

## A CATALOG OF EARTHQUAKE EFFECTS ON THE WESTERN HIGHLAND RIM, TENNESSEE

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### ABSTRACT

A cataloging was conducted of the effects of earthquakes on the northern portion of the Western Highland Rim (1811-1968) for the purpose of providing Modified Mercalli intensity ratings for planners, engineers, and geologists. The data, although ordinal in type and limited, should provide general guidelines for seismic considerations in the design of engineered structures, particularly multi-storied and some one-

storied structures built on fill, slopes, or over filled sink holes.

Historically, the study area experiences anomalous intensity effects from earthquakes originating in the New Madrid earthquake zone. The explanation is thought to be related, in part, to: (1) the karst terrane in the study area; (2) areal extent of alluvial, colluvial, and loessial deposits; and (3) the thickness and weathering character of the regolith.

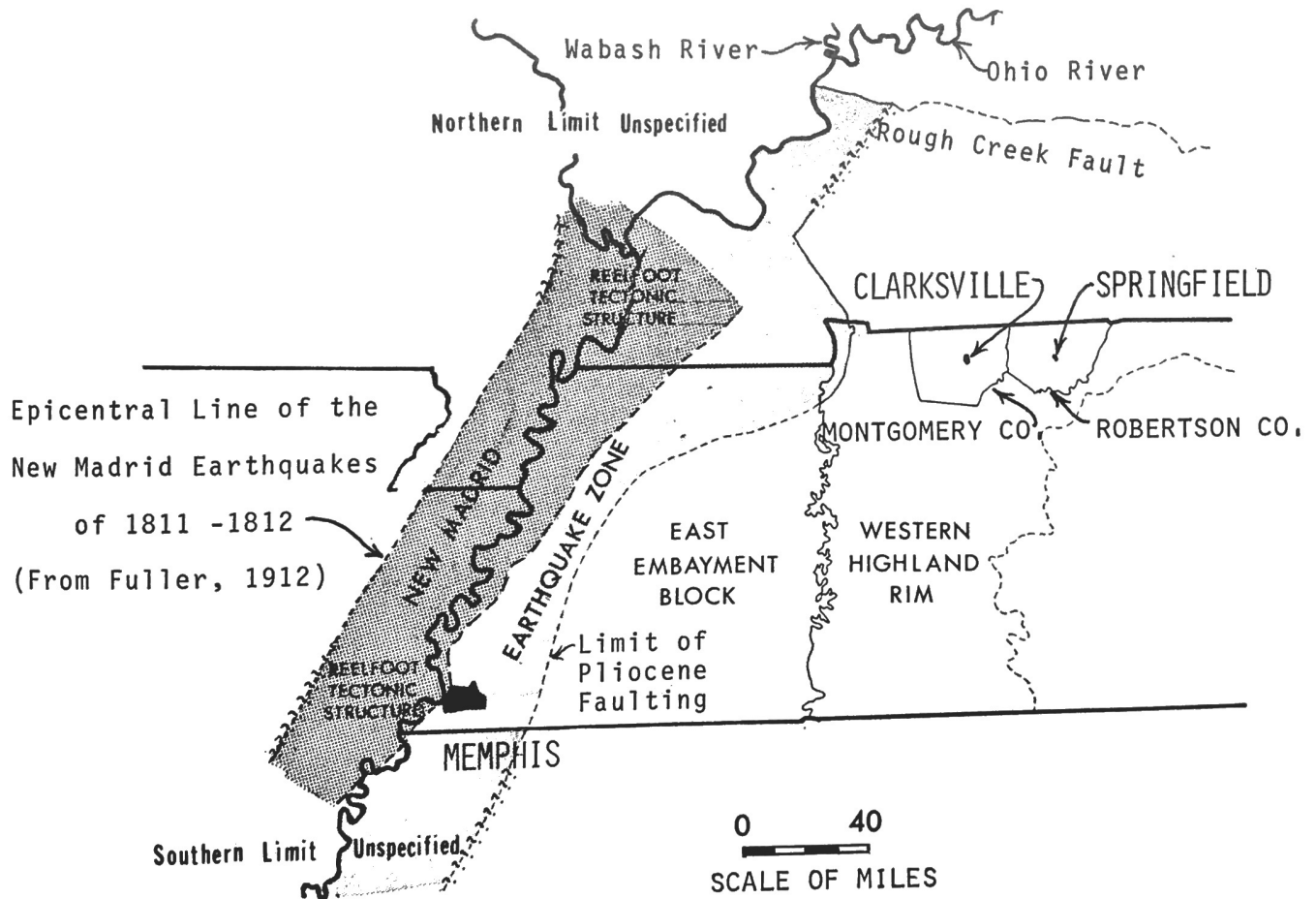


FIG. 1: *The New Madrid earthquake zone and adjacent study area.*

## INTRODUCTION

The cataloging of earthquakes and their visible effects in Tennessee is not new (Moneymaker, 1954, 1955, and 1957). Father J. F. Buisson St. Cosme, a French missionary, recorded the earliest written account of an earthquake in Tennessee while encamped near Memphis, on Christmas Day, 1699 (Williams, 1928). The Mississippi Embayment, particularly that area north of Memphis, first attracted seismologic interest following the series of three severe earthquakes in the New Madrid earthquake zone on December 16, 1811, January 23, 1812, and February 7, 1812 (Mitchill, 1815; Shaler, 1869; Fuller, 1912). Stearns and Wilson (1972) defined the New Madrid earthquake zone for a nuclear reactor siting study along the Tennessee River (Fig. 1).

Algermissen (1966), in a study of seismic risk, indicated that the upper Mississippi Embayment shares the dubious honor of being rated as serious a seismic risk as southern California. A search of the seismic literature dealing with the New Madrid earthquake zone indicated that approximately 312 earthquakes have occurred in the zone. Lyell (1849), Glenn (1906), and Fuller (1912) described rather convincing evidence of severe earthquakes in the New Madrid area long before European man's occupation of the area. Immediately to the east of the Mississippi Embayment in Middle Tennessee is the Western Highland Rim. The Western Highland Rim has been the epicentral area of only 11 earthquakes since 1843, apparently with little known effects (Stearns and Wilson, 1972). The authors believe that the northern portion of the Western Highland Rim, particularly those areas of karst terrane, has experienced anomalous earthquake effects from events ranging in epicentral intensity from V to XII.

