CIRCULAR 78

An Instrumental Study of New Mexico Earthquakes

by ALLAN R. SANFORD

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO

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Abstract

Data from seismic stations in New Mexico and surrounding states were used to establish locations and magnitudes of shocks that occurred within the state from January 1, 1962 to June 30, 1964. The number and strengths of shocks detected during this period indicated a seismicity for New Mexico about one fiftieth as great as Southern California. The strongest shocks (M > 3.5) recorded during the study originated in the northeastern part of the state, a region from which only one felt shock has been reported in more than sixty years. The majority of the located shocks were confined to the western half of the state and followed a geographical distribution in general agreement with the historical reports of earthquakes in the state.

A prediction of seismic activity in west-central New Mexico was made on the basis of the numbers and magnitudes of shocks detected from that region during the two and one-half years. The predicted activity was much lower than the known seismicity from historical records. This result illustrates the possible dangers involved in making long-range predictions of seismicity based on short periods of observations.

Introduction

This circular reports the strengths and the locations of instrumentally detected earthquakes that occurred within New Mexico from January 1, 1962 to June 30, 1964. Special emphasis is placed on shocks recorded from west-central New Mexico, a region which has had fairly high seismicity in the past (Northrop, 1945, 1947, 1961; Sanford, 1963).

Prior to 1960, nearly all information on the strengths and distribution of earthquakes in New Mexico was determined without the aid of instruments. The strength and location of a shock were based on qualitative observations of the intensity of ground vibrations. The latter can be determined from what people feel, do, and observe during an earthquake and also from the degree of damage to structures (Richter, 1958, p. 135). Unfortunately, these measures of earthquake intensity are dependent on the type of ground as well as proximity to the shock. Under equivalent conditions, the ground motion on loosely consolidated alluvial materials common to many valleys in New Mexico could be ten times larger than the motion on competent rocks outcropping in the mountains (Gutenberg, 1957). Thus, an earthquake in a mountainous region of New Mexico could be felt more intensely and do more damage in bordering valley areas than in the immediate vicinity of the shock. In this instance, the degree and location of maximum intensity of ground motion would *not* give a true indication of the strength and location of the shock.

Another difficulty with noninstrumental studies of earthquakes is the effect of population density. In regions where numbers of people are concentrated, reports of shocks are likely to be high and vice versa. Since vast areas of New Mexico are lightly populated, noninstrumental studies could have missed some small but significant areas of seismic activity.

Despite these difficulties, much useful qualitative information on the strengths, locations, and modes of occurrence of New Mexico earthquakes has been obtained from noninstrumental studies. (See Bagg, 1904; Reid, 1911; Heck, 1938; U.S. Coast and Geodetic Surv., ser. nos. 483, 511, 539, 553, 563, 579, 593, 600, 610, 619, 629, 637, 647, 655, 746, 749, 762, and 773; Northrop, 1945, 1947, 1961; Sanford). The noninstrumental data have one principal advantage over the instrumental data discussed in this report: they cover a much longer time period. Until several more years of instrumental studies are completed, we will have to rely on these older and less perfect data for some important conclusions on the seismicity of New Mexico.

Instrumental studies of earthquakes in this state started in June 1960 when high-magnification seismographs were placed in operation on the campus of the New Mexico Institute of Mining and Technology at Socorro. Most of the seismic research at NMIMT has been concentrated on shocks originating close to Socorro (Sanford and Holmes, 1961, 1962; Sanford) because information from other stations located in this or adjacent states was not available in sufficient quantity for a study of the seismicity of the entire state. This situation changed about the beginning of 1962 when stations at Albuquerque and Las Cruces, New Mexico, and Payson, Arizona, began continuous operation. By 1964, a sufficient amount of data had accumulated from these and other stations (established earlier than 1962 in nearby states) for a fairly good instrumental study of earthquakes throughout New Mexico. The results of this study, supported by the National Science Foundation under NSF Grant GP3089, are presented herewith.

Table 1 lists the important data for seismograph stations used in this study. The author greatly appreciates the co-operation and help of the Air Force Technical Applications Center (AFTAC), the U.S. Coast and Geodetic Survey (USCG), Texas Western College (Dr. H. S. Slusher), and Texas Technological College (Prof. D. H. Shurbet).

TABLE 1. LOCATION OF SEISMOGRAPH STATIONS USED IN STUDY OF NEW MEXICO EARTHQUAKES

STATION	LOCATION	LATITUDE (NORTH)	LONGITUDE (WEST)	ELEVATION (METERS)	OPERATOR
Soc	Socorro, N. Mex.	34°04.2′	106°56.6′	1510	NMIMT
Alb	Albuquerque, N. Mex.	34°56.5′	106°27.5′	1853	USCGS
LC	Las Cruces, N. Mex.	32°24.1′	106°36.0′	1590	AFTAC
TF	Payson, Ariz.	34°16.1′	111°16.2′	1492	AFTAC
Tuc	Tucson, Ariz.	*32°14.8′	110°50.1′	700	
		†32°18.6′	110°46.8′	985	USCGS
EP	El Paso, Tex.	31°46.3′	106°30.4′	1186	Texas Western
Lub	Lubbock, Tex.	33°35′	101°51′	982	Texas Tech.
WM	Ft. Sill, Okla.	34°43.1′	98°35.4′	505	AFTAC
DR	Durango, Colo.	37°27.9′	107°47.0′	2220	AFTAC

* Before December 1962.
† After December 1962.

