(200) R295 NO.78-131 3 1818 00073206 3

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GEOLOGICAL SURVEY, IReports - Open file socies]

A SEISMIC REFRACTION EXPERIMENT PERFORMED IN THE MELONES RESERVOIR REGION OF THE METAMORPHIC BELT, CENTRAL CALIFORNIA

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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 km². Due to the renewed interest in the region, data obtained from the experiment are presented here.



Figure 1. Map showing the shots, fixed stations (three-letter names), and arrays (one-letter names) superimposed on an abstract of the geologic maps (from Rogers, 1966). Not shown is T on line 3, 22 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. Also, 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.

TABLE 1

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

STA	Lat N	Lon W	Elev (M)	May 1972	Hr Min Sec Universal Time
BMR	37 ⁰ 46.50'	120 ⁰ 03.57'	838	24	08:00:02.10Z
CCM	38 ⁰ 06.35'	120 ⁰ 24.76'	646	23	23:02:01.25
GSR	37 ⁰ 42.27'	120 ⁰ 15.84'	335	25	08:35:00.57
LGR	37 ⁰ 38.92'	120 ⁰ 24.48'	146	23	08:30:00.26
NHR	38 ⁰ 08.10'	120 ⁰ 47.13'	213	25	08:05:01.07
PAC	37 ⁰ 56.30'	120 ⁰ 32.76'	286	26	23:21:50.25
WLR	38 ⁰ 08.76'	120 ⁰ 56.51'	101	23	08:00:01.07

TABLE 2

Coordinates of fixed stations

STA	Lat N	Lon W	Elev (M)
AFR	37 ⁰ 29.33'	120 ⁰ 01.04'	610
BMR	37 ⁰ 46.54'	120 ⁰ 03.69'	823
BRO	38 ⁰ 00.50'	120 ⁰ 24.95'	387
BVR	37 ⁰ 33.66'	120 ⁰ 06.72'	610
CGR	38 ⁰ 06.81'	120 ⁰ 24.63'	585
CNS	37 ⁰ 56.31'	120 ⁰ 31.76'	373
COP	37 ⁰ 58.38'	120 ⁰ 37.11'	336
CRH	38 ⁰ 01.11'	120 ⁰ 30.59'	475
CSR	38 ⁰ 12.92'	120 ⁰ 51.75'	128
DHR	38 ⁰ 22.31'	120 ⁰ 59.80'	113
FWL	38 ⁰ 01.14'	120 ⁰ 35.00'	880
GSR	37 ⁰ 42.31'	120 ⁰ 15.84'	335
JAS	37 ⁰ 56.80'	120 ⁰ 26.30'	457
JVR	38 ⁰ 18.09'	120 ⁰ 56.98'	85
KFR	37 ⁰ 47.60'	120 ⁰ 37.90'	171
LGR	37 ⁰ 38.95'	120 ⁰ 24.34'	152
LVR	38 ⁰ 13.24'	120 ⁰ 19.48'	1219
MCM	37 ⁰ 53.16'	120 ⁰ 30.43'	362
NHR	38 ⁰ 08.20'	120 ⁰ 47.08'	219
OBF	37 ⁰ 53.99'	120 ⁰ 34.07'	176
ODR	37 ⁰ 47.04'	120 ⁰ 43.80'	79
SGR	37 ⁰ 37.95'	120 ⁰ 09.23'	480
STN	37 ⁰ 54.24'	120 ⁰ 24.36'	366
WLR	38 ⁰ 08.80'	120 ⁰ 56.41'	107

