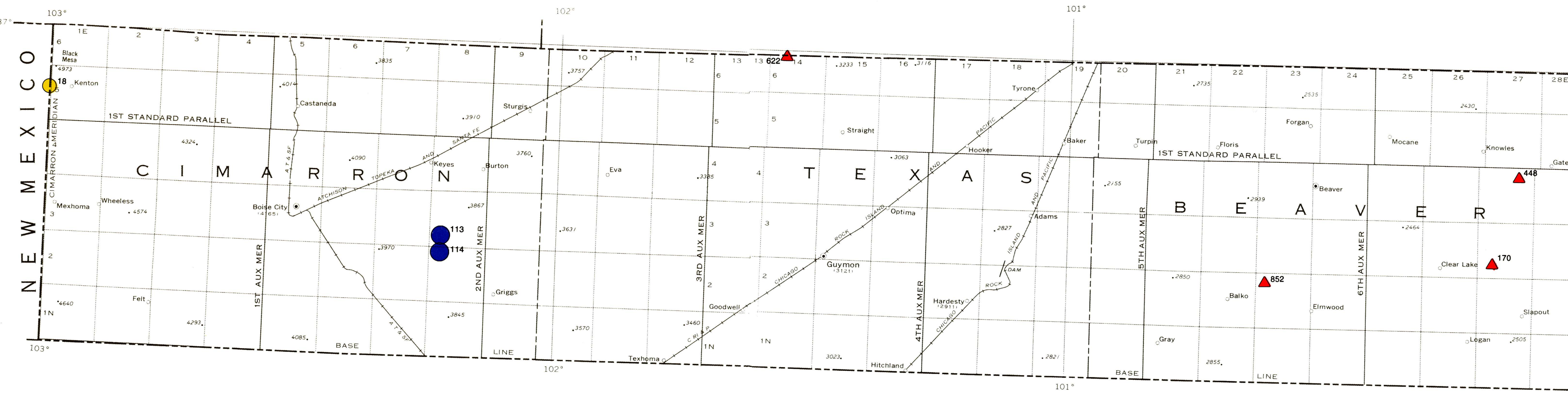
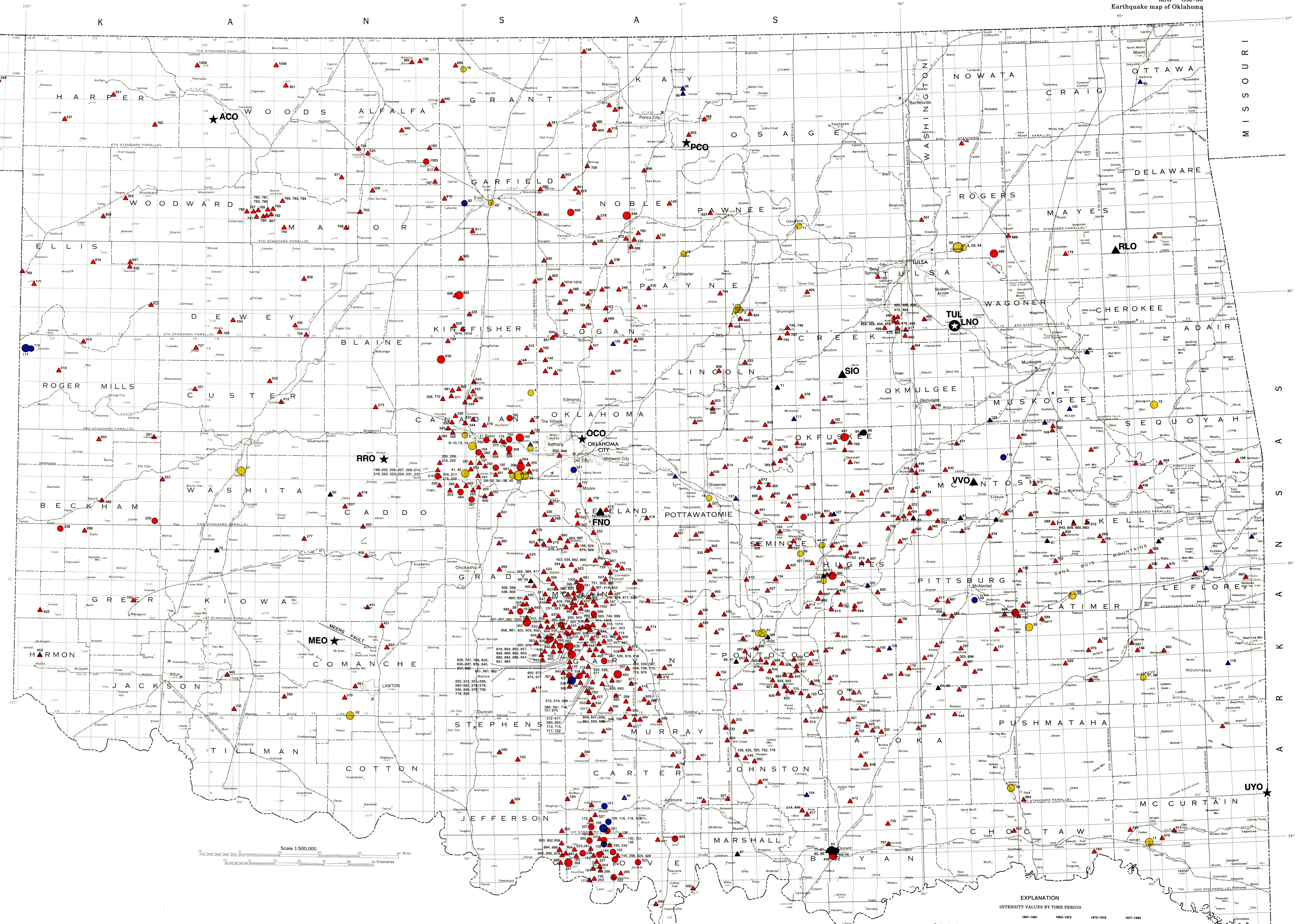
OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, Director






