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ONSHORE-OFFSHORE WIDE-ANGLE SEISMIC RECORDINGS FROM CENTRAL OREGON: THE FIVE-DAY RECORDER DATA

By

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ABSTRACT

The U.S. Geological Survey and Oregon State University deployed an onshore array of seismic recorders during marine seismic reflection profiling of the central Oregon margin conducted in September 1989. The marine reflection profile was acquired using a tuned 128 liter (7800 cu. in.) airgun array towed by a commercial seismic ship. Eight three-component land stations temporarily deployed in coastal central Oregon continuously recorded the airgun signals at large offsets. This report describes the onshore experiment, provides the locations and times of operation of all the recorders, presents the data reduction scheme, and illustrates the recorded wide-angle seismic data.

INTRODUCTION AND OBJECTIVES

In September, 1989, investigators from Oregon State University, University of Texas at Austin, and the U.S. Geological Survey (USGS) collaborated to collect a seismic reflection profile and wide-angle seismic recordings along the reflection line in central, coastal Oregon displayed in Figure 1 (Trehu and others, 1990; Lin and Trehu, 1991). This study was followed in 1991 by an onshore seismic refraction profile that overlapped and extended the 1989 profile east to the Cascade foothills. Results from an inversion of the travel times recorded during the 1989 and 1991 experiments were presented by Trehu and others (1992a,b).

In the following we report the primary wide-angle data resulting from the onshore-offshore seismic reflection/refraction investigation of the crustal structure of the Oregon continental margin. Wide-angle profiles obtained by a deployment of University of Texas at Austin ocean-bottom seismometers during the acquisition of the reflection line (Trehu and Nakamura, 1993) and during the 1991 onshore experiment (Trehu and others, 1993) are described in companion Open-file Reports.

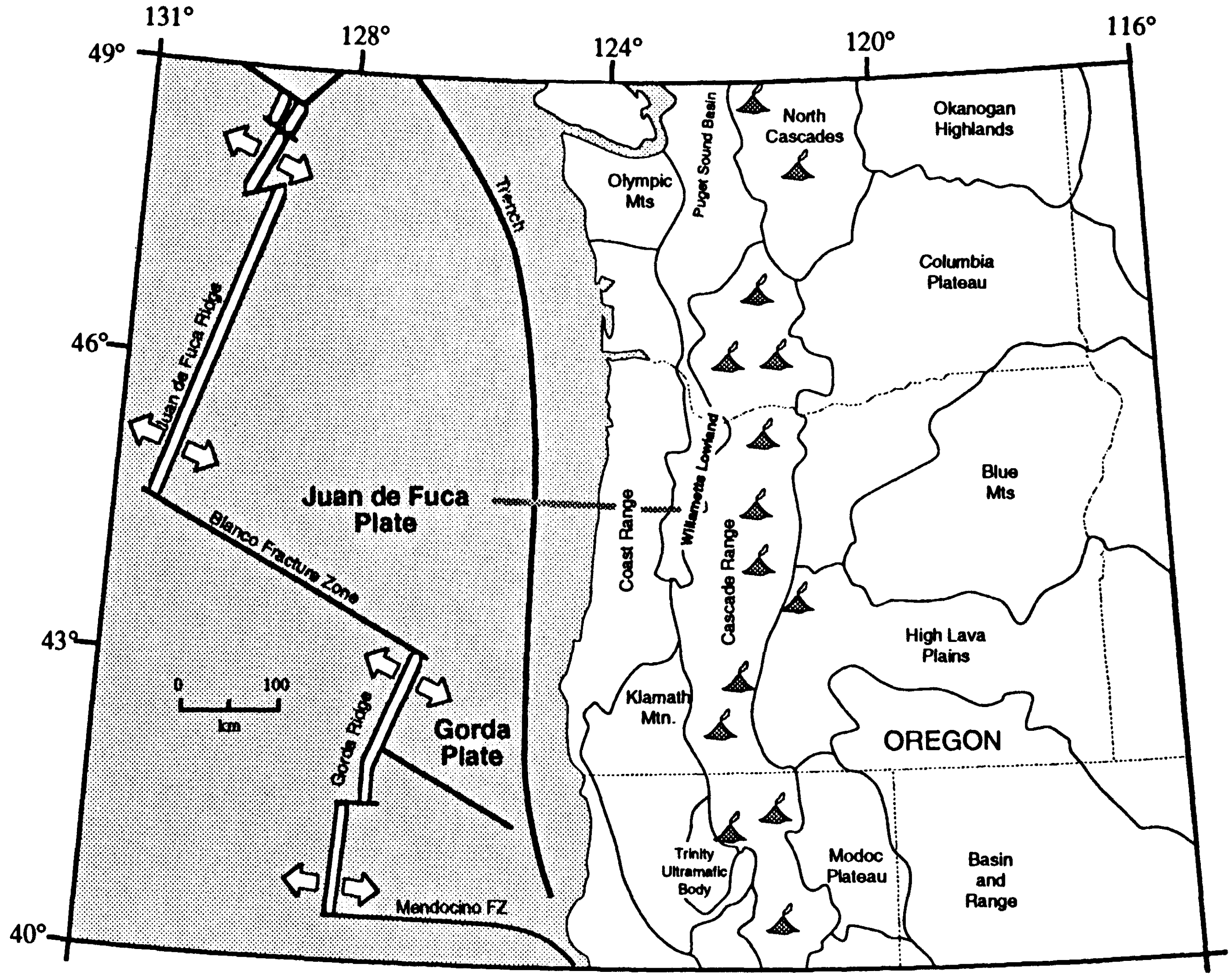

Figure 1. Location map of Pacific Northwest showing the study area and position of 1989 onshore-offshore seismic experiment in central Oregon as a heavy gray line.

