GEOLOGICAL SURVEY CIRCULAR 799-A, B

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Recent Earthquake Activity and Focal Mechanisms in the Western Transverse Ranges, California

Late Quaternary Deformation in the Western Transverse Ranges, California

To accompany U. S. Geological Survey Miscellaneous Field Studies Map MF-1032, by R. F. Yerkes and W. H. K. Lee

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EARTHQUAKE ACTIVITY AND QUATERNARY DEFORMATION OF THE WESTERN TRANSVERSE RANGES, CALIFORNIA

GEOLOGICAL SURVEY CIRCULAR 799-A

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By W. H. K. Lee, R. F. Yerkes, and M. Simirenko

INTRODUCTION

The east-west-trending Transverse Ranges Province is a portion of the complex Pacific-American plate boundary where tectonism has accelerated during late Cenozoic time, perhaps reaching a maximum in Quaternary time. The contemporary seismic setting of the Transverse Ranges in relation to the rest of southern California is indicated by the distribution of recent large earthquakes (fig. 1). During the past 60 years, 24 earthquakes of local magnitude 6 or greater have occurred in southern California. Five of these occurred in the western Transverse Ranges: the Santa Barbara earthquake of 1925 (magnitude 6.3), the Point Arguello earthquake of 1927 (magnitude 7.5), the Santa Barbara earthquake of 1941 (magnitude 6), the San Fernando earthquake of 1971 (magnitude 6.4), and the Point Mugu earthquake of 1973 (magnitude 6).

We report here the earthquake activity in the western Transverse Ranges for a six-year period from 1970 through 1976. The studied area extends from lat 33°45' N. to 34°45' N. and from long 118°30' E. to 120°30' E. (boxed area in fig. 1). This region includes the Santa Barbara Channel and surrounding area, the Ventura Basin, and the coastal and offshore area south of the Santa Monica Mountains and the Channel Islands.

The San Fernando earthquake sequence has been extensively studied (Allen and others, 1971, 1973; Tucker and Brune, 1973; Whitcomb and others, 1973, among others), and we have not restudied that sequence.

Acknowledgments.—We wish to thank the Seismological Laboratory of the California Institute of Technology, Geophysical Laboratory of the University of Southern California, and the California Department of Water Resources for making their seismic data and seismograms available to us. We are also indebted to Jim Buika, Travis Houck, and Sharon Kirkman for assistance in data processing.

PREVIOUS INVESTIGATIONS

Reliable accounts of California earthquakes date from about 1800. The earliest reports are found in notes of Spanish explorers and early settlers and in the records of the Franciscan missions. The earthquake history before installation of seismographs in the 1900's is summarized in various reports describing earthquake effects such as Townley and Allen (1939) and Richter (1958). Since 1932, instrumentally recorded earthquakes throughout southern California have been reported by the Seismological Laboratory of the California Institute of Technology at Pasadena. Results from this seismograph network have been synthesized by Allen, St. Amand, Richter, and Nordquist (1965), who related the earthquake data from 1934 to 1963 to the regional geologic structures in southern California. More recently, earthquake data obtained by the California Institute of Technology were summarized systematically in Hileman, Allen, and Nordquist (1973), Friedman, Whitcomb, Allen, and Hileman (1976), and Fuis, Friedman, and Hileman (1977).

Sylvester, Smith, and Scholz (1970) studied the earthquake swarm that occurred in the Santa Barbara Channel from June 26 to August 3, 1968, and discussed their results with respect to the seismic history of the channel and hydrocarbon exploration and withdrawal. An offshore oilwell blowout on January 28, 1969, drew national attention to the effects of oil pollution and provided the impetus for preparing a report on the geology, petroleum development, and seismicity of the Santa Barbara Channel region (U.S. Geological Survey Professional Paper 679). In that report, Hamilton and others (1969) reviewed the seismicity of the channel area and its possible associated effects on the region and noted that the limitations of the existing seismic network precluded identification of individual active faults within the channel.

In order to improve earthquake monitoring, a new network of seismograph stations surrounding the Santa Barbara Channel was established by the U.S. Geological Survey in late 1969. Lee and Vedder (1973) reported the earthquakes located by this network for 1970 and 1971 and showed that the earthquake activity appears to be spatially related to recognized faults in the region.

On February 21, 1973, a magnitude 6 earthquake occurred in the vicinity of Point Mugu at the southeast end of the Santa Barbara Channel.

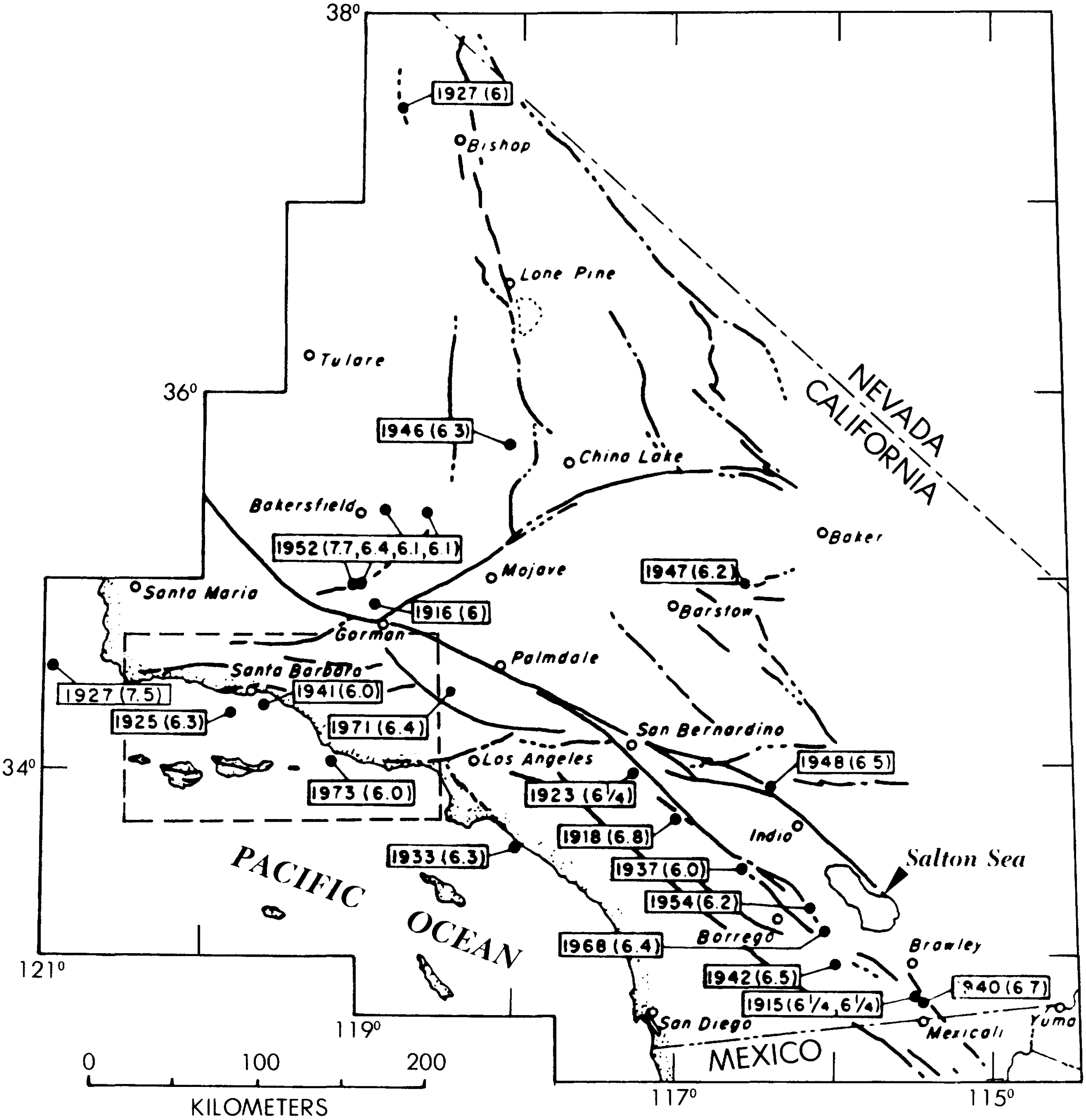

Figure 1.—Southern California showing epicenters of earthquakes of magnitude 6 and greater since 1912. Area of this study shown by box. Faults are shown by solid lines, dashed where approximately located. Modified from Allen, St. Amand, Richter, and Nordquist (1965).

Ellsworth and others (1973), who reported the seismological investigations of this earthquake sequence, noted that the complex fault zone associated with the southern boundary of the Transverse Ranges constitutes a significant earthquake hazard. Stierman and Ellsworth (1976) found that most aftershocks of the Point Mugu earthquake clustered in a region 5 km in diameter centered 6 km southeast of the main shock, and that the strain release within the imbricate fault zone was controlled by slip on preexisting planes of weakness under the influence of a compressive stress oriented northeast-southwest. Source parameters of the Point Mugu earthquake were estimated by Boore and Stierman (1976) from strong-motion recordings at Port Hueneme and Pasadena. They preferred a fault model in which rupture spread radially from the focal point, and they concluded that the area of initial rupture was smaller than the area outlined by the aftershock distribution. They also showed evidence that the rupture process involved a multiple earthquake.

Castle, Church, Elliott, and Savage (1977) investigated elevation changes in the epicentral region of the Point Mugu earthquake, and found that between 1960 and 1968 surveys, the upper (northern) plate of the west-trending Santa Monica fault rose by 3 to 4 cm at least as far west as Point Mugu, and this uplift is consistent with continuing thrusting along the north-dipping southern frontal fault system of the Transverse Ranges. From 1968 to 1971, the 1960-68 vertical-movement pattern was crudely reversed in both form and magnitude, a feature suggesting left-lateral reverse creep at depth and (or) onset of dilatancy. Between 1971 (pre-earthquake) and 1973 (post-earthquake), the upper plate of the Santa Monica fault underwent uplift that nearly restored the 1971 surface to its 1968 configuration. Because the observed rebound during 1971-73 is approximately an order of magnitude greater than the coseismic uplift calculated from dislocation modeling, Castle, Church, Elliott, and Savage (1977) concluded that this 1971-73 uplift might have been mainly preseismic and perhaps indicative of an evolving dilatant volume. The question of dilatancy before the Point Mugu earthquake was studied by Stewart (1973) using seismic arrival times.

In an environmental impact study of oil and gas development on the outer continental shelf in Santa Barbara Channel (U.S. Geological Survey, 1975), W. H. K. Lee and W. L. Ellsworth reviewed the earthquake history in some detail and prepared an extensive list of significant felt earthquakes for the period from 1800 through 1973. They concluded that the maximum credible earthquake for engineering design purposes is an event of magnitude 7.5 occurring anywhere in the Santa Barbara Channel region, and they urged a more systematic and thorough study of the region with regard to earthquake hazards.

SEISMOGRAPH STATIONS

The principal data used for the present study came from the 30 telemetered seismograph stations operated by the U.S. Geological Survey in and near the western Transverse Ranges (pl. 1[1]). These stations were supplemented by 18 temporary stations operated by the U.S. Geological Survey for two months after the 1973 Point Mugu earthquake. In addition, we made use of arrival times recorded by seismograph stations operated by the California Institute of Technology, University of Southern California, and California Department of Water Resources whenever needed to improve earthquake locations. A total of 105 stations were used in the present study. Station data including coordinates, elevations, and dates of operation are listed in table 1, and station locations with respect to geographical and structural features are shown in plate 1.

The equipment at each USGS telemetered station includes a vertical-component 1-Hz seismometer, a package containing a preamplifier, a voltage-controlled oscillator, and batteries. The frequency-modulated tone produced at each station is carried by wire (or radio from offshore stations) to a terminal where it is combined with tones from seven other stations. The resulting multiplexed signals are then transmitted by telephone line to Menlo Park, Calif. There, the eight channels of seismic data on each telephone line are separated, demodulated, and recorded on a 16-mm film recorder (Develocorder). In addition, two timing signals (radio station WWVB and a local time code) are recorded simultaneously with the seismic signals. Magnification for individual stations is adjusted according to the background noise level in steps of 6 db. Most of the USGS seismograph stations are operated at a magnification of about 100,000 at 1 Hz. As a backup, the signals transmitted on the telephone lines are also recorded on analog tapes. Playbacks from these tapes supplement the film recordings.

Equipment recording methods used by other institutions for their seismograph stations are similar to those used by the U.S. Geological Survey. In addition, the California Institute of Technology and the California Department of Water Resources operated some 3-component stations, the records of which greatly facilitate the reading of S-arrivals.

In response to the San Fernando and Point Mugu earthquakes, many additional seismograph stations have been installed in southern California with support from the U.S. Geological Survey. At present, the California Institute of Technology, U.S. Geological Survey, University of Southern California, and California Department of Water Resources operate over 200 seismograph stations in southern California.

ROUTINE DATA PROCESSING AND ANALYSIS

The principal recordings of seismic signals from the USGS stations are 16-mm films. The films were scanned daily to prepare a log of events. Earthquakes with signal durations of 20 seconds or greater were always timed. This duration corresponds to a magnitude cutoff of about 1-3/4. Events of less than 20-second duration were timed if there were three or more impulsive arrivals. During the timing process, P-arrival time, first P motion, S-arrival time, maximum amplitude and period, and signal durations were read whenever possible and necessary.

The data were then processed by computer to give origin time, hypocenter location, magnitude, and fault-plane solution of the earthquakes. Earthquakes were located mainly on the

[1] Plates published separately as U.S.G.S. Miscellaneous Field Studies Map MF-1032.

Table 1.—*Locations, dates of operation, and delays of seismographic stations used in this study*

Station		Geographic location		Elevation[1]	Delay	On-date[1]			Off-date[2]		
Inst.	Code	N Latitude	W Longitude	(m)	(s)	Year	Month	Day	Year	Month	Day
USGS	SBAI	34 0.79	119 26.23	104	0.05	1973	3	1			
USGS	SBCC	34 56.48	120 10.32	610	0.23	1969	11	24			
USGS	SBCD	34 22.12	119 20.63	213	0.20	1971	11	22			
USGS	SBCL	34 24.75	119 21.67	177	0.04	1969	11	24	1971	11	
USGS	SBLC	34 29.79	119 42.81	1190	-0.04	1969	11	11			
USGS	SBLG	34 6.57	119 3.85	415	-0.11	1969	11	24			
USGS	SBLP	34 33.62	120 24.03	134	-0.05	1969	11	24			
USGS	SBSC	33 59.68	119 37.99	457	-0.06	1969	11	24			
USGS	SBSM	34 2.25	120 20.99	172	-0.03	1969	11	24			
USGS	SBSN	33 14.70	119 30.40	259	-0.01	1970	3	30			
USGS	CAM	34 15.27	119 1.99	271	0.20	1973	6	16			
USGS	CJP	34 10.92	118 59.21	317	-0.01	1973	6	18			
USGS	CLP	34 5.33	118 57.85	549	-0.17	1973	6	16			
USGS	ECF	34 27.48	119 5.44	1005	0.30	1974	6	15			
USGS	EGG	34 7.95	119 8.85		0.0	1973	6	16	1973	7	
USGS	KYP	34 6.10	118 52.77	701	-0.15	1973	6	18			
USGS	OCB	34 2.20	119 1.00	-75	0.22	1973	6	18			
USGS	PTD	34 0.25	118 48.37	41	0.04	1973	6	18			
USGS	SAD	34 4.88	118 39.90	727	-0.15	1973	8	26			
USGS	SIP	34 12.26	118 46.92	701	0.0	1973	6	18			
USGS	SUF	34 24.58	119 12.15		0.39	1973	7	13	1973	8	
USGS	CAS	35 55.90	120 20.22	1189	0.0	1970	12	15			
USGS	GDH	35 49.86	120 21.17	433	-0.08	1968	3	21			
USGS	JOL	36 5.02	121 10.15	336	0.0	1969	6	18			
USGS	PKF	35 52.91	120 24.81	469	0.0	1968	1	11			
USGS	PNC	36 33.73	121 38.18	305	0.0	1967	9	24			
USGS	PTV	36 6.50	120 43.27	506	0.0	1970	4	16			
USGS	SHG	36 24.83	121 15.22	192	0.0	1969	6	18			
USGS	TAY	35 56.73	120 28.45	552	0.0	1968	1	12			
USGS	WKR	35 48.87	120 30.67	503	0.21	1968	1	11			
USGS	AGOR	34 9.52	118 44.52		0.07	1973	2	24	1973	4	14
USGS	CAMH	34 15.19	119 2.28		0.0	1973	2	23	1973	4	12
USGS	CLEF	34 13.07	118 54.64		0.13	1973	2	24	1973	4	12
USGS	DEER	34 4.02	118 59.20		-0.03	1973	2	23	1973	4	13
USGS	DUME	34 0.25	118 48.38		0.29	1973	2	12	1973	4	12
USGS	EGGR	34 7.87	119 8.82		-0.01	1973	2	22	1973	4	13
USGS	LEMN	34 10.79	119 1.57		-0.08	1973	2	23	1973	4	13
USGS	LONG	34 19.77	118 56.82		0.0	1973	2	25	1973	3	14
USGS	MUGU	34 6.87	119 4.00		0.0	1973	2	25	1973	3	10
USGS	NIDO	34 4.45	118 40.84		-0.22	1973	2	24	1973	3	15
USGS	POTR	34 9.37	118 59.33		0.0	1973	2	22	1973	2	25
USGS	SBOB	34 2.20	119 1.00		0.0	1973	3	29	1973	4	14
USGS	SHER	34 7.44	118 51.57		0.01	1973	2	22	1973	4	13
USGS	SIMI	34 14.81	118 48.28		0.0	1973	2	24	1973	3	14
USGS	SQPT	34 3.37	118 55.94		0.03	1973	2	22	1973	4	13
USGS	SYCA	34 8.37	118 58.06		0.0	1973	2	23	1973	4	13
USGS	TPNG	34 6.47	118 36.34		0.0	1973	2	25	1973	3	14
USGS	WIND	34 5.15	119 2.20		-0.14	1973	2	22	1973	2	25
CIT	BAR	32 40.80	116 40.30	510	0.0	1952	1	17			
CIT	CIS	33 24.40	118 24.20	485	-0.06	1971	7	1			
CIT	CLC	35 49.00	117 35.80	766	0.0	1949	7	8			
CIT	CWC	36 26.30	118 4.70	1620	0.0	1965	10	13			
CIT	FTC	34 52.40	118 53.60	990	-0.14	1952	11	21	1970	9	
CIT	GLA	33 3.15	114 49.59	627	0.0	1966	12	20			
CIT	GSC	35 18.10	116 48.30	990	0.0	1961	11	7			

Table 1.—*Locations, dates of operation, and delays of seismographic stations used in this study*—Con'd.

Station		Geographic location		Elevation[1]	Delay	On-date[1]			Off-date[2]		
Inst.	Code	N Latitude	W Longitude	(m)	(s)	Year	Month	Day	Year	Month	Day
CIT	HAY	33 42.50	115 38.30	439	0.0	1956	6	20			
CIT	IKP	32 38.93	116 6.48	957	0.0	1972	11	8			
CIT	IRC	34 23.40	118 24.00	580	0.03	1971	11	1			
CIT	ISA	35 39.80	118 28.40	835	0.09	1967	4	5			
CIT	LGC	33 50.15	118 9.02	17	0.0	1971	7	7			
CIT	MWC	34 13.43	118 3.46	1730	0.06	1928	4	23			
CIT	PAS	34 8.90	118 10.30	295	-0.05	1927	3	17			
CIT	PLM	33 21.20	116 51.70	1692	0.0	1939	9	7			
CIT	RVR	33 59.60	117 22.50	260	-0.25	1926	10	19			
CIT	SBB	34 41.30	117 49.50	850	0.12						
CIT	SBC	34 26.50	119 42.80	90	0.17	1927	5	10			
CIT	SCI	32 58.80	118 32.80	219	0.27	1971	11	11			
CIT	SCR	34 6.37	118 27.25		-0.23						
CIT	SCY	34 6.37	118 27.25	287	0.12						
CIT	SJQ	33 37.20	117 50.70	165	0.0	1971	7	7			
CIT	SJR	33 37.20	117 50.70		0.34	1971	7	7			
CIT	SPH	33 44.80	118 20.08	445	0.18	1971	7	7			
CIT	SWM	34 43.10	118 34.90	1220	-0.03	1966	3	7			
CIT	SYP	34 31.60	119 58.70	1305	-0.13	1967	6	7			
CIT	TCC	33 59.67	118 0.77	299	0.0	1971	7	7			
CIT	TCN	33 59.67	118 0.77		0.0						
CIT	TIN	37 3.30	118 13.70	1195	0.0	1929	9	4			
CIT	TPC	34 6.35	116 2.92	720	0.0	1972	5	5			
CIT	TWL	34 16.70	118 35.67	390	0.05	1971	11	1			
CIT	VPD	33 48.96	117 45.73	183	0.11	1971	7	7			
CIT	WDY	35 42.00	118 50.60	500	0.0	1952	8	5	1970	8	
CIT	CSRP	34 8.55	118 55.56		0.20						
CIT	CVGR	34 7.46	119 7.97		0.15						
CIT	CHOS	34 9.65	119 2.68		0.0						
CIT	CBKB	34 4.62	118 52.80		0.0						
CIT	CBSC	34 4.50	119 0.60		0.0						
CDWR	CSP	34 17.88	117 21.45	1268	0.0						
CDWR	CSL	34 14.94	117 16.68	1490	0.0						
CDWR	MRD	34 20.57	117 14.46	975	0.0						
CDWR	PEC	33 53.52	117 9.64	616	0.34						
CDWR	PYR	34 34.08	118 44.46	1247	0.17						
UCB	FRI	36 59.50	119 42.50	119	0.0						
USC	BHR	34 0.51	118 21.72		0.0						
USC	DHB	34 1.05	118 23.13		0.01						
USC	DRP	33 46.70	118 13.00		0.0						
USC	FMA	33 42.75	118 17.47		-0.10						
USC	GFP	34 7.76	118 18.59		0.05						
USC	HCM	33 59.64	118 22.98		0.0						
USC	IPC	33 58.24	118 20.07		0.0						
USC	JBF	33 59.58	118 20.68		0.0						
USC	LCL	33 50.00	118 11.41		0.16						
USC	LCM	34 1.07	118 17.22		0.0						
USC	LNA	33 47.35	118 3.27		0.63						
USC	RCP	33 46.66	118 8.00		0.67						
USC	TPR	34 5.33	118 35.20		-0.31						

[1]Blanks, elevation or date not known.

[2]Blanks, station still active.

basis of P-arrival times from seismograph stations with clear arrivals. S-arrivals were used to supplement the P-arrivals whenever possible and necessary. The HYPO71 computer program (Lee and Lahr, 1975) was used to locate hypocenters, compute magnitudes, and plot first-motion patterns. This program employs Geiger's (1912) method to determine hypocenters by minimizing the residuals between observed and calculated arrivals. Travel times from a trial hypocenter to the stations and their partial derivatives are computed on the assumption of a horizontal multi-layer model by a technique introduced by Eaton (1969).

There are no published descriptions of the configuration and nature of the crust beneath the western Transverse Ranges as determined by explosion seismology. Shor and Raitt (1958) interpreted the crustal structure of a part of the continental borderland of southern California by seismic-refraction methods, but their seismic profiles are well south of the Santa Barbara Channel. Although Healy (1963) reported several crustal models that are consistent with data obtained from two reversed seismic-refraction profiles between San Francisco and Los Angeles, his profiles transect only the northeastern part of the region covered in the present study.

We have adopted the four-layer model of Healy (1963, p. 5783) as an approximation to the crustal structure beneath the study area. This model is specified in the following table:

Layer	Depth (km)	P velocity (km/s)
1	0.0 to 2.6	3.0
2	2.6 to 16.7	6.1
3	16.7 to 26.1	7.0
4	below 26.1	8.1

We further assumed that the ratio of P-velocity to S-velocity is constant and has a value of 1.78. Station corrections as given by Lee and Vedder (1973) were used for initial location of earthquakes.

