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Earthquakes in Louisiana

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Introduction

An earthquake can be defined as a sudden, sometimes violent trembling or shaking of the ground caused by the release of stored energy in the rocks beneath the earth's surface. Underground tectonic forces that are continually applied to brittle rocks tend to deform or bend the rocks slightly. However, when the stress from the forces exceeds the strength of the rocks, they will break suddenly. These sudden movements produce vibrations known as seismic waves that travel through the earth and along its surface. Seismic waves are responsible for the trembling and shaking known as an earthquake.

Earthquakes occur within areas of weakness in the earth's crust, revealed by fractures and faults. A fault is a relatively thin boundary—an essentially planar zone or surface in three dimensions—where rocks rupture to produce two blocks that move in various directions relative to one another (figure 1). Most faults are the product of repeated movement over a long period of time.

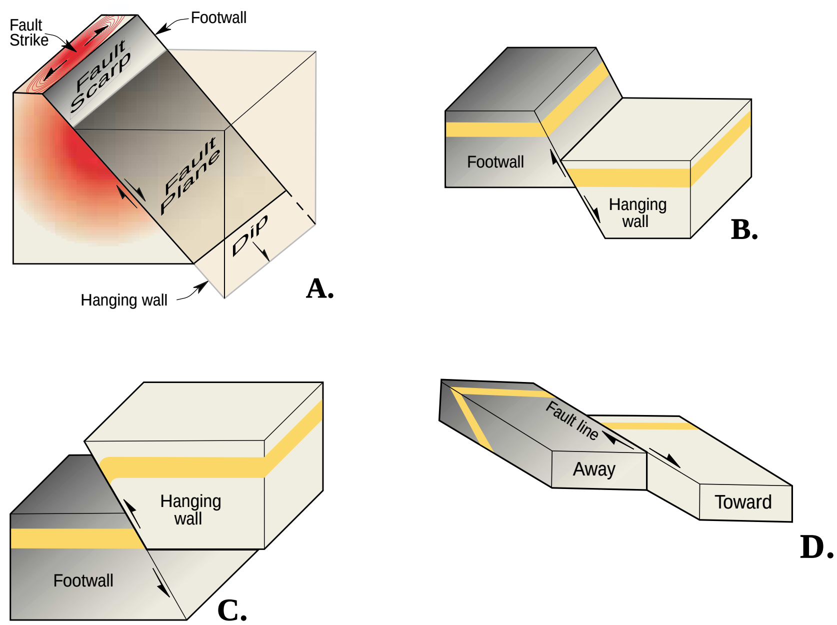

Figure 1. Block diagrams showing fault types and nomenclature. (A) fault nomenclature, (B) normal fault, (C) thrust fault, and (D) strike-slip fault. Compiled from figures 2–5 of Case (1986; used with permission of the Wyoming Geological Survey).