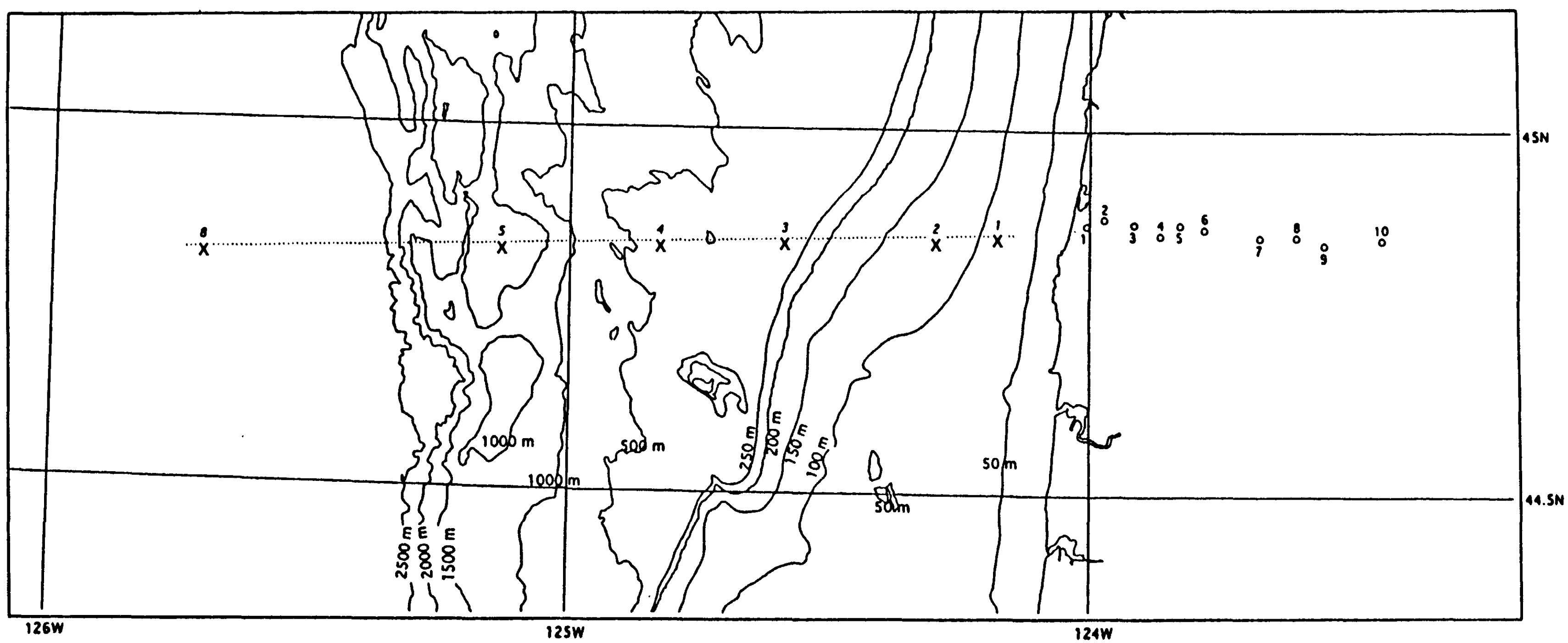

FIGURE 2A. Map of central Oregon showing the locations of the marine reflection line (dotted line), temporary seismic onshore recorders (large dots), ocean bottom seismometers (x's), and offshore bathymetry in meters.

DATA ACQUISITION AND PROCESSING

The airgun array used for marine reflection profiling also served as a sound source for onshore seismic recorders positioned across the coast ranges and Willamette Valley in Central Oregon. The tuned airgun array towed by the commercial seismic vessel totalled 128 liters (7800 cu. in.) and generated seismic signals for a temporary onshore seismic recorder array (Figure 2A). A simplified line drawing of the multichannel seismic reflection profile is presented in Figure 2B (Lin and Trehu, 1991). The goals of the wide-angle recording were to place constraints on the mid- to lower-crustal structure beneath the continental shelf and Coast Range.

TABLE 1. 5-day Recorder Locations and Elevations

Site No.	Name	Latitude (N) Deg. Min.	Longitude (W) Deg. Min.	Elevation (m)
OR-1	Schoolhouse Ck.	44 51.990	124 00.360	134
OR-2	Cannery Mtn.	44 52.560	123 58.290	305
OR-3	Bear Creek	44 52.170	123 54.810	91
OR-4*	Cedar Creek	44 51.280	123 51.750	372
OR-5	Werner Camp	44 52.130	123 49.480	396
OR-6	Black Tank Saddle	44 51.780	123 46.670	503
OR-7	Valsetz Lake	44 51.130	123 40.340	512
OR-8*	Fanno Ridge	44 51.200	123 36.030	854
OR-9	Little Luckiamute Rd.	44 50.510	123 32.760	685
OR-10	Falls City	44 50.970	123 26.090	130

*Stations OR-4 and OR-8 consisted of a transmitter broadcasting signals from a vertical seismometer only.

The wide-angle data were recorded using analog three-component, five-day seismic recorders described by Criley and Eaton (1978). These instruments have been used primarily for recording aftershock sequences and teleseismic studies of the lithosphere and record continuously using 1/2 inch analog magnetic tape. The combined frequency response of the 1 Hz geophones and internal five-day recorder electronics is heavily weighted to frequencies less than 15 Hz.

The field procedures used to deploy the five-day recorders were identical to those described for a similar experiment in north-central California (Brocher and others, 1992). For our study, the five-day recorders were deployed across the Coast Range along logging roads at about 5 km intervals and were turned on prior to the acquisition of the marine reflection lines. At two sites (OR-4 and 8), seismic signals from only a vertical-component seismometer were telemetered to an adjacent five-day recorder for recording. Timing of the data obtained from the five-day recorders was determined from the WWVB time code recorded by each receiver.

The playback and digitization of the five-day tapes, the formating of the digitized data into SEG-Y format, and the subsequent processing of the record sections is described in the Appendix. After reduction to a velocity of 8 km/s the record sections were written to tape in SEG-Y (see Appendix).

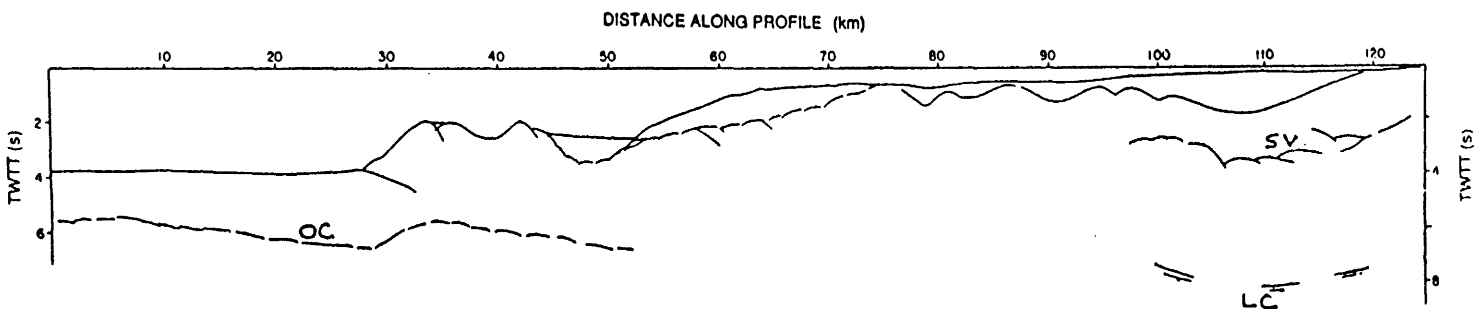

FIGURE 2B. Simplified line drawing of the unmigrated 27 to 28-fold seismic reflection line showing the position of the Neogene basins. The top of the oceanic crust (OC), top of the Siletz Volcanics (SV), and a reflection from within the lower crust (LC) are also shown. For further discussion see Lin and Trehu (1991).

DESCRIPTION OF THE DATA

Ten wide-angle seismic profiles (common receiver gathers) were recorded onshore during the acquisition of the marine reflection line. Table 2 lists the source-receiver ranges provided by each receiver. Figures 3 to 12 illustrate the ten profiles, bandpass filtered between 7 and 11 Hz with 4 Hz wide tapers on each side, reduced using a velocity of 8 km/s, and corrected for geometrical spreading by multiplying trace amplitudes by a factor of $Range^{0.7}$. We illustrate here only records from the vertical seismometer component. As a rule, data quality was highest in the center of the array, between Stations OR-4 and OR-7 (Figures 2A and 7-9), located in remote sites on or near bedrock exposures. The data obtained at the largest ranges of the records obtained at Stations OR-1 through OR-3 are fairly noisy, perhaps due to the proximity of the coast and an active rock quarry at the site of Station OR-2. Noise levels on the largest ranges of the records obtained at Stations OR-8 through OR-10 resemble those of OR-1 through OR-3, although the causes must differ. Cultural noise may have been an important factor in the data quality: noise levels dramatically increase for the largest ranges of the profiles which were acquired after 6:30 AM local time on a weekday.

