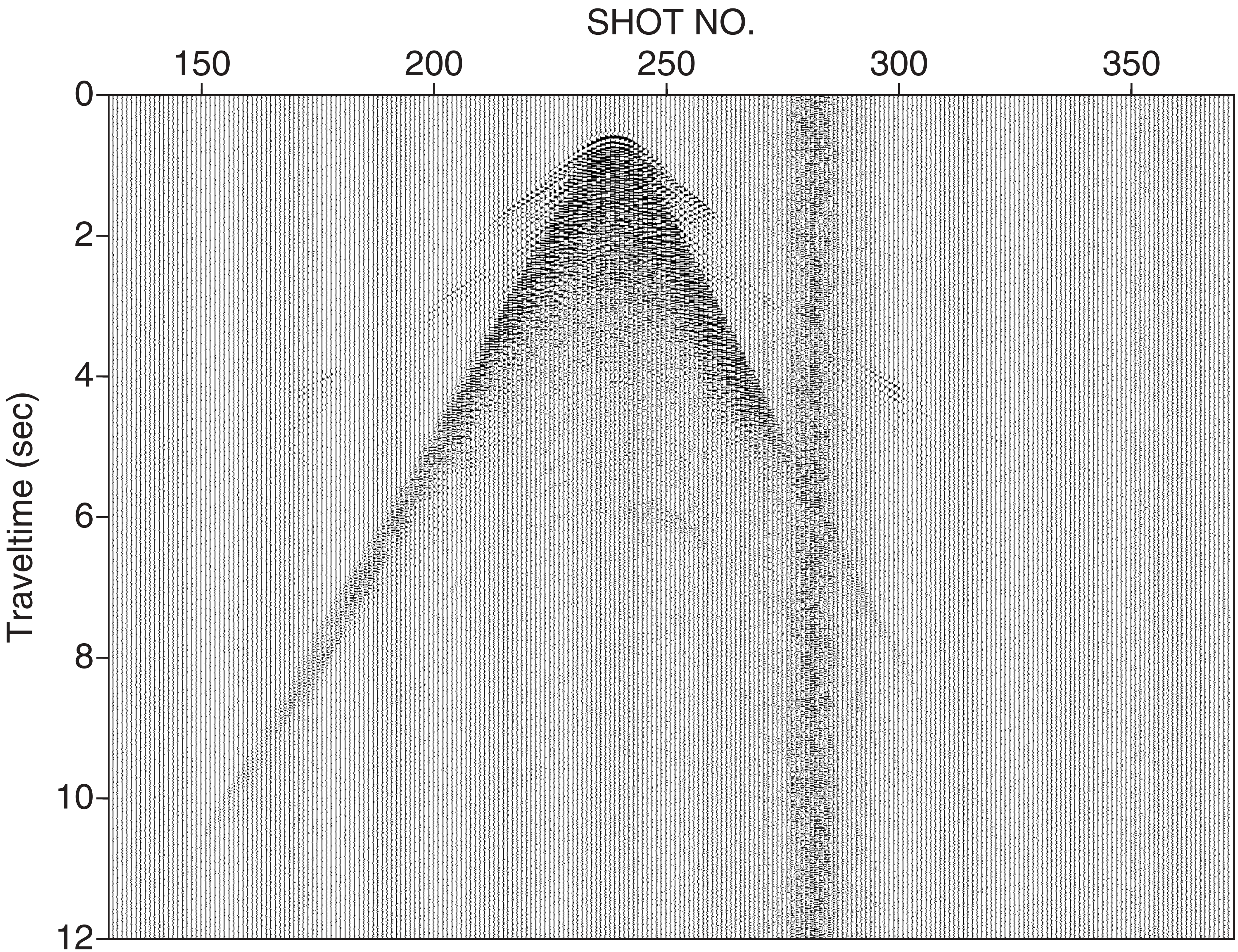


Figure 15. Record section for ESP 4 in the western Strait of Juan de Fuca.

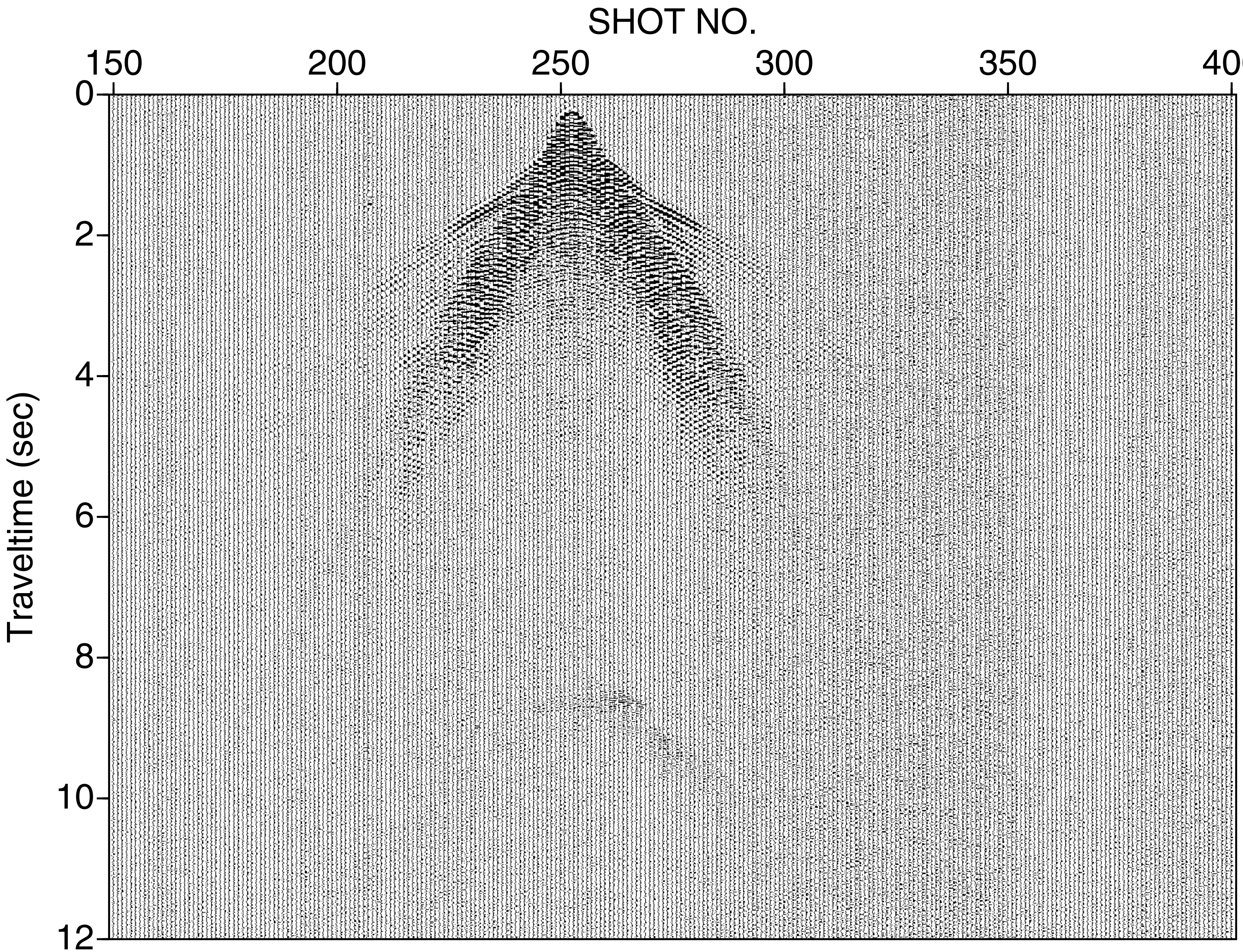


Figure 16. Record section for ESP 5 in the southern Strait of Georgia.

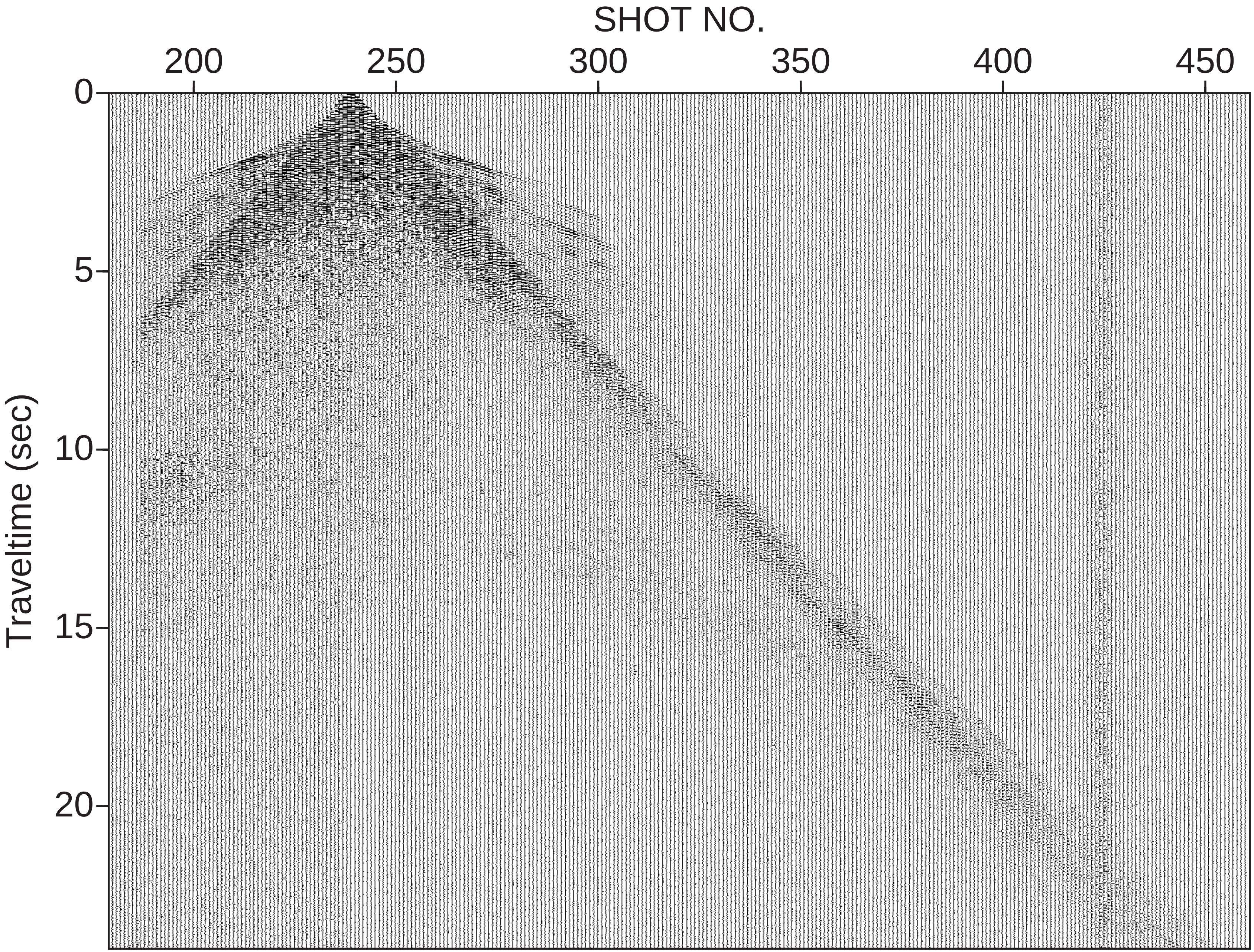


Figure 17. Record section for ESP 6 in the Strait of Georgia.

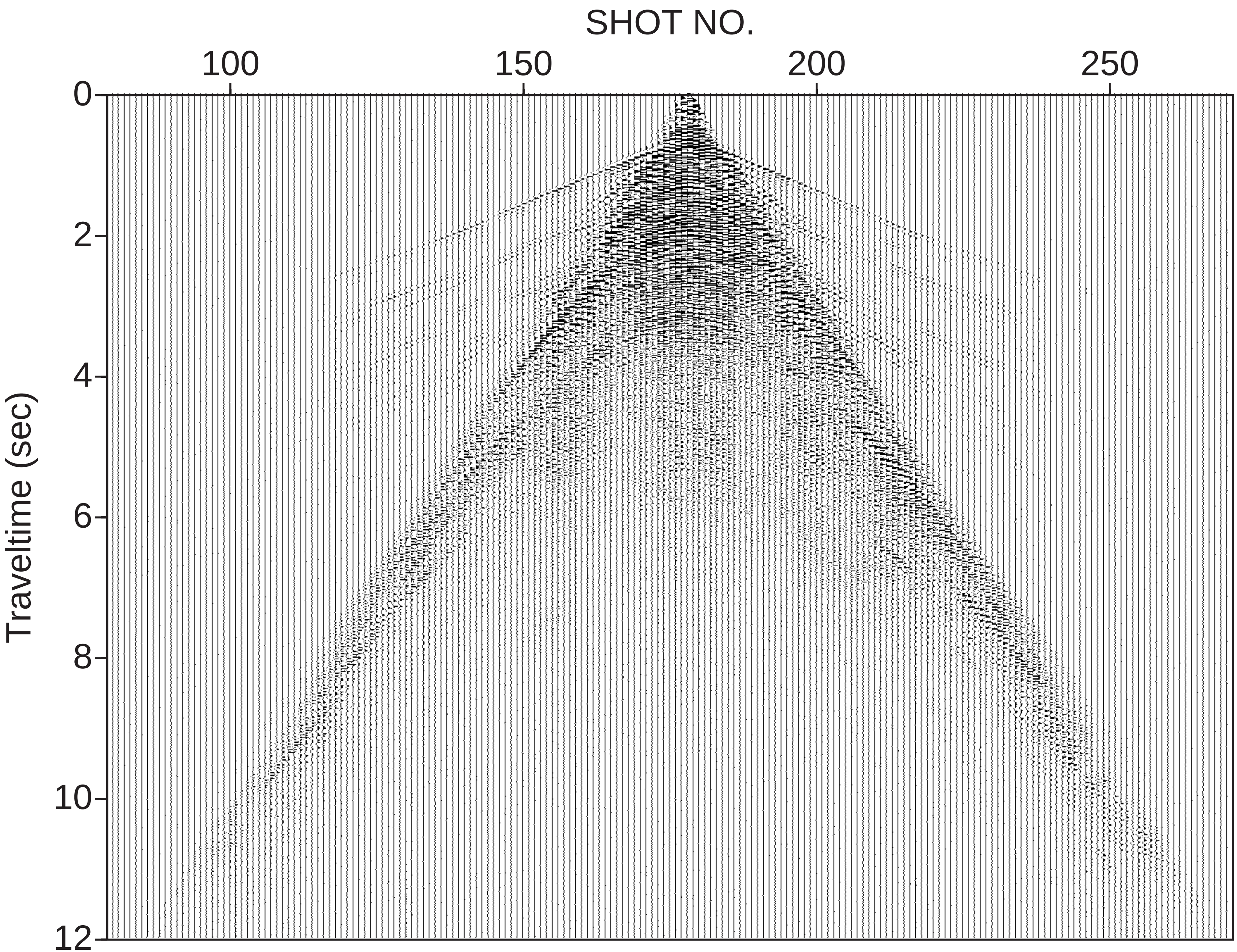


Figure 18. Record section for ESP 7 in the Strait of Georgia.

