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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

ONSHORE-OFFSHORE WIDE-ANGLE SEISMIC RECORDINGS OF THE 1989 ALASKAN EDGE PROFILE: FIVE-DAY RECORDER DATA

By

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ABSTRACT

The U.S. Geological Survey (USGS) deployed seismic recorders at three sites during marine seismic reflection profiling of the southern Alaska margin conducted by EDGE, a consortium of academic investigators. The EDGE marine reflection profiles were acquired in July 1989 using a tuned 128 liter (7800 cu. in.) airgun array towed from a commercial seismic ship. Three three-component land stations deployed in southern Alaska continuously recorded the airgun signals produced by the reflection profiling at large offsets. This report describes the experiment, provides the locations and times of operation of the recorders, presents the data reduction scheme followed, and illustrates the wide-angle seismic data recorded by the USGS.

DATA ACQUISITION AND PROCESSING

In July, 1989, EDGE, a consortium of academic investigators, the University of Alaska, the University of Texas at Austin, and the U.S. Geological Survey (USGS) collaborated to collect marine seismic reflection profiles and wide-angle seismic recordings in southern Alaska (fig. 1A) (Moore and others, 1991). The EDGE profiles attempted to image the deep crustal structure from the Pacific plate across the Aleutian trench and the forearc south of the Kenai Peninsula to the arc, represented by Augustine Volcano (fig. 1B). In the following we report the primary wide-angle data recorded by the USGS as a part of this onshore-offshore seismic reflection and refraction investigation of the crustal structure of the Alaskan continental margin.

The airgun array used to acquire the EDGE reflection profiles also served as a sound source for onshore seismic recorders positioned on the Kenai Peninsula in southern Alaska. The 128 liter (7800 cu. in.) tuned airgun array generated seismic signals for a seismic recorder array consisting of about 15 permanent University of Alaska Geophysical Institute (UAIG) stations, two ocean-bottom seismometers (OBSs) deployed by Dale S. Sawyer of the University of Texas at Austin, and four temporary five-day recorders deployed by the USGS (fig. 1C). This report only describes the wide-angle seismic reflection and refraction data obtained from the USGS five-day recorders.

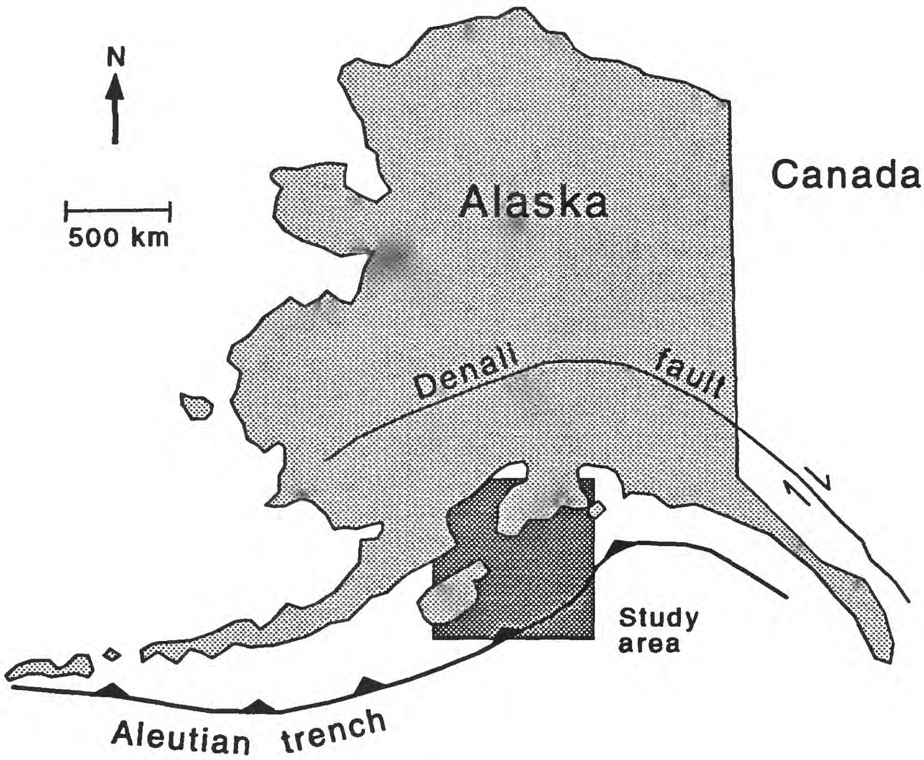

FIGURE 1. (A) Map of Alaska showing the study area (darkened region), Aleutian trench, and the strike-slip Denali fault.

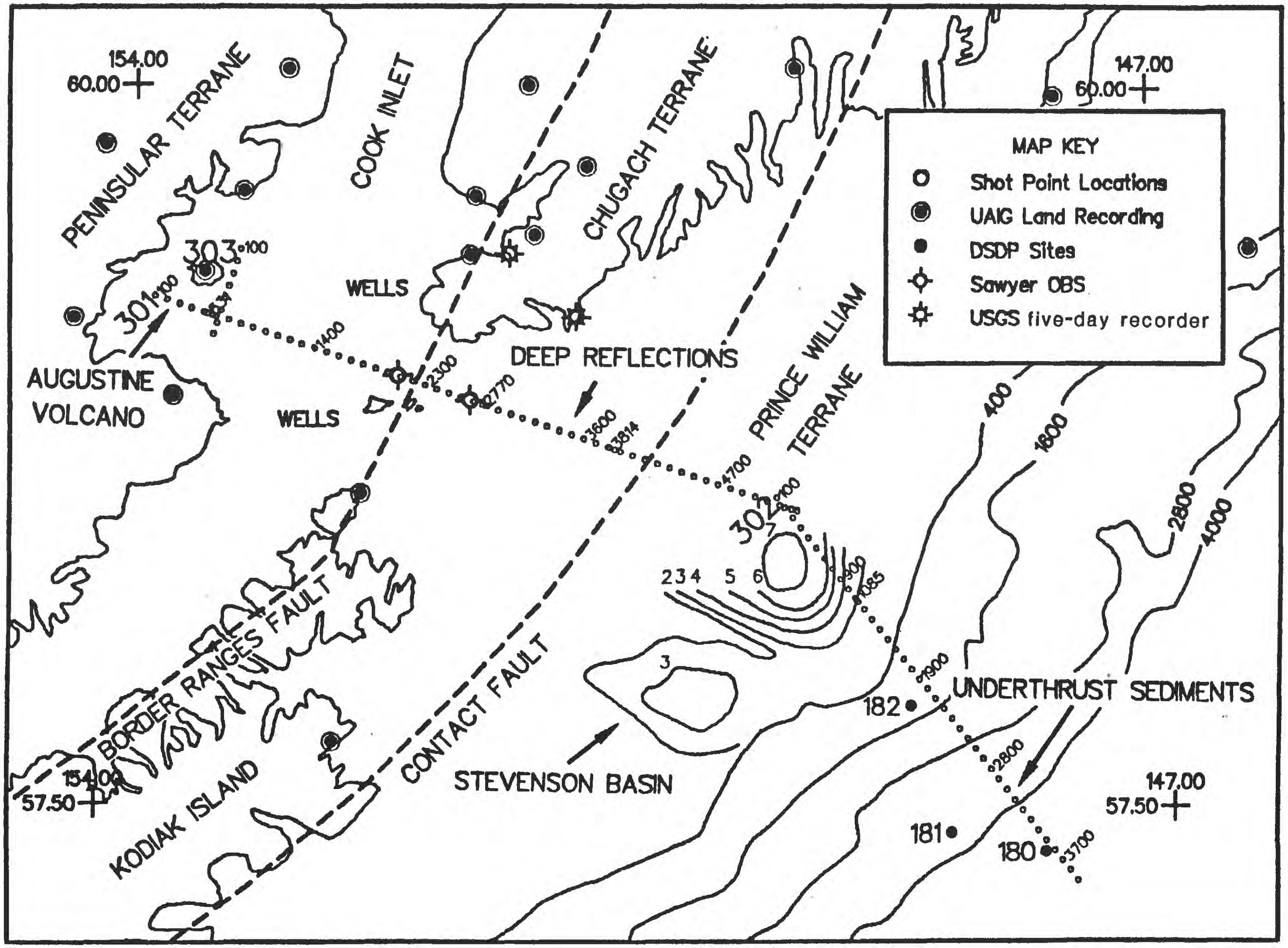

FIGURE 1. (B) Map of southern Alaska showing the locations of marine reflection lines 301-303, temporary and permanent seismic recording stations (various symbols), industry wells in Cook Inlet, DSDP holes on the continental slope, and selected faults and geographic features. The thickness of post-middle Miocene sediments in kilometers is contoured for Stevenson Basin, seaward of the Contact fault.

