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DATA REPORT FOR PIGGYBACK WIDE-ANGLE RECORDINGS OF THE 1993 SAN FRANCISCO BAY AREA, CALIFORNIA, SEISMIC REFRACTION EXPERIMENT

By

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ABSTRACT

Knowledge of the deep crustal structure in northern California is fundamental to the understanding of the tectonic processes associated with, and earthquake hazards posed by, ongoing transpression. This report presents the primary data resulting from a seismic refraction investigation of the crustal structure in the San Francisco Bay Area conducted in May 1993. The U.S. Geological Survey deployed a portable array of seismic recorders transverse to and straddling the San Andreas fault at the latitude of Loma Prieta during seismic refraction profiling of the San Francisco Bay Area. The seismic array, consisting of 22 vertical-component (cassette recorder) and eleven three-component (five-day recorder) stations, recorded eleven chemical explosions in a fan geometry at large offsets. This report describes the experiment, the locations and times of operation of all the recorders, and the data reduction scheme, and illustrates the wide-angle seismic data.

DATA ACQUISITION AND PROCESSING

The Loma Prieta magnitude 7.1 earthquake of October 17, 1989 acted as a catalyst for framework studies aimed at better understanding the crustal structure in its vicinity (U.S. Geological Survey Staff, 1990). In May, 1990, the U.S. Geological Survey (USGS) conducted a marine seismic reflection investigation of the central California margin (Lewis, 1990). The air gun array was used as a sound source for seismic recorders deployed onshore across the epicentral region of the Loma Prieta earthquake (Brocher et al., 1992; Page and Brocher, 1993). An array of 13 stations stretched from the coast landward some 92 km across Loma Prieta, and recorded reflection line 38 (fig. 1). The goals of the 1990 wide-angle recording were to place constraints on the mid- to lower-crustal structure in the vicinity of the epicenter of the 1989 Loma Prieta earthquake.

Refraction profiling along the Hayward and San Andreas faults conducted in May, 1993 (Kohler and Catchings, 1994), provided the opportunity to reverse refraction coverage along the

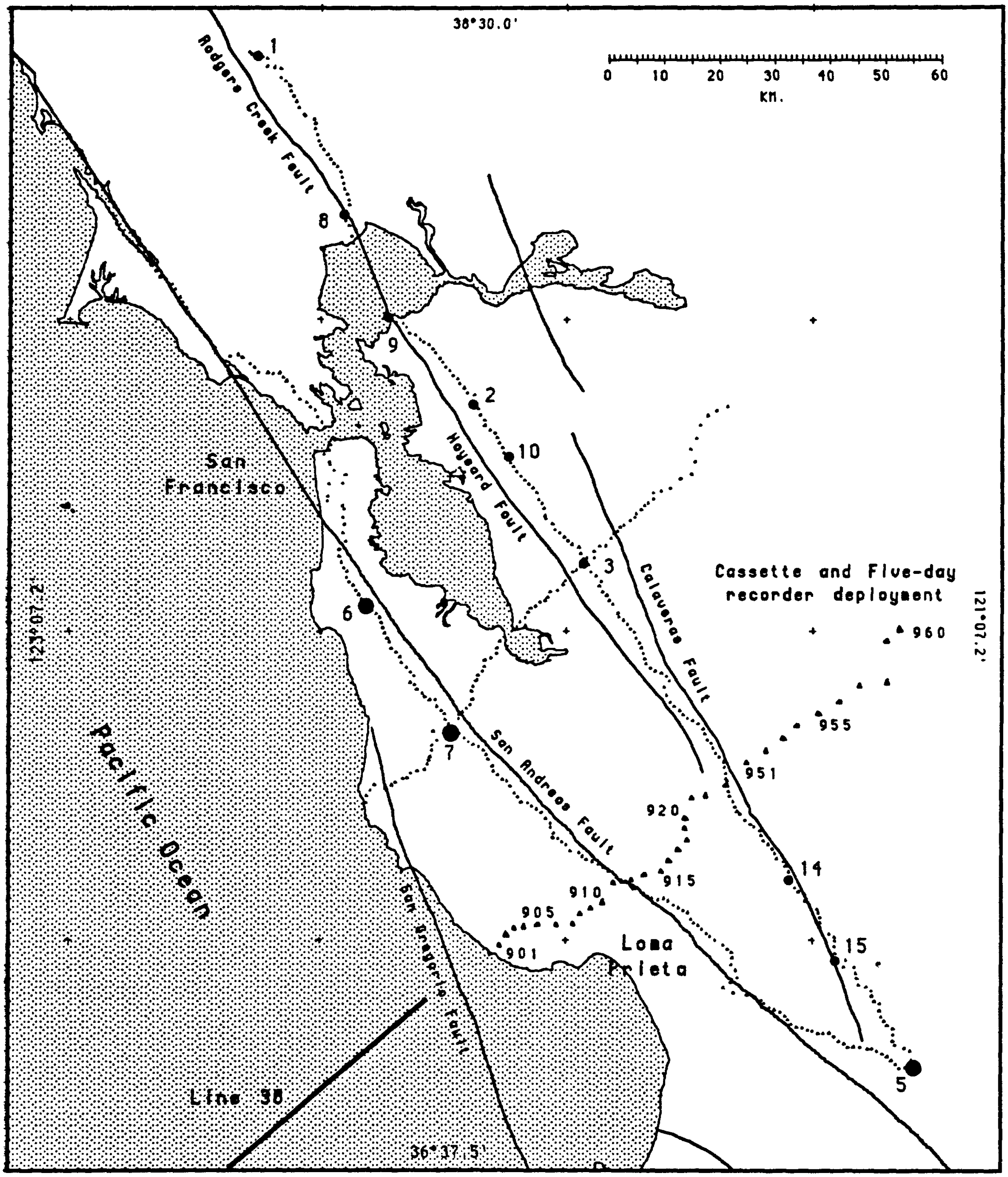

FIGURE 1. Map of the San Francisco Bay Area showing the study area. Portable receiver sites are shown as small dots. USGS seismic cassette and five-day recorders were deployed at stations 901 to 960. Successful chemical shotpoints are represented by numbered solid circles. Heavy lines are prominent fault traces.

May 1990 deployment. To record these chemical explosions an array consisting of 22 cassette recorders (901-922) and 11 five-day recorders (950-960) was deployed along the 1990 Loma Prieta transect (see Table 1). The locations and elevations of the cassette and five-day recorders summarized in Table 1 were obtained using GPS receivers operated in differential mode or from topographic maps plotted at a scale of 1:24,000. These receiver locations and elevations are estimated to be accurate to within a few tens of meters.

The USGS seismic cassette recorders, described by Murphy (1988), were individually programmed to record the shot windows. The cassette recorders were deployed twice to record all 17 planned explosions. Each recorder is connected to a Mark Products L4A 2-Hz vertical-component geophone. The signal from this geophone passes through three parallel amplifiers, each with an adjustable gain setting. The three seismic signals plus an internally generated time code (IRIG-E) and a fixed reference frequency are recorded as a multiplexed signal on analog cassette tape. A programmable memory board in each unit allows data to be recorded during ten predetermined time windows. Prior to recording the seismic data, the instrument records a geophone pulse, an amplification step, and 10-Hz sine-wave calibration signals at 1, 10, 100, and 1000 mv. The frequency response curve for the system peaks at about 20 Hz. Drifts of the internal clocks of the cassette recorders were determined for each deployment using a master clock. Attenuations for all cassette recorders were set at 12, 30, and 48 dB.

