STATE OF ARKANSAS
ARKANSAS GEOLOGICAL SURVEY
George C. Branner
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EARTHQUAKE RISKS IN ARKANSAS

A Statistical Study Covering the Period from 1811 to 1931

By

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October 24, 1932

Hon. Harvey Parnell,
Governor, State of Arkansas,
Little Rock, Arkansas.

Sir:

I have the honor to submit herewith the report, "Earthquake Risks in Arkansas," which is a statistical study covering the period from 1811 to 1931, by George C. Branner and J. M. Hansell.

Information concerning earthquake risks in the state has been requested from this department from time to time by insurance companies and by residents of northeast Arkansas. In this paper an attempt is made to compile and interpret available data concerning those earthquakes which have affected the central Mississippi Valley, and Arkansas in particular.

Respectfully submitted,

George C. Branner

State Geologist.

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ABSTRACT

Northeast Arkansas lies within the central Mississippi Valley earthquake region of the United States. The three greatest earthquakes which have affected Arkansas have been the New Madrid earthquake of 1811 to 1813, the Memphis earthquake of 1843, and the Charleston earthquake of 1895. Of the total number of earthquakes which have been felt in Arkansas, 95 per cent have affected the northeast portion of the state while only eight per cent have affected the entire state. The greatest percentage (85 per cent) of earthquakes felt in the state has been of medium intensity, rated between I and VII on the Rossi-Forel scale. Only nine per cent of the earthquakes felt in the state from 1811 to 1931 have been of sufficient intensity to endanger life. Since 1909 the average periodicity has been one earthquake every 6.7 months. The continuation of frequent small shocks of low intensity in northeast Arkansas may probably prevent the building up of earth stresses which will produce an earthquake of great severity. The earthquakes of northeast Arkansas are apparently caused by movements in the basement rocks underlying the Gulf Coastal Plain.

INTRODUCTION

This paper endeavors to set forth essential data concerning the distribution of the earthquakes which have affected the central Mississippi Valley, and especially the State of Arkansas, with the object in view of presenting a fairly clear picture of the earthquake situation within the state. The information given is of particular interest to residents of northeast Arkansas and is of value of insurance companies as an aid in the determination of premium rates on policies which offer protection against damage or destruction by earthquakes. Engineers and architects will also find this information helpful in determining the necessity for earthquake-proof types of construction. The record of earthquakes is also of historical and educational interest.

Some interesting data have recently been gathered by John R. Freeman 1/ who states that in the entire state of California where there has been a large amount of fire or property damage due to earthquakes, the total claims paid on earthquake insurance from 1921 to 1930 amounted to only $1,302,253, although the premiums paid for that period amounted to $13,929,520. This period included the Santa Barbara earthquake of 1925. Mr. Freeman also states that during the above period over the portion of the United States lying east of the Rocky Mountains, the actual earthquake damage was so small it could have been covered by standard fire insurance policies with trifling additions to the rate. He further states that in regions where earthquake risks are serious, buildings can be so constructed as to minimize the risk of damage at an increase in cost roughly estimated at not more than 15 per cent.

Comparatively little information is available concerning the earthquake which took place in the Mississippi Valley region prior to 1909. Following is a list of all source material utilized:

U. S. Weather Bureau, Monthly Weather Review, 1876-1925.

A. H. Purdue, The Charleston (Missouri) Earthquake, Indiana Academy of Science, 1895.

1/ Freeman, J. R., Earthquake damage and earthquake insurance; New York; McGraw-Hill Book Company, 1932.

M. L. Fuller, The New Madrid Earthquake, U. S. Geological Survey Bulletin 494, 1906.

Seismological Society of America, Bulletins 1911-1930.
U. S. Coast and Geodetic Survey Seismological Reports as follows:

Serial No. 503, January, February, March, 1925.
" " 337, April, May, June, 1925.
" " 363, July, August, September, 1925,
" " 388, October, November, December, 1925.
" " 395, January, February, March, 1926.
" " 406, April, May, June, 1926.
" " 424, July, August, September, 1926.
" " 431, October, November, December, 1926.
" " 463, January, February, March, 1927.
" " 468, April, May, June, 1927.
" " 495, July, August, September, 1927.
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N. H. Heck, Earth quake History of the United States, U. S. Coast and Geodetic Survey Special Publication 149, 1928.
N. H. Heck and R. R. Bodle, United States Earthquakes, U. S. Coast and Geodetic Survey Serial 483, 1928.
N. H. Heck and R. R. Bodle, United States Earthquakes, U. S. Coast and Geodetic Survey Serial 511, 1929.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to Capt. N. H. Heck, of the U. S. Coast and Geodetic Survey for constructive criticism of this paper and for supplying unpublished data concerning the distribution of earthquakes in the United States. Acknowledgment is also due to James B. Macelwane, S. J., Director of the Department of Geophysics of St. Louis University, for suggestions for broadening the scope of this report.

GENERAL CONSIDERATIONS REGARDING EARTHQUAKES

Cause

An earthquake is a vibration or shaking of the earth and usually can be definitely associated with earth movements and fracturing of the earth's crust. Upon sudden fracture, vibrations are set up in the earth at and near the fracture and these travel through the earth, decreasing in intensity with the distance travelled.

Most scientists hold to the concept that the earth's crust is unstable. In general, this means that although some portions of the earth's crust are stable, other portions are slowly rising, and still others are sinking. It follows that, in areas of instability, stresses are always present. Some parts may be under compressive stresses while others may be under tension or torsion. The release of any one, or a combination, of these stresses by sudden fracture will produce an earthquake.

Stresses set up in the earth's crust in regions of instability may find re-

lease in gradual movement along pre-existing lines of slip or faults, or may cause the formation of new lines of faulting. If these stresses are gradually relieved along pre-existing lines of slip, no appreciable tremors will result, whereas stresses finding no gradual release may build up beyond the strength of the earth's crust and be suddenly released by fracture, causing an earthquake.

The intensity of an earthquake is greatest at its epicenter, which is the area on the earth's surface above the point, line, or zone of origin. Usually the slipping which causes the earthquake relieves the stress and no further movement takes place until stresses have again built up to a breaking point. This may require only a short time or a period of years, depending on the character and cause of the stresses.

Intensity

The intensity of an earthquake shock at its point of origin varies with the amount of movement, the character of the local surface formations, the size of the area affected by the movement, the rapidity of the movement, and the depth at which movement occurs. Earthquake intensities are usually classified according to the Rossi-Forel scale of intensities. This scale is used in this paper and is given below:

Rossi-Forel Scale of Intensities

I. Microseismic shock. Recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. Extremely feeble shock. Recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. Very feeble shock. Felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. Feeble shock. Felt by several persons in motion; disturbance of movable objects, doors, windows; cracking of ceilings.

V. Shock of moderate intensity. Felt generally by everyone; disturbance of furniture, beds, etc.; ringing of some bells.

VI. Fairly strong shock. General awakening of those asleep; general ringing of bells; oscillation of chandeliers; stopping of clocks; visible agitation of trees and shrubs; some startled persons leaving their dwellings.