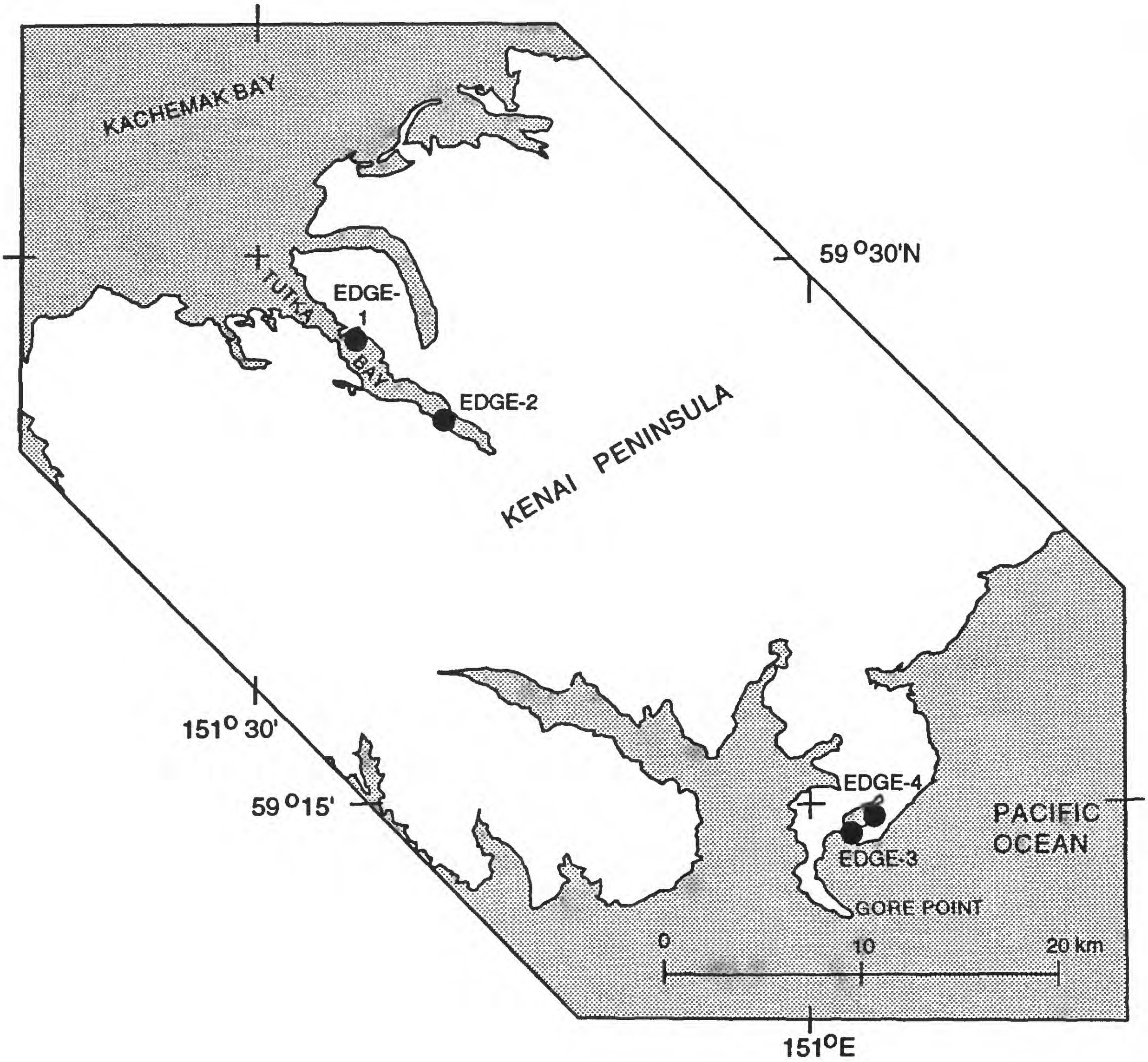

FIGURE 1. (C) Map of Kenai peninsula showing the locations of the four 5-day recorders deployed by the UGSG (filled circles).

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 followed were similar to those described for a 1988 onshore-offshore experiment in southern Alaska further to the northeast (Brocher and Moses, 1990). For our study, the five-day recorders were deployed on the Kenai Peninsula by floatplane and by helicopter and turned on prior to the acquisition of the marine reflection lines. Two recorders were deployed within 6 kilometers of each other at each of two sites, Tutka Bay and Gore Lake, to insure data recovery (Table 1). Unfortunately one recorder at Gore Lake did not function (EDGE-4) and the other (EDGE-3) could not be revisited midway through the experiment to change tape and battery. Station EDGE-3 at Gore Lake thus recorded only about 1/3 of the airgun signals generated by the multichannel vessel.

TABLE 1. 5-day Recorder Locations and Elevations

Site No.	Name	Latitude (N) Deg. Min.	Longitude (W) Deg. Min.	Elevation (m)
EDGE-1	Tutka Bay	59 27.6739	151 24.4322	0
EDGE-2	Tutka Bay	59 25.4783	151 19.7881	0
EDGE-3	Gore Lake	59 14.1739	150 58.0085	0
EDGE-4*	Gore Lake	59 14.630	150 56.610	0

*This station malfunctioned and did not record any data.

The internal clock of the five-day recorders was calibrated by WWVB radio signals recorded by each receiver. Comparison of the internal clock and WWVB time code signals allowed us to accurately determine and remove the drift of the internal clock. Drift rates of the internal clock for the receivers determined from this comparison ranged from 23.5679 milliseconds/day at station EDGE-1 to 184.3003 milliseconds/day at station EDGE-2. The drift rate of the internal clock at station EDGE-3 was measured as 137.5796 milliseconds/day.

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. The Appendix also briefly describes the SEG-Y format in which the tapes were written. Record sections reduced using a velocity of 8 km/s were written to tape.

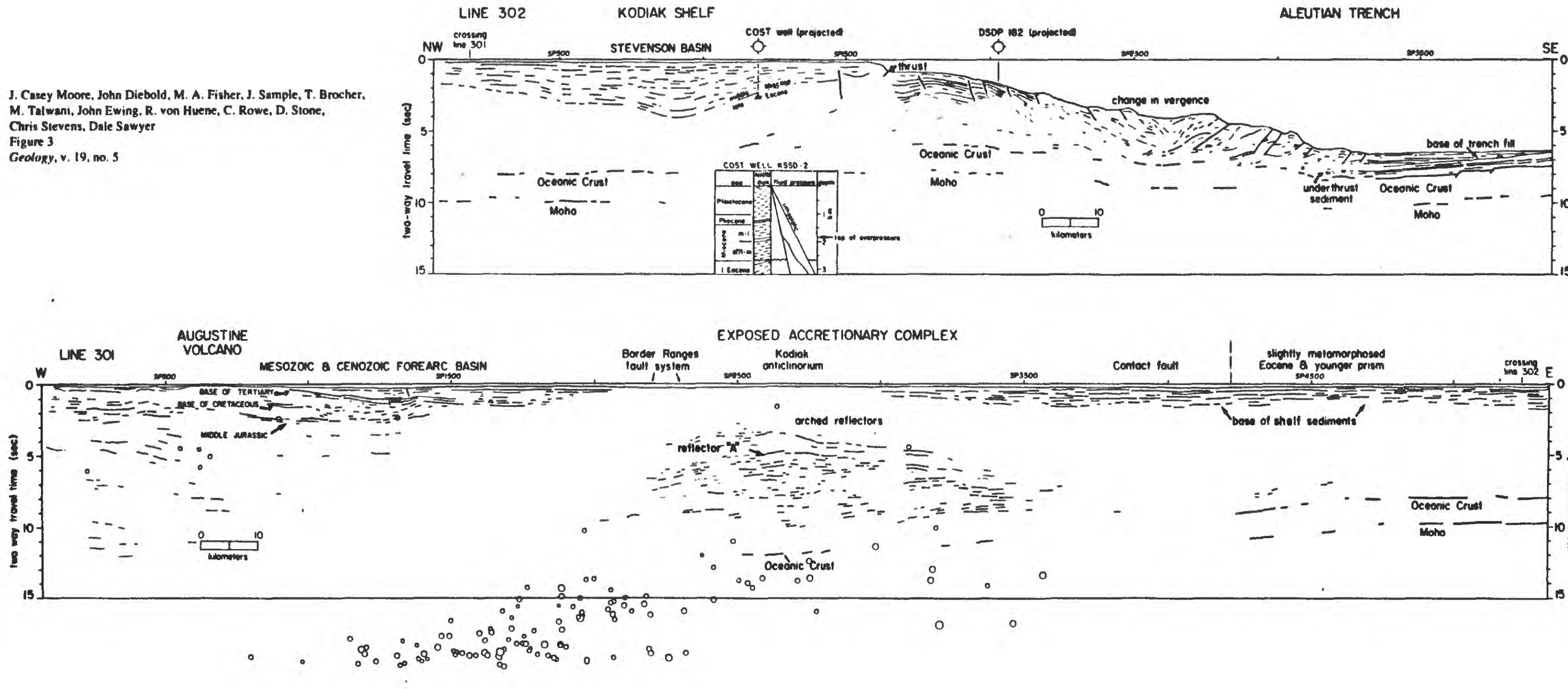

FIGURE 2. Line drawing of the 40-fold seismic reflection lines 301 and 302 showing the major structural elements revealed by these profiles (from Moore and others, 1991). Earthquake hypocenters and COST and DSDP well control has been projected onto the sections.

