THE RELATIONSHIP

BETWEEN

EARTHQUAKES AND TECTONICS

D. J. O'Halloran

Thesis of

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Thesis accepted by :

J. T. Wilson — May 31, 1949
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Signature — Date

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Signature — Date

THE RELATIONSHIP BETWEEN

EARTHQUAKES AND TECTONICS

MAY 1, 1949

D. J. O'HALLORAN

May 1, 1949

Assistant Professor J. T. Wilson
Department of Geology
University of Michigan
Ann Arbor, Michigan

Dear Sir:

The subject of the enclosed report is The Relationship Between Earthquakes And Tectonics. It was assigned on September 25, 1948 and is now submitted as a requirement for a Master of Science Degree.

The subject matter is based on references, publications, and information derived from the cooperation of members of the staff of the Geology Department of the University of Michigan.

Yours truly,

Daniel J. O'Halloran

Daniel J. O'Halloran

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ABSTRACT

Contrary to the general concept that interior portions of continents, which are far removed from mountainous areas, are completely stable, the central states of the United States have shown considerable seismic activity.

A belt of seismic activity envelopes the lower Mississippi River, the State of Ohio, and the St. Lawrence lowland. The fact that this belt parallels an eastern belt which includes the Appalachian provinces, seems to indicate future orogenic movement which is as yet deep-seated and has not manifested itself in surface features.

The location of the major earthquakes in the eastern Appalachian belt may indicate that the Pennsylvanian, Permian, and older orogenies continued southward to the Gulf of Mexico, and probably under the Gulf, instead of swinging westward to include the Ouachita and Ozark Mountains. The westward course to the Ouachitas may be just an important branch of the main orogenic belt. However, evidence is lacking because of the thick sedimentary cover of the Mississippi embayment.

INTRODUCTION

The purpose of this study is to correlate the earthquakes that occurred in the period 1915-1944 inclusive, with the tectonic provinces of the Eastern United States.

The Eastern United States has been divided into three regions, following Heck[1], for the purpose of listing and correlating the earthquakes; the Northeastern Region, including New England, New York, and the St. Lawrence lowland; the Eastern Region, which includes the Appalachian provinces; and the Central Region, which extends from the Mississippi River east to the Appalachian provinces.

The arrangement into regions has been made chiefly to separate the major division of seismic activity and to facilitate tectonic correlation.

The earthquakes have been evaluated according to the Richter magnitude scale. Only the larger shocks (magnitude 3, or greater), have been given consideration.

The positions of the earthquake epicenters were plotted on an overlay of the American Association of Petroleum Geologists' Tectonic Map of the United States.

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[1] See bibliography

PREPARATION FOR MAP

Method of Evaluating Data

In the Earthquake History of the United States[1] earthquakes are discussed according to the locality of the epicenter, the area within which the disturbance was felt, and the intensity of the disturbance. For some earthquakes the area over which it was felt could not be determined accurately and, therefore, was omitted.

The intensity information, which is given in the Rossi-Ferrel Scale of Intensity*, was utilized in the evaluation of earthquakes for this study by converting the data from the Rossi-Ferrel Scale to the Modified Mercalli Scale of Intensity*, and by applying the results in the equations listed below.

In which:

- E- energy of shock in ergs
- h- hypocentral depth in killometers
- t_0- duration of maximum wave group at the epicenter in seconds
- T_e- period of vibration at the epicenter in seconds
- a_0- maximum ground acceleration at the epicenter in cm/secs = gals
- a_r- acceleration of ground at the limit of perceptibility in cm/secs = gals
- M - earthquake magnitude

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* See appendix

I_0 - seismic intensity of Modified Mercalli Scale at the epicenter

R - value of hypocentral distance at the limit of perceptibility

When Richter's Theoretical Equation of Energy of an Earthquake[2], namely

$$\log E = 14.9 + 2\log h + \log t_0 + 2\log T_0 + \log a_0 \quad (1)$$

is applied to shocks with focal depths other than eighteen kilometers, the factors t_0 and T_0 must be expressed as functions of energy instead of magnitude in order to find a functional relation between energy and magnitude in Richter's equations[2],

$$\log t_0 = -0.7 + 1/4\ M \quad (2)$$

and

$$\log T = -1.5 + 0.22\ M \quad (3)$$

Then, if Richter's final energy-magnitude equation[2],

$$\log E = 11.3 + 1.8\ M \quad (4)$$

is used to replace M in equations (2) and (3) by E, it is found that

$$\log t_0 = -2.3 + 0.14 \log E \quad (2a)$$

and

$$\log T = -3.76 + 0.24 \log E \quad (3a).$$

When equations (2a) and (3a) are substituted in equation (1), the result is that

$$\log E = 11.1 + 3.2 \log h + 3.2 \log a_0 \quad (5)$$

Then when Richter's equation relating intensity and maximum ground acceleration[2],

