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DATA REPORT FOR SEISMIC REFRACTION SURVEYS CONDUCTED FROM 1980 TO  
1982 IN THE LIVERMORE VALLEY AND THE SANTA CRUZ MOUNTAINS,  
CALIFORNIA

By

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## **ABSTRACT**

We provide documentation for two seismic refraction profiles acquired by the U.S. Geological Survey in the San Francisco Bay area between 1980 and 1982 in Livermore Valley and the Santa Cruz Mountains. We also include the waveforms and travel times from five aftershocks of the April 1980 Livermore earthquake that were recorded on temporary seismic stations and that have not been published. Although seismic refraction profiles from the 1980 Livermore study were published, none of the other data for this experiment, including shot times and locations, receiver locations, data quality, and travel times, have been reported. Similarly, such data from the 1981 to 1982 seismic refraction survey in the Santa Cruz Mountains included here have not been published. The first-arrival travel times from these profiles are reported in the hope that they can be used for three-dimensional velocity models in the San Francisco Bay area, particularly for the Livermore Valley and Santa Cruz Mountains.

## INTRODUCTION

The purpose of this report is to provide documentation of two older seismic refraction profiles acquired by the U.S. Geological Survey in the San Francisco Bay area. These surveys were conducted in the time period from 1980 through 1982 in Livermore Valley and the Santa Cruz Mountains. Although seismic refraction profiles for the 1980 Livermore Valley study have been published (Meltzer et al., 1987), little of the basic data for this experiment, including shot times, shotpoint locations, receiver locations, quality of the recorded data, and travel times, have been reported. No data from a 1981-to-1982 seismic refraction study of the Santa Cruz Mountains have been previously published. The travel times from these profiles are reported in the hope that they can be used for three-dimensional velocity models in the San Francisco Bay area, and particularly for the Livermore Valley and the Santa Cruz Mountains (Brocher et al., 1997; Jachens et al., 1997; Wentworth et al., 1997).

Data from the refraction studies in the Livermore Valley were utilized by at least three different studies (Followill and Mills, 1982; Taylor and Scheimer, 1982; Meltzer et al., 1987). These studies were initiated in response to a sequence of earthquakes in the Livermore area in 1980 (Cockerham et al., 1980). None of the published studies presented shotpoint, receiver, or travel time data from the 1980 seismic refraction profiles in the Livermore Valley.

Data from the refraction studies in the southern Santa Clara Valley, near San Juan Bautista, were published by Mooney and Luetgert (1982), Bluming et al. (1985), and Mooney and Colburn (1985). Mooney and Colburn (1985) published shotpoint and receiver information, as well as first-arrival travel times, for three shots in a 1981 seismic refraction profile trending from Watsonville to northeast of Gilroy. Bluming et al. (1985) discussed data from three shotpoints along or near the Calaveras fault. Initial results were presented for 3 additional shots in the Santa Cruz Mountains by Boken and Mooney (1982), but the basic data and waveforms from these shots have never been published. We present shotpoint, receiver location, record section, and travel time data from these three shotpoints in the Santa Cruz Mountains.

## METHODOLOGY

### Shotpoints

Typically, shotholes were drilled 36 meters deep (20 cm in diameter), loaded with several hundred kilograms of high-velocity ammonium nitrate explosive, tamped from the top of the explosive charge to the surface with gravel, and fired automatically according to clock time (Healy et al., 1982). A signal from an U.S. Geological Survey's (USGS) master reference clock triggered an electric blasting cap, which sequentially caused the primacord, boosters, and the blasting agent to detonate. The blasting cap detonation signal (cap break), the USGS master reference clock's IRIG E time code, and the radio-received WWVB time code were recorded on a Kiowa® paper strip-chart record. The shot origin times were determined from the cap break on the paper record assuming that the explosives detonated at the exact time of the cap break. The reported shot times are accurate to within  $\pm 2$  milliseconds.

### Instrumentation and Data Reduction

The seismic energy generated by the explosions were recorded by 100 portable seismic cassette-tape recorders, whose analog electronics were described by Murphy (1988) (Fig. 1). Each recorder consisted of a single, vertical-component, 2-Hz geophone, a chronometer, a calibrator, a tape deck, a tape-speed-compensation tone generator, three independent amplifiers commonly set 18 dB apart in gain (a factor of 8), and a WWVB radio receiver (Fig. 1).

When recording, the voltage output from the seismometer was split without amplification and sent to three parallel amplifier circuit boards. Each circuit board amplified the seismic signal in three stages and then frequency modulated the signal. Amplification at the last two stages could be set by the user. An internal precision clock signal was also frequency modulated. The three data carrier frequencies, the clock carrier frequency, and a tape-speed compensation carrier frequency were summed and recorded on a cassette tape.

Prior to deployment, field technicians programmed turn-on times into the memory of the recorders to record up to ten shot time windows using a device called a Hand Held Tester (HHT; Healy et al., 1982). One day prior to recording shots, technicians used the HHT to synchronize the clock of each recorder to Greenwich Mean Time (GMT), as determined by a USGS master reference clock (the same clocks used to trigger the shooting system). After the shots were recorded, the clock unit of each instrument was compared to the master reference clock, and a clock (chronometer) drift time (in milliseconds) was recorded in the field notes. USGS master clocks, which drift approximately one millisecond per week, were periodically checked against the standard WWVB time signal.

Information pertaining to the operation of each recorder was entered on field data sheets by the field deployment team. Each field team deployed 20 cassette recorders in the field. Chronometer corrections at shot time were calculated from each clock drift time assuming a linear drift rate (see Field Data Tables). Both the data sheets and the chronometer corrections were written to a file used by the digitizing program. During the digitizing process, the cassette tapes were played back, and the signals were demultiplexed and demodulated. To prevent accidental shifting of the data-carrier frequencies, the tape-speed compensation carrier frequency was demultiplexed and sent to a circuit board that continuously adjusted the speed of the tape deck such that the tape-speed compensation carrier frequency matched a locally generated reference frequency. An analog-to-digital converter converted the signals to digital data that were stored on 8-inch floppy disks. The analog data were digitized for 20 seconds, starting  $(X/6 - 2)$  seconds prior to shot time, where  $X$  is the shot point to recorder distance in kilometers. The sampling rate for digitizing was 200 samples per second. The system response (including recorder and digitizing system) peaked at about 20 Hz (Fig. 2).

## Receiver Locations

Locations and elevations for seismic recording stations and shot points were determined using USGS 1:24,000 topographic maps. All the locations are estimated to be accurate to within 15 meters.

## Receiver Velocity Response

The complete system velocity response  $A_g(t)$  was roughly flat between 2 and 30 Hz and the approximate ground motion is given by:

$$A_g(t) = \frac{A(t)}{R_{GLE} R_{SA} R_{VCO} D_{DSC} D_{ADC}} = \frac{A(t)}{(409.6) R_{SA}}$$

where  $A(t)$  is the amplitude response and  $R_{GLE}$ ,  $R_{SA}$ ,  $R_{VCO}$ ,  $D_{DSC}$ , and  $D_{ADC}$  are the amplitude factors of the major electronic gain components (Fig. 2). Values for these parameters are as follows:

$R_{GLE}$ , 1 Volt/cm/sec

$R_{SA}$ , dimensionless gain variable (Volt/Volt)

$R_{VCO}$ , 25 Hz/Volt

$D_{DSC}$ , 0.04 Volt/Hz

$D_{ADC}$ , 409.6 counts/Volt.

The recording unit also performed and recorded a series of diagnostic tests and calibrations prior to recording each separate shot time window. The calibrations provided a complete system calibration scheme and were used to verify the actual gain of each data channel and the operation of the seismometer.

## Field Data Tables

The field data tables are organized by team-shots, defined as twenty recordings of a shot point made by one of the five deployment teams. Header information for each team-shot includes team numbers, shot numbers, shotpoint numbers, and shot times. Columnized information includes station location numbers (LOC), distance from the shots (DIST; in km), azimuths (AZIM; in degrees from North), unit numbers (UNIT), chronometer corrections (CHRON; in milliseconds; these subtracted from chronometer readings during digitization), channel digitized and gain settings of the three channels (C1, C2, C3), and tape grade codes.



## Tape-Grade Code

A number is assigned to each cassette tape as it is digitized to signify the data quality. These codes appear in the last column of the field data tables.

- 0 - Normal Function
- 1 - Tape Did Not Run
- 2 - Tape Ran But No Signal
- 3 - Tape Skipped Record Time
- 4 - Tape Ran Fast Forward; No Signal
- 5 - Tape Rewound and Erased
- 6 - Weak Signal; Cannot Read Time Code; Low Record Level
- 7 - Noise, Continuous Calibration Or Periodic Offsets
- 8 - Noise, Sinusoidal
- 9 - Noise, Spike
- 10 - Noise, WWVB Cross-Feed
- 11 - Noise, Periodic Ticks
- 12 - Noise, Random
- 13 - Bad Clock
- 14 - Off Frequency, Tape Speed Problem?
- 16 - Incomplete Record; Recorder Stopped
- 17 - Noisy or Weak Time Code
- 19 - Turned on Too Early
- 20 - In For Repair; Not Deployed
- 21 - Geophone Disconnected Or Shorted (?)
- 22 - Wrong Unit Number
- 23 - Wrong Gain Settings
- 24 - Turned on Too Late
- 25 - Bad Geophone Test
- 26 - One or More Channels Missing
- 27 - Noisy or Weak WWVB
- 28 - Instrument or Tape Damaged In Field
- 29 - Wrong Time During Turn-On
- 30 - Digitized Without Calibration
- 31 - Amplifier Out of Balance
- 32 - Location Not on Map; Wrong Location

## SEG Y Tape Format

Appendix 1 presents header information for the SEG Y tapes written for both the experiments described here.

## Seismic Refraction and Aftershock Investigations in Livermore Valley

### Introduction

In response to the 24 January 1980 earthquake ( $M = 5.8$ ), whose epicenter was located 17 km north of Livermore, California (Cockerham et al., 1980), the USGS and Lawrence Livermore National Laboratory (LLNL) conducted aftershock recording and seismic refraction profiling in the Livermore area (Fig. 3).

### Seismic Refraction Profiles

Two reversed seismic-refraction profiles were conducted to better define the compressional-wave velocity structure of the upper crust in the Livermore area (Meltzer et al., 1987). Five separate explosions were fired from three shotpoints and recorded with 100 portable seismic recorders at different azimuths along the Greenville-Diablo fault systems. The North-South profile extended 70 km along the Greenville-Diablo and Tesla fault systems, where station spacing was approximately 0.25 km, and shotpoint 1 and 2 were fired (Fig. 3). The Northwest-Southeast profile extended 75 km from San Ramon southeast to Tracy, California, where shots were fired at shotpoint 3 and shotpoint 1 (Fig. 3). On the Northwest-Southeast profile, station spacing averaged 0.3 to 0.6 km.

Seismograms were recorded along a North-South profile from three separate explosions at shotpoint 1 (shots 1, 2, and 4). These seismograms were combined to produce composite record sections shown in Figures 4 and 6. The seismograms recorded along the profile from shotpoint 2 were from a single explosion. Record sections are plotted with maximum trace amplitudes normalized to a common value. Negative distances on the horizontal axis on the record sections indicate positions north of the shotpoints on the North-South profile and west of the shotpoints on the Northwest-Southeast profile (Figs. 4-7).

Also included in this report are a list of refraction shot point locations and shot times (Appendix 2), seismic recorder locations (Appendix 3), field data files with tape grade codes (Appendices 4-8), and appendices containing the first-arrival travel time picks for the refraction shots (Appendices 9-12).

### Aftershock Records

Shortly after the Livermore mainshock the USGS deployed 100 portable seismographs in the vicinity of Livermore Valley to record aftershocks. One week later the aftershock deployment was repeated, and a 435-kg chemical explosion was detonated 12 km east of the City of Livermore to calibrate station corrections for analysis of the earthquake data.

Five microearthquakes (each recorded by a minimum of 60 stations during the first aftershock deployment) have been digitized, plotted, and are presented in this report without interpretation (Figs. 8-12).

Also included in this report are a list of microearthquake hypocenters and origin times (Appendix 2), seismic recorder locations (Appendix 3), and appendices containing the first-arrival travel time picks for the microearthquakes (Appendices 9-17).

### Data Processing and Picking First-Arrival Times

First-arrival travel times were picked from the record sections using cross-hairs displayed on a computer graphics terminal (Appendices 9-17). Weights were assigned for first-arrival times as follows:

- 0 - Excellent
- 1 - Good
- 2 - Fair
- 3 - Weak or Noisy
- 4 - Poor

Columnized information in Appendices 9-17 includes seismograph location number, weight, unreduced travel-time picks (difference between chronometer reading and origin time of shot), the reduced time ( $T - x/6$ ;  $x$  is distance), distance (km), and azimuth (degrees from North) of the seismograph from the shot point.

## Seismic Refraction Investigations in the Santa Cruz Mountains

### Introduction

In 1981 and 1982, as part of a larger investigation called the San Juan Bautista seismic refraction experiment, the USGS conducted a seismic refraction study of the Santa Cruz mountains in west-central California. Two refraction profiles were acquired, a N-S trending line called the Davenport profile, and a profile subparallel to the San Andreas fault called the La Honda line. The purpose of the experiment was to gain an understanding of the crustal structure west of the San Andreas fault, especially the depth to basement and the basement velocity. Two refraction lines were acquired using three shotpoints (Figure 13). Shotpoint locations and origin times are provided in Appendix 18. Receiver locations are given in Appendix 19.

### Davenport Profile

The first refraction line was a north-south trending profile referred to as the Davenport-Los Altos (D-LA) line (Fig. 13). Shot point 6, at the northernmost end of the line, was located in a quarry near Los Altos. Shot point 5, at the southern end of the line, was in a quarry near the town of Davenport. The Davenport-Los Altos line was 35 km long. The seismic data for this line are shown in Figure 14.

### La Honda Profile

The second refraction line was 70 km long and was called the La Honda line (Fig. 13, squares). Only one shot, shot point 7, in the middle, was recorded along this line. The seismic data for this line are given in Figure 15.

### Field Data Tables

Field data tables, with a format identical to those presented for the 1980 Livermore Valley experiment, are presented in Appendices 20 to 22. Columnized information in these tables includes station location numbers (LOC), distance from the shots (DIST; in km), azimuths (AZIM; in degrees from North), unit numbers (UNIT), chronometer corrections (CHRON; in milliseconds; these subtracted from chronometer readings during digitization), channel digitized and gain settings of the three channels (C1, C2, C3), and tape grade codes. For an explanation of the tape grade codes please see the Methodology section.

### Travel Times

Travel times picked by hand from paper copies of record sections are shown in Appendices 23 to 25. Columnized information in Appendices 23-25 includes seismograph location number, distance (km), unreduced travel-time picks (difference between chronometer reading and origin time of shot), the reduced time ( $T - x/6$ ;  $x$  is distance), and azimuth (degrees from North) of the seismograph from the shot point.

### Interpretation of Travel Times

A preliminary, and previously unpublished, interpretation of the seismic travel times, by Boken and Mooney (1982), is presented in Appendix 26. First arrival travel times were matched by forward modeling using velocity models shown in Figures 16 and 17; the fits to the observed arrivals are shown in Figures 14 and 15. Given the geologic complexity of the study area, the lack of reversal of the La Honda line, and the availability of only 2 shotpoints for the Davenport

line, the models shown in Figures 16 and 17 must be considered as non-unique. The models shown and discussed in Appendix 26 are provided only to provide an indication of the structures sampled by the refraction lines.

### **SUMMARY**

We provide data, including shotpoint times and locations, receiver locations, field data tables, record sections and first arrival travel times for two different seismic refraction studies conducted by the USGS in the San Francisco Bay Area in the early 1980s. In addition, we provide aftershock origin times and locations and first arrival travel times for five aftershocks of the 1980 Livermore earthquake.

### **ACKNOWLEDGEMENTS**

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## Appendix 1. Archive Tape Data Format

Archive data tapes are written in SEG Y standard format (Barry et al., 1975). Recording density is 1600 bits per inch (BPI), phase encoded (PE). In order to accommodate seismic refraction data, some minor changes have been made to the tape header fields. A complete list of header fields is provided in the card image portion of the reel identification header, shown below:

C 1	Reel Identification Header Bytes :
C 2	3217 -3218 Sampling Interval (microsecs).
C 3	3221 -3222 Number of Samples Per Trace.
C 4	3225 -3226 Data Sample Format Code.
C 5	3255 -3256 Measurement System (1 = Meters; 2 = Feet)
C 6	
C 7	
C 8	Trace Identification Header Bytes :
C 9	1 - 4 Trace Sequence Number Within Reel.
C10	5 - 8 Trace Sequence Number Within Reel.
C11	9 - 12 Station Location Number.
C12	29 - 30 Trace ID Code (1 = Seismic Data).
C13	37 - 40 Shotpoint-Receiver Distance (m).
C14	41 - 44 Station Elevation (m).
C15	45 - 48 Shotpoint Elevation (m).
C16	49 - 52 Source Depth (m).
C17	69 - 70 Scalar to be Applied to all Elevations.
C18	71 - 72 Scalar to be Applied to all Coordinates.
C19	73 - 76 Shotpoint Coordinate - X.
C20	77 - 80 Shotpoint Coordinate - Y.
C21	81 - 84 Receiver Coordinate - X.
C22	85 - 88 Receiver Coordinate - Y.
C23	89 - 90 Coordinate Units (1 = Meters; 2 = Seconds of Arc).
C24	115 - 116 Number of Samples in this Trace.
C25	117 - 118 Sample Interval in Microseconds for this Trace.
C26	121 - 122 Instrument Attenuation in dB.
C27	157 - 158 Shot Time - Year.
C28	159 - 160 Shot Time - Day of Year.
C29	161 - 162 Shot Time - Hour of Day (24 Hour Clock).
C30	163 - 164 Shot Time - Minute of Hour.
C31	165 - 166 Shot Time - Second of Minute.
C32	167 - 168 Time Basis Code (2 = Gmt).
C33	181 - 182 Shot Time - Milliseconds.
C34	183 - 184 Shotpoint Location Number.
C35	185 - 186 Recording Instrument Unit Number.
C36	191 - 192 Distance Weighting Exponent (Hundredths).
C37	193 - 194 Shot Sequence Number (Shot Number).
C38	195 - 196 Shot Size (Kg).
C39	197 - 200 Shotpoint - Station Azimuth (Sec of Arc).
C40	201 - 204 Time of First Point Minus Shot Time (Msec)

The data point format is "32 bit floating point", and the appropriate bytes (3225-3226) of the binary reel id header contain a value of 1. The trace amplitudes have not been adjusted for

instrument gain, but the gain correction factor can be estimated from the instrument attenuation value (att) specified in bytes 121-122. To correct for gain, the data should be demeaned and then multiplied by

$$10^{(\text{att}/20)}$$

The measurement system (bytes 3255-3256 of the binary reel header) is set to 1 (meters).

Shotpoint and receiver coordinates are in seconds of arc (byte field 89-90). The coordinate scalar multiplier (bytes 71-72) is set to -100, so the coordinates (bytes 73-88) are in hundredths of a second of arc.

Bytes 157-166 and bytes 181-182 refer to the shot detonation time. The time of the first data sample is found by adding the shot detonation time to the time specified in bytes 201-204.

Since there is no weighting of amplitudes with distance for archive tapes, the distance weighting exponent (bytes 191-192) is not used.

Shot sequence number (bytes 193-194) refers to the order in which shots were fired during the field campaign.

## Appendix 2. Livermore Shotpoints and Earthquakes Locations and Origin Times

### Shotpoint locations and times

Shot Number	Date	Shotpoint Number	Latitude (North)	Longitude (East)	Shot time (GMT) Day Hr MinSec
1.	2/02/1980	1	37 40.20	121 33.18	033 09 00 0.014
2.	3/21/1980	1	37 30.22	121 33.19	081 08 00 0.009
3.	3/21/1980	3	37 46.18	121 56.12	081 11 00 0.010
4.	4/04/1980	1	37 40.21	121 33.18	095 08 00 0.009
5.	4/04/1980	2	37 54.09	121 47.34	095 10 00 0.010

### Microearthquake event locations and times

Event Number	Date	Latitude (North)	Longitude (East)	Event time (GMT) Day Hr Mn Sec
1.	1/25/1980	37 50.25	121 48.69	025 09 04 38.08
2.	1/25/1980	37 48.17	121 47.95	025 23 08 54.77
3.	1/25/1980	37 43.03	121 46.76	025 23 11 34.19
4.	1/26/1980	37 47.22	121 46.66	026 04 03 26.05
5.	1/26/1980	37 45.55	121 44.85	026 04 33 56.68



### Appendix 3. U.S.G.S. Seismic Recorder Locations, Livermore 1980

Loc. No.	Latitude (Deg,Min,Sec)	Longitude (Deg,Min,Sec)	Elevation (feet)
1	37 40 12.3	121 33 10.9	1320
2	37 40 13.5	121 33 11.7	1320
3	37 46 11.3	121 56 07.4	500
4	37 40 12.9	121 33 11.3	1320
5	37 54 05.4	121 47 20.6	350
6	37 17 56.0	121 27 41.2	2140
7	37 29 17.2	121 02 46.5	50
8	38 11 37.6	122 04 20.1	5
9	37 38 24.5	120 43 08.2	150
10	37 05 49.4	120 49 46.4	95
11	37 49 36.1	121 24 37.9	3
12	37 39 55.4	121 39 21.8	1020
101	37 43 36.7	121 43 29.8	530
102	37 44 46.0	121 43 27.4	640
103	37 45 10.9	121 43 51.9	760
104	37 45 53.3	121 44 04.6	890
105	37 46 32.6	121 44 26.2	740
106	37 47 18.7	121 44 53.1	600
107	37 48 04.3	121 44 49.7	490
108	37 49 13.7	121 43 41.5	460
109	37 50 11.7	121 43 35.6	320
110	37 50 49.0	121 42 49.9	340
111	37 50 58.9	121 41 48.3	200
112	37 51 28.5	121 41 40.4	180
113	37 52 30.0	121 41 48.7	125
114	37 52 32.7	121 43 07.3	200
115	37 52 14.4	121 44 08.2	230
116	37 53 47.5	121 42 02.5	110
117	37 54 39.2	121 41 53.6	95
118	37 57 22.6	121 41 41.3	50
119	37 59 01.1	121 41 42.8	25
121	37 56 01.1	121 55 38.7	435
122	37 55 31.1	121 54 54.9	590
124	37 54 32.8	121 52 37.9	1000
125	37 52 33.4	121 51 19.3	774
126	37 52 46.3	121 51 59.6	765
127	37 53 21.0	121 52 06.9	710
128	37 54 22.1	121 52 24.1	734
129	37 53 52.0	121 51 40.4	610
130	37 53 29.9	121 50 54.2	570
131	37 53 11.8	121 50 20.9	515
132	37 53 08.5	121 49 41.1	500
133	37 53 25.8	121 48 23.7	410
134	37 53 33.8	121 47 52.6	365
135	37 53 09.3	121 46 55.1	350
136	37 52 47.9	121 46 18.8	295
137	37 52 26.5	121 45 31.2	280
138	37 53 15.1	121 48 58.9	457
139	37 53 30.3	121 47 25.4	470
140	37 56 29.4	121 55 56.4	400
141	37 43 20.0	121 46 20.4	525
142	37 44 12.1	121 43 52.4	555
143	37 45 07.9	121 46 07.2	604
144	37 45 34.5	121 46 40.3	640
145	37 46 06.2	121 46 48.8	780
146	37 46 30.8	121 46 39.5	950
147	37 46 58.9	121 46 16.0	1187
148	37 47 20.3	121 46 08.2	1460
149	37 47 54.5	121 46 47.9	1840
150	37 48 12.0	121 47 09.0	2020
151	37 48 35.4	121 47 32.4	2091
152	37 49 08.2	121 47 43.7	2020
153	37 49 32.7	121 47 59.4	1800
154	37 50 00.4	121 48 20.0	1620
155	37 50 21.4	121 48 57.8	1260
156	37 50 31.1	121 49 25.8	1160
157	37 50 40.5	121 50 02.0	1040
158	37 51 07.9	121 50 47.4	940
159	37 51 46.4	121 51 09.5	910
160	37 52 15.6	121 51 21.3	840
161	37 42 44.8	121 41 48.3	600
162	37 41 49.8	121 42 11.9	565
163	37 39 53.7	121 43 04.8	650
164	37 39 53.5	121 41 45.5	715
165	37 39 51.4	121 40 51.7	760
166	37 39 41.9	121 40 08.5	830
167	37 39 02.5	121 39 18.6	960
168	37 38 41.9	121 38 45.3	1060
169	37 38 42.6	121 37 44.9	1360
170	37 39 07.1	121 36 47.5	1530
171	37 38 24.9	121 35 32.5	830
172	37 38 16.7	121 34 18.7	755
173	37 38 08.1	121 33 17.0	700
174	37 37 46.7	121 31 54.4	610
175	37 37 54.1	121 30 23.3	539
176	37 38 25.1	121 29 23.6	490
177	37 39 24.5	121 29 05.6	420
178	37 39 58.2	121 27 47.8	310
179	37 42 37.2	121 27 07.3	107
180	37 43 55.5	121 27 06.8	50
181	37 49 09.2	121 58 20.2	470
182	37 48 55.9	121 57 47.3	420
183	37 48 30.3	121 57 00.5	500
184	37 48 10.5	121 56 15.7	540
185	37 47 57.4	121 55 23.7	620
186	37 47 55.8	121 54 39.8	640
187	37 47 59.7	121 53 41.9	726
188	37 47 58.4	121 52 49.3	735
189	37 48 27.8	121 51 28.7	759