The analog three-component, five-day seismic recorders, have been described by Criley and Eaton (1978). One vertical and two horizontal Mark Products L-4C 1 Hz seismometers were recorded at all land stations. The signals from these seismometers passes through two parallel amplifiers, to record high and low gain signals. These instruments are frequently used by the USGS for earthquake aftershock studies and teleseismic studies of lithospheric structure. Each recorder is capable of recording continuous seismic data on analog magnetic tape for a duration of up to five days. The five-day recorders were deployed over a period of time lasting several days, turned on prior to the shots, and picked up after all the shots had been fired. Table 2 provides a listing of the times for which each five-day recorder continuously recorded data.

The playback and digitization of the analog cassette recorder tapes and the formating of the digitized data into SEG-Y format was standard as described elsewhere (Murphy, 1989). The sample rate for digitizing was 200 samples per second. Record sections were reduced using a velocity of 6 km/s.

TABLE 1. 5-day and Cassette Recorder Locations and Elevations

Site No.	Plot ID	Name	Latitude (N) Deg. Min.	Longitude (W) Deg. Min.	Elevation (m)
LP-1a	901	Sand Hill Bluff	36 57.4888	122 09.0901	24
LP-1	902	Majors Creek	36 59.5184	122 08.1283	177
LP-1b	903	Bald Mtn. Sch.	37 00.6402	122 07.3206	256
LP-1c	904	Smith Grade	37 01.1964	122 06.3084	243
LP-2	905	Empire Grade	37 01.3824	122 05.1348	365
LP-2a	906	Henry Cowell Pk.	37 01.6088	122 03.4898	137
LP-2b	907	Glen Canyon	37 01.6620	122 01.0872	159
LP-3	908	Happy Valley	37 01.6753	121 59.1644	58
LP-3a	909	Crystal Creek	37 02.6910	121 58.3233	152
LP-3b	910	Laurel Glen	37 03.2346	121 57.0204	118
LP-4	911	Olive Springs	37 03.8435	121 55.5707	171
LP-4a	912	Spanish Ranch	37 05.6605	121 54.2173	445
LP-4b	913	Loma Prieta Road	37 05.9538	121 52.0518	751
LP-5	914	Loma Prieta	37 06.4818	121 50.5464	1034
LP-5a	915	Llagas Creek	37 06.7860	121 48.4590	336
LP-5b	916	Allison Canyon	37 07.9842	121 47.4546	247
LP-6	917	Casa Loma Rd.	37 08.8872	121 46.4040	199
LP-6a	918	Pine Tree Canyon	37 09.9096	121 45.2880	186
LP-6b	919	Calero Reservoir	37 10.9494	121 45.6222	153
LP-7	920	Bailey Road	37 11.9382	121 45.5040	97
LP-7a	921	Metcalf Road	37 14.2326	121 42.9948	374
LP-7b	922	Metcalf Canyon	37 13.9295	121 44.7083	91
LP-8	950	Coe Ranch	37 15.537	121 40.305	367
LP-9	951	San Felipe Ranch	37 17.328	121 38.050	853
LP-9a	952	Castle Ridge	37 18.531	121 35.698	1153
LP-9b	953	Isabel Valley	37 19.686	121 33.658	713
LP-10	954	Arnold Ranch	37 20.968	121 32.019	649
LP-10a	955	San Antonio Valley	37 22.137	121 29.377	611
LP-11	956	Beauregard Creek	37 23.296	121 26.890	750
LP-11a	957	Del Puerto Canyon	37 24.774	121 24.380	415
LP-12	958	Arkansas Canyon	37 25.212	121 21.042	323
LP-12a	959	Mt. Oso	37 29.088	121 21.174	780
LP-13	960	Ingram Canyon	37 30.290	121 19.602	312

TABLE 2. 5-day Recorder Times of Operation

Site No.	Name	Time On JD Hr. Min.	Time Off JD Hr.Min.
LP-8	Coe Ranch	144 1920	151 1324
LP-9	San Felipe Ranch	144 1823	149 0000*
LP-9a	Castle Ridge	145 2040	152 1747
LP-9b	Isabel Valley	145 2238	152 1946
LP-10	Arnold Ranch	145 1849	148 1957
LP-10a	San Antonio Valley	144 2140	148 2202
LP-11	Beauregard Creek	144 2323	148 2341
LP-11a	Del Puerto Canyon	145 0040	149 0103
LP-12	Arkansas Canyon	146 0221	149 0232
LP-12a	Mt. Oso	145 2000	149 1548
LP-13	Ingram Canyon	145 2155	149 1749

*Nominal end time for this station; actual end time not yet determined.

DESCRIPTION OF THE DATA

Eleven wide-angle seismic profiles were recorded during the May 1993 experiment. Table 3 provides a list of shot times, sizes, and locations for these chemical explosions from Kohler and Catchings (1994). In addition, recordings were made for six chemical shots that failed to produce seismic waves, perhaps due to the failure to add hollow glass spheres to the explosive (E. Criley, personal communication, May 1993). This data report does not illustrate the recordings made of these failed shots and they will not be discussed further.

The eleven successful chemical shots were recorded in a fan geometry. The best recordings were obtained from shots which generally employed 905 kg (2000 lbs) of explosive or more or were located relatively near the recorder array (shotpoints 5, 7, 14, 6, and 3). Fair records were produced by shotpoints 8 and 2. Poor records were produced by shotpoints 15, 1, 10, and 9, which were all small charges (136 kgs or less), many of which were located at large distances from the cassette recorder deployment. Figures 2 to 12 provide examples of the records obtained from each shotpoint, reduced using a velocity of 6 km/s. Traces are plotted as a function of range from the chemical shotpoint. Only records from the cassette recorders are presented in this report.

TABLE 3. Shot times, sizes, and locations

Shot Point	UTC Time (Day Hr:Min)	Charge size (kgs)	Latitude (Deg., Min)	Longitude (Deg., Min)	Elev. (m)
5	146 08:00	1357	36 47.561	121 17.626	299
7	146 08:02	905	37 20.138	122 13.928	536
6	146 08:08	905	37 32.412	122 24.361	340
15	148 07:02	90	36 58.031	121 27.150	44
3	148 07:04	905	37 36.460	121 57.899	411
8	148 07:08	90	38 10.065	122 27.100	2
1	148 07:12	1810	38 25.404	122 37.747	280
2	148 08:00	271	37 51.892	122 11.295	244
14	148 09:02	90	37 05.855	121 32.714	253
10	148 09:06	136	37 46.793	122 06.972	198
9	148 09:08	136	38 00.225	122 21.868	21