Because of the difficulties in maintaining precise calibrations of seismograph stations, maximum amplitude and period were not used to determine earthquake magnitude. Instead, magnitudes were estimated by the signal-duration method introduced by Lee, Bennett, and Meagher (1972). The magnitude for a given earthquake is the average value of magnitude estimates at various stations. Station magnitude (M) is derived from its recorded signal duration (τ) according to the formula

$$M = -0.87 + 2.00 \log (\tau) + 0.0035\Delta,$$

where Δ is the epicentral distance in kilometers. The signal duration is the period from the onset of the first P-arrival to the point where the trace amplitude (peak to trough) falls below 1 cm as it appears on the Geotech film viewer (20X magnification) for seismic signals recorded on 16-mm Develocorder films.

Lee and Vedder (1973) compared magnitudes determined by the above method with the traditional local magnitudes determined by the California Institute of Technology (CIT) for the 24 earthquakes in the Santa Barbara Channel region which appeared in both the U.S. Geological Survey (USGS) and CIT 1970-71 earthquake catalogs. They concluded that the magnitude determined by USGS agrees well (within 1/4 unit) with that determined by CIT, but that the USGS magnitude may be systematically lower than the CIT magnitude by 0.1 unit. These results are remarkable because the coefficients in the duration-magnitude equation are those determined for central California earthquakes.

RELOCATION OF 1970-75 EARTHQUAKES

Routine analysis of earthquakes in the western Transverse Ranges has been carried out using USGS stations. 1970-71 earthquake data for the Santa Barbara Channel region were published by Lee and Vedder (1973). Similar data for 1972-73 were listed in an open-file report by Kirkman and Ellsworth (1977a). For the Santa Monica Mountains area, Kirkman and Ellsworth (1977b) summarized the earthquake data for the period February 21 to December 31, 1973; the Point Mugu earthquake sequence was extensively studied by Stierman and Ellsworth (1976). The 1974-75 data in the western Transverse Ranges were routinely analyzed by two of us (Simirenko and Lee) but were not published.

For the present study, we started with the routine data on file in the USGS. That list was combined with earthquake lists prepared independently by CIT, the University of Southern California (USC), and the California Department of Water Resources (CDWR). The combined list has a total of about 2,000 earthquakes, of which 1,110 events are in or near our study area. Arrival times from CIT, USC, and CDWR were added to the USGS data. Earthquakes were then located using the combined arrival-time data by the HYPO71 program. A study of the results indicated that for some earthquakes, certain critical stations were not read and some stations had large residuals. We then reread seismograms for these events at USGS, CIT, USC, and CDWR to correct errors and to obtain arrival times that were not read routinely before.

The horizontal multi-layer model of crustal structure used in earthquake location is inadequate to describe the complexity of the earth's crust beneath the western Transverse Ranges. A standard method to improve the simple crustal model is to derive station corrections from earthquake P-residuals. We divided the study region into areas of 5 minutes latitude by 5 minutes longitude and selected a sample of the best-recorded earthquakes in these areas. These earthquakes were then used as master events in an iterative procedure to derive a set of station corrections. The results are included in table 1. However, corrections for some stations could not be derived for lack of data, and they were assumed to be zero.

We used the station corrections derived from the master events to relocate the 1,110 events in or near our study area. We rejected 158 earthquakes that had magnitudes less than 1 and also rejected 322 earthquakes that were relocated outside the study area, that belonged to the San Fernando earthquake sequence, or had insufficient data for even approximate locations. This treatment yielded a total of 630 adequately located earthquakes in the study area. A few of these events, however, may be explosions.

EARTHQUAKE HYPOCENTERS AND THEIR ACCURACY

The 630 earthquakes that occurred in the western Transverse Ranges for the six-year period from 1970 to 1975 are listed chronologically in table 2 (p.16). Included are the origin time, location of hypocenter (epicenter and focal depth), magnitude, and number of arrival times used. In addition, five parameters are listed as a means of evaluating the quality of hypocenter solution Q: (1) the largest azimuthal separation between stations (α), (2) epicentral distance to the nearest station (β), (3) root-mean-square error of the time residuals, (4) standard error of the epicenter, and (5) standard error of the focal depth. On the basis of these parameters, the general reliability of each earthquake solution is graded as either excellent (A), good (B), fair (C), or poor (D). Criteria for quality classification are listed in table 3.

A brief discussion of the accuracy of hypocenter solutions was given by Lee, Eaton, and Brabb (1971). To obtain a reliable epicenter, the largest azimuthal separation between stations (α) should be less than 180° so that the earthquake epicenter is surrounded by stations. To obtain a reliable focal depth, epicentral distance to the nearest station (β) should be less than the focal depth, so that there is a direct ray-path. In addition, systematic errors arise from uncertainties in the crustal velocity model. These errors cannot be determined without controlled experiments, such as calibrated explosions in the focal region. Owing to irregular distribution of stations and occasional loss of data from critical stations, the quality of hypocenter solutions in table 2 varies. Although standard errors of epicenters and focal depth are given, they must be interpreted with caution, especially for quality C and D solutions. These standard errors are computed with respect to the assumed crustal velocity model, which is not necessarily a good approximation to the real earth.

Because we do not have accurately calibrated explosions in the western Transverse Ranges, it is difficult to ascertain the hypocenter accuracy of our earthquake solutions. Extrapolation from experience in central California suggests that earthquake locations in the western Transverse Ranges are accurate to about 5 km in general (table 3). This conclusion is supported by the fact that we were able to locate several offshore explosions near Santa Cruz Island within 5 km of their approximate positions as given by the U.S. Navy.

DISTRIBUTION OF EARTHQUAKE HYPOCENTERS

The temporal variation of seismicity in the western Transverse Ranges for the period 1970-75 is difficult to assess because the distribution of seismograph stations changed rapidly. Some increase in the number of earthquakes located in the later years is undoubtedly related to an increase in the number of stations.

The spatial variation of seismicity in the western Transverse Ranges can be assessed over the period 1970-75 because we have shown that the location errors are generally not large.

Table 3.—*Criteria for determining* Q

[Q is based on both the station distribution with respect to the earthquake and the statistical measures of the solution, and both are rated by independent schemes. Q is taken as the average of the ratings from the two schemes: an A and a C yield a B; two B's yield a B. When ratings are only one level apart the lower one is used: an A and a B yield a B. >, greater than, <, less than]

Q	Solution quality of hypocenter		Station distribution			Statistical measures		
	Epicenter	Focal depth	*NO*	*GAP*	*DMIN*	*RMS*	*ERH*	*ERZ*
A	Excellent	Good	>5	≤ 90°	≤ Depth or 5 km	< 0.15 s	< 1.0 km	< 2.0 km
B	Good	Fair	>5	≤ 135	≤ 2 x Depth or 10 km	< 0.30	< 2.5	< 5.0
C	Fair	Poor	>5	≤ 180	≤ 50 km	< 0.50	< 5.0	> 5.0
D	Poor	Poor	<6	> 180	> 50 km	> 0.50	> 5.0	> 5.0

Plate 1 shows a plot of relocated earthquake epicenters in the western Transverse Ranges from 1970 to 1975. Most of the earthquake epicenters in plate 1 may be loosely grouped into three east-west-trending sets: (1) along the southern front of the Transverse Ranges, corresponding to a complex fault zone that includes the Santa Monica-Anacapa fault, the Malibu Coast fault, and the Santa Cruz Island fault; (2) along the east-central part of the Santa Barbara Channel, corresponding to the Pitas Point-Ventura fault, Oak Ridge fault, and several other east-west-trending faults detected by acoustic profiling; and (3) along the Santa Barbara coast and parallel to the coast to the east, corresponding to the Red Mountain and San Cayetano faults, Arroyo Parida fault, and several unnamed faults 5 to 10 km offshore. Significant earthquake activity was also detected outside the study area south of Santa Rosa Island and seaward to Point Arguello.

Many of the faults in the western Transverse Ranges that show evidence of Holocene or late Quaternary displacement, including most of the faults in groups (1) and (3) above, are reverse faults. Because most of these faults are not vertical, epicenters of earthquakes associated with them do not generally aline with their surface traces. Epicentral distances from the surface trace depend on focal depths and the dip of the fault. Because earthquake hypocenters and fault dips are uncertain the relation between earthquake epicenters and mapped faults is usually not certain. Nevertheless, the approximate association of earthquake epicenters with mapped faults is striking. In order to further delineate the association, we plotted earthquake epicenters using symbols representing their focal depths (pl. 2). Focal depths generally increase north of mapped faults, as would be expected from the local geology.

To further illustrate possible associations between earthquake hypocenters and mapped faults, we constructed four cross sections (A-A', B-B', C-C', and D-D') as shown on plate 2. Earthquake hypocenters up to 6 km from line A-A' were projected at right angles onto the cross section as shown in figure 2. To eliminate poorly determined hypocenters, we used only quality A, B, and C solutions.

Two methods were used to test the associations between hypocenters and surface fault traces. In the first, we assumed that the earthquakes were separate groups to be associated with the nearest known surface fault trace and tested the distribution of hypocenters about the fault trace using the method of York (1966), in which x and y coordinates are assumed to be equally subject to error and fitted to a least-squares line. For section A-A' this test indicates that fault X and the Mesa-Arroyo Parida fault are near-vertical and that fault Y dips about 77° north (fig. 2*A*).

In the second method, the apparent dips of the primary focal planes of the fault-plane solutions were projected onto the sections parallel to structure. For section A-A', this test suggests that the Pitas Point fault may generate much of the seismicity north of its map trace, possibly including the Santa Barbara earthquake of Aug. 13, 1978 (event SB 78, fig. 2*B*).

Cross section B-B' extends north-south through the Pitas Point and Red Mountain faults. The data projected on the cross section were chosen with the same criteria as for section A-A'. From the results (fig. 3), we deduce that the dip

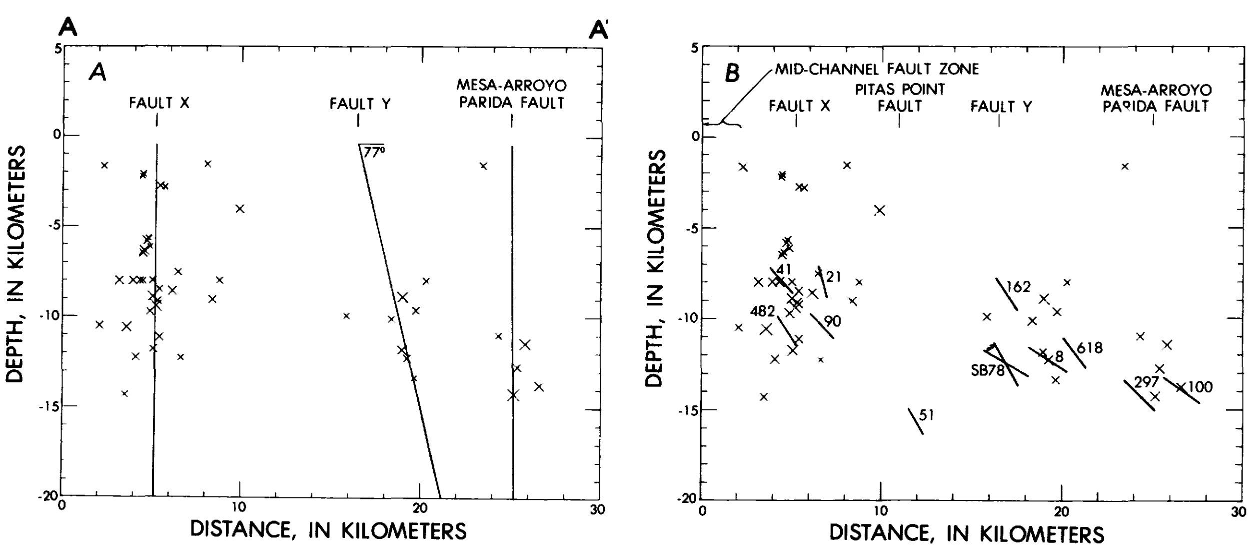

Figure 2.—Cross-sectional plots of hypocenters along line A-A' (pl. 2). Size of symbol is proportional to earthquake magnitude. *A*, Distribution of hypocenters tested by using method of York (1966). *B*, Heavy bars represent apparent dip of primary focal plane of numbered event as projected parallel to structure. (Hypocenters projected normal to line of section.) Numbers refer to plate 2 and table 4.

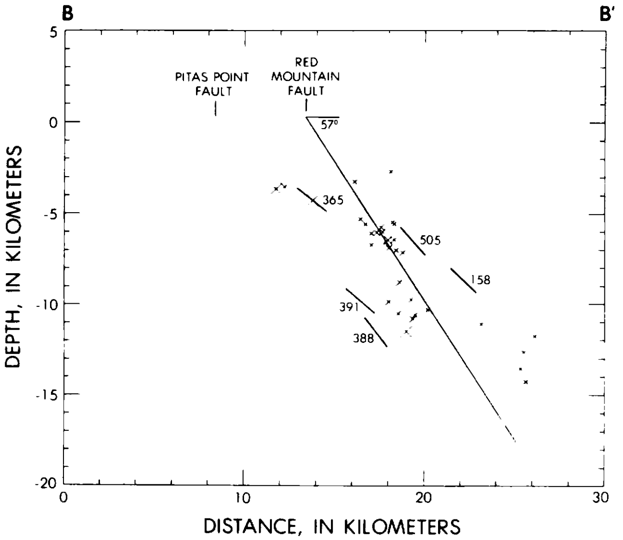

Figure 3.—Cross-sectional plot of hypocenters along line B-B' (pl. 2). Size of symbol is proportional to magnitude. Heavy bars represent apparent dip of primary focal plane of numbered event as projected parallel to structure. (Hypocenters projected normal to line of section.) Numbers refer to plate 2 and table 4.

angle for the Red Mountain fault from the hypocenter data is 57°N. This is in excellent agreement with a dip of 60°N based on well data (R. S. Yeats, written commun., 1978). The projected apparent dips of primary focal planes also indicate that some of the seismicity in this area may be associated with the Pitas Point fault.

Cross sections C-C' and D-D' are constructed perpendicular to the Anacapa fault in the Point Mugu area (pl. 2). Earthquake hypocenters (solution quality A and B only) up to 3 km from line C-C' were projected onto the cross section (fig. 4). We deduce that the Anacapa fault dips 48°N, in excellent agreement with a dip of 44°N obtained from the fault-plane solution for the magnitude-6 Point Mugu earthquake. Cross section D-D' extends through the Point Mugu aftershock area. Earthquake hypocenters (solution quality A and B only) up to 3 km from line D-D' were projected onto the cross section (fig. 5). The hypocenters in cross section D-D' may be separated into two groups associated respectively with the Anacapa fault and fault Z. From the hypocenter data, we deduce that the Anacapa fault dips 45°N, in excellent agreement with the result from cross section C-C' and almost identical to the dip of 44°N deduced from the fault-plane solution of the Point Mugu main shock. The dip for fault Z is 41°N, which is very close to that for the Anacapa fault.

EARTHQUAKE FOCAL MECHANISMS

The HYPO71 computer program plots the P-wave first motions of an earthquake in an equal-area projection of the lower focal hemisphere. The

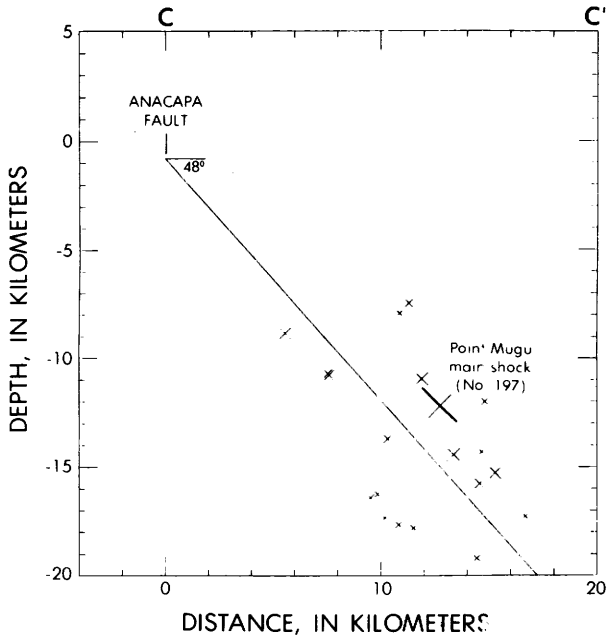

Figure 4.—Cross-sectional plot of hypocenters along line C-C' (pl. 2). Size of symbol is proportional to earthquake magnitude. Heavy bar represents apparent dip of primary focal plane of numbered event as projected parallel to structure. (Hypocenters projected normal to line of section.) Number refers to plate 2 and table 4.

position of a first-motion reading in the focal hemisphere plot is determined by (1) the azimuthal angle between the earthquake epicenter and the station, and (2) the emergence angle of the seismic ray from the earthquake focus to the sta-

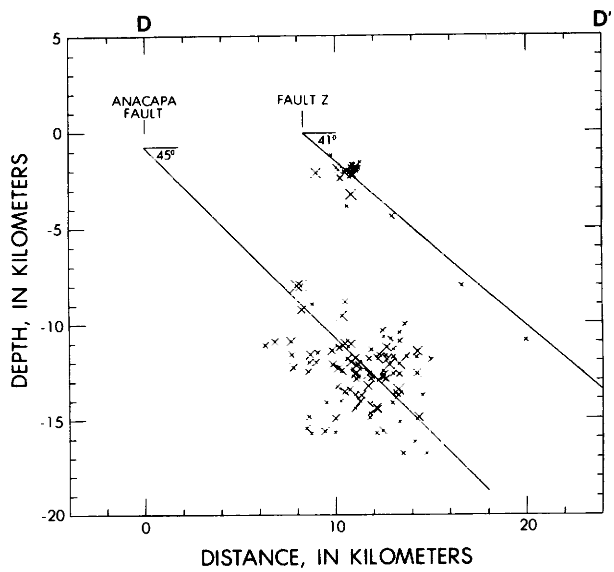

Figure 5.—Cross-sectional plot of hypocenters along line D-D' (pl. 2). Size of symbol is proportional to earthquake magnitude.

tion. If there are enough accurate first-motion readings from a well-located earthquake (at least six), it is generally a simple task to derive the fault-plane solution manually from the first-motion plot generated by the HYPO71 program.

In practice, there are difficulties and complications. First, the polarity of a seismograph station may have been reversed so that the first-motion reading from the seismogram is opposite to reality. Second, the distribution of seismograph stations is variable with respect to a given earthquake. Third, the first motion of a P-wave at noisy or distant stations may be difficult to identify. Fourth, it is difficult to locate an earthquake accurately without a dense network of stations and calibrated explosions. Therefore, great care must be taken in order to obtain an accurate earthquake focal mechanism. We illustrate these difficulties with an example.

Lee and Vedder (1973) published a fault-plane solution constructed from composite first motions of ten small earthquakes in the Santa Barbara Channel (fig. 6). They inferred a left-lateral strike-slip motion on a north-dipping, east-west-trending fault. However, their solution is unique only if the two first-motion readings at station PYR are accurate. Our re-examination suggests that this is probably not the case—the P-arrivals at PYR are emergent and not clearly defined for these earthquakes and it is difficult to correctly identify the first motion. If we reverse or ignore these two questionable readings, an entirely different fault-plane solution is obtained, as shown in figure 6*B*.

In the present study, we took several steps to reduce the chance of errors in fault-plane solutions. First, we systematically determined the polarity of USGS stations using large teleseisms or nuclear explosions (see Houck and others, 1976 for details). Second, we rejected fault-plane solutions derived from data of marginal quality or quantity. Third, we carefully re-examined the first-motion readings of promising fault-plane solutions before we accepted them. As a result, we obtained 49 acceptable solutions from several hundred first-motion plots (table 4). These fault-plane solutions are shown in plate 2, and individual solutions are shown in figure 7. We note that most fault-plane solutions show reverse faulting along east-trending faults which may dip either north or south. We chose the north-dipping fault planes because they best fit the local geology and the distribution of earthquake hypocenters. A detailed discussion of the earthquake focal mechanisms and their tectonic implications is given in Chapter B of this report.

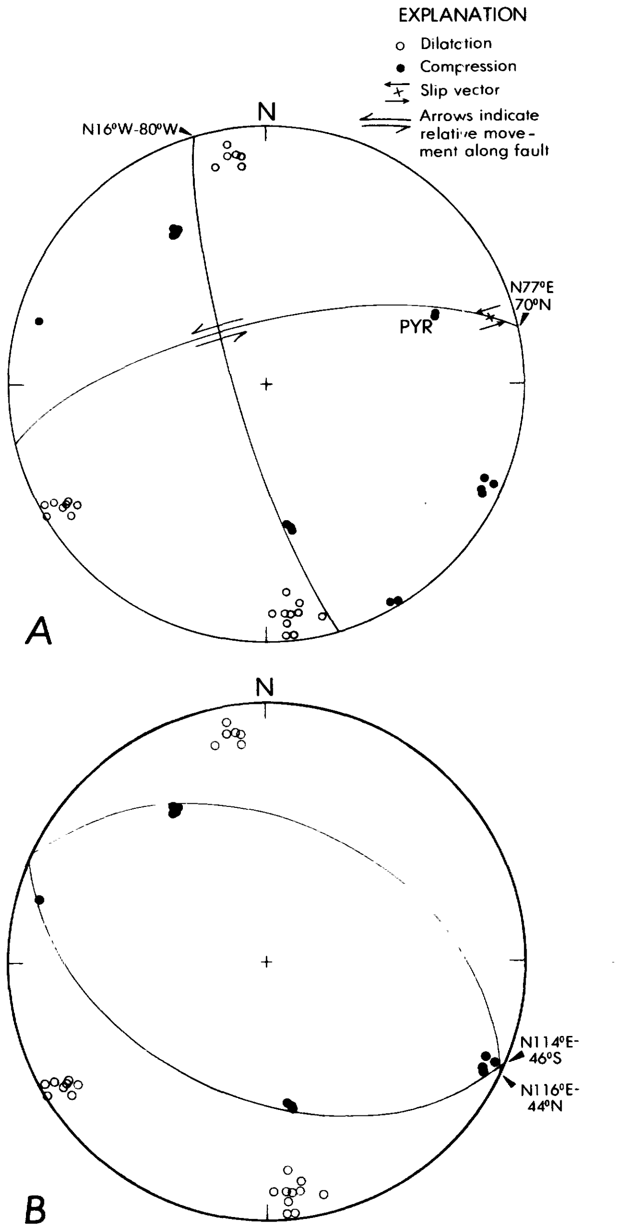

Figure 6.—Fault-plane solutions based on composite first motions of 10 earthquakes in Santa Barbara Channel, from Lee and Vedder (1973). *A*, Solution includes readings at station PYR. *B*, Alternative fault-plane solution excludes readings from two distant stations (PYR and SBCC).