The purpose of this paper is to catalog earthquake effects experienced on the northern portion of the Western Highland Rim with particular emphasis on Montgomery County, Tennessee. The authors also intend to examine the contention that the Highland Rim is rarely affected by earthquakes and that those earthquakes felt are almost all in the attenuated fringe zone (Modified Mercalli intensity rating of IV or less) (Stearns and Wilson, 1972). The Modified Mercalli (MM) intensity rating assigned to the study area for local earthquake effects should provide general guidelines for use by planners, engineers, and geologists in evaluating seismic risk for some types of engineered structures.

## NATURE OF DATA UTILIZED

The Modified Mercalli intensity ratings (Wood and Newmann, 1931) assigned by the authors to seismic

events experienced in the study area are recognized for their limitations. First, the total absence of accelerometer, ground displacement, or particle velocity data in the study area makes Modified Mercalli intensity ratings, hereafter known as MM ratings, the only data available for planning and engineering purposes. Recently, some important work (Nuttli, 1973, 1973b; Howell and Shultz, 1975) has been done relating intensities, ground motion, and earthquake magnitudes in the Mississippi River Valley, but all are of an empirical nature and beyond the scope of this paper.

The Modified Mercalli scale genetically is an intensity scale based on a measure of observable earthquake effects on the physical environment and man-made structures. Although the Richter magnitude will not vary, owing to its definition, the Modified Mercalli rating will vary from area to area and within a given area depending upon such factors as: (1) magnitude of the earthquake (i.e., energy released at the focus); (2) distance from the epicenter; (3) nature of the local geologic setting; and (4) structural characteristics of the building in which the observer is stationed during the earthquake.

Thirdly, the MM ratings have been based primarily on first-hand accounts of observers living in the Clarksville, Montgomery County, area. The observational record begins in December 1811, and ends in November, 1968. Data sources include diaries, quotations from letters, and original newspaper articles from 1815 to 1968. Only those portions of text upon which each MM rating is collectively based are included in the paper. Data on an isolated basis will be utilized from Christian County, Kentucky, and Stewart and Robertson Counties, Tennessee.

Fourthly, the Modified Mercalli scale may be statistically biased in favor of magnifying the intensity effects produced by earthquakes prior to 1820. Stearns and Wilson (1972) indicate that the lack of engineered structures in West Tennessee during the first two decades of the nineteenth century and the inferior quality of masonry mortar severely restrict the applicability of the Modified Mercalli scale. All of the above restrictions have been considered in assigning MM ratings in this paper.