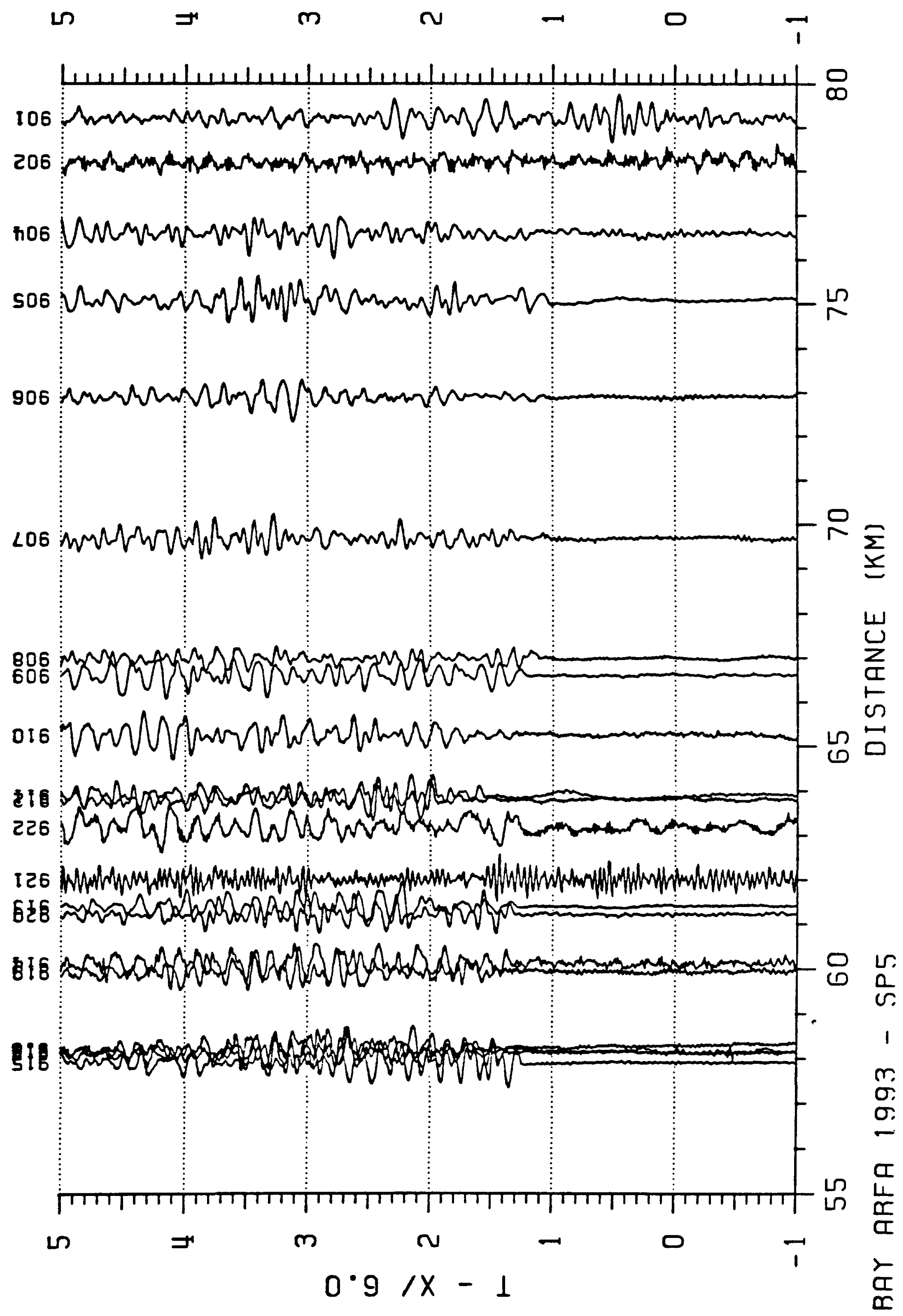

FIGURE 2. Refraction profile from shotpoint 5. The record section has been linearly reduced using a velocity of 6 km/s.

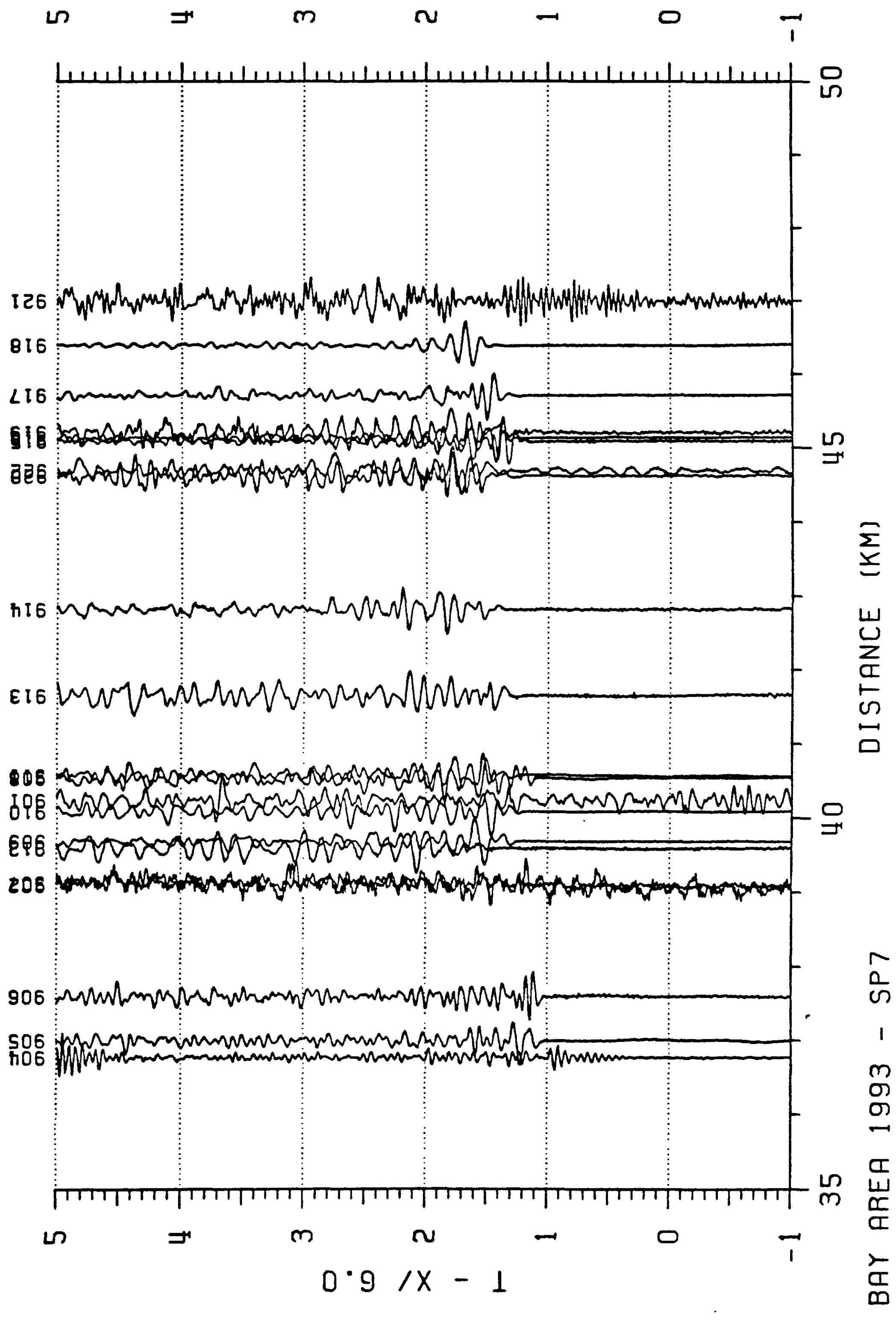

FIGURE 3. Refraction profile from shotpoint 7. The record section has been linearly reduced using a velocity of 6 km/s.