DEFINITIONS AND PROCEDURES

DEFINITIONS

A few definitions of seismological terms are useful in understanding the material which follows:

Focus. The point beneath the surface at which the earthquake occurs.

Epicenter. A point on the surface directly above the focus.

P wave. A compressional or longitudinal elastic wave which propagates through the solid materials of the earth.

S wave. A shear or transverse elastic wave which propagates through the earth at about 0.6 of the P-wave velocity.

S-P. The time interval on the seismogram between the arrivals of the P and S waves.

P-0. The time it takes the P wave to travel from the focus to the station.

Origin time. The time at which the earthquake occurred at the focus.

Magnitude. A measure of the strength of an earthquake that is independent of the distance between the focus and the point of observation.

SH and *SV.* Horizontal and vertical components of the S wave.

PROCEDURE FOR LOCATING SHOCKS

The method used to locate New Mexico earthquakes was based on the procedure described by Richter (1958, pp. 320-323). The location of a shock involved four steps: (1) determination of a tentative origin time for each shock from the measured S-P intervals; (2) assignment of a depth of focus of either 5 or 10 km; (3) calculation of the distances between stations and epicenter from the P-0 intervals and a T-Δ function (in this instance a graph relating time of travel to distance of travel for the two depths of focus); and (4) determination of the epicenter from the intersection of circles whose radii are the calculated distances from step (3). Frequently, step (4) did not yield a satisfacttory intersection of arcs. In most of these instances, the fit could be improved by adjusting the origin time and repeating the third and fourth steps. Adjustment of origin time is a legitimate procedure inasmuch as origin times based on S-P can be in error because of the difficulty in identifying the beginning of the S phase. All final determinations of epicenters were checked by reversing the location procedure; that is, by calculating (1) the distances (Δ) between epicenter and stations, (2) the travel times (P-O) between focus and stations, and (3) the origin times. Agreement in calculated origin time for each station indicated a correct location.

Figure 1 summarizes the crustal structures for New Mexico deduced from seismograms of explosions. The crustal model of Tatel and Tuve (1955) is based on explosions in the mining districts of eastern Arizona and western New Mexico. The models of Stewart and Pakiser (1962) and Romney et al. (1962) are based on the Project Gnome atomic explosion near Carlsbad on December 10, 1961. All the crustal models are calculated from unreversed profiles—a procedure which can lead to errors in determining both velocities and depths.

Although the data in Figure 1 are limited and possibly contain some error, they do indicate that no single crustal structure will be valid for the entire state. For this reason, the time-distance relationship used to locate earthquakes is based on a simple crustal model close to the average of those appearing in Figure 1. The crustal model adopted consists of a single 39-kilometer-thick layer with a velocity of 6.0 km/sec overlying subcrustal material with a velocity of 8.0 km/sec. Two time-distance curves, one for a depth of focus of 5 km and the other for a depth of focus of 10 km, were calculated on the basis of this crustal structure.

METHOD OF ASSIGNING MAGNITUDES

Magnitude can be expressed by the equation $M \log A — \log A_0$, where A is the maximum trace amplitude of the S phase (in millimeters) on the seismogram and A_0 is the corresponding trace amplitude for a particular-strength earthquake selected as a standard. The numbers obtained for M are dependent on the magnification and frequency response of the seismograph used and on the selection of the standard shock whose amplitudes at various distances are the values A_0.

Richter, who first devised a usable magnitude scale for study of local shocks, based his scale on the Wood—Anderson seismograph, an instrument with a natural period of 0.8 second, a static magnification of 2800, and a damping of 0.8 critical. He further defined his standard shock (the

