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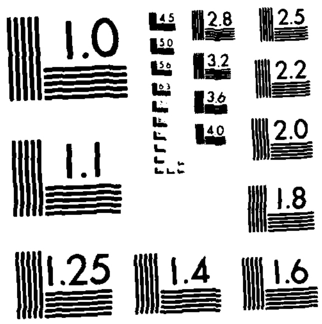

US Army Corps of Engineers

GEOTECHNICAL LABORATORY

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SEISMIC STABILITY EVALUATION OF ALBEN BARKLEY DAM AND LAKE PROJECT

Volume 2

GEOLOGICAL AND SEISMOLOGICAL EVALUATION

by

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Geotechnical Laboratory

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Waterways Experiment Station, Corps of Engineers
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The region in which Barkley Dam is located was divided into four seismic source zones. Zone 1, the New Madrid source, was seen to provide the severest shaking at Barkley damsite. The maximum earthquake is m_b = 7.5 and is attenuated 118 km. The Santa Barbara record for the 1952 Kern County, California, earthquake was scaled to an acceleration of 0.24 g, a velocity of approximately 35 cm/sec, and a duration ($\geq$0.05 g) of approximately 60 sec.

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PREFACE

The US Army Engineer Waterways Experiment Station (WES) was authorized to conduct this study by the US Army Engineer District, Nashville, by DA 2544, No. 77-112. This report is Volume 2 of a 5-volume set which documents the seismic stability evaluation of Alben Barkley Dam and Lake Project. The 5 volumes are as follows:

Volume 1: Executive Summary

Volume 2: Geological and Seismological Evaluation

Volume 3: Field and Laboratory Investigations

Volume 4: Liquefaction Susceptibility Evaluation and Post-Earthquake Strength Determination

Volume 5: Stability Evaluation of Geotechnical Structures

The work in this volume was coordinated by Dr. E. L. Krinitzsky, Engineering Geology and Rock Mechanics Division (EGRMD). Dr. R. G. Stearns, Professor of Geology at Vanderbilt University, was engaged to provide the geological background and the earthquake history. Mr. D. J. Leeds, Consultant in seismology, and Dr. O. W. Nuttli, Professor of Seismology at St. Louis University, were enlisted to provide earthquake motions for the Barkley damsite. Technical advisors who participated in discussions leading to the acceptance of the test earthquake motions were Drs. H. B. Seed, G. Castro, L. T. Long, and A. Nieto. The results of the discussions were summarized and reviewed by Dr. E. L. Krinitzsky. The project was under the direction of Ms. M. E. Hynes-Griffin who was Principal Investigator. Overall direction was provided by Dr. D. C. Banks, Chief, EGRMD, and Dr. W. F. Marcuson III, Chief, Geotechnical Laboratory (GL).

COL Allen F. Grum, USA, was Director of WES. Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
miles (U. S. statute)	1.609347	kilometres
square miles	2.58998	square kilometres

SEISMIC STABILITY EVALUATION OF ALBEN BARKLEY DAM
AND LAKE PROJECT
GEOLOGICAL AND SEISMOLOGICAL EVALUATION

PART I: INTRODUCTION

General

1. The Barkley Dam is about 115 km from the source area of the New Madrid earthquakes of 1811-1812. Four major earthquakes are deduced to have occurred (Street and Nuttli 1984). Two occurred on 16 December 1811, one on 23 January 1812, and one on 7 February 1812. Body wave magnitudes of 7.2, 7.0, 7.1, and 7.3, respectively, were estimated by Street and Nuttli for these events. These earthquakes are among the severest in North America and, because of low attenuations in central and eastern United States, they were felt as far away as Canada, the East Coast, and southern Louisiana. In addition, there were hundreds of aftershocks, a dozen of which were felt over much of the central United States. Other major earthquakes that have happened in the New Madrid seismic zone since then are the 5 January 1843 event near Memphis, Tenn., with a body wave magnitude of 6.0; the 31 October 1895 event near Charleston, Mo., magnitude 6.2; and the 9 November 1968 event in south-central Ill., of magnitude 5.5. The Charleston, Mo., earthquake occurred 100 km from Barkley Dam. In addition there has been continuous microearthquake activity in the New Madrid area and miscellaneous smaller, felt earthquakes in the central United States.

Objective

2. This study undertakes to summarize the geological and seismological factors that are relevant for assessing the earthquake hazards at Barkley Dam and to specify earthquake ground motions at the damsite that are appropriate for the evaluation of seismic safety.

PART II: EARTHQUAKE ZONES

General

3. The geology and the seismic history in the general region of Barkley Dam was studied by Richard G. Stearns of Vanderbilt University. His investigation dated 22 January 1978 is included in Appendix A of this report. Supplementary earthquakes to 1981 were added by Mr. Dale L. Barefoot.

4. The area considered by Stearns is located approximately 87°00' to 90°00' west longitude and 36°00' to 38°00' north latitude. It includes most of the New Madrid area and the seismic areas of southern Illinois.

5. Stearns examined the geologic history and the patterns of faulting. He concluded that there were no active faults, that is, faults with surface evidence of geologically recent fault movement, at or near the Barkley Dam. Active faults can be interpreted only in the New Madrid area.

Seismic Zones

6. Stearns established four seismic zones which he deemed to be appropriate for the region in which Barkley Dam is situated. He also assigned the Modified Mercalli intensities and Richter magnitudes for these zones in an approximate manner. His zones are shown in Figure 1 which is taken from his report.

Zone I: The New Madrid Seismic Zone is an area in which high intensity earthquakes can originate. Modified Mercalli (MM) Intensity is potentially XI, a Richter magnitude 7.0. The maximum earthquake may occur in any place in this zone.

Zone II: A floating earthquake is postulated of MM Intensity IX, or Richter magnitude of approximately 6.0. The area borders the New Madrid zone and includes the area of the 1895 Charleston, Mo., earthquake of magnitude 6.2 which is regarded as the biggest that this zone will generate.

Zone III: A floating earthquake is postulated of maximum MM Intensity of VII and Richter magnitude of about 5.0. The area includes the site of Barkley Dam.

Zone IV: A floating earthquake is interpreted of maximum MM Intensity of VII and Richter magnitude of 5.7. The area encompasses the seismically active region of southern Illinois.

7. A description of the MM intensity scale is provided in Figure 2.

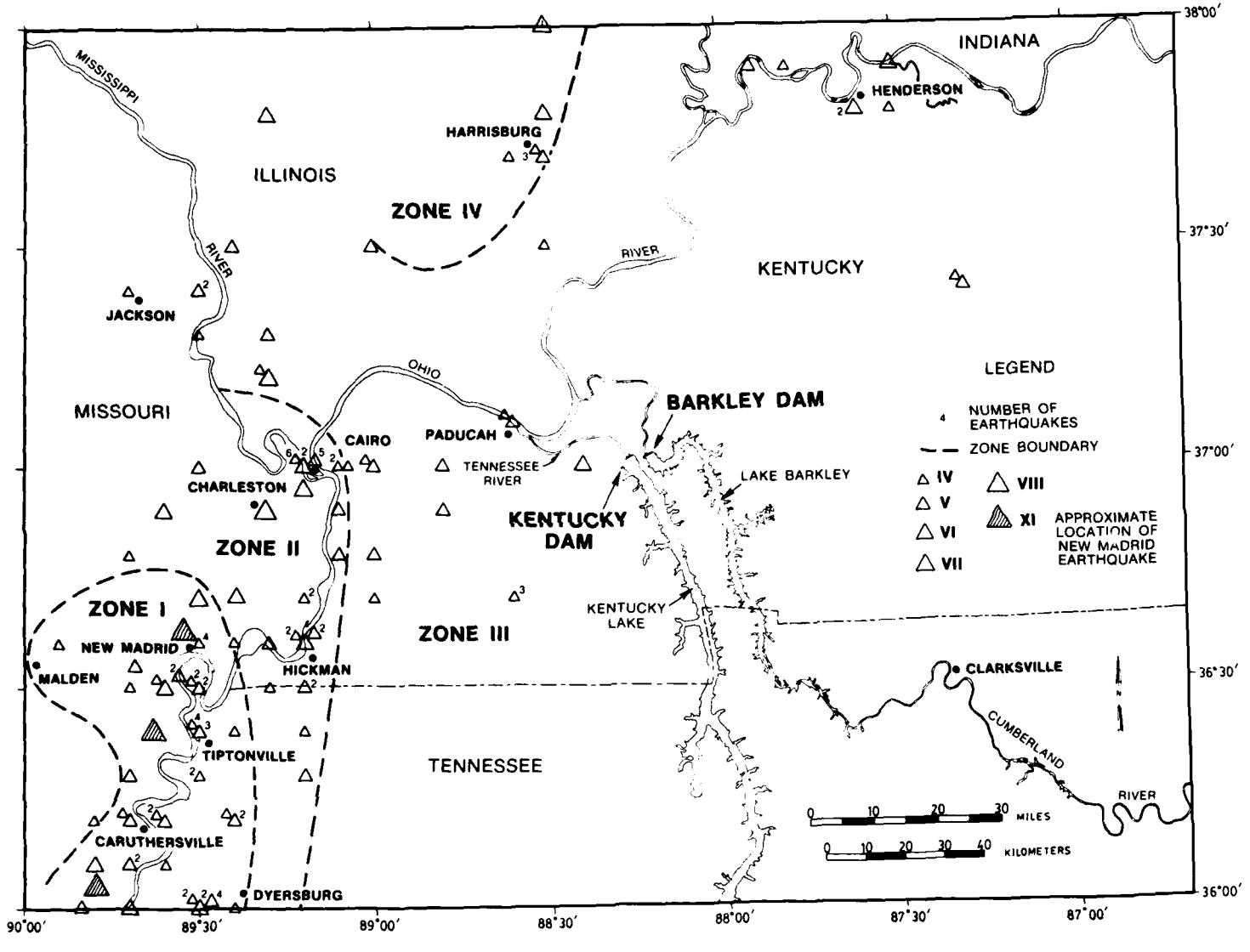

Figure 1. Earthquake history and seismic zones in the region of Barkley Dam
From Stearns (Appendix A)

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 motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building. Standing motor cars 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 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 construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great 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 from 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 pipe lines 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 thrown upward into the air.

Figure 2. Modified Mercalli (MM) intensity scale

PART III: EARTHQUAKE MOTIONS

General

8. David J. Leeds, consultant in seismology, met with Stearns for discussions prior to acceptance of the seismic zones. Leeds, in concurrence with Stearns, modified the magnitude values and proceeded to provide seismic ground motions based on Zones I, II, and III of Stearns' four seismic zones. Leeds' motions and recommended accelerograms are contained in Appendix B. Leeds' report was dated 15 January 1978. Subsequently, on 19 July 1978, Otto W. Nuttli, Professor of Seismology at St. Louis University, provided motions for a Zone IV source area in southern Illinois. His recommendations are contained in Appendix C.

Peak Motions

9. The peak motions that were specified were in conformity with Engineer Regulation 1110-2-1806 which defines the earthquakes as the most severe believed possible for the site.

10. MM intensities at the Barkley damsite for maximum earthquakes originating in the four seismic zones were interpreted by Leeds and Nuttli in 1978 as follows:

Source	Magnitude m_b	MM Source I_o	Epicentral Distance km	MM Site I_s
Zone I	7.5	XI	118	IX
Zone II	6.5	IX	85	VIII
Zone III	5.5	VII	0	VII
Zone IV	6.5	IX	65	VIII

11. Thus the severest MM intensity at the damsite was judged to be IX and to come from a source in the New Madrid seismic zone.

12. Peak motions at the damsite were assigned by Leeds and Nuttli as follows:

Source	Horizontal Acceleration g	Horizontal Velocity cm/sec	Displacement cm	Duration (a 0.05 g) sec
Zone I	0.28	40	22	10
Zone II	0.23	32	18	10
Zone III	0.18	25	15	10
Zone IV	0.23	32	18	10

13. Leeds proposed that the Taft and Santa Barbara records of the 1952 Kern County, Calif., earthquake be used for a source in Zone I; Lake Hughes #1 and Castaic records of the 1971 San Fernando earthquake be used for a source in Zone II; and the Logan, Utah, record of 1942 be used for a source in Zone III.

14. Subsequently, Nuttli and Herrmann published Report 12 on Credible Earthquakes for the Central United States (1978) and Nuttli published Report 16 on The Relation of Sustained Maximum Ground Acceleration and Velocity to Earthquake Intensity and Magnitude (1979). These reports and new data from the Imperial Valley, Calif., earthquake of 15 October 1979 caused personnel at WES to reconsider the motions that were accepted for Barkley damsite. In November 1979, a new set of motions were generated and these were presented to the advisors.

15. Nuttli recommended new values based on the improved charts cited above in April 1980. His additional values for a source for the Wabash zone, or Zone IV, were

> Peak horizontal acceleration = 0.21 g at frequency of 4 Hz
> Peak horizontal velocity = 38 cm/sec at frequency of 2 Hz
> Duration of motion which will exceed 0.05 g = 15 to 20 sec

16. On 27 August 1980, the technical advisors, Drs. H. B. Seed, G. Castro, L. T. Long, and A. Nieto, considered recommendations by Krinitzsky and Nuttli and together it was agreed that the dam be checked for the following test earthquake which would represent the worst conditions for any earthquake:

> Peak horizontal acceleration = 0.24 g at frequency of 2 Hz
> Peak horizontal velocity = 50 cm/sec at frequency of 1 Hz
> Duration of motion which will exceed 0.05 g = 25 sec

17. A Santa Barbara record with a scaled peak acceleration of 0.24 g was used. The peak velocity was about 35 cm/sec; the duration was about 60 sec. The full record was used in the testing procedure despite the much longer duration. Scaling the time increment of a digitized earthquake accelerogram was undesirable because it alters the frequency content of the record. Mr. Leeds recommended the use of the 1952 Kern County, Santa Barbara Courthouse and Taft Lincoln School earthquake records. In the initial dynamic analyses, scaled versions of the S69°E component of the Taft Lincoln School record and the S48°E component of the Santa Barbara Courthouse record were used. Dynamic analyses, using the Santa Barbara Courthouse record

consistently resulted in more severe earthquake-induced stresses, and this record also more closely matched the ground motions recommended by the advisors, so the Taft Lincoln School record was deleted from ensuing analyses. The S48°E component of the Santa Barbara Courthouse record scaled to 0.24 g with a resulting scaled velocity of 35 cm/sec and duration of approximately 60 seconds was taken to be a satisfactory match with the recommended target earthquake motions of 0.24 g, 50 cm/sec, and 25 seconds. Qualitatively, in the dynamic analyses for liquefaction evaluation, the somewhat lower than target peak velocity is compensated for by the somewhat longer than target duration. The advisors approved the record, the scaling procedures, and the manner in which the scaled record was applied in the dynamic analyses. The advisors further agreed that the procedure used for dynamic analyses reflected the latest accepted methods, and that the induced earthquake stress calculations were correct and appropriate for the liquefaction evaluation.

18. In the dynamic analyses, a strain-compatible site period of 1.14 seconds was computed and damping values ranged from 7 to 21 percent of critical. Examination of the response spectra in Appendix B reveals that a site period of 1.14 seconds does not fall exactly on a velocity or acceleration peak, but it is contained within the strong response section of the spectra, periods between 0 and 2 seconds. Nor does the response of 1.14 seconds fall on a trough in the spectra. This pattern of response indicates that the record is well suited to the site. In the dynamic analyses, the Santa Barbara Courthouse S48°E record scaled to 0.24 g was deconvolved through a firm sand soil profile, which Professor Seed advised was representative of the recording site. A bedrock outcrop motion with a peak acceleration of 0.14 g was computed in the deconvolution step. This record was propagated up through the Barkley soil profile. The peak ground surface acceleration at the Barkley site was computed to be 0.15 g. These resu'ts further indicate no excessive amplifications resulted from the input motions. Since these results were obtained from the dynamic analyses, they will be discussed in the report on the liquefaction evaluations.

PART IV: REVIEW OF EARTHQUAKE SOURCES

General

19. Many geological and seismological investigations are under way in the New Madrid area and the knowledge and understanding of the region is developing rapidly. Consequently, it is necessary to consider whether any of the ideas arrived at in 1980 in relation to the Barkley damsite are in need of change.

The New Madrid Source Zone I

20. The isoseismal boundaries for a composite maximum intensity map of the 1811-1812 New Madrid earthquake are shown in Figure 3. The map was prepared by Stearns and Wilson (1972). It is noteworthy that control points from the available data show a sharp indentation of the contours near the Barkley damsite. The damsite is in a zone of MM VII. If one uses a generalized attenuation, as Leeds did, one gets MM IX for the site. The MM IX was judged to be desirable because of uncertainties in the intensity data and the question of whether the pattern of the isoseismal contours would be repeated in the event of another earthquake.

21. More recently, a composite isoseismal map for a worst case New Madrid event was prepared by Hopper, Algermissen, and Dobrovolny (1983). Their isoseismals for the Barkley damsite are shown in Figure 4. Their interpretation is for a MM IX at the Barkley damsite. Theirs, however, is a free interpretation of worst conditions, and they elongated their maximum zones along river valleys on the assumption that greater damage would be experienced in those directions. Though they corroborate the MM IX that was accepted by Leeds (Appendix B) for the Barkley damsite, the MM IX is clearly a worst possible case.

22. A very careful reexamination of the data relating to the New Madrid earthquakes was carried out by Street and Nuttli (1984). Their interpretations for the intensities observed for the four major New Madrid earthquakes are shown in Figures 5-8. MM intensities of VI and VII are the severest near the Barkley damsite. It appears from considering these data that MM IX for

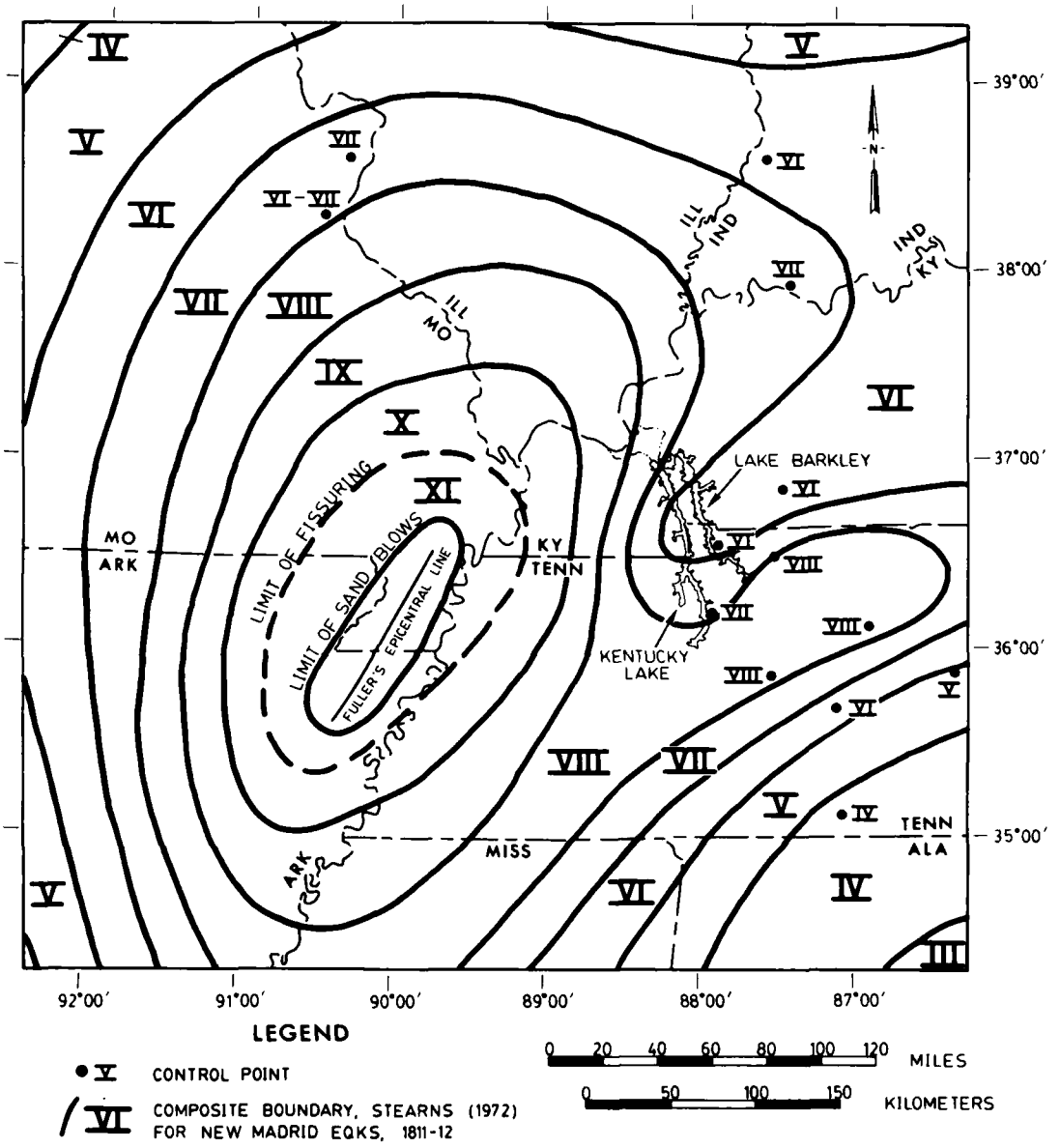

Figure 3. Composite maximum intensity map of the 1811-1812 New Madrid, Mo., earthquakes (from Stearns and Wilson 1972)

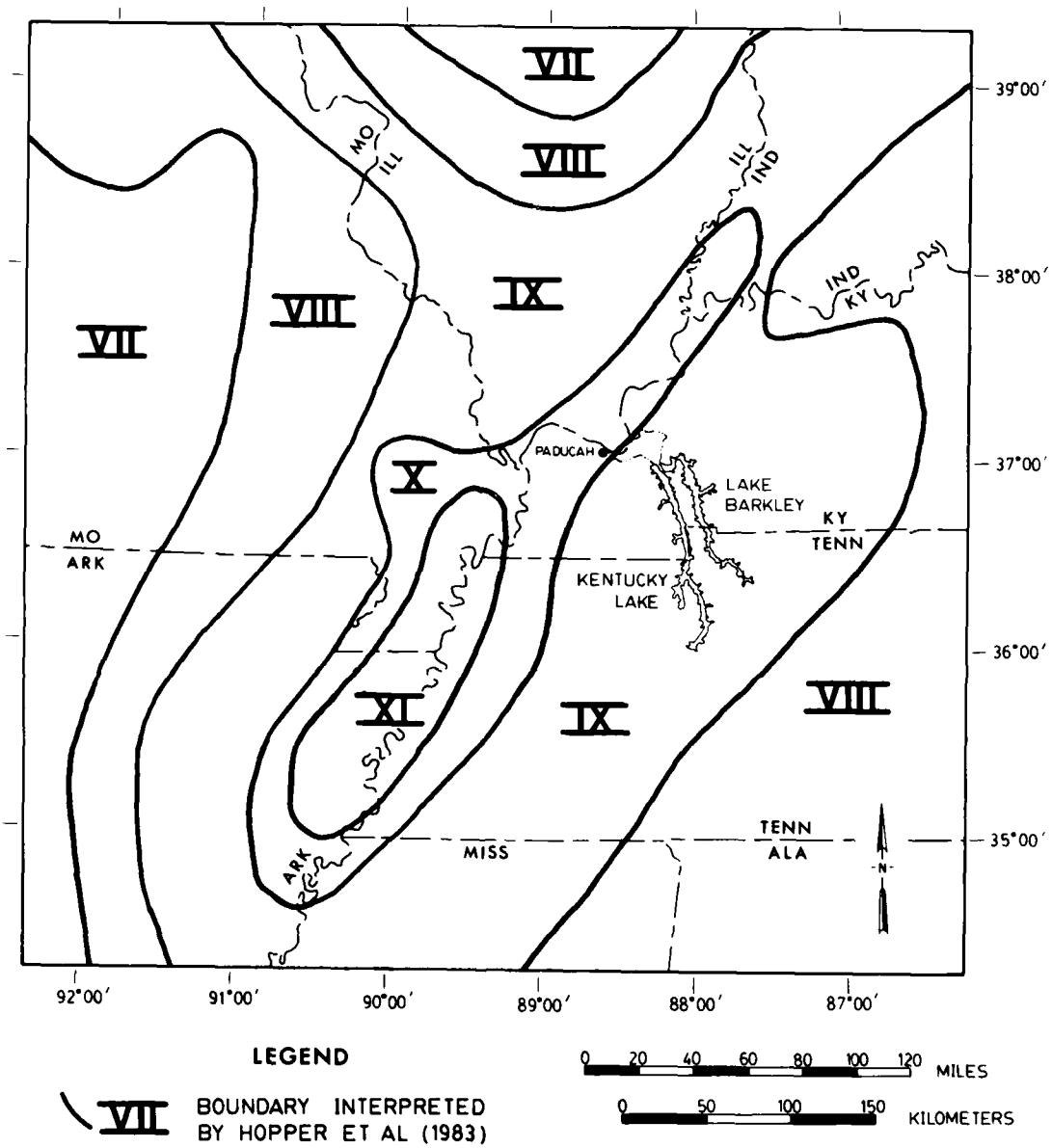

Figure 4. Isoseismals for MM intensity from a worst case New Madrid earthquake (from Hopper, Algermissen and Dobrovolny 1983)

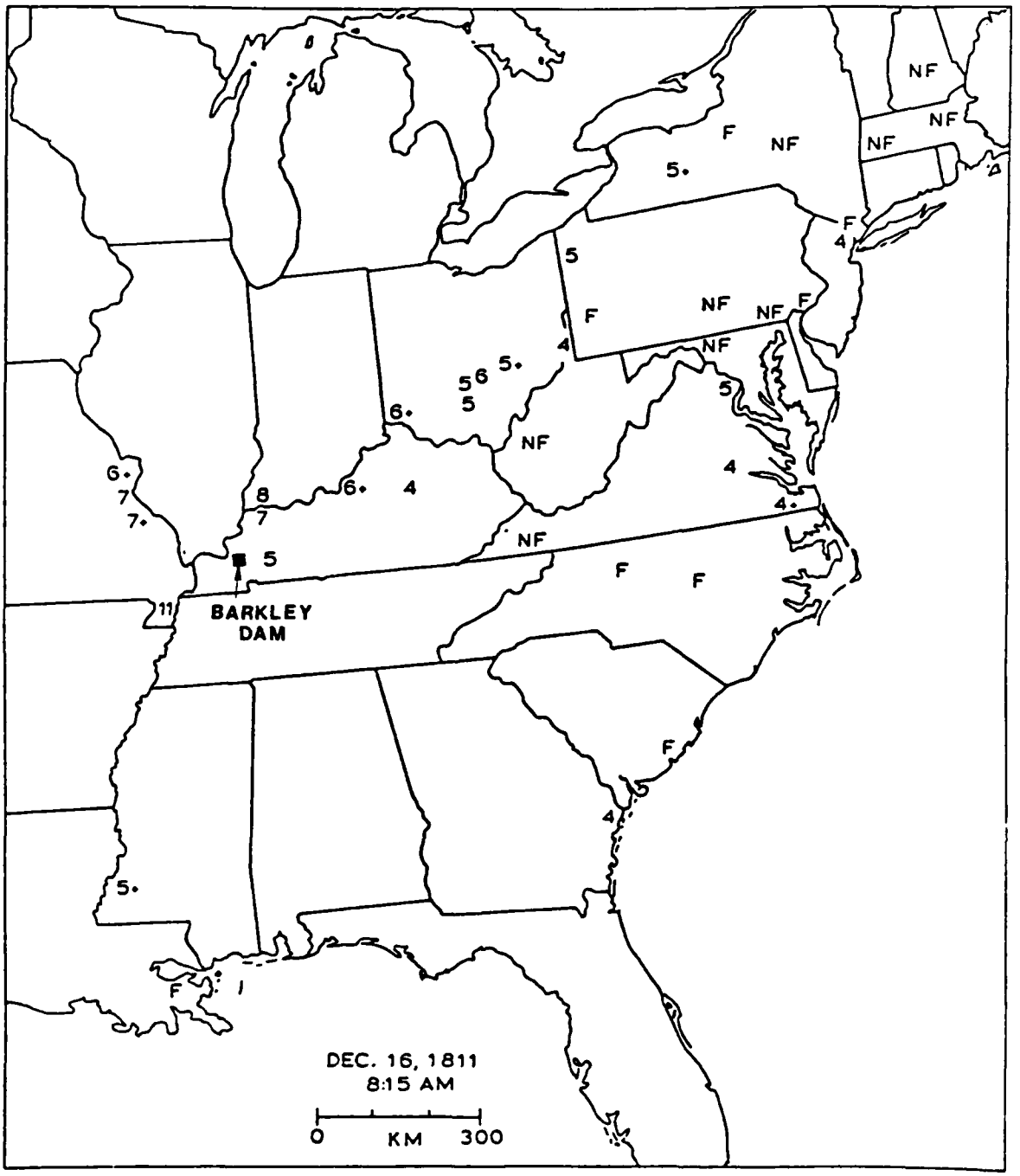

Figure 5. MM intensity data (in Arabic numerals) for the earthquake of 16 December 1811, 8:15 AM, New Madrid, Mo. (from Street and Nuttli 1984)