TABLE 2. Wide-angle Seismic Profiles

Site No.	Recorded Ranges (km)
OR-1	10.7-137.8
OR-2	13.5-140.5
OR-3	18.0-145.1
OR-4	21.9-149.1
OR-5	25.0-152.2
OR-6	28.6-155.8
OR-7	37.0-164.0
OR-8	42.6-169.8
OR-9	47.0-174.1
OR-10	55.7-182.9

The wide-angle records show several characteristic arrivals (figs. 3-12). First arrivals observed on all the records having apparent velocities of 3.5 to 6 km/s, and in some cases to source-receiver ranges in excess of 100 km, are interpreted as refractions from the upper and midcrust (Pg), see Figure 8. The apparent velocities of these arrivals are strongly affected by shallow structure offshore. Arrivals having an apparent velocity close to 8 km/s observed at ranges in excess of 120 km on records from Stations OR-5 through OR-7 are interpreted as refractions from the upper mantle, or Pn (fig. 8). Large-amplitude secondary arrivals recorded at Stations OR-5 through OR-10 are interpreted as reflections from the top of the upper mantle, the Moho, designated as PmP (fig. 8). A possible set of weaker and shallower wide-angle reflections from the mid-crust are observed on records obtained at Stations OR-1 through OR-5 (e.g., fig. 7). Secondary arrivals that propagated with a velocity of 1.5 km/s, the acoustic velocity of seawater, are observed at Stations OR-1 through OR-4, which were deployed nearest the coast.

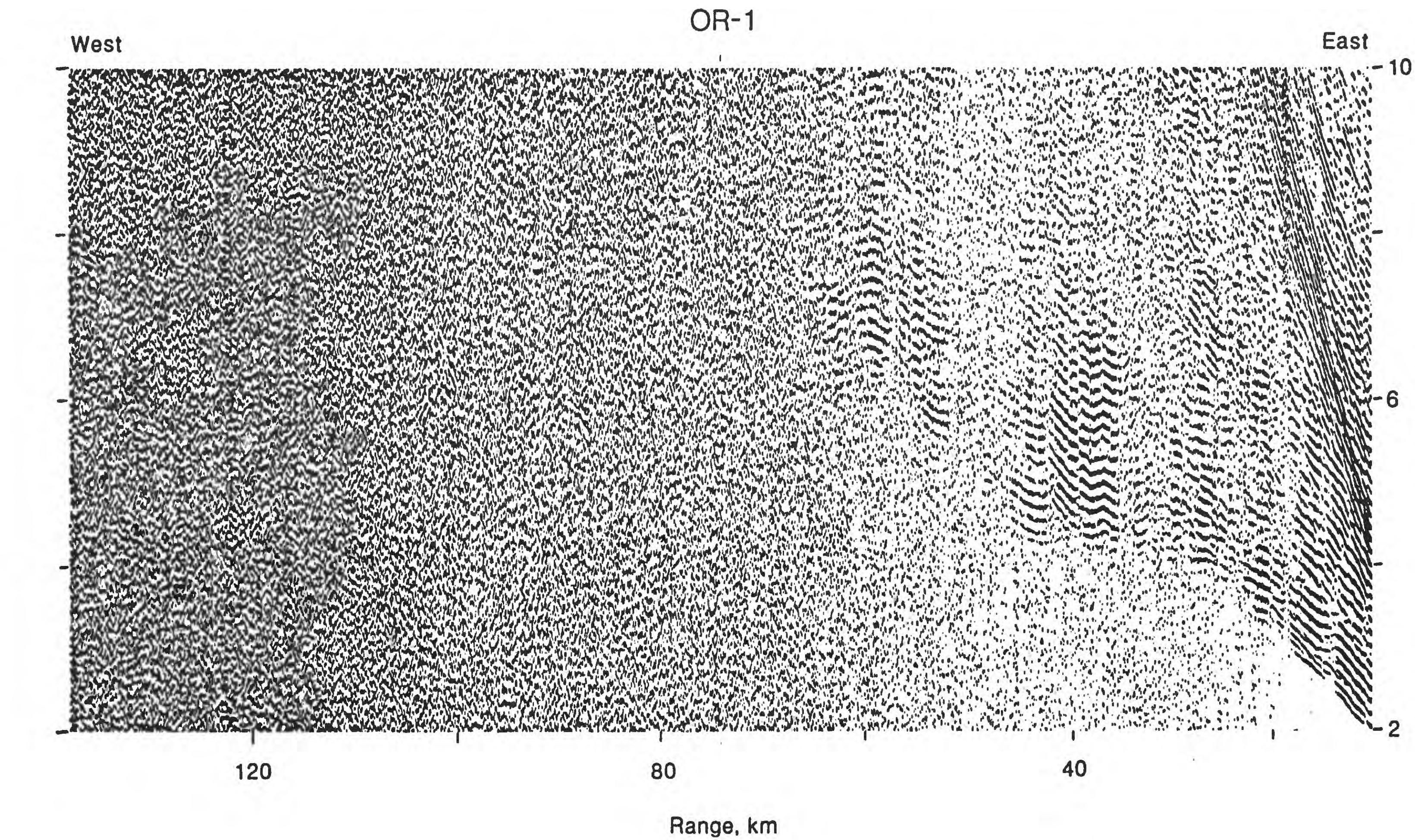

FIGURE 3. Receiver gather OR-1. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

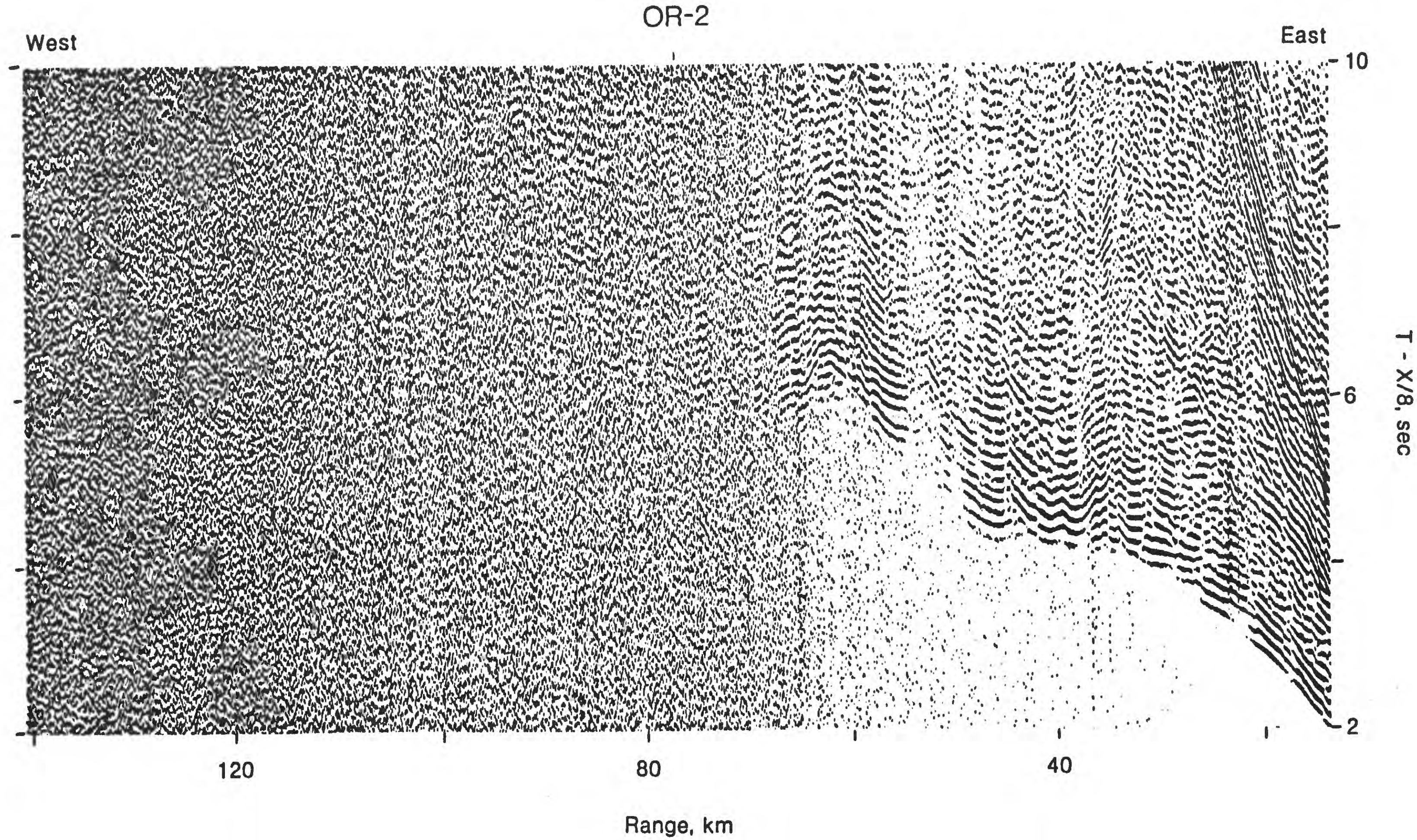

FIGURE 4. Receiver gather OR-2. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