190	37 47 35.5	121 51 45.5	710	244	37 44 22.4	121 42 41.5	620
191	37 46 51.6	121 51 41.0	650	245	37 44 49.4	121 42 29.6	610
192	37 46 17.1	121 51 41.9	580	246	37 42 44.0	121 41 47.4	600
193	37 45 43.3	121 51 57.5	550	247	37 42 26.5	121 41 45.9	605
194	37 44 54.3	121 52 15.3	515	248	37 42 10.2	121 41 45.9	600
195	37 44 04.5	121 51 59.8	470	249	37 41 40.4	121 41 43.9	615
196	37 43 32.6	121 52 12.2	430	250	37 41 39.4	121 41 10.5	665
197	37 42 51.4	121 52 14.8	395	251	37 41 39.4	121 40 42.1	710
198	37 40 30.1	121 48 15.8	415	252	37 41 35.1	121 40 18.1	760
199	37 39 20.8	121 48 17.5	420	253	37 41 23.4	121 39 54.6	860
200	37 39 19.5	121 49 32.7	440	254	37 41 09.0	121 39 32.1	940
201	37 48 50.6	122 02 42.3	1040	255	37 41 14.1	121 38 54.4	1120
202	37 48 38.5	122 02 31.0	960	256	37 41 12.5	121 38 24.8	1290
203	37 48 23.3	122 02 08.9	920	257	37 41 11.8	121 37 43.2	1600
204	37 48 10.3	122 01 55.9	920	258	37 41 13.1	121 36 40.5	1260
205	37 47 53.4	122 01 35.1	800	259	37 41 12.5	121 35 48.1	1025
206	37 47 42.5	122 01 06.6	780	260	37 41 51.5	121 35 16.8	721
207	37 47 25.3	122 00 38.3	730	261	37 35 32.4	121 26 03.5	752
208	37 47 13.3	122 00 20.6	730	262	37 35 53.7	121 26 28.5	780
210	37 47 03.4	122 00 00.5	740	263	37 36 11.6	121 27 02.8	820
211	37 46 43.0	121 59 53.1	600	264	37 36 43.7	121 27 27.5	841
212	37 46 14.0	121 58 29.1	440	265	37 37 01.6	121 27 51.2	760
213	37 46 14.5	121 57 32.9	440	266	37 37 05.9	121 28 08.9	720
214	37 46 06.5	121 56 37.0	711	267	37 37 14.0	121 28 22.5	680
215	37 46 11.2	121 56 08.1	510	268	37 37 22.2	121 28 31.4	646
216	37 50 34.6	122 06 06.6	580	269	37 37 36.7	121 28 46.9	630
217	37 50 17.5	122 05 45.8	600	270	37 37 43.9	121 29 03.7	590
218	37 49 51.2	122 05 11.8	800	271	37 37 59.3	121 29 06.9	550
219	37 49 46.7	122 04 22.1	930	272	37 38 10.9	121 29 12.4	520
220	37 50 58.0	122 06 23.5	550	273	37 38 25.1	121 29 23.6	490
221	37 43 37.5	121 43 22.5	530	274	37 38 36.0	121 31 04.0	990
222	37 43 37.1	121 43 56.8	515	275	37 39 01.3	121 31 43.6	1230
223	37 43 50.7	121 43 57.8	530	276	37 39 24.8	121 32 15.0	1340
224	37 43 50.7	121 44 29.1	525	277	37 39 30.0	121 32 52.5	1140
225	37 43 51.3	121 44 46.3	524	278	37 39 59.4	121 33 00.4	1280
226	37 44 15.9	121 44 46.0	545	279	37 40 13.2	121 33 14.9	1320
227	37 44 16.1	121 45 14.2	545	281	37 47 59.0	121 55 35.9	575
228	37 44 16.0	121 46 07.2	555	282	37 47 34.1	121 55 29.4	580
229	37 44 44.8	121 46 08.1	580	283	37 47 10.6	121 55 19.1	540
230	37 45 03.9	121 46 07.6	604	284	37 46 47.3	121 55 19.6	540
231	37 45 08.6	121 46 55.7	620	285	37 46 22.9	121 55 16.2	540
232	37 45 24.1	121 47 28.0	690	286	37 46 01.4	121 55 01.4	500
233	37 45 56.0	121 47 38.9	740	287	37 45 37.5	121 54 53.1	460
234	37 46 06.9	121 47 52.1	780	288	37 47 55.3	121 55 04.9	620
235	37 46 17.5	121 48 34.2	826	289	37 47 52.9	121 54 16.6	600
236	37 46 21.7	121 48 54.3	812	290	37 46 53.3	121 53 55.9	580
237	37 46 33.4	121 49 39.9	720	291	37 47 59.6	121 53 43.0	726
238	37 46 46.6	121 50 10.8	660	292	37 47 58.6	121 52 49.9	735
239	37 46 43.1	121 50 36.3	655	293	37 47 49.8	121 52 05.5	720
240	37 46 33.8	121 51 00.3	660	294	37 47 23.0	121 51 45.9	680
241	37 43 19.5	121 42 33.9	550	295	37 46 58.6	121 51 41.6	650
242	37 43 39.7	121 42 35.9	555	296	37 45 46.2	121 44 06.9	920
243	37 43 59.5	121 42 41.7	550	297	37 52 03.5	121 44 27.0	230

299	37 49 03.6	121 38 28.9	200	352	37 41 40.2	121 40 27.4	735
300	37 47 14.0	121 36 21.9	140	353	37 41 30.1	121 40 07.8	810
301	37 53 15.9	121 46 22.0	380	354	37 41 13.3	121 39 45.8	900
302	37 53 26.8	121 46 07.1	320	355	37 41 09.4	121 39 12.5	1040
303	37 53 43.4	121 45 54.9	270	356	37 41 12.9	121 38 45.6	1120
304	37 53 45.9	121 46 05.8	290	357	37 41 08.3	121 38 11.7	1380
305	37 53 47.8	121 46 20.4	270	358	37 41 11.8	121 37 04.0	1330
306	37 53 56.0	121 46 51.0	310	359	37 41 15.7	121 36 13.6	1130
307	37 54 08.1	121 47 12.9	340	360	37 41 28.1	121 35 29.0	900
308	37 54 05.0	121 47 19.0	350	361	37 36 25.9	121 27 15.4	845
310	37 52 29.4	121 45 37.9	280	362	37 36 32.1	121 27 20.7	845
312	37 52 11.8	121 44 38.2	250	363	37 36 38.1	121 27 24.0	880
313	37 52 16.2	121 44 11.6	230	364	37 36 48.2	121 27 33.6	840
314	37 52 25.6	121 43 29.9	190	365	37 36 55.3	121 27 44.0	790
315	37 52 33.0	121 43 06.1	210	366	37 37 07.7	121 27 59.9	760
316	37 52 38.4	121 42 32.7	234	367	37 37 09.4	121 28 17.1	680
317	37 52 35.1	121 42 08.6	180	369	37 37 22.2	121 28 31.4	646
318	37 52 30.0	121 41 44.1	125	370	37 37 30.5	121 28 37.2	630
319	37 51 59.6	121 41 51.2	180	371	37 37 40.8	121 28 54.4	610
320	37 51 28.2	121 41 40.4	180	372	37 37 53.0	121 29 06.7	570
321	37 35 32.3	121 24 15.0	560	373	37 38 04.3	121 29 12.2	540
322	37 34 58.8	121 25 09.4	640	374	37 38 18.1	121 29 21.5	490
323	37 34 48.3	121 22 25.6	550	375	37 38 29.5	121 30 40.6	940
324	37 34 35.3	121 25 54.6	820	376	37 38 49.7	121 31 26.1	1160
325	37 33 44.7	121 22 24.6	530	377	37 39 08.9	121 32 06.7	1320
326	37 33 28.6	121 22 38.2	580	378	37 39 09.8	121 32 42.8	1050
327	37 33 45.1	121 23 45.2	680	379	37 39 42.6	121 32 56.4	1320
328	37 33 00.8	121 22 07.0	800	380	37 40 13.2	121 33 14.9	1320
329	37 32 44.0	121 21 45.0	1560	381	37 51 29.2	121 41 40.9	180
330	37 32 32.7	121 21 31.8	1280	382	37 43 11.5	121 43 24.0	525
331	37 32 08.4	121 20 31.2	1030	383	37 43 36.5	121 43 24.0	530
332	37 31 25.9	121 20 36.1	910	384	37 43 58.4	121 43 22.0	560
333	37 31 03.2	121 19 55.6	800	385	37 44 24.1	121 43 19.5	590
334	37 30 42.6	121 19 17.5	770	386	37 44 47.5	121 43 27.7	640
335	37 30 14.9	121 19 13.1	720	387	37 45 04.7	121 43 48.9	730
336	37 26 38.6	121 17 32.3	700	388	37 45 28.1	121 43 53.1	880
337	37 27 12.9	121 16 12.3	580	389	37 45 54.1	121 44 04.1	890
341	37 43 08.7	121 42 34.9	555	390	37 46 15.5	121 44 06.1	790
342	37 43 31.2	121 42 35.4	555	391	37 46 33.4	121 44 27.2	750
343	37 43 53.1	121 42 38.8	550	392	37 46 57.2	121 44 41.8	770
344	37 44 09.0	121 42 48.6	560	393	37 47 23.5	121 44 51.7	620
345	37 44 35.1	121 42 38.8	600	394	37 47 52.7	121 44 59.8	580
346	37 42 51.8	121 41 52.2	590	395	37 48 23.9	121 44 27.2	420
347	37 42 36.2	121 41 54.2	600	396	37 48 50.7	121 43 58.2	380
348	37 42 16.0	121 41 44.4	605	397	37 49 25.1	121 43 38.1	367
349	37 41 50.7	121 41 43.9	615	398	37 50 19.8	121 43 32.1	295
350	37 41 39.4	121 41 22.9	655	399	37 50 51.1	121 42 47.0	360
351	37 41 41.0	121 40 52.4	690	400	37 50 58.6	121 41 51.5	210

**Appendix 4. Field Data Table, Livermore, 1980, Shot Point 1 (Shot 1), Shot Time:  
033:09:00:00.014**

Shot Number 1 Team 1

	LOC	DIST (KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	101	16.419	292.6	15	8	3	24	6	42	0
2	102	17.296	299.2	17	3	3	24	6	42	0
3	103	18.198	300.4	24	2	3	24	6	42	0
4	104	19.153	303.3	25	4	3	24	6	42	0
5	105	20.271	305.3	26	0	3	24	6	42	0
6	106	21.645	307.4	32	4	3	24	6	42	0
7	107	22.460	310.4	36	3	3	24	6	42	0
8	108	22.735	317.2	38	5	3	24	6	42	0
9	109	23.985	320.4	44	-11		24	6	42	12
10	110	24.211	324.2	58	0	3	24	6	42	0
11	111	23.616	327.6	94	-3	3	24	6	42	0
12	112	24.292	329.1	60	6	3	24	6	42	0
13	113	26.035	330.9	71	30	3	24	6	42	0
14	114	27.094	327.4	85	0	3	24	6	42	0/30
15	115	27.466	324.2	90	0	3	24	6	42	0
16	116	28.297	332.6	103	1	3	24	6	42	0/30
17	117	29.629	334.4	106	0		24	6	42	7/13
18	118	34.129	338.5	130	8	3	24	6	42	0
19	119	36.983	340.2	146	-6	3	24	6	42	0
20	1	0.000	180.0	125	8	3	24	6	42	0

Shot Number 1 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	121	44.077	311.6	145	6		24	6	42	28
2	122	42.664	311.6	30	2		24	6	42	1
3				33	--		24	6	42	1
4	124	38.974	312.9	34	-3	1	24	6	42	0
5	125	35.092	310.6	49	5	1	24	6	42	0
6	126	36.101	310.1	51	10	1	24	6	42	0
7	127	36.932	311.2	52	6	1	24	6	42	0
8	128	38.503	312.9	55	7	1	24	6	42	0
9	129	37.089	312.9	62	0		24	6	42	28
10	130	35.801	313.4	63	2	3	24	6	42	0
11	131	34.825	313.6	64	4	3	24	6	42	0
12	132	34.056	314.6	142	15	3	24	6	42	0
13	133	33.127	317.6	104	3	3	24	6	42	0
14	134	32.804	318.9	105	10	1	24	6	42	0
15	135	31.315	319.9	110	19	3	24	6	42	0
16	136	30.239	320.4	118	11	3	24	6	42	0
17	137	28.992	321.3	124	-10		24	6	42	1
18	138	33.475	316.1	137	21	3	24	6	42	0
19	139	32.287	319.6	97	2	3	24	6	42	0
20	140	44.980	312.0	10	31	1	24	6	42	0

Shot Number 1 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	141	20.187	286.7	18	-2	3	24	6	42	0
2	142	17.365	295.2	74	17	3	24	6	42	0
3	143	21.084	295.6	65	2		24	6	42	25
4	144	22.172	296.6	35	-13		24	6	42	25
5	145	22.809	298.6	87	0	3	24	6	42	0
6	146	22.985	300.5	143	-7		24	6	42	0
7	147	22.950	303.1	98	13	3	24	6	42	0
8	148	23.158	304.7	76	-11		24	6	42	6/7
9	149	24.561	305.5	40	3	3	24	6	42	0
10	150	25.295	305.8	43	7	3	24	6	42	0
11	151	26.180	306.3	22	6	3	24	6	42	0
12	152	27.011	307.7	113	0	3	24	6	42	0
13	153	27.779	308.5	133	5	3	24	6	42	0
14	154	28.705	309.2	1	13	3	24	6	42	0
15	155	29.831	309.0	79	2	3	24	6	42	0
16	156	30.553	308.6	101	7	1	24	6	42	0
17	157	31.426	308.0	100	9		24	6	42	0
18	158	32.821	308.0	112	12		24	6	42	25
19	159	33.982	309.0	75	7	3	24	6	42	0
20	160	34.775	309.9	89	3	3	24	6	42	0

Shot Number 1 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	161	13.520	290.3	14	2	3	24	6	42	0
2	162	13.590	282.8	19	-14	3	24	6	42	0
3	163	14.567	267.7	39	0	3	24	6	42	0
4	164	12.625	267.4	48	6	3	24	6	42	0
5	165	11.310	266.7	53	11	3	24	6	42	0
6	166	10.276	264.8	56	3		24	6	42	12
7	167	9.264	256.6	66	14	3	24	6	42	0
8	168	8.658	251.2	69	3		24	6	42	1
9	169	7.263	247.6	70	5		24	6	42	1
10	170	5.676	249.3	72	6	3	24	6	42	0
11	171	4.797	226.3	77	6	1	24	6	42	0
12	172	3.932	205.0	93	7	3	24	6	42	0
13	173	3.831	182.2	96	20	3	24	6	42	0
14	174	4.867	157.3	115	-7	3	24	6	42	0
15	175	5.920	136.0	119	0		24	6	42	20
16	176	6.480	120.7	121	0	3	24	6	42	0
17	177	6.192	103.8	122	10	3	24	6	42	0
18	178	7.931	93.1	132	6		24	6	42	1
19	179	9.968	63.4	134	5	3	24	6	42	0
20	180	11.265	52.4	139	2	3	24	6	42	0

Shot Number 1 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	181	40.489	294.1	31	3	3	24	6	42	0
2	182	39.586	294.1	28	14	3	24	6	42	0
3	183	38.222	293.7	23	7	3	24	6	42	0
4	184	36.973	293.5	12	14	3	24	6	42	0
5	185	35.646	293.7	3	6		24	6	42	0
6	186	34.642	294.4	45	2	3	24	6	42	0
7	187	33.409	295.6	73	4	3	24	6	42	0
8	188	32.234	296.5	78	-12		24	6	42	1
9	189	30.915	299.6	82	3	3	24	6	42	0
10	190	30.520	296.6	83	13		24	6	42	25
11	191	29.841	294.4	88	7	3	24	6	42	0
12	192	29.441	292.5	92	6	3	24	6	42	0
13	193	29.418	290.3	99	7	3	24	6	42	0
14	194	29.348	287.2	107	7	3	24	6	42	0
15	195	28.565	284.5	108	39	1	24	6	42	0
16	196	28.632	282.5	120	6	3	24	6	42	0
17	197	28.451	279.9	128	7		24	6	42	25
18	198	22.183	271.4	129	2	1	24	6	42	0
19	199	22.276	265.9	131	9	3	24	6	42	0
20	200	24.117	266.1	136	15		24	6	42	3

**Appendix 5. Field Data Table, Livermore, 1980, Shot Point 1 (Shot 2), Shot Time:  
081:08:00:00.009**

Shot Number 2 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	201	46.188	290.2	15	8	2	24	6	42	0
2	202	45.802	289.9	17	5	1	24	6	42	0
3	203	45.136	289.5	24	2	1	24	6	42	0
4	204	44.703	289.2	25	-3	1	24	6	42	0
5	205	44.053	288.8	26	-2	1	24	6	42	0
6	206	43.286	288.6	32	3	1	24	6	42	0
7	207	42.461	288.3	36	4	1	24	6	42	0
8	208	41.936	288.0	38	4	1	24	6	42	0
9				44	--		24	6	42	20
10	210	41.374	287.8	58	5	1	24	6	42	0
11	211	41.015	287.0	60	-3	1	24	6	42	0
12	212	38.789	286.6	71	-2		24	6	42	3
13	213	37.477	287.3	85	31		24	6	42	25
14	214	36.098	287.6	90	0	1	24	6	42	0
15	215	35.468	288.1	94	7		24	6	42	25
16	216	51.997	291.6	103	2		24	6	42	1
17	217	51.334	291.3	106	-2		24	6	42	3
18	218	50.267	290.8	125	11	1	24	6	42	0
19	219	49.082	291.1	130	-6		24	6	42	1
20	220	52.647	292.2	146	4		24	6	42	8/12

Shot Number 2 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	221	16.231	292.8	10	44	2	24	6	42	0
2	222	17.004	291.7	30	9	2	24	6	42	1
3	223	17.185	292.9	33	0		24	6	42	0
4	224	17.896	292.0	34	-82		24	6	42	0
5	225	18.293	291.5	49	15	2	24	6	42	0
6	226	18.577	293.7	51	19		24	6	42	25
7	227	19.214	292.9	52	0	2	24	6	42	0
8	228	20.414	291.5	55	17		24	6	42	12
9	229	20.777	293.7	62	0		24	6	42	0
10	230	21.009	295.2	63	5	2	24	6	42	1
11	231	22.138	294.3	64	11		24	6	42	12
12	232	23.057	294.5	97	9		24	6	42	12
13	233	23.719	296.4	104	7	2	24	6	42	0
14	234	24.159	296.8	105	26	3	24	6	42	0
15	235	25.226	296.4	110	26	3	24	6	42	0
16	236	25.725	296.2	118	17	3	24	6	42	0
17	237	26.886	295.8	124	-22	2	24	6	42	15/25
18	238	27.745	295.9	137	39	2	24	6	42	0
19	239	28.262	295.2	142	31	2	24	6	42	0
20	240	28.677	294.1	145	17	2	24	6	42	0

Shot Number 2 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	241	14.920	292.6	43	8	1	24	6	42	0
2	242	15.212	294.7	1	13		24	6	42	1
3	243	15.606	296.5	79	2	1	24	6	42	0
4	244	15.927	298.8	101	7	1	24	6	42	0
5	245	16.097	301.9	18	-2		24	6	42	3
6	246	13.459	290.2	87	0		24	6	42	1
7	247	13.249	288.0	65	3		24	6	42	12
8	248	13.102	285.9	112	13	1	24	6	42	0
9	249	12.835	282.1	22	6	1	24	6	42	0
10	250	12.028	282.7	89	3		24	6	42	1
11	251	11.350	283.5	74	18	1	24	6	42	0
12	252	10.747	283.5	113	0	1	24	6	42	0
13	253	10.106	282.3	35	-12	1	24	6	42	0
14	254	9.477	280.4	75	7	1	24	6	42	0
15	255	8.602	282.5	98	13	1	24	6	42	0
16	256	7.886	283.3	40	4	1	24	6	42	0
17	257	6.891	285.1	100	9		24	6	42	15/25
18	258	5.437	289.8	76	-12	3	24	6	42	0
19	259	4.244	295.4	143	-7	3	24	6	42	0
20	260	4.303	314.6	133	6	3	24	6	42	0

Shot Number 2 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	261	13.612	129.5	14	2	1	24	6	68	0
2	262	12.724	129.0	19	-15	2	24	6	68	0
3	263	11.722	129.5	39	1	3	24	6	68	0
4	264	10.632	127.5	48	-3	1	24	6	68	0
5				53	0		24	6	68	20
6	265	9.835	127.0	56	3	1	24	6	68	0
7	266	9.410	127.9	66	7	1	24	6	68	0
8	267	8.994	128.0	69	3	1	24	6	68	0
9	268	8.666	127.5	70	4		24	6	68	12
10	269	8.094	126.7	72	9	1	24	6	68	0
11	270	7.631	127.2	77	5	3	24	6	68	0
12	271	7.290	124.6	93	6	3	24	6	68	0
13	272	6.977	122.8	96	17	3	24	6	68	0
14	273	6.514	120.9	115	-4	3	24	6	68	0
15	274	4.339	133.8	119	-9		24	6	88	12
16	275	3.101	135.8	121	-2	3	24	6	68	0
17	276	2.045	137.2	122	13	3	24	6	68	0
18	277	1.420	160.7	132	6		24	6	68	1
19	278	0.516	147.4	134	4	3	24	6	68	0
20	279	0.078	264.4	139	2	3	24	6	68	0



Shot Number 2 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	281	35.907	293.6	136	26	2	24	6	42	0
2	282	35.461	292.5	131	19	2	24	6	42	0
3	283	34.957	291.6	129	7		24	6	42	12/15
4	284	34.712	290.5	128	13	2	24	6	42	0
5	285	34.378	289.3	120	10	2	24	6	42	0
6	286	33.821	288.5	108	45		24	6	42	6/13
7	287	33.404	287.4	107	13		24	6	42	12
8	288	35.166	293.9	99	11		24	6	42	1
9	289	34.058	294.6	92	13	2	24	6	42	0
10	290	32.867	292.0	88	18		24	6	42	12
11	291	33.398	295.5	83	24	2	24	6	42	0
12	292	32.216	296.4	82	6		24	6	42	12
13	293	31.124	296.9	78	-21		24	6	42	12
14	294	30.327	295.9	73	8		24	6	42	25
15	295	29.911	294.7	45	3		24	6	42	3
16	296	19.044	302.6	31	6	2	24	6	42	0
17	297	27.430	322.9	28	27		24	6	42	12
18				23	0		24	6	42	1
19	299	18.093	334.6	12	25	2	24	6	42	0
20	300	13.778	340.2	3	13		24	6	42	1

**Appendix 6. Field Data Table, Livermore, 1980, Shot Point 3 (Shot 3), Shot Time:  
081:11:00:00.010**

Shot Number 3 Team 1

	<u>LOC</u>	<u>DIST(KM)</u>	<u>AZIM</u>	<u>UNIT</u>	<u>CHRON</u>	<u>CHAN</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>TAPE GRADE</u>
1	201	10.838	296.9	15	9	3	24	6	42	0
2	202	10.426	295.8	17	5	3	24	6	42	0
3	203	9.738	294.7	24	2	3	24	6	42	0
4	204	9.283	293.3	25	-3	3	24	6	42	0
5	205	8.614	291.4	26	-3	3	24	6	42	0
6	206	7.843	291.0	32	3	3	24	6	42	0
7	207	7.011	289.0	36	5	3	24	6	42	0
8	208	6.485	287.1	38	5	3	24	6	42	0
9				44	--		24	6	42	20
10	210	5.927	285.7	58	6	3	24	6	42	0
11	211	5.611	280.0	60	-4	3	24	6	42	0
12	212	3.470	271.3	71	-3	3	24	6	42	0
13	213	2.096	272.7	85	37	3	24	6	42	0
14	214	0.741	258.6	90	0	3	24	6	42	0
15	215	0.018	262.0	94	8	3	24	6	42	0
16	216	16.756	299.0	103	2		24	6	42	1
17	217	16.059	298.2	106	-2		24	6	42	12
18	218	14.945	297.0	125	13	1	24	6	42	0
19	219	13.806	298.7	130	-8		24	6	42	1
20	220	17.471	300.4	146	5	1	24	6	42	0

Shot Number 3 Team 2

	<u>LOC</u>	<u>DIST(KM)</u>	<u>AZIM</u>	<u>UNIT</u>	<u>CHRON</u>	<u>CHAN</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>TAPE GRADE</u>
1	221	19.316	104.2	10	48		24	6	42	12
2	222	18.507	104.9	30	6		24	6	42	1
3	223	18.380	103.6	33	--		24	6	42	0
4	224	17.634	104.2	34	-6	1	24	6	42	0
5	225	17.223	104.5	49	14		24	6	42	25
6	226	17.055	102.0	51	27		24	6	42	25
7	227	16.379	102.5	52	16	1	24	6	42	0
8	228	15.117	103.6	55	19	3	24	6	42	0
9	229	14.908	100.3	62	-2		24	6	42	0
10	230	14.826	098.1	63	6	1	24	6	42	1
11	231	13.642	098.2	64	10	3	24	6	42	0
12	232	12.794	096.5	97	9		24	6	42	0
13	233	12.455	092.2	104	8	3	24	6	42	0
14	234	12.122	090.6	105	27	3	24	6	42	0
15	235	11.092	089.0	110	48	3	24	6	42	0
16	236	10.603	088.3	118	28	3	24	6	42	0
17	237	9.507	085.9	124	-23	3	24	6	42	0
18	238	8.794	082.9	137	53		24	6	42	13
19	239	8.162	083.1	142	39	3	24	6	42	0
20	240	7.546	084.7	145	16	3	24	6	42	0

