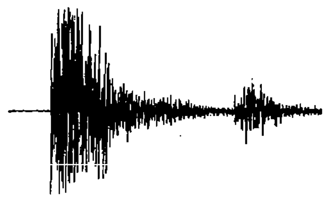
OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, *Director*

OKLAHOMA EARTHQUAKE CATALOG



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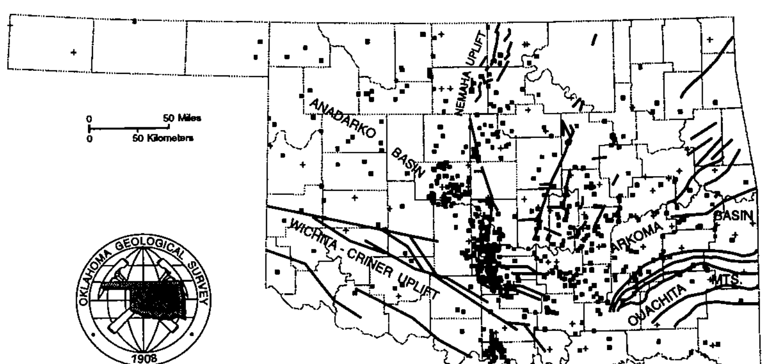

(Text to accompany MAP GM-35)

The University of Oklahoma
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1995

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OKLAHOMA EARTHQUAKE CATALOG

James E. Lawson, Jr., and Kenneth V. Luza

INTRODUCTION

More than 930,000 earthquakes occur throughout the world each year (Tarbuck and Lutgens, 1990). Approximately 95% of these earthquakes have a magnitude of <2.5 and usually are not felt by humans. Only 20 earthquakes, on average, exceed a magnitude 7.0 each year. An earthquake that exceeds a magnitude 7.0 is considered to be a major earthquake and serious damage could result.

Earthquakes tend to occur in belts or zones. For example, narrow belts of earthquake epicenters coincide with oceanic ridges where plates separate, such as in the mid-Atlantic and east Pacific Oceans. Earthquakes also occur where plates collide and/or slide past each other. Although most earthquakes originate at plate boundaries, a small percentage occur within plates. The New Madrid earthquakes of 1811–12 are examples of large and destructive intraplate earthquakes in the United States.

The New Madrid earthquakes of 1811 and 1812 are probably the earliest historical earthquake tremors felt in Oklahoma (Arkansas Territory) by residents in southeastern Oklahoma settlements. An earthquake that occurred on October 22, 1882, was reported felt over northeastern Texas, Oklahoma, Arkansas, Kansas, and Missouri. This earthquake produced Modified Mercalli (MM)-VIII intensity effects near Fort Gibson, Oklahoma (Cherokee Advocate, October 27, 1882; Indian-Pioneer Papers, p. 167). Carlson (1984) reevaluated the felt-report information and relocated the epicenter from Paris, Texas, to southeastern Oklahoma. However, the limited number of felt reports in Oklahoma and nearby states makes the location indeterminate. The earliest documented earthquake in Oklahoma occurred near Jefferson, Grant County, on December 2, 1897 (Stover and others, 1981). The next oldest known Oklahoma earthquake happened near Cushing in December 1900. This event was followed by two additional earthquakes in the same area in April 1901 (Wells, 1975).

The accompanying earthquake map of Oklahoma and catalog show the location of earthquake epicenters and their corresponding intensity values arranged into four time-period intervals. The beginning of each new time period represents a major change in seismic instrumentation, which resulted in improved earthquake detection and location accuracy. The map is intended for use as a guide to earthquake intensity and epicentral locations. The epicentral locations are based on data that may vary greatly in accuracy, particularly regarding earthquakes that occurred prior to 1960.

GLOSSARY OF EARTHQUAKE NOMENCLATURE

aftershock: An earthquake that follows a larger earthquake and originates at or near the focus of the larger earthquake.

coda: The later part of an earthquake recording on a seismogram following the early, identifiable surface waves.

earthquake: Shaking and/or vibrations of the Earth caused by the sudden displacement of rocks below the Earth's surface.

epicenter: Point on the Earth's surface directly above the earthquake source (focus).

fault: A break within the Earth's crust along which rock surfaces have moved past each other.

focal depth: The distance from the Earth's surface to the earthquake origin.

great-circle distance: The shortest distance measured on a sphere, such as the Earth's surface, between any two points.

hertz (Hz): A unit of frequency equal to one cycle per second.

hypocenter: A point within the Earth where the center of the earthquake originates; also focus.

intensity (of an earthquake): Numerical scale devised to relate observable effects to earthquake size; the Modified Mercalli intensity scale of 1931 is the most commonly used scale in the United States.

magnitude: Measurement of energy released by an earthquake. Several magnitude scales have been devised to make energy determinations; one of the better known is Richter magnitude.

nanometer: One billionth of a meter.

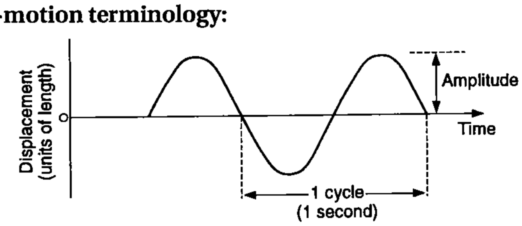
P wave: A longitudinal body wave or compressional wave produced by an earthquake (see Appendix 1, page 23).

S wave: A transverse body wave or shear wave produced by an earthquake (see Appendix 1, page 23).

seismogram: The record made by a seismograph.

seismograph: An instrument that records vibrations of the Earth, especially earthquakes.

wave-motion terminology:



This particular wave completes one cycle in 1 second; it has a period of 1 second and a frequency of one cycle per second or 1 hertz. Most earthquake phases resemble sine waves.

TECTONIC SETTING

Oklahoma is situated near the southern end of a geologic region referred to as the Stable Central Province (King, 1951; Hadley and Devine, 1974). This province, covering >2.5 million km², extends westward from the Appalachians to the eastern edge of the Rocky Mountains and from the Gulf Coastal Plain to south-central Canada.

The geologic and tectonic record in Oklahoma is mainly characterized by marine sedimentation which was terminated by episodes of uplift, gentle folding, and erosion, which, in turn, were followed by renewed sedimentation occurring on the unconformable surfaces (Ham and Wilson, 1967). The three principal mountain belts in Oklahoma are the Ouachita, Arbuckle, and Wichita Mountains (Fig. 1). These were the sites of folding, faulting, and uplift during the Pennsylvanian and Early Permian Periods. In addition to exposing a great variety of structures, these fold belts brought to the surface igneous rocks in the Arbuckle and Wichita Mountain areas and exposed thick sequences of folded and faulted Paleozoic sedimentary rocks in the Ouachita Mountains. Principal sites of sedimentation were in elongated basins that subsided more rapidly than adjacent areas and received sediments 3,000–12,000 m thick. The major sedimentary basins were confined to the southern half of the State and include the Anadarko, Arkoma, Ardmore, Marietta, and Hollis basins and also the Ouachita basin at the site of the present Ouachita Mountains. The Nemaha uplift, a prominent feature in central Oklahoma, is a long north-south structure that extends northward from central Oklahoma through Kansas and into Nebraska. The Oklahoma portion of the uplift is 16–32 km wide and nearly 240 km long. The Nemaha uplift, which developed mainly during the Pennsylvanian, consists of small crustal blocks that were raised sharply along the axis of the uplift. Uplifted crustal blocks that make up the Nemaha uplift are typically 5–8 km wide and 8–32 km long and are bounded by faults on the east and/or west sides of the Nemaha structures.

There has been little tectonic activity in the Stable Central Province since Late Pennsylvanian time. The historical record of seismicity in the region has been limited, with a notable exception in the area of New Madrid, Missouri, and adjacent regions in Kentucky, Tennessee, and Illinois.

EARTHQUAKE INVENTORY

Seismographs are instruments designed and operated to record earthquake waves. Prior to about 1950, the few seismographs that operated in states adjacent to Oklahoma were not sensitive enough to detect most earthquakes occurring in the State. Only written records of humans having felt earthquakes were available. These records were usually in local newspapers only. Some of the larger earthquakes felt were listed in the "Seismological Notes" column of the bimonthly bulletin of the Seismological Society of America. A more complete listing appeared, beginning about 1929, in the annual publication *United States Earthquakes*.

Seismographs were first operated in Oklahoma in 1961 at the Jersey Production Research Co.'s (now Exxon) Leonard Earth Sciences Observatory in south-

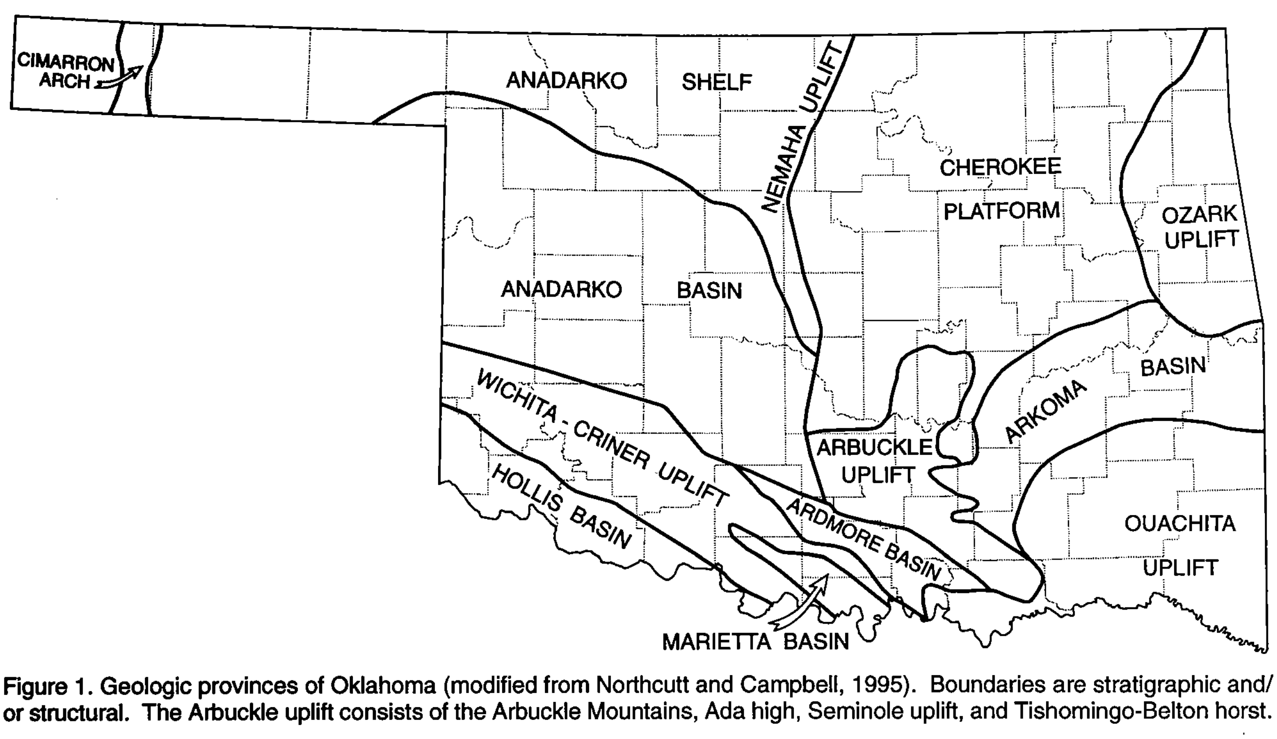


Figure 1. Geologic provinces of Oklahoma (modified from Northcutt and Campbell, 1995). Boundaries are stratigraphic and/or structural. The Arbuckle uplift consists of the Arbuckle Mountains, Ada high, Seminole uplift, and Tishomingo-Belton horst.

ern Tulsa County and at the U.S. Air Force Advanced Research Projects Agency's Wichita Mountains Seismological Observatory in Comanche County. The Leonard Earth Sciences Observatory was designated by the abbreviation TUL from 1961 up to and including its current operation by the Oklahoma Geological Survey. The Air Force installation in Comanche County, designated by the abbreviation WMO, has, for several reasons, played little part in studying local earthquakes. It was designed and operated primarily to detect and distinguish between distant earthquakes and distant underground nuclear tests. WMO closed in 1968 after several years of sharply curtailed activity. Both WMO and TUL seismographs made excellent recordings of P waves from distant earthquakes, but they partially filtered out high-frequency waves characteristic of nearby earthquakes.

Eysteinn Tryggvason, formerly an earthquake seismologist at the University of Tulsa, acted as a consultant to Jersey Production Research in interpreting TUL seismograms. In 1964, he compiled historical information on Oklahoma earthquakes, primarily from *United States Earthquakes* and Kalb (1964). This study led to the development of a formula used to assign a local Richter magnitude (ML) to some of the historical earthquakes based on the size of the area in which they were felt. Tryggvason also searched the TUL short-period seismic records of January 1962 through September 1963 and found 10 Oklahoma earthquakes and nine events which he classified as "natural or artificial (construction and quarry blasts) earthquakes" (Eysteinn Tryggvason, personal communication, 1964). The seismograms from WMO and seismograph stations in other states were used to make location determinations of the 19 events. TUL-seismogram trace amplitudes also were used to determine approximate local Richter magnitudes (ML).

Jerry Docekal (1970), for his Ph.D. dissertation at the University of Nebraska, made an extensive study of earthquakes of the Midcontinent, which included local newspaper accounts of Oklahoma earthquakes. Docekal located more details of felt effects of many Oklahoma shocks. A program was established in 1970 to reduce information on Oklahoma earthquakes to a standard 80-column computer format with the intention of keypunching the information about each earthquake onto one 80-column computer card. The TUL short-period (SP) seismograms were searched for regional events (Oklahoma and vicinity). Of the few that were found, some were located with the aid of arrival times at other stations such as FAV (Fayetteville, Arkansas), LUB (Lubbock, Texas), GOL (Golden, Colorado), and ALQ (Albuquerque, New Mexico). Others were located using the TUL records alone; the distance to the epicenter was determined by the interval between S and P phases and the direction of movement by the ratio of north-south and east-west motion of the S waves. This method was applicable only where the initial P-motion direction was clear on short-period, vertical (SPZ), north-south and east-west seismograms. At least half of the regional events seen did not produce arrivals at other stations or clear first motions at TUL and, therefore, went unlocated.

A new vertical-motion short-period seismograph sensitive to high frequencies was added at TUL in April 1972. This improvement enabled the detection of many more regional earthquakes. However, most of these additional events could not be located other than specifying their distance from TUL. In 1974, Jim Zollweg, St. Louis University, scanned several thousand short-period seismograms in the TUL archives and added some events to the Oklahoma list. Unfortunately, with the notable exception of an aftershock sequence near Durant, Oklahoma, few of these events were locatable.

In the early 1970s, TUL became one of about 50 agencies throughout the world that report epicenters directly to the International Seismological Centre in Newbury, England, for publication in its monthly bulletin and semiannual catalog. In 1975, the Observatory began officially to furnish the National Oceanic and Atmospheric Administration (NOAA) with data on earthquakes felt in Oklahoma for the annual publication of *United States Earthquakes.*

Knowledge of an earthquake, at least in historic times, depended entirely on the perception and sensitivity of people. An earthquake produces seismic waves with vibrations that can be felt and/or heard by humans, and a large earthquake may also cause damage to buildings or other man-made objects as well as altering river courses and felling trees.

In 1902, Giuseppi Mercalli, Italian seismologist and volcanologist, developed a 12-value intensity scale to relate earthquake size to felt and observed earthquake effects. Wood and Neumann (1931) modified Mercalli's intensity scale for construction conditions in California. The modified Mercalli (MM) intensity scale is now used in most of the United States. An abridged version of this scale is given in Table 1.

From 1882 to 1994, 132 Oklahoma earthquakes were reported felt (Table 2). The largest known felt Oklahoma earthquake occurred near El Reno, Canadian County, on April 9, 1952. This magnitude-5.5 (mb, Gutenberg and Richter) earthquake was felt in Austin, Texas, as well as Des Moines, Iowa, and covered a felt area of ~362,000 km^2 (Kalb, 1964; Docekal, 1970; von Hake, 1976). This earthquake produced MM VII–VIII intensity effects near the epicenter. The U.S. Coast and Geodetic Survey sent questionnaires to every postmaster in the affected area. The information on the returned questionnaires provided data for Murphy and Cloud's (1954) isoseismal (lines of equal earthquake intensity) map for the El Reno earthquake (Fig. 2). The map, which was later modified by Docekal (1970), shows an elongated felt area that appears to follow the "basement" bedrock high that comprises the Nemaha uplift.

Smaller Oklahoma earthquakes that are reported felt generally do not produce a sufficient number of felt reports to create an isoseismal map. Since 1975, four Oklahoma felt earthquakes produced enough felt reports to produce earthquake-intensity maps. From telephone interviews, questionnaires, and newspaper accounts, Lawson and DuBois (1976) compiled a felt-report map for the Foster, Garvin County, Oklahoma earthquake, November 29, 1975 (Fig. 3). This magnitude-3.6 (mbLg) earthquake produced MM IV–V intensity effects near the epicenter. Recently cracked foundations were observed at two locations northwest of Foster, Oklahoma (Fig. 3). The felt reports showed a nonuniform distribution of intensity data. Lawson and DuBois (1976) concluded that the bedrock and surficial geology was, in part, responsible for the wide variation in felt reports.

TABLE 1. — MODIFIED MERCALLI (MM) EARTHQUAKE-INTENSITY SCALE
(Abridged) (Modified from Wood and Neumann, 1931)

I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings. Automobiles may rock slightly.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, doors, windows disturbed. Automobiles rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction. Shock noticed by persons driving automobiles.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings; great in poorly built structures. Fall of chimneys, stacks, columns. Persons driving automobiles disturbed.
IX	Damaged considerable even in specially designed structures; well-designed frame structures thrown out of plumb. Buildings shifted off foundations. Ground cracked conspicuously.
X	Some well-built wooden structures destroyed; ground badly cracked, rails bent. Landslides and shifting of sand and mud.
XI	Few if any (masonry) structures remain standing. Broad fissures in ground.
XII	Damage total. Waves seen on ground surfaces.

On January 24, 1987, a magnitude-3.1 (mbLg) earthquake occurred ~15 km west of Kingfisher, north-central Oklahoma. This earthquake had a felt area of ~900 km^2 and no damage was reported (Fig. 4). MM-V intensity effects in the Hennessey, Kingfisher, and Okarche areas were reported. On December 8, 1987, a magnitude-3.7 (mbLg) earthquake was centered 14 km southwest of Hennessey. Some minor damage, such as broken windows, cracked plaster, and broken knickknacks, was reported. The earthquake, which had a felt area of 11,200 km^2, produced MM-VI intensity effects in the Hennessey, Kingfisher, and Piedmont areas (Fig. 4).

On November 15, 1990, a magnitude-3.9 (mbLg) earthquake occurred 10 km southeast of Lindsay. The earthquake shook northern Garvin County and parts of McClain, Stephens, and Grady Counties (Fig. 5). The felt area covered >856 km^2 and MM-VI intensity effects were reported in the vicinity of the epicenter. The earthquake caused items to be thrown off shelves in a grocery store and some knickknacks fell from shelves.

The accumulated earthquake data displayed on the *Earthquake Map of Oklahoma* were grouped according to earthquake intensity as well as four time intervals chosen to reflect changes, such as seismograph improvements, that enhanced the detection and location of Oklahoma earthquakes. During the first time period, 1897–1961 (yellow symbols), all earthquakes in Oklahoma were located either from historical accounts or from seismograph stations outside the State. The epicentral locations within this time interval may vary as much as 50 km from the location shown on the map. The next interval, 1962–72 (green symbols), coincides with the operation of the first two seismograph stations (WMO and TUL) in Oklahoma. The seismographs at these stations provided excellent records of distant earthquakes. Although the location and detection of small local earthquakes were improved greatly by the presence of these two stations, most local earthquakes went unrecorded because of the poor high-frequency-response characteristics of the WMO and TUL seismographs. Station TUL began to record high-frequency seismograms in 1973. This greatly increased the capability to detect small earthquakes and to discriminate earthquakes from quarry blasts (blue symbols, 1973–76). However, the location of earthquakes depended on finding felt reports and/or having clear first-motion directions and horizontal-amplitude measurements made from the seismic records at the Observatory (TUL). For both the green and blue color-coded data, the location accuracy may vary as much as 20 km from the location shown on the map. The last group of symbols (red) shows earthquake intensity data for 1977–93. This time period coincides with the operation of a Statewide network of seismograph stations. The red color-coded data have a location accuracy that may vary as much as 5 km from the location shown on the map.

TABLE 2. — EARTHQUAKES THAT WERE REPORTED FELT IN OKLAHOMA, 1882–1994

Event no.	Date	Origin time (UTC)[a]	County	Intensity MM[b]	Magnitudes[c] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
1a	1882 Oct 22	2200		8				Eastern Oklahoma	
1b	1897 Dec 02		Grant	4				36.9	98.0
1	1900 Dec		Payne	4				36.0	96.8
2	1901 Apr 01		Payne	F				36.0	96.8
3	1901 Apr 08	1330	Payne	F				36.0	96.8
4	1908 Jul 19		Canadian	3				35.7	97.7
5	1910		Canadian	F				35.5	98.0
6	1915 Oct 08		Rogers	F		3.9		36.2	95.8
7	1918		Canadian	4				35.5	97.7
8	1918 Sep 10	1630	Canadian	5		3.4		35.5	98.0
9	1918 Sep 11	0630	Canadian	6		3.4		35.5	98.0
10	1918 Sep 11	0900	Canadian	6				35.5	98.0
11	1924 Jun 03		Pawnee	3				36.3	96.5
12	1926 Jun 20	1420	Sequoyah	5		4.3		35.6	94.9
13	1929 Dec 28	0030	Canadian	6		4.0		35.5	98.0
14	1933 Aug 19	1930	Canadian	5		3.3		35.5	98.0
16	1935 Nov 29		Payne	F				36.2	97.0
17	1936 Mar 14	1720	McCurtain	5		3.6		34.0	95.0
18	1936 Jul 12	0023	Cimarron	F		3.3		36.9	103.0
19	1937 Jun 08	1426	Pottawatomie	4		3.6		35.3	96.9
20	1939 Jun 01	0730	Hughes	4		4.4		35.0	96.4
21	1941 Oct 18	0748	Washita	5		3.2		35.4	99.0
22	1942 Jun 12	0550	Garfield	3		3.7		36.4	97.9
23	1952 Apr 09	1629 15	Canadian	7		5.0		35.4	97.8
24	1952 Apr 11	1830	Canadian	F				35.4	97.8
25	1952 Apr 11	2030	Canadian	4		3.8		35.4	97.8
26	1952 Apr 16		Canadian	F				35.4	97.8
27	1952 Apr 16		Canadian	F				35.4	97.8
28	1952 Apr 16		Canadian	F				35.4	97.8
29	1952 Apr 16		Canadian	F				35.4	97.8
30	1952 Apr 16		Canadian	F				35.4	97.8
31	1952 Apr 16		Canadian	F				35.4	97.8
32	1952 Apr 16	0558	Canadian	F		3.8		35.4	97.8
33	1952 Apr 16	0605	Canadian	5		3.8		35.4	97.8
34	1952 May 01	1140	Canadian	F				35.4	97.8
35	1952 May 02	0155	Canadian	F				35.4	97.8
36	1952 Jul 17	0030	Canadian	F				35.4	97.8
37	1952 Jul 17	0200	Canadian	F				35.4	97.8
38	1952 Aug 14	2140	Canadian	4				35.4	97.8
39	1952 Oct 08	0415	Seminole	4				35.1	96.5
40	1953 Mar 16	1250	Canadian	3				35.4	97.8
41	1953 Mar 17	1312	Canadian	5				35.4	98.0
42	1953 Mar 17	1425	Canadian	6		3.8		35.4	98.0
43	1953 Jun 06	1740	Pontotoc	4				34.8	96.7
44	1954 Apr		Hughes	4				35.1	96.4
45	1954 Apr 11		Hughes	4				35.1	96.4

TABLE 2 *(continued).* — EARTHQUAKES THAT WERE REPORTED FELT IN OKLAHOMA, 1882–1994

Event no.	Date	Origin time (UTC)[a]	County	Intensity MM[b]	Magnitudes[c] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
46	1954 Apr 12	2305	Hughes	4				35.1	96.4
47	1954 Apr 13	1848	Hughes	4				35.1	96.4
49	1956 Apr 02	1603 18	Pushmataha	5		3.8		34.2	95.6
50	1956 Oct 30	1036 21	Rogers	7		4.1		36.2	95.8
51	1959 Jun 15	1245	Pontotoc	5		4.0		34.8	96.7
52	1959 Jun 17	1027 07	Comanche	6		4.2		34.5	98.5
53	1960 Mar 18	2130	Rogers	F				36.2	95.8
54	1960 Mar 18	2330	Rogers	F				36.2	95.8
55	1961 Jan 11	0140	Latimer	5		3.8		34.8	95.5
57	1961 Apr 27	0300	Pushmataha	F				34.6	95.0
58	1961 Apr 27	0500	Pushmataha	F				34.6	95.0
59	1961 Apr 27	0730	Latimer	5		4.1		34.9	95.3
73	1968 Oct 11	0222 55	Bryan	F	2.3		2.0	34.0	96.4
74	1968 Oct 11	0240 42	Bryan	F	1.9		1.6	34.0	96.4
75	1968 Oct 11	0855 42	Bryan	F	2.8		2.3	34.0	96.4
76	1968 Oct 11	0933 37	Bryan	F	2.4		2.0	34.0	96.4
83	1968 Oct 14	1442 54	Bryan	6	3.5		3.1	34.0	96.4
88	1969 May 02	1133 22.50	Okfuskee	F		3.5		35.5	96.2
92	1973 Jan 10	1638 15.30	Garfield	1		2.3		36.4	98.0
101	1974 Dec 16	0230 18.80	Oklahoma	3	2.4			35.4	97.47
105	1975 Sep 13	0125 02.10	Carter	5		3.4		34.1	97.40
108	1975 Nov 29	1429 41.20	Garvin	5		3.6		34.65	97.53
109	1975 Dec 19	0529 25.00	Carter	2		2.5		34.1	97.4
112	1976 Mar 16	0739 45.30	McIntosh	4	2.7			35.43	95.6
113	1976 Mar 30	0653 16.00	Cimarron	5		2.1		36.68	102.25
114	1976 Mar 30	0927 02.00	Cimarron	5		2.7		36.68	102.25
115	1976 Apr 16	1859 46.10	Roger Mills	4		3.4		35.87	99.97
116	1976 Apr 17	0248 05.70	Carter	2		2.4		34.1	97.4
117	1976 Apr 19	0442 43.90	Roger Mills	5		3.5		35.87	99.97
119	1976 Jun 23	0821 17.80	Carter	3		2.7		34.1	97.4
120	1976 Jun 24	0802 39.50	Carter	2	1.4			34.1	97.4
121	1976 Sep 20	0940 16.20	Carter	3		2.1		34.16	97.4
128	1976 Dec 17		Love	F				34.1	97.4
129	1976 Dec 19	0826 36.70	Pittsburg	1		2.9		34.92	95.73
130	1977 Feb 04	2052 29.28	Love	2		1.9		34.065	97.370
131	1977 Feb 10	0128 16.26	Love	2		2.0		34.065	97.370
135	1977 Mar 26	2137 12.59	Love	3		2.3		34.065	97.370
155	1978 Mar 09	0630 50.82	Love	2		2.5	2.5	34.010	97.378
163	1978 May 17	2311 15.65	Canadian	1	2.1	2.3	2.0	35.525	97.910
164	1978 May 18	0019 22.43	Canadian	3	2.5	2.7	2.5	35.502	97.949
165	1978 May 18	0032 17.57	Canadian	2	2.2	2.1	2.1	35.601	97.828
192	1979 Mar 13	2329 22.56	Canadian	2	1.7			35.421	97.851
193	1979 Mar 14	0310 56.83	Canadian	4	2.0	1.9	1.8	35.498	97.826
195	1979 Mar 14	0437 15.27	Canadian	5	2.2	2.2	2.1	35.519	97.781
215	1979 Mar 18	2044 19.47	Canadian	3	2.9	2.8	2.5	35.379	98.124
221	1979 Mar 18	2319 01.29	Carter	3	2.5	2.3	2.2	34.100	97.448