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[2] See bibliography.

$$\log a = I/3 - 1/2 \qquad (6)$$

Which is independent of h, is applied to equation (5), the result is

$$\log E = 9.5 \quad 3.2 \log h \quad 1.1 I_0 \qquad (7).$$

Equation (7) was utilized in evaluating earthquakes whenever Heck[1] omitted the area over which the disturbance was felt, by assuming h to always be 35 kilometers. In some cases the computed magnitude was far too great, and in these instances the group to which the earthquake would usually be assigned was changed to remedy the excessive magnitude caused by the use of the arbitrary depth of 35 kilometers.

For earthquakes of given area, the relation which Richter established for intensity, depth, and radius of perceptibility[2] was used, namely:

$$a_0 h^2 = a_r R^2 \qquad (8)$$

When $a_r = 1$, equation (7) results in

$$\log E = 11.1 \quad 6.4 \log R - 3.2 \log h \qquad (9)$$

Then when equations (7) and (9) are added, and divided by 2, an equation independent of h results,

$$\log E = 10.3 + 3.2 \log R + 0.55 I_0 \qquad (10).$$

Equation (4) was used for the determination of magnitude.

Regional Lists of Earthquakes

The lists of earthquakes that accompany each regional discussion on the following pages include all data necessary for computation, plus the results of computation.

The first column, Locality, indicates the geographical location of the epicenter. The positions have been located as accurately as possible from existing data. In some cases the positions indicated represent the place of maximud disturbance; in others, all available information has been plotted on a map and the probable origin deduced from this plotting.

The second column, Date of each earthquake, may be considered accurate, since the selection of 1915 as the first year to be considered eliminates inaccuracy. Numerous seismological stations were operating at that time and the areas near the seismic activity were populated sufficiently to enable investigators to obtain pertinent data concerning the shocks.

The Area over which the earthquake was felt is recorded in the third column; however, the exact area is always somewhat indefinite and probably in most cases is approximately that area included within isoseismal 3. Nevertheless, the estimated area affected, in connection with the estimated maximum intensity, is the best gauge of judging the importance of an earthquake.

In the following lists, the estimated area may be assumed as accurate, except where question marks appear. In such instances, where information was lacking, the earthquake was evaluated by equation (7), (Page 5)

Column four, Rossi-Forrel Intensity, contains the intensity given by Heck[1]. This intensity was converted and used in the evaluation of each earthquake.

The next two columns denote the results of computation; the Energy of the earthquake, and the Magnitude.

The final column indicates the arbitrary Group into which each earthquake was placed, based on magnitude evaluation, for plotting on the accompanying map, according to the following scale;

1) Magnitude greater than 5.4 - destructive.

2) Magnitude 4.0 - 5.4 - slight damage.

3) Magnitude less than 4.0 - strong enough to be felt generally.

Northeastern Regian. This region envelops New England, the portion of Canada adjacent to it, and also the State of New York because of its geologic similiarity.

The region has had a comparatively large number of earthquakes, many of the Magnitude group 2, and many of the Magnitude 1 group. Some geologists attribute these earthquakes to the return to normalcy of the earth's crust after the retreat of the Pliestocene glacial load.

The earthquakes in northeastern New York outline the Adirondack Uplift, while the others in New England appear to be associated with the northeasterly trend of the Appalachian system.

Further discussion of the region will be found in the discussion of Tectonic Correlation, later in the paper.