TABLE 3

Coordinates of array stations

Line 1

STA	Lat N	Lon W	Elev (M)
H 1	38 ⁰ 05.25'	120 ⁰ 52.37'	67
H 4	38 ⁰ 04.46'	120 ⁰ 52.12'	79
H 5	38 ⁰ 04.25'	120 ⁰ 51.92'	107
H 6	38 ⁰ 04.06'	120 ⁰ 51.89'	110
I 4	37 ⁰ 50.86'	120 ⁰ 37.97'	183
I 6	37 ⁰ 50.36'	120 ⁰ 37.52'	165
J 1	37 ⁰ 57.26'	120 ⁰ 41.05'	268
J 3	37 ⁰ 56.71'	120 ⁰ 40.67'	256
K 6	38 ⁰ 00.31'	120 ⁰ 51.02'	75
P 1	38 ⁰ 08.29'	120 ⁰ 56.19'	88
P 2	38 ⁰ 08.52'	120 ⁰ 56.34'	91
P 3	38 ⁰ 08.83'	120 ⁰ 56.56'	98
Q 6	37 ⁰ 46.58'	120 ⁰ 33.11'	140
R 4	37 ⁰ 41.74'	120 ⁰ 28.12'	152
R 5	37 ⁰ 41.28'	120 ⁰ 28.13'	128
R 6	37 ⁰ 41.03'	120 ⁰ 28.11'	128
Т 3	37 ⁰ 45.93'	120 ⁰ 28.05'	310

TABLE 3 (cont)

Coordinates of array stations

Line 2

STA	Lat N	Lon W	Elev (M)
I 1	38 ⁰ 00.58'	120 ⁰ 40.12'	329
I 2	38 ⁰ 00.38'	120 ⁰ 39.90'	341
I 3	38 ⁰ 00.21'	120 ⁰ 39.75'	341
I 4	37 ⁰ 59.98'	120 ⁰ 39.58'	335
I 5	37 ⁰ 59.77'	120 ⁰ 39.24'	329
I 6	37 ⁰ 59.53'	120 ⁰ 39.04'	329
J 2	38 ⁰ 03.03'	120 ⁰ 40.27'	518
J 3	38 ⁰ 02.66'	120 ⁰ 39.98'	548
J 5	38 ⁰ 02.36'	120 ⁰ 39.70'	573
K 1	37 ⁰ 53.30'	120 ⁰ 29.11'	366
К З	37 ⁰ 52.90'	120 ⁰ 28.66'	396
K 4	37 ⁰ 52.84'	120 ⁰ 28.32'	396
K 6	37 ⁰ 52.73'	120 ⁰ 27.62'	366
L 1	38 ⁰ 06.39'	120 ⁰ 45.21'	341
L 2	38 ⁰ 06.14'	120 ⁰ 45.06'	354
L 3	38 ⁰ 05.91'	120 ⁰ 44.89'	366
L 5	38 ⁰ 05.50'	120 ⁰ 44.45'	390
L 6	38 ⁰ 05.19'	120 ⁰ 44.29'	384
P 1	38 ⁰ 07.55'	120 ⁰ 47.0 '	226
P 2	38 ⁰ 07.81'	120 ⁰ 47.12'	226
P 3	38 ⁰ 08.07'	120 ⁰ 47.06'	217
Q 3	37 ⁰ 56.54'	120 ⁰ 35.66'	293
Q 4	37 ⁰ 56.78'	120 ⁰ 35.81'	280
Q 5	37 ⁰ 56.94'	120 ⁰ 35.96'	286
Q 6	37 ⁰ 57.12'	120 ⁰ 36.22'	293
R 1	37 ⁰ 45.85'	120 ⁰ 19.61'	411
R 2	37 ⁰ 45.68'	120 ⁰ 19.65'	381
R 4	37 ⁰ 45.37'	120 ⁰ 19.44'	351
R 5	37 ⁰ 45.20'	120 ⁰ 19.65'	305
R 6	37 ⁰ 45.02'	120 ⁰ 19.64'	274

S 1	37 ⁰ 42.36'	120 ⁰ 15.90'	354
S 2	37 ⁰ 42.05'	120 ⁰ 15.59'	293
S 3	37 ⁰ 42.21'	120 ⁰ 15.82'	335
T 1	37 ⁰ 47.63'	120 ⁰ 25.31'	305
T 2	37 ⁰ 47.54'	120 ⁰ 25.18'	305
T 3	37 ⁰ 47.37'	120 ⁰ 24.92'	305
Τ4	37 ⁰ 47.21'	120 ⁰ 24.67'	305
T 5	37 ⁰ 46.95'	120 ⁰ 24.53'	305

TABLE 3 (cont)