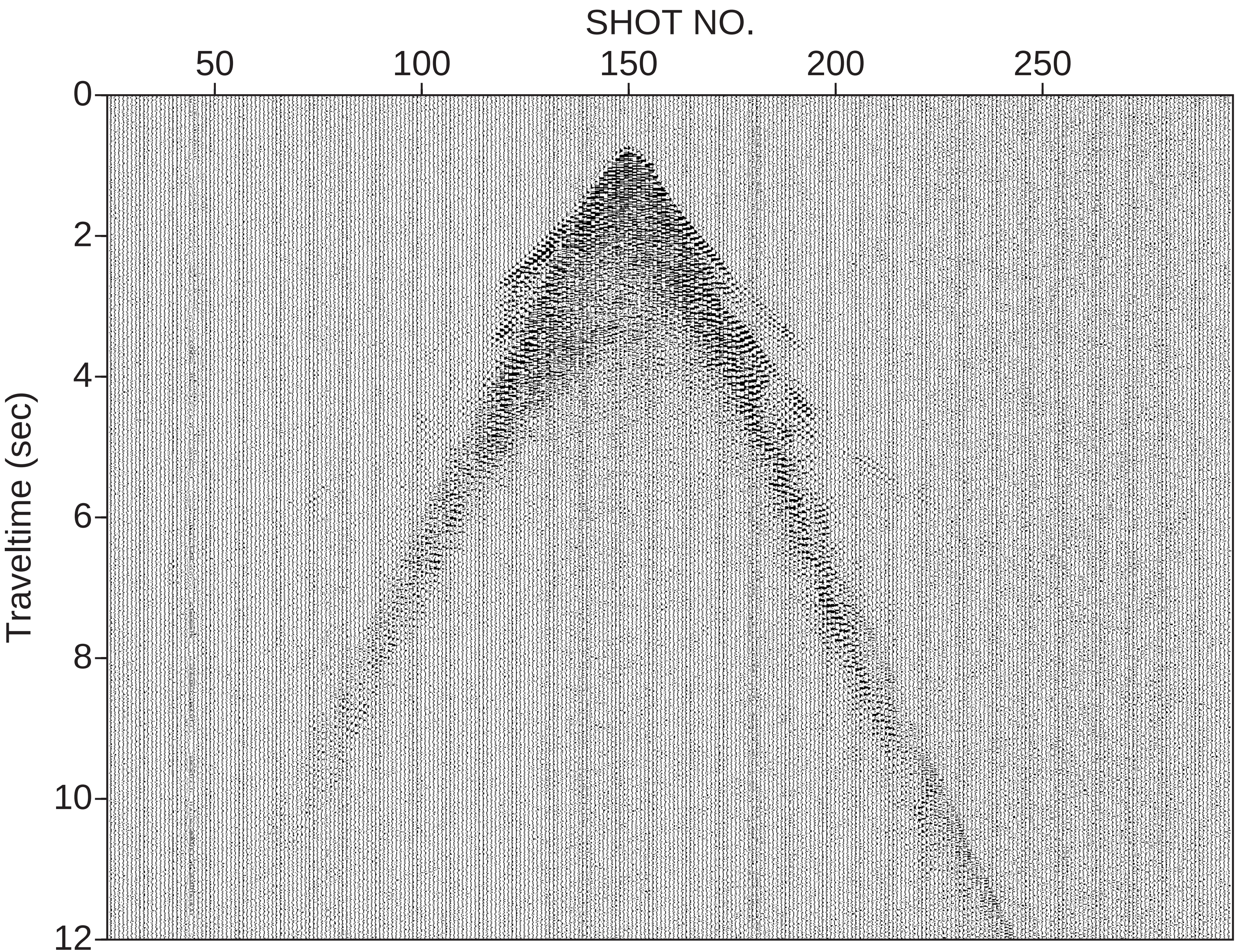


Figure 19. Record section for ESP 9 in Puget Sound.

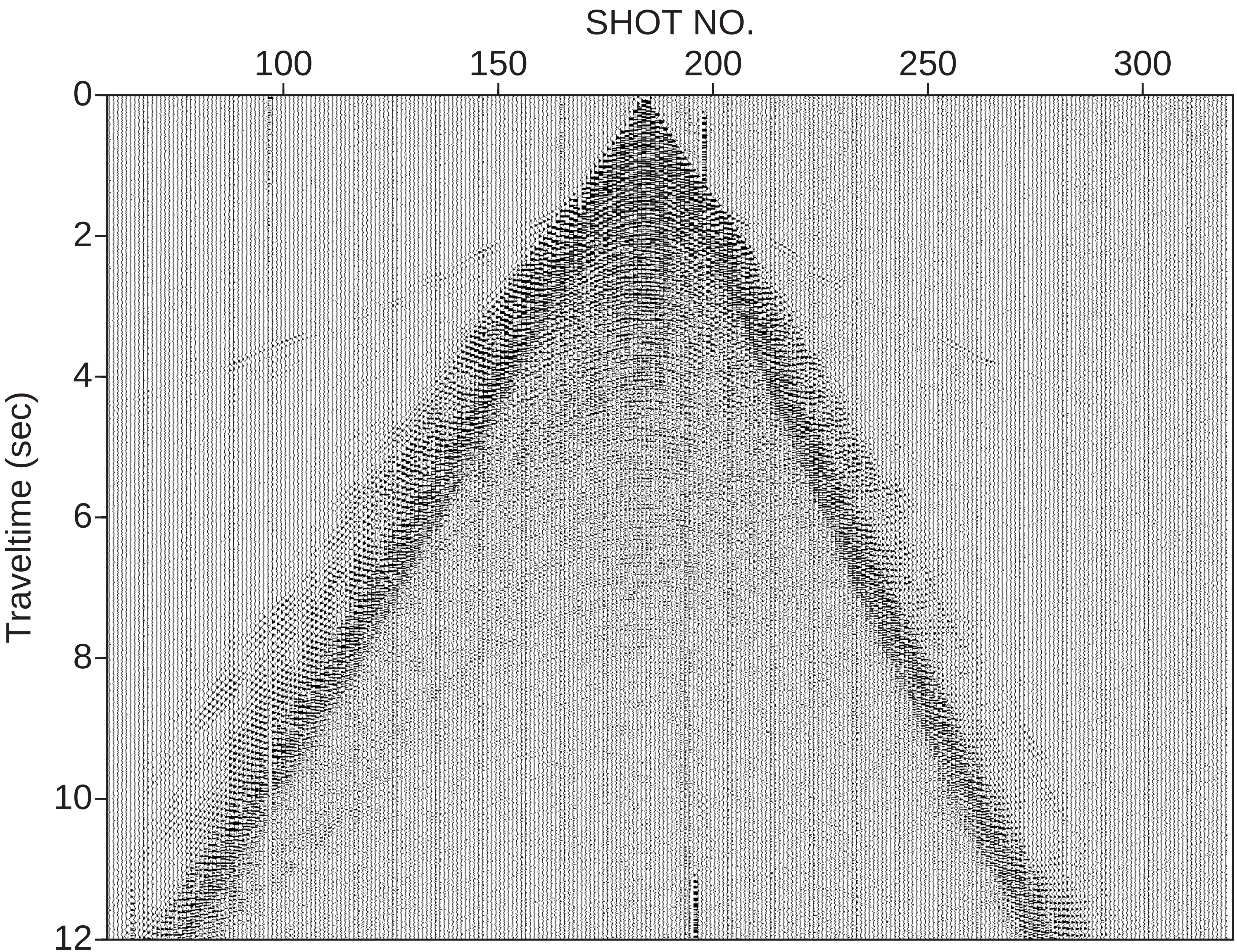


Figure 20. Record section for ESP 12 in the eastern Strait of Juan de Fuca.

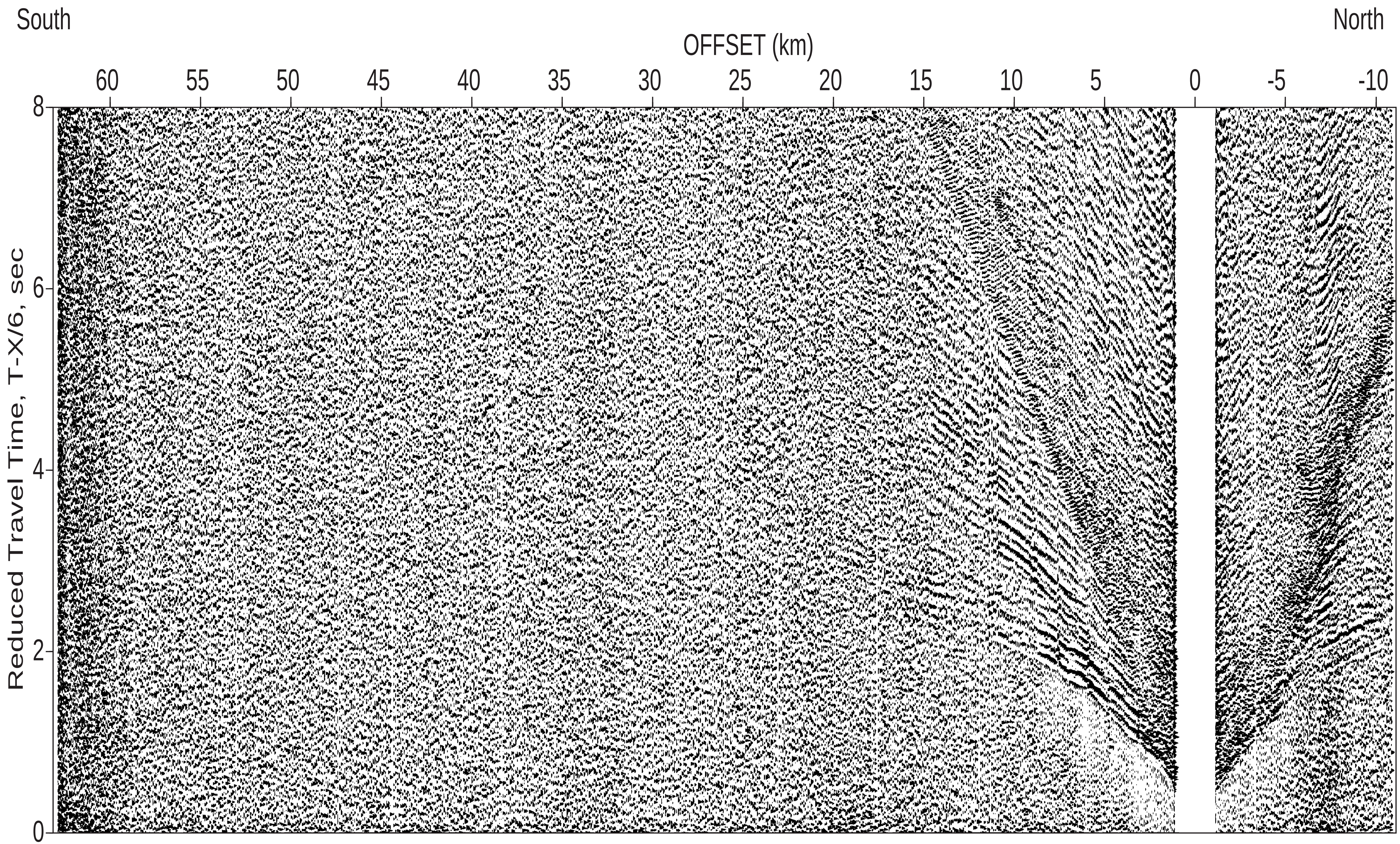


Figure 21. OBS record section for the vertical geophone component of USGS OBS1 (instrument c9) for airgun shots in Puget Sound.

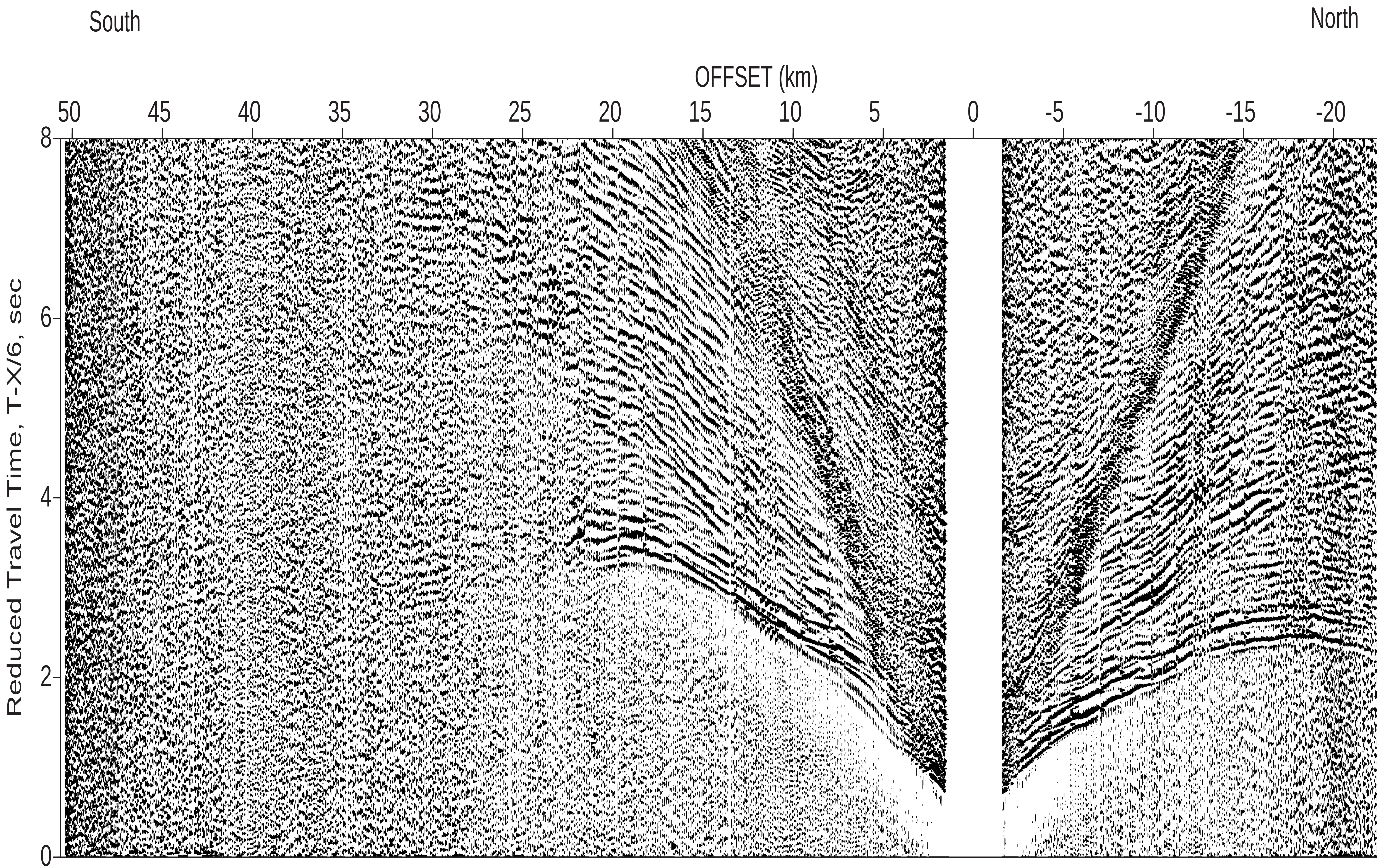


Figure 22. OBS record section for the hydrophone component of USGS OBS3 (instrument a1) for airgun shots in Puget Sound.