TABLE 2 *(continued)*. — EARTHQUAKES THAT WERE REPORTED FELT IN OKLAHOMA, 1882–1994

Event no.	Date	Origin time (UTC)[a]	County	Intensity MM[b]	Magnitudes[c] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
236	1979 May 22	0349 23.77	Love	3	1.8	1.9	2.0	34.027	97.470
239	1979 Jun 07	0739 35.56	Beckham	3	3.2	2.9	3.0	35.187	99.812
247	1979 Jul 25	0315 37.27	Love	5		2.7	2.3	33.967	97.549
256	1979 Sep 13	0049 22.97	Beckham	4	3.3	3.4	3.1	35.217	99.362
264	1979 Sep 16	1557 20.84	Grady	4	2.5	2.5	2.2	35.343	97.997
267	1979 Sep 17	2041 50.53	Grady	4	2.6	2.5	2.3	35.320	97.968
274	1979 Dec 09	2312 58.66	Love	3	2.8	2.5	2.4	33.988	97.353
282	1980 Feb 05	0432 35.45	Love	3	2.1	2.3	1.9	34.046	97.451
308	1980 Nov 01	0526 13.85	Canadian	3	1.9	2.0	2.0	35.472	97.836
309	1980 Nov 02	1000 49.03	Canadian	5	3.0	3.0	2.8	35.429	97.777
321	1980 Dec 04	0123 16.96	Carter	F	1.9	1.8	1.7	34.096	97.401
322	1980 Dec 04	2348 43.22	Love	F	2.1		2.1	33.942	97.352
323	1980 Dec 05	0007 26.29	Love	F	2.6	2.4	2.4	33.909	97.284
406	1982 May 03	0754 48.65	Bryan	6	2.8	3.0	2.6	33.990	96.473
489	1984 Jan 06	1714 49.81	Rogers	5	2.5		2.5	36.161	95.582
492	1984 Jan 24	1534 09.63	Hughes	5	3.1	2.8	2.7	35.033	96.366
493	1984 Feb 03	0438 28.04	Garvin	5		3.2	3.1	34.665	97.356
494	1984 Feb 10	1839 13.56	Love	4	2.4		2.2	34.049	97.415
497	1984 Mar 03	1142 02.36	Okfuskee	5	2.7	2.6	2.7	35.514	96.301
517	1984 Nov 20	1057 31.98	Garvin	4	3.0	3.1	2.7	34.707	97.410
534	1985 May 03	0733 40.40	Garvin	4	2.5	2.5	2.6	34.656	97.484
537	1985 May 05	0139 30.78	Garvin	F	3.0	2.9	2.8	34.664	97.529
538	1985 May 05	0216 02.65	Garvin	F	2.4	2.2	2.3	34.836	97.455
541	1985 May 06	0211 16.16	McClain	5	2.2	2.3	2.4	34.969	97.482
636	1987 Jan 24	1608 17.01	Kingfisher	5	3.4	3.1	2.8	35.828	98.097
695	1987 Dec 08	0142 40.28	Kingfisher	6		3.7	3.6	36.055	98.024
828	1990 Sep 16	2113 33.38	Pittsburg	5	3.2	2.4	3.0	34.855	95.577
838	1990 Nov 15	1144 41.63	Garvin	6	4.0	3.9	3.0	34.761	97.550
841	1990 Nov 16	2047 15.06	Garvin	F	2.5		2.4	34.787	97.611
849	1991 Jan 24	0500 27.65	Noble	5			2.8	36.352	97.271
883	1991 Dec 09	1607 14.51	Garvin	2	2.3		2.1	34.768	97.592
889	1991 Dec 10	1200 29.64	McClain	2	2.3	1.8	2.1	34.868	97.448
917	1992 Jun 30	0125 48.25	Seminole	2	2.9	2.3	2.5	35.277	96.495
926	1992 Oct 05	0444 08.56	Garfield	5	2.9	2.6	2.8	36.357	97.506
938	1992 Dec 17	0401 19.28	Garvin	2	2.5	2.6	2.6	34.843	97.580
939	1992 Dec 17	0718 05.65	Garvin	5	3.8	3.5	3.1	34.730	97.541
949	1993 Jan 30	0442 53.63	Love	F	1.8	2.0	2.0	34.052	97.084
953	1993 Mar 11	0115 01.08	McIntosh	2		2.7	2.4	35.230	95.932
1003	1993 Oct 19	1659 52.41	Alfalfa	F	3.1	2.8	2.5	36.546	98.173
1067	1994 Apr 29	0328 59.63	Garfield	F		2.8	2.5	36.203	98.052

[a]UTC refers to Coordinated Universal Time, formerly Greenwich Mean Time. The first two digits refer to the hour on a 24-hour clock. The next two digits refer to the minute, and the remaining digits are the second. To convert to local Central Standard Time, subtract 6 hours.

[b]Modified Mercalli (MM) earthquake-intensity scale (see Table 1). Arabic numbers (instead of Roman numerals) are used to denote intensity values in the catalog; "F" indicates earthquake was reported felt, intensity unknown, generally ≤4.

[c]See page 17 for discussion of magnitude scales.

SEISMOGRAPH NETWORK

The data required for location of local earthquakes consist of the arrival times of P and S phases at several (at least three) separate locations (see Appendix 1 for phase nomenclature). These arrival times are obtained from seismograms, a record containing wiggly lines that represent vertical ground motion over a frequency range of 1 Hz to ~20 Hz. The seismograms also are used to determine amplitude of ground motion, which is used to calculate earthquake magnitude.

Seismograms are recorded by seismographs. A modern seismograph consists of four basic sections: seismometer, signal conditioner, recorder, and timing system. The seismometer converts ground motion into a varying electric potential. The signal conditioner includes a solid-state amplifier or amplifiers to increase the varying potential produced by the seismometer and, usually, electronic filters to attenuate some frequencies and pass other frequencies. The recorder is usually a drum with a line (recorded in ink) representing earth motion. The line follows a spiral path around the drum. When the seismogram is removed, it appears as a sheet with a number of parallel wiggly lines, each one representing a successive 10- or 15-minute period, depending on the rate of rotation of the drum. The timing systems are crystal-controlled oscillator clocks that produce an offset in the seismogram trace at the beginning of each minute to allow precise measurement of seismic phase-arrival times. The timing system usually is compared daily to radio time signals broadcast by the National Bureau of Standards.

In Oklahoma, ground motion is recorded at 11 widely separated locations (Fig. 6; Table 3). The Oklahoma Geological Survey Observatory, the main recording and research facility (stations TUL and LNO) is located near Leonard, Oklahoma, southeastern Tulsa County. This facility, formerly the Leonard Earth Sciences Observatory, was operated by Jersey Production Research Co. (now Exxon) from December 1961 to 1965 and by the University of Oklahoma from 1965 to 1978 as the OU Earth Sciences Observatory. In July 1978, the Observatory was transferred to the Oklahoma Geological Survey. Before 1972, the seismographs, designed to record phases from distant earthquakes, were not optimum for recording the higher frequencies characteristic of local earthquakes. Beginning in 1972, the recording of local earthquakes was improved greatly by the development and operation of additional seismographs.

Station TUL records 15 continuous seismic signals from sensors located at five stations. The data are recorded, analyzed, and archived on a GSE digital seismic system provided by the Defense Advanced Research Projects Agency/Nuclear Monitoring Research Office.

Signals are digitized by two Geotech RDAS (Remote Data Acquisition System) units at either 36,000 or 1,200 24-bit samples per second. The RDAS then applies digital anti-alias filtering to eliminate frequencies too high for the final sampling rate. After one to three digital filter and resampling stages, the RDAS produces 60, 40, 20, or 10 24-bit samples per second. The samples are time-tagged by RDAS clocks locked to very low-frequency Omega Navigation/Time signal receivers. The signals are passed by RS422 serial links to an AST 386/25 RTDS (Real Time Data Server) computer, which has a Lynx™ real-time Unix-like operating system. The partially processed signals are passed by ethernet to a Sun Sparc 2+ Unix workstation with 64 megabytes of memory, two 660-megabyte disks, two 2.1-gigabyte disks, and two 2.3-gigabyte Exabyte™ tape drives. All of the data from the most recent two weeks are retained on disk. Each day, data from the preceding day (167 million bytes) are automatically archived onto Exabyte™ tape. All Oklahoma earthquakes, and other selected events, are placed in named de-archive directories. An

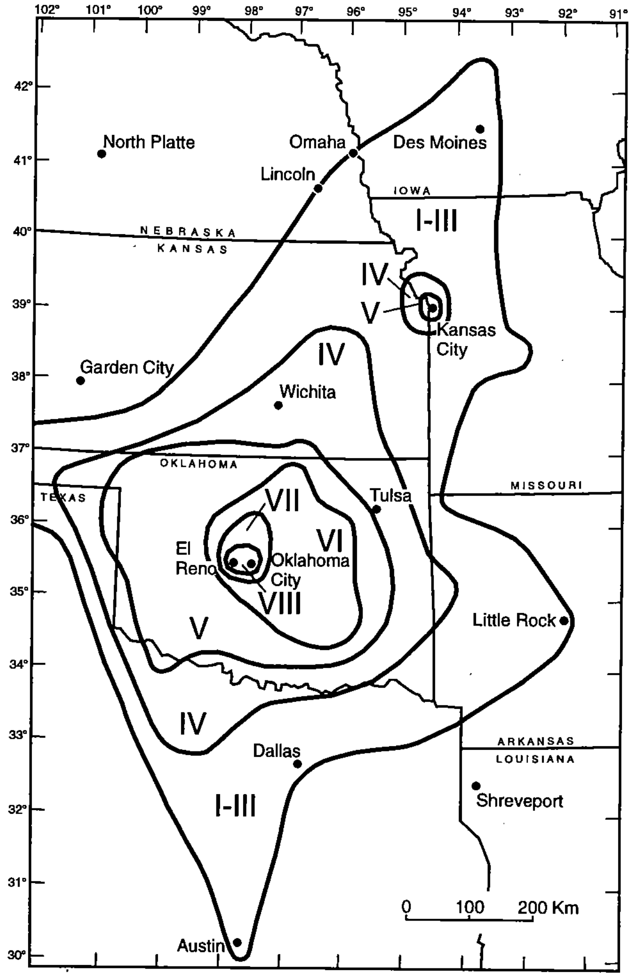


Figure 2. Isoseismal (lines of equal earthquake intensity) map for El Reno earthquake, Canadian County (modified from Murphy and Cloud, 1954; Docekal, 1970). Felt area appears to follow "basement" bedrock high that comprises the Nemaha uplift.

Oracle™ data base on the Sun Sparc 2+ keeps track of every second of data on the permanent archive tapes, all data on disk, and data in the de-archive directories. Data analysis is done by Teledyne-Geotech and Science Applications International Corp. software on the Sun Sparc 2+ workstation.

The digital system signals are from three sensors in the Observatory vault (international station abbreviation TUL); from three sensors in a borehole on the Observatory property (station LNO); and from single sensors located at Rose Lookout (RLO) in Mayes County, at the Bald Hill Ranch near Vivian (VVO) in McIntosh County, and at the Jackson Ranch near Slick (SIO) in Creek County. Examples of four digitally recorded Oklahoma earthquakes are shown in Appendix 3.

TUL has three (vertical, north-south, east-west) Geotech GS-13 seismometers which produce 40-sample-per-second short-period signals. A three-component broadband Geotech KS54000-0103 seismometer in a 120-m-deep borehole produces seven digital data channels. Three are broadband signals from seismic signals in vertical, north-south, and east-west directions. From the broadband signals the Sun Sparc 2+ workstation derives three long-period signals. A seventh signal, the vertical earth tides, is recorded from the vertical mass displacement signal from the KS54000-0103. The broadband signals are archived at 10 samples per second, and the long-period and vertical-

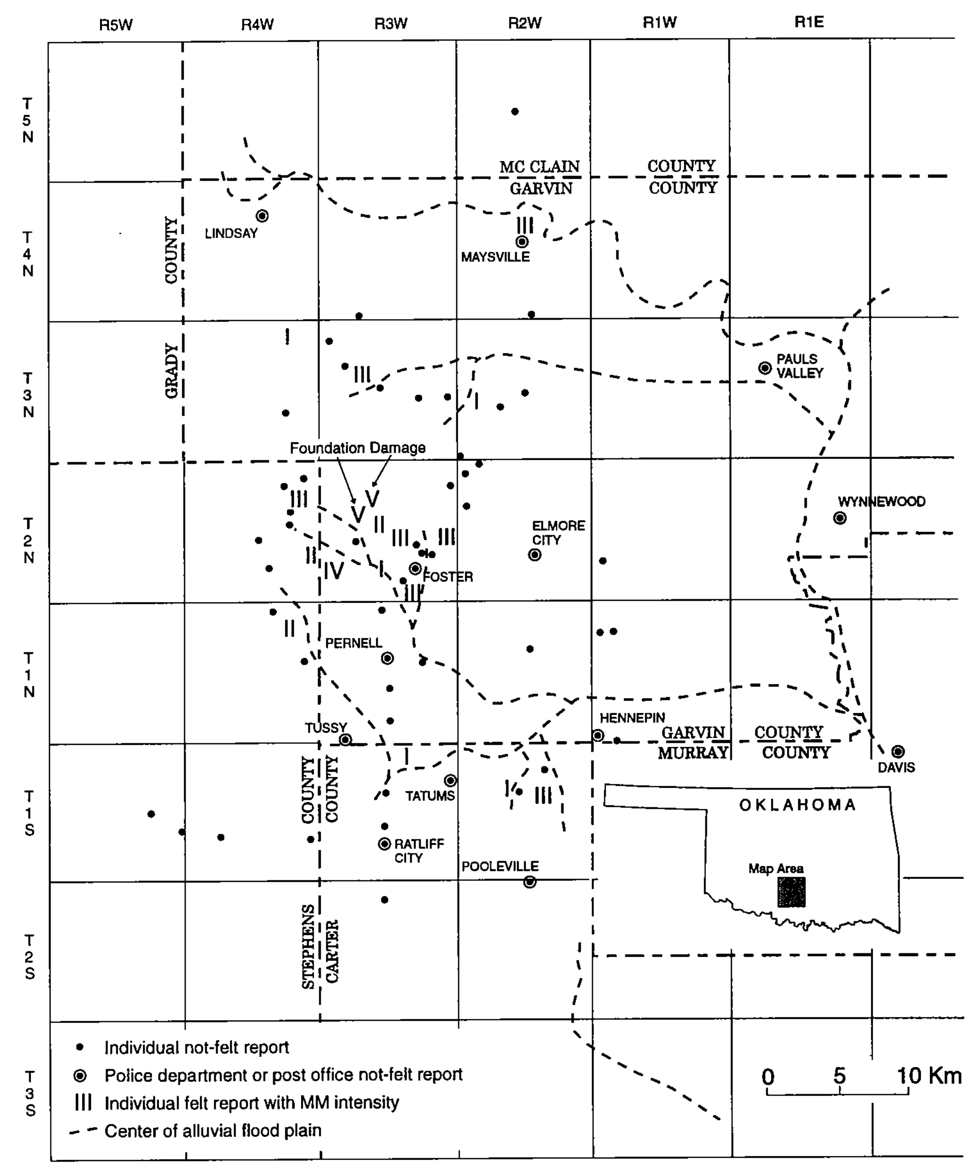


Figure 3. Map of Foster earthquake, November 29, 1975, Garvin County (modified from Lawson and DuBois, 1976).

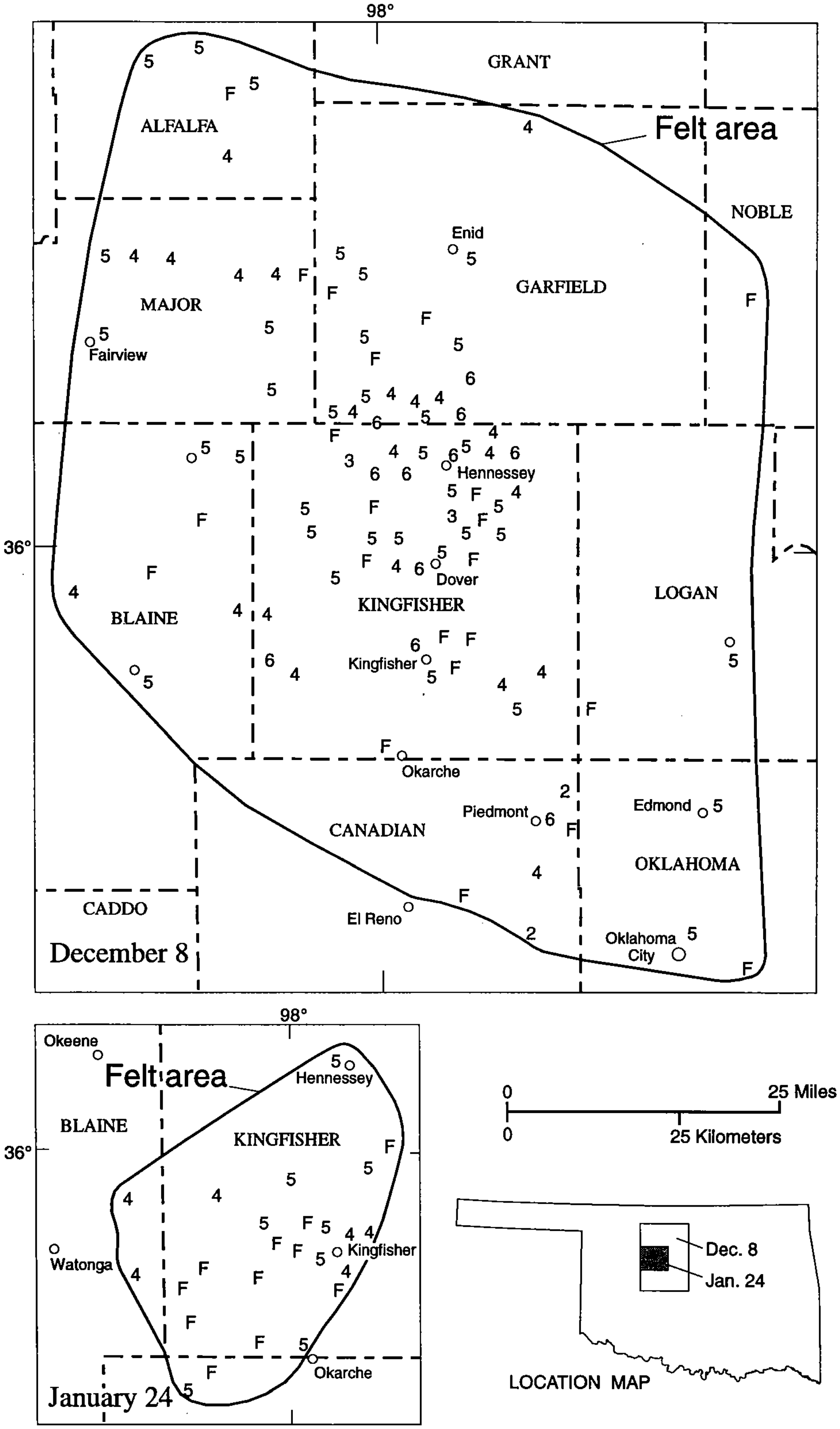


Figure 4. Modified Mercalli (MM) intensity values for the January 24 and December 8, 1987, Kingfisher County earthquakes (Lawson and Luza, 1988).

earth-tide signals are recorded at one sample per second. On November 10, 1994, the broadband sample rate was increased from 10 samples per second to 20 samples per second. This increase was for two purposes. One was to allow the broadband borehole seismometer to record higher frequencies (≤8 Hz) characteristic of Oklahoma earthquakes. The other was to make the signals compatible for the GSETT-3 (Group of Scientific Experts Technical Test-3), which begins in 1995. GSETT-3 is a prototype international seismic-monitoring system to detect underground nuclear tests. Data segments will be copied automatically and sent to the International Data Center by Internet without affecting the recording and analysis of Oklahoma earthquakes.

An Internet gopher server running on a Sun Sparc SLC allows anyone on the Internet to copy digital data on disk, as well as several documents such as the Oklahoma Earthquake Catalog in one single list, or a series of two-year lists. The gopher can be contacted with "gopher (space) wealaka.okgeosurveyl. gov" or using WWW clients with "gopher://wealaka.okgeosurveyl. gov/". The broadband signals are seldom used in the study of Oklahoma earthquakes; the long-period signals are never used. The short-period signals are particularly useful in calculating the direction of arrival of waves by digital calculation of polarization.

The LNO station has a Geotech 20171A seismometer in a 4.5-m-deep borehole and two Geotech 23900 (a deep-hole version of the 20171A) seismometers at 432- and 748-m depths in a borehole that is 1 m away from the 4.5-m-deep hole. The LNO equipment is provided and partially supported by Lawrence Livermore National Laboratories. The three LNO signals are digitized by a second RDAS near the borehole and recorded and archived at 60 samples per second. This allows recording of higher frequency waves than is possible with the 40-sample-per-second data. The higher frequencies are particularly prominent in nearby (Oklahoma and adjacent areas) earthquakes. At frequencies above 10 Hz, the high-frequency background noise produced by wind and cultural activity is almost absent at the 748-m-deep sensor. It is particularly important for recording signals from smaller Oklahoma earthquakes, which are very difficult to see on seismograms from near-surface seismometers.

RLO, VVO, and SIO (Fig. 6) have Geotech S-13 seismometers in shallow tank vaults. The seismic signals are amplified and used to frequency modulate an audio tone that is transmitted to Leonard with 500-mW FM transmitters at various frequencies in the 216–220-mHz band. The signals are received by antennas on a 40-m-high tower at Leonard, the tones are discriminated to produce a voltage which is proportional to the remote seismometer voltage, and the voltages are digitized at 40 samples per second by the vault RDAS.

A fourth radio-telemetry station, FNO, was installed in central Oklahoma on April 28, 1992. The seismometer, Geotech S-13, is located on a concrete pad, ~7 km northeast of the Oklahoma Geological Survey's (OGS) building. A discriminator converts the audio-

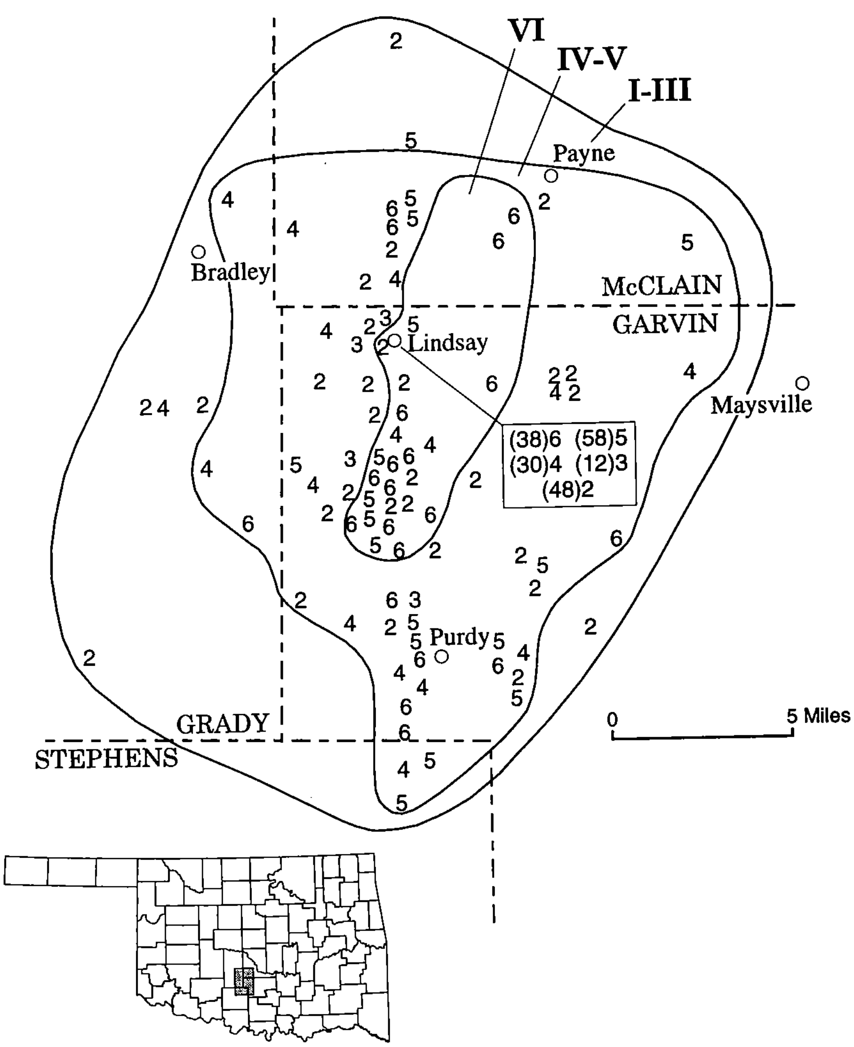


Figure 5. Modified Mercalli (MM) intensity values for the November 15, 1990, Lindsay, Garvin County, earthquake (Lawson and others, 1991).