VII. Strong shock. Overthrow of movable objects, fall of plaster; ringing of church bells; general panic; without damage to buildings.

VIII. Very strong shock. Fall of chimneys, cracks in the walls of buildings.

IX. Extremely strong shock. Partial or total destruction of some buildings.

X. Shock of extreme intensity. Great disaster; ruins; disturbance of the strata, fissures in the ground; rock falls from mountains.

Method of Recording and Locating

Earthquakes are recorded with seismographs. These are highly sensitive instruments which record the time and intensity of earth vibrations. The seismograph records three types of vibrations or waves produced by an earthquake, which are classed as (1) longitudinal or compressional waves, in which the particles move in the line of propagation, (2) transverse or shear waves, in which the particles move at right angles to the line of propagation, and (3) circumferential waves, in which the movement of particles is very complex. These three classes of waves travel at different velocities, the first two through the earth and the third at or near the earth's surface. Seismographs record these waves in the order in which they are received. By comparing the time of the reception of the three types of waves, the distance from the receiving station to the point of origin of an earthquake can be estimated. By comparing the records of several widely-spaced seismological stations, the approximate location of an earthquake can be determined.

Seismological Stations in the South Central Mississippi Valley

Six seismological stations are located in the south central part of the Mississippi Valley region. These, with their dates of installation, are as follows:

City	Location	Date installed
St. Louis, Missouri	St. Louis University	October 22, 1909
Lawrence, Kansas	University of Kansas	1909
New Orleans, Louisiana	Loyola University	July 31, 1910
Mobile, Alabama	Spring Hill College	October 10, 1910
Florissant, Missouri	St. Louis University	August, 1928
Little Rock, Arkansas	St. John's Seminary	December 6, 1930

These stations, with the exception of the one at Lawrence, Kansas, operated by the University of Kansas, are operated by the Jesuit Seismological Association. The Association, through its Central Station in St. Louis, is giving especial attention to the study of the Mississippi Valley earthquakes and their epicenters, and has issued data in regard to them in its Preliminary Bulletins. All stations cooperate with the United States Coast and Geodetic Survey.

EARTHQUAKES IN NORTH AMERICA AFFECTING THE CENTRAL MISSISSIPPI VALLEY

The regions in the United States most affected by earthquakes are shown in the shaded areas in Plate I. Within the United States, it will be noted that, in addition to the main (Cordilleran) earthquake zone (Area 1) along the Pacific Coast, there are four general areas subject to earthquake disturbances. One of these (Area 2) is in the Rocky Mountain region; the second (Area 3), which is the one considered in this paper, is in the central Mississippi Valley region centering approximately at the mouth of the Ohio; the third (Area 4) follows the Appalachian Mountain system; and the fourth (Area 5) is a small area on the Coastal Plain in the vicinity of Charleston, South Carolina.

Fuller 2/ gives a summary of earthquakes in the central Mississippi Valley region preceding 1811, but, as the records of these are not as reliable as those of the earthquakes following the year 1811, they are not included in this paper. It must be remembered that, prior to 1909, instruments for the detection of earthquakes were little used in the central Mississippi Valley region and, consequently, before 1909 records of the intensities of the shocks and the areas affected are not as accurate as those recorded by the seismological stations.

In order to form a perspective of the Arkansas earthquake problem, it is necessary to study the distribution of earthquakes within the central Mississippi Valley region. A list of the earthquakes which have affected the central Mississippi Valley since 1811, with relevant data, has been compiled from available records, and is shown in Table 1. Those earthquakes which have affected any part of Arkansas are capitalized.

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
*/1811, Dec. 16	NEW MADRID, MISSOURI 2a/	1,000,000	X	564
1820, Nov. 9	Cape Girardeau, Missouri	5,000 or less	I-V	40 ?
1827, Aug. 9	New Albana, Indiana	Local	VII	Local
/1843, Jan. 4	MEMPHIS, TENNESSEE	400,000	IX	356
1857, Oct. 8	Illinois, near St. Louis	7,500	VII	49
/1865, Aug. 17	SOUTHEAST MISSOURI	24,000	VII	87
-1867, Apr. 24	KANSAS	300,000	VII-VIII	308
1875, Nov. 8	Kansas	8,000	V	51
1876, Sept. 25	Southern Illinois and Indiana	4,000 ?	III-IV	35 ?

2/ Fuller, M. L., The New Madrid earthquake: U. S. Geol. Survey Bull. 494, pp. 11-12, 1912.

2a/ Jones, E. Lester, Earthquake Investigation in the United States: Serial No. 304, Dept. of Commerce. "This earthquake was felt over a great part of the United States. Good evidence exists that another earthquake similar in intensity occurred in the same region about 100 years before. A lasting result of these earthquakes is the lowering of the level of a large extent of the country in southeast Missouri and northeast Arkansas, now known as the 'Sunken country.' At a more recent date there would have been more towns and villages and developed farmland to be damaged."

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive (cont.)