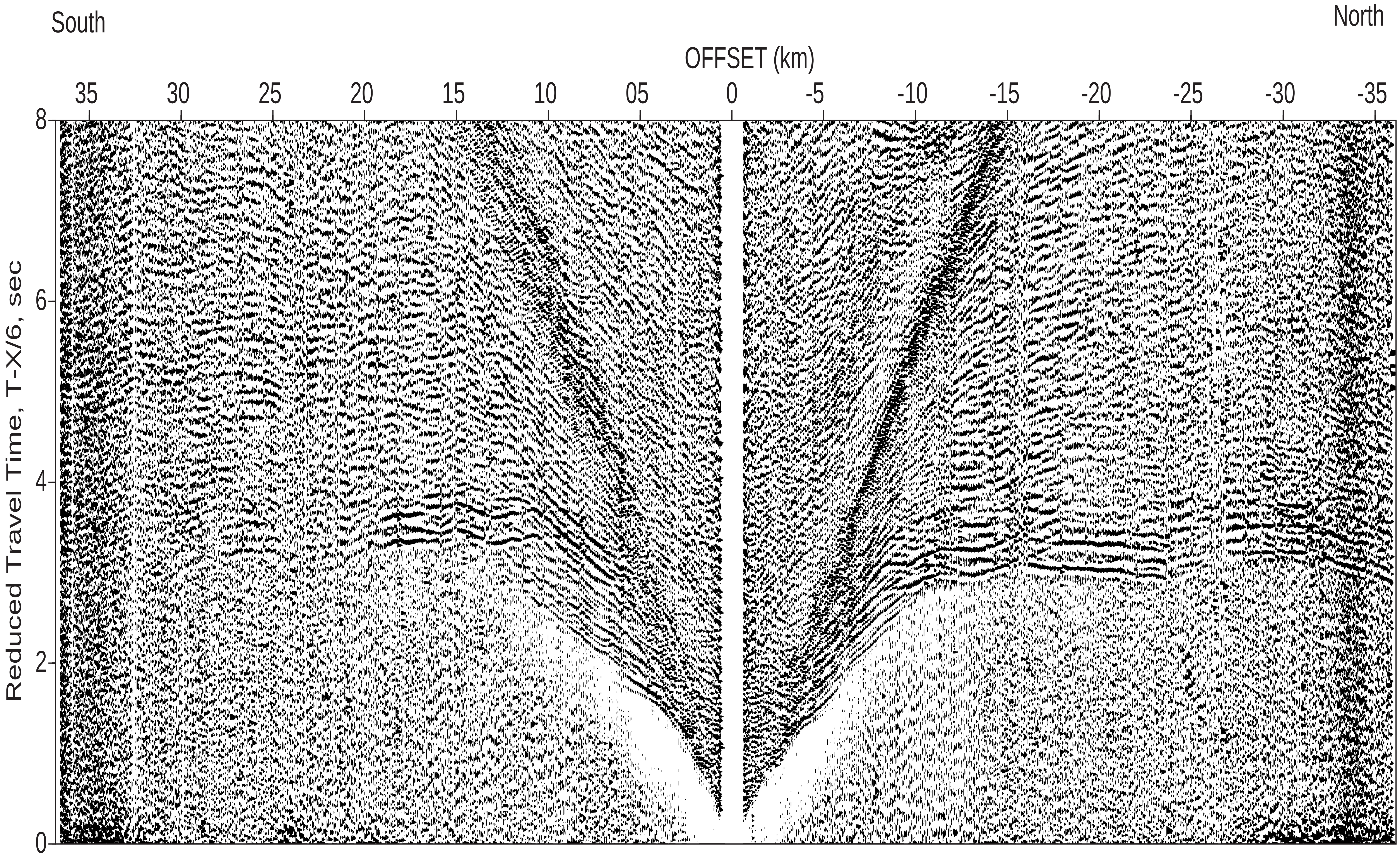


Figure 23. OBS record section for the vertical geophone component of USGS OBS5 (instrument d1) for airgun shots in Puget Sound.

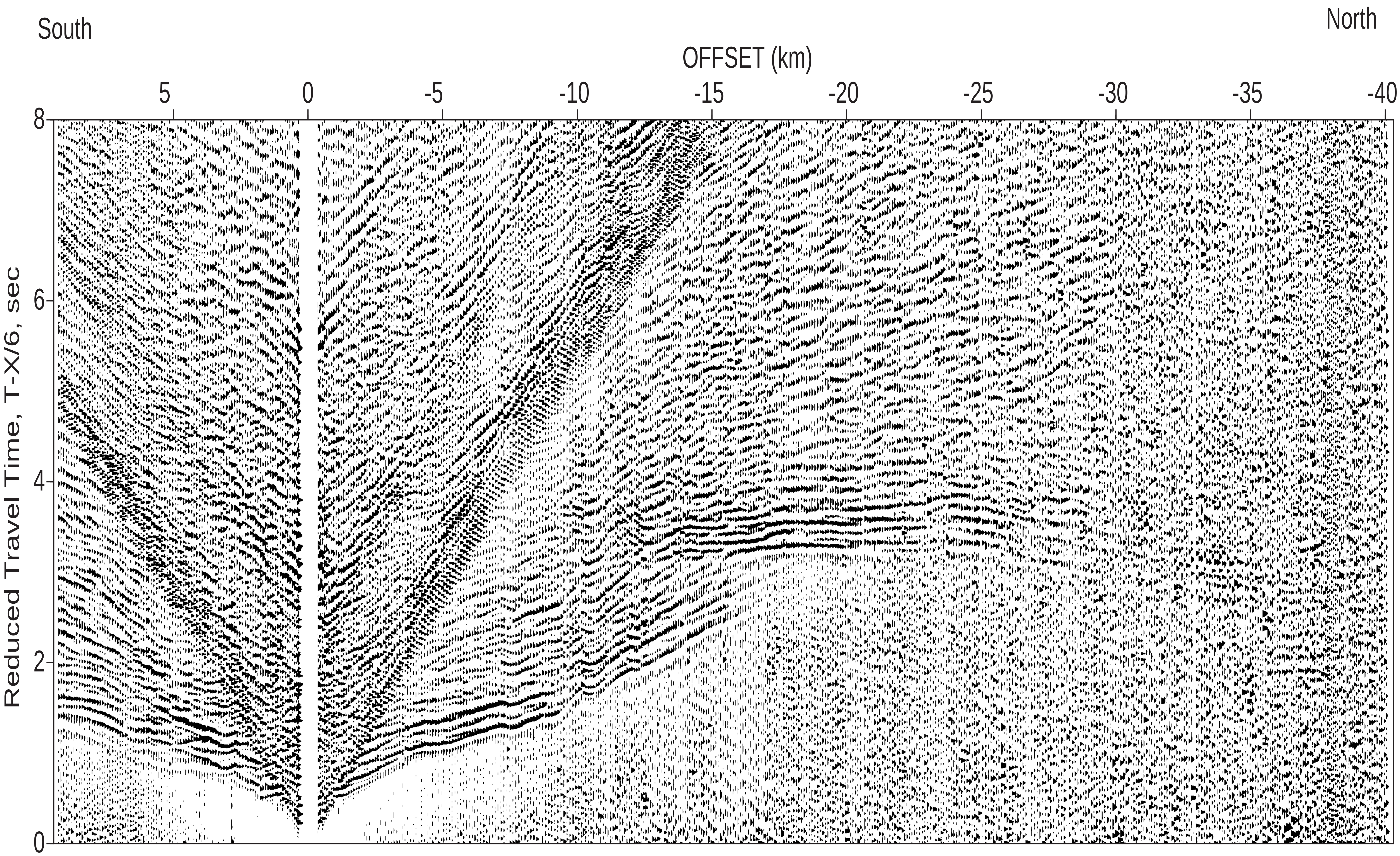


Figure 24. OBS record section for the vertical geophone component of USGS OBS7 (instrument a8) for airgun shots in Puget Sound.

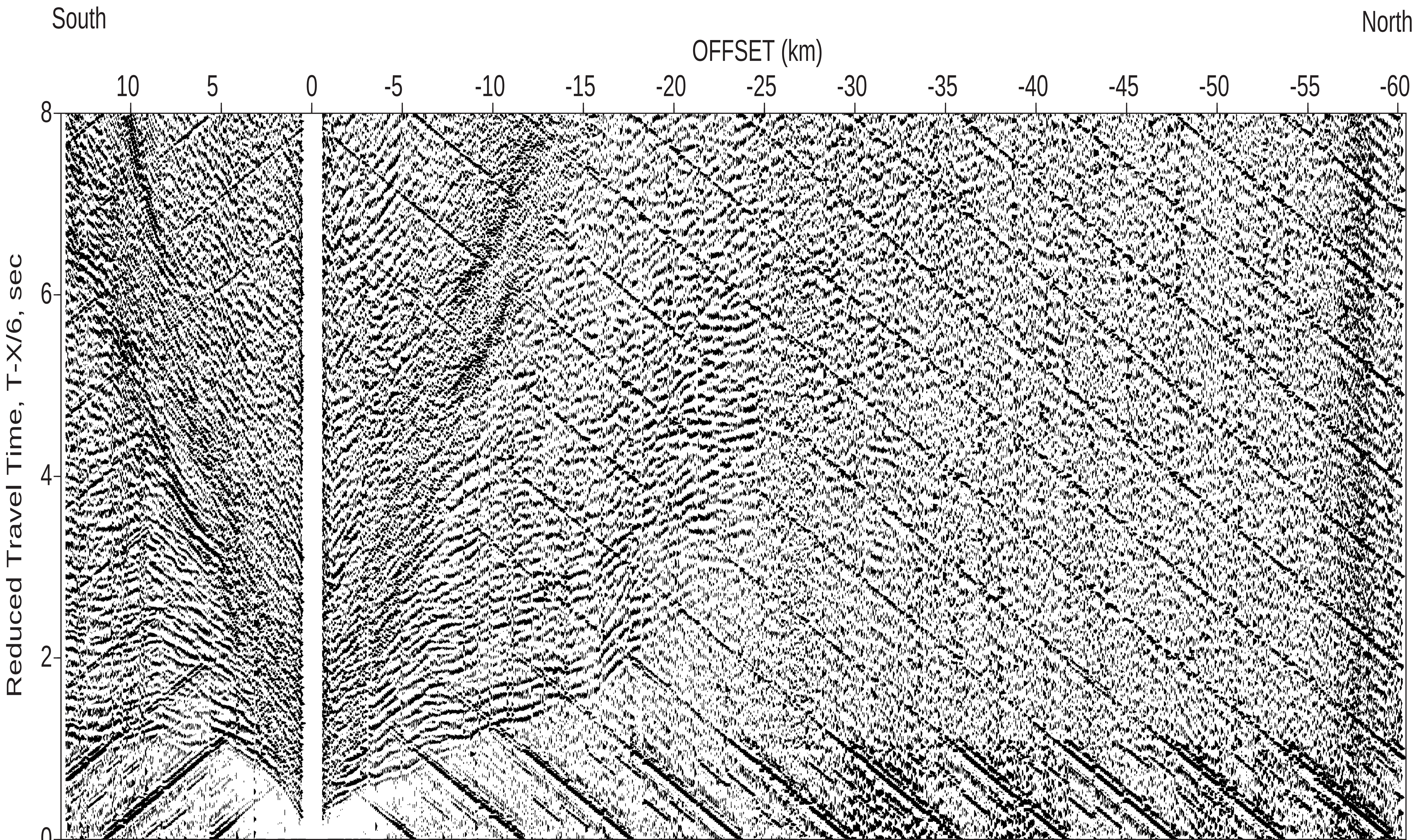


Figure 25. OBS record section for the vertical geophone component of USGS OBS8 (instrument c1) for airgun shots in Puget Sound.