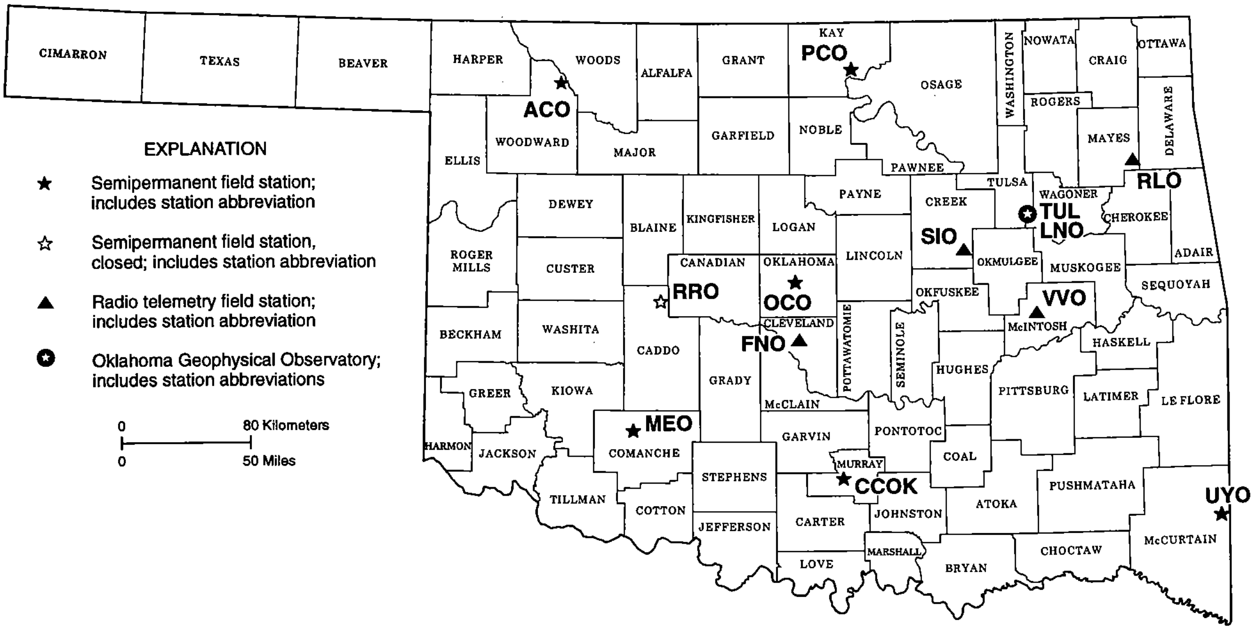


Figure 6. Locations of seismograph stations in Oklahoma.

signal frequency fluctuations to a voltage output. The voltage-output is amplified and recorded by a Sprengnether MEQ-800 seismograph recorder (located in an OGS display case) at 60 mm/min trace speed.

In the Leonard vault, seven additional seismometers produce analog (wiggly-line) recordings on paper-drum recorders. Eleven such recordings are produced, five of which are the proper frequencies to record some aspect of nearby earthquakes. One paper recording is produced from each of RLO, VVO, and SIO. There are no LNO paper records. The paper records are used as a digital system backup, and to scan for earthquakes faster than is possible on computer screens.

In addition to the digital and analog seismograms recorded at the OGS Observatory, seismograms are recorded by six volunteer-operated seismographs. Each consists of a Geotech S-13 short-period vertical-motion-sensing seismometer in a shallow tank vault (Fig. 7), or in an abandoned mine shaft (station MEO) or large-diameter, hand-dug, shallow water well (station UYO). A shallow buried (2–10-cm) shielded cable carries the seismometer signal over distances varying from 60 to 200 m to the volunteer's house or building. A Sprengnether MEQ-800B seismic recorder, which combines in one unit the signal conditioners (amplifiers, filters), a crystal-controlled timing system (clock), and a drum recorder, is placed in a room chosen for the volunteer's convenience. A shortwave radio receiver to receive National Bureau of Standards time signals is placed beside the drum recorder. To check for time accuracy, the timing system is switched to make marks each second instead of every minute, and the timing-system marks and the radio second marks are recorded simultaneously on the seismogram. By advancing or retarding the clock until the marks coincide, the volunteer can keep the clock within 16 milliseconds of National Bureau of Standards time. These six stations, called semipermanent, volunteer-operated stations, are at sites provided by individuals or State agencies and are operated by volunteers who change and label seismograms daily and check the timing system with National Bureau of Standards radio time signals. The volunteers mail in the seismograms weekly (or more often, if requested). When immediate data for a felt Oklahoma earthquake is required, several stations fax seismograms to Leonard.

Table 3 lists the latitude, longitude, elevation in meters, and geographical name of Station TUL/LNO, the radio-telemetry stations (RLO, SIO, VVO, FNO), active volunteer stations (ACO, PCO, OCO, MEO, UYO, CCOK), and the volunteer stations that were closed.

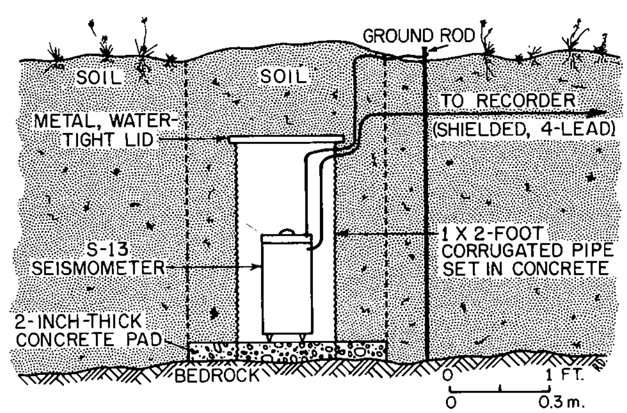


Figure 7. Diagrammatic representation of an S-13 seismometer installation (Luza, 1978).

TABLE 3. — OKLAHOMA STATION LOCATIONS AND OPERATORS

Station abbr.	Name	County	Latitude (°N.)	Longitude (°W.)	Elevation (m)	Operator	Operating date(s) (year/month/day)
Active Field Stations							
TUL	near Leonard	Tulsa	35.919	95.793	256	OGS staff	61/12/08
ACO	Alabaster Cavern State Park	Woodward	36.699	99.146	521	Sheri Beagley and staff	77/06/22
PCO	Ponca City	Kay	36.691	96.978	325	H. Walther/S. Sheehan	77/07/05
OCO	Oklahoma City Omniplex	Oklahoma	35.524	97.474	351	Greg Christenson and staff	82/05/21
MEO	Meers Store (mine shaft)	Comanche	34.784	98.585	465	J. and C. Maranto	85/06/11
UYO	Union Valley (15-m-deep well)	McCurtain	34.167	94.459	231	Steve Due	89/04/15
LNO	near Leonard (borehole)	Tulsa	35.911	95.793	–487	OGS staff	89/12/07
CCOK	Camp Classen	Murray	34.458	97.156	293	Jim Parry and staff	94/08/10
Active Radio-Telemetry Stations							
RLO	Rose Lookout Tower	Mayes	36.167	95.025	363	Oma L. McCustion and OGS staff	77/07/22
SIO	Slick	Creek	35.746	96.307	323	J. H. (Sonny) Davis and OGS staff	78/07/12
VVO	Vivian	McIntosh	35.337	95.737	224	O. B. (Boots) Adams and OGS staff	85/09/11
FNO	Franklin 2	Cleveland	35.258	97.401	357	Jim and Jo Mustoe and OGS staff	92/04/28
Closed Field Stations							
WMO	southeast of Meers	Comanche	34.718	98.589	505	U.S. Air Force	61/01/01–68/12/31*
MZO	Mazie Landing	Mayes	36.132	95.300	182	Randy Blackwell	76/09/16–78/06/16
OLO	Oologah	Rogers	36.457	95.711	196	T/T/C Estes	76/11/29–77/08/07
WLO	southeast of Wilson	Love	34.065	97.370	284	James L. Steel	77/04/25–85/02/20
CRO	Carnasaw Mountain Lookout Tower	McCurtain	34.150	94.556	302	Wanda Webb	77/05/17–80/07/23
QMO	Quartz Mountain State Park	Greer	34.893	99.307	479	J. Briley	77/07/29–81/03/11
MRO	Meridian	Logan	35.836	97.227	294	Roy F. Starks	78/03/16–82/09/04
RRO	Red Rock Canyon State Park	Caddo	35.457	98.358	482	David Sutton and staff	78/08/09–93/08/17
CDO	Cedar Creek	McCurtain	34.190	94.773	230	Jim Martin	80/08/01–81/03/25
QZO	Quartz Mountain State Park	Greer	34.905	99.305	488	Lodge staff	81/03/20–88/12/23
FKO	Franklin	Cleveland	35.261	97.386	351	Jud Ahern	87/11/09–92/09/23
PKO	Pickens	McCurtain	34.397	95.031	264	Gerald Craddock	87/11/16–87/12/21
BHO	Bethel	McCurtain	34.367	94.867	143	Annalisa Henderson	81/05/01–87/10/15
Closed Radio-Telemetry Station							
GBO	Fort Gibson	Cherokee	35.853	95.184	302	Wayne Harrold	79/07/19–84/12/31

*NOTE: All seismic records from station WMO are located at the Oklahoma Geological Survey's main recording facility, near Leonard, OK.

The table also gives names of the volunteer primarily responsible for the station. At some stations several volunteers have operated the station by turn.

One additional closed station on the map, WMO, was operated by the U.S. Air Force from November 1961 to June 1968 to detect distant underground nuclear tests and distinguish them from earthquakes. The frequency passbands of the WMO seismographs greatly attenuated high-frequency waves from near earthquakes, which made the detection and location of Oklahoma earthquakes quite difficult.

EARTHQUAKE CATALOG

Data Reduction and Archiving

Seismic traces from the TUL vault vertical seismometer (TUL sz), the deepest borehole short-period vertical seismometer of station LNO (LNO/sz1) and one radio-telemetry site (usually VVO) are displayed on a 19-in. monitor on the Sun Sparc 2+. The traces are band passed through 0.4–4.0-Hz digital filters and are displayed in 90-min segments. A fourth, long-period vertical trace is displayed, but it records only waves from distant earthquakes. The 90-min traces are fuzzy lines with spikes showing signals above the noise. Distant earthquakes of magnitude ≥5.0 are usually identifiable by the shape of the spike and the following long-period surface waves. Other spikes represent local or regional earthquakes or surface-mine blasts. There are from 10 to 30 recordable surface-mine blasts each weekday, two to five on Saturday, and one or two on Sunday.

The monitor display is zoomed on a 60-sec segment surrounding each spike, and the event is identified by its appearance. If it is a P-wave from a distant earthquake, the display is zoomed to 15 sec and the arrival time, frequency, amplitude, and polarization (direction) are measured, calculated, and recorded for transmission to international data centers.

If a spike is identified as a possible near or regional earthquake, nine traces are displayed on the monitor (TUL sz, sn, se; LNO sz1, sz2, sz3; RLO sz; VVO sz; SIO sz). They are then filtered and unfiltered repeatedly to enhance and identify the phases. One set of filters, developed at NORESS (Norwegian Experimental Seismic System) is described by Mykkeltveit and others (1990). Using the time interval between phases, the distance can be determined; the direction is determined from polarization (using the TUL vault vertical, north-south, and east-west signals). The distance and direction give an approximate location, which is then improved by incorporating arrival times from remote sites RLO, VVO, and SIO. At this point, a short press release is issued from the OGS offices at Norman. Paper seismograms also are searched for regional and local earthquakes. At times, a small earthquake may be spotted initially only on the digital system or only on paper seismograms.

The next stage is de-archiving digital data from the nine short-period signals (listed in the preceding paragraph). These are put in a permanent named disk file and indexed in the on-line Oracle™ data base.

Each quarter, paper seismograms from all volunteer stations and from Observatory seismograms are carefully searched for local earthquakes. Arrival times are measured and added to those already determined from the digital system. As many as two or three additional earthquakes may be found. These are de-archived from Exabyte™ tapes for digital system analysis.

Arrival times, signal durations, and various signal amplitudes are entered into a location program running on a Hewlett-Packard 9825T computer. After each location is finalized, it is entered into an Oklahoma earthquake catalog maintained by Hewlett-Packard 9825T and linked 9835A computers. This catalog is used to produce lists (by date, by county, by latitude–longitude rectangle, and several other choices), and to produce maps with a six-color Hewlett-Packard 7975A plotter.

Catalog

A desktop computer system, including linked HP-9825T and HP-9835A computers, hard and flexible disks, and printers, is used to calculate and catalog local earthquake epicenters. Any earthquake within Oklahoma or within about 100–200 km of Oklahoma's borders is considered a local earthquake. A catalog containing date, origin time, county, intensity, magnitude, location, focal depth, and references is printed in page-sized format. Appendix 2 contains all Oklahoma earthquake data displayed in a modified version of the regional earthquake catalog. Each event is sequentially numbered and arranged according to date and origin time. The numbering system is compatible with the system used for the *Earthquake Map of Oklahoma* (Lawson and others, 1979) and subsequent additions (Lawson and Luza, 1980–90,1993–95; Lawson and others, 1991,1992).

The date and time are given in UTC. UTC refers to Coordinated Universal Time, formerly Greenwich Mean Time. The first two digits refer to the hour on a 24-hour clock. The next two digits refer to the minute, and the remaining digits are the seconds. To convert to local Central Standard Time, subtract 6 hours.

Earthquake magnitude is a measurement of energy and is based on data from seismograph records. The magnitude of a local earthquake is determined by taking the logarithm (base 10) of the largest ground motion recorded during the arrival of a seismic-wave type and applying a standard correction for distance to the epicenter. When the magnitude value is increased one unit, the amplitude of the earthquake waves increases 10 times. There are several different scales used to report magnitude. The earthquake catalog has three magnitude scales, which are mbLg (Nuttli), m3Hz (Nuttli), and MDUR (Lawson). Each magnitude scale was established to accommodate specific criteria, such as the distance from the epicenter, as well as the availability of certain seismic data.

For earthquake epicenters located 11–222 km from a seismograph station, Otto Nuttli developed the m3Hz magnitude scale (Zollweg, 1974). This magnitude is derived from the following expression:

$$\text{m3Hz} = \log(A/T) - 1.63 + 0.87\log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Lg waves (short period surface waves traveling in the upper crust, probably equivalent to Sg waves), near 3 Hz in frequency, measured in nanometers; T is the period of the Lg waves measured in seconds; and Δ is the great-circle distance from epicenter to station measured in kilometers.

In 1979, St. Louis University (Stauder and others, 1979) modified the formulas for m3Hz. This modification was used by the OGS Observatory beginning January 1, 1982. The modified formulas had the advantage of extending the distance range for measurement of m3Hz out to 400 km, but also had the disadvantage of increasing m3Hz by about 0.12 units compared to the previous formula. Their formulas were given in terms of $\log(A)$ but were restricted to wave periods of 0.2–0.5 sec. In order to use $\log(A/T)$, we assumed a period of 0.35 sec in converting the formulas for our use. The resulting equations are:

(epicenter 10–100 km from a seismograph)

$$\text{m3Hz} = \log(A/T) - 1.46 + 0.88\log(\Delta)$$

(epicenter 100–200 km from a seismograph)

$$\text{m3Hz} = \log(A/T) - 1.82 + 1.06\log(\Delta)$$

(epicenter 200–400 km from a seismograph)

$$\text{m3Hz} = \log(A/T) - 2.35 + 1.29\log(\Delta).$$

Otto Nuttli's (1973) earthquake magnitude, mbLg, for seismograph stations located between 55.6 and 445 km from the epicenter, is derived from the following equation:

$$\text{mbLg} = \log(A/T) - 1.09 + 0.90\log(\Delta).$$

Where seismograph stations are located between 445 and 3,360 km from the epicenter, mbLg is defined as:

$$\text{mbLg} = \log(A/T) - 3.10 + 1.66\log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Lg waves, near 1 Hz in frequency, measured in nanometers; T is the period of Lg waves measured in seconds; and Δ is the great-circle distance from epicenter to station measured in kilometers.

The MDUR magnitude scale was developed by Lawson (1978) for earthquakes in Oklahoma and adjacent areas. It is defined as:

$$\text{MDUR} = 1.86\log(\text{DUR}) - 1.49,$$

where DUR is the duration or difference, in seconds, between the Pg-wave arrival time and the time the final coda amplitude decreases to twice the background-noise amplitude. Before 1981, if the Pn wave was the first arrival, the interval between the earthquake-origin time and the decrease of the coda to twice the background-noise amplitude was measured instead. Beginning January 1, 1982, the interval from the beginning of the P wave (whether it was Pg, P*, or Pn) to the decrease of the coda to twice the background-noise amplitude was used.

The depth to the earthquake hypocenter is measured in kilometers. For most Oklahoma earthquakes

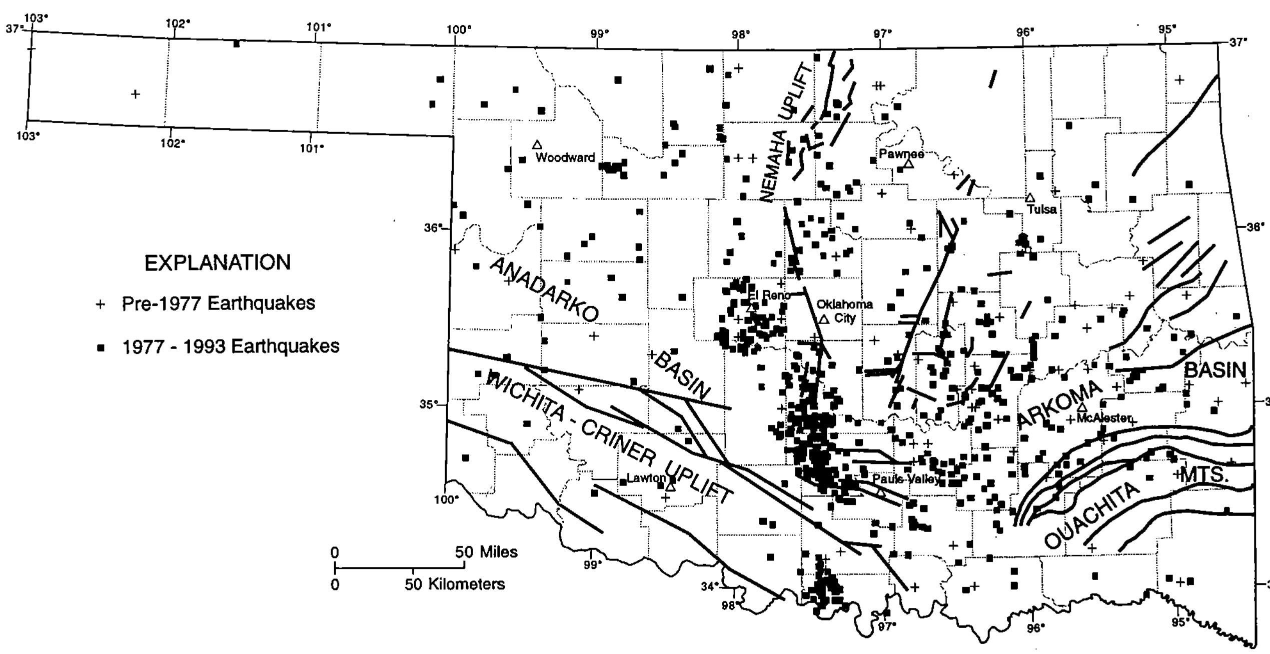


Figure 8. Map of selected basins, uplifts, and faults in Oklahoma with earthquake-epicenter locations, 1897–1993.

this focal depth is unknown. In almost all Oklahoma events, the stations are several times farther from the epicenter than the likely depth of the event. This makes the locations indeterminate at depth, which usually requires that the hypocenter depth be restrained to an arbitrary 5 km for purposes of computing latitude, longitude, and origin time. All available evidence indicates that no Oklahoma hypocenters have been deeper than 15–20 km.

EARTHQUAKE DISTRIBUTION

Of the approximately 50 earthquakes that are located in Oklahoma each year, only one to two earthquakes, on the average, are reported felt. Prior to 1962, all earthquakes in Oklahoma (59) were known either from historical accounts or from seismograph stations outside the State. From 1962 through 1976, after the first seismographs were installed in late 1961, 70 additional earthquakes were added to the earthquake data base. In 1977, the Statewide network of seismograph stations greatly improved earthquake detection and location. From 1977 through 1993, more than 880 additional earthquakes were located in Oklahoma, mostly of magnitudes <2.5 (Fig. 8). The earthquake-epicenter data produce at least three seismic trends worthy of discussion. These trends are located in north-central Oklahoma, the eastern margin of the Anadarko basin, and the Arkoma basin–Ouachita Mountains area.

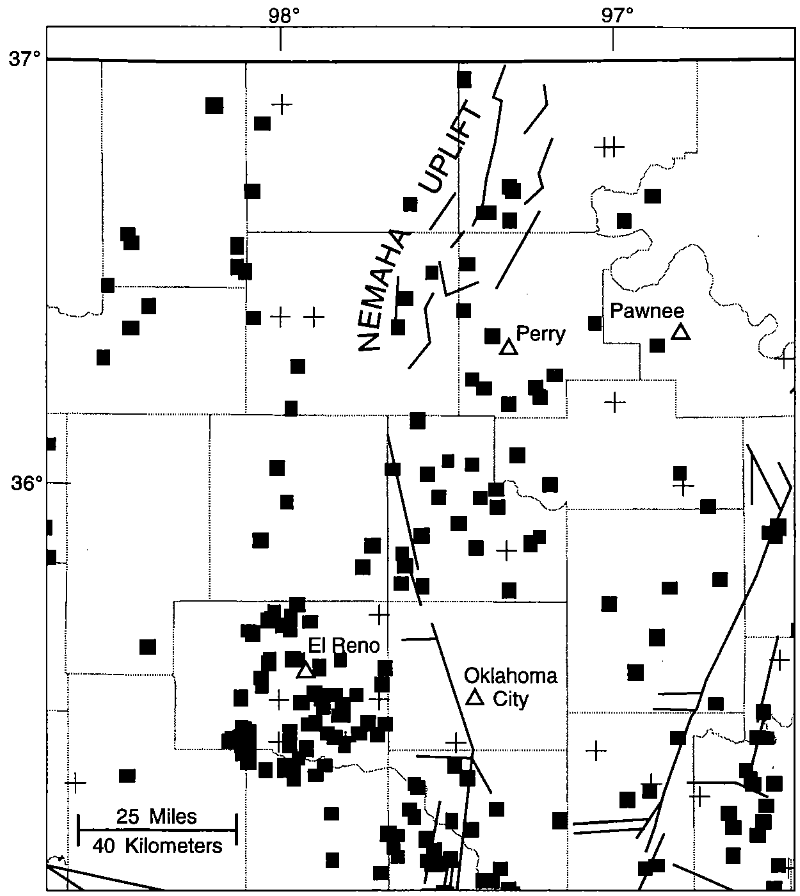


Figure 9. Distribution of north-central Oklahoma pre-1977 earthquake epicenters (+) and 1977–93 earthquake epicenters (■). Open triangles show selected city locations; solid lines indicate faults, structure generalized.

North-Central Oklahoma

Prior to the installation of the Statewide earthquake-station network, more than half of the known Oklahoma earthquakes occurred in Canadian County (Appendix 2). After the El Reno earthquake of 1952, magnitude 5.5 (mb, Gutenberg and Richter), no earthquakes were reported for this region until 1978.

The pre-1977 earthquake data and the 1977–93 earthquake data for north-central Oklahoma are shown in Figure 9. There appears to be a 40-km-wide, 145-km-long earthquake zone that extends northeastward from near El Reno toward Perry (Noble County). Most of the earthquakes have occurred in the vicinity of the El Reno–Mustang area, which has been the site of numerous earthquakes since 1908.

Correlation of historical and recent earthquake activity with known structural features remains unclear. Some fault features that cut pre-Pennsylvanian rocks, which were compiled from Wheeler (1960), Jordan (1962), Luza and Lawson (1983), and unpublished reports, are shown in Figure 9. The El Reno–Perry trend appears to cut diagonally across the Nemaha uplift structures at about a 30° angle. The southern end of this trend appears to be more active than the middle and northern parts. The recent as well as the historic earthquake data seem to support this observation.

Anadarko Basin

More than 350 located earthquake events have taken place in the Anadarko basin since 1897. A majority of the Anadarko basin earthquakes have occurred within a 135-km-long by 40-km-wide zone situated between Canadian County and the south edge of Garvin County. More than 90% of the earthquakes within this zone have taken place since 1977 (Fig. 10). The increase in seismic activity is, in part, related to improved earthquake detection capabilities. The southern end of this trend closely parallels the Central Oklahoma fault zone (sometimes referred to as the McClain County fault zone), which is about 40 km wide and 60 km long.

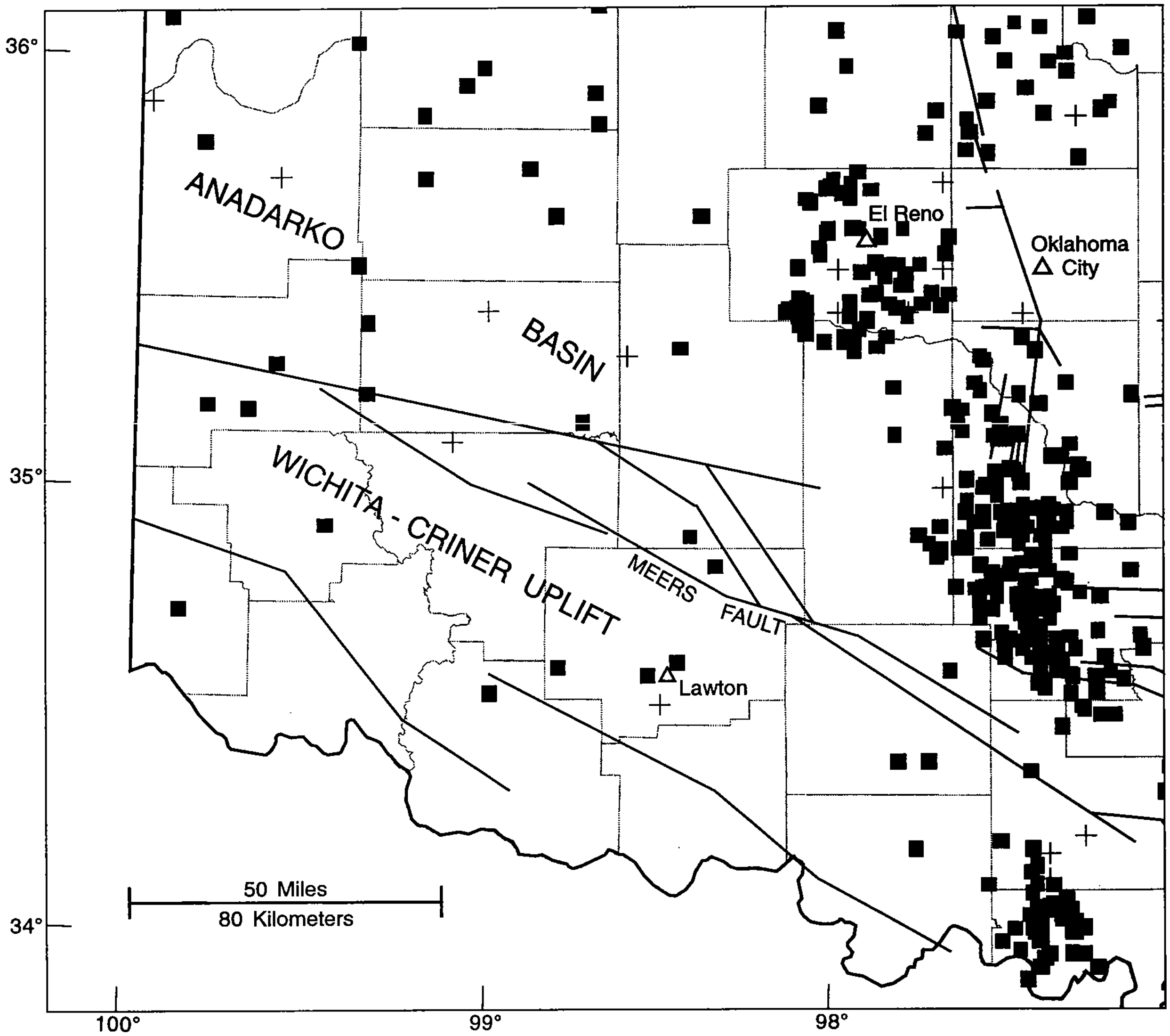


Figure 10. Distribution of Anadarko basin and vicinity pre-1977 earthquake epicenters (+) and the 1977–93 earthquake epicenters (■). Open triangles show selected city locations; solid lines indicate faults, structure generalized.

