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Seismicity in the Basin and Range province of Texas and northeastern Chihuahua, Mexico

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SEISMICITY IN THE BASIN AND RANGE PROVINCE OF TEXAS AND NORTHEASTERN CHIHUAHUA, MEXICO*

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INTRODUCTION

A four-year seismic study begun in January, 1976 has found the Basin and Range Province of West Texas and the adjacent areas of Mexico to be more seismically active than heretofore known. A five-station University of Texas seismic array covering the eastern and western sides of the Marfa Basin (table 1, fig. 1) has located or detected approximately 300 local and regional earthquakes (m_ℓ<3.7) with a S-P time of less than 30 seconds. None of these local earthquakes has been located by U.S. Geological Survey instruments. Areas of detectable seismicity include the Van Horn area, the Marfa Basin (particularly the eastern side), and the Texas–Mexico border between latitude 30° and 31°N. The seismic pattern in the eastern side of the Marfa Basin forms a diffuse zone and is believed to represent an active fault, still unmapped. Seismicity along the eastern side of the Marfa Basin coincides with Muehlberger's (1978) proposed eastern boundary of Basin and Range faulting.

Hypocenter locations reported here were obtainnd by using the computer program HYPO 71 (Lee and Lahr, 1975) with P-wave arrival times and, whenever possible, S-wave arrivals. The crustal model used to locate these earthquakes comprises three layers having velocities of 4.49, 6.18 and 6.75 km/sec, respectively, overlying a 8.37 km/sec half-space (Dumas, in preparation).

SEISMICITY OF THE VAN HORN AREA

The extensive mining and blasting west of Van Horn pose a problem in determining the seismicity of that area. The quarries are located in an area characterized by numerous thrusts, normal and strike-slip faults striking northwestward (King, 1935). As the dates and times of the blasts could not be obtained, all located events (natural or artificial) have been plotted in Figure 1. However, it is known that most of the blasts occurred between 2130 and 2400 (GMT). While it is uncertain as to the fraction of the located events that are natural, not all the located events are blasts. A few events have been tentatively identified as earthquakes; whether these events were triggered by the mining operation is still undetermined.

Southwest of Van Horn and east of station EM, a few events have been located and identified as earthquakes. These events may indicate a northern active branch of the Rim Rock fault, which may be part of the western boundary of the Salt Basin Graben. The first event ever located instrumentally in the Van Horn area occurred on March 6, 1962, at 31.2°N and 104.8°W (Sanford and Toppozada, 1974).

SEISMICITY IN THE MARFA BASIN

The area north to northwest of Valentine, Texas, is the most active in the Basin and Range Province of West Texas. This is the northern end of a diffuse zone of seismic activity striking northwestward, which must indicate an active fault or faults (referred to as the Valentine fault or fault zone); however, geologic field evidence of faulting is lacking. Such evidence would likely be obscured by the thick alluvium in the Marfa Basin.

A revised epicenter for the magnitude 6.4 Texas earthquake of 1931 is located at 30.69°N and 104.57°W, near the northern end of this active zone. An analysis of the first-motion data suggests that the 1931 earthquake was caused by motion on a right-lateral strike-slip fault, striking N59°W and dipping 70°NE (Dumas and others, in press).

To our knowledge, the latest earthquake felt by local residents in the Valentine area occurred on August 1, 1975, only a few days before the installation of the first network station MOT.

The largest event we have detected instrumentally in the Marfa Basin occurred on July 18, 1978, along this zone of earthquakes. The epicenter of that event was 30.25°N and 104.55°W, and its magnitude (m_ℓ) was 2.6. The epicenter was obtained from the S-P time at MOT and by wave-form comparison with other events located in the Marfa Basin (Nakamura, 1978). The earthquake was preceded by at least 28 foreshocks with magnitudes between 0.3 and 2.1. The total duration of this sequence, from the first detectable shock to the main event, was five days. Following the 2.6 m_ℓ main shock, no aftershocks were detected.

In the western side of the Marfa Basin the seismicity is lower than in the eastern side, three events have been located between stations MR and BR. They are probably associated with the southern section of the Rim Rock Fault system. Figures 2 and 3 show suites of seismograms for events located in the Basin and Range province.

SEISMICITY ALONG THE TEXAS–MEXICO BORDER

The epicenters plotted in Figure 1 for this area are accurate to within 8 km, even though they lie outside the array. The largest

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Table 1. Station names, coordinates, elevation, and station corrections.