## EPICENTRAL MM RATINGS OF X-XII

The most severe earthquake episode recorded in the New Madrid earthquake zone in historic times began on December 16, 1811, and extended through March

15, 1813. During this fifteen month period, some 2000 to 3000 aftershocks were recorded. Three events, December 16, 1811, January 23, 1812, and February 7, 1812 were of sufficient magnitude to be felt over an area of approximately 1.5 to 2.0 million square miles (Mitchill, 1815; Fuller, 1912). These three events are assigned an epicentral MM rating of XII based on field work (Lyell, 1850; Fuller, 1912) interpreted by Money-maker (1954), Nuttli (1973b) and Stearns and Wilson (1972). The epicenters of the three seismic events described above occurred along a line from Jonesboro, Arkansas, to New Madrid, Missouri (Fuller, 1912). The three earthquakes produced surface waves of sufficient magnitude to affect the study area approximately 140 miles to the east-southeast.

Dr. Peter H. Cole, resident of Clarksville, Tennessee from 1808-23, sent a series of three letters to Dr. Samuel L. Mitchill, noted physician and natural scientist. Dr. Cole utilized his geologic training under Dr. Mitchill to describe in some detail the observed effects of the 1811-12 New Madrid earthquake sequence experienced in the study area. Dr. Cole, in a letter dated December 15, 1812, stated that

(1) "We had a tolerably severe one on the 16th. They have destroyed a number of chimneys in the area and terrified many of the inhabitants" (Mitchill, 1815).

Dr. Cole in a letter dated January 26, 1813, stated that

(2) "... on that occasion a new limestone spring broke out about twenty feet above the original spring" (Mitchill, 1815).

(3) "Some springs ceased to run for some time" (Mitchill, 1815).

(4) "... others (springs) ran muddy several hours after the earth had been convulsed" (Mitchill, 1815).

(5) "In the County of Christian (Kentucky), a fine and fresh spring of water was observed to run very muddy for several hours" (Mitchill, 1815).

(6) "... (spring) had been converted to one of the strongest brimstone springs I have ever met with" (Mitchill, 1815).

A letter to a Knoxville editor (*Wilson's Knoxville Gazette*, January 20, 1812) from a friend at Dover, Stewart County, Tennessee, states that

(7) "... a small piece of ground on Well's Creek in this county (Stewart) has sunk so as to form a sink hole ... the place is but about 20 or 30 feet square."

A Baptist pastor in the Clarksville area, Elder Reuben Ross, wrote in his diary (December, 1811)

(8) "... ground shaking under my feet ... thrown from my horse ... the shocks, which continued until after day (break?) were very severe—so much so that the heaviest houses seemed to be hacked to pieces " ... panic-

stricken neighbors spent the entire day outside" (Ross, 1882).

Elder Ross diary (circa January - March 1812)

(9) "Some believed the earth to be in constant vibratory motion, because as they affirmed, anyone laying his hand on the top rails of a common fence could perceive a constant movement of the rails" (Ross, 1882).

A letter from a gentleman (name unknown) in Rogersville, traveling somewhere between Clarksville and Nashville (?), in a letter to the editor of the *Wilson's Knoxville Gazette* dated January 27, 1812, states

(10) "The motion appeared to come from the west ... the shock was much greater than that felt on the morning of the 16th (December 16, 1811). Indeed it was so great that the motion of the earth much resembled that of a ship on a heavy sea."

## EPICENTRAL MM RATINGS OF VII-IX

After the series of 1811-1812 earthquakes only six events with an MM rating of VII or greater are believed to have affected the study area. A major seismic event occurred in the Memphis area on January 4, 1843. Heinrich (1941), Eppley (1958), and Stearns and Wilson (1972) have assigned an MM rating of IX, IX-X, and VIII for this earthquake, respectively. Another earthquake on August 18, 1865, occurred near Memphis and was assigned an MM rating of VII (Heck, 1938). The authors have been unable to locate any local records of significance for either event. The *Clarksville Leaf-Chronicle* microfilm is incomplete for several intervals from 1849-1915. An estimated MM rating is assigned for these events along with others for which data is unavailable (Table 1).

The next major seismic event in this MM-rating class to be felt locally occurred on October 31, 1895. The earthquake epicenter was near Charleston, Missouri. Coffman and others (1970) assigned an MM rating of VII to the event which was experienced over some 2.0 million square miles. The *Tobacco Leaf Chronicle (Clarksville Leaf-Chronicle)* dated November 1, 1895, states

(11) "It was like the sensation on board a large steamer [sic] driving at full steam against the current."