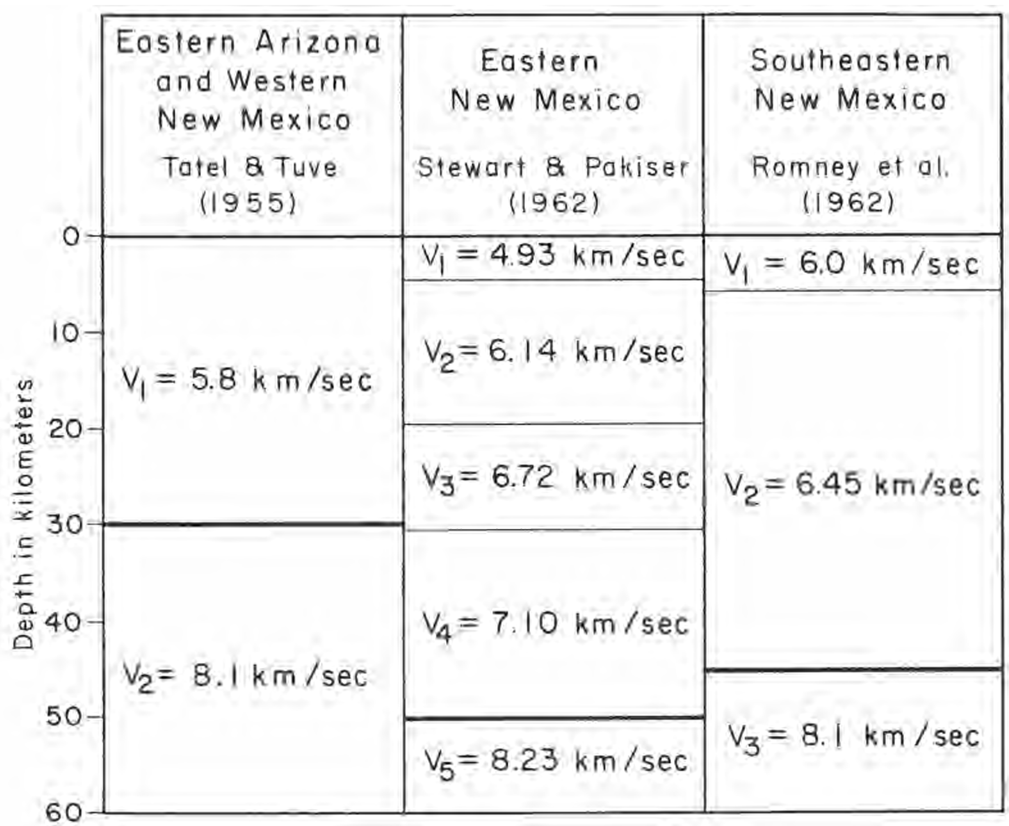

Figure 1

CRUSTAL STRUCTURE IN NEW MEXICO DETERMINED FROM SEISMOGRAMS OF EXPLOSIONS magnitude zero shock) as an earthquake which would produce a trace deflection of one thousandth of a millimeter when recorded by a Wood—Anderson seismograph at a distance of 100 kilometers.

The direct application of the Richter scale to New Mexico earthquakes was impossible because none of the available data came from Wood—Anderson seismographs. Faced with the problem of indicating the relative strengths of New Mexico earthquakes, the author decided to rate shocks on the basis of the amplitude a Wood—Anderson instrument would produce had it recorded these shocks. He also adopted the values used by Richter for the amplitudes A_o of the standard shock. For reasons clearly outlined by Richter (1958, p. 345), this procedure may not necessarily give a shock of fixed energy release the same magnitude in New Mexico as it would have in California.

Most of the magnitudes were calculated from the maximum SH ground motions (the component recorded by a Wood—Anderson seismograph) reported by the station at Las Cruces. Where no SH amplitude information was available from the Las Cruces station, assignment of magnitude was made on the basis of the maximum SV ground motion at Albuquerque. The relation between SV motion at Albuquerque and magnitude was established from data on shocks detected by both the Las Cruces and Albuquerque stations.

These procedures for assigning magnitudes cannot be expected to produce a completely accurate and finely divided grading of shocks. Although the magnitudes in the tables which follow are given to the nearest tenth, they should be interpreted only as rough indicators of the relative strengths of the shocks.

Seismic Activity, All of New Mexico

Figure 2 and Table 2 summarize the important data on New Mexico shocks detected by three or more stations (three is the minimum number of stations from which a unique location can be determined). The largest concentration of located shocks—mostly weak events—is in the west-central part of the state. Although there is abundant historical evidence for activity in this region, it should be pointed out that there is a greater probability of locating shocks in this area than elsewhere in the state because this region lies midway along a line connecting the three principal stations used in the study, Albuquerque, Socorro, and Las Cruces.