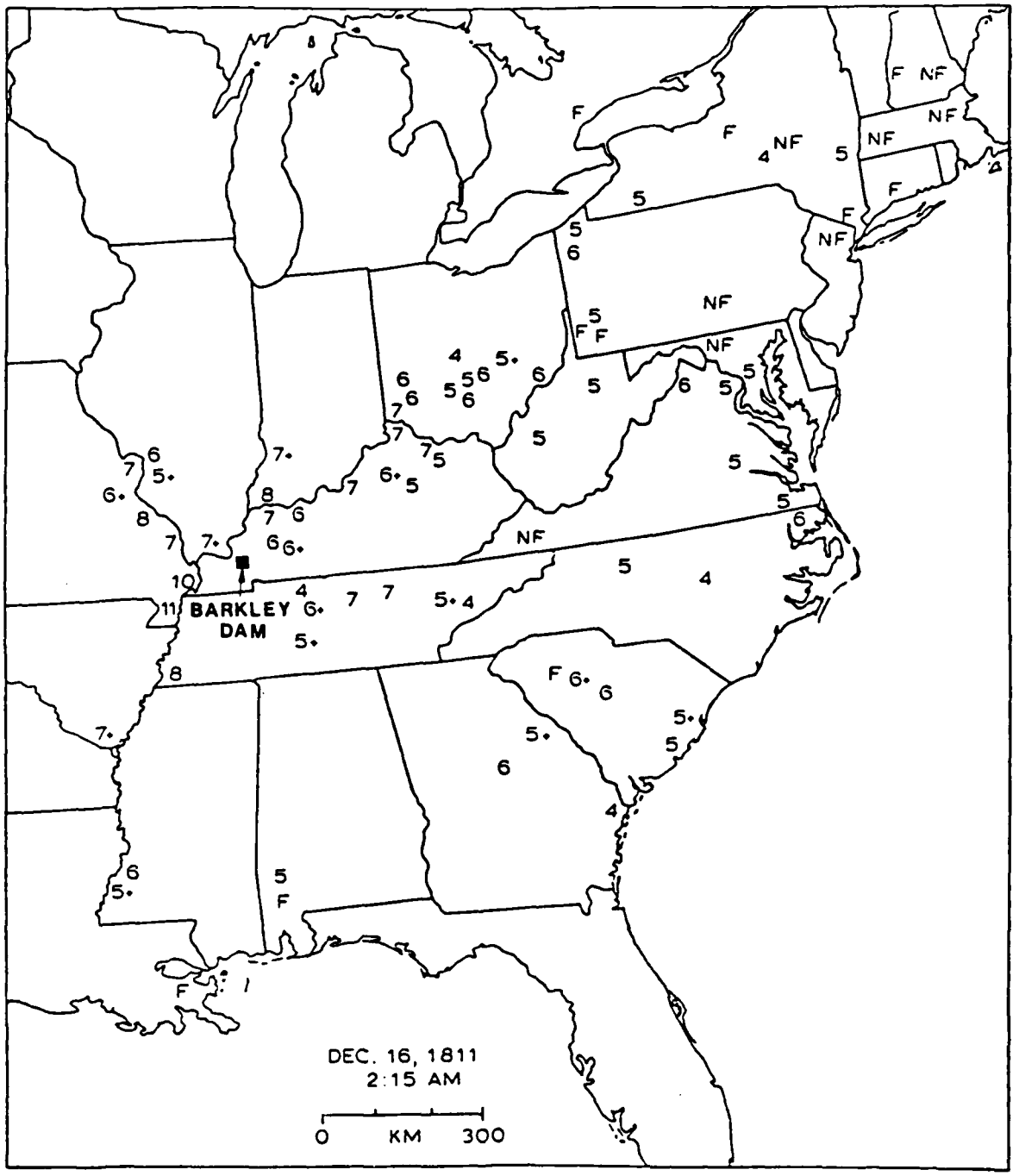

Figure 6. MM intensity data (in Arabic numerals) for the earthquake of 16 December 1811, 2:15 PM, New Madrid, Mo. (from Street and Nuttli 1984)

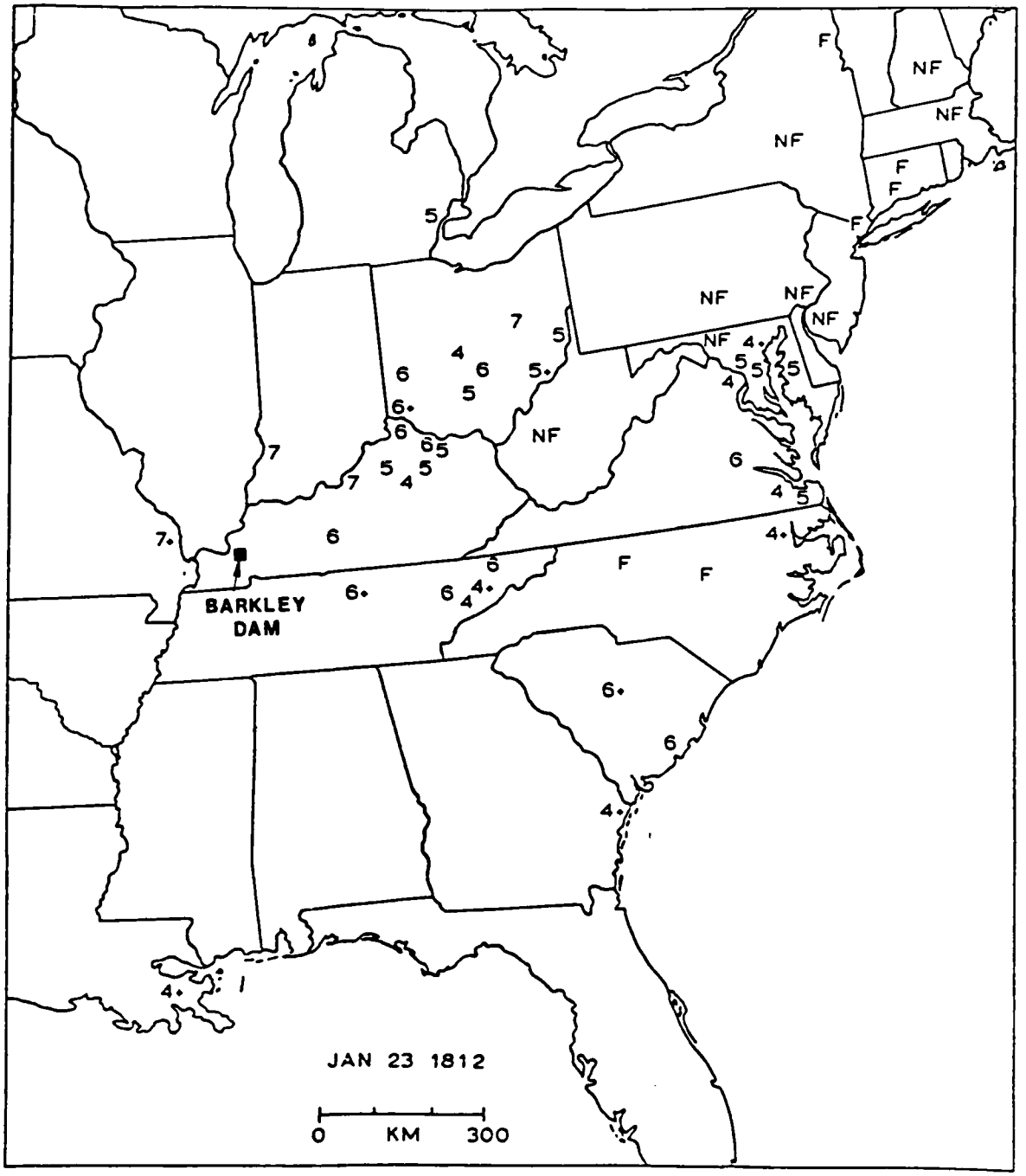

Figure 7. MM intensity data (in Arabic numerals) for the earthquake of 23 January 1812, New Madrid, Mo. (from Street and Nuttli 1984)

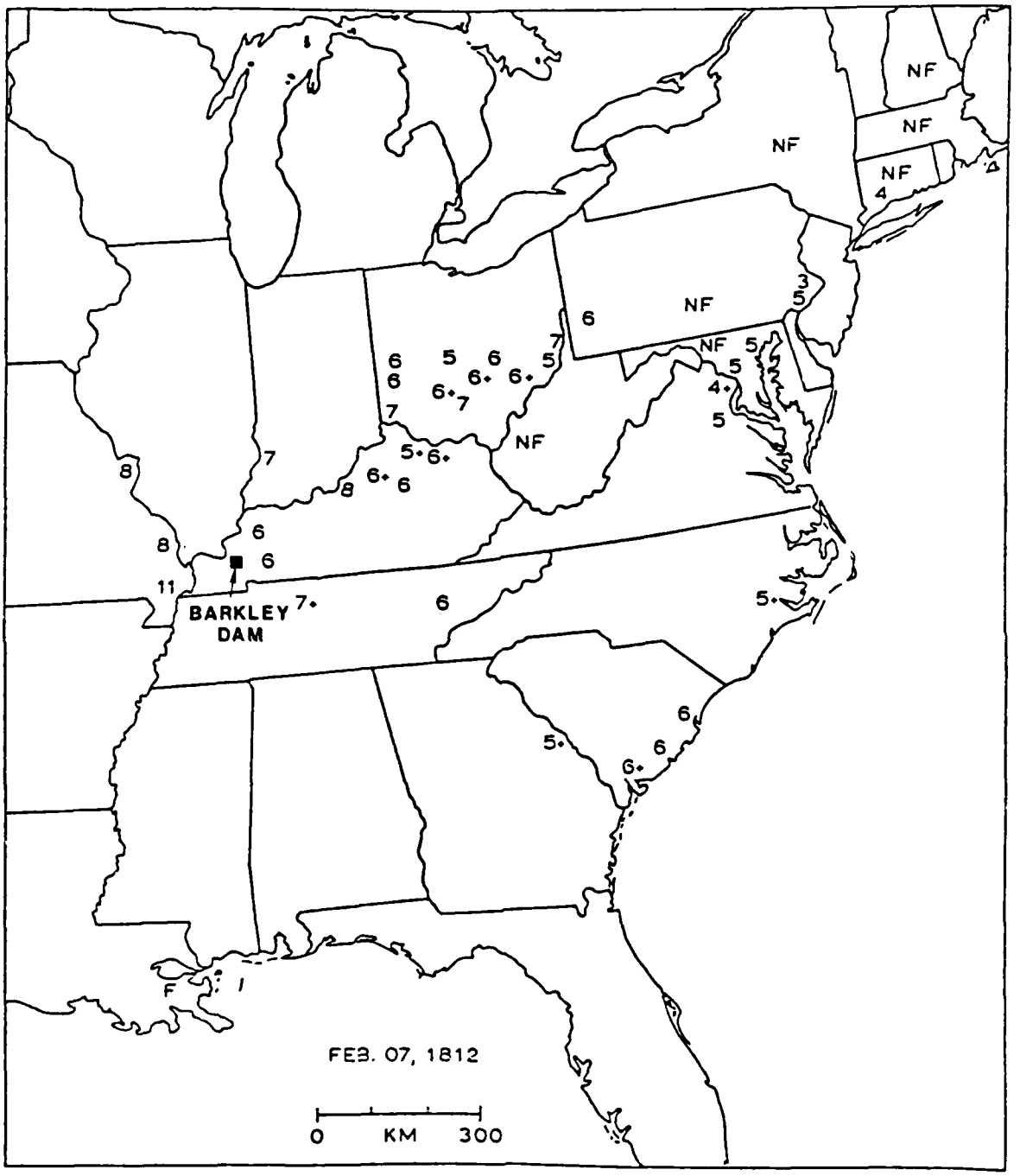

Figure 8. MM intensity data (in Arabic numerals) for the earthquake of 7 February 1812, New Madrid, Mo. (from Street and Nuttli 1984)

Barkley damsite is too conservative. The MM intensity can be reduced to VIII and still be regarded as a conservative value.

23. The causative faults in the New Madrid source zone are becoming identified on the basis principally of their microearthquake activity. Figure 9 shows the accumulated data for the period 1976 to 1982 as reported by Herrmann (1984). There are segments of faults in two directions, northwest-southeast and southwest-northeast. These faults abut each other.

24. The current interpretation of tectonism in the New Madrid area is shown schematically in Figure 10 from Braile et al. (1984). Regional compressive stresses are activating ancient faults in a buried rift which underlies the downwarping of the Mississippi Embayment. Deep seismic profiles together with gravity and magnetic maps, cited by the authors, confirm this interpretation.

25. The boundary of the New Madrid source area, or Zone I, is shown in Figure 9. It fully encompasses the earthquake sensitive area. No changes in the boundary of Zone I are needed.

Zone II

26. A study was made by Hopper and Algermissen (1980) of the Charleston, Mo., earthquake of 31 October 1895 in which they plotted the intensity data and contoured interpreted isoseismal contours. They indicated an MM VII at Barkley damsite for the $m_b = 6.2$ earthquake.

27. The above-mentioned data were plotted by Krinitzsky and Barefoot in 1984 and are shown in Figure 11. An MM intensity of VII was felt at Paducah, Ky. Barkley damsite can be interpreted to be in a zone of MM VI.

28. The Zone II attenuated earthquake with an MM intensity of VIII at the damsite is too conservative. MM VII at the damsite for a Zone II source is indicated.

Zone III

29. The historic data (Stover, Reagor, and Algermissen, 1979) show one MM VI earthquake near the Ohio River. It is located almost at the junction of Indiana, Illinois, and Kentucky. Otherwise, Barkley damsite is in a

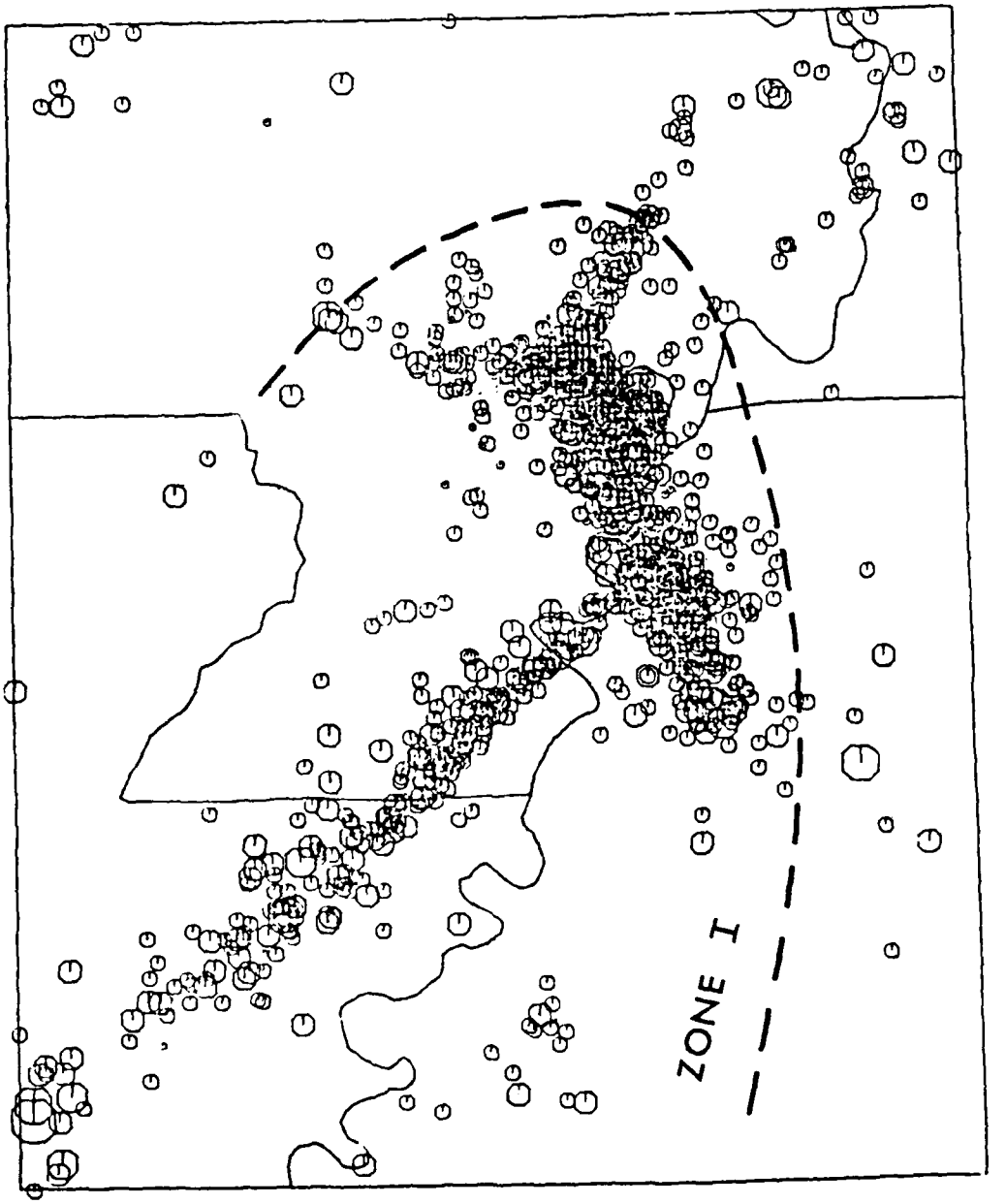

Figure 9. Location of microearthquakes in the New Madrid, Mo., source area (from Herrmann 1984); also shown is the boundary for Zone I of this report

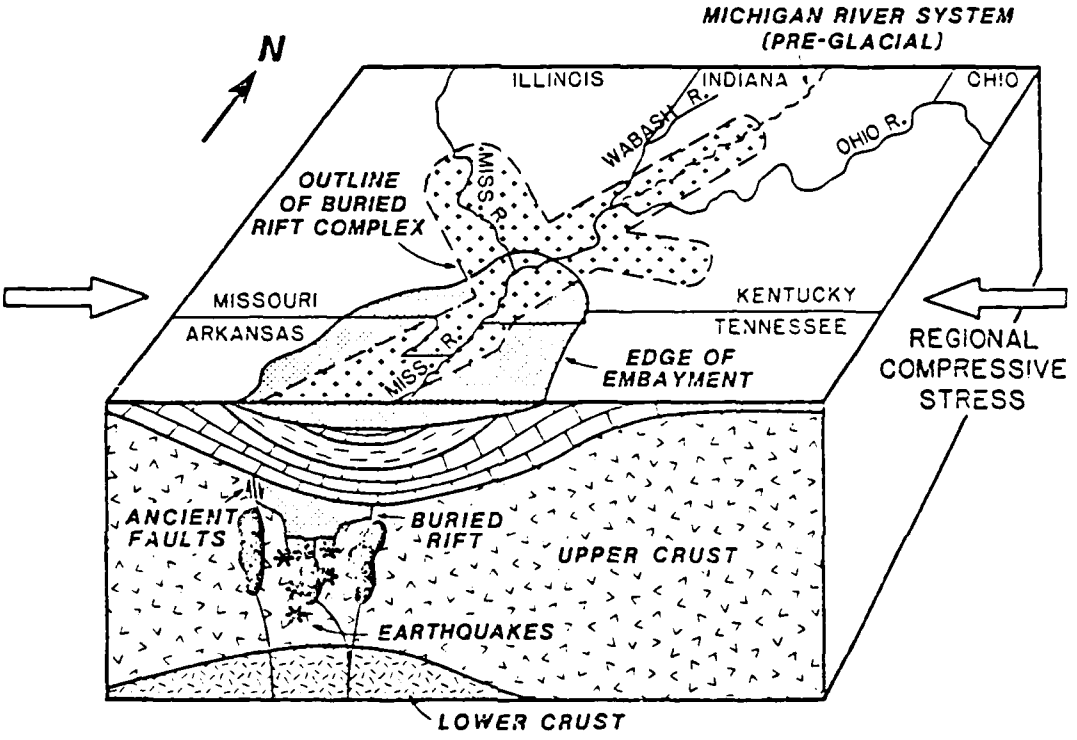

Figure 10. Schematic interpretation of the New Madrid rift complex and the inferred source of earthquakes (Braile et al. 1984)

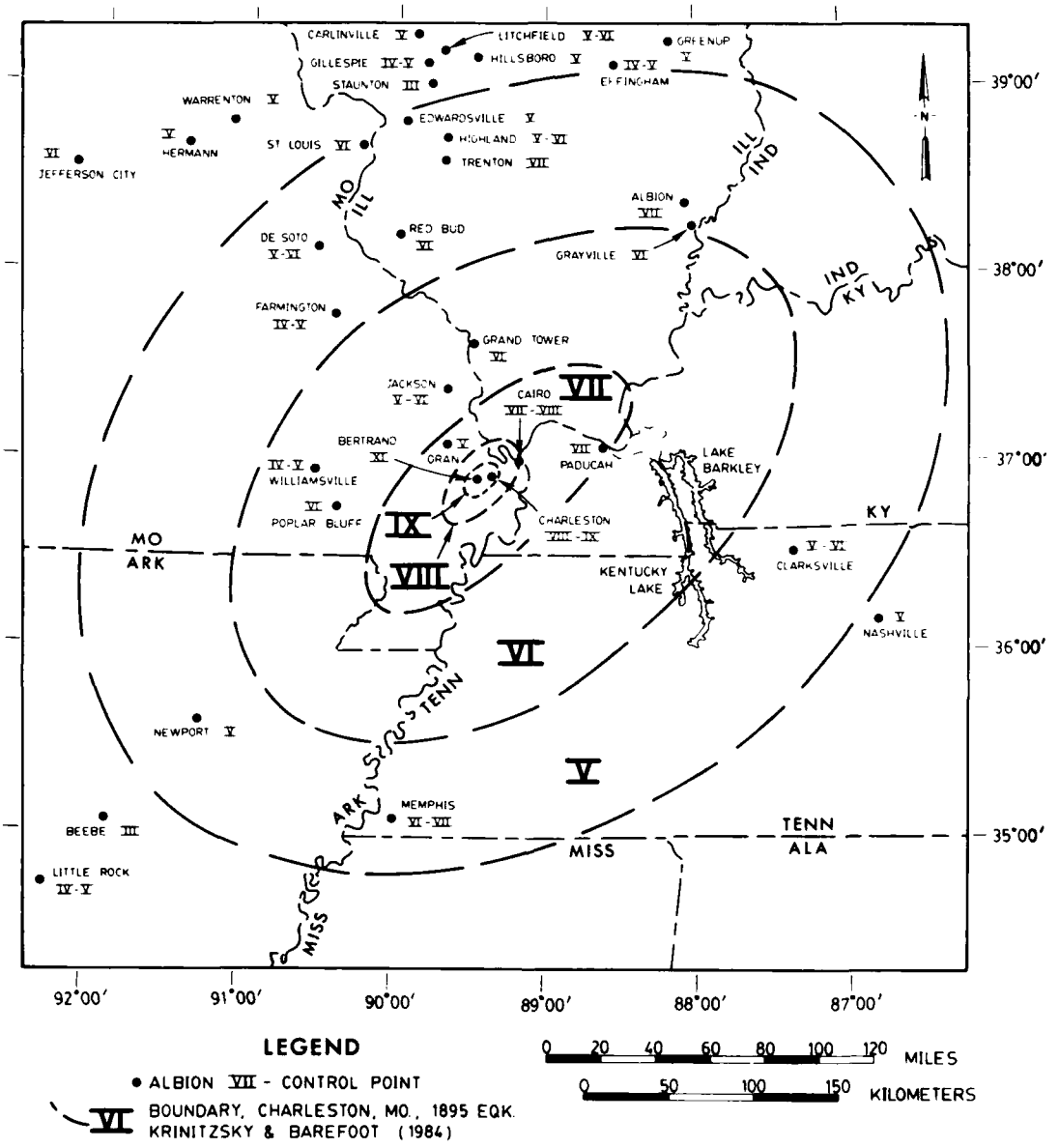

Figure 11. MM intensity contours for the earthquake of 31 October 1895, Charleston, Mo.

relatively aseismic area in which the severest earthquakes were MM V for a period reaching back to 1779. A floating earthquake of MM VI for Zone III is judged to be reasonably conservative.

Zone IV

30. A reexamination of historic intensities (Stover, Reagor, and Algermissen, 1979) shows that the severest earthquakes were MM intensity VII. There have been only two such events over a recorded period that extends back to 1795. It appears that a maximum earthquake of MM VIII is reasonably conservative for this source area.

PART V: REVIEW OF EARTHQUAKE MOTIONS

General

31. The Krinitzsky and Chang (1977) motions for MM intensities which were cited by Leeds and Nuttli have since been updated with the inclusion of additional data from large earthquakes. The new charts were published by Krinitzsky and Marcuson (1983). Figure 12 shows horizontal acceleration, velocity, and duration for MM intensity in the far field for a hard site and a major source earthquake, such as $M \geq 7$. These charts are suitable for an earthquake from Zone I. Figure 13 shows the same relationships except that the source earthquake is moderate with $M \leq 6.9$. The latter is suitable for Zones II and IV. The chart should be used for Zone III, also, though that zone has a floating earthquake that may come to the site. The unlikelihood of an earthquake at the site, in this area of very low seismicity, and the focal depth which should be 12 km or more below the surface, suggests that near field charts would be unnecessarily conservative to use.

32. In addition, Nuttli and Herrmann (1984) have provided charts for the central United States which relate horizontal acceleration (Figure 14) and horizontal velocity (Figure 15) to earthquake body wave magnitude and epicentral distance. Their values are means with a standard deviation of 0.24 at the $m_b = 5.0$ curve. Deviations are not available at other levels nor are there any charts for duration.

Revised Motions

33. Using the reexamined values for MM intensity at the Barkley damsite the following relationships are believed to be conservative:

Earthquake Source	Magnitude m_b	MM I_o	Epicentral Distance km	MM I_s
Zone I	7.5	XI	118	VIII
Zone II	6.5	IX	85	VII
Zone III	5.0	VI	0	VI
Zone IV	6.0	VIII	65	VII

34. Corresponding motions using the charts of Nuttli and Herrmann follow. These are mean values as it is not possible to interpret the dispersion in the data from their presentation.

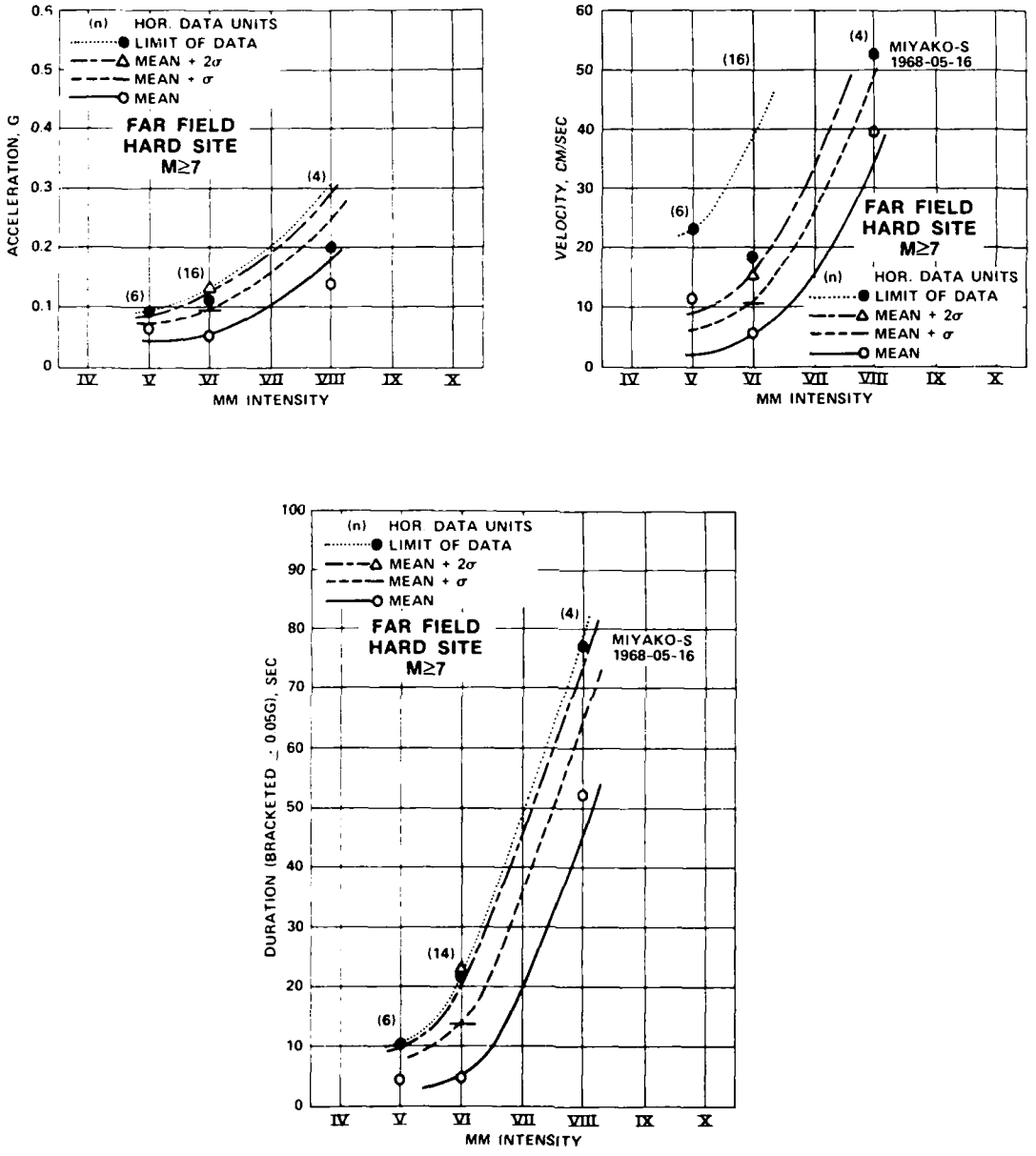

Figure 12. MM intensity-related motions for far-field horizontal acceleration, velocity, and duration for a hard-site and a source earthquake in which $M \geq 7$ (Krinitzsky and Marcuson 1983)