Coordinates of array stations

Line 3

STA	Lat N	Lon W	Elev (MO
H 1	37 ⁰ 56.74'	120 ⁰ 16.42'	823
I 3	38 ⁰ 10.59'	120 ⁰ 28.61'	634
J 1	38 ⁰ 00.74'	120 ⁰ 17.08'	793
К З	38 ⁰ 03.17'	120 ⁰ 21.27'	1000
P 1	38 ⁰ 14.34'	120 ⁰ 35.45'	610
Q 1	37 ⁰ 51.06'	120 ⁰ 08.73'	899
Q 2	37 ⁰ 51.06'	120 ⁰ 09.07'	899
Q 3	37 ⁰ 50.98'	120 ⁰ 09.30'	899
Q 4	37 ⁰ 51.03'	120 ⁰ 09.72'	914
R 1	37 ⁰ 48.79'	120 ⁰ 07.30'	930
R 4	37 ⁰ 48.15'	120 ⁰ 07.27'	930
R 5	37 ⁰ 47.79'	120 ⁰ 07.38'	945
R 6	37 ⁰ 47.55'	120 ⁰ 07.25'	960
S 1	37 ⁰ 47.06'	120 ⁰ 03.82'	838
S 2	37 ⁰ 46.82'	120 ⁰ 03.70'	838
T 1	37 ⁰ 36.37'	119 ⁰ 55.60'	1067
Т 4	37 ⁰ 35.98'	119 ⁰ 55.09'	1082

P-WAVE TRAVEL TIMES

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 $0<\Delta<20$ km, normally all of the first P-wave arrivals at the arrays were read. For $\Delta>20$ 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 Equality (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 km/sec arrived first, and a strong coherent arrival followed it with a velocity of 6 to 7 km/sec, see Figure 4.

TABLE 4. The travel time information

Shot	E1 M	ev	N	Coordinat	es	
BMR	83	8	37 46	.50 1	w 20	3.57
Sta	Elev M	Azi deg	Dist km	Trv Tm sec	Q	
BMR	823	113	0.19	0.03	Ι	
S 2	838	162	0.62	0.14	T	
S 1	838	160	1.10	0.24	Ť	
R 6	960	110	5.74	1.06	Ť	
R 5	945	113	6.08	1.12	Ĩ	
R 4	930	119	6.23	1.14	Ť	
R 1	930	128	6.92	1.28	T	
01	899	138	11.34	2.06	T	
0 2	899	136	11.68	2.09	T	
0 3	899	135	11.81	2.11	Ť	
04	914	133	12.32	2.35	T	
SGR	480	28	17.87	3.24	Ť	
T 1	1067	328	22.10	4.06	Ĩ	
T 4	1082	327	23.11	4.22	Ť	
BVR	610	11	24.20	4.33	Ĩ	
H 1	823	135	26.72	4.57	Ī	
AFR	610	353	31.98	5.58	Ĩ	
J 1	792	143	32.96	5.61	Ĩ	
LGR	152	65	33.57	5.84	Ī	
STN	366	115	33.69	5.68	Ι	
К З	1000	140	40.30	6.80	I	
BRO	387	130	40.66	6.84	T	
CRH	475	124	47.95	7.98	Ī	
KFR	171	92	50.44	8.73	E	
FWL	884	120	53.45	8.85	Е	
LVR	1219	155	54.68	9.45	E	
I 3	634	141	57.71	9.40	I	
ODR	79	91	59.08	10.27	Ι	
P 1	610	138	69.50	11.34	Ι	
NHR	219	122	75.32	12.24	I	
CSR	128	125	85.81	14.00	F	

Shot	Ele	ev	(Coordinat	es	
	М		N		W	
CCM	64	6	38 6.	.35 1	20	24.76
C± a	Flore	A = -	Diet		0	
Sta	M	deg	km	sec	Q	
CGR	585	193	0.87	0.00	I	
BRO	387	1	10.83	1.74	Ι	
CRH	475	41	12.91	2.17	Ι	
LVR	1219	211	14.90	2.63	Ι	
JAS	457	7	17.81	3.08	Ι	
FWL	884	57	17.81	3.08	Ι	
STN	366	359	22.41	3.65	Е	
COP	335	51	23.32	3.99	Е	
NHR	219	96	32.80	5.44	Ι	
CSR	128	107	41.26	6.93	Ι	
GSR	335	344	46.35	7.41	Ι	
WLR	107	96	46.48	8.13	Ι	
LGR	152	359	50.69	8.44	Ι	
SGR	480	337	57.26	9.15	E	

