DARTED STATES (DEPARTMENT OF THE INTERIOR)

A SEISMIC REFRACTION EXPERIMENT
PERFORMED IN THE MELONES RESERVOIR REGION OF THE METAMORPHIC BELT, CENTRAL CALIFORNIA
by
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Open-File Report 78-131 April 1978


This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

ABSTRACT
A seismic refraction experiment was conducted in the metamorphic belt of central California during May 1972. Seven charges were fired during the experiment. Three seismic refraction lines, 75 to 125 km long, were made in the belt. Also, data were gathered for regional travel-time calibrations. The experimental data are presented. They include P-wave travel times, station locations, shot locations, and shot origin times.

## INTRODUCTION

A seismic refraction experiment was conducted by the U. S. Geological Survey (USGS) in the western foothills of the Sierra Nevada Mountains of central California during May 1972. The region (Figure 1) is called the metamorphic belt. The purpose of the experiment was to provide a P-wave travel-time calibration for this area of complex geology, and to provide seismic data for modeling the upper crust. To achieve these objectives, the experiment was conducted to produce data both for seismic refraction line and time-term analyses. Three seismic refraction lines were made (lines 1, 2, and 3, Figure 1). The lines ranged from 75 to 125 km in length. The P-wave paths for the regional travel-time studies cross an area approximately $3000 \mathrm{~km}^{2}$. Due to the renewed interest in the region, data obtained from the experiment are presented here.

EXPLANATION

SEDIMENTARY AND EXTRUSIVE ROCKS
$\square$ CENOZOIC SEDIMENTARY DEPOSITS
$\square$ PRE-CRETACEOUS METAVOLCANIC METASEDIMENTARY AND SEDIMENTARY ROCKS

## INTRUSIVE ROCKS


$\square$

[^0]
$120^{\circ} 00^{\prime}$

Figure 1. Map showing the shots, fixed stations (three-1etter names), and arrays (one-1etter names) superimposed on an abstract of the geologic maps (from Rogers, 1966). Not shown is $T$ on line $3,22 \mathrm{~km}$ southeast of BMR. PAC is 170 km east of San Francisco.

## ACQUISITION OF THE DATA

Seven charges were fired during the experiment. Their sites are given in Table 1. Five of the shots (LGR, WLR, GSR, NHR, BMR) were one-ton charges detonated and timed by USGS personnel. The times are thought to be correct to within 0.02 sec . The other two (PAC and CCM) were quarry explosions; hence, their origin times are known only approximately. The origin time given for PAC is its arrival time at a station 230 m from the shot, and the origin time given for CCM is its arrival time at CGR, 870 m from the shot. The time reference to these stations has been made so that the true origin times can be estimated when the P -wave velocities at the sites are known.

The seismic data produced by the shots were recorded by two different types of stations: (1) seismic stations deployed at fixed locations throughout the experiment, and (2) four- or six-element seismic arrays, maximum aperature 2.5 km , deployed sequentially on the three different lines shown on Figure 1. Arrays are given one-letter names and the fixed stations are given three-letter names. A fixed station was sited within 300 m of each of the USGS shots; therefore, each of the pairs was given a common name. A1so, an array was sited at each of the USGS shots.

Locations of the stations and arrays are presented on Figure 1 and in Table 2 and 3. These locations were determined from the positions of the sites plotted by the field crews on maps of scale $1: 24,000$. The positions are thought to be within 200 m of their true map locations.

Coordinates of positions where charges were fired and the origin times of the charges

| STA | Lat <br> N | Lon <br> W | Elev <br> $(\mathrm{M})$ | May <br> 1972 | Hr Min <br> Universal Time |
| :--- | :---: | :---: | :---: | :---: | :--- |
| BMR | $37^{\circ} 46.50^{\prime}$ | $120^{\circ} 03.57^{\prime}$ | 838 | 24 | $08: 00: 02.102$ |
| CCM | $38^{\circ} 06.35^{\prime}$ | $120^{\circ} 24.76^{\prime}$ | 646 | 23 | $23: 02: 01.25$ |
| GSR | $37^{\circ} 42.27^{\prime}$ | $120^{\circ} 15.84^{\prime}$ | 335 | 25 | $08: 35: 00.57$ |
| LGR | $37^{\circ} 38.92^{\prime}$ | $120^{\circ} 24.48^{\prime}$ | 146 | 23 | $08: 30: 00.26$ |
| NHR | $38^{\circ} 08.10^{\prime}$ | $120^{\circ} 47.13^{\prime}$ | 213 | 25 | $08: 05: 01.07$ |
| PAC | $37^{\circ} 56.30^{\prime}$ | $120^{\circ} 32.76^{\prime}$ | 286 | 26 | $23: 21: 50.25$ |
| WLR | $38^{\circ} 08.76^{\prime}$ | $120^{\circ} 56.51^{\prime}$ | 101 | 23 | $08: 00: 01.07$ |