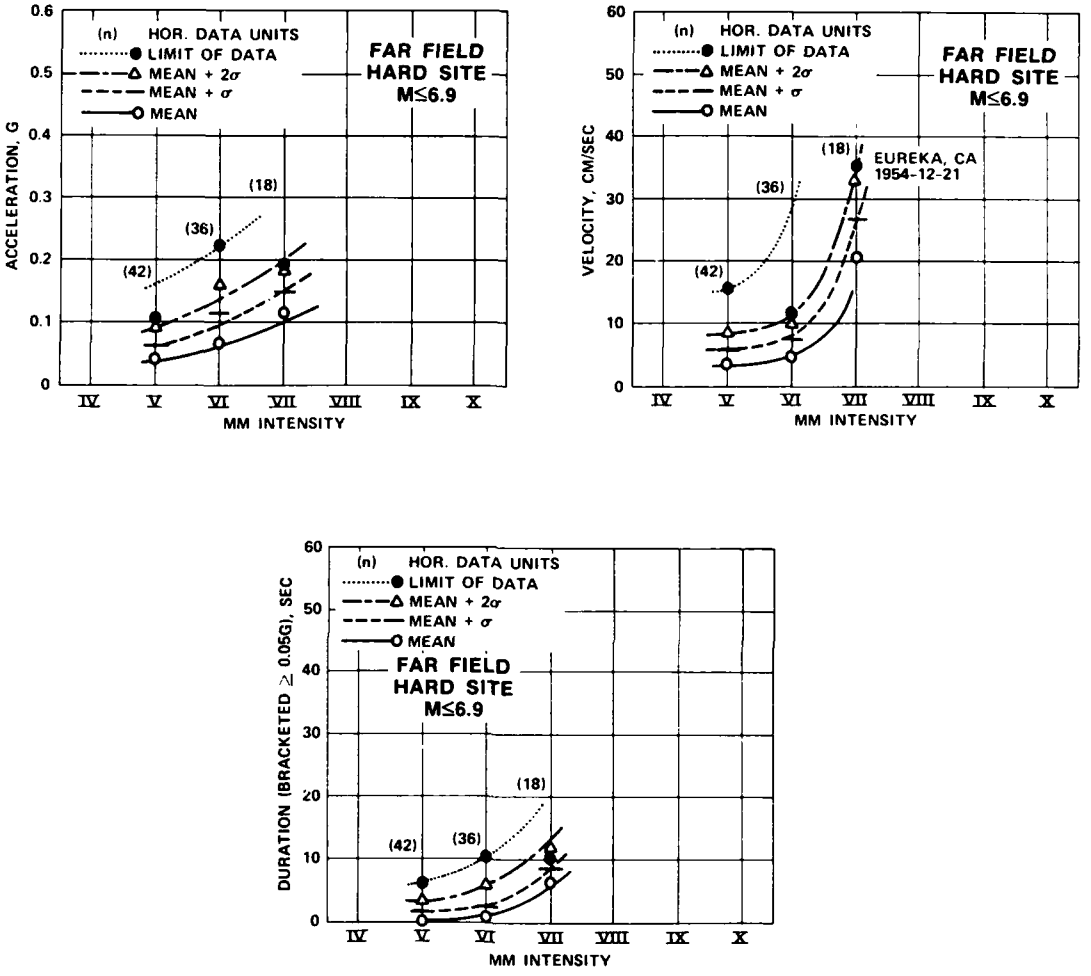

Figure 13. MM intensity-related motions for far-field horizontal acceleration, velocity, and duration for a hard-site and a source earthquake in which $M \leq 6.9$ (Krinitzsky and Marcuson 1983)

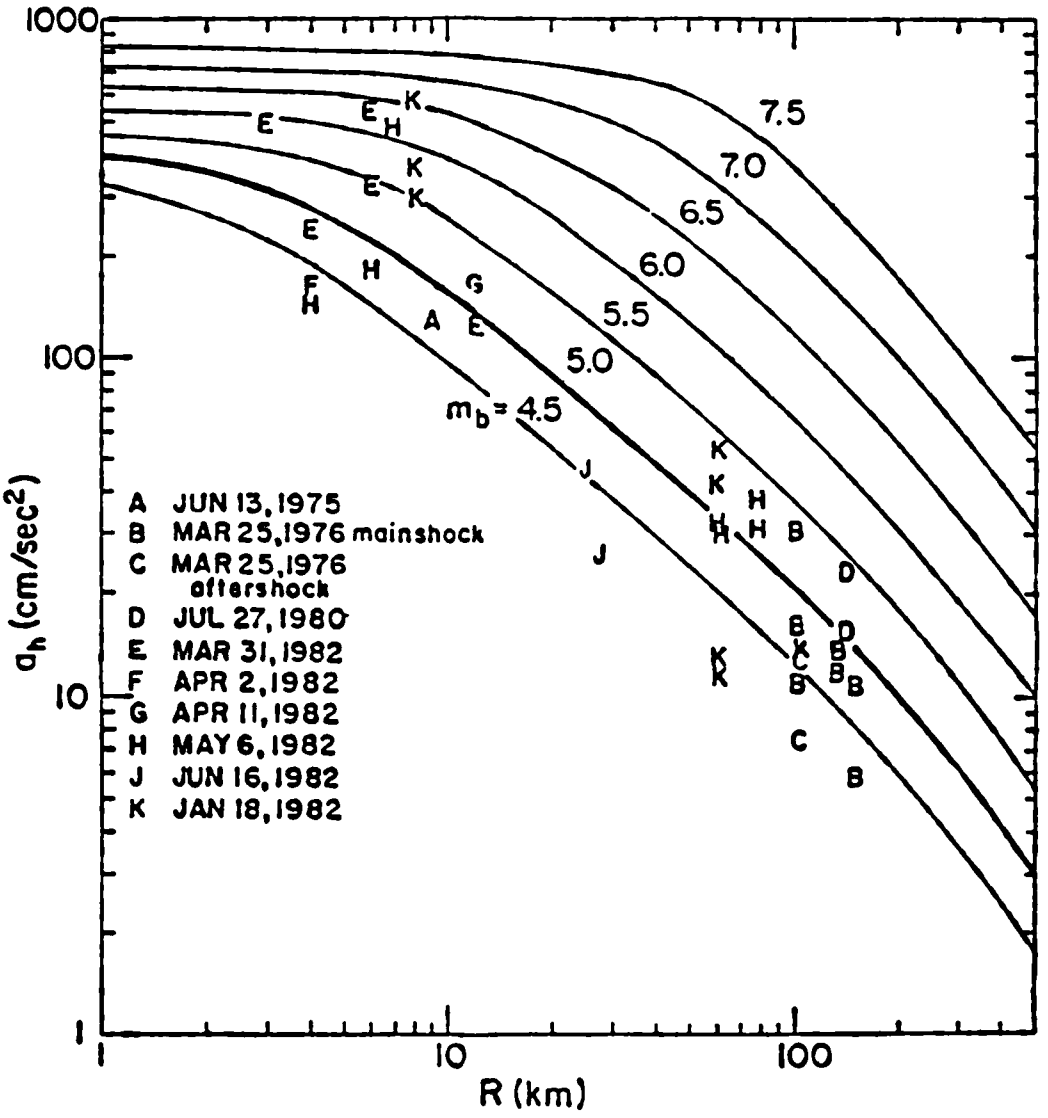

Figure 14. Mean horizontal acceleration for body wave magnitude and epicentral distance. Standard deviation at m_b = 5.0 is 0.24 (from Nuttli and Herrmann 1984)

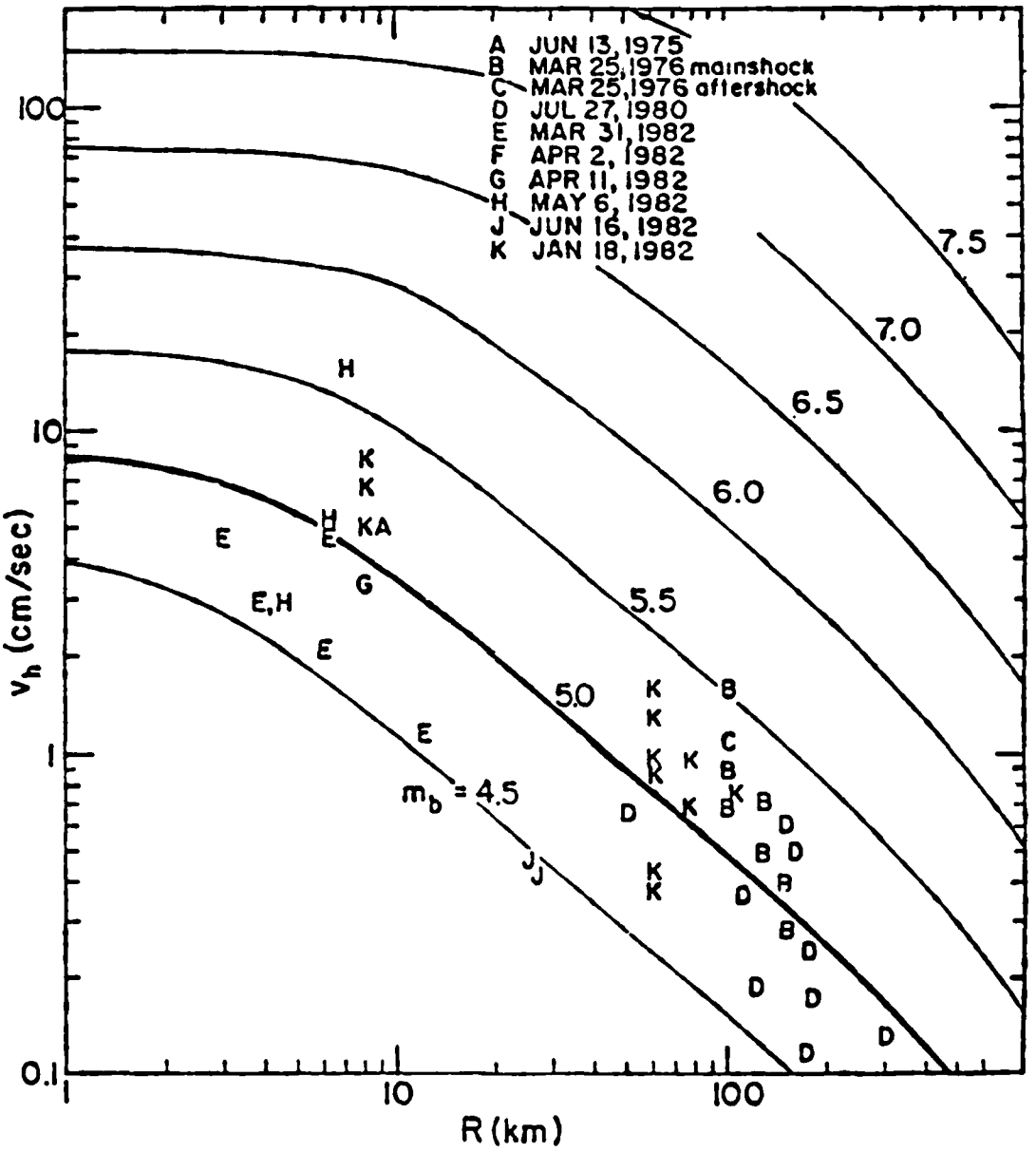

Figure 15. Mean horizontal velocity for body wave magnitude and epicentral distance. Standard deviation at m_b = 5.0 is 0.24 (from Nuttli and Herrmann 1984)

Earthquake Source	Horizontal Acceleration Mean Value g	Horizontal Velocity Mean Value cm/sec
Zone I	0.30	120
Zone II	0.12	18
Zone III	0.40	8
Zone IV	0.09	18

35. Motions using the Krinitzsky and Chang charts (Krinitzsky and Marcuson 1983) are

Earthquake Source	MM I_s	Horizontal Acceleration Mean + σ g	Horizontal Velocity Mean + σ cm/sec	Duration, ≥ 0.05 g Mean + σ sec
Zone I	VIII	0.25	49	64
Zone II	VII	0.15	27	8
Zone III	VI	0.09	8	3
Zone IV	VII	0.15	27	8

36. There is good agreement between Nuttli and Herrmann and Krinitzsky-Chang for accelerations for sources in Zones I, II, and IV. The high acceleration of 0.40 for Nuttli-Herrmann's Zone III is a close-in, high spike or high frequency component for a small earthquake. It would also be low energy. The lower value given by Krinitzsky-Chang postulates no event occurring directly at the dam and assumes that the high frequency spike will not be registered at the dam. It should be noted, however, that the Nuttli-Herrmann values are means and Krinitzsky-Chang's are mean + σs. In the velocities, there is a reasonable agreement for Zones II to IV between Nuttli-Herrmann and Krinitzsky-Chang, considering that Nuttli and Herrmann's are mean values and they are being compared with mean + σ. The velocities for a Zone I source, however, are totally disparate, being about 120 cm/sec as compared to 49 cm/sec. The writer spoke with Professor Nuttli concerning this disparity. Professor Nuttli said that he agreed to the motions used for the scaled Santa Barbara record as referred to earlier.* Professor Nuttli added, "We feel confident about extrapolation up to m_b = 6.5. Beyond that, curves need to be tested against data for large magnitude earthquakes."

* Personal communication, 29 June 1984.

PART VI: CONCLUSIONS

37. The region in which Barkley dam is located was divided into four seismic source zones. Zone I is the area in which a New Madrid earthquake may occur, Zone II is an area peripheral to the New Madrid zone and in which a lesser earthquake may occur, Zone III is the residual area with the least seismicity, and Zone IV is the seismically active area of southern Illinois. Motions were assigned at the Barkley damsite from maximum earthquakes in each of those zones.

38. Zone I, the New Madrid source, was postulated to provide the severest earthquake shaking at Barkley damsite. Zone I is capable of generating a maximum earthquake of m_b = 7.5 and an MMI_o = XI. Attenuated 118 km from source to damsite, the I_s = IX. The I_s was subsequently reduced to MMI = VIII based on more recent examination of the intensity data for the New Madrid earthquakes of 1811-1812.

39. A test earthquake was arrived at which used a scaled Santa Barbara record for the 1952 Kern County, Calif., earthquake. The record was scaled to horizontal peak values of an acceleration at 0.24 g, a velocity at approximately 35 cm/sec, and a duration of approximately 60 sec. An updating of data for intensity versus motion shows that the values are justified today on the order of acceleration at 0.25 g, a velocity at 49 cm/sec, and a duration ($\geq$0.05 g) of 64 sec. These values are so reasonably close to those for the test earthquake that no changes are deemed necessary.

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APPENDIX A

EARTHQUAKES AND GEOLOGY OF THE BARKLEY DAM AREA IN RELATION TO THE NEW MADRID EARTHQUAKE REGION TO 1977

by

Dr. Richard G. Stearns
Vanderbilt University
Nashville, Tennessee

WITH SUPPLEMENTARY EARTHQUAKES TO 1981

by

Dale E. Barefoot
Waterways Experiment Station
Vicksburg, Mississippi

EARTHQUAKES AND GEOLOGY OF THE BARKLEY DAM AREA IN RELATION TO THE NEW MADRID EARTHQUAKE REGION

INTRODUCTION

This report is mainly directed toward earthquake history of the region, locations and time of movement (if known) of faults, and the main tectonic elements affecting the northeast part of the New Madrid earthquake region in Mesozoic to Recent geologic time. Its purpose is to present relevant information and relate geology and earthquake occurrences, so as to zone the northeast portion of the New Madrid Earthquake area nearest Barkley dam (Plate 1).

The earthquake area is divided into three zones. The dam is in Zone III, the area of smallest earthquakes. Historically VII earthquakes have originated only at and west of the Lower Mississippi and Ohio Rivers, but attenuated effects of larger earthquakes farther west have equaled or exceeded this intensity in Zone III near the dam. Intensity VII shaking would therefore have to be anticipated at some time, but the epicenter probably will be far west or southwest of the dam. Zone III is separated from Zone II mainly on the basis of geology. In Zone II intensity XI earthquakes occurred in 1811-12 and probably will occur again sometime. Zones I and II are separated on the basis of historic earthquake occurrence since 1812 (Plate 1) and micro-earthquake records over a recent 3 year period (Plate 2).

EARTHQUAKE HISTORY

A report is presented in the appendix locating and describing all earthquakes since 1699 known to have occurred in the area of interest. Included with the appendix is a series of isoseismal maps showing lateral intensity patterns from several earthquakes. Probably the earliest 1811-12 series maps are the most important of these, because a great earthquake having an epicentral intensity greater than about IX has not occurred since 1812.

A map showing the intensity and location of epicenters is also presented (Plate 1) for an area from 36 to 38° latitude and 86 to 90° longitude. This map displays the large number of earthquakes to the west near and beyond the Mississippi River, contrasted with the earthquake epicenters in the rest of the region shown. Higher intensity (VII +) earthquakes occur to the west, but none are recorded to the east. A special compilation of microearthquakes detected by the St. Louis University seismic net is also presented (Plate 2). This shows a great concentration of microearthquakes west of, and running roughly parallel with the Mississippi River in Arkansas and adjacent to Missouri, with a concentration extending across the Mississippi River a few miles between Dyersburg and Reelfoot Lake in northwest Tennessee. This swarm of earthquakes could well mark the most active area from which dangerous earthquakes are likely to originate. Earthquake locations on these two plates are a basis for drawing earthquake zone limits.

A table of earthquakes felt in the vicinity of the dam follows. Most originated in the New Madrid area.

TABLE 1

List of Earthquakes Felt in the Vicinity of Barkley Dam

Date	(Isoseismal Map if in This Text)	MM Intensity Estimate in Vicinity of Dam	Location of the Epicenter
1811, December 16	(Fig. 3)	VII (VIII felt SE of Dam just as far from the epicenter)	36°, 90°; N.E. Arkansas near the Missouri border
1812, January 23	(Fig. 4)	About VI	36.4°, 90°; SE Missouri in "bootheel"
1812, February 7		VI	36.3°, 89.9°; SE Missouri in "bootheel"
1843, January 4	(Fig. 5)	V-VI	35.5°, 90.5°; NE Arkansas
1849, March 12		Felt slightly	36.6°, 89.2°; Hickman, Ky.
1857, October 8	(Fig. 6)	III-IV	38.7°, 89.2°; South-central Illinois
1865, August 17		Felt, probably IV or less	36.7°, 89.5; Mississippi Valley
1878, November 18-19		Felt, maybe V	36.0°, 89.7°; SE Missouri
1883, January 11		Felt slightly	37.0°, 89.2°; Near Cairo, Illinois
1886, August 31		IV-VI	32.9°, 80.0°; Charleston, South Carolina
1887, August 2		Felt, about III-IV	37.0°, 89.2°; Cairo, Illinois
1895, October 31	(Fig. 7)	VI-VII	36.9°, 89.4°; Charleston, Missouri
1903, November 4		Probably Felt	36.9°, 89.3°; SE Missouri
1905, August 21		Felt, probably V or less	36.9°, 89.6°; Sikeston, Missouri
1909, September 27		Probably Felt slightly	39.5°, 87.4°; Wabash Valley, Indiana
1915, December 7		Felt, probably IV or less	37.0°, 89.2°; Cairo, Illinois
1917, April 9	(Fig. 8)	III	38.1°, 90.2°; Ste. Genevieve, Missouri
1922, March 23		Felt, probably about III	36.9°, 88.8°; Paducah-Mayfield-Columbus, Ky.
1922, November 26		Felt, probably about III or IV	37.8°, 88.5°; Southern Illinois

TABLE 1 Continued

Date	(Isoseismal Map if in This Text)	MM Intensity Estimate in Vicinity of Dam	Location of the Epicenter
1924, March 2		Felt slightly	36.9°, 89.1°; Cairo, Illinois
1925, September 2		Felt, probably IV or less	37.8°, 87.6°; Henderson, Kentucky
1934, August 19	(Fig. 9)	II	36.9°, 89.2°; Rodney, Missouri
1955, January 25	(Fig. 10)	Maybe barely felt	36.0°, 89.5°; Finley, Tennessee
1962, February 2	(Fig. 12)	III-IV	36.5°, 89.6°; Catron, Mo.
1963, March 3	(Fig. 13)	IV or less	36.7°, 90.1°; Southeast Missouri
1965, October 20	(Fig. 14)	Felt, probably I-III	37.5°, 91.1°; Centerville, Missouri
1968, November 9	(Fig. 15)	V	38.0°, 88.5°; Hamilton County, Illinois
1976, March 24	(Fig. 16)	II-IV	35.6°, 90.5°; Northeast Arkansas

Note - This list is essentially complete since 1878. A significant number of earthquakes before that time probably occurred but are not known.

GEOLOGY

Tectonic Elements

The main tectonic elements of the region are of two groupings. First, the surficial divisions which are the Mississippi Embayment of the coastal plain and the surrounding plateaus (Fig. 1). The buried, or partly buried larger divisions, are the Pascola arch to the southwest and the southern extension of the Illinois basin (Fig. 2).

The Mississippi Embayment

The Mississippi Embayment trough is a southwest-plunging syncline filled with Cretaceous and Eocene unconsolidated sediment. These deposits are thickest (about 2,000 feet*) to the southwest along the Mississippi River, and thin to zero a few miles west of the dam. At the limits of the embayment to the north and east are upper Cretaceous sands and clays. The approximate limit of these sediments is presented on the fault map (Plate 3) because at this boundary most faults (cutting older rocks outside the coastal plain) stop, showing that they have mostly not moved since the Cretaceous sediments buried them about 60 million years ago. A few faults cut through to the surface showing some movement in places since Eocene and even early Pleistocene time.

The Pascola Arch

The Pascola arch lies buried beneath the coastal plain (Fig. 2). Its crest crosses the Mississippi River at about 36° 15' latitude, and its north flank (-2,000 foot contour

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

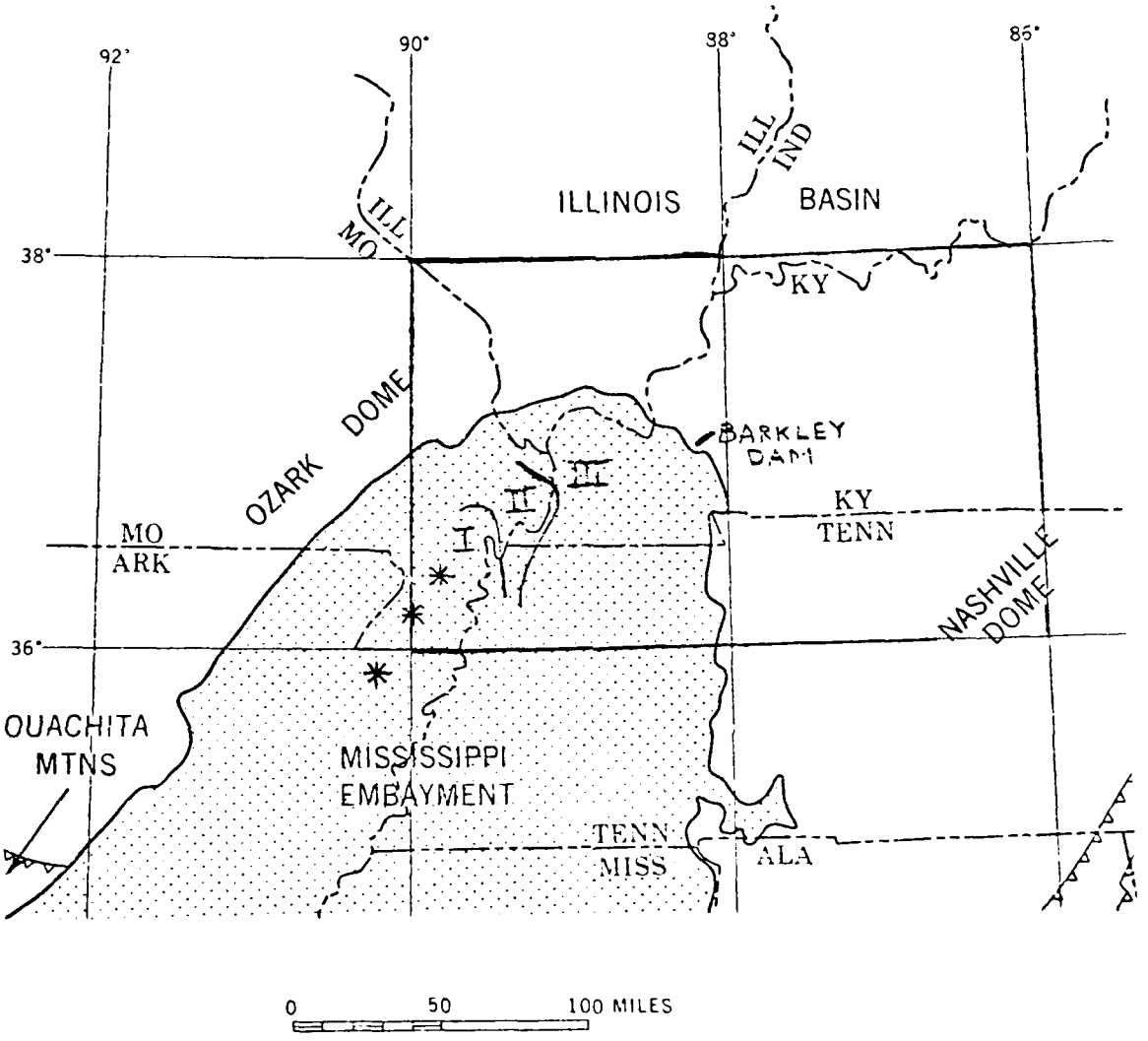

Figure 1 - Regional setting showing Mississippi Embayment (stippled area), the approximate locations of the 3 great earthquakes in the 1811-1812 series and the zone boundaries. The area of compilation of earthquake history and faults is also drawn

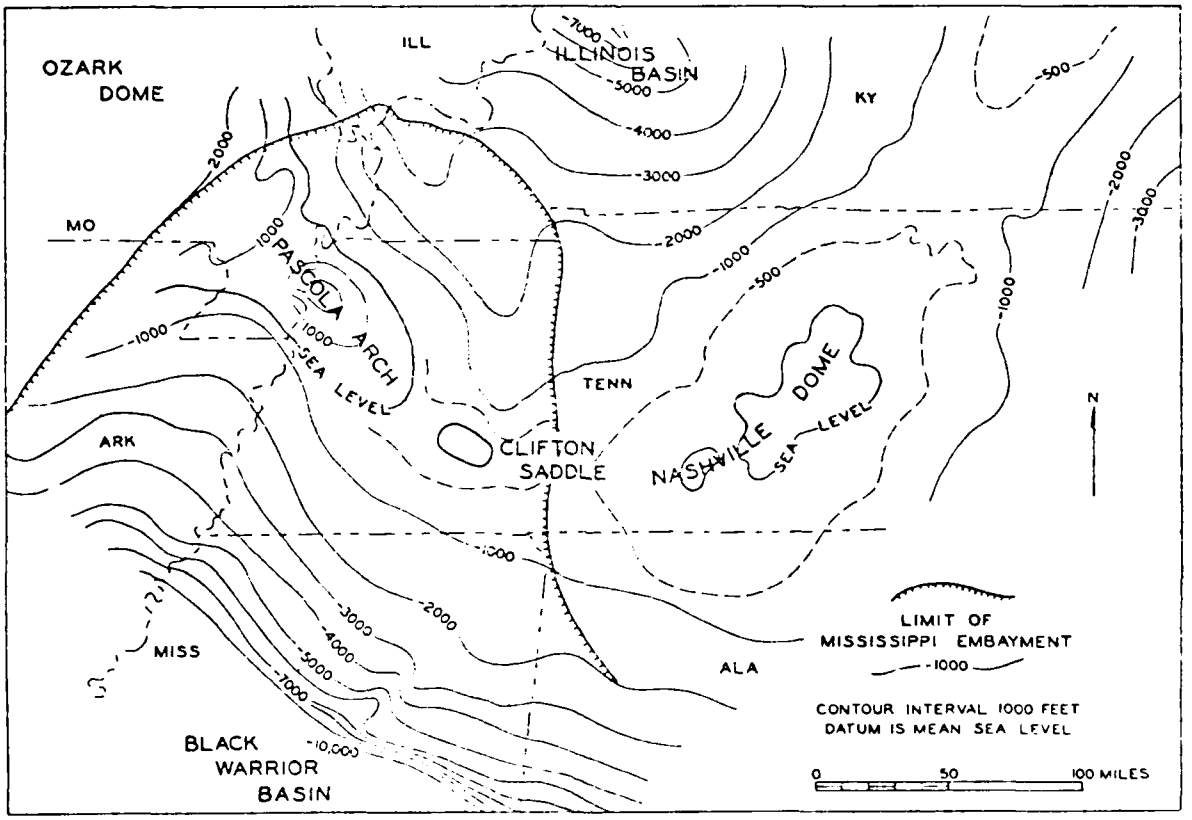

Figure 2 - Present Paleozoic structure as shown by configuration of the top of the Knox Dolomite. (From Stearns and Marcher 1962, Fig. 2)

line on Fig. 2) crosses the Mississippi River at about 36° 47' latitude. This feature has undergone large vertical movement. In late Paleozoic to Mesozoic time it was uplifted more than 10,000 feet, but since the Cretaceous has been depressed again about 4,000 feet with maximum subsidence near the Mississippi River. The area of maximum vertical movement, particularly the latest depression is the approximate place of origin for the 1811-1812 great earthquakes, and this coincidence is believed to be significant.

Faults (Plate 3)

Faulting is prominent in the region, and the outcropping faults are drawn on Plate 3.* At least a few faults occur at the

*Sources for the fault data on Plate 3 are as follows:

For Illinois

Heyl, A. V., Brock, M. R., Jolly, J. L., and Wells, C. E., 1965, Fault map of the Paducah Quadrangle in "Regional Structure of southeast Missouri and Illinois-Kentucky mineral districts." U. S. Geol. Surv. Bull. 1202 B., scale 1:250,000.

For Kentucky

Schwalb, H. R., Wilson, E. N., and Sutton, D. G., 1971, Oil and gas map of Kentucky, sheets 1 and 2, Ky. Geol. Surv. Univ. of Ky., Series X, scale 1:250,000.

Hayes, W. H., 1964, Geology of the Grand Rivers Quadrangle, Kentucky. U. S. Geol. Surv. Quad. Map, GQ-328, 1:24,000.

Amos, D. H. and W. I. Finch, 1968, Geologic map of the Calvert City Quadrangle, Livingstone and Marshall Counties, Kentucky, U. S. Geol. Surv. Quad. Map, GQ-731.

Lambert, T. W. and L. M. MacCary, 1964, Geology of the Briensburg Quadrangle, Kentucky. U. S. Geol. Surv. Map. GQ-327.

Fox, K. F., Jr. and W. W. Olive, 1966, Geologic Map of the Birmingham Point Quadrangle, Western Kentucky, U. S. Geol. Surv. Quad. Map, GQ-471.

For Missouri

McCracken, Mary, 1971, Structure map of Missouri, Mo. Geol. Surv. and Water Resources.

For Tennessee

Hardeman, W. D. and others, 1966, Geologic map of Tennessee, Tenn. Div. Geol. West Sheet and West Central Sheets, scale 1:250,000.

surface throughout the region, but they are most abundant in areas where old (Paleozoic) rocks crop out. Although most faults have been inactive since late Paleozoic or early Mesozoic time, some are known to have been active since the high level alluvium was deposited in early Pleistocene or late Pliocene time. The time of faulting relative to geologic formations (from the Cumberland River southwestward) is indicated by a note next to the traces of the faults for which this information is known. Faults in the vicinity (within about 10 miles) of Barkley Dam are not known to have moved later than early Pleistocene and many are pre-Cretaceous.* About 25 miles southwest of the dam some faults are known to offset the high level ancient alluvium but are there in turn buried by Pleistocene loess. The youngest faults that offset Pleistocene loess and even Recent alluvium occur along and in the Mississippi River Alluvial Plain and their closest known occurrence is about 58 miles west of the dam.