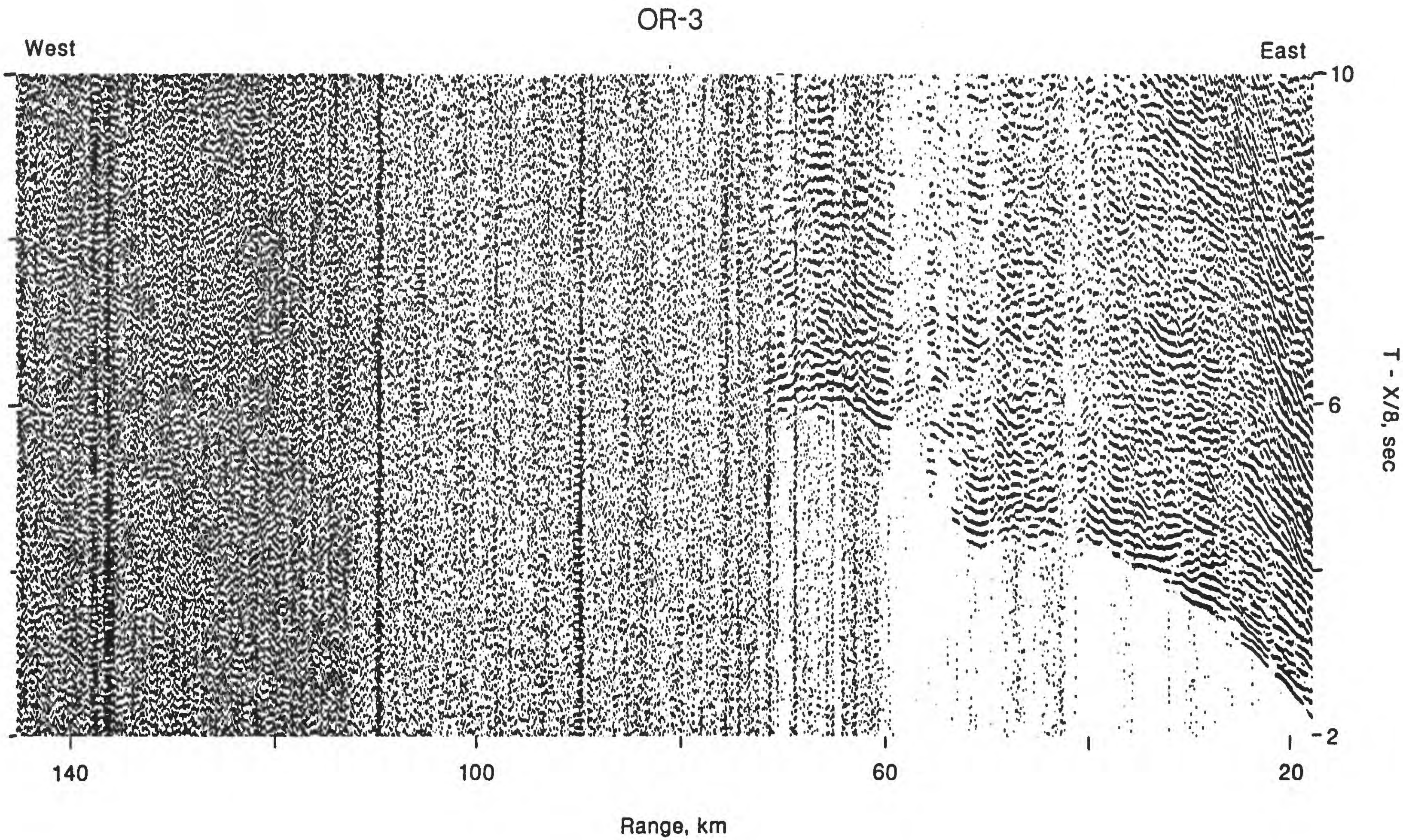

FIGURE 5. Receiver gather OR-3. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

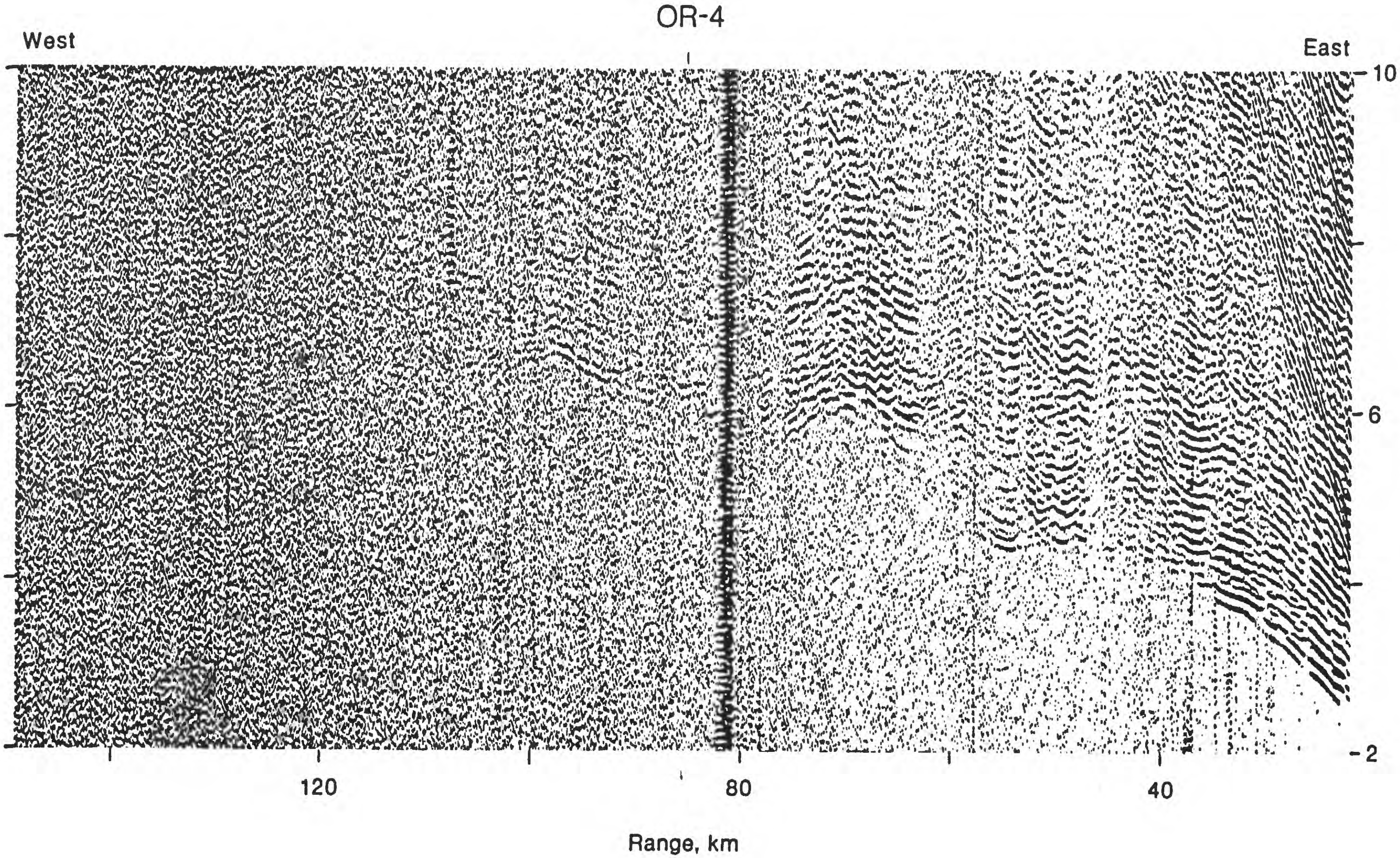

FIGURE 6. Receiver gather OR-4. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