## Oklahoma Earthquake Catalog: 1882-1993

| Event No.[a] | Year | Mo | Da | UTC[b] Hr | Mn | Sec | County | In[c] MM | Magnitude[d] 3Hz | bLg | DUR | Lat °N | Long °W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 1882 | Oct | 22 | 22 | 00 | | | 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 | 13 | 30 | | 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 | 16 | 30 | | Canadian | 5 | | 3.4 | | 35.5 | 98.0 |
| 9 | 1918 | Sep | 11 | 06 | 30 | | Canadian | 6 | | 3.4 | | 35.5 | 98.0 |
| 10 | 1918 | Sep | 11 | 09 | 00 | | Canadian | 4 | | | | 35.5 | 98.0 |

## FOOTNOTES

[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, 1980–91, 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.

***Modified Mercalli (MM) Earthquake-Intensity Scale (abridged):***

- 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 Damage 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.

[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 ten) 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 on this map. 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, probably equivalent to Sg waves), near 1 Hz in frequency, measured in nanometers; $T$ is the period of Lg waves measured in seconds; and $\Delta$ 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:

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

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 $\Delta$ 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)
$$m3Hz = \log(A/T) - 1.46 + 0.88\log(\Delta)$$
(epicenter 100–200 km from a seismograph)
$$m3Hz = \log(A/T) - 1.82 + 1.06\log(\Delta)$$
(epicenter 200–400 km from a seismograph)
$$m3Hz = \log(A/T) - 2.35 + 1.29\log(\Delta).$$

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

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

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 70-1017.
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.