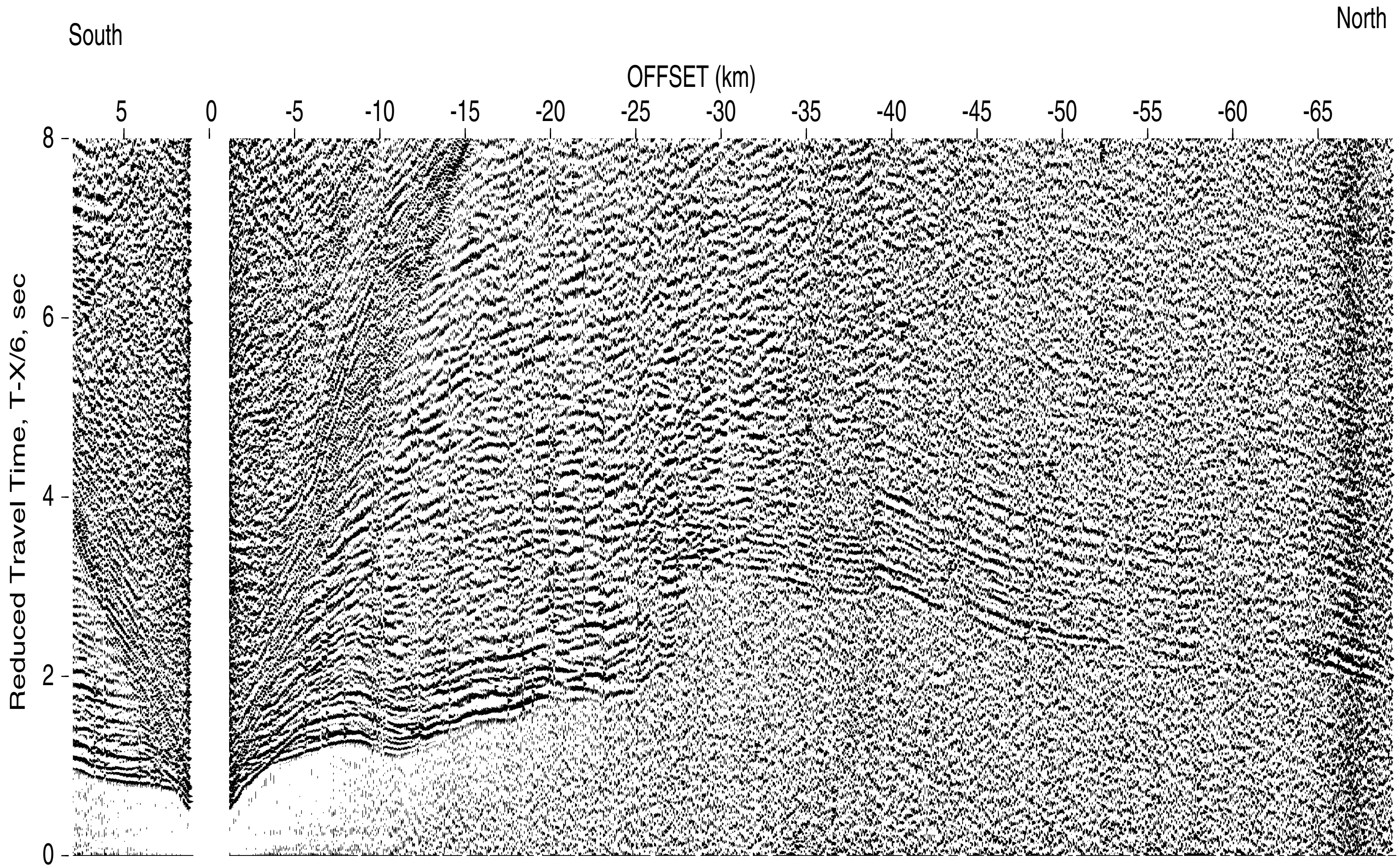


Figure 26. OBS record section for the hydrophone component of USGS OBS9 (instrument a4) for airgun shots in Puget Sound.

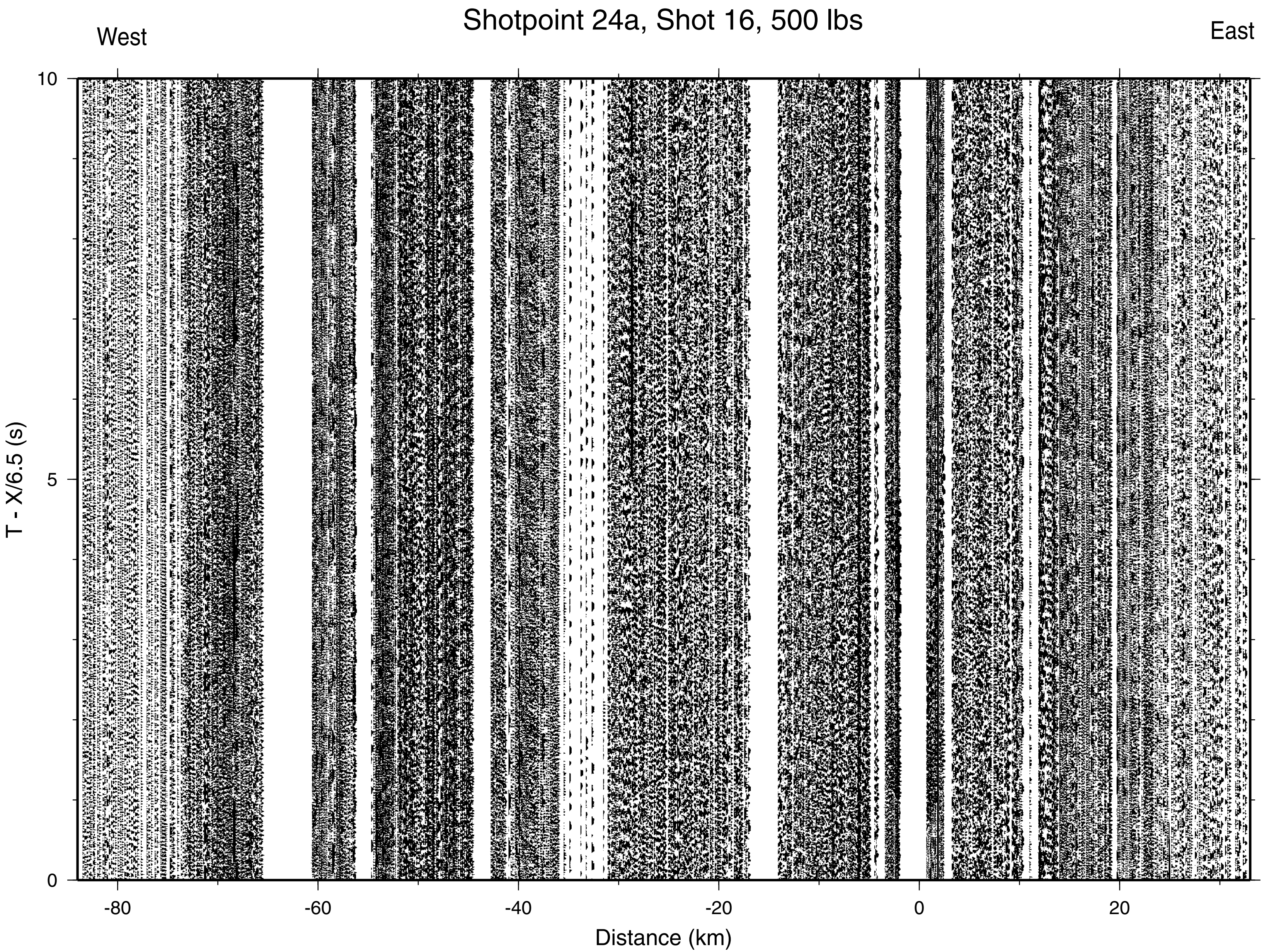


Figure 27. Reduced record section for Shotpoint 24a, vertical component only, for Lines 1 and 2.

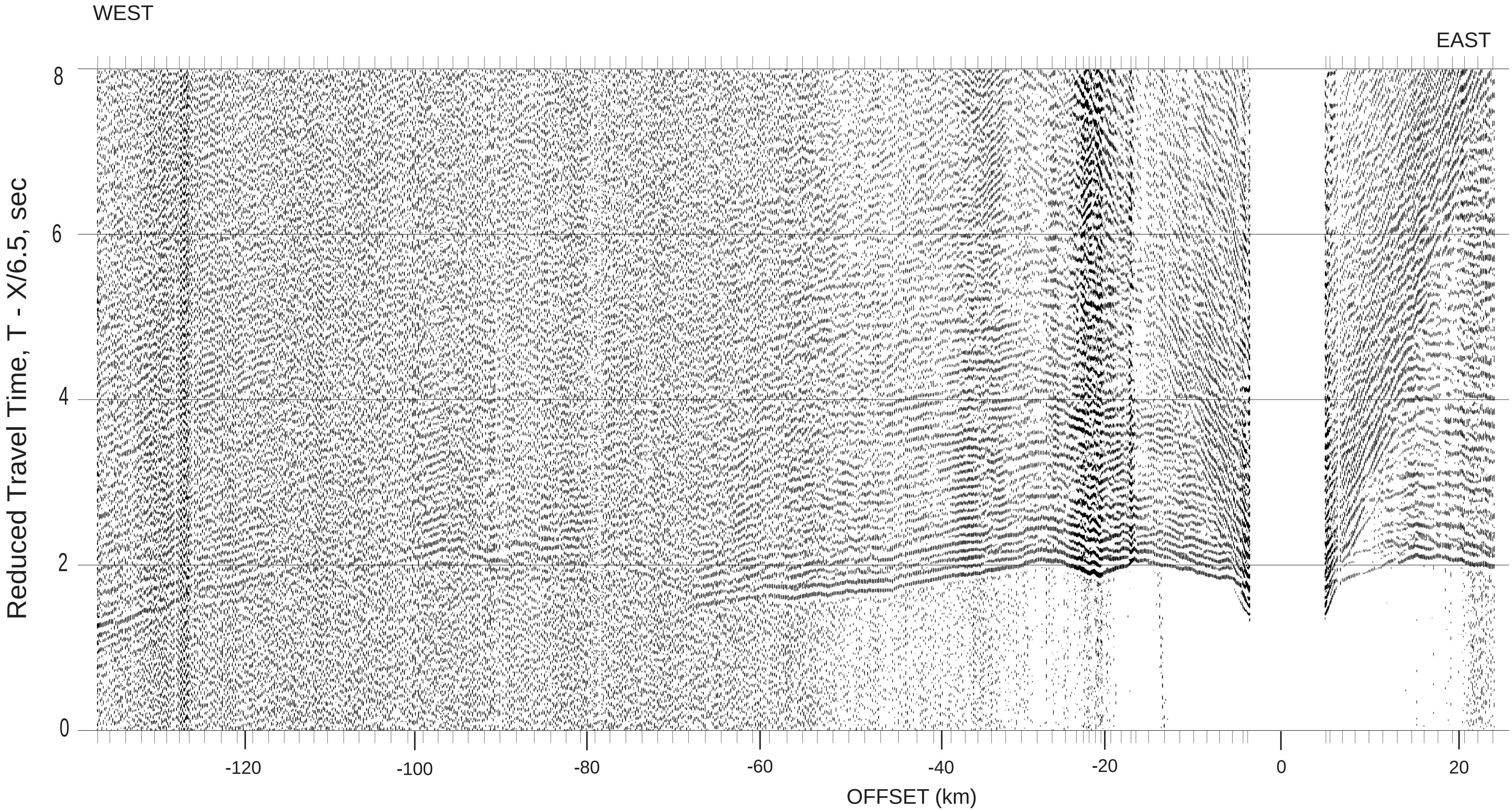


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Figure 28. Reftek record section for the vertical geophone component of station OR06 (9006) for Line 4 in the Strait of Juan de Fuca.

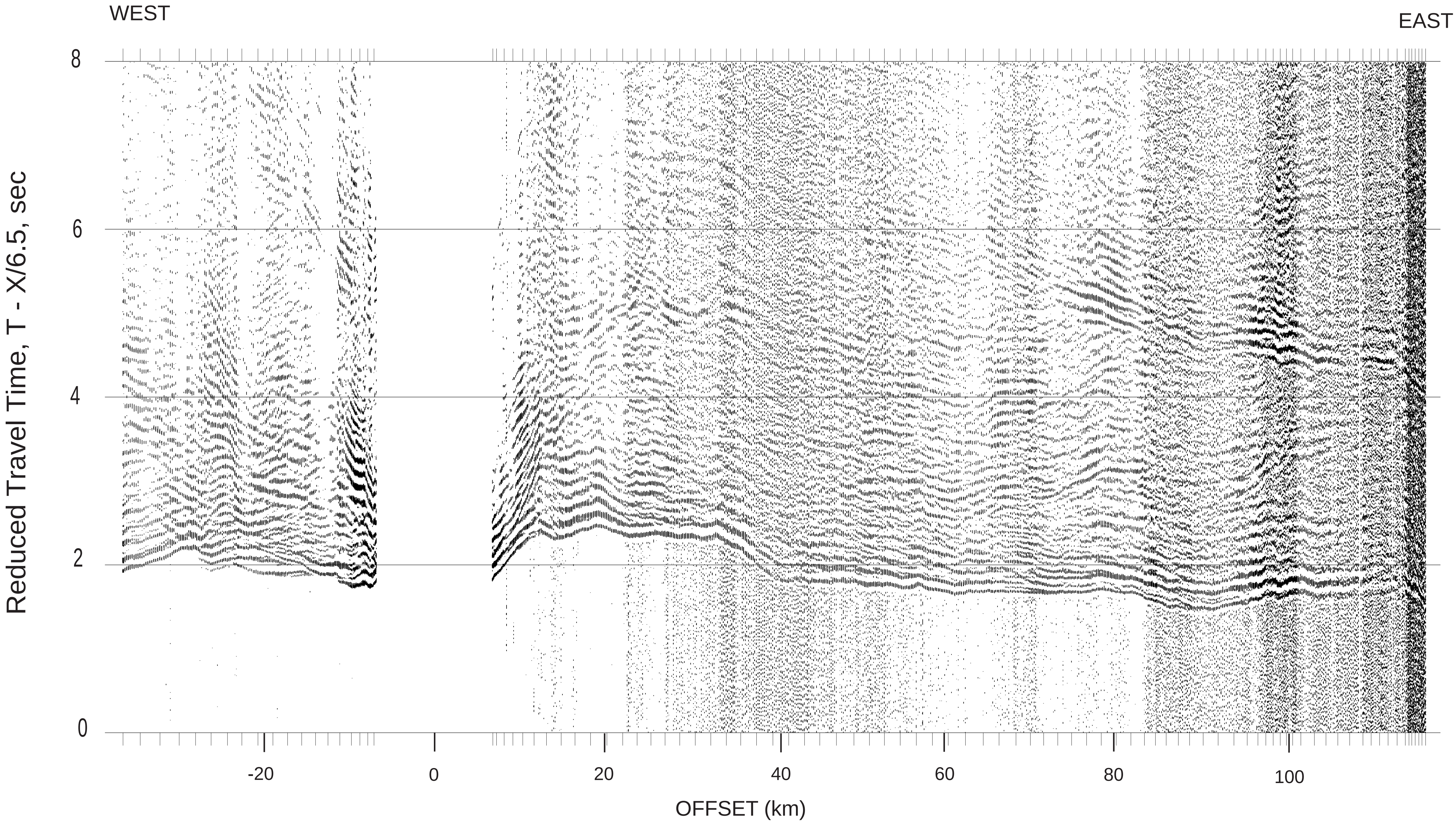

Figure 29. Reftek record section for the vertical component of site 9022 (OR22) for Line 4 in the Strait of Juan de Fuca.