(12) "... like being in a train over rough track with brake applied."

(13) "Swinging lamps and pictures swayed too and fro, window rollers kept up a constant rattle, and much of the bric-a-brac about the house tumbled from shelves."

(14) "Chimney's collapsed ... bricks were shaken from chimneys."

The last earthquake definitely in this MM range to affect the Western Highland Rim was an MM event of VII located in Hamilton County, Illinois, on November 9, 1968. The earthquake, based on the amplitude record at St. Louis University, rated a 5.5 on the Richter scale (Heigold, 1968). The Western Highland Rim experienced a number of observable effects. The *Clarksville Leaf-Chronicle* (November 10, 1968) reported

TABLE 1: Summary of the earthquake intensity history of the Western Highland Rim.

Date	Epicenter	Epicentral Intensity	Local Intensity	Source of Local Intensity	Adjusted Local Intensity	Quotations Utilized For Local Assignment (#)
12/16/1811	Northeastern Arkansas	XII	VI-VII	Stearns and Wilson (1972)	VIII-IX	2, 3, 4, 5, 7, 8, 10
1/23/1812	New Madrid, Missouri	XII	VI-VII	Stearns and Wilson (1972)	VIII-IX	2, 3, 4, 5, 7, 8, 10
2/7/1812	New Madrid Missouri	XII	III-IV	Stearns and Wilson (1972)	VIII-IX	2, 3, 4, 5, 7, 8, 10
1/4/1843	Memphis Area	IX	—	—	IV-V*	—
8/17/1865	Memphis Area	VII	—	—	II-III**	—
4/12/1883	Cairo, Illinois	VII	—	—	IV-V**	—
10/31/1895	Charleston, Missouri	VII	V	Coffman and Cloud (1970)	VI-VII	13, 14, 11(?), 12(?)
4/29/1899	Vincennes area, Indiana	VI-VII	—	—	IV-V*	—
11/4/1903	St. Louis, Missouri	VI-VII	—	—	IV-V**	—
8/21/1905	Sikeston, Missouri	VI	IV-V	Stearns and Wilson (1972) <sup>1</sup>	IV-V**	—
11/18/1916	Hickman, Kentucky	VI-VII	—	—	V-VI**	—
4/9/1917	St. Genevieve, Missouri	VI	III	Heck (1938)	III-IV*	—
11/26/1922	El Dorado, Illinois	V	III	Stearns and Wilson (1972) <sup>1</sup>	III*	—
9/2/1925	Henderson, Kentucky	V-VI	—	—	IV-V	21
5/7-8/1927	New Madrid, Missouri	VI-VII	IV	Stearns and Wilson (1972) <sup>1</sup>	IV	20
8/19/1934	Rodney, Missouri	VI	III	Tison (1963)	III	22
3/3/1963	New Madrid, Missouri	VI	I-II	Stearns and Wilson (1972)	III-IV	23
11/9/1968	Broughton, Illinois	VII	III-IV V	Stearns and Wilson (1972) Coffman and Cloud (1970)	V-VI	16, 17, 19

\* Estimate based on John Nick Barker diary (unpublished) Clarksville-Montgomery County library—Mr. Barker recognized only that an earthquake occurred.

\*\* Estimate based on knowledge of the area; newspaper microfilm missing for that time interval.

\* Estimate based on knowledge of the area; newspaper carried no story.

<sup>1</sup> Study provided effects; no local MM assignment made.

(?) Report of interest but difficult to evaluate.

(15) "Sheriff Joel Plummer, on the 2nd floor of the jail, said, 'the building began swaying at 11:04 a.m. . . . noise sounded like the third floor was going to drop into our laps . . . floors trembled under my feet . . . windows rattling.'"

(16) "People ran into streets, buildings swayed."

(17) "'Sounded like car struck house,' one woman commented who had experienced that event (car striking house) a year before . . . awakened day sleepers . . . bed appeared to rise off the floor."

(18) "At Memorial Hospital desk started moving and the trash-can lid began to sway."

The *Springfield Herald* (November 10, 1968) reported

(19) "The only known damage in the local area was some cracks in the clock tower at the courthouse, along with damage to numerous chimneys of private homes."