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
1877, June 15	Carbondale, Illinois	9,500 ?	III-V	55 ?
1877, Nov. 14	East Nebraska	140,000	VII	210
1878, Jan. 8	Cairo, Illinois	3,000 ?	II-III	32 ?
✓1878, Mar. 12	COLUMBUS, KENTUCKY	70,000 ?	VI-VII	150 ?
1878, Nov. 19	Cairo, Illinois	3,000	II	30 ?
✓1878, Nov. 19	SOUTHEAST MISSOURI	150,000	VII	217
1879, July 26	Cairo, Illinois	?	?	?
✓1879, Sept. 26	MEMPHIS, TENNESSEE	4,000 ?	III-IV	35 ?
✓1880, July 13	MEMPHIS, TENNESSEE	9,500 ?	IV-V	55 ?
1882, May 25	LaSalle, Illinois	70,000 ?	VI-VII	150 ?
1882, July 20	South Illinois	3,000	V	31
1882, July 28	Ironton, Missouri	9,500 ?	I-V	55 ?
✓1882, Sept. 27	SOUTH ILLINOIS	40,000	VI-VII	112
1882, Oct. 14	St. Louis, Missouri	40,000 ?	I-III	112 ?
1882, Oct. 15	South Illinois	40,000	V-VI	112
-1882, Oct. 22	ARKANSAS	135,000	VII-VIII	207
✓1883, Jan. 11	MISSOURI AND TENNESSEE	80,000	VI-VII	159
✓1883, Apr. 12	CAIRO, ILLINOIS	250,000 ?	VIII	280 ?
✓1883, June 11	MEMPHIS, TENNESSEE	Local	VI-VII	Local
✓1883, July 14	CAIRO, ILLINOIS	10,000	V	80 ?
-1883, Dec. 5	BOONE COUNTY, ARKANSAS	Local	V	Local
1884, Feb. 15	Caledonia, Missouri	Local	III	Local
1886, Mar. 18	Cairo, Illinois	3,000?	II-III	30 ?
✓1886, Aug. 31	CHARLESTON, SOUTH CAROLINA	3,000,000	X	1,000 ?
1887, Feb. 6	Vincennes, Indiana	75,000	VI	153
✓1889, July 19	MEMPHIS, TENNESSEE	Local	VI-VII	Local
1891, July 26	Evansville, Indiana	Local	VI-VII	Local
o✓1895, Oct. 31	CHARLESTON, MISSOURI	1,000,000	VIII-IX	564
✓1897, Apr. 25	OSCEOLA, ARKANSAS	3,000 ?	III	32 ?
1897, Apr. 30	Tennessee and Illinois	3,000	I-V	31
✓1898, June 14	CORNING AND OSCEOLA, ARKANSAS	30,000	III	100 ?
1899, Apr. 29	Southwest Indiana	40,000	VI	112
1902, Jan. 24	Missouri	40,000	VI-VII	112
✓1903, Feb. 8	SOUTH ILLINOIS	70,000	VII	148
1903, Nov. 4	St. Louis, Missouri	70,000	VI-VII	148
✓1903, Nov. 27	NEW MADRID, MISSOURI	70,000	V	148
1904, Oct. 27	Kansas	2,700	V	29
✓1905, Jan. 27	GADSEN, ALABAMA	250,000	VI-VII	282
1905, Apr. 13	Keokuk, Iowa	5,000	V	40
✓1905, Aug. 21	SOUTHEAST MISSOURI	40,000	VI	112
1906, Jan. 7	Manhattan, Kansas	10,000	VII-VIII	56
1906, May 11	Petersburg, Indiana	800	V	16
1907, July 4	Farmington, Missouri	400	V	11
✓1908, Sept. 28	NEW MADRID, MISSOURI	5,000	IV-V	40
1908, Oct. 27	Cairo, Illinois	5,000	V-VI	40

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive (cont.)

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
✓1909, May 26	ROCKFORD, ILLINOIS	500,000	VIII	398
1909, July 18	Illinois	40,000	VII-VIII	112
1909, Aug. 16	Southwest Illinois	18,000 ?	IV-V	76
1909, Sept. 27	Indiana	30,000	VIII	98
✓1909, Oct. 23	SOUTHEAST MISSOURI	40,000	V-VI	112
1909, Oct. 23	Robinson, Illinois	30,000	V-VI	98
-1911, Mar. 31	RISON, ARKANSAS	18,000	VII	76
1912, Jan. 2	Joliet, Illinois	40,000	VI	80
1913, Apr. 17	East Tennessee	240,000	VII-VIII	280
1913, June 9	Humbolt, Tennessee	4,000 ?	III-IV	35 ?
1913, Oct. 16	Sterling, Illinois	4,000 ?	III-IV	35 ?
1914, Mar. 5	Northern Alabama	125,000 ?	IV	200 ?
1915, Feb. 5	Harrisburg, Illinois	9,500 ?	IV-V	55 ?
1915, Feb. 19	Mound City, Illinois	4,000 ?	IV	35 ?
1915, Apr. 15	Olney, Illinois	3,000 ?	II	30 ?
1915, Apr. 29	New Madrid, Missouri	200	IV-V	8
1915, Oct. 8	Muskogee, Oklahoma	3,000 ?	III	32 ?
1915, Oct. 26	Mayfield, Kentucky	Local	V	Local
✓1915, Dec. 7	NEAR MOUTH OF OHIO RIVER	60,000	VI	140
1916, Jan. 7	Worthington, Indiana	3,000 ?	III	32 ?
✓1916, Feb. 21	SKYLAND, NORTH CAROLINA	200,000	VI	250 ?
✓1916, May 21	NEW MADRID, MISSOURI	7,500	IV	50
✓1916, Aug. 24	NEW MADRID, MISSOURI	3,000 ?	III	32 ?
1916, Oct. 18	Easonville, Alabama	100,000	VIII	180 ?
1916, Nov. 4	Birmingham, Alabama	3,000 ?	III	32 ?
1916, Dec. 19	Hickman, Kentucky	Local	V-VI	Local
✓1917, Apr. 9	EAST MISSOURI	200,000	VII	252
1917, May 9	Hendrickson, Missouri	4,000 ?	IV	35 ?
✓1917, June 9	NEW MADRID, MISSOURI	30,000 ?	IV	100 ?
1917, June 30	Greensboro, Alabama	9,500 ?	IV-V	55 ?
1918, Feb. 18	Cairo, Illinois	3,000 ?	III	32 ?
1918, Sept. 10	Oklahoma	Local	VI	Local
✓1918, Oct. 4	BLACK ROCK, ARKANSAS	30,000	V	98
✓1918, Oct. 13	HOXIE, ARKANSAS	9,500 ?	V	55 ?
✓1918, Oct. 15	WEST TENNESSEE	20,000	V-VI	80
1919, Feb. 10	S. W. Indiana and N. W. Kentucky	Local	?	?
1919, May 23	Hickman, Kentucky	3,000 ?	III	32 ?
1919, May 24	Hickman, Kentucky	3,000 ?	III	32 ?
1919, May 25	South Indiana	18,000	V	76
✓1919, May 26	BARDWELL AND HICKMAN, KENTUCKY	8,000	III	50
1919, May 27	Wichita, Kansas	9,500 ?	IV-V	55 ?
1919, May 28	Tiptonville, Tennessee	3,000 ?	III	32 ?
1919, July 26	Wichita, Kansas	4,000 ?	IV	35 ?
✓1919, Nov. 3	POCAHONTAS, ARKANSAS	Local	III-V	Local
1920, Feb. 28	Springfield, Missouri	4,000	IV	35
1920, Apr. 7	Springville, Tennessee	3,000 ?	II	30 ?

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive (cont.)