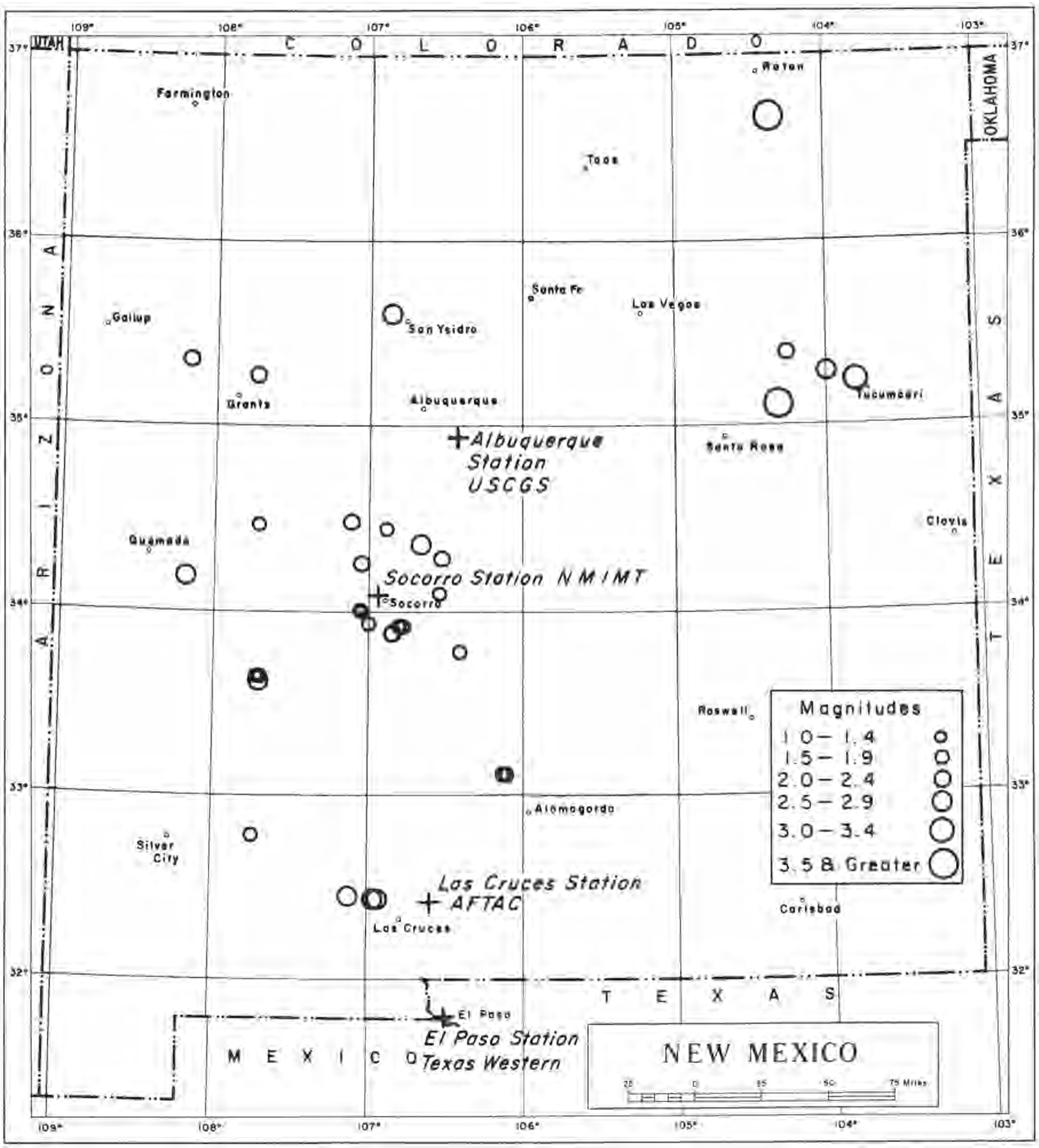

Figure 2

MAP OF NEW MEXICO SHOWING LOCATIONS OF EARTHQUAKES DETECTED BY SEISMOGRAPHS FROM JANUARY 1, 1962 TO JUNE 30, 1964

TABLE 2. TIMES, MAGNITUDES, AND LOCATIONS OF NEW. MEXICO EARTHQUAKES FROM JANUARY 1, 1962 THROUGH JUNE 30, 1964

DATE	ORIGIN TIME (GCT)	MAGNITUDE	EPICENTER LAT. N.	EPICENTER LONG. W.	DEPTH OF FOCUS (KM)	STATIONS
1962						
Jan. 3	23:29:54.2	3.0	35°12′	103°47′	10	Soc, Alb, LC, Lub, WM
Jan. 24	15:12:43.7	1.8	33°57′	106°50′	5	Soc, Alb, LC
Jan. 24	15:53:14.6	1.5	33°57′	106°50′	5	Soc, Alb, LC
Mar. 3	18:16:48.1	1.8	33°49′	106°21′	10	Soc, Alb, LC
Mar. 22	04:23:53.6	2.3	34°25′	107°06′	5	Soc, Alb, LC
Apr. 9	23:42:59.5	2.0	34°16′	106°31′	10	Soc, Alb, LC
May 2	23:21:18.0	2.0	34°14′	107°02′	5	Soc, Alb, LC
June 14	07:27:55.8	2.8	35°35′	106°52′	10	Soc, Alb, LC, Tuc
June 25	02:35:26.2	2.6[a]	34°12′	108°11′	10	Soc, Alb, Tuc
June 25	10:00:45.8	1.8[a]	33°57′	107°00′	5	Soc, Alb, Tuc
Dec. 15	20:20:34.0	2.1	33°56′	106°51′	5	Soc, Alb, LC
Dec. 19	13:04:05.2	1.5[a]	34°23′	106°54′	5	Soc, Alb, TF
1963						
Feb. 22	07:02:08.1	2.9[a]	32°26′	106°59′	10	Soc, Alb, LC, TF, Tuc
Feb. 22	08:53:17.7	2.8[a]	32°26′	106°59′	10	Soc, Alb, LC
Mar. 6	14:49:36.2	2.5[a]	33°40′	107°41′	5	Soc, Alb, TF
Mar. 6	18:05:13.0	1.7[a]	33°40′	107°41′	5	Soc, Alb, Tuc
Mar. 8	06:16:47.8	1.7[a]	33°40′	107°41′	10	Soc, Alb, TF, Tuc
May 27	12:54:56.3	1.5	32°46′	107°46′	10	Soc, Alb, LC
June 2	05:07:36.2	2.5	34°18′	106°37′	5	Soc, Alb, LC
June 6	08:05:32.6	3.7	36°41′	104°22′	10	Soc, Alb, LC, TF, WM
July 3	19:08:00.6	1.7	34°00′	107°02′	5	Soc, Alb, LC, TF, Tuc, DR
Aug. 19	00:08:23.4	2.9[a]	32°27′	107°08′	10	Soc, Alb, TF, Tuc, EP
Aug. 21	00:23:21.2	2.0	35°18′	108°08′	10	Soc, Alb, DR
Aug. 27	05:18:17.0	2.3	35°16′	107°45′	10	Soc, Alb, DR
Dec. 19	16:47:29.6	>3.6[a]	35°06′	104°15′	10	Soc, Alb, LC, TF, Tuc, EP, Lub, WM
Dec. 30	08:48:14.6	1.8	34°04′	106°32′	5	Soc, Alb, LC
1964						
Feb. 11	09:24:38.4	2.4	35°27′	104°12′	10	Soc, Alb, LC, TF, WM
Mar. 3	01:26:29.6	2.6	35°15′	104°00′	10	Soc, Alb, LC
Mar. 29	12:46:33.8	1.5[a]	34°23′	107°43′	10	Soc, Alb, TF, Tuc
June 18	20:20:18.4	1.8	33°07′	106°07′	10	Soc, Alb, LC
June 19	05:28:39.4	1.8	33°07′	106°07′	10	Soc, Alb, LC, Tuc
June 29	08:11:11.6	1.1[a]	34°00′	107°02′	5	Soc, Alb, LC