DESCRIPTION OF THE DATA

Eight wide-angle seismic profiles (common receiver gathers) were recorded onshore during the acquisition of EDGE reflection lines 301 to 303. Table 2 lists the source-receiver ranges provided by each receiver, and indicates the closest approach of the multichannel vessel to the receiver (middle number). Note that there is about 10 km overlap between lines 301 and 302 (Figure 1B). Both sets of recorders were deployed in a fan geometry with respect to Line 303. Figures 3 to 8 illustrate the records obtained at the three stations, reduced using a velocity of 8 km/s and corrected for geometrical spreading by multiplying trace amplitudes by a factor of Range$^{0.7}$. Only records from the vertical seismometer component are presented in this report.

TABLE 2. Wide-angle Seismic Profiles

		Recorded Ranges (km)		
Site No.	Location	Line 301	Line 302	Line 303
EDGE-1	Tutka Bay	137.6-58.8-149.6	140.4-332.7	103.6-118.3
EDGE-2	Tutka Bay	141.5-56.2-143.7	134.5-326.7	108.1-121.5
EDGE-3	Gore Lake	161.6-47.2	Not recorded	131.2-139.0

The wide-angle records show at least three sets of arrivals (figs. 3-8). The first group of arrivals are refractions from the upper crust (Pg) which are observed to source-receiver ranges in excess of 100 km. The Pg arrivals have apparent velocities of about 6 km/s. A second set of arrivals is represented by reflections from the top of the upper mantle, the Moho, and is designated as PmP. These arrivals are interpreted as PmP because they are normally the strongest secondary arrivals observed on the records, and because they frequently display the largest amplitudes of all recorded arrivals. Refractions from the upper mantle, Pn arrivals, are also observed to the farthest ranges of 330 km.

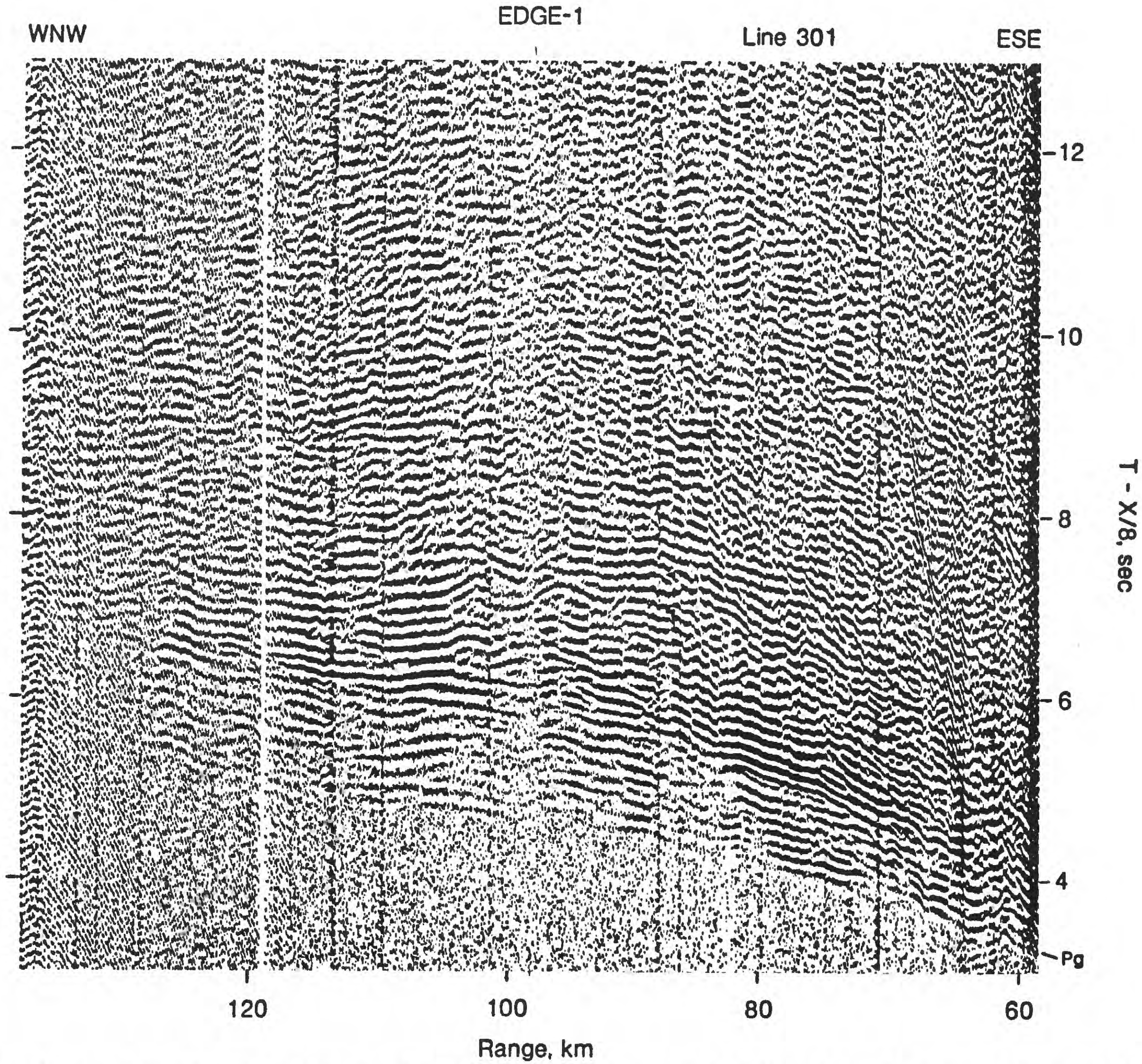

FIGURE 3. Receiver gather EDGE-1 at Tutka Bay for northwestern half of line 301. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