## Coordinates of fixed stations

| STA | $\begin{gathered} \text { Lat } \\ \mathrm{N} \end{gathered}$ | $\underset{\mathrm{W}}{\mathrm{Lon}}$ | Elev <br> (M) |
| :---: | :---: | :---: | :---: |
| AFR | $37^{\circ} 29.33^{\prime}$ | $120^{\circ} 01.04^{\prime}$ | 610 |
| BMR | $37^{\circ} 46.54{ }^{\prime}$ | $120^{\circ} 03.69^{\prime}$ | 823 |
| BRO | $33^{\circ} 00.50^{\prime}$ | $120^{\circ} 24.95^{\prime}$ | 387 |
| BVR | $37^{\circ} 33.66^{\prime}$ | $120^{\circ} 06.72^{\prime}$ | 610 |
| CGR | $38^{\circ} 06.81^{\prime}$ | $120^{\circ} 24.63^{\prime}$ | 585 |
| CNS | $37^{\circ} 56.31{ }^{\prime}$ | $120^{\circ} 31.76^{\prime}$ | 373 |
| COP | $37^{\circ} 58.38{ }^{\prime}$ | $120^{\circ} 37.11^{\prime}$ | 336 |
| CRH | $38^{\circ} 01.11^{\prime}$ | $120^{\circ} 30.59^{\prime}$ | 475 |
| CSR | $38^{\circ} 12.92^{\prime}$ | $120^{\circ} 51.75^{\prime}$ | 128 |
| DHR | $38^{\circ} 22.31^{\prime}$ | $120^{\circ} 59.80^{\prime}$ | 113 |
| FWL | $38^{\circ} 01.14{ }^{\prime}$ | $120^{\circ} 35.00^{\prime}$ | 880 |
| GSR | $37^{\circ} 42.31{ }^{\prime}$ | $120^{\circ} 15.84^{\prime}$ | 335 |
| JAS | $37^{\circ} 56.80^{\prime}$ | $120^{\circ} 26.30^{\prime}$ | 457 |
| JVR | $38^{\circ} 18.09^{\prime}$ | $120^{\circ} 56.98^{\prime}$ | 85 |
| KFR | $37^{\circ} 47.60{ }^{\prime}$ | $120^{\circ} 37.90^{\prime}$ | 171 |
| LGR | $37^{\circ} 38.95{ }^{\prime}$ | $120^{\circ} 24.34^{\prime}$ | 152 |
| LVR | $38^{\circ} 13.24{ }^{\prime}$ | $120^{\circ} 19.48^{\prime}$ | 1219 |
| MCM | $37^{\circ} 53.16^{\prime}$ | $120^{\circ} 30.43{ }^{\prime}$ | 362 |
| NHR | $38^{\circ} 08.20^{\prime}$ | $120^{\circ} 47.08^{\prime}$ | 219 |
| OBF | $37^{\circ} 53.99^{\prime}$ | $120^{\circ} 34.07{ }^{\prime}$ | 176 |
| ODR | $37^{\circ} 47.04^{\prime}$ | $120^{\circ} 43.80^{\prime}$ | 79 |
| SGR | $37^{\circ} 37.95{ }^{\prime}$ | $120^{\circ} 09.23^{\prime}$ | 480 |
| STN | $37^{\circ} 54.24^{\prime}$ | $120^{\circ} 24.36{ }^{\prime}$ | 366 |
| WLR | $38^{\circ} 08.80^{\prime}$ | $120^{\circ} 56.41^{\prime}$ | 107 |