## Shot Number 3 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	241	20.608	104.9	43	19		24	6	42	15
2	242	20.409	103.2	1	31		24	6	42	1
3	243	20.136	101.6	79	6	1	24	6	42	0
4	244	20.012	099.7	101	17	1	24	6	42	0
5	245	20.176	097.2	18	-2	1	24	6	42	0
6	246	22.005	106.9	87	2		24	6	42	1
7	247	22.202	108.2	65	7	1	24	6	42	0
8	248	22.365	109.4	112	30	1	24	6	42	0
9	249	22.732	111.6	22	15	1	24	6	42	0
10	250	23.506	110.9	89	8		24	6	42	1
11	251	24.157	110.3	74	42	1	24	6	42	0
12	252	24.755	110.1	113	0	1	24	6	42	0
13	253	25.420	110.4	35	-15	1	24	6	42	0
14	254	26.094	110.9	75	9	1	24	6	42	0
15	255	26.904	109.9	98	31	1	24	6	42	0
16	256	27.601	109.5	40	9	1	24	6	42	0
17	257	28.572	108.9	100	22		24	6	42	3
18	258	30.016	107.8	76	-24	1	24	6	42	0
19	259	31.245	107.1	143	-14	1	24	6	42	0
20	260	31.653	104.7	133	14	1	24	6	42	0

## Shot Number 3 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	261	48.390	114.0	14	3	2	24	6	42	0
2	262	47.565	113.6	19	-18	2	24	6	42	3
3	263	46.572	113.4	39	1	2	24	6	42	1
4	264	45.626	112.6	48	-4	2	24	6	42	0
5				53	0		24	6	42	25
6	265	44.878	112.2	56	3	2	24	6	42	0
7	266	44.426	112.2	66	9	2	24	6	42	0
8	267	44.023	112.1	69	4	2	24	6	42	0
9	268	43.725	111.9	70	5		24	6	42	25
10	269	43.207	111.5	72	12	1	24	6	42	0
11	270	42.742	111.5	77	6	1	24	6	42	0
12	271	42.497	110.9	93	7	1	24	6	42	0
13	272	42.242	110.5	96	21	1	24	6	42	0
14	273	41.833	110.1	115	-5	1	24	6	42	0
15	274	39.409	110.9	119	-12	1	24	6	42	0
16	275	38.227	110.3	121	-3		24	6	42	3
17	276	37.254	109.7	122	16	1	24	6	42	0
18	277	36.334	109.9	132	7		24	6	42	1
19	278	35.853	108.7	134	5		24	6	42	12
20	279	35.380	108.2	139	2	1	24	6	42	0

Shot Number 3 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	281	3.410	13.1	136	28	3	24	6	42	0
2	282	2.715	20.0	131	21	3	24	6	42	0
3	283	2.177	32.9	129	7	3	24	6	42	0
4	284	1.613	46.5	128	15	3	24	6	42	0
5	285	1.303	74.1	120	12	3	24	6	42	0
6	286	1.644	100.7	108	49	3	24	6	42	0
7	287	2.095	119.8	107	14	3	24	6	42	0
8	288	3.552	25.5	99	12		24	6	42	1
9	289	4.141	40.9	92	14	3	24	6	42	0
10	290	3.469	68.1	88	19	3	24	6	42	0
11	291	4.861	46.6	83	27	3	24	6	42	0
12	292	5.855	55.6	82	6	3	24	6	42	0
13	293	6.653	62.8	78	-23	3	24	6	42	0
14	294	6.770	70.9	73	9	3	24	6	42	0
15	295	6.667	77.4	45	3	3	24	6	42	0
16	296	17.652	92.5	31	7	1	24	6	42	0
17	297	20.282	57.6	28	30	1	24	6	42	0
18				23	0		24	6	42	1
19	299	26.436	78.4	12	27	1	24	6	42	0
20	300	29.074	86.2	3	14		24	6	42	1

**Appendix 7. Field Data Table, Livermore, 1980, Shot Point 1 (Shot 4), Shot  
Time:095:08:00:00.009**

Shot Number 4 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	301	30.939	321.3	15	5	1	24	6	42	0
2	302	30.976	322.2	17	0	1	24	6	42	0
3	303	31.202	323.2	24	1		24	6	42	3
4	304	31.423	322.9	25	-4	1	24	6	42	0
5	305	31.687	322.5	26	--	1	24	6	42	0
6	306	32.347	321.7	32	1	1	24	6	64	0
7	307	32.971	321.3	36	2		24	6	72	3
8	308	32.990	321.0	38	5		24	6	96	3
9				44	-13		24	6	42	1
10	310	29.145	321.2	58	--	1	24	6	42	0
11				60	-6		24	6	42	1
12	312	27.818	322.8	71	-10	1	24	6	42	0
13	313	27.540	324.1	85	25	1	24	6	42	0
14	314	27.192	326.2	90	--	3	24	6	42	0
15	315	27.067	327.5	94	6	1	24	6	42	0
16	316	26.778	329.1	103	2	1	24	6	42	0
17	317	26.392	330.1	106	-2		24	6	42	3
18	318	25.960	331.1	125	8	1	24	6	42	0
19	319	25.232	329.7	130	-6		24	6	42	12
20	320	24.264	329.1	146	0		24	6	42	25

Shot Number 4 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	321	15.741	123.3	10	0		24	6	42	1
2	322	15.277	129.3	30	8	1	24	6	42	0
3	323	18.731	122.3	33	11	3	24	6	42	0
4	324	14.933	134.2	34	-7		24	6	42	1
5	325	19.868	127.0	49	17		24	6	42	1
6	326	19.911	128.8	51	32		24	6	42	1
7	327	18.322	130.7	52	20		24	6	42	1
8	328	21.047	129.3	55	23		24	6	42	1
9	329	21.791	129.4	62	-2		24	6	42	1
10	330	22.263	129.6	63	8	2	24	6	42	0
11	331	23.889	128.7	64	12		24	6	42	1
12	332	24.641	131.3	97	0		24	6	42	1
13	333	25.851	131.0	104	10	2	24	6	42	0
14	334	26.975	130.7	105	32	2	24	6	42	0
15	335	27.618	131.9	110	58	2	24	6	42	0
16	336	34.079	137.4	118	34		24	6	42	1
17	337	34.696	133.9	124	-28	1	24	6	42	0
18				137	64		24	6	42	20
19				142	47		24	6	42	20
20				145	19		24	6	42	20

## Shot Number 4 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	341	14.832	291.4	43	23	3	24	6	42	0
2	342	15.111	293.9	1	37	3	24	6	42	0
3	343	15.471	296.0	79	7	3	24	6	42	0
4	344	15.905	297.2	101	20	3	24	6	42	0
5	345	16.080	300.2	18	-3	3	24	6	42	0
6	346	13.671	291.0	87	3		24	6	42	1
7	347	13.553	289.0	65	9	3	24	6	42	0
8	348	13.133	286.8	112	36	3	24	6	42	0
9	349	12.918	283.5	22	18	3	24	6	42	0
10	350	12.337	282.5	89	10		24	6	42	1
11	351	11.620	283.5	74	50	3	24	6	42	0
12	352	11.020	284.1	113	0	3	24	6	42	0
13	353	10.480	283.1	35	-12	3	24	6	42	0
14	354	9.845	280.9	75	5	3	24	6	42	0
15	355	9.020	281.1	98	38		24	6	42	1
16	356	8.397	282.7	40	11	3	24	6	42	0
17	357	7.558	283.1	100	27	3	24	6	42	0
18	358	5.985	287.7	76	-29		24	6	54	1
19	359	4.868	293.4	143	-17	1	24	6	68	0
20	360	4.094	304.5	133	17		24	6	64	1

## Shot Number 4 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	380	0.088	276.6	14	5	3	24	6	94	0
2	379	1.004	158.7	19	-33	3	24	6	94	0
3	378	2.067	160.3	39	1		24	6	94	12
4	377	2.531	141.3	48	-5	3	24	6	54	0
5	376	3.638	134.8	53	25	3	24	6	54	0
6	375	4.879	130.8	56	6	3	24	6	42	0
7	374	6.652	122.1	66	16	3	24	6	42	0
8	373	7.075	124.1	69	3	3	24	6	42	0
9	372	7.386	125.7	70	4	3	24	6	42	0
10	371	7.851	126.7	72	14	3	24	6	42	0
11	370	8.379	126.7	77	13	3	24	6	42	0
12	369	8.647	127.5	93	14	3	24	6	42	0
13				96	45		24	6	42	1
14	367	9.166	128.1	115	-3	3	24	6	42	0
15	366	9.534	126.8	119	-27		24	6	42	6/13
16	365	10.075	127.2	121	-3		24	6	42	6/13
17	364	10.410	127.3	122	33	3	24	6	42	0
18	363	10.786	127.9	132	10	3	24	6	42	0
19	362	10.965	128.4	134	11	3	24	6	42	0
20	361	11.185	128.7	139	4	3	24	6	42	0

Shot Number 4 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	381	24.297	329.1	3	6		24	6	42	13
2	382	15.988	290.1	12	12		24	6	42	6
3	383	16.268	292.7	23	5	1	24	6	42	0
4	384	16.496	294.9	28	13	1	24	6	42	0
5	385	16.792	297.5	31	3	3	24	6	42	0
6	386	17.309	299.3	45	1	1	24	6	42	0
7	387	18.023	299.9	73	3	1	24	6	42	0
8	388	18.481	301.7	78	-10		24	6	42	1
9	389	19.138	303.3	82	5	1	24	6	42	0
10	390	19.548	304.9	83	11	3	24	6	42	0
11	391	20.287	305.3	88	7	3	24	6	42	0
12	392	21.008	306.4	92	5	3	24	6	42	0
13	393	21.688	307.7	99	7	1	24	6	42	0
14	394	22.404	309.3	107	6	1	24	6	42	0
15	395	22.428	312.4	108	17	1	24	6	42	0
16	396	22.488	315.2	120	4	1	24	6	42	0
17	397	22.920	318.0	128	5		24	6	42	25
18	398	24.103	320.9	129	3	1	24	6	42	0
19	399	24.200	324.4	131	8	3	24	6	42	0
20	400	23.632	327.4	136	11	1	24	6	42	0

**Appendix 8. Field Data Table, Livermore, 1980, Shot Point 2 (Shot 5), Shot  
Time:095:10:00:00.010**

Shot Number 5 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	301	2.092	136.8	15	6	3	24	6	42	0
2	302	2.154	123.5	17	0		24	6	42	3
3	303	2.201	107.9	24	1	3	24	6	42	0
4	304	1.924	108.2	25	-5	3	24	6	42	0
5	305	1.569	110.2	26	--	3	24	6	42	0
6	306	0.779	111.8	32	1	3	24	6	64	0
7	307	0.206	66.4	36	2	3	24	6	72	0
8	308	0.042	108.9	38	5	3	24	6	96	0
9				44	-15		24	6	42	1
10	310	3.881	139.7	58	--	3	24	6	42	0
11				60	-7		24	6	42	1
12	312	5.294	131.4	71	-12	3	24	6	42	0
13	313	5.716	126.1	85	29	3	24	6	42	0
14	314	6.424	118.6	90	--	3	24	6	42	0
15	315	6.840	114.6	94	7		24	6	42	6/13
16	316	7.529	110.9	103	2	3	24	6	42	0
17	317	8.117	110.1	106	-2	3	24	6	42	0
18	318	8.733	109.7	125	10	3	24	6	42	0
19	319	8.935	115.7	130	-7		24	6	42	3
20	320	9.624	120.2	146	0	2	24	6	42	0

Shot Number 5 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	321	48.254	135.3	10	0		24	6	42	1
2	322	48.081	137.3	30	5	1	24	6	42	0
3	323	51.112	134.3	33	12	1	24	6	42	0
4	324	47.883	138.9	34	0		24	6	42	1
5	325	52.519	135.8	49	0		24	6	42	1
6	326	52.647	136.4	51	0		24	6	42	1
7	327	51.154	137.3	52	0		24	6	42	1
8	328	53.797	136.4	55	0		24	6	42	1
9	329	54.543	136.4	62	0		24	6	42	1
10	330	55.018	136.4	63	2	1	24	6	42	0
11	331	56.588	135.8	64	0		24	6	42	1
12	332	57.457	136.8	97	0		24	6	42	1
13	333	58.647	136.6	104	13	1	24	6	42	0
14	334	59.752	136.4	105	13	1	24	6	42	0
15	335	60.447	136.9	110	8	1	24	6	42	0
16	336	67.069	139.2	118	0		24	6	42	1
17	337	67.584	137.4	124	-7	1	24	6	42	0
18				137	0		24	6	42	20
19				142	0		24	6	42	20
20				145	0		24	6	42	20



## Shot Number 5 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	341	21.420	161.0	43	9	3	24	6	42	0
2	342	20.759	160.4	1	12	3	24	6	42	0
3	343	20.098	159.9	79	-2	3	24	6	42	0
4	344	19.554	160.1	101	8	3	24	6	42	0
5	345	18.886	158.6	18	0	3	24	6	42	0
6	346	22.267	158.9	87	-3		24	6	42	1
7	347	22.698	159.4	65	1	3	24	6	42	0
8	348	23.367	159.4	112	8	3	24	6	42	0
9	349	24.103	160.0	22	5	3	24	6	42	0
10	350	24.608	159.2	89	20		24	6	42	3
11	351	24.839	157.5	74	12	3	24	6	42	0
12	352	25.101	156.3	113	--	3	24	6	42	0
13	353	25.582	155.5	35	-14	3	24	6	42	0
14	354	26.276	154.9	75	6	3	24	6	42	0
15	355	26.739	153.5	98	8		24	6	42	3
16	356	26.944	152.1	40	3	3	24	6	42	0
17	357	27.467	150.7	100	11	3	24	6	42	0
18	358	28.222	147.7	76	-17		24	6	54	1
19	359	28.801	145.5	143	-21	1	24	6	68	0
20	360	29.124	143.3	133	6		24	6	64	1

## Shot Number 5 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	380	32.962	141.1	14	5	1	24	6	94	0
2	379	33.983	141.5	19	-35	1	24	6	94	0
3	378	34.984	142.1	39	1		24	6	94	25
4	377	35.556	141.0	48	-6	3	24	6	54	0
5	376	36.644	140.4	53	27	1	24	6	54	0
6	375	37.836	139.7	56	6	1	24	6	42	0
7	374	39.376	137.9	66	17	1	24	6	42	0
8	373	39.844	138.0	69	4	1	24	6	42	0
9	372	40.195	138.2	70	5	1	24	6	42	0
10	371	40.676	138.3	72	15	3	24	6	42	0
11	370	41.193	138.1	77	14	3	24	6	42	0
12	369	41.479	138.2	93	15	1	24	6	42	0
13				96	48		24	6	42	1
14	367	42.008	138.2	115	-3	1	24	6	42	0
15	366	42.329	137.8	119	-28	3	24	6	42	0
16	365	42.874	137.8	121	-3		24	6	42	6
17	364	43.207	137.7	122	35	3	24	6	42	0
18	363	43.594	137.8	132	11	1	24	6	42	0
19	362	43.788	137.9	134	12	1	24	6	42	0
20	361	44.015	137.9	139	5	1	24	6	42	0

Shot Number 5 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	381	9.598	120.1	3	7	3	24	6	42	0
2	382	20.975	164.0	12	13		24	6	42	1
3	383	20.235	163.4	23	6		24	6	42	25
4	384	19.605	162.7	28	15	3	24	6	42	0
5	385	18.867	161.8	31	3	3	24	6	42	0
6	386	18.120	161.7	45	1	3	24	6	42	0
7	387	17.457	162.7	73	4	3	24	6	42	0
8	388	16.737	162.4	78	-11		24	6	42	1
9	389	15.891	162.4	82	6	3	24	6	42	0
10	390	15.249	161.8	83	13	3	24	6	42	0
11	391	14.566	163.1	88	8	3	24	6	42	0
12	392	13.760	163.6	92	6	3	24	6	42	0
13	393	12.914	163.6	99	8	3	24	6	42	0
14	394	11.994	163.3	107	6	3	24	6	42	0
15	395	11.351	158.1	108	20	3	24	6	42	0
16	396	10.891	153.0	120	5	3	24	6	42	0
17	397	10.211	147.8	128	6		24	6	42	12
18	398	8.922	141.2	129	3	3	24	6	42	0
19	399	8.979	131.9	131	9	3	24	6	42	0
20	400	9.892	125.6	136	12	3	24	6	42	0

### Appendix 9. First-Arrival Times: Livermore North-South Profile, Shotpoint Number 1

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.						
						367	1	2.843	1.316	9.166	128.117
						369	1	2.716	1.275	8.647	127.486
						370	1	2.625	1.229	8.379	126.680
						371	1	2.462	1.153	7.851	126.668
						372	0	2.350	1.119	7.386	125.715
						373	1	2.240	1.061	7.075	124.073
102	2	4.813	1.930	-17.296	299.196	374	0	2.158	1.049	6.652	122.142
103	3	4.992	1.959	-18.198	300.386	375	0	1.711	0.898	4.879	130.803
104	2	5.116	1.924	-19.153	303.292	376	0	1.371	0.765	3.638	134.833
105	1	5.372	1.994	-20.271	305.338	377	0	1.013	0.591	2.531	141.270
108	1	5.829	2.040	-22.735	317.232	379	1	0.439	0.272	1.004	158.724
110	3	6.128	2.092	-24.211	324.171	380	0	0.038	0.023	0.088	276.623
111	3	6.226	2.290	-23.616	327.575	383	2	4.589	1.878	-16.268	292.694
113	1	6.872	2.533	-26.035	330.874	384	2	4.656	1.907	-16.496	294.921
128	3	8.666	2.249	-38.503	312.877	385	1	4.735	1.936	-16.792	297.466
130	2	8.256	2.290	-35.801	313.382	386	2	4.792	1.907	-17.309	299.279
131	2	8.111	2.307	-34.825	313.636	387	1	4.963	1.959	-18.023	299.940
132	2	7.879	2.203	-34.056	314.644	389	1	5.137	1.948	-19.138	303.341
133	1	7.909	2.388	-33.127	317.602	390	2	5.182	1.924	-19.548	304.882
134	1	7.763	2.295	-32.804	318.876	391	1	5.387	2.006	-20.287	305.327
135	3	7.578	2.359	-31.315	319.903	392	2	5.466	1.965	-21.008	306.395
136	2	7.399	2.359	-30.239	320.385	393	2	5.568	1.953	-21.688	307.745
140	3	9.595	2.098	-44.980	312.045	394	2	5.763	2.029	-22.404	309.254
176	0	2.059	0.979	-6.480	120.671	396	3	5.777	2.029	-22.488	315.228
196	3	7.288	2.516	-28.632	282.456	398	2	6.179	2.162	-24.103	320.917
301	3	7.516	2.359	-30.939	321.286	400	3	6.118	2.179	-23.632	327.394
304	4	7.620	2.382	-31.423	322.906						
305	4	7.664	2.382	-31.687	322.457						
306	4	7.750	2.359	-32.347	321.676						
310	3	7.199	2.342	-29.145	321.175						
312	3	6.949	2.313	-27.818	322.819						
313	3	6.938	2.348	-27.540	324.071						
314	3	6.926	2.394	-27.192	326.170						
315	3	6.940	2.429	-27.067	327.463						
316	3	6.834	2.371	-26.778	329.129						
318	3	6.860	2.533	-25.960	331.089						
322	1	4.343	1.797	15.277	129.333						
323	2	5.150	2.029	18.731	122.291						
330	3	5.310	1.600	22.263	129.587						
333	3	5.908	1.600	25.851	130.962						
334	2	6.095	1.600	26.975	130.681						
335	2	6.116	1.513	27.618	131.874						
337	4	7.429	1.646	34.696	133.875						
341	2	4.292	1.820	-14.832	291.428						
342	1	4.368	1.849	-15.111	293.870						
343	2	4.410	1.832	-15.471	296.022						
344	2	4.500	1.849	-15.905	297.236						
345	1	4.413	1.733	-16.080	300.177						
347	2	4.003	1.745	-13.553	289.029						
348	2	3.951	1.762	-13.133	286.797						
349	1	3.909	1.756	-12.918	283.496						
351	2	3.560	1.623	-11.620	283.510						
352	2	3.349	1.513	-11.020	284.134						
353	2	3.213	1.466	-10.480	283.121						
354	0	3.072	1.432	-9.845	280.908						
356	0	2.750	1.350	-8.397	282.734						
357	1	2.483	1.223	-7.558	283.051						
359	0	1.739	0.927	-4.868	293.420						
361	1	3.429	1.565	11.185	128.729						
362	1	3.375	1.548	10.965	128.379						
363	1	3.316	1.519	10.786	127.869						
364	1	3.213	1.478	10.410	127.317						

### Appendix 10. First-Arrival Times: Livermore North-South Profile, Shotpoint Number 2

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.						
						385	3	5.022	1.878	18.867	161.787
						386	3	4.855	1.835	18.120	161.673
						387	3	4.727	1.817	17.457	162.747
						389	1	4.261	1.613	15.891	162.398
						390	1	4.080	1.539	15.249	161.819
						391	0	3.901	1.474	14.566	163.070
						392	0	3.689	1.395	13.760	163.612
						393	0	3.461	1.308	12.914	163.617
						394	0	3.234	1.235	11.994	163.320
						395	0	3.022	1.130	11.351	158.072
						396	0	2.976	1.161	10.891	152.973
						398	1	2.535	1.048	8.922	141.232
						399	1	2.562	1.065	8.979	131.858
						400	0	2.866	1.217	9.892	125.604
301	0	0.714	0.365	2.092	136.809						
303	0	0.775	0.408	2.201	107.945						
304	1	0.677	0.356	1.924	108.218						
305	0	0.531	0.269	1.569	110.194						
306	0	0.295	0.165	0.779	111.819						
307	0	0.121	0.087	0.206	066.353						
308	0	0.011	0.004	0.042	108.892						
310	0	1.264	0.617	3.881	139.706						
312	0	1.656	0.774	5.294	131.431						
313	0	1.813	0.861	5.716	126.078						
314	0	2.049	0.978	6.424	118.628						
316	0	2.437	1.182	7.529	110.871						
317	0	2.653	1.300	8.117	110.051						
318	0	2.764	1.308	8.733	109.682						
320	1	2.834	1.230	9.624	120.241						
322	2	10.466	2.452	48.081	137.323						
323	3	11.079	2.561	51.112	134.261						
330	3	10.987	1.817	55.018	136.416						
333	4	11.522	1.748	58.647	136.602						
334		11.667	1.708	59.752	136.370						
335	3	11.648	1.574	60.447	136.852						
337		13.129	1.865	67.584	137.356						
341		5.683	2.113	21.420	160.954						
342	3	5.538	2.078	20.759	160.359						
343	3	5.363	2.013	20.098	159.941						
344	3	5.220	1.961	19.554	160.107						
345	3	4.969	1.822	18.886	158.594						
347	3	6.035	2.252	22.698	159.404						
348	3	6.207	2.313	23.367	159.390						
349	2	6.330	2.313	24.103	160.017						
351	3	6.401	2.261	24.839	157.518						
352	2	6.466	2.282	25.101	156.251						
353	2	6.629	2.365	25.582	155.548						
354	2	6.657	2.278	26.276	154.943						
356	2	6.795	2.304	26.944	152.114						
357	2	6.882	2.304	27.467	150.729						
359	2	7.065	2.265	28.801	145.484						
361	2	9.792	2.456	44.015	137.911						
362	2	9.737	2.439	43.788	137.870						
363	2	9.726	2.461	43.594	137.784						
364	1	9.666	2.465	43.207	137.739						
366	1	9.515	2.461	42.329	137.840						
367	1	9.418	2.417	42.008	138.217						
369	1	9.322	2.408	41.479	138.214						
370	1	9.331	2.465	41.193	138.122						
371	2	9.223	2.443	40.676	138.267						
372	1	9.073	2.374	40.195	138.229						
373	2	9.075	2.435	39.844	138.043						
374	2	8.997	2.435	39.376	137.876						
375	3	8.719	2.413	37.836	139.696						
376	2	8.520	2.413	36.644	140.392						
377	2	8.361	2.435	35.556	141.021						
379	2	8.016	2.352	33.983	141.516						
380	2	7.846	2.352	32.962	141.109						
381	1	2.830	1.230	9.598	120.115						
384	3	4.950	1.682	19.605	162.678						

### Appendix 11. First-Arrival Times: Livermore Northwest-Southeast Profile, Shotpoint 1

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.
201	4	10.602	2.904	-46.188	290.191
202	4	10.538	2.904	-45.802	289.873
203	4	10.392	2.869	-45.136	289.547
204	3	10.250	2.800	-44.703	289.200
205	4	10.142	2.800	-44.053	288.774
206	3	10.014	2.800	-43.286	288.650
207	4	9.848	2.771	-42.461	288.274
208	4	9.714	2.724	-41.936	287.976
210	4	9.585	2.690	-41.374	287.784
211	4	9.502	2.666	-41.015	287.024
214	4	8.631	2.614	-36.098	287.550
218	4	11.247	2.869	-50.267	290.752
222	2	4.666	1.832	-17.004	291.664
224	2	4.855	1.872	-17.896	291.978
225	3	5.002	1.953	-18.293	291.541
227	3	5.231	2.029	-19.214	292.911
230	2	5.582	2.081	-21.009	295.224
233	3	6.208	2.255	-23.719	296.440
234	3	6.281	2.255	-24.159	296.812
235	4	6.442	2.237	-25.226	296.413
236	4	6.583	2.295	-25.725	296.188
237	4	6.747	2.266	-26.886	295.827
238	4	6.890	2.266	-27.745	295.905
239	3	7.029	2.319	-28.262	295.155
240	4	7.075	2.295	-28.677	294.134
241	3	4.330	1.843	-14.920	292.608
243	3	4.409	1.808	-15.606	296.522
244	3	4.486	1.832	-15.927	298.805
248	3	3.917	1.733	-13.102	285.935
249	2	3.901	1.762	-12.835	282.055
251	1	3.486	1.594	-11.350	283.497
252	1	3.275	1.484	-10.747	283.544
253	1	3.116	1.432	-10.106	282.325
254	1	2.930	1.350	-9.477	280.413
255	0	2.802	1.368	-8.602	282.550
256	1	2.578	1.263	-7.886	283.350
258	1	1.926	1.020	-5.437	289.757
259	1	1.542	0.834	-4.244	295.411
260	1	1.540	0.823	-4.303	314.596
261	0	4.036	1.768	13.612	129.531
262	3	3.761	1.640	12.724	129.010
263	3	3.559	1.606	11.722	129.504
264	1	3.227	1.455	10.632	127.471
265	1	3.024	1.385	9.835	126.976
266	1	2.913	1.345	9.410	127.924
267	1	2.797	1.298	8.994	127.977
269	1	2.543	1.194	8.094	126.670
270	0	2.431	1.159	7.631	127.190
271	0	2.334	1.119	7.290	124.580
272	0	2.212	1.049	6.977	122.784
273	0	2.071	0.985	6.514	120.856
275	1	1.160	0.643	3.101	135.843
276	0	0.833	0.492	2.045	137.192
278	1	0.271	0.185	0.516	147.406
279	0	0.042	0.029	0.078	264.377
281	3	8.355	2.371	-35.907	293.561
282	4	8.281	2.371	-35.461	292.522
284	4	8.156	2.371	-34.712	290.476
289	3	8.064	2.388	-34.058	294.574
291	3	7.920	2.353	-33.398	295.484
296	2	5.127	1.953	-19.044	302.587
299	2	4.888	1.872	-18.093	334.584