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Types of Faults

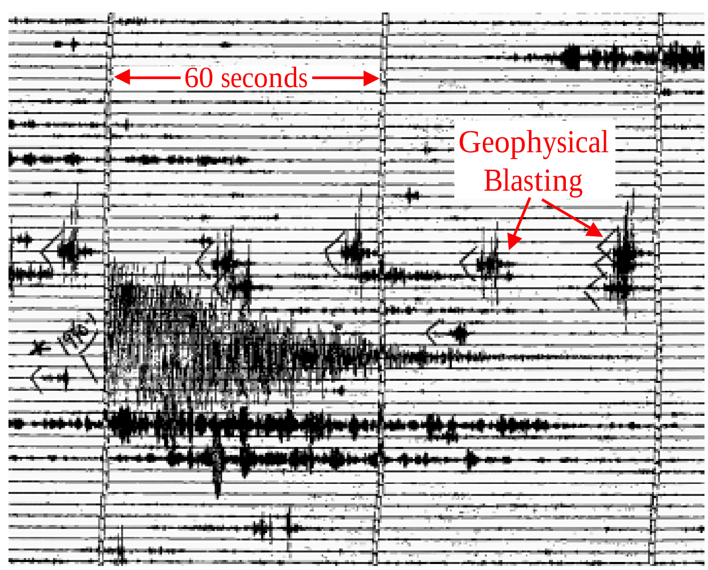
If the movement of the blocks is predominantly horizontal relative to the earth's surface, then the fault is called a strike-slip fault, owing to the fact that movement is parallel to the strike or direction of the fault trace (Fig. 1-D). When movement of the blocks has a substantial vertical component, the fault is called a dip-slip fault (Fig. 1-A,1-B,1-C). Dip-slip faults are further classified by their sense of movement relative to the hanging wall block (above the fault) and footwall block (below the fault) (Fig. 1-B,1-C). If the hanging wall block drops down relative to the footwall block, the fault is a normal fault (Fig. 1-B). If the hanging wall block moves up relative to the footwall block, the fault is a reverse fault (Fig. 1-C). More often in nature the movement along faults is some combination of strike-slip and dip-slip (normal or reverse). A common type of fault found in Louisiana is a special type of normal fault known as a listric (shovel-shaped) growth fault.

Measurement of Earthquakes

The size of an earthquake can be expressed by either intensity or magnitude. Magnitude is based on an instrumental recording that is related to energy released by an earthquake, while intensity describes the felt effects[1] of an earthquake.

Magnitudes: Earthquakes are recorded on seismographs, which are instruments designed to record ground motions. Seismographs produce permanent records known as seismograms. It is from seismograms recorded on seismographs at different geographic locations that scientists can calculate an earthquake's location and size. Today, the size of an earthquake is most often expressed in terms of a numeric value that is related to the amount of energy released at the earthquake's center. This value is known as the magnitude of the earthquake. Magnitude is a logarithmic measure of the earthquake's size. It is an open-ended scale with no top or bottom values. The most famous magnitude scale was developed by Charles Richter in 1935 to measure local magnitudes in California. Using the logarithmic scale, it is based on a standard instrument (seismograph) normalized to account for the separation of the instrument and the earthquake. Every time the magnitude goes up by one unit (say from 4.4 to 5.4), the amplitude of the earthquake waves increases 10 times on a seismogram. The relationship between magnitude and earthquake energy is not exact, but it has been estimated that with each whole step increase in magnitude the associated seismic energy increases about 30 times. For example, the energy generated by a magnitude 5.0 earthquake represents energy about 30 times greater than a magnitude 4.0 and 900 times (30x30) larger than a magnitude 3.0 event. Currently, there are many different magnitude scales based on different types of waves produced by an earthquake and recorded on seismographs.

Intensities: Historically, before the development of seismographs and magnitude scales, the size of earthquakes was measured using intensity scales. Intensity scales that were developed through the years group earthquake effects into Roman numeral values from I–XII. A number of different intensity scales have been devised over the past century, but the scale generally used in North America and many other countries is the Mercalli Scale as modified by Wood and Neumann in 1931, known today as the Modified Mercalli Intensity Scale (MMI). Table 1 presents a version of this scale. Using this intensity scale, it is possible to summarize the relative severity of the felt effects of an earthquake by constructing maps of the affected region divided into areas of equal intensity. These maps are known as isoseismal maps. It was—and still is in some cases—through the construction of isoseismal maps that the epicenter (earthquake's center) can be located at or near centers of areas experiencing the highest ground-shaking intensity. However, there can be considerable uncertainty in locating the epicenters utilizing this method because it depends heavily upon population density of the region in which the earthquake occurred. The information chronicled here on earthquakes in Louisiana consists mostly of intensity data.



Sample record showing the Lake Charles earthquake of October 16, 1983. The magnitiude was estimated to be approximately 3.8. The recording station was located 11km (7 miles) from the epicenter. Other marked signals are geophysical blasts. The regularly spaced rectangular marks are minute marks.

