

CIRCULAR 102

An Instrumental Study of
New Mexico Earthquakes
July 1, 1964, through Dec. 31, 1967

by ALLAN R. SANFORD and DANIEL J. CASH

STATE BUREAU OF MINES AND MINERAL RESOURCES NEW
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Abstract

This circular describes the natural seismic activity within or very close to New Mexico during the period from July 1, 1964, through December 1, 1967. Origin times, locations, and magnitudes are listed for all earthquakes with magnitudes greater than or equal to 2.7. The most significant seismic event during the period of study was a magnitude

5.5 earthquake near Dulce on January 23, 1966. This earthquake (the strongest to occur in New Mexico for 28 years), with its aftershocks, accounts for more than half the total seismic activity during the 3 1/2 year period. The remaining activity was broadly distributed over the state, with the strongest shocks coming from the northeastern quadrant.

Introduction

In 1965, the New Mexico Institute of Mining and Technology published a circular (no. 78) entitled "An Instrumental Study of New Mexico Earthquakes" (Sanford, 1965). It lists magnitudes and geographic locations of earthquakes that occurred within New Mexico from January 1, 1962, to July 1, 1964. All shocks during this time that could be located instrumentally are listed. Because the three New Mexico stations used in the study were distributed along the Rio Grande Valley from Albuquerque to Las Cruces, the earthquakes reported are most numerous in the vicinity of these stations. Weak shocks near these stations were clearly recorded, whereas shocks of similar strength at considerable distances from the stations (for example, the northeastern quadrant of the state) were either poorly recorded or not recorded at all. Thus the distribution of

earthquake epicenters shown in Figure 2 of Circular 78 is not a completely accurate representation of the seismicity of New Mexico.

Some of the bias inherent in the earthquake statistics appearing in Circular 78 can be removed by considering only shocks having magnitudes greater than 2.7. Events of this magnitude can generally be detected, regardless of location, by some stations in bordering states as well as by the New Mexico stations. Table 3 in Circular 78 lists shocks with magnitudes of 2.75 or greater for the period January 1, 1962, through June 30, 1964. The data on New Mexico earthquakes presented herewith are basically an extension of Table 3 to cover the period from July 1, 1964, through December 31, 1967.

PROCEDURES

ORIGIN TIMES AND LOCATIONS

Whenever available, origin times and epicenter coordinates reported by the United States Coast and Geodetic Survey (USCGS) have been used in this report. Two types of data distributed by the USCGS were consulted, (1) Preliminary Determination of Epicenters (PDE) reports and (2) Seismological Bulletins (MSI series). The PDE results are preliminary and do not always agree exactly with the data listed in the Seismological Bulletins. However, the latter bulletins are not available for approximately two years. To avoid this delay, we have relied on the PDE reports for the period October 1966 through December 1967.

A majority of the New Mexico earthquakes (exclusive of aftershocks) reported in this circular were not mentioned by the USCGS. The procedure used to determine origin times and epicenters for these events is described in Circular 78 (p. 2). A list of stations employed in this work is given in Table 1 herewith.

METHODS OF ASSIGNING MAGNITUDES

Three magnitudes are listed: (1) USCGS, (2) Albuquerque, and (3) Socorro. Magnitudes assigned by the USCGS are based on the amplitudes of the P phases (Richter, 1958, p. 688-690). Magnitudes calculated from Albuquerque and Socorro seismograms are based on the amplitudes of the S phases. For Albuquerque, the maximum SH ground motion at that station was converted to an equivalent trace amplitude on a Wood-Anderson seismogram. The magnitudes were then computed using the original magnitude scale definition of Richter (1958, p. 338-342). A similar procedure was used for Socorro magnitudes, except that for these computations it was necessary to substitute maximum SV motion for maximum SH motion. Checks at the Socorro station indicate SH averages about 1.5 times as large as SV. This correction factor was included in the Socorro magnitude computations.

EARTHQUAKE DATA

By far the most significant seismic event to occur in New Mexico from July 1, 1964, through December 31, 1967, was the Dulce earthquake of January 23, 1966. This earthquake was followed by 26 aftershocks with magnitudes in excess of 2.7. The total number of events, with M 2.7, from elsewhere in the state for the entire 3 1/2-year period was only 19. In order that the latter events not be overlooked, two listings of earthquakes are presented. Table 2 lists only Dulce shocks and Table 3 lists all remaining shocks within or bordering New Mexico.