Only a few earthquakes are known to have occurred in the shelf and deep portions of the basin. The Amarillo-Wichita uplift and associated fault zone are very quiet seismically compared to McClain, Garvin, and Canadian Counties. Perhaps when the stress along the frontal fault zone is periodically relieved, as by a substantial break such as the Meers fault (Crone and Luza, 1990), the region may experience very low seismic activity for a considerable time.

Arkoma-Ouachita Region

A majority of the earthquakes in this region occur along and north of the Choctaw frontal fault zone. Prior to 1961, 11 earthquakes were reported felt in this region. Most of these earthquakes had Modified Mercalli (MM) intensity effects of IV to V and calculated magnitudes of <3. The largest known earthquake took place near the intersection of the Ouachita frontal fault zone and Arbuckle Mountain structures near Durant on October 14, 1968. This earthquake produced MM intensity effects of VI and the felt area was relatively small, ~1,000 km^2.

The pre-1977 earthquake data (~50 earthquakes), when combined with the 1977–93 earthquake data, produce a broad pattern of epicenter locations in the Arkoma basin (Fig. 11). The area between the Choctaw and Windingstair faults contains a few earthquakes. The region south of the Windingstair fault is seismically very quiet.

Approximately 90% of all earthquakes in the Arkoma-Ouachita region were instrumentally located. Typical earthquake-magnitude values range from 1.8 to 2.5, and focal depths are generally shallow, 5 km.

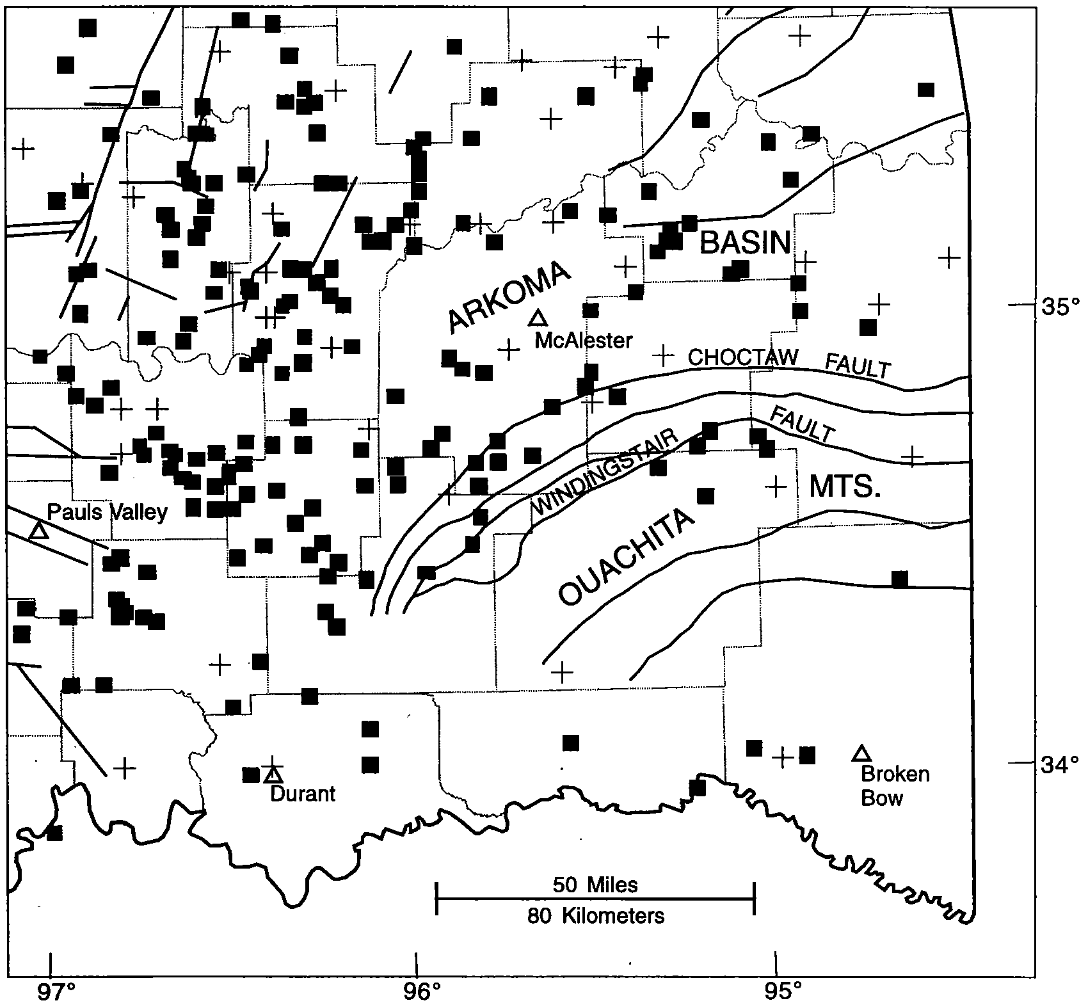


Figure 11. Distribution of southeastern Oklahoma pre-1977 earthquake epicenters (+) and the 1977–93 earthquake epicenters (■). Open triangles show selected city locations; solid lines indicate faults, structure generalized.

Discussion

The network has a 50% probability of locating magnitude ≥1.6 earthquakes and a 90% probability of locating a magnitude ≥2.0 earthquake. Prior to 1977, Oklahoma had 128 known earthquakes (Fig. 8). From 1977 through 1993, 888 additional earthquakes were located in Oklahoma, mostly of magnitudes <2.5 (Fig. 8). The network has enabled the Oklahoma Geological Survey to identify areas not previously known to be seismically active. For example, most of the earthquakes between Norman and Pauls Valley would have gone undetected before the network was operational.

We have made good progress toward the identification of earthquake-prone areas in Oklahoma. Earthquake-source mechanisms, focal-depth determinations, and fault-plane solutions remain elusive. It will take several years of locating small-magnitude earthquakes and deeper and larger-magnitude earthquakes before specific earthquake generating structures can be identified. Apparently many of the earthquake-generating structures are buried deeply.

Earthquake detection and location accuracy have been improved greatly since the installation of the Statewide network of seismograph stations. The frequency of earthquake events and the possible correlation of earthquakes to specific tectonic elements in Oklahoma are being studied. It is hoped that this information will provide a more complete data base that can be used to develop numerical estimates of earthquake risk, giving the approximate frequency of the earthquakes of any given size for various regions of Oklahoma. Numerical risk estimates could be used for better design of large-scale structures, such as dams, high-rise buildings, and power plants, as well as to provide the necessary information to evaluate insurance rates.

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Appendix 1

Earthquake-Phase Nomenclature

For purposes of earthquake location and phase identification, the average crustal structure of Oklahoma is represented by a two-layer crust over the mantle (Fig. 12). Each layer is 20 km thick. The upper layer is probably composed of *sial*, rocks like granite that are rich in silicon and aluminum. Its contact with the lower layer is called the Conrad discontinuity. The lower layer probably is made of rocks like gabbro or basalt which are called *sima* because they are rich in silicon and magnesium. The contact between the lower layer and mantle is called the Mohorovicic discontinuity. The upper mantle is probably composed of ultrabasic rocks like peridotite or dunite. Such a simplified cross section of the average crust is called a model. The model also specifies P-wave (longitudinal waves in which the rock vibrates in the direction in which the wave is traveling) and S-wave (transverse waves in which the rock vibrates perpendicular to the direction in which the wave is traveling) velocities for the two layers and the upper mantle. This particular model was developed by Nuttli and others (1969) for eastern Missouri, northeastern Arkansas, southern Illinois, western Tennessee, and western Kentucky. However, it gives excellent results for Oklahoma also. This model ignores sedimentary layers that may be as thick as 15 km in the Anadarko basin and other basins in Oklahoma, but it does represent a good average structure for the entire State.

P and S waves travel outward from the hypocenter in all directions, but in Figure 12 we have drawn only those waves that travel to the particular seismograph shown. The P wave traveling in a direct line is called Pg. Another P wave, called P*, is for part of its path traveling in the top of the second layer. This occurs because the particular ray shown is critically refracted from the first into the second layer (critical refraction implies that the wave is bent to travel parallel to the contact). Waves are always refracted when they pass from one layer to another in which they travel at a different velocity. Another P wave, Pn, is refracted along the top of the upper mantle.

Because Pn and P* lose energy on each refraction, and because they travel farther than Pg, they are smaller than Pg and usually are not seen. They are obscured on the seismogram by the larger Pg. However, beyond 160–180 km away from the earthquake, the extra distance traveled by P* and Pn is more than made up for by their higher velocity along the lower part of their path, and they arrive before Pg and may be seen clearly. There also are corresponding S waves, called Sg, S*, and Sn, traveling similar paths. Beyond ~1,000 km from the hypocenter, the P and S waves have traveled a curved path deep in the mantle. There are no separate phases owing to layering. The phases recorded at these distances are simply called P and S.

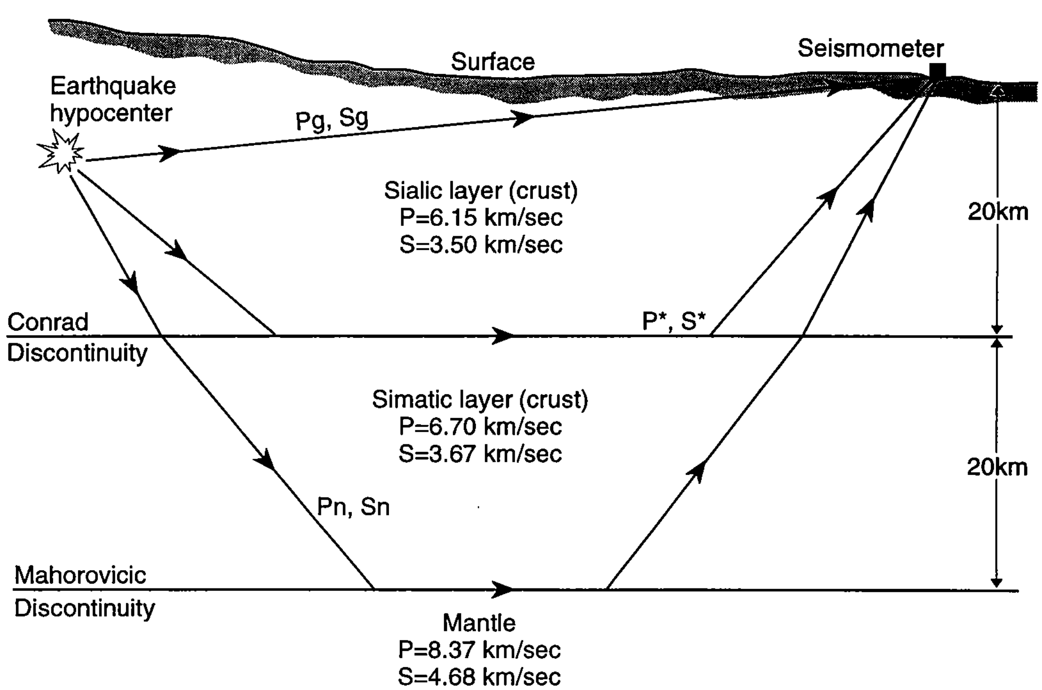


Figure 12. Crustal model used in locating Oklahoma earthquakes (modified from Nuttli and others, 1969).

Appendix 2

Catalog of Earthquakes in Oklahoma, 1882–1994

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
1a	**1882** Oct 22	2200		8				Eastern Oklahoma	
1b	**1897** Dec 02		Grant	4				36.9	98.0
1	**1900** Dec		Payne	4				36.0	96.8
2	**1901** Apr 01		Payne	F				36.0	96.8
3	1901 Apr 08	1330	Payne	F				36.0	96.8
4	**1908** Jul 19		Canadian	3				35.7	97.7
5	**1910**		Canadian	F				35.5	98.0
6	**1915** Oct 08		Rogers	F		3.9		36.2	95.8
7	**1918**		Canadian	4				35.5	97.7
8	1918 Sep 10	1630	Canadian	5		3.4		35.5	98.0
9	1918 Sep 11	0630	Canadian	6		3.4		35.5	98.0
10	1918 Sep 11	0900	Canadian	6				35.5	98.0
11	**1924** Jun 03		Pawnee	3				36.3	96.5
12	**1926** Jun 20	1420	Sequoyah	5		4.3		35.6	94.9
13	**1929** Dec 28	0030	Canadian	6		4.0		35.5	98.0
14	**1933** Aug 19	1930	Canadian	5		3.3		35.5	98.0
15	(See footnote a.)								
16	**1935** Nov 29		Payne	F				36.2	97.0
17	**1936** Mar 14	1720	McCurtain	5		3.6		34.0	95.0
18	1936 Jul 12	0023	Cimarron	F		3.3		36.9	103.0
19	**1937** Jun 08	1426	Pottawatomie	4		3.6		35.3	96.9
20	**1939** Jun 01	0730	Hughes	4		4.4		35.0	96.4
21	**1941** Oct 18	0748	Washita	5		3.2		35.4	99.0
22	**1942** Jun 12	0550	Garfield	3		3.7		36.4	97.9
23	**1952** Apr 09	1629 15	Canadian	7		5.0		35.4	97.8
24	1952 Apr 11	1830	Canadian	F				35.4	97.8
25	1952 Apr 11	2030	Canadian	4		3.8		35.4	97.8
26	1952 Apr 16		Canadian	F				35.4	97.8
27	1952 Apr 16		Canadian	F				35.4	97.8
28	1952 Apr 16		Canadian	F				35.4	97.8
29	1952 Apr 16		Canadian	F				35.4	97.8
30	1952 Apr 16		Canadian	F				35.4	97.8
31	1952 Apr 16		Canadian	F				35.4	97.8
32	1952 Apr 16	0558	Canadian	F		3.8		35.4	97.8
33	1952 Apr 16	0605	Canadian	5		3.8		35.4	97.8
34	1952 May 01	1140	Canadian	F				35.4	97.8
35	1952 May 02	0155	Canadian	F				35.4	97.8
36	1952 Jul 17	0030	Canadian	F				35.4	97.8
37	1952 Jul 17	0200	Canadian	F				35.4	97.8
38	1952 Aug 14	2140	Canadian	4				35.4	97.8
39	1952 Oct 08	0415	Seminole	4				35.1	96.5
40	**1953** Mar 16	1250	Canadian	3				35.4	97.8
41	1953 Mar 17	1312	Canadian	5				35.4	98.0
42	1953 Mar 17	1425	Canadian	6		3.8		35.4	98.0
43	1953 Jun 06	1740	Pontotoc	4				34.8	96.7
44	**1954** Apr		Hughes	4				35.1	96.4
45	1954 Apr 11		Hughes	4				35.1	96.4
46	1954 Apr 12	2305	Hughes	4				35.1	96.4
47	1954 Apr 13	1848	Hughes	4				35.1	96.4
48	(See footnote a.)								

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
49	**1956** Apr 02	1603 18	Pushmataha	5		3.8		34.2	95.6
50	1956 Oct 30	1036 21	Rogers	7		4.1		36.2	95.8
51	**1959** Jun 15	1245	Pontotoc	5		4.0		34.8	96.7
52	1959 Jun 17	1027 07	Comanche	6		4.2		34.5	98.5
53	**1960** Mar 18	2130	Rogers	F				36.2	95.8
54	1960 Mar 18	2330	Rogers	F				36.2	95.8
55	**1961** Jan 11	0140	Latimer	5		3.8		34.8	95.5
56	(See footnote a.)								
57	1961 Apr 27	0300	Pushmataha	F				34.6	95.0
58	1961 Apr 27	0500	Pushmataha	F				34.6	95.0
59	1961 Apr 27	0730	Latimer	5		4.1		34.9	95.3
60	**1962** Apr 28	0609 11	Caddo				2.4	35.3	98.6
61	1962 May 18	0240 29.30	Pittsburg				2.1	35.1	95.4
62	1962 Aug 04	0018 07.30	Pittsburg				1.8	35.2	95.6
63	1962 Sep 01	0209 56.10	Hughes				1.9	35.2	96.0
64	**1963** Jan 15	0533 37.50	Atoka				2.0	34.6	95.9
65	1963 Mar 13	0933 34	Atoka				2.6	34.6	95.9
66	1963 Jun 12	1208 31	Pontotoc				1.4	34.7	96.8
67	1963 Jun 12	1638 52	Pontotoc				2.4	34.7	96.8
68	1963 Jul 14	0808 23.20	Grady				1.4	35.0	97.7
69	1963 Jul 14	0810 27	Grady				1.9	35.0	97.7
70	**1964** Feb 02	0822 44.10	Kiowa				2.2	35.1	99.1
71	**1966** Mar 26	0517 09	Creek		2.3			35.7	99.6
73	**1968** Oct 11	0222 55	Bryan	F	2.3		2.0	34.0	96.4
74	1968 Oct 11	0240 42	Bryan	F	1.9		1.6	34.0	96.4
75	1968 Oct 11	0855 42	Bryan	F	2.8		2.3	34.0	96.4
76	1968 Oct 11	0933 37	Bryan	F	2.4		2.0	34.0	96.4
77	1968 Oct 11	2144 57	Bryan			2.0	1.6	34.0	96.4
78	1968 Oct 12	0350 28	Bryan		1.8	1.2		34.0	96.4
79	1968 Oct 12	1119 06	Bryan		1.8			34.0	96.4
80	1968 Oct 12	2146 44	Bryan			2.6	2.0	34.0	96.4
81	1968 Oct 14	0345 20	Bryan		2.0		1.6	34.0	96.4
83	1968 Oct 14	1442 54	Bryan	6	3.5		3.1	34.0	96.4
85	1968 Oct 17	2154 57	Bryan			2.0	1.6	34.0	96.4
86	1968 Oct 18	2114 10	Bryan			2.8	2.1	34.0	96.4
87	1968 Nov 15	1041 25	Marshall		2.6		2.4	34.0	96.8
88	**1969** May 02	1133 22.50	Okfuskee	F		3.5		35.5	96.2
89	1969 May 02	1154 16	Okfuskee				0.8	35.5	96.2
90	**1971** Mar 01	1927 32.10	Le Flore				2.6	35.1	94.9
91	1971 Mar 13	1922 15.30	McIntosh			2.7		35.2	95.8
92	**1973** Jan 10	1638 15.30	Garfield	1		2.3		36.4	98.0
93	1973 Sep 28	2203 03.10	Ottawa		2.0			36.8	94.9
94	1973 Oct 27	1008 45.40	Muskogee		1.9			35.8	95.2
95	1973 Nov 13	2343 39.30	Kay		1.9			36.8	97.0
96	1973 Nov 18	1003 52.70	Le Flore		2.5			35.0	94.7
97	1973 Dec 25	0411 32.00	Le Flore		2.9	2.8		35.1	94.5
98	**1974** Jan 03	2212 05.80	Kay		2.7	2.2		36.8	97.03
99	1974 May 10	0115 17.80	Carter				2.6	34.2	97.3
100	1974 Nov 10	0619 18.60	Pontotoc		2.7			34.8	96.8
101	1974 Dec 16	0230 18.80	Oklahoma	3	2.4			35.4	97.47
102	**1975** Mar 31	0952 06.00	Muskogee		2.9			35.606	95.296
103	1975 May 25	1658 46.10	Hughes		2.0			35.0	96.38
104	1975 Jun 16	0159 28.20	Johnston		2.9			34.23	96.54
105	1975 Sep 13	0125 02.10	Carter	5		3.4		34.1	97.40
106	1975 Oct 12	0258 11.50	Canadian				3.2	35.5	97.7
107	1975 Oct 30	0037 14.10	Pottawatomie		2.7			35.27	96.76
108	1975 Nov 29	1429 41.20	Garvin	5		3.6		34.65	97.53
109	1975 Dec 19	0529 25.00	Carter	2		2.5		34.1	97.4

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
110	**1976** Jan 20	0005 25.40	McIntosh		2.1			35.54	95.42
111	1976 Feb 16	0559 49.10	Okfuskee			2.3		35.59	96.52
112	1976 Mar 16	0739 45.30	McIntosh	4	2.7			35.43	95.6
113	1976 Mar 30	0653 16.00	Cimarron	5		2.1		36.68	102.25
114	1976 Mar 30	0927 02.00	Cimarron	5		2.7		36.68	102.25
115	1976 Apr 16	1859 46.10	Roger Mills	4		3.4		35.87	99.97
116	1976 Apr 17	0248 05.70	Carter	2		2.4		34.1	97.4
117	1976 Apr 19	0442 43.90	Roger Mills	5		3.5		35.87	99.97
118	1976 Jun 07	0130 49.60	Le Flore				1.9	34.66	94.62
119	1976 Jun 23	0821 17.80	Carter	3		2.7		34.1	97.4
120	1976 Jun 24	0802 39.50	Carter	2	1.4			34.1	97.4
121	1976 Sep 20	0940 16.20	Carter	3		2.1		34.16	97.4
122	1976 Oct 03	1631 08.80	Hughes		2.3			34.93	96.22
123	1976 Oct 19	1351 36.90	Muskogee		1.6			35.56	95.68
124	1976 Oct 20	0405 39.80	Coal		2.8	2.5		34.75	96.12
125	1976 Oct 22	1715 50.50	Pottawatomie			3.0		35.38	97.06
126	1976 Nov 11	1612 21.90	Logan			2.2		35.85	97.32
127	1976 Nov 19	0552 24.80	Hughes		2.3			35.23	96.38
128	1976 Dec 17		Love	F				34.1	97.4
129	1976 Dec 19	0826 36.70	Pittsburg	1		2.9		34.92	95.73
130	**1977** Feb 04	2052 29.28	Love	2		1.9		34.065	97.370
131	1977 Feb 10	0128 16.26	Love	2		2.0		34.065	97.370
132	1977 Mar 03	1408 16.52	Noble		1.9	1.6		36.263	97.437
133	1977 Mar 09	1621 08.06	Coal		2.1		2.0	34.588	96.511
134	1977 Mar 12	2104 19.63	Seminole		2.5	2.3	2.7	34.994	96.625
135	1977 Mar 26	2137 12.59	Love	3		2.3		34.065	97.370
136	1977 Apr 28	0230 56.12	Payne		2.0	1.8	2.1	36.009	97.201
137	1977 May 22	1215 04.65	Noble		1.5	1.4	1.3	36.240	97.246
138	1977 Jun 16	0202 46.56	Love			2.0	1.8	34.041	97.358
139	1977 Jun 16	2224 24.13	Love				1.8	33.909	97.444
140	1977 Jun 30	2303 21.99	Carter		2.8	2.5	2.1	34.193	96.958
141	1977 Jul 10	0839 09.29	Okfuskee		2.0	1.6	2.0	35.476	96.304
142	1977 Aug 10	0011 18.19	Garvin		1.5	1.9	1.9	34.677	97.546
143	1977 Sep 12	0236 30.06	Choctaw		2.5		2.4	33.947	95.243
144	1977 Sep 26	0155 10.63	Love			1.6	1.4	33.987	97.346
145	1977 Sep 29	0719 01.13	Noble		2.1		2.1	36.394	97.072
146	1977 Oct 06	0036 08.35	Kingfisher		1.8	2.0	1.7	35.820	97.767
147	1977 Dec 08	1947 40.22	Canadian		2.3	2.0	2.0	35.449	97.927
148	**1978** Jan 08	0416 33.56	Kay		1.5		1.5	36.971	97.463
149	1978 Jan 08	1019 17.65	Logan		2.1	2.0	2.2	35.824	97.642
150	1978 Feb 10	0642 02.39	Coal		2.1	1.5	1.9	34.712	96.157
151	1978 Feb 14	0109 38.64	Logan		1.7		1.7	35.777	97.585
152	1978 Feb 21	1112 48.11	Tillman		2.5	2.2	2.0	34.535	99.003
153	1978 Mar 03	0224 37.28	Hughes		2.5	2.1	2.4	35.086	96.278
154	1978 Mar 05	1446 50.48	Le Flore		3.1	2.9	2.7	34.699	95.033
155	1978 Mar 09	0630 50.82	Love	2		2.5	2.5	34.010	97.378
156	1978 Apr 02	2132 48.08	Atoka		2.5	2.3	2.5	34.635	96.057
157	1978 Apr 11	0851 02.43	Pittsburg		1.7		1.8	34.693	95.681
158	1978 Apr 13	0343 50.76	Johnston		1.9	2.0	1.9	34.351	96.820
159	1978 Apr 19	1420 54.06	Tulsa		1.5		1.1	36.088	96.136
160	1978 Apr 20	0813 04.00	Coal		1.7		1.6	34.586	96.293
161	1978 May 01	2259 13.38	McCurtain		2.1	2.2	2.2	34.400	94.673
162	1978 May 04	0435 52.89	Okfuskee		1.3		1.5	35.588	96.345
163	1978 May 17	2311 15.65	Canadian	1	2.1	2.3	2.0	35.525	97.910
164	1978 May 18	0019 22.43	Canadian	3	2.5	2.7	2.5	35.502	97.949
165	1978 May 18	0032 17.57	Canadian	2	2.2	2.1	2.1	35.601	97.828
166	1978 May 19	0039 37.46	McClain		1.7	2.0	1.9	35.135	97.503
167	1978 May 19	0627 32.70	Logan		1.8		1.4	36.002	97.367
168	1978 May 28	0919 00.22	Hughes		2.1	0.9	1.8	35.213	96.144
169	1978 Jun 22	0510 15.54	Dewey		2.0		2.2	35.923	99.089
170	1978 Aug 03	0035 37.09	Beaver		2.3	2.1	2.4	36.689	100.162
171	1978 Aug 06	0428 56.83	Ellis		3.0	2.2	2.6	36.073	99.935
172	1978 Aug 08	1207 48.69	Carter		2.3	2.2	1.9	34.127	97.463
173	1978 Aug 26	1457 51.99	Carter				1.4	34.178	97.463
174	1978 Sep 08	0516 06.60	Mayes				1.4	36.155	95.275