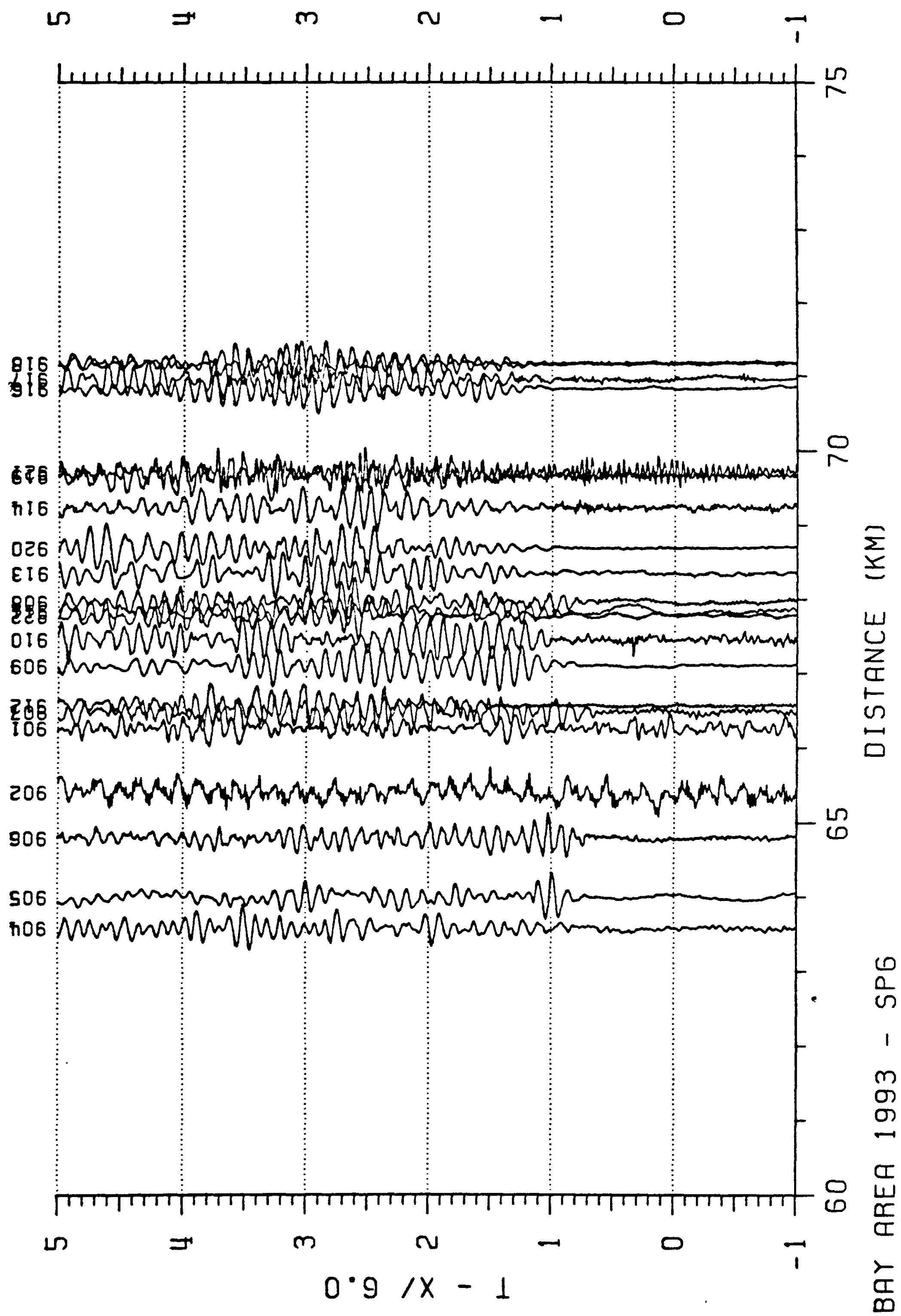

FIGURE 4. Refraction profile from shotpoint 6. The record section has been linearly reduced using a velocity of 6 km/s.

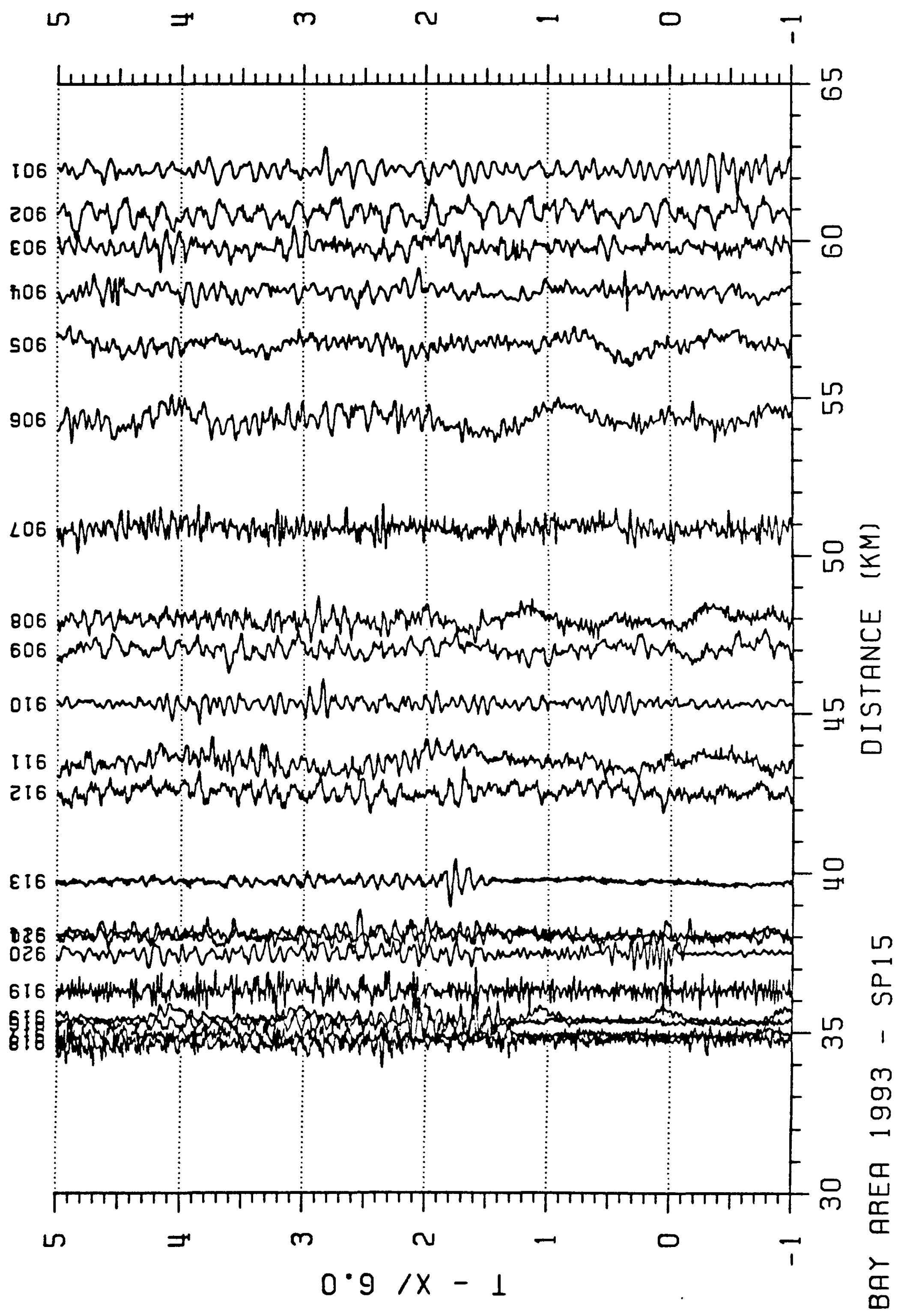

FIGURE 5. Refraction profile from shotpoint 15. The record section has been linearly reduced using a velocity of 6 km/s.