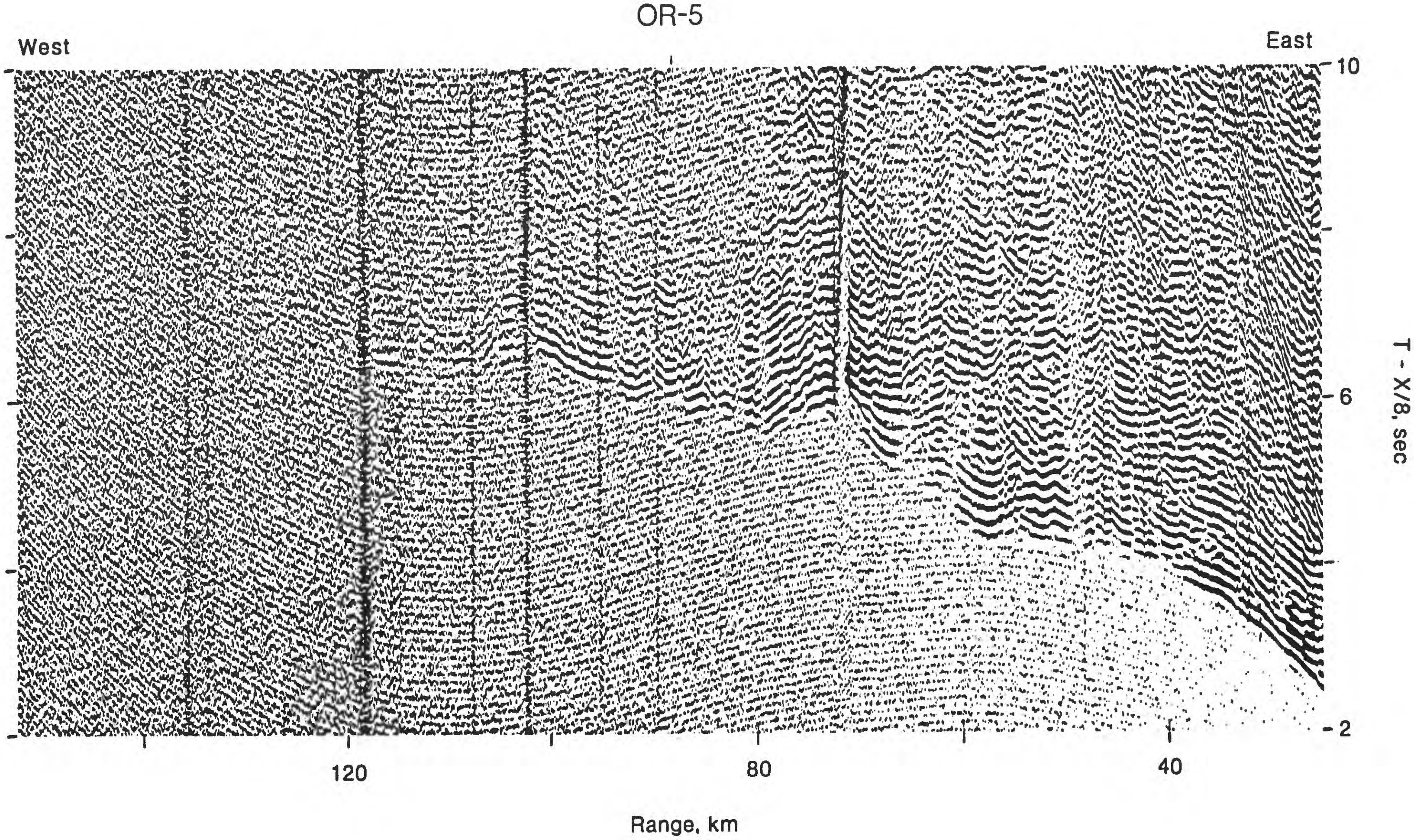

FIGURE 7. Receiver gather OR-5. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

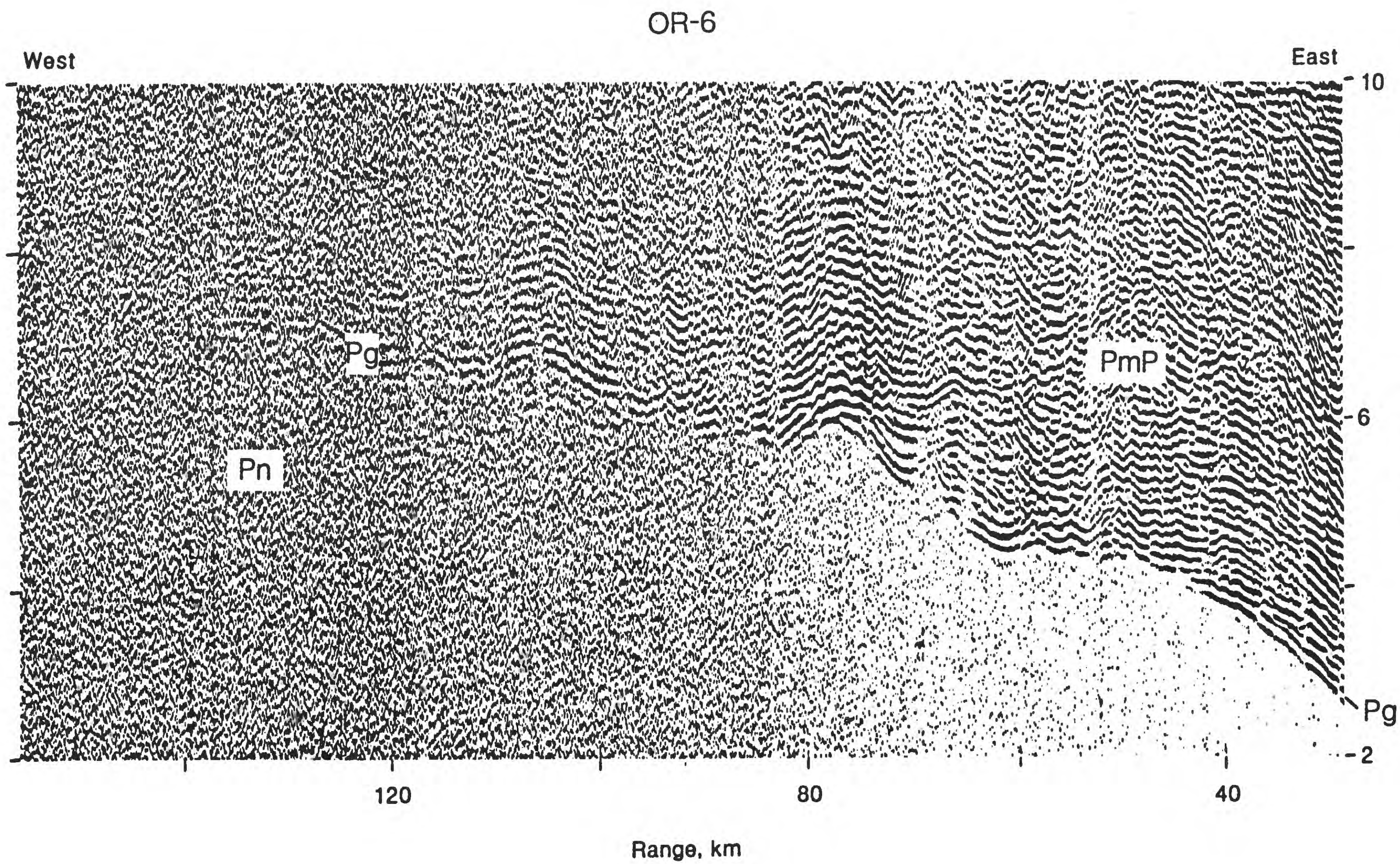

FIGURE 8. Receiver gather OR-6. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