These tables give date, origin time, epicenter coordinates, three magnitudes, and the stations used by New

Mexico Tech to locate the shocks. The columns following the date indicate whether the event was located by USCGS or NMT. Symbols SB and PDE in the CGS column indicate the source of the information, whether Seismological Bulletins or the Preliminary Determination of Epicenters reports. In the magnitude columns, the following symbols designate reasons for the absence of a magnitude value: (1) NL, not listed by USCGS; (2) S, too strong; (3) W, too weak; (4) F, too faint; (5) NR, no record. The NR category includes events obscured by noise and events lost during the changing of a record as well as absence of a record for a prolonged period.

The earthquakes listed in the tables are plotted in Figure 1. Also located on the map are the eight shocks from Circular 78 with magnitudes equal to or greater than 2.7.

DISCUSSION

DULCE, NEW MEXICO, EARTHQUAKE

The magnitude 5.5 earthquake that occurred near Dulce, New Mexico, on January 23, 1966, was the strongest shock to occur in New Mexico in 28 years. On September 17, 1938, an earthquake of the same magnitude as the Dulce shock occurred in the Mogollon Mountains (epicenter, 33.2°N, 108.6°W) of southwestern New Mexico (Neumann, 1940). The other region of New Mexico known to have had shocks of magnitude 5.5 or greater is the Rio Grande Valley in the vicinity of Socorro (Sanford, 1963).

The Dulce earthquake was felt over an area of 15,000 square miles in northwestern New Mexico and southwestern Colorado. The maximum intensity of the shock was VII at Dulce where nearly every structure in the town was affected to some extent. The estimate of damage was \$200,000, a fairly large sum if one considers the small size of the town (population about 2000). A detailed account of damage and other effects of the Dulce earthquake is given in the ESSA-USCGS publication *Abstracts of Earthquake Reports, MSA 129, January-March, 1966*. This report gives a good description of the type of damage to expect when, as is likely, shocks of similar magnitude occur elsewhere in the state.

The Dulce earthquake was followed by a prolonged series of aftershocks. These were most numerous in few hours and days following the main shock. However, aftershocks of considerable strength continued to come from this region for nearly a year (table 2). Excluding the latter part of January 1966, aftershock activity was most intense in May and June.

If the main Dulce shock was preceded by foreshocks, these events were below the level of detection at Albuquerque (magnitude less than 2.0). Thus, the earthquake sequence at Dulce can be summarized as a strong main event followed by a series of aftershocks whose strength and numbers generally decreased with time. Although this type of earthquake sequence is the one most often observed in the world as a whole, it is quite different from those