[a] Based on SV motion at Albuquerque.

STRONGEST EARTHQUAKES

The strongest earthquakes during the two-and-one-half-year period occurred in the northeastern section of the state. With the exception of a fairly strong shock near Cimarron on August 3, 1952 (U.S. Coast and Geodetic Surv., ser. no. 773), no felt shocks have been reported from this quadrant of the state in more than sixty years. Inasmuch as the population over much of this region is sparse, this may be an area where noninstrumental studies have missed significant activity in the past.

The other strong shocks occurring during the period of study were scattered throughout the western half of the state, which is the general pattern expected on the basis of earlier noninstrumental studies of activity. As strong shocks may be important in future research on the seismicity of New Mexico, an additional and more detailed listing of data for these shocks ($M > 2.75$) is given in Table 3.

Seven shocks with $M > 2.75$ are listed in Table 3. By comparison, Southern California (32.5°N. to 36°N. latitude, 115°W. to 120°W. longitude) would have about 60 times as many shocks

TABLE 3. DATA ON NEW MEXICO EARTHQUAKES WITH MAGNITUDES GREATER THAN 2.75, JANUARY 1, 1962 THROUGH TUNE 30. 1964

DATE			ORIGIN TIME			MAGNI-		DEPTH OF FOCUS			TIMES			Δ
YR.	MO.	DAY	HR.	MIN.	SEC.	TUDE	EPICENTER	(KM)	STATIONS	PHASES	HR.	MIN.	SEC.	(KM)
62	Jan.	3	23	29	54.2	3.0	35°12′N	10	Alb	iPn	23	30	31.0	245
							103°47′W			iSn	23	30	58.2	
									Lub	ePn	23	30	32	251
										eLg	23	30	55	
									Soc	iPn	23	30	41.5	317
										iSn	23	31	15.7	
									LC	ePn	23	30	52.8	405
										eSn	23	31	39	
									WM	ep	23	31	08.4	475
										es	23	31	59.9	
										e(Sur)	23	32	05.5	
62	June	14	07	27	55.8	2.8	35°35′N	10	Alb	ip	07	28	09.3	80
							106°52′W			is	07	28	18.8	
									Soc	ep	07	28	23.6	168
										is	07	28	46.1	
									LC	ep	07	28	56.0	353
										es	07	29	37	
									Tuc	ep	07	29	22.0	524
63	Feb.	22	07	02	08.1	2.9*	32°26′N	10	LC	ep	07	02	14.1	36
							106°59′W			es?	07	02	34	
									Soc	ip	07	02	37.2	182
										is	07	02	58.5	
									Alb	ep	07	02	56.0	279
										es	07	03	31.0	
									Tuc	ePn	07	02	57.0?	359
										eL	07	03	44.0?	
									TF	ePn	07	03	11.0	450
										eSn?	07	04	11.5	
63	Feb.	22	08	53	17.7	2.8*	32°26′N	10	LC	ep	08	53	23.3	36
							106°59′W			es	08	53	27	
									Soc	ip	08	53	45.9	182
										es	08	54	07.3	
									Alb	ep	08	54	07	279
										es	08	54	43	
63	June	6	08	05	32.6	3.7	36°40.8′N	10	Alb	iPn	08	06	13.5	268
							104°22.2′W			i	08	06	15.9	
										iSn	08	06	43.6	
									Soc	ep	08	06	32.3	373
										es	08	07	15.7	
									LC	ePn	08	06	47.5	516
										e	08	06	56	
									WM	ePn	08	06	51.0	567
										ep	08	07	06.0	
									TF	ePn	08	07	05.6	681
63	Aug.	19	00	08	23.4	2.9*	32°27′N	10	EP	ip	00	08	39.6	96
							107°08′W			s?	00	08	50.0	
									Soc	ip	00	08	53.6	181
										is	00	09	15.4	
									Alb	ep	00	09	10.3	283
										es	00	09	42.6	
									Tuc	ePn	00	09	13.0	345
									TF	ePn	00	09	25.2	436
										e	00	10	26.0	
63	Dec.	19	16	47	29.6	>3.6*	35°06′N	10	Alb	iPn	16	48	02.0	203
							104°15′W			iSn	16	48	25.8	
									Lub	ePn	16	48	11½	278
										eLg	16	48	38	
									Soc	iPn	16	48	12.2	274
										iSn	16	48	43.1	
									LC	ePn	16	48	23.1	369
										eSn	16	49	04	
									EP	ep?	16	48	34.6	425
										es?	16	49	20.5	
									WM	ePn	16	48	40.4	519
										ep	16	48	51.6	
										e(Sur)	16	49	50.0	
									TF	ep?	16	49	06.6	648
										es	16	50	27.0	
									Tuc	ep	16	49	21.5	678
										e	16	50	36.0	

* Based on SV motion at Albuquerque.

exceeding this magnitude in the same time period (Knopoff, 1964). Thus, the over-all seismicity of New Mexico is quite low when compared to a highly seismic area such as Southern California. While the over-all seismicity may be low, small segments of this state, for example, the area surrounding Socorro, may have a degree of seismicity equivalent to most sections of Southern California (Richter, 1959).