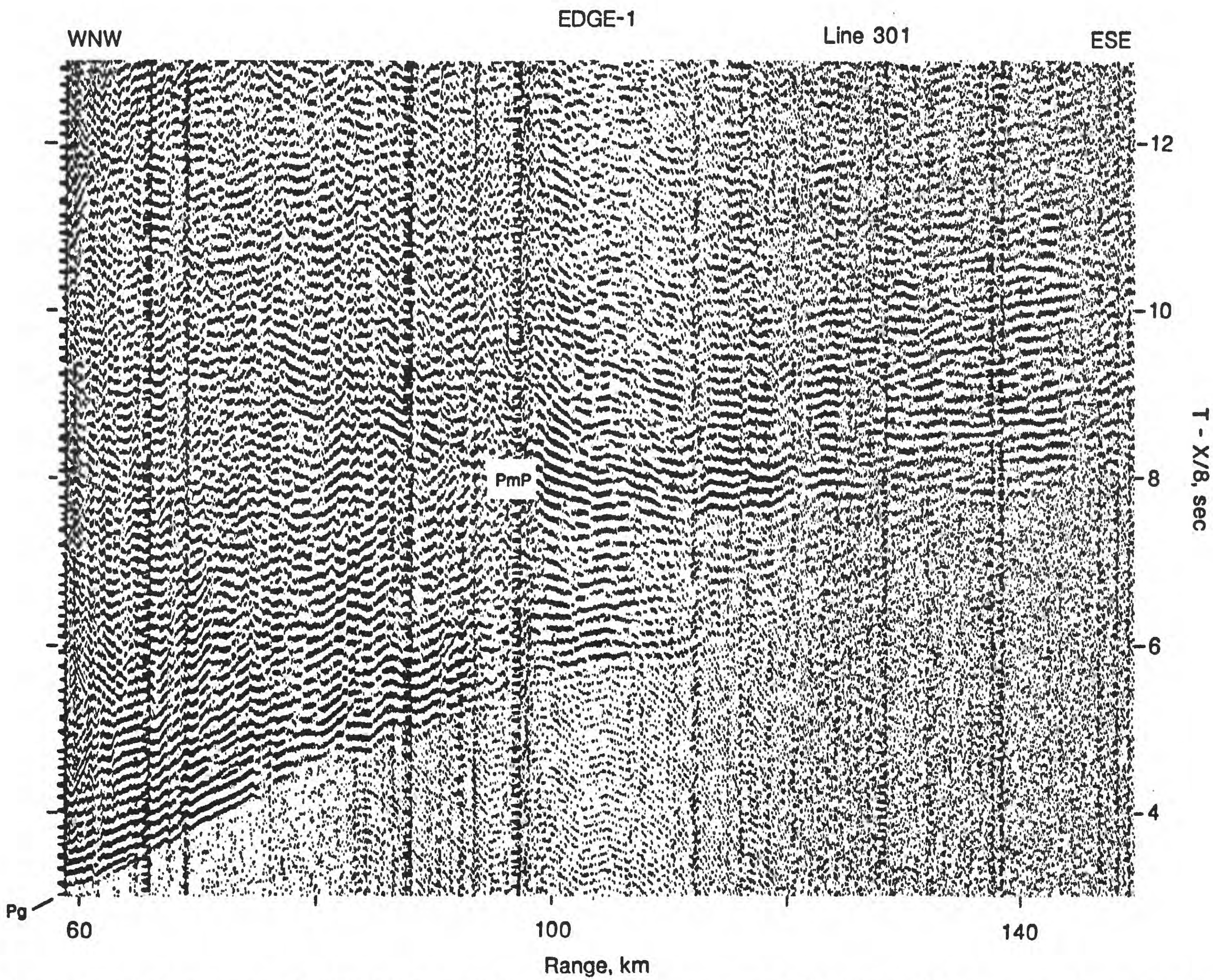

FIGURE 3 continued. Receiver gather EDGE-1 at Tutka Bay for southeastern half of line 301. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

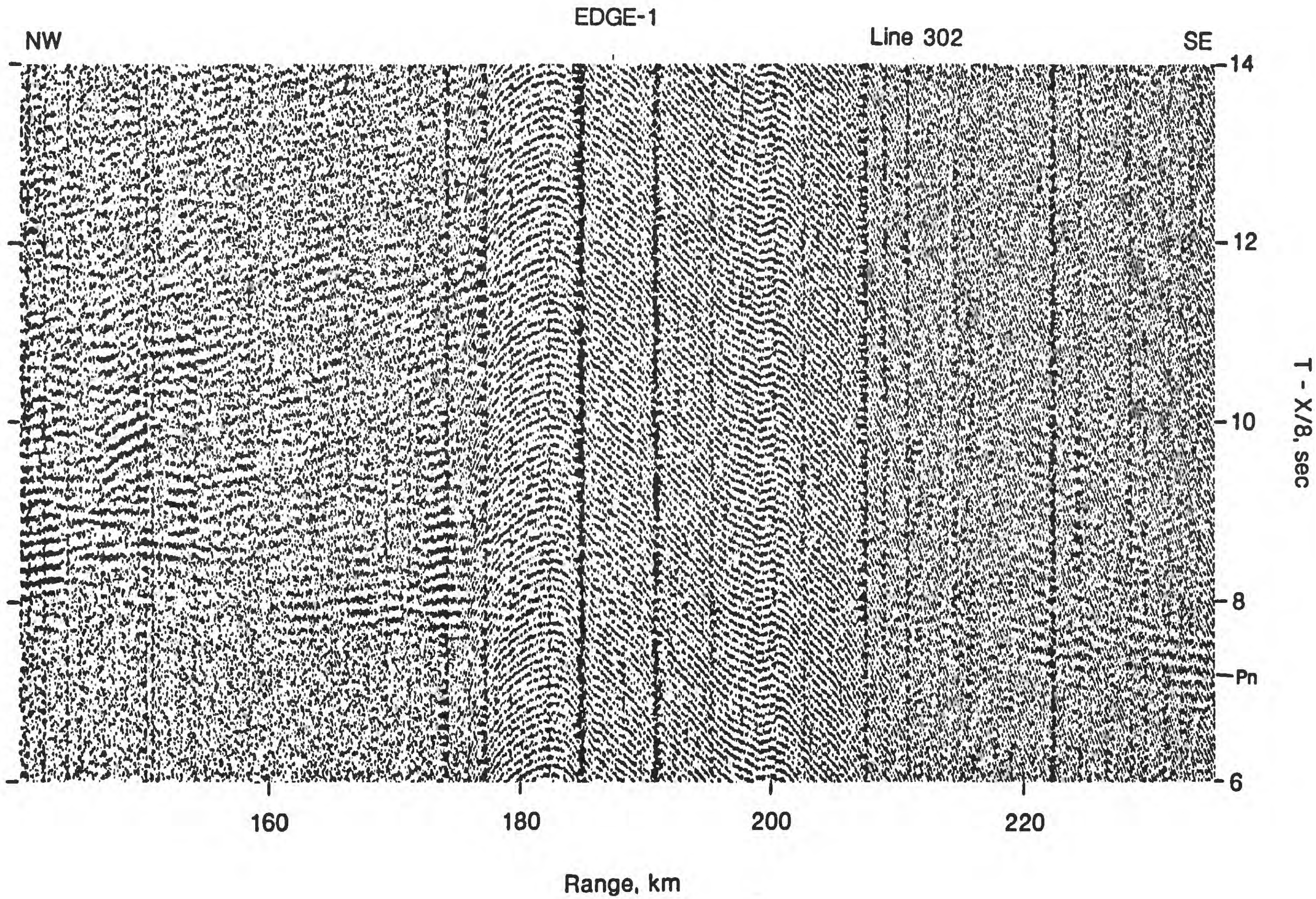

FIGURE 3 continued. Receiver gather EDGE-1 at Tutka Bay for northwestern half of line 302. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

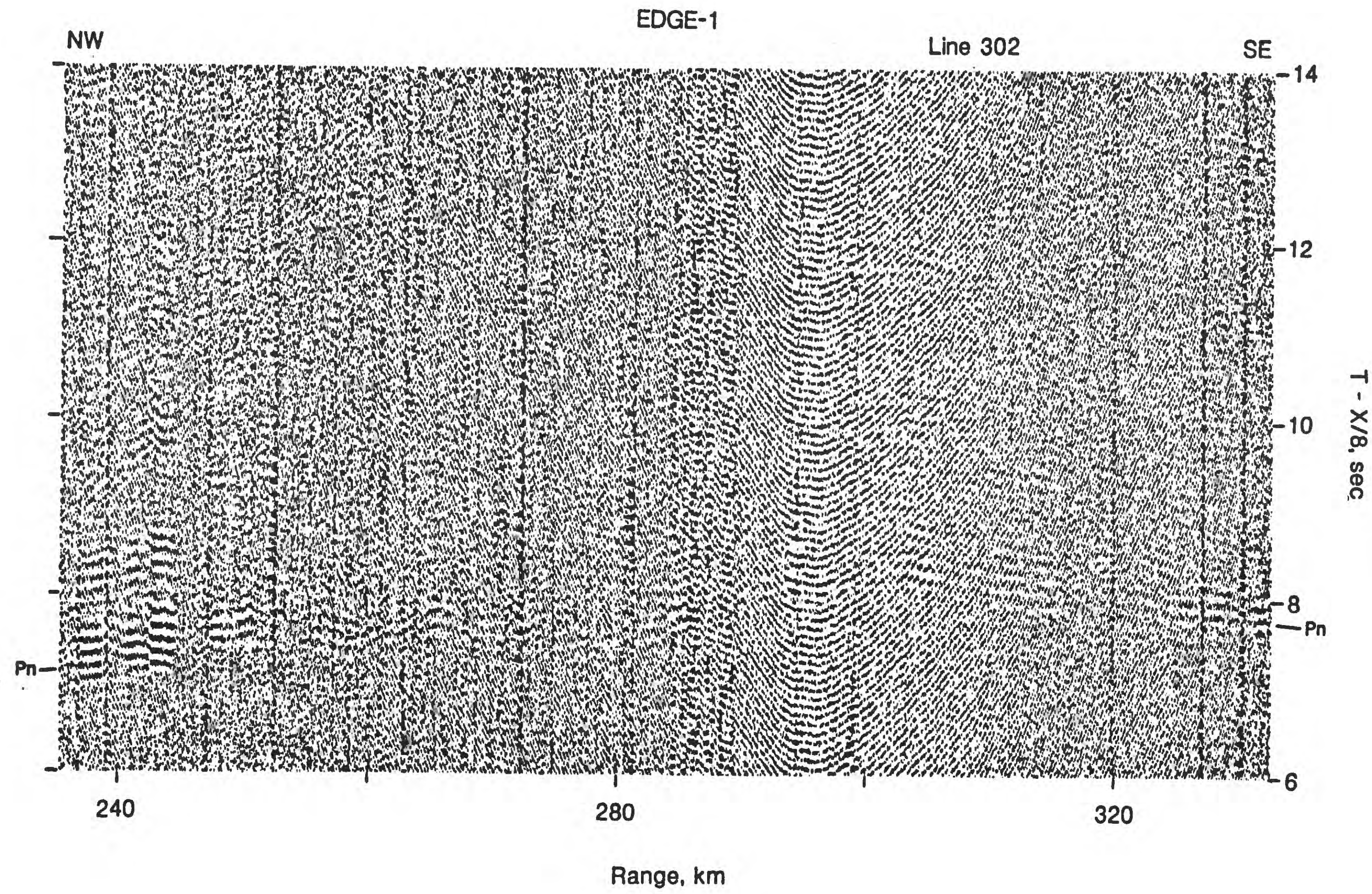

FIGURE 3 continued. Receiver gather EDGE-1 at Tutka Bay for southeastern half of line 302. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