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
175	1978 Sep 26	2117 17.72	Canadian		2.2	2.2	2.2	35.519	97.866
176	1978 Sep 27	0156 03.81	Canadian		2.2	2.1	2.2	35.519	97.843
177	1978 Sep 27	2056 03.75	Love		2.4		1.9	33.883	97.477
178	1978 Dec 08	1118 53.92	Atoka		2.0	1.8	1.7	34.676	96.063
179	1978 Dec 19	0200 28.87	Haskell		1.2	1.7	1.7	35.086	95.125
180	1978 Dec 27	2200 30.02	Love		2.0		1.9	33.996	97.512
181	1978 Dec 28	0530 32.43	Love		1.4	1.9	1.5	34.080	97.462
182	1978 Dec 28	1354 09.81	Love		1.9	2.1	1.9	33.991	97.456
183	**1979** Jan 08	1135 42.99	Alfalfa		2.0	2.1	1.9	36.579	98.146
184	1979 Jan 24	0515 46.35	Love		1.4		1.5	33.985	97.434
185	1979 Jan 24	0525 32.00	Love		1.8	2.1	1.9	34.022	97.381
186	1979 Jan 28	1024 9.34	Sequoyah		1.4		1.7	35.483	94.568
187	1979 Jan 29	1920 10.40	McClain		2.4	2.6	2.3	34.916	97.383
188	1979 Feb 01	1231 32.28	Pittsburg		1.8	1.7	2.1	34.830	96.062
189	1979 Feb 04	1655 59.96	Garvin		2.6	2.5	2.6	34.672	97.157
190	1979 Feb 05	1423 40.05	Hughes		2.2	1.8	2.2	35.177	96.092
191	1979 Mar 01	0342 18.77	Love		1.9	2.0	1.8	33.969	97.446
192	1979 Mar 13	2329 22.56	Canadian	2	1.7			35.421	97.851
193	1979 Mar 14	0310 56.83	Canadian	4	2.0	1.9	1.8	35.498	97.826
194	1979 Mar 14	0402 43.05	Logan		1.4		1.5	35.781	97.650
195	1979 Mar 14	0437 15.27	Canadian	5	2.2	2.2	2.1	35.519	97.781
196	1979 Mar 15	1038 10.48	Canadian		1.6		1.6	35.689	97.923
197	1979 Mar 16	1238 17.42	Alfalfa		2.0	1.9	2.0	36.517	98.123
198	1979 Mar 18	1725 39.66	Canadian		1.6		1.5	35.377	98.100
199	1979 Mar 18	1733 09.23	Canadian				0.8	35.410	98.115
200	1979 Mar 18	1735 16.41	Canadian				1.0	35.410	98.115
201	1979 Mar 18	1739 51.71	Canadian		1.5		1.3	35.410	98.115
202	1979 Mar 18	1744 31.59	Canadian		1.6		1.4	35.410	98.115
203	1979 Mar 18	1752 52.20	Grady		1.8		1.5	35.344	98.053
204	1979 Mar 18	1755 36.84	Canadian		1.6		1.1	35.384	98.110
205	1979 Mar 18	1807 17.57	Canadian		2.0	2.0	1.8	35.439	98.118
206	1979 Mar 18	1814 53.81	Canadian		1.9	1.7	1.5	35.410	98.116
207	1979 Mar 18	1830 36.85	Canadian		2.3	2.3	2.0	35.418	98.108
208	1979 Mar 18	1846 29.65	Canadian		1.9	2.0	1.6	35.443	98.126
209	1979 Mar 18	1857 23.95	Canadian		2.0	2.0	1.8	35.416	98.130
210	1979 Mar 18	1913 50.60	Canadian		2.4	2.4	1.9	35.418	98.155
211	1979 Mar 18	1930 21.23	Canadian		2.2	2.2	1.8	35.418	98.101
212	1979 Mar 18	1941 57.26	Canadian		2.2	2.0	1.8	35.406	98.110
213	1979 Mar 18	2005 30.54	Canadian		2.7	2.5	2.0	35.416	98.110
214	1979 Mar 18	2024 11.90	Canadian		2.3		1.8	35.420	98.110
215	1979 Mar 18	2044 19.47	Canadian	3	2.9	2.8	2.5	35.379	98.124
216	1979 Mar 18	2107 41.09	Canadian		2.0	1.8	1.5	35.429	98.114
217	1979 Mar 18	2116 54.63	Canadian		1.9	1.8	1.3	35.379	98.118
218	1979 Mar 18	2142 10.54	Canadian		2.4	2.5	2.1	35.394	98.108
219	1979 Mar 18	2208 20.53	Canadian		2.1	1.9	1.7	35.396	98.126
220	1979 Mar 18	2242 17.44	Canadian		2.0	1.9	1.5	35.416	98.126
221	1979 Mar 18	2319 01.29	Carter	3	2.5	2.3	2.2	34.100	97.448
222	1979 Mar 18	2340 39.22	Canadian		2.2	2.0	1.7	35.433	98.102
223	1979 Mar 19	0054 32.65	Canadian		2.1	2.0	1.7	35.408	98.102
224	1979 Mar 19	0342 55.14	Canadian		2.5	2.5	2.3	35.400	98.110
225	1979 Mar 21	0455 56.19	Hughes		1.8	1.2	1.7	35.043	96.349
226	1979 Mar 23	0131 48.66	Love				1.3	34.034	97.430
227	1979 Mar 23	0601 39.99	Love				1.8	34.022	97.440
228	1979 Mar 23	0757 37.46	Caddo		1.9	1.8	1.7	35.361	98.108
229	1979 Mar 23	0841 14.13	Canadian		2.0	1.9	1.9	35.387	98.108
230	1979 Mar 23	1043 54.67	Canadian		1.5		0.9	35.605	97.974
231	1979 Mar 23	1726 02.40	Canadian		2.1		1.8	35.411	98.163
232	1979 Apr 01	1229 10.76	Canadian		1.8	1.7	1.9	35.420	98.132
233	1979 Apr 22	0922 52.46	Lincoln		1.6		1.8	35.789	96.711
234	1979 May 08	1123 34.88	Logan		2.1	1.9	2.2	35.923	97.480
235	1979 May 12	2156 41.18	McClain		2.1	1.9	2.3	35.301	97.601
236	1979 May 22	0349 23.77	Love	3	1.8	1.9	2.0	34.027	97.470
237	1979 May 23	1730 08.30	Love			2.2	2.0	34.055	97.405
238	1979 Jun 01	1100 01.61	Noble		1.6	1.4	1.1	36.207	97.330
239	1979 Jun 07	0739 35.56	Beckham	3	3.2	2.9	3.0	35.187	99.812
240	1979 Jun 19	0449 56.95	Pittsburg		1.9	1.4	2.0	34.715	95.965

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
241	1979 Jun 19	0453 13.53	Pittsburg		1.8		1.9	34.746	95.932
242	1979 Jul 01	0700 16.28	Love		1.9	1.8	2.0	34.028	97.383
243	1979 Jul 04	0345 21.29	Canadian		2.3	2.3	2.2	35.705	97.978
244	1979 Jul 07	0115 33.23	Pittsburg		2.4	1.6	2.1	34.879	95.814
245	1979 Jul 13	0748 13.44	McCurtain		1.3		1.8	34.033	95.087
246	1979 Jul 24	0224 06.27	Logan		2.8	2.5	2.5	36.070	97.506
247	1979 Jul 25	0315 37.27	Love	5		2.7	2.3	33.967	97.549
248	1979 Jul 31	1911 05.62	Payne		2.4	2.5	1.9	36.086	97.305
249	1979 Aug 03	1029 11.63	Canadian		2.0	1.9	1.7	35.683	98.005
250	1979 Aug 09	0004 14.86	Love		1.8	2.3	2.0	33.930	97.432
251	1979 Aug 16	0727 12.82	McClain		1.7	1.9	1.7	34.953	97.602
252	1979 Aug 19	0158 07.85	Cleveland		2.4	2.2	2.0	35.203	97.445
253	1979 Sep 04	0740 11.97	Garvin		2.2	2.3	2.0	34.799	97.557
254	1979 Sep 05	0238 48.48	Canadian		1.7	1.9	1.5	35.429	97.871
255	1979 Sep 05	0404 34.49	Canadian		1.8	1.8	1.5	35.427	97.717
256	1979 Sep 13	0049 22.97	Beckham	4	3.3	3.4	3.1	35.217	99.362
257	1979 Sep 13	0219 51.28	Washita		1.9		2.1	35.380	99.360
258	1979 Sep 15	0342 25.39	Canadian		1.8		1.7	35.493	97.882
259	1979 Sep 15	1401 19.38	Grady		2.0	1.9	1.9	35.369	97.952
260	1979 Sep 16	0604 53.11	Grady		1.7		1.6	35.355	97.997
261	1979 Sep 16	0627 58.42	Canadian		1.7		1.5	35.435	97.981
262	1979 Sep 16	1042 05.85	Canadian		2.0	2.0	1.9	35.455	97.905
263	1979 Sep 16	1107 00.23	Grady		1.9	1.8	1.8	35.355	97.989
264	1979 Sep 16	1557 20.84	Grady	4	2.5	2.5	2.2	35.343	97.997
265	1979 Sep 16	2216 42.17	Grady		2.1	1.9	1.9	35.355	97.966
266	1979 Sep 17	1438 09.60	Haskell		1.6	1.8	1.7	35.063	94.937
267	1979 Sep 17	2041 50.53	Grady	4	2.6	2.5	2.3	35.320	97.968
268	1979 Oct 06	1108 51.92	Pittsburg		1.5		1.6	34.887	95.873
269	1979 Oct 21	0729 07.55	Coal		2.3	2.2	2.4	34.502	96.432
270	1979 Nov 07	0554 09.84	Canadian		2.1		1.9	35.510	97.888
271	1979 Nov 11	1026 57.33	Canadian		2.2	1.9	2.1	35.695	98.050
272	1979 Nov 16	0550 15.60	Hughes				1.3	35.285	95.987
273	1979 Nov 27	0910 36.79	Blaine		3.3	3.3	2.9	35.630	98.408
274	1979 Dec 09	2312 58.66	Love	3	2.8	2.5	2.4	33.988	97.353
275	1979 Dec 10	0825 14.82	Hughes		1.8	1.5	2.0	34.965	96.307
276	1979 Dec 14	1320 09.02	McClain		1.8	1.9	1.8	35.187	97.664
277	1979 Dec 16	1237 37.49	Washita		2.5		2.2	35.158	98.741
278	1979 Dec 20	1458 26.81	Noble		2.1		1.9	36.367	97.379
279	**1980** Jan 05	0711 31.21	Canadian		1.9	1.6	1.7	35.586	97.894
280	1980 Jan 12	0712 56.45	Garfield		1.7		1.4	36.453	97.642
281	1980 Feb 03	0046 30.05	Love		2.2	1.9	2.0	33.994	97.463
282	1980 Feb 05	0432 35.45	Love	3	2.1	2.3	1.9	34.046	97.451
283	1980 Mar 09	0357 10.56	Haskell		1.2	1.4	1.4	35.100	95.100
284	1980 Mar 17	1402 31.21	McClain		2.3	2.2	1.9	35.047	97.566
285	1980 Mar 19	2250 57.93	McClain		2.4	2.4	2.0	34.980	97.644
286	1980 Mar 23	0749 01.56	Kay			1.4	1.4	36.655	97.391
287	1980 Apr 01	2116 32.26	Pontotoc		1.9	1.8	1.8	34.726	96.762
288	1980 Apr 08	1918 06.93	Haskell		2.1		2.1	35.165	95.301
289	1980 Apr 29	1959 51.18	Garvin		2.0	2.4	1.8	34.578	97.285
290	1980 May 28	0405 45.65	Garfield		1.8			36.168	97.602
291	1980 May 30	0744 02.72	Roger Mills		3.0	2.6	2.5	35.512	99.390
292	1980 Jun 03	2141 50.31	Latimer		2.3	2.1	1.7	35.000	94.932
293	1980 Jun 06	0131 27.86	Canadian		2.6	2.3	2.2	35.402	97.983
294	1980 Jun 06	0318 12.45	Logan		1.5			36.039	97.570
295	1980 Jun 08	2333 34.30	Love		2.1	1.9	1.7	33.940	97.323
296	1980 Jun 09	0550 42.20	Love			1.8	1.4	33.940	97.417
297	1980 Jun 15	1250 51.95	Pittsburg				1.2	34.728	95.778
298	1980 Jul 08	0134 44.01	Love		2.3	2.5	2.4	34.002	97.354
299	1980 Jul 18	1429 46.88	Beckham			3.2	2.8	35.180	99.698
300	1980 Aug 05	1713 32.96	Jefferson				2.2	34.096	97.588
301	1980 Aug 10	1010 02.58	Woods		2.3	2.2		36.843	98.871
302	1980 Sep 07	0150 14.23	Cleveland		1.9		2.2	34.953	97.258
303	1980 Sep 07	0806 20.87	Pittsburg		1.6	1.4	1.8	34.680	95.840
304	1980 Oct 04	0902 20.56	Pontotoc		2.2	1.8	2.1	34.694	96.612
305	1980 Oct 08	0833 05.97	McClain		1.9	1.9	2.1	35.084	97.405

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
306	1980 Oct 21	0902 55.01	Kay		1.7	0.9		36.707	97.318
307	1980 Oct 28	0503 04.99	Cleveland		1.7	1.8	1.8	35.225	97.495
308	1980 Nov 01	0526 13.85	Canadian	3	1.9	2.0	2.0	35.472	97.836
309	1980 Nov 02	1000 49.03	Canadian	5	3.0	3.0	2.8	35.429	97.777
310	1980 Nov 07	0046 33.07	Kay		2.1	1.7	2.0	36.638	97.326
311	1980 Nov 07	0050 11.34	Kay		1.7	1.6	1.7	36.716	97.326
312	1980 Nov 13	0023 39.10	Haskell		1.5		1.7	35.196	95.235
313	1980 Nov 13	2355 48.18	Carter		1.8	1.8	1.8	34.367	97.077
314	1980 Nov 15	1206 59.08	Garvin		1.7	1.8	1.6	34.820	97.187
315	1980 Nov 20	0950 39.73	Kingfisher		1.5		1.6	35.871	97.733
316	1980 Nov 21	1025 53.61	Garvin		1.9	1.9	1.9	34.857	97.359
317	1980 Nov 22	0334 10.24	Alfalfa		2.3	1.8	2.1	36.527	98.146
318	1980 Nov 22	1935 02.77	Okmulgee		2.7	2.5	2.7	35.379	95.995
319	1980 Nov 22	2004 30.13	Okmulgee		1.8	1.4	1.7	35.356	95.987
320	1980 Nov 30	2344 01.99	Garvin		2.3	1.8	2.2	34.795	97.360
321	1980 Dec 04	0123 16.96	Carter	F	1.9	1.8	1.7	34.096	97.401
322	1980 Dec 04	2348 43.22	Love	F	2.1		2.1	33.942	97.352
323	1980 Dec 05	0007 26.29	Love	F	2.6	2.4	2.4	33.909	97.284
324	1980 Dec 05	0953 23.98	Love		2.2	2.0	2.0	34.002	97.323
325	1980 Dec 17	1249 45.46	Garvin		2.8	2.9	2.8	34.855	97.464
326	1980 Dec 21	1405 55.45	McClain		2.2	2.1	2.2	35.017	97.592
327	1980 Dec 30	1517 52.59	McClain		1.8		1.7	34.953	97.362
328	**1981** Jan 04	1734 08.46	Canadian		2.3	2.2	2.2	35.664	98.097
329	1981 Feb 04	0338 19.08	Creek		1.8	1.5	1.8	35.661	96.388
330	1981 Feb 18	1233 47.61	McClain		2.0	2.0	2.1	34.902	97.491
331	1981 Feb 20	0220 29.71	Custer		2.4	2.2	2.3	35.707	99.202
332	1981 Mar 08	1447 08.15	Canadian		1.9	1.9	1.9	35.593	98.047
333	1981 Mar 08	1540 57.01	Canadian		2.2	2.3	2.3	35.601	97.961
334	1981 Mar 25	0722 19.27	McClain		1.7	2.0	2.0	34.925	97.412
335	1981 Apr 25	0407 22.32	Pottawatomie		1.7	1.5	2.0	35.117	96.903
336	1981 Apr 27	0004 03.25	Okmulgee		2.0		2.1	35.602	95.882
337	1981 Apr 27	0751 08.11	Pottawatomie		1.6		1.7	35.293	96.916
338	1981 May 05	1129 54.68	Atoka			1.9	2.1	34.560	95.828
339	1981 May 15	0513 52.00	Canadian		1.9	1.7	1.9	35.473	97.817
340	1981 Jun 10	1605 23.14	Pontotoc		2.1	1.7	1.9	34.714	96.684
341	1981 Jun 17	0502 24.82	Grant		1.9		1.9	36.675	97.625
342	1981 Jul 01	2243 30.07	McClain		2.3	2.5	2.7	34.953	97.550
343	1981 Jul 08	0256 29.89	Garfield		1.4			36.513	97.557
344	1981 Jul 08	0328 30.93	Canadian		1.7	1.7	1.7	35.602	98.041
345	1981 Jul 09	0100 39.96	Canadian		1.7	1.9	1.7	35.558	98.069
346	1981 Jul 09	0620 28.29	Canadian		1.5	1.7	1.5	35.539	98.065
347	1981 Jul 09	2247 11.10	McClain		2.3		2.4	34.955	97.651
348	1981 Jul 10	0316 56.10	Canadian		1.5		1.4	35.514	98.128
349	1981 Jul 10	0723 11.90	McClain		1.6	1.7	1.8	34.930	97.624
350	1981 Jul 10	2239 18.45	Garvin		1.8	2.3	1.6	34.544	97.283
351	1981 Jul 11	1914 24.90	Grady		1.0			34.853	97.732
352	1981 Jul 11	1921 07.63	Grady		1.7	1.9	1.8	34.858	97.719
353	1981 Jul 11	1926 39.20	Grady		0.9			34.853	97.732
354	1981 Jul 11	1928 07.25	Grady		1.1			34.853	97.732
355	1981 Jul 11	1930 38.19	Grady		1.0			34.853	97.732
356	1981 Jul 11	1934 53.98	Grady		1.2			34.853	97.732
357	1981 Jul 11	1936 38.40	Grady		0.9			34.853	97.732
358	1981 Jul 11	1944 47.96	McClain		1.9	1.9	1.9	34.870	97.669
359	1981 Jul 11	2004 29.21	Grady		1.8	1.9	1.8	34.919	97.724
360	1981 Jul 11	2006 57.63	Grady		2.1	2.3	2.3	34.868	97.724
361	1981 Jul 11	2019 23.72	Grady	2	2.0	2.2	2.2	34.881	97.751
362	1981 Jul 11	2109 21.84	Grady	5	2.9	3.5	3.0	34.853	97.732
363	1981 Jul 12	0426 49.04	Grady		1.5	1.6	1.5	34.776	97.676
364	1981 Jul 12	1829 25.53	McClain		1.9	2.2	1.8	34.947	97.427
365	1981 Jul 14	0408 15.36	Okfuskee		0.7			35.418	96.604
366	1981 Jul 15	1831 33.83	Garvin		2.0	2.3	1.9	34.537	97.350
367	1981 Jul 20	0953 31.08	McClain		1.9	2.0	2.0	34.971	97.411
368	1981 Jul 25	0004 31.72	Osage		1.6		1.5	36.693	96.904
369	1981 Jul 26	0423 03.72	Noble		1.7		1.8	36.224	97.232
370	1981 Jul 31	2324 25.91	Latimer		1.7		2.0	34.709	95.222
371	1981 Sep 06	1752 54.93	Woods		2.3		2.2	36.480	98.531

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
372	1981 Sep 17	1931 00.46	Johnston		2.3		1.9	34.481	96.823
373	1981 Sep 28	1136 07.58	Roger Mills		1.2		1.8	36.015	99.400
374	1981 Oct 24	0535 42.27	Pittsburg		1.3		1.7	35.167	95.777
375	1981 Nov 05	1647 22.06	Canadian		2.1	2.0	1.9	35.677	97.982
376	1981 Nov 06	1928 25.31	Pontotoc		2.0		2.2	34.676	96.682
377	1981 Nov 09	0936 55.47	Garvin		1.9	1.7	1.9	34.796	97.480
378	1981 Nov 12	0059 39.29	Creek		1.1		1.6	35.668	96.479
379	1981 Dec 04	0313 07.34	Grady		1.8	2.0	1.9	35.195	97.691
380	1981 Dec 04	0531 40.01	McClain		2.0	2.2	2.1	35.137	97.659
381	1981 Dec 09	2150 03.65	Comanche		1.8		2.1	34.608	98.465
382	1981 Dec 17	0522 53.76	Grady		2.2	2.0	2.1	35.132	97.852
383	1981 Dec 17	0544 54.70	Garfield		2.7	2.9	2.6	36.387	97.661
384	1981 Dec 19	0249 53.21	Love		1.2		1.8	33.948	97.495
385	**1982** Jan 12	2340 25.00	Garvin		2.0			34.742	97.406
386	1982 Jan 13	0056 38.98	McClain		2.0	1.8		34.949	97.492
387	1982 Jan 13	0404 24.42	Garvin		2.4	2.2	2.0	34.643	97.337
388	1982 Jan 13	0704 47.65	McClain		2.2	2.0	2.1	34.961	97.477
389	1982 Jan 13	0713 08.26	McClain		1.8	1.8		35.025	97.561
390	1982 Jan 15	0952 16.96	Canadian		2.8	2.7	2.6	35.714	98.029
391	1982 Mar 13	0141 49.93	Canadian		2.6	2.5	2.6	35.699	98.038
392	1982 Mar 15	0658 25.60	Alfalfa		2.4		2.0	36.908	98.226
393	1982 Mar 15	2107 50.27	McClain		1.8		1.8	34.934	97.600
394	1982 Mar 15	2118 18.92	Carter		1.8		1.8	34.358	97.467
395	1982 Mar 15	2139 10.98	Garvin		2.3		2.2	34.832	97.608
396	1982 Mar 15	2230 09.37	Garvin		2.3		2.1	34.780	97.600
397	1982 Mar 15	2344 39.84	Stephens		1.6		1.7	34.663	97.600
398	1982 Mar 16	0021 42.02	Comanche		2.4		1.9	34.593	98.805
399	1982 Mar 16	0158 56.74	McClain		1.5		1.5	34.895	97.653
400	1982 Mar 16	0636 27.90	Garvin		1.7		1.7	34.776	97.623
401	1982 Mar 16	2050 29.41	Murray				1.7	34.347	96.961
402	1982 Mar 16	2101 54.45	Garvin		2.0		1.7	34.749	97.610
403	1982 Mar 18	0951 52.95	Garvin		1.9		2.0	34.715	97.608
404	1982 Mar 23	1417 09.98	Coal		2.5	2.3	2.0	34.729	96.399
405	1982 Mar 24	0448 36.20	Creek		2.4		1.7	36.051	96.452
406	1982 May 03	0754 48.65	Bryan	6	2.8	3.0	2.6	33.990	96.473
407	1982 May 12	0141 40.74	Okfuskee		2.1	1.5	1.8	35.324	95.987
408	1982 May 21	1638 44.02	Pontotoc		1.9	1.8	1.9	34.703	96.668
409	1982 May 29	2043 17.32	McClain		2.1	2.3	2.4	34.934	97.539
410	1982 May 30	2343 25.24	Okfuskee		2.3		1.6	35.301	96.213
411	1982 Jun 13	0413 42.83	McClain		1.8	1.8	1.8	34.992	97.557
412	1982 Jun 13	0615 36.73	Canadian		2.1	1.7	1.8	35.451	97.698
413	1982 Jul 08	0115 37.52	Pontotoc		1.8		1.7	34.856	96.842
414	1982 Jul 09	0338 11.35	McClain		2.0			34.963	97.432
415	1982 Jul 09	0427 46.80	Garvin		1.5			34.586	97.240
416	1982 Jul 09	0700 54.95	Garvin		1.9			34.644	97.150
417	1982 Jul 09	0902 50.59	McClain		2.2	1.9	2.3	34.925	97.418
418	1982 Jul 09	0929 34.61	Cleveland		1.9			35.226	97.180
419	1982 Jul 20	0336 46.22	Stephens		2.0	2.1	2.2	34.590	97.694
420	1982 Jul 26	0449 21.61	Seminole		2.0	2.1	2.1	35.063	96.561
421	1982 Aug 03	1932 06.24	Coal		2.0	2.2	2.1	34.481	96.303
422	1982 Aug 05	1010 43.31	McClain		2.3	1.9	2.2	35.043	97.497
423	1982 Aug 11	2117 26.83	Garvin		2.3	2.1	2.1	34.565	97.432
424	1982 Aug 13	1558 07.15	Hughes		1.8	2.2	2.2	35.242	96.006
425	1982 Aug 18	1018 56.86	Coal		2.6	2.7	2.5	34.465	96.227
426	1982 Aug 22	0101 02.42	Garvin		2.3		1.8	34.840	96.936
427	1982 Aug 22	0446 15.32	Hughes		2.0		1.9	35.069	96.459
428	1982 Sep 08	1235 10.75	Love		2.6	2.5	2.4	34.014	97.338
429	1982 Sep 10	1131 16.69	Pittsburg		2.1		2.0	35.223	95.464
430	1982 Sep 21	1155 55.82	Love		2.2	2.3		33.866	97.003
431	1982 Sep 22	0400 33.69	Caddo		2.6	2.2	2.4	34.894	98.429
432	1982 Nov 16	0602 28.42	Dewey		2.3		1.5	35.839	98.705
433	1982 Nov 16	0827 25.90	Kingfisher		2.2	1.6	1.6	35.972	97.991
434	1982 Dec 14	2149 55.09	Carter		2.2	2.7	2.1	34.463	97.378
435	1982 Dec 15	0433 21.62	Johnston		1.8		1.7	34.246	96.440
436	1982 Dec 18	0841 12.09	McClain		2.0	1.9	2.1	34.887	97.588