**Appendix 12. First-Arrival Times: Livermore Northwest-Southeast Profile, Shotpoint Number 3**

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.						
201	1	3.447	1.640	-10.838	296.938	252	2	6.857	2.732	24.755	110.118
202	1	3.187	1.449	-10.426	295.804	253	3	7.026	2.789	25.420	110.433
203	1	3.166	1.543	-9.738	294.709	254	2	7.189	2.840	26.094	110.924
204	1	3.030	1.482	-9.283	293.284	255	2	7.346	2.862	26.904	109.911
205	1	2.909	1.474	-8.614	291.423	256	3	7.513	2.913	27.601	109.494
206	1	2.772	1.465	-7.843	290.997	258	4	7.792	2.789	30.016	107.836
207	1	2.586	1.417	-7.011	288.999	259	4	7.954	2.746	31.245	107.145
208	1	2.494	1.413	-6.485	287.132	260	4	7.949	2.674	31.653	104.659
210	1	2.401	1.413	-5.927	285.717	261	4	10.811	2.746	48.390	114.018
211	1	2.278	1.343	-5.611	280.025	263	4	10.508	2.746	46.572	113.390
212	0	1.630	1.052	-3.470	271.349	264	4	10.503	2.898	45.626	112.553
213	0	1.023	0.674	-2.096	272.686	265	4	10.327	2.847	44.878	112.187
214	0	0.388	0.265	-0.741	258.592	266	4	10.295	2.891	44.426	112.241
215	0	0.007	0.004	-0.018	262.032	267	3	10.293	2.956	44.023	112.105
218	2	4.264	1.774	-14.945	296.976	269	4	10.157	2.956	43.207	111.543
220	2	4.877	1.965	-17.471	300.391	270	4	10.080	2.956	42.742	111.470
222	3	4.939	2.000	17.634	104.228	271	4	10.039	2.956	42.497	110.913
224	3	4.691	1.961	16.379	102.524	272	3	10.047	3.007	42.242	110.523
227	3	4.598	2.078	15.117	103.599	273	3	9.979	3.007	41.833	110.094
228	2	4.598	2.078	15.117	103.599	274	4	9.264	2.695	39.409	110.865
230	1	4.436	1.965	14.826	98.058	276	4	8.904	2.695	37.254	109.657
231	2	4.230	1.956	13.642	98.152	279	3	8.534	2.637	35.380	108.181
233	1	3.949	1.874	12.455	92.164	281	0	1.455	0.887	3.410	13.055
234	0	3.894	1.874	12.122	90.634	282	0	1.161	0.708	2.715	20.005
235	1	3.683	1.835	11.092	89.020	283	0	0.967	0.604	2.177	32.855
236	1	3.606	1.839	10.603	88.263	284	0	0.721	0.452	1.613	46.455
237	1	3.350	1.765	9.507	85.888	285	0	0.600	0.382	1.303	74.082
239	0	3.030	1.669	8.162	83.093	286	0	0.765	0.491	1.644	100.686
240	0	2.844	1.587	7.546	84.727	287	0	0.984	0.635	2.095	119.830
243	4	5.892	2.536	20.136	101.640	289	0	1.720	1.030	4.141	40.868
244	4	5.907	2.572	20.012	99.658	290	0	1.487	0.908	3.469	68.066
245	4	5.928	2.565	20.176	97.188	291	0	1.949	1.139	4.861	46.623
247	3	6.099	2.398	22.202	108.189	292	0	2.302	1.326	5.855	55.609
248	3	6.198	2.471	22.365	109.415	293	0	2.539	1.430	6.653	62.829
249	3	6.419	2.630	22.732	111.554	294	2	2.593	1.465	6.770	70.943
251	2	6.678	2.652	24.157	110.304	295	0	2.594	1.482	6.667	77.358
						296	3	4.894	1.952	17.652	92.517
						297	4	5.873	2.492	20.282	57.626
						299	3	7.268	2.862	26.436	78.411

### Appendix 13. First-Arrival Times: Livermore Microearthquake Number 1

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.
101	1	3.242	0.833	14.454	148.164
102	1	3.077	0.956	12.725	142.854
103	0	2.900	0.942	11.751	142.924
104	1	2.683	0.927	10.533	139.989
105	0	2.444	0.898	9.273	137.674
107	0	2.064	0.905	6.954	125.422
108	0	2.081	0.818	7.574	104.454
109	0	2.043	0.797	7.478	90.785
110	0	2.182	0.739	8.658	83.037
112	0	2.604	0.847	10.539	77.582
113	0	2.761	0.942	10.913	67.579
114	0	2.389	0.855	9.205	62.530
115	0	2.068	0.797	7.627	61.133
117	0	3.319	1.174	12.872	50.738
119	0	4.681	1.485	19.174	32.231
122	1	2.979	0.753	13.354	316.877
124	2	2.253	0.616	9.826	323.976
125	1	1.966	1.007	5.753	317.858
126	1	1.954	0.833	6.726	313.928
127	2	1.988	0.717	7.624	318.779
128	1	2.191	0.630	9.363	324.456
129	2	2.013	0.681	7.993	326.813
130	1	2.029	0.891	6.831	331.622
131	1	1.965	0.971	5.969	335.965
133	1	1.896	0.913	5.899	4.203
134	0	1.917	0.876	6.245	11.012
136	0	1.839	0.862	5.863	36.479
137	0	1.832	0.804	6.170	48.916
141	1	3.332	1.123	13.253	164.905
142	0	2.916	0.710	13.235	147.700
144	0	2.501	0.978	9.142	161.090
145	0	2.315	0.956	8.151	160.255
146	0	2.160	0.905	7.526	156.665
147	0	2.140	0.971	7.015	149.540
148	0	2.043	0.949	6.562	145.170
149	0	1.893	1.036	5.144	147.343
150	0	1.822	1.087	4.413	149.198
151	0	1.700	1.116	3.504	151.202
152	1	1.669	1.253	2.495	145.580
153	0	1.617	1.340	1.658	141.761
154	0	1.629	1.514	0.690	130.766
158	1	1.965	1.384	3.486	297.882
159	0	2.119	1.355	4.588	307.895
161	1	3.760	0.898	17.171	143.933
162	1	3.906	0.862	18.263	148.529
163	1	4.663	1.188	20.852	156.725
164	1	4.695	1.079	21.697	152.014
165	1	4.625	0.891	22.404	149.116
182	0	3.674	1.413	13.570	259.644
183	0	3.394	1.289	12.627	255.183
186	0	2.873	1.246	9.760	243.909
187	0	2.640	1.232	8.450	240.431
188	0	2.404	1.174	7.383	235.226
189	0	2.028	1.152	5.260	231.058
190	0	2.314	1.203	6.668	222.471
191	0	2.486	1.210	7.656	215.014

## Appendix 14. First-Arrival Times: Livermore Microearthquake Number 2

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.						
						150	1	2.145	1.949	1.175	87.233
						151	2	2.120	1.956	0.983	37.786
						152	2	2.064	1.761	1.818	10.282
						153	1	2.069	1.645	2.546	358.654
						155	1	2.138	1.420	4.310	339.805
101	2	2.800	1.021	10.671	142.207	156	1	2.230	1.420	4.858	333.435
104	0	2.397	1.217	7.081	126.578	157	1	2.294	1.369	5.551	326.569
105	1	2.270	1.275	5.972	120.248	158	2	2.676	1.529	6.883	322.732
106	1	2.215	1.420	4.770	109.436	159	2	2.679	1.318	8.160	324.768
107	1	2.184	1.420	4.586	92.291	161	3	3.082	0.833	13.494	138.028
108	0	2.301	1.210	6.549	72.613	163	2	3.953	1.137	16.897	154.951
112	1	2.820	0.978	11.054	56.421	164	2	4.098	1.130	17.810	149.288
113	3	3.037	1.029	12.052	48.346	168	2	4.151	0.463	22.126	142.366
114	0	2.785	0.992	10.755	41.191	169	2	4.398	0.558	23.043	139.419
121	3	3.535	0.471	18.388	322.142	170	2	4.521	0.616	23.433	135.601
124	2	2.941	0.666	13.647	329.794	171	2	4.637	0.362	25.653	134.704
125	2	2.612	1.029	9.502	328.627	176	3	6.412	0.963	32.694	123.485
126	1	2.758	1.029	10.376	325.136	177	1	5.820	0.471	32.098	120.326
127	1	2.647	0.753	11.365	327.472	178	3	6.414	0.869	33.268	117.126
128	3	2.894	0.695	13.195	330.338	179	2	6.349	0.971	32.268	108.549
129	1	2.760	0.782	11.868	332.599	180	3	6.381	1.116	31.591	104.394
131	2	2.642	0.985	9.942	339.279	182	3	3.657	1.239	14.507	275.569
132	1	2.496	0.905	9.543	344.536	185	2	3.156	1.333	10.937	267.932
133	0	2.538	0.913	9.752	356.158	186	0	2.984	1.340	9.864	267.414
134	3	2.467	0.804	9.978	0.617	187	1	2.842	1.434	8.444	267.810
136	1	2.445	0.963	8.892	15.664	188	0	2.693	1.500	7.161	267.092
137	1	2.372	0.927	8.669	24.286	189	0	2.389	1.521	5.207	275.970
138	0	2.536	0.949	9.522	350.858	190	0	2.542	1.594	5.692	259.152
141	0	2.912	1.369	9.256	165.195	191	2	2.484	1.485	5.992	246.151
142	0	2.578	1.000	9.472	140.797	192	2	2.578	1.492	6.516	237.635
144	0	2.344	1.485	5.155	158.650	193	1	2.708	1.471	7.425	232.423
145	1	2.180	1.485	4.172	156.441	194	1	2.957	1.500	8.743	226.309
146	0	2.107	1.507	3.602	148.255	195	3	2.938	1.333	9.628	218.116
147	2	2.123	1.572	3.308	131.681	197	2	3.316	1.369	11.681	212.704
148	1	2.085	1.572	3.075	120.037	199	1	3.996	1.275	16.328	181.761



### Appendix 15. First-Arrival Times: Livermore Microearthquake Number 3

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.
104	2	2.168	-0.250	14.507	275.569
112	4	2.300	-0.586	17.315	25.550
137	2	1.091	-1.827	17.505	5.971
141	1	2.740	2.601	0.834	47.842
144	1	1.915	1.130	4.709	1.579
145	2	1.614	0.666	5.685	359.200
146	1	1.538	0.463	6.447	1.321
150	1	1.213	-0.384	9.582	356.573
151	3	0.976	-0.748	10.348	353.648
152	2	0.859	-1.038	11.386	352.823
153	2	0.981	-1.050	12.188	351.474
154	1	0.741	-1.444	13.110	349.847
155	2	0.820	-1.502	13.934	346.572
156	2	0.828	-1.572	14.397	344.198
157	2	0.813	-1.676	14.935	341.225
158	3	1.044	-1.641	16.111	338.453
163	3	2.705	1.384	7.930	136.995
164	1	1.923	0.362	9.367	128.288
165	3	3.293	1.547	10.473	124.100
168	1	3.573	1.199	14.239	124.253
169	3	3.917	1.339	15.473	121.101
170	3	4.260	1.536	16.343	116.273
186	2	1.926	-0.528	14.726	307.984
187	3	1.770	-0.517	13.719	312.031
188	2	1.576	-0.551	12.763	315.766
189	2	1.170	-0.864	12.206	325.416
190	2	1.463	-0.401	11.183	318.974
191	3	1.090	-0.598	10.124	314.417
194	1	2.399	0.934	8.787	293.251
199	3	2.790	1.594	7.175	198.286

### Appendix 16. First-Arrival Times: Livermore Microearthquake Number 4

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.						
						151	1	2.578	2.104	2.844	333.005
						152	1	2.634	1.988	3.878	336.144
						153	1	2.717	1.930	4.725	335.591
						154	1	2.719	1.768	5.710	334.520
						155	1	2.782	1.663	6.716	329.775
101	1	2.648	1.292	8.132	145.161	156	1	2.874	1.652	7.332	326.330
105	1	2.420	1.837	3.497	110.955	158	1	3.259	1.686	9.438	320.047
106	2	2.388	1.953	2.611	86.262	159	1	3.505	1.721	10.701	321.917
107	1	2.449	1.930	3.116	59.658	161	1	3.043	1.223	10.923	139.246
108	0	2.617	1.663	5.726	49.554	162	1	3.212	1.223	11.934	146.677
112	1	3.246	1.454	10.748	42.913	163	1	3.877	1.454	14.535	158.785
113	0	3.561	1.547	12.083	36.066	164	2	3.804	1.246	15.349	152.016
114	0	3.322	1.466	11.136	27.791	165	2	3.796	1.118	16.068	147.971
116	1	3.890	1.570	13.916	29.138	169	1	3.418	0.005	20.478	140.244
120	3	3.931	1.397	15.206	196.184	170	1	4.397	0.921	20.853	135.939
121	2	4.377	0.886	20.941	321.005	171	0	4.732	0.886	23.071	134.909
124	2	3.715	1.026	16.136	327.126	172	0	4.979	0.886	24.554	132.346
125	2	3.665	1.663	12.009	325.281	176	1	4.787	-0.238	30.150	122.684
126	1	3.838	1.686	12.912	322.702	177	0	5.747	0.817	29.583	119.238
127	1	3.513	1.199	13.879	324.785	179	2	6.247	1.257	29.935	106.511
128	1	3.696	1.083	15.677	327.505	180	2	6.044	1.153	29.348	101.987
129	3	2.242	-0.146	14.326	329.112	181	1	4.546	1.628	17.508	281.784
130	2	3.883	1.686	13.178	331.809	182	1	4.413	1.640	16.637	280.967
133	0	3.346	1.385	11.767	347.507	183	3	4.017	1.454	15.376	278.888
134	1	3.340	1.362	11.870	351.354	184	1	3.996	1.628	14.205	277.141
135	0	3.285	1.454	10.986	358.020	185	0	3.836	1.686	12.896	276.066
136	0	3.211	1.489	10.332	2.824	186	0	3.401	1.431	11.821	276.375
137	1	3.135	1.501	9.803	9.831	187	0	3.529	1.791	10.431	277.906
138	0	3.364	1.420	11.667	343.031	189	1	2.972	1.733	7.436	288.009
141	1	2.980	1.779	7.206	176.250	190	1	3.113	1.860	7.515	275.240
144	1	2.391	1.883	3.043	180.316	191	1	3.013	1.779	7.404	264.846
145	2	2.427	2.081	2.079	186.237	192	0	3.092	1.826	7.598	256.832
146	1	2.356	2.139	1.306	179.911	193	0	3.132	1.756	8.257	250.397
147	1	2.376	2.254	0.727	127.439	195	0	3.383	1.756	9.761	233.414
148	1	2.423	2.289	0.800	74.179	197	1	3.547	1.628	11.510	225.473
149	1	2.481	2.266	1.290	350.949	198	0	3.922	1.814	12.650	190.734
150	1	2.522	2.197	1.952	338.380	199	1	4.042	1.582	14.759	189.346

## Appendix 17. First-Arrival Times: Livermore Microearthquake Number 5

Loc. No.	Weight	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Dist.	Azim.
104	0	2.158	1.941	1.297	61.108
105	1	2.171	1.849	1.936	18.292
106	1	2.172	1.628	3.260	359.078
107	1	2.324	1.547	4.663	0.388
108	1	2.554	1.385	7.013	14.031
112	2	3.370	1.385	11.911	23.043
113	1	3.734	1.466	13.607	19.124
114	1	3.559	1.362	13.186	11.088
116	1	4.214	1.582	15.791	15.126
121	4	4.986	0.817	25.015	320.725
124	2	4.238	0.875	20.181	325.548
125	2	3.993	1.315	16.067	323.763
126	2	3.960	1.130	16.982	321.882
127	2	4.027	1.037	17.940	323.538
128	2	4.173	0.886	19.719	325.813
129	2	4.131	1.072	18.354	326.942
131	1	3.879	1.165	16.284	330.302
132	3	3.752	1.130	15.734	333.200
134	1	3.721	1.141	15.475	343.322
134	1	3.721	1.141	15.475	343.322
135	1	3.598	1.199	14.392	347.821
136	2	3.544	1.281	13.579	350.900
137	1	3.330	1.199	12.786	355.591
138	1	3.711	1.130	15.484	336.951
142	1	2.154	1.675	2.877	150.079
144	1	2.132	1.686	2.676	270.979
145	1	2.185	1.675	3.061	289.517
146	1	2.196	1.663	3.200	303.872
147	1	2.190	1.628	3.367	321.825
149	1	2.417	1.547	5.218	326.743
150	1	2.528	1.536	5.954	325.441
151	1	2.646	1.501	6.871	324.919
152	1	2.789	1.478	7.867	327.504
153	1	2.825	1.373	8.712	328.045
154	1	2.990	1.373	9.701	328.183
155	1	3.084	1.292	10.748	325.817
156	1	3.167	1.269	11.388	323.815
159	2	3.870	1.408	14.773	321.192

**Appendix 18. Santa Cruz Mountains Shotpoint Information. Shot times are Greenwich Mean Time (GMT).**

<u>Shot Point</u>	<u>Shot Date</u>	<u>Shot Time (Hour:Min.Sec)</u>	<u>Shot Latitude</u>	<u>Shot Longitude</u>	<u>Elevation (feet)</u>
5	9/22/81	12:44.7	37.029842	-122.15015	237
6	3/11/82	06:04.8	37.321617	-122.11138	350
7	6/5/82	15:00.0	37.339756	-122.27948	280

## Appendix 19. U.S.G.S. Seismic Recorder Locations, Santa Cruz Mountains 1981-1982

Loc. No.	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet)				
101	36.900192	-121.800323	18	156	37.040653	-121.622437	82
102	36.897102	-121.834343	21	157	37.040871	-121.617584	94
103	36.899220	-121.830429	30	158	37.042423	-121.612053	91
104	36.901772	-121.822998	48	159	37.040829	-121.607574	76
105	36.898354	-121.819466	36	160	37.039680	-121.603638	70
106	36.898983	-121.813866	36	161	37.074104	-121.505981	243
107	36.917835	-121.816505	48	162	37.072914	-121.498596	243
108	36.916000	-121.810982	42	163	37.076874	-121.496002	243
109	36.911331	-121.802635	6	164	37.077133	-121.491333	243
110	36.911762	-121.795525	6	165	37.072311	-121.484917	252
111	36.913925	-121.786415	6	166	37.072701	-121.479950	254
112	36.915138	-121.779488	6	167	37.072483	-121.473984	262
113	36.923630	-121.779648	18	168	37.073368	-121.469772	262
114	36.928734	-121.776711	27	169	37.076374	-121.465858	259
115	36.940716	-121.768440	33	170	37.085518	-121.466179	268
116	36.939049	-121.760414	28	171	37.389400	-121.477341	646
117	36.938465	-121.753677	27	172	37.408905	-121.407501	402
118	36.944130	-121.737068	18	173	37.444042	-121.292328	201
119	36.752056	-121.595116	213	174	37.475830	-121.226669	103
120	36.752056	-121.595116	213	175	37.678889	-120.360861	297
121	36.944347	-121.736984	18	177	37.701083	-120.294111	429
122	36.947376	-121.734673	30	178	37.704000	-120.249639	281
123	36.950359	-121.731949	33	179	37.709889	-120.216917	457
124	36.953194	-121.728958	42	180	37.734111	-120.162389	896
125	36.956089	-121.726883	47	181	37.035812	-121.594276	67
126	36.959869	-121.722649	57	182	37.037022	-121.589638	67
127	36.963245	-121.720627	76	183	37.037952	-121.585289	67
128	36.967247	-121.720573	94	184	37.042294	-121.582092	68
129	36.972046	-121.720055	140	185	37.045647	-121.570900	68
130	36.975765	-121.717979	164	186	37.046337	-121.566826	67
131	36.980503	-121.717331	243	187	37.047939	-121.560997	67
132	36.985043	-121.712532	284	188	37.049149	-121.556328	68
133	36.990688	-121.712257	353	189	37.050579	-121.552307	71
134	36.995983	-121.716110	402	190	37.051765	-121.548851	79
135	36.994537	-121.705467	328	191	37.042618	-121.539131	73
136	36.989735	-121.697838	268	192	37.043919	-121.534920	83
137	36.991703	-121.689186	213	193	37.047527	-121.531059	103
138	36.996483	-121.686218	176	194	37.051594	-121.526665	115
139	37.002640	-121.683655	158	195	37.054577	-121.523529	149
140	37.007156	-121.682281	158	196	37.056740	-121.519646	170
141	37.003418	-121.677048	146	197	37.065132	-121.520775	271
142	37.003242	-121.671791	134	198	37.070084	-121.518616	280
143	37.006165	-121.667206	121	199	37.074127	-121.515137	268
144	37.009083	-121.665260	109	200	37.068981	-121.511139	353
145	37.011570	-121.660866	109	201	37.063942	-122.144318	538
146	37.012348	-121.657173	109	202	37.067490	-122.140488	579
147	37.013557	-121.652100	100	203	37.071747	-122.142509	585
148	37.013409	-121.646599	94	204	37.076180	-122.141159	609
149	37.013493	-121.641716	94	205	37.080807	-122.139481	638
150	37.013622	-121.636383	85	206	37.085148	-122.134544	682
151	37.012543	-121.630394	76	207	37.090794	-122.135216	738
152	37.012630	-121.625542	91	208	37.095310	-122.139832	771
153	37.028046	-121.636322	91	209	37.101021	-122.141823	749
154	37.037735	-121.626472	103	210	37.104416	-122.139664	734
155	37.041885	-121.626060	106	211	37.107445	-122.141930	743
				212	37.109085	-122.145821	762
				213	37.111141	-122.147980	774
				214	37.113564	-122.151001	790

215	37.116093	-122.154617	798	284	37.054752	-122.159996	463
216	37.119576	-122.156860	790	285	37.054363	-122.168396	390
217	37.123272	-122.158775	774	286	37.051292	-122.159653	426
218	37.126015	-122.161316	787	287	37.001644	-122.178802	18
219	37.128567	-122.163315	786	288	37.006531	-122.174568	18
220	37.131271	-122.166611	801	289	37.009838	-122.174110	24
224	37.307884	-122.070801	140	290	37.015396	-122.172188	24
225	37.306438	-122.073593	134	291	37.020329	-122.166016	79
226	37.301765	-122.075218	140	292	37.025127	-122.164398	201
227	37.297787	-122.078735	164	294	37.036697	-122.150696	371
228	37.296143	-122.083145	158	295	37.042210	-122.149803	384
229	37.291149	-122.080551	170	296	37.043983	-122.154305	390
230	37.287624	-122.079140	164	297	37.047508	-122.154144	390
231	37.284275	-122.076027	164	299	37.029842	-122.150154	237
232	37.279408	-122.072594	182	300	37.029842	-122.150154	237
233	37.276489	-122.074486	188	321	37.314091	-122.088448	188
234	37.273029	-122.079140	207	322	37.317986	-122.098923	316
235	37.272598	-122.081985	213	323	37.318806	-122.105042	341
236	37.271950	-122.085495	219	328	37.294910	-122.081253	164
237	37.268814	-122.089203	243	329	37.290760	-122.080711	176
238	37.268490	-122.091988	237	330	37.287300	-122.078331	176
239	37.266151	-122.093208	274	332	37.279301	-122.072372	176
240	37.265137	-122.095322	316	334	37.272705	-122.082115	213
241	37.258823	-122.120399	786	335	37.283951	-122.074135	176
242	37.255711	-122.124702	768	336	37.280598	-122.074219	182
243	37.255535	-122.131226	768	337	37.269138	-122.088470	243
244	37.251080	-122.135612	762	338	37.265568	-122.092804	274
245	37.246178	-122.138695	755	339	37.264488	-122.096779	329
246	37.245636	-122.149895	652	340	37.265568	-122.099297	341
247	37.241096	-122.152138	621	341	37.259083	-122.120239	804
248	37.235279	-122.144218	573	342	37.255783	-122.124596	780
249	37.231148	-122.148056	518	343	37.255512	-122.131561	768
250	37.226933	-122.147408	502	344	37.250973	-122.135689	755
251	37.223904	-122.151657	457	345	37.246071	-122.138733	743
252	37.220337	-122.152061	441	346	37.245636	-122.150032	646
253	37.216076	-122.152878	426	347	37.241043	-122.152122	609
254	37.211342	-122.155579	381	348	37.238014	-122.147461	597
255	37.205807	-122.156387	402	349	37.235043	-122.144081	573
256	37.201527	-122.156013	414	350	37.231258	-122.147865	538
257	37.201374	-122.162071	438	351	37.226826	-122.147461	499
258	37.196941	-122.161476	475	352	37.224663	-122.151253	463
259	37.193264	-122.167511	524	353	37.220078	-122.151680	441
261	37.131702	-122.166786	792	354	37.216068	-122.152740	426
262	37.134235	-122.169838	792	355	37.211578	-122.155785	386
263	37.139099	-122.171860	749	356	37.205807	-122.156525	402
264	37.143250	-122.181099	609	357	37.201427	-122.156120	421
265	37.146408	-122.177261	505	358	37.201374	-122.161987	438
266	37.148052	-122.172775	438	359	37.196835	-122.161598	475
267	37.148182	-122.161751	262	360	37.192997	-122.167847	524
268	37.151684	-122.159424	243	361	37.127918	-122.163208	786
269	37.154667	-122.160934	243	362	37.156162	-122.160393	246
270	37.157978	-122.160667	252	363	37.176441	-122.161850	286
271	37.161652	-122.161880	256	383	37.017342	-122.167229	137
272	37.164833	-122.161446	259	401	37.048027	-122.152283	417
273	37.167812	-122.162094	262	402	37.055290	-122.152367	441
274	37.169868	-122.162094	274	403	37.062752	-122.146423	520
275	37.173695	-122.162369	283	404	37.071404	-122.142860	573
276	37.176140	-122.161797	283	405	37.080917	-122.139351	638
277	37.179016	-122.161369	304	406	37.085171	-122.134682	685
278	37.181892	-122.158989	353	407	37.092762	-122.140152	746
281	37.065605	-122.151146	524	408	37.101128	-122.141663	694
282	37.062534	-122.157516	463	409	37.108200	-122.143036	754
283	37.059704	-122.158379	463	410	37.113499	-122.151108	790