Shot	Ele	ev	N	Coordinat	es	
GSR	33	5	37 42	.27 1	20	15.84
Sta	Elev M	Azi deg	Dist km	Trv Tm sec	Q	
S 3 1 2 6 5 4 2 1 SGR 5 4 3 2 R R STN 6 6 5 4 3 3 1 1 M AFR SOLOR STO 1 STO 2 R R R R STN 6 6 5 4 3 3 1 1 M AFR SOLOR STO 2 2 2 2 COLOR STO 2 3 4 5 6 H R L 1 5 R 1 M CSR SOLOR STO 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	335 354 293 274 305 351 381 411 480 152 305 305 305 305 305 305 305 305 305 306 367 293 288 273 1219 226 219 107 128	$\begin{array}{c} 345\\ 152\\ 318\\ 132\\ 134\\ 137\\ 138\\ 140\\ 309\\ 64\\ 124\\ 125\\ 125\\ 246\\ 320\\ 151\\ 138\\ 138\\ 137\\ 136\\ 136\\ 136\\ 136\\ 136\\ 136\\ 136\\ 136$	0.11 0.19 0.55 7.55 7.79 7.80 8.43 8.63 12.58 13.93 15.42 15.87 16.34 16.83 19.52 20.83 25.43 25.95 26.80 27.22 28.21 28.21 29.40 32.37 33.87 34.93 36.27 39.28 39.74 40.10 40.61 41.02 42.01 44.81 49.15 51.04 57.54 66.31 77.09 77.34	0.03 0.06 0.10 1.27 1.30 1.42 1.45 2.09 2.51 2.57 2.64 2.73 2.81 3.46 3.35 4.26 4.19 4.30 4.37 4.59 4.30 4.37 4.59 4.50 4.74 4.50 5.87 5.81 6.07 6.36 6.52 6.44 6.60 6.52 6.44 6.60 5.30 5.87 5.81 6.07 6.36 6.52 6.44 6.60 6.52 6.44 6.60 7.58 7.95 8.23 9.60 10.77 12.95 12.77	I I I I I I I I I I I I I I J E I I J E I I I I	

LGR1463738.9212024.4StaElevAziDistTrv TmQMdegkmsecLGR1522550.210.06IR61281266.611.20IR51281296.921.25IR41521347.471.35IGSR33524414.172.53IQ614013819.023.34ISGR48027522.513.94IKFR17112925.434.52IMCM36316227.754.87IBVR61029027.894.80ISTN36618028.345.07II616513828.544.85IOBF17715331.235.37IODR7911832.125.72IBMR82324533.655.90IAFR61029738.816.63IBRO38717939.936.96ICOP33515340.496.85IJ126814441.746.87ICRH47516842.027.39E	Shot	E1e M	ev	(N	Coordinat	tes	
StaElev MAzi degDist kmTrv Tm secQLGR152255 0.21 0.06 IR 6128126 6.61 1.20 IR 5128129 6.92 1.25 IR 4152134 7.47 1.35 IGSR33524414.17 2.53 IQ 614013819.02 3.34 ISGR48027522.51 3.94 IKFR17112925.43 4.52 IMCM36316227.75 4.87 IBVR61029027.89 4.80 ISTN36618028.34 5.07 II616513828.54 4.85 IOBF177153 31.23 5.37 IODR79118 32.12 5.72 IBMR823245 33.65 5.90 IAFR610297 38.81 6.63 IBRO387179 39.93 6.96 ICOP 335 153 40.49 6.85 IJ1268144 41.74 6.87 ICRH475168 42.02 7.39 E	LGR	140	5	37 38	.92]	20	24.48
LGR 152 255 0.21 0.06 1 R6 128 126 6.61 1.20 1 R5 128 129 6.92 1.25 1 R4 152 134 7.47 1.35 1 GSR 335 244 14.17 2.53 1 Q6 140 138 19.02 3.34 1 SGR 480 275 22.51 3.94 1 KFR 171 129 25.43 4.52 1 MCM 363 162 27.75 4.87 1 BVR 610 290 27.89 4.80 1 STN 366 180 28.34 5.07 1 I6 165 138 28.54 4.85 1 OBF 177 153 31.23 5.37 1 ODR 79 118 32.12 5.72 1 BMR 823 245 33.65 5.90 1 AFR 610 297 38.81 6.63 1 BRO 387 179 39.93 6.96 1 COP 335 153 40.49 6.85 1 J 268 144 41.74 6.87 1 CRH 475 168 42.02 7.39 E	Sta	Elev M	Azi deg	Dist km	Trv Tm sec	Q	
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	LGR R 6 R 5 R 4 GSR Q 6 SGR KFR MCM BVR STN I 6 OBF ODR BMR AFR BRO COP J 1 CRH FWL K 6 NHR WLR CSR DHR	$152 \\ 128 \\ 128 \\ 152 \\ 335 \\ 140 \\ 480 \\ 171 \\ 363 \\ 610 \\ 366 \\ 165 \\ 177 \\ 79 \\ 823 \\ 610 \\ 387 \\ 335 \\ 268 \\ 475 \\ 884 \\ 75 \\ 219 \\ 107 \\ 128 \\ 113 \\ $	255 126 129 134 244 138 275 129 162 290 180 138 153 118 245 297 179 153 144 168 159 135 149 140 148 147	0.21 6.61 6.92 7.47 14.17 19.02 22.51 25.43 27.75 27.89 28.34 28.54 31.23 32.12 33.65 38.81 39.93 40.49 41.74 42.02 43.91 55.52 63.49 72.43 74.52 95.48	0.06 1.20 1.25 1.35 2.53 3.34 3.94 4.52 4.87 4.80 5.07 4.85 5.37 5.72 5.90 6.63 6.96 6.85 6.87 7.39 7.54 9.38 10.47 12.07 12.24 15.78	$\begin{array}{c} I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\I\\E\\E\\E\\E\\E$	