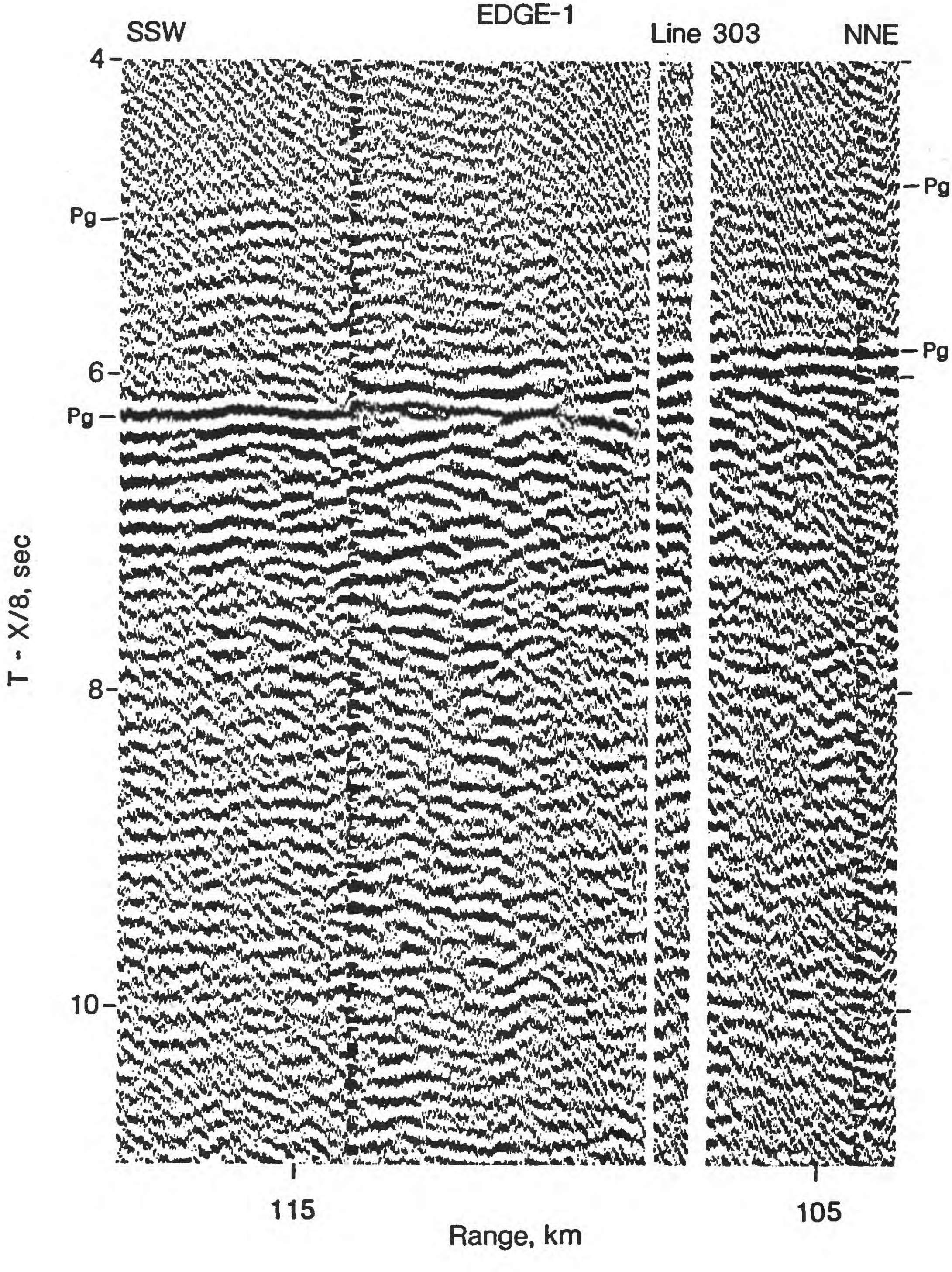

FIGURE 4. Receiver gather EDGE-1 at Tutka Bay for line 303. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

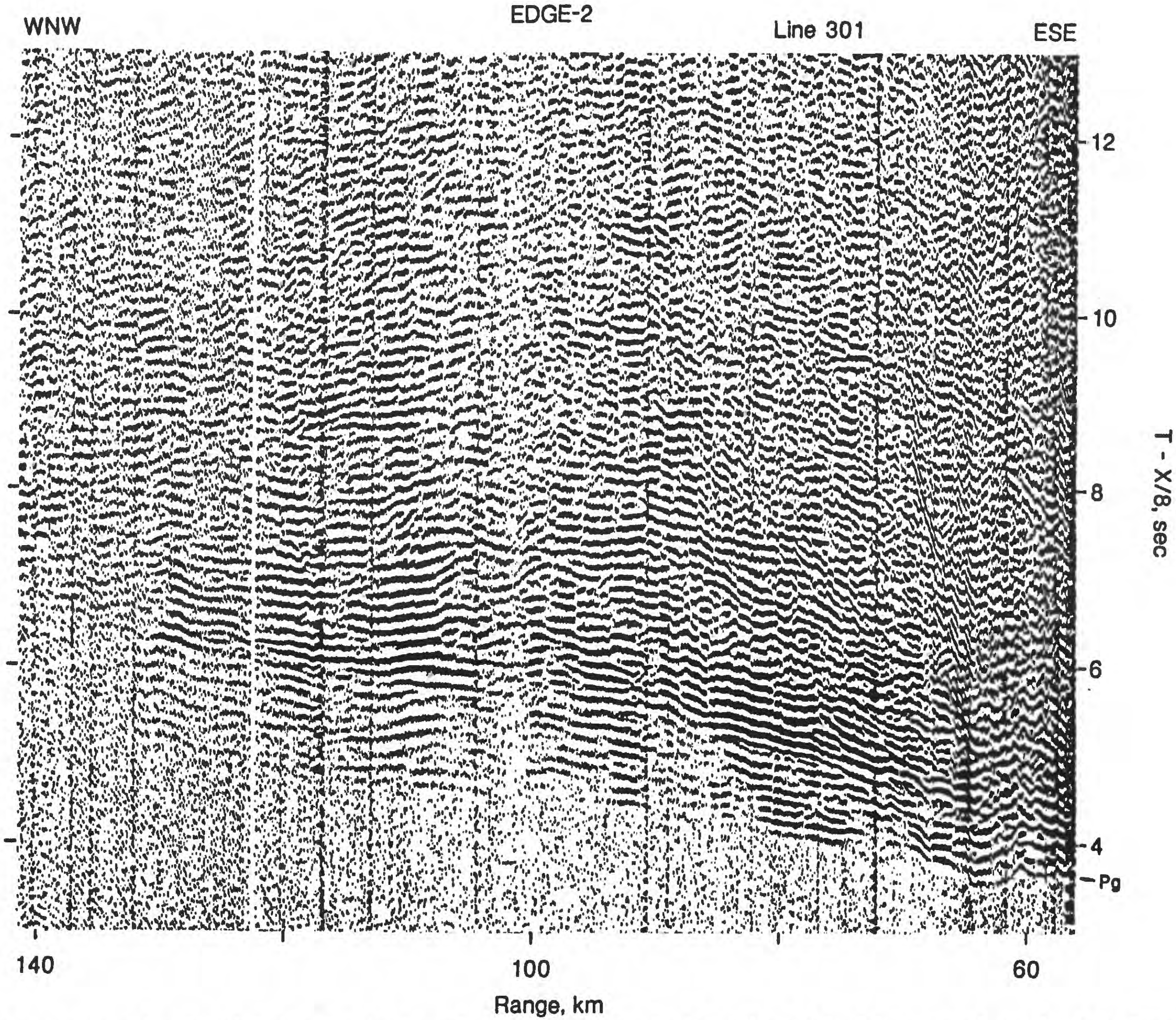

FIGURE 5. Receiver gather EDGE-2 at Tutka Bay for northwestern half of line 301. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