TABLE 3
Coordinates of array stations
Line 1

| STA | Lat | Lon W | Elev <br> (M) |
| :---: | :---: | :---: | :---: |
| H 1 | $38^{\circ} 05.25^{\prime}$ | $120^{\circ} 52.37{ }^{\text {\% }}$ | 67 |
| H 4 | $38^{\circ} 04.46^{\prime}$ | $120^{\circ} 52.12^{\prime}$ | 79 |
| H 5 | $38^{\circ} 04.25^{\prime}$ | $120^{\circ} 51.92^{\prime}$ | 107 |
| H 6 | $38^{\circ} 04.06^{\prime}$ | $120^{\circ} 51.89^{\prime}$ | 110 |
| I 4 | $37^{\circ} 50.86^{\prime}$ | $120^{\circ} 37.97{ }^{\prime}$ | 183 |
| I 6 | $37^{\circ} 50.36{ }^{\prime}$ | $120^{\circ} 37.52^{\prime}$ | 165 |
| J 1 | $37^{\circ} 57.26^{\prime}$ | $120^{\circ} 41.05^{\prime}$ | 268 |
| J 3 | $37^{\circ} 56.71{ }^{\prime}$ | $120^{\circ} 40.67^{\prime}$ | 256 |
| K 6 | $38^{\circ} 00.31{ }^{\prime}$ | $120^{\circ} 51.02{ }^{\prime}$ | 75 |
| P 1 | $38^{\circ} 08.29^{\prime}$ | $120^{\circ} 56.19^{\prime}$ | 88 |
| P 2 | $38^{\circ} 08.52^{\prime}$ | $120^{\circ} 56.34{ }^{\prime}$ | 91 |
| P 3 | $38^{\circ} 08.83{ }^{\prime}$ | $120^{\circ} 56.56{ }^{\prime}$ | 98 |
| Q 6 | $37^{\circ} 46.58{ }^{\prime}$ | $120^{\circ} 33.11^{\prime}$ | 140 |
| R 4 | $37^{\circ} 41.74{ }^{\prime}$ | $120^{\circ} 28.12^{\prime}$ | 152 |
| R 5 | $37^{\circ} 41.28^{\prime}$ | $120^{\circ} 28.13^{\prime}$ | 128 |
| R 6 | $37^{\circ} 41.03^{\prime}$ | $120^{\circ} 28.11^{\prime}$ | 128 |
| T 3 | $37^{\circ} 45.93$ ' | $120^{\circ} 28.05^{\prime}$ | 310 |

Coordinates of array stations
Line 2

STA
Lat
N
$38^{\circ} 00.58^{\prime}$
$38^{\circ} 00.38^{\prime}$
$38^{\circ} 00.21^{\prime}$
$37^{\circ} 59.98^{\prime}$
$37^{\circ} 59.77^{\prime}$
$37^{\circ} 59.53^{\prime}$
$38^{\circ} 03.03^{\prime}$
$38^{\circ} 02.66^{\prime}$
$38^{\circ} 02.36^{\prime}$
$37^{\circ} 53.30^{\prime}$
$37^{\circ} 52.90^{\prime}$
$37^{\circ} 52.84^{\prime}$
$37^{\circ} 52.73^{\prime}$
$38^{\circ} 06.39^{\prime}$
$38^{\circ} 06.14^{\prime}$
$38^{\circ} 05.91^{\prime}$
$38^{\circ} 05.50^{\prime}$
$38^{\circ} 05.19^{\prime}$
$38^{\circ} 07.55^{\prime}$
$38^{\circ} 07.81^{\prime}$
$38^{\circ} 08.07^{\prime}$
$37^{\circ} 56.54^{\prime}$
$37^{\circ} 56.78^{\prime}$
$37^{\circ} 56.94^{\prime}$
$37^{\circ} 57.12^{\prime}$
$37^{\circ} 45.85^{\prime}$
$37^{\circ} 45.68^{\prime}$
$37^{\circ} 45.37^{\prime}$
$37^{\circ} 45.20^{\prime}$
$37^{\circ} 45.02^{\prime}$