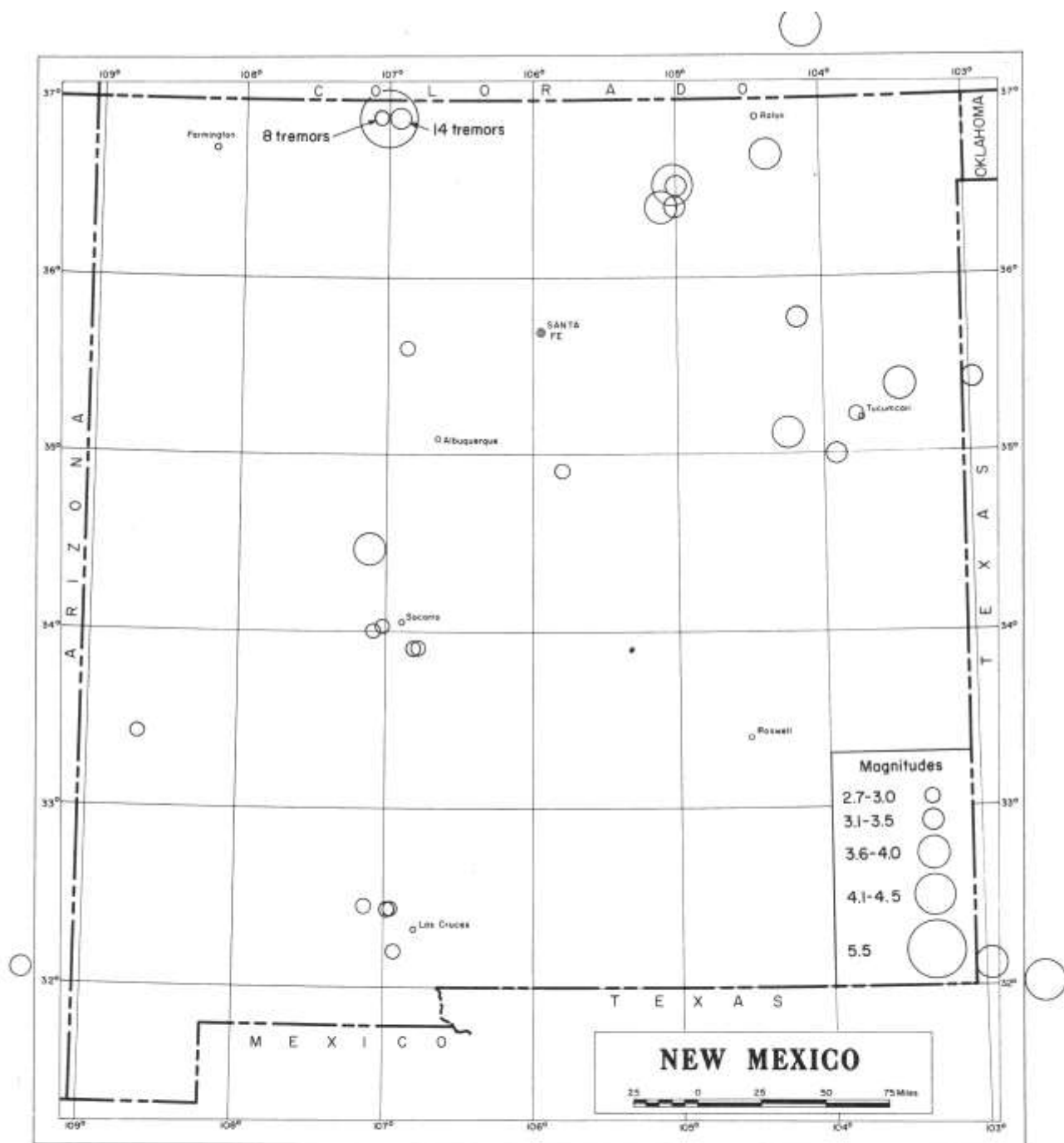


Figure 1
 LOCATIONS OF NEW MEXICO EARTHQUAKES
 with $M \geq 2.7$ for the period 1962 through 1967

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

STATION	LOCATION	LATITUDE (north)	LONGITUDE (west)	ELEVATION (meters)
SNM	Socorro, New Mexico	34°04.2'	106°56.6'	1511
ALQ	Albuquerque, New Mexico	34°56.5'	106° 27.5'	1853
GOL	Golden, Colorado	39°42.0'	105° 22.3'	2359
WMO	Ft. Sill, Oklahoma	34°43.1'	98°35.3'	505
LUB	Lubbock, Texas	33°35.0'	101°52.0'	200
UBO	Vernal, Utah	40°19.3'	109° 34.1'	1596
TFO	Payson, Arizona	34°17.2'	111°16.0'	1609
GCA	Page, Arizona	36°58.4'	111°35.6'	1339
EPT	El Paso, Texas	31°46.3'	106°30.4'	1186
LCN	Las Cruces, New Mexico	32°24.1'	106°36.0'	1580
KNU	Kanab, Utah	37°01.4'	112°49.6'	1740
JR	Jerome, Arizona	34°49.5'	111°59.4'	1310
TUC	Tucson, Arizona	32°18.6'	110°46.8'	985

TABLE 2. DULCE, NEW MEXICO, EARTHQUAKES, JANUARY 23, 1966, THROUGH JANUARY 6, 1967
(Magnitudes greater than or equal to 2.7)