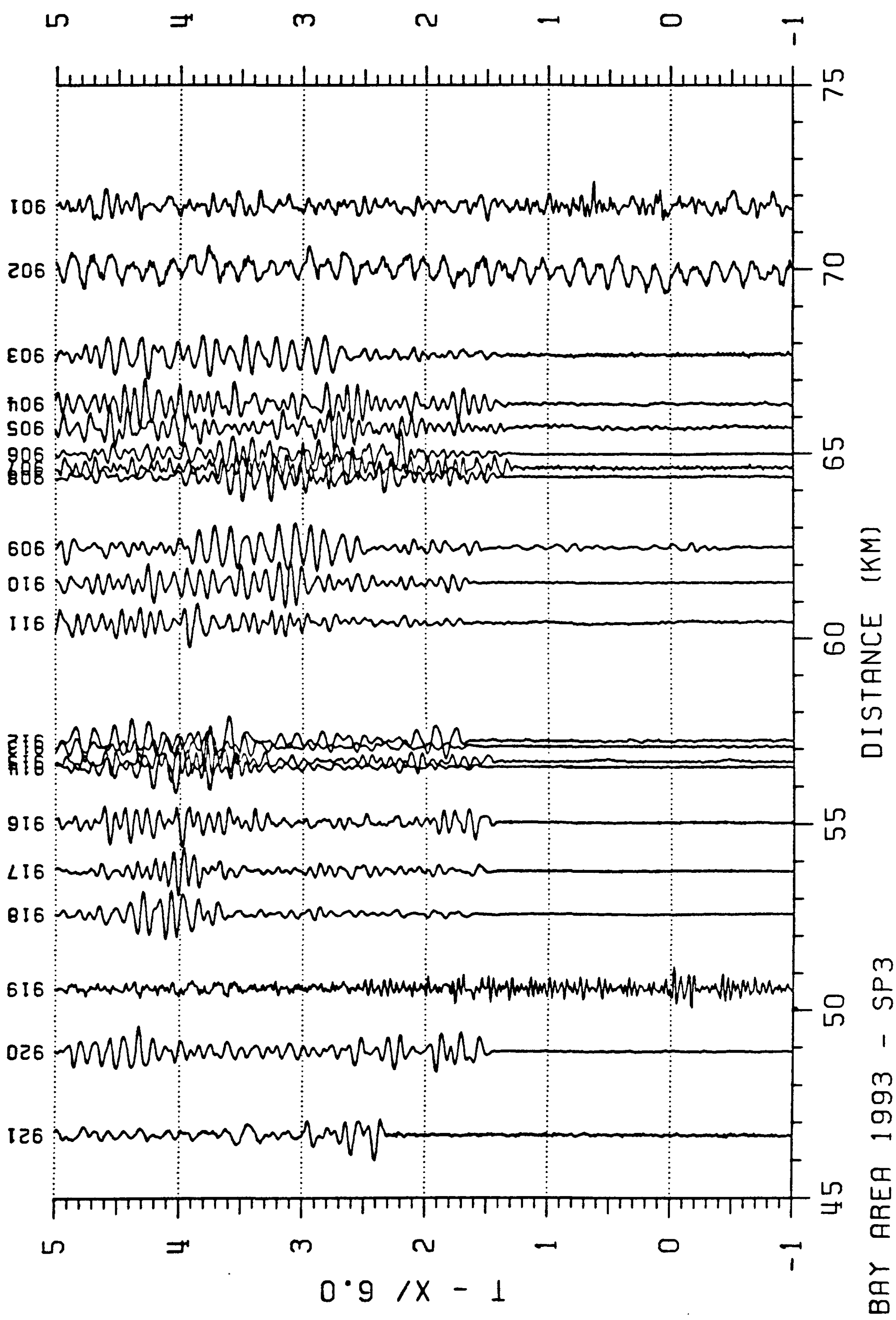

FIGURE 6. Refraction profile from shotpoint 3. The record section has been linearly reduced using a velocity of 6 km/s.