	Station	Lat.	Long.	Elev. (m)	Corr.
MOT	McDonald Observatory	30.68N	104.01W	2080	0.10
BP	(MT1) Boracho Peak	30.93N	104.39W	1720	-0.03
EM	(MT2) Eagle Mountain	30.90N	105.08W	2088	0.10
MR	(MT3) Miller Ranch	30.53N	104.67W	1584	0.06
BR	(MT4) Brite Ranch	30.27N	104.58W	1584	-0.13

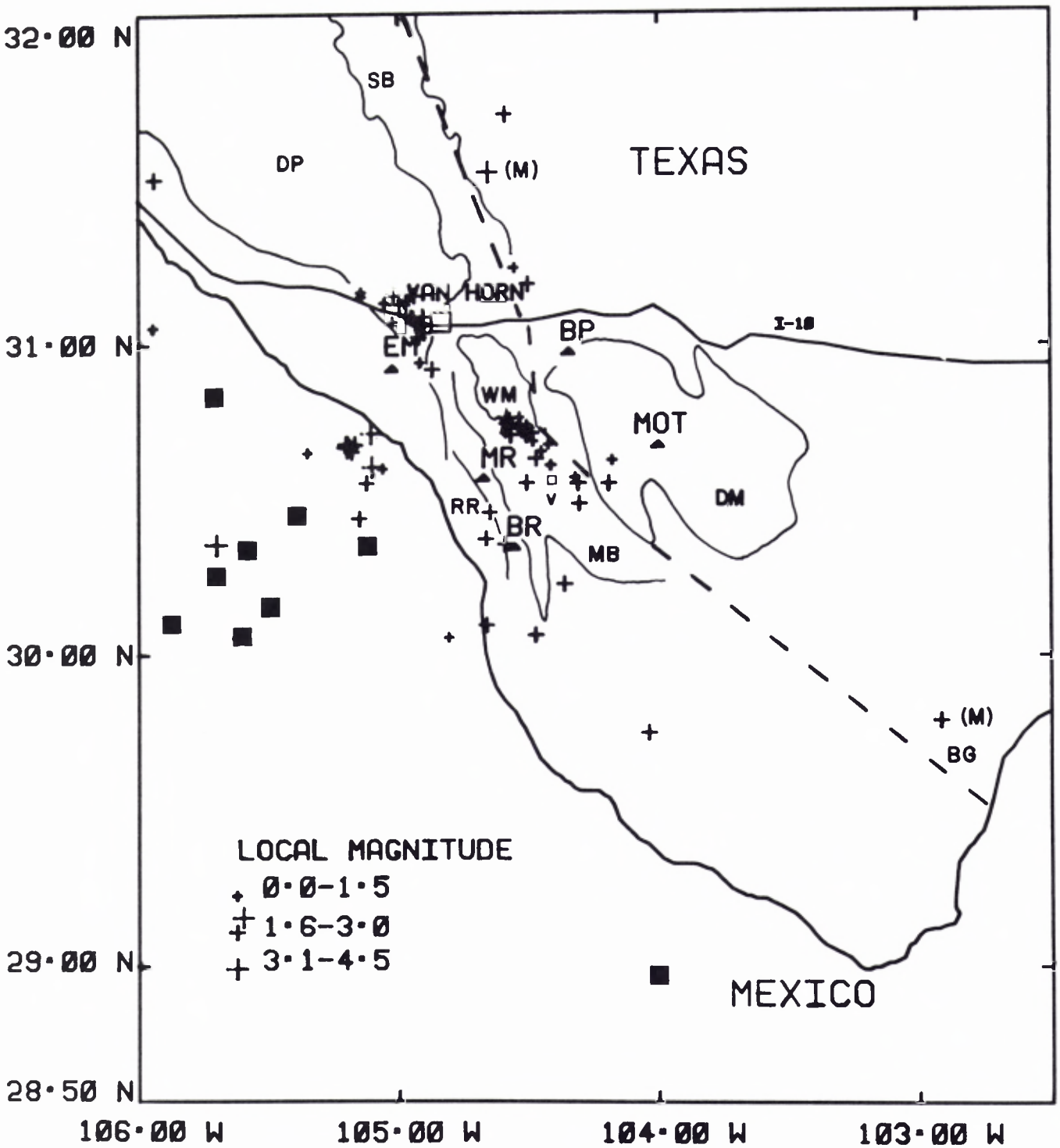


Figure 1. Seismicity map of the Basin and Range Province and the adjacent area of Mexico. Crosses (+) indicate epicenters located by the five-station seismic array. The stations are indicated by triangles (▲) and locations and abbreviations are given in Table 1. Pre-1975 epicenters located by the USGS are indicated by solid squares (■). Abbreviations for structural features are: BG–Black Gap Area, DM–Davis Mountains, DP–Diablo Plateau, MB–Marfa Basin, RR–Rim Rock Fault, SB–Salt Basin graben, and WM–Wylie Mountains. The dashed line marks Muehlberger's (1979) proposed eastern boundary of Basin and Range faulting. Multiple earthquakes with the same epicenter are indicated by (M). The town of Valentine (V) is indicated by the small open square (□).