[1]"Felt effects" refers to effects felt or otherwise observed by people; "felt events" refers to seismic events felt by people.

Table 1.

Modified Mercalli Intensity Scale of 1931 (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. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing vehicles may rock slightly. Vibration like passing of truck. Duration estimated.

IV. Felt indoors by many during the day, outdoors by few. At night, some persons are awakened. Dishes, windows and doors are disturbed; walls make cracking sound. Sensation like heavy truck striking building; standing vehicles are rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many persons are frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construc tion; slight to moderate damage in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving vehicles.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings, with partial collapse; extensive damage in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water levels (?). Disturbs persons driving vehicles.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; extensive damage in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable along river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects are thrown upward into the air.

Source: Wood and Neumann (1931)

Louisiana Faults and Earthquakes

Louisiana lies within the geologic tectonic province known as the Gulf Coast Basin. It is within this deep basin that basement rock structures are covered by thick sedimentary rocks. Typical geologic structures of this province are generally characterized by southerly dipping and thickening sedimentary strata disrupted by salt domes and regional systems of relatively shallow listric growth faults (normal faults). These fault systems trend for considerable distances, roughly paralleling the Louisiana coastline. The major fault systems occurring in Louisiana are presented in figure 2. Those in south Louisiana are growth faults thought to have originally formed during periods of accelerated basin subsidence; mechanisms invoked to explain their formation have included overloading in areas of voluminous sedimentation, differential compaction of deposited sediments, abnormally high fluid pressure, and gravity sliding. Active movement within most of these fault zones is thought to have occurred during periods of rapid localized sediment deposition, mostly during periods of geologic time known as the Miocene and Oligocene epochs (approximately 5 to 36 million years ago). Some, perhaps most, are again active following reactivation in the recent geologic past. It should be noted that none of the faults in north Louisiana are known to be active.

Evidence of the existence of most of the faults in south Louisiana was originally provided by data gathered from many years of underground oil exploration. Only a few were considered active and traceable along the ground until recently, when subtle escarpments were mapped over much of southwestern Louisiana and shown to be similar in character to those associated with the well-known faults of the Baton Rouge system in southeastern Louisiana. Contemporary evidence of movement along this system has been documented by cracking of buildings and pavements that straddle fault traces in Baton Rouge, Scotlandville, and Denham Springs. So far as is known, movement along this and other fault systems within the thick sedimentary basin fill of Louisiana is related to a process of gradual creep as opposed to the sudden breaking of rock associated with earthquakes. No detected earthquakes have definitely been attributed to any of the specific mapped fault systems.

Although Louisiana lies in an area of low seismic risk, a number of historical earthquakes have occurred in our state. They have tended to be of low magnitude and occur with low frequency. Figure 3 shows earthquake locations in Louisiana from the U.S. Geological Survey's historical record (this and additional earthquake information is accessible and can be queried at http://wwwneic.cr.usgs.gov/neis/epic/epic_rect.html). Table 2 lists the plotted earthquakes.