NORTHEASTERN REGION

LOCALITY	DATE	AREA MI^2	ROSSI-FORREL INTEN-SITY	ENERGY ERGS	RICHTER MAGNITUDE	GROUP
Lake George, N. Y.	Jan.5,16	300	5	$2.2x10^{16}$	2.88	1
Mohawk Val-ley, N. Y.	Feb.2,16	8,000	4-5	$3.9x10^{18}$	4.05	2
New York City	Jun.8,16	?	5	$8.7x10^{19}$	4.80	1
Glen Falls, N. Y.	Nov.1,16	300	6	$2.5x10^{17}$	3.39	1
N.Y. & Canada	May 22,17	15,000	4-5	$2.5x10^{19}$	4.63	2
South Maine	Aug.21,18	15,000	7-8	$8.9x10^{20}$	5.36	2
Glen Falls, N. Y.	Jan. 19,21	?	5	$8.7x10^{19}$	4.80	1
New Hamp-shire	Sept.30,24	30,000	5	$1.4x10^{20}$	4.90	2
E. Massach-usetts	Jan.7,25	20,000	5	$7.1x10^{19}$	4.75	2
SE. Mass-achusetts	Apr.24,25	1,600	5	$3.2x10^{17}$	3.44	1
New Hamp. & Maine	Oct.9,25	15,000	7	$2.5x10^{21}$	5.51	3
Hartford, Conn.	Nov.14,25	850	5	$1.2x10^{17}$	3.22	1
New Ipswich, N. H.	Mar.18,26	800	5	$1.0x10^{17}$	3.17	1
New Rochelle, N. Y.	Apr.11,26	150	5	$7.9x10^{15}$	2.55	1
West Maine	Aug.28,26	3,000	6	$1.0x10^{18}$	3.72	1
Concord, N. Hamp.	Mar.8,27	600	5	$6.3x10^{16}$	3.05	1
Canton, New York	Mar.14,27	250	4	$4.5x10^{15}$	2.41	1
Saranac LK. N. Y.	Mar.18,28	12,000	6	$2.5x10^{18}$	3.94	1
Berlin, New Hamp.	Apr.25,28	3,000	5	$2.5x10^{17}$	3.39	1
Auburn, Maine	Feb.5,29	2,000	5	$1.3x10^{16}$	2.66	1

NORTHEASTERN REGION (Con't.)

LOCALITY	DATE	AREA MI^2	ROSSI-FORREL INTENSITY	ENERGY ERGS	RICHTER MAGNITUDE	GROUP
Attica, N.Y.	Aug.12,29	100,000	9	$1.4x10^{23}$	6.58	3
Lk. George, N. Y.	Apr.20,31	60,000	8	$1.6x10^{22}$	6.05	3
St. Johnsville, N.Y.	Oct.29,33	?	4	$6.9x10^{19}$	4.19	1
Adirondack MTS.	Apr.14,34	8,000	6	$5.0x10^{19}$	4.66	2
Cape Cod, Mass.	Apr.23,35	?	4	$6.9x10^{18}$	4.19	1
Canton, N.Y.	Mar.10,37	?	4	$6.9x10^{18}$	4.19	1
Bangor, Maine	Aug.22,38	3,500	5	$1.1x10^{17}$	3.29	1
Buzzards Bay, Mass.	Jan.28,40	2,000	4	$3.5x10^{15}$	2.36	1
Lk. Ossipee, N. H.	Dec.20,40	50,000	7	$1.0x10^{21}$	5.39	2
Dover-Foxcroft, Me.	Jan.14,43	50,000	5	$7.1x10^{18}$	4.19	2
Massena, N.Y.	Sept.5,44	175,000	8	$1.0x10^{23}$	6.50	3

CANADA

R. Quelle Mouth.	Feb.28,25	2,000,000	9	$1.8x10^{25}$	7.78	3

Eastern Region. The Eastern Region includes the states of the Atlantic Coastal Plain, the Appalachian provinces, and the Gulf Coastal Plain.

This region is one of moderate seismic activity, with the earthquakes corresponding somewhat to the trend of the Appalachian system. This correspondance may be indicative of the adjustments that generally occur in mountainous area after the forces of mountain building have become inactive.

The Coastal Plains are relatively devoid of prominent earthquakes, although a few do exist. These exceptions will be discussed later.