The zone of Recent faulting, where it crosses the buried Pascola arch makes the east limit of the area in which dangerous earthquake shaking can originate. Within this area danger is probably greater toward the south (high on the flanks and on the crest of the buried Pascola arch).

*Strictly speaking many faults near the dam offset Paleozoic rocks but are not buried by anything but soil. The last time these faults moved cannot be determined. It is believed that those that do cut through or are buried by post-Paleozoic rock are a sufficient sample to indicate age of faulting for the others.

Geologic Rock Units

Geologic rock units that occur throughout the region from Barkley Dam to the New Madrid area and are most important in dating faults are as follows from youngest to oldest:

Recent alluvium most of which was deposited in the last 10-15,000 years or so. This material is not known to be disturbed by faulting closer to Barkley Dam than the area just west of Reelfoot Lake in extreme NW Tennessee (this area will be included in Earthquake Zone I).

Loess is Pleistocene in age and most was probably deposited long before 10,000 years ago. This material is widely deposited across the region between Barkley Dam and the Mississippi River. It buries many faults that cut the next oldest geologic unit showing that fault movement stopped in mid Pleistocene or earlier time.

High level continental alluvium ("Lafayette Formation"). This material was deposited in early Pleistocene or Pliocene (?) time. Its age is hundreds of thousands to millions of years. It buries many faults in the vicinity of Barkley Dam, but is disturbed by faulting about 10 miles to the west.

A stratigraphic chart showing the formations in the vicinity of the dam is given below.

STRATIGRAPHIC CHART SHOWING
THE GEOLOGIC COLUMN IN THE
VICINITY OF BARKLEY DAM

Age	Formation of Group Name (Authority)	Rock Type	Approximate Thickness	Approximate Cumulative Under Reservoir
Recent and Pleistocene(?)	Alluvium (fills valley bottoms) (1)	Unconsolidated silt, clay, sand and gravel; mostly silt.	Variable 0-90 feet	about 50 (Actual drill records should be consulted for an accurate thickness if needed)
Pleistocene	Loess (mantles upland) (1)	Silt	0-7 feet	
Pleistocene and Pliocene(?)	Gravel (1)	Unconsolidated gravel and sand	Variable 0-60+	
Cretaceous	McNairy and Tuscaloosa formations (1)	Unconsolidated sand Weakly consolidated gravel	Variable 0-150 or more	
Mississippian	Upper St. Louis and 150 feet or so of the Lower Member (above reservoir in upland nearby & beside Alluvium next to valley) (1)	Limestone	About 300 feet crops out	
	Buried Lower St. Louis, Salem and Warsaw Limestones (1)		About 410-440	450-590
	Fort Payne Formation (2), (3)	Cherty limestone	About 600	1050-1090

CHART (Cont'd)

Age	Formation of Group Name (Authority)	Rock Type	Approximate Thickness	Approxomate Cumulative Under Reservoir
Devonian	Chattanooga Shale (3)	Black shale	More than 100 perhaps 150 feet	About 1200
Devonian	Clear Creek & Bailey (4)	Cherty limestone	about 500 feet	1700 feet
Silurian	Decatur Ls (4)	Limestone		
	Brownsport Fm. (4)	Limestone & shaly LS		
	Louisville Ls. (4)	Limestone		
	Waldron Shale (4)	Shale		
	Laurel Ls. (4)	Limestone		
	Osgood Fm. (4)	Limestone		
	Brassfield Fm. (4)	Cherty Limestone	300 feet	2000 feet
Ordovician (4)	Maquoketa Shale (4)	Shale	about 300 feet	2300 feet
	Kimmsick Ls (4, Plattin Ls (4), Dutchtown & Joachim Formations (4)	All limestone	Ordovician below Maquoketa including Upper Knox is about 4200 feet	
Ordovician (4)	Upper Knox Dolomite (4)	includes Dolomite; also sandy & cherty limestone & dolomite		6500 feet

CHART (Cont'd)

Age	Formation of Group Name (Authority)	Rock Type	Approximate Thickness	Approximate Cumulative Under Reservoir
Cambrian	Lower Knox Dolomite	Includes various formations similar to the Ordovician (?)	about 1300 feet	7800 feet
	Bonterre/Dolomite (4)	Dolomite & hard shale	about 1500 feet	9300 feet
	Lamotte Sandstone & older sediments (4,5)	Dolomitic & limy hard sandstone & siltstone	about 3000 feet thick	about 12,500 feet (5)
Precambrian	Basement (5)	Hard igneous & metamorphic rock		

(1) Hays, Wm. R., 1964, "Geology of the Grand Rivers Quadrangle, Kentucky," U. S. Geol. Surv. Map GQ-328.

(2) Lambert, T. W., and MacCary, L. M., 1964, "Geology of the Briensburg Quadrangle, Kentucky," U.S. Geol. Surv. Map GQ-327.

(3) Amos, Dewey, and Finch, Warren I., 1968, "Geology of the Calvert City Quadrangle, Kentucky," U.S. Geol. Surv. Map GQ-731.

(4) Schwalb, Howard R., 1969, "Paleozoic Geology of the Jackson Purchase Region, Kentucky," Ky. Geol. Surv. Series X, Rept. Inv. No. 10.

(5) Buschbach, T. C., 1977, "Top of Precambrian Basement," work map, scale 1:1,000,000 New Madrid Study Group.

REGIONAL GRAVITY PATTERN

Tectonic features are associated with lateral variations in rocks at depth. Ancient features, such as those developed in Paleozoic or Precambrian time though long inactive, still show strongly on geophysical maps. Gravity patterns (Hildenbrand and others, 1977)* is presented as an example (Plate 4). This map covers the area from 88° to 90° longitude and 36° to 38° latitude. Barkley Dam is on the east center side of this map and the New Madrid earthquake area is to the west and south.

The most striking pattern is the series of northwest-trending anomalies covering most of the mapped area to the northeast. The boundary of this area is believed to be significant as the north flank of the Pascola arch has the same trend and approximately follows this boundary, and the intersection of the Pascola arch and the Mississippi Embayment trough axis is the area from which dangerous earthquakes have come in the past. These are ancient features; even in areas of abundant faults, few are parallel to these anomalies, a notable exception is the Ste. Genevieve fault system to the northwest.

This area is bounded on the southwest by a line beginning on the east edge of the map at about 36° 15'; from there it extends northwestward crossing the 89° longitude line at about 36° 45';

*Hildenbrand, T. G., Ervin, C. P., Hendricks, John, Keller, G. R., McGinnis, L. D., and Stearns, R. G., "Bouguer gravity map of the northern Mississippi Embayment, parts of Missouri, Arkansas, Tennessee, Kentucky, and Illinois", U.S.G.S. Open File Report 77-228, 1977.

it crosses the 37° latitude line at about 89° 15'; and the 90° longitude line at about 37° 30'. The area continues north and east beyond the map. Barkley Dam is within this area of northwest-trending anomalies and its boundary described above is about 55 km southwest of the dam at its closest point.

South of this boundary a northeast trend dominates. This reflects the Precambrian Reelfoot rift whose ancient east margin trends northward beginning at the bottom center of the map. This northeast trend is roughly parallel with the present microearthquake trend (Plate 2). West of the Mississippi River the northwest-trending zero milligal contour line is approximately the boundary traced above, and it is also the northeast limit of the micro seismic area on Plate 2.

ZONATION OF THE NE SIDE OF THE REELFOOT SEISMIC AREA

General

The zone boundaries are drawn on the basis of surface geology (faults), deeper geology (buried pre-Cretaceous Pascola arch), and historic seismic data including the microearthquakes from the St. Louis Net. Zones are I, II, (IV)* and III, from highest to lowest intensity. The Zone II-III boundary is mainly geological; the Zone I-II boundary is mainly based on the historic earthquake record (as is the boundary between III and IV).*

Zones I, II, III, and IV

Zone I is the area where high intensity earthquakes can originate; intensities are likely to be up to XI (and magnitude could exceed 7.0).** Zone II is that area in which earthquakes with intensities up to IX could originate (and magnitude could be greater than about 6.0). Zone III includes all the exterior region east and northeast of Zone II within which earthquakes could originate with intensities up to VII (and magnitude up to about 5.0). Zone IV is an intermediate intensity area, perhaps somewhat like but less than Zone II. In this zone earthquakes with epicentral intensity of about VII and a magnitude of about 5.7 could occur.* The boundaries are defined below from lowest to highest earthquake intensities, and they are drawn on Plate 1.

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* Zone IV-III boundary was drawn by O. W. Nuttli (personal communication) from earthquake data, much of which is north of the area of this compilation.

** Magnitude estimates are derived from those assigned by Nuttli (1974, 1976) to particular earthquakes biggest for the zones, as for example Feb. 7, 1812, Oct. 31, 1895.

Zone Boundaries

The Zone II-III boundary is drawn to include the lengthy faults near the Mississippi Embayment syncline axis along the Mississippi River (Plate 3). Its northern limit is the north flank of the Pascola arch west of the Mississippi River; it crosses the Mississippi River trending northwestward at Columbus, Kentucky (about 36° 47' latitude); from there it trends nearly due south to a point about 4 miles east of Hickman Ky.; from there it trends southwestward just east of the northeast-trending fault. It follows the Mississippi River bluffs southwestward to about latitude 36° 15' where it turns south.

The Zone I-II boundary is mainly based on records of historic earthquakes, but Zone I also includes faults in the Mississippi River alluvial plain that have demonstrably been active in the last few hundred or few thousand years. Zone I includes the swarms of microearthquakes detected by the St. Louis University net and its north and east boundary is drawn on Plate 2. The boundary extends northward from 3 miles N.E. of Bogota, Tennessee, across the west edge of Reelfoot Lake past a point 5 miles east of New Madrid, Missouri, curving slightly westward to cross US I-55 about 8 miles south of Sikeston, Missouri where it trends westward. This boundary is about 25 miles east and north of the epicenter of the northmost and perhaps greatest (Feb. 7, 1812) earthquake of the great New Madrid series as located on Plate 1.

CHRONOLOGICAL LIST AND DESCRIPTION OF SIGNIFICANT EARTHQUAKES AROUND BARKLEY DAM

Area of Coverage

This earthquake history includes all earthquakes known to have occurred in the area from 36 to 38° N latitude and 86 to 90° W longitude. It includes the Mississippi Valley downstream from Ste. Genevieve, Missouri and the Ohio and Cumberland valleys downstream from Louisville, Kentucky and Nashville, Tennessee. In this area is most of the New Madrid earthquake region nearest the dam.

Significant earthquakes outside the main area of interest have been included. These are larger earthquakes known or suspected to have been felt in the vicinity of the dam.

Emphasis on Intensity Data

The two reasons to emphasize intensity data for the entire record down to the present are the nature of historic data and isoseismal maps which show lateral effects. Before 1930 experience and damage reports constitute the record, so the 280 year record has only 50 years of instrumental data. Even today isoseismal maps are used to present the pattern of lateral effects. Because the main earthquake danger to places outside the high intensity earthquake zones (such as the area near Barkley Dam) are such lateral effects, intensity data are especially meaningful.

Isoseismal Maps

Isoseismal maps present the lateral effects of earthquakes. Before seismographs were used in this area (about 1930) such maps were a main means of estimating the location of earthquake epicenters, and up to the present they are the main means of presenting the pattern of lateral effects through variation in intensity. Fourteen isoseismal maps are presented herein.

Time and Completeness of Coverage

All known earthquakes since 1699, and up through 1976 have been included. A few in 1977 are also included. As records are searched, more earthquakes are continually being discovered, so future lists will undoubtedly include earthquakes not in this chronology.

Sources of Data

A previous chronology (through 1968) compiled by the writer and C. W. Wilson, Jr. (1972) was used as a start for this list. Events recopied from that chronology are not individually referenced herein. Data sources for that chronology are compiled in the annotated bibliography in Stearns and Wilson (1972). Sources for additions and corrections for that chronology are individually cited in this text.

A main source of data are publications of the U. S. Coast and Geodetic Survey, N.O.A.A. and U.S.G.S. in "United States

Earthquakes." This report is issued each year, and in addition reports called "Earthquake History of the U.S." published periodically compile lists including previously unlisted events. At the time of this compilation, the most recent year published for "U.S. Earthquakes" is 1974 and the most recent history is complete through 1970.

An important source of new and detailed data in the New Madrid earthquake area are quarterly reports by St. Louis University (Stauder and others) listing events detected by an array of sensitive seismographs set in and near the Missouri bootheel. Many of the events they detect were not felt, but some were. They are a main source of data since 1974 for epicenters of felt earthquakes as well as thosenot felt in the New Madrid area.

Geologic Services Branch of TVA is compiling a chronology which I was kindly permitted to examine. Many events come from that list. A numerical reference is given with the events obtained from the T.V.A. list. This number is one assigned by their compilers, and the actual reference is not further cited herein.

Professor Nuttli kindly permitted me to see his manuscript compilation of earthquakes in the Central United States. Data from that source are cited in this text. Some changes in the locations of earthquakes plotted on Plate 1 have resulted from

his list. These changes are not significant to the pattern of earthquakes on the plate.

Except for interpretations concerning locations (or lack of locations) of epicenters, some gathering of newspaper records, and a few interpretive comments, information in this chronology comes from others. It is merely gathered for convenience by the present compiler.

Main sources for the chronology are listed below:

McClain, W. C., and Myers, O. H., 1970, Seismic history and seismicity of the southeastern region of the United States, ORNL-4582, UC-51, Geology and Mineralogy, Oak Ridge Natl. Lab.

Nuttli, O. W., 1973, Mississippi Valley earthquakes of 1811-12; intensities, ground motion and magnitudes, Seis. Soc. Amer. Bull., Vol. 63, No. 1, p. 230.

Nuttli, O. W. (Compiled June 1976) Earthquakes in the Central United States of $m_b \geq 3.0$, unpublished manuscript.

Nuttli, Otto W., and Zollweg, James E., 1974, "The relation between felt area and magnitude for Central United States earthquakes," Seis. Soc. Amer. Bull., Vol. 64, No. 1, pp. 73-85.

St. Louis University, Stauder, William and others, 1974 to present, Southeast Missouri regional seismic network quarterly bulletin, Geophysics Depart, St. Louis University.

Stearns, Richard G., and Wilson, Charles W., Jr., 1972, Relationships of earthquakes and geology in West Tennessee and adjacent areas, Tenn. Valley Authority, Knoxville, Tenn., 302 p., including 128 page earthquake chronology.

Tennessee Valley Authority, 1977, Radial seismicity search of events, unpublished computer-stored list of earthquakes.

U.S. Department of Commerce, Coast and Geodetic Surveys; United States Earthquakes, published from 1928 to 1968.

U.S. Department of Commerce, NOAA, Environmental Data Service, United States Earthquakes, published from 1969 to 1972.

U.S. Department of Commerce, NOAA, Environmental Data Service, 1973, Earthquake History of the United States, Publication 41-1, Revised Edition (Through 1970). Edited by Jerry L. Coffman, and Carl A. von Hake.

U.S. Department of Commerce, NOAA, and U.S. Department of the Interior, U.S.G.S., United States Earthquakes, 1973 and 1974.

U.S. Geological Survey, United States Earthquakes, 1975 and 1976, Circulars 749-A and 766-A.

U.S. Weather Bureau, Monthly Weather Review, Monthly publication, 1914 to 1923.

Style of Presentation

The entries are arranged in chronological order, beginning with the first reported shock in 1699. On the first line of each entry is the date, followed by the local standard time (Military time and Greenwich time, reported in most sources, have been converted to Central Standard Time, to the nearest minute), the rating (intensity and/or magnitude), and the availability of isoseismal maps. Most of the ratings are intensity values, which are indicated by Roman numerals; magnitude is expressed in Arabic numerals.

The second line of each entry identifies the epicenter by name and by latitude and longitude; locations of the epicenter by estimates from descriptions are given in parentheses. Epicenters located by seismograph are given without parentheses. In some cases the size of the felt area is given.

Differences in the List By Historical Periods

Earthquakes Before The Civil War

This region was thinly settled before the great earthquakes of 1811-12. Essentially all the area of Kentucky and Tennessee west of Barkley Dam was Indian Territory. The west bank of the Mississippi was Louisiana Territory which was settled only by a few communities along the river. Except by river, communication was slow and poor. It is certain that many small earthquakes went unnoticed and/or unrecorded. For those that were noticed and recorded, most reports were made by transient soldiers, travelers and explorers; the information as to date and time, extent, and effects is nonexistent or sketchy.

The great earthquakes of 1811-12 and the powerful earthquake of January 4, 1843, could not fail to be noticed and recorded in newspapers, and considerable information exists for them; but many others went unrecorded, or were recorded in records not yet discovered. Many will be discovered as historic researchers become aware of an interest in the occurrence of earthquakes, and as those interested in earthquakes themselves delve into historic sources.

An example of a strong earthquake newly "discovered" is that of March 12, 1849 about which a correspondent of the Nashville Weekly Whig stated that "We have conversed with many of the old

inhabitants (of Hickman, Ky., a community subject to many earthquakes), and they all concur in the opinion that "the shake on Monday night was the severest in their recollection." This record was "discovered" by the compiler in a personal copy of the Nashville Weekly Whig presented by a friend who is a descendant of the editor. Presumably this earthquake was as severe at Hickman as that of Jan. 4, 1843 during which it was difficult to stand in places as far apart as Memphis, St. Louis and Louisville, Kentucky.

The early period is considered by this compiler to extend to the Civil War, because fewer records are readily accessible for that period in the region, and many local newspaper collections are incomplete in libraries for that time. During the Civil War itself, probably fewer people paid attention to earthquakes, and indeed many earthquakes may have been attributed to military events.

Earthquakes from the Civil War through 1930

Even after the Civil War until 1871 this chronology only lists about one earthquake each year. This could be owing to a quiet period, but is it also likely that records remained obscure and people's attention was on other phenomena through the war and reconstruction period. Even so, a powerful earthquake on August 17, 1865 was reported, so similar powerful ones probably did not occur or we would know about them.

Since 1872 many earthquakes are reported, and a record began in the American Journal of Science by Charles Green Rockwood. The compiler believes that for earthquakes of intensity VII or greater the record since 1872 is uniformly good.

Records from 1872 to 1930, though abundant, are nearly all personal experience. Though seismographs were invented earlier, and many earthquakes of the region were recorded by seismograph in the 1920s, no seismograph determined epicenter was recorded in the area of this chronology until 1934 when the Rodney, Missouri earthquake was located.

Period from 1931 to 1973

During this period, readily available newspaper records, and seismographs make the record relatively complete. It is likely that only relatively small earthquakes of intensity II-IV have been missed, and few of these.

That there indeed are "quiet years" is shown by the record of only one earthquake of 1935, 1948, and 1961. In 1968 microearthquakes were recorded in the New Madrid area by Lammlein, Sbar, and Dohrman (1971). Nuttli, in his 1976 list, indicates many earthquakes from 1957 to 1973 that were not reported to be felt.

1974 to Present

Intensified interest in earthquakes has led to placement of a sensitive seismic net in the New Madrid region by St. Louis University. Within the region microearthquakes are recorded (see Plate 2) and the seismographs also locate events well outside the net

1699, December 25, 1:00 p.m.* IV

Memphis area

Father J. F. Buisson St. Cosme, a French missionary on a voyage down the Mississippi River reports an earthquake on Christmas Day, 1699:

> On the 24th we cabined early so that our people might prepare for the great feast of Christmas. We made a little chapel; we sang a high mass at midnight where our people and all the French attended their duties. Christmas Day was spent in saying our masses, all which our people heard and in the afternoon we chanted Vespers. We were greatly astonished to see the earth tremble at one clock (sic) in the afternoon, and although this earthquake did not last long, it was violent enough for all to perceive it easily. (Williams, Samuel Cole: Early Travels in the Tennessee Country, Johnson City, Tennessee 1928, p. 66.)

1779, date and time unknown

Northern Ky. area

Felt in northern Kentucky and probably farther north. (Earthquake History of U.S. through 1970, p. 46).

1791 or 1792, April or May, 7:00 a.m. IV-V

Northern and eastern Ky.

Shock was preceded by rumbling noise and furniture moved. (Earthquake History of U.S. through 1970, p. 46).

1795, January 8, 3:00 a.m. III-V

Mississippi Valley (37.9 89.9)

This earthquake is reported by Shaler (1869) as follows:

*Local times as reported, mainly Central Standard Time for later dates.

At 3 A.M. on the 8th of January 1795, a considerable shock was felt at Kaskaskia, in the Territory of Illinois and in the part of Kentucky to the south. Its direction was * * * from west to east, its duration about one minute and a half. A subterranean noise accompanied the shock.

1811, December 16, 2:00 a.m. XI — ISOSEISMAL Maps Figs. 3 & 4

New Madrid, Missouri (36 90)

Nuttli (1972) placed the epicenter of this earthquake in Arkansas along the St. Francis River in the lake area (his Figs. 1 and 2).

1812, January 23, 9:00 a.m. X

New Madrid, Missouri (36.4 90.0)

Epicenter is placed on Fuller's line at 90° longitude.

1812, February 7, 3:45 a.m. XI — ISOSEISMAL MAP Fig. 5.

New Madrid, Missouri (36.3 89.9)

This location is also on Fuller's line at the center of curvature of the rounded northeast end of the sand blow area, as drawn by Fuller.

The great series of earthquakes of 1811-1812, known collectively as the New Madrid earthquake, is too well known to require detailed treatment in this paper. The following account is quoted from Fuller (1912):

A little after 2 o'clock on the morning of December 16, the inhabitants of the region were suddenly awakened by the groaning, creaking, and cracking of the timbers of the houses or cabins in which they were sleeping, by the rattle of furniture thrown down, and by the crash of falling chimneys. In fear and trembling they hurriedly groped their way from their houses to escape the falling debris, and remained shivering in the winter air until morning, the repeated shocks at intervals during the night keeping them from returning to their weakened or tottering dwellings. Daylight brought little improvement to their situation, for early in the morning another shock, preceded by a low rumbling and fully as severe as the first, was experienced. The ground rose and fell as earth waves, like the long, low

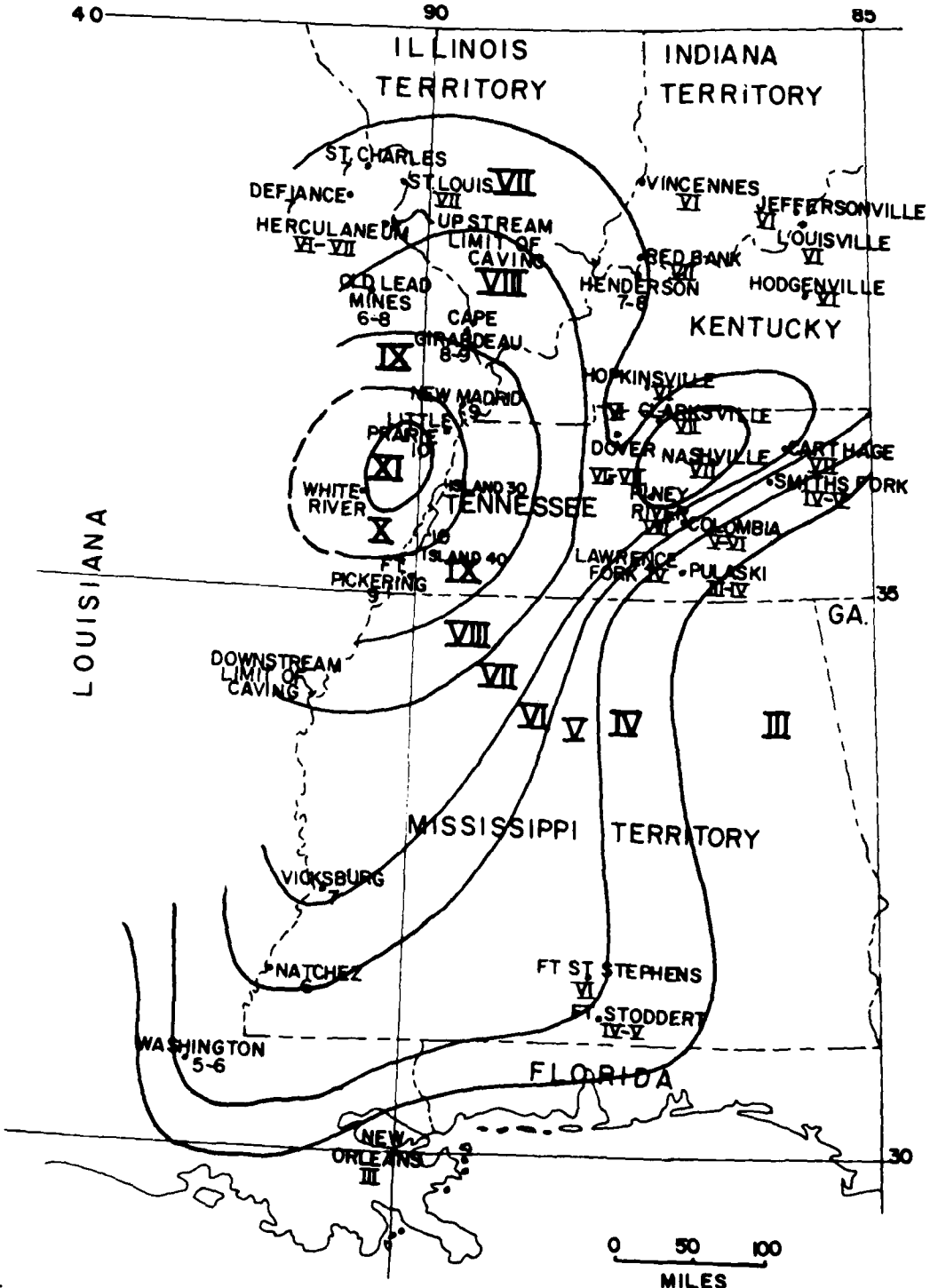


Figure 3 - Isoseismal map for the earthquake of December 16, 1811. This map was drawn by the present compiler using intensity data from Stearns and Wilson, 1972 (Figure 2.9A-4) in Roman numerals, supplemented by data from Nuttli (1974 and personal communication) in arabic numerals

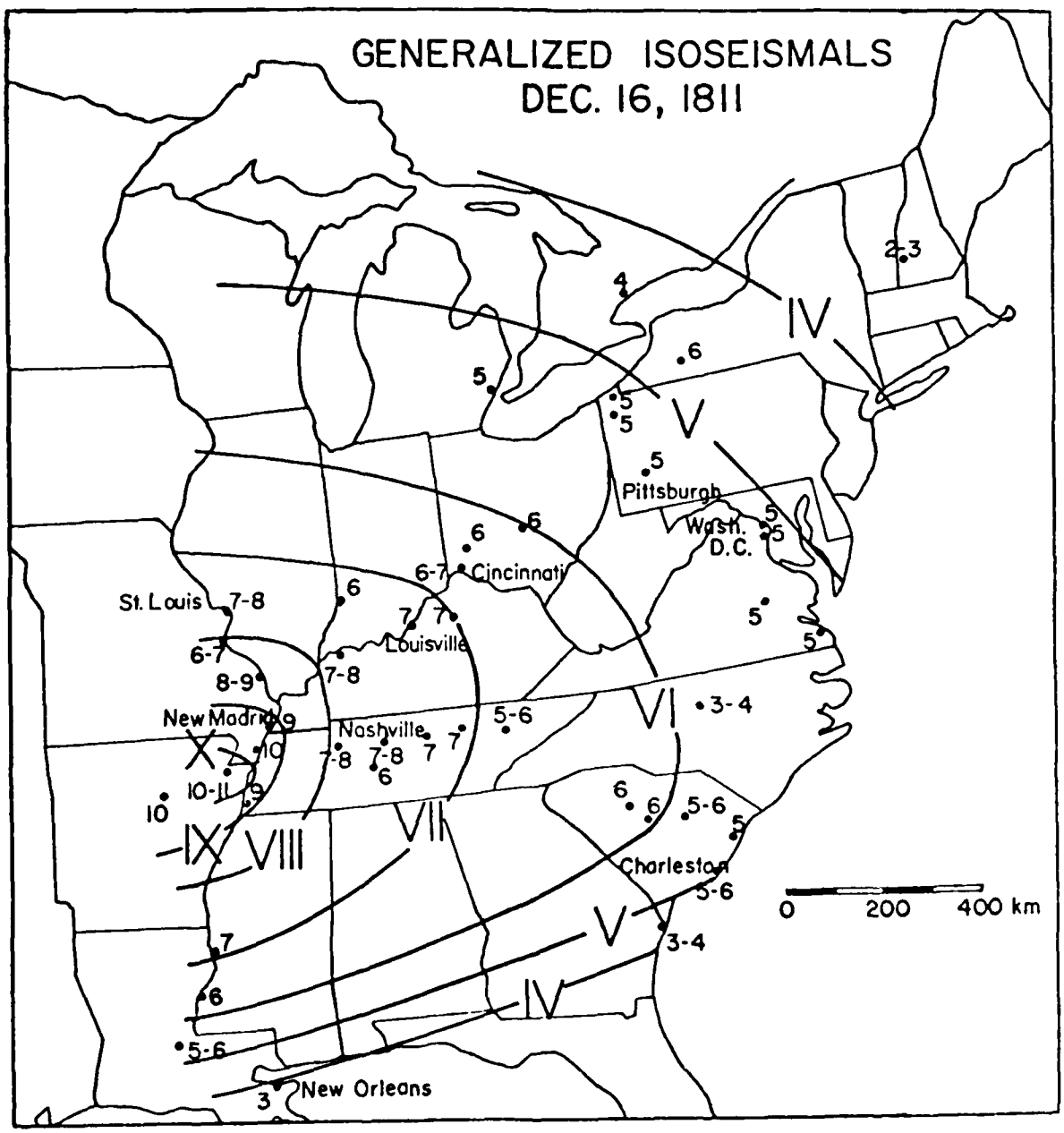


Figure 4 - Isoseismal map for the earthquake of December 16, 1811 (Nuttli, 1973, Bull. Seis. Soc.Amer., p. 230)

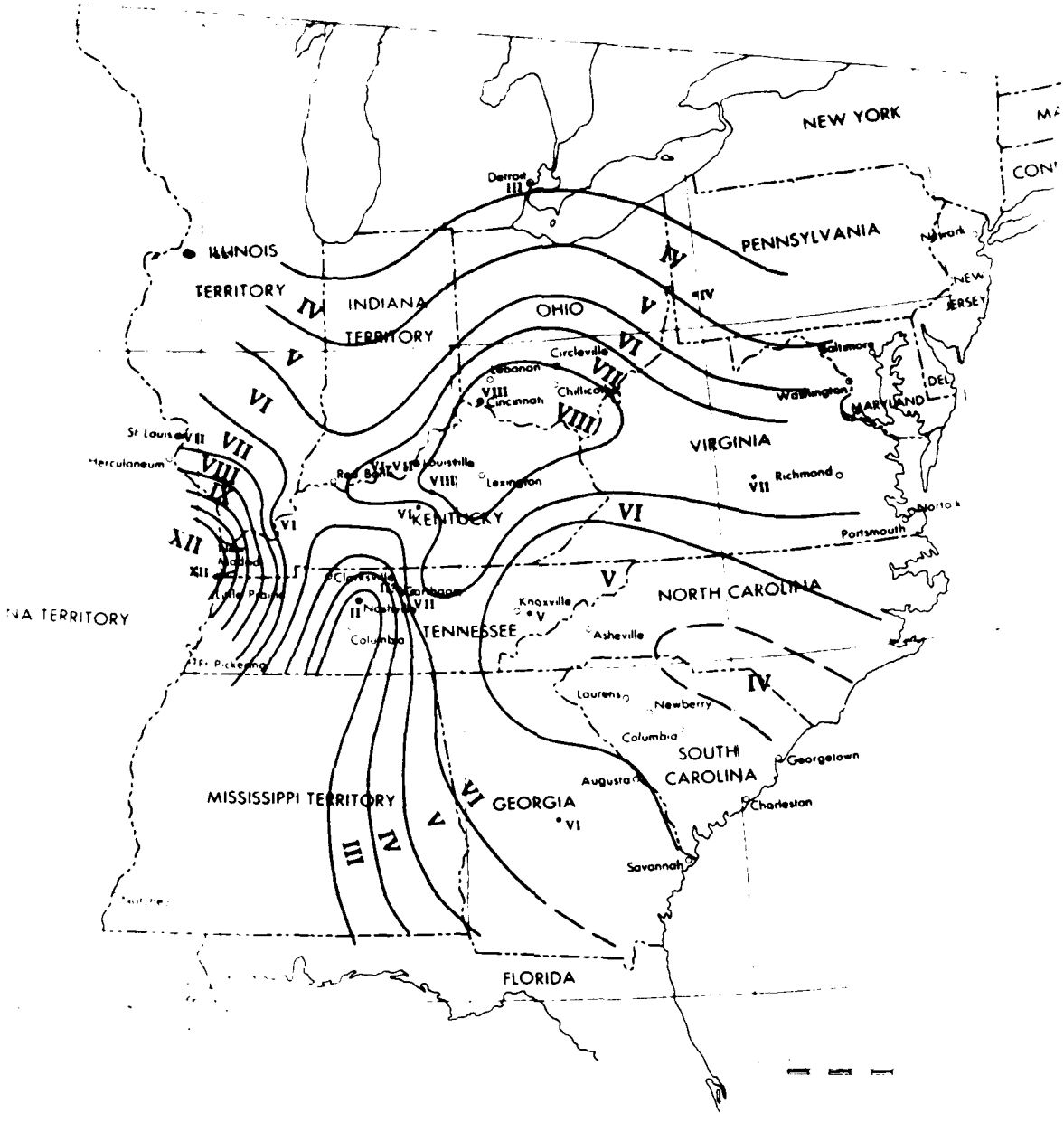


Figure 5 - Isoseismal map for the earthquake of February 7, 1812 (Stearns and Wilson, 1972, Fig. 2.9A-5)

swell of the sea, passed across its surface, tilting the trees until their branches interlocked and opening the soil in deep cracks as the surface was bent.