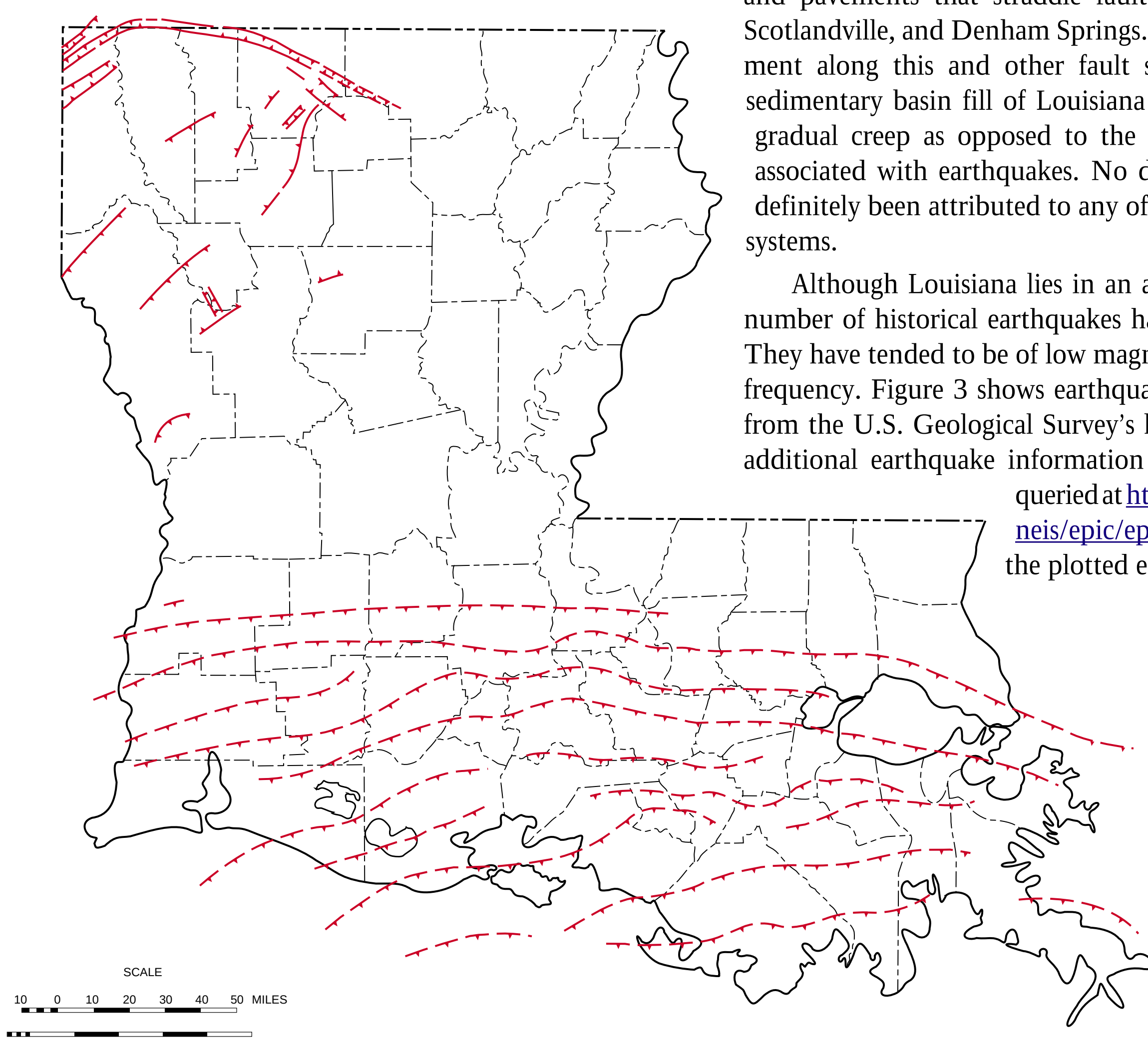


Figure 2. Generalized subsurface faults in Louisiana. North Louisiana faults are from Gulf Coast Association of Geological Societies and American Association of Petroleum Geologists (1972; used with permission). The dashed lines in south Louisiana, rather than representing discrete faults, mark the approximate northernmost edges of different zones of growth faults having different ages of formation (from Murray 1961; used with permission of the author).

Table 2.