DISCUSSION

The primary finding of this study is that independent seismological evidence fully supports geologic evidence that much of the western Transverse Ranges is dominated by north-dipping reverse faults that form extensive east-trending zones, especially the Anacapa-Santa Monica, Mid-Channel, Pitas Point-Ventura, and Red Mountain-San Cayetano faults. The geometry and characteristics of these faults have been deduced from both the spatial distribution of earthquake hypocenters and fault-plane solutions of well-recorded earthquakes, as well as surface and subsurface geologic data. Our work demonstrates that detailed studies of earthquakes from a sufficient number of local seismographic stations

Table 4.—*Data on mapped focal mechanisms*

Event no.	Map coord	Time (GCT) Yr Mo Dy	Time (GCT) Hr:Mn:Sc	Depth (km)	Mag	Focal planes Primary Azi	Primary Dip	Auxiliary Azi	Auxiliary Dip	P-axis Azi	P-axis Pl	Slip Vector Azi	Slip Vector Pl
8	C2	70-02-20	7:35:35	12.3	2.4	116	35N	116	55S	26	0	26	35
21	D2	70-04-16	21:55:48	8.9	2.9	108	76N	50	24S	0	30	304	48
30	D3	70-05-25	2:57:54	8.0	2.7	156	44E	170	46W	72	2	80	44
35	B4	70-06-20	15:27:31	8.0	3.1	146	60E	146	30W	56	0	56	60
40	F2	70-08-26	1: 8:59	8.0	3.6	112	60N	160	40S	42	12	70	60
41	D2	70-08-29	8:14:16	8.0	2.3	118	50N	164	50W	50	0	72	40
51	C2	70-12-06	1:19:33	15.5	2.0	98	60N	144	40W	26	13	54	50
64	H2	71-02-16	4:37: 3	5.4	3.6	96	50N	80	44S	0	0	10	48
74	H3	71-04-02	5:40:24	3.4	3.8	100	42N	78	52S	178	3	347	39
90	D2	71-05-07	2: 3:21	10.4	2.6	118	50N	118	40S	28	5	26	50
100	C2	71-05-15	16:54:13	13.7	2.7	90	35N	138	60W	214	15	46	24
129	F2	71-11-04	19:17:39	11.1	2.5	177	56S	177	34N	176	11	176	56
144	A2	72-01-17	5:49:58	10.3	2.7	116	76N	116	14S	26	21	10	75
158	D2	72-04-04	5: 2:56	8.7	3.1	108	44N	86	48S	186	5	356	42
162	C2	72-04-17	0:28:38	8.9	3.0	95	57N	42	46S	340	6	312	44
165	H4	72-06-11	11: 5: 4	10.9	2.8	134	84N	52	36S	21	25	330	53
166	C2	72-06-15	16:42: 9	13.4	2.2	130	65N	13	45W	68	12	102	45
172	G3	72-07-14	23: 1:15	6.6	2.7	107	70N	134	25S	21	21	46	67
173	G1	72-07-27	1:12: 4	8.0	3.0	90	85N	24	10E	346	45	292	79
197	F3	73-02-21	14:45:57	12.2	5.9	86	44N	86	46S	356	0	347	44
288	H4	73-03-26	1:27:44	8.0	2.5	100	28N	144	70W	220	23	54	20
297	C2	73-03-29	17:54:16	14.2	3.3	108	45N	136	50W	213	4	32	40
357	E4	73-08-06	23:29:16	13.8	5.0	115	50E	130	50S	211	5	44	48
359	E4	73-08-06	23:53:46	13.7	1.9	150	62E	130	30S	53	15	40	60
365	E2	73-08-15	2:16:21	4.3	3.0	112	40N	112	50S	202	5	22	40
371	F4	73-08-20	14: 1:49	8.0	2.5	104	60N	87	30S	8	15	3	60
376	F2	73-08-24	9: 4:55	13.4	2.4	120	50N	158	50S	228	2	70	44
385	H3	73-09-02	6:28: 3	13.9	2.3	46	44N	91	56S	162	6	1	34
388	E2	73-09-04	9:11:25	11.5	3.4	103	52N	72	42S	358	6	340	48
391	E2	73-09-07	15:18:10	9.9	2.6	98	40N	98	50S	189	5	8	40
396	F2	73-09-13	13: 7:45	12.1	2.2	146	48E	136	40W	52	6	47	47
397	F2	73-09-13	13: 8:37	16.0	2.2	142	50E	148	40W	54	5	12	42
418	H2	73-11-14	17:15:31	13.1	2.2	142	60E	142	30W	52	0	52	60
426	G3	73-12-20	14:23:21	13.3	2.1	152	50E	6	44W	78	5	96	44
428	H2	73-12-25	6: 9: 3	11.3	2.1	120	58N	162	36W	48	14	78	48
449	D2	74-02-27	12:25:36	8.0	2.3	114	52N	70	48S	2	2	340	42
450	H2	74-03-03	16:29: 1	12.9	2.2	158	32E	154	66W	66	12	54	32
472	F3	74-04-25	8:23:53	8.9	2.8	91	72N	118	20S	6	27	28	70
482	D3	74-07-09	0:58:49	10.8	2.0	122	60N	122	30S	32	15	34	60
505	E2	74-09-23	2:22:59	6.5	2.0	128	54N	128	36S	36	9	36	54
553	G4	75-01-11	14:44:18	13.0	2.5	85	45N	85	45S	6	0	6	45
555	H4	75-01-23	3:48:42	8.0	2.8	114	90N	24	90E	339	0	114	0
557	H3	75-01-28	5:22:22	8.0	2.4	52	50N	96	50S	344	0	6	40
558	D2	75-01-28	9:45:49	8.0	2.5	137	54E	108	40S	33	7	18	50
570	H3	75-03-01	5:45: 4	6.6	2.0	128	56N	72	52S	11	3	342	38
575	G1	75-03-24	10:32:25	12.2	2.7	98	60N	118	32S	15	15	28	58
576	G2	75-04-10	21:19:26	6.7	2.0	90	44N	126	52S	200	4	34	40
618	D2	75-10-09	6:16:56	11.8	2.6	77	50N	96	42S	356	6	8	48
625	H4	75-11-03	3:42:17	16.6	1.8	132	84N	45	54S	20	35	314	35
SB 78	D2	78-08-13	22:54:52	12.5	5.1	114	40N	158	60S	229	10	68	30

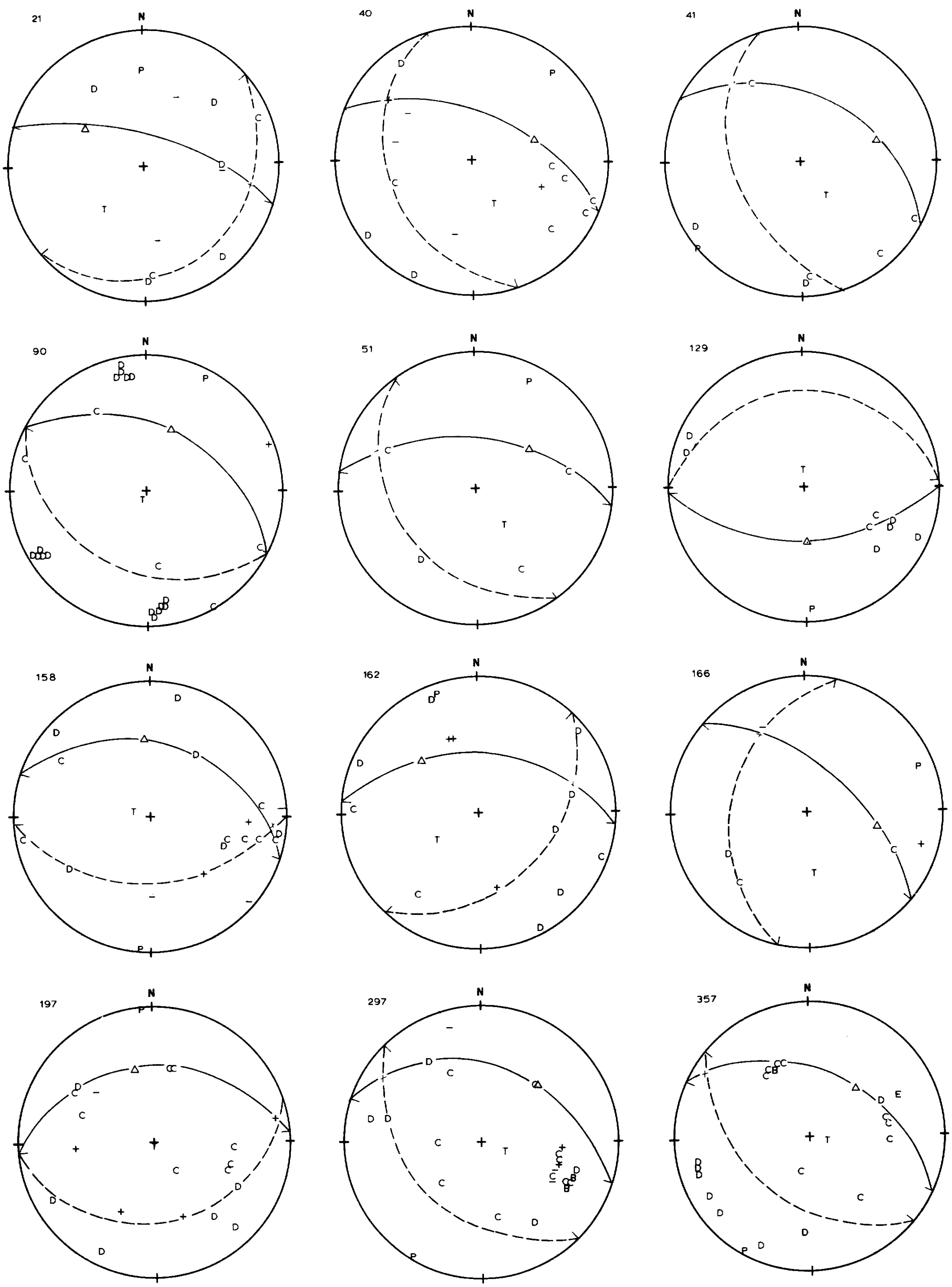

Figure 7.—First-motion data and focal mechanisms for selected events from 1970 through 1975 for western Transverse Ranges. Numbers keyed to plate 4, and table 1. C, compression; D, dilatation; B, two compressions; E, two dilatations; +, weak compression; -, weak dilatation; T, tension axis; P, pressure axis; Δ, slip vector; solid arc, primary focal plane; dashed arc, auxiliary plane. Equal-area projection of lower focal hemisphere.

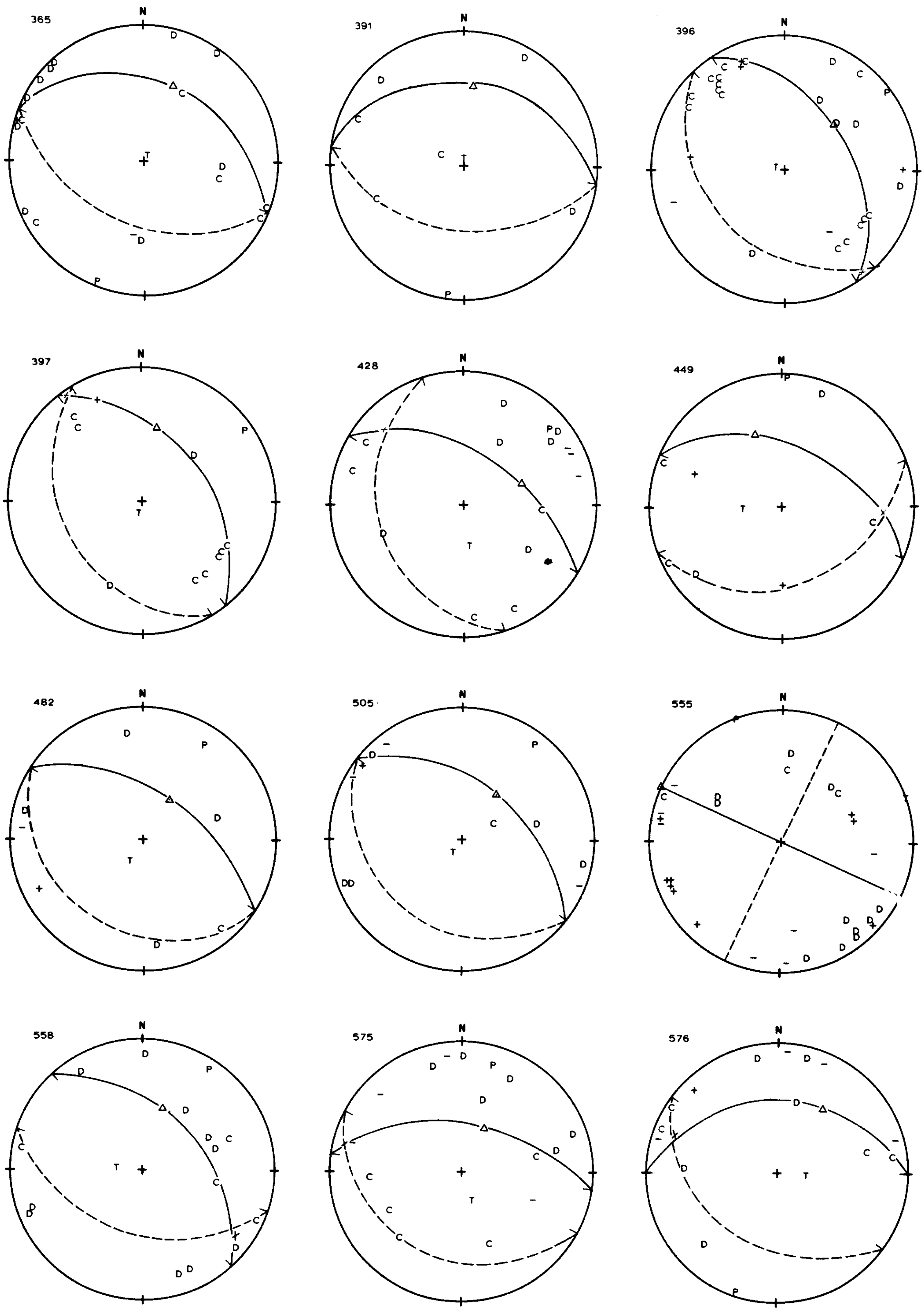

Figure 7.—Continued.

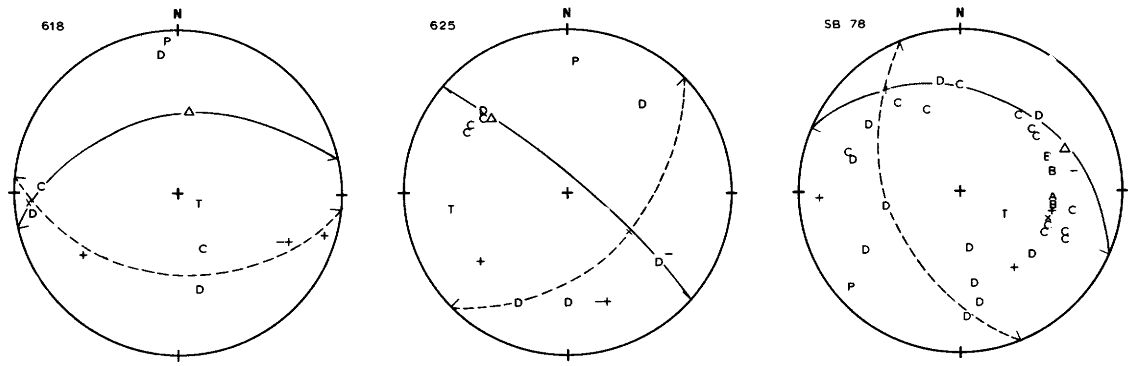

Figure 7.—Continued.

can help delineate active faults in three dimensions and aid in the interpretation of local geology and tectonic features.

Our locations for the Point Mugu earthquake and its aftershocks differ slightly from those given by Stierman and Ellsworth (1976). For example, we located the main shock about 2 km south of that given by Stierman and Ellsworth and about 5 km shallower. These differences result because (1) we used more arrival times, and (2) we used a different crustal velocity model and station delays. By studying a small area in greater detail, Stierman and Ellsworth (1976) have constructed a far more realistic crustal model for the Point Mugu area; our model was deduced for the whole western Transverse Ranges. Nevertheless, it is interesting to note that the difference in epicenter location is generally within one standard error given by these two sets of solutions, whereas the difference in focal depth is generally within two standard errors.

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Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*

[The following data are given for each event:

Origin time in Greenwich Civil Time: second through seventh columns.

Epicenter in degrees and minutes of north latitude (LAT N) and west longitude (LONG W).

DEPTH, depth of focus in kilometers.

MAG, Richter magnitude of the earthquake.

NO, number of stations used in locating earthquake.

GAP, largest azimuthal separation in degrees between stations.

DMIN, epicentral distance in kilometers to the nearest station.

RMS, root-mean-square error of the time residuals: $RMS = [\Sigma_i (R_i^2/No)]^{1/2}$ where R_i is the observed seismic-wave arrival time minus the computed time at the ith station.

ERH, standard error of the epicenter in kilometers: $ERH = [SDX^2-SDY^2]^{1/2}$. SDX and SDY are the standard errors in latitude and longitude, respectively, of the epicenter. When $NO < 5$, ERH cannot be computed and is left blank.

ERZ, standard error of the focal depth in kilometers. When $NO < 5$, ERZ cannot be computed and is left blank. If $ERZ \geq 20$ km, it is also left blank.

Q, solution quality of the hypocenter. This measure is intended to indicate the general reliability of each solution. See table 3 for criteria that determine Q]

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
1	1970	JAN	2	10	45	21.5	34-15.9	119-41.5	9.4	3.4	10	152	19.8	0.16	1.3	1.2	C
2			2	19	57	47.5	34-17.7	119-42.9	3.8	2.6	8	229	16.3	0.22	2.9	4.3	D
3			8	5	17	42.9	34-29.3	119-18.6	8.0	2.3	7	191	37.0	0.25	9.5	6.3	D
4			10	2	47	2.9	34-25.7	119- 8.6	12.6	3.0	16	140	40.1	0.27	1.6	1.1	C
5			14	17	17	4.7	34-23.0	119-52.2	4.2	2.0	7	180	18.8	0.10	0.8	14.1	D
6			29	15	32	59.4	34-25.2	119-55.4	13.9	1.9	6	156	12.8	0.13	1.5	1.4	C
7		FEB	14	12	56	24.7	34-14.5	119-40.7	8.0	2.4	7	79	27.7	0.19	1.5	3.1	C
8			20	7	35	35.2	34-23.4	119-46.0	12.3	2.4	8	118	7.6	0.08	0.7	0.6	B
9		MAR	4	17	24	57.3	34-22.6	120- 8.2	11.2	1.9	6	121	31.8	0.25	2.7	13.6	C
10			7	16	48	50.5	33-56.5	118-49.5	5.3	2.7	9	201	28.9	0.23	2.4	2.5	C
11			13	20	40	9.7	34-24.3	119-34.0	12.7	1.8	6	140	17.0	0.07	0.8	0.9	B
12			20	12	48	43.8	34-21.4	120-24.1	8.0	1.9	6	188	22.7	0.26	4.0		D
13			20	13	18	36.6	34-21.3	120-25.4	8.0	2.0	6	196	22.9	0.21	3.3	17.5	D
14			23	13	16	9.4	34- 2.5	119- 6.7	7.9	1.9	7	182	8.7	0.18	1.9	2.0	C
15			26	22	0	20.8	34-15.9	119-37.6	8.0	2.7	12	86	21.2	0.29	1.9	2.6	C
16			29	13	11	6.3	34- 3.6	118-59.2	8.0	1.9	5	241	9.0	0.03	0.6	0.7	C
17			29	16	7	17.8	34-15.6	119-38.0	11.3	1.8	6	124	27.2	0.05	1.4	0.8	C
18			31	11	1	51.5	34-15.8	119-34.7	4.5	2.8	12	80	23.3	0.20	1.0	2.1	C
19		APR	6	23	3	50.6	34-22.6	119-37.0	8.0	2.1	6	154	11.3	0.12	2.0	5.3	C
20			15	23	32	4.0	34-22.4	120-24.1	8.0	1.9	6	188	20.8	0.26	2.9	11.2	D
21			16	21	55	48.5	34-15.7	119-42.2	8.9	2.9	13	76	19.9	0.17	0.9	1.1	C
22			19	7	11	58.8	34-28.6	119-49.3	3.2	2.1	6	113	10.1	0.12	0.4	6.8	C
23			20	7	31	47.4	34-24.7	118-32.7	2.0	2.7	7	112	34.2	0.24	1.5	15.4	C
24			22	2	43	29.8	34-31.4	119-25.3	4.3	2.1	7	142	26.9	0.27	1.7	12.8	C
25			23	10	42	53.3	34-26.5	119-24.4	8.0	2.5	8	131	28.2	0.16	1.4	1.6	C
26			30	3	59	42.8	34-14.2	119-33.9	6.9	2.7	10	90	26.5	0.15	0.9	1.3	B
27		MAY	2	1	52	3.3	34-15.4	119-33.4	6.4	2.3	7	94	29.9	0.11	1.0	1.9	B
28			2	15	43	39.3	34-21.2	120-25.4	8.0	2.2	6	196	23.0	0.26	4.3		D
29			16	1	47	24.5	34-27.0	119-47.2	11.4	3.3	17	60	6.7	0.27	1.2	0.9	B
30			25	2	57	54.4	34-14.7	119-44.5	8.0	2.7	11	87	21.9	0.11	0.7	0.9	B
31			25	9	12	52.6	34-14.3	119-46.0	1.7	1.9	8	146	23.2	0.13	1.1	1.0	C
32		JUN	11	1	13	0.1	34-20.2	120- 2.8	3.0	2.7	6	151	22.1	0.18	1.8	15.5	C
33			20	14	2	29.4	34-41.7	119-30.1	8.0	2.1	8	167	29.3	0.29	2.0	4.8	C
34			20	15	23	16.3	33-45.0	120- 4.8	8.3	2.5	6	185	40.5	0.04	0.5	0.6	C
35			20	15	27	31.2	33-45.8	120- 4.2	8.0	3.1	8	182	39.9	0.18	1.6	2.0	C
36		JUL	1	20	0	41.2	34- 2.2	118-51.0	0.5	1.8	6	205	21.3	0.06	0.7	6.6	D
37			4	10	9	35.1	34-42.6	119-31.3	5.9	2.4	9	96	29.5	0.16	1.1	1.8	C
38			24	11	55	27.1	34- 0.9	119- 8.4	4.9	2.5	9	168	12.6	0.10	0.6	1.0	B
39			29	21	13	18.1	34-35.3	119-50.0	5.2	2.4	12	84	14.9	0.34	1.9	3.4	C
40		AUG	26	1	8	59.6	34-19.2	119-14.1	8.0	3.6	13	75	15.5	0.27	1.3	1.6	B