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
1920, Apr. 30	Centralia, Illinois	4,000 ?	IV	35 ?
1920, May 1	Missouri	10,000	V	56
1920, Oct. 3	Harrisonville, Missouri	3,000 ?	II	30 ?
/1921, Jan. 10	NEW MADRID, MISSOURI	4,000 ?	IV	35 ?
1921, Feb. 27	Cairo, Illinois	3,000 ?	III	32 ?
1921, Mar. 14	Terre Haute, Indiana	?	?	?
1921, Sept. 9	Waterloo, Illinois	4,000 ?	IV	35 ?
1921, Oct. 1	Harrisburg, Illinois	4,000 ?	III-IV	35 ?
1921, Oct. 9	Waterloo, Illinois	3,000 ?	III	32 ?
1922, Jan. 11	Mount Vernon, Indiana	9,500 ?	V	55 ?
/1922, Mar. 22	SOUTH ILLINOIS	25,000	V	89
/1922, Mar. 30	FARMINGTON, TENNESSEE	70,000 ?	V	150 ?
/1922, Nov. 26	PADUCAH, KENTUCKY	30,000 ?	IV	100 ?
1923, Mar. 9	Greenville, Illinois	4,000 ?	IV	35 ?
1923, Mar. 18	Southern Illinois	?	?	?
/1923, Mar. 27	WYATTE, MISSISSIPPI	4,000 ?	IV	35 ?
1923, May 6	Cairo, Illinois	4,000 ?	IV	35 ?
1923, May 15	Cairo, Illinois	3,000 ?	II	30 ?
/1923, Oct. 28	NORTHEAST ARKANSAS	40,000	VIII	112
1923, Nov. 9	Tallula, Illinois	25,000 ?	V-VI	90 ?
/1923, Nov. 26	MARKED TREE, ARKANSAS	4,000 ?	IV	35 ?
/1923, Dec. 31	ARKANSAS	30,000	V	98
/1924, Jan. 1	BLYTHEVILLE, ARKANSAS	70,000 ?	V	150 ?
/1924, Mar. 2	KENTUCKY	150,000	VI	217
/1924, June 7	TIPTONVILLE, TENNESSEE	9,500 ?	IV-V	55 ?
1925, Jan. 26	Waterloo, Illinois	4,000 ?	III-IV	35 ?
/1925, Jan. 27	BATESVILLE, ARKANSAS	Local	III	Local
1925, Mar. 1	Cairo, Illinois	3,000 ?	I	30 ?
1925, Apr. 27	Indiana	100,000	VI	176
1925, May 13	Kentucky	3,000	V	31
-1925, July 8	HARRISON, ARKANSAS	4,000 ?	IV	35 ?
1925, July 30	Amarillo, Texas	200,000	VI	252
1925, Sept. 2	Kentucky	75,000	VI-VII	153
1925, Sept. 20	Henderson, Kentucky	9,500 ?	III-V	55 ?
1926, Mar. 22	Harrisburg, Illinois	4,000 ?	IV	35 ?
1926, Apr. 28	Kenton, Tennessee	4,000 ?	IV	35 ?
1926, June 20	Muskogee, Oklahoma	4,000 ?	II-IV	35 ?
/1926, Oct. 27	POPLAR BLUFF, MISSOURI	4,000 ?	IV	35 ?
/1926, Dec. 13	PARMA, MISSOURI	3,000 ?	III	32 ?
/1926, Dec. 16	TIPTONVILLE, TENNESSEE	4,000 ?	IV	35 ?
1927, Jan. 7	McPherson, Kansas	4,000 ?	IV	35 ?
1927, Feb. 1	Jackson Missouri	4,000 ?	IV	35 ?
/1927, Feb. 3	POPLAR BLUFF, MISSOURI	3,000 ?	II	30 ?
1927, Mar. 18	Kansas	300	V	10
1927, Apr. 18	Ridgely, Tennessee	4,000 ?	III-IV	35 ?
/1927, May 7	NORTHEAST ARKANSAS	130,000	VII	206

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive (cont.)

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
1927, July 20	Central and east Tennessee	70,000	VI-VII	150
/1927, Aug. 13	TIPTONVILLE, TENNESSEE	25,000 ?	IV-VI	90 ?
1927, Oct. 8	Chattanooga, Tenn.	9,500 ?	V	55 ?
1927, Nov. 13	Jackson, Mississippi	3,000 ?	III	32 ?
1927, Dec. 15	Brentwood, Louisiana	4,000 ?	IV	35 ?
1928, Mar. 6	Columbia, Tennessee	2,000 ?	I-V	25 ?
1928, Mar. 17	12 miles from St. Louis	450 ?	I	12 ?
1928, Apr. 15	Cape Girardeau, Missouri	Local	I-V	Local
1928, Apr. 23	Hickman, Kentucky	Local	I-V	Local
1928, May 31	New Madrid, Missouri	Local	I-V	Local
1928, Nov. 8	Beloit, Kansas	Local	I-V	Local
/1928, Nov. 10	BLACK ROCK, ARKANSAS	Local	I-V	Local
/1928, Dec. 25	BLACK ROCK, ARKANSAS	Local	I-V	Local
1929, Feb. 14	Princetown, Indiana	1,000 ?	I-IV	18
1929, Feb. 26	Arcadia, Missouri	Local	I-IV	Local
1929, May 12	Tiptonville, Tennessee	Local	I-IV	36
1929, July 28	Burrwood, Louisiana	3,000 ?	III	32 ?
1929, Sept. 23	Manhattan, Kansas	15,000	V	68
1929, Oct. 21	Junction City, Kansas	8,000	V	51
1929, Oct. 23	Junction City, Kansas	Local	I-IV	Local
1929, Nov. 26	Ashland, Kansas	Local	IV-V	Local
1929, Dec. 7	Manhattan, Kansas	1,000	V	18
1929, Dec. 27	El Reno, Oklahoma	8,000	I-IV	51
1930, Jan. 2	Ripley, Tennessee	Local	II	Local
/1930, Jan. 26	BLACK ROCK, ARKANSAS	Local	I-III	Local
/1930, Feb. 18	MARKED TREE, ARKANSAS	Local	I-II	Local
1930, Feb. 25	Cairo, Illinois	Local	III	Local
1930, Mar. 26	Raleigh, Tennessee	Local	II	Local
/1930, Mar. 27	MEMPHIS, TENNESSEE	Local	I-IV	Local
1930, Apr. 2	Caruthersville, Missouri	Local	I-IV	Local
1930, May 28	Hannibal, Missouri	Local	I-V	Local
1930, Aug. 8	Hannibal, Missouri	Local	I-V	Local
1930, Aug. 29	(Blandville, Kentucky (Barlow, Kentucky (Cairo, Illinois (New Madrid, Missouri	200 ?	V	8
1930, Sept. 1	(Hickman, Kentucky (Tiptonville, Tennessee	550 ?	IV-V	13
1930, Sept. 3	Blandville, Kentucky	Local	I-III	Local
1930, Oct. 19	New Orleans, Louisiana	12,000 ?	III-IV	60
-1930, Nov. 16	MALVERN, ARKANSAS	350 ?	V	10
1930, Dec. 23	St. Louis, Missouri	Local	IV-V	Local
1931, Jan. 5	Elliston, Indiana	320 ?	I-IV	10
1931, Apr. 1	Cairo, Illinois	Local	I-III	Local
1931, Apr. 6	Berkely, Kentucky	Local	III-IV	Local
1931, May 5	Oneonta and Montgomery, Alabama	20,000	V-VI	79

Table 1. - Earthquakes affecting the Mississippi Valley region from 1811 to 1931 inclusive (cont.)