Felt earthquakes in and around Louisiana

Event	Year	Month	Day	Orig Time (UTC)	Lat	Long	Depth (km)	Mag
1	1843	2	14		30.00	-90.00		
2	1843	2	15		30.00	-90.00		
3	1882	4	12	05:00	30.00	-90.00		
4	1886	1	22	16:38	30.40	-92.00		
5	1905	2	3		30.50	-91.10		
6	1927	12	15	04:30	29.00	-89.40		3.9
7	1929	7	28	17:00	29.00	-89.40		3.8
8	1930	10	19	12:17	30.00	-91.00		4.2
9	1940	12	2	16:16	33.00	-94.00		
10	1941	6	28	18:30	32.40	-90.90		
11	1947	9	20	21:30	31.90	-92.70		
12	1958	11	6	23:08	30.00	-90.00		
13	1958	11	19	18:15	30.30	-91.10		
14	1959	10	15	15:45	29.60	-93.10		3.8
15	1964	4	24	01:20:54.2	31.38	-93.81	1	3.7
16	1964	4	24	03:36:18	31.30	-93.80		2.6
17	1964	4	24	07:33:51.9	31.42	-93.81	5	3.7
18	1964	4	24	07:47:17.1	31.38	-93.80	5	3.2
19	1964	4	24	07:50:56.0	31.30	-93.80		2.6
20	1964	4	24	12:07:08.2	31.48	-93.79	9	3.2
21	1964	4	24	12:54:17.0	31.30	-93.80		2.9
22	1964	4	24	17:22:13.0	31.30	-93.80		2.8
23	1964	4	24	23:03:50.0	31.30	-93.80		2.6
24	1964	4	25	03:23:08.0	31.30	-93.80		2.6
25	1964	4	25	04:05:33.0	31.30	-93.80		2.9
26	1964	4	25	06:02:33.0	31.30	-93.80		2.9
27	1964	4	26	02:35:24.0	31.30	-93.80		2.7
28	1964	4	26	03:24:50.2	31.55	-93.78	5	3.3
29	1964	4	27	21:50:27.0	31.30	-93.80		3.2
30	1964	4	28	00:24:07.0	31.30	-93.80		3.1
31	1964	4	28	00:30:45.7	31.40	-93.82	6	3.4
32	1964	4	28	21:18:35.0	31.30	-93.80		4.4
33	1964	4	28	21:18:41.0	31.63	-93.80	14	4.4
34	1964	4	30	20:30	31.50	-93.80		3.0
35	1964	5	2	06:34:54.0	31.30	-93.80		3.3
36	1964	5	3	03:24:12.0	31.30	-93.80		3.0
37	1964	5	7	20:10	31.50	-93.80		3.2
38	1964	8	16	11:35:31.0	31.40	-93.80		2.9
39	1964	8	19	23:58:55.0	31.30	-93.80	2.7	
40	1981	2	13	02:15	30.00	-91.80		
41	1981	2	18	06:33:48.2	29.56	-91.46	5	3.0
42	1983	10	16	19:40:50.8	30.24	-93.39	5[2]	3.8
43	1994	6	10	23:34:02.9	33.01	-92.67	5	3.2

[2] Hypocenter reported by the U.S. Geological Survey, National Earthquake Information Center, based on regional data; Stevenson and Agnew (1988) reported a hypocenter of 14km based on local data.

The Donaldsonville, Louisiana, earthquake of October 19, 1930 (event #8), is the largest earthquake to have occurred in Louisiana, with a MM intensity of VI. Other historical felt events include the Catahoula, Louisiana, earthquake of May 7, 1842; the New Orleans earthquake of November 6, 1958 (event #12); and the Baton Rouge earthquake of November 19, 1958 (event #13). The epicentral MM Intensities of these three earthquakes were III-IV, IV, and V, respectively. Following is a discussion of the effects of some of the significant earthquakes felt or observed in Louisiana. The numbers in parentheses refer to selected numbered event locations on figure 3 and in table 2. Various sources were used to compile this information: Fuller (1912), unpublished studies by Gulf States Utilities in connection with licensing of the River Bend Nuclear power plant, *Earthquake History of the United States* (Coffman, von Hake, and Stover, 1982), Nuttli (1973), Nuttli (1982), and newspaper articles of the time as noted.