On May 7, 1927 an earthquake occurred in the Mississippi Valley with its epicenter located near New Madrid, Missouri. The event was assigned an MM rating of VI by Heinrich (1941) and a VII by Stearns and Wilson (1972). The *Clarksville Leaf-Chronicle* (May 8, 1927) reported

(20) "Rattling of window shutters and window panes."

#### EPICENTRAL MM RATINGS V-VI

The New Madrid earthquake zone has been the epicentral area for approximately 85 to 90 seismic events rated at V-VI since 1699. Locally, the available observational data on this MM-rating class are only on twentieth century earthquakes. This can be explained by recognizing that V-VI events produce little noticeable ground motion at distances greater than 100 miles from the epicenter. Secondly, few engineered structures over three stories exist in the study area resulting in a statistical bias in favor of non-observance of minor local effects (i.e.; MM events locally of I-IV). The fact that the effects in this MM category occurred at a distance of 140 to 160 miles is an anomaly. The bulk of the earthquakes in this category since 1900 have apparently not affected the study area.

With the present records available, the first documentable seismic event in this category affecting the study area occurred on September 2, 1925. The epicenter was located near Henderson, Kentucky and was assigned an MM rating of V-VI (Eppley, 1958). The *Clarksville Leaf-Chronicle* (September 2, 1925) states

(21) "Windows were jarred, dishes rattled, houses slightly shaken . . . awakened several citizens . . . coming when it did the old alarm clock was robbed of its duty, late sleepers being jarred from the land of nod."

The next significant earthquake in this category to affect the Western Highland Rim occurred on August 19, 1934, with an epicenter at Rodney, Missouri (between Cairo, Illinois and Charleston, Missouri). The earthquake was assigned an MM rating of VI (Bradford and Dahm, 1935). The *Clarksville Leaf-Chronicle* (August 20, 1934) indicated

(22) "pronounced enough to be detected in buildings which trembled slightly (around) 6:00 P.M. Sunday evening."

On March 3, 1963, near New Madrid, Missouri, an earthquake occurred. The event was assigned an epicentral intensity of VI (Coffman and others, 1970). The *Clarksville Leaf-Chronicle* on March 4, 1963 reported

(23) "A slight tremor was noticed . . . some residents thought it was vibration from super-sonic jets."

#### SUMMARY AND CONCLUSIONS

The Western Highland Rim in general and the Clarksville area specifically have experienced the effects of at least nine, and probably eighteen earthquakes that had epicenters in the New Madrid earthquake zone since 1811. The incomplete earthquake record is, in part, related to: (1) poor communications (2) very low population density (1790-1830); (3) the Civil War and subsequent interruption of the Clarksville newspaper (occupation); and (4) microfilm gaps. Five earthquakes have produced known structural damage. The remaining thirteen produced, or are estimated to have produced, noticeable effects.

The data (Table 1) definitely indicate that the study area does react anomalously to earthquakes occurring in the New Madrid earthquake zone. The anomaly is over and above the abnormal sensitivity of the upper Mississippi Embayment to earthquakes as described by Nuttli (1973a, 1973b). The earthquakes for which local data are available produced seismic effects greater than the seismic literature indicated. The anomalous response of the northern portion of the Western Highland Rim to earthquakes appears related to: (1) the delicate nature of the karst terrane (Kemmerly, 1975a, 1975b); (2) the areal extent of alluvial, colluvial, and loessial deposits; and (3) the thickness and weathering character of the regolith, particularly the clayey deposits. All of the above factors are thought to either minimize surface wave attenuation (as measured by decrements in the MM ratings) or amplify locally the surface wave amplitudes through some type of differential response to resonance. The limestone-clay matrix boundary characteristics in the sink holes, and the vibrational characteristics of the siphon-like bowl and the swallet conduit are believed to play a critical role in maximizing terrain response to surface wave passage, particularly near a frequency of 0.3 Hertz.

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## COURT SUGGESTS COLLEGE MUST TRY TO FIND JOB FOR TENURED TEACHER

The U.S. Court of Appeals for the District of Columbia said this week that when a university dismisses a tenured professor because of a reduction in funds or the need for a change in curriculum it must have flexibility, but that "an institution truly motivated only by financial considerations would not hesitate to place the tenured professor in another suitable position if one can be found, even if this means displacing a nontenured instructor."

The court issued an opinion in the case of Prof. Boris S. Browzin who was dismissed by Catholic University in 1971. Browzin was a tenured professor in the university's School of Engineering and Architecture and sued the university in U.S. District Court on grounds that his dismissal was a breach of contract.