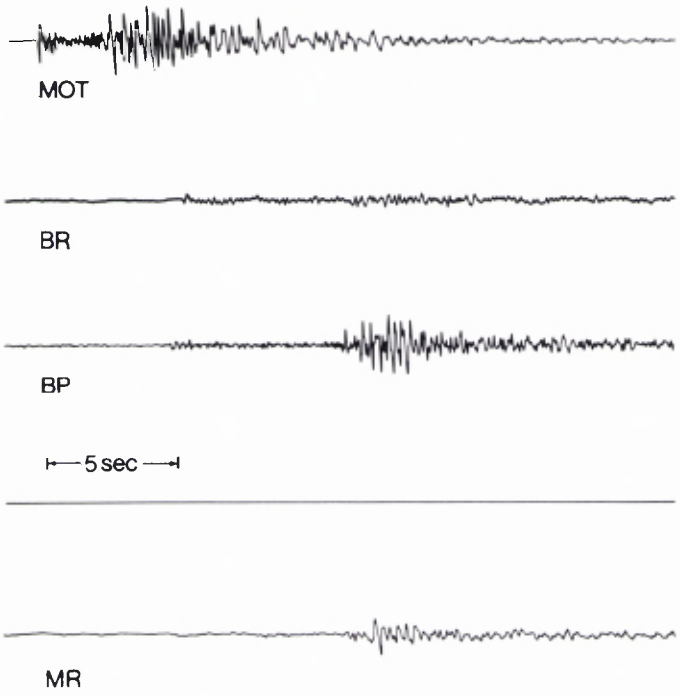


Figure 2. Seismograms of an event located in the eastern side of the Marfa Basin along the Valentine fault. This event occurred on July 25, 1979 and had a magnitude (m_Q) of 1.1 (see Appendix). Station abbreviations are as in Table 1.

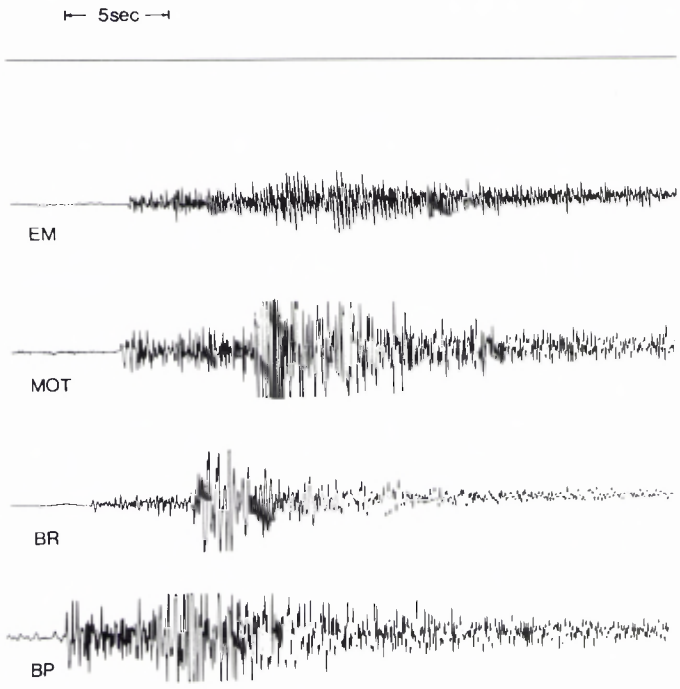


Figure 3. Seismograms of an event located in the eastern side of the Marfa Basin along the Valentine fault. This event occurred on May 30, 1978 and had a magnitude (m_Q) of 2.2 (see Appendix). Station abbreviations are as in Table 1.

earthquake detected in the area by our array had a magnitude (m_Q) of 3.6. The earthquakes shown for the Texas–Mexico area in Figure 1 (the solid squares indicate larger pre-1975 events located by the USGS over a longer time period), indicate a north-south seismic trend that is probably associated with the Sierra Blanca Range and a northeasterly trend that is approximately perpendicular to the strike of the local geology in northeastern Chihuahua.