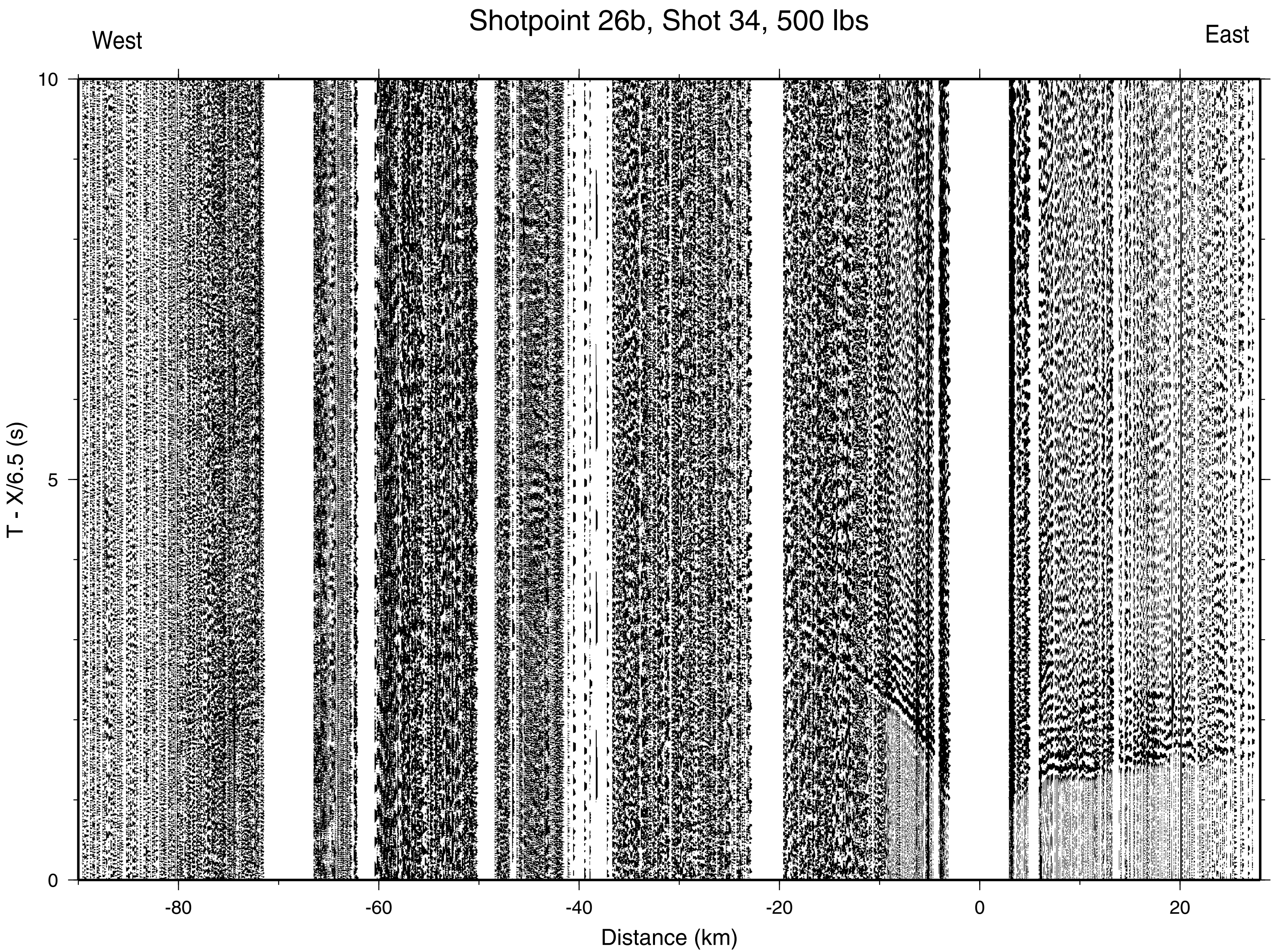

Figure 30. Reduced record section for Shotpoint 26b, vertical component only, for Lines 1 and 2.

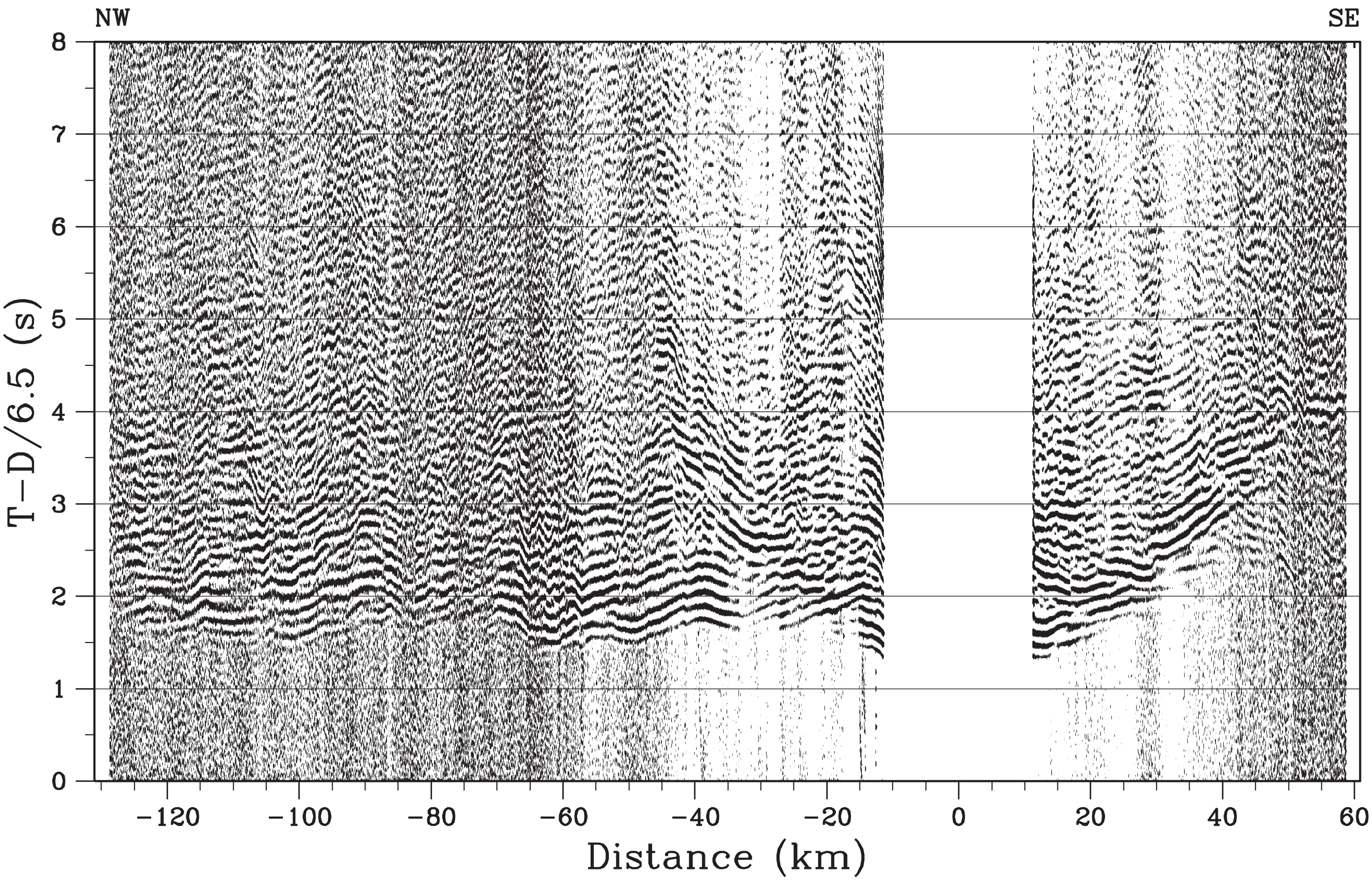

Figure 31. Record section for Reftek station CA19 (11019) for Line 6 in the Strait of Georgia.

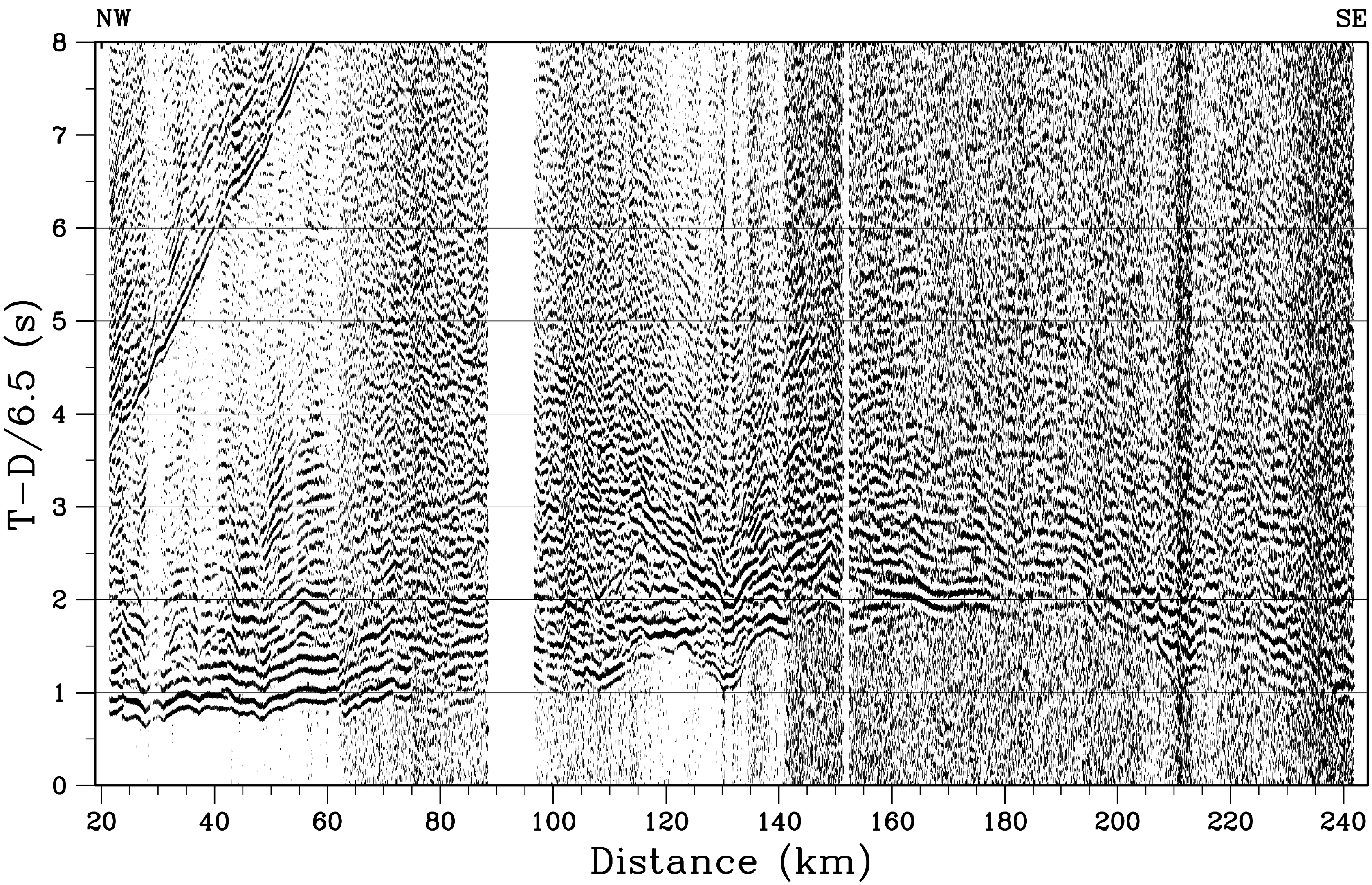

Figure 32. Record section for Reftek station CA50 (11050) for Line 5 in the Strait of Georgia.

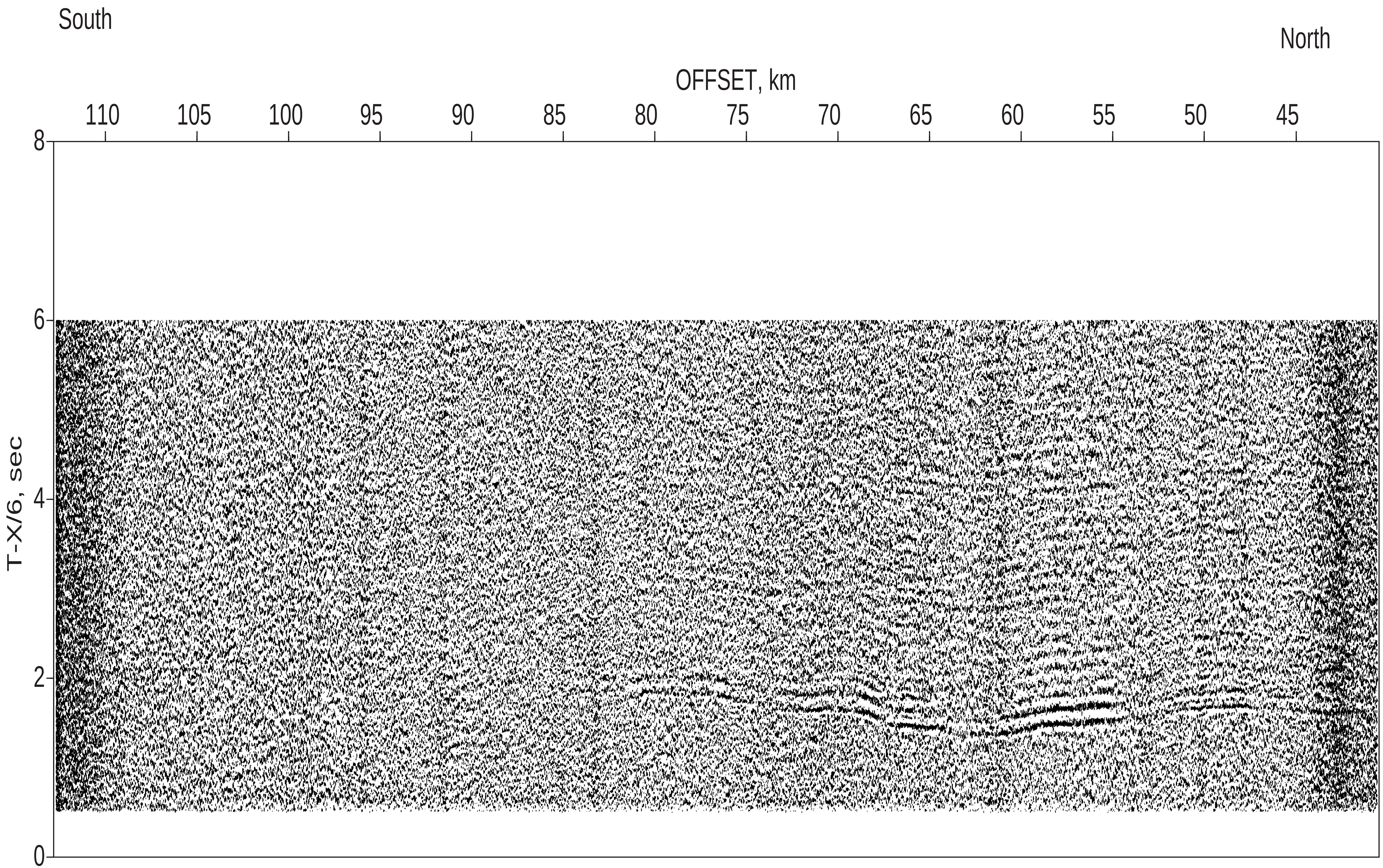

Figure 33. Record section for Reftek station 1011 for Line 9 in Puget Sound.