Date	Locality	Estimated area affected (sq. mi.)	Intensity Rossi-Forel scale	Maximum distance felt from epicenter
1931, July 18	(Tiptonville, Tennessee (New Madrid, Missouri	300	IV	9
1931, Aug. 9	(Overland Park, Kansas (Kansas City, Missouri	80	V	5
⁄1931, Dec. 10	BLYTHEVILLE, ARKANSAS (BATESVILLE, MISSISSIPPI		I-V	Local
-1931, Dec. 16	(MEMPHIS, TENNESSEE (HELENA AND BRINKLEY, ARKANSAS	6,000 ?	IV-VI	43

* A succession of shocks, beginning December 16, 1811, which occurred throughout the year 1812, and were last recorded December 12, 1813. Collectively these are classified as the New Madrid earthquake of 1811. The total number of known shocks is 1,882.

⁄ Earthquakes affecting northeast Arkansas.
- Earthquakes affecting Arkansas other than in the north east part.
o A succession of at least six shocks.

The approximate locations of the earthquakes in the above list are shown in Plate II. Each separate earthquake is represented on this plate by a circle, the assumption being that the area affected can be limited by a circle, the radius of which is equal to the greatest distance from the epicenter at which the earthquake was felt. The probability that the shape of an area affected by an earthquake will be even approximately circular is slight, but without more accurate data, this is the best compromise that can be made.

According to the above table, 2,078 shocks affecting the central Mississippi Valley in the 121-year period from 1811 to 1931 inclusive. This figure is misleading, however, as 1,882 of the shocks can be related to the New Madrid earthquake of 1811-1813, and six to the Charleston earthquake of 1895, which leaves only 190 for the entire period from 1811 through 1931, excluding the New Madrid and Charleston earthquakes. If the New Madrid and Charleston earthquakes are classed as one disturbance each, the total number of earthquakes affecting the central Mississippi Valley since 1811 will be 192. The record is probably incomplete but it is as full as can be made without extensive research. Only since 1925, when the United States Coast and Geodetic Survey was provided with funds to make investigations and to compile information on earthquakes, have the records been completely compiled.

Prior to 1925 the United States Weather Bureau had charge of collection of earthquake data, and summaries were published regularly by that Bureau in the Monthly Weather Review.

A study of the list of earthquakes (Table 1) which have affected the Mississippi Valley region indicated that 158 (82 per cent) of the 192 earthquakes as defined above were not sufficiently strong to cause property damage (Intensities

I-VI), and only seven (four per cent) of the 192 were strong enough to endanger life (Intensities VIII-X). Of these seven severe earthquakes, only three were sufficiently severe to endanger life seriously and the area of extreme danger was relatively small.

EARTHQUAKES AFFECTING ARKANSAS

The greatest earthquakes which have affected both Arkansas and the Mississippi Valley region are the New Madrid earthquake of 1811, the Memphis earthquake of 1843, and the Charleston earthquake of 1895. The epicentral zone of the New Madrid earthquake lay between New Madrid, Missouri, and Tyronza, Arkansas, and had a length of 75 miles. (See Pl. III.) This earthquake, which is classed as one of the 20 greatest earthquakes of the world and was the most severe earthquake which has occurred in the United States in historic times, consisted of a succession of shocks of different intensities, beginning December 16, 1811, and lasting throughout the years 1812 and 1913. The nearest points at which systematic attempts were made to record the shocks of the New Madrid earthquake were at Louisville, Kentucky, and Cincinnati, Ohio. These records have been listed by Fuller 3/. At Louisville, 250 miles from the epicenter, 1,764 shocks were recorded between December 16, 1811, and May 6, 1812. Apparently the recording of shocks felt at Louisville ceased at the latter date. At Cincinnati, 340 miles from the epicenter, 41 periods of shocks were recorded, eight of which occured between May 5, 1812, and December 12, 1813, and it is probable that only the strongest disturbances were noted. Shocks of slight intensity, similar to the majority of those recorded at Louisville prior to May 5, 1812, probably continudd throughout the period of disturbance and, if noted, would probably have brought the total number of shocks to several thousand. The available data indicate, however, that there were at least 1,882 earthquake shocks which originated in the New Madrid earthquake area between December 16, 1811, and December 12, 1813.

Perhaps the most severe shock was felt at the beginning of the New Madrid disturbance on December 16, 1811, although two other shocks of nearly equal intensity, one on January 23, 1812, and the other on February 7, 1812, were felt over two-thirds of the area of the United States and as far away as Charleston, South Carolina, Washington, D. C., and Detroit, Michigan. These three earthquakes created havoc in the area where the shock was greatest and strongly affected the states of Missouri, Arkansas, Illinois, Tennessee, and Kentucky. In the area of greatest intensity, sand and water were forced to the surface along fissures forming sand blows, narrow trenches were formed by subsidence along faults, landslides occurred along steep stream banks, and warping of the surface produced domes and depressions, the latter being known as "sunk lands." St. Francis Lake, Tyronza Lake, and Big Lake in Arkansas, Lake Nicorny in Missouri, and Reelfoot Lake in Tennessee, as well as numerous swamps, occupy portions of the "sunk lands." The Tiptonville, Tennessee, dome was formed by this earthquake and also possibly the domes at Blytheville, Arkansas, and west of Tyronza Lake. The map (Pl. III) shows the epicentral area of the New Madrid earthquake, the areas of sand blows, landslides and marked fissuring, and the "sunk lands" and lakes and domes. Many of the lakes, among which are St. Francis Lake and Big Lake, have been artificially drained in recent years, but they are shown in Plate III as they existed in 1905.

3/ Fuller, M. L., Op. cit.

Concerning the results of the New Madrid earthquake, Heck 4/states:

> "A lasting result of these earthquakes is the lowering of the level of a large extent of the country in southeast Missouri and northeast Arkansas, now known as the 'sunken country.' At a more recent date there would have been more towns and villages and developed farm land to be damaged. Happening as it did before development started, it served for many years as useful purpose and benefited the Mississippi Valley as a whole. At time of flood the sunken country, with its many lakes and bayous, served as a reservoir to hold back a large part of the flood water, not giving them back to the river until after the flood has passed. This had the surprising result that for fully established flood conditions the flow was greater at the mouth of the Ohio River than at the mouth of the Mississippi River at New Orleans. In recent years levees have been built and the land cultivated. However, the lakes and bayous serve as drainage for this region, and the water is carried into the river farther downstream."

An earthquake with an intensity of IX occurred at Memphis, Tennessee, on January,4, 1843. No details concerning this earthquake have been obtained, but it probably ranks second in intensity within the Mississippi Valley region.

A severe earthquake, which had its epicentral zone near Charleston, Missouri, about 25 miles northeast of New Madrid, occured on October 31, 1895. This earthquake consisted of six separate shocks, three of which were felt on October 31, one on November 1, another on November 2, and the last on November 17, 1895. The earthquake was felt as far as Wichita, Kansas, and Atlanta, Georgia, and probably ranks third in intensity within the Mississippi Valley region in historic times. This earthquake has been briefly described by Purdue 5/.