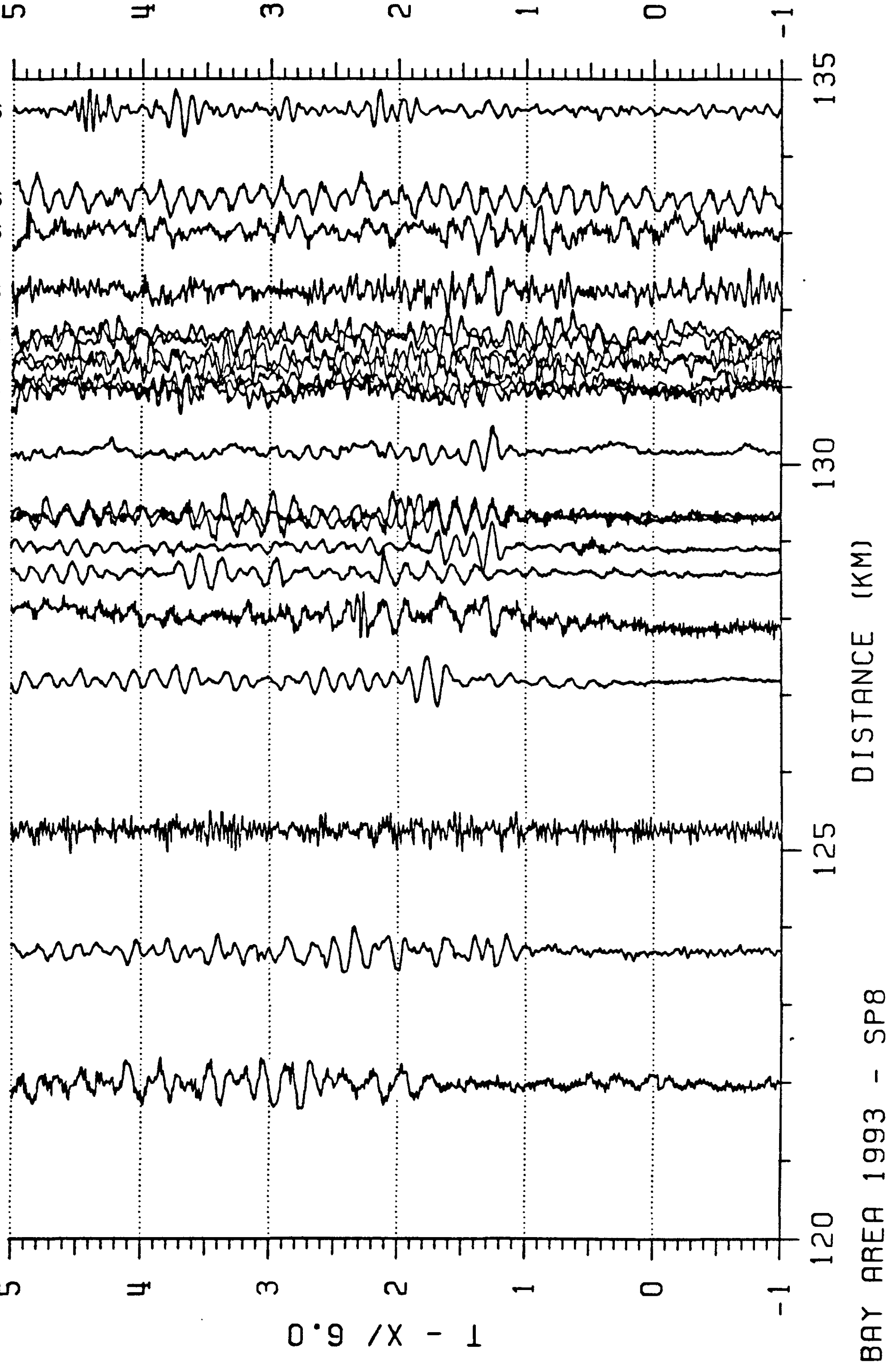

FIGURE 7. Refraction profile from shotpoint 8. The record section has been linearly reduced using a velocity of 6 km/s.

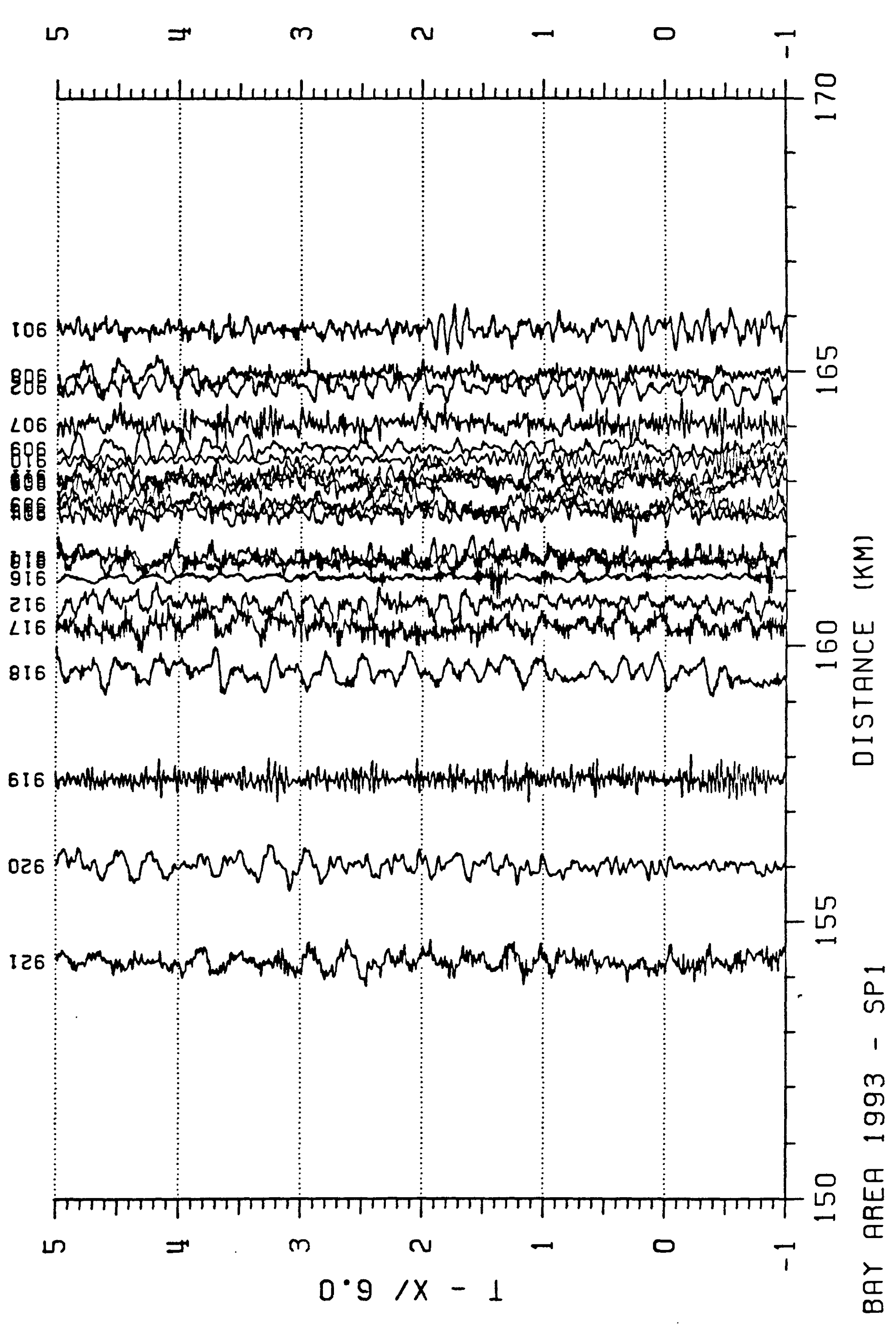

FIGURE 8. Refraction profile from shotpoint 1. The record section has been linearly reduced using a velocity of 6 km/s.