May 7, 1842: The epicenter of this MM Intensity III-IV earthquake was lightly felt for a duration of 2 to 3 seconds over a 1,350-square-mile area in the Gulf Coast Basin southwest of Baton Rouge, near the town of Catahoula. Fluctuations were noted in the water level of a lake located east of Catahoula and along the banks of Bayou Teche. The earthquake was also felt at St. Martinville, and Opelousas (Daily Picayune, New Orleans, La., May 9, 1842). This first felt event does not appear in table 2 or on the location map (figure 3); the epicenter may not have been sufficiently well defined to locate it.

October 19, 1930 (#8): The epicenter of this MM Intensity VI earthquake was located near Donaldsonville, Louisiana. The closest seismograph stations at Loyola University in New Orleans and at Spring Hill College in Mobile, Alabama, were inoperative at the time of this earthquake, making it impossible to determine the epicenter from instrumental data. The earthquake was strong enough to be recorded on the seismograph at Georgetown University in Washington, D.C.

Intensity data indicated that the earthquake was felt over a 15,000-square-mile area of southeastern Louisiana. An MM Intensity VI was assigned, based upon scattered instances of damage within the MM Intensity V-VI area. At Napoleonville, chimneys were damaged and windows broken; at White Castle, plaster cracked and small objects were overturned; at Gonzales and Donaldsonville, "brick chimneys of several residences were damaged, some being cracked almost from the top to bottom while parts of others, above the roof, were knocked down" (The Donaldsonville Chief, Donaldsonville, Louisiana, November 1930).

Other towns to experience MM Intensity V effects included Morgan City, Elemans, Franklin, Berwick, and Plaquemine, where small objects were overturned, doors and windows rattled, pictures fell, hanging objects swung, walls and houses creaked, and trees and bushes were shaken. In New Orleans, this earthquake caused floors and beds to rock for 6 to 15 seconds. "In some instances, beds were rolled two or three feet, causing their occupants to awaken startled, pictures to loosen from walls, dishes to rattle, and house foundations to creak loudly" (Times Picayune, New Orleans, Louisiana, October 20, 1930). The earthquake was also felt by many people in the Baton Rouge area as a brief undulating or rolling motion that shook walls, lights, and windows (Baton Rouge Morning Advocate, October 20, 1930).

November 6, 1958 (#12): This MM Intensity IV earthquake was confined to an area within a five- to seven-mile radius of downtown New Orleans, extending from Lake Pontchartrain on the north to Gretna on the south and from Harahan on the west to Arabi on the east. The earthquake was recorded as a 15 second vibration on the seismographs at Loyola University in New Orleans. The assigned MM Intensity IV is based on reports of maximum effects as windows shook and doors rattled (Times Picayune, New Orleans, November 8, 1958, and New Orleans States and Items, November 7, 1958).