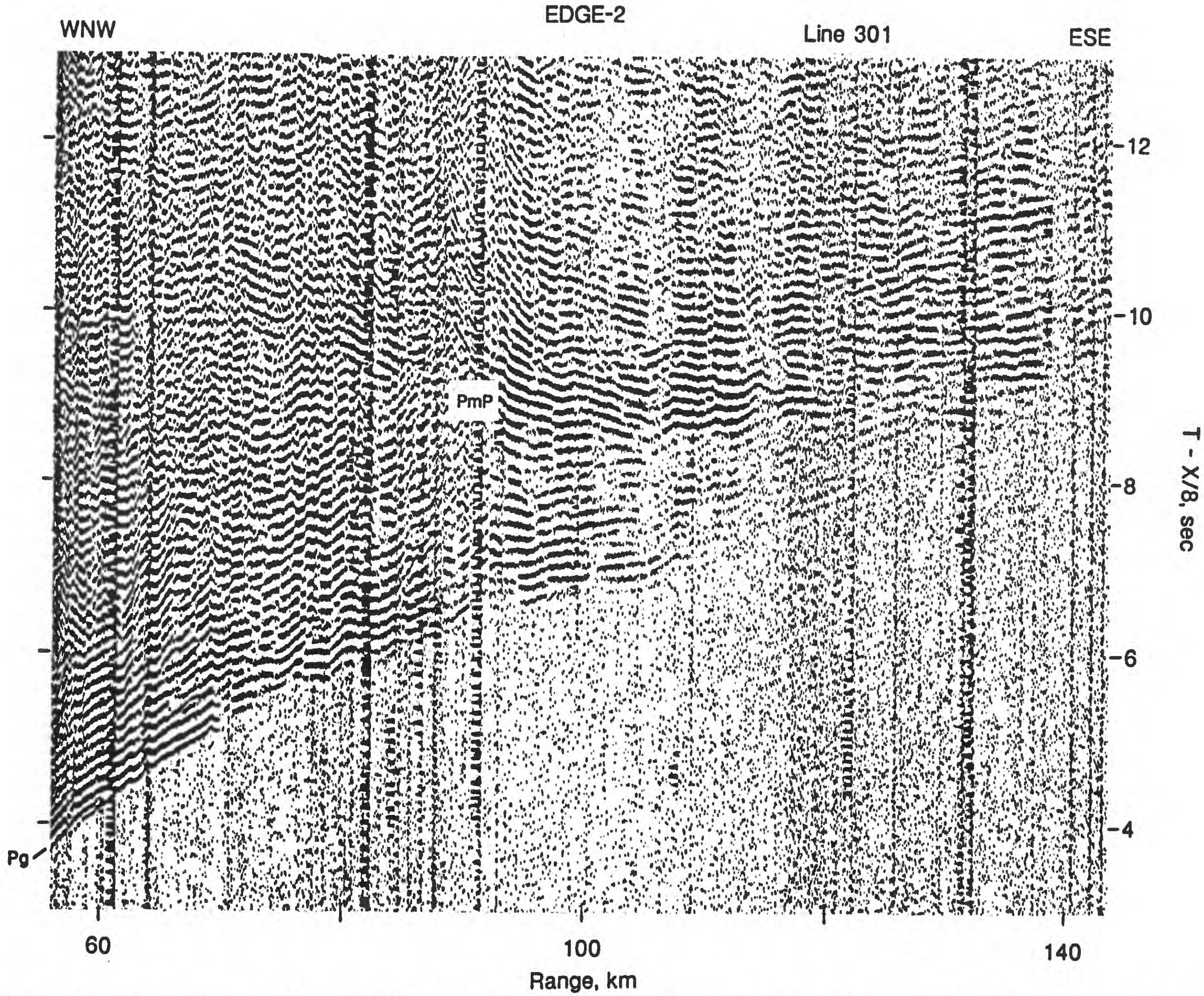

FIGURE 5 continued. Receiver gather EDGE-2 at Tutka Bay for southeastern half of line 301. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

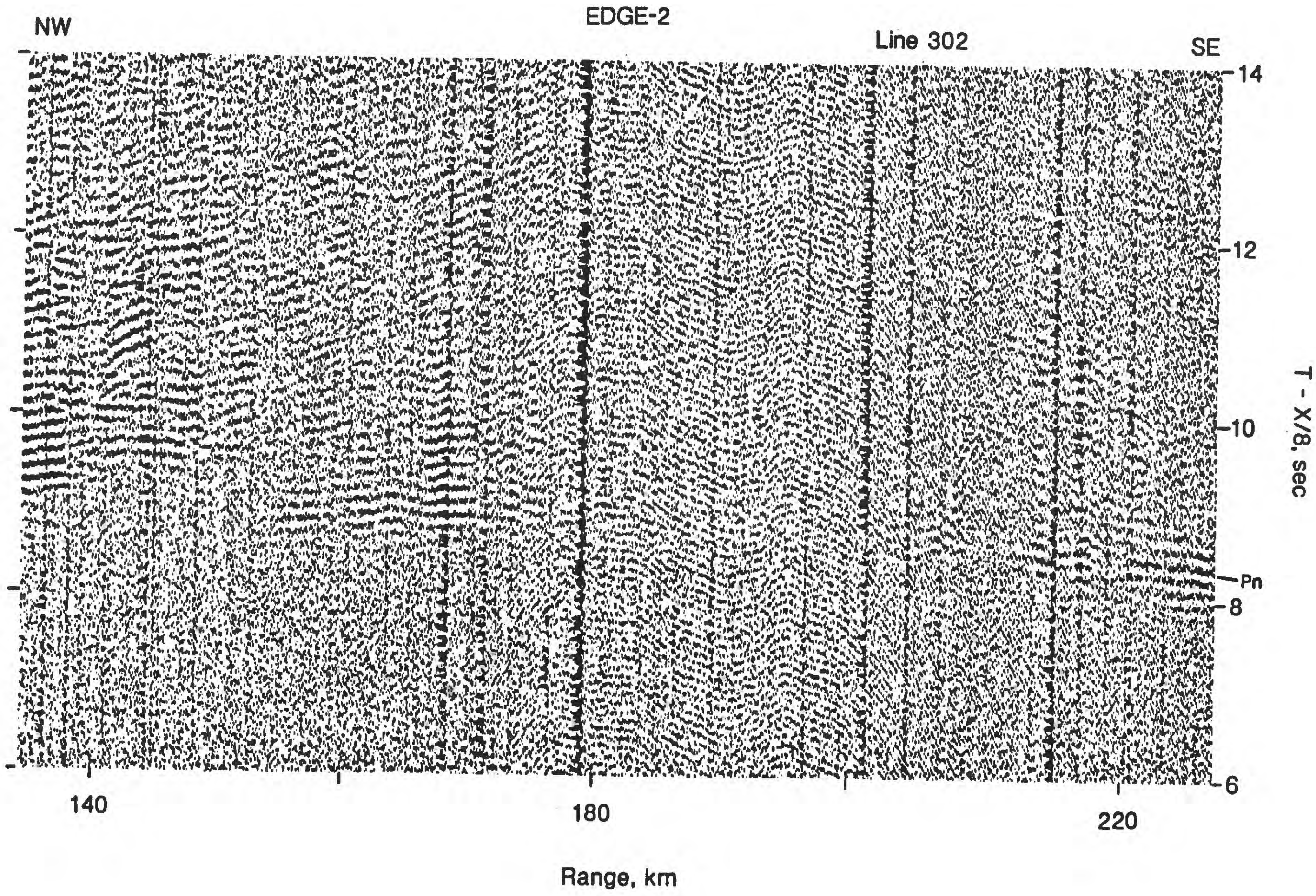

FIGURE 5 continued. Receiver gather EDGE-2 at Tutka Bay for northwestern half of line 302. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to $Range^{0.7}$.