Lon
W
Elev (M)
$120^{\circ} 40.12^{\prime}$ 329 $120^{\circ} 39.90^{\prime}$ 341 $120^{\circ} 39.75^{\prime}$ 341 $120^{\circ} 39.58^{\prime}$ 335
$120^{\circ} 39.24^{\prime}$ 329
$120^{\circ} 39.04^{\prime}$ 329
$120^{\circ} 40.27^{\prime}$ 518
$120^{\circ} 39.98^{\prime}$ 548
$120^{\circ} 39.70^{\prime}$ 573
$120^{\circ} 29.11^{\prime}$ 366
$120^{\circ} 28.66^{\prime}$ 396
$120^{\circ} 28.32^{\prime}$ 396
$120^{\circ} 27.62^{\prime}$ 366
$120^{\circ} 45.21^{\prime}$ 341
$120^{\circ} 45.06^{\prime}$ 354
$120^{\circ} 44.89^{\prime} \quad 366$
$120^{\circ} 44.45^{\prime}$ 390
$120^{\circ} 44.29^{\prime}$ 384
$120^{\circ} 47.0^{\prime} \quad 226$
$120^{\circ} 47.12^{\prime} \quad 226$
$120^{\circ} 47.06^{\prime} \quad 217$
$120^{\circ} 35.66^{\prime} \quad 293$
$120^{\circ} 35.81^{\prime} \quad 280$
$120^{\circ} 35.96^{\prime} \quad 286$
$120^{\circ} 36.22^{\prime} \quad 293$
$120^{\circ} 19.61^{\prime} \quad 411$
$120^{\circ} 19.65^{\prime} \quad 381$
$120^{\circ} 19.44^{\prime} \quad 351$
$120^{\circ} 19.65^{\prime} \quad 305$
$120^{\circ} 19.64^{\prime} \quad 274$

| S 1 | $37^{\circ} 42.36^{\prime}$ | $120^{\circ} 15.90^{\prime}$ | 354 |
| :--- | :--- | :--- | :--- |
| S 2 | $37^{\circ} 42.05^{\prime}$ | $120^{\circ} 15.59^{\prime}$ | 293 |
| S 3 | $37^{\circ} 42.21^{\prime}$ | $120^{\circ} 15.82^{\prime}$ | 335 |
| T 1 | $37^{\circ} 47.63^{\prime}$ | $120^{\circ} 25.31^{\prime}$ | 305 |
| T 2 | $37^{\circ} 47.54^{\prime}$ | $120^{\circ} 25.18^{\prime}$ | 305 |
| T 3 | $37^{\circ} 47.37^{\prime}$ | $120^{\circ} 24.92^{\prime}$ | 305 |
| T 4 | $37^{\circ} 47.21^{\prime}$ | $120^{\circ} 24.67^{\prime}$ | 305 |
| T 5 | $37^{\circ} 46.95^{\prime}$ | $120^{\circ} 24.53^{\prime}$ | 305 |

Coordinates of array stations
Line 3

| STA | $\begin{gathered} \text { Lat } \\ \mathrm{N} \end{gathered}$ | $\begin{gathered} \text { Lon } \\ \mathrm{W} \end{gathered}$ | Elev (M0 |
| :---: | :---: | :---: | :---: |
| H 1 | $37^{\circ} 56.74{ }^{\prime}$ | $120^{\circ} 16.42^{\prime}$ | 823 |
| I 3 | $38^{\circ} 10.59^{\prime}$ | $120^{\circ} 28.61^{\prime}$ | 634 |
| J 1 | $38^{\circ} 00.74{ }^{\prime}$ | $120^{\circ} 17.08^{\prime}$ | 793 |
| K 3 | $38^{\circ} 03.17^{\prime}$ | $120^{\circ} 21.27^{\prime}$ | 1000 |
| P 1 | $38^{\circ} 14.34{ }^{\prime}$ | $120^{\circ} 35.45^{\prime}$ | 610 |
| Q 1 | $37^{\circ} 51.06{ }^{\prime}$ | $120^{\circ} 08.73$, | 899 |
| Q 2 | $37^{\circ} 51.06^{\prime}$ | $120^{\circ} 09.07$ ' | 899 |
| Q 3 | $37^{\circ} 50.98^{\prime}$ | $120^{\circ} 09.30^{\prime}$ | 899 |
| Q 4 | $37^{\circ} 51.03^{\prime}$ | $120^{\circ} 09.72^{\prime}$ | 914 |
| R 1 | $37^{\circ} 48.79^{\prime}$ | $120^{\circ} 07.30^{\prime}$ | 930 |
| R 4 | $37^{\circ} 48.15^{\prime}$ | $120^{\circ} 07.27^{\prime}$ | 930 |
| R 5 | $37^{\circ} 47.79^{\prime}$ | $120^{\circ} 07.38^{\prime}$ | 945 |
| R 6 | $37^{\circ} 47.55^{\prime}$ | $120^{\circ} 07.25^{\prime}$ | 960 |
| S 1 | $37^{\circ} 47.06^{\prime}$ | $120^{\circ} 03.82^{\prime}$ | 838 |
| S 2 | $37^{\circ} 46.82^{\prime}$ | $120^{\circ} 03.70^{\prime}$ | 838 |
| T 1 | $37^{\circ} 36.37^{\prime}$ | $119^{\circ} 55.60{ }^{\prime}$ | 1067 |
| T 4 | $37^{\circ} 35.98^{\prime}$ | $119^{\circ} 55.09$ ' | 1082 |