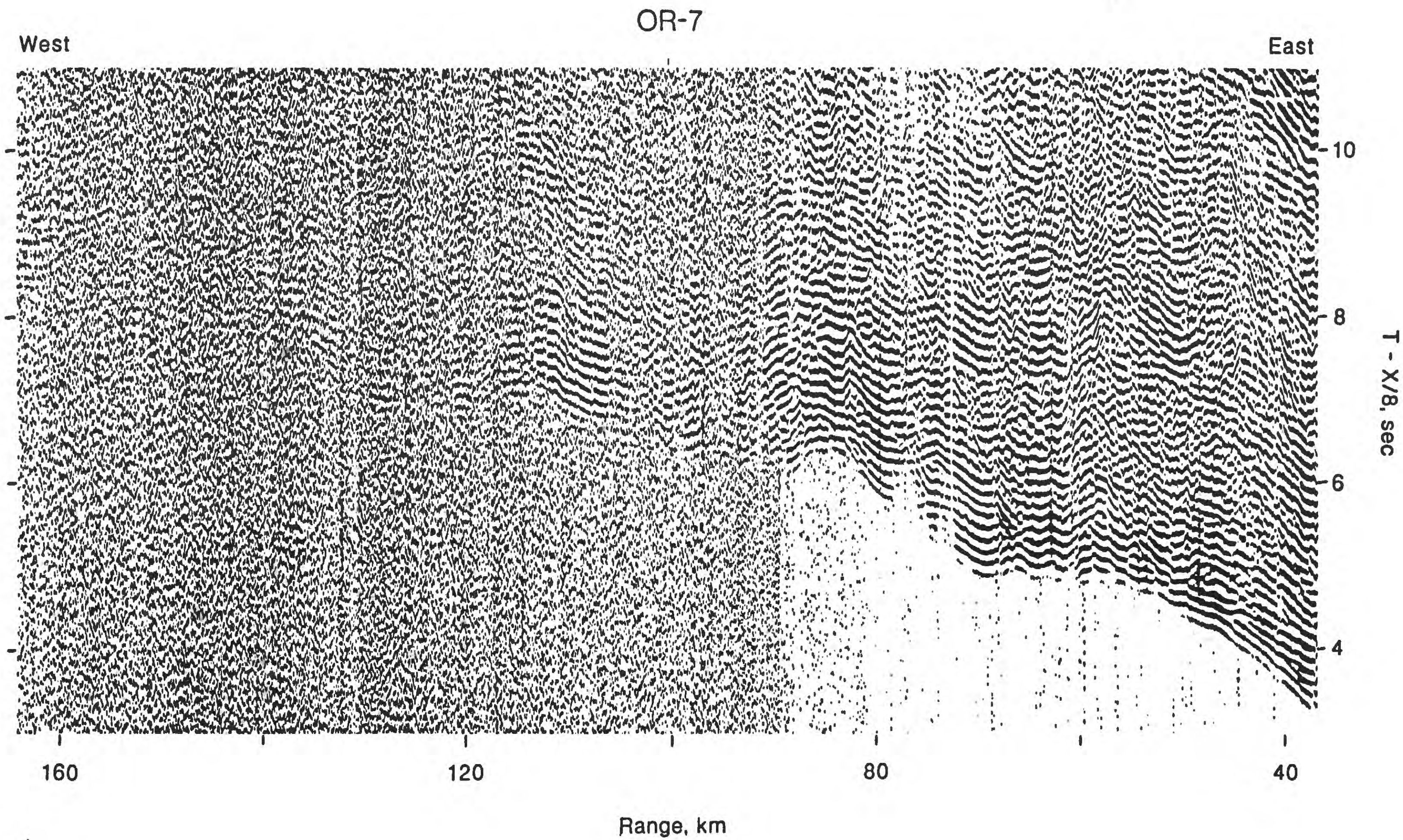

FIGURE 9. Receiver gather OR-7. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

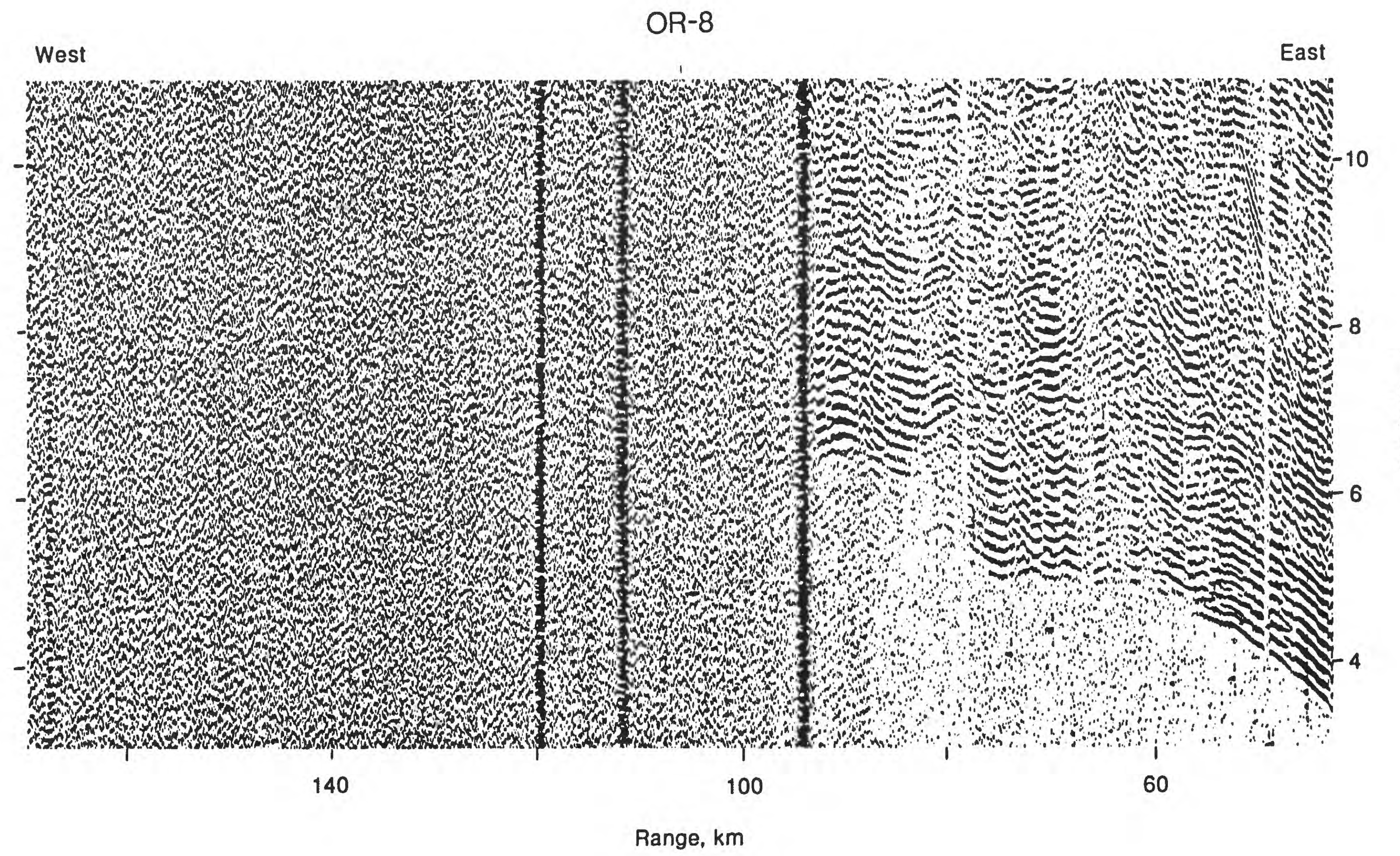

FIGURE 10. Receiver gather OR-8. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