EASTERN REGION

LOCALITY	DATE	AREA MI^2	ROSSI-FORREL INTENSITY	ENERGY ERGS	RICHTER MAGNITUDE	GROUP
N. Carolina	Oct.29,15	1,200	5	1.9×10^{17}	4.44	2
N.W. Carolina	Feb.21,16	200,000	7	3.5×10^{22}	6.25	3
N.W. Carolina	Aug.26,16	3,800	5	1.3×10^{18}	3.77	1
Alabama	Oct.18,16	100,000	8	3.9×10^{23}	6.83	3
Virginia	Apr.10,18	100,000	8	3.9×10^{23}	6.83	3
Tennessee	Jun.22,18	3,000	4-5	7.9×10^{17}	3.66	1
Virginia	Sept.5,19	?	6	1.0×10^{21}	5.41	1
E. Tennessee	Dec.24,20	?	5	8.7×10^{19}	4.80	1
New Jersey	Jan.26,21	150	5	7.9×10^{15}	2.55	1
Virginia	Jul.25,21	?	5	8.7×10^{19}	4.80	1
Virginia	Aug.7,21	?	5	8.7×10^{19}	4.80	1
N.W. Carolina	Oct.20,24	56,000	5-6	3.5×10^{20}	5.14	2
New Jersey	May 31,27	1,200	8	8.9×10^{18}	4.27	2
Virginia	Jun.10,27	2,500	7	7.9×10^{18}	4.22	2
Alabama	Jun.16,27	1,800	6	5.0×10^{18}	4.11	2
N.W. Carolina	Nov.2,28	40,000	6	7.1×10^{20}	5.30	2
Cen. Virginia	Dec.26,29	?	5-6	8.7×10^{19}	4.80	2
N. Alabama	May 5,31	6,500	5	1.1×10^{19}	4.30	2
Trenton, N. J.	Jan.24,33	600	5	6.3×10^{16}	3.05	1
Summerville, S. C.	Dec.19,33	?	4-5	6.2×10^{18}	4.18	2
Erie, Penn.	Oct.29,33	?	5	8.7×10^{19}	4.80	2
N. Car.-Georgia	Jan.1,35	7,000	5-6	1.1×10^{19}	4.30	2
Cen. New Jersey	Aug.22,38	5,000	5	7.1×10^{18}	4.79	2
Anniston, Ala.	May 4,39	?	5	8.7×10^{19}	4.80	2
Salem Cty. N. J.	Nov.14,39	6,000	5	8.9×10^{18}	4.25	2
Murray Lk. S.C.	July.26,45	25,000	6	3.2×10^{20}	5.11	2

__Central Region__. The Central Region includes the area from the State of Mississippi to the Great Lakes.

Although apparently a "relatively stable" portion of the continent, this region is one of considerable seismic activity. Many large earthquakes have occured, mostly centered in the great river valleys of the upper Mississippi and Ohio Rivers. While others follow no definite pattern and are scattered throughout the region.