Landslides swept down the steeper bluffs and hillsides; considerable areas were uplifted, and still larger areas sunk and became covered with water emerging from below through fissures or little "craterlets" or accumulating from the obstruction of the surface drainage. On the Mississippi great waves were created, which overwhelmed many boats and washed others high upon the shore, the return current breaking off thousands of trees and carrying them out into the river. High banks caved and were precipitated into the river, sand bars and points of islands gave way, and whole islands disappeared.

During December 16 and 17 shocks continued at short intervals but gradually diminished in intensity. They occurred at longer intervals until January 23, when there was another shock, similar in intensity and destructiveness to the first. This shock was followed by about two weeks of quiescence, but on February 7 there were several alarming and destructive shocks, the last equaling or surpassing any previous disturbance, and for several days the earth was in a nearly constant tremor.

For fully a year from this date small shocks occurred at intervals of a few days, but as there were no other destructive shocks the people gradually became accustomed to the vibrations and gave little or no further attention to them.

These earthquakes consisted of thousands of individual shocks, a few of which were quite violent and were felt over extensive areas. The initial shock at about 2:00 a.m. December 16, 1811, was one of the most severe. It was felt over an area of about 2,000,000 square miles and resulted in topographic changes over an estimated area of 30,000 to 50,000 square miles. It was followed at about 2:30 a.m. by a somewhat less severe shock, which was followed, in turn, by 27 light shocks at intervals of six to ten minutes. At daylight, a shock equal in intensity to the first occurred and was followed within an hour or so by two other shocks, one

of which was very severe." Another violent shock occurred at 11:00 a.m. On the following day, strong to "severe" shocks occurred at 5:00 a.m., 7:00 a.m., 12:00 noon, and 7:30 p.m. On December 18, "slight" to "violent" shocks occurred at 3:00 a.m. to 4:00 a.m., 6:00 a.m., 12 noon, 6:00 p.m. and 9:00 p.m. Other shocks were felt on the twenty-first at 4:30 a.m. A shock "as violent as worst of preceding" occurred on January 23, 1812. Shocks were felt at frequent intervals between January 23 and February 4, on which date a shock "nearly as severe as any" occurred. Four "severe" shocks occurred on February 5, followed by a shock described as "hard" and "big" on February 7. Subsequently, shocks were felt at frequent intervals for several months. From December 16 to March 15, a total of 1874 shocks were recorded in Louisville, Kentucky. As shocks continued to occur at frequent intervals for at least two years, the total number of shocks was actually much greater.

It is not unlikely that between 2000 and 3000 shocks were felt in Tennessee in 1811 and 1812. Even as late as July, 1816, shocks occurred every few days in the New Madrid area. The great shocks of December 16, 1811, January 23, 1812, and February 7, 1812, were felt throughout the eastern United States.

1816, July 25, 9:00 a.m. and 3:00 p.m. III-IV

New Madrid, Missouri (36.6 89.5)

Heinrich (1941) quotes from the Missouri Gazette for July 31, 1816, as follows:

> We had (in New Madrid) on Thursday last two distinct shocks of earthquake, one in the forenoon about nine o'clock, the other about three o'clock P.M. which revived in a small degree the apprehensions of danger among the populace here. It is not unusual to have shocks here every few days, but these mentioned above were more severe than usual.

1816, about 12:00 midnight III

New Madrid, Missouri (36.6 89.5)

In the published account of a voyage down the Mississippi River in 1816, Mr. Tilly Buttrick reports an earthquake as follows:

> Getting into the Mississippi River, our first stop at any town was at New Madrid. We made the boat fast to the shore, and about twelve o'clock at night was awaked by a noise which appeared like a cable drawing over the boat's side. I started and went on deck; found all quiet. My fear was that the boat had struck a drift and was running over a log; but on inquiry found it was an earthquake. (Voyages, Travels and Discoveries of Tilly Buttrick, Jr., 1812-1819, Boston 1831. This account is reprinted in Thwaites, Reuben Gold: Early Western Travels 1748-1846, Vol. VIII, Cleveland, Ohio, 1905, p. 59.)

1818, March II-V

Mississippi Valley

A traveler going down the Mississippi River in March, 1818,

> . . . experienced eight or ten shocks, some of them so severe as to shake from their places loose articles in the boat. Each shock continued about two minutes and was preceded by a rumbling noise like distant thunder or the discharge of a cannon at a great distance. We experienced light shocks, at intervals, for a distance of one hundred miles below Little Prairie. (Williams, S. C. Beginnings of West Tennessee, Johnson City, Tennessee, 1930, p. 93; quoting James McBride, of the Miami Country, Qr. Pubs. Hist. and Phil. Soc. of Ohio, Vol. V, p. 27.)

1819, September 2, 2:30 a.m. III-IV

Mississippi Valley

Heinrich (1941) quotes from the St. Louis Enquirer, September 22, 1819, as follows:

> The shock of an earthquake was sensibly felt at St. Louis, Cape Girardeau, New Madrid and throughout a large extent of country along the Mississippi on the morning of the 2d inst., between 2 and 3 o'clock.

This earthquake is reported to have been felt at 2:30 a.m. at Edwardsville, Illinois, where

> ". . . it appeared to move in the direction from S.S.W. to N.N.E.; and the oscillations of the earth continued about one and a half minutes."

1820, November 9, 4:00 p.m. IV

Cape Girardeau, Missouri (37.3 89.5)

> On the 9th at four p.m. the shock of an earthquake was felt. The agitation was such as to cause considerable motion in the furniture and other loose articles in the room where we were sitting. Before we had time to collect our thoughts and run out of the house, it had ceased entirely; we had, therefore, no opportunity to form an opinion of its direction. Several others occurred in the time of our stay at the Cape, but they all happened at night and were all of short duration. "Shakes," as these concussions are called by the inhabitants, are in this part of the country extremely frequent and are spoken of as matters of every day occurrences. (Long, Major S. H. -- Account of An Expedition from Pittsburgh to the Rocky Mountains in the Years 1819, 1820, London, 1823. Quoted from Thwaites, Reuben Gold: Early Western Travels, Vol. 17, p. 88).

1820, III-IV

New Madrid, Missouri (36.6 89.5)

> Several persons, passengers on board a steamboat, ascending the Mississippi, in 1820, went on

shore near New Madrid. In one of the houses which they entered they found a small collection of books. As they were amusing themselves with these, they felt the house so violently shake, that they were scarce able to stand upon their feet; some consternation was of course felt, and as several of the persons were ladies, much terror was expressed: "Don't be alarmed," said the lady of the house, "Its nothing but an earthquake." James, Dr. Edwin (Footnote to Major S. H. Long's Account of an Expedition from Pittsburgh to the Rocky Mountains in the years 1819, 1820, London, 1823; reprinted in Thwaites, Reuben Gold: Early Western Travels 1748-1846, Vol. 17, Cleveland, Ohio, 1905, p. 88).

1834, November 20, 1:40 p.m. V

Northern Ky. area

Shock lasted 30-40 seconds; houses shook; plaster cracked; sounds like distant thunder. (U.S. Dept. Comm. 1973, p. 46.)

1839, September 5, III-IV

Mayfield, Kentucky (36.7 88.6)

An earthquake lasting several seconds was felt at Mayfield, Kentucky, only 16 miles north of the Kentucky-Tennessee state line. The shock was strong enough to rattle windows and shift furniture.

1841, December 27, 11:50 p.m. V

Western Kentucky (36.6 89.2)

Severe shock accompanied by a rumbling noise near Hickman, Kentucky. Homes shook and objects displaced. River was grealy agitated, although no wind was reported.

1842, May 27, 11:00 p.m. IV

Hickman, Kentucky (36.6 89.2)

An earthquake accompanied by "violent rumblings," was felt at Hickman, then Mills Point, Kentucky, some 5 miles north of the Tennessee-Kentucky state line.

1842, November 4, 12:30 and 2:30 a.m. V

Hickman, Ky. (36.5 89.2)

Two shocks.

(TVA Chronology, 57)

1843, January 4, 8:45 p.m. VIII ISOSEISMAL MAP Fig. 6

New Madrid Region (35.5 90.5) 400,000 sq. mi.

A severe earthquake, with its center somewhere in the New Madrid region, was felt as far eastward as the Atlantic seaboard, northeastward to Providence, Rhode Island, and westward to points beyond the frontier posts. It was felt strongly throughout Arkansas, Tennessee, the Carolinas, and over large sections of other states. In Memphis, it was very destructive, causing chimneys to topple, walls to crack, and similar phenomena. In Knoxville, it was strongly felt and caused considerable alarm but did no damage. It was sharply felt at Nashville, Tennessee, and St. Louis, Missouri where chimneys fell and people were frightened. Persons standing or walking found it difficult to stand upright in St. Louis, Missouri, and Louisville, Kentucky. In the New Madrid region in Missouri, subsidence of the land reportedly gave rise to a lake, which was said to have developed with sufficient suddenness to drown some hunters. Heck (1938) assigns an intensity of 9 (Rossi-Forel Scale) to this earthquake. Three shocks were reported at Van Buren, Arkansas.

Nuttli (1974, Seis. Soc. Amer. Bull. p 1205) assigns magnitude of 6.1. His list of 1976 assigns an epicentral intensity of VIII and a magnitude of 6.0.

1843, January 16

Reported in Nashville City Directory 1860-61 p. 17. Maybe this is the same earthquake as Feb. 16, 1843 but misreported in the Directory

1843, February 16, 11:00 p.m. V

St. Louis, Missouri (35.5 90.5)

This earthquake affected a wide area and was felt at St. Louis, Missouri, Louisville, Kentucky, and Nashville, Tennessee. Press reports, stating the time as ". . . about 11 o'clock" p.m., indicate that the shock was light

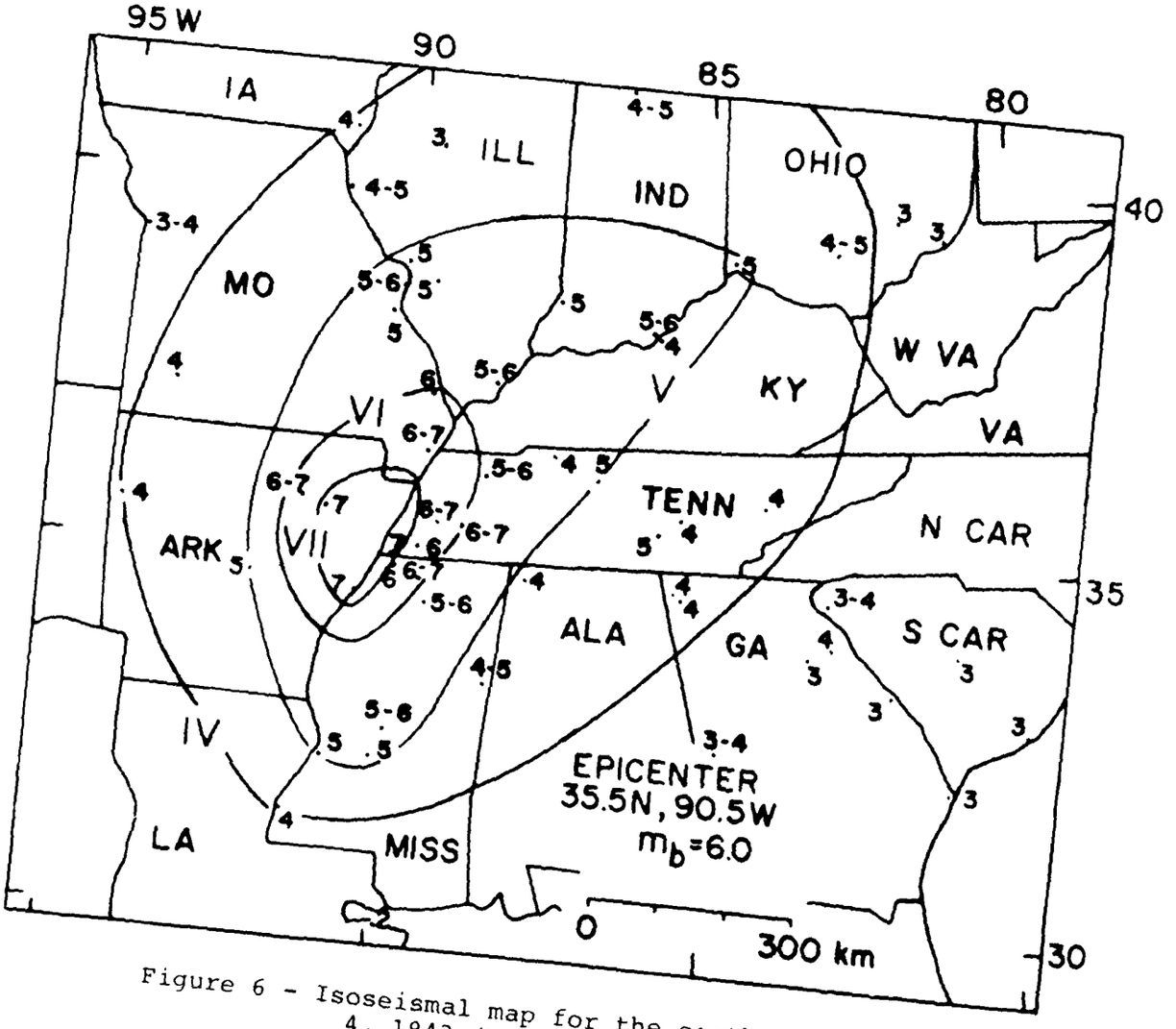


Figure 6 - Isoseismal map for the earthquake of January 4, 1843 (Nuttli, 1974, Bull. Seis. Soc. Amer., p. 1205)

at Nashville (Knoxville Register, February 23, 1843). Nuttli assigns this to the same location as the January 4 earthquake in his 1976 list.

1843, June 13, 9:00 a.m. III

Hickman, Kentucky (36.6 89.2)

A light shock at Mills Point, now Hickman, Kentucky is reported by the Knoxville Register, June 28, 1843.

1846, March 26, 11:25 a.m. II-III

New Madrid, Missouri (36.6 89.5)

On his second visit to the United States, Sir Charles Lyell spent a few days in the New Madrid area late in March, 1846, and reported this earthquake as follows:

> While I was riding with Mr. Love he stopped his horse and asked me if I did not feel the shock of an earthquake. When my attention was called to it, I fancied I had preceived it, but was not sure. He said they were frequent, although he had not felt one for the last fortnight. It was now three years since they had been seriously alarmed by any movement. We looked at our watches, and when we returned to the farm he inquired of the family if anything had happened. They said they had felt a shock, and heard a sound like distant thunder, at twenty-five minutes past eleven o'clock, which agreed exactly with the time when my companion had felt the motion. (Lyell, Sir Charles: A Second Visit to the United States of America, Second Edition Revised and Corrected. Vol. 2, p. 236).

1848, January 24 V

Hickman, Ky. (36.6 89.2)

(Nuttli, 1976)

1849, March 12, 4 a.m. and 11 a.m. VI+ ?

Hickman, Kentucky (36.6 89.2)

"That Earthquake. -- The Hickman (Ky.) News Letter says:

The citizens of our town experienced the severest earthquake on Monday night, March 12th, that has been felt in these regions since the year 1811. — We have conversed with many of the old inhabitants, and they all concur in the opinion that "the shake on Monday night was the severest in their recollection."

(Nashville Weekly Whig, Mar. 30, 1849, p. 825.)

also

"EARTHQUAKE. — The shock of an earthquake was distinctly felt at Memphis, at 4 o'clock on the morning of the 12th inst., and another at 11 A.M. on the same day. These shocks were preceded by heavy rains."
(Nashville Weekly Whig, Mar. 23, 1849, p. 809).

1852, August 19

New Madrid, Mo. (36.6 89.5)

TVA Chronology, 105)

1853, August 28 III

Hickman, Ky. (36.6 89.2)

(TVA Chronology, 16)

1853, December 18 IV-V

Hickman, Ky. (36.6 89.2)

(TVA Chronology, 16, 57) Nuttli (1976) lists this date on Dec. 12.

1855, May 2, 9:33 p.m. IV-V

Cairo, Illinois (37.0 89.2)

Houses were shaken "tremendously."

1855, May 3, 4:00 a.m. III-IV

Cairo, Illinois (37.0 89.2)

Two shocks, about five minutes apart and each lasting about five seconds, felt at Cairo, Illinois. "The vibratory motion and the rumbling noise were distinctly felt and heard throughout the town."

1856, November 9 IV-V

Mississippi Valley (36.6 89.5)

Earthquake shocks felt widely in the Mississippi Valley. Localities in the affected area include Cairo and DeSoto, Illinois; Paducah, Kentucky; and Memphis, Tennessee. An observer at DeSoto reported that his house "rocked violently." Nuttli (1976) locates this earthquake north of New Madrid Missouri.

1857, February IV

New Madrid, Mo. (36.6 89.5)

Date and time unknown. (Nuttli, 1976)

1857, October 8, 4:00 and 4:07 a.m. VI-VII ISOSEISMAL MAP Fig. 7

Mississippi Valley (38.7 89.2) 7,500 sq. mi.

Two strong shocks at St. Louis, Missouri, and three shocks at Centralia, Illinois. Felt at numerous localities in the Mississippi Valley south of Hannibal, Missouri. The southern limit of the affected area is unknown, but there is a strong probability that the shocks were felt in Tennesseee. At St. Louis, near the epicenter, large buildings rocked to and fro, bricks were dislocated, plaster fell, furniture shifted, and loose objects toppled from shelves. The river was in tumult and the animals were frightened.

Nuttli (1974, Seis. Soc. Amer. Bull., p 1203) suggests a magnitude of 5.4, and presents an isoseismal map.

1858, September 21 V-VI

Near Hickman, Ky. (36.5 89.2)

(TVA Chronology, 16; the location is from Nuttli, 1976).

1860, August 7, 11:30 a.m. IV-V

Henderson, Ky. (37.8 87.5)

(TVA Chronology, 16)

PROBABLY MANY UNRECORDED EARTHQUAKES OCCURED DURING THE CIVIL WAR.

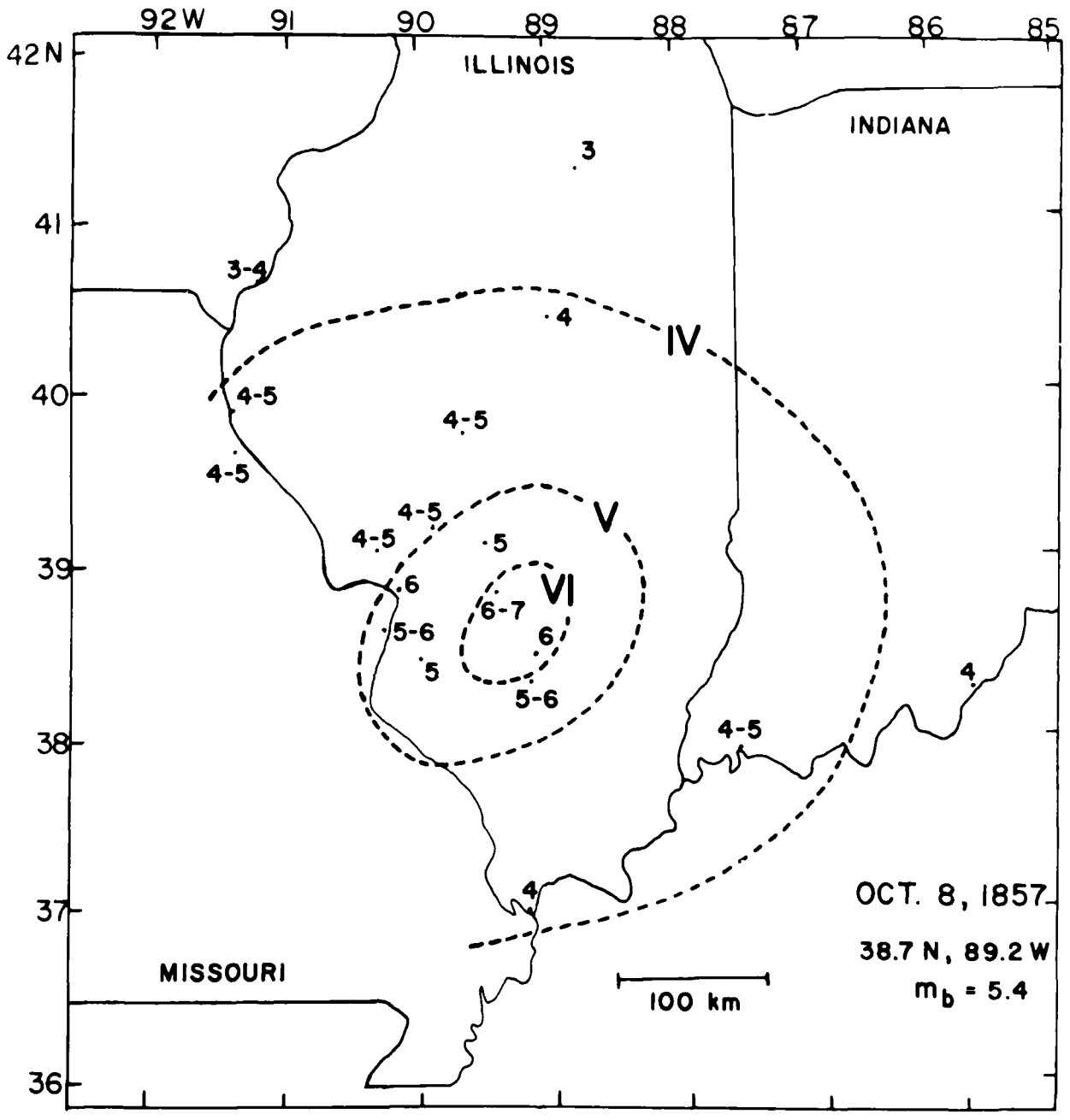


Figure 7 - Isoseismal map for the earthquake of October 8, 1857 (from Nuttli, 1974, Seis. Soc. Amer. Bull. p. 1205)

1865, August 17, 9:00 a.m. VII

Mississippi Valley (36.7 89.5) 24,000 sq. mi.

A strong earthquake felt widely over the Mississippi Valley in Tennessee, Missouri, Illinois, Kentucky, Arkansas and Mississippi. The vibrations were especially strong at Memphis, where chimneys were thrown down, and at New Madrid and St. Louis. Other localities in the affected area include La Grange, Tennessee; Holly Springs and Grenada, Mississippi; and Du Quoin and Springfield, Illinois.

Nuttli (1974) estimates the epicenter to have been north of Memphis near Dyersburg, and presents map of intensity values.

1865 , September 7, 8:15 a.m. III-IV

Mississippi Valley

At a quarter past 8 o'clock this morning, the 7th, we had another shock, shaking houses &c. considerably. It was not accompanied by much noise--came from a westerly direction, and lasted about half a minute." Reported by John T. Scott in a letter. (American Journal of Science, 2nd Series, vol. XL, 1865, p. 364).

1868, November 21 III

Hickman, Ky. (36.6 89.2)

(TVA Chronology, 16)

1870, December 4 III-IV

Near Hickman, Ky. (36.6 89.2)

(TVA Chronology, 16, 57) Nuttli, 1976, lists the date as Dec. 14.

1871, July 24 III

Cairo, Illinois (37.0 89.2)

A light shock at Cairo, Illinois.

1872, February 8, 5:00 a.m. IV

Cairo, Illinois (37.0 89.2)

A light shock lasting about 20 seconds at Cairo, Illinois. An observer who experienced the shock in bed on the second floor of a brick house reported: "It seemed to me that something struck the head of my bed with considerable violence from the southeast, making quite a noise and shaking the entire house. The shaking continued for several seconds with varying intensity."

1872, March 26, "a.m." III

Paducah, Kentucky (37.1 88.6)

A light shock at Paducah, Kentucky.

1873, May 3, 3:00 p.m. III-IV

Mississippi Valley (36.0 89.6)

Two "severe" shocks with "waves north to south" felt at Memphis and throughout Gibson and Carroll Counties, Tennessee, and at Cairo, Illinois. Nuttli in his 1976 list assigns the location given above.

1874, July 4, I-II

Cairo, Illinois (37.0 89.2)

1874, July 9, 4:00 p.m. III

Cairo, Illinois (37.0 89.2)

1875, October 7 III-IV

Mississippi Valley (36.0 89.7)

Light shocks at Memphis, Tennessee, and Cairo, Illinois.

1878, March 12, 4:00 a.m. V

Columbus, Kentucky (36.8 89.1)

1878, March 12, Cont'd.

A severe shock at Columbus, Kentucky, caused a section of the bluff along the Mississippi River to cave. Reported in northeast Arkansas.

1878, November 18-19, 11:52 p.m. VI-VIII

Mississippi Valley (36.0 89.7) 150,000 sq. mi.

A moderately strong earthquake felt over an area of 150,000 square miles in Missouri, Tennessee, Illinois, Kentucky, Arkansas, Alabama, and other states. The disturbance was greatest along the Mississippi River between Memphis and Cairo and was universally felt in this area. At Memphis, the vibrations were "heavy." At Cairo, where the disturbance lasted about 40 seconds, an initial trembling motion was followed by a rocking motion which, in turn, was followed by a second period of trembling. A second shock, much lighter than the first, was felt at 5:10 a.m. on the 19th. Reported at Little Rock and Clarksville. Nuttli (1976) locates this earthquake at 36.7°, 89.3°.

1879, July 26, 11:45 a.m. II-III

Cairo and Mound City, Illinois (37.1 89.2)

A light shock of a few seconds duration at Cairo and Mound City, Illinois.

1882, July 20, 4:00 a.m. V

Mississippi Valley (37.0 89.2) 3,000 sq. mi.

A shock lasting about 15 seconds at Cairo, Illinois. Felt also at Collinsville, Illinois, and Charleston, Missouri.

1882, July 28 III

Ironton, Missouri (37.6 90.6)

(TVA Chronology, 94)

1882, September 27, 4:20 a.m. VI-VII

Southern Illinois (39.0 89.5) 40,000 sq. mi.

A strong earthquake which affected an area of 40,000 or more square miles in Illinois, Indiana, Kentucky, Missouri, and possibly other states. A subterranean rumbling sound was heard nearly everywhere in the affected area, and in some places more than one shock was reported. At St. Louis, "the shock was first noticed as a rolling even noise, followed by twelve distinct vibrations at intervals of a second. The first vibration was the most violent shock and lasted about fifteen seconds." At many places, chimneys were cracked, small objects overthrown and suspended objects set to swinging. The location is from Nuttli, 1976.

1883, January 11, 1:12 a.m. V-VI

Mississippi Valley (37.0 89.2) 80,000 sq. mi.

A moderately strong earthquake which affected about 80,000 square miles in Tennessee, Missouri, Illinois, Kentucky, Mississippi, and Arkansas. It was felt generally in the Mississippi Valley from Memphis to St. Louis, and as far east in Tennessee as Clarksville and Nashville. There were three shocks at Memphis and four at St. Louis. The vibrations rocked buildings, set chandeliers to swinging and rang engine bells. An early shock was felt at Protem, Taney County, Missouri (36.5° 92.9°) on January 10 at noon. The location is from Nuttli, 1976.