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
41	1970	AUG	29	8	14	16.9	34-15.1	119-42.1	8.0	2.3	8	107	21.0	0.19	1.4	2.8	C
42		SEP	7	9	35	56.4	34-30.6	119-44.8	1.6	2.6	8	125	3.3	0.07	0.6	0.3	B
43			12	19	17	32.4	34-26.9	119-25.9	7.0	3.2	10	185	7.6	0.15	1.8	1.5	C
44			12	20	52	14.0	34-15.4	119-38.5	4.9	1.4	6	123	27.5	0.14	1.5		C
45		OCT	6	8	0	46.9	34-16.6	119-42.5	12.3	1.6	7	129	24.4	0.11	0.7	0.8	B
46			17	20	17	5.7	34-34.6	119-49.6	3.9	2.5	10	158	13.8	0.12	1.1	1.6	C
47		NOV	7	15	54	31.2	34-25.6	119-27.3	6.3	2.4	6	148	25.0	0.24	3.1	5.5	C
48			8	8	27	8.9	33-52.0	120-16.8	8.0	2.4	7	207	19.9	0.15	14.0	13.7	D
49			15	5	10	5.0	34-26.4	119-40.0	23.5	1.9	4	185	7.5	0.01			C
50			22	12	0	31.8	34- 7.9	119- 2.0	12.6	1.9	5	199	3.8	0.02	0.7	0.8	C
51		DEC	6	1	19	33.2	34-20.8	119-51.4	15.5	2.0	6	215	16.9	0.12	4.8	2.0	D
52			9	13	3	56.1	34-24.2	119- 8.6	6.9	2.7	7	106	20.0	0.09	0.9	1.3	B
53			18	15	29	42.4	33-52.1	118-39.4	2.3	3.1	9	145	46.1	0.21	1.6	10.7	C
54			30	9	50	6.5	34-17.4	119-46.1	1.6	2.0	8	135	17.6	0.18	1.4	1.8	C
55			31	23	5	11.4	34-42.7	120-17.3	8.0	3.0	8	121	19.7	0.21	1.5	2.0	C
56	1971	JAN	1	20	36	20.2	34-19.4	119-17.9	3.7	3.1	8	168	11.5	0.31	3.5	8.9	C
57			8	9	31	2.1	34- 1.1	119-41.9	20.0	1.9	7	104	6.6	0.13	1.4	1.3	B
58			8	10	15	41.0	34- 1.9	119-40.4	19.4	1.4	7	133	5.5	0.25	2.3	3.6	B
59		FEB	1	17	9	50.5	34-14.9	119- 8.0	5.6	2.5	6	119	16.6	0.08	0.5	0.9	B
60			5	1	36	46.8	34-28.1	119-26.9	5.0	2.1	5	138	24.6	0.21	4.4		D
61			11	4	7	15.5	34-14.7	118-31.0	1.1	3.3	9	111	33.6	0.20	2.4	15.3	C
62			13	6	44	54.7	34-19.3	118-32.0	0.7	3.2	10	97	33.3	0.23	1.1	8.7	C
63			15	23	33	11.0	34-17.5	118-33.6	0.8	2.9	6	133	34.9	0.22	2.2		C
64			16	4	37	3.9	34-14.9	118-32.2	5.4	3.6	6	144	35.4	0.16	1.8	2.1	C
65			20	23	15	57.0	34-15.3	118-34.1	4.8	3.9	6	143	38.2	0.23	2.6	3.6	C
66			21	2	42	11.6	34-17.1	118-33.1	8.0	3.8	6	134	35.9	0.12	1.2	1.5	C
67			22	10	35	54.8	34-17.1	118-30.9	0.7	3.1	7	133	35.1	0.19	1.1	8.5	C
68		MAR	5	14	29	59.4	33-46.8	120- 3.4	10.8	2.3	5	177	39.4	0.05	1.0	1.0	C
69			16	13	22	43.8	34-15.0	119-42.6	0.8	2.2	5	132	27.4	0.09	1.1		D
70			17	11	27	28.2	34-27.3	118-33.1	0.7	2.7	6	173	21.4	0.18	2.3		C
71			20	3	49	15.1	34-26.6	118-34.4	0.2	2.8	7	113	20.6	0.28	2.8		C
72			25	0	40	29.4	34-17.6	119-33.4	6.4	1.9	5	138	22.3	0.09	1.5	14.3	D
73		APR	1	21	55	47.3	34-13.8	118-32.7	0.6	2.9	8	150	35.6	0.16	0.8	9.5	C
74			2	5	40	24.1	34-14.4	118-32.9	3.4	3.8	9	113	36.2	0.21	1.6	1.9	C
75			6	9	46	31.0	34-23.9	118-45.9	7.1	2.7	5	160	61.3	0.04	1.1	1.3	C
76			6	10	26	31.0	34-27.0	118-42.0	2.9	2.9	6	145	59.0	0.13	2.4	2.8	C
77			6	10	27	53.8	34-26.2	118-40.6	9.1	3.4	5	150	56.5	0.02	0.6	0.7	C
78			6	10	28	16.7	34-33.0	118-38.5	8.0	3.6	4	133	62.2	0.20			C
79			15	11	14	31.9	34- 9.0	118-32.4	8.0	4.2	8	187	34.0	0.22	4.0	1.6	D
80			15	18	4	15.9	34- 9.0	118-31.1	9.1	3.2	13	166	32.0	0.27	2.6	1.2	C
81			18	22	27	38.1	34-26.6	118-42.4	8.0	3.8	12	103	14.2	0.09	0.5	0.5	B
82			19	13	49	11.8	34-27.0	118-43.2	5.1	2.5	10	103	13.2	0.17	0.9	1.4	C
83			21	3	12	10.1	34- 9.8	119-38.1	14.3	1.9	7	122	18.7	0.13	1.4	1.3	B
84			23	6	43	5.1	34-27.2	118-43.1	4.7	3.4	10	103	49.8	0.16	1.2	1.5	C
85			24	0	24	18.1	34-39.7	120-21.7	6.0	2.5	4	156	11.8	0.00			C
86		MAY	5	1	17	32.3	34-27.1	118-30.0	6.7	2.6	8	159	25.6	0.07	0.8	0.7	B
87			7	1	22	30.2	34-14.9	119-40.6	9.2	3.0	13	77	21.7	0.27	1.2	1.6	C
88			7	1	23	37.6	34-15.8	119-41.2	11.8	2.4	6	109	26.0	0.06	0.5	0.7	B
89			7	1	52	10.9	34-15.7	119-41.2	8.0	1.8	6	77	26.1	0.06	0.6	5.9	C
90			7	2	3	21.9	34-15.0	119-40.3	10.4	2.6	8	76	27.6	0.28	1.8	2.7	C
91			7	2	16	6.1	34-16.1	119-41.7	2.8	1.8	6	127	25.4	0.12	0.9		C
92			7	4	40	12.6	34-15.6	119-41.3	6.1	1.6	8	110	26.3	0.10	0.7	5.0	C
93			7	9	26	16.3	34-15.4	119-42.4	8.0	2.0	7	106	26.7	0.21	1.6	2.7	C
94			7	11	6	52.4	34-15.6	119-41.7	5.7	1.9	6	108	26.3	0.10	1.0	15.8	C
95			7	18	33	14.4	34-17.6	119-39.5	2.3	2.3	7	77	23.1	0.14	1.0	14.0	C
96			7	18	36	43.8	34-15.4	119-41.5	6.5	2.3	6	109	26.6	0.06	0.7	8.2	C
97			10	19	54	24.8	34-27.2	118-42.6	7.3	2.6	7	104	13.1	0.08	0.6	0.9	B
98			12	14	51	24.2	34-19.6	119-21.1	3.6	2.5	7	83	9.5	0.44	1.5	19.1	C
99			15	15	21	58.4	34-15.4	119-41.2	8.0	1.9	7	102	26.6	0.10	0.7	1.5	B
100			15	16	54	13.9	34-27.4	119-46.3	13.7	2.7	10	84	5.6	0.10	0.7	0.5	A

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
101	1971	JUN	2	11	52	0.3	34-17.1	118-30.1	0.3	3.6	11	103	33.9	0.16	1.4	7.7	C
102			4	2	34	45.9	34-18.8	118-30.7	5.8	2.1	5	140	35.2	0.07	1.1	1.6	C
103			10	12	38	25.7	34-14.1	119-41.3	10.5	2.3	8	79	27.2	0.21	1.3	2.2	C
104			18	15	30	30.7	33-53.8	119-39.9	12.6	1.7	6	115	11.2	0.05	0.6	0.5	B
105			22	14	9	51.4	34-24.7	118-32.8	0.2	2.3	7	159	24.9	0.23	2.3		C
106		JUL	4	2	40	49.8	33-51.7	118-42.2	5.2	2.6	9	157	33.1	0.11	1.0	1.8	B
107			10	10	36	16.4	34-15.7	119-41.9	8.0	2.1	9	76	26.0	0.29	1.7	3.0	C
108			10	14	52	36.7	34-15.9	119-42.3	8.5	1.8	7	130	25.6	0.05	0.5	0.5	B
109			13	13	10	26.9	33-50.1	120- 4.0	12.4	2.8	9	169	34.6	0.13	1.2	1.1	C
110			19	16	31	49.9	33-45.7	120- 7.2	6.8	1.9	8	190	37.3	0.29	2.2	2.3	C
111		AUG	7	7	34	36.4	34-16.6	118-31.7	5.8	3.1	9	166	35.9	0.14	1.6	1.1	C
112			12	11	38	24.4	34-15.2	119-38.2	10.9	2.2	6	112	27.9	0.14	1.5	1.6	C
113			27	12	45	15.4	34-38.7	119-55.9	8.0	1.9	4	163	25.9	0.03			C
114			30	17	58	36.8	34-30.9	118-55.0	8.0	2.7	6	137	17.3	0.07	0.8	0.9	B
115			31	7	54	23.4	34- 0.4	120-15.6	7.2	1.9	7	201	9.0	0.13	1.6	2.4	C
116		SEP	13	1	3	3.7	34-15.0	119-42.3	10.6	2.8	10	82	27.4	0.16	1.0	1.3	C
117			13	1	12	27.2	34-15.6	119-41.8	5.8	2.6	11	79	20.3	0.25	1.3	2.4	C
118			17	1	46	29.3	34-33.8	120-23.5	1.1	2.3	4	140	0.8	0.00			C
119			17	9	19	5.1	34-17.5	119-43.6	9.0	2.4	6	94	22.7	0.07	0.7	1.0	B
120			18	9	3	24.8	34-17.8	119-44.3	8.0	2.1	7	158	22.4	0.15	1.4	9.0	C
121			22	0	25	35.0	34-15.9	119-41.3	11.1	2.2	7	77	25.7	0.14	1.2	1.3	C
122			24	0	30	41.0	34-23.5	119-54.0	8.0	2.1	5	95	20.7	0.14	3.7		D
123			27	20	59	3.2	34-17.7	119-21.2	8.0	3.2	14	108	33.7	0.19	1.0	1.1	C
124		OCT	4	7	53	51.3	34-18.4	119-45.8	4.0	2.5	7	80	21.6	0.18	1.3		C
125			26	14	24	10.5	33-52.3	119-17.7	8.0	2.1	9	157	34.0	0.10	0.6	0.9	B
126			28	16	17	58.6	34-15.5	119-41.2	6.3	2.8	6	111	26.6	0.19	3.2		C
127			29	3	47	9.4	34-15.3	119-39.3	8.0	2.9	10	79	27.3	0.24	1.5	2.1	C
128		NOV	4	18	22	37.5	34-27.8	119-27.5	8.0	2.0	5	161	23.8	0.40	0.4	4.8	D
129			4	19	17	39.1	34-15.9	119- 3.9	11.1	2.5	6	180	17.3	0.14	2.1	2.1	C
130			16	0	37	8.9	34- 6.1	118-49.9	3.2	2.1	6	151	21.5	0.16	2.1	3.6	C
131			23	0	36	57.9	34- 3.8	118-49.6	0.5	2.1	6	133	22.6	0.18	2.5		C
132		DEC	14	21	21	11.9	34-22.9	119-18.5	5.5	2.0	9	139	3.6	0.10	0.6	0.8	B
133			15	18	47	44.4	34-22.6	119-18.5	6.6	1.4	7	138	3.4	0.07	0.5	0.9	B
134			18	0	35	36.2	34- 7.0	118-49.1	3.4	2.1	8	112	22.8	0.16	1.2	2.4	C
135			19	2	13	36.3	34-23.1	119-19.2	8.8	2.5	9	121	2.8	0.14	0.8	0.8	B
136			20	14	29	31.2	34-18.3	120-16.1	8.0	2.1	7	142	30.6	0.25	2.2	3.7	C
137			21	8	40	19.5	34-43.9	118-55.4	9.7	2.9	14	169	24.7	0.23	1.8	1.5	C
138			30	19	17	54.1	34- 6.1	120- 8.3	8.0	2.2	6	146	20.7	0.24	2.6	3.9	C
139			30	23	3	41.2	34-16.3	119-41.1	8.3	2.2	7	100	25.2	0.09	0.7	1.2	B
140	1972	JAN	13	22	51	55.7	34- 3.1	118-47.5	6.1	2.1	7	131	25.9	0.23	2.6	3.6	C
141			15	22	7	33.8	34- 6.8	118-49.9	0.5	2.1	7	109	21.5	0.19	1.8	19.2	C
142			16	17	46	57.7	34- 4.4	119-40.9	15.7	1.7	6	113	9.9	0.07	1.1	0.9	B
143			17	4	57	12.4	34-18.6	120-16.1	8.0	1.9	6	142	30.3	0.21	2.0	5.6	C
144			17	5	49	58.2	34-17.8	120-15.7	10.3	2.7	8	141	29.9	0.32	2.6	3.3	C
145			17	8	23	49.8	34-18.7	120-17.5	8.0	2.1	7	150	29.4	0.08	0.5	1.5	B
146			17	9	10	37.6	34-17.8	120-15.7	8.0	2.6	9	141	29.8	0.29	1.8	3.4	C
147			20	23	36	29.8	34- 6.1	118-50.2	1.8	2.2	8	147	21.0	0.18	1.5	1.3	C
148			25	17	16	47.1	34-23.1	118-30.1	5.5	2.1	5	161	30.0	0.05	0.7	15.0	D
149			31	6	40	26.4	34-14.1	119-34.0	14.2	2.3	7	79	25.3	0.08	0.7	0.8	B
150		FEB	10	3	48	51.8	34-26.0	118-36.6	7.9	1.3	7	143	17.2	0.05	0.4	0.7	B
151			13	8	57	45.7	34-18.7	120-17.2	2.2	1.7	6	148	29.5	0.06	0.5	0.5	B
152			19	0	26	49.4	34-25.7	119-26.5	6.0	2.7	10	126	11.2	0.37	2.2	3.2	C
153		MAR	2	5	2	0.9	34- 0.8	118-33.8	3.5	1.9	7	115	14.4	0.08	1.0		C
154			15	11	13	13.2	34- 0.7	119- 7.0	4.1	2.1	7	179	11.9	0.19	2.2	5.1	C
155			15	13	33	3.1	34-26.5	119- 9.1	14.3	2.3	7	153	19.5	0.17	1.5	1.5	C
156			18	6	52	43.0	34-17.2	119-10.7	6.7	2.6	9	104	17.8	0.18	1.2	1.5	C
157			19	5	6	21.7	34-15.7	119-42.6	0.6	2.2	5	131	26.1	0.01	0.1		D
158		APR	4	5	2	56.6	34-27.5	119-30.3	8.7	3.1	15	129	17.8	0.15	0.8	0.8	C
159			12	1	32	44.9	34-27.2	119-16.0	11.8	2.2	8	132	11.8	0.12	1.0	1.0	B
160			14	8	5	3.9	34-23.9	119-49.3	9.9	3.1	13	63	11.1	0.09	0.4	0.4	B

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
161	1972	APR	14	18	9	26.8	34-24.0	119-48.7	8.0	1.8	6	71	14.0	0.12	1.4	6.5	C
162			17	0	28	38.4	34-23.3	119-48.8	8.9	3.0	14	64	11.0	0.19	0.8	1.0	B
163			27	4	45	16.1	34- 4.2	118-58.9	12.8	3.1	11	125	8.8	0.27	1.9	1.4	B
164		JUN	6	12	2	22.3	34-11.8	119-47.4	8.0	1.7	6	104	26.7	0.23	2.3	4.6	C
165			11	11	5	4.5	33-52.4	118-43.3	10.9	2.8	8	115	35.7	0.29	2.5	2.6	C
166			15	16	42	9.6	34-25.5	119-52.7	13.4	2.2	6	87	17.1	0.07	0.7	0.7	B
167			18	18	4	13.0	34-34.4	120-29.6	7.8	2.6	7	192	8.6	0.09	1.1	0.6	C
168			19	3	21	36.9	34-11.9	119-44.6	10.4	1.8	6	97	24.7	0.16	1.6	3.1	C
169			20	5	8	8.3	33-54.8	119-34.8	11.9	1.5	8	215	10.3	0.11	1.1	0.9	C
170			24	1	36	49.5	34-39.0	118-42.8	2.3	2.4	7	185	9.4	0.36	4.6	4.3	D
171			26	21	22	39.3	34-20.3	119-23.1	2.1	2.2	5	108	5.1	0.21	2.7		D
172		JUL	14	23	1	15.7	34- 3.0	118-47.8	6.6	2.7	10	74	25.5	0.23	1.3	2.5	C
173			27	1	12	4.4	34-43.2	118-56.9	8.0	3.0	13	169	25.5	0.31	2.9	2.7	C
174			27	19	58	43.5	34-24.3	119-30.3	10.8	1.8	7	121	15.3	0.09	0.8	1.0	B
175		AUG	1	6	52	44.3	34-15.4	119-40.4	5.1	2.4	6	105	26.9	0.12	1.2		C
176			4	9	25	14.7	34- 5.5	119- 3.6	14.1	2.2	5	175	2.0	0.03	0.5	0.2	C
177			4	19	36	9.8	34- 3.5	119- 8.1	16.5	2.4	7	152	8.7	0.15	1.6	1.0	C
178			7	10	17	50.3	34-15.9	119-26.6	10.1	2.7	7	94	14.7	0.15	1.3	1.5	B
179			18	3	37	3.3	34-42.8	120-16.3	8.0	2.5	5	165	20.7	0.14	1.3	1.9	C
180			24	11	41	48.8	34- 5.1	119-14.1	8.6	2.8	6	175	16.0	0.03	0.3	0.4	B
181		SEP	16	14	26	34.2	34-35.5	118-46.4	1.1	2.7	7	118	4.0	0.10	1.1	0.8	B
182		NOV	1	15	56	18.9	34-26.9	119-15.4	6.5	2.2	7	131	11.9	0.11	1.1	1.5	B
183			5	11	34	10.7	34-16.3	119-41.6	8.6	2.8	5	126	31.3	0.08	1.2	1.9	C
184			9	22	48	5.1	34- 3.2	118-47.7	5.1	2.5	11	92	25.6	0.21	1.8	3.6	C
185			18	19	33	24.9	34-16.8	118-34.1	6.7	1.8	9	96	2.4	0.22	1.4	1.9	B
186			23	18	56	48.6	34-25.1	118-32.1	3.5	1.9	6	153	12.9	0.12	0.7	8.9	C
187		DEC	1	1	42	25.6	34-37.3	118-45.2	5.0	2.2	6	130	6.0	0.33	5.1	6.7	C
188			13	7	12	42.4	33-54.7	119-37.0	7.8	2.3	6	109	9.3	0.10	1.0	1.7	B
189			22	13	6	28.3	34- 0.2	118-32.9	8.0	2.6	8	128	14.3	0.15	1.4	2.1	B
190	1973	JAN	4	20	31	9.2	34-15.0	119-35.3	11.1	2.8	9	83	26.0	0.21	1.2	1.4	C
191			6	1	44	12.5	34-40.3	118-44.2	0.2	2.4	6	116	69.2	0.25	3.7		D
192			7	3	51	39.0	33-52.7	118-40.4	8.0	2.1	10	151	32.4	0.18	1.4	8.5	C
193		FEB	8	9	3	32.5	34-25.7	119-49.3	1.5	2.1	5	130	12.5	0.10	1.9	1.7	C
194			8	16	38	15.5	33-58.9	118-42.2	6.6	2.8	16	66	26.8	0.18	0.9	1.4	C
195			14	19	8	33.3	34- 5.4	119- 3.2	14.0	2.2	6	176	2.3	0.17	2.3	1.1	C
196			17	7	48	5.6	33-56.2	119-41.0	13.3	1.6	5	112	7.9	0.04	0.7	0.4	C
197			21	14	45	57.2	34- 4.7	119- 2.3	12.2	5.9	16	62	4.2	0.26	1.2	1.1	B
198			21	14	52	15.5	34- 1.1	118-57.7	8.0	2.9	10	159	13.9	0.19	1.5	1.6	C
199			21	14	55	7.9	34- 1.7	118-58.4	8.0	3.4	16	67	12.4	0.21	0.9	1.4	B
200			21	14	56	44.7	34- 1.9	118-58.9	8.0	3.3	12	91	11.6	0.16	0.9	1.6	B
201			21	15	7	8.0	34- 3.0	118-59.8	11.3	2.1	9	66	9.1	0.22	1.5	1.6	B
202			21	15	10	16.9	34- 2.4	118-59.7	11.5	2.0	8	66	10.0	0.19	1.6	2.0	B
203			21	15	18	6.5	34- 1.8	119- 0.6	10.9	2.9	11	86	47.2	0.14	0.9	1.2	B
204			21	15	32	14.9	34- 3.3	118-59.0	11.1	2.9	8	88	9.7	0.11	0.9	1.0	A
205			21	15	48	15.9	34- 5.4	118-59.7	13.0	2.1	7	144	6.8	0.22	2.3	1.8	C
206			21	15	48	29.7	34- 5.4	119- 0.2	11.5	2.6	9	83	6.0	0.12	0.9	0.8	A
207			21	15	59	26.9	34- 4.4	119- 2.7	11.0	3.4	11	64	4.5	0.15	0.9	1.1	B
208			21	16	12	24.6	34- 4.9	118-57.4	12.6	2.2	8	89	10.4	0.10	0.9	1.0	A
209			21	16	18	30.9	34- 3.1	118-57.2	12.6	2.9	10	91	12.1	0.08	0.6	0.5	B
210			21	17	1	4.6	34- 4.7	118-57.6	11.7	2.1	6	104	10.2	0.09	1.3	1.4	B
211			21	17	4	32.4	34- 2.6	118-58.2	12.2	2.5	7	97	11.4	0.20	2.1	2.2	B
212			21	18	37	13.6	34- 3.2	118-57.9	14.4	2.6	7	95	11.0	0.16	1.4	1.1	B
213			21	18	54	9.1	34- 2.8	118-58.3	12.4	2.6	10	89	10.9	0.10	0.7	0.7	A
214			21	19	23	22.6	34- 2.9	118-59.7	14.9	2.3	8	66	9.3	0.15	1.3	0.9	B
215			21	19	28	58.6	34- 5.9	119- 1.0	15.3	2.7	8	81	4.5	0.09	0.8	0.5	A
216			21	20	41	38.7	34- 4.4	118-59.2	12.1	2.4	8	91	8.2	0.08	0.7	0.7	B
217			21	23	55	2.6	34- 4.5	118-58.2	13.5	3.1	13	68	9.4	0.13	0.7	0.6	A
218			22	0	14	42.0	34- 4.6	118-58.5	12.1	3.2	14	68	8.6	0.16	0.8	0.7	B
219			22	0	50	2.7	34- 5.2	118-58.7	14.9	2.5	12	79	7.9	0.09	0.6	0.3	A
220			22	1	0	30.9	34- 4.4	118-59.4	11.9	2.4	12	64	8.0	0.15	0.9	0.8	B