It is assumed from the above that a total of 1,888 recorded shocks from the New Madrid and Charleston earthquakes affected Arkansas. If we class the New Madrid and Charleston disturbances as one earthquake each, then, as stated previously, 192 earthquakes were reported in the central Mississippi Valley from 1811 through 1931. From a study of Plate II, it is estimated that 66 of these affected Arkansas. If the 64 shocks which have affected Arkansas, exclusive of the New Madrid and Charleston earthquakes, are added to the total of 1,888 shocks recorded from these two earthquakes, then a total of 1,952 earthquake shocks has affected Arkansas from 1811 to 1931 inclusive.

Distribution

A study of Plate II shows clearly that the central Mississippi Valley earthquake area centers in a relatively small region in southeastern Missouri, southern Illinois, southwestern Kentucky, and northwestern Tennessee around the mouth of the Ohio River. Northeast Arkansas has therefore been affected by the greatest number of earthquakes and southwest Arkansas by the least number. The following table gives comparative figures for the number of earthquakes in

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4/ Heck, N. H., Earthquake investigation in the United States: U. S. Coast and Geodetic Survey Serial 456, p. 6, 1929.

5/ Purdue, A. H., The Charleston (Mo.) earthquake: Ind. Acad. Sc. Pr., pp. 51-53, 1895.

differnt portions of Arkansas:

Table 2. - Earthquakes affecting different parts of Arkansas from 1811 to 1931 inclusive

Section affected	Number of earthquakes	Intensities					Per cent of total of 66 earthquakes
		Local	I-V	VI-VIII	IX-X	I-X	
Northeast	63	9	44	7	3	0	95
Northwest	18	1	13	4	0	0	27
Southwest	12	1	9	2	0	0	18
Southeast	20	0	18	2	0	0	30
Whole state	5	0	0	0	0	5	8

The above table necessarily contains duplications. For instance, an earthquake which affected northeast Arkansas and also northwest Arkansas, is included in the figures for both areas; or an earthquake which affected the entire state is included in the figures for each section of the state. It will be noticed in the above table that 95 per cent of the total number of 66 earthquakes felt in Arkansas have affected northeast Arkansas, while only eight per cent have affected the entire state. The northeast portion of the state is, therefore, the area where earthquakes are most likely to occur.

Intensity

The intensities of the earthquakes which have affected Arkansas are shown in the following tables:

Table 3. - Intensity and number of earthquakes in Arkansas from 1811 to 1931 inclusive

Intensity	Number	Per cent
I-II	21	32
I-III	7	11
I-IV	9	14
I-V	16	24
I-VI	3	5
I-VII	4	6
I-VIII	2	3
III-VI	1	1
III-IX	1	1
IV-IX	1	1
IV-X	1	1
	66	99

In the above table it will be noted that 56 (85 per cent) of the 66 earthquakes affecting Arkansas were of intensities too low to cause property damage (Intensities I-VI); 10 (15 per cent) were of intensities sufficiently strong to cause property damage (Intensities VII-X), and six (nine per cent) were sufficiently strong to endanger life (Intensities VIII-X). Three of the six strong earthquakes were locally of Intensities IX-X and there was extreme danger to life.

In considering the figures in Table 3, it must be remembered that intensity

decreases with the distance from the epicenter of an earthquake and, although the percentages of shocks strong enough to cause property damage and to endanger life appear high, these percentages will only hold for an area of not more than a few hundred square miles within the state. This is especially true of those severe shocks of Intensities VIII-X which are of such violence as to endanger life.

Periodicity

The years in which earthquakes have affected Arkansas, the number of shocks felt in any one year, and the yearly interval between earthquakes, are shown in Table 4.

Table 4. - Periodicity of earthquakes affecting Arkansas from 1811 to 1931 inclusive

Year	Number of earthquakes	Number of years between quakes
*/1811-1813	1	0
/1843	1	32
/1865	1	22
-1867	1	2
/1878	2	11
/1879	1	1
/1880	1	1
/1882	1	2
-1882	1	0
/1883	4	1
-1883	1	0
/1886	1	3
/1889	1	3
*/1895	1	6
/1897	1	2
/1898	1	1
/1903	2	5
/1905	2	2
/1908	1	3
/1909	2	1
-1911	1	2
/1915	1	4
/1916	3	1
/1917	2	1
/1918	3	1
/1919	2	1
/1921	1	2
/1922	3	1
/1923	4	1
/1924	3	1
/1925	1	1
-1925	1	0
/1926	3	1
/1927	3	1
/1928	2	1
/1930	3	2

Table 4. - Periodicity of earthquakes affecting Arkansas from 1811 to 1931 inclusive (cont.)

Year	Number of earthquakes	Number of years between quakes
-1930	1	0
⁄1931	1	1
-1931	1	0

* New Madrid earthquake of 1811 and Charleston earthquake of 1895 classed as one earthquake each.
⁄ Earthquakes affecting northeast Arkansas.
- Earthquakes affecting Arkansas other than in the northeast part.

From a study of the above table it will be noted that, since 1905, there has been an apparent increase in the number of earthquakes affecting Arkansas and a shorter time interval separating them than in the interval between 1811 and 1905. This apparent increase is, at least in part, due to the availability of seismograph records in the Mississippi Valley region since 1909. Thus, in the 23-year period from 1909 to 1931 inclusive, since the installation of the first seismograph in the Mississippi Valley, 41 earthquakes, an average of one earthquake every 6.7 months or approximately two earthquakes per year, have affected Arkansas as compared to 25 earthquakes during the 97-year period from 1811 to 1908 inclusive, an average of one every 3.9 years.

The periodicity of the earthquakes which have affected Arkansas is shown in Plate IV. This chart has been compiled from data obtained from Plate II. In its construction, it has been assumed that the limits of the effect of an earthquake can be represented by a circle, the center of which is at the epicenter of the earthquake, and the radius of which is equal to the maximum distance at which the shock was felt. It is further assumed that an earthquake shock is felt with equal intensities at equal distances in all directions from its epicenter. By dividing the radius into nine equal parts, each part corresponding to an intensity on the Rossi-Forel scale, an intensity at any point on the radius may be estimated. Thus, for the New Madrid earthquake of 1811, Plate II indicates that its intensity ranged from X in northeast Arkansas to IV in extreme southwest Arkansas. It is believed that only that part of the chart which shows earthquakes between 1909 and 1931 merits study in considering the periodicity of earthquakes, because seismograph records are available only for that time interval.