The P-wave travel times are given in Table 4. All readings were made twice. All of the first $P$ waves recorded at the fixed stations were timed. Also, for $0<\Delta<20 \mathrm{~km}$, normally all of the first $P$-wave arrivals at the arrays were read. For $\Delta>20 \mathrm{~km}$, normally only the first $P$ wave with the clearest onset was read at each array; not all of the $P$ waves were timed because the uncertainties in many of the arrival times are a significant fraction of the travel times across the small (2.5 km or less) arrays.

P waves with well defined onsets are given an $I$ quality and examples of them are shown in Figure 2. Their onsets are measurable with a repeatability of about 0.03 sec . Arrivals with poorly defined onsets are given an $E$ quality ( $Q$ ). The travel times for $P$ waves of $E$ quality are upper bound values. $P$ waves are clearly present at the time read. Some well defined secondary phases were read with a repeatability of about 0.05 sec . They are designated by J.

Two unusual features were noted on some of the seismograms of refraction line 2: (1) in two instances, weak precursors to the main arrivals were found and seen in Figure 3, and (2) in one instance, a signal of 7 to $8 \mathrm{~km} / \mathrm{sec}$ arrived first, and a strong coherent arrival followed it with a velocity of 6 to $7 \mathrm{~km} / \mathrm{sec}$, see Figure 4 .

TABLE 4. The travel time information

| Shot |  |  |  | oordinat |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| BMR |  |  | 37 |  | ${ }^{W}$ | 3.57 |
| Sta | $\underset{\mathrm{M}}{\mathrm{El}}$ | $\begin{aligned} & \text { Azi } \\ & \text { deg } \end{aligned}$ | $\begin{gathered} \text { Dist } \\ \text { km } \end{gathered}$ | $\begin{gathered} \text { Trv Tm } \\ \text { sec } \end{gathered}$ | Q |  |
| $B M R$ | 823 | 113 | 0.19 | 0.03 | I |  |
| S 2 | 838 | 162 | 0.62 | 0.14 | I |  |
| S 1 | 838 | 160 | 1.10 | 0.24 | I |  |
| R 6 | 960 | 110 | 5.74 | 1.06 | I |  |
| R 5 | 945 | 113 | 6.08 | 1.12 | I |  |
| R 4 | 930 | 119 | 6.23 | 1.14 | I |  |
| R 1 | 930 | 128 | 6.92 | 1.28 | I |  |
| Q 1 | 899 | 138 | 11.34 | 2.06 | I |  |
| Q 2 | 899 | 136 | 11.68 | 2.09 | I |  |
| Q 3 | 899 | 135 | 11.81 | 2.11 | I |  |
| Q 4 | 914 | 133 | 12.32 | 2.35 | I |  |
| SGR | 480 | 28 | 17.87 | 3.24 | I |  |
| T 1 | 1067 | 328 | 22.10 | 4.06 | I |  |
| T 4 | 1082 | 327 | 23.11 | 4.22 | I |  |
| BVR | 610 | 11 | 24.20 | 4.33 | I |  |
| H 1 | 823 | 135 | 26.72 | 4.57 | I |  |
| AFR | 610 | 353 | 31.98 | 5.58 | I |  |
| J 1 | 792 | 143 | 32.96 | 5.61 | I |  |
| LGR | 152 | 65 | 33.57 | 5.84 | I |  |
| STN | 366 | 115 | 33.69 | 5.68 | I |  |
| K 3 | 1000 | 140 | 40.30 | 6.80 | I |  |
| BRO | 387 | 130 | 40.66 | 6.84 | I |  |
| CRH | 475 | 124 | 47.95 | 7.93 | , |  |
| KFR | 171 | 92 | 50.44 | 8.73 | E |  |
| FWL | 884 | 120 | 53.45 | 8.85 | E |  |
| LVR | 1219 | 155 | 54.68 | 9.45 | E |  |
| 13 | 634 | 141 | 57.71 | 9.40 | I |  |
| ODR | 79 | 91 | 59.08 | 10.27 | I |  |
| P 1 | 610 | 138 | 69.50 | 11.34 | I |  |
| NHR | 219 | 122 | 75.32 | 12.24 | 1 |  |
| CSR | 128 | 125 | 85.81 | 14.00 | E |  |