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
221	1973	FEB	22	3	8	46.4	34- 2.0	119- 3.0	10.8	2.4	14	67	8.5	0.20	1.1	1.2	B
222			22	4	16	46.4	34- 2.7	118-59.0	11.4	2.8	14	73	10.1	0.17	0.9	0.8	B
223			22	4	20	43.2	34- 3.4	118-57.5	14.1	2.6	11	72	7.7	0.14	0.9	0.6	A
224			22	4	40	3.5	34- 3.2	119- 0.1	13.6	2.2	9	86	8.4	0.07	0.5	0.4	A
225			22	5	29	6.3	34- 2.1	118-59.2	11.6	2.5	13	77	10.8	0.20	1.2	1.1	B
226			22	6	29	24.1	34- 3.1	118-59.1	11.0	2.5	13	69	9.6	0.20	1.3	1.2	B
227			22	6	33	23.6	34- 1.4	119- 1.6	11.4	2.2	9	85	10.1	0.23	1.6	1.7	B
228			22	7	21	39.8	34- 3.5	118-59.4	12.9	2.4	13	65	8.9	0.20	1.2	1.0	B
229			22	9	30	15.8	34- 5.0	119- 1.9	14.4	3.7	20	69	0.5	0.08	0.4	0.2	A
230			22	9	47	31.1	34- 4.2	118-58.5	12.9	2.3	14	64	4.2	0.09	0.5	0.3	A
231			22	10	6	41.0	34- 3.5	118-58.2	13.8	2.3	11	65	3.5	0.13	0.8	0.5	A
232			22	11	22	52.8	34- 2.2	118-59.7	12.0	2.0	8	124	6.2	0.09	0.9	0.6	B
233			22	11	56	27.9	34- 1.8	119- 0.0	12.3	2.5	16	77	7.0	0.19	1.1	0.8	B
234			22	13	35	59.6	33-59.0	118-57.4	3.2	2.1	6	124	8.4	0.18	0.5	6.8	C
235			22	15	22	47.3	34- 4.2	119- 0.3	11.9	2.8	12	67	6.9	0.27	1.5	1.2	B
236			22	21	24	33.2	34- 3.3	118-58.4	15.0	1.6	7	177	3.7	0.12	1.9	1.3	C
237			22	21	35	31.5	34- 3.3	118-58.7	13.3	1.9	8	159	4.2	0.12	1.3	0.8	C
238			22	22	20	17.0	34- 2.9	118-58.8	13.3	2.0	10	98	4.4	0.08	0.6	0.4	B
239			23	2	44	24.4	34- 4.1	118-58.5	12.6	1.1	6	174	4.2	0.03	0.5	1.1	B
240			23	6	40	56.4	34- 5.3	118-58.8	13.8	1.6	8	71	2.4	0.05	0.6	1.4	A
241			23	8	17	18.8	34- 2.9	118-58.4	12.4	2.9	22	66	2.3	0.09	0.4	0.3	A
242			23	11	52	11.8	34- 4.9	119- 0.6	11.2	1.4	6	165	2.5	0.01	0.3	0.6	B
243			23	13	30	20.6	34- 4.1	118-58.1	12.5	1.1	6	172	3.6	0.05	0.9	1.7	B
244			23	21	17	26.1	34- 2.9	119- 0.1	13.4	1.6	11	159	2.4	0.15	1.3	1.0	C
245			23	23	15	55.0	34- 4.1	118-58.6	12.8	1.5	10	145	1.0	0.09	0.9	0.8	B
246			23	23	30	3.4	34- 5.1	119- 2.1	14.9	1.5	9	145	0.2	0.17	1.8	2.0	C
247			24	1	25	1.9	34- 3.8	119- 3.4	9.3	2.1	12	168	3.1	0.20	1.6	1.1	C
248			24	3	49	36.2	34- 4.3	118-58.1	10.8	1.6	15	137	1.8	0.06	0.3	0.3	B
249			24	5	37	57.4	34- 4.8	119- 0.3	12.6	1.7	13	150	2.2	0.08	0.5	0.8	B
250			24	7	52	19.1	34- 2.9	118-59.3	15.7	1.5	13	159	2.2	0.07	0.6	0.8	B
251			24	9	7	4.4	34- 4.1	118-58.5	15.6	2.1	22	64	1.1	0.12	0.6	0.3	A
252			24	10	55	4.9	34- 3.6	118-59.4	15.0	1.7	15	189	0.9	0.09	0.7	0.6	C
253			24	12	58	58.1	34- 3.4	119- 2.9	17.3	1.8	13	158	3.4	0.09	0.7	0.7	B
254			24	13	12	30.6	34- 4.3	118-57.1	13.6	1.9	17	64	2.5	0.05	0.3	0.2	A
255			24	13	26	31.3	34- 3.2	118-58.3	12.0	2.2	21	65	2.0	0.13	0.6	0.5	A
256			24	13	48	33.8	34- 4.9	118-57.3	11.8	1.7	10	96	3.3	0.05	0.4	0.4	B
257			24	18	39	18.0	34- 5.0	119- 0.6	17.7	1.5	8	146	2.5	0.02	0.3	0.5	B
258			24	20	24	48.1	34- 4.1	118-58.5	10.4	1.7	13	146	1.1	0.11	0.7	1.0	B
259			24	22	48	37.6	34- 3.8	118-58.4	10.8	1.6	13	193	3.9	0.09	0.5	0.6	C
260			25	6	44	37.3	34- 4.7	118-59.7	15.1	1.1	12	130	1.5	0.08	1.0	1.6	B
261			25	10	10	37.6	34- 4.1	118-58.7	9.6	1.2	14	149	0.8	0.16	1.4	1.9	C
262			26	6	50	39.6	34- 4.1	118-59.8	14.4	2.7	21	64	1.0	0.12	0.5	0.4	A
263			26	11	30	21.1	34- 3.0	118-58.9	14.1	1.7	19	66	2.0	0.17	0.8	0.6	B
264			26	15	57	57.3	34- 6.4	118-58.2	8.0	1.5	11	76	3.7	0.28	2.3	3.9	B
265			27	2	10	22.5	34- 2.2	118-59.7	15.7	2.3	22	67	3.4	0.17	0.7	0.5	B
266			27	4	19	4.8	34- 4.5	118-58.3	13.8	2.5	26	64	1.6	0.17	0.7	0.5	B
267			27	8	45	30.9	34- 3.3	118-58.4	13.7	1.9	17	99	1.8	0.15	0.8	0.7	B
268			27	11	49	16.2	34- 1.7	118-59.7	11.6	1.8	15	126	6.5	0.13	0.9	1.0	B
269			28	12	36	10.6	34- 2.1	118-59.7	15.5	2.7	27	67	3.7	0.18	0.7	0.4	B
270		MAR	1	18	41	41.5	34- 3.4	118-59.9	13.5	2.4	20	88	1.6	0.18	0.8	0.6	B
271			2	7	35	51.0	34- 4.1	119- 1.4	15.3	1.9	15	157	3.5	0.17	1.1	0.8	C
272			2	14	31	21.0	34- 4.4	118-58.4	14.1	1.3	12	125	1.4	0.12	1.2	1.8	B
273			3	4	44	10.4	33-46.8	119-59.7	12.5	1.8	5	168	41.1	0.07	1.2	1.3	C
274			5	12	55	59.7	34- 2.1	118-58.9	14.9	3.0	27	67	3.6	0.19	0.7	0.5	B
275			6	6	27	37.2	33-55.8	118-31.3	16.0	2.3	11	237	20.4	0.19	2.4	0.8	C
276			6	19	16	3.8	34-24.0	119-30.8	10.5	2.4	6	135	16.0	0.10	1.4	1.5	C
277			7	0	39	2.0	34- 2.6	118-59.7	15.6	2.5	23	66	5.9	0.21	0.9	0.5	B
278			7	12	56	22.5	34- 4.5	119- 1.8	13.2	1.9	18	158	4.9	0.16	1.0	0.7	C
279			7	23	49	51.9	33-49.2	118-41.0	8.0	2.5	12	162	23.3	0.16	1.1	8.3	C
280			10	1	40	52.1	34- 3.7	118-57.8	12.9	2.0	22	119	2.3	0.19	0.8	0.8	B

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
281	1973	MAR	10	21	52	37.8	34-15.2	119-43.4	12.2	2.3	5	168	26.9	0.03	0.7	0.8	C
282			11	19	19	38.0	34-26.4	118-36.9	1.3	2.2	10	100	18.1	0.17	0.9		C
283			16	22	38	20.5	34- 3.5	118-59.3	12.2	3.0	19	65	5.2	0.20	0.9	0.7	B
284			17	0	54	35.7	34- 3.8	118-58.7	12.6	3.3	22	65	1.0	0.13	0.5	0.3	A
285			21	9	27	19.7	34- 5.2	118-59.5	16.2	1.3	8	121	2.2	0.02	0.3	0.6	B
286			22	3	49	17.6	34- 4.4	119- 1.8	16.6	1.6	10	157	4.0	0.12	1.3	0.8	C
287			23	8	32	21.2	34- 4.5	118-58.9	12.6	1.9	9	95	0.9	0.03	0.4	0.4	B
288			26	1	27	44.9	33-53.7	118-41.2	8.0	2.5	21	72	16.4	0.17	0.7	1.1	C
289			26	9	30	37.3	34- 3.6	118-57.7	11.9	1.7	10	174	2.4	0.07	0.7	1.0	B
290			26	9	30	41.2	34- 4.1	118-57.7	11.3	2.1	15	149	2.3	0.10	0.5	0.5	B
291			26	15	13	25.5	34- 3.4	118-59.1	12.6	2.6	18	65	1.1	0.16	0.8	0.6	B
292			26	15	26	26.6	34- 4.1	118-59.3	11.6	1.7	13	67	0.2	0.17	1.1	1.0	B
293			27	0	39	19.0	34- 4.0	119- 1.1	11.3	2.0	10	112	3.0	0.26	2.1	1.9	B
294			28	0	20	11.3	34-10.6	118-59.5	1.4	1.4	6	200	3.2	0.01	0.2	0.0	C
295			28	6	29	39.8	34- 3.9	118-56.9	10.7	1.0	6	149	1.8	0.02	0.7	1.2	B
296			28	18	43	53.7	34- 4.7	118-58.4	10.0	1.6	8	99	1.8	0.03	0.4	0.6	B
297			29	17	54	16.9	34-26.6	119-47.0	14.2	3.3	17	80	6.5	0.17	0.9	0.6	B
298			29	21	35	33.9	33-58.8	118-32.8	2.4	2.6	23	85	15.2	0.18	0.8	8.7	C
299			31	5	33	49.8	34- 2.3	118-46.3	8.0	1.6	7	172	4.2	0.21	2.6	5.0	C
300			31	9	53	26.7	34- 3.7	118-57.6	11.4	1.5	14	171	2.5	0.14	1.0	0.7	B
301		APR	2	17	35	9.1	34- 4.6	118-58.7	10.5	1.3	7	98	1.4	0.04	0.5	0.8	B
302			4	23	25	4.4	34- 8.3	118-59.3	10.9	1.4	6	81	1.9	0.26	4.3	4.2	B
303			4	23	27	30.9	34-23.1	119-34.5	11.6	1.8	5	141	17.7	0.03	0.5	2.0	C
304			5	8	40	2.2	34- 2.4	118-59.6	12.0	2.0	13	120	2.2	0.08	0.6	0.5	B
305			5	11	4	28.7	34-30.4	119- 4.2	14.4	2.0	5	168	29.4	0.22	6.5	4.5	D
306			5	11	5	37.6	34-30.3	119- 4.4	15.1	1.9	5	168	29.1	0.10	2.8	2.1	D
307			5	14	35	45.8	34- 4.5	118-59.0	11.8	1.6	9	93	0.9	0.07	0.8	1.3	B
308			7	21	0	28.3	34- 5.4	118-58.1	11.9	1.7	12	70	3.2	0.04	0.2	0.2	A
309			8	1	36	30.0	33-57.3	119-14.3	4.8	1.7	9	161	19.5	0.15	1.1	12.9	C
310			8	2	26	30.5	34- 2.3	119- 4.0	10.6	1.8	15	263	7.9	0.11	0.7	1.0	C
311			11	6	0	19.6	34- 5.5	119- 0.9	14.3	1.2	8	156	3.8	0.03	0.6	1.2	B
312			12	19	52	1.4	34- 5.6	119- 1.1	12.0	1.6	7	156	4.1	0.05	0.8	0.9	B
313			17	10	15	14.2	33-55.9	119-13.0	4.9	2.0	6	164	22.3	0.14	1.3	16.6	C
314			17	12	27	4.5	34- 9.3	119-10.2	8.0	1.9	5	151	10.9	0.17	9.0		D
315			17	15	44	40.4	34-25.7	119-46.1	1.6	2.1	6	109	9.2	0.02	0.2	0.3	B
316			19	10	25	30.9	34-40.1	118-45.2	12.7	2.9	12	169	11.2	0.23	1.5	1.1	C
317			19	19	29	43.6	33-57.0	118-42.9	1.9	2.1	11	149	29.7	0.20	1.4		C
318			20	21	14	6.4	33-59.9	118-55.9	7.3	2.1	7	254	17.3	0.17	2.6	2.6	D
319			23	16	15	16.3	34-25.9	120- 3.3	14.7	2.4	7	82	12.6	0.10	0.8	0.7	A
320			27	17	57	42.0	34- 0.3	119- 6.7	3.5	2.2	9	240	12.4	0.19	1.6	18.9	D
321			30	17	18	57.7	34-22.6	119-35.1	1.0	1.8	6	134	17.8	0.12	1.1	1.9	C
322		MAY	8	14	0	53.6	34-26.0	118-54.9	2.2	2.4	6	132	21.9	0.21	2.1		C
323			8	17	18	12.1	34-25.4	118-54.8	8.0	1.9	7	128	22.6	0.43	3.8		C
324			11	2	35	36.3	33-58.4	118-33.0	3.7	2.5	17	130	15.6	0.16	0.7	1.8	C
325			11	16	30	38.4	34- 9.4	119-11.3	8.0	2.2	5	146	12.6	0.06	1.3	5.3	D
326			12	21	55	23.3	34- 0.8	119- 1.9	6.4	3.1	14	91	11.1	0.19	1.0	1.5	B
327			14	0	5	40.9	34- 1.9	119- 2.5	10.7	2.2	8	107	8.8	0.15	1.3	1.2	B
328			16	2	10	39.4	34-26.7	119-46.1	12.7	2.3	8	106	5.0	0.18	1.6	1.2	B
329			16	13	29	36.3	34-18.0	119-47.0	5.1	1.7	5	83	22.7	0.23	2.1		D
330			19	22	26	2.6	34-19.4	119-10.8	3.3	1.9	5	125	15.9	0.32	2.3		D
331			19	22	35	38.9	34-20.1	119-11.3	3.1	2.0	5	127	14.8	0.30	1.6		D
332			24	8	30	22.3	33-58.8	118-59.2	0.9	2.0	8	161	16.0	0.11	0.9		C
333			30	3	35	47.6	34-20.4	119-20.9	0.2	1.9	5	125	3.1	0.25	3.5	3.8	D
334		JUN	5	5	9	50.6	34-25.8	118-35.8	0.6	2.5	9	101	16.8	0.12	0.7		C
335			5	6	35	4.2	34-18.1	119-56.0	17.5	1.6	6	99	29.6	0.12	1.6	14.9	C
336			6	3	14	10.9	34-19.2	119-12.6	5.9	2.5	10	109	13.5	0.19	1.1	1.5	C
337			8	19	45	28.1	34-11.8	120- 0.8	4.2	1.7	6	118	35.8	0.24	2.0		C
338			15	5	27	13.6	33-59.8	119- 9.6	8.0	2.4	7	143	15.3	0.06	0.8	1.6	B
339			21	7	9	6.0	34- 3.2	118-50.1	3.6	1.4	6	137	6.0	0.11	0.6	6.1	C
340			22	21	47	14.9	34- 3.3	118-48.3	1.5	1.7	6	174	5.7	0.11	3.3	2.9	C

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
341	1973	JUN	22	22	59	52.6	33-45.3	120- 5.8	6.6	2.5	7	188	39.2	0.16	1.6	1.6	C
342			27	7	20	50.6	34- 3.0	118-59.5	2.0	1.9	9	131	2.7	0.10	0.8	0.5	B
343		JUL	5	21	53	44.0	34- 3.5	119- 1.1	13.3	2.1	9	121	2.4	0.11	1.0	0.6	B
344			8	5	18	38.0	34- 3.6	118-59.4	12.2	2.0	12	84	3.5	0.11	0.7	0.6	A
345			14	5	48	6.7	34- 0.7	118-49.2	13.5	2.0	13	91	1.5	0.14	1.0	0.8	B
346			14	8	6	57.6	34- 2.1	119- 2.0	13.1	2.0	13	166	1.5	0.15	1.0	1.0	C
347			15	12	19	24.3	34- 4.0	119- 3.8	17.6	1.6	10	133	4.8	0.08	0.7	0.7	B
348			15	19	54	1.3	34-22.1	118-31.3	14.8	1.8	14	86	11.5	0.13	0.7	0.7	A
349			16	15	43	56.2	34-17.8	119-51.9	16.3	1.6	6	91	26.2	0.08	1.2	1.5	B
350			18	6	9	30.9	34- 2.1	118-44.4	5.7	1.6	10	167	7.0	0.23	1.8	2.7	C
351			24	6	57	25.9	34- 2.3	119- 1.1	12.5	2.5	21	66	0.2	0.22	0.9	0.7	B
352			25	16	16	35.4	34-43.0	119- 3.5	3.3	1.9	12	232	33.4	0.27	2.4		D
353			26	22	17	48.5	33-59.7	118-43.9	2.4	1.6	8	289	7.0	0.15	5.8	3.5	D
354			29	7	57	12.7	34- 3.2	118-57.6	11.8	2.3	15	98	3.9	0.17	0.9	0.8	B
355		AUG	3	3	9	0.4	34-17.0	119-51.8	13.5	1.7	8	151	27.4	0.19	1.5	1.6	C
356			3	23	32	55.9	34- 3.7	119- 5.0	16.2	1.6	12	146	5.6	0.12	1.0	0.7	B
357			6	23	29	16.8	33-58.3	119-27.1	13.8	5.0	16	97	4.8	0.11	0.6	0.4	B
358			6	23	47	35.5	33-58.9	119-27.3	12.9	1.9	14	96	3.8	0.14	0.7	0.7	B
359			6	23	53	46.4	33-58.9	119-27.1	13.7	1.9	14	96	3.6	0.10	0.5	0.4	B
360			7	0	16	59.4	33-58.7	119-26.9	12.9	1.4	11	201	3.9	0.12	1.1	1.1	C
361			7	1	40	50.3	33-59.2	119-26.8	14.9	1.9	12	102	3.1	0.12	0.8	0.5	B
362			10	19	30	38.3	34-11.3	118-58.4	1.6	1.1	7	121	1.5	0.14	1.2	0.5	B
363			13	23	2	39.5	34- 2.8	118-58.8	15.8	1.9	14	145	3.6	0.19	1.3	0.6	C
364			15	0	38	9.3	34-27.0	119- 3.1	8.0	1.6	12	173	14.5	0.19	1.0	5.3	C
365			15	2	16	21.9	34-20.5	119-20.7	4.3	3.0	15	148	3.1	0.22	1.3	1.8	C
366			16	21	10	18.2	33-58.0	119-27.1	13.1	1.7	10	110	5.3	0.09	0.6	0.5	B
367			16	23	24	6.9	34- 3.7	118-48.8	2.6	1.4	9	163	6.4	0.16	1.1		C
368			17	15	46	56.3	34-26.8	119-13.0	12.1	1.6	9	156	4.3	0.10	0.7	1.1	B
369			19	9	22	50.5	34- 3.9	119- 2.3	7.5	1.8	11	159	3.7	0.11	0.9	1.2	B
370			20	13	32	57.8	33-57.2	119-10.2	9.9	1.8	11	143	17.0	0.11	1.0	2.0	C
371			20	14	1	49.3	33-57.4	119-10.6	8.0	2.5	21	73	17.1	0.12	0.5	0.7	B
372			21	5	29	23.4	34- 4.4	118-59.8	11.7	1.3	7	132	3.4	0.07	1.0	0.7	B
373			22	19	27	38.4	34-16.2	119-44.7	14.4	2.2	8	206	25.4	0.15	1.9	1.3	C
374			23	8	8	17.5	34- 4.5	119- 4.3	17.8	1.8	8	129	3.9	0.08	0.9	0.9	B
375			23	8	20	8.3	34- 3.1	118-57.9	12.5	1.8	8	140	4.0	0.11	1.1	1.1	C
376			24	9	4	55.4	34-25.9	119-13.0	13.4	2.4	17	152	2.8	0.20	1.1	0.9	C
377			25	5	27	10.6	34-17.0	119-39.0	10.9	2.4	9	150	24.3	0.11	0.9	1.1	B
378			27	19	56	19.9	34- 2.8	118-59.4	3.6	2.0	10	159	5.2	0.15	1.3	4.5	C
379			27	20	5	44.0	34- 2.5	118-59.2	2.6	1.9	9	213	5.7	0.20	1.9	1.7	C
380			28	21	57	30.2	34- 2.7	118-47.4	6.0	1.5	8	128	4.7	0.12	1.3	3.3	B
381			29	10	27	23.5	34- 3.1	118-59.9	2.4	1.8	9	119	2.4	0.07	0.7	0.4	B
382			30	14	3	22.3	34-11.2	119- 7.3	2.2	1.4	10	171	10.1	0.17	1.2	1.4	C
383			31	1	24	33.7	34-23.5	119-22.2	10.8	2.2	15	141	3.4	0.12	0.7	0.6	B
384			31	5	42	32.3	34-23.4	119-22.2	9.8	1.9	12	141	3.4	0.12	0.6	1.0	B
385		SEP	2	6	28	3.9	34- 1.1	118-44.9	13.9	2.3	17	100	5.6	0.16	0.9	0.6	B
386			2	8	35	15.9	34-26.2	119-45.6	11.0	2.0	11	162	8.0	0.13	1.2	0.9	C
387			3	12	21	51.4	34- 2.0	118-50.4	13.7	1.2	9	135	4.5	0.08	0.8	1.4	B
388			4	9	11	25.9	34-23.3	119-21.8	11.5	3.4	22	113	2.8	0.19	0.7	0.7	B
389			4	9	28	29.5	34-23.0	119-22.6	10.5	1.8	11	139	3.5	0.13	0.9	1.2	B
390			4	22	16	53.0	34- 2.2	118-48.1	6.1	1.7	7	119	3.7	0.10	1.4	3.0	B
391			7	15	18	10.8	34-22.8	119-22.1	9.9	2.6	13	120	2.6	0.18	1.0	1.1	B
392			7	15	18	58.4	34-22.5	119-21.6	0.5	2.0	8	219	1.6	0.15	1.5	0.5	C
393			7	15	19	56.8	34-23.5	119-21.9	10.6	1.9	11	141	3.3	0.14	0.8	1.3	B
394			8	4	13	53.9	34-26.3	119-13.6	15.6	1.8	12	154	13.2	0.14	1.2	0.8	C
395			13	12	51	41.3	34-27.7	119-12.8	12.0	1.5	12	160	15.8	0.20	1.2	3.9	C
396			13	13	7	45.4	34-26.3	119-13.0	12.1	2.1	14	154	14.0	0.18	1.1	1.7	C
397			13	13	8	37.9	34-26.7	119-14.3	16.0	2.2	16	156	12.9	0.13	0.9	0.6	B
398			15	23	4	50.4	34-19.6	118-34.6	9.3	1.8	13	113	5.6	0.12	0.7	1.2	B
399			20	11	31	20.7	34-27.7	118-34.3	11.6	1.4	12	215	17.7	0.26	3.0	3.4	D
400			20	22	7	44.9	34- 1.0	119- 0.7	11.1	2.0	19	68	2.2	0.12	0.5	0.6	A