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
437	1982 Dec 19	0515 42.94	McClain		3.0	2.9	2.7	34.891	97.584
438	1982 Dec 19	2145 00.07	Haskell				1.8	35.290	94.950
439	1982 Dec 20	2210 46.13	Okfuskee		2.3	2.3	2.4	35.305	96.256
440	1982 Dec 21	1808 48.38	Murray		2.1	2.2	2.0	34.489	97.237
441	1982 Dec 22	1742 53.73	Canadian		2.4	2.8	2.4	35.396	97.932
442	**1983** Jan 10	1706 43.75	Grant		2.7	2.5	2.4	36.704	98.107
443	1983 Jan 21	0005 04.58	Haskell		1.8		2.0	35.165	95.282
444	1983 Feb 01	0719 38.08	Hughes		1.7		1.3	35.082	96.272
445	1983 Feb 17	1951 00.43	Creek		1.7		1.9	35.862	96.067
446	1983 Feb 19	0059 32.94	Okmulgee		1.7	1.3	1.7	35.399	95.975
447	1983 Mar 10	0806 04.14	Hughes		2.6	2.3	2.6	35.035	96.202
448	1983 Mar 11	1650 48.26	Beaver		2.9	2.8	2.8	36.827	100.115
449	1983 Mar 13	1017 20.85	Seminole				1.9	35.309	96.557
450	1983 Mar 28	0932 24.86	Pontotoc		2.1		1.9	34.635	96.561
451	1983 May 15	0400 23.58	Comanche		2.8	2.7	2.6	34.827	98.360
452	1983 May 16	2108 21.08	Harmon		2.8	2.8	2.5	34.718	99.883
453	1983 Jun 21	1832 59.87	McClain		2.6	2.9	2.5	34.959	97.405
454	1983 Jun 22	0529 52.24	Creek		1.6		1.8	35.932	96.037
455	1983 Jun 22	0535 46.13	Seminole		1.8	1.3		35.321	96.623
456	1983 Jun 22	0910 47.07	Creek		1.3		1.3	35.932	96.043
457	1983 Jul 05	2002 25.84	Pontotoc		2.4	2.4	2.3	34.667	96.519
458	1983 Jul 08	0650 21.36	Creek		1.6		2.0	35.946	96.054
459	1983 Jul 24	2159 58.71	Creek		1.0		1.5	35.950	96.054
460	1983 Jul 26	1010 56.69	McIntosh		1.6		1.9	35.489	95.518
461	1983 Jul 27	0557 43.45	Garvin		2.1	1.9	2.2	34.855	97.425
462	1983 Aug 03	0431 24.22	Tulsa		1.2		1.4	35.883	96.011
463	1983 Aug 08	0407 11.19	Garvin		2.0		1.9	34.731	97.416
464	1983 Aug 10	0100 40.34	Okmulgee		1.5		2.0	35.848	95.980
465	1983 Aug 10	1908 37.95	Creek		1.4		1.5	35.948	96.043
466	1983 Aug 12	0700 27.81	Creek		1.6		2.1	35.950	96.041
467	1983 Aug 18	0638 16.68	Garvin		1.7	1.7	1.8	34.741	97.404
468	1983 Aug 19	1352 05.91	Creek		1.6		1.7	35.957	96.043
469	1983 Aug 20	0546 01.39	Atoka		2.1	1.9	2.3	34.435	95.984
470	1983 Aug 20	1128 43.42	Coal				1.5	34.728	96.319
471	1983 Aug 24	1010 03.43	McIntosh				1.4	35.493	95.787
472	1983 Aug 30	0032 02.58	Creek		1.7		2.0	35.946	96.043
473	1983 Sep 28	0016 15.35	Atoka		1.5		1.9	34.166	96.305
474	1983 Sep 28	0126 01.33	Cleveland		1.9		2.2	35.250	97.367
475	1983 Oct 06	0709 25.29	Logan		1.7	1.4	2.2	35.985	97.537
476	1983 Oct 23	1934 46.93	Pontotoc		2.9	2.9	2.7	34.817	96.888
477	1983 Nov 13	0527 52.82	Tulsa		1.3		2.0	35.918	96.027
478	1983 Nov 20	0803 24.66	Creek		1.0		1.3	35.936	96.031
479	1983 Nov 21	0553 20.14	Creek		1.1		1.5	35.926	96.035
480	1983 Nov 23	1436 17.57	Garvin		2.1	2.1	2.1	34.731	97.485
481	1983 Nov 27	1633 42.84	Muskogee				1.7	35.431	95.200
482	1983 Nov 29	0349 18.14	Tulsa		0.9		1.1	35.942	95.925
483	1983 Dec 04	0536 00.18	Payne				1.5	35.961	96.746
484	1983 Dec 11	0501 22.25	Creek		0.9		1.3	35.946	96.043
485	1983 Dec 11	0713 44.57	Creek		1.3		1.8	35.920	96.033
486	1983 Dec 11	0734 25.13	Creek		1.5		2.1	35.930	96.031
487	1983 Dec 19	1424 53.32	Pittsburg		2.0	1.7	1.9	34.682	95.774
488	1983 Dec 29	1046 44.26	Beckham		2.3	2.2	2.4	35.284	99.620
489	**1984** Jan 06	1714 49.81	Rogers	5	2.5		2.5	36.161	95.582
490	1984 Jan 23	1037 04.30	Seminole		1.5		1.7	35.207	96.674
491	1984 Jan 23	1101 56.21	Seminole		2.2		2.1	35.234	96.690
492	1984 Jan 24	1534 09.63	Hughes	5	3.1	2.8	2.7	35.033	96.366
493	1984 Feb 03	0438 28.04	Garvin	5		3.2	3.1	34.665	97.356
494	1984 Feb 10	1839 13.56	Love	4	2.4		2.2	34.049	97.415
495	1984 Feb 20	0147 22.00	Grant		2.1		2.0	36.870	98.087
496	1984 Feb 20	1148 49.51	Okfuskee		2.3		2.1	35.485	96.358
497	1984 Mar 03	1142 02.36	Okfuskee	5	2.7	2.6	2.7	35.514	96.301
498	1984 Mar 16	1713 30.18	Hughes		2.5	2.1	2.3	35.117	96.315
499	1984 Apr 18	0836 37.22	Creek		1.2		1.5	35.922	96.074
500	1984 Apr 21	0538 02.16	Pittsburg		1.9	1.5	1.8	35.233	95.563

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d]			Latitude (°N.)	Longitude (°W.)
					3Hz	bLg	DUR		
501	1984 Apr 28	2255 40.71	Tulsa		1.1		1.1	36.297	95.921
502	1984 May 27	1213 27.31	McClain		2.1	1.7	2.0	34.889	96.965
503	1984 May 31	0236 58.32	Custer		1.5		2.0	35.735	98.903
504	1984 Jun 03	0814 13.11	Logan		2.0		2.2	35.895	97.593
505	1984 Jun 11	0508 45.67	Garfield		1.5		1.8	36.196	97.979
506	1984 Jul 09	0306 03.73	Pittsburg		1.9	2.2	2.4	34.629	95.834
507	1984 Jul 13	1656 12.35	McClain				2.2	35.020	97.358
508	1984 Aug 17	1804 01.85	Garvin		2.7	2.5	2.4	34.767	97.326
509	1984 Aug 18	0404 21.63	Coal		1.8	1.7	1.9	34.553	96.336
510	1984 Sep 08	0332 25.39	Coal		2.1	1.8	1.9	34.625	96.393
511	1984 Sep 17	0959 10.06	McClain		1.9	2.0	2.2	35.009	97.600
512	1984 Oct 04	1225 09.29	Garvin		2.5	2.6	2.5	34.741	97.502
513	1984 Nov 04	0701 22.88	Seminole		1.5		1.7	34.965	96.745
514	1984 Nov 04	0837 39.76	Johnston		2.2	2.0	2.0	34.144	96.518
515	1984 Nov 16	1150 04.51	Garvin		2.1		2.0	34.641	97.487
516	1984 Nov 18	1314 09.89	Garvin		2.3	2.1	2.1	34.644	97.440
517	1984 Nov 20	1057 31.98	Garvin	4	3.0	3.1	2.7	34.707	97.410
518	1984 Nov 25	0336 35.64	Seminole		1.9		2.0	35.340	96.635
519	1984 Nov 27	0208 47.88	Roger Mills		1.5		1.9	35.786	99.837
520	1984 Nov 30	1326 07.92	Alfalfa		2.1		2.2	36.580	98.466
521	1984 Dec 08	0504 42.02	Harper		2.0		2.1	36.777	99.591
522	1984 Dec 11	0621 24.18	Pontotoc		1.8		1.9	34.658	96.520
523	1984 Dec 29	0344 46.80	McClain		1.6	1.7	1.9	35.027	97.648
524	1984 Dec 29	0430 59.23	Garvin		2.1	1.9	2.1	34.609	97.437
525	**1985** Jan 23	0039 48.68	Johnston		2.1	2.1	2.2	34.352	96.826
526	1985 Jan 24	1212 42.40	McClain		2.5	2.5	2.5	34.924	97.427
527	1985 Feb 01	0907 24.89	Carter		1.8	2.0	2.1	34.143	97.449
528	1985 Feb 10	1415 52.21	Major		3.0	2.8	2.7	36.433	98.412
529	1985 Feb 28	1756 57.73	Pushmataha		2.4	2.3	2.3	34.661	95.339
530	1985 Mar 15	0522 09.32	Garvin		1.7	1.9	2.1	34.758	97.437
531	1985 Apr 14	0719 05.41	Harper		1.6		1.8	36.691	99.806
532	1985 Apr 17	0539 49.06	Ellis		2.0		2.2	36.141	99.495
533	1985 Apr 24	1031 58.77	Grady		1.9		2.0	35.101	97.710
534	1985 May 03	0733 40.40	Garvin	4	2.5	2.5	2.6	34.656	97.484
535	1985 May 03	1135 47.06	Garvin		2.1	1.9	2.1	34.647	97.540
536	1985 May 04	1205 19.00	Garvin		2.0	2.0	2.3	34.807	97.549
537	1985 May 05	0139 30.78	Garvin	F	3.0	2.9	2.8	34.664	97.529
538	1985 May 05	0216 02.65	Garvin	F	2.4	2.2	2.3	34.836	97.455
539	1985 May 05	2027 47.26	McClain		1.8	1.8	1.9	34.910	97.541
540	1985 May 05	2129 15.95	Murray		1.3		1.6	34.508	97.323
541	1985 May 06	0211 16.16	McClain	5	2.2	2.3	2.4	34.969	97.482
542	1985 May 07	1722 04.91	Lincoln		2.3	1.9	2.4	35.496	96.727
543	1985 May 26	1000 49.96	Kingfisher		2.1	1.7	2.1	35.731	97.963
544	1985 Jun 03	0713 34.47	Atoka		2.1		2.0	34.500	95.851
545	1985 Jun 06	1150 18.80	Seminole		1.8		1.6	35.188	96.608
546	1985 Jun 22	1401 55.05	Johnston		2.1	1.9	2.0	34.345	96.760
547	1985 Jul 12	0435 37.76	Logan		1.8	1.7	2.2	35.863	97.421
548	1985 Jul 27	2000 08.29	Noble		2.2		1.8	36.240	97.405
549	1985 Aug 06	1944 14.58	Haskell		2.4	2.5	2.0	35.378	95.008
550	1985 Aug 11	1016 23.22	Dewey		2.7		2.5	35.964	99.037
551	1985 Aug 20	1817 38.35	Garvin				1.7	34.759	97.482
552	1985 Aug 20	1831 53.24	Garvin				1.6	34.759	97.482
553	1985 Aug 20	1937 40.77	Garvin				1.7	34.759	97.482
554	1985 Aug 20	1943 31.33	Garvin				1.5	34.759	97.482
555	1985 Aug 20	1949 51.81	Garvin				1.4	34.759	97.482
556	1985 Aug 20	1950 35.10	Garvin		2.6	2.3	2.2	34.751	97.498
557	1985 Aug 20	2034 46.14	Garvin				1.4	34.759	97.482
558	1985 Aug 20	2230 14.92	Garvin		2.5	2.5	2.2	34.759	97.468
559	1985 Aug 20	2303 46.94	Garvin		2.6	2.3	2.4	34.732	97.476
560	1985 Aug 21	0037 33.32	Garvin				1.5	34.759	97.482
561	1985 Aug 21	0146 13.31	Garvin				2.1	34.759	97.482
562	1985 Aug 21	0212 57.04	Garvin				2.4	34.759	97.482
563	1985 Aug 21	0856 38.97	Garvin				1.7	34.759	97.482
564	1985 Aug 22	0906 52.20	Woodward		1.7		1.9	36.386	99.537
565	1985 Aug 28	0231 51.12	Stephens				2.0	34.382	97.844

Event no.[a]	Date			Origin time (UTC)[b]		County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
566	1985	Sep	17	0958	44.10	Coal		1.8	1.8	1.8	34.618	96.471
567	1985	Sep	23	0103	44.10	Le Flore		3.3	2.9	2.6	34.725	95.059
568	1985	Oct	24	1212	19.98	McClain		2.1	1.8	2.0	35.232	97.607
569	1985	Nov	07	0835	33.76	Jefferson		1.8	2.0	2.2	34.181	97.790
570	1985	Dec	10	0059	06.04	Comanche		2.2	2.1	2.2	34.577	98.549
571	1985	Dec	28	1011	37.92	Hughes		2.1		2.2	35.118	96.232
572	1985	Dec	31	1815	30.90	Garvin				1.8	34.703	97.459
573	1985	Dec	31	1827	26.12	Garvin		3.0	2.7	2.5	34.703	97.459
574	1985	Dec	31	1920	38.52	Garvin				1.9	34.703	97.459
575	1985	Dec	31	1921	26.80	Garvin				1.8	34.703	97.459
576	1985	Dec	31	1931	49.15	Garvin				1.7	34.703	97.459
577	1985	Dec	31	2148	03.77	Garvin		2.3	2.3	2.2	34.704	97.460
578	1985	Dec	31	2245	03.76	Garvin		2.4		2.2	34.765	97.490
579	**1986**	Jan	01	0134	07.41	Garvin		2.2	1.9	2.3	34.764	97.473
580	1986	Jan	01	0220	46.17	Garvin		1.9	1.9	2.0	34.656	97.436
581	1986	Jan	01	0640	44.52	Garvin		1.6		1.8	34.683	97.451
582	1986	Jan	01	0808	07.63	Garvin		1.7		2.1	34.625	97.537
583	1986	Jan	01	0946	38.73	Garvin		1.5		2.1	34.703	97.459
584	1986	Jan	03	0612	13.41	Carter				2.2	34.197	97.554
585	1986	Jan	03	1924	34.00	Logan				2.2	35.851	97.646
586	1986	Jan	07	1225	10.81	Pottawatomie		1.8		1.6	35.274	96.987
587	1986	Jan	09	0349	26.82	Garvin		1.8		2.2	34.726	97.464
588	1986	Jan	25	2233	07.40	Pontotoc		2.0		2.0	34.753	96.720
589	1986	Jan	26	0203	40.65	Garvin		2.5	2.5	2.4	34.728	97.456
590	1986	Jan	26	1212	12.62	Garvin				2.2	34.748	97.472
591	1986	Jan	27	0237	23.85	Grady		2.2	2.1	2.3	35.238	97.858
592	1986	Jan	27	0503	50.38	Grady		2.5	2.4	2.4	35.348	97.878
593	1986	Feb	06	1050	13.75	Garvin		1.6		1.8	34.560	97.446
594	1986	Feb	14	0609	05.41	Latimer		2.5	1.8	2.3	34.821	95.442
595	1986	Feb	24	2352	22.43	Garvin		2.6	2.3	2.1	34.626	97.417
596	1986	Feb	25	0526	20.33	Pottawatomie		1.7		1.6	35.023	96.923
597	1986	Mar	13	0946	26.55	Seminole		1.5		1.6	35.117	96.546
598	1986	Apr	05	1454	53.00	Johnston		1.6	1.6	1.9	34.446	96.749
599	1986	Apr	16	1952	08.80	Coal		2.3	2.0	2.0	34.631	96.149
600	1986	Apr	29	2357	18.65	Hughes		1.9		1.5	35.165	96.003
601	1986	Apr	30	0336	10.71	McClain		2.0		2.2	34.931	97.360
602	1986	May	25	1027	44.82	Delaware		2.1	1.4	2.2	36.229	94.877
603	1986	Jun	01	1952	38.19	Lincoln		2.1	1.5	2.0	35.656	96.897
604	1986	Jun	02	0708	11.21	Pontotoc		1.3		1.1	34.652	96.651
605	1986	Jun	10	0748	01.66	Choctaw		2.0	1.5	1.9	34.056	95.592
606	1986	Jun	15	2200	54.27	Lincoln		1.3		1.6	35.767	96.859
607	1986	Jun	30	1955	51.16	Pontotoc		2.7	2.0	2.3	34.706	96.752
608	1986	Jul	26	0417	23.83	Pontotoc		2.6	2.3	2.3	34.591	96.620
609	1986	Aug	04	2336	06.82	Haskell		1.2		1.7	35.165	95.296
610	1986	Sep	02	1319	59.04	Pontotoc		2.1		2.0	34.684	96.483
611	1986	Sep	02	1537	09.90	Murray		1.9		1.7	34.489	97.270
612	1986	Sep	04	1733	17.41	Coal		2.8	2.6	2.5	34.477	96.503
613	1986	Sep	16	0105	16.94	Hughes		2.5		2.3	34.884	96.370
614	1986	Sep	23	0549	27.96	Pontotoc		2.0		1.8	34.903	96.468
615	1986	Oct	07	1206	39.12	Seminole		2.2		2.5	35.257	96.580
616	1986	Oct	13	1742	44.71	Garvin		2.6	2.3	2.0	34.750	97.421
617	1986	Oct	18	2112	16.49	Pittsburg				1.1	34.915	95.909
618	1986	Oct	30	0124	34.80	Garvin		2.0		1.8	34.759	97.409
619	1986	Nov	01	0130	35.93	Le Flore		1.6		1.5	34.962	94.747
620	1986	Nov	02	0124	03.59	Hughes		1.5		1.4	34.940	96.179
621	1986	Nov	02	0400	11.97	Johnston		1.9		1.7	34.192	96.855
622	1986	Nov	05	1334	46.18	Texas		2.8		2.4	36.993	101.561
623	1986	Nov	26	2053	38.63	McClain		2.2	1.8	1.8	34.957	97.526
624	1986	Nov	26	2216	56.53	McClain		2.0	1.9	2.0	35.125	97.541
625	1986	Nov	27	0612	15.90	Grady		1.5	1.8	2.0	35.158	97.671
626	1986	Dec	04	1750	11.83	Logan		2.7	2.4	2.2	35.766	97.328
627	1986	Dec	14	1156	18.54	Seminole		1.7		1.6	34.959	96.642
628	1986	Dec	21	1732	58.13	Seminole		2.8	2.8	2.6	35.142	96.676
629	1986	Dec	23	2110	47.62	Garvin				1.6	34.572	97.204
630	1986	Dec	25	0846	17.38	McIntosh		1.9	1.4	1.7	35.399	95.839

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
631	**1987** Jan 06	0800 49.33	Garvin				1.9	34.815	97.576
632	1987 Jan 10	0321 49.95	Garvin		2.7	2.3	2.3	34.552	97.425
633	1987 Jan 12	0609 02.22	Garvin		2.3	2.1	2.0	34.652	97.390
634	1987 Jan 16	0316 25.33	Garvin				1.7	34.812	97.526
635	1987 Jan 17	0413 53.77	McClain		2.3	2.3	2.2	35.051	97.517
636	1987 Jan 24	1608 17.01	Kingfisher	5	3.4	3.1	2.8	35.828	98.097
637	1987 Jan 27	0636 23.00	Pawnee				1.5	36.339	96.885
638	1987 Jan 29	0000 53.22	Atoka		2.5	2.6	2.3	34.318	96.234
639	1987 Feb 04	1345 23.93	Garvin				1.7	34.757	97.558
640	1987 Feb 16	0053 56.45	Lincoln				1.3	35.574	96.960
641	1987 Feb 19	0550 11.47	Garvin		2.0	2.1	2.1	34.836	97.488
642	1987 Feb 26	0204 07.15	Seminole		2.0	1.9	2.1	35.308	96.620
643	1987 Mar 14	0443 03.54	Hughes			2.8	2.7	34.790	96.331
644	1987 Apr 22	0129 37.34	Garvin				1.5	34.603	97.384
645	1987 Apr 22	0140 00.61	Garvin		1.7		2.0	34.845	97.515
646	1987 Apr 22	0316 34.91	Garvin		1.9	1.5	1.9	34.764	97.503
647	1987 Apr 22	0627 47.84	Garvin		2.4	2.0	2.4	34.591	97.394
648	1987 Apr 22	0855 05.60	Garvin				1.9	34.817	97.421
649	1987 Apr 22	0935 26.00	Garvin				1.4	34.591	97.394
650	1987 Apr 22	0946 51.31	Garvin		2.0	1.4	2.1	34.692	97.437
651	1987 Apr 22	1123 09.45	Garvin				1.5	34.591	97.394
652	1987 Apr 22	1301 37.89	Garvin		2.3	2.2	2.3	34.798	97.460
653	1987 May 07	0733 45.89	Osage		1.8		1.9	36.636	96.986
654	1987 May 15	0829 07.53	Canadian		2.2		2.1	35.455	97.749
655	1987 May 17	0541 04.87	Logan		2.0	1.7	2.0	35.890	97.236
656	1987 May 17	1501 19.86	Logan		1.6		1.5	35.878	97.264
657	1987 May 28	1918 02.67	Garvin		1.8		1.6	34.683	97.276
658	1987 Jun 01	1744 33.18	Garvin		2.8	2.9	2.6	34.615	97.380
659	1987 Jun 02	2025 36.96	Pontotoc		2.2		1.9	34.707	96.555
660	1987 Jun 07	0735 24.33	Haskell				1.5	35.165	95.280
661	1987 Jun 18	0221 56.74	Hughes		1.7	1.9	2.1	35.118	96.347
662	1987 Jun 29	0726 20.96	Johnston		2.0	1.5	1.7	34.335	96.726
663	1987 Jul 05	2223 00.58	Haskell		2.2		2.1	35.188	95.289
664	1987 Jul 08	0339 28.79	Sequoyah				1.5	35.393	94.892
665	1987 Jul 12	1144 50.94	McClain				1.6	34.886	97.421
666	1987 Jul 18	1511 44.75	Hughes		2.2		1.7	34.927	96.437
667	1987 Aug 23	1706 46.49	Hughes		1.8		2.0	34.945	96.421
668	1987 Aug 29	0936 24.62	Hughes				1.6	35.079	96.464
669	1987 Sep 03	2210 12.42	Garvin		2.3	2.1	1.9	34.623	97.401
670	1987 Sep 05	0342 48.46	Garvin		1.4		1.5	34.779	97.475
671	1987 Sep 06	1014 22.26	Garvin		2.0	2.4	2.0	34.600	97.435
672	1987 Sep 07	0713 24.87	Garvin				1.6	34.759	97.273
673	1987 Sep 17	1238 39.34	McCurtain		1.3		1.6	34.014	94.945
674	1987 Sep 21	1331 52.93	Cleveland		1.6	1.7	1.7	35.310	97.608
675	1987 Sep 21	1353 24.77	McClain		2.2	2.2	2.1	35.119	97.536
676	1987 Sep 21	1359 59.47	McClain		1.4		1.9	35.249	97.626
677	1987 Sep 21	1410 09.97	Garvin		1.2		1.6	34.623	97.259
678	1987 Sep 21	1425 07.07	McClain		2.0	1.9	2.0	35.129	97.570
679	1987 Sep 21	1452 45.57	McClain		1.7		1.9	35.119	97.557
680	1987 Sep 21	1508 08.37	McClain		1.8	2.0	2.0	35.178	97.575
681	1987 Sep 21	1600 32.05	McClain		1.3		1.7	35.025	97.493
682	1987 Sep 21	1609 58.21	McClain		1.7		1.9	35.056	97.524
683	1987 Sep 22	0508 36.11	McClain		0.7			35.155	97.552
684	1987 Sep 22	0527 13.27	McClain		1.4		1.8	35.046	97.518
685	1987 Sep 22	0607 35.83	McClain		2.0	2.0	2.3	35.145	97.552
686	1987 Sep 22	0715 37.50	Grady		1.8	1.9	2.1	34.900	97.786
687	1987 Sep 24	0218 47.39	Canadian		1.4		1.8	35.406	97.815
688	1987 Oct 02	0522 20.74	Rogers				1.2	36.240	95.534
689	1987 Oct 05	0358 47.36	Logan		2.0		1.7	35.961	97.359
690	1987 Oct 23	1401 49.23	Grady		2.9	2.5	2.4	35.328	97.904
691	1987 Oct 29	0753 33.65	Seminole		2.6	1.9	2.5	35.215	96.589
692	1987 Nov 13	0304 56.30	Hughes				1.1	35.204	96.370
693	1987 Dec 06	1743 48.18	Garvin		3.0	2.6	2.5	34.664	97.394
694	1987 Dec 07	0044 00.95	Garvin				2.0	34.581	97.348
695	1987 Dec 08	0142 40.28	Kingfisher	6		3.7	3.6	36.055	98.024
696	1987 Dec 08	0145 47.47	Kingfisher		2.5			36.056	98.030