| ShotCCM | $\begin{gathered} \text { Elev } \\ \text { M } \\ 646 \end{gathered}$ |  | Coordinates |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  Coordinat  <br> 38 N  <br> 38.35 1  |  |  |  |
|  |  |  |  | 24.76 |
| Sta | Elev | Azi |  |  | Dist | Trv Tm |  |  |
|  | M | deg | km | sec |  |  |
| CGR | 585 | 193 | 0.87 | 0.00 |  |  |
| BRO | 387 | 1 | 10.83 | 1.74 |  |  |
| $\mathrm{CRH}$ | 475 | 41 | 12.91 | 2.17 |  |  |
| LVR | 1219 | 211 | 14.90 | 2.63 |  |  |
| JAS | 457 | 7 | 17.81 | 3.08 |  |  |
| FWL | 884 | 57 | 17.81 | 3.08 |  |  |
| STN | 366 | 359 | 22.41 | 3.65 |  |  |
| COP | 335 | 51 | 23.32 | 3.99 |  |  |
| NHR | 219 | 96 | 32.80 | 5.44 |  |  |
| CSR | 128 | 107 | 41.26 | 6.93 |  |  |
| GSR | 335 | 344 | 46.35 | 7.41 |  |  |
| WLR | 107 | 96 | 46.48 | 8.13 |  |  |
| LGR | 152 | 359 | 50.69 | 8.44 |  |  |
| SGR | 480 | 337 | 57.26 | 9.15 |  |  |


| Shot | Elev |  | Coordinates |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | M | N |  | W |  |
| GSR | 335 | 37 | 42.27 | 120 | 15.34 |


| Sta | Elev M | $\begin{aligned} & \text { Azi } \\ & \text { deg } \end{aligned}$ | $\begin{gathered} \text { Dist } \\ \text { km } \end{gathered}$ | $\begin{gathered} \text { Trv Tm } \\ \text { sec } \end{gathered}$ | Q |
| :---: | :---: | :---: | :---: | :---: | :---: |
| S 3 | 335 | 345 | 0.11 | 0.03 | I |
| S 1 | 354 | 152 | 0.19 | 0.06 | I |
| S 2 | 293 | 318 | 0.55 | 0.10 | I |
| R 6 | 274 | 132 | 7.55 | 1.27 | I |
| R 5 | 305 | 134 | 7.79 | 1.30 | I |
| R 4 | 351 | 137 | 7.30 | 1.30 | I |
| R 2 | 381 | 138 | 8.43 | 1.42 | I |
| R 1 | 411 | 140 | 8.63 | 1.45 | I |
| SGR | 480 | 309 | 12.58 | 2.09 | I |
| LGR | 152 | 64 | 13.93 | 2.51 | I |
| T 5 | 305 | 124 | 15.42 | 2.57 | I |
| T 4 | 305 | 125 | 15.87 | 2.64 | I |
| T 3 | 305 | 125 | 16.34 | 2.73 | I |
| T 2 | 305 | 125 | 16.83 | 2.81 | I |
| BMR | 823 | 246 | 19.52 | 3.46 | I |
| BVR | 610 | 320 | 20.83 | 3.35 | I |
| STN | 366 | 151 | 25.43 | 4.26 | I |
| K 6 | 366 | 138 | 25.95 | 4.19 | I |
| K 6 | 366 | 138 | 25.95 | 4.40 | J |
| K 5 | 390 | 138 | 26.37 | 4.29 | E |
| K 4 | 396 | 137 | 26.80 | 4.30 | I |
| K 3 | 396 | 136 | 27.22 | 4.37 | I |
| K 3 | 396 | 136 | 27.22 | 4.59 | J |
| K 1 | 366 | 136 | 28.21 | 4.50 | I |
| K 1 | 366 | 136 | 28.21 | 4.74 | J |
| MCM | 363 | 133 | 29.40 | 4.76 | E |
| AFR | 610 | 318 | 32.37 | 5.30 | I |
| KFR | 171 | 107 | 33.87 | 5.87 | I |
| CNS | 373 | 138 | 34.93 | 5.81 | I |
| BRO | 387 | 158 | 36.27 | 6.07 | I |
| Q 3 | 293 | 132 | 39.28 | 6.36 | E |
| Q 3 | 293 | 132 | 39.28 | 6.52 | J |
| Q 4 | 286 | 132 | 39.74 | 6.44 | I |
| Q 5 | 280 | 133 | 40.10 | 6.60 | J |
| Q 6 | 268 | 133 | 40.61 | 6.68 | J |
| CRH | 475 | 148 | 41.02 | 6.83 | I |
| ODR | 79 | 102 | 42.01 | 7.36 | I |
| FNL | 884 | 141 | 44.81 | 7.58 | E |
| I 1 | 329 | 134 | 49.15 | 7.95 | I |
| J 5 | 573 | 137 | 51.04 | 8.23 | I |
| LVR | 1219 | 175 | 57.54 | 9.60 | I |
| P 1 | 226 | 136 | 65.38 | 10.73 | E |
| NH:R | 219 | 136 | 66.31 | 10.77 | E |
| WLR | 107 | 130 | 77.09 | 12.95 | E |
| CSR | 128 | 7 | 77 | 12.77 | E |