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
401	1973	SEP	26	3	56	11.5	34-30.0	118-49.7	8.0	1.8	10	154	10.9	0.28	2.7	10.9	C
402		OCT	4	22	6	3.1	34-10.7	119- 7.8	12.8	1.4	10	95	9.8	0.12	0.9	1.1	B
403			6	16	4	47.9	34- 2.0	119- 0.6	8.0	1.8	17	185	0.7	0.14	0.7	0.9	C
404			9	1	11	46.6	34-28.0	119-29.2	8.0	1.7	14	162	17.0	0.17	0.9	1.5	C
405			10	22	3	13.8	34- 3.2	118-47.8	1.1	1.3	6	113	5.5	0.05	0.9	1.0	B
406			12	4	25	18.1	34- 3.2	118-53.9	10.7	2.2	17	113	5.7	0.14	0.7	0.7	B
407			15	8	11	52.1	34-22.9	119-44.0	10.1	2.1	16	68	6.8	0.13	0.7	0.6	A
408			15	21	57	6.3	34- 3.0	118-47.7	2.2	1.1	7	118	5.1	0.06	0.5		C
409			16	23	37	33.2	34-10.6	119- 0.4	1.2	1.3	7	129	1.9	0.06	0.5	0.3	B
410			21	3	45	43.4	34- 4.7	118-57.9	14.6	1.1	9	136	1.2	0.12	1.2	1.1	C
411			24	21	45	14.9	34- 2.6	118-47.9	6.0	1.1	6	119	4.3	0.07	1.2	3.2	B
412			25	19	24	43.3	34-10.6	119- 0.4	1.1	1.3	8	128	1.9	0.06	0.4	0.3	B
413			26	16	45	11.7	34- 1.9	118-53.9	4.5	1.9	8	163	7.9	0.03	0.3	1.4	B
414			30	14	51	5.1	34- 2.5	118-58.8	14.1	1.3	9	155	3.4	0.07	1.0	1.5	B
415		NOV	1	22	43	59.2	34-17.6	119-30.6	4.7	2.0	11	102	17.4	0.14	0.7	10.8	C
416			6	16	16	1.8	34- 2.4	119- 1.2	16.4	1.4	9	125	0.4	0.05	0.6	0.4	B
417			8	23	15	15.4	34- 2.9	118-47.9	4.9	1.0	7	114	5.0	0.05	0.7	2.4	B
418			14	17	15	31.4	34-17.0	118-32.9	13.1	2.2	18	148	4.3	0.19	1.0	0.9	C
419			15	1	4	28.5	34-10.6	119- 0.5	1.1	1.0	7	131	2.0	0.03	0.3	0.2	B
420			25	15	42	52.3	34-11.4	119- 6.5	18.5	1.6	11	92	9.8	0.10	0.8	1.0	B
421			27	7	9	31.0	33-59.0	119-14.2	2.7	1.7	12	123	18.8	0.13	0.8		C
422		DEC	5	19	29	53.2	34- 3.7	119- 2.5	7.9	1.4	12	120	3.6	0.11	0.7	0.8	B
423			7	12	0	15.2	33-48.5	120- 0.4	11.9	2.5	8	165	40.2	0.22	2.5	1.8	C
424			12	10	1	37.9	34- 4.1	118-58.8	12.3	1.8	11	136	2.6	0.15	1.2	0.7	C
425			14	19	21	37.0	34-24.8	118-34.7	8.0	1.7	9	124	15.0	0.15	1.0	4.6	B
426			20	14	23	21.4	34- 4.4	118-56.0	13.3	2.1	18	64	3.3	0.18	0.8	0.7	B
427			24	6	23	44.0	34-15.1	118-36.8	6.5	1.8	10	105	3.5	0.15	0.9	1.4	B
428			25	6	9	3.6	34-21.2	118-32.2	11.3	2.1	12	109	9.9	0.13	0.7	1.2	B
429			25	17	0	34.6	34-15.3	118-34.3	0.1	1.2	8	71	3.3	0.19	1.2	1.3	B
430			26	10	23	50.6	34-25.6	118-34.3	2.8	1.5	8	149	16.3	0.14	1.3		C
431			28	23	15	15.3	34- 3.2	118-47.8	2.4	1.3	7	114	5.5	0.08	0.7		C
432			30	19	34	20.6	33-58.3	118-46.3	16.3	1.7	9	249	15.7	0.10	1.5	1.7	C
433	1974	JAN	9	20	2	34.6	34-10.6	119- 0.1	1.4	1.5	6	123	1.5	0.03	0.4	0.2	B
434			10	18	41	59.8	34- 3.6	119- 3.3	13.7	2.1	12	117	4.4	0.20	1.6	1.0	B
435			10	22	26	17.8	34- 5.5	119- 0.8	11.3	1.5	8	109	4.5	0.06	0.6	0.9	B
436			12	2	24	9.6	34- 3.8	118-57.9	15.7	2.2	9	154	10.5	0.20	1.5	0.9	C
437			17	8	0	15.3	34- 5.7	119- 2.7	13.8	1.5	8	155	2.4	0.07	1.4	2.1	C
438			18	17	8	16.5	34- 5.1	118-51.8	17.2	1.5	8	100	2.4	0.05	0.6	1.1	B
439			21	18	35	55.7	34-30.7	118-42.2	15.7	1.8	14	145	7.1	0.12	0.8	0.5	B
440			23	1	43	35.4	34-15.7	119-45.6	9.7	2.2	9	104	31.8	0.12	0.9	0.9	B
441			25	5	2	25.3	34- 3.6	118-54.2	12.7	1.2	8	132	5.2	0.04	0.4	0.8	B
442			25	7	27	21.4	33-55.0	118-42.9	8.0	1.9	14	221	12.9	0.13	0.9	3.0	C
443		FEB	1	18	57	32.7	34- 3.7	119- 0.3	2.3	1.3	8	166	3.0	0.09	1.7	1.2	C
444			1	23	58	35.5	34- 2.3	119- 0.3	8.0	1.5	10	158	1.1	0.13	1.2	1.4	C
445			14	12	33	16.1	34-29.4	119- 4.9	12.4	1.8	13	148	27.5	0.17	0.9	1.1	C
446			20	5	18	14.9	33-57.3	119-26.7	11.3	2.1	13	113	6.6	0.17	1.0	0.8	B
447			22	12	49	48.4	34-16.4	119-31.0	12.2	1.8	6	125	19.1	0.04	0.4	0.7	B
448			23	8	34	36.2	34- 3.3	118-56.3	14.9	1.3	7	139	4.4	0.14	2.0	2.2	C
449			27	12	25	36.6	34-15.6	119-31.0	8.0	2.3	15	87	20.0	0.22	0.9	1.2	C
450		MAR	3	16	29	1.8	34-20.0	118-34.7	12.9	2.2	10	172	6.2	0.15	1.2	1.9	C
451			3	16	32	35.1	34- 2.0	118-59.6	9.2	2.3	14	129	2.1	0.17	1.0	0.8	B
452			3	16	59	23.4	34- 3.3	119- 0.3	8.9	2.3	14	93	2.3	0.25	1.5	1.1	B
453			4	0	34	12.7	34-20.9	118-31.2	10.4	1.6	9	191	10.5	0.05	0.5	0.7	C
454			4	0	41	8.7	34-21.1	118-31.2	10.3	1.3	8	109	10.6	0.06	0.5	1.1	B
455			7	6	29	8.3	33-55.5	118-42.6	8.0	1.9	11	154	12.4	0.20	1.2	2.4	C
456			10	12	34	30.1	33-51.7	120- 2.8	10.9	1.8	11	161	34.2	0.18	1.0	0.9	C
457			12	3	3	13.3	34-23.2	118-34.7	2.0	1.1	10	126	12.2	0.22	1.4		C
458			17	3	12	44.3	34- 3.5	118-59.8	1.9	1.5	8	110	3.1	0.06	0.4	0.2	B
459			18	2	37	25.8	34- 2.8	118-54.7	12.7	2.0	15	96	6.7	0.12	0.7	0.6	B
460			28	18	20	37.3	33-51.9	119-23.0	1.8	1.7	8	132	17.1	0.12	0.8		C

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
461	1974	MAR	30	1	12	36.2	34- 5.1	118-50.8	13.1	1.8	11	94	3.6	0.13	1.0	1.0	B
462			31	11	20	47.7	34- 1.2	118-44.9	5.9	2.6	16	80	5.6	0.09	0.4	0.6	A
463		APR	1	19	56	13.3	34- 4.1	118-59.5	14.5	2.2	17	64	3.5	0.14	0.7	0.4	A
464			2	9	46	30.2	34- 3.1	118-57.9	13.7	1.5	8	168	4.2	0.09	1.5	1.0	C
465			2	10	16	59.1	34-29.8	118-46.1	14.0	2.0	8	108	8.4	0.09	0.9	0.6	B
466			3	10	46	21.7	34- 3.3	118-53.8	11.3	2.5	14	88	5.4	0.13	0.7	0.7	A
467			5	1	39	37.8	34- 2.8	118-56.3	11.4	2.5	14	100	5.3	0.09	0.5	0.5	B
468			11	8	0	58.0	34- 4.2	119- 0.6	15.7	1.4	6	122	3.8	0.02	0.5	0.9	B
469			14	10	29	15.2	34- 5.7	119- 2.4	19.2	1.6	10	94	2.8	0.08	0.8	0.6	B
470			22	14	53	34.3	34-17.8	118-32.6	9.4	2.1	13	153	5.1	0.22	1.5	2.3	C
471			24	0	9	16.2	34- 5.7	118-51.7	1.7	1.2	8	92	1.8	0.11	0.6	0.3	B
472			25	8	23	53.5	34- 1.5	119- 5.8	8.9	2.8	14	159	7.6	0.11	0.7	0.8	B
473			25	8	28	42.3	34- 1.8	119- 5.0	9.9	1.9	16	190	6.2	0.15	0.9	0.7	C
474		MAY	1	6	2	30.6	34-23.7	119-46.8	9.6	2.1	11	96	12.9	0.26	1.7	1.9	B
475			10	22	21	29.5	34- 3.8	118-54.3	13.8	1.1	8	128	6.2	0.06	0.6	1.1	B
476			11	16	22	13.3	34-26.2	118-35.4	11.9	1.5	12	205	17.5	0.14	0.9	1.8	C
477			22	19	46	44.0	34- 3.1	118-58.6	14.1	1.5	11	137	4.1	0.15	1.0	1.5	C
478			22	23	39	48.4	34- 2.3	119- 0.0	9.0	1.4	8	161	1.5	0.10	1.0	1.5	B
479			28	9	55	0.5	34-24.5	119-56.6	20.8	2.0	7	118	54.0	0.20	2.2	3.0	C
480		JUN	21	2	5	18.1	34- 5.5	119- 1.1	15.8	2.3	17	89	4.7	0.11	0.7	0.3	A
481		JUL	6	21	36	59.1	34- 2.8	119- 1.8	16.4	1.8	12	129	1.6	0.08	0.6	0.4	B
482			9	0	58	49.3	34-14.2	119-40.6	10.9	2.0	14	79	22.9	0.26	1.1	1.7	C
483			12	6	27	44.2	34- 0.4	118-48.9	9.8	1.9	16	177	0.8	0.23	1.6	1.3	C
484			23	5	31	30.8	34- 3.8	118-58.8	14.2	1.5	9	117	3.2	0.07	0.9	1.5	B
485			25	16	13	41.8	33-56.2	118-51.7	7.2	2.3	12	226	9.2	0.13	1.5	1.7	C
486			26	23	27	51.7	34-10.4	119- 0.4	1.1	1.0	6	128	2.1	0.03	0.3	0.2	B
487		AUG	12	1	43	27.3	34-15.9	119-42.9	9.1	2.1	11	81	19.6	0.13	0.7	1.3	B
488			12	11	6	25.1	34-16.5	119-41.2	7.5	1.9	6	145	18.6	0.03	0.5	0.8	B
489			12	19	28	10.6	34-15.9	119-43.2	2.8	2.4	9	81	19.5	0.21	1.3		C
490			19	7	33	48.6	34-16.2	119-38.9	14.3	1.9	7	118	25.8	0.14	1.1	1.2	B
491			25	0	46	30.6	33-56.2	118-40.3	10.8	2.0	11	230	14.5	0.09	1.0	1.7	C
492			30	11	57	48.1	34-21.7	119-20.6	3.3	1.9	8	139	0.7	0.11	3.9	5.0	C
493		SEP	6	14	40	43.1	34-18.9	118-30.7	17.4	2.4	10	112	27.8	0.19	1.3	12.2	C
494			7	23	40	35.0	34-18.4	118-31.1	6.8	2.1	12	106	7.7	0.11	0.6	1.1	B
495			9	1	28	22.9	34-22.1	119-19.9	5.6	1.3	10	178	1.2	0.10	0.7	0.7	B
496			9	3	41	46.8	34-22.6	119-19.1	6.0	1.4	10	136	2.4	0.11	0.7	1.0	B
497			9	4	22	55.4	34-22.8	119-19.6	6.9	1.7	11	138	1.9	0.10	0.6	0.9	B
498			9	22	5	50.7	34-22.2	119-19.7	6.1	1.4	11	179	1.4	0.09	0.7	0.7	B
499			10	1	42	33.2	34-22.5	119-19.5	5.8	1.9	12	138	1.9	0.09	0.5	0.8	B
500			10	3	54	39.7	34-22.2	119-19.5	6.7	1.5	12	136	1.7	0.08	0.3	0.6	B
501			10	10	1	18.1	34-23.2	119-20.3	7.2	1.7	13	140	2.0	0.14	0.7	1.1	B
502			13	3	55	2.6	34-21.9	119-20.0	5.3	1.5	8	177	1.0	0.05	0.5	0.5	B
503			13	3	56	24.9	34-22.4	119-20.0	6.0	1.6	11	137	1.1	0.07	0.4	0.5	B
504			17	7	10	54.3	34-23.0	119-19.2	7.0	1.6	11	139	2.7	0.15	0.9	1.3	C
505			23	2	22	59.6	34-22.7	119-19.4	6.5	2.0	16	138	2.2	0.13	0.6	0.9	B
506			23	2	28	6.7	34-22.9	119-20.1	6.4	1.8	13	139	1.6	0.13	0.7	1.0	B
507			24	2	21	49.3	34-29.0	119- 3.8	17.2	2.3	18	158	3.7	0.19	1.0	1.4	C
508			26	19	58	33.2	34-22.8	119-19.3	2.7	1.4	9	138	2.4	0.12	1.0	10.5	C
509		OCT	8	0	56	4.4	34- 2.3	118-59.0	2.1	3.4	14	106	3.1	0.27	1.3	0.8	B
510			8	1	2	39.9	34- 3.4	119- 0.0	1.7	1.4	6	105	2.8	0.04	0.3	0.1	B
511			8	1	7	49.8	34- 3.4	118-59.8	1.9	1.4	7	111	2.9	0.04	0.3	0.1	B
512			8	1	8	53.4	34- 3.6	118-59.9	1.9	1.7	7	104	3.0	0.04	0.3	0.1	B
513			8	1	11	10.1	34- 3.7	119- 0.1	1.6	1.2	6	105	3.1	0.06	0.5	0.2	B
514			8	1	17	9.5	34- 3.4	118-59.8	2.1	1.7	7	113	2.9	0.04	0.6	0.4	B
515			8	1	34	54.9	34- 3.6	119- 0.0	1.9	1.6	7	103	2.9	0.05	0.3	0.1	B
516			8	1	50	7.4	34- 3.4	118-59.9	1.8	1.5	7	109	2.8	0.06	0.3	0.1	B
517			8	2	30	21.1	34- 3.4	118-59.5	2.0	1.7	7	118	3.2	0.03	0.2	0.1	B
518			8	3	0	16.9	34- 3.5	118-59.6	2.0	1.7	7	112	3.2	0.06	0.4	0.2	B
519			8	5	59	5.9	34- 3.5	118-59.4	2.0	1.5	5	116	3.4	0.01	0.0	0.0	C
520			8	11	35	58.1	34- 3.3	118-59.8	2.5	1.5	7	115	2.7	0.05	0.4		C

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
521	1974	OCT	9	9	25	57.4	34- 3.2	118-59.9	2.1	1.1	6	116	2.6	0.06	0.9	0.6	B
522			9	9	26	57.3	34- 3.5	118-59.9	1.7	1.1	7	106	2.9	0.03	0.2	0.1	B
523			9	9	28	9.5	34- 3.3	118-59.6	2.0	1.1	6	119	2.9	0.06	1.0	0.7	B
524			9	21	42	41.0	34- 3.5	118-59.8	2.2	1.7	8	109	3.0	0.06	0.6	0.5	B
525			10	18	9	50.7	34- 3.6	118-59.7	1.9	1.3	7	132	3.3	0.05	0.4	0.1	B
526			12	9	54	57.4	34- 3.3	118-59.3	3.3	2.9	17	68	3.4	0.14	0.6	1.7	A
527			12	10	9	39.9	34- 4.5	118-59.3	4.4	1.6	9	97	2.7	0.15	1.0	2.0	B
528			12	10	11	19.4	34- 3.5	118-59.8	1.9	1.8	8	109	3.1	0.05	0.3	0.1	B
529			12	10	25	8.1	34- 2.9	119- 0.3	1.2	1.0	7	113	1.6	0.08	0.5	0.2	B
530			15	22	40	30.1	34-10.2	118-59.9	1.1	1.6	9	149	1.7	0.04	0.5	0.3	B
531			18	23	25	24.6	34- 3.5	119- 0.2	1.7	1.2	7	107	2.7	0.04	0.3	0.1	B
532			22	0	6	24.1	34- 3.4	119- 0.4	2.3	1.1	7	118	2.4	0.05	0.8	0.5	B
533		NOV	6	0	31	2.2	34- 3.3	118-59.9	3.9	1.1	7	111	2.6	0.05	0.5	1.3	B
534			11	5	47	56.6	34- 3.9	118-59.6	14.9	1.6	10	104	3.7	0.06	0.6	0.5	B
535			14	9	41	1.4	34- 3.6	118-59.9	1.9	1.3	7	106	3.1	0.04	0.3	0.1	B
536			14	9	51	5.2	34- 3.5	118-59.9	1.9	1.0	7	106	2.9	0.06	0.4	0.2	B
537			14	11	4	48.3	34- 3.6	118-59.9	1.9	1.0	7	105	3.2	0.05	0.3	0.1	B
538			15	6	25	32.0	34- 3.3	119- 0.2	2.1	1.2	7	106	2.4	0.03	0.4	0.3	B
539			17	3	47	22.0	34-22.5	119-40.9	6.3	1.8	13	88	13.7	0.22	1.2	8.3	C
540			27	18	37	18.6	34- 5.3	118-57.9	16.8	1.4	8	98	0.1	0.03	0.4	0.6	B
541		DEC	1	11	28	37.2	34-25.6	118-34.2	0.5	2.1	8	112	16.2	0.15	1.0		C
542			4	20	12	23.0	34- 4.0	119- 0.1	14.7	1.2	6	134	3.6	0.04	0.9	1.5	B
543			7	7	12	7.7	34- 5.4	119- 0.4	8.0	1.0	6	104	4.0	0.34	4.4	9.9	C
544			9	22	29	25.3	34-10.4	119- 0.7	0.7	1.1	9	134	2.5	0.09	0.6	0.5	B
545			19	7	57	2.9	34- 3.8	118-44.5	4.0	1.3	8	148	7.3	0.17	1.1	10.1	C
546			20	10	22	31.0	34-23.6	119-41.5	13.3	1.8	9	113	11.6	0.12	1.0	0.9	B
547			20	14	23	19.0	34- 5.5	118-52.0	12.5	2.1	12	72	1.7	0.13	0.8	0.8	A
548			25	11	16	38.2	34- 2.3	119- 0.5	8.7	1.8	7	196	0.8	0.09	1.7	1.7	C
549			27	12	19	46.8	34-17.5	120- 3.2	11.8	2.5	12	127	27.0	0.20	1.2	1.1	C
550			29	22	10	4.1	34-15.1	119-36.5	8.0	2.1	7	87	27.6	0.18	1.4	4.6	C
551			29	22	37	0.9	34-15.6	119-35.8	15.3	1.9	8	87	26.2	0.10	0.8	0.8	B
552	1975	JAN	7	4	44	53.1	34- 6.8	119- 1.5	17.3	1.2	9	139	6.2	0.05	0.6	0.4	B
553			11	14	44	18.4	33-59.4	118-51.7	13.0	2.5	14	157	5.4	0.12	0.8	0.5	B
554			19	2	35	9.4	34-23.9	119-22.1	10.3	1.1	8	147	4.0	0.13	1.1	0.9	C
555			23	3	48	42.4	33-53.8	118-41.9	8.0	2.8	26	54	15.3	0.16	0.6	0.8	B
556			24	11	1	53.7	34- 1.4	119- 1.1	10.9	2.1	13	112	1.5	0.11	0.8	0.7	B
557			28	5	22	22.7	34-10.9	118-38.3	8.0	2.4	14	149	11.4	0.21	1.3	2.1	C
558			28	9	45	49.9	34-16.8	119-37.4	8.0	2.5	19	82	19.6	0.23	0.9	1.2	C
559			29	6	8	56.3	34-25.5	119-19.1	11.1	1.2	9	158	6.7	0.08	0.6	0.9	B
560			30	12	18	52.8	33-59.8	119-10.2	8.1	1.4	14	191	15.8	0.12	1.0	1.8	C
561			31	5	17	57.2	34-17.1	119-38.2	8.0	1.3	7	164	24.6	0.23	2.7		C
562		FEB	4	15	27	23.4	34- 3.9	118-47.6	8.3	1.4	9	108	6.8	0.13	1.1	2.7	B
563			8	17	36	34.5	34- 4.0	118-47.2	7.0	1.8	12	113	7.2	0.15	0.9	1.9	B
564			14	22	14	44.2	33-57.2	119-38.1	8.9	1.6	13	202	4.6	0.23	2.1	1.6	C
565			16	5	0	45.1	33-49.8	118-49.9	8.0	1.8	12	280	19.6	0.12	1.9	2.2	C
566			23	10	21	59.0	34- 3.8	118-59.1	13.3	2.7	21	54	3.4	0.20	0.8	0.6	B
567			26	6	20	5.7	34-25.1	119-56.8	10.9	1.7	12	82	12.4	0.24	1.3	1.7	B
568			26	6	53	18.7	34-25.0	119-56.1	11.1	1.9	7	84	12.8	0.06	0.6	0.8	B
569			27	7	31	50.4	34-25.6	119-57.3	2.5	1.4	7	140	23.5	0.14	1.3	1.6	C
570		MAR	1	5	45	4.2	34- 1.2	118-43.2	6.6	2.0	13	85	8.1	0.14	0.7	1.1	B
571			15	0	6	10.3	34-26.7	119-16.7	11.4	2.0	14	156	10.4	0.14	0.6	1.1	B
572			15	1	25	26.1	34-26.7	119-17.1	13.5	1.1	10	167	10.1	0.09	0.7	0.8	B
573			17	16	29	25.7	34-31.8	118-53.8	16.2	3.0	20	147	15.0	0.17	0.8	0.7	C
574			23	22	42	28.1	33-55.9	119-39.4	10.2	1.9	11	111	7.3	0.10	0.7	0.6	B
575			24	10	32	25.1	34-30.1	118-53.1	12.2	2.7	16	111	15.2	0.16	0.6	0.7	B
576		APR	10	21	19	26.6	34-29.2	118-50.4	6.7	2.1	12	133	12.8	0.20	1.1	2.5	B
577			11	3	31	40.7	34-27.1	119-19.3	11.8	1.6	13	159	9.5	0.16	1.0	1.2	C
578			11	21	6	5.5	34- 3.1	118-59.8	9.6	3.1	22	47	2.5	0.18	0.6	0.6	B
579			12	6	37	5.9	34- 3.2	118-59.5	11.9	2.1	13	100	3.0	0.17	1.0	1.0	B
580			14	4	55	8.2	34- 2.0	119- 1.5	16.6	1.7	12	166	0.9	0.21	1.5	0.8	C

Table 2.—*List of earthquakes in the western Transverse Ranges, 1970-75*—Continued