Cause

The center of earthquake disturbances of the central Mississippi Valley region is at the head of the Mississippi embayment. This embayment is a plain of Cretaceous, Tertiary, and Quaternary beds, which is known as the Gulf Coastal Plain. This plain extends northward from the Gulf of Mexico as a narrowing belt to the mouth of Ohio River, and forms the southern and southeastern half of Arkansas. On both sides of this plain are rocks of Paleozoic age which, in the center of the earthquake area, form the floor of the depression in which the Cretaceous, Tertiary, and Quaternary rocks of the Gulf Coastal Plain were deposited. The Paleozoic rocks are consolidated sandstones, limestones, and shales, whereas the Tertiary formation is mostly unconsolidated sands, clays, and marls. Con-

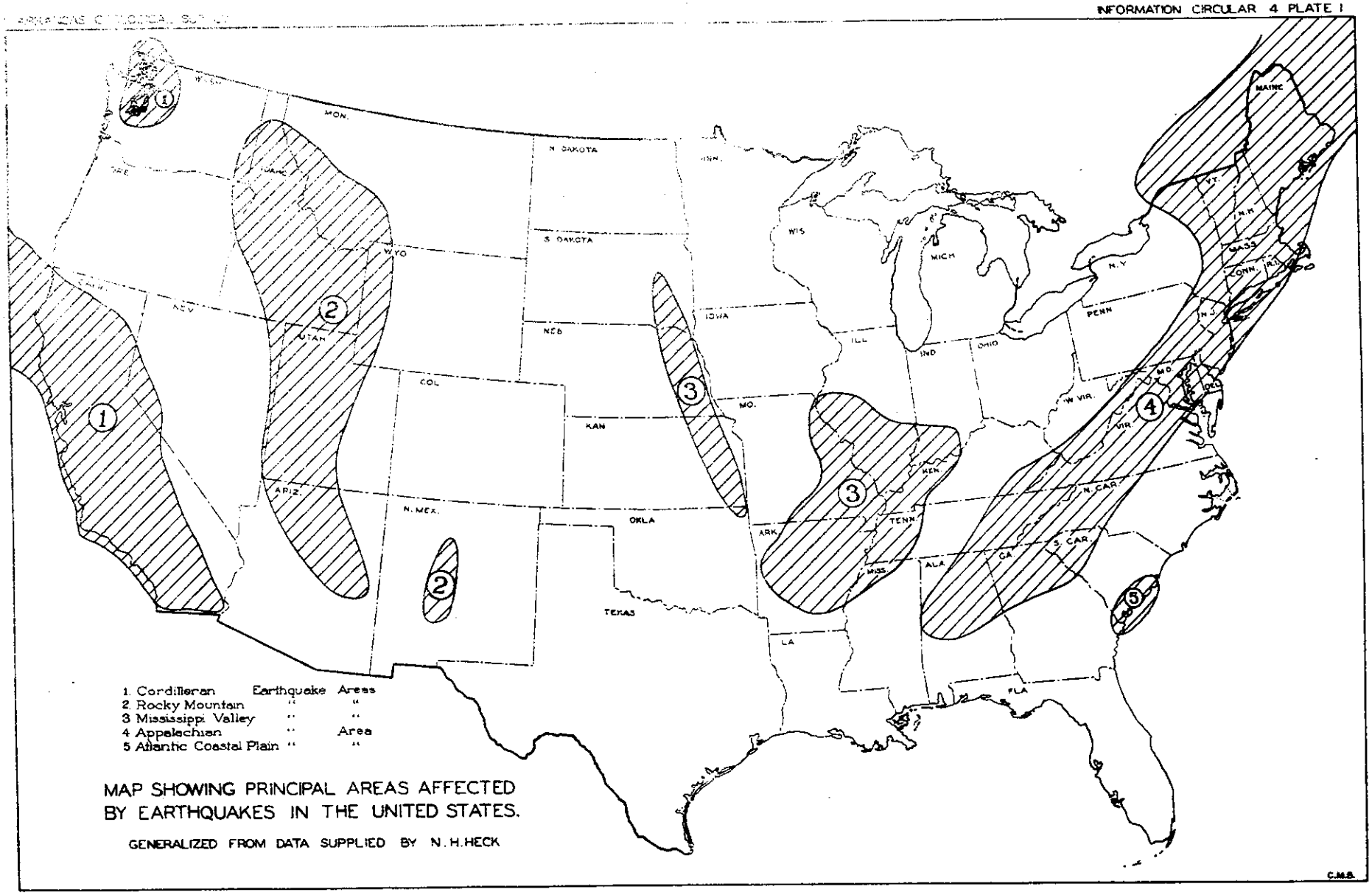
cerning the cause of the New Madrid earthquake, Fuller 6/ says "....it seems clear that the ultimate cause lies in forces operating beneath the embayment deposits. The action may be associated either with the processes of folding or warping incident to a depression and deepening of the basin." The severity of the New Madrid earthquake near its epicenter was probably due largely to the fact that the surface deposits consist of a thick series of unconsolidated, water-saturated Tertiary and Quaternary sands, clays, and marls, which, under the shock of the strong earthquake, were much more violently agitated than the firmly cemented Paleozoic rocks bordering the embayment.

The same forces which caused the New Madrid earthquake probably are acting today to cause the earthquakes in northeast Arkansas. Some of the local shocks in limestone regions may be due to the slump of overlying material into solution cavities.

Conclusions

From the foregoing data, it is to be concluded that northeast Arkansas has suffered the majority of earthquake shocks of sufficient intensity to endanger life and damage property, and thatthis part of the state will continue to be shaken by earthquakes of varying degrees of intensity every six months to one year. There may be small shocks in other sections of the state but at considerably greater intervals than in the north east part. The fact that there are frequent small shocks of low intensity in northeast Arkansas probably means that, as stresses build up in the Paleozoic basement rocks, they are released by small movements. If this is the case, as long as these small periodic releases continue, it seems probably that the stresses will not be able to build up to the point where sudden fracture will produce an earthquake comparable in severity to the New Madrid earthquake.

6/ Fuller, M. T., Op. cit., p. 105.