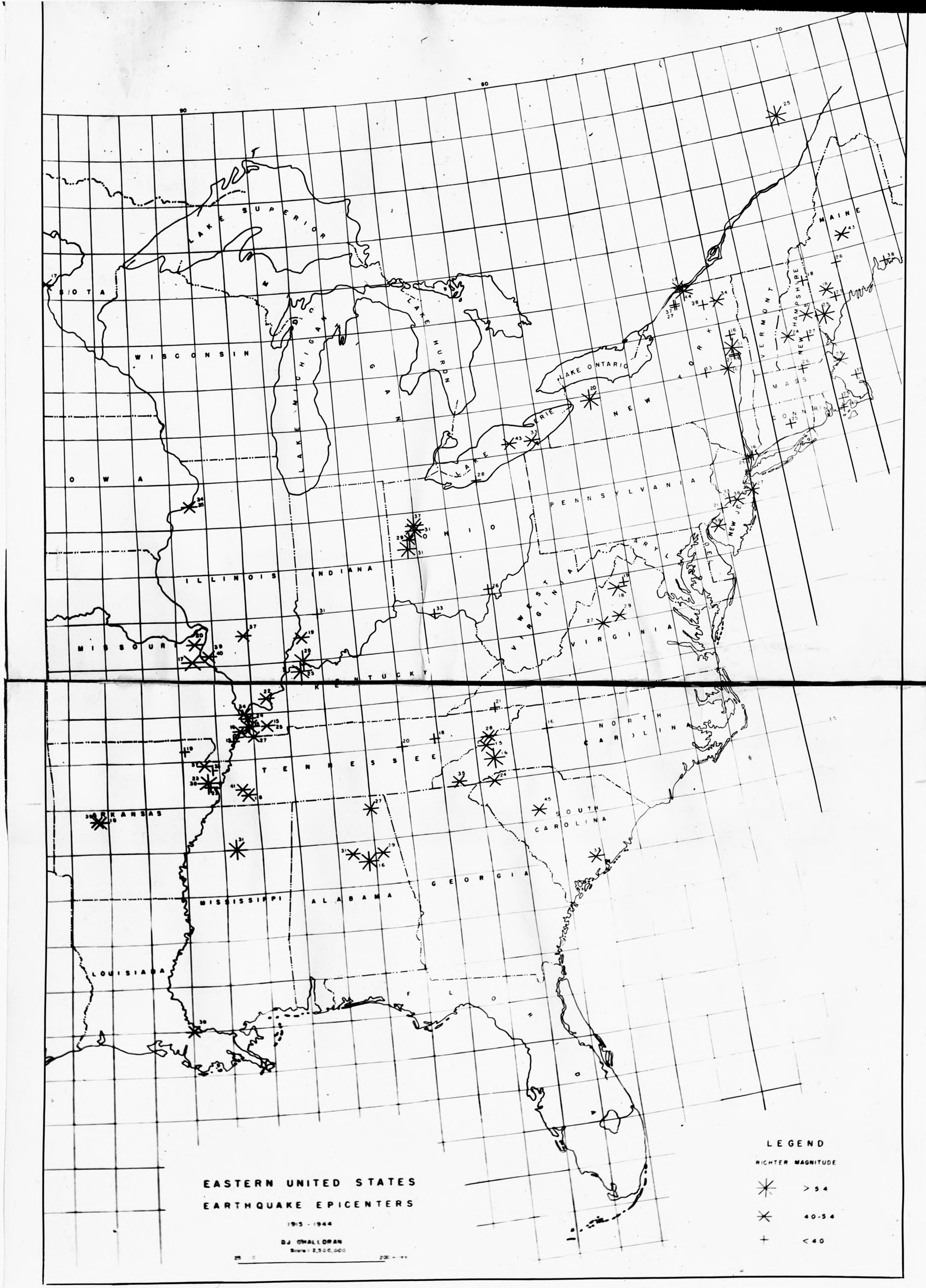
Surface effects are relatively rare because of the thick cover of sediments overlying the affected material, thus making exploratory determination impossible.

CENTRAL REGION

LOCALITY	DATE	AREA MI^2	ROSSI-FORREL INTEN-SITY	ENERGY ERGS	RICHTER MAGNITUDE	GROUP
New Madrid, Mo.	Apr.28,15	200	4-5	$1.3x10^{16}$	2.32	1
Mayfield, Ky.	Oct.26,15	?	5	$8.7x10^{19}$	4.80	1
Ohio R. mouth	Dec.7, 15	60,000	6	$1.3x10^{21}$	5.44	3
Hichham,Ky.	Dec.18,16	?	5	$8.7x10^{19}$	4.80	2
E. Missouri	Apr.9,17	200,000	6	$6.3x10^{21}$	5.83	3
Minnesota	Sept.3,17	10,000	6	$7.9x10^{19}$	4.77	2
Arkansas	Oct.4,18	30,000	5	$1.1x10^{20}$	4.86	2
W. Tennes-see	Oct.16,18	20,000	5-6	$7.1x10^{19}$	4.75	2
So. Indiana	May 25,19	18,000	5	$5.6x10^{18}$	4.69	2
Arkansas	Nov.3,19	?	4	$6.9x10^{18}$	4.19	1
Missouri	May 1,20	10,000	5	$2.2x10^{19}$	4.47	2
So. Illinois	Mar.22,22	25,000	5	$8.9x10^{19}$	4.25	2
Arkansas	Oct.28,23	40,000	8	$1.0x10^{22}$	5.94	3
Tallula. Ill.	Nov. 9,23	?	5	$8.7x10^{19}$	4.80	1
Kentucky	Mar.2,24	15,000	6	$1.6x10^{20}$	4.94	2
Indiana	Apr.26,25	100,000	6	$2.8x10^{21}$	5.63	3
Kentucky	May 13,25	3,000	5	$8.9x10^{17}$	3.69	1
Kentucky	Sept.2,25	75,000	6-7	$1.9x10^{21}$	5.55	3
Ohio & W. Virginia	Nov.5,26	350	6	$7.9x10^{16}$	3.22	1
Mississippi Val.	May 7,27	130,000	7	$5.0x10^{21}$	5.22	2
Clev. & Lorain, O	Sept.9,28	1,500	5	$1.9x10^{18}$	3.90	1
Bellefontaine O.	Mar.8,29	5,000	5	$7.1x10^{18}$	4.19	2
Louisiana	Oct.19,30	15,000	7	$1.6x10^{20}$	4. 94	2
Elliston, Ind.	Jan.5, 31	500	5	$5.1x10^{16}$	3.00	1
Anna, Ohio	Sept.20,31	40,000	8	$8.9x10^{21}$	5.91	3
North, Miss.	Dec.16,31	65,000	6-7	$1.6x10^{21}$	5.50	3