NO.	MO.	DAY	LOCATED BY		ORIGIN TIME			EPICENTER		MAGNITUDE			STATIONS USED
			CGS	NMT	HR.	MIN.	SEC.	LAT. N	LONG. W	CGS	ALQ	SNM	
1966													
1	Jan	23	SB		01	56	38.8	37.0	107.0	5.5	S	S	
2	Jan	23	SB		02	08	35.*	37.0	107.0	NL	2.8	3.6	
3	Jan	23	SB		02	13	13.5	36.9	107.0	NL	2.9	3.4	
4	Jan	23	SB		06	14	15.6	36.9	107.2	4.2	3.2	3.8	
5	Jan	23	SB		11	01	7.1	36.9	107.2	4.3	3.1	3.8	
6	Jan	23	SB		19	43	19.7	36.9	107.1	4.5	3.0	3.8	
7	Jan	23	SB		23	48	08.1	36.9	107.0	4.6	S	S	
8	Jan	24	SB		22	06	50.*	36.9	107.1	NL	2.6	3.5	
9	Jan	25	SB		10	38	05.0	36.8	107.1	4.0	3.1	3.8	
10	Jan	25	SB		15	32	49.*	36.8	107.1	NL	2.7	W	
11	Jan	27	SB		07	48	29.*	36.9	106.9	NL	3.0	3.6	
12	Jan	29	SB		11	21	51.3	37.0	106.9	NL	2.8	3.6	
13	Jan	29	SB		18	38	48.*	37.0	106.9	NL	2.7	3.4	
14	Feb	27	SB		18	07	52.*	36.9	107.0	NL	3.2	NR	
15	Mar	8		X	20	37	14.	37.0	107.0		2.8	3.2	SNM,GOL,UBO,TFO, KNU,ALQ
16	Mar	22		X	04	39	48.	36.9	106.8		2.5	3.1	SNM,GOL,UBO,TFO, KNU,GCA,ALQ
17	Apr	14	SB		15	07	30.*	37.0	107.0	NL	2.7	3.3	
18	May	8	SB		17	23	38.3	36.9	107.0	4.5	2.9	3.6	
19	May	8	SB		17	50	36.8	37.0	106.8	3.9	2.9	3.5	
20	May	9	SB		02	08	54.0	36.9	106.9	4.2	2.5	2.9	
21	May	9	SB		02	57	23.6	37.0	106.9	4.4	2.8	3.4	
22	May	19	SB		00	26	42.2	36.9	107.0	4.1	3.2	3.8	
23	June	1	SB		17	17	12.9	36.9	107.0	NL	2.9	3.5	
24	June	4	SB		10	29	39.0	36.9	107.0	4.0	3.2	3.7	
25	June	21	SB		05	24	38.2	36.9	107.0	4.2	2.8	NR	
26	July	24	SB		02	48	50.*	36.9	107.0	3.4	2.6	NR	
1967													
27	Jan	6	PDE		15	41	15.6	36.9	107.0	4.3	NR	NR	

* Indicates epicenter determined from incomplete or less reliable data.

TABLE 3. NEW MEXICO EARTHQUAKES, JULY 1 , 1964, THROUGH DECEMBER 31,1967
(Exclusive of shocks listed in Table 2; magnitudes greater than or equal to 2.7)

NO.	MO.	DAY	LOCATED BY		ORIGIN TIME			EPICENTER		MAGNITUDE			STATIONS USED
			CGS	NMT	HR.	MIN.	SEC.	LAT. N	LONG. W	CGS	ALQ	SNM	
1965													
1	Feb	3		X	11	32	35	35.4	103.4		3.6	4.2	SNM,LUB,GOL,WMO, TFO,UBO,ALQ
2	Feb	3		X	19	59	32	321	103.0		4.1	3.8	SNM,LUB,WMO,UBO, LCN,EPT,ALQ
3	Apr	10		X	07	00	55	34.0	107.1		2.7	S	SNM,ALQ
4	July	28		X	03	52	06	339	106.8		3.0	S	SNM,JR,WMO,LUB,ALQ
5	July	28		X	04	38	53	339	106.8		2.7	S	SNM,JR,ALQ
6	Dec	29		X	00	50	24	34.6	105.8		2.6	3.1	SNM,LUB,UBO,ALQ
1966													
7	Apr	21		X	14	14	12	35.4	103.0		3.4	3.8	SNM,GOL,LUB,WMO, TFO,UBO,ALQ
8	Aug	14	SB		15	25	52.5	32.0	102.6	3.4	4.2	4.5	
9	Sep	17		X	09	25	21	321	109.4			3.2	3.4
10	Sep	17		X	21	30	15	35.0	103.9		F	3.6	SNM,ALQ,GOL,LUB, UBO,EPT
11	Sep	24	SB		07	33	46.4	36.5	105.0	3.8	F	S	
12	Sep	24	SB		08	27	10*	365	105.0	3.4	F	3.6	
13	Sep	25	SB		10	10	41*	36.4	105.1	3.8	F	S	
14	Sep	25	SB		12	22	40.5	36.5	105.1	3.6	F	3.7	
15	Oct	3	PDE		02	26	01.9	37.4	104.1	4.5	F	S	
16	Oct	6		X	06	29	53	35.8	104.2			3.1	3.8
1967													
17	Jan	16		X	18	14	36	34.5	107.1		NR	St	SNM,TFO,UBO,ALQ
or													
18	July	29		X	05	49	39	34.3 33.6	106.4 108.7		NR	3.0	SNM,TFO,UBO,ALQ
19	Sep	29		X	03	52	46	32.2	107.0		NR	3.2	SNM,TFO,UBO,WMO, LCN,EPT,ALQ,