1883, April 12, 2:36 a.m. VI-VII

Cairo, Illinois (37.0 89.2)

A strong shock characterized by "short jerky vibrations" felt at Cairo, Illinois. Houses were shaken violently, awakening everyone. The disturbance lasted about 30 seconds.

1883, June 11, 12:16 p.m.

The Memphis earthquake reported for this day is really the Jan. 11 earthquake according to Moneymaker.

1883, July 6, 11:15 a.m. III

Cairo, Illinois (37.0 89.2)

A light tremor of short duration at Cairo, Illinois.

1883, July 14, 1:30 a.m. IV-V

Cairo, Illinois Wickliffe, Kentucky (37.0 89.1) 10,000 sq. mi.

A shock of 8 seconds duration at Cairo, Illinois, and Wickliffe, Kentucky. Window glass in the courthouse at Wickliffe was reported broken.

1883, December 5, 9:20 a.m. V

Melbourne, and Ravenden Springs,Arkansas (36.3 91.8)

Felt in Boone and Izard Counties. Buildings shaken. Noise like thunder. Broke glassware and crockery. Slides in railroad cut.

(Branner and Hansell, 1933, p. 6; and McClain and Myers. 1970, p. 24; Eppley, 1965, p. 40.) Heinrich 1941, p. 196. Nuttli (1976) locates this earthquake farther east at 91.2°.

1883, December 6 V

Southeast Missouri (36.3 91.2)

Seven shocks at St. Louis. Also felt at Memphis and in Arkansas. The intensity and location are from Nuttli's 1976 list.

1884, February 14, 6 a.m. III

(37.7 90.7)

Nuttli's 1976 list.

1886, March 18, 11:15 a.m. VI

Cairo, Illinois (37.0 89.2)

A heavy shock at Cairo, Illinois. The vibrations are reported to have moved from west to east and to have continued about 15 seconds. Nuttli, 1976, lists the intensity of VI.

1886, August 31 about 8:51 p.m.; 8:59 C.S.T. X

Charleston, South Carolina (32.9 80.0)

This earthquake originated well over 500 miles east of the Mississippi Embayment, but it shook the area near the Mississippi River an intensity of IV to VI. West of the Mississippi effects diminished abruptly. Central Tennessee and Central Kentucky experienced a shaking of about VI. This earthquake shook the New Madrid area much less than the 1811 earthquake shook Charleston, which indicates that the New Madrid earthquake was significantly greater than this better documented Charleston event.

Detailed reports are given in the Ninth Annual Report of the United States Geological Survey (Dutton, ----, 1887-88 Report, pages 203-528). Some details as reported therein follow:

> "Memphis (Tennessee) ... violent shock; a rapid oscillating; many fled to the streets, numbers in night dress; guests at Peabody Hotel rushed downstairs; many women went into hysterics; equally severe all over the city."
> "Milan (Tennessee) Gibson County ... very generally felt in buildings; some were awakened ... clerk on south side of desk was thrown forward; no damage save cracked plastering."
> "Clarksville (Tennessee) ... houses vibrated."
> "Humboldt (Tennessee) ... a low indistinct sound."
> "Nashville (Tennessee) ... distinct shocks; very perceptible in tall buildings, but not felt by a majority of people."
> "New Madrid (Missouri) ... rocking chairs rocked gently; almost unnoticed at the time because several slight shocks occur every year."

"Cairo (Illinois) ... severest felt in many years; clocks stopped, buildings shook, chandeliers swung, and people generally left houses .... ceiling cracked in post office. Several clocks stopped."
"Paducah (Kentucky) ... very distinct in some portions of city; hardly perceptible in others. Doors rattled and chairs moved; panic at opera house; people rushed out pell mell ..."
"Owensborough (Kentucky) ... Distinctly felt all over city; two story houses rocked, and many ran into the streets."

1887, August 2, 12:36 p.m. V

Cairo, Illinois (37.0 89.2)

A "severe" shock centered somewhere near Cairo, Illinois. and felt over a wide area in Tennessee, Missouri, Kentucky and Illinois. It was strongly felt at Nashville, Gallatin, Clarksville, Chattanooga, Tullahoma, McMinnville, Columbia, Jackson, and Union City, Tennessee, and at St. Louis, Missouri.

1891, July 26, 8:28 p.m. VI

Southern Indiana (37.9 87.5)

Centered at Evansville, Indiana.

1891, September 26, 10:55 p.m. V

Cairo, Illinois (37.0 89.2)

A strong earthquake felt in the Mississippi Valley near Cairo, Illinois. Described as beginning slowly and gaining strength in a few seconds. Movable objects "jigged" and trees swayed as if blown by the wind.

1895, October 18, 12:10 a.m.; 3:00 a.m. III

New Madrid, Missouri (36.6 89.5)

Two light shocks at New Madrid, Missouri.

1895, October 30, 8:30 a.m.; 2:00 p.m.; 4:30 p.m. III

Corning, Arkansas (36.4 90.6)

Three light shocks at Corning, Arkansas.

1895, October 31, 5:00 a.m. VIII ISOSEISMAL MAP Fig. 8

Charleston, Missouri (36.9 89.4) 1,000,000 sq. mi.

One of the two really great earthquakes in the Mississippi Valley since the New Madrid earthquake of 1811-1812. It attained destructive intensities at several places. At Charleston, Missouri, near the epicenter, the damage to structures was heavy. At Cairo, Illinois, and Memphis, Tennessee, several chimneys were thrown down. Near Bertrand, Missouri, hundreds of mounds of white sand were thrown up. It was felt at Knoxville, where the intensity was probably about IV.

This earthquake was felt over an area of about 1,000,000 square miles in about 23 states, including the entire state of Tennessee. Felt in Arkansas.

> "The disturbance was felt over a comparatively extensive region embracing New Mexico and Nebraska on the west, some portions of Canada on the north, Louisiana and Georgia on the south, and North Carolina and the District of Columbia on the east."

The earthquake evidently had maximum intensity near Charleston, Missouri, where every building in the commercial block was damaged. Every structure "rocked" and many walls were cracked. East of Charleston, near Bertrand, waterspouts were reported, and "hundreds" of mounds six to ten feet in diameter composed of white sand were thrown up. In Cairo, Illinois, many chimneys fell. The courthouse and the library were considerably damaged and the brick steeple of St. Joseph's church (Catholic) was cracked and twisted so that it had to be removed. One pier on the Illinois Central Railroad bridge over the Ohio River was cracked. Several chimneys were reported thrown down in the suburbs of Memphis, Tennessee. At Poplar Bluff the movement was described as rocking and seemed to be east-west. A noise "like a cyclone" preceded the shock. This earthquake was felt throughout the state of Missouri and probably ranks second in intensity to the New Madrid series of 1811-1812. In this respect it either exceeds or equals the intensity of the shock of January 4, 1843. At Charleston, aftershocks were reported: on November 1 at 8:16 p.m., and on November 2 at 2:00 and 11:00 a.m. Branner and Hansell state that an aftershock was felt on November 17 (Heinrich, 1941).

Nuttli (1974) estimates the magnitude of this earthquake as 6.2.

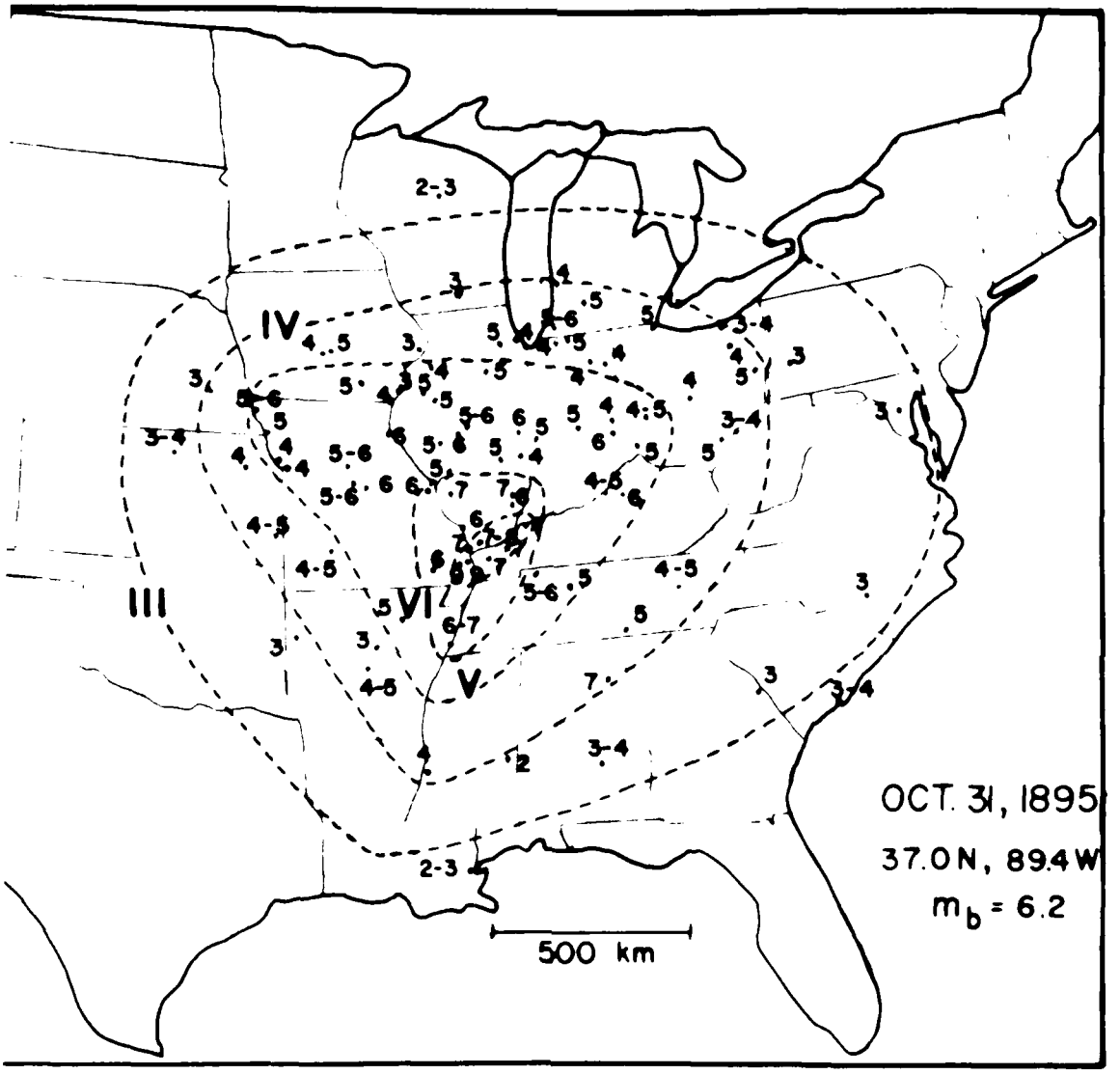


Figure 8 - Isoseismal map for the Charleston, Missouri earthquake of October 31, 1895 (from Nuttli, 1974, Seis. Soc. Amer. Bull., p. 1207)

1895, November 1, 8:16 p.m. IV

Charleston Missouri area

Aftershock of the Charleston, Missouri, earthquake felt at Memphis, Tennessee.

1895, November 2, 2:00 a.m. and 11:00 am. III-IV

Charleston Missouri area

Two aftershocks of the Charleston, Missouri, earthquake

1895, November 17 III-IV

Charleston Missouri area

Aftershock of the Charleston, Missouri earthquake.

1897, April 30, 10:00 p.m. IV-V

Mississippi Valley (36.7 88.6) 3,000 sq. mi.

A strong shock, lasting about 20 seconds, felt in western Tennessee, western Kentucky, southern Illinois and southern Indiana.

1898, June 14, 9:20 a.m. III-IV

Mississippi Valley

A light shock felt throughout the New Madrid area in the Mississippi Valley. The affected area extended over parts of several states, including Missouri, Tennessee, Kentucky, Arkansas and Alabama. In Tennessee, it was reported felt at Memphis, Bolivar and Wilderville. In Arkansas, it was felt at Corning and Osceola.

1899, April 29, 8:05 p.m. VI-VII

Southern Indiana (38.8 87.0) 40,000 sq. mi.

A strong shock felt over an area of 40,000 square miles in southern Indiana, southern Illinois, and western Kentucky. The southern limit of the affected area is not known. Nuttli (1976) lists the location and intensity given.

1901, February 14, 6:15 p.m. IV

(36.0 90.0)

Nuttli's 1976 list.

1903, February 8, 6:20 p.m. VI

Mississippi Valley (37.8 89.3) 70,000 sq. mi.

A strong earthquake was felt over an area of about 70,000 square miles in southern Illinois, eastern Missouri, western Kentucky and possibly portions of other states. The shock was strong at Cairo, some 35 miles north of Tennessee. At Murphysboro, Illinois, chimneys were thrown down.

1903, October 4, 8:56 p.m. V-VI

Mississippi Valley (37.0 90.0)

A light shock at Memphis and at St. Louis. It was "felt strongly" also in the "lead belt" south of St. Louis.

1903, November 4, 12:15 and 1:18 p.m. VI & VII

Mississippi Valley (36.9 89.3) 70,000 sq. mi.

Two shocks were felt over an area of about 70,000 square miles in eight states in the Mississippi Valley. The entire western section of Tennessee was affected. At Memphis the shocks were light. The disturbance was most severe at New Madrid and Cairo, where walls were cracked, and at Cape Girardeau, where chimneys were thrown down. Felt in Arkansas. Nuttli (1976) lists the location and two intensity values shown.

1903, November 24, 9:20 a.m. III

New Madrid, Missouri (36.6 89.5)

A shock at New Madrid, Missouri.

1903, November 25 III

New Madrid, Missouri (36.6 89.5)

Tremors at New Madrid, Missouri.

1903, November 27, 1:00 and 3:00 a.m. both V

Mississippi Valley (36.5 89.5) 70,000 sq. mi.

Two strong shocks at New Madrid, Missouri, Cairo, Illinois, and Paducah, Kentucky. According to Branner and Hansell (1937), the earthquake affected an area of 70,000 square miles, including all of western Tennessee. Nuttli (1976) lists the location and two intensities given.

1905, August 21, 11:08 p.m. VI-VII

Sikeston, Missouri (36.9 89.6) 40,000 sq. mi.

This earthquake, apparently centered near Sikeston, Missouri, was felt over a wide area in Missouri, Tennessee, Arkansas, Kentucky, Illinois, Indiana and Mississippi. Chimneys were thrown down and walls were cracked at Sikeston. In Tennessee, the disturbance was strongly felt at Union City, Brownsville, Memphis, Paris, Clarksville, and Nashville. Three shocks accompanied by noise, were reported at some localities. Owensboro (IV-V); Paducah (III-IV); Henderson, Ky. (III). The epicentral intensity is from Nuttli's 1976 list.

1907, July 4, 3:00 a.m. IV-V

(37.8 90.4)

(Nuttli's 1976 list).

1908, September 28, 1:34 p.m. IV

New Madrid, Missouri-Cairo, Illinois (36.7 89.2)
5,000 sq. mi.

A light shock at New Madrid, Missouri, and Cairo, Illinois.

1908, October 27, 6:27 p.m. IV-V

Cairo, Illinois-New Madrid, Missouri (37.0 89.2)
5,000 sq. mi.

A light shock which rattled windows and doors "considerably" at Cairo. Felt also at New Madrid, Missouri.

1908, December 27, 3:15 p.m. IV

(37.0 89.0)

(Nuttli's 1976 list)

1908, December 31, III

Blandville, Kentucky (36.9 88.9)

Several light shocks at Blandville (Ballard County), Kentucky.

1909, September 27, 3:45 and 3:50 a.m. VII

Wabash Valley, Indiana (39.5 87.4) 30,000 sq. mi.

This earthquake, centered in Indiana between Terre Haute and Vincennes, was felt over a wide area in Indiana, Illinois, Kentucky, Missouri, Arkansas, Tennessee and possibly other states. In the epicentral area, chimneys were thrown down and window panes were broken. (Location from Nuttli's 1976 list).

1909, October 22, 4:00 p.m. IV

Ironton, Mo. (37.6 90.7)

Three shocks. (TVA Chronology, 31)

1909, October 23, 1:10 a.m. V-VI

Mississippi Valley (37.0 89.5) 40,000 sq. mi.

A moderately strong earthquake which affected an area of at least 40,000 square miles in Missouri, Arkansas, Tennessee, Mississippi, Kentucky, Illinois, and Indiana. It was felt at Memphis and northward across the state along the Mississippi Valley. (Location from Nuttli's 1976 list).

1915, February 5, 12:55 a.m. IV-V

Southern Illinois (37.7 88.5)

Centered at Harrisburg, Illinois.

1915, February 18, 10:35 p.m. II-III

Cairo and Mound City, Illinois (37.1 89.2)

A light shock at Cairo and at Mound city, Illinois. Nuttli (1976) lists the intensity as IV.

1915, April 28, 5:40 p.m. IV-V

Tiptonville, Tennessee and New Madrid, Missouri
(36.5 89.5) 200 sq. mi.

One strong shock, attended by a rumbling sound, at Tiptonville, Tennessee, and New Madrid, Missouri.

1915, October 26, 1:40 a.m. IV-V

Mayfield, Kentucky (36.7 88.6)

One shock lasting about three seconds at Mayfield, Kentucky. Pictures were shaken from walls.

1915, December 7, 12:40 p.m. V-VI

Cairo, Illinois (37.0 89.2) 60,000 sq. mi.

Two shocks were felt over an area of 60,000 square miles in Missouri, Arkansas, Tennessee, Kentucky, Illinois, and Mississippi. Although centered somewhere in the vicinity of Cairo, Illinois, the earthquake was felt over the entire Mississippi Valley section of Tennessee and as far eastward as Murfreesboro in Middle Tennessee. Buildings were strongly shaken, windows and dishes rattled, and loose objects were shaken from shelves. Nuttli (1976) locates the epicenter farther south at 36.7°.

1916, February 17 III

New Burnside, Illinois (37.6 88.8)

1916, May 21, 12:24 p.m. IV

New Madrid, Missouri-Cairo, Illinois
(36.7 89.2) 7,500 sq. mi.

A shock accompanied by a rumbling noise at New Madrid and Cairo.

1916, August 24, 3:00 a.m. IV

Mississippi Valley (37.0 89.2)

A shock at New Madrid and Cairo and two shocks at Anna, Illinois. Some sleepers were awakened. Location and intensity are from Nuttli (1976).

1916, October 19, 2:00 a.m. III

Mayfield, Kentucky (36.7 88.6)

One shock lasting about 50 seconds at Mayfield, Kentucky.

1916, December 18, 11:42 p.m. V-VI

Hickman, Kentucky - New Madrid, Missouri (36.6 89.3)

Two shocks accompanied by a rumbling noise at Hickman, Kentucky, and New Madrid, Missouri. Bricks were shaken from chimneys.

1917, April 9, 2:52 p.m. VI ISOSEISMAL MAP Fig. 9

Ste. Genevieve, Missouri (38.1 90.2) 200,000 sq. mi.

A strong earthquake centered near St. Genevieve, Missouri, affected an area of at least 200,000 square miles in eleven states -- Missouri, Arkansas, Illinois, Kentucky, Tennessee, Mississippi, Indiana, Ohio, Kansas, Iowa, and Wisconsin. In the epicentral area, buildings rocked, bricks were thrown from chimneys, window panes were broken, and people were alarmed. In Tennessee, the shock was felt in the Mississippi Valley from Tiptonville to Memphis. Felt between St. Louis and New Madrid. Location from Nuttli's 1976 list.

1917, May 8, 9:00 a.m. III

Hendrickson, Missouri (36.9 90.5)

A light shock at Hendrickson, Butler County, Missouri. Nuttli (1976) does not list this shock. Perhaps it actually occurred May 9.

1917, May 9, 3:00 and 9:00 a.m. III

Hendrickson, Missouri (36.9 90.5)

Two light shocks at Hendrickson, Missouri. Aftershocks.

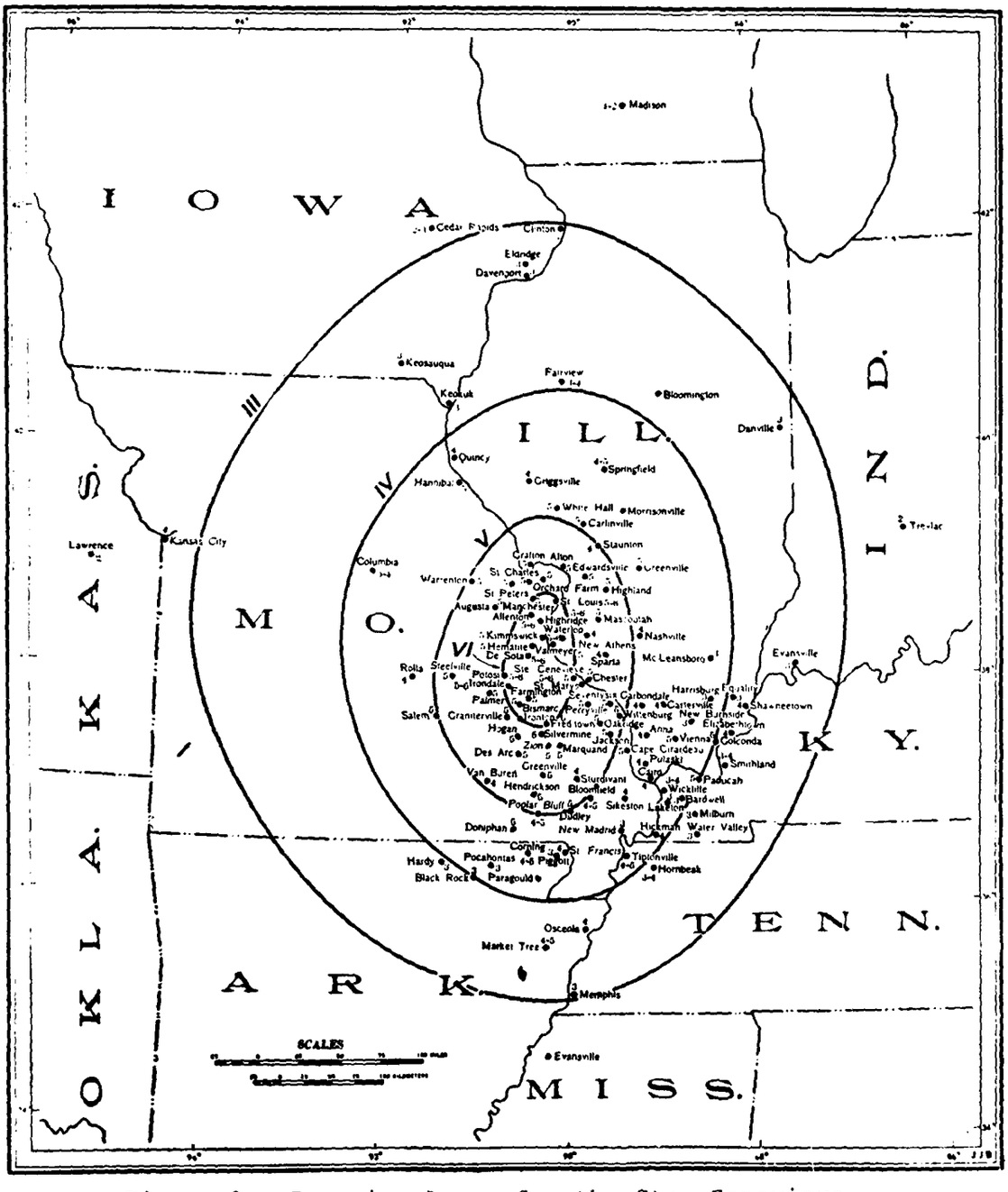


Figure 9 - Isoseismal map for the Ste. Genevieve, Missouri, earthquake of April 9, 1917 (Finch 1917, p. 92, Fig. 1)

1917, June 9, 7:14 a.m. IV

Mississippi Valley (36.7 89.0)

A light shock felt at New Madrid, Missouri, Cairo, Illinois, and Springville, Henry County, Tennessee. (Some authors erroneously state that the shock was felt at Springfield, Tennessee.) Nuttli (1976) lists the location farther west at 90.4.

1918, February 17, 2:10 a.m. IV

Cairo, Illinois (37.0 89.2)

At Cairo, Illinois, "one shock accompanied by a faint sound and an abrupt E–W rocking."

1918, October 13, 3:30 to 4:00 a.m. IV-V 1,500 sq. mi.

Mississippi Valley (36.1 91.1)

Three abrupt shocks at Black Rock, Arkansas. This earthquake attained its maximum intensity at Hoxie and Pocahontas, where trembling and rocking motions were accompanied by a rumbling noise. Felt also at Jonesboro, Arkansas.

1918, October 15, 8:15 p.m. V

New Madrid, Missouri (36.1 91.1) 50,000 sq. mi.

This earthquake was felt at widely separated points in Tennessee, Arkansas, and Illinois. It was centered somewhere near New Madrid, and affected an area of 50,000 square miles or more. The motion was described as "trembling and rocking." In Tennessee, it was felt at Union City, Memphis, Savannah, and Clarksville. Other points within the affected area include Black Rock and Hardy Arkansas, and Cairo and Anna, Illinois. Location and intensity is from the TVA 1976 list.

1919, February 10, 9:37 p.m. III-IV

Henderson, Ky. (37.8 87.5)

(TVA Chronology, 57).

1919, April 8, 2:40 a.m. III-IV

Ravenden, Arkansas (36.2 91.2)

Seismic origin questioned.

(McClain and Myers 1970, p. 30.)

1919, May 23, 6:30 a.m. III

Hickman, Kentucky (36.6 89.2)

One shock, accompanied by rumbling, at Hickman, Kentucky.

1919, May 24, 7:30 a.m. III

Hickman, Kentucky (36.6 89.2)

A light shock at Hickman, Kentucky. Aftershocks.

1919, May 26, 7:25 a.m. III

Mississippi Valley (36.9 89.0) 8,000 sq. mi.

Three shocks accompanied by a rumbling noise at Cairo, Illinois; Bardwell and Hickman, Kentucky; and at New Madrid, Missouri.

1919, May 28, 5:30 a.m. III

Hickman, Kentucky (36.6 89.2)

A light shock at Hickman, Kentucky. Aftershock.

1919, May 28, 7:45 a.m. III

Tiptonville, Tennessee (36.4 89.5)

An earthquake at Tiptonville, Tennessee. (This shock is reported 2 hours and 15 minutes later than that at Hickman, Kentucky, on the same date.)

1919, November 3, 2:40 p.m. IV-V

Pocahontas, Arkansas (36.2 90.9)

One shock, accompanied by a loud rumbling noise, felt by many at Pocahontas,Arkansas.

1920, April 7, 2:45 p.m. II

Paris, Tennessee (36.3 88.2)

(Nuttli, 1976).

1921, January 9, 3:54 p.m. IV

Mississippi Valley (36.5 89.3)

A light earthquake felt at Tiptonville, Tennessee; New Madrid, Missouri; and Hickman, Kentucky.

1921, February 27, 4:16 p.m. III

Cairo, Illinois (37.0 89.2)

One shock, accompanied by rumbling, felt by many at Cairo, Illinois.

1921, March 31, 2:30 p.m. IV

Kentucky-Indiana border (37.9 87.8)

(TVA Chronology, 97). Location is from Nuttli (1976).

1921, September 2, 8:00 a.m. III

Wilson County, Tennessee (36.0 86.1)

Several shocks, accompanied by loud noises, were felt by many in Statesville.

1921, September 21, III

(36.0 86.1)

(Nuttli's 1976 list).

1921, October 1, 3:00 a.m. IV

Harrisburg, Illinois (37.7 88.5)

(TVA Chronology, 97).

1922, January 10, 9:42 p.m. V

Kentucky-Indiana border (est. 37.9 87.9)

(TVA Chronology, 63)

1922, March 22, 4:20 p.m. V

Clinton and Columbus, Ky. (36.8 89.0)

Felt from Wilson, Arkansas, and Waterloo, Illinois to Paducah, Ky. Strongest at Columbus and Clinton Kentucky. (Monthly Weather Review, March, 1922, p. 169).

1922, March 22, 4:30 p.m. V

Anna and New Burnside, Illinois (37.5 89.0)

Felt from Jonesboro, Arkansas to New Burnside, Illinois, to Marion, Ky. to Poplar Bluff, Missouri to Memphis, Tennessee. Strongest at Jackson, Missouri, and Anna and New Burnside, Illinois. (Monthly Weather Review, March, 1922, p. 169).

1922, March 22, 8:20 p.m. V

"Cairo Area," Missouri and Illinois (37.5 89.4 about)

Felt from Blytheville, Arkansas to Poplar Bluff, Missouri to Harrisburg, Illinois and Terre Haute, Indiana to Troy, Tennessee. Not reported felt in Kentucky by Weather Bureau observers. Strongest at Jackson, Missouri, Troy, Tennessee, and Anna and New Burnside, Illinois. (Monthly Weather Review, March, 1922 p. 169).

1922, March 23, about 4 to 4:30 p.m. V

Paducah-Mayfield-Columbus, Ky. (36.9 88.8)

Felt from the Mississippi River on the west to Owensboro, Kentucky on the north and east, and Fulton Kentucky on the south. Not reported felt in Missouri, Illinois, Tennessee or Indiana. Strongest at Columbus, Mayfield and Paducah. (Monthly Weather Review, March, 1922, p. 16.)

1922, March 30, 10:53 a.m. IV-V

Mississippi Valley (36.1 89.6)

An earthquake which affected parts of Kentucky, Missouri, Illinois, and Tennessee was felt at Memphis and other points in Tennessee along the Mississippi River, and as far to the east as Farmington (Marshall County), Tennessee. Location and intensity are from Nuttli's list (1976).

1922, November 26, 9:31 p.m. VI-VII

Mississippi Valley (37.8 88.5)

An earthquake which affected parts of five states was felt at Dickson, Clarksville, and Nashville, Tennessee. The same earthquake was felt at St. Louis, where walls swayed, and at numerous localities in Illinois, Kentucky, and Indiana. The intensity and location are from Nuttli's 1976 list.

1923, May 6, 1:50 a.m. III

Cairo, Illinois (37.0 89.2)

One shock at Cairo, Illinois.

1923, May 15, 5:42 p.m. III

Cairo, Illinois (37.0 89.2)

One shock at Cairo, Illinois.