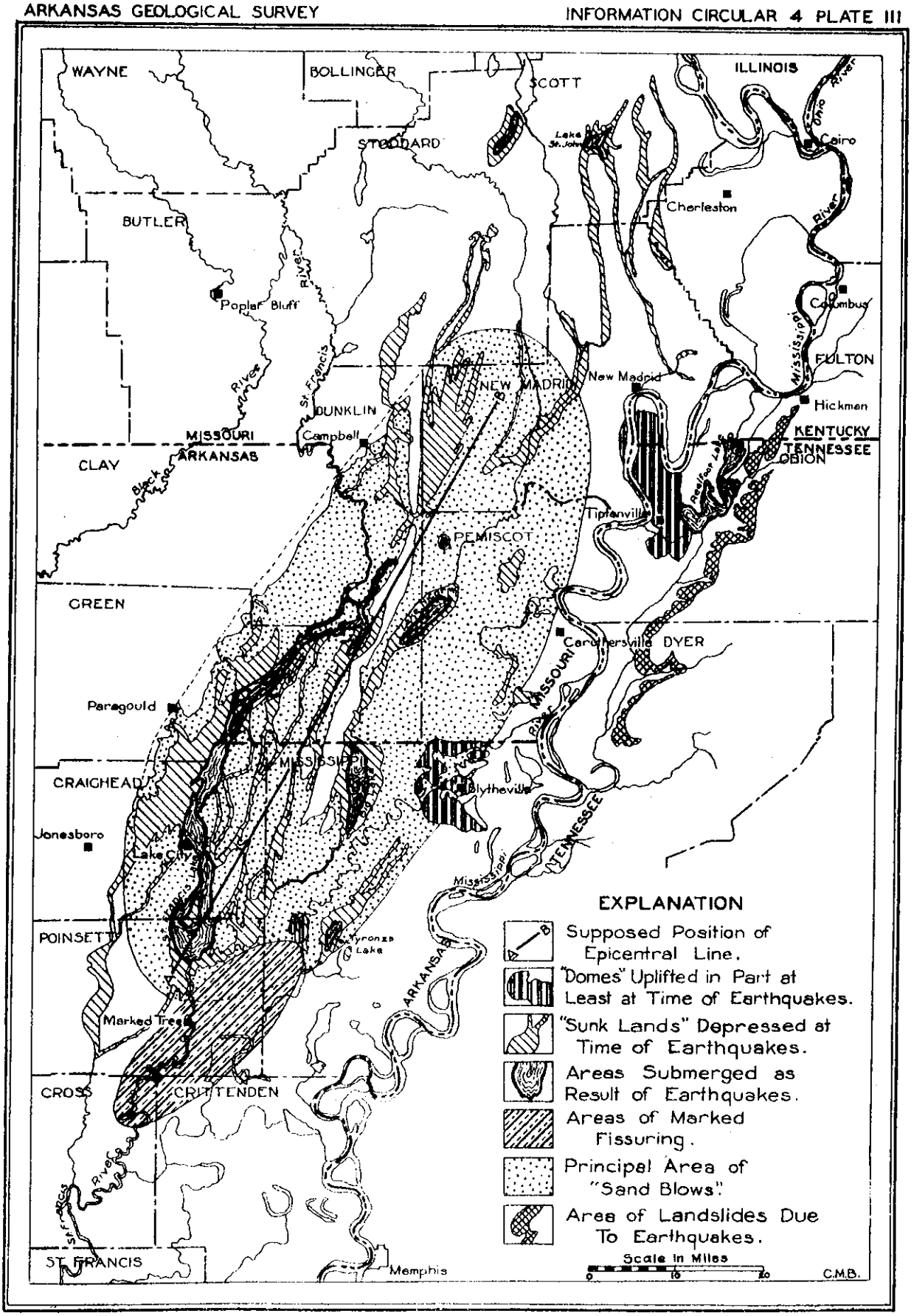


1. Cordilleran Earthquake Areas
2. Rocky Mountain " "
3. Mississippi Valley " "
4. Appalachian " Area
5. Atlantic Coastal Plain " "

MAP SHOWING PRINCIPAL AREAS AFFECTED BY EARTHQUAKES IN THE UNITED STATES.

GENERALIZED FROM DATA SUPPLIED BY N. H. HECK

C.M.B.



MAP OF EARTHQUAKE FEATURES OF THE NEW MADRID DISTRICT
After M. L. Fuller in his report on "The New Madrid Earthquake,"
United States Geological Survey Bulletin 494, 1912

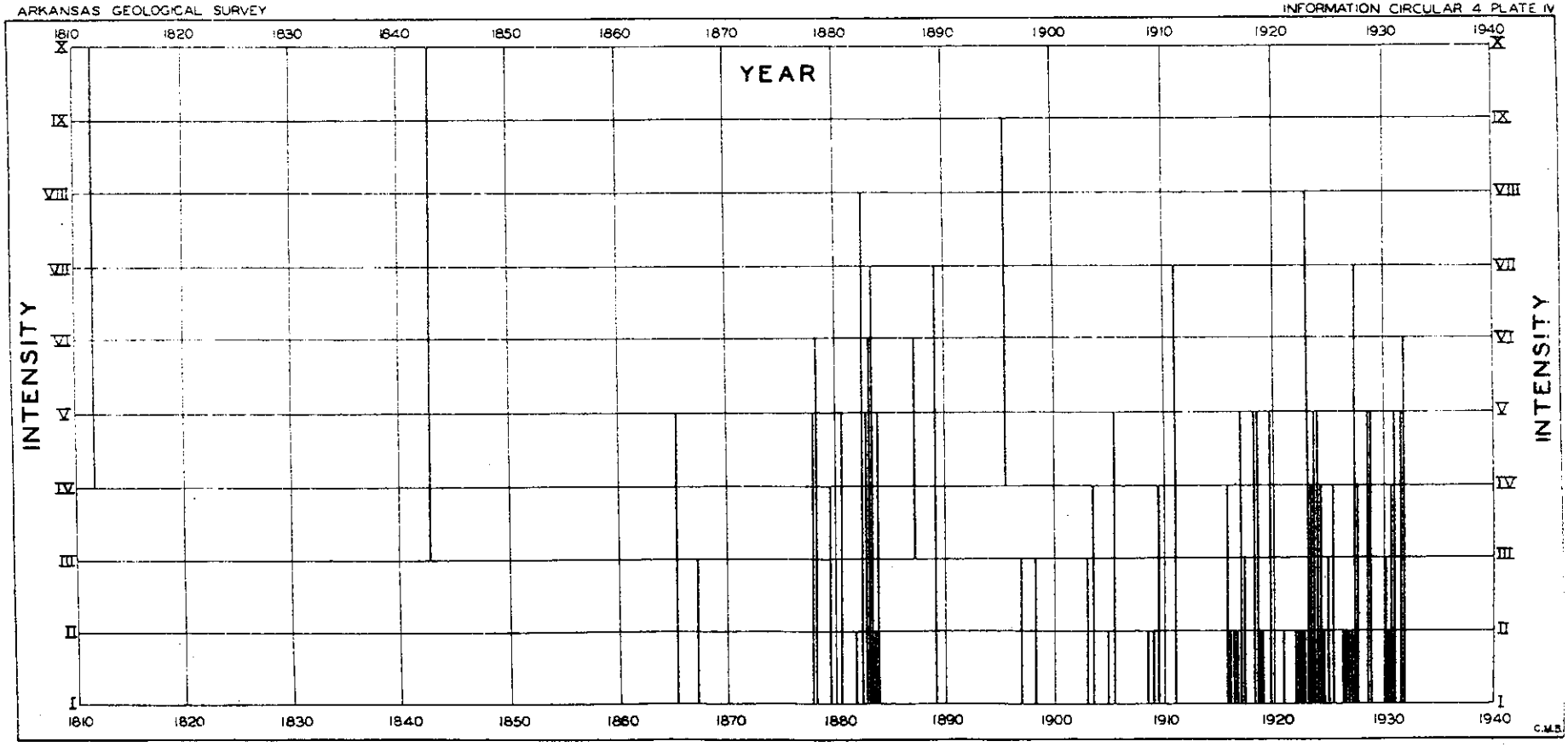


CHART SHOWING FREQUENCY AND INTENSITY OF EARTHQUAKES
WHICH HAVE AFFECTED ARKANSAS FROM 1811 TO 1931