* Indicates epicenter determined from incomplete or less reliable data. f Greater than 3.6 on basis of amplitudes at distant stations.

associated with strong shocks at Socorro in 1906 and Mogollon Mountain in 1938. The main shocks of the latter sequences were preceded by a considerable amount of seismic activity. For the Socorro earthquakes of 1906, ten days of minor seismic activity preceded the first of three strong shocks. The strongest shock of the entire sequence did not occur until about four months after the beginning of seismic activity. For the Mogollon Mountain earthquakes, the main shock appeared to have been preceded by about a month of minor seismic activity (Neumann, 1940).

The fact that the Dulce earthquake sequence differs from those at Socorro and Mogollon Mountain may be related to differences in geologic structure between these regions. The Socorro and Mogollon Mountain areas lie in regions in which complex graben structures have developed in very recent geologic times (Robert H. Weber, personal communication). On the other hand, the principal structural feature of the Dulce region is a northwest-trending line of anticlines and domes, probably of late Eocene age, modified by steep faulting, probably of very late Miocene age (Dane, 1948).

SEISMIC ACTIVITY, ALL OF NEW MEXICO

The pattern of seismic activity from mid-1964 through 1967 was similar in most respects to the previous 2 1/2 years. The strongest shocks, with the exception of Dulce, originated in the northeastern quadrant of the state. Noninstrumental studies of seismic activity prior to 1960 indicate very few shocks from this region. However, because the population over much of the northeastern section is low, significant activity could have gone unreported.

Even instrumental studies may have failed to detect all the weaker shocks from the northeastern part of the state. Notice on Figure 1 that only one shock with magnitude from 2.7 to 3.0 has been located in this region. Normally weak earthquakes are more numerous than strong earthquakes, so the expected number of shocks with magnitude 2.7 to 3.0 is much greater than that observed. At Socorro, the maximum trace amplitude on a seismogram for a 2.8 earthquake located in the northeast corner of the state is only a few millimeters. Such events could be overlooked in routine analysis of the records.

Some earthquakes that have epicenters outside New Mexico have been included in Table 3 and Figure 1. These events were listed because their locations are sufficiently uncertain that they could have occurred in New Mexico. Among the shocks that lie just outside New Mexico's

borders, the two most interesting are numbers 2 and 8 in Table 3. These earthquakes lie very close to the southeastern corner of the state, a region that apparently has not had any sort of seismic activity in the past.

Two additional shocks that may rate special attention are numbers 4 and 5 in Table 3. These two earthquakes occurred 28 kilometers southeast of Socorro in the same area that experienced a remarkable earthquake swarm two months before. Between 18:00 GMT May 26 and 11:00 GMT June 4, the Socorro station recorded 209 earthquakes from this area, 136 within the first 24 hours. Despite the large number of shocks, no single event during the swarm exceeded magnitude 2.6. The total number of shocks on July 28, the day of the two shocks listed in Table 3, was only 4.

MAGNITUDES

The magnitudes of Dulce aftershocks computed on the basis of maximum S-phase amplitudes at Socorro and Albuquerque are significantly smaller than USCGS magnitudes, which are based on P-wave amplitudes. The discrepancy may arise from the radiation pattern of the Dulce shocks; that is, Socorro and Albuquerque may lie close to the nodal plane for no S-wave radiation. Because the Albuquerque magnitudes are consistently less than the Socorro magnitudes, the nodal plane would lie east of the Albuquerque station.

A comparison of the Dulce aftershock magnitudes indicates a more consistent difference between those of Albuquerque and Socorro than between those of Albuquerque and USCGS. The average difference between Albuquerque and Socorro magnitudes was 0.63, with a standard deviation of only 0.13. On the other hand, the difference between Albuquerque and USCGS magnitudes was 1.2, with a standard deviation of 0.33. These numbers suggest that the data used to calculate the USCGS magnitudes did not come from the same distribution of stations for all aftershocks.

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