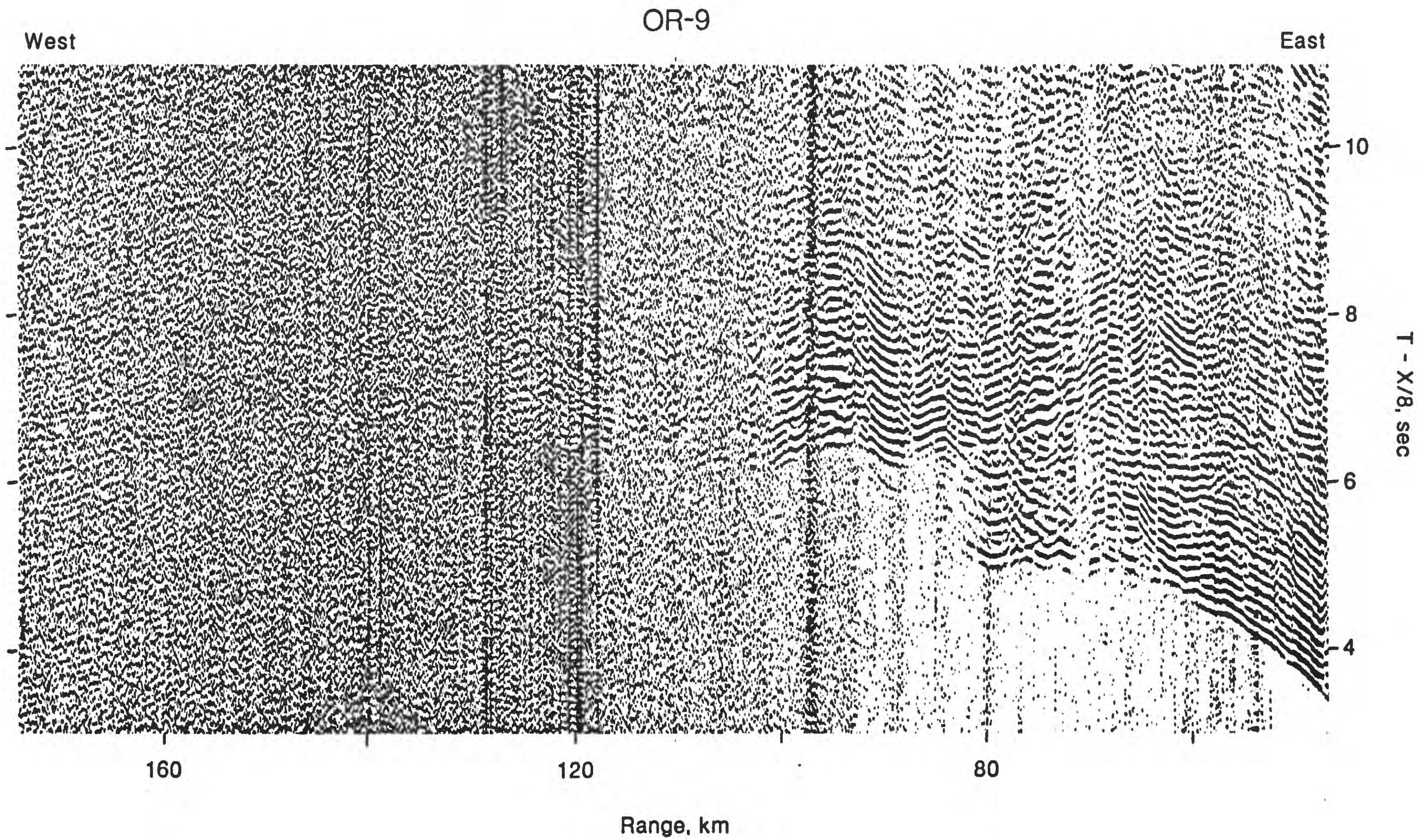

FIGURE 11. Receiver gather OR-9. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

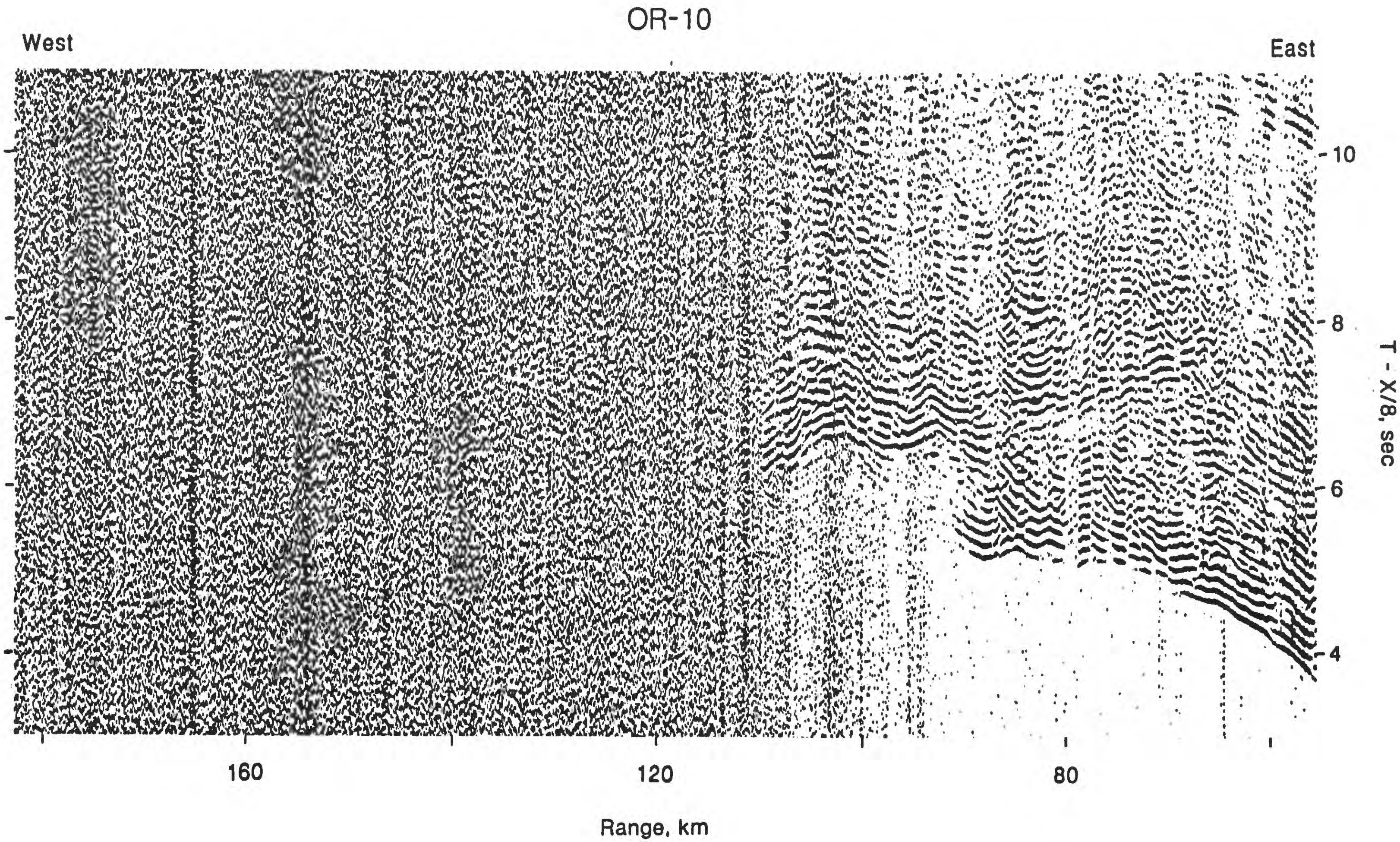

FIGURE 12. Receiver gather recorded at Station OR-10. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

APPENDIX

The following sections summarize the procedures used during the acquisition, digitizing, and processing of the wide-angle five-day recorder data. We focus on those procedures used to determine shot times and source-receiver offsets.