| Shot | Elev |  | Coordinates |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | M |  | N | W |  |
| LGR | 146 | 37 | 38.92 | $120^{2}$ | 24.48 |


| Sta | Elev |
| :---: | :---: | :---: | :---: | :---: | :---: |
| M |  | | Azi |
| :---: |
| deg |$\quad$| Dist |
| :---: |
| km | | Trv Tm |
| :---: |
| Sec |$\quad$ Q


| LGR | 152 | 255 | 0.21 | 0.06 | I |
| :--- | ---: | ---: | ---: | ---: | ---: |
| R 6 | 128 | 126 | 6.61 | 1.20 | I |
| R 5 | 128 | 129 | 6.92 | 1.25 | I |
| R 4 | 152 | 134 | 7.47 | 1.35 | I |
| GSR | 335 | 244 | 14.17 | 2.53 | I |
| Q 6 | 140 | 138 | 19.02 | 3.34 | I |
| SGR | 480 | 275 | 22.51 | 3.94 | I |
| KFR | 171 | 129 | 25.43 | 4.52 | I |
| MCM | 363 | 162 | 27.75 | 4.87 | I |
| BVR | 610 | 290 | 27.89 | 4.80 | I |
| STN | 366 | 180 | 28.34 | 5.07 | I |
| I 6 | 165 | 138 | 28.54 | 4.85 | I |
| OBF | 177 | 153 | 31.23 | 5.37 | I |
| ODR | 79 | 118 | 32.12 | 5.72 | I |
| BMR | 823 | 245 | 33.65 | 5.90 | I |
| AFR | 610 | 297 | 38.81 | 6.63 | I |
| BRO | 387 | 179 | 39.93 | 6.96 | I |
| COP | 335 | 153 | 40.49 | 6.85 | I |
| J 1 | 268 | 144 | 41.74 | 6.87 | I |
| CRH | 475 | 168 | 42.02 | 7.39 | E |
| FWL | 884 | 159 | 43.91 | 7.54 | E |
| K 6 | 75 | 135 | 55.52 | 9.38 | I |
| NHR | 219 | 149 | 63.49 | 10.47 | E |
| WLR | 107 | 140 | 72.43 | 12.07 | E |
| CSR | 128 | 148 | 74.52 | 12.24 | E |
| DHR | 113 | 147 | 95.48 | 15.78 | E |


| Shot | Elev | Coordinates |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | M | N |  | W |  |
| PAC | 286 | 37 | 56.30 | $120^{3}$ | 32.76 |


| Sta | Elev |
| :---: | :---: | :---: | :---: | :---: |
| M |  | | Azi |
| :---: |
| deg | Dist | Trv Tm |
| :---: |
| kn |