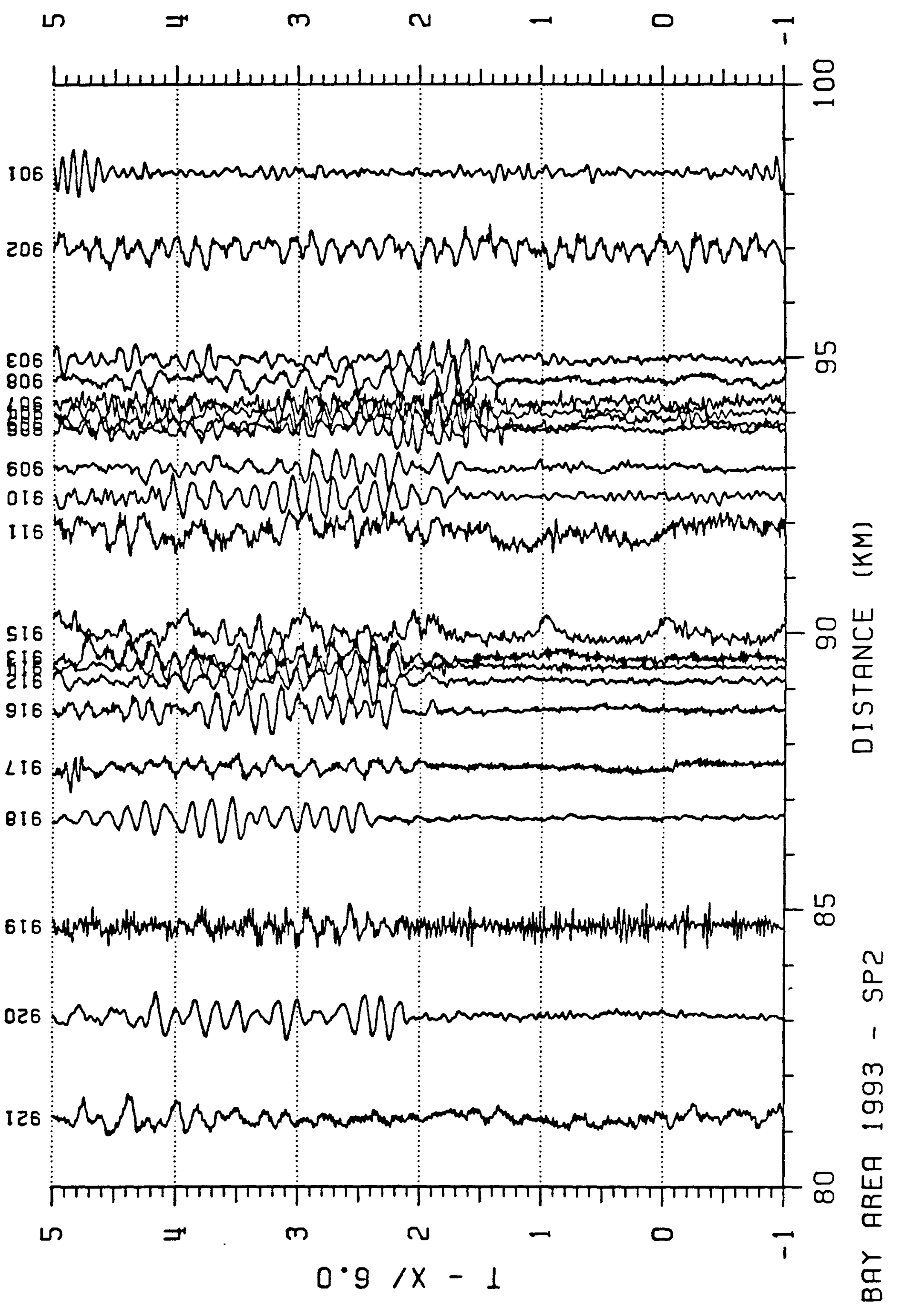

FIGURE 9. Refraction profile from shotpoint 2. The record section has been linearly reduced using a velocity of 6 km/s.

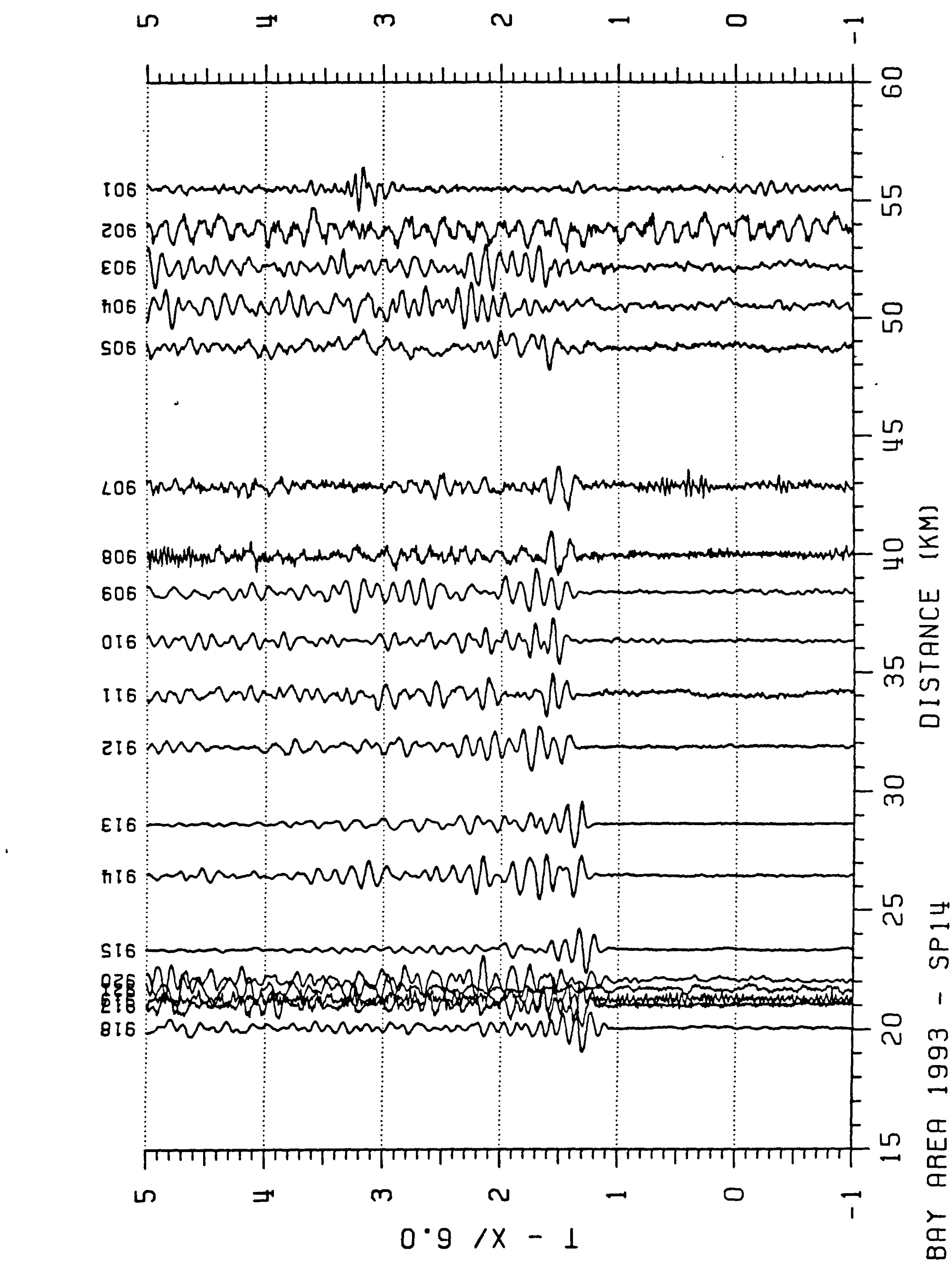

FIGURE 10. Refraction profile from shotpoint 14. The record section has been linearly reduced using a velocity of 6 km/s.