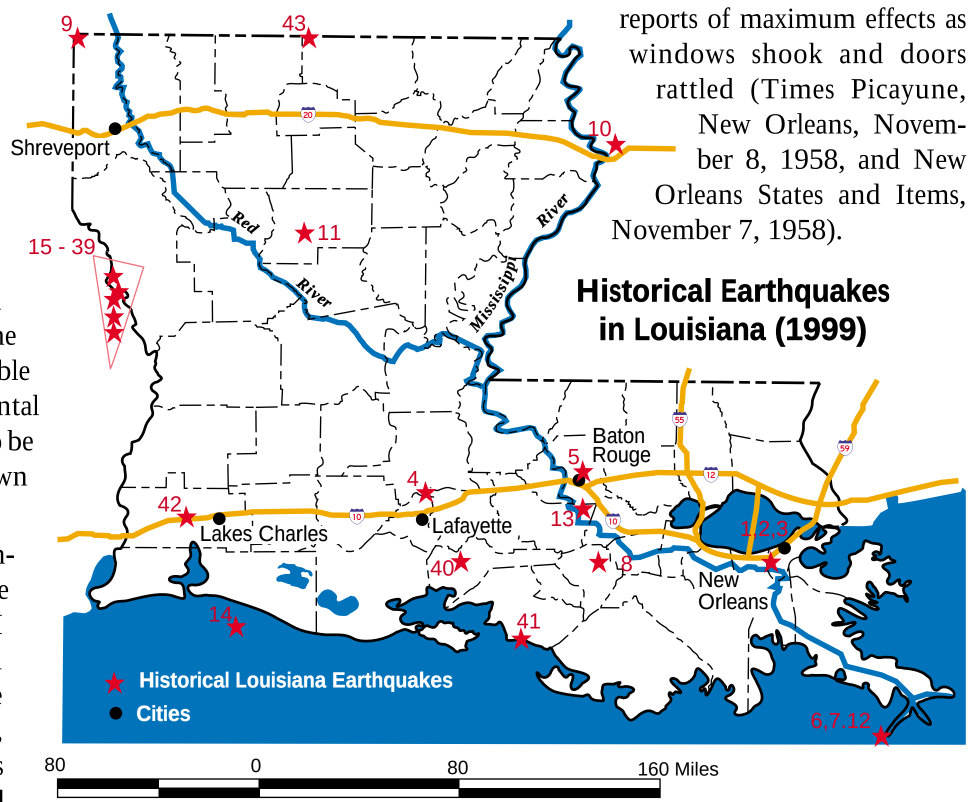


Figure 3. Historical felt earthquake locations in and around Louisiana, from the U.S. Geological Survey's historical record (http://wwwneic.cr.usgs.gov/neis/epic/epic_rect.html).

November 19, 1958 (#13): This earthquake with an MM Intensity V was reported felt in Baton Rouge, Baker, and Denham Springs. The estimated 10 second period of felt vibration was not immediately recognized as an earthquake; many thought it was an explosion or sonic boom (Baton Rouge Morning Advocate, Baton Rouge, November 20, 1958).

October 15, 1959 (#14): This earthquake of MM Intensity IV was felt over approximately 3,000 square miles in southwestern Louisiana, extending from Cameron on the southwest to DeQuincy on the north to Lake Arthur on the east. Maximum effects were noted at Creole and Grand Chenier on the southern Louisiana coast, where objects and windows rattled.

April 24, 1964 to August 16, 1964 (#15-39): Within this time span, a series of earthquakes occurred mostly in Texas near the Texas-Louisiana border, generally between the Toledo Bend Reservoir and the Sam Rayburn Reservoir. Epicentral MM Intensities ranged from IV to VI, and body-wave Magnitudes ranged from 3.0 to 4.0. These earthquakes were felt over small areas, and the epicenters appear to have been shallow, less than 5 kilometers deep. At the time of these events, the Sam Rayburn Reservoir was being filled, and the Toledo Bend Dam was being constructed. A deployment of portable seismograph instrumentation from July to September 1964 recorded more than 70 micro-earthquakes. Events 16–40 plotted on figure 3 and listed in Table 2 represent the best-located of the series. Earthquake activity in this area abruptly decreased in frequency, intensity, and magnitude after the three-month period, with the last reported event occurring on August 19, 1964. No local earthquakes were recorded after September 1964 (Henley 1965).

October 16, 1983 (#42), The only earthquake in Louisiana to be recorded and located by locally deployed instruments is the Lake Charles earthquake of 1983. This is described in a paper in the Bulletin of the Seismological Society of America (1988) by D. A. Stevenson and J. D. Agnew. The authors infer that a deep-seated ("basement") fault was responsible for this earthquake, but the depth (14+ kilometers) precludes detailed knowledge of the specific fault; the main point made by the authors is that such a fault could be controlling the placement and activity of shallower "growth" faults in the thick sediments overlying the crystalline basement. Not one of the earthquakes that has occurred in Louisiana has been attributed to any specific fault. This is in large part because of the paucity of seismograph stations located in the state.