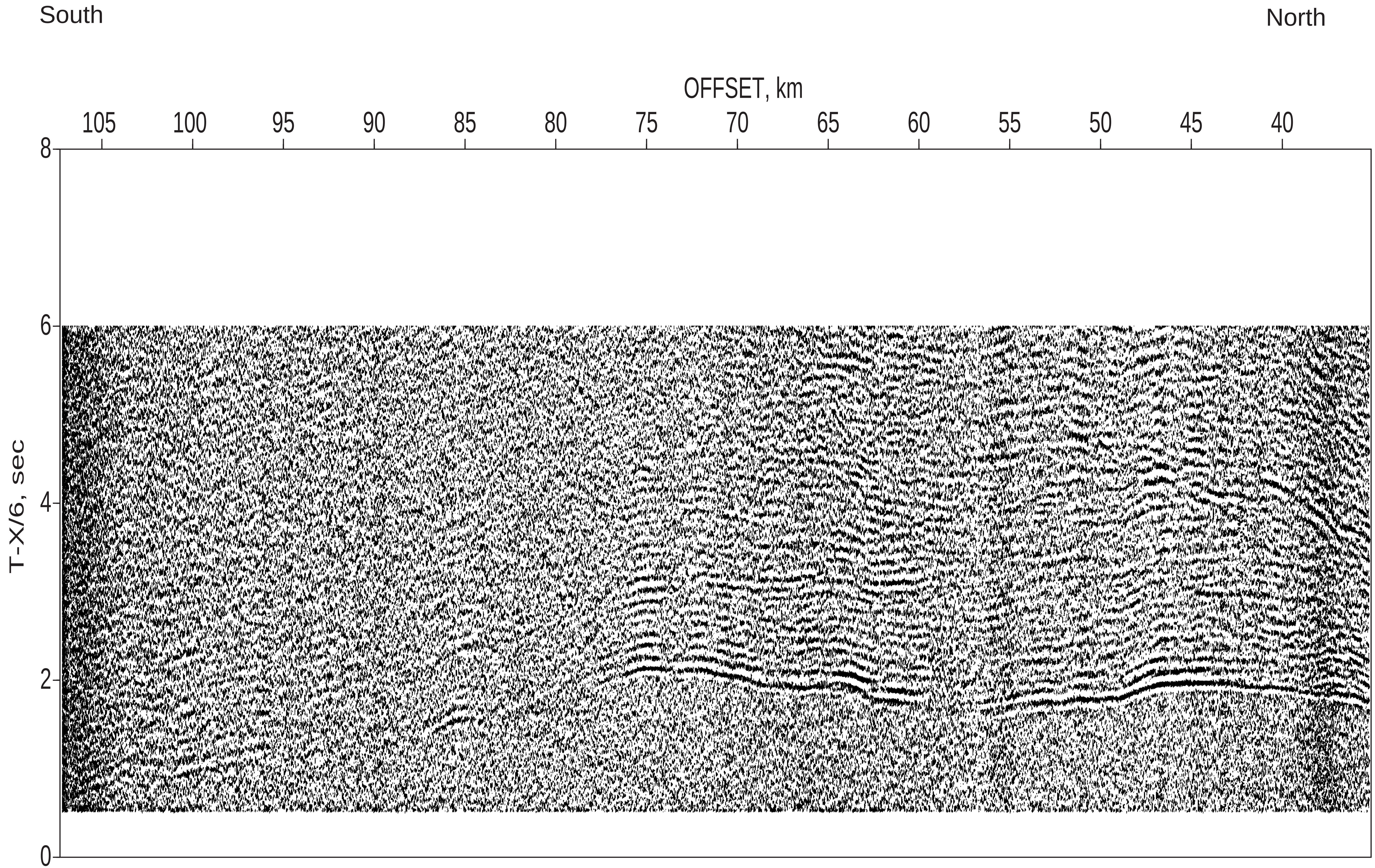

Figure 34. Record section for Reftek station 1012 for Line 9 in Puget Sound.

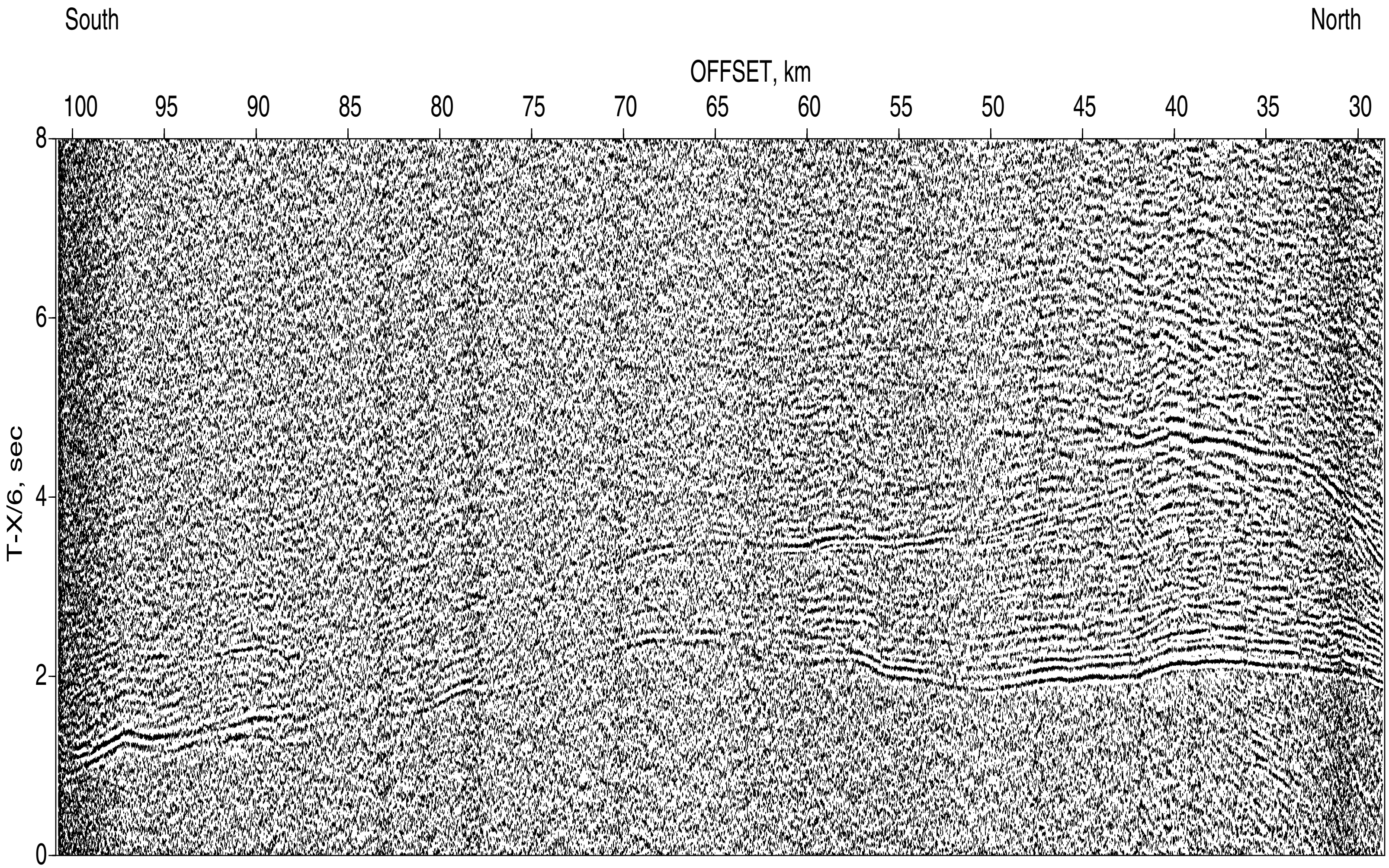

Figure 35. Record section for Reftek station 1013 for Line 9 in Puget Sound.

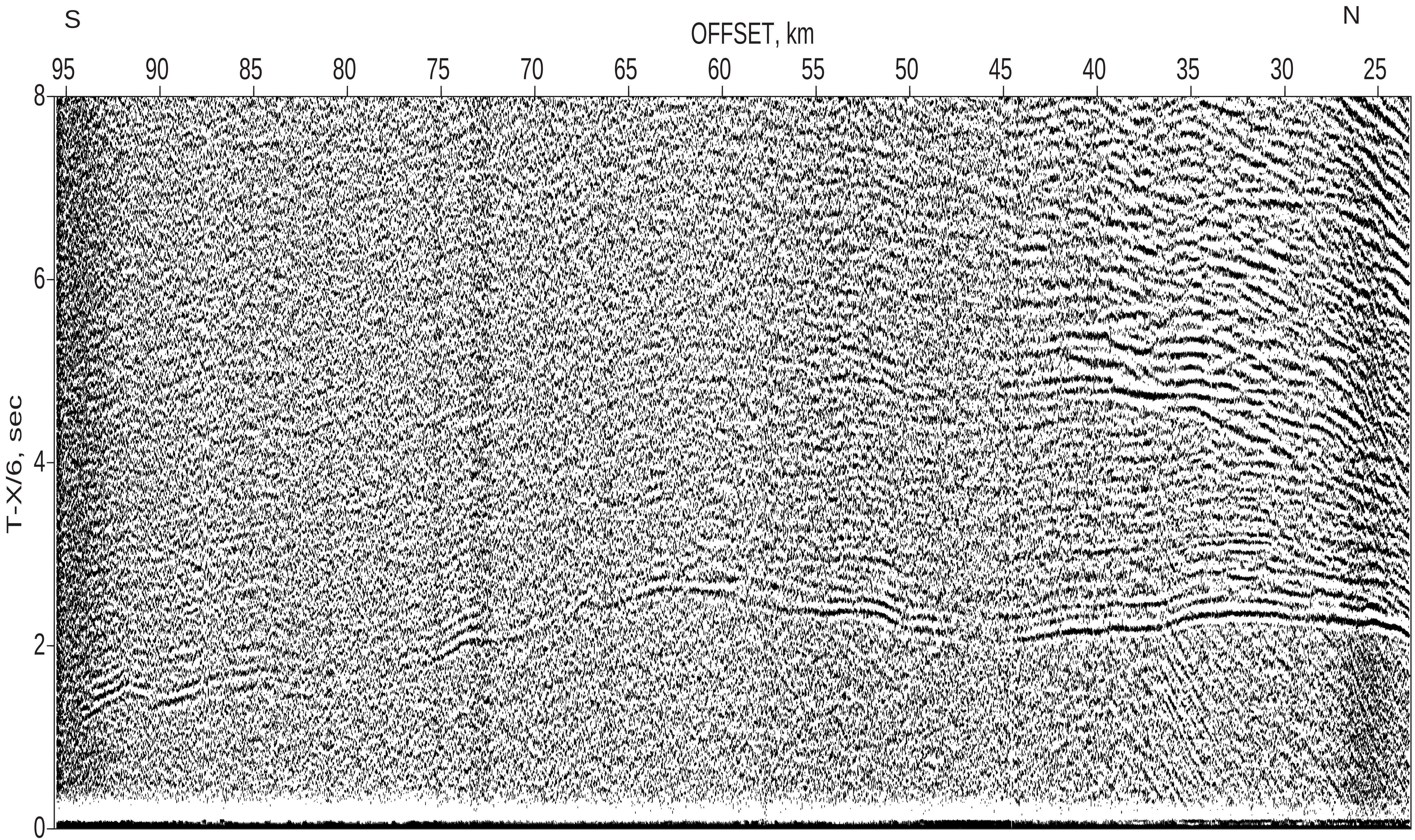

Figure 36. Record section for Reftek station 1014 for Line 9 in Puget Sound.

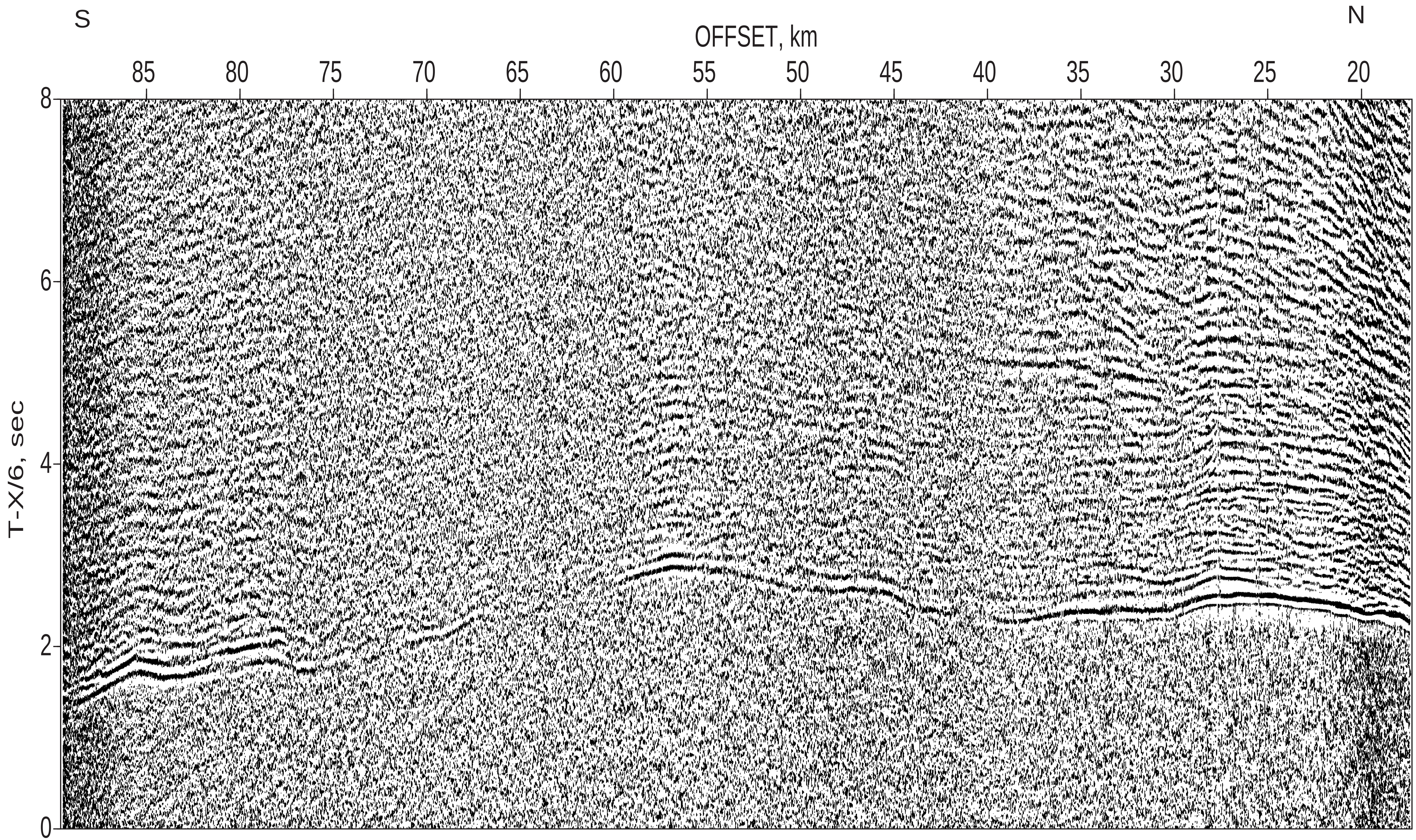

Figure 37. Record section for Reftek station 1015 for Line 9 in Puget Sound.