LOCATION ACCURACY

Factors influencing the accuracy of the epicenters in Tables 2 and 3 are (1) the magnitude of the shock, (2) the number of stations detecting the shock, (3) the distance and azimuth of the epicenter relative to the three stations in New Mexico, and (4) the travel time curves used in the location procedure. At the present time, not enough information is available on the crustal structure of New Mexico to estimate the errors introduced by using the same travel time relation for all shocks. An analytical evaluation of the effects of the other factors on location accuracy is difficult and impractical, because, in general, the conditions affecting location accuracy differ considerably from one earthquake to another. However, generalizations can be made which indicate in a qualitative way the relative precision of the locations listed in the tables.

First, the accuracy of the location will improve as the number of recording stations increases and the magnitude of the shock increases. Second, an earthquake of given strength can be located more accurately in the west-central part of the state than elsewhere, because in this region the distance from the shock to the three principal stations in this study (Albuquerque, Socorro, and Las Cruces) is not great. Third, a shock of given strength in the west-central region will have a more accurate location if it occurs to one side rather than along the line connecting the Albuquerque, Socorro, and Las Cruces stations. The exception to this last generalization occurs when a shock is very close to one of the recording stations, a fairly frequent event at Socorro.

These generalizations can be used to place the location error between $\pm$ 6 km and $\pm$ 35 km. The lower limit is for shocks of magnitude 1.8 or greater that occurred near the stations in New Mexico. The upper limit applies to the weaker events ($M < 3.0$) detected at distances greater than 200 km from the principal stations.

Seismic Activity, West-Central New Mexico

Figure 3 and Table 4 summarize the important data on shocks located in west-central New Mexico, an area arbitrarily defined as extending from 33°45'N. to 35°00'N. latitude and from

TABLE 4. TIMES, MAGNITUDES, AND LOCATIONS OF EARTHQUAKES IN WEST-CENTRAL NEW MEXICO* FROM JANUARY 1, 1962 THROUGH JUNE 30, 1964

DATE	ORIGIN TIME (GCT)	MAGNITUDE	EPICENTER LAT. N.	EPICENTER LONG. W.	DEPTH OF FOCUS (KM)	STATIONS
1962						
Jan. 24	15:12:43.7	1.8	33°57′	106°50′	5	Soc, Alb, LC
Jan. 24	15:53:14.6	1.5	33°57′	106°50′	5	Soc, Alb, LC
Mar. 3	18:16:48.1	1.8	33°49′	106°21′	10	Soc, Alb, LC
Mar. 18	11:37:55.6	1.5[a]	33°59′	107°04′	5	Soc, Alb
Mar. 22	04:23:53.6	2.3	34°25′	107°06′	5	Soc, Alb, LC
Apr. 9	23:42:59.5	2.0	34°16′	106°31′	5	Soc, Alb, LC
May 2	23:21:18.0	2.0	34°14′	107°02′	5	Soc, Alb, LC
May 15	04:02:06.8	1.4[a]	34°09′	107°05′	5	Soc, Alb
May 19	11:41:48.7	1.5[a]	34°17′	106°54′	5	Soc, Alb
June 7	09:54:08.1	1.6[a]	34°22′	106°46′	5	Soc, Alb
June 12	19:10:21.2	1.9[a]	34°16′	106°55′	5	Soc, Alb
June 16	09:49:31.4	1.0[a]	34°23′	106°49′	5	Soc, Alb
June 16	16:15:39.6	1.4[a]	34°24′	106°56′	5	Soc, Alb
June 25	10:00:45.8	1.8[a]	33°57′	107°00′	5	Soc, Alb, Tuc
June 27	04:49:16.0	2.7[a]	34°02′	107°01′	5	Soc, Alb
July 29	04:59:03.1	1.1[a]	34°20′	106°48′	5	Soc, Alb
July 29	07:40:40.6	1.2[a]	34°21′	106°53′	5	Soc, Alb
July 29	17:25:12.6	0.7[a]	34°21′	106°57′	5	Soc, Alb
Aug. 24	00:25:55.3	1.3[a]	34°06′	107°01′	5	Soc, Alb
Sept. 22	02:40:59.9	1.6[a]	34°13′	107°05′	5	Soc, Alb
Sept. 27	02:56:36.8	1.8[a]	34°24′	106°49′	5	Soc, Alb
Nov. 7	13:27:04.6	0.8[a]	34°28′	107°05′	5	Soc, Alb
Dec. 13	06:11:16.0	1.4[a]	34°19′	106°49′	5	Soc, Alb
Dec. 15	20:20:34.0	2.1	33°56′	106°51′	5	Soc, Alb, LC
Dec. 19	13:04:05.2	1.5[a]	34°23′	106°54′	5	Soc, Alb, TF
Dec. 23	11:38:15.7	0.8[a]	34°24′	106°59′	5	Soc, Alb
1963						
Jan. 6	04:33:42.5	1.0[a]	34°25′	106°58′	5	Soc, Alb
Apr. 9	03:54:33.8	1.3[a]	34°26′	106°58′	5	Soc, Alb
Apr. 20	23:31:26.8	1.1[a]	34°35′	107°01′	5	Soc, Alb
May 18	08:20:36.8	1.7[a]	34°02′	107°03′	5	Soc, Alb
June 2	05:07:36.2	2.5	34°18′	106°37′	5	Soc, Alb, LC
July 3	19:08:00.6	1.7	34°00′	107°02′	5	Soc, Alb, LC, TF, Tuc, DR
July 3	19:12:06.2	1.5[a]	34°01′	107°05′	5	Soc, Alb
Aug. 13	04:26:14.3	1.6[a]	34°10′	106°56′	5	Soc, Alb
Sept. 12	11:36:32.6	0.9[a]	34°20′	107°03′	5	Soc, Alb
Sept. 15	07:21:37.1	1.4[a]	34°09′	106°55′	5	Soc, Alb
Oct. 7	08:32:50.0	1.4[a]	34°06′	106°56′	5	Soc, Alb
Oct. 7	20:43:37.8	1.2[a]	34°19′	107°01′	5	Soc, Alb
Dec. 13	14:15:41.5	1.1[a]	34°34′	106°46′	5	Soc, Alb
Dec. 13	14:40:25.0	1.4[a]	34°36′	106°52′	5	Soc, Alb
Dec. 30	08:48:14.6	1.8	34°04′	106°32′	5	Soc, Alb, LC
1964						
Feb. 4	18:58:12.2	1.1[a]	34°04′	107°06′	5	Soc, Alb
June 29	08:11:11.6	1.1[a]	34°00′	107°02′	5	Soc, Alb, LC