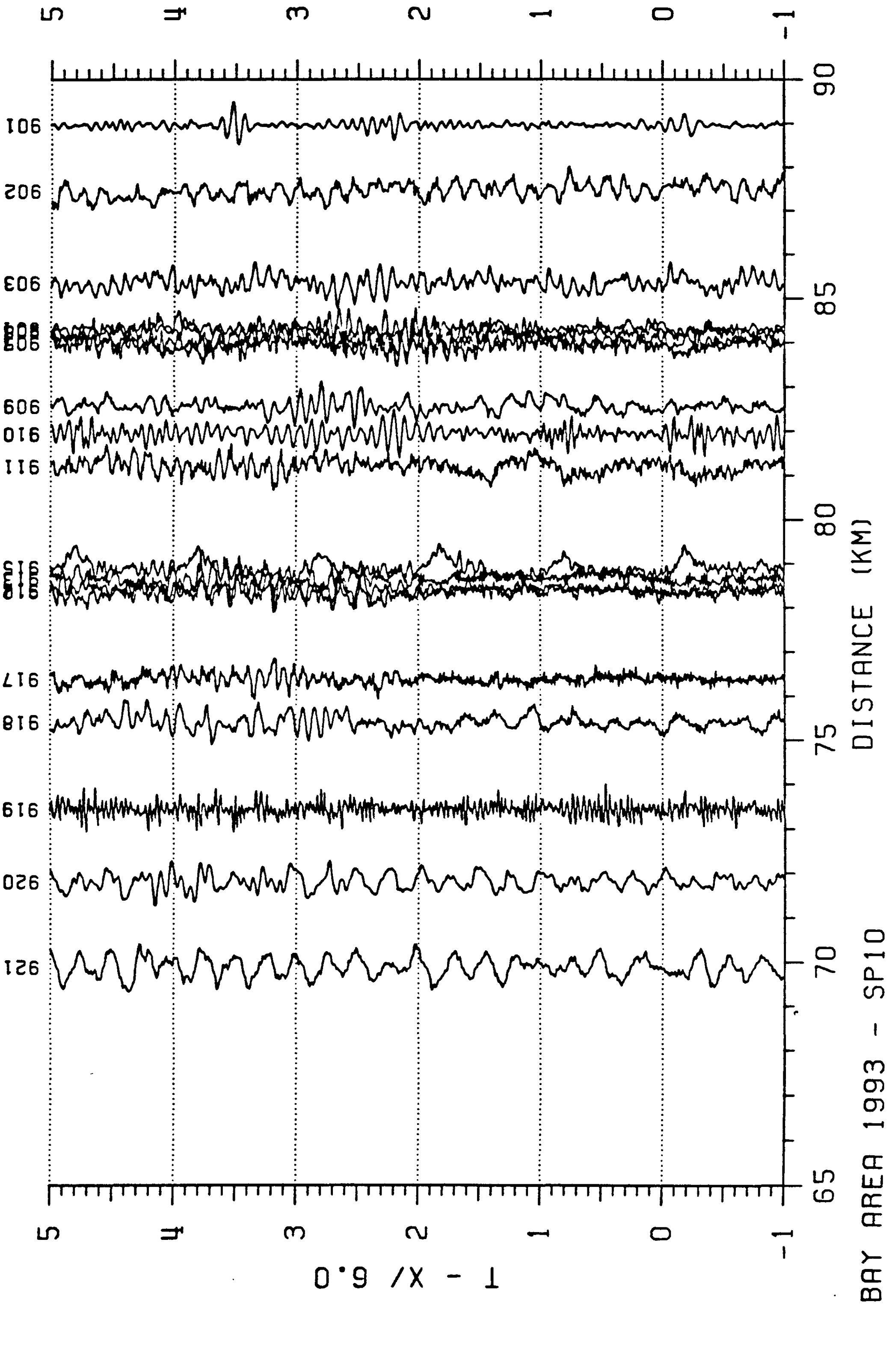

FIGURE 11. Refraction profile from shotpoint 10. The record section has been linearly reduced using a velocity of 6 km/s.

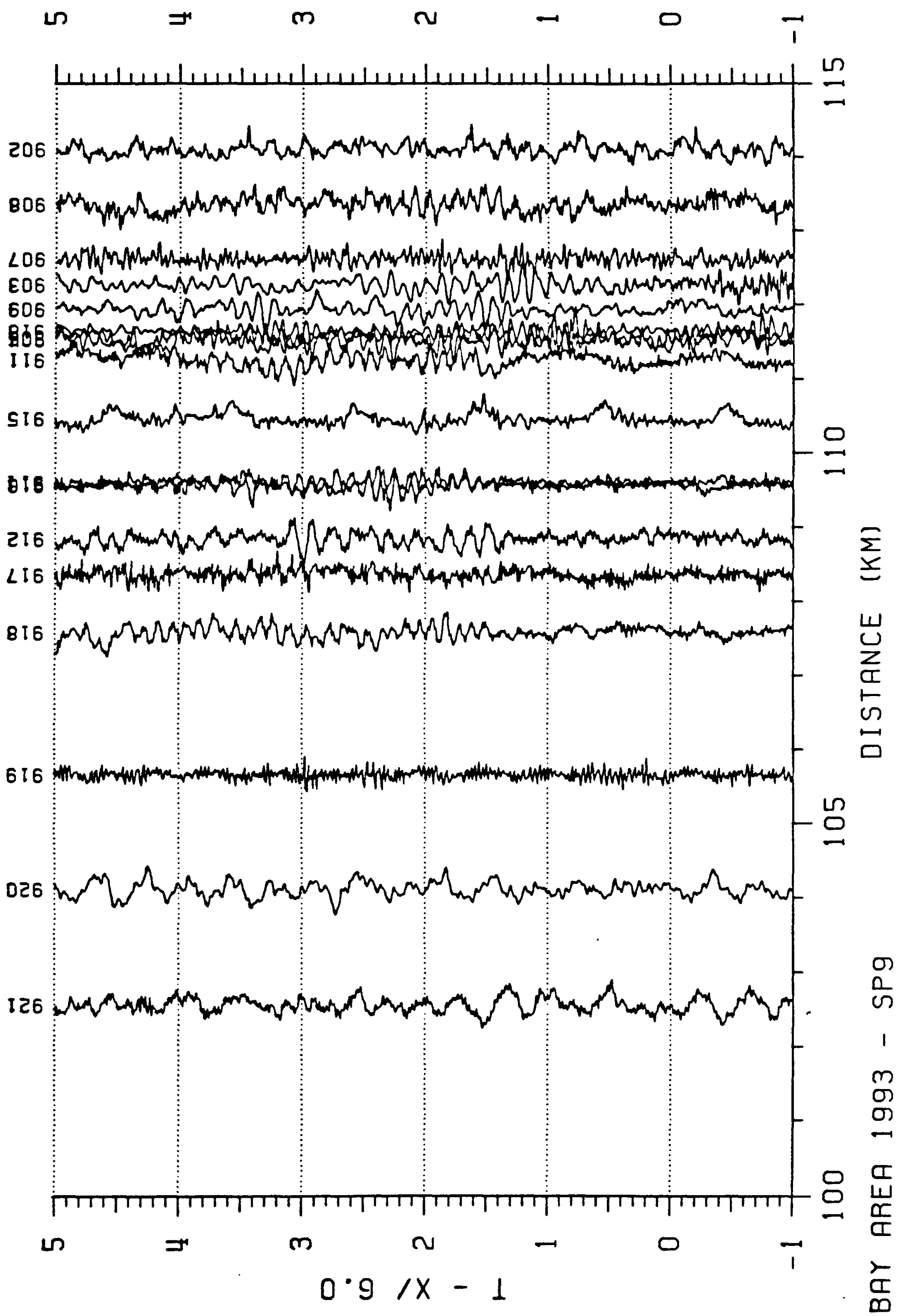

FIGURE 12. Refraction profile from shotpoint 9. The record section has been linearly reduced using a velocity of 6 km/s.

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