Large Historical Earthquakes Felt in Louisiana

New Madrid, Missouri, 1811-1812: On December 16, 1811, at 2:15 a.m. (local time), a major earthquake shook the Central United States and much of the Eastern United States. It was the first in a series of strong events that continued through the spring of 1812 and then for more than 5 years after that at a reduced frequency and intensity. An isoseismal map prepared by Otto Nuttli (1973) indicates that MM Intensities V-VI were most likely experienced by persons living in the northern half of Louisiana, with MM Intensities of III-IV experienced by people in the southern half of the state. No reports have been found of the effects of these events on the northern areas of Louisiana. However, a letter published in the Natchez Weekly Chronicle offers an account of the effects of these earthquakes at Natchez, Mississippi, across the river from our state. The letter dated December 18, 1811, states:

Several clocks stopped at two or at about 10 minutes after. Several articles were thrown off the shelves; crockery was sent rolling about the floor, articles suspended from the ceiling of stores vibrated rapidly without any air to disturb them for about nine inches; the plastering in the rooms of some houses was cracked and injured.

The largest of the series of events occurred on February 7, 1812, and was apparently felt in New Orleans and reported as a slow oscillatory motion, rather than as a strong shaking (Moniteur de la Louisiane, February 11, 1812).

Today, the New Madrid seismic zone remains the area most likely to produce earthquakes that could affect Louisiana. This is primarily due to the combination of proximity of the seismic zone to the state, frequency of recorded seismic events, and great magnitude of some of the historic seismic events. The effects would, of course, depend upon the magnitude of the earthquakes originating from that region. An investigation of the potential for transmittal of seismic energy (and risk) from the New Madrid seismic zone along wrench faults (ancient zones of crustal weakness formed during the separation of continents) into Louisiana was addressed in an LGS open-file report (Meloy and Zimmerman 1997). This report concluded that the presence of the wrench faults does not *increase* the seismic risk to Louisiana from the New Madrid seismic zone.

March 27, 1964: The Prince William Sound, Alaska, earthquake, magnitude 8.3, was not felt in Louisiana. However, there were reports of long-period surface waves which set up seiches or periodic oscillations of the surface of closed bodies of water in the Gulf Coast region. The effects of the seiches were noticed in the rivers and bayous of the New Orleans area, where considerable damage was done to many boats and barges, which slammed against piers or were torn from their moorings. Most accounts indicate that water oscillations had a peak-to-peak amplitude of approximately 6 feet, with a period of oscillation on the order of 5 seconds. The Amite River, east of Baton

Rouge, had peak-to-peak oscillations on the order of 4 feet for a duration of 20 minutes. In Baton Rouge, the water in swimming pools, including the pool on the fourth floor of the Capitol House Hotel, was disturbed. Water disturbances "were not particularly noticeable" along the Mississippi River (Baton Rouge Morning Advocate, March 28, 1964).

Conclusion

Although Louisiana is not seismically active, it is evident from the historical record that small earthquakes occasionally do occur here. The U.S. Geological Survey has an ongoing project called the National Seismic Hazard Mapping Project. Their web site (http://geohazards.cr.usgs.gov/eq/html/ceusmap.shtml) has many interesting maps describing seismic hazards throughout the United States. This USGS site is where seismic hazard maps can be viewed for sections of the country, including Louisiana. The New Madrid seismic zone is the area most likely to produce earthquakes that could affect Louisiana. Other more immediate geologic faulting hazards in Louisiana are associated with growth faults. Many of the growth faults, located primarily in the southern portion of the state, show movement as a gradual form of fault creep rather than in conjunction with detectable earthquakes. These faults pose a threat more to property than life. The Baton Rouge fault system is an excellent example of this phenomenon, and experience with the damage it has caused exemplifies the notion that cautious planning in areas where known growth faults intersect the land surface is advisable.

For More Information

http://wwwneic.cr.usgs.gov/neis/epic/epic_rect.html

http://geohazards.cr.usgs.gov/eq/html/ceusmap.shtml

http://www.udel.edu/dgs/webpubl.html

(This URL is for the *Web Publications* website of the Delaware Geological Survey; click on the SP 23, Earthquake Basics link for an article of that title by Stefanie Baxter in pdf format.)

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