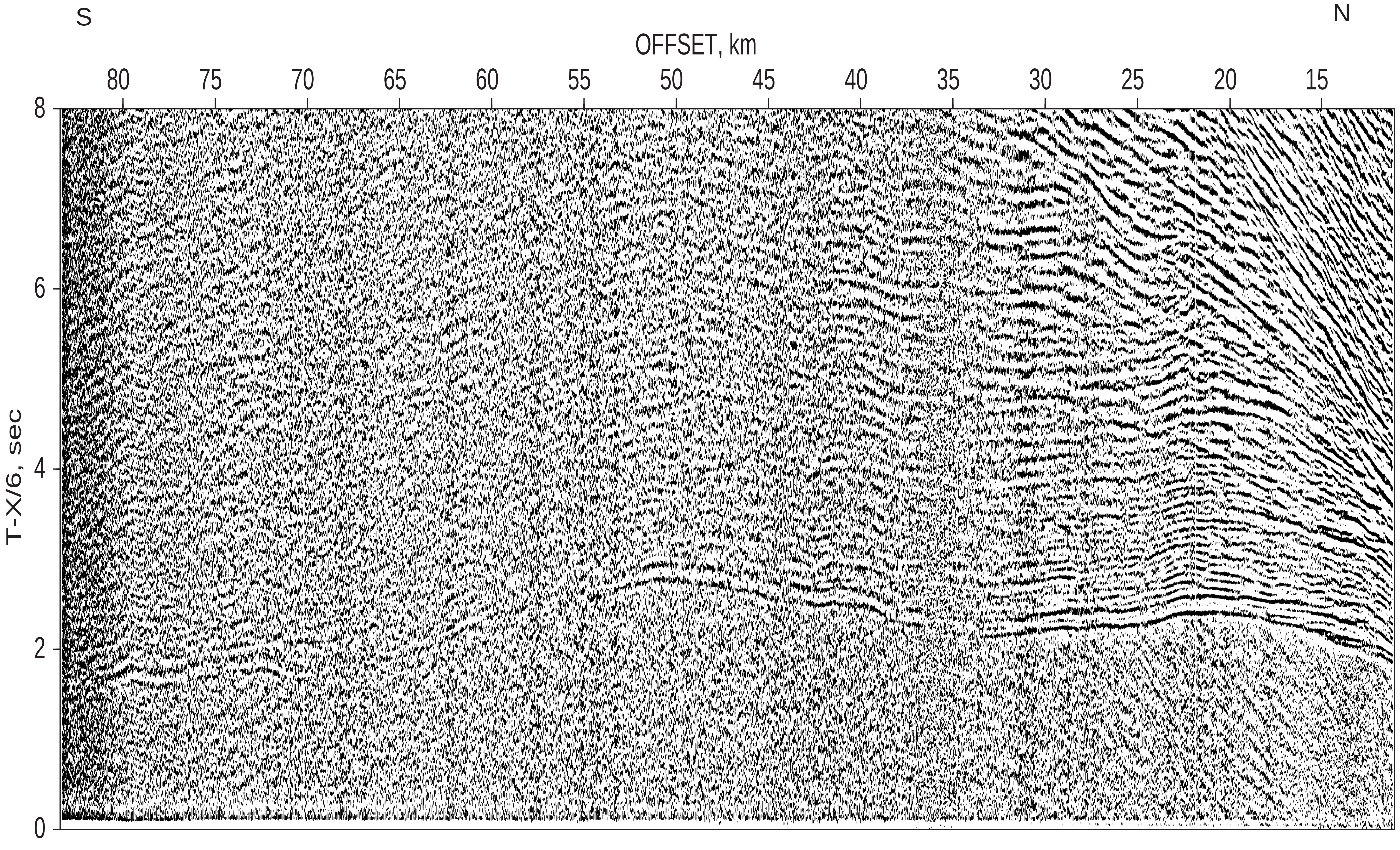

Figure 38. Record section for Reftek station 1016 for Line 9 in Puget Sound.

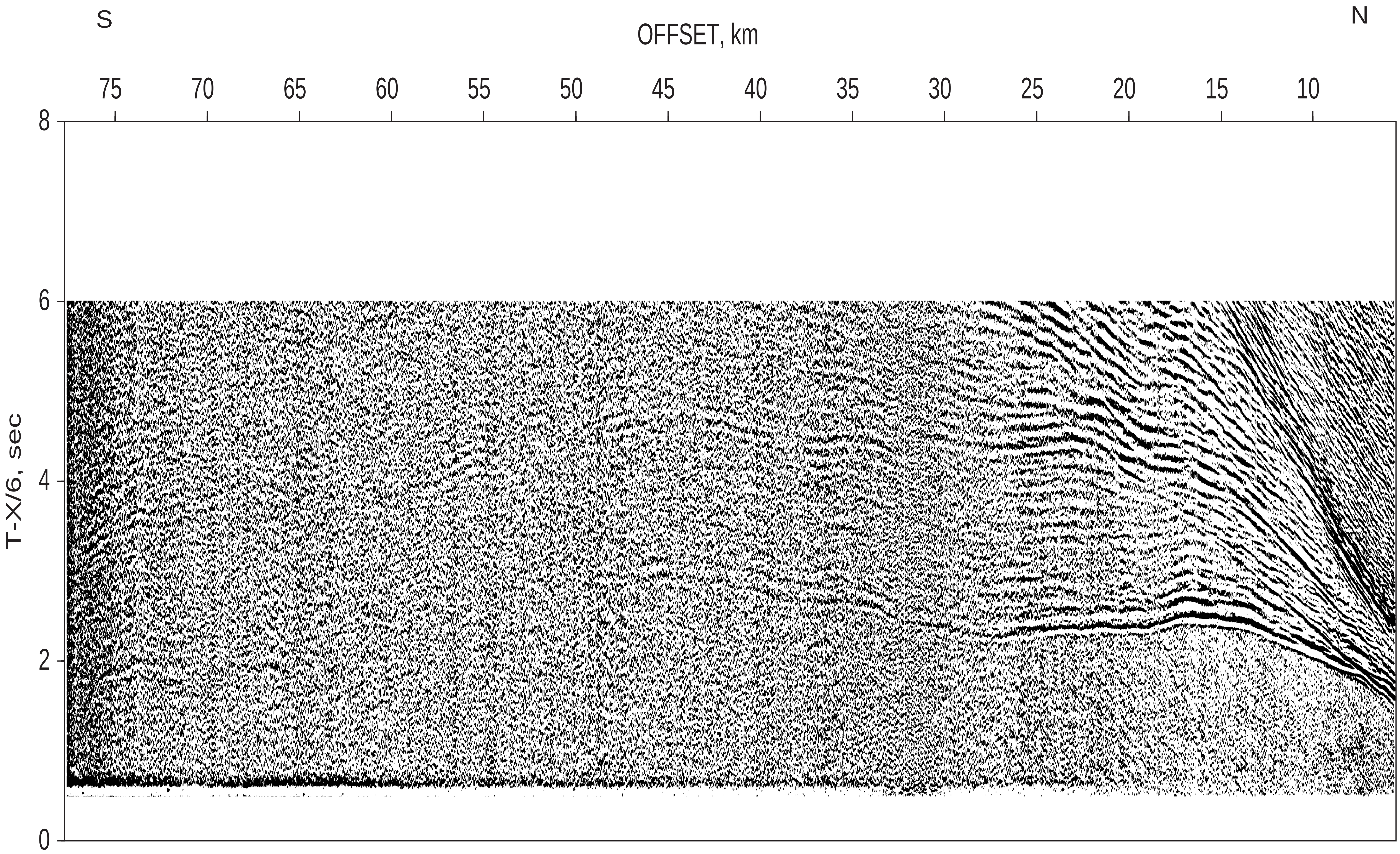

Figure 39. Record section for Reftek station 1017 for Line 9 in Puget Sound.

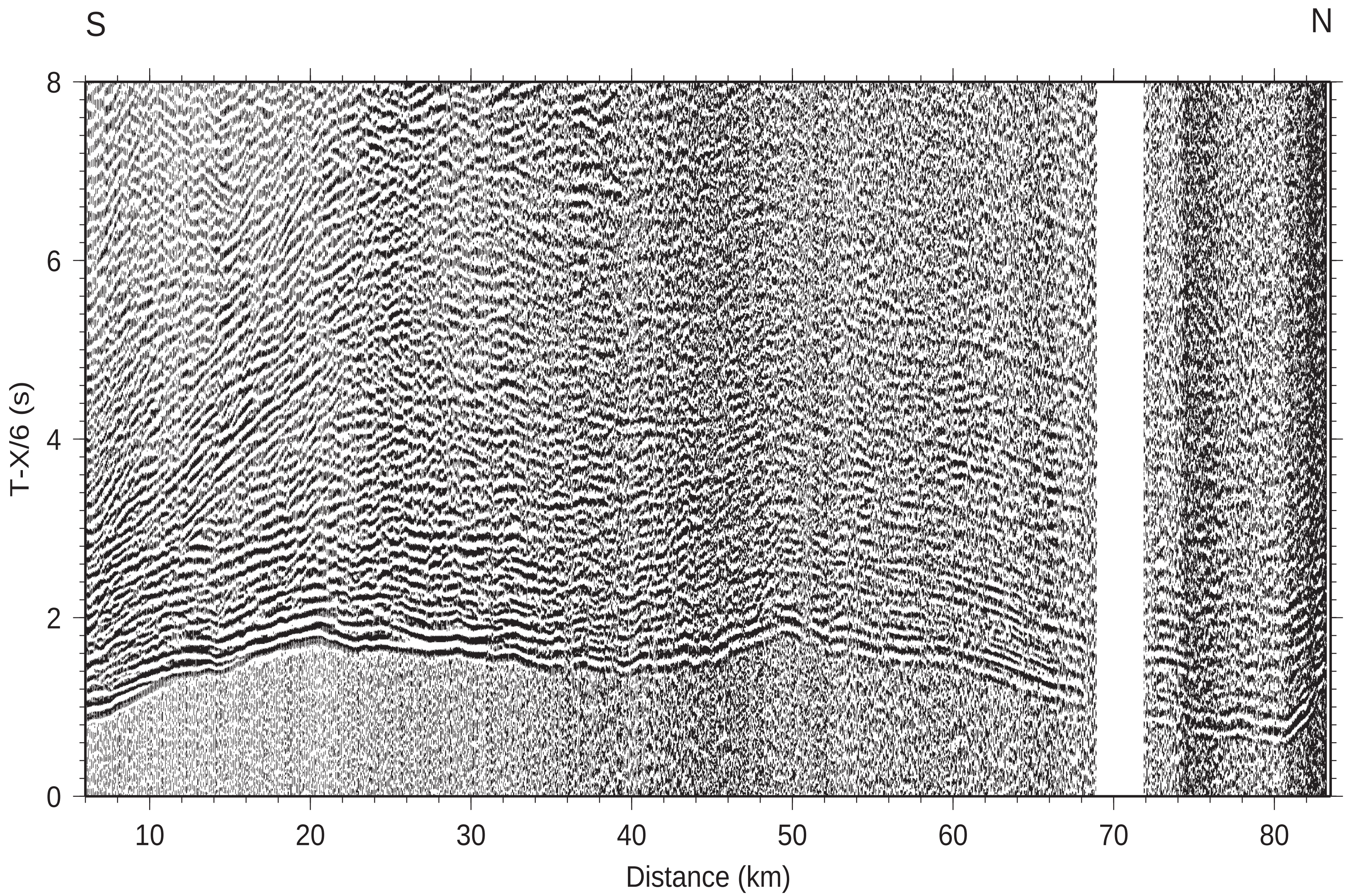

Figure 40. Record section for Reftek station 7007 for Line 3 in Hood Canal.