Seismic activity has also been detected along the eastern boundary of the Salt Basin graben (SB) and in the region just north of Black Gap (BG, fig. 1). For these and other areas outside the network, the threshold of detectability is larger than for the area within. Thus, five events located on or near the eastern boundary of the Salt Basin graben may represent more activity along this trend than Figure 1 indicates.

Seismograms from three earthquakes located in the Black Gap area have identical waveforms. In an area that is as structurally complex as the Basin and Range Province, this could occur only if the ray paths and hypocenters are nearly the same for all three events—*i.e.*, if the hypocenters are within a fraction of a wave length or approximately 1 km of each other (Nakamura, 1978).

Not all events recorded by the network are plotted in Figure 1. Of the total number of earthquakes detected at MOT, 10 percent (approximately 50 earthquakes) were detected at one or two remote stations. Earthquakes with S-P times between 1 and 3 sec and magnitudes less than 0.3 were detected only at the BR Station. These events, thus, are located between 88 and 25 km from the BR station and are probably associated with the southern section of the Rim Rock fault. Likewise, numerous events with S-P times less than 2.5 sec (epicentral distance less than 20 km) were detected only at station MOT; however, because of the numerous faults in the Davis Mountains these events were not assigned to a particular fault.

Numerous events with hypocenters located in northern Mexico were also recorded; however, the errors in epicenter location are quite large and these events were not plotted in Figure 1. None of these Mexican events were located or detected by local or regional WWSSN stations (Waverly Person, USGS, personal communication).

All located events are listed in the Appendix. The error associated with the focal depth calculated from times of first arrivals is inherently large. Nevertheless, all earthquakes located in this region appear to be shallow crustal events.

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APPENDIX

A list of all earthquakes located by the UT/NASA seismic array.

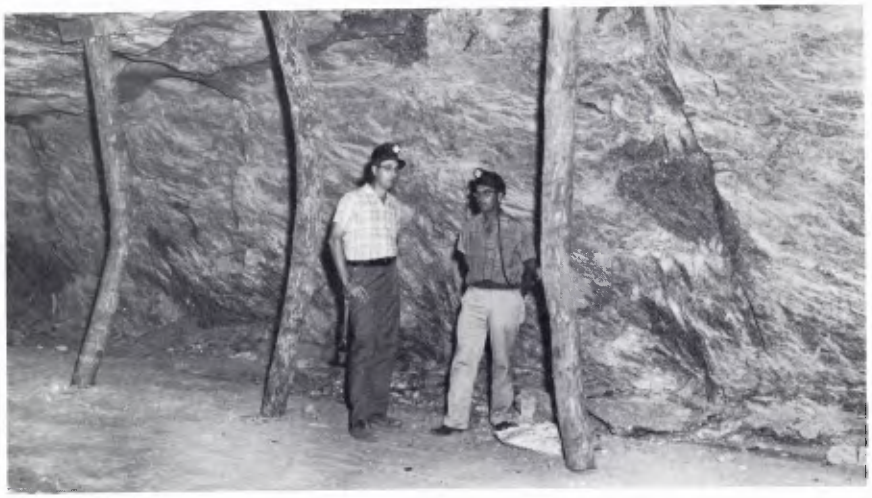
Selected Headings	*Explanation*
mag	Duration magnitude.
no	Number of station readings used to locate earthquakes.
gap	Largest azimuthal separation between stations in degrees.
dmin	Epicentral distance in km to the nearest station.
rms	Root mean square error of time residuals, in seconds.
erh	Standard error of the epicentral location, in km.
erz	Standard error of the focal depth, in km.
q	Solution quality of hypocenter (Lee and Lahr, 1975).
*	Depth held fixed at 4 km.