Shot	Ele	ev		Coordina	tes	
	М		N		W	
PAC	280	5	37 56	.30	120	32.76
C+-	111		D		0	
Sta	Elev	AZI	Dist	Trv Im	Q	
	141	ueg	KIII	Sec		
CNS	373	269	1.47	0.25	Ι	
MCM	363	330	6.74	1.13	Ι	
COP	335	121	7.44	1.28	Ι	
CRH	475	200	9.45	1.79	Ι	
JAS	457	264	9.51	1.82	Ι	
FWL	884	160	9.53	1.68	Ι	
STN	366	287	12.89	2.29	Ι	
BRO	387	236	13.83	2.58	Ι	
KFR	171	25	17.77	3.19	Ι	
ODR	79	43	23.57	4.37	Ι	
NHR	219	136	30.39	4.89	Ι	
GSR	335	316	35.86	5.68	E	
LVR	1219	212	36.87	6.37	Ι	
BMR	823	293	46.30	7.62	Ι	
DHR	113	141	62.25	10.53	E	

Shot	Ele	ev		Coordina	tes	
	М		N		W	
WLR	10	1	38 8	.76	120	56.51
Sta	Elev	Azi	Dist	Trv Tm	Q	
	М	deg	km	sec		
P 3	98	151	0.15	0.08	I	
WLR	107	243	0.16	0.11	Ť	
P 2	91	331	0.51	0.33	Ť	
P 1	88	332	0.99	0.57	Ť	
H 1	67	317	8.88	1.81	Ť	
H 4	79	321	10.22	2.03	Î	
CSR	128	222	10.37	2.05	Ī	
H 5	107	321	10.71	2.13	I	
H 6	110	322	11.01	2.16	Ι	
NHR	219	274	13.82	2.78	Ι	
JVR	85	178	17.27	3.17	Ι	
DHR	113	169	25.52	4.49	Ι	
J 1	268	313	31.05	5.48	Ι	
J 3	256	314	32.16	5.66	Ι	
CRH	475	290	40.46	7.34	Ι	
OBF	177	310	42.72	7.55	E	
I 4	183	321	42.82	7.41	E	
KFR	171	325	47.70	8.23	Ι	
BRO	387	288	48.62	8.67	Ι	
Q 6	140	320	53.46	9.04	E	
Ť 3	310	315	59.33	9.96	Е	
R 4	152	320	65.03	10.93	Е	











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

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