| CNS | 373 | 269 | 1.47 | 0.25 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| MCM | 363 | 330 | 6.74 | 1.13 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| COP | 335 | 121 | 7.44 | 1.23 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| CRH | 475 | 200 | 9.45 | 1.79 | I |
| :--- | :--- | :--- | :--- | :--- | :--- |


| JAS | 457 | 264 | 9.51 | 1.82 |
| :--- | :--- | :--- | :--- | :--- |


| FNL | 884 | 160 | 9.53 | 1.68 | I |
| :--- | :--- | :--- | :--- | :--- | :--- |


| STN | 366 | 287 | 12.89 | 2.29 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| BRO | 387 | 236 | 13.83 | 2.58 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| KFR | 171 | 25 | 17.77 | 3.19 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| ODR | 79 | 43 | 23.57 | 4.37 | I |
| :--- | :--- | :--- | :--- | :--- | :--- |


| NHR | 219 | 136 | 30.39 | 4.89 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| GSR | 335 | 316 | 35.86 | 5.68 | $E$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| LVR | 1219 | 212 | 36.87 | 6.37 | I |
| :--- | :--- | :--- | :--- | :--- | :--- |


| $B M R$ | 823 | 293 | 46.30 | 7.62 | $I$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| DHR | 113 | 141 | 62.25 | 10.53 | $E$ |
| :--- | :--- | :--- | :--- | :--- | :--- |


| Shot | $\begin{gathered} \text { Elev } \\ \text { M } \\ 101 \end{gathered}$ |  | Coordinates |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $\begin{array}{ll} \\ 38 & \mathrm{~N} \\ 8.76\end{array}$ |  | W |  |
| WLR |  |  |  | 56.51 |
| Sta | $\underset{\mathrm{M}}{\mathrm{Elev}}$ | $\begin{aligned} & \mathrm{Azi} \\ & \text { deg } \end{aligned}$ |  |  | Dist km | Trv Tm sec | Q |  |
|  |  |  |  |  |  |  |
| P 3 | 98 | 151 | 0.15 | 0.08 | I |  |  |
| WLR | 107 | 243 | 0.16 | 0.11 | I |  |  |
| P 2 | 91 | 331 | 0.51 | 0.33 | I |  |  |
| P 1 | 88 | 332 | 0.99 | 0.57 | I |  |  |
| H 1 | 67 | 317 | 8.88 | 1.81 | I |  |  |
| H 4 | 79 | 321 | 10.22 | 2.03 | I |  |  |
| CSR | 128 | 222 | 10.37 | 2.05 | I |  |  |
| H 5 | 107 | 321 | 10.71 | 2.13 | I |  |  |
| H 6 | 110 | 322 | 11.01 | 2.16 | I |  |  |
| NHR | 219 | 274 | 13.82 | 2.78 | I |  |  |
| JVR | 85 | 178 | 17.27 | 3.17 | I |  |  |
| DHR | 113 | 169 | 25.52 | 4.49 | I |  |  |
| J 1 | 268 | 313 | 31.05 | 5.48 | I |  |  |
| J 3 | 256 | 314 | 32.16 | 5.66 | I |  |  |
| CRH | 475 | 290 | 40.46 | 7.34 | I |  |  |
| OBF | 177 | 310 | 42.72 | 7.55 | E |  |  |
| I 4 | 183 | 321 | 42.82 | 7.41 | E |  |  |
| KFR | 171 | 325 | 47.70 | 8.23 | I |  |  |
| BRO | 387 | 288 | 48.62 | 8.67 | I |  |  |
| Q 6 | 140 | 320 | 53.46 | 9.04 | E |  |  |
| T 3 | 310 | 315 | 59.33 | 9.96 | E |  |  |
| R 4 | 152 | 320 | 65.03 | 10.93 | E |  |  |



Figure 2. Examples of seismograms showing I quality P-wave onsets.


Figure 3. Seismograms of 1ine 2 that show precursors (dots) to the primary arrivals (arrows).


Figure 4. Seismogram that shows an initial arrival of high P-wave velocity of 7 to $8 \mathrm{~km} / \mathrm{sec}$ followed by one of lower velocity ( 6 to $7 \mathrm{~km} / \mathrm{sec}$ ).

Rogers, T. H. (1966). Geologic map of California, Olaf P. Jenkins edition, San Jose sheet, Calif. Div. Mines and Geoz., San Francisco.


[^0]:    ULTRABASIC ROCKS