EVENT	YEAR	MON	DY	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
581	1975	APR	20	11	8	47.6	34-29.0	118-51.1	8.0	2.2	15	134	13.9	0.12	0.5	0.8	B
582			24	7	2	26.7	34- 2.9	118-59.5	1.9	2.0	8	133	2.7	0.11	1.2	0.9	B
583			25	0	1	25.8	34- 2.9	118-59.3	16.5	1.4	9	138	2.9	0.12	1.6	1.2	C
584			27	13	2	8.6	34- 5.4	119- 0.4	14.3	1.4	8	160	3.9	0.10	1.1	0.8	C
585			29	10	25	32.6	34-17.0	119-38.1	11.6	1.9	8	86	24.7	0.20	1.3	1.9	C
586		MAY	1	17	53	58.6	34-26.9	119-17.4	14.3	1.1	8	169	10.1	0.03	0.3	0.2	B
587			19	12	51	40.9	34-28.4	119- 3.8	12.0	1.6	9	158	3.1	0.10	0.9	1.2	B
588			26	3	12	16.7	34- 4.7	118-58.8	16.8	1.5	8	99	1.8	0.03	0.4	0.6	B
589			28	5	56	10.6	34-26.8	119-17.5	12.6	1.2	9	168	9.9	0.08	0.7	0.6	B
590			28	12	59	48.8	34- 2.1	118-59.6	12.5	2.1	14	107	2.1	0.14	0.9	0.7	B
591		JUN	5	1	27	45.6	34-24.2	119-16.4	2.5	1.7	12	145	7.5	0.22	1.1	0.8	C
592			5	15	28	29.6	34-25.7	119-52.9	12.3	1.8	8	89	17.2	0.06	0.4	0.6	B
593			6	13	7	12.4	34-12.1	119-25.4	0.6	1.5	9	113	19.9	0.12	0.8		C
594			9	16	5	13.8	34- 2.3	119- 1.9	13.3	1.5	10	165	1.3	0.17	1.6	1.8	C
595			10	11	43	14.6	34- 0.9	118-45.1	8.7	2.1	11	123	5.3	0.14	1.0	1.1	B
596			21	20	3	41.9	34- 1.6	119- 1.1	4.6	1.9	10	212	1.1	0.21	2.0	2.1	C
597			26	20	36	51.3	34-15.5	119-32.7	10.6	2.1	10	87	22.2	0.15	0.8	1.3	B
598			26	20	59	6.4	34-15.9	119-32.0	14.3	1.7	8	130	20.9	0.06	0.5	0.7	B
599		JUL	5	12	41	30.5	33-50.2	119-59.8	4.2	1.9	6	234	37.9	0.12	2.9		D
600			6	2	19	40.8	34- 3.7	118-53.1	9.9	2.3	8	162	17.3	0.16	1.9	1.8	C
601			10	14	7	16.1	34-15.2	119-36.8	8.0	2.3	13	81	22.8	0.24	1.1	2.4	C
602			12	22	16	22.5	34- 4.6	118-58.5	10.9	1.4	9	132	5.8	0.16	1.3	1.6	B
603			13	0	39	42.2	34- 4.4	118-58.1	11.3	1.6	10	111	6.0	0.18	1.4	2.5	B
604			14	22	15	54.5	34-26.4	118-32.9	0.1	2.3	14	74	14.6	0.20	0.8	11.0	C
605			15	7	15	36.3	33-54.5	120-13.6	2.2	2.0	7	241	18.3	0.17	3.7	3.2	D
606			16	21	36	30.0	33-52.3	120-14.3	3.0	2.3	5	255	21.1	0.15	5.2	3.4	D
607			18	0	41	43.6	34-23.2	119-33.1	8.0	1.7	7	130	19.1	0.18	1.3	7.1	C
608			24	7	2	10.7	33-52.9	118-43.1	5.1	1.9	16	143	15.8	0.21	1.7	3.5	C
609			24	7	8	24.0	33-51.9	118-42.6	0.3	1.8	21	133	17.7	0.23	0.9	11.2	C
610			30	19	46	38.1	34-21.6	119-42.8	9.9	2.2	21	92	15.2	0.18	0.8	0.7	B
611		SEP	2	7	8	38.0	34- 2.8	118-58.4	6.9	1.4	9	148	4.2	0.11	1.1	1.9	C
612			24	16	23	3.3	34-20.1	118-32.2	8.6	1.7	14	76	8.2	0.16	0.7	1.2	B
613			25	13	36	16.7	33-56.1	118-55.5	13.0	1.5	9	267	13.4	0.12	1.4	3.0	C
614			26	6	6	34.7	34- 2.8	119- 1.1	8.0	1.3	8	157	1.1	0.08	0.8	1.1	B
615		OCT	2	22	36	40.3	34-12.9	119- 6.0	8.2	1.3	10	135	7.6	0.14	1.0	2.0	B
616			3	8	59	17.1	34-11.7	119- 7.5	5.2	2.1	12	95	10.7	0.16	0.9	4.8	C
617			5	15	10	10.5	34- 2.5	118-57.1	13.4	2.0	13	158	5.4	0.16	1.3	1.0	C
618			9	6	16	56.2	34-23.3	119-41.1	11.8	2.6	17	89	6.5	0.17	0.8	0.7	B
619			9	22	39	21.3	34-15.4	119-45.2	2.2	1.8	7	87	26.8	0.14	1.0		C
620			9	23	42	21.1	34-14.9	119-44.2	14.3	1.9	10	86	27.6	0.31	1.9	1.8	C
621			9	23	48	17.6	34-15.4	119-45.3	2.1	1.8	6	87	26.8	0.13	1.2		C
622			10	7	59	52.8	34-14.5	119-32.1	12.2	1.8	11	145	22.6	0.17	1.7	1.7	C
623			24	14	20	40.9	33-48.3	118-50.8	8.0	1.8	10	196	22.3	0.16	2.1	2.4	C
624		NOV	2	2	27	43.9	34-22.9	119-18.7	5.6	1.4	9	138	3.3	0.13	0.9	1.4	B
625			3	3	42	17.4	33-51.8	118-35.3	16.6	1.8	12	141	23.9	0.19	1.4	1.0	C
626		DEC	25	14	35	19.3	33-59.5	119- 6.6	8.0	2.9	16	136	28.1	0.20	1.4	2.0	C
627			25	14	41	23.5	34- 1.1	119- 4.5	9.9	2.1	11	190	10.2	0.15	1.4	1.4	C
628			28	7	5	33.8	34-11.1	119-53.7	14.8	2.7	7	179	32.1	0.15	2.6	2.5	C
629			28	19	12	24.2	34-21.6	120-20.7	9.5	3.1	6	255	35.7	0.07	2.2	0.9	C
630			29	10	35	23.1	34- 1.9	119- 6.2	1.8	2.4	7	167	25.5	0.26	2.6		C
SB78	1978	AUG	13	22	54	52.4	34-22.1	119-42.9	12.5	4.9	16	68	4.0	0.05	0.2	0.4	A

Late Quaternary Deformation in the Western Transverse Ranges, California

By R. F. Yerkes and W. H. K. Lee

EARTHQUAKE ACTIVITY AND QUATERNARY DEFORMATION OF THE WESTERN TRANSVERSE RANGES, CALIFORNIA

GEOLOGICAL SURVEY CIRCULAR 799-B

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ILLUSTRATIONS

[Plates published separately as U.S. Geological Survey Miscellaneous Field Studies Map MF-1032]

TABLES

Late Quaternary Deformation in the Western Transverse Ranges, California

By R. F. Yerkes and W. H. K. Lee

INTRODUCTION

The Transverse Ranges are a dominant geomorphic-structural province of southern California. Relative to adjoining terrain, they are distinctive not only in their east-west trend, but in the type, age, and history of their exposed basement rocks; in the spectacular rates of deformation as indicated by the imposing fault-controlled mountain fronts and extremely deep basins filled with young, intensely deformed deposits; and, perhaps most of all, in their long resistance to successful palinspastic restoration in the tectonic history of southern California. A new and significant phase in interpreting southern California geology was introduced by analyses of the 1971 San Fernando earthquake (Wesson and others, 1971; Whitcomb, 1971; Whitcomb and others, 1973), which verified not only the structural dominance but also the activity of the several north-dipping reverse faults that characterize the Transverse Ranges west of the San Andreas fault and bound them on the south.

We report on the seismicity, focal mechanisms, and related aspects of geology as based on seismic data recorded during 1970-75 in a large part of the western Transverse Ranges. The area covered by the present study is shown in figure 1; it includes most of the Transverse Ranges west of the San Gabriel fault and spans the Santa Ynez and Anacapa-Santa Monica faults, which form the northern and southern boundaries of the province. Also shown in figure 1 are the epicenters of located historic earthquakes of magnitude 6 or greater, all of which were associated with recognized faults. Of these larger earthquakes, the five in the western Transverse Ranges, especially the 1971 San Fernando and 1973 Point Mugu, are associated with east-trending north-dipping reverse faults. Fault-plane solutions for the San Fernando and Point Mugu earthquakes verify these associations and indicate north- to northeast-trending subhorizontal P axes (Wesson and others, 1971; Whitcomb, 1971; Ellsworth and others, 1973).

SEISMICITY

MAP DISTRIBUTION

The epicenters of 630 earthquakes that took place in the six-year period 1970 through 1975 are plotted on plate 1[1], as are the surface traces of mapped faults. Location quality of epicenters, derivation of local magnitude, and associated data for the earthquakes are given in Chapter A of this report.

Ninety-seven percent of the epicenters are located south of the Santa Ynez fault; none are obviously associated with the fault. The few events north of the fault were not recorded well enough for fault-plane solutions, and none are obviously associated with mapped faults. The same is true for events northeast of the San Gabriel fault. No attempt was made to relocate earthquakes of the San Fernando sequence, as it was extensively studied by Whitcomb, Allen, Garmany, and Hileman (1973).

Many of the events south of the Santa Ynez fault can be associated geometrically with specific faults on the basis of focal mechanisms and hypocentral depths (table 1). The best associations are made for the Red Mountain, Pitas Point-Ventura, Mid-Channel, and Anacapa faults. Stratigraphic and geomorphic evidence indicates that all the faults listed have ruptured the ground surface during late Quaternary time (pl. 1, Ziony and others, 1974). The Red Mountain and Pitas Point-Ventura faults have probably ruptured in Holocene time.

The quality of the associations between earthquakes and specific faults is illustrated by two examples. A vertical section (figs. 4 and 5 of Chap. A) shows that projected hypocenters of the 1973 Point Mugu earthquake sequence and the projected trace of the Anacapa fault coincide. Also, the subsurface trace of the Red Mountain fault, located independently on the basis of well data (R.S. Yeats, written commun., 1978), matches the distribution of hypocenters. These and other examples support our procedure (table 1) of deriving fault dips on the basis of geometrical associations between surface traces, hypocentral depths, and focal mechanisms.

DEPTH

Within the western Transverse Ranges, the deepest hypocenters are 19 km for an event in the north-central part of Santa Barbara Channel and 17 km for an event in the Oxnard Plain; in

[1] Plates published separately as U.S. Geological Survey Miscellaneous Field Studies Map MF-1032.

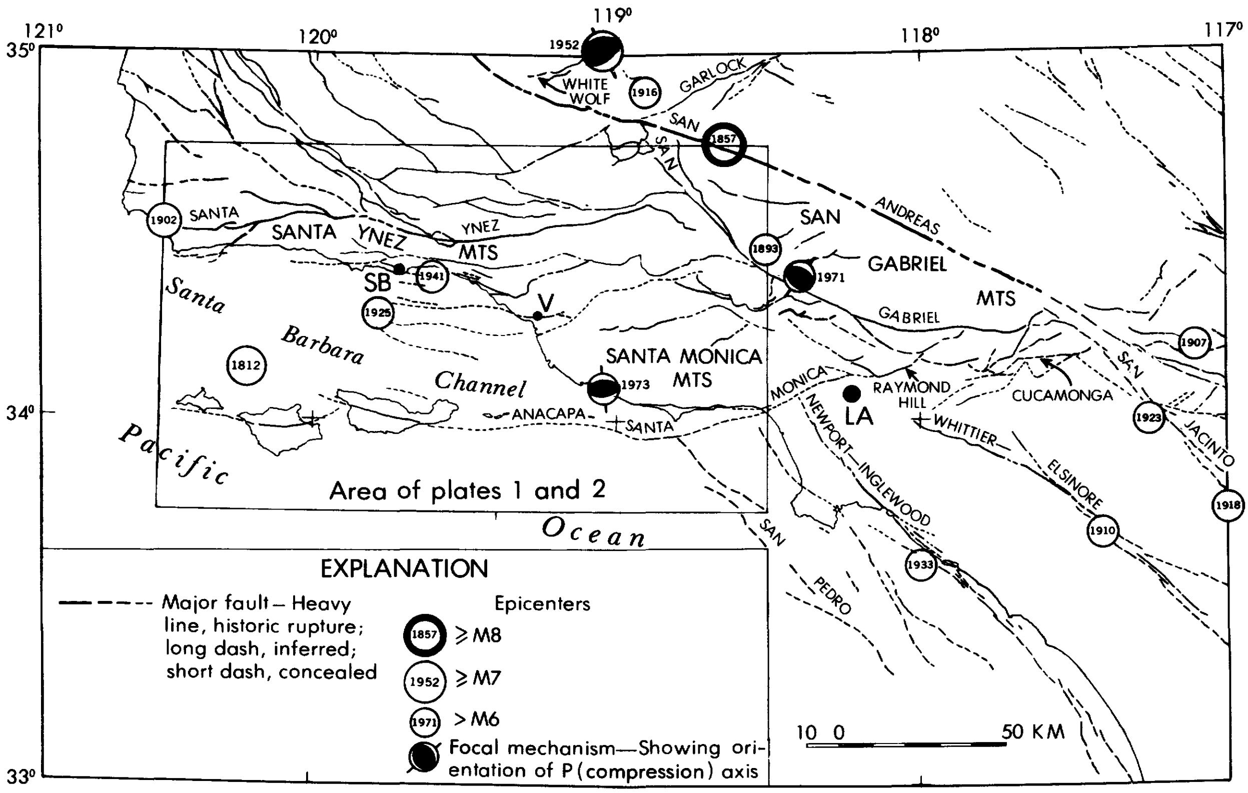


Figure 1.—Part of southern California showing area investigated, and relations of western Transverse Ranges (bounded by Santa Ynez, San Gabriel, and Anacapa-Santa Monica faults) to major faults and epicenters of large earthquakes. SB, Santa Barbara; V, Ventura; LA, Los Angeles. Modified from Jennings and others (1973).

addition, aftershocks of the 1973 Point Mugu sequence were as deep as 19 km. However, the depths of earthquakes in the band of seismicity that extends from the central and northern Santa Barbara Channel to the east center of the map area generally range from 13 to 16 km. The hypocenters do not delineate any east-west or north-south plunge.

The type and distribution of basement rocks that underlie the Upper Cretaceous and Cenozoic sedimentary rock sequence of the western Transverse Ranges between the Santa Monica and Santa Ynez Mountains are completely unknown. Regional-scale maps showing inferred structure contours on the "basement" rock surface for this area have been published (Curran and others, 1971, fig. 5; Nagle and Parker, 1971, fig. 13). Comparison of the contours shown on these maps with the focal depths of recorded earthquakes suggests that the seismicity is generated within the basement rock sequence or near its surface, but no strong correlations in trend or plunge are apparent.

FAULT-PLANE SOLUTIONS

Quality.—A set of 50 fault-plane solutions for earthquakes of local magnitude 2 or larger was selected from a total of about 200 on the basis of quality of location and solution. For most of the events tabulated, location and solution quality are "C" or better; the location is known to 5 km or less and the orientation of the nodal planes is known to ± 11° or less. First-motion data for events cited in table 1 are plotted in figure 7 and listed in table 4 of Chapter A of this report. Many of the events can be associated geometrically with mapped faults; the distribution of the fault-plane solutions relative to mapped faults is shown in plate 2. All of the solutions along and north of the Anacapa-Santa Monica fault indicate reverse displacement and can be associated geometrically with reverse faults that show geologic evidence of late Quaternary displacement at the ground surface, especially the Red Mountain fault, the Pitas Point-Ventura fault (which traverses the city of Ventura), the Mid-Channel fault zone, and the Anacapa fault.

Some northwest-trending faults south of the Anacapa-Santa Monica fault are associated with fault-plane solutions: two solutions along or near the San Pedro Escarpment indicate right-lateral movement, whereas the 1973 Anacapa earthquake near Anacapa Island (event 357, pl. 2) is best associated geometrically with northeast-dipping reverse movement, perhaps on one of the faults mapped along the southwest flank of Santa Cruz-Catalina Ridge.

P axes.— The orientations of P axes are inferred to be equivalent to the direction of

Table 1.—*Fault-plane solutions geometrically associated with specific faults*

Fault	Category[1]	Event number[2]	Depth (km)	Apparent dip
Red Mountain[3]	H	158, 396, 397, 505	5½-11	63° N.
Pitas Point	H, L	8?, 100, 162?, 365, 388, 391, 618, SB78?	12-14	60° N.
Ventura	H	40	4-8	60° N.
San Cayetano	Q, L	576?	8-16?	60-70° N.
Mid-Channel	Q	41, 51, 90, 449, 482, 558	8-14	65° N.
Oak Ridge	L	129	11	61° S.
Santa Susana	L	428	5?-11	65° N.
San Pedro	P	555, 625	5-11	~90°
Anacapa	P	197 + 30 aftershocks	8-16	44° N.
East Santa Cruz basin	Q, P	357?	13-15	38° N.

[1] Letter indicates geologic time span of latest known surface movement; H, Holocene; L, late Pleistocene; Q, early Pleistocene; P, late Pliocene.

[2] Events are listed in table 4 (chap. A) and plotted on plate 2. SB78 is the Santa Barbara earthquake of August 13, 1978.

[3] Subsurface location verified by well data.

maximum compressive stress for the analyzed events (fig. 2). Most (82 percent) are within 15° of horizontal and 60 percent are within 10°. The two maxima, at due north and N. 50° E., bracket the approximate normal to the San Andreas fault (at N. 24° E.) as well as the P axis for the 1971 San Fernando earthquake.

Slip vectors.—The distribution, orientation, and classification of slip vectors are plotted in figure 3. A dominant maximum shows a plunge of about 55° NE., indicating reverse-left-oblique displacement. Subsidiary maxima at 45° N. and 45° E. indicate north-over-south reverse displacement and left-lateral strike slip, respectively. The shaded field defined by these maxima contains 70 percent of the points. This field is dominated by reverse-left-oblique slip, which characterized the 1971 San Fernando earthquake, and north-over-south reverse slip, which characterized the 1973 Point Mugu earthquake. As indicated on figure 3 by slip vectors for the 1971 San Fernando (SF) and 1973 Point Mugu (PM) earthquakes, the displacements for the smaller earthquakes in the western Transverse Ranges are fully representative of the larger events with known displacements.

Summary.—Fault-plane solutions for events in the western Transverse Ranges can be associated with segments of several east-trending north-dipping reverse faults, especially the Red Mountain, Pitas Point-Ventura, Mid-Channel, and Anacapa faults. Geologic evidence indicates that these segments have ruptured the ground surface during late Quaternary time. The solu-

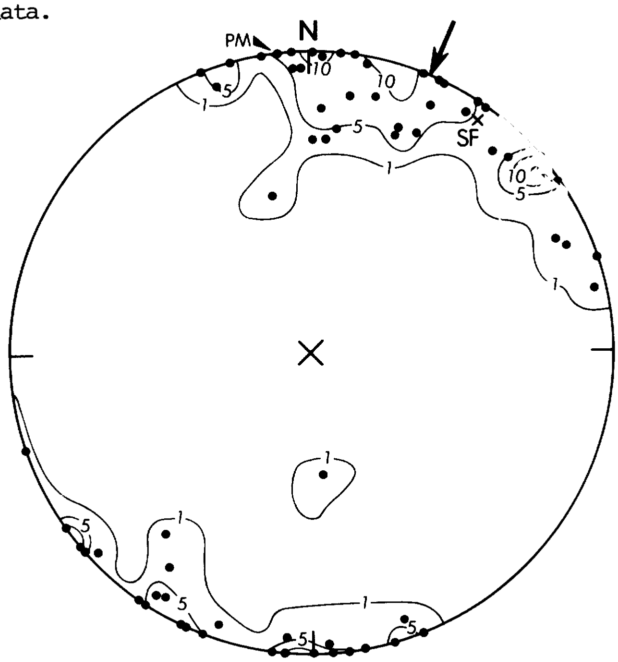
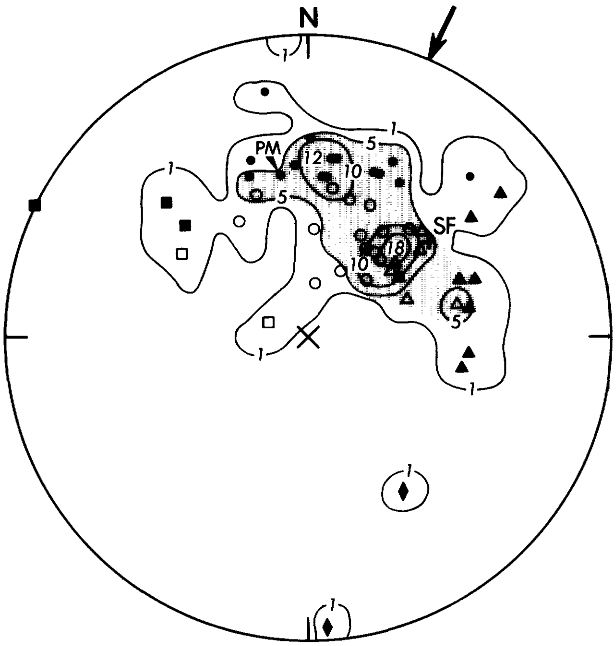


Figure 2.—Stereoplot showing distribution and orientation of P axes for 51 events, 1970-75, excluding aftershocks of 1973 Point Mugu sequence. PM, Point Mugu main shock; SF, 1971 San Fernando main shock (not contoured). Contours, 1 percent, 5 percent, and 10 percent per 1 percent area; lower hemisphere projection. Arrow at N. 24° E. normal to San Andreas fault. See table 4, chapter A for data.



EXPLANATION

- ● North-dipping thrust
- ○ North-dipping reverse, dip 45°
- ▲ Left-reverse oblique, dip 45°
- △ Reverse-left oblique
- ■ Right-reverse oblique
- □ Reverse-right oblique
- ♦ South-dipping reverse

Figure 3.—Stereoplot showing distribution, orientation, and classification of slip vectors for 51 events, 1970 through 1975, excluding aftershocks of 1973 Point Mugu sequence. PM, Point Mugu main shock; SF, 1971 San Fernando main shock (not contoured). Contours 1 percent, 5 percent, 10 percent, and 15 percent per 1 percent area; lower hemisphere projection. Shaded area contains 70 percent of the points. Arrow at N. 24° E. marks approximate normal to San Andreas fault.

tions indicate near-horizontal P axes oriented generally within 30° of normal to the great bend of the San Andreas fault. The dominant type of displacement indicated by slip vectors varies between north-over-south reverse and reverse-left-oblique. These characteristics pertain to the entire range of magnitudes recorded within the network area, as well as to larger earthquakes such as the 1971 San Fernando and 1973 Point Mugu events.

EFFECTS OF DEFORMATION

In addition to the prominent topographic and geologic effects of the numerous east-trending folds and faults, well illustrated on the geologic map of southern Ventura County (Weber and others, 1974), unusually high rates of deformation across east-trending reverse faults of the western Transverse Ranges are evidenced by geodetic leveling, uplift of dated marine terrace deposits, and stratigraphic separation of dated strata.

GEODETIC EVIDENCE

Comparison of repeated level lines along the coast from the Ventura River to the Santa Barbara-Ventura County line and northward along the river has confirmed a minimum average tilt up to the north of nearly 13 microradians over the period 1920-68 across the Red Mountain-Pitas Point-Ventura set of faults (Buchanan-Banks and others, 1975); the relative uplift rate is about 5 m per thousand years.

Similarly, comparison of 1960 and 1968 level surveys shows that the upper (northern) plate of the west-trending Anacapa ("Santa Monica") reverse fault rose by 30-40 mm at least as far west as Point Mugu, consistent with continued thrusting along this frontal system of the Transverse Ranges (Castle and others, 1978). Additional warping between 1968 and 1971 perhaps indicates left-lateral reverse creep at depth, and 1971-73 (post-1973 earthquake) data indicate additional upper-plate uplift of more than 30 mm.

Regional maps of elevation changes in the western Transverse Ranges east of long 119°15' (Ventura) based on comparisons of 1960/61-1968/69 and 1968/69-1971 (post San Fernando earthquake) levelings show strong gradient changes associated with the Oak Ridge, Santa Rosa, Santa Susana-San Fernando-Sierra Madre, and Malibu Coast (Anacapa?) faults (Castle and others, 1975, figs. 2 and 5). Of these, only the Santa Rosa fault was not associated with recorded seismicity during the 1970-75 interval. The data coverage does not include the San Cayetano fault, but it does show that no prominent gradient changes were associated with the Santa Monica and Raymond Hill faults east of the shoreline.