CENTRAL REGION (Con't.)

LOCALITY	DATE	AREA MI^2	ROSSI-FORREL INTENSITY	ENERGY ERGS	RICHTER MAGNITUDE	GROUP
Maysville, Ky.	May 28,33	600	5	$6.3x10^{16}$	3.05	1
Manila, Ark.	Dec.9,33	100	5	$3.7x10^{15}$	2.37	1
Rodney, Mo.	Apr.19,34	28,000	6	$3.9x10^{20}$	5.16	2
Illinois	Nov.12,34	20,000	5	$7.1x10^{19}$	4.75	2
Rock Is., Ill.	Jan.5,35	20,000	4	$2.0x10^{19}$	4.44	2
W. Ohio	Mar.2,37	90,000	8	$3.2x10^{22}$	6.22	3
W. Ohio	Mar.9,37	150,000	8	$6.5x10^{23}$	6.94	3
N.E. Ark.	May 16,37	25,000	5	$7.9x10^{19}$	4.77	2
Centralia, Ill.	Nov.17,37	?	5	$8.7x10^{24}$	4.80	2
N. E. Arkansas	Sept.17,38	90,000	4	$2.2x10^{20}$	4.02	2
Arkadelphia, Ark.	June 19,39	?	5	$8.7x10^{19}$	4.80	2
Griggs, Ill.	Nov.23,39	150,000	5	$1.8x10^{21}$	5.53	3
Waterloo, Ill.	Nov.23,40	?	6	$1.1x10^{21}$	5.41	2
Covington, Tenn.	Nov.16,41	?	5	$8.7x10^{19}$	4.80	2
Lake Erie	Mar.8,43	40,000	4	$5.6x10^{19}$	4.69	2


EASTERN UNITED STATES
EARTHQUAKE EPICENTERS
1915 - 1944
DJ O'HALLORAN
Scale 1:2,500,000
LEGEND
RICHTER MAGNITUDE
> 5.4
4.0-5.4
< 4.0
MAINE
NEW HAMPSHIRE
VERMONT
MASS
CONN
NEW YORK
LAKE ONTARIO
LAKE ERIE
LAKE HURON
LAKE MICHIGAN
LAKE SUPERIOR
MICHIGAN
WISCONSIN
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW JERSEY
DEL
MARYLAND
WEST VIRGINIA
VIRGINIA
KENTUCKY
MISSOURI
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
MISSISSIPPI
ARKANSAS
LOUISIANA
FLORIDA

Explanation of Map

The map, included as a part of this paper, was made from an overlay of the eastern half of the Tectonic Map of the United States. The Tectonic Map was selected to enable the author to directly correlate the region of seismic activity with the structure of the corresponding regions.

The epicenters of the earthquakes were carefully located by longitude and latitude and plotted on the overlay according to groups, namely: Group 1; Group 2; Group 3.

Two major patterns of earthquake distribution are apparent on the map; (1) the northeasterly trend of the seismic activity in the Appalachian provinces; and (2) the important trend which lies to the west and suggests a belt that parallels the Appalachian belt.

Each region and belt will be discussed fully on the following pages.