411	37.121975	-122.158371	789	481	37.270065	-122.245132	304
412	37.128567	-122.163422	792	482	37.275085	-122.246971	329
413	37.133759	-122.168892	792	483	37.279278	-122.248077	323
414	37.138428	-122.176857	731	484	37.284813	-122.246834	371
415	37.036503	-122.150963	371	485	37.290047	-122.248535	335
416	37.031616	-122.142227	349	486	37.290287	-122.255913	335
417	37.025692	-122.133301	207	487	37.290718	-122.262596	310
418	37.020329	-122.128311	173	488	37.296707	-122.266731	280
419	37.011570	-122.175568	48	489	37.302395	-122.274178	304
420	37.002964	-122.176643	24	490	37.308208	-122.271904	134
421	37.461040	-122.343666	548	491	37.315994	-122.275146	134
422	37.457970	-122.337158	585	492	37.322266	-122.275826	170
423	37.450939	-122.337570	621	493	37.326698	-122.279152	219
424	37.447266	-122.332146	621	494	37.332428	-122.280510	240
425	37.443371	-122.325874	627	495	37.340229	-122.279205	280
426	37.438400	-122.321404	621	496	37.340553	-122.288498	207
427	37.434399	-122.317062	609	497	37.342716	-122.295143	207
428	37.428886	-122.311234	621	498	37.348728	-122.296280	359
429	37.425316	-122.313004	633	499	37.354694	-122.297577	371
430	37.418720	-122.317879	670	500	37.360146	-122.294380	341
431	37.413273	-122.309616	688				
432	37.407326	-122.306496	694				
433	37.402569	-122.297829	658				
434	37.395973	-122.291389	670				
435	37.389919	-122.297562	658				
436	37.382675	-122.295265	609				
437	37.376728	-122.295532	670				
438	37.370850	-122.297569	560				
439	37.366955	-122.302315	463				
440	37.361984	-122.298523	365				
441	37.467201	-122.347122	499				
442	37.471310	-122.354919	462				
443	37.478878	-122.358582	414				
444	37.487312	-122.362244	340				
445	37.492607	-122.365097	268				
446	37.498554	-122.369438	304				
447	37.505947	-122.372559	320				
448	37.507946	-122.371407	320				
450	37.515190	-122.376350	320				
451	37.521084	-122.378448	320				
453	37.527180	-122.386932	320				
454	37.529625	-122.391075	320				
455	37.535030	-122.397385	335				
456	37.540058	-122.404984	335				
457	37.545181	-122.411369	335				
458	37.551613	-122.415581	304				
459	37.557724	-122.421387	259				
461	37.252033	-122.266426	493				
462	37.248512	-122.260582	536				
463	37.247410	-122.255821	536				
464	37.244904	-122.249321	566				
465	37.241226	-122.242241	591				
466	37.234932	-122.234100	640				
467	37.230026	-122.227501	664				
470	37.216034	-122.220528	676				
471	37.214931	-122.215851	707				
472	37.211819	-122.210609	688				
473	37.207191	-122.206055	670				
474	37.202995	-122.203323	658				
477	37.184746	-122.183731	341				
478	37.184746	-122.183731	341				
479	37.173157	-122.167168	274				
480	37.157436	-122.161316	243				

**Appendix 20. Field Data Table, Santa Cruz Mountains, 1981, Shot Point 5, Shot  
Time:265:22:12:44.741**

Shot Number 5 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	201	3.820	7.8	15	11	24	6	42		3
2	202	4.265	11.6	17	43	2 24	6	42		0
3	203	4.700	8.3	24	-18	2 24	6	42		0
4	204	5.204	8.8	25	-2	24	6	42		12
5	205	5.735	9.5	26	2	1 24	6	42		0
6	206	6.293	12.7	32	11	1 24	6	42		0
7	207	6.893	11.1	36	6	1 24	6	42		0
8	208	7.323	7.2	38	-5	1 24	6	42		0
9	209	7.934	5.4	44	7	1 24	6	42		0
10	210	8.328	6.4	58	-2	3 24	6	42		0
11	211	8.643	4.9	60	-5	1 24	6	42		0
12	212	8.802	2.5	71	--	24	6	42		16
13	213	9.024	1.2	85	12	24	6	42		16
14	214	9.291	359.5	90	17	1 24	6	42		0
15	216	9.976	356.6	94	9	1 24	6	42		0
16	217	10.397	355.8	103	3	1 24	6	42		0
17	218	10.719	354.7	106	-6	1 24	6	42		0
18	219	11.018	353.9	125	-8	1 24	6	42		0
19	220	11.351	352.6	130	12	1 24	6	42		0
20	215	9.580	357.6	146	9	1 24	6	42		0

Shot Number 5 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1				10	--	24	6	42		20
2				13	--	24	6	42		20
3				30	--	24	6	42		20
4	224	31.651	12.9	34	2	1 24	6	42		0
5	225	31.440	12.5	49	3	24	6	42		25
6	226	30.903	12.4	51	2	1 24	6	42		0
7	227	30.405	12.0	52	2	1 24	6	42		0
8	228	30.147	11.4	55	2	24	6	42		3
9	229	29.651	12.0	62	1	1 24	6	42		0
10	230	29.295	12.4	63	2	1 24	6	42		0
11	231	28.994	13.1	64	3	1 24	6	42		0
12	232	28.540	14.0	97	3	1 24	6	42		0
13	233	28.185	13.8	104	3	1 24	6	42		0
14	234	27.716	13.2	105	6	1 24	6	42		0
15	235	27.613	12.7	110	8	1 24	6	42		0
16	236	27.476	12.1	118	6	1 24	6	42		0
17	237	27.068	11.5	124	4	1 24	6	42		0
18	238	26.984	11.0	137	3	24	6	42		12
19	239	26.708	10.9	142	-4	2 24	6	42		0
20	240	26.563	10.6	145	4	1 24	6		42	0



Shot Number 5 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1				1	0	24	6	42		20
2	241	25.549	5.9	18	-5	1 24	6	42		0
3	242	25.168	5.2	22	10	24	6	42		4
4	243	25.103	3.8	35	-23	1 24	6	42		0
5	244	24.586	3.0	40	8	1 24	6	42		0
6	245	24.030	2.4	43	-8	1 24	6	42		0
7	246	23.948	0.1	65	6	24	6	42		3
8	247	23.445	359.6	74	18	3 24	6	42		0
9	248	22.805	1.3	75	10	1 24	6	42		0
10	249	22.341	0.5	76	-10	3 24	6	42		0
11	250	21.874	0.6	79	6	3 24	6	42		0
12	251	21.537	359.6	87	2	1 24	6	42		0
13	252	21.141	359.5	89	10	1 24	6	42		0
14	253	20.669	359.3	98	8	1 24	6	42		0
15	254	20.148	358.6	100	6	1 24	6	42		0
16	255	19.536	358.4	101	14	1 24	6	42		0
17	256	19.060	358.4	112	8	1 24	6	42		0
18	257	19.065	356.8	113	-4	1 24	6	42		0
19	258	18.571	356.9	133	12	1 24	6	42		0
20	259	18.201	355.1	143	-13	1 24	6	42		0

Shot Number 5 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	278	16.892	357.3	14	-3	2 24	6	42		0
2	277	16.585	356.6	19	-48	24	6	42		3
3	276	16.268	356.4	39	3	1 24	6	42		0
4	275	16.001	356.1	48	-29	1 24	6	42		0
5	274	15.576	356.1	53	6	1 24	6	42		0
6	273	15.348	356.0	56	11	24	6	42		3
7	272	15.014	356.2	66	13	1 24	6	42		0
8	271	14.665	355.9	69	--	24	6	42		1
9	270	14.251	356.2	70	16	1 24	6	42		0
10	269	13.886	356.0	72	11	1 24	6	42		0
11	268	13.547	356.5	77	6	3 24	6	42		0
12	267	13.173	355.5	93	15	24	6	42		13
13	266	13.272	351.3	96	-2	1 24	6	42		0
14	265	13.159	349.4	115	10	1 24	6	42		0
15	264	12.883	347.7	119	8	3 24	6	42		0
16				121	--	24	6	42		20
17				122	--	24	6	42		20
18	263	12.278	351.0	132	--	24	6	42		1
19	262	11.717	351.4	134	4	1 24	6	42		0
20	261	11.400	352.5	139	9	2 24	6	42		0

Shot Number 5 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE	
1	281	3.970	358.7	3	6	3 24	6	42	0		
2	282	3.687	349.8	12	5	3 24	6	42	0		
3	283	3.394	347.5	23	9	3 24	6	42	0		
4	284	2.900	342.4	28	15	3 24	6	42	0		
5	285	3.168	329.2	31	9	3 24	6	42	0		
6	286	2.526	340.5	45	1	3 24	6	42	0		
7	287	4.036	219.2	73	1	24	6	42	1		
8	288	3.378	220.0	78	-14	3 24	6	42	0		
9	289	3.078	223.8	82	0	3 24	6	42	0		
10	290	2.533	230.7	83	17	3 24	6	42	0		
11	291	1.763	233.2	88	15	3 24	6	42	0		
12	292	1.371	247.6	92	7	3 24	6	42	0		
13				99	7	24	6	42	32		
14	294	0.762	356.4	107	-29	3 24	6	42	0		
15	295	1.373	1.3	108	10	3 24	6	42	0		
16	296	1.612	346.8	120	5	3 24	6	42	0		
17	297	1.992	349.7	128	6	3 24	6	42	0		
18				129	2	24	6	42	32		
19	299	0.000	180.0	131	10	3 24	6	94	0	SP5	
20	300	0.000	180.0	136	6	3 24	6	94	0	SP5	

**Appendix 21. Field Data Table, Santa Cruz Mountains, 1982, Shot Point 6, Shot  
Time:070:22:06:04.775.**

Shot Number 6 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	201	28.745	185.8	15	14	24	6	42		
2	202	28.321	185.2	17	84	24	6	42		
3	203	27.867	185.7	24	-54	1 24	6	42		
4	204	27.366	185.5	25	-28	1 24	6	42		
5	205	26.841	185.3	26	0	24	6	42		
6	206	26.323	184.5	32	49	24	6	42		
7	207	25.704	184.7	36	4	24	6	42		
8	208	25.242	185.7	38	5	3 24	6	42		
9	209	24.630	186.3	44	11	24	6	42		
10	210	24.235	185.9	58	3	1 24	6	42		
11	211	23.923	186.5	60	-12	1 24	6	42		
12	212	23.784	187.4	71	24	1 24	6	42		
13	213	23.583	187.9	85	3	1 24	6	42		
14	214	23.356	188.7	90	46	1 24	6	42		
15	215	23.129	189.6	94	23	1 24	6	42		
16	216	22.783	190.2	103	5	1 24	6	42		
17	217	22.410	190.8	106	-7	24	6	42		
18	218	22.155	191.5	125	-25	1 24	6	42		
19	219	21.915	192.1	130	32	2 24	6	42		
20	220	21.686	193.1	146	5	1 24	6	42		

Shot Number 6 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	335	5.327	141.7	10	127	1 36	18	54		0
2	322	1.176	110.0	13	-10	3 56	38	74		0
3	323	0.643	119.0	30	9	3 56	38	74		0
4	224	3.907	113.0	34	13	3 24	6	42		0
5	225	3.750	116.7	49	20	3 24	6	42		0
6	226	3.890	124.5	51	47	24	6	42		16
7	227	3.921	132.4	52	54	3 24	6	42		0
8	328	3.990	138.0	55	5	3 24	6	42		0
9	329	4.373	141.5	62	-5	3 24	6	42		0
10	330	4.805	142.4	63	3	3 24	6	42		0
11	231	5.196	142.9	64	10	3 36	18	54		0
12	332	5.832	143.6	97	2	3 36	18	54		0
13				104	--	36	18	54		1
14	334	6.017	154.4	105	33	3 36	18	54		0
15	321	2.198	112.3	110	40	3 56	38	74		0
16	336	5.620	144.1	118	4	36	18	54		21
17	337	6.168	160.8	124	-14	3 36	18	54		0
18	338	6.435	165.2	137	35	3 36	18	54		0
19	339	6.471	168.5	142	40	3 24	6	42		0
20	340	6.312	170.2	145	42	1 56	38	74		0

Shot Number 6 Team 3

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	341	6.984	186.5	1	26	3 24	6	42		0
2	342	7.400	189.1	18	-24	3 24	6	42		0
3	343	7.551	193.7	22	24	24	6	42		28
4	344	8.131	195.4	35	-55	3 24	6	42		0
5	345	8.728	196.1	40	--	24	6	42		1
6	346	9.102	202.1	43	-3	3 24	6	42		0
7	347	9.644	202.0	65	28	3 24	6	42		0
8	348	9.814	199.0	74	25	3 24	6	42		0
9	349	10.036	196.8	75	29	3 24	6	42		0
10	350	10.537	197.9	76	-51	3 24	6	42		0
11	351	10.996	196.9	79	2	3 24	6	42		0
12	352	11.326	198.2	87	--	24	6	42		1
13	353	11.822	197.6	89	11	3 24	6	42		0
14	354	12.275	197.4	98	-24	3 24	6	42		0
15	355	12.831	197.9	100	12	3 24	6	42		0
16	356	13.462	197.3	101	37	1 24	6	42		0
17	357	13.916	196.6	112	11	3 24	6	42		0
18	358	14.079	198.6	113	-12	3 24	6	42		0
19	359	14.547	197.8	133	24	3 24	6	42		0
20	360	15.128	199.3	143	22	1 24	6	42		0

Shot Number 6 Team 4

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	363	16.722	195.5	14	67	1 24	6	42		0
2	277	16.435	195.7	19	-65	24	6	42		0
3	362	18.870	193.3	39	0	24	6	42		0
4	275	17.028	195.4	48	85	1 24	6	42		0
5	274	17.432	195.0	53	-14716	1 24	6	42		0
6	273	17.652	194.8	56	27	1 24	6	42		0
7	272	17.958	194.3	66	32	1 24	6	42		0
8	271	18.310	194.2	69	16	24	6	42		1
9	361	21.983	192.1	70	60	1 24	6	42		0
10	269	19.043	193.4	72	39	1 24	6	42		0
11	268	19.335	192.7	77	25	1 24	6	42		0
12	267	19.760	193.1	93	55	1 24	6	42		0
13	266	20.018	195.8	96	1	1 24	6	42		0
14	265	20.304	196.7	115	21	1 24	6	42		0
15	264	20.739	197.4	119	8	24	6	42		1
16	263	20.955	194.8	132	22	24	6	42		0
17	262	21.433	194.0	134	33	1 24	6	42		0
18	261	21.642	193.1	139	11	1 24	6	42		0
19										
20										

Shot Number 6 Team 5

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	6	0.000	180.0	3	16	3 64	46	82		0
2	6	0.000	180.0	12	10	3 64	46	82		0
3	287	36.011	189.6	23	-5	24	6	42		1
4	288	35.415	189.1	28	43	1 24	6	42		0/12
5	289	35.046	189.1	31	11	1 24	6	42		0/12
6	290	34.410	189.0	45	0	3 24	6	42		0
7	383	34.130	188.4	73	-15	3 24	6	42		0
8	291	33.787	188.3	78	41	1 24	6	42		0
9	292	33.239	188.1	82	-4	3 24	6	42		0
10				83	0	24	6	42		32
11				88	32	24	6	42		32
12				92	16	24	6	42		25
13	294	31.812	186.3	99	32	24	6	42		1
14	295	31.195	186.3	107	-30	1 24	6	42		0
15	296	31.046	187.1	108	25	1 24	6	42		0
16	297	30.656	187.1	120	12	1 24	6	42		0
17	286	30.305	188.1	128	0	1 24	6	42		0
18	284	29.929	188.3	129	-2	1 24	6	42		0
19	283	29.365	188.2	131	0	1 24	6	42		0
20	282	29.043	188.1	136	25	1 24	6	42		0

**Appendix 22. Field Data Table, Santa Cruz Mountains, 1982, Shot Point 7, Shot  
Time:156:06:14:59.964**

Shot Number 7 Team 1

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	401	34.289	160.8	1	33	24	6	42		1
2	402	33.526	160.3	2	-170	1	24	6	42	0
3	403	32.933	159.0	3	22	24	6	42		2
4	404	32.156	157.8	4	167	3	24	6	42	0
5	405	31.303	156.6	5	-8	3	24	6	42	0
6	406	31.040	155.5	6	21	1	24	6	42	0
7	407	30.072	155.7	7	11	1	24	6	42	0
8	408	29.171	155.2	8	138	1	24	6	42	0
9	409	28.408	154.8	9	160		24	6	42	1
10	410	27.573	155.6	10	158		24	6	42	2
11	411	26.451	156.0	11	133		24	6	42	21
12	412	25.601	156.3	12	24	1	24	6	42	0
13	413	24.879	156.8	13	26	1	24	6	42	0
14	414	24.128	157.8	14	60	1	24	6	42	0
15	415	35.536	161.3	15	20	1	24	6	42	0
16	416	36.304	160.4	16	70		24	6	42	12
17	417	37.193	159.6	17	104	1	24	6	42	0
18	418	37.906	159.3	18	-6	3	24	6	42	0
19	419	37.572	165.8	19	-59	1	24	6	42	0
20	420	38.476	166.3	20	36		24	6	42	3

Shot Number 7 Team 2

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	421	14.611	337.1	21	-26	1	30	12	48	0
2	422	14.079	338.7	22	0	1	30	12	48	0
3	423	13.369	337.4	23	31	1	30	12	48	0
4	424	12.811	338.7	24	0	1	30	12	48	0
5	425	12.211	340.3	25	9	1	30	12	48	0
6	426	11.560	341.3	26	0	1	30	12	48	0
7	427	11.018	342.4	27	0	1	30	12	48	0
8	428	10.284	344.1	28	54		30	12	48	1
9	429	9.949	342.6	29	--		30	12	48	1
10	430	9.400	338.8	30	31		30	12	48	1
11	431	8.585	341.9	31	29	3	30	12	48	0
12	432	7.872	342.3	32	56		30	12	48	1
13	433	7.158	346.9	33	28		30	12	48	2
14	434	6.328	350.4	34	37	3	30	12	48	0
15	435	5.793	343.9	35	-37	1	30	12	48	0
16	436	4.964	343.6	36	25		30	12	48	1
17	437	4.343	340.9	37	61	3	30	12	48	0
18	438	3.805	335.1	38	23	3	30	12	48	0
19	439	3.634	326.2	39	18		30	12	48	12/21
20	440	2.989	325.6	40	313	30	12	48	0	

## Shot Number 7 Team 3

	LOC	DIST(km)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	459	27.256	332.6	41	10	2	30	12	68	0
2	453	22.872	335.4	42	34		30	12	68	1
3	448	20.363	336.4	43	-6	1	30	12	88	0
4	442	16.055	335.4	44	14	1	30	12	68	0
5	455	24.053	334.3	45	15	1	30	12	68	0
6	457	25.613	332.9	46	-29		30	12	68	25
7	458	26.418	332.9	47	75	1	30	12	68	0
8	454	23.272	334.9	48	103	1	30	12	68	0
9	443	16.954	335.6	49	0		30	12	68	25
10	446	19.339	335.7	50	49		30	12	68	25
11	445	18.580	335.9	51	90	1	30	12	68	0
12	451	21.948	336.5	52	64	1	30	12	68	0
13				53	28		30	12	68	1
14				54	--		30	12	68	20
15	450	21.274	336.2	55	35	1	30	12	68	0
16	447	20.201	335.9	56	224	1	30	12	68	0
17	444	17.941	335.9	57	71	1	30	12	68	0
18				58	16		30	12	68	1
19	456	24.850	333.5	59	31	1	30	12	68	0
20	441	15.360	337.1	60	2	1	30	12	68	0

## Shot Number 7 Team 4

	LOC	DIST(km)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	461	9.804	173.2	61	19	3	24	6	42	0
2	462	10.264	170.6	62	37		24	6	42	0
3	463	10.461	168.4	63	9	3	24	6	42	0
4	464	10.861	165.7	64	11	3	24	6	42	0
5	465	11.423	163.2	65	22	3	24	6	42	0
6	466	12.310	160.9	66	19	3	24	6	42	0
7	467	13.021	159.3	67	30	3	24	6	42	0
8	468			68	21		24	6	42	1/16
9	469			69	10		24	6	42	1
10	470	14.692	159.2	70	41	3	24	6	42	0
11	471	14.958	157.8	71	25		24	6	42	0
12	472	15.457	156.7	72	21	3	24	6	42	0
13	473	16.089	156.1	73	-8	3	24	6	42	0
14	474	16.613	156.0	74	29	3	24	6	42	0
15	475			75	19		24	6	42	1
16	476			76	-30		24	6	42	1
17	477	19.185	153.7	77	13	3	24	6	42	0
18	478	19.185	153.7	78	48		24	6	42	1/20
19	479	21.003	151.7	79	11		24	6	42	0
20	480	22.788	152.6	80	18	3	24	6	42	0

Shot Number 7 Team 5

	LOC	DIST(km)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	482	7.734	158.1	81	-9	24	6	42	13/17	
2	483	7.266	157.5	82	0	3 24	6	42	0	
3	484	6.750	154.6	83	5	3 24	6	42	0	
4	481	8.312	158.5	84	--	24	6	42	1	
5	485	6.161	153.6	85	0	24	6	42	1	
6	486	5.874	159.2	86	0	3 24	6	42	0	
7	487	5.644	164.6	87	4	24	6	42	13/17	
8	488	4.909	166.7	88	7	3 24	6	42	0	
9	489	4.173	173.5	89	2	3 24	6	42	0	
10	490	3.565	169.1	90	5	3 24	6	42	0	
11	491	2.665	171.7	91	0	24	6	42	25	
12	492	1.968	170.5	92	4	2 24	6	42	0	
13	493	1.449	178.9	93	5	3 24	6	42	0/12	
14	494	0.818	186.4	94	1	3 24	6	42	0	
15	495	0.058	024.9	95	2	3 24	6	42	0/15	
16	496	0.804	276.3	96	-4	3 24	6	42	0/6	
17	497	1.426	283.3	97	0	24	6	42	21	
18	498	1.791	303.8	98	-4	3 24	6	42	0	
19	499	2.306	316.0	99	1	3 24	6	42	0	
20	500	2.620	329.7	100	0	3 24	6	42	0	