1923, November 28, 6:30 a.m. III

(37.5 87.3)

(Nuttli, 1976).

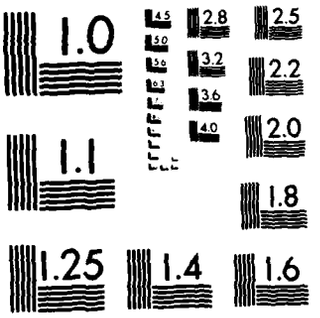
1923, November 29, 5:20 a.m. III

Cairo, Illinois - Wickliffe, Kentucky (37.0 89.1)

A light tremor felt by many at Cairo, Illinois, and Wickliffe, Kentucky.

AD-A170 665 SEISMIC STABILITY EVALUATION OF ALBEN BARKLEY DAM AND LAKE PROJECT VOLUME.. (U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTE.. E L KRINITZSKY 2/3

UNCLASSIFIED JUN 86 WES/TR/GL-86-7 F/G 8/11 NL



1924, March 2, 5:18 a.m. V

Mississippi Valley (36.9 89.1) 25,000 sq. mi.

This earthquake affected an area of at least 25,000 square miles in western Kentucky, western Tennessee, southeastern Missouri, and southern Illinois. In Tennessee, it was felt at Savannah, Nashville, and Clarksville.

1924, April 2, 5:15 a.m. IV

Ohio Valley (37.1 88.6)

A shock felt at Paducah, Kentucky, and at points in southern illinois.

1924, April 3, 5:30 a.m. III-IV

Clarksville, Tennessee (36.5 87.3)

(TVA Chronology, 25) Nuttli (1976) does not list this shock.

1924, June 6, 11:42 p.m. IV

Tiptonville, Tennessee (36.4 89.5)

One light earthquake shock accompanied by rumblings at Tiptonville, Tennessee. Felt and heard by many.

1925, January 27, 4:40 p.m. III-IV

Batesville, Arkansas (36.2 91.7)

Also felt in Calico Rock, Evening Shake, and Mammoth Spring.

(U.S.C. & G Seismo. Report January, February, March 1925, p. 7). The location is from Nuttli (1976).

1925, April 26, 10:05 p.m. VI-VIII

Ohio Valley (38.3 87.6) 100,000 sq. mi.

This moderately strong earthquake was widely felt in Kentucky, Illinois, Indiana, and Ohio. It was strongest at Princeton and Evansville, Indiana and Louisville, Kentucky. At Evansville crowds fled from theaters. At Princeton chimneys were knocked from houses. At Louisville houses creaked and dishes were broken. (U.S.C.& G.,

Seismo. Rept., April, May, June, 1925, p. 3-5). Location and intensity are from Nuttli (1976).

1925, May 13, 6:00 a.m. IV

Mississippi Valley (36.7 88.6)

A light earthquake in western Kentucky and southern Illinois. It was felt at Clinton, Mayfield, Cadiz, Blandville, Paducah, and Wickliffe, Kentucky; and at Cairo and Metropolis, Illinois.

1925, September 2, 5:55 a.m. VI

Henderson, Kentucky (37.8 87.6) 75,000 sq. mi.

This earthquake, centered near Henderson, Kentucky, was felt at numerous places in Kentucky, Illinois, and Indiana and at Nashville, Tennessee.

1925, September 20, 3:00 a.m. VI

Ohio Valley (37.8 87.6)

Earthquake shocks were felt over a sizeable area in western Kentucky and southern Indiana. These shocks, ranging from one to three in number, were probably aftershocks of the September 2 earthquake. At Henderson and Owensboro, Kentucky, two additional shocks were felt at 5:00 a.m.

1926, March 22, 8:30 a.m. IV

Southern Illinois (37.7 88.5)

Centered at Harrisburg, Illinois.

1926, April 27, 8:16 p.m. III

Kenton (Obion County), Tennessee (36.2 89.0)

A light earthquake attended by a roaring noise was felt and heard by several persons at Kenton, Obion County, Tennessee. Windows rattled and houses swayed.

1926, October 27, 10:22 and 10:25 a.m. IV-V

Poplar Bluff, Missouri (36.8 90.4)

Two earth tremors at Poplar Bluff, Missouri, shook buildings, rattled windows, and caused pictures to swing on walls. In the business section, people ran into the streets. Several shocks were reported by the press. Aftershock. Nuttli (1976) does not list this earthquake.

1926, December 13, 5:03 p.m. III

Parma, Missouri (36.6 89.8)

Buildings at Parma, Missouri, were "jarred" by one shock.

1926, December 17 IV

Tiptonville, Tennessee (36.4 89.5)

Two shocks, about a minute apart, at Tiptonville, Tennessee. Buildings rocked abruptly, frightening a few people. Aftershock.

1927, January 31, 7:30 p.m. IV

Jackson, Missouri (37.4 89.7)

Sharp tremors lasting about 30 seconds were felt at Jackson, Missouri. Furniture reportedly was moved.

1927, February 3, 2:00 a.m. IV

Poplar Bluff, Missouri (36.8 90.4)

Earthquake shocks of sufficient intensity to rattle dishes and windows were felt at Poplar Bluff, Missouri.

1927, April 18, 4:30 a.m. and 6:30 a.m. IV

Ridgely (Lake County), Tennessee (36.3 89.5)

A shock at Ridgely, Lake County, Tennessee, followed at 6:30 a.m. by two additional shocks in rapid succession. Aftershocks.

1927, August 13, 10:00 a.m. V

Tiptonville, Tennessee (36.4 89.5)

A light earthquake at Tiptonville, Tennessee. "Many buildings creaked; rapid trembling motion."

1928, April 15, 5:00 a.m. III

Mississippi Valley (36.6 89.5)

A light shock at New Madrid, Missouri. Light shocks were reported also at Cape Girardeau, and Jackson, Missouri, at 9:05 a.m.

1928, April 23, 5:00 a.m. III

Hickman, Kentucky (36.6 89.2)

"Trembling" was felt by many at Hickman, Kentucky.

1928, May 31, 4:40 p.m. IV

New Madrid, Missouri (36.6 89.5)

A light earthquake characterized by a trembling motion was felt at New Madrid, Missouri. (There is some uncertainty as to the date of this earthquake; it may have occurred a few days earlier.)

1928, November 10, 12:20 a.m. IV

Black Rock, Arkansas (36.2 91.1)

Intensity from Nuttli (1976).

1928, December 25, 9:25 p.m. III

Black Rock, Arkansas (36.2 91.1)

Windows rattled.

1929, February 26, 2:15 a.m. III

Arcadia, Missouri (37.9 90.6)

(TVA Chronology, 93)

1929, May 12, 9:50 p.m. III

Tiptonville, Tennessee - Hickman, Kentucky (36.5 89.3)

A few light bumping shocks accompanied by a muffled roar, and lasting about three seconds, were felt and heard at Tiptonville, Tennessee, and at Hickman, Kentucky.

1930, February 25, 6:35 a.m. III

Cairo, Illinois (37.0 89.2)

A light but abrupt shock felt by several at Cairo.

1930, April 2, 3:39 a.m. IV

Caruthersville, Missouri (36.2 89.7)

A light shock rattled dishes and windows at Caruthersville, Missouri. Felt in Lake and Dyer Counties, Tennessee.

1930, August 13, 2:00 p.m. II

New Madrid, Missouri (36.6 89.5)

A light shock at New Madrid, Missouri. This appears to be the first small earthquake that has an origin time listed to the nearest second (Nuttli, 1976).

1930, August 29, 12:27 a.m. V

Blandville and Barlow, Ballard County, Kentucky -

Cairo, Illinois (37.0 89.0)

Four shocks in quick succession felt at Blandville, rattled dishes, windows, and other loose objects. Sleepers were awakened by cracking, thundering, rattling, roaring noise. One shock at Cairo was accompanied by up and down motion. A sizeable area in Missouri was affected by this earthquake. A part of Lake County, Tennessee was within the affected area. Ramirez (1931, p. 162) presents an isoseismal map.

1930, September 1, 2:30 p.m. IV

Marston, Missouri (36.6 89.4)

Light but abrupt earthquake shocks were felt in the tri-state area about New Madrid. Shock abrupt and generally felt at Hickman, Kentucky. North-south motion felt by many at New Madrid. Three seconds duration. Two shocks felt at Tiptonville, Tennessee, rapid trembling and bumping. Affected area included all of Lake County, the western half of Obion, and the northwestern part of Dyer County, Tennessee. The disturbance was also felt at Woodland Mills, Tennessee. Steele, New Madrid, Gideon, Kennet, Dorena, Clarkston, Kewanee, and Marston, Missouri. At the latter locality an old chimney was thrown down and bottles toppled from the shelves in a drugstore. Ramirez (1931, p. 166) presents an isoseismal map of this earthquake.

1930, September 3, 6:00 a.m. and 11:30 p.m. III

Blandville, Ballard County, Kentucky (36.9 88.9)

Two light shocks at Blandville, Ballard County, Kentucky.

1931, April 1, 5:20 p.m. III

Mississippi Valley (36.7 88.6)

A light earthquake shock was felt at Cairo, Illinois; and at Lovelaceville, Mayfield, and Hopkinsville, Kentucky. The distribution of these localities indicates that the affected area was sizeable.

1931, April 6, 9:37 a.m. III

Berkley, Kentucky (36.8 89.1)

A light shock was felt in western Kentucky and recorded at St. Louis. Felt at Berkley, Bardwell, and Lovelaceville, Carlisle County, Kentucky, strongest at Berkley. Dishes rattled and pictures swayed.

1931, July 18, 8:52 a.m. IV

Tiptonville, Tennessee - New Madrid, Missouri

(36.5 89.5)

A sharp tremor reported to be "more severe than any in 10 or 15 years" was felt at Tiptonville, Tennessee, and New Madrid, Missouri. Houses shook, windows rattled, and trees and telephone line poles swayed. People were alarmed, but no damage was done.

1931, November 27, 3:23 a.m. III

Nashville, Tennessee (36.15 86.8)

Several light shocks were reported at Nashville. "The compilers question the seismic origin of these shocks."

1932, November 22, 1:57 a.m. III

Blytheville and Paragould, Arkansas (36.0 90.2)

A light shock at Blytheville and Paragould, Arkansas. Location is from Nuttli's 1976 list.

1933, March 11, 6:48 and 7:04 a.m. III

Poplar Bluff, Missouri (36.8 90.4)

Two distinct shocks at Poplar Bluff, Missouri. "Windows rattled and pictures shook."

1933, July 13, 8:43 a.m. III

St. Marys, Missouri (37.9 89.9)

Felt at St. Marys, Missouri, Ste. Genevieve County. Intensity from Nuttli (1976).

1933, August 3, 10:35 p.m. III-IV

St. Marys, Missouri (37.9 89.9)

". . . preceded by sound like distant thunder and wound up as loud crash when building seemed to rise up and shake." No damage.

1933, Oct. 24, time unknown III

Cape Girardeau, Missouri (37.3 89.5)

(TVA Chronology, 31)

1934, April 17, 7:53 a.m. III

St. Marys, Missouri (37.9 90.0)

(TVA Chronology, 93, 31)

1934, May 15, 8:28 a.m. III-IV

St. Marys, Missouri, (37.9 89.9)

(TVA Chronology, 93, 31)

1934, July 3, 9:10 a.m. II

Hayti, Missouri (36.3 89.8)

Slight shock. (U.S. Earthquakes 1934, p. 10).

1934, August 19, 6:47 p.m. VII ISOSEISMAL MAP Fig. 10

Rodney, Missouri 36.95 89.2 20,000 sq. mi.

An earthquake centered at Rodney, Missouri, affected an area of about 30,000 square miles in Missouri, Arkansas, Tennessee, Kentucky, and Illinois. Destructive intensity area 230 square miles. At Charleston, Missouri, window panes were broken, chimneys were thrown down or damaged and objects were thrown from shelves. There was no damage in Tennessee, but the earthquake was felt at Miston (IV), where people were alarmed sufficiently to run out of doors.

An aftershock was felt at Cairo, Illinois, and at Wickliffe, Kentucky, at 9:37 p.m.

A report on this shock by D. C. Bradford and C. G. Dahm appears in the Bulletin of the Seismological Society of America, vol. 25, no. 2, pp. 154 to 160. The following quotations are taken from that report. The shock

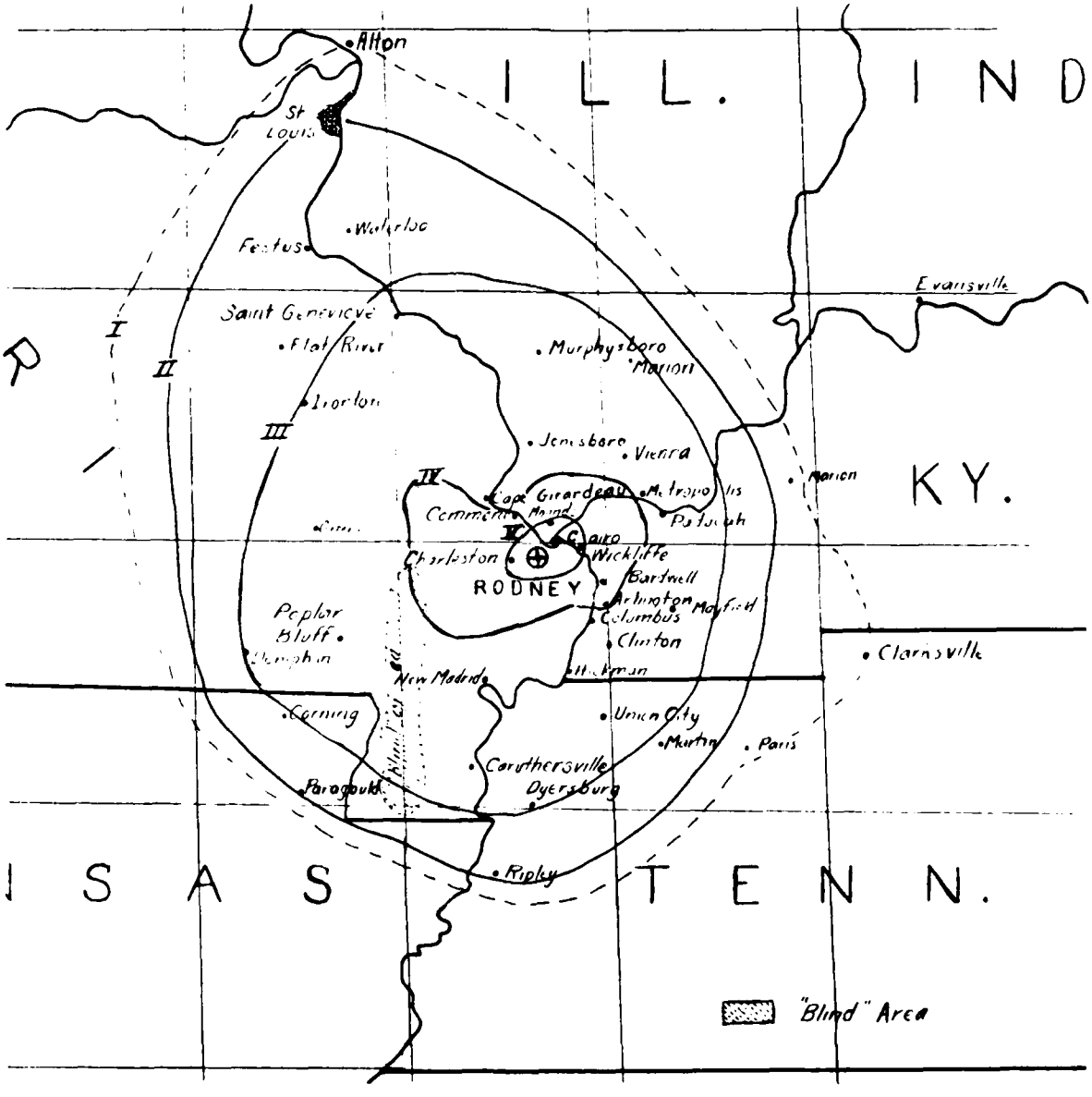


Figure 10 - Isoseismal map for the Rodney, Missouri, earthquake of August 19, 1934 (Bradford and Dahm, 1935, p. 155, Fig. 1)

* * * occurred in the immediate vicinity of the station of Rodney on the Missouri Pacific Railroad midway between Cairo, Illinois and Charleston, Missouri. This earthquake just reached destructive proportions * * * . At Charleston windows were broken, chimneys were overthrown or damaged, and articles were knocked from shelves. At Cairo, Mounds, and Mound City, Illinois, as also in Wickliffe, Kentucky, the same effects were observed. The area thus affected by destructive force approximated 230 square miles.

The intersection of the arcs from the three stations locates the epicenter at the point whose coordinates are 36.95° north latitude, 89.2° west longitude. This point is almost precisely in the center of the area in which destruction took place.

The stations referred to are St. Louis, Pittsburgh, and Georgetown.

At most of the places characterized below as intensity VI damage consisted of broken or fallen chimneys, shattered windows, cracked plaster, and falling of articles from shelves.

1934, October 29, 8:26 p.m. IV

Hartsville, Illinois 37.5 88.5 1,500 sq. mi.

The following quotations are from an article on this shock by Cornelius G. Dahm, which appears in the Bulletin of the Seismological Society of America, vol. 25, no. 3, July 1935, pp. 253-257.

The earthquake was felt over about 1,500 square miles of territory. The principal part of this area is shaped like an arrowhead. Within it a maximum intensity of IV in the Wood-Neumann scale was attained, though this was rather exceptional and was not true in the center of the area. An intensity of II-III was general in the region of perceptibility, but definite gradations were difficult to establish, since the earthquake was not very strong, and, as far as is known to the writer, caused no visible damage.

1934 Oct. 29 cont'd.

The coordinates of the epicenter of the southeastern Illinois earthquake obtained by choosing the point of intersection of the arcs of Florissant and Little Rock are 37° 31' N., 88° 30' W. This epicenter lies in Pope County, Ill., about 2 miles southeast of the Little town of Hartsville, and is at approximately the center of the area in which the earthquake was felt.

Perhaps the most striking and interesting feature of this little earthquake is that it seems to be correlated with a known fault. The epicenter lies on the Herod Fault at the point of intersection of another fault apparently unnamed. Both faults are indicated on the Geologic Map of Illinois (1917) published by the Illinois Geological Survey.

1935, July 23, 7:28 p.m. IV

Tiptonville, Tennessee (36.4 89.5)

Two abrupt bumping shocks were felt by several at Tiptonville, Tennessee.

1936, February 16, 11:05 p.m. IV

Hayti, Missouri (36.2 89.8)

A light shock at Hayti, Missouri.

1936, August 2, 4:15 p.m. III

Mississippi Valley (36.7 89.0)

A light earthquake shock was felt at widely separated points east of the Mississippi River, including Tiptonville, Springville (Henry County), and Hickory Point (Montgomery County), Tennessee; and Cairo, Illinois. The location is from Nuttli (1976).

1936, October 20, 3:17 p.m. I

Mississippi Valley (36.6 89.5)

A light shock in the New Madrid area was recorded at the Florissant Station.

1936, October 31, 10:11 a.m. I

Mississippi Valley (36.6 89.5)

A light shock centered in southeastern Missouri was recorded at the Florissant and Little Rock Stations.

1936, November 23, 3:38 a.m. II-III

Butler County, Missouri 36,8 90.6

(TVA Chronology, 31, 93)

1936, November 25, 11:42 a.m. II-III

Butler County, Missouri 36.8 90.6

(TVA Chronology, 31, 93)

1936, December 20, 4:41 p.m. III

Cape Girardeau, Missouri (37.3 89.5)

(U.S. Earthquakes 1936, p. 10).

1937, January 30, 2:57 a.m. III

Caruthersville, Missouri 36.2 89.7

Epicenter reported by the Geophysical Department of St. Louis University.

Felt slightly at Caruthersville, Kennett, Marston, and Swift in Missouri; and at Dyersburg, Elbridge, Hornbeak, Tiptonville and Troy in Tennessee. At Elbridge (III) the vibrations reportedly cracked the mortar in a few cisterns. Not felt at New Madrid and Pascola in Missouri; Newbern and Polk in Tennessee; and Blytheville, Arkansas. This shock occurred at the height of the flood of the Ohio and St. Francis Rivers.

1937, March 18, 5:58 p.m. III

Perryville, Missouri (37.7 89.8)

(TVA Chronology, 31)

1937, May 16, 6:50 p.m. III-V

Northeastern Arkansas 36.08 90.38 21,000-25,000 sq. mi.

Epicenter reported by the Geophysics Department of St. Louis University.

This light earthquake was felt over an area of more than 21,000 square miles in Arkansas, Tennessee, Missouri, Kentucky, Illinois, and Mississippi.

1937, June 23, 9:44 a.m. III

Tiptonville, Tennessee (36.4 89.5)

A light "bumping" shock at Tiptonville, Tennessee.

1937, October 5, 4:58 p.m. III

New Madrid, Missouri (36.6 89.5)

A light tremor at New Madrid, Missouri.

1938, January 16, 10:18 p.m. II-III

Perryville, Missouri (37.7 89.9)

Slight shock felt at St. Mary's Seminary, Perry County.

1938, March 16, 4:12 a.m. II

Mississippi Valley (36.6 89.5)

A light tremor "with origin probably in the New Madrid area" was recorded at Florissant.

1938, September 19 III

Tiptonville, Tennessee (36.4 89.5)

A light earthquake shock was felt at Tiptonville, Tennessee. This is not listed by Nuttli (1976).

1938, September 28, 5:32 a.m. III

Malden, Missouri (36.6 90.0)

A moderate earthquake at Malden, Missouri, was recorded at Florissant.

1939, April 15, 11:30 a.m. III-IV

Mississippi Valley (36.7 89.6)

A light earthquake was felt at New Madrid, East Prairie, Marston, Lilbourn, Gideon, and Matthews, Missouri.

1940, February 4, 11:33 a.m. II-III

Cape Girardeau and Commerce, Mo. (37.2 89.5)

Slight local tremor, recorded on local seismograph.

1940, May 31, 1:02 p.m. IV-V

Ohio Valley (37.1 88.6) 1,000 sq. mi.

A light earthquake affected an area of about 1,000 square miles in the Ohio River valley from Henderson, Kentucky, to Cairo, Illinois. The shock lasted about 15 seconds and attained maximum intensity at Paducah, where canned goods were shaken from shelves in a grocery store. It was moderately strong at Metropolis and nearby localities in southern Illinois, but light at both Cairo and Henderson. There were no reports that the disturbance was felt at Kentucky Dam, Benton, Murray, Mayfield, or Fulton.

1940, September 19 5:43 a.m. III

New Madrid, Missouri (36.6 89.5)

(TVA Chronology, 39) Time from Nuttli's 1976 list.

1940, October 10 1:34 p.m. II-III

New Madrid, Mo. (36.6 89.5)

(TVA Chronology, 39) Time from Nuttli's 1976 list.

1940, December 28 about 8:30 p.m. III

Evansville, Indiana and Owensboro, Kentucky (37.8 87.2)

Very light shock reported by a few residents of Evansville and Owensboro. (U.S. Earthquakes, 1940, p. 14).

1941, October 8, 1:51 a.m. IV

Tiptonville, Tennessee - Blytheville, Arkansas (36.2 89.8)

A mild shock was felt at Tiptonville, Tennessee, and Blytheville, Arkansas.

1941, October 21, 10:53 a.m. IV

Cairo, Illinois - Wickliffe, Kentucky (37.0 89.1)

A shock was felt at Cairo, Illinois, and Wickliffe, Kentucky. At Cairo, furniture swayed, and dishes and windows rattled.

1941, October 26, 10:00 p.m. III

Cape Girardeau, Missouri (37.3 89.5)

Several people at Cape Girardeau, Missouri, felt a light shock. Nuttli locates this earthquake near New Madrid (36.7^{o} 89.7^{o}) on the 1976 list.

1942, March 29, 6:43 a.m. IV

(37.7 88.6)

(Nuttli's 1976 list)

1942, August 31, 4:28 a.m. IV

Cairo, Illinois (37.0 89.2)

A shock at Cairo was felt by many; some awakened.

1942, November 30, 10:53 a.m. III

New Madrid Area (36.8 89.7)

(Nuttli's 1976 list).

1944, January 7, 12:18 a.m. III

Mississippi Valley 37.5 89.7

This light shock was felt in Perry, Cape Girardeau, and possibly other counties in eastern Missouri and in neighboring counties in Illinois. It was noticed at Jackson, Cape Girardeau, Perryville, Brazeau, and Oak Ridge, but it was not generally felt.

1944, September 25, 6:37 a.m. III-IV

St. Louis, Missouri (37.9 90.0)

A light earthquake centered near St. Louis affected a large area in Missouri, southern Illinois, and southwestern Indiana. It was felt as far southward as Cairo, with an intensity of II-III. Location is from Nuttli's 1976 list.

1944, December 23, time unknown IV

Caruthersville, Missouri (36.2 89.7)

(TVA Chronology, 39)

1945, January 15, 1:05 a.m. about III

St. Francois County, Missouri (37.8 90.6)

Fifteen miles west of Farmington, St. Francois County, Little Saline Creek. Farmington paper states that residents of the community felt a sharp quake that rattled dishes and shook entire houses, but no damage. Heinrich (1949) relates to Ste. Genevieve faults. Nuttli (1976) lists the location farther east at 90.2°.

1945, May 2, 5:22 a.m. IV

Marston, Missouri (36.5 89.6)

(TVA Chronology, 79) Time is from Nuttli's 1976 list.

1945, July 24, time unknown I

Gallatin County, Illinois (37.7 88.3)

(TVA Chronology, 37, 68)

1945, August 6, 5:52 & 10:05 p.m. III

Caruthersville, Missouri (36.2 89.7)

(TVA Chronology, 79) Times are from Nuttli's 1976 list.

1945, September 23, 1:22 a.m. III-IV

Cairo, Illinois (37.0 89.2)

A light shock awakened perhaps 5 percent of the population. (U.S. Earthquakes, 1945, p. 6, Nuttli (1976) places this earthquake near Blytheville, Arkansas.

1945, October 27, 4:42 a.m. III

Near New Madrid, Missouri (36.5 89.6)

(TVA Chronology, 79) Time is from Nuttli's 1976 list.

1945, November 13, 3:21 a.m. IV

Cairo, Illinois (37.0 89.2)

An extensive area in southern Illinois, eastern Missouri, and western Kentucky was affected by an earthquake centered near Cairo, Illinois. The shock was noticed at Perryville, Missouri, about 60 miles northwest of Cairo.

1946, May 15, 12:10 a.m. III-IV

Ripley County, Missouri (36.6 90.7)

Felt in Missouri, Kentucky and Tennessee. Heinrich relates to deep-seated faults near edge of Ozarks.

1946, October 7, 7:12 p.m. IV-V

Missouri-Illinois area (37.5 90.6)

Epicenter about midway between Chloride and French Mills, Missouri, in the vicinity of Hogan fault. Felt over about 3,000 square miles in Missouri and a small portion of Illinois. Residents of Annapolis, Lesterville, Lodi, Saco, and Vulcan reported very distinct rumblings like dynamite or big motors underground.

1947, January 16, 10:23 a.m. II-III

Cairo, Illinois (37.0 89.2)

(TVA Chronology, 79) Time from Nuttli's 1976 list.

1947, March 26 VI

37.0 88.4

(Nuttli, 1976)

1947, December 1, 2:47 a.m. III-IV

Poplar Bluff, Missouri 36.7 90.6

Felt in Missouri and Arkansas. "Many residents at New Madrid and Poplar Bluff, Mo. were aroused from their sleep by an earthquake centered near Poplar Bluff. The state highway patrol reported a rumbling sound several seconds before the "explosion," which "sounded like a truck ran into the side of a building.

1949, January 14, 9:45 p.m. V

Mississippi Valley (36.2 89.7) 7,000 sq. mi.

An earthquake of moderately high intensity was felt over an area of some 7000 square miles in western Tennessee, eastern Arkansas, southeastern Missouri, western Kentucky, and southern Illinois. In Tennessee, it was felt at Memphis, Brownsville, Covington, Ripley, Jackson, Huntingdon, Union City, Milan, Paris, Trenton, and Newbern. At Paris it shook pillows from beds, and "made floor lamps do crazy dances," overturning some of them. At Tiptonville, the disturbance was described as a hard shock followed by "three pulsing, rolling waves" about a second apart. Other localities reporting the shock include New Madrid, Poplar Bluff, Sikeston, Kennett, Hayti, Lilbourn, Malden, Caruthersville, Portage, and Chaffee, Missouri; Mayfield, and Murray Kentucky; Cairo, Illinois; and Osceola, Blythesville, Luxora, and Wynne, Arkansas.

1949, January 31, time unknown V

Near Caruthersville, Missouri (36.3 89.7)

(Nuttli, 1976).

1949, August 13, 3:45 p.m. III

Mississippi Valley (36.2 89.7)

A light earthquake was felt in Missouri and Tennessee in the vicinity of Caruthersville, Missouri.

1950, May 1, 9:30 a.m. II

Gideon, Missouri (36.5 89.9)

Felt by a few.

(U.S.C. & G. United States Earthquakes 1950, p. 6; and McClain and Myers 1970, p. 36.)

1952, February 20, 4:35 p.m. V

Tiptonville, Tennessee - Hickman, Kentucky 36.4 89.5

This earthquake was felt throughout the New Madrid region of northwestern Tennessee, southwestern Kentucky, southeastern Missouri, and northeastern Arkansas. The epicenter seems to have been between Tiptonville, Tennessee, and Hickman, Kentucky. At Tiptonville, two shocks were reported, each of them lasting a few seconds. Buildings shook and creaked; light fixtures swayed, and furniture shifted; some merchandise toppled from a store shelf. Frightened people ran into the streets. At the Tiptonville High School, about 50 persons had assembled in the gymnasium to donate blood to the American Red Cross for wounded soldiers in Korea. When the building began to shake and tables moved, all donors rushed out of doors. At Hickman, Kentucky window displays in stores toppled and bottles were shaken from the shelves in liquor stores. Dishes and windows rattled at Union City, Tennessee. Felt by many at Shawnee Steam Plant and Paducah, Kentucky. Felt in Dyer, Henry, Houston, Lake, Obion, Tipton, and Weakley Counties, Tenn.; in Ballard, Calloway, Carlisle, Fulton, Graves, Hickman, and McCracken Counties, Ky.; Mississippi, New Madrid, and Pemiscot Counties, Missouri; and Clay County, Arkansas.

1952, March 16 (Sunday), 7:30 p.m. III-IV

Dyersburg, Tennessee (36.0 89.4)

A light earthquake was felt by many residents of Dyersburg, especially in the North Side section. Buildings were

shaken perceptibly. One observer reported that "it felt as though a truck had run into the side of our home." Another said it "made the radio station studio walls quiver."

1952, May 28, 3:54 a.m. III-IV

Catron, Missouri (36.6 89.7)

A light shock centered in New Madrid County, Missouri. Felt in New Madrid County, especially at Catron where a jeweler reported one of his atmospheric pressure clocks jarred 3 minutes off the correct time. Also felt in Dunklin and Pemiscot Counties, Mo.; Phillippi and Miston, Tennessee; and Oakton, Kentucky. Felt in Hickman County, Kentucky, and Lake and Dyer Counties, Tennessee. Location is from Nuttli's 1976 list.

1952, July 16 (Wednesday) 5;49 and 6:09 p.m. IV-VI

Dyersburg, Tennessee (36.2 89.6)

Two earthquake shocks were felt strongly over the western part of Dyer County. Both shocks were felt at Dyersburg, Finley and Jenkinsville. The first shock, which came at 5:49 p.m. was much the stronger. Observers in Dyersburg reported hearing a low rumbling sound approaching from the southwest a few seconds before the earthquake was felt. Dishes, doors and windows rattled; mirrors and pictures swayed on walls; and houses creaked. Frightened residents ran out of their homes. The second shock came about 20 minutes after the first and was felt over the same area.

1952, October 16, 10:16 p.m. IV

Dyersburg, Tennessee (36.2 89.6)

Awakened several. Windows rattled and homes swayed gently. Felt at Finley and Lenox, Dyer County. Recorded on St. Louis University seismographs. Aftershocks reported at 10:30, 10:35 and 10:46 p.m. One observer described the shocks as "making the house shake and the lights quiver." Houses swayed, and doors and windows rattled. (U.S. Earthquakes, 1952, p. 9).

1952, December 28, 10:59 a.m. III

Mississippi County, Missouri (36.9 89.3)

This light earthquake, probably centered in Mississippi

1952, Dec. 28, Cont'd.

County, Missouri, was felt in southeastern Missouri, western Kentucky and northwestern Tennessee.

1953, January 26, Monday, 12:48 and 1:48 a.m. IV

Finley (Dyer County), Tennessee (36.0 89.5)

The western portion of Dyer County was visited by two earthquake shocks in the early morning hours. The first shock, described by some observers as "a hard jolt," came at 12:48 a.m. and was sufficiently strong to awaken most of the residents in the town of Finley. It was accompanied by a low rolling, rumbling sound which approached from the west and faded away in the east. About an hour later, a second shock, much lighter than the first, was felt by a few people. Although some four hundred people were awakened and startled by the first shock, no damage was reported.

1953, January 26, 5:18 p.m. III

Finley (Dyer County), Tennessee (36.0 89.5)

Centered near Finley and also felt in Boothspoint and Lane. The St. Louis and Florissant seismographs recorded faint traces.

1953, February 11, 4:51 a.m. IV

New Madrid, Missouri (36.6 89.5)

A moderately strong earthquake was felt at several points in Missouri, Tennessee and Kentucky. Intensity IV was attained at Dorena, Kewaunee, Marston, New Madrid, Parma, Point Pleasant and Risco, Missouri; and at Hornbeak, Tigrett and Tiptonville, Tennessee, where dishes and windows rattled, houses shook and few awakened. The earthquake was felt also at Catron, Conran, Gobler, Hermondale, Lilbourn and Talapoosa, Missouri; Hickman, Kentucky; and Elbridge (Obion County), Tennessee.

1953, February 17, 5:45 a.m. and 6:17 p.m. IV

Finley, Tennessee (36.0 89.5)

Felt by several. Windows and dishes rattled in some homes.

1953, February 18, 11:05 p.m. III

Finley (Dyer County), Tennessee (36.0 89.5)

Windows rattled in several homes. Duration only a few seconds.

1953, May 6, 1:50 a.m. III

Cairo, Illinois (37.0 89.2)

(TVA Chronology, 57)

1953, May 15, 5:42 p.m. III

Cairo, Illinois (37.0 89.2)

(TVA Chronology, 57).

1954, January 17, 1:15 a.m. IV

Dyersburg, Tennessee (36.0 89.4)

Awakened some residents who heard tinkling glassware on dressing tables as houses were shaken. Felt in Finley.

1954, February 2, 10:53 a.m. VI

Poplar Bluff, Missouri - Pocahontas, Arkansas (36.7 90.3)

Tremor centered in New Madrid, Mo., area with slight damage in Poplar Bluff (plaster knocked from ceiling) and Pocahontas (split wall of school building, damage less than $100). Numerous felt reports, some greater than intensity IV were received from the adjoining four state areas of Arkansas, Illinois, Missouri, and Tennessee. The location is from Nuttli's 1976 list.

1955, January 25, 1:24 a.m. VI ISOSEISMAL MAP Fig. 11

Finley, Tennessee 36.0 89.5 30,000-40,000 sq. mi.

The earthquake was felt from Lepanto, Ark., northward to Paducah, Ky., and eastward to Birmingham, Ala. In southeast Missouri and western Tennessee, several reported shattered windows and damaged plaster walls. Along the New Madrid Fault line, thousands of people were awakened.

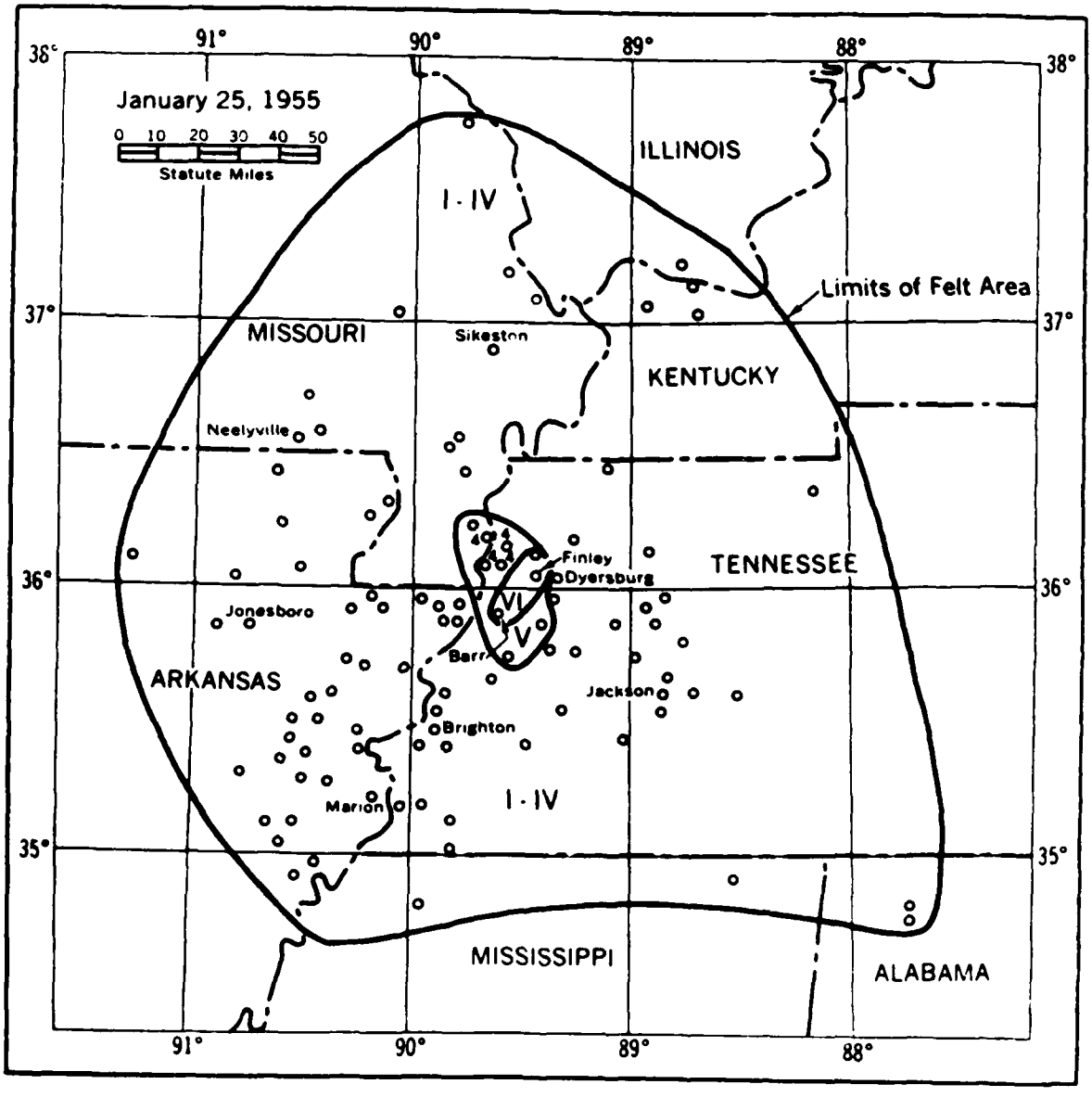


Figure 11 - Isoseismal map for the Finley, Tennessee, earthquake of January 25, 1955 (U.S. Coast and Geodetic Survey 1955, p. 10, Fig. 3)

1955, January 25, Cont'd.

Police stations and telephone exchange were deluged with calls. (The earthquake was recorded on the seismographs at St. Louis University and the University of Arkansas.)

Intensity VI in Tennessee

Barr - Felt by and awakened all. Roaring sounds heard.

Dyersburg - Felt by nerly all. Many awakened. Furniture shifted several inches. A brick pillar supporting a porch was shaken down. Shock preceded by noise described as like a tornado approaching.

Finley - Felt by all. Several houses cracked; plaster walls and ceilings cracked. Canned goods shaken from shelves in a grocery store on Highway 78. An observer reported that her bed left the floor at times. Rumbling noise heard during the earthquake.

Intensity V in Missouri

Hayti - Felt by many. Windows cracked in telephone exchange.

Intensity V in Tennessee

Halls - Felt by nearly all. Many awakened. Windows and doors rattled. Rumbling noise heard before and after earthquake. Duration about 15 to 30 seconds.

Ripley - Felt by and awakened nearly all. Rumbling noise like heavy distant explosion heard during earthquake.

1955, March 29, 3:03 a.m. VI

Finley, Tennessee (36.0 89.5)

Felt by all. 'aster cracked in one home. A roaring noise and violent aking was reported. Felt by and awakened many in Caruthersville, Missouri. (III) Also felt at Dell, Arkansas, Braggadocio, Gobler, and Hayti, Missouri; and Elbridge, Hornbeak, Miston, and Woodland Mills, Tennessee.

1955, April 11, 4:50 a.m. II

Harrisburg, Illinois (37.7 88.5)

Mild tremor lasting only a few seconds. (U.S. Earthquakes, 1955, p. 13).

1955, September 5, 7:45 p.m. and 8:00 p.m. V

Finley and Dyersburg, Tennessee (36.0 89.5)

Felt by and frightened many. At Finley houses shook, and windows and dishes rattled. There was a "rumble that sounded like a freight train." Children watching a television program were frightened and ran out of the room. One observer said the tremor felt as if it were "lifting my house from its foundation." At Dyersburg the local radio station was flooded with calls. Many people rushed out of their homes to find out the cause of the disturbance. One observer said her house shook for several seconds, "starting out weakly, reaching a peak, and then gradually subsiding." Dishes rattled by vibrations. A table lamp "danced a jig."

1955, September 24, 12:45 p.m. III-IV

Tiptonville, Tennessee (36.4 89.5)

A hard shock lasting about four seconds jarred Tiptonville, Tennessee, at 12:45 p.m. Hard jolt as if truck had hit building. Felt by many. Houses shook; dishes moved on table; loose objects rattled. Dishes and windows rattling were reported in a home 1 mile northeast of Tiptonville. People at lunch reported feeling the table shake and seeing dishes move.

1955, December 13, 1:45-1:56 a.m. V

Finley, Tennessee (36.0 89.5)

Sleepers in western Dyer County were awakened by two earthquake shocks, the first at 1:45 a.m. CST and the second at 1:56 a.m. CST. The first shock was the harder of the two. Both of the shocks were felt by many residents of Finley. The intensity is from Nuttli's 1976 list.

1956, January 23, 11:00 p.m. II-III

Caruthersville, Missouri (36.2 89.7)

Felt in Lake and Dyer Counties, Tennessee.

1956, October 29, 3:24 a.m. V

Caruthersville, Missouri (36.1 89.7)

Felt by and awakened many. Houses shook. Sounded like an explosion. Felt throughout southeastern Missouri and in Lake and Dyer County, Tennessee. Recorded by the seismograph at Saint Louis University. Location from Nuttli's 1976 list.

1956, November 25, 10:13 p.m. VI

Wayne County, Missouri (37.1 90.6) 21,500 sq. mi.

Felt over an area of approximately 21,500 square miles of Arkansas, Illinois, Kentucky, Missouri, and Tennessee. Minor damage occurred at Grubville, Richmond Heights, (suburb of St. Louis), St. Louis, Mo., where windows were shattered and walls cracked, and at Sturdivant, Mo., where concrete porch was cracked. Police and newspaper switchboards swamped with calls of inquiry. Many persons thought there had been an explosion. An isoseismal map of this earthquake is presented in U.S. Earthquakes (p. 15, Fig. 6).

1957, March 26, 2:27 a.m. V

Paducah, Kentucky (37.1 88.6)

Felt by and awakened many. Buildings creaked; loose objects rattled. Newspaper and radio switchboards were swamped with calls of inquiry. Most people thought a big explosion had occurred somewhere in the area. Disturbed objects observed by several. Trembling motion. Felt by and awakened several at Smithland, where buildings creaked and loose objects rattled. Thunderous sounds heard by several. Recorded by the Saint Louis seismograph.

1957, August 17, 5 p.m. IV

Bogota, Tennessee (36.2 89.4)

Felt by many. Buildings shook; windows and dishes rattled; canned goods in stores jolted. Duration several seconds, but gave residents "quite a scare." Time is from Nuttli's 1976 list.

1958, January 26, 10:56 a.m. V

Caruthersville, Missouri (36.1 89.7)

Felt by many; several alarmed. Kitchen utensil and clock fell to floor; dishes clattered; windows rattled; floors shook. Intensity (damage) IV at Caruthersville, New Madrid, and Sikeston, Missouri. Recorded by the Saint Louis seismograph. At Caruthersville,the concrete Courthouse "shook substantially." The location is from Nuttli's 1976 list.

1958, January 27, 11:57 p.m. V

Illinois-Kentucky-Missouri border (37.3 89.3)

Felt over an area approximately 3000 square miles of Illinois, Kentucky and Missouri. Recorded by the Saint Louis seismograph.

Intensity (Damage) V in Illinois

Cairo - Felt by and awakened many. Violent shaking. Faint rumble heard before shock.

Grand Tower - Felt by and awakened many. Many thought their furnaces had exploded.

Mounds - Felt by, awakened, and frightened many. Houses rocked.

Intensity (Damage) V in Kentucky

Paducah - Felt by and awakened many. Press reported two people thrown from beds. Houses rocked; windows rattled.

Intensity (Damage) V in Missouri

Cape Girardeau - Felt by, awakened, and frightened many. Police switchboards swamped with calls from anxious residents. Some thought their furnaces had exploded.

1958, April 8, 4:25 p.m. V

Obion County, Tennessee (36.3 89.2) 400 sq. mi.

A light earthquake centered in Obion County was felt over an area of 400 square miles. Maximum intensity (damage) V occurred at Troy, where nearly all ran from homes; windows rattled; houses shook. Felt by nearly all at Obion, where the shock was accompanied by thunderlike noises. Also felt intensity (damage) IV at Elbridge (few alarmed), Hornbeak, Lane, Trimble, Union City and Woodland Mills. Recorded by the Saint Louis Seismograph.

1958, April 26, 1:30 a.m. IV

Lake County, Tennessee (36.4 89.5)

Felt by and awakened many. Many reported a roaring noise resembling thunder, then a sudden jar. The shock was also felt at Caruthersville, Missouri. Intensity is from Nuttli's 1976 list.

1958, November 7, 8:42 p.m. VI ISOSEISMAL MAP Fig. 12

Wabash River (38 4 87.9) 33,000 square mi.

Felt over an area of approximately 33,000 square miles of Illinois, Indiana, Kentucky, and Missouri. Recorded by Saint Louis seismograph.

Intensity (Damage) VI in Illinois

Bartelso - Felt. Cracked basement floor of new home. "Felt like building was getting a big push--lots of rattling."

Dale - Felt. Plaster cracked and fell. Floor vibrated; sounded like the roaring of a train.

Mauni - Felt by and alarmed many. Basement wall cracked; wall paper damaged. Dishes and windows rattled. Many thought their furnaces had exploded.

Mount Carmel - Felt by nearly all; many alarmed. Canned goods fell from shelves. Over 4,000 calls to the telephone company seeking cause of shock or noise. Buildings shook; loose objects rattled. Also felt by hundreds of football fans in stadium in the eastern section of Mount Carmel.

Sumner - Felt by and alarmed many. Water heater displaced. Buildings shook; disturbed objects observed by many.

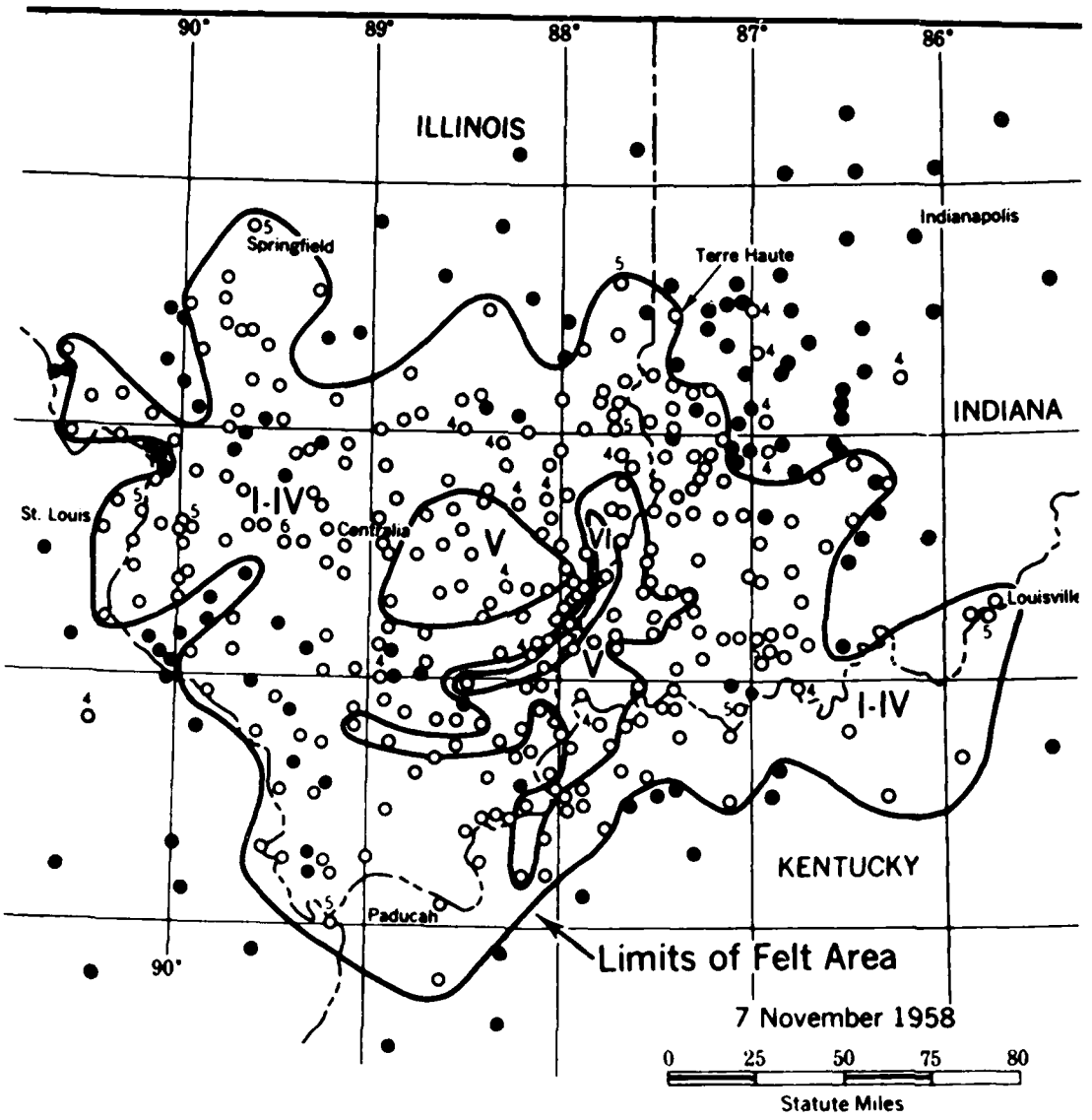


Figure 12 - Isoseismal map for the Wabash River earthquake of November 7, 1958 (U.S. Coast and Geodetic Survey, 1958, p. 10, Fig. 3)

1958, Nov. 7, Cont'd

Intensity (Damage) V in Illinois

Albion - Felt by many. Small amount of plaster fell from ceiling. Houses shook; dishes rattled.

Barnhill - Felt by all. House cracked and popped as if settling. Swaying, rocking motion from east to west; gradual onset.

Bone Gap - Felt by nearly all. Sounded like truck hit side of building.

Bridgeport - Felt by all. Buildings creaked; loose objects rattled. Sounded like jet breaking the sound barrier or truck hitting side of building.

Cairo - Felt by many; few alarmed. Mason jars displaced on shelf. Buildings shook; dishes rattled; venetian blinds, curtains, hanging lamps swayed violently. Rumbling sounds like approaching train heard before shock.

Clay City - Felt by nearly all.

Crossville - Felt by nearly all; many alarmed.

Ellery - Felt by all. Houses shook; windows and dishes rattled.

Emma - Felt by nearly all. Heavy jolt. Some thought their furnaces had exploded.

Equality - Felt by all; few alarmed. Buildings creaked; loose objects rattled. Abrupt onset; explosivelike sounds.

Harrisburg - Felt by all. Buildings creaked; loose objects rattled. Rumbling sounds heard by many. Rapid onset; rocking north-south motion.

Herald - Felt by nearly all.

Herrin - Felt by many. Mayor of town reported he was knocked out of bed.

Johnsonville - Felt by many; general alarm. Slight damage to ornaments. Buildings shook; loose objects rattled. Loud roaring sounds heard by many. Abrupt onset; bumping motion.

Keenes - Felt by almost all. Buildings shook; loose objects rattled. Rumbling sounds heard. Abrupt onset; trembling motion.

Lawrenceville - Felt by nearly all; few alarmed. Buildings shook; loose objects rattled. Thunderous sounds heard 1 second before shock. Gradual onset; trembling motion.

Marion - Felt by and alarmed many. Buildings shook; loose objects rattled. Bumping, swaying motion.

Mill Shoals - Felt by all. Buildings shook; dishes rattled.

Mount Vernon - Felt by and alarmed many. Numerous calls to the city police. Houses shook; loose objects rattled; swaying motion.

O'Fallon - Felt by all.

Orchardeville - Felt by all. Windows and doors rattled; heavy vibration.

Paris - Felt. Slight damage reported.

Pinkstaff - Felt by and alarmed many. Bed rocked. Abrupt onset; bumping, rocking motion.

Ridgway - Felt by all. Buildings shook; loose objects rattled. Sounded like a large truck--roaring and vibrating. Abrupt onset; trembling motion.

Rinard - Felt by many. Lamps fell from tables and dishes from shelves. Sounded like gas furnace had exploded. Gradual onset; bumping motion.

Robinson - Felt by all. Rumbling sounds heard by many.

St. Francisville - Felt by and alarmed many. Windows rattled. Rumbling sound followed shock.

Sims - Felt by nearly all; few alarmed. Buildings shook; loose objects rattled. Rapid onset; trembling motion; earth sounds heard by many.

Springfield - Felt by many. Plaster shaken loose from ceilings; buildings shook; loose ojbects rattled. Moderate earth sounds heard by many. Abrupt onset; trembling motion.

Xenia - Felt by nearly all.

Intensity (Damge) V in Indiana

Cynthia - Felt by all. Houses shook.

Evansville - Felt by and alarmed many. Buildings creaked; loose objects rattled. Police and Weather Bureau switchboards swamped with calls from anxious residents. Dishes, tables, and chairs moved. Described as "everything from an explosion to a plane crash."

Fort Branch - Felt by several. Plaster fell; windows rattled.

Haubstadt - Felt by nearly all.

Hazleton - Felt by nearly all; general alarm. Buildings creaked; loose objects rattled. Disturbed objects observed by several.

Mount Vernon - Felt by nearly all; many alarmed. Police switchboards swamped with calls. Houses shook; dishes rattled in cabinet.

New Harmony - Felt by nearly all. Stove and refrigerator "danced." Buildings creaked; loose objects rattled. Trembling motion.

Oakland City - Felt by and alarmed many. Buildings shook; dishes and utensils rattled. Books in bookcases slipped but did not fall. Roaring and whistling sounds heard about 1 minute before earthquake.

1958, Nov. 7, Cont'd

Owensville - Felt by all. Loud, rumbling sounds heard by many.

Princeton - Felt by all. Explosivelike sounds heard by many.

Rockport - Felt by all; many alarmed. Numerous calls to newspaper office from anxious residents. Houses shook; chairs quivered; smokingstand "danced."

Santa Claus - Felt by all. Steam pipes rattled.

Stewartsville - Felt by all. Noticeable shaking. Rumbling sounds heard by many.

Terre Haute - Felt by and alarmed several. Vibrations moved end of heavy sectional davenport 1 inch. Pillow on davenport fell. Dishes rattled; furniture and lights shook. Roaring sounds heard by many.

Intensity (Damage) V in Kentucky

Corydon - Felt by all. Dishes and windows rattled.

Dyersburg - Felt by all. Windows rattled.

Louisville - Felt by nearly all. Houses shook; windows rattled; furniture moved.

Morganfield - Felt by many; few alarmed. Pictures and dishes displaced. Buildings creaked; loose objects rattled. Earth sounds heard by several at beginning of earthquake.

Sturgis - Felt by nearly all.

1959, January 21, 9:35 a.m. IV

Ridgely, Tennessee (36.3 89.5)

A light shock felt by many and lasting three to five seconds. Buildings vibrated; dishes, doors, and windows rattled; cans and bottles on shelves were shaken. Preceded by explosive sound.

1959, February 13, 2:37 a.m. V

Bogota, Tennessee (36.2 89.4) 170 sq. mi.

Felt over an area of about 170 square miles of Dyer, Lake and Obion counties. At Bogota many were awakened. Houses were shaken; dishes, doors, and windows rattled. Two separate shocks about 2 minutes apart reported by one observer. Roaring sounds heard. Felt intensity (damage) IV at Miston. Also felt at Lane (III), Lenox (II), and Ridgely (II). After shock.

1959, December 21, 10:25 a.m. V

Finley, Tennessee (36.0 89.5) 400 sq. mi.

Felt over an area of approximately 400 square miles of Dyer, Lake, and Lauderdale counties, Tenn., and Pemiscot County, Mo. At Finley, people were alarmed and ran outside; plastered walls and ceilings cracked; objects thrown from shelves; doors jarred open; furniture shifted. A washing machine in operation "started dancing around." A chimney cracked at Lenox. At McCullough's Chapel, 2.7 miles northeast of Finley, one observer had to hold onto a table to keep from falling. The shock was strongly felt at Bogota, Boothsville, Dyersburg, and Miston. Felt by one at Caruthersville, Mo.

1960, January 28, 3:38 p.m. V

Finley, Tennessee (36.0 89.5) 230 sq. mi.

A light earthquake shock was felt over an area of 230 square miles. The felt area was limited very largely to Dyer County, although it includes small areas in Lauderdale County, Tennessee, and Pemiscot County, Missouri. At Finley, where the intensity was a little higher than III, the shock rattled dishes, doors, windows and loose objects, and was felt a little less strongly at Dyersburg and Lenox, and with a force of II at Boothspoint on the east bank of the Mississippi River. At Lenox, a noise accompanied the shock.

1960, April 21, 4:45 a.m. V

Lake County, Tennessee (36.4 89.5)

Felt by and awakened many. Houses vibrated. Rumbling sounds like distant thunder heard by many.

1961, September 9, 4:43 p.m. IV

Arkansas-Missouri border 36.4 91.3

Felt by many at Doniphan, Mo., where buildings shook, and loose objects rattled. Rapid onset; sounded like a sonic boom. At Pocahontas, Ark., felt by several. Doors rattled. Abrupt onset; bumping motion.

1962, February 2, 12:44 a.m. VI 4.2 ISOSEISMAL MAP Fig. 13

Catron and Marston, Missouri 36.5 89.6 35,000 sq. mi.

Focal depth 25 km. Felt by, awakened, and alarmed many over a 35,000 square mile area of Arkansas, Illinois, Kentucky, Missouri, and Tennessee. Maximum intensity (damage) VI was reported at Catron and Marston, Missouri.

Questionnaire canvass conducted by Saint Louis University.

Intensity (Damage) VI in Missouri

Catron - Felt by and awakened nearly all. Slight damage. Walls and plaster cracked. Two water pipes reported broken. Buildings creaked; loose objects rattled. Light fixtures and window sash weights swayed.

Marston - Felt by, awakened, and alarmed many. Slight damage. One chimney destroyed; two partially damaged; some windows cracked. Objects fell to the west. Buildings rattled and shook.

Intensity (Damage) V in Arkansas

Jonesboro - Felt by nearly all. Windows rattled. Continuous roar with occasional vibrations--some fairly heavy.

Maynard - Felt by nearly all. Windows and dishes rattled; rumbling sounds heard.

Osceola - Felt. Broke window in dining room at the Harris Restaurant.

Tulot - Felt by and awakened nearly all. Creaking of buildings and rattling of loose objects heard by few. Abrupt onset; trembling motion.

Intensity (Damage) V in Kentucky

Boaz - Felt by and awakened many. Buildings creaked; loose objects and windows rattled. Loud rattling earth sounds heard. Rapid onset; rumbling and shaking motion.

Intensity (Damage) V in Missouri

Cape Girardeau - Felt by, awakened and frightened many. Buildings rocked; loose objects and venetian blinds rattled,