Data Playback and Digitizing

We digitized the five-day recorder tapes at 100 samples/sec using the computer program xdetectv implemented on a Everex 386/25 MHz computer 4 Mbytes of internal memory and 300 Mbytes of hard disk memory. Xdetectv is a version of xdetect, described by Tottingham and Lee (1989). The analog tape drive was manually positioned to the desired time on the tape for the start of digitizing with the aid of an IRIG-C clock code reader. Up to 260-minute-long blocks of analog data were digitized in a single pass requiring about 13 minutes of playback time. The digitized data were temporarily stored in Seismic Unified Data System (SUDS) format on the Everex computer (Ward and Williams, 1992), then transfered to a 2 GByte disk drive on a VAX 11/785, where the data were demultiplexed into two different time code channels and 6 seismometer channels (three low gain channels and three high gain channels).

WWVB time code broadcast from Denver, Colorado, in addition to an internal clock code in IRIG-C format, were recorded continuously at each station. WWVB time was used to determine the time on the digitized files because it is accurate to a few milliseconds.

We converted the digitized WWVB clock code to a binary signal and filtered this binary code to remove short (1 to 3 sample long) noise pulses in the time code. Our program then read the time of the first minute mark and counted second marks (where the binary code changes from zero to one) to determine time within the digitized file to within 10 milliseconds. The digitized file was then broken into individual traces for each airgun shot based on the travel time for that receiver, using a reduction velocity of 8 km/s. The reduced travel time was calculated from a list of shot times and locations, the receiver location, and the reduction velocity (8 km/s). 23 seconds of data were saved for each trace. The individual traces were then written in SEG-Y format to a 9-track digital tape.

Most of the software used for this processing sequence was described by Brocher and Moses (1990), now merged into a single program called SUDTOSEGYTEST.FOR on a VAX 11/785 computer. The SUDS files are read from and SEG-Y files are written to the same disk. The record sections were plotted using DISCO Processing Software running on a VAX 11/785 computer.

Recorder Locations and Elevations

The locations and elevations of the five-day recorders summarized in Table 1 were obtained using 1:24,000 scale USGS topographic maps. These receiver locations and elevations are accurate to within a few tens of meters.

Recorder Times of Operations

The five-day recorders and transmitter stations were deployed over a period of several days and were then turned on just prior to the acquisition of the seismic reflection line. Table 3 therefore provides a listing of the times for which each five-day instrument recorded data.

TABLE 3. 5-day Recorder Times of Operation

Site No.	Name	Time On Day Hr. Min.	Time Off Day Hr.Min.
OR-1	Schoolhouse Cr.	259 1945	263 0045
OR-2	Cannery Mtn.	259 2151	262 2351
OR-3	Bear Creek	260 0025	262 2300
OR-4*	Cedar Creek	260 0025	262 2300
OR-5	Werner Camp	260 0208	262 2151
OR-6	BlackTank Saddle	260 0331	262 2035
OR-7	Valsetz Lake	260 2214	262 1921
OR-8*	Fanno Ridge	260 2214	262 1921
OR-9	Little Luckiamute R.	260 1835	262 1737
OR-10	Falls City	260 1713	262 1634

*Transmitter Station consisting of vertical component seismometer only.

Shot Instant Timing

Shot instant times of the airgun array were obtained using a PC-based recorder located on the commercial seismic vessel. A Kinemetrics True Time satellite clock receiver (model 468), set for the local time delay to the GOES satellite, and stabilized using a high-precision Cesium oscillator, provided the absolute time base recorded on the commercial vessel. The GOES clock receiver produces time accurate to a millisecond.

Navigation

Navigation onboard the commercial seismic vessel was accomplished using Starfix. The locations of the airgun shots are provided in a companion Open-file Report presenting the ocean-bottom seismometer data obtained during this experiment (Trehu and Nakamura, 1993).

Factors Influencing Data Quality

Data quality was highest for stations near the center of the receiver array (OR-5 through OR-7), where the seismometers were deployed in remote sites on or near outcrops of Siletz River basalts (Table 4). Data quality was also reasonably high for the record from Station OR-9, located on an Oligocene mafic intrusion. Data quality generally decreased as the distance of the station from the coast decreased, suggesting that surf (microseism) noise may have lowered the data quality for the sites near the coast (OR-1 to OR-3).

Cultural noise probably degraded data quality somewhat, as the farthest half of the profile was recorded after 6:30 AM local time on a weekday. An active quarry at the site of OR-2 probably degraded the data quality recorded for the fartherest ranges of nearby stations. Station OR-10 was deployed in shale outcrop close to Falls City, and either the propagation through sedimentary rocks and/or higher levels of cultural noise may have degraded the data quality from this station.

TABLE 4. Types of Seismometer Plants

Site No.	Name	Seismometer Plant Description
OR-1	Schoolhouse Cr.	Partially consolidated soil
OR-2	Cannery Mtn.	Weathered basaltic bedrock
OR-3	Bear Creek	Weathered basaltic bedrock
OR-4	Cedar Creek	Soil derived from basalt bedrock
OR-5	Werner Camp	Weathered pillow lava bedrock
OR-6	Black Tank Saddle	Weathered basaltic bedrock
OR-7	Valsetz Lake	Apparent landslide debris composed of weathered volcanic rocks
OR-8	Fanno Ridge	Basaltic bedrock
OR-9	Little Luckiamute R.	Mafic intrusion within basaltic bedrock
OR-10	Falls City	Weathered shale bedrock

SEG-Y Tape Format

The wide-angle seismic reflection/refraction profiles were written to 9-track tapes in SEG-Y format. Three traces were written for each shot and receiver pair; trace 1 contains the high gain N/S horizontal seismometer component. Trace 2 contains the high-gain vertical seismometer component and Trace 3 contains the high-gain E/W horizontal seismometer component. Each trace contains a 240-byte trace header of 2- and 4-byte integers describing the specific trace and 2301 2-byte integer data samples. The location of each value in the SEG-Y trace header as described by Barry and others (1975) was slightly modified as described by Luetgert and others (1990). All trace integer values were byte swapped from DEC to SEGY-IBM format and are written in SEGY-IBM16INT format. An End of Tape (EOT) mark was written at the end of each 12-inch, 6250 BPI, SEG-Y tape.

ACKNOWLEDGEMENTS

Boise Cascade kindly gave us permission to locate 5-day recorders on their property, and Ranger Dave Marlow gave us permission to locate 5-day recorders in the Siuslaw National Forest. Parke Snavely gave us a geologic overview of the deployment region and guided us to abandoned quarries that provided excellent sites for the five-day recorders. John Coakley of the USGS-Menlo Park helped to deploy the 5-day recorders. Yosio Nakamura provided and installed the PC-based system used to record airgun shot times, and Guy Cochrane was the observer on the shooting ship during data acquisition. Tim Holt of Oregon State University initially digitized and plotted the data. H.M. Iyer and Bill Lutter critically reviewed an earlier draft of this report.

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