### Appendix 23. First-Arrival Times: Santa Cruz Mountains Shotpoint 5

Loc. No.	Dist. (km)	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Azimuth					
					SJ248	22.805	4.741	0.940	1.3
					SJ249	22.341	4.694	0.970	0.5
					SJ250	21.874	4.686	1.040	0.6
					SJ251	21.537			359.6
					SJ252	21.141	4.454	0.930	359.5
					SJ253	20.669	4.265	0.820	359.3
					SJ254	20.148	4.208	0.850	358.6
					SJ255	19.536	4.056	0.800	358.4
					SJ256	19.06			358.4
					SJ257	19.065			356.8
					SJ258	18.571	3.815	0.720	356.9
					SJ259	18.201	3.734	0.700	355.1
					SJ278	16.892	3.445	0.630	357.3
					SJ277	16.585			356.6
					SJ276	16.268	3.261	0.550	356.4
					SJ275	16.001	3.217	0.550	356.1
					SJ274	15.576	3.076	0.480	356.1
					SJ273	15.348			356.0
					SJ272	15.014	2.972	0.470	356.2
					SJ271	14.665			355.9
					SJ270	14.251	2.755	0.380	356.2
					SJ269	13.886	2.654	0.340	356.0
					SJ268	13.547			356.5
					SJ267	13.173			355.5
					SJ266	13.272	2.532	0.320	351.3
					SJ265	13.159	2.513	0.320	349.4
					SJ264	12.883	2.467	0.320	347.7
					SJ263	12.278			351.0
					SJ262	11.717	2.313	0.360	351.4
					SJ261	11.4	2.200	0.300	352.5
					SJ281	3.97	0.822	0.160	358.7
					SJ282	3.687			349.8
					SJ283	3.394	0.676	0.110	347.5
					SJ284	2.9	0.613	0.130	342.4
					SJ285	3.168			329.2
					SJ286	2.526	0.521	0.100	340.5
					SJ287	4.036			219.2
					SJ288	3.378	1.053	0.490	220.0
					SJ289	3.078	0.973	0.460	223.8
					SJ290	2.533	0.822	0.400	230.7
					SJ291	1.763	0.534	0.240	233.2
					SJ292	1.371	0.359	0.130	247.6
					SJ294	0.762	0.167	0.040	356.4
					SJ295	1.373	0.269	0.040	1.3
					SJ296	1.612	0.329	0.060	346.8
					SJ297	1.992			349.7
					SJ299	0			180
					SJ300	0			180
SJ201	3.82			7.8					
SJ202	4.265			11.6					
SJ203	4.7			8.3					
SJ204	5.204			8.8					
SJ205	5.735	1.106	0.150	9.5					
SJ206	6.293	1.169	0.120	12.7					
SJ207	6.893			11.1					
SJ208	7.323			7.2					
SJ209	7.934	1.522	0.200	5.4					
SJ210	8.328			6.4					
SJ211	8.643	1.661	0.220	4.9					
SJ212	8.802			2.5					
SJ213	9.024	1.704	0.200	1.2					
SJ214	9.291			359.5					
SJ216	9.976	1.963	0.300	356.6					
SJ217	10.397	2.033	0.300	355.8					
SJ218	10.719	2.067	0.280	354.7					
SJ219	11.018			353.9					
SJ220	11.351	2.242	0.350	352.6					
SJ215	9.58	1.827	0.230	357.6					
SJ224	31.651			12.9					
SJ225	31.44			12.5					
SJ226	30.903			12.4					
SJ227	30.405			12					
SJ228	30.147			11.4					
SJ229	29.651			12					
SJ230	29.295			12.4					
SJ231	28.994			13.1					
SJ232	28.54	5.477	0.720	14					
SJ233	28.185	5.438	0.740	13.8					
SJ234	27.716	5.389	0.770	13.2					
SJ235	27.613	5.392	0.790	12.7					
SJ236	27.476	5.379	0.800	12.1					
SJ237	27.068	5.341	0.830	11.5					
SJ238	26.984			11					
SJ239	26.708	5.271	0.820	10.9					
SJ240	26.563	5.327	0.900	10.6					
SJ241	25.549	5.228	0.970	5.9					
SJ242	25.168			5.2					
SJ243	25.103	5.124	0.940	3.8					
SJ244	24.586			3					
SJ245	24.03	4.945	0.940	2.4					
SJ246	23.948			0.1					
SJ247	23.445			359.6					

## Appendix 24. First-Arrival Times: Santa Cruz Mountains Shotpoint 6

Loc. No.	Dist. (km)	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Azimuth					
					SJ358	14.079	3.447	1.100	198.6
					SJ359	14.547	3.575	1.150	197.8
					SJ360	15.128	3.681	1.160	199.3
					SJ363	16.722			195.5
					SJ277	16.435			195.7
					SJ362	18.870			193.3
SJ201	28.745			185.8	SJ275	17.028	3.988	1.150	195.4
SJ202	28.321			185.2	SJ274	17.432	4.045	1.140	195.0
SJ203	27.867	5.485	0.840	185.7	SJ273	17.652	4.042	1.100	194.8
SJ204	27.366	5.411	0.850	185.5	SJ272	17.958	4.093	1.100	194.3
SJ205	26.841			185.3	SJ271	18.310			194.2
SJ206	26.323			184.5	SJ361	21.983	4.664	1.000	192.1
SJ207	25.704			184.7	SJ269	19.043	4.374	1.200	193.4
SJ208	25.242			185.7	SJ268	19.335			192.7
SJ209	24.630			186.3	SJ267	19.760	4.413	1.120	193.1
SJ210	24.235	5.059	1.020	185.9	SJ266	20.018	4.396	1.060	195.8
SJ211	23.923			186.5	SJ265	20.304	4.434	1.050	196.7
SJ212	23.784			187.4	SJ264	20.739			197.4
SJ213	23.583	4.861	0.930	187.9	SJ263	20.955			194.8
SJ214	23.356	4.883	0.990	188.7	SJ262	21.433	4.662	1.090	194.0
SJ215	23.129	4.875	1.020	189.6	SJ261	21.642			193.1
SJ216	22.783	4.817	1.020	190.2	SJ287	36.011			189.6
SJ217	22.410			190.8	SJ288	35.415	6.953	1.050	189.1
SJ218	22.155	4.683	0.990	191.5	SJ289	35.046	6.931	1.090	189.1
SJ219	21.915			192.1	SJ290	34.410	6.835	1.100	189.0
SJ220	21.686	4.684	1.070	193.1	SJ383	34.130			188.4
SJ335	5.327	1.338	0.450	141.7	SJ291	33.787	6.671	1.040	188.3
SJ322	1.176	0.276	0.080	110.0	SJ292	33.239	6.540	1.000	188.1
SJ323	0.643	0.117	0.010	119.0	SJ294	31.812			186.3
SJ224	3.907	1.051	0.400	113.0	SJ295	31.195			186.3
SJ225	3.750	0.975	0.350	116.7	SJ296	31.046	6.024	0.850	187.1
SJ226	3.890			124.5	SJ297	30.656	5.969	0.860	187.1
SJ227	3.921			132.4	SJ286	30.305	5.911	0.860	188.1
SJ328	3.990	0.965	0.300	138.0	SJ284	29.929	5.878	0.890	188.3
SJ329	4.373	1.069	0.340	141.5	SJ283	29.365	5.764	0.870	188.2
SJ330	4.805	1.201	0.400	142.4	SJ282	29.043	5.721	0.880	188.1
SJ231	5.196	1.286	0.420	142.9					
SJ332	5.832	1.422	0.450	143.6					
SJ334	6.017	1.503	0.500	154.4					
SJ321	2.198	0.516	0.150	112.3					
SJ336	5.620			144.1					
SJ337	6.168	1.408	0.380	160.8					
SJ338	6.435	1.493	0.420	165.2					
SJ339	6.471			168.5					
SJ340	6.312	1.502	0.450	170.2					
SJ341	6.984	1.814	0.650	186.5					
SJ342	7.400	1.853	0.620	189.1					
SJ343	7.551			193.7					
SJ344	8.131	2.045	0.690	195.4					
SJ345	8.728			196.1					
SJ346	9.102	2.287	0.770	202.1					
SJ347	9.644	2.387	0.780	202.0					
SJ348	9.814	2.426	0.790	199.0					
SJ349	10.036	2.443	0.770	196.8					
SJ350	10.537	2.606	0.850	197.9					
SJ351	10.996	2.713	0.880	196.9					
SJ352	11.326			198.2					
SJ353	11.822	2.980	1.010	197.6					
SJ354	12.275	3.066	1.020	197.4					
SJ355	12.831	3.219	1.080	197.9					
SJ356	13.462	3.344	1.100	197.3					
SJ357	13.916			196.6					

## Appendix 25. First-Arrival Times: Santa Cruz Mountains Shotpoint 7

Loc. No.	Dist. (km)	Unreduced Travel Time (sec)	Reduced Travel Time (T-x/6, sec)	Azimuth					
SJ402	33.526	6.588	1.00	160.3	SJ450	21.274	4.936	1.39	336.2
SJ403	32.933			159.0	SJ451	21.948	4.998	1.34	336.5
SJ404	32.156	6.169	0.81	157.8	SJ452				
SJ405	31.303	6.457	1.24	156.6	SJ453	22.872			335.4
SJ406	31.040	6.373	1.20	155.5	SJ454	23.272	5.189	1.31	334.9
SJ407	30.072	6.902	1.89	155.7	SJ455	24.053	5.309	1.30	334.3
SJ408	29.171	6.182	1.32	155.2	SJ456	24.850	5.382	1.24	335.5
SJ409	28.408			154.8	SJ457	25.613			332.9
SJ410	27.573			155.6	SJ458	26.418	5.633	1.23	332.9
SJ411	26.451			156.0	SJ459	27.256	5.763	1.22	332.6
SJ412	25.601	5.607	1.34	156.3	SJ460				
SJ413	24.879	5.487	1.34	156.8	SJ461	9.804	2.974	1.34	173.2
SJ414	24.128	5.421	1.40	157.8	SJ462	10.264			170.6
SJ415	35.536	7.023	1.10	161.3	SJ463	10.461	3.094	1.35	168.4
SJ416	36.304			160.4	SJ464	10.861	3.230	1.42	165.7
SJ417	37.193	7.199	1.00	159.6	SJ465	11.423	3.264	1.36	163.2
SJ418	37.906	7.498	1.18	159.3	SJ466	12.310	3.432	1.38	160.9
SJ419	37.572	7.562	1.30	165.8	SJ467	13.021	3.540	1.37	159.3
SJ420	38.476			166.3	SJ468				
SJ421	14.611	3.645	1.21	337.1	SJ469				
SJ422	14.079	3.577	1.23	338.7	SJ470	14.692	3.769	1.32	159.2
SJ423	13.369	3.428	1.20	337.4	SJ471	14.958			157.8
SJ424	12.811	3.275	1.14	338.7	SJ472	15.457	3.926	1.35	156.7
SJ425	12.211	3.135	1.10	340.3	SJ473	16.089	4.032	1.35	156.1
SJ426	11.560	3.047	1.12	341.3	SJ474	16.613	4.129	1.36	156.0
SJ427	11.018	2.956	1.12	342.4	SJ475				
SJ428	10.284			344.1	SJ476				
SJ429	9.949			342.6	SJ477	19.185	4.598	1.40	153.7
SJ430	9.400			338.8	SJ478	19.185			153.7
SJ431	8.585	2.451	1.02	341.9	SJ479	21.003			151.7
SJ432	7.872			342.3	SJ480	22.788	5.268	1.47	152.6
SJ433	7.158			346.9	SJ481	8.312			158.5
SJ434	6.328	1.925	0.87	350.4	SJ482	7.734			158.1
SJ435	5.793	1.816	0.85	343.9	SJ483	7.266	2.401	1.19	157.5
SJ436	4.964			343.6	SJ484	6.750	2.305	1.18	154.6
SJ437	4.343	1.624	0.90	340.9	SJ485	6.161			153.6
SJ438	3.805	1.074	0.44	335.1	SJ486	5.874	1.969	0.99	159.2
SJ439	3.634			326.2	SJ487	5.644			164.6
SJ440	2.989	0.918	0.42	325.6	SJ488	4.909	1.598	0.78	166.7
SJ441	15.360	3.810	1.25	337.1	SJ489	4.173	1.406	0.71	173.5
SJ442	16.055	3.966	1.29	335.4	SJ490	3.565	1.134	0.54	169.1
SJ443	16.954			335.6	SJ491	2.665			171.7
SJ444	17.941	4.350	1.36	335.9	SJ492	1.968	0.638	0.31	170.5
SJ445	18.580	4.397	1.30	335.9	SJ493	1.449	0.522	0.28	178.9
SJ446	19.339			335.7	SJ494	0.818	0.436	0.30	186.4
SJ447	20.201	4.567	1.20	335.9	SJ495	0.058	0.030	0.02	24.9
SJ448	20.363	4.694	1.30	336.4	SJ496	0.804	0.284	0.15	276.3
SJ449					SJ497	1.426			283.3
					SJ498	1.791	0.639	0.34	303.8
					SJ499	2.306	0.804	0.42	316.0
					SJ500	2.620	0.867	0.43	329.7

## **Appendix 26. Unpublished Report (dated December 1982) on the Structure of the Santa Cruz Mountains, by Annette Boken and Walter D. Mooney**

The following discussion concerns a preliminary interpretation of the Davenport and La Honda refraction lines by Boken and Mooney (1982). Given the geologic complexity of the study area, the lack of reversal of the La Honda line, and the presence of only 2 shotpoints along the Davenport line, the models presented below must be considered to be relatively poorly constrained and non-unique. They are presented below only to provide the reader an indication of the structure sampled by the seismic refraction lines.

### Davenport Profile

The Davenport profile is a 35-km-long reversed refraction line (Fig. 13). The surface geology crossed by the line includes the Franciscan Assemblage to the north at Los Altos (Fig. 13). After crossing the San Andreas fault, the profile line traverses Tertiary sediments surrounding the Butano fault. Proceeding south, it crosses the Zayante-Ben Lomond fault and the granite of Ben Lomond Mountain. After traversing metasediments, the line ends in Tertiary marine sediments.

First arrivals on the Los Altos (shot point 6) record section show an apparent velocity of 4.0 km/s for the first layer and of 6.55 km/s for the second layer (Fig. 14). Alternate travel time advances and delays on the more complicated Davenport SP 5 record section suggest that the velocities of the near surface is not laterally homogeneous, especially near the southern end of the profile. In addition, whereas the crossover distance (to the basement refractor) for the Los Altos record section is 15 km, that of the Davenport record section is 22 km (Fig. 14), suggesting an up-dip of the second layer in a southerly direction.

A preliminary velocity model for these data is shown in Figure 16. The velocities that best fit the mapped geology of the area and first arrivals in the data are: 4.0 km/s for Tertiary sediments and 6.1 km/s for the basement layer from the Los Altos quarry (SP6). The depth to basement south of the San Andreas Fault zone is 3.5 km (Fig. 16). (Depth to basement and basement velocity north of the fault are not well-constrained.) Granites of Ben Lomond Mountain are exposed at the surface to the south of the Zayante-Ben Lomond fault, and the near-surface crustal layer has a velocity of 5.5 km/s down to a depth of 3 km, where its velocity increases to 6.1 km/s. Nine km south of the Zayante-Ben Lomond fault the surficial granite ends and metasediments begin. Here the upper layer velocity decreases to 5.0 km/s and the basement layer to 5.7 km/s. Tertiary sediments with a velocity of 3.1 km/s down to 1 km depth are modeled south of the Davenport quarry.

### La Honda Profile

The unreversed La Honda refraction line is 70 km long (Fig. 13, squares). The La Honda line begins to the north in the Franciscan Assemblage and follows the west edge of the San Andreas fault. It traverses Tertiary sediments in the La Honda basin and the Pilarcitos, Butano, and Zayante-Ben Lomond faults before it reaches Davenport. This line, like the Davenport line, crosses the granite of Ben Lomond Mountain before ending in Tertiary marine sediments in the south. Only one shot, shot point 7, in the middle, was recorded along this line. Thus, the interpretation given below is non-unique, as other structural models fit the travel times equally well. Additional data are required to reduce the ambiguity of this interpretation.

The record section from La Honda (SP7) is shown in Figure 15. To the southeast, there are three branches, with velocities of 3.0 km/s for the near-surface layer and apparent velocities of

5.6 and 7.0 km/s following. The data fit a model with similar velocities and layer thicknesses as obtained for the N-S profile, with some changes near the shot point. First, the near surface layer (La Honda basin filling sedimentary rocks) at the shot point has a velocity of 3.0 km/s. Second, the basement near the shot point has an apparent a velocity of 5.7 km/s. This section of the basement to the north of the Butano fault had a velocity of 6.1 km/s in the model for the north-south profile.

To the northwest, there are also three branches, with apparent velocities of 3.3, 5.0, and 7.0 km/s. The 7.0 km/s branch suggests an up-dip of the basement to the northwest. Although this section of the data is not reversed, a preliminary model has been calculated and is shown at the bottom of Figure 17. Gravity data, shown in the middle of the figure, provide a check for this preliminary model. Except for the clear gravity high near km 30 where there are high-velocity near surface rocks around Ben Lomond Mountain, the gravity follows basement depth, rising to the northwest and southeast.

The aeromagnetic cross-section to the southeast (Fig. 17, top right) shows a slight rise over the 6.1 km/s section of the basement. It has been suggested that the basement in this area is gabbroic (Ross, 1978). A better understanding of the aeromagnetic data to the northwest and a confirmation of the location of the boundary between the 5.7 and 6.1 km/s basement are needed.

### Conclusions

We can draw four conclusions about the study area, subject to the above caveats concerning lack of reversal of the La Honda line and the presence of only 2 shotpoints along the Davenport line. First, Ben Lomond Mountain is an uplifted block of granitic rock having higher velocities than the surrounding Tertiary sedimentary and metasedimentary rocks. Second, the Tertiary sediments in the La Honda basin north of Ben Lomond Mountain are at least 3 km deep. Third, the top of the basement interface dips at 10° north from Davenport to the San Andreas fault. Fourth, the basement velocity appears to lie between 5.7 and 6.1 km/s; lower velocities in the basement are found in the southern and northwestern portions of the study area.

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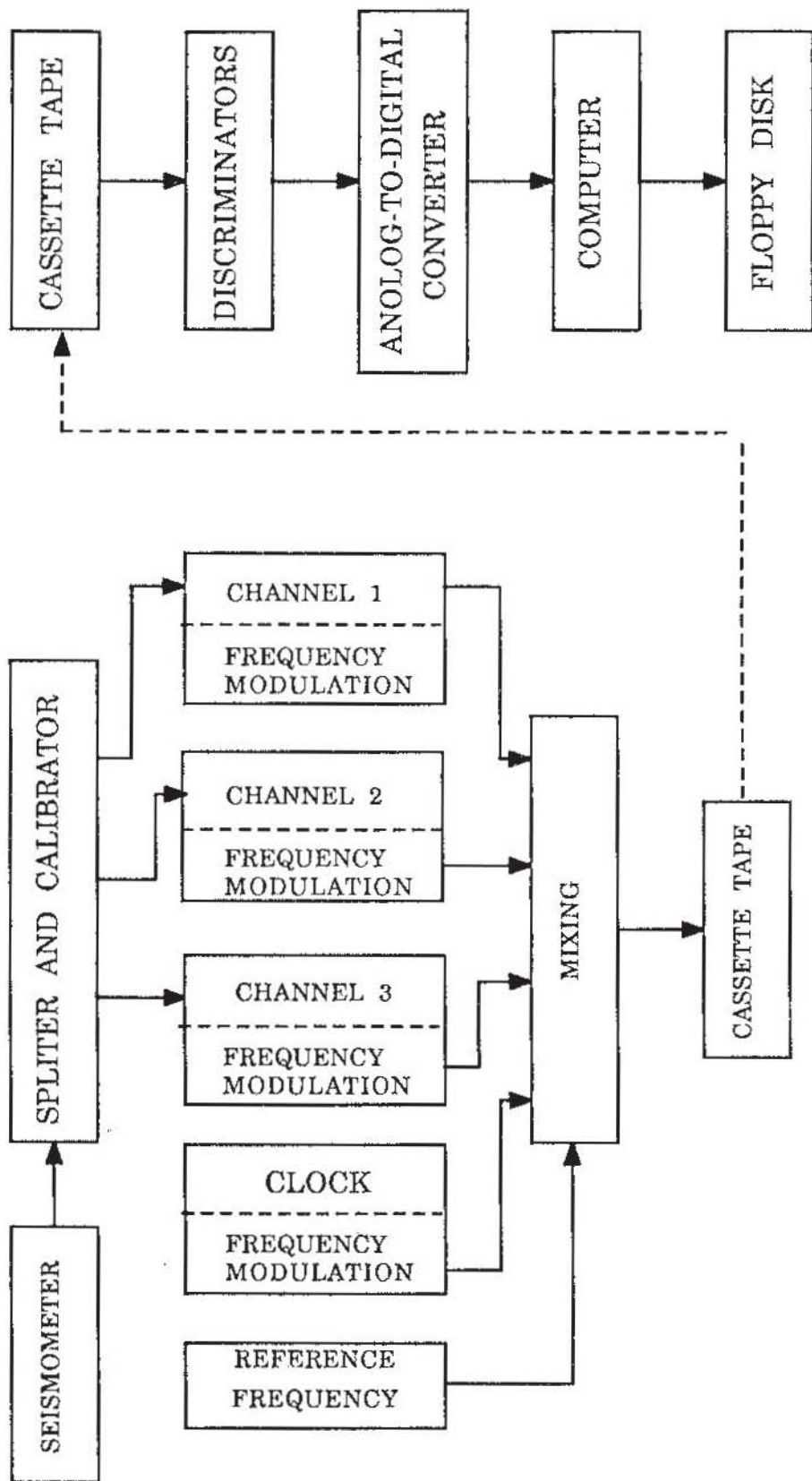


Figure 1. Schematic diagram showing the data acquisition and processing system.

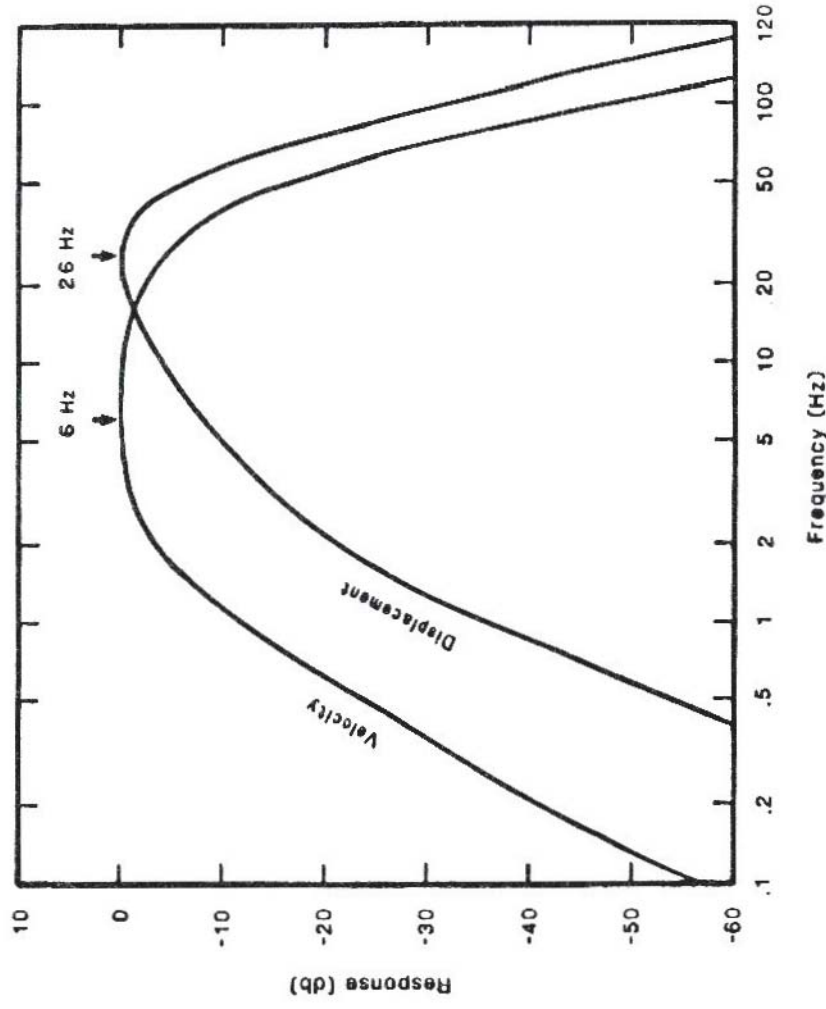


Figure 2. Theoretical transfer function curves for the USGS short-period seismic refraction system (both recorder and digitizer). Solid lines are the displacement and velocity normalized amplitude (from Dawson and Stauber, 1986).



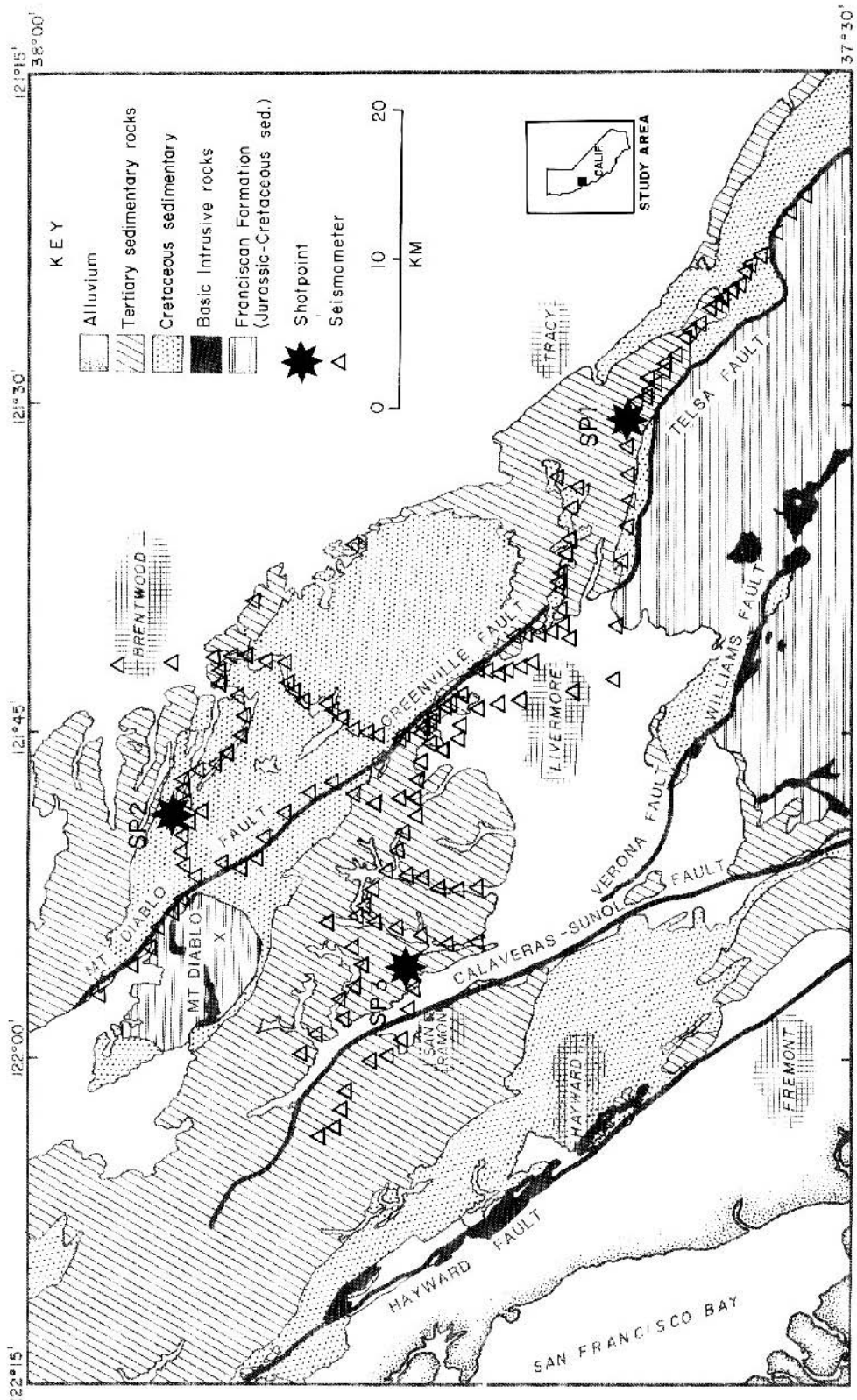


Figure 3. Map of the Livermore area showing the locations of the seismic recorders (triangles) and shotpoints used in the 1980 seismic refraction study.