TECTONIC CORRELATION

Appalachian Region

The Appalachian Region as here defined corresponds to the belt of the Appalachian and older orogenies, namely that area extending northeast from Louisiana through Virginia, southeastern New York, and all of New England.

Southern area. The southern area of the Appalachian Region includes Louisiana, Alabama, Tennessee, and North and South Carolina.

A major earthquake occurred in southern Louisiana in 1930, while northeastern Alabama has had four major earthquakes within the period 1915-1944, and two earlier ones in 1886 and 1905.

It is the contention of the author that these earthquakes and those that occurred in North Carolina, Tennessee, and South Carolina could be included within the limits of a proposed extension of the Appalachian axis, thereby extending the axis under the Mississippian embayment.

The above theory is contrary to some geologic schools of thought which maintain that the axis curved westward in its southern extent to include the Ozark and Ouachita Mountains. However, this westward curvature, although considered an important division is, according to the new theory, regarded only as a branch of the major axis that extends to the Gulf Coastal Plain and probably under it.

Another group of epicenters associated with the Applachian belt bisects the State of South Carolina. Three major earthquakes have occurred within the defined period in addition to the devastating earthquake of 1886 in Charleston, thus indicating a distinct seaward trend to the branch.

<u>Central area</u>. In the northern part of Virginia there is another group of major earthquakes, which have occurred between 1919 and 1929.

Also, three major and two minor earthquakes have occurred in the last two decades in the State of New Jersey. They are in the Newark Basin and in the general line of epicenters from Louisiana to New England.

<u>Northern area</u>. New England has had considerable seismic activity with many major earthquakes. As previously mentioned, some geologists attribute the activity typical of post-glacial uplift; however, this theory has not been proved.

Evidence of the correlation of the Appalachian Region can be found by consulting the accompanying map facing page 16.

Adirondack Uplift

The Adirondack uplift is discussed as a separate region because, except for the earthquakes on its western flank, it appears to be independent from the Appalachian Region and the Mississippi-St. Lawrence Region, which will be discussed next.

When the earthquakes which have occurred in the period from 1915-1944, had been plotted on the map, they formed a semi-circular pattern on the eastern side of northwestern New York State. This pattern defines, relatively well, the topographic limits of the Adirondack uplift which rose in Cambrian and Ordovician time, and was elevated and broken again in Silurian time by normal faults in the vicinity. It may be that these earthquakes indicate readjustments along the old normal faults.

The chronological succession of the earthquakes, i.e.; 1916, 1917, 1921, 1927, 1928, 1933, 1934, 1944, an interval of roughly six years, may be an indication of important tectonic movements.

Mississippi River - St. Lawrence Region

The third and most important region to be discussed covers the area from the lower Mississippi River northeastward through the mouth of the Ohio River, the State of Ohio, Lake Erie, Lake Ontario and along the St. Lawrence River.

The earthquakes of this region form a belt that remarkably parallels the Appalachian belt of the east and lies approximately 450 miles to the west of it.

The belt will first be discussed by areas and then as a unit.

Southern area. The southern area comprises Arkansas, eastern Missouri, southwestern Tennessee, Illinois, and southwestern Indiana.

Two earthquakes have occurred in central Arkansas, one in 1918, and one 1939. Their epicenters are near the northern flank of the Ouachita Mountains, and near the southern part of the Arkansas Basin, which lies adjacent to the Ouachita Range in the north.

An unusual grouping of earthquakes has occurred along the part of the Mississippi River that borders the states of Arkansas, Tennessee, Missouri, Illinois, and Indiana. Sixteen major earthquakes occurred during the period from 1915 to 1941 in which the longest lapse between activity was only six years. These earthquakes well define the many late Paleozoic faults of the Rough Creek Fault Zone and the Ste. Genevieve Fault which are covered by Tertiary deposits.

Near the Rough Creek Fault Zone there is evidence of Tertiary igneous activity, with mineralization in the form of fluorite deposits within the area.

Seismic activity in 1934 and 1935 resulted in two moderate earthquakes in northwestern Illinois. These may be associated with a deep seated fault in that area.[3]

<u>Central area</u>. The central area includes the area around Lima, Ohio and Lake Erie.