DEFORMED MARINE TERRACES

At least three deformed marine terraces are exposed along the Santa Barbara-Ventura coast at elevations ranging from 2 to at least 226 m (table 2). The ages of mollusks from deposits on the terraces have been estimated by amino-acid stereochemistry at 2,500, 45,000, and 80,000 years (J. F. Wehmiller, written commun., 1978). The 45,000-yr terrace is exposed at elevations of 26 m or less along the seacliff for about 70 km west of long 119° near Carpinteria, where the Red Mountain and associated faults intersect the shoreline (pl. 1). East of that point all the terraces, including the 2,500-yr terrace, are tilted up to the north and east (fig. 4). Apparent average rates of uplift in this area for the last 45,000 years exceed 3 m per thousand years as referred to present sea level, including the rate for the 2,500-yr terrace. Rates of 5 to 6 m per thousand years are indicated, again for the youngest terrace, if present-day elevations are referred to pre-existing sea levels. Even greater rates, up to 9 m per thousand years,

Table 2.—*Elevations and estimated ages of collections from uplifted marine terraces*

Number in fig. 4	Collection number[1]	Name	Elevation (m) Locality	Shoreline angle[2]	At T_o[3]	Estimated age[4] (10^3 yrs)	Uplift rate (m/10^3 yr) Max.	Min.
1	M5790	Goleta	5	~15	-55	45	1.6	0.3
2	Y440B	Carpinteria	26	~40	-55	(45)	2.1	.9
3	Y440A	Rincon Point	50	N.a.	-55	(45)	2.3	1.1
4	M7245	Punta	146	N.a.	-55	45	4.5	3.2
5	M7229	Punta Gorda	125	N.a.	-55	45	4.0	2.8
6	M7230	Rincon oil field	215	N.a.	-55	45	6.0	4.8
7	M7249	Rincon oil field	216	N.a.	-55	(45)	6.0	5.0
7a	M7283	Rincon oil field	262	N.a.	-55	45	7.0	5.8
8	M7273[5]	Rincon oil field	354	N.a.	-55	(45)	9.1	7.8
9	Y438B	Punta Gorda	2	11	0	(2.5)	5.2	5.2
10	M7228	Culvert 390.06	6	15	0	2.5[6]	6.0	6.0
11	M7242	Ventura	117	120	-13	80±10	1.7	1.5
12	Y413B	Ventura	15	N.a.	-13	80±10	.4	.2

[1] Localities shown on plate 1.

[2] N.a., not available.

[3] T_o, time of formation; from Bloom and others (1974).

[4] Age estimates by sterochemical analysis of mollusks by J. F. Wehmiller, University of Delaware, Newark, Delaware; estimates in parentheses based on map continuity with dated sample.

[5] Float of shells and rounded pebbles.

[6] Radiocarbon analysis.

are suggested by the presence of scattered shells and rounded pebbles at ridge tops up to 354 m high.

DISTRIBUTION OF DEFORMATION

The north-dipping, east-trending Red Mountain fault and associated San Cayetano, Santa Susana, Pitas Point-Ventura, and Mid-Channel faults coincide in general with an east-trending band of seismicity that extends across the north half of the area of plate 1. Detailed surface and subsurface investigations show that very large separations and late Quaternary movements have occurred on the Red Mountain fault, the Pitas Point-Ventura fault, and segments of the San Cayetano and Santa Susana faults.

Red Mountain fault.—Well data from the San Miguelito oilfield area west of the Ventura River show that upper Eocene and lower Miocene strata are thrust over Pliocene and Pleistocene strata by the Red Mountain fault (R. S. Yeats, written commun.). The age of the youngest strata involved in the faulting is not well determined on the basis of the well data. However, the fault truncates a syncline that, east of the Ventura River, involves the San Pedro Formation as used by Weber and others (1973), which has been dated at 0.4 to <0.2 million years B.P. on the basis of radiometric and stereochemical age estimates (fig. 5). On the assumption that the thrust faulting followed the folding, much or all of the 7,500 m of separation on the Red Mountain fault could have occurred during about the last one-half to one million years.

Pitas Point-Ventura fault.—Where crossed by a seismic profile about 2 km offshore in the northeastern part of the Santa Barbara Channel,

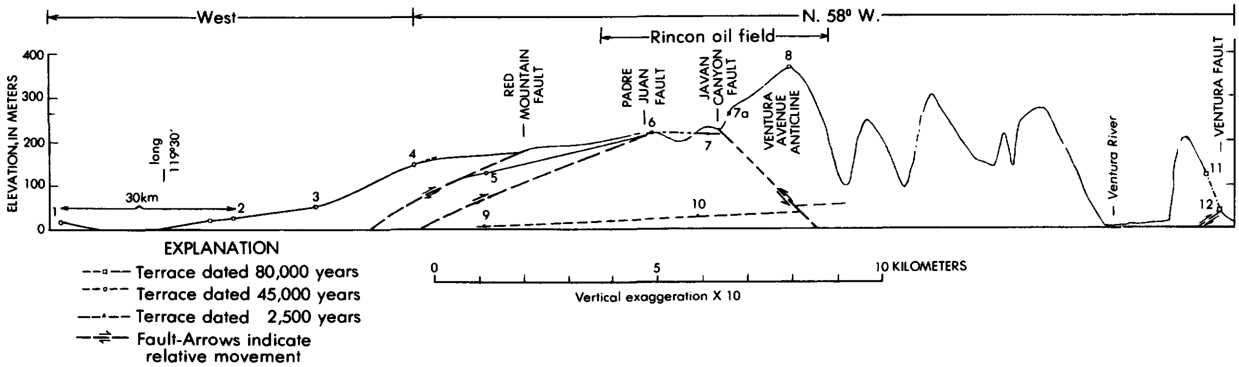


Figure 4.—Section along Santa Barbara-Ventura coast showing deformation of dated marine terraces. Numbered localities keyed to table 2.

the Pitas Point fault appears as a north-dipping reverse fault that displaces a late Pleistocene erosion surface about 25 m up on the north; it appears to cut Holocene strata but not the seafloor (Greene, 1976, p. 508-509; figs. 4, 6).

Extensive data are available for the Ventura fault (Sarna-Wojcicki and others, 1976). The surface trace is marked by a prominent, linear, south-facing scarp as much as 12 m high and about 10 km long; it is bounded on the north by an uplifted bench. Except where locally buried by young surficial deposits, the escarpment forms the boundary between old alluvial fan deposits, deformed marine terrace deposits, or deformed bedrock, all overlain by old soils on the north and young, undeformed surficial deposits overlain by young soils on the south. The gradients of all but the largest streams that cross the escarpment are deflected upward on the north by about 25 m. Test trenches cut in surficial deposits across the escarpment show numerous small soil-filled cracks that commonly are traceable downward into east-trending high-angle faults with separations as large as 40 cm. The southerly dips of strata in the trenches and adjacent boreholes increase downward south of the escarpment. The youngest strata cut by the fault are apparently Holocene.

No direct evidence is available as to the amount of displacement across the Ventura fault. A north-south structure section about 4 km east of the Ventura River shows apparent vertical separation of about 245 m, up on the north, at the base of lower Pleistocene strata (Ogle and Hacker, 1969), although that interpretation is based on permissive evidence. A similar structure section another 5 km to the east, based on more closely spaced and abundant data, shows an apparent vertical separation of as much as 275 m at the base of upper Pleistocene strata. An unknown component of left-lateral slip is indicated locally by small folds having near-vertical axes in bedrock just north of the fault, and by the fault-plane solution of an associated earthquake (no. 40, table 4 of Chap. A).

San Cayetano fault.—Apparent stratigraphic separation across segments of the San Cayetano fault diminishes eastward from a maximum of 7,300-9,000 m (vertical, up on the north) at Sespe Creek (6 km east of long 119°) (Fine, 1954; Cemen, 1977), where low scarps in late Quaternary stream terrace deposits coincide with the fault trace. Ten kilometers east of Fillmore, late Quaternary alluvium north of the Santa Clara River is warped along the buried inferred trace of the fault (Cemen, 1977). Youthful geomorphic features and upthrust Quaternary gravel beds at several localities along its trace suggest at least late Quaternary activity at the surface.

Santa Susana fault.—The apparent stratigraphic separation across faults of the Santa Susana set is at least 4,000 m, which includes about 2,000 m vertical offset (up on the north) and 3,200 m left-lateral strike slip (Yeats and others, 1977). The hanging wall locally is expressed topographically; the fault locally cuts late Pleistocene fan deposits, and northeast-trending elements along the west margin of San Fernando Valley ruptured during the 1971 San Fernando earthquake.

Mid-Channel fault zone.—Published data on faults of the Mid-Channel zone are sparse. A report by Campbell and others (1975) includes an interpretive section (B-B') through the area of most intense seismic activity near long 119°45' W., lat 34°15' N. The section shows a fault-bounded gentle anticline ("12-mile reef") that coincides with the Mid-Channel zone. A medial fault cuts upward to the seafloor, but the south-bounding fault is truncated by the Holocene part of the undivided Quaternary deposits (unit Q) and the north-bounding fault cuts upward about halfway through the lower Pleistocene part of the lower Pleistocene and upper Pliocene strata (unit Qpl). A vertical separation of about 50 m, up on the north, at the base of the upper Pliocene marine strata (unit Tpu) is shown for the north-bounding fault; a separation of similar amount, down on the north, is shown for the south-bounding fault. No vertical separation is shown on the medial fault.

A possible correlative of the north boundary fault of the zone (the isolated segment at long 119°30' W., lat 34°11' N.) is illustrated in a seismic profile and interpretive section by

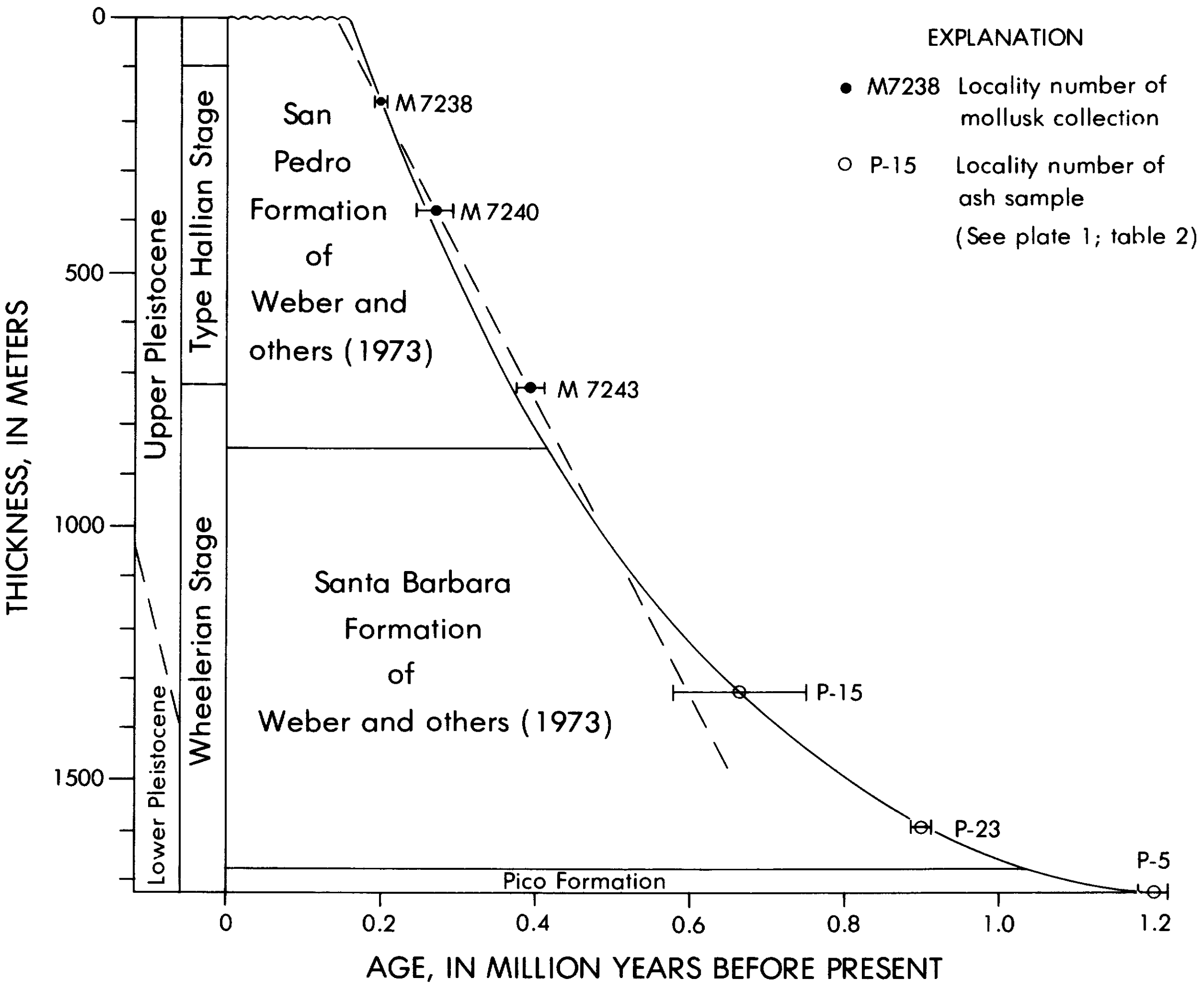


Figure 5.—Age estimates of mollusk collections and ash samples from Pleistocene strata in Hall Canyon area, near Ventura, and their stratigraphic and microfaunal stage correlations. Stratigraphic boundaries of Hallian Stage from Natland (1952, pl. 7). Age estimates on mollusks by J. F. Wehmiller; age estimates on ashes based on analyses and correlations by A. M. Sarna-Wojcicki.

Greene (1976), fig. 8, "Santa Barbara slope" fault). The section indicates about 120 m of vertical separation, up on the north, and the profile suggests that the fault cuts through lower Pleistocene deposits (unit Qs) to the seafloor. These interpretations, coupled with the geometric associations of the focal mechanisms, indicate that the Mid-Channel zone is seismically active, but whether one fault or more is active cannot be determined. The fault-plane solutions associated with the Mid-Channel zone occur in the general area where the Oak Ridge fault, which onshore is known to dip south and to parallel the south flank of the Ventura basin syncline, intersects the Mid-Channel zone. The dip of the mid-channel faults is thus not easily evaluated, and their association with the fault-plane solutions is weak.

Oak Ridge fault.—The Oak Ridge is a gently to steeply south-dipping reverse fault, the surface trace of which generally follows the south bank of the Santa Clara River. At South Mountain, just west of long 119°, the fault thrusts lower Miocene and upper Eocene strata over late Pleistocene strata, for an apparent stratigraphic separation of at least 2,000 m (Baddley, 1954). Near Saticoy, displacement in late Quaternary sediments has caused a ground-water barrier. Offshore data from seismic profiles between long 119°15' and 119°30' indicate that Pleistocene strata are upthrown on the south more than 135 m; no surface displacement at the seafloor is known (Greene, 1976). Available data indicate that displacement is dominantly reverse (see fig. 7, Chap. A, and pl. 2, event 129).

Anacapa-Santa Monica fault.—The Anacapa and Santa Monica faults are major elements of an east-trending zone of deformation that marks the southern front of the Transverse Ranges along the south flank of the Santa Monica and San Gabriel

Mountains. Other elements of the zone include the Raymond Hill and Cucamonga faults; the zone extends east onshore for about 100 km, and all faults are north-dipping reverse faults. East of its intersection with the shoreline at Santa Monica, two or more subparallel elements of the zone are recognized. One, generally called Santa Monica, is alined with a north-dipping reverse fault at the mouth of Potrero Canyon that cuts upper Pleistocene terrace deposits; to the east it is associated with topographic scarps in upper Pleistocene terrace deposits. Other elements locally are associated with a ground-water barrier in Pleistocene deposits; in the Santa Monica area, a topographic scarp in upper Pleistocene deposits is alined with the barrier (Hill and others, 1977).

The apparent stratigraphic separation across these faults is variable from west to east, according to well data. Northward dips of 40° to 70° and apparent reverse separations of 1,770 to 2,133 m at the top of middle Miocene strata are reported for the Sawtelle oil field-Beverly Hills oil field area (Knapp and others, 1962; Eschner and Scribner, 1972; Lang and Dressen, 1975) 8-15 km east of the shoreline at Santa Monica. Separations at the surface of the buried basement complex are poorly known, but a published structural contour map based on a density-residual gravity model shows vertical separations in the range of 2,400-3,660 m (McCulloh, 1960, fig. 150.1). However, vertical separations at basement may be a relatively small component of displacement across the zone, which is inferred to include a large component of left-lateral strike slip (Campbell and Yerkes, 1976), in part to account for juxtaposition of dissimilar basement rocks and pre-upper Miocene sequences west of the Newport-Inglewood zone. West of the shoreline, the fault zone includes a northern branch, the Malibu Coast fault, and a southern, offshore branch, the Anacapa fault (pl. 1). The Anacapa fault is the southern boundary of Transverse Ranges physiography, as defined by the east-trending structures of Point Dume (Junger and Wagner, 1977, fig. 4), whereas the Malibu Coast fault is a recognized boundary between wholly dissimilar rock sequences (Campbell and others, 1966).

The total vertical separation across the Anacapa fault is unknown. Up-to-the-north separations of 1,000 to 2,000 m are indicated by structure contours on the Miocene-Pliocene unconformity, and 200 to 600 m on lower Pliocene strata, in the area south and southwest of Point Dume (Junger and Wagner, 1977, fig. 7, profiles C-C', D-D'). The seismic profiles indicate that Quaternary sediments in that area are not cut by the fault.

The Malibu Coast fault dips north at 30°-70° and all evidence indicates reverse dip slip; it marks the zone of deformation along which the Santa Monica Mountains block overrides the low-lying terrain to the south. Stratigraphic separation across the zone is indeterminate, since it juxtaposes unlike rock sequences along its entire length. Topographic relief across the

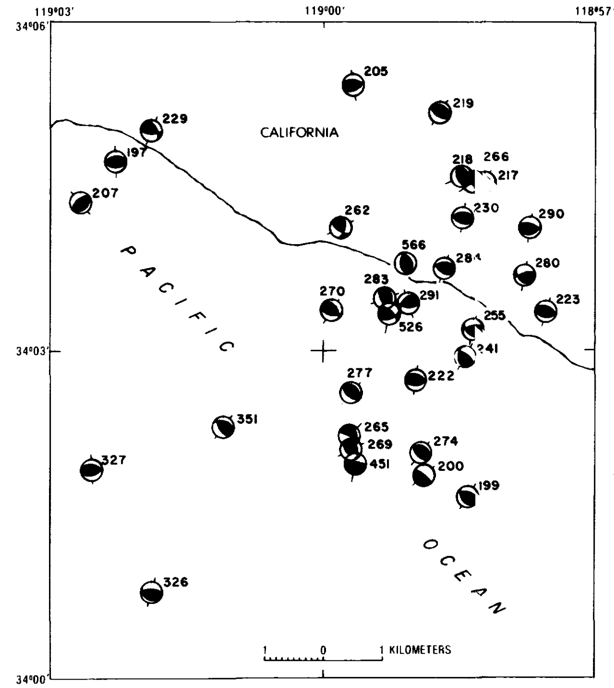


Figure 6.—Focal mechanisms for 1973 Point Mugu earthquake (No. 197) and aftershocks. Numbers indicate sequence of events (see table 2, Chap. A). Compressional quadrants dark, dilatational quadrants light; lower focal hemisphere. Bar shows orientation of P axis. Diagrams located at epicenter of event. Location and area of map shown on plate 2.

zone is at least 850 m, but very large left-lateral strike slip (60-90 km) in late middle Miocene time has been inferred on regional grounds (Campbell and Yerkes, 1976). Elements of the fault have thrust late Pleistocene (about 105,000 years old) marine terrace deposits more than 15 m over upper Miocene strata at one locality near Malibu Canyon, and deposits of similar age are cut by faults in the zone at several other localities along its length.

The fault-plane solution for the 1973 Point Mugu earthquake is well constrained and indicates reverse displacement; one of the nodal planes dips about 44° north and is geometrically and geologically compatible with the Anacapa fault (Ellsworth and others, 1973; Stierman and Ellsworth, 1976; figs. 4 and 5 in Chap. A of this report).

Although the somewhat diverse focal mechanisms and spatial distribution of the aftershocks do not correlate well with the nodal plane of the main shock (fig. 6; Stierman and Ellsworth, 1976), they do indicate dominantly reverse faulting on chiefly north-dipping faults in response to northeast-southwest compressive stress, as do other earthquakes along the zone.

A composite fault-plane solution based on five events along but just south of the trend of the Santa Monica fault, near the east end of the

Santa Monica Mountains about 25 km east of the map area, indicates a steeply north-dipping fault with predominant reverse displacement, a moderate component of left-lateral strike slip, a slip vector plunging about 55° N. 66° E., and a P axis plunging about 28° N. 18° E. (Hill and others, 1977, pl. 4, fig. 8). This solution is consistent with those reported from this study.

The segment of the Anacapa-Santa Monica fault between long 118°45' W. and 118°20' W. (15 km east of the present map area) was relatively free of recorded seismicity during the 1970-75 period, whereas many events were recorded throughout the area to the south. The latter area is bounded by the northwest-trending San Pedro escarpment and Newport-Inglewood zones, each of which is characterized by dominantly right-lateral strike slip on the basis of geologic or seismologic evidence or both (see for example Hill and others, 1977, pl. 4, fig. 6; Buika and Teng, 1978). Buika and Teng (1978) note the same concentration of seismicity (during 1973-76) along the northwest-trending faults south of the Santa Monica fault system and relatively sparse seismicity in the Santa Monica Mountains to the north. They view this as evidence that the northwest-trending faults are terminated by the Santa Monica fault system and that the Santa Monica Mountains are acting as a passive and coherent structural block. They also conclude that the Santa Monica fault system was the locus of chiefly north-over-south reverse-left-oblique slip as a result of compressive stress oriented northeast-southwest.

Anacapa earthquake.—The 1973 "Anacapa" earthquake and an aftershock (events 357 and 359, pl. 2) have epicenters very close to the Anacapa fault but are best associated geometrically with northwest-trending faults located on the Santa Cruz-Catalina Ridge 7 to 12 km southwest of the epicenters. Some northwest-trending folds and short fault segments have been mapped in that general area, including a northeast-dipping thrust fault, but no satisfactory correlation is known.

1978 Santa Barbara earthquake.—The Santa Barbara earthquake of August 13, 1978 (event SB78, pl. 2), occurred in the same general area as the larger 1925 and 1941 earthquakes; its epicenter perhaps was between those of the earlier events.

The distribution of main-shock and aftershock hypocenters describes a surface striking N. 65°-70° W. and dipping north (Lee and others, 1978, figs. 3 and 5). This surface trends toward the shoreline at Goleta, where the largest accelerations were measured and most extensive damage occurred. The fault-plane solution, distribution of aftershocks, and local geology indicate reverse slip on a fault dipping 30°-60° N. The rupture surface and fault-plane solution are not clearly associated with a recognized fault but may be associated with the Pitas Point or nearby fault (see Chap. A, fig. 2).

SUMMARY AND CONCLUSIONS

Focal mechanisms based on some 200 magnitude 2 to 6 events for the six-year period 1970 through 1975 in the western Transverse Ranges reflect the same stress regime as larger earthquakes in the province for which records are available: near-horizontal pressure axes directed generally normal to the great bend of the San Andreas fault. The inferred compressive stress is expressed chiefly by seismicity and reverse displacement along several major zones of east-trending reverse faults (Red Mountain-San Cayetano, Pitas Point-Ventura, Mid-Channel, and Anacapa-Santa Monica); some left-lateral strike slip also is indicated. This type of deformation is entirely typical of that measured after the 1971 San Fernando earthquake over an area of more than 250 square kilometers:

1. 1.4-m vertical (up on the north) separation across the rupture zone.
2. 1.9-m left-lateral separation.
3. 0.55-m north-south shortening normal to the fault trace.
4. Differential arching and depression of more than 2 m, which accentuated pre-existing landforms.
5. Horizontal deformation on a regional scale that lengthened northwest-trending control lines.

Most significantly, the evidence on rate and sense of deformation is mutually consistent for individual faults: geologic data on age and sense of latest displacement and amount and sense of stratigraphic separation, geodetic data on tilting of coastal areas underlain by faults, uplift of dated marine terrace deposits in coastal areas underlain by faults, and associated focal mechanisms. The indicated average rates of vertical deformation (5-10 m per thousand years) have been constant at least over the last 45,000 years.

The east-trending reverse faults that dominate the structure of the western Transverse Ranges are slip surfaces along which many kilometers of north-south shortening and a lesser amount of east-west extension have occurred in late Quaternary time. At the present rates, all the measured compressive deformation within the western Transverse Ranges could have occurred during the last 0.5 to 1 million years.

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