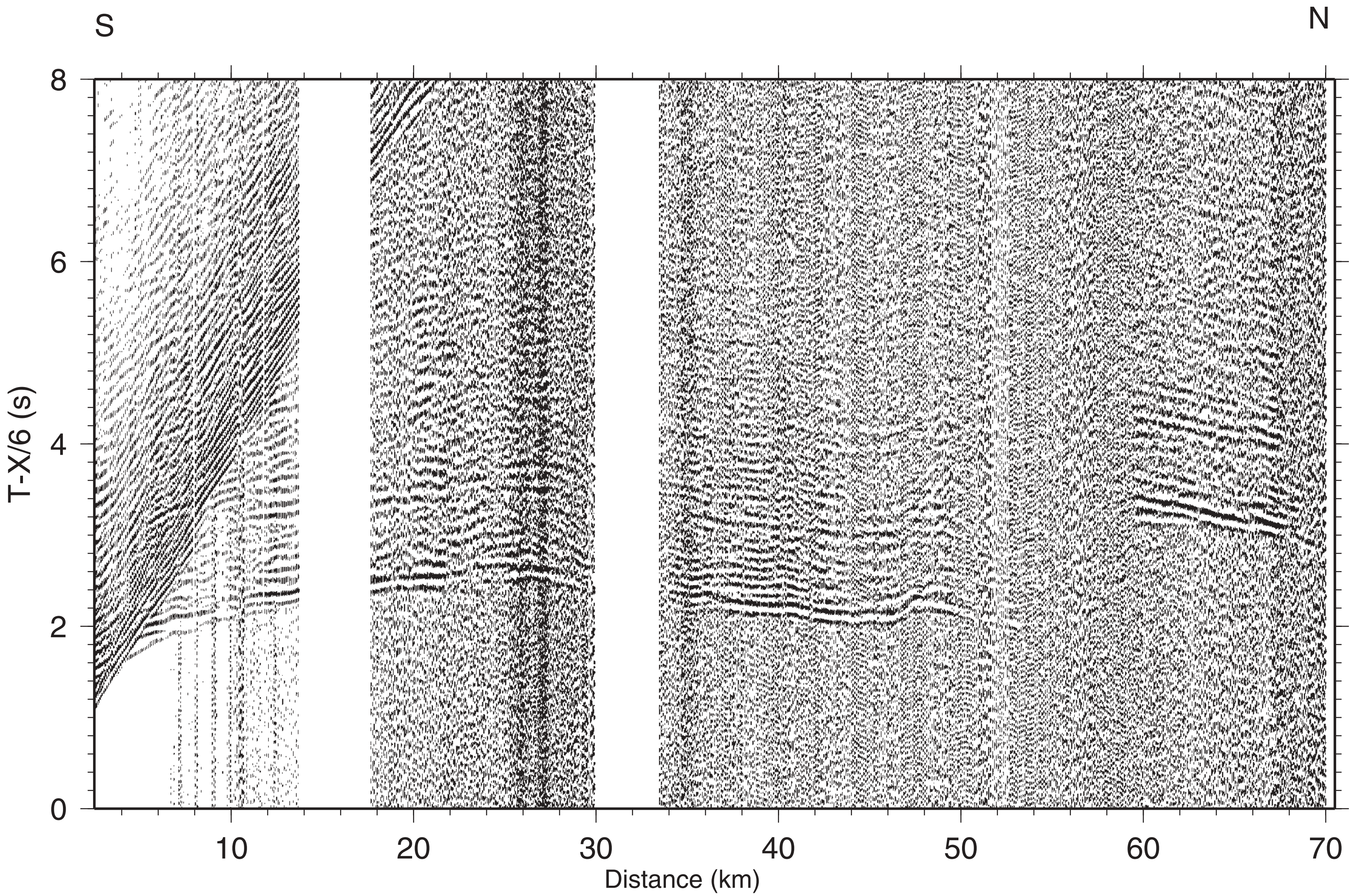

Figure 41. Record section for Reftek station 8003 for Line 2 in Puget Sound.

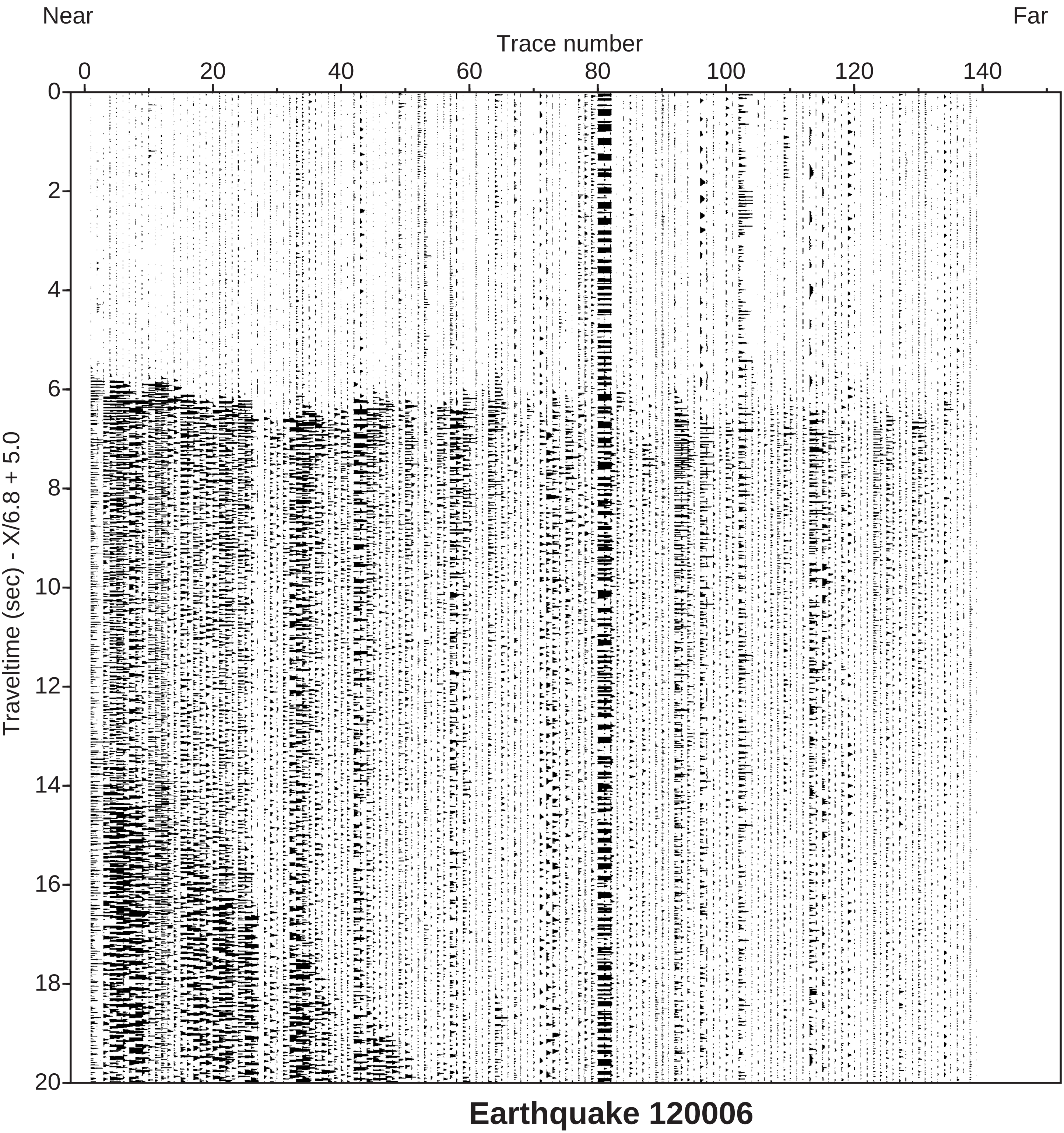

Figure 42. Record section for the M2.8 earthquake event 120006, located 11.7 km WSW of Morton, Washington, at 16.9 km depth. Each trace represents a recording made by a different Reftek station. The traces are ordered from nearest to farthest from the event epicenter.

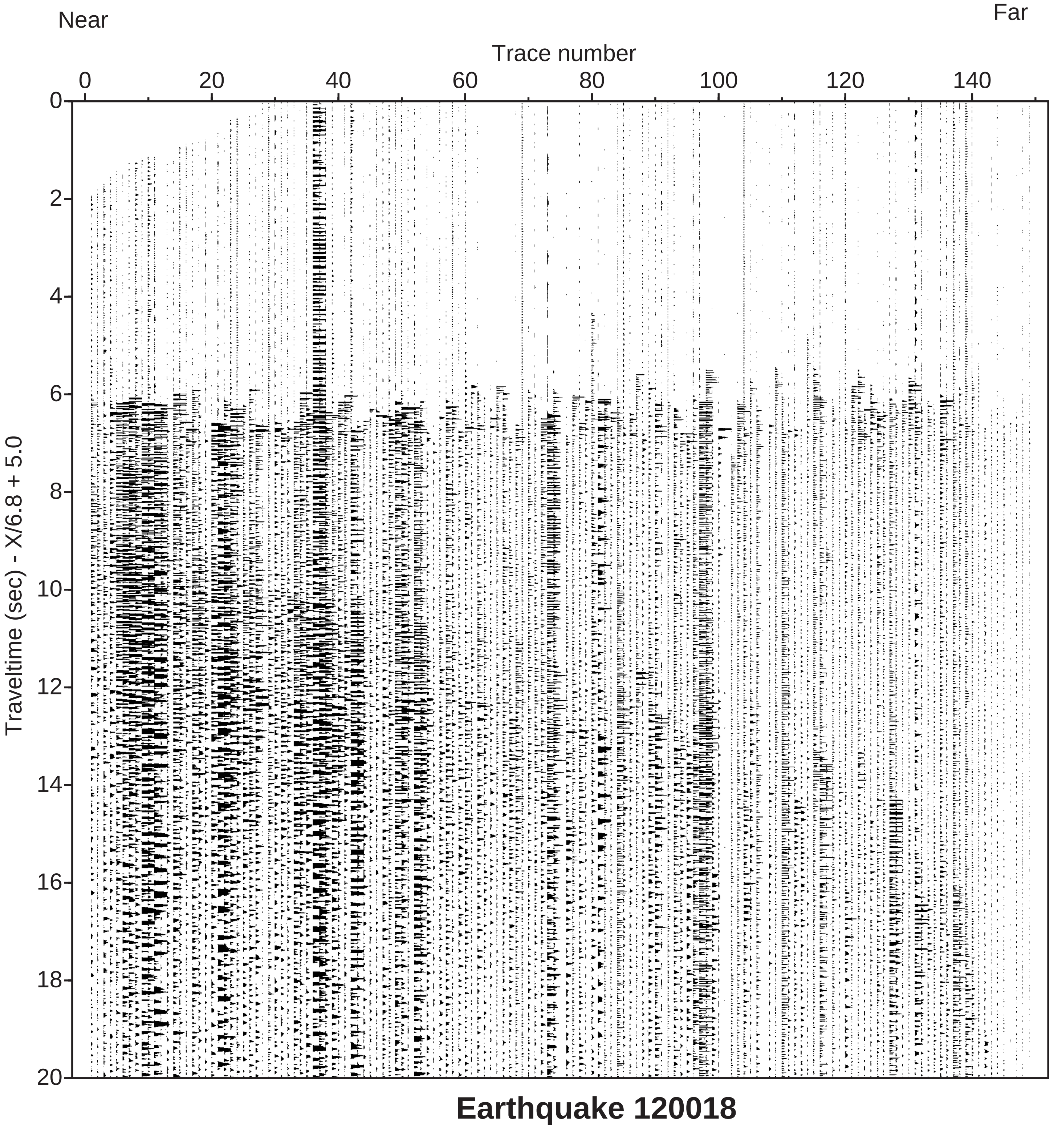

Figure 43. Record section for the M2.3 earthquake event 120018, located 6.3 km SSW of Seattle, Washington, at 21.1 km depth. Each trace represents a recording made by a different Reftek station. The traces are ordered from nearest to farthest from the event epicenter.

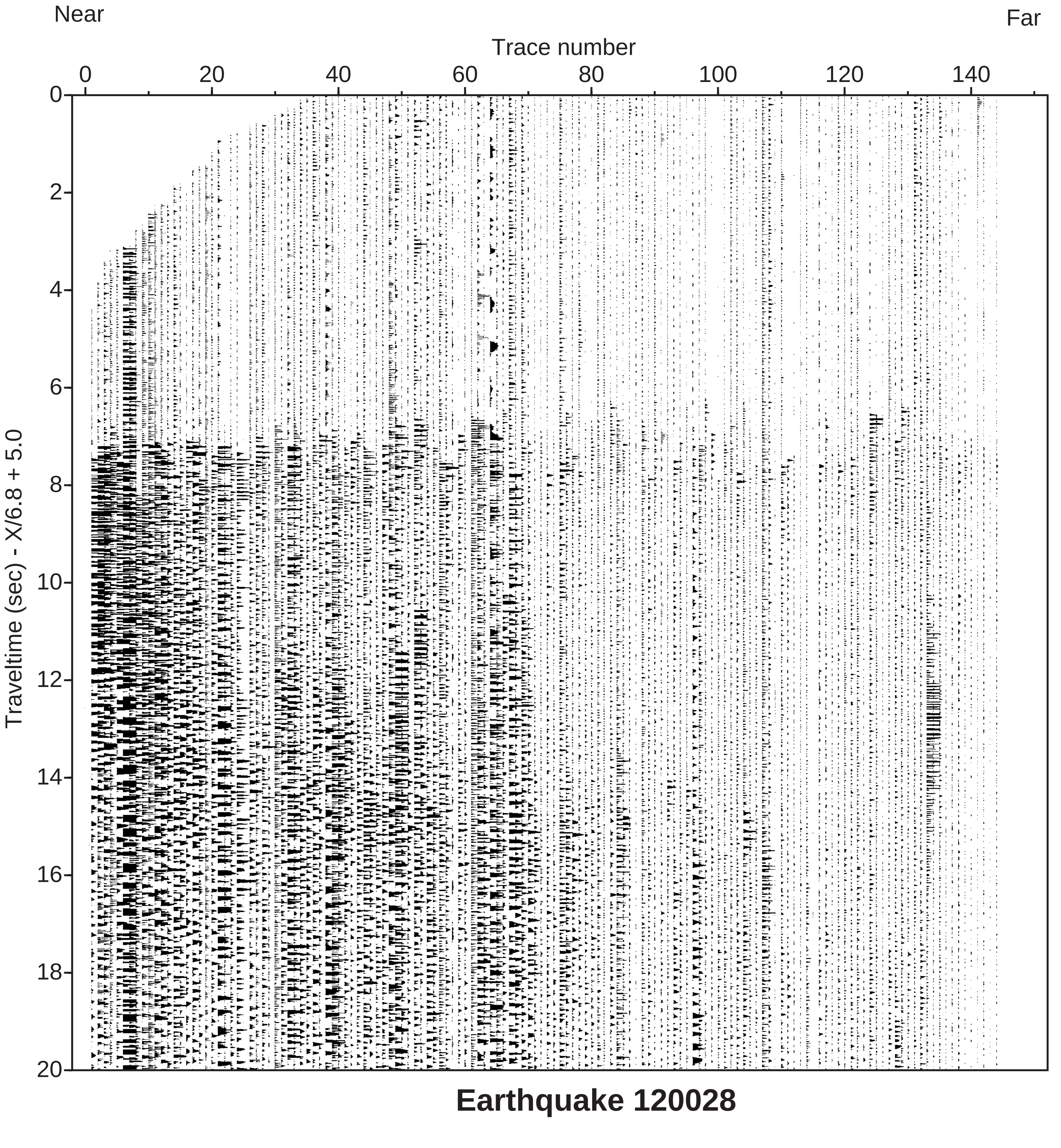

Figure 44. Record section for the M2.1 earthquake event 120028, located 3 km ESE of Bellevue, Washington, at 2.8 km depth. Each trace represents a recording made by a different Reftek station. The traces are ordered from nearest to farthest from the event epicenter.