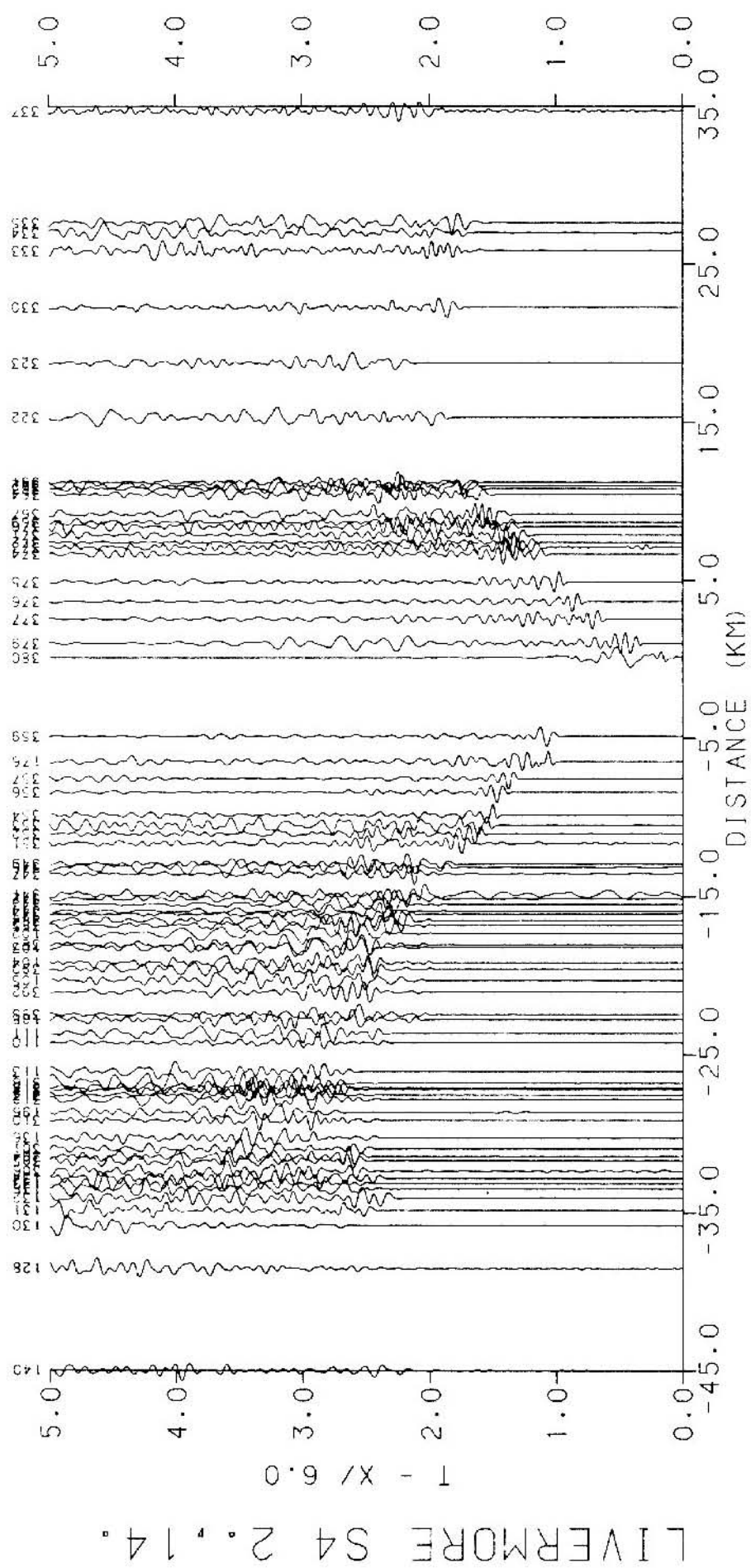


Figure 4. Reduced record section for shotpoint 1 (shot 4), for the north-south profile.

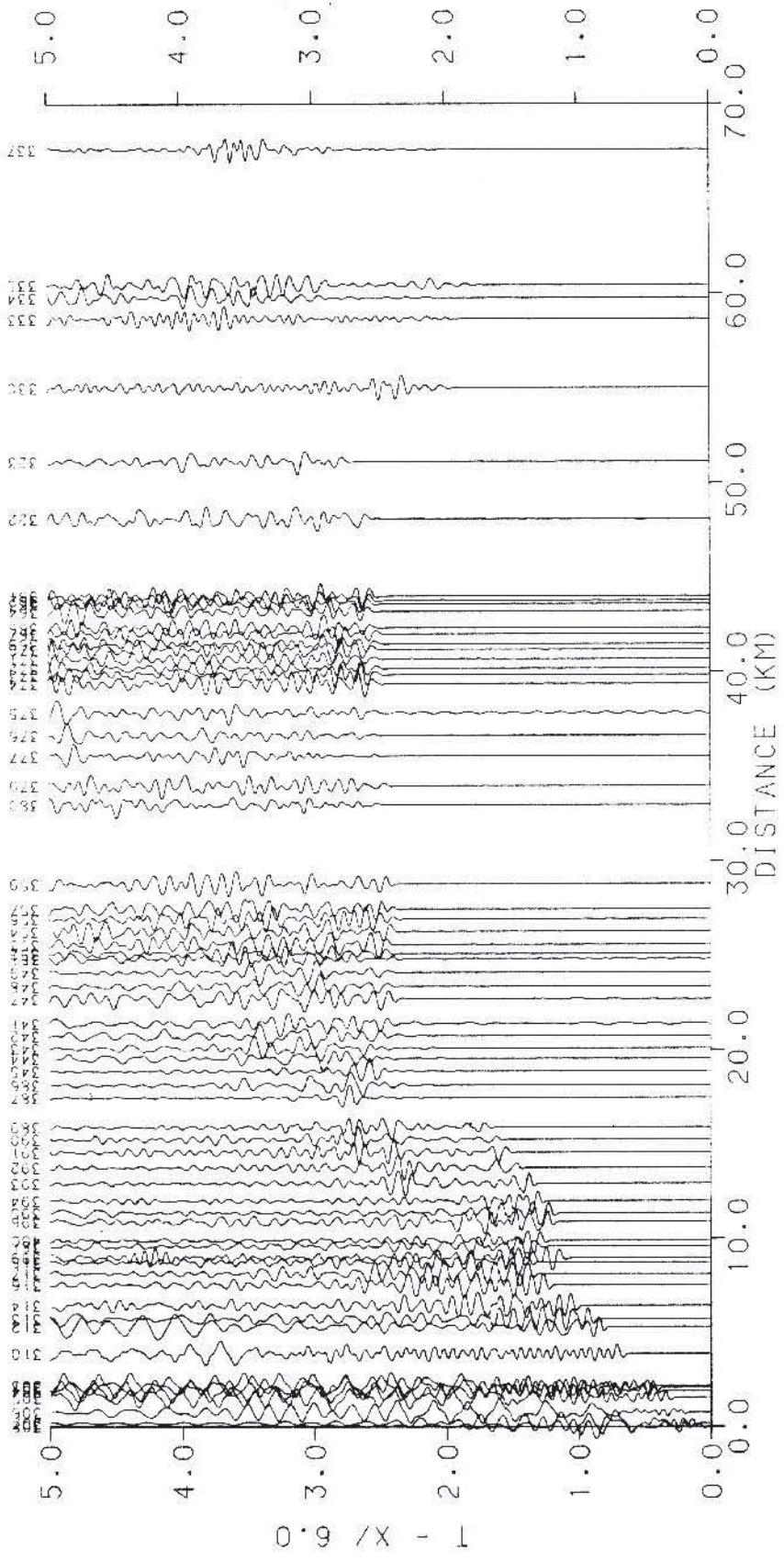


Figure 5. Reduced record section for shotpoint 2 (shot 5), for the north-south profile.

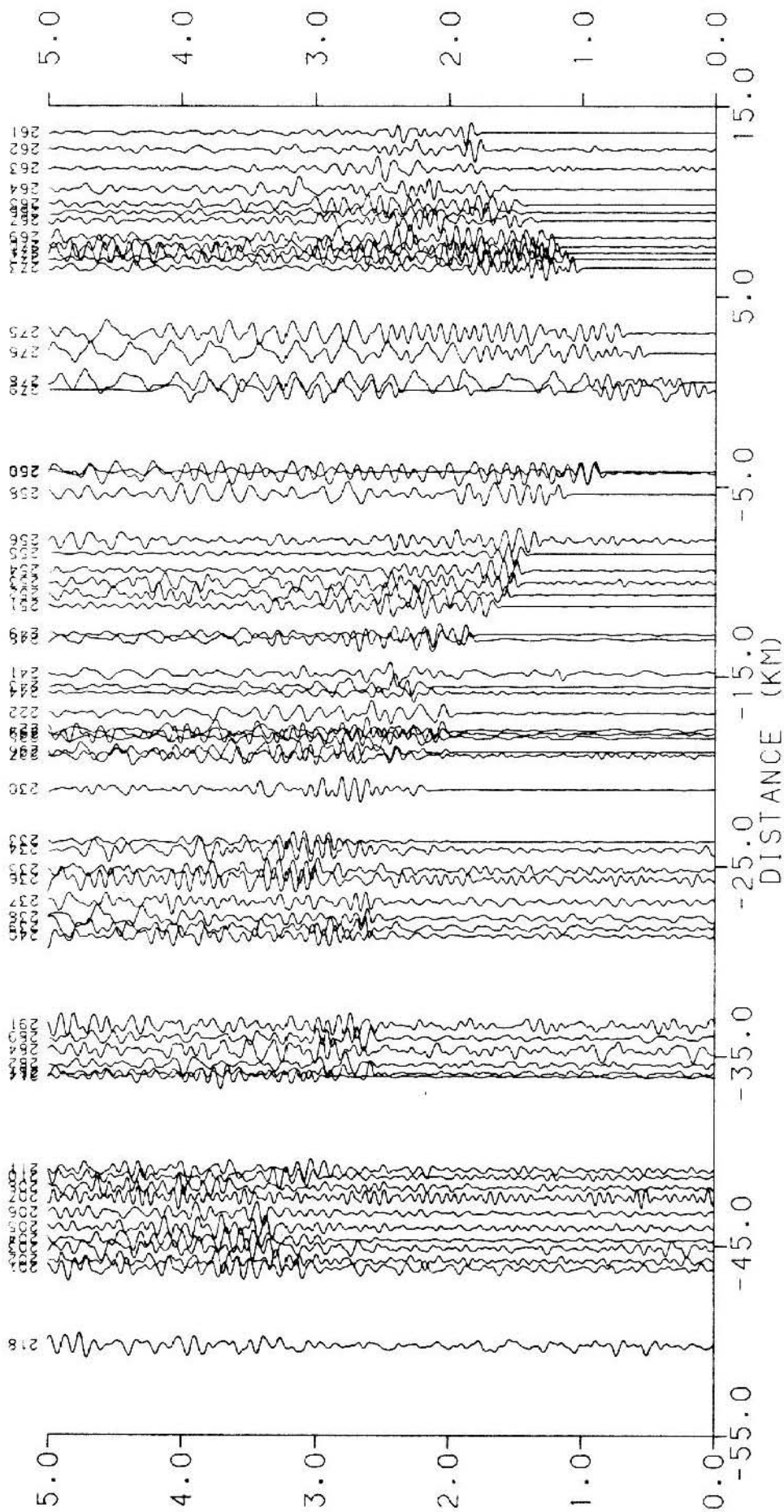


Figure 6. Reduced record section for Livermore shotpoint 1 (shot 2), for the NW-SE profile.

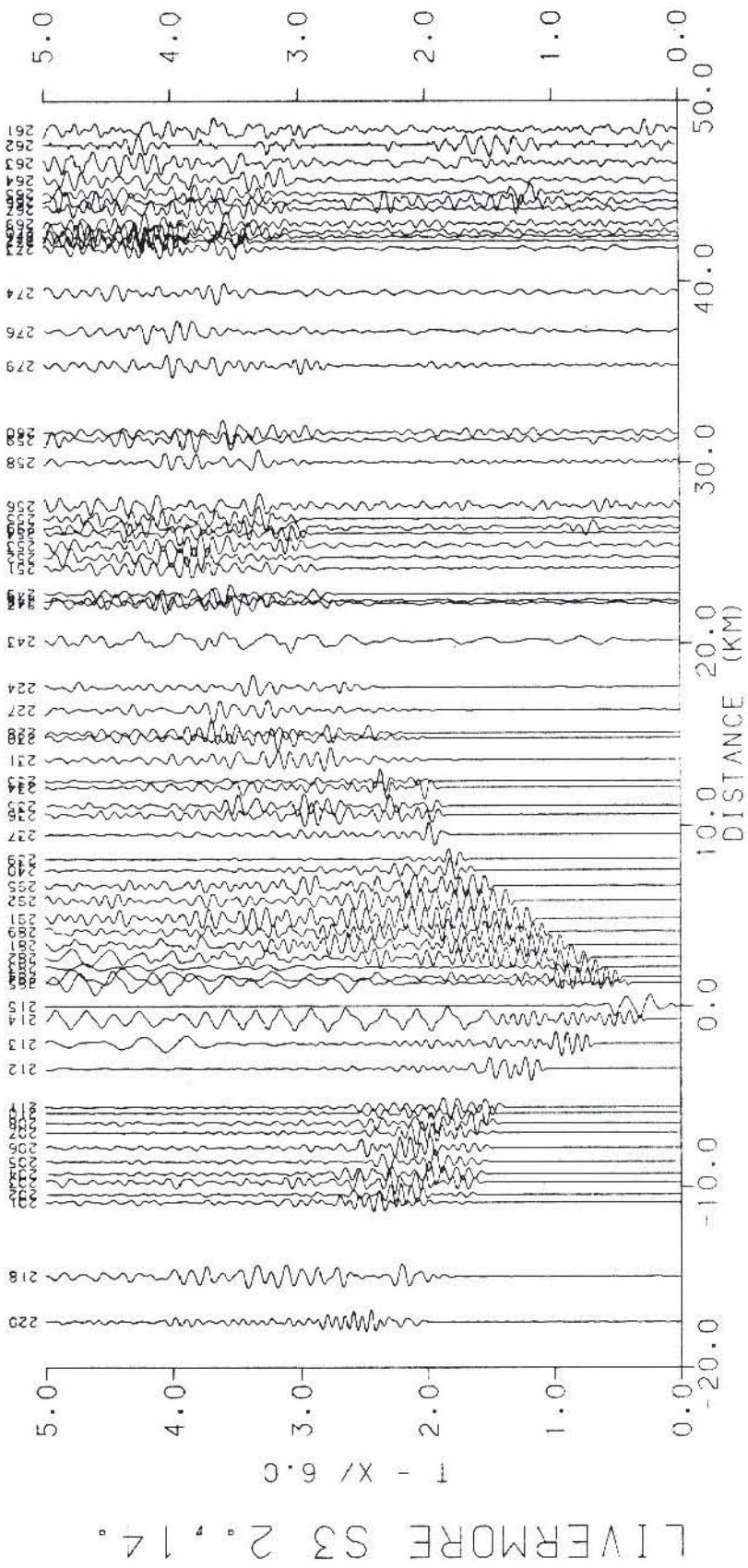


Figure 7. Reduced record section for Livermore Shotpoint 3.

# LIVERMORE EARTHQUAKES 1980 #1

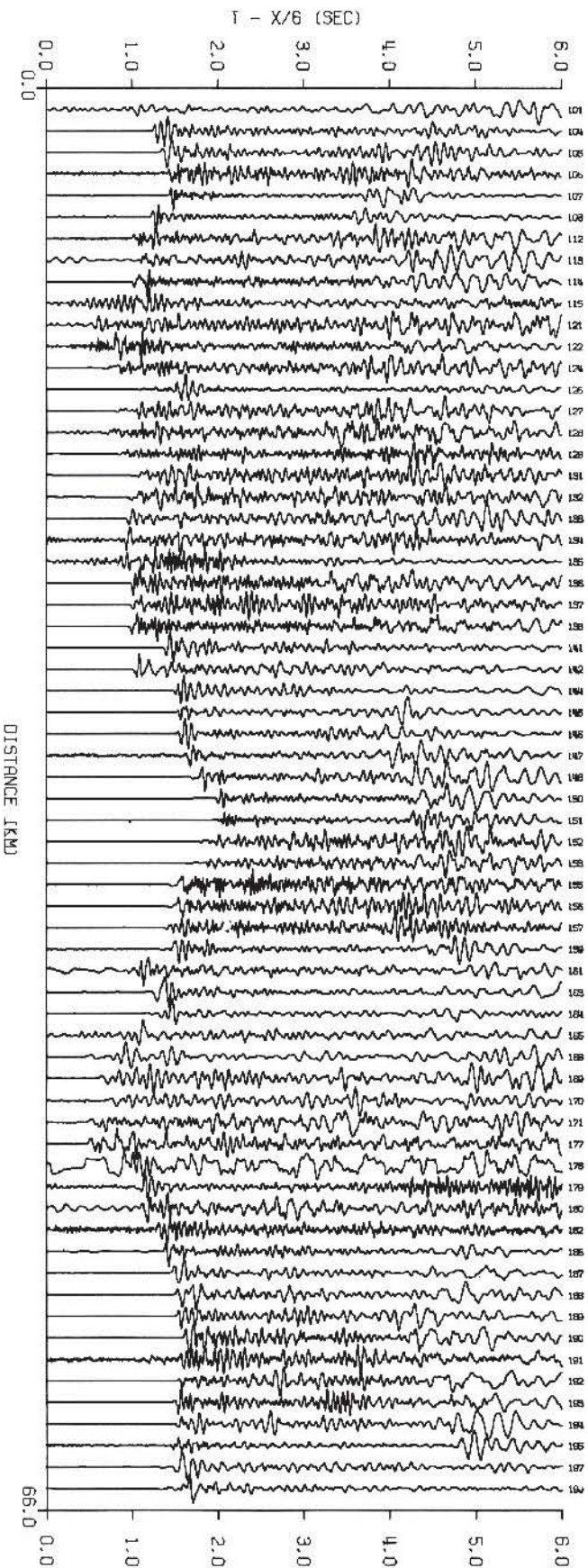


Figure 8. Reduced record section for Livermore microearthquake number 1.

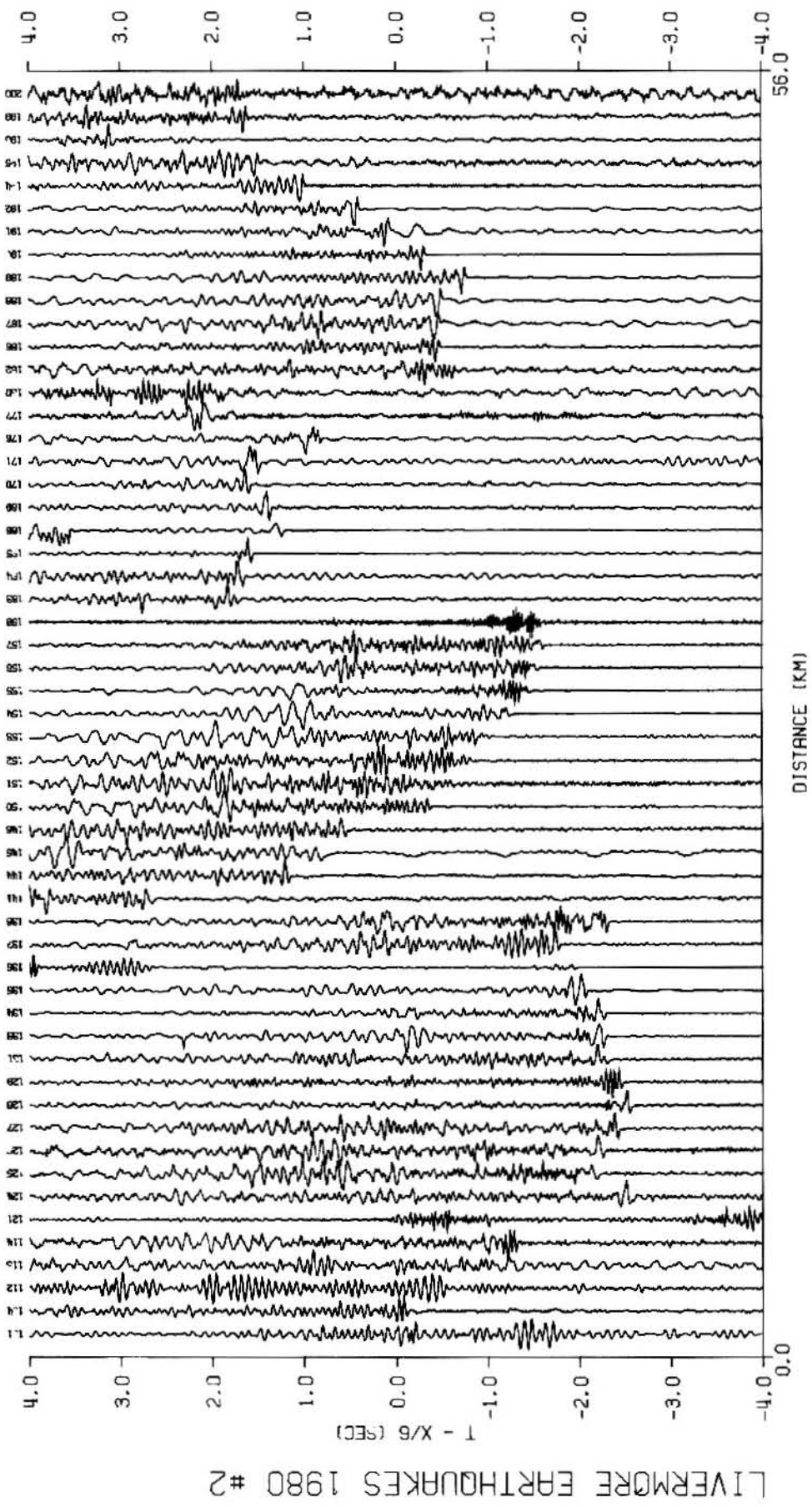


Figure 9. Reduced record section for Livermore microearthquake number 2.

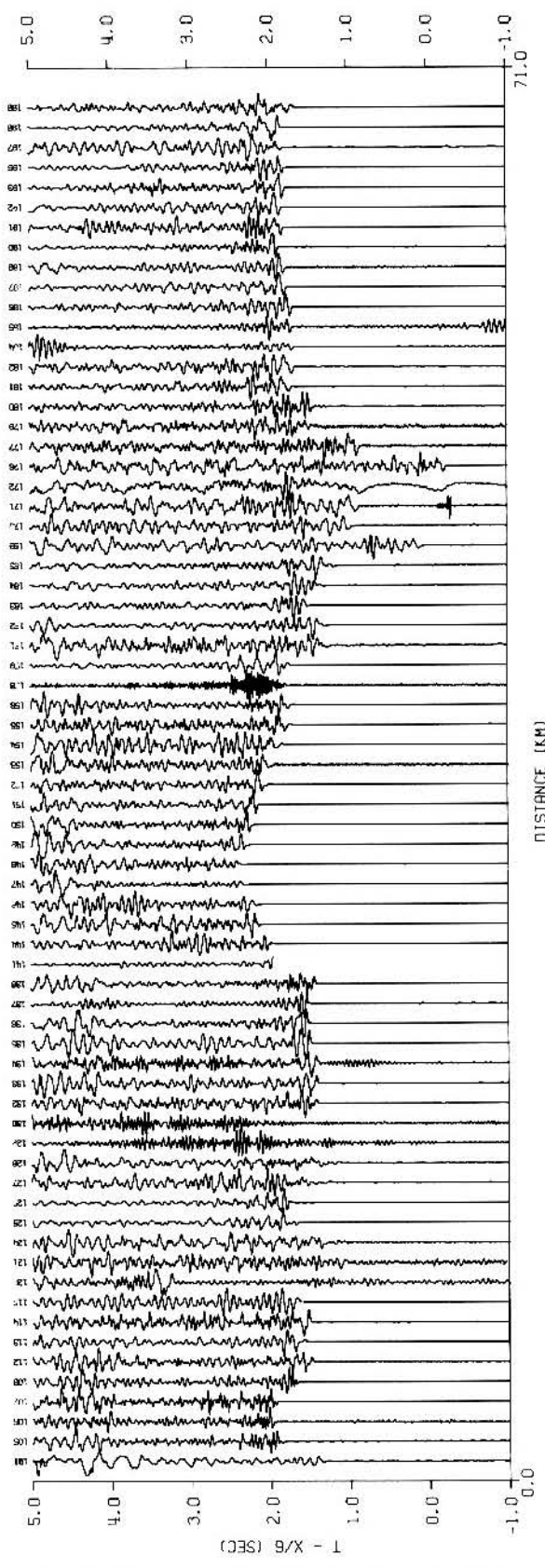


Figure 10. Reduced record section for Livermore microearthquake number 3.



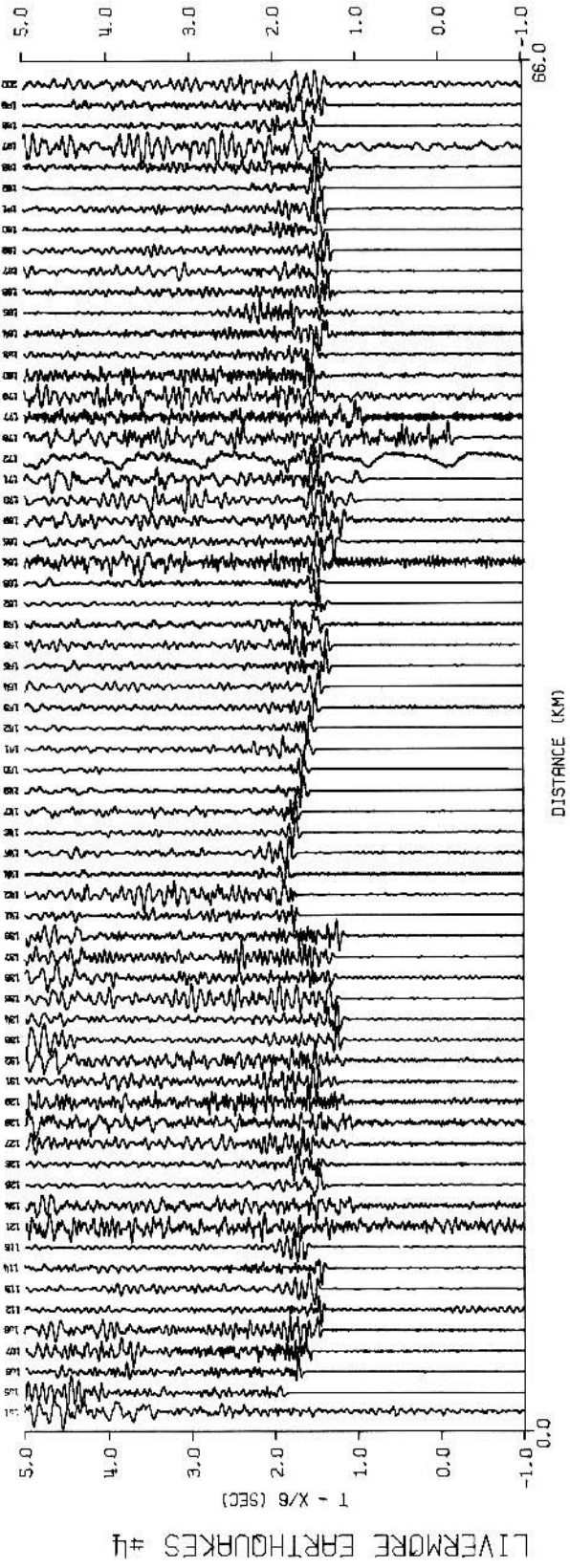


Figure 11. Reduced record section for Livermore microearthquake number 4.

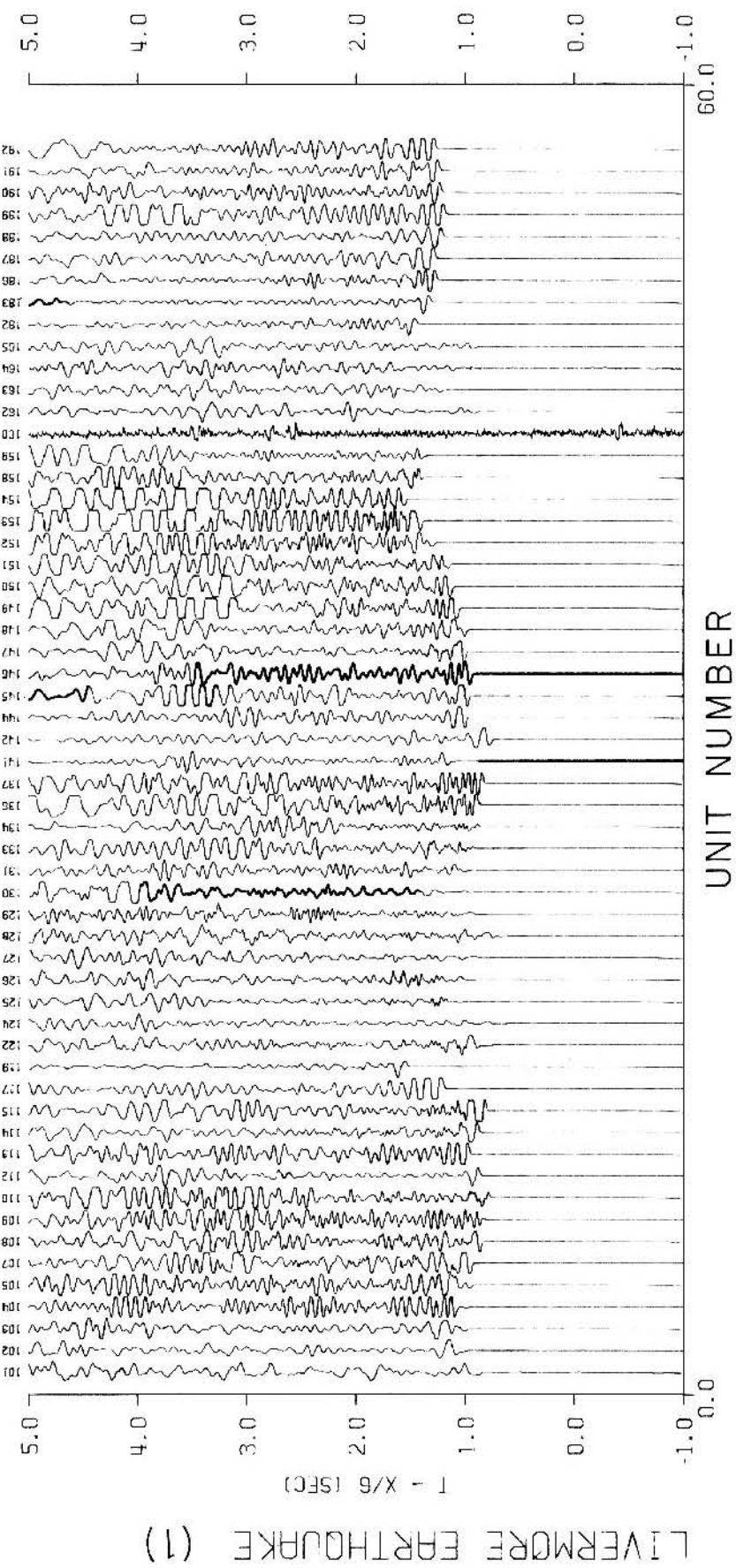


Figure 12. Reduced record section for Livermore microearthquake number 5.

# SANTA CRUZ REFRACTION: INSTRUMENT LOCATIONS

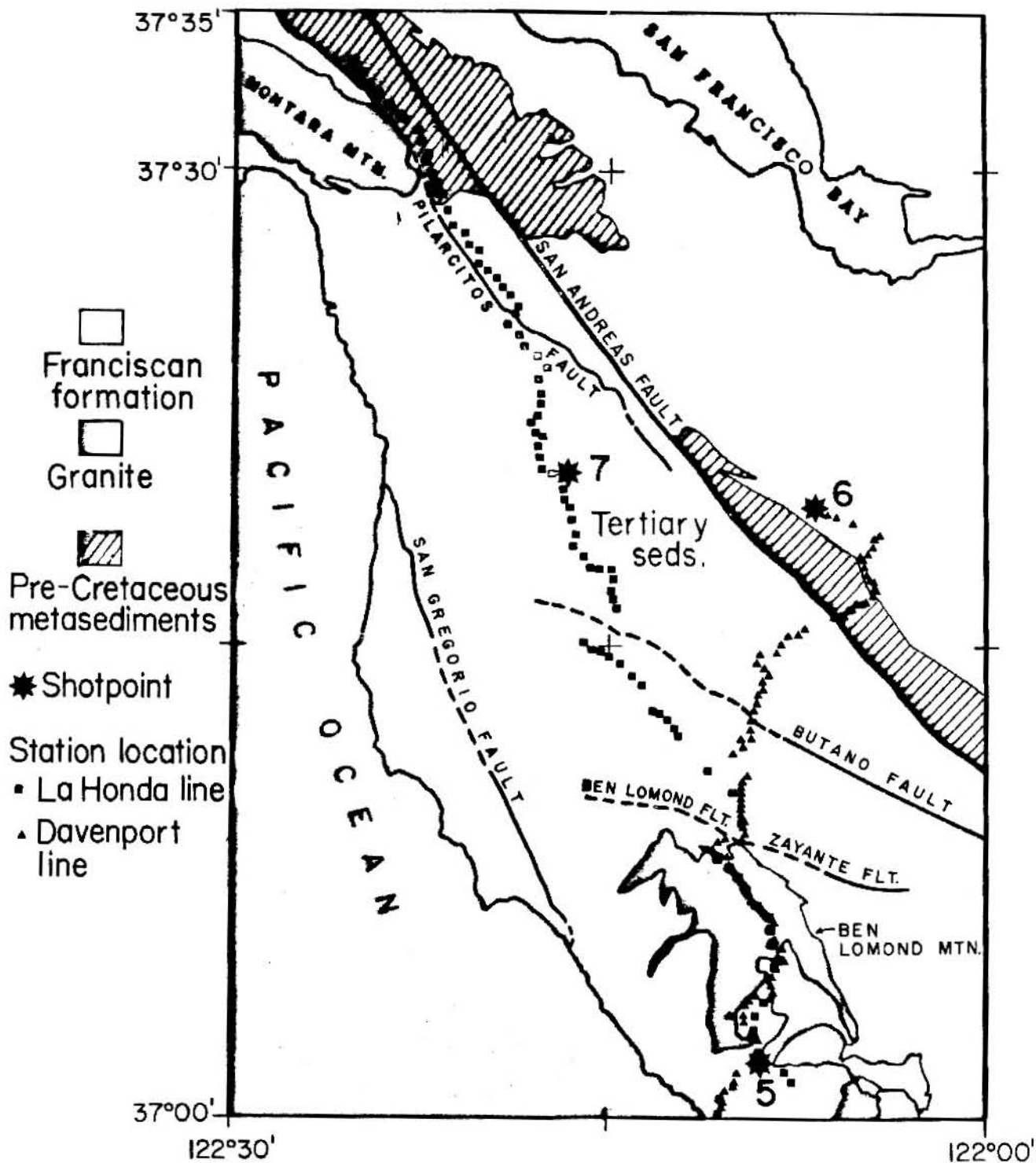


Figure 13. Map of the Santa Cruz Mountains showing locations of seismic recorders (filled squares) and shotpoints.

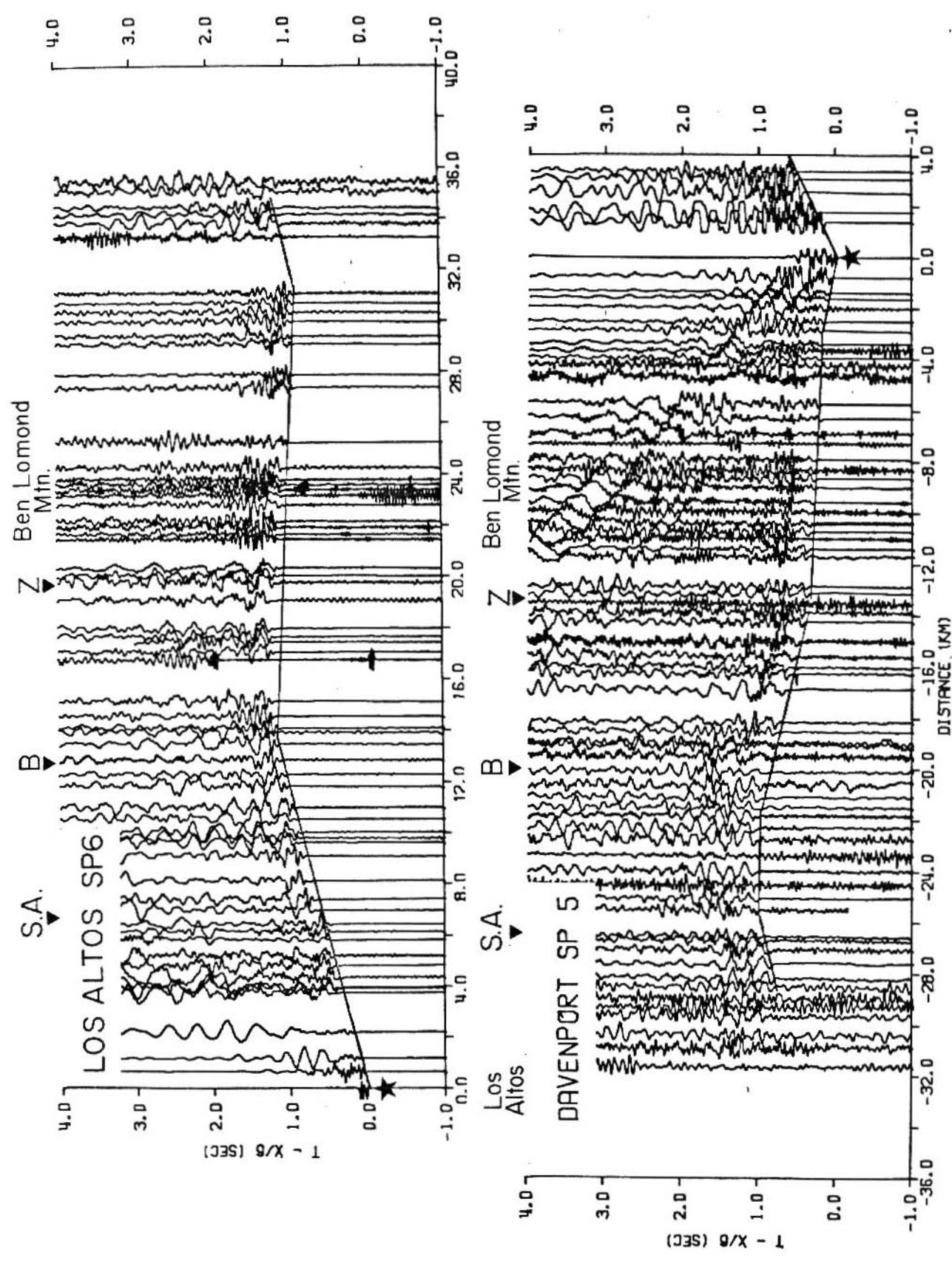


Figure 14. Reduced record sections for Shotpoints 5 and 6 in the Santa Cruz Mountains. Abbreviations: San Andreas fault (S.A.), Butano fault (B), Zayante fault (Z).

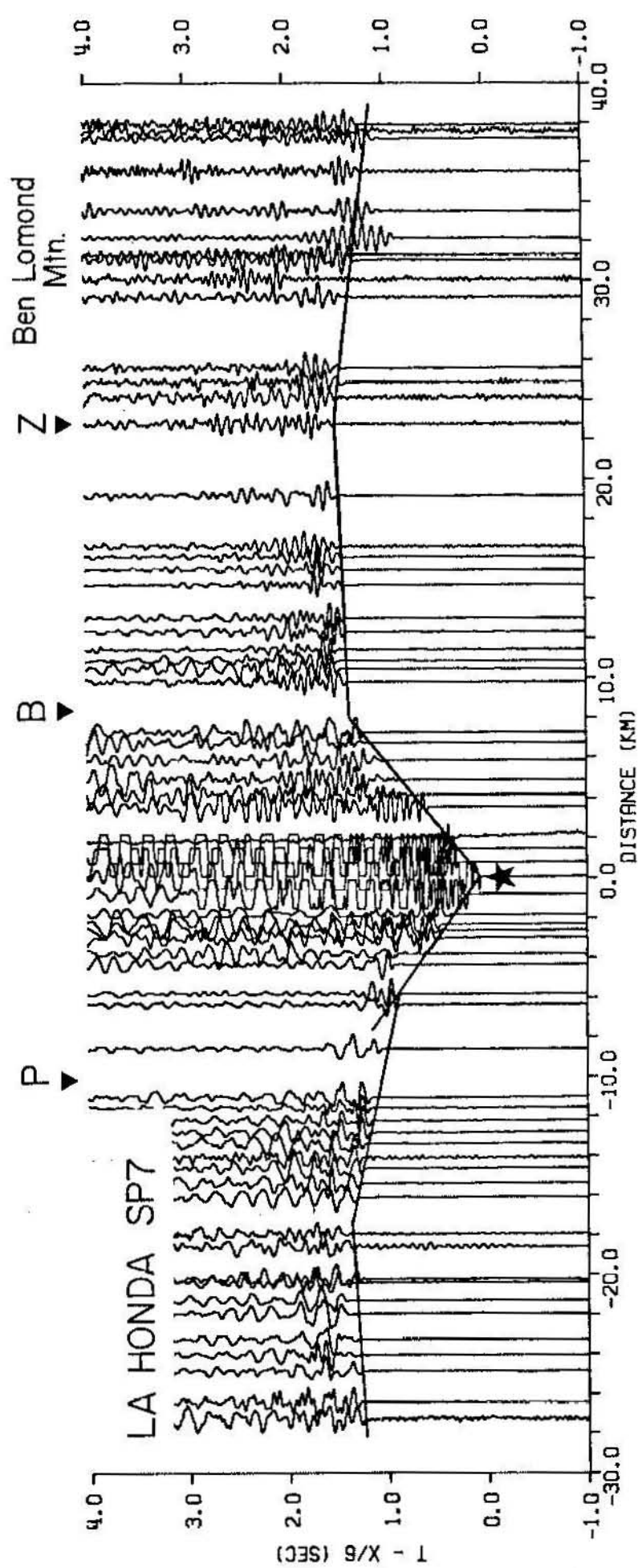


Figure 14. Reduced record section from La Honda Shotpoint 7 from Boken and Mooney (1982).

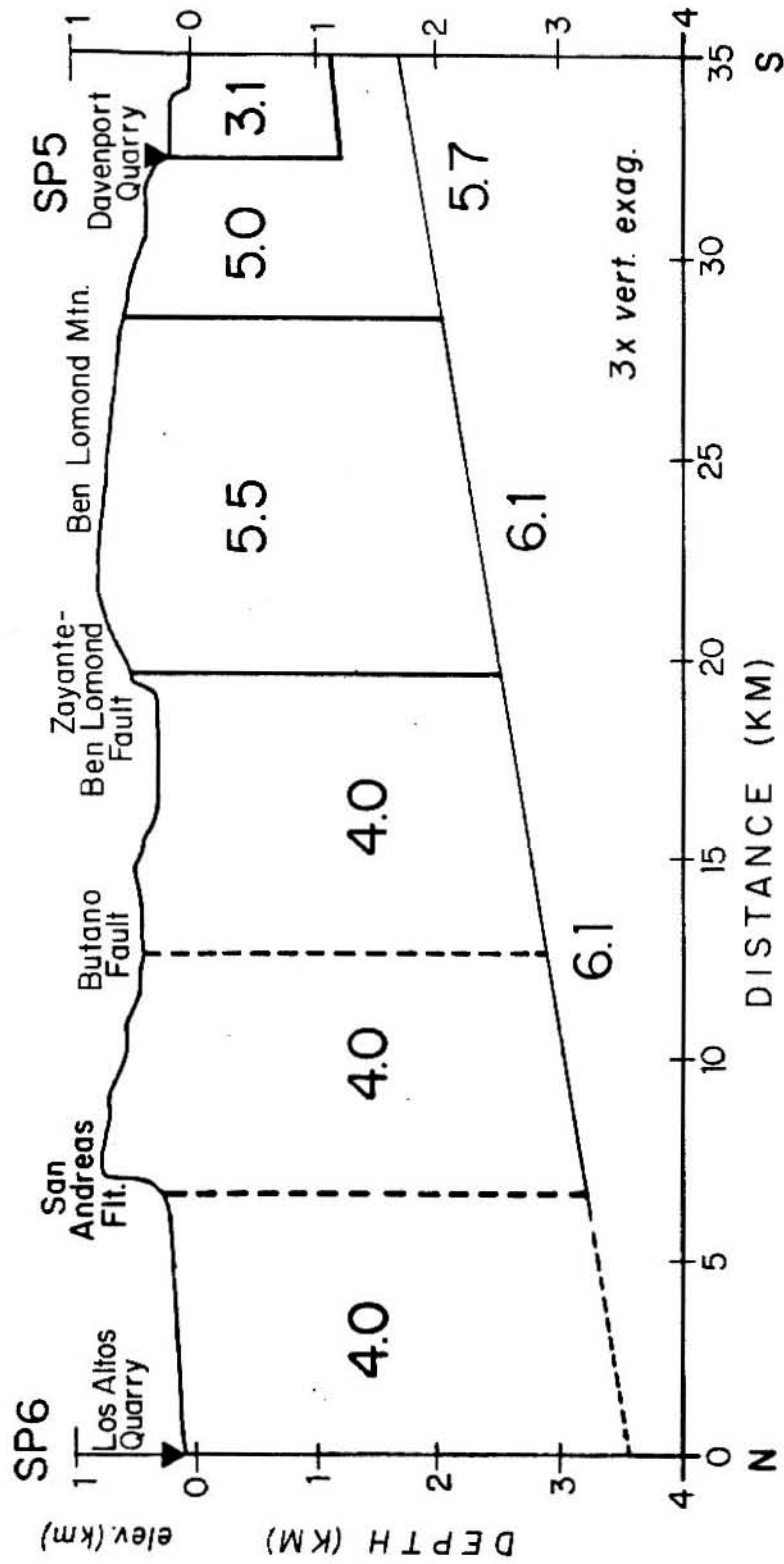


Figure 16. Velocity model prepared by Boken and Mooney (1982). Velocities are shown as kilometers/sec.

# GRAVITY and AEROMAGNETIC X-SECTIONS

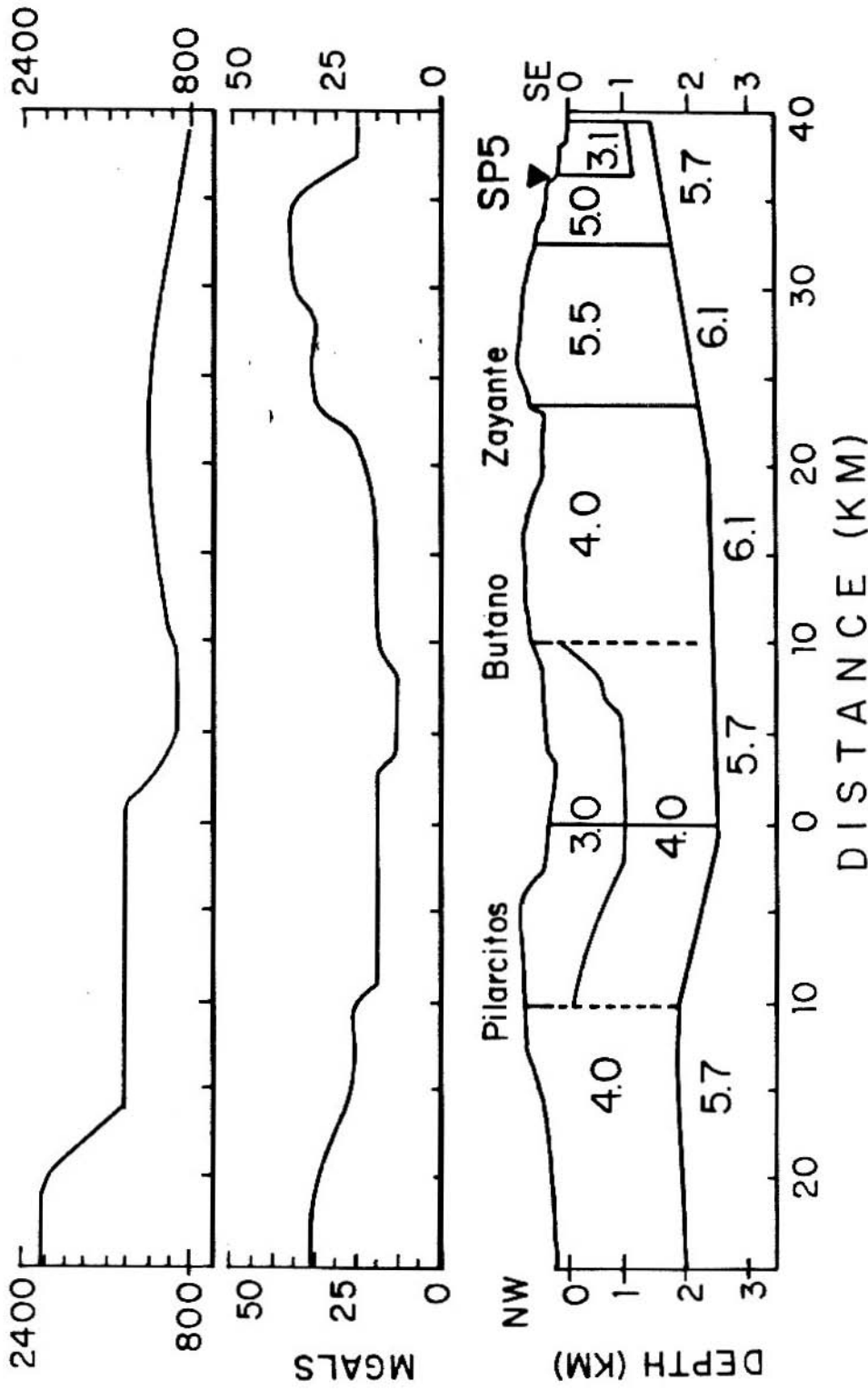


Figure 17. Aeromagnetic profile, gravity profile, and velocity model for the La Honda line from Boken and Mooney (1982).