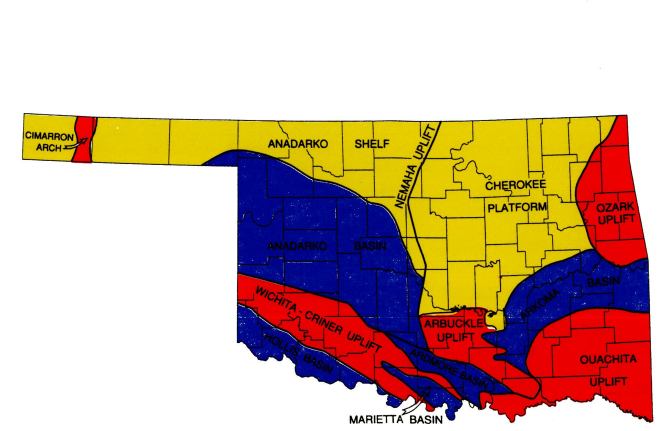



Figure 1. Generalized geologic province map of Oklahoma (modified from Northcutt and Campbell, 1995). Boundaries are stratigraphic and/or structural. The Arbuckle uplift consists of the Arbuckle Mountains, Ada high, Seminole uplift, and Tishomingo-Belton horst.

## OKLAHOMA EARTHQUAKE HISTORY

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, which occurred on October 22, 1882, was reported felt over northeastern Texas, Oklahoma, Arkansas, Kansas, and Missouri. This earthquake produced MM–VIII Intensity effects near Fort Gibson, Oklahoma (Cherokee Advocate, October 27, 1882; Indian-Pioneer Papers, p. 167). Carlson (1964) 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 largest known Oklahoma earthquake occurred near El Reno on April 9, 1952. This earthquake was felt in Austin, Texas, as well as Des Moines, Iowa, and covered a felt area of ~362,000 km² (Kalb, 1964; Docekal, 1970; von Hake, 1976). From 1897 through 1993, 1,015 earthquakes have been located in Oklahoma.

The earthquake intensity data are grouped into four time-period intervals. The first time period, 1882 to 1961, represents an interval in which all earthquakes in Oklahoma (shown in yellow) either were located from historical accounts or from seismograph stations outside the State. The epicentral locations within this time period may vary as much as 50 km from the location shown on the map.

In late 1961, the first two seismograph stations were installed in Oklahoma. One was located in the Wichita Mountains by the United States Air Force, and the other was built near Leonard, station TUL, by Jersey Production Research Company which operated it until 1965. From 1965 to 1978, TUL was operated by The University of Oklahoma. In 1978, it was transferred to the Oklahoma Geological Survey. The short-period seismographs at these stations utilized passbands, between 0.5 to 1.5 hertz, which provide good records for distant earthquakes. Although the location and detection of small local earthquakes were greatly improved by the presence of these two stations, the records from seismographs with short-period passbands are of little use in recording small local earthquakes. For this time period, 1962–1972, the earthquakes are shown in green. In 1973, the TUL began to record selected high-frequency seismic responses at increased magnifications. This greatly increased our capability to detect small earthquakes and to discriminate earthquakes from quarry blasts. However, the location of earthquakes depended either on finding felt reports and (or) having clear first-motion directions and horizontal-amplitude measurements made from the seismic records. The earthquake locations within this time period, 1973–1976, are shown in blue. 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.

In 1976, a program was begun to install seven semipermanent, volunteer-operated seismograph stations and three radio-telemetry stations in Oklahoma with support from the U.S. Nuclear Regulatory Commission (Luza, 1978). These additional seismograph stations have tremendously improved earthquake detection and location accuracy in the State of Oklahoma as well as in the adjacent states. From 1977–1993, 888 earthquakes were detected and located in Oklahoma. These data, shown in red, have a location accuracy that may vary as much as 5 km from the location shown on the map.

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# EARTHQUAKE MAP OF OKLAHOMA

## Earthquakes shown through 1993

This map is intended for use as a guide only 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 1962.

James E. Lawson, Jr. and Kenneth V. Luza
1995