* Between 33°45′N. and 35°00′N. latitude and 106°15′W. and 107°15′W. longitude.

[a] Based on SV motion at Albuquerque.

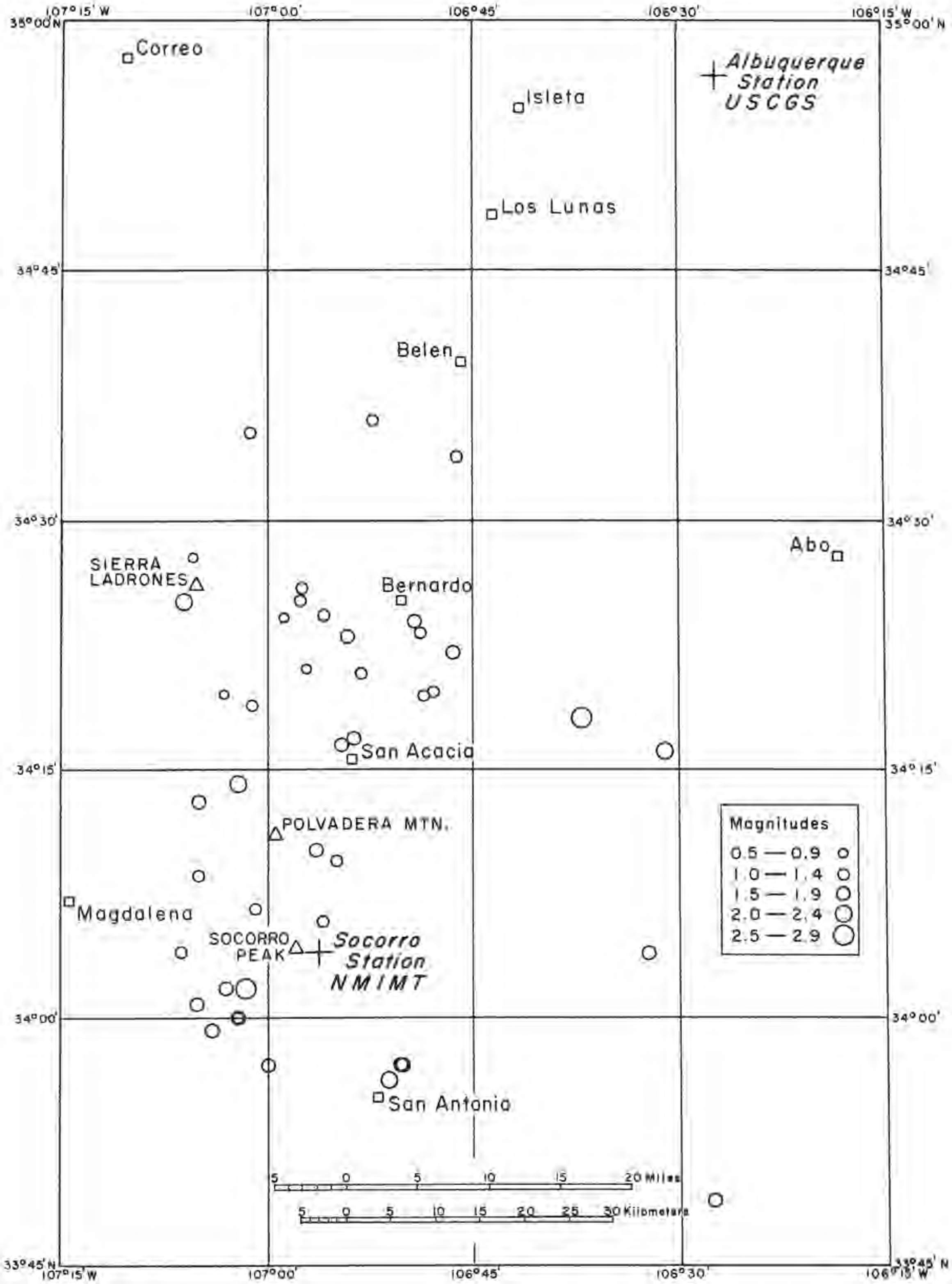

Figure 3

MAP OF WEST-CENTRAL NEW MEXICO SHOWING LOCATIONS OF EARTHQUAKES DETECTED BY SEISMOGRAPHS FROM JANUARY 1, 1962 TO JUNE 30, 1964

106°15'W. to 107°15'W. longitude. This region is of special interest because nearly 90 per cent of the strongest shocks reported in New Mexico between 1890 and 1960 originated within its boundaries. These stronger shocks had radii of perception in excess of 120 kilometers and estimated Richter magnitudes of 5 or greater; thus not too many other shocks of this size elsewhere in the state could have gone undetected, even in the low population areas. All evidence indicates that the high seismicity of west-central New Mexico determined from the noninstrumental data is real and not simply the result of population density.

EARTHQUAKE LOCATIONS

Figure 3 and Table 4 include locations for many shocks detected by two stations only, Socorro and Albuquerque. When only two distances to the epicenter are known and the depth is prescribed, the location procedure yields two possible locations. In this study, the westernmost of the two possible locations was selected as the epicenter of the shock. The location obtained for a series of shocks that occurred north of Socorro in July 1960 (Sanford and Holmes, 1961) appears to support selection of the western location as the epicenter. The epicenter for this series of shocks, from three-component records, was 37 km N. 16 W. from Socorro at the base of the Sierra Ladrones. Since 1960, six other shocks north of Socorro have been recorded at high speeds on closely spaced networks of 3 to 5 vertical seismometers. The epicenters for all these shocks are northwest of Socorro (from N. 11 W. to N. 58 W). However, in view of possible horizontal refractions of the ray path, this evidence for the more westerly epicenters is not conclusive.

Errors in location may be quite high even if the westernmost of the two possible locations is correct. Because many of the shocks occurred close to a line connecting the two stations, the two locations, found from the intersection of the arcs, can shift a great deal (mostly east-west) with small errors in the distances from the stations to the epicenter.

Location of shocks in the west-central region was based on assigned depths of focus of 5 km. Although the real depths of focus may deviate considerably from this value, studies of shocks near Socorro do indicate that 5 km may be close to the mean depth (Sanford).

DISTRIBUTION OF ACTIVITY