date	hr	min	sec	lat n	long w	depth	mag	no	dmin	gap	rms	erh	erz	q
JUL 11 77	17	19	37.61	30-58.80	104-53.80	4.00*	2.0	8	20	213	0.37	13.7	15.2	D
11	20	15	29.54	31- 4.22	105- 0.64	3.64	1.3	7	20	265	0.73	14.9	10.9	D
12	19	14	24.07	31- 1.00	105- 1.00	20.45	1.5	5	14	254	0.22	7.0	5.3	D
16	17	47	31.30	29-44.74	105-33.70	1.44	1.9	9	110	321	0.91	14.2	9.7	D
28	12	17	17.81	31- 6.00	105- 1.00	4.00*	1.9	8	23	274	0.94	21.2	14.3	D
28	23	35	43.11	31- 0.27	104-54.55	4.00*	1.8	7	20	225	0.21	19.5	19.6	D
30	16	17	15.98	31- 1.00	104-54.80	2.00	1.5	8	21	230	1.28	70.3	72.6	D
AUG 1	16	44	51.10	30-58.00	104-55.09	4.00*	1.8	7	17	210	1.23	44.0	50.2	D
3	16	22	47.18	30-53.00	104-54.91	4.00*	1.6	8	16	167	1.57	26.2	41.9	D
7	19	28	47.96	31- 4.58	105- 3.00	13.00	1.5	7	20	276	0.51	6.5	19.2	D
8	20	43	59.68	31- 2.15	104-57.85	9.75	2.0	9	19	246	0.60	13.6	8.7	D
9	16	07	0.35	31- 2.52	104-39.12	4.00*	1.9	6	57	301	0.19	12.0	11.5	D
21	3	1	8.21	30-33.07	105- 5.67	21.56	3.3	9	41	270	0.99	24.7	11.2	D
OCT 29	0	49	11.56	30-30.00	104-11.26	4.00*	1.9	10	27	195	0.77	8.8	9.8	D
NOV 5	12	28	53.72	31- 5.09	104-58.15	8.28	1.9	5	23	260	0.75			D
JAN 24 78	1	17	2.36	31-30.06	104-39.15	2.46	3.2	4	68	190	0.03			C
FEB 18	14	22	7.98	30-37.15	105-11.66	2.00	2.0	6	33	278	0.32	3.4	3.0	D
18	14	22	22.10	30-39.43	105- 6.00	1.12	3.6	4	27	255	0.04			C
18	14	29	20.33	30-37.35	105- 9.72	2.50	2.5	8	32	272	0.28	3.0	1.4	D
18	15	29	36.96	30-36.00	105-10.84	2.00	1.9	6	35	277	0.37	6.7	5.5	D
18	16	44	4.73	30-36.85	105-11.46	2.00	1.8	6	33	278	0.30	5.8	4.9	D
18	17	30	8.47	30-36.84	105-11.49	0.40	2.9	8	33	278	0.31	3.2	1.6	D
18	17	54	9.77	30-36.74	105-11.45	0.32	2.3	8	34	278	0.28	2.9	1.4	D
18	18	45	16.54	30-37.45	105-11.92	2.00	2.1	8	33	279	0.34	6.8	5.4	D
19	7	5	18.70	30-36.89	105-11.00	2.00	1.9	7	33	277	0.32	10.2	8.9	D
19	12	11	59.99	30-36.85	105-11.68	0.69	2.9	8	34	279	0.35	3.6	1.7	D
20	2	52	55.45	30-37.33	105-11.89	2.00	1.9	8	33	279	0.32	5.9	4.9	D
MAR 21	0	14	10.61	30-26.00	104-18.00	2.00	1.7	5	37	241	0.45	0.2	0.1	D
APR 6	9	13	27.45	30-51.68	104-51.75	4.00*	2.0	6	41	287	0.15	7.1	5.3	D
12	23	5	0.01	30-39.52	104-29.07	2.27	1.9	5	23	145	0.55	0.3	4.8	D
MAY 30	13	19	31.70	30-39.14	104-33.77	10.70	2.2	8	35	117	0.69	3.8		D
JUN 3	11	40	18.24	30-24.23	104-38.63	2.73	2.4	6	16	165	0.22	4.0	5.3	C
6	20	5	0.08	30-18.00	104-35.00	18.94	2.2	4	3	150	1.02			D
JUL 18				30-30.00	104-33.00		2.6							
AUG 28	20	33	38.35	31- 1.81	104-56.74	9.26	1.7	7	19	240	0.38	11.7	7.4	D
SEP 2	7	16	45.35	30-40.14	104-31.85	12.52	1.2	8	21	97	0.60	3.6	27.8	C
29	17	59	41.38	30-19.10	104-39.41	2.00	2.2	4	9	231	0.95			D