Event no.[a]	Date			Origin time (UTC)[b]		County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
697	1987	Dec	12	0304	24.67	Kingfisher		1.6		1.9	36.049	97.678
698	1987	Dec	16	0704	58.60	Pittsburg		2.3		2.1	34.877	95.512
699	1987	Dec	29	0439	19.16	Garvin		2.5		2.1	34.619	97.462
700	**1988**	Jan	02	0947	28.24	Pittsburg				1.3	34.846	95.534
701	1988	Jan	06	1304	12.33	Pontotoc		2.4	2.2	2.2	34.644	96.624
702	1988	Jan	11	0436	53.06	Hughes		2.1		2.2	35.174	96.126
703	1988	Jan	30	2259	20.37	Major		2.0	1.9	2.1	36.380	98.466
704	1988	Mar	19	0927	37.70	Payne				1.4	36.041	96.824
705	1988	Mar	24	0225	47.87	Okfuskee		2.3		2.3	35.414	96.573
706	1988	Mar	30	1546	55.29	Major		2.2		2.3	36.310	98.543
707	1988	Apr	21	1058	08.13	Dewey		1.3		1.7	35.855	99.207
708	1988	Apr	29	1459	56.63	Garvin		1.5		1.8	34.741	97.469
709	1988	Apr	29	1523	55.99	Garvin		1.9		2.0	34.716	97.483
710	1988	Apr	29	1527	27.67	Garvin		1.3		1.7	34.714	97.473
711	1988	Apr	29	1539	18.09	McClain		1.0		1.6	34.884	97.496
712	1988	Apr	29	1549	47.62	Garvin		1.0		1.5	34.736	97.469
713	1988	Apr	29	1607	28.87	Garvin		2.3	2.0	2.3	34.695	97.478
714	1988	Apr	29	1718	06.14	Garvin		2.6	2.5	2.4	34.682	97.471
715	1988	Apr	29	1839	40.86	Garvin		2.2	1.9	2.1	34.688	97.473
716	1988	Apr	29	1841	52.96	Garvin		1.2			34.668	97.453
717	1988	Apr	29	1907	53.15	Garvin		1.3		1.7	34.674	97.473
718	1988	Apr	29	1909	53.92	Garvin		1.3		1.7	34.780	97.473
719	1988	Apr	29	1928	57.96	Garvin		1.5		1.9	34.717	97.492
720	1988	Apr	29	2028	25.67	Garvin		1.3		1.7	34.590	97.437
721	1988	Apr	29	2246	08.53	Garvin		1.1		1.7	34.656	97.448
722	1988	Apr	29	2309	45.40	Garvin		2.7	2.2	2.5	34.663	97.473
723	1988	May	01	2041	25.99	Johnston				1.7	34.356	96.804
724	1988	May	26	1835	39.44	Alfalfa		2.1		2.2	36.599	98.478
725	1988	Jun	05	0256	55.47	Latimer		2.3	1.6	2.1	34.743	95.190
726	1988	Jun	14	0214	50.04	Noble		2.0		1.8	36.533	97.455
727	1988	Jun	21	2312	45.62	Coal		2.2	1.4	2.1	34.507	96.263
728	1988	Jul	05	2322	41.59	Dewey		2.7	2.3	2.5	35.910	98.710
729	1988	Jul	24	0813	54.75	McClain		1.7		1.7	35.084	97.373
730	1988	Aug	29	0056	50.45	McIntosh				0.9	35.532	95.355
731	1988	Sep	18	1144	30.14	McClain		1.9		1.9	34.926	97.191
732	1988	Sep	28	1848	34.02	Johnston		2.2	1.9	1.8	34.465	96.847
733	1988	Oct	03	2202	00.97	Coal		2.2	1.6	2.0	34.427	96.148
734	1988	Oct	12	1011	45.99	Kingfisher		2.3	2.1	2.2	35.883	98.075
735	1988	Oct	13	1442	06.75	Bryan		2.3	2.9	2.4	34.091	96.144
736	1988	Oct	19	0719	31.53	Canadian				1.4	35.549	97.709
737	1988	Oct	19	0734	40.27	Canadian				1.3	35.584	97.698
738	1988	Oct	21	1031	19.43	Alfalfa				1.7	36.907	98.214
739	1988	Nov	07	1253	37.76	Pittsburg		1.8		1.9	35.013	95.515
740	1988	Nov	28	2348	43.54	Pittsburg				1.4	34.801	95.623
741	1988	Nov	29	0236	33.68	Okfuskee				1.4	35.419	96.270
742	1988	Dec	01	1107	24.70	Pottawatomie				1.7	34.926	97.031
743	1988	Dec	02	0630	27.62	Creek		1.8		2.0	35.898	96.565
744	1988	Dec	03	1920	33.84	McClain		1.9	1.9	2.0	34.898	97.435
745	1988	Dec	07	1238	42.49	Creek		1.5		1.8	35.914	96.538
746	1988	Dec	08	0210	25.46	Creek		1.2		1.3	35.914	96.542
747	1988	Dec	12	0326	39.23	Creek				1.5	35.894	96.542
748	**1989**	Jan	05	0648	46.15	Rogers				1.8	36.575	95.707
749	1989	Jan	24	0019	03.36	McIntosh				1.7	35.511	95.364
750	1989	Jan	31	2258	39.91	Stephens				2.0	34.361	97.775
751	1989	Jan	31	2315	06.39	McClain			2.5	2.6	34.918	97.472
752	1989	Feb	07	2222	46.67	Johnston		2.1	2.0	2.2	34.386	96.831
753	1989	Feb	20	1159	18.01	Seminole		2.0		2.1	35.324	96.464
754	1989	Feb	23	0043	55.66	McIntosh				1.4	35.212	95.862
755	1989	Mar	08	0031	29.99	Coal		2.5	2.3	2.5	34.431	96.253
756	1989	Apr	02	0720	40.27	Pontotoc		2.0		1.9	34.664	96.859
757	1989	Apr	14	0357	43.34	Garvin				1.8	34.778	97.562
758	1989	Apr	14	0653	04.03	Garvin				2.0	34.774	97.562
759	1989	Apr	19	2006	36.95	Carter				1.7	34.313	97.089
760	1989	May	03	0121	58.12	Greer		2.1		2.2	34.912	99.475

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
761	1989 May 03	0553 00.45	Hughes				1.5	34.910	96.317
762	1989 May 03	0709 54.89	Harper		1.9		2.3	36.665	99.408
763	1989 May 15	0925 03.42	Pittsburg				1.5	35.048	95.386
764	1989 May 18	1129 27.61	Logan				1.8	35.984	97.414
765	1989 May 29	2255 32.21	Noble		2.0		2.0	36.271	97.193
766	1989 Jun 02	0948 46.38	Haskell				1.6	35.275	95.345
767	1989 Jun 12	1420 47.58	Atoka		2.2		1.8	34.355	96.261
768	1989 Jun 20	0307 26.30	Okfuskee				1.4	35.480	96.585
769	1989 Jun 22	0808 56.46	Okfuskee				1.1	35.485	96.276
770	1989 Jun 30	0553 24.79	Pontotoc				1.4	34.589	96.557
771	1989 Jul 06	0456 39.36	Pontotoc				1.8	34.585	96.517
772	1989 Jul 09	1812 39.62	Canadian				1.9	35.667	98.108
773	1989 Jul 16	0517 51.48	Cleveland				1.3	35.109	97.354
774	1989 Jul 16	0533 53.13	McClain				1.4	35.029	97.355
775	1989 Jul 16	0554 08.73	Cleveland				1.6	35.064	97.332
776	1989 Jul 16	0641 32.11	Cleveland		1.9	1.8	2.0	35.052	97.320
777	1989 Jul 16	0817 18.54	Cleveland		1.8	1.8	1.9	35.355	97.490
778	1989 Jul 16	1042 59.71	Cleveland				1.8	35.326	97.453
779	1989 Jul 19	0151 43.27	Johnston		1.8		1.7	34.373	96.824
780	1989 Jul 19	1011 58.13	Major		1.3		1.7	36.360	98.883
781	1989 Jul 19	1449 19.35	Major		2.3		2.1	36.360	98.883
782	1989 Jul 19	1539 31.83	Woodward		2.1		2.1	36.360	98.977
783	1989 Jul 19	2029 12.09	Major				1.7	36.360	98.883
784	1989 Jul 19	2054 58.60	Major		2.2		1.9	36.311	98.824
785	1989 Jul 20	0232 08.26	Major		1.6		1.8	36.360	98.860
786	1989 Jul 20	0249 49.89	Major		2.7	2.2	2.6	36.360	98.883
787	1989 Jul 20	0316 54.51	Major		2.3		2.1	36.362	98.946
788	1989 Jul 20	0352 33.33	Major		1.9		2.0	36.364	98.938
789	1989 Jul 20	0607 51.54	Major		3.1	2.5	2.8	36.382	98.818
790	1989 Jul 20	1021 08.81	Major		2.1		2.2	36.347	98.931
791	1989 Jul 20	1106 51.96	Major		2.0		2.0	36.337	98.923
792	1989 Jul 21	0422 16.43	Major		2.1		2.0	36.351	98.865
793	1989 Jul 22	1827 36.49	Major				1.8	36.382	98.818
794	1989 Jul 22	2132 24.74	Major				1.9	36.382	98.818
795	1989 Jul 26	0858 55.53	Pushmataha		2.1	1.8	2.2	34.593	95.208
796	1989 Aug 07	0754 06.68	McClain		2.4		2.2	34.918	97.507
797	1989 Aug 29	2358 17.70	Bryan				1.9	34.012	96.146
798	1989 Sep 16	0103 48.53	Murray				1.9	34.503	97.314
799	1989 Sep 27	0712 23.40	Ellis		2.5	2.5	2.3	36.127	99.995
800	1989 Sep 29	0349 19.13	McClain		2.2	2.0	2.2	34.871	97.652
801	1989 Oct 04	1319 25.63	Garfield		2.0		1.6	36.425	97.464
802	1989 Oct 05	0605 16.45	Haskell		2.2	1.5	2.1	35.139	95.326
803	1989 Oct 12	0533 22.54	Logan		1.9		1.9	36.061	97.437
804	1989 Oct 14	0131 29.25	Kay		1.6		1.9	36.653	97.404
805	1989 Nov 03	0648 58.69	Pottawatomie		1.9		1.8	35.109	96.932
806	1989 Nov 22	1153 54.62	Garvin		1.8		1.8	34.800	97.380
807	1989 Dec 09	1817 35.20	Major		2.0		2.1	36.339	98.892
808	1989 Dec 15	2242 28.10	Ellis		2.5		2.4	36.335	99.634
809	1989 Dec 27	0431 48.09	Dewey		1.5		1.9	36.104	98.709
810	**1990** Jan 08	0927 01.74	Garfield				2.2	36.402	98.093
811	1990 Jan 15	2115 37.51	Garfield				1.7	36.293	97.964
812	1990 Feb 07	1202 14.06	Custer		2.6	2.1	2.5	35.629	98.827
813	1990 Feb 16	1935 10.18	Pontotoc		2.2		1.8	34.732	96.476
814	1990 Feb 25	0731 20.76	Pottawatomie		1.2		1.5	35.418	96.837
815	1990 Apr 02	2043 07.84	Hughes				2.6	35.057	96.239
816	1990 Apr 19	2135 04.58	Garvin		2.8		2.2	34.734	97.578
817	1990 Apr 23	2226 49.61	Hughes		2.5	1.8	2.4	35.223	96.050
818	1990 May 16	1112 38.25	Caddo		1.6		1.8	35.325	98.464
819	1990 May 25	0138 33.66	Garvin		2.6	2.0	2.2	34.816	97.394
820	1990 Jun 22	1612 18.56	Garvin				2.0	34.831	97.483
821	1990 Jul 15	0026 23.96	Pottawatomie		2.1		2.1	35.170	97.044
822	1990 Jul 16	0057 55.33	Cleveland				1.6	35.248	97.518
823	1990 Jul 17	0113 19.61	Harmon			2.8	2.8	34.885	99.905
824	1990 Jul 24	0843 51.41	Comanche		1.5		1.7	34.758	98.351
825	1990 Aug 12	0122 23.16	Pontotoc		2.6		2.2	34.593	96.578

Event no.[a]	Date			Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
826	1990	Aug	12	0129 30.54	Pontotoc		2.1		2.0	34.601	96.574
827	1990	Sep	04	2232 25.78	McClain		2.4		2.0	34.976	97.585
828	1990	Sep	16	2113 33.38	Pittsburg	5	3.2	2.4	3.0	34.855	95.577
829	1990	Oct	02	0314 05.89	Kingfisher				1.8	35.941	98.042
830	1990	Oct	11	1107 22.14	Garvin		3.6	3.0	1.9	34.777	97.503
831	1990	Oct	21	1807 15.54	Hughes				0.8	35.234	96.374
832	1990	Nov	08	1451 55.89	Oklahoma		2.6	1.8	2.0	35.455	97.572
833	1990	Nov	15	1029 48.68	Garvin		1.8	1.5	2.2	34.761	97.550
834	1990	Nov	15	1049 31.49	Grady				2.0	34.794	97.677
835	1990	Nov	15	1106 13.97	Garvin				1.3	34.761	97.550
836	1990	Nov	15	1115 39.61	Garvin		2.1	1.7	2.0	34.761	97.550
837	1990	Nov	15	1118 10.46	Garvin				1.2	34.761	97.550
838	1990	Nov	15	1144 41.63	Garvin	6	4.0	3.9	3.0	34.761	97.550
839	1990	Nov	15	1214 39.29	Garvin		2.3	1.6	2.0	34.761	97.550
840	1990	Nov	15	1254 31.97	Garvin				1.6	34.761	97.550
841	1990	Nov	16	2047 15.06	Garvin	F	2.5		2.4	34.787	97.611
842	1990	Nov	19	1539 11.45	Garvin		1.8	1.4	2.3	34.765	97.599
843	1990	Nov	19	2111 27.41	Murray		1.8	1.4	2.2	34.484	97.130
844	1990	Nov	20	1725 17.87	Garvin		2.6	2.1	2.2	34.836	97.644
845	1990	Nov	22	0245 53.47	Stephens		2.7	2.2	2.2	34.668	97.570
846	1990	Dec	12	0753 27.80	Johnston		2.5	2.1	1.8	34.152	96.542
847	**1991**	Jan	09	0745 59.01	Woodward				1.6	36.167	99.505
848	1991	Jan	14	0101 06.06	Garvin		1.6	1.7	2.2	34.746	97.460
849	1991	Jan	24	0500 27.65	Noble	5			2.8	36.352	97.271
850	1991	Mar	14	0849 03.03	Roger Mills				2.0	35.511	99.644
851	1991	Mar	15	1045 37.45	Logan		1.8	1.2	1.7	35.885	97.605
852	1991	Mar	15	1417 30.33	Beaver				2.4	36.659	100.603
853	1991	Mar	22	0649 57.64	McClain		1.7		1.9	34.968	97.513
854	1991	Apr	21	0713 21.75	Garvin			1.6	1.6	34.713	97.585
855	1991	Apr	21	1609 04.09	Garvin			2.0	2.0	34.748	97.620
856	1991	Apr	21	1655 45.39	Garvin			2.5	2.4	34.812	97.635
857	1991	Apr	22	1516 50.40	Garvin				2.0	34.714	97.605
858	1991	Apr	22	1645 04.76	Caddo				2.0	35.098	98.442
859	1991	Apr	22	1704 13.97	Garvin				2.2	34.768	97.585
860	1991	Apr	22	1727 27.92	Garvin				2.1	34.741	97.585
861	1991	Apr	22	1808 54.05	Garvin				2.3	34.799	97.632
862	1991	Apr	22	1811 18.46	Garvin		2.2	1.8	2.4	34.760	97.585
863	1991	Apr	22	2251 22.20	Garvin		2.3	2.2	1.9	34.762	97.633
864	1991	May	05	1207 27.40	Pushmataha			1.7	1.4	34.168	95.550
865	1991	May	05	2154 45.70	Lincoln		2.1		2.6	35.627	96.897
866	1991	May	06	0413 30.75	Seminole			1.3	1.7	35.293	96.698
867	1991	May	09	1005 50.07	Pittsburg		1.3	1.1	1.1	34.910	95.866
868	1991	May	10	0437 56.45	Pontotoc		1.7	1.2	1.1	34.683	96.635
869	1991	May	28	1905 12.25	Pontotoc				1.7	34.605	96.808
870	1991	May	31	2311 54.37	Le Flore		1.9	2.0	1.7	35.006	94.884
871	1991	Jun	30	0811 05.64	Pontotoc		1.8	1.5	1.8	34.785	96.777
872	1991	Jul	05	2031 10.25	Noble		2.3		2.1	36.256	97.264
873	1991	Jul	09	0838 45.17	Seminole		1.3	1.1	1.4	35.347	96.687
874	1991	Jul	11	0624 50.71	Ellis		1.7	1.8	2.0	36.165	99.648
875	1991	Jul	20	0953 45.70	Coal		2.0		1.7	34.435	96.189
876	1991	Jul	20	1117 52.01	Atoka		2.5	2.3	2.2	34.477	95.956
877	1991	Jul	25	1024 14.65	Johnston		1.7	1.3	1.5	34.118	96.487
878	1991	Aug	07	1040 15.79	Pittsburg		1.0	0.8	1.0	35.142	95.665
879	1991	Aug	08	1838 01.77	Garfield		2.6	1.9	2.5	36.423	97.475
880	1991	Sep	25	1759 21.16	Garvin		2.4	2.1	2.1	34.744	97.553
881	1991	Oct	03	0655 44.77	Garvin		2.6	2.4	2.2	34.741	97.667
882	1991	Oct	25	0131 26.93	Pontotoc		1.8	1.6	1.4	34.640	96.589
883	1991	Dec	09	1607 14.51	Garvin	2	2.3		2.1	34.768	97.592
884	1991	Dec	09	1706 01.39	Garvin		2.4	2.0	2.1	34.752	97.585
885	1991	Dec	09	1714 22.14	Grady		2.0	1.5	1.9	34.971	97.717
886	1991	Dec	09	1738 57.16	Garvin				1.8	34.752	97.600
887	1991	Dec	09	1759 34.23	Grady		2.6	2.4	2.3	34.893	97.702
888	1991	Dec	09	2011 58.45	Grady		1.9	1.9	1.8	34.905	97.702
889	1991	Dec	10	1200 29.64	McClain	2	2.3	1.8	2.1	34.868	97.448
890	1991	Dec	12	0315 21.33	Grady		1.4		1.9	34.924	97.706
891	1991	Dec	28	0445 59.82	Canadian		1.4		1.8	35.393	97.850

Event no.[a]	Date			Origin time (UTC)[b]		County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
892	**1992**	Jan	08	1310	53.46	Jefferson		1.9	1.7	2.2	33.994	97.585
893	1992	Jan	13	1715	22.56	Garvin		2.2	1.8	2.0	34.824	97.589
894	1992	Jan	22	0241	22.34	Jefferson			2.2	2.3	34.026	97.585
895	1992	Jan	25	1234	53.76	Jefferson		1.7		2.1	33.987	97.591
896	1992	Jan	27	1548	29.85	Jefferson		2.0		2.2	34.014	97.585
897	1992	Jan	29	0946	22.66	Hughes		0.9	1.2	1.8	35.127	96.071
898	1992	Feb	16	0230	18.52	Jefferson		1.7	1.7	2.1	33.967	97.589
899	1992	Feb	17	1454	32.88	Love		2.3	2.2	2.1	33.811	97.173
900	1992	Feb	26	2251	15.86	Jefferson		2.3	2.4	2.2	34.039	97.577
901	1992	Mar	01	0550	14.59	Jefferson		1.7	1.8	2.0	34.002	97.569
902	1992	Mar	02	0508	27.47	Jefferson		1.5		1.9	34.033	97.569
903	1992	Mar	10	2248	07.74	Johnston		2.0	2.0	1.8	34.415	96.843
904	1992	Mar	20	1115	25.78	Love		1.7	1.8	2.0	33.955	97.413
905	1992	Mar	20	1239	35.02	Garvin		2.3	2.0	2.2	34.808	97.663
906	1992	Mar	23	1033	05.51	Love		1.7	1.7	1.9	34.018	97.522
907	1992	Mar	24	0238	56.13	Lincoln				1.6	35.500	96.624
908	1992	Mar	24	1301	23.99	Jefferson				2.2	34.049	97.569
909	1992	Apr	27	1741	47.84	Garvin			1.9	2.3	34.800	97.656
910	1992	Apr	28	0922	45.95	Payne			1.5	1.9	36.076	97.170
911	1992	May	20	0325	12.05	Hughes		1.7		1.8	35.016	96.394
912	1992	May	26	0100	44.31	McIntosh				1.6	35.321	95.456
913	1992	May	30	0728	28.19	McCurtain			2.4	2.1	34.038	94.892
914	1992	May	30	0915	36.10	Jefferson			2.7	2.4	33.994	97.581
915	1992	Jun	07	0346	31.51	Seminole		1.5	1.0	1.6	35.136	96.542
916	1992	Jun	19	1752	37.85	Hughes		2.0	1.9	1.9	34.946	96.339
917	1992	Jun	30	0125	48.25	Seminole	2	2.9	2.3	2.5	35.277	96.495
918	1992	Jul	07	0611	15.75	Garvin		2.1		1.7	34.757	97.651
919	1992	Jul	10	1232	00.98	Ellis		2.1		2.5	35.869	99.702
920	1992	Jul	17	1623	26.58	Logan				1.8	36.099	96.723
921	1992	Aug	09	2105	46.71	Pontotoc				1.9	34.618	96.623
922	1992	Aug	10	1121	22.63	Pontotoc		2.4	1.9	1.9	34.601	96.588
923	1992	Aug	10	2003	03.86	McClain		2.8	2.8	2.6	35.038	97.510
924	1992	Oct	03	2358	48.28	Payne				2.2	35.974	96.723
925	1992	Oct	04	2125	13.61	Caddo		2.5	2.0	2.4	35.199	98.440
926	1992	Oct	05	0444	08.56	Garfield	5	2.9	2.6	2.8	36.357	97.506
927	1992	Oct	05	0531	47.68	Okfuskee				1.9	35.321	96.112
928	1992	Oct	27	0646	32.65	Okfuskee				1.4	35.502	96.512
929	1992	Nov	18	2140	48.08	McClain		2.0	2.0	2.1	35.117	97.518
930	1992	Nov	19	1822	30.62	Garvin		2.0	1.6	1.8	34.808	97.573
931	1992	Nov	21	0221	43.59	Grady		2.2	2.2	2.3	34.921	97.717
932	1992	Nov	21	1858	26.86	Garvin		1.9	2.0	2.0	34.802	97.633
933	1992	Nov	23	1156	09.06	Garvin		2.4	2.3	2.3	34.837	97.676
934	1992	Dec	02	0814	56.74	Garvin		1.7	1.8	1.8	34.808	97.502
935	1992	Dec	02	1017	22.07	Hughes				1.4	35.235	96.401
936	1992	Dec	13	0609	03.44	Pottawatomie		1.6		1.8	35.382	96.904
937	1992	Dec	17	0335	24.90	Garvin				1.7	34.773	97.557
938	1992	Dec	17	0401	19.28	Garvin	2	2.5	2.6	2.6	34.843	97.580
939	1992	Dec	17	0718	05.65	Garvin	5	3.8	3.5	3.1	34.730	97.541
940	1992	Dec	18	2142	45.58	Kiowa				2.0	34.657	99.063
941	1992	Dec	20	1235	20.79	Garvin		2.3	1.9	2.2	34.752	97.520
942	1992	Dec	22	0431	51.35	Lincoln				1.1	35.569	96.664
943	1992	Dec	29	0351	41.53	Garvin		1.7	1.7	2.0	34.796	97.572
944	1992	Dec	30	0454	54.38	Oklahoma		1.4		1.1	35.461	97.568
945	**1993**	Jan	11	0446	19.61	McClain		1.6		1.5	34.929	97.463
946	1993	Jan	14	1706	10.19	Alfalfa		3.2	3.1	2.7	36.663	98.283
947	1993	Jan	21	0749	08.38	Hughes		2.1		2.0	34.894	96.268
948	1993	Jan	21	0819	03.94	Hughes		2.5		2.1	34.886	96.270
949	1993	Jan	30	0442	53.63	Love	F	1.8	2.0	2.0	34.052	97.084
950	1993	Feb	13	1945	03.36	Garvin				2.3	34.716	97.541
951	1993	Feb	13	2057	24.55	Garvin				2.2	34.748	97.573
952	1993	Feb	14	2312	38.00	Garvin				1.9	34.790	97.456
953	1993	Mar	11	0115	01.08	McIntosh	2		2.7	2.4	35.230	95.932
954	1993	Mar	11	0205	50.39	McIntosh				1.8	35.301	95.949
955	1993	Mar	17	1721	25.68	Garvin		2.3	2.2	2.2	34.820	97.557
956	1993	Mar	24	1037	29.06	Garvin		2.2	2.2	2.1	34.835	97.666
957	1993	Mar	26	0252	17.17	Garvin		2.1	2.0	2.0	34.773	97.401