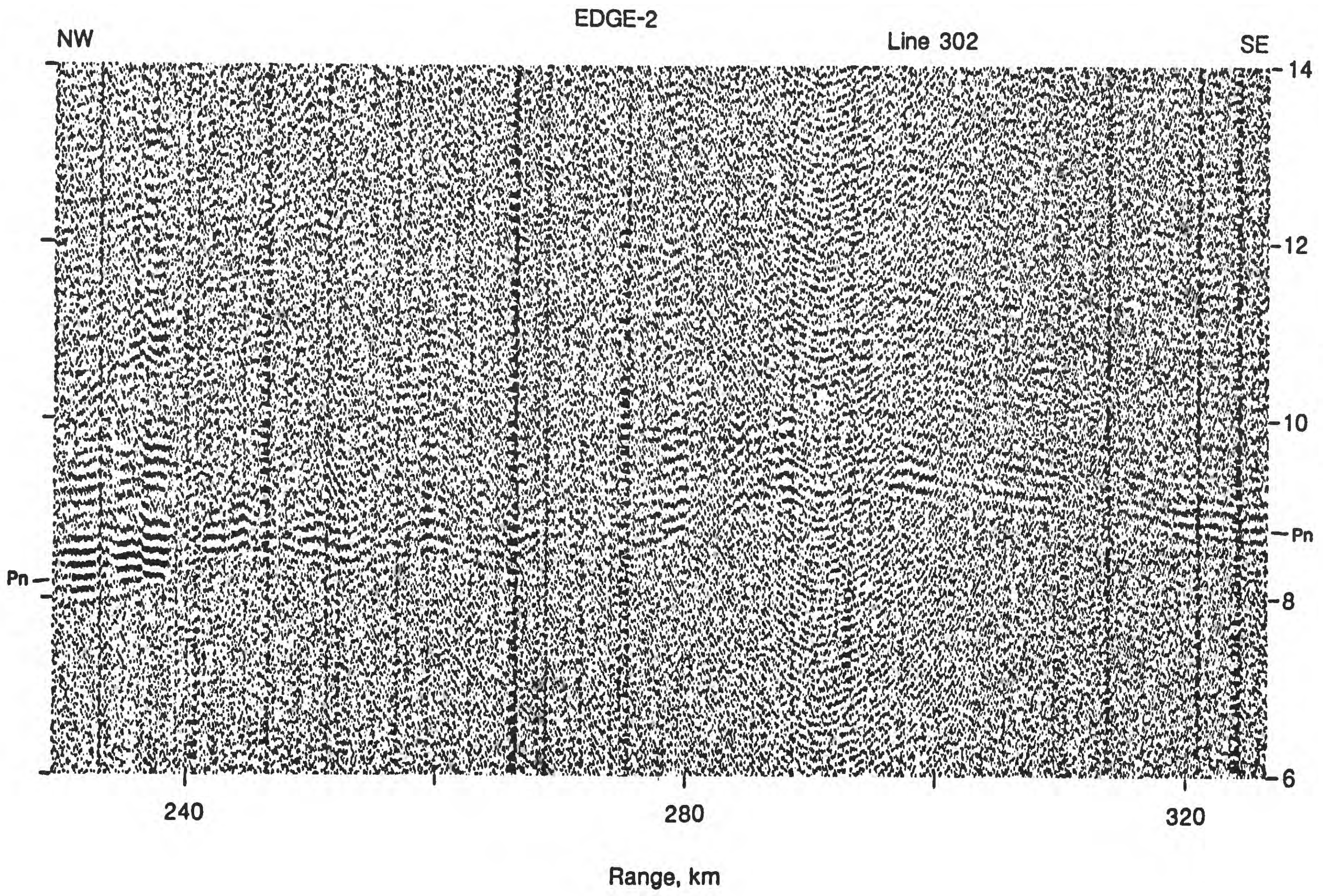

FIGURE 5 continued. Receiver gather EDGE-2 at Tutka Bay for southeastern half of lines 302. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

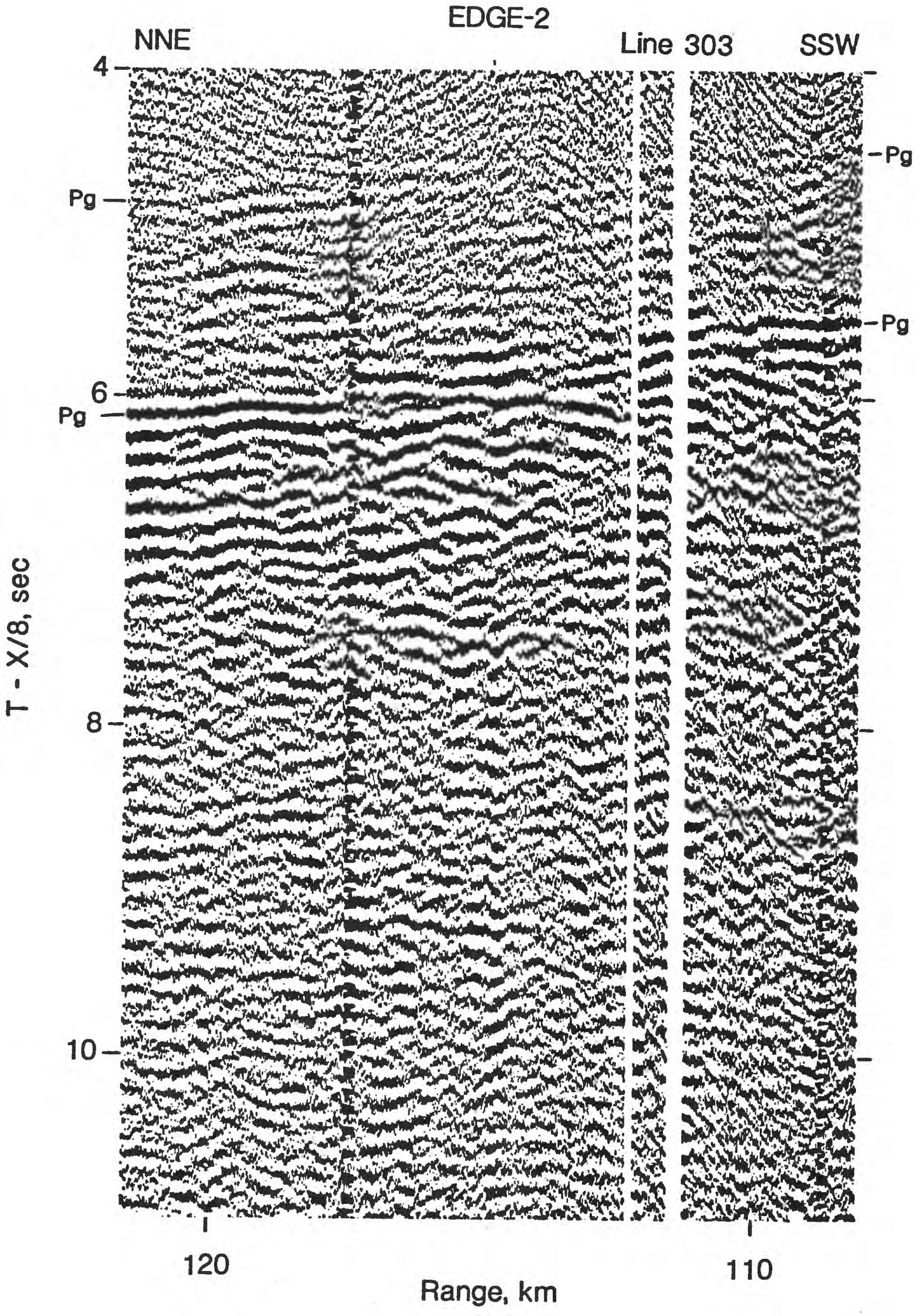

FIGURE 6. Receiver gather EDGE-2 at Tutka Bay for line 303. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