date	hr	min	sec	lat n	long w	depth	mag	no	dmin	gap	rms	erh	erz	q
DEC 20	1	3	21.78	30-37.97	104-28.69	6.35	1.0	6	22	155	0.52	6.8	6.6	D
JAN 11 79	3	49	9.86	30-33.44	104-24.62	5.87	1.0	6	25	192	0.29	1.9	2.4	C
15	0	36	35.81	30-35.81	105-21.04	8.26	1.5	9	42	282	0.31	9.8	11.3	D
19	9	7	55.15	30-30.00	105- 7.14	2.40	1.8	8	43	249	0.29	3.2	1.8	D
FEB 13	19	3	13.43	30-10.29	104-21.47	1.80	1.8	6	50	292	0.61	7.4	7.2	D
16	23	50	32.50	31- 1.96	104-54.00	7.77	2.0	6	50	305	0.16	17.4	16.5	D
MAR 17	19	49	2.36	30-39.54	104-35.02	16.53	1.1	6	17	182	0.52	9.5	16.8	D
24	14	55	36.52	30-31.07	104-19.92	8.40	1.1	7	32	161	0.48	0.9	1.7	C
28	5	51	35.41	29-41.64	104- 2.21	2.00	1.8	7	83	319	0.15	19.5	20.3	D
28	14	57	18.46	30-38.76	104-30.22	8.64	1.3	8	20	148	0.59	4.2	3.4	D
29	13	52	29.17	30-40.84	104-32.26	9.03	1.3	8	21	170	0.54	4.8	3.5	D
29	9	35	40.91	29-35.47	102-55.05	4.00*	2.5	8	160	336	0.54			D
JUN 9	1	28	59.12	30-39.12	104-30.14	9.38	1.9	7	21	149	0.38	3.6	2.8	C
10	10	47	49.47	30-30.00	104-18.28	4.00*	1.7	8	35	171	0.64	3.7	4.4	D
17	17	37	30.33	30-40.48	104-31.71	11.31	1.7	6	31	199	0.13	1.2	36.4	D
21	10	32	3.46	30-36.06	104-26.68	0.40	1.2	8	23	121	0.62	1.1		D
22	5	58	15.97	30-34.66	104-28.06	5.43	1.7	7	20	122	0.35	2.6	3.8	C
25	17	23	36.81	30-34.41	104-10.54	7.18	1.1	8	20	175	0.43	6.6	6.9	D
28	3	37	9.40	31-11.41	104-33.10	20.67	1.5	6	33	316	0.07	1.5	1.7	C
28	19	22	45.41	30-23.06	105- 8.84	2.00	1.9	5	56	307	0.25	2.4		D
JUL 10	21	30	27.21	30-40.40	104-29.53	10.99	0.9	6	30	188	0.25	2.4		D
10	21	46	15.80	30-42.48	104-31.92	11.99	0.9	6	28	203	0.65	1.8	32.5	D
10	22	2	22.43	30-40.10	104-29.83	8.03	0.9	6	31	189	0.53	0.5	0.8	D
10	3	7	56.01	30-37.37	104-25.16	2.36	0.7	6	34	163	0.95	0.5	15.2	D
AUG 4	21	31	8.18	30-50.13	104-13.91	4.00*	1.0	8	18	184	1.07	40.5	31.7	D
FEB 5 80	23	56	56.82	30- 0.50	104-28.01	26.02	2.1	8	31	298	0.16	2.4	2.1	C



Fluffgrass plant, *Erioneuron pulchellum*.



C. L. Jones, geologist, Mineral Deposits Branch, and C. M. McConnell, mining engineer, Mining Branch, U. S. Geological Survey, studying a problem of subsidence in a U. S. Potash Company mine on federally owned land near Carlsbad. Eddy County, New Mexico, 1957. Patterson photo.



R. S. Fulton, regional mining supervisor, and C. M. McConnell, mining engineer, U. S. Geological Survey, watch loading operations deep within the Duval Sulphur and Potash Company mine near Carlsbad, Eddy County, New Mexico, 1957. Patterson photo.



Capitol Peak, San Andres Mountains from the east. Granite capped by Bliss sandstone, El Paso and Montoya limestones. Peak of Magdalena limestone. Tularosa quadrangle, Socorro County, New Mexico, October 11, 1917. N. H. Darton photo.