Another prominent group of major earthquakes located near Lima, Ohio, directly north of the Cincinnati arch and on the west flank of the Findlay arch, where the Findlay arch begins to flatten out southward, appears on the map.

The occurrence of major earthquakes in the Lima area, twice in 1931 and 1937, seems to indicate the possibility of more strong shocks in the future.

There has been a small earthquake in the southern part of Lake Erie and two larger earthquakes in the north central part.

<u>Northern area</u>. The northern area envelopes western New York and the St. Lawrence lowland.

Southwestern New York suffered a strong shock in 1920, and the northwestern part of the State, adjacent to the

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3 See bibliography

western side of the Adirondack uplift, suffered strong shocks in 1917 and 1944 with more moderate shocks in 1927 and 1937. The northern shocks are located along the St. Lawrence River. Along the St. Lawrence River, north of Quebec City, Quebec, the lowland is the western trace of the Taconic thrust called Logans' fault. This trace separates shield geology from the Taconic and Acadian orogenic belts.

Many other earthquakes have occurred along the St. Lawrence River to the northeast, but data of Canadian origin are lacking, with the exception of the extremely strong shock which occurred at the mouth of the River Quelle in 1925. This earthquake further extends to the northeast the Mississippi - St. Lawrence Region, belt of seismisity.

The descriptions by area compose a regional picture. It is possible to visualize, from the map a long belt striking northeast and including all the earthquakes in the region. It is notable that this western belt parallels closely the eastern Appalachian belt.

If more evidence of ingeneous activity could be located within the belt, the presence of an inner arch developing parallel to the old orogenic belt of the Appalachians could be assumed. The parallelism of the eastern orogenic belt and the western belt seems to support the theory of a future orogenic movement which is yet deep seated and has not manifested itself in surface features.

SUMMARY

The seismic activity of the Eastern and Northeastern Region, follows the belt of the Appalachian orogenies.

The major earthquakes in New England may have occurred as a result of post-glacial uplift or by tectonic adjustments within ancient belts of mountain building.

In the southern Appalachian Region, it is believed by several geologists that the orogenic belt swings to the west, and connects with the Ouachita thrusts and folds. However, the zone of epicenters, as plotted on the map, may indicate that the axis did not swing westward, but instead that they continued southward into the Gulf Coastal Plain.

The seismic activity that has occurred in the period 1914 to 1944 in the Central Region may be interconnected to form a belt that strikes northeastward and is remarkably parallel to the eastern Appalachian belt. This parallelism may indicate that an inner belt of orogeny is developing similar to that to the east. This inner belt of orogeny is yet deep-seated and has not manifested itself in surface features.

The evidence for this theory is: The parallelism of the belts; the strong shocks along the assumed belt; the mineralization in its southern area; and possible mineralization in its central area.

The conclusions drawn are purely theoretical, and further exploration and evidence are necessary to confirm or disaprove the theories.

APPENDIX

RICHTER MAGNITUDE SCALE*

Richter Instrumental Scale	Magnitude	Energy
Strong enough to be felt	2	10^{12} ergs
Slight damage	4.5	10^{17} ergs
Moderately destructive	6	10^{20} ergs
Largest recorded	8.5	10^{25} ergs

* Bulletin of Seismological Society of America, Vol. 25, No. 1 (1935), p. 132.

Conversion of Rossi-Forrel Scale of Intensity to Modified Mercalli Scale of Intensity.

Rossi-Forrel Scale	Modified Mercalli Scale
1-2	2
3	3
4-5	4
5-6	5
6-7	6
8-	7
8 -9-	8
9	9

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[3]Fryxell, F. M., "The Earthquakes of 1934 and 1935 in Northwestern Illinois and Ajacent Parts of Iowa." Bulletin of the Seismological Society of America, Vol. 32 (1940), p. 213.


EASTERN UNITED STATES
EARTHQUAKE EPICENTERS
1915 - 1944
D.J. O'HALLORAN
Scale 1:2,500,000
25 0 200 miles
LEGEND
RICHTER MAGNITUDE
> 5.4
4.0 - 5.4
< 4.0
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
MISSOURI
KENTUCKY
TENNESSEE
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
NEW JERSEY
VERMONT
NEW HAMPSHIRE
MAINE
MASS.
CONN.
R.I.
90
80
70
40
35
30