Despite possible large errors in the location of some shocks, an interesting conclusion can be drawn from the distribution of shocks shown in Figure 3. The activity in the southern part of this region is greater than in the northern part. An analysis of nighttime events (with $M > 1$) detected at Albuquerque indicates that this distribution is real and cannot be attributed to differences in magnifications and frequency responses between instruments at Socorro and Albuquerque. The distribution shown also agrees fairly well with the historical data on earthquakes in the west-central region (Northrop, 1945, 1947). Of the twelve large shocks (estimated Richter magnitudes of 5 or greater) that occurred in this region from 1890 to 1960, eight were felt most intensely at Socorro, one was strongest at Bernardo, and the remaining three were most severe at or near Albuquerque.

PREDICTED SEISMICITY

For limited areas as well as the world at large, numbers of shocks and magnitude can be related by the expression (Richter, 1958, p. 359) $\log N = A - bM$, where N is the number of shocks of magnitude M or greater per unit of time. The 28 shocks in Table 4 with magnitudes greater than 1.4 were used to establish the constants A and b in the equation (weaker shocks were not included because some of these may have gone undetected). The value of b, which is independent of time, was 1.15, in close agreement with those reported for other areas. The value of A, 4.06, was computed for a 25-year period by assuming that the values of N would be ten times larger than those observed during the two-and-one-half-year period from January 1, 1962 to June 30, 1964.

The expression thus obtained for west-central New Mexico predicts a strongest shock of magnitude 3.5 for a twenty-five-year period. This contradicts the known seismicity of the region because at least four shocks of this magnitude occurred within 40 km of Socorro from 1960 to 1961 (Sanford and Holmes, 1961, 1962). This rather marked discrepancy indicates that long-range predictions of seismicity derived from short periods of observations can be most misleading.

Summary

From January 1, 1962 to June 30, 1964, the over-all seismicity of New Mexico was quite low compared to more active regions such as Southern California. The strongest shocks recorded during this period occurred in the northeast quadrant of the state, a region from which little activity has been reported in the past. The majority of the epicenters were confined to the western half of the state and followed a pattern in general agreement with the earlier noninstrumental reports of earthquakes.

A prediction of activity in west-central New Mexico based on the numbers and magnitudes of shocks observed during the two-and-one-half-year period was much lower than the known historical activity of the region. This result illustrates the possible dangers involved in making long-range predictions of seismicity based on short periods of observations.

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