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
958	1993 Apr 06	0756 03.78	McClain		2.3	2.3	2.2	34.911	97.514
959	1993 Apr 13	1815 20.31	McClain		2.1	1.8	1.9	34.913	97.494
960	1993 May 07	1641 35.42	Garvin		2.6		2.3	34.593	97.463
961	1993 May 07	1750 37.70	Garvin		2.4	2.1	2.1	34.738	97.541
962	1993 May 09	2252 11.19	McClain		2.8	2.6	2.3	34.898	97.533
963	1993 May 19	2022 26.87	Le Flore		2.2	2.0	1.5	34.698	94.912
964	1993 May 26	0921 59.55	Pittsburg		1.3		1.6	34.850	95.602
965	1993 May 26	0939 33.27	Pottawatomie				1.3	34.941	96.897
966	1993 Jun 10	1159 00.56	Garvin		2.3	2.3	2.0	34.792	97.428
967	1993 Jun 18	2257 52.18	Le Flore		2.2		1.9	34.952	94.529
968	1993 Jul 09	0418 49.86	Lincoln				1.0	35.938	96.799
969	1993 Jul 09	0428 18.78	Garvin				1.9	34.854	97.460
970	1993 Jul 09	2138 49.44	McClain		2.0	1.9	1.9	34.913	97.463
971	1993 Jul 14	0026 15.84	Love		2.4	2.7	2.2	34.038	97.158
972	1993 Jul 16	0321 43.79	Garvin		1.9		1.7	34.716	97.516
973	1993 Jul 16	0323 00.18	Garvin		2.1		1.8	34.807	97.557
974	1993 Jul 16	0337 16.51	Garvin		1.9		1.8	34.709	97.552
975	1993 Jul 16	0353 39.63	Garvin		1.8		1.7	34.623	97.508
976	1993 Jul 16	0412 16.14	Garvin		2.1	1.4	2.0	34.726	97.510
977	1993 Jul 16	0424 30.56	Garvin		2.0		2.0	34.718	97.526
978	1993 Jul 16	0508 44.55	McClain				1.6	34.938	97.630
979	1993 Jul 16	0658 43.10	Garvin		1.4		1.8	34.791	97.589
980	1993 Jul 16	0820 59.89	Garvin		1.7		2.0	34.749	97.502
981	1993 Jul 16	1128 27.98	Garvin		2.3	2.2	2.2	34.729	97.530
982	1993 Jul 17	0950 46.75	Garvin		2.0		2.0	34.734	97.526
983	1993 Jul 18	1358 01.24	Garvin		1.7	1.5	2.0	34.743	97.559
984	1993 Jul 20	1750 23.55	Murray		2.0	2.4	2.0	34.488	97.256
985	1993 Jul 22	0235 24.22	McIntosh		1.6	1.5	1.9	35.173	95.925
986	1993 Aug 08	0603 27.36	McClain		1.6	1.4	2.0	34.937	97.463
987	1993 Aug 10	2117 13.15	Garvin		1.7		1.9	34.765	97.408
988	1993 Aug 12	1526 40.38	Garvin		2.1	2.2	1.8	34.550	97.190
989	1993 Aug 29	0910 51.79	Grady				1.3	35.045	97.850
990	1993 Aug 30	0730 02.01	Grady		1.5		1.9	34.941	97.733
991	1993 Sep 02	0528 02.73	McClain				1.7	34.913	97.494
992	1993 Sep 06	0506 36.25	Garvin				1.4	34.713	97.663
993	1993 Sep 06	0618 21.60	Garvin				1.3	34.819	97.436
994	1993 Sep 06	1227 09.63	Logan				1.7	36.070	97.383
995	1993 Sep 17	1000 02.40	McClain		2.0	1.9	1.9	34.933	97.447
996	1993 Sep 18	1018 03.07	Noble		1.6		1.7	36.507	97.184
997	1993 Sep 28	0731 41.07	McClain		1.5		1.9	35.062	97.365
998	1993 Oct 05	0545 46.53	Pittsburg		1.8		1.6	34.692	95.816
999	1993 Oct 13	0844 03.15	McClain		2.1	2.0	1.9	34.874	97.424
1000	1993 Oct 14	1914 38.91	Grady		2.5	2.6	1.8	34.859	97.713
1001	1993 Oct 15	0926 32.71	Garvin		2.0	1.9	1.8	34.849	97.643
1002	1993 Oct 15	1541 54.23	McClain		1.9		1.8	34.908	97.422
1003	1993 Oct 19	1659 52.41	Alfalfa	F	3.1	2.8	2.5	36.546	98.173
1004	1993 Oct 24	0632 23.75	McClain		1.6	1.5	1.7	34.937	97.518
1005	1993 Oct 30	0154 43.96	Garvin		2.9	2.7	2.3	34.847	97.436
1006	1993 Nov 11	2137 04.74	Woods				1.9	36.898	98.849
1007	1993 Nov 22	2146 19.80	Caddo		2.0		1.4	35.284	98.538
1008	1993 Nov 27	0021 03.51	McClain		1.8	1.7	1.7	34.998	97.503
1009	1993 Nov 29	0302 32.84	Woods		1.9		2.3	36.894	99.209
1010	1993 Dec 03	2129 42.08	Logan				1.8	36.091	97.557
1011	1993 Dec 03	2136 56.06	Logan		2.0	2.0	1.9	36.091	97.557
1012	1993 Dec 03	2140 10.90	Logan				1.6	36.091	97.557
1013	1993 Dec 06	0407 29.91	Garvin		2.5	2.3	2.0	34.839	97.401
1014	1993 Dec 07	0335 38.50	Kingfisher				1.6	35.934	98.005
1015	1993 Dec 07	0339 43.40	Kingfisher				2.4	35.934	98.005
1016	1993 Dec 20	1720 40.40	Garvin		2.4		2.2	34.648	97.502
1017	1993 Dec 20	1743 55.40	Garvin				1.9	34.524	97.456
1018	**1994** Jan 11	0118 34.50	McClain		2.2	2.6	2.4	34.976	97.416
1019	1994 Jan 16	2006 48.31	Major		2.1	2.0	2.1	36.402	98.115
1020	1994 Feb 05	0453 33.11	Caddo		2.0		1.4	34.946	98.155
1021	1994 Feb 06	1228 24.08	Creek		1.8	1.4	1.8	35.683	96.370
1022	1994 Feb 24	1711 02.42	Grady		1.9	1.9	2.4	35.370	98.063
1023	1994 Feb 24	2342 39.48	Grady		2.1	2.6	2.6	34.773	97.686

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
1024	1994 Feb 25	1638 01.35	Pontotoc		2.0	2.1	2.3	34.820	96.588
1025	1994 Feb 25	2237 16.50	Pontotoc		1.2		1.8	34.880	96.628
1026	1994 Feb 25	2347 58.64	Grady		2.0	1.8	2.2	34.771	97.680
1027	1994 Mar 04	2242 54.65	Roger Mills		1.8			35.882	99.951
1028	1994 Mar 06	0200 12.12	Roger Mills		1.9			35.824	99.787
1029	1994 Mar 11	1531 06.13	Harper		2.2			36.734	99.689
1030	1994 Mar 24	0453 01.75	Roger Mills		2.1			35.824	99.834
1031	1994 Mar 24	1114 46.47	Custer		2.3			35.721	98.944
1032	1994 Apr 05	0914 47.47	Custer		2.0			35.547	98.819
1033	1994 Apr 05	0918 57.45	McClain		1.7	1.6	2.0	35.023	97.559
1034	1994 Apr 14	2150 05.13	Grady		2.4	2.3	2.3	34.690	97.725
1035	1994 Apr 14	2222 20.25	Stephens		1.9	2.0	2.2	34.641	97.743
1036	1994 Apr 14	2236 21.67	Stephens		2.7	2.7	2.2	34.643	97.733
1037	1994 Apr 14	2355 55.04	Stephens		1.9		1.8	34.391	97.774
1038	1994 Apr 15	0119 52.04	Stephens		2.5	2.8	2.0	34.643	97.714
1039	1994 Apr 15	0233 00.11	Stephens		2.1	1.9	1.9	34.580	97.630
1040	1994 Apr 15	0340 04.13	Grady		2.3	2.2	1.7	34.687	97.706
1041	1994 Apr 15	0342 52.27	Seminole		1.7			35.195	96.626
1042	1994 Apr 15	0354 19.76	Grady		2.0		1.3	35.055	98.012
1043	1994 Apr 15	0400 20.47	Blaine		1.9		2.1	35.690	98.600
1044	1994 Apr 15	0414 48.58	Blaine		1.6		1.9	35.844	98.628
1045	1994 Apr 15	0417 40.38	Carter		1.6		2.1	34.323	97.507
1046	1994 Apr 15	0420 52.14	Grady		2.1	1.9	2.0	34.721	97.741
1047	1994 Apr 15	0438 26.53	Grady		1.7		2.2	34.717	97.745
1048	1994 Apr 15	0443 45.62	Stephens		2.2	2.5	2.1	34.670	97.741
1049	1994 Apr 15	0528 33.07	Stephens		1.9	2.1	2.0	34.651	97.721
1050	1994 Apr 15	0640 10.25	Stephens		1.9	1.9	2.3	34.627	97.710
1051	1994 Apr 15	0813 59.96	Stephens		1.9		1.8	34.676	97.721
1052	1994 Apr 15	1004 41.88	Grady		1.8	1.6	1.8	34.709	97.878
1053	1994 Apr 15	1152 55.26	Grady		1.7		2.1	34.690	97.749
1054	1994 Apr 15	1427 20.12	Stephens				2.3	34.648	97.737
1055	1994 Apr 15	1637 52.73	Grady		2.3	2.1	1.8	34.682	97.721
1056	1994 Apr 15	1732 14.11	Grady		2.0		1.6	34.726	97.682
1057	1994 Apr 15	1946 14.43	Stephens		2.8		1.9	34.601	97.713
1058	1994 Apr 15	2213 18.33	Stephens		2.3		1.8	34.674	97.710
1059	1994 Apr 15	2340 45.41	Stephens		2.0		1.9	34.612	97.710
1060	1994 Apr 16	0135 56.69	Stephens		2.1	1.9	1.8	34.565	97.694
1061	1994 Apr 16	0415 45.30	Grady		1.6		1.9	34.731	97.731
1062	1994 Apr 16	0720 29.99	Stephens		3.1	2.9	2.7	34.663	97.713
1063	1994 Apr 26	1345 07.07	Garvin				2.1	34.823	97.655
1064	1994 Apr 26	1510 16.32	Grady		2.2	2.0	1.9	34.862	97.702
1065	1994 Apr 26	1641 13.13	Garvin		2.0	1.8	1.8	34.854	97.655
1066	1994 Apr 27	0600 14.53	Garvin		1.6		2.1	34.826	97.632
1067	1994 Apr 29	0328 59.63	Garfield	F		2.8	2.5	36.203	98.052
1068	1994 May 03	1805 03.13	Carter		1.9		1.6	34.190	97.100
1069	1994 May 04	0614 25.16	Garvin		1.6	1.6	2.2	34.737	97.655
1070	1994 May 04	0759 27.74	Stephens		1.6		1.7	34.651	97.647
1071	1994 May 04	0847 43.32	Garvin		1.8	1.7	1.8	34.791	97.647
1072	1994 May 04	0905 26.84	Garvin		2.0	1.6	1.9	34.787	97.647
1073	1994 May 04	1018 42.70	Canadian		1.7		1.6	35.448	98.061
1074	1994 May 04	1634 46.58	Garvin				2.3	34.760	97.632
1075	1994 May 17	1709 21.65	Garvin		2.2		2.0	34.659	97.490
1076	1994 May 17	1953 02.74	Garvin				1.8	34.662	97.467
1077	1994 May 23	1705 43.16	Canadian				2.2	35.565	98.102
1078	1994 May 24	0107 34.02	McClain		1.6		2.2	34.881	97.635
1079	1994 Jun 21	0313 53.45	Carter		1.4		1.5	34.451	97.448
1080	1994 Jul 04	0728 28.38	Garvin		2.8	2.7	2.3	34.652	97.498
1081	1994 Jul 08	0123 26.22	Le Flore		2.1	2.2	1.8	35.134	94.675
1082	1994 Jul 13	1405 55.29	Pontotoc		2.1	1.6	1.9	34.620	96.561
1083	1994 Jul 19	1644 36.36	McClain		2.0		1.5	34.863	97.584
1084	1994 Jul 20	0437 58.89	McClain		1.5	1.6	1.8	35.113	97.539
1085	1994 Aug 03	1145 06.63	Johnston		2.0		1.5	34.403	96.753
1086	1994 Aug 08	1255 46.00	Beckham				1.8	35.159	99.960
1087	1994 Aug 15	0219 32.94	McClain		2.4	1.8	1.9	34.935	97.268
1088	1994 Aug 17	0123 59.40	Tillman				1.6	34.534	99.085
1089	1994 Aug 24	0403 50.66	Stephens		1.4		1.6	34.453	97.651
1090	1994 Aug 25	0445 00.47	Garvin		2.2	2.1	2.0	34.679	97.473

Event no.[a]	Date	Origin time (UTC)[b]	County	Intensity MM[c]	Magnitudes[d] 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)
1091	1994 Sep 06	1417 35.28	McClain		2.3	1.7	1.9	34.912	97.460
1092	1994 Sep 23	0722 35.93	Grady		1.5		1.6	34.776	97.682
1093	1994 Sep 23	0924 43.65	Grady				2.0	34.768	97.710
1094	1994 Sep 23	1142 38.92	Grady				1.8	34.815	97.684
1095	1994 Sep 23	2136 53.26	Grady				1.7	34.754	97.690
1096	1994 Sep 24	0647 14.63	Grady		1.6		1.6	34.823	97.690
1097	1994 Sep 24	1426 53.38	Grady				1.7	34.815	97.710
1098	1994 Sep 24	1506 33.47	Grady		2.5	2.3	1.6	34.831	97.686
1099	1994 Sep 26	0831 05.52	Carter		1.4		1.5	34.288	96.987
1100	1994 Sep 30	0307 30.47	McClain		2.2	1.8	1.9	34.867	97.447
1101	1994 Sep 30	1501 02.00	Murray				1.5	34.401	97.147
1102	1994 Oct 01	0454 46.13	McClain		2.7	2.6	2.1	34.882	97.494
1103	1994 Oct 05	0834 42.23	Pontotoc			1.9	2.2	34.820	96.811
1104	1994 Oct 13	1351 43.61	Garvin		1.9		2.0	34.531	97.447
1105	1994 Oct 13	1654 46.69	Garvin		2.6	2.5	1.9	34.679	97.471
1106	1994 Oct 15	2039 47.54	Garvin		2.2		2.0	34.601	97.471
1107	1994 Nov 13	1633 26.96	Dewey				2.2	35.954	99.058
1108	1994 Nov 15	0342 49.01	Okfuskee		1.6	1.4	1.6	35.503	96.350
1109	1994 Nov 30	0829 27.58	Grady		2.0	1.7	1.7	34.848	97.687
1110	1994 Dec 13	1032 06.72	Caddo		1.4		2.1	34.868	98.471
1111	1994 Dec 20	0412 22.08	Garvin				2.0	34.794	97.523
1112	1994 Dec 20	0415 09.08	Garvin				1.8	34.805	97.519
1113	1994 Dec 20	0419 39.28	Garvin				1.9	34.830	97.534
1114	1994 Dec 20	0429 38.96	Garvin				2.0	34.759	97.538
1115	1994 Dec 20	0449 16.15	Garvin				1.8	34.770	97.523
1116	1994 Dec 20	0506 19.62	Garvin				1.8	34.792	97.503
1117	1994 Dec 20	0509 03.30	Garvin		1.8		2.1	34.759	97.519
1118	1994 Dec 20	0556 04.50	Garvin				2.2	34.778	97.531
1119	1994 Dec 20	0600 19.43	Garvin		1.5		1.8	34.762	97.531
1120	1994 Dec 20	0634 27.22	Garvin		1.5		1.7	34.794	97.531
1121	1994 Dec 20	1733 08.62	Garvin				1.8	34.762	97.491
1122	1994 Dec 20	2204 36.40	Murray		1.6	2.0	1.6	34.395	97.296
1123	1994 Dec 21	0838 26.66	Garvin		2.0	1.7	1.8	34.739	97.503
1124	1994 Dec 22	0334 39.81	Garvin		1.4		1.7	34.776	97.521
1125	1994 Dec 22	1412 59.63	Garvin		2.0	1.7	1.9	34.692	97.468
1126	1994 Dec 22	1437 26.40	Garvin				1.7	34.718	97.501
1127	1994 Dec 22	1543 16.13	Garvin				2.5	34.700	97.499
1128	1994 Dec 23	1141 02.36	Garvin		1.7	1.6	1.8	34.671	97.479
1129	1994 Dec 23	2156 16.89	Garvin		2.5	2.2	2.0	34.671	97.463
1130	1994 Dec 30	0826 44.52	Garvin		2.1	1.7	1.8	34.729	97.655

[a] Each event is sequentially numbered and arranged according to date and origin time. The numbering system is compatible with the system used for the *Earthquake Map of Oklahoma* (Lawson and others, 1979) and subsequent additions (Lawson and Luza, 1980–90, 1993–94; Lawson and others, 1991,1992). Changes to the original catalog include the following: (1) addition of events 1a and 1b; (2) relocation of event 15 from south of Hugo, Oklahoma, to northeast Texas; (3) deletion of non-earthquake event 48, near Edmond, Oklahoma (Lawson, 1984); (4) deletion of event 56 due to lack of documentation; and (5) changed event 70 to a non-felt earthquake.

[b] The date and time are given in UTC. UTC refers to Coordinated Universal Time, formerly Greenwich Mean Time. The first two digits refer to the hour on a 24-hour clock. The next two digits refer to the minute, and the remaining digits are the seconds. To convert to local Central Standard Time, subtract 6 hours.

[c] The Modified Mercalli Intensity scale describes an earthquake's effects to structures built by humans, changes to the Earth's surface, and felt reports. Intensity values, which range from I to XII, are determined from eyewitness reports and field investigations. Mercalli's original scale was modified by Wood and Neumann (1931) to adapt to construction conditions in California. Arabic numbers (instead of Roman numerals) are used to denote intensity values in the catalog; "F" indicates earthquake was reported felt, intensity unknown, generally ≤4.

[d] Earthquake magnitude is a measure of earthquake size as determined from seismograph records. The magnitude of a local earthquake is determined by taking the logarithm (base 10) of the largest ground motion recorded during the arrival of a seismic-wave type and applying a standard correction for distance to the epicenter. When the magnitude value is increased one unit, the amplitude of the earthquake waves increases 10 times. There are several different scales used to report magnitude. Three magnitude scales, mbLg (Nuttli), m3Hz (Nuttli), and MDUR (Lawson), are used in the earthquake catalog. Each magnitude scale was established to accommodate specific criteria, such as the distance from the epicenter, as well as the availability of certain seismic data.

Otto Nuttli's (1973) earthquake magnitude, mbLg, for seismograph stations located between 55.6 and 445 km from the epicenter, is derived from the following equation:

$$mbLg = \log(A/T) - 1.09 + 0.90 \log(\Delta).$$

Where seismograph stations are located between 445 and 3,360 km from the epicenter, mbLg is defined as:

$$mbLg = \log(A/T) - 3.10 + 1.66 \log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Lg waves (short period surface waves traveling in the upper crust,

(continued on next page)

probably equivalent to Sg waves), near 1 Hz in frequency, measured in nanometers; T is the period of Lg waves measured in seconds; and Δ is the great-circle distance from epicenter to station measured in kilometers.

For earthquake epicenters located 11–222 km from a seismograph station, Otto Nuttli developed the m3Hz magnitude scale (Zollweg, 1974). This magnitude is derived from the following expression:

$$\text{m3Hz} = \log(A/T) - 1.63 + 0.87 \log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Lg waves, near 3 Hz in frequency, measured in nanometers; T is the period of the Lg waves measured in seconds; and Δ is the great-circle distance from epicenter to station measured in kilometers.

In 1979, St. Louis University (Stauder and others, 1979) modified the formulas for m3Hz. This modification was used by the Oklahoma Geological Survey (OGS) Observatory beginning January 1, 1982. The modified formulas had the advantage of extending the distance range for measurement of m3Hz out to 400 km, but also had the disadvantage of increasing m3Hz by about 0.12 units compared to the previous formula. Their formulas were given in terms of log(A) but were restricted to wave periods of 0.2–0.5 sec. In order to use log(A/T), we assumed a period of 0.35 sec in converting the formulas for our use. The resulting equations are:

(epicenter 10–100 km from a seismograph)
$$\text{m3Hz} = \log(A/T) - 1.46 + 0.88 \log(\Delta)$$

(epicenter 100–200 km from a seismograph)
$$\text{m3Hz} = \log(A/T) - 1.82 + 1.06 \log(\Delta)$$

(epicenter 200–400 km from a seismograph)
$$\text{m3Hz} = \log(A/T) - 2.35 + 1.29 \log(\Delta).$$

The MDUR magnitude scale was developed by Lawson (1978) for earthquakes in Oklahoma and adjacent areas. It is defined as:

$$\text{MDUR} = 1.86 \log(\text{DUR}) - 1.49,$$

where DUR is the duration or difference, in seconds, between the Pg-wave arrival time and the time the final coda amplitude decreases to twice the background-noise amplitude. Before 1981, if the Pn wave was the first arrival, the interval between the earthquake-origin time and the decrease of the coda to twice the background-noise amplitude was measured instead. Beginning January 1, 1982, the interval from the beginning of the P wave (whether it was Pg, P*, or Pn) to the decrease of the coda to twice the background-noise amplitude was used.

GENERAL NOTES

Focal depths (the depth to the earthquake hypocenter measured in kilometers) are not shown in the catalog. For most Oklahoma earthquakes the focal depth is unknown. In almost all Oklahoma events, the stations are several times farther from the epicenter than the likely depth of the event. This makes the locations indeterminate at depth, which usually requires that the hypocenter depth be restrained to an arbitrary 5 km for purposes of computing latitude, longitude, and origin time. All available evidence indicates that no Oklahoma hypocenters have occurred deeper than 15–20 km.

Sources for earthquake data used to develop the earthquake catalog are as follows:

Docekal, Jerry (1970): event numbers 1a, 1b, 4, 7, 9–14, 17–27, 36–43, 45–47, 49–52, 55, and 57–59.

Carlson, S. M. (1984): event number 1a.

Kalb, Bill (1964): event numbers 5, 6, 11, 18, 19, 23–25, 28–35, 38, 46, 47, 51–55.

Oklahoma Geological Survey publications: event numbers 70–1130.

Tryggvason, Eysteinn (1964): event numbers 5, 6, 16–18, 20–35, 37–41, 43, 45–47, 49–55, 60–69.

Wells, L. L. (1975): event numbers 1–3.

United States Earthquakes—annual publications: event numbers 7, 14, 17, 18, 20–27, 32, 34–47, 49–52, 55, 57–59, 72–76.

Zollweg, James (1974): event numbers 71, 73–87, 89.

Appendix 3

Examples of Digitally Recorded Oklahoma Earthquakes

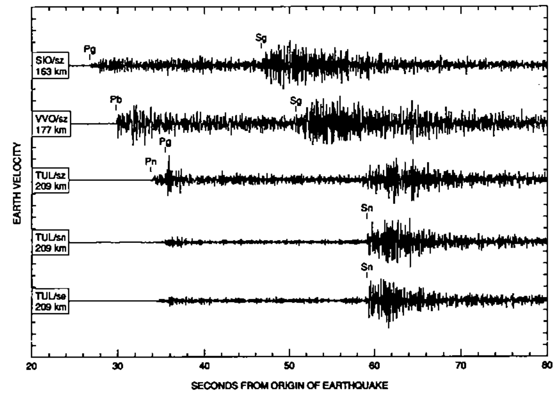


Figure 13. Earthquake in Garvin County, July 4, 1994. Magnitude mbLg = 2.7. The distance of the earthquake to each station is on the station tag. Only vertical earth velocity was recorded at stations SIO and VVO. At TUL (Leonard), vertical (sz), north-south (sn), and east-west (se) earth velocities were recorded. The first recorded P motion is different at different distances. SIO recorded Pg first, VVO recorded Pb (another symbol for P*) first, and TUL recorded Pn first. The units of measurement for earth velocity are arbitrary; the display software scales each trace separately.

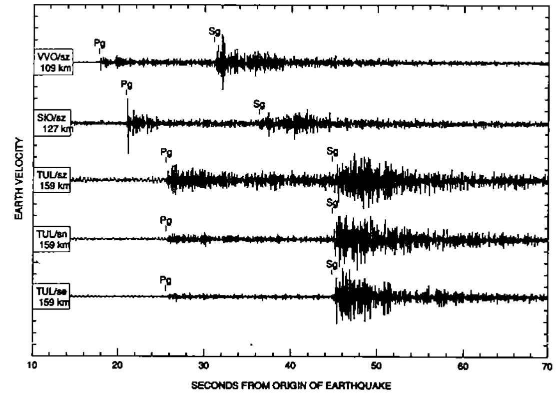


Figure 14. Earthquake in Pontotoc County, July 13, 1994. Magnitude mbLg = 1.6. The distance of the earthquake to each station is on the station tag. Only vertical earth velocity was recorded at stations VVO and SIO. At TUL (Leonard), vertical (sz), north-south (sn), and east-west (se) earth velocities were recorded. At these distances, Pg is the first arrival at all stations. Because the stations VVO and SIO are at different angles relative to the direction of fault slip of the earthquake, VVO recorded a small Pg and large Sg, in contrast to the large Pg and small Sg at SIO. The units of measurement for earth velocity are arbitrary; the display software scales each trace separately.

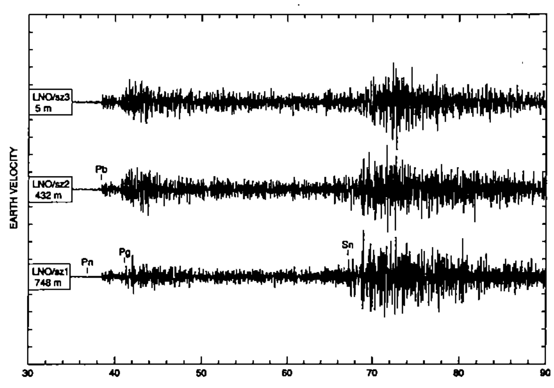


Figure 15. Earthquake in Alfalfa County, January 14, 1993. Magnitude mbLg = 3.1. This earthquake was felt with MM intensity IV in Jet and Sand Creek, and MM intensity II in Cherokee, Carmen, and Wynoka. These recordings are from three seismometers in a deep borehole at Leonard. Abbreviations LNO and TUL are both used at the Oklahoma Geological Survey Observatory near Leonard. LNO is used for the deep borehole seismometers. The earthquake was 238 km from Leonard. The depths below ground surface of each seismometer are shown on the station tag. Each of these seismometers senses vertical earth velocity only. The units for measurement of earth velocity are arbitrary; the display software scales each trace separately. (See Fig. 16.)

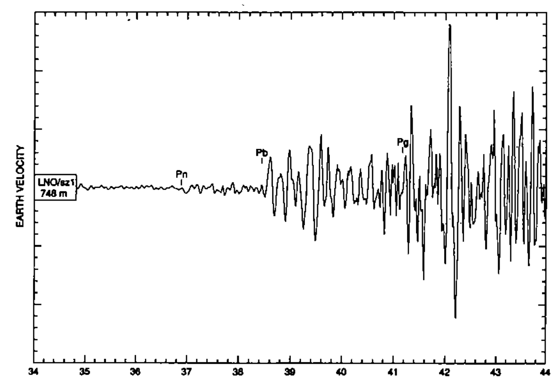
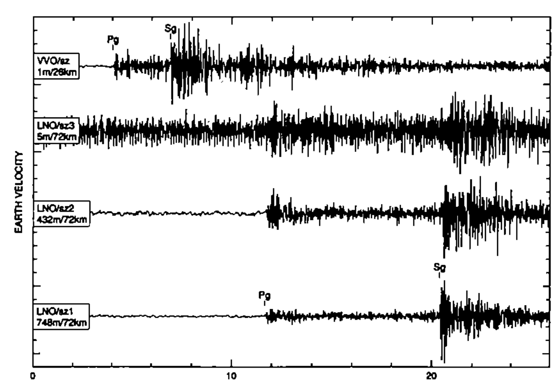


Figure 16. Earthquake in Alfalfa County, January 14, 1993. This recording is vertical earth velocity from a seismometer 748 m (2,454 ft) deep in a borehole near Leonard. Pn, Pb (another name for P*), and Pg are all clearly visible.

Figure 17 (right). Earthquake in McIntosh County, May 26, 1992. Magnitude MDUR = 1.6. Each station tag includes the depth of the seismometer below the surface in meters and the distance from the earthquake to the seismometer in kilometers. Station VVO is only 26 km from the earthquake. The VVO signal is much larger than ground noise. Near Leonard, 72 km from the earthquake the signal has become so small that it is almost covered by wind and other surface noise on the seismometer only 5 m below the surface. At 432-m and 748-m depths, the surface noise is almost totally eliminated, leaving clear signals. The units for measurement of earth velocity are arbitrary; the display software scales each trace separately.



OKLAHOMA GEOLOGICAL SURVEY
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