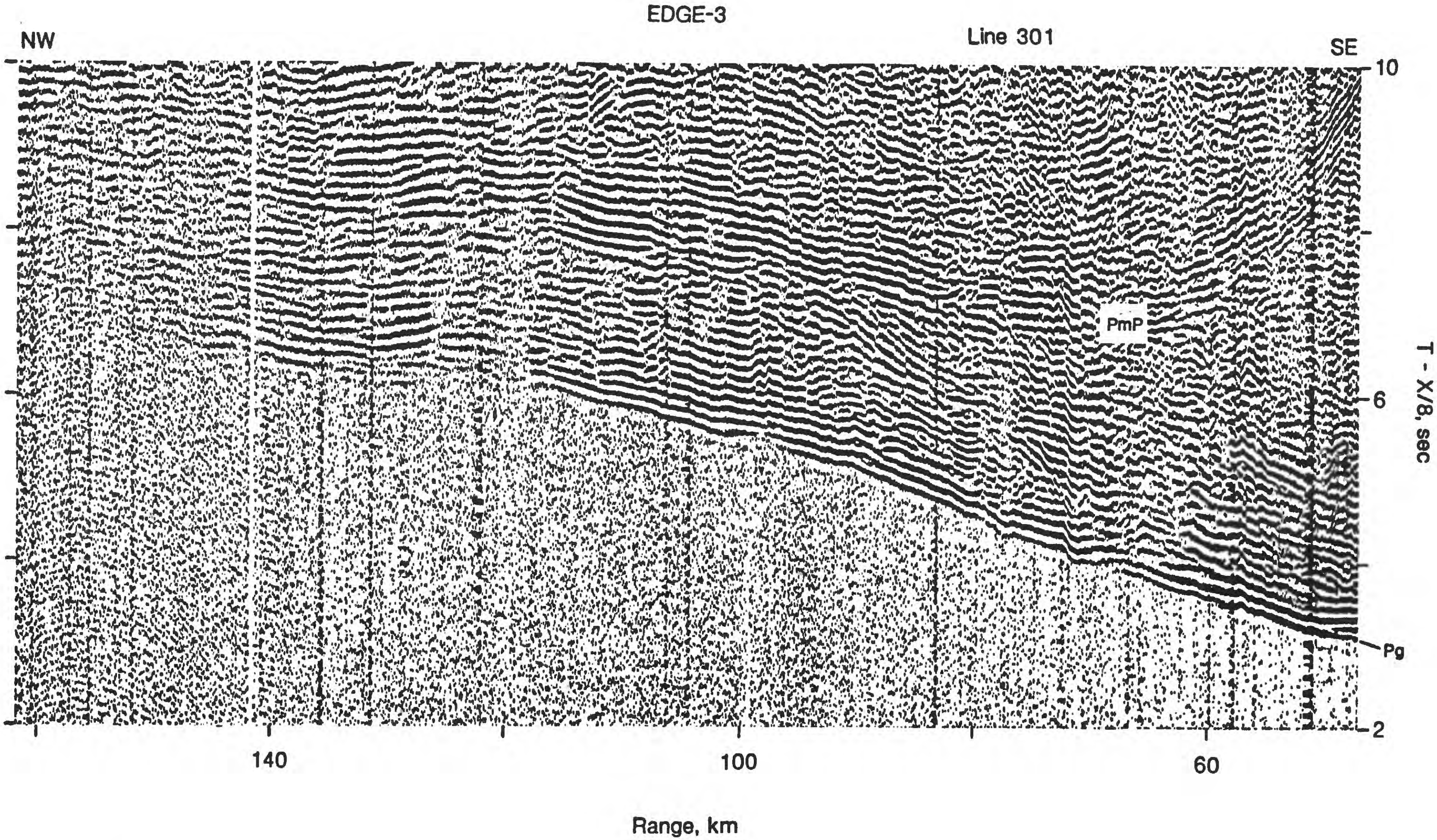

FIGURE 7. Receiver gather EDGE-3 at Gore Lake for the northwestern half of line 301. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

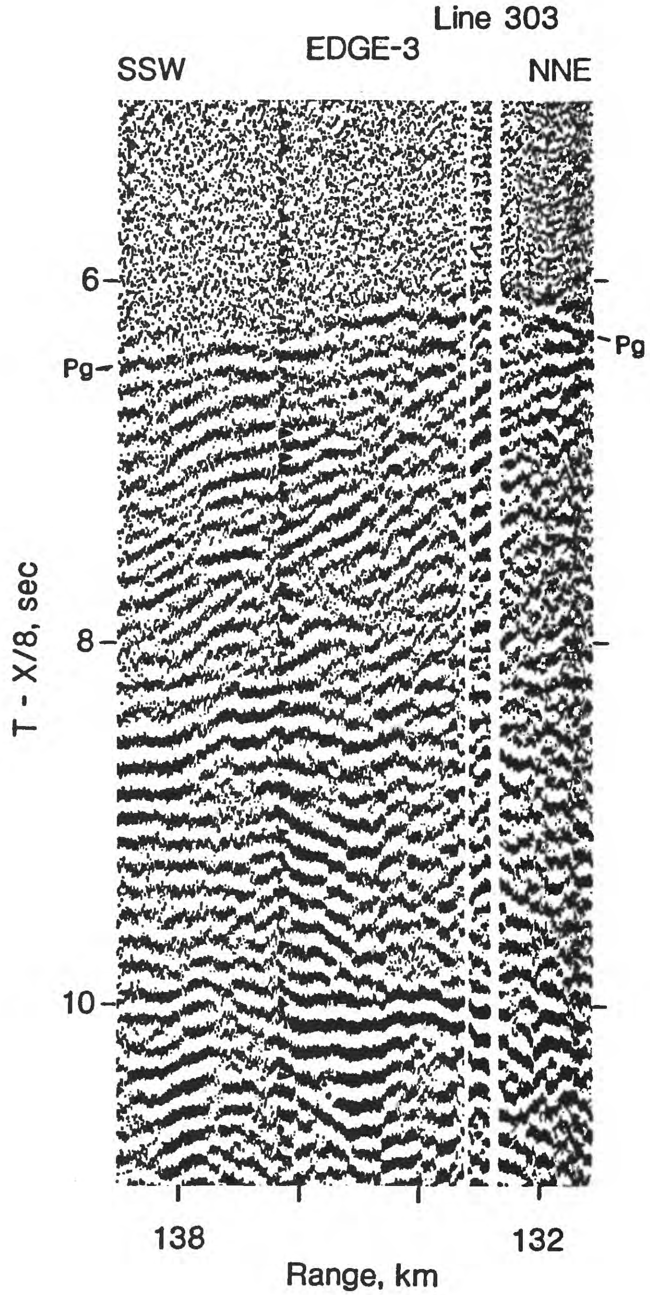

FIGURE 8. Receiver gather EDGE-3 at Gore Lake for line 303. The record section has been linearly reduced using a velocity of 8 km/s and trace amplitudes have been scaled according to Range$^{0.7}$.

APPENDIX

The following sections summarize the procedures used during the acquisition, digitizing, and processing of the wide-angle five-day recorder data.

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 with 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, accurate to a few milliseconds, was well recorded at each station for a 3 to 4 hour window centered at 0700 UCT. For the bulk of the recording, however, we relied on an internal clock code in IRIG-C format. The large drift rates of the five-day recorder internal clocks required us to correct for internal clock drift using the WWVB code as described by Brocher and Moses (1990).

We converted the digitized internal 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. 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), and is merged into a single program called SUDTOSEGYTEST.FOR on a VAX 11/785. 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 were deployed and turned on over a two day period prior to the acquisition of the EDGE seismic reflection line. Table 3 therefore provides a listing of the day of the year and UCT 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.
EDGE-1	Tutka Bay	182 0113	191 1738
EDGE-2	Tutka Bay	182 0133	191 1733
EDGE-3	Gore Lake	180 2115	184 1010

Shot Instant Timing

Shot instant times of the airgun array were obtained using a PC-based recorder located on the commercial seismic vessel. A Kinematics 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 an absolute time base recorded on the commercial vessel accurate to a millisecond.

TABLE 4. Times of Airgun Profiling

GMT Begin Day HRMIN	Lat. (N) Degrees	Long. (W) Degrees	GMT End Day HRMIN	Lat. (N) Degrees	Long. (W) Degrees
		Line 301			
183 1105	59.27522	153.79991	185 1455	58.56900	149.45940
		Line 302			
185 1837	58.61644	149.59125	186 2327	57.23455	147.61995
		Line 303			
183 0256	59.45000	153.23334	183 0647	59.14933	153.39250

Navigation

Navigation onboard the commercial seismic vessel was accomplished using a combination of radio-based Loran-C and satellite-based Starfix navigation. The estimated accuracy of these combined navigation systems is 200 to 300 m.

SEG-Y Tape Format

The wide-angle seismic reflection and 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

Suzanne Millington provided permission to locate the 5-day recorders within Kachemak Bay State Wilderness Park. Gonzalo Mendoza of the USGS-Menlo Park deployed the 5-day recorders. Dale Sawyer provided the PC-based system used to record airgun shot times. Willie Lee and Phil Dawson provided assistance in getting the new digitizing system working. Manik Talwani and John Ewing at the Houston Area Research Council (HARC) supported our field work. The EDGE program is supported by the National Science Foundation. Will Kohler and M. Iyer provided helpful review comments on the manuscript.

REFERENCES CITED

Barry, K.M., D.A. Cravers, and C.W. Kneale, 1975, Recommended standards for digital tape formats: *Geophysics, v. 40*, p. 344-352.

Brocher, T.M., and M.J. Moses, 1990, Wide-angle seismic recordings obtained during the TACT multichannel reflection profiling in the northern Gulf of Alaska: *U.S. Geological Survey, Open-file Report 90-663*, 40 pp.

Criley, E., and J. Eaton, 1978, Five-day recorder seismic system: *U.S. Geological Survey Open-file Report 78-266*, 85 pp.

Luetgert, J., S. Hughes, J. Cipar, S. Mangino, D. Forsyth, and I. Asudeh, 1990, Data report for O-NYNEX the 1988 Grenville-Appalachian seismic refraction experiment in Ontario, New York, and New England: *U.S. Geological Survey Open-file Report 90-426*, 51 pp.

Moore, J.C., J. Diebold, M.A. Fisher, J. Sample, T.M. Brocher, M. Talwani, J.I. Ewing, R. von Huene, C. Rowe, D. Stone, C. Stevens, and D. Sawyer, 1991, EDGE deep seismic reflection transect of the eastern Aleutian arc-trench layered lowered crust reveals underplating and continental growth: *Geology, v. 19*, p. 420-424.

Tottingham, D.M., and W.H.K. Lee, 1989, User manual for XDETECT, in W.H.K. Lee, editor, Toolbox for seismic data acquisition, processing, and analysis, *International Association of Seismology and Physics of the Earth Interior (IASPEI) Software Library Vol. 1,* p. 89-118.

Ward, P. L., and F. Williams, 1992, The Seismic Unified Data System, Version 2.0: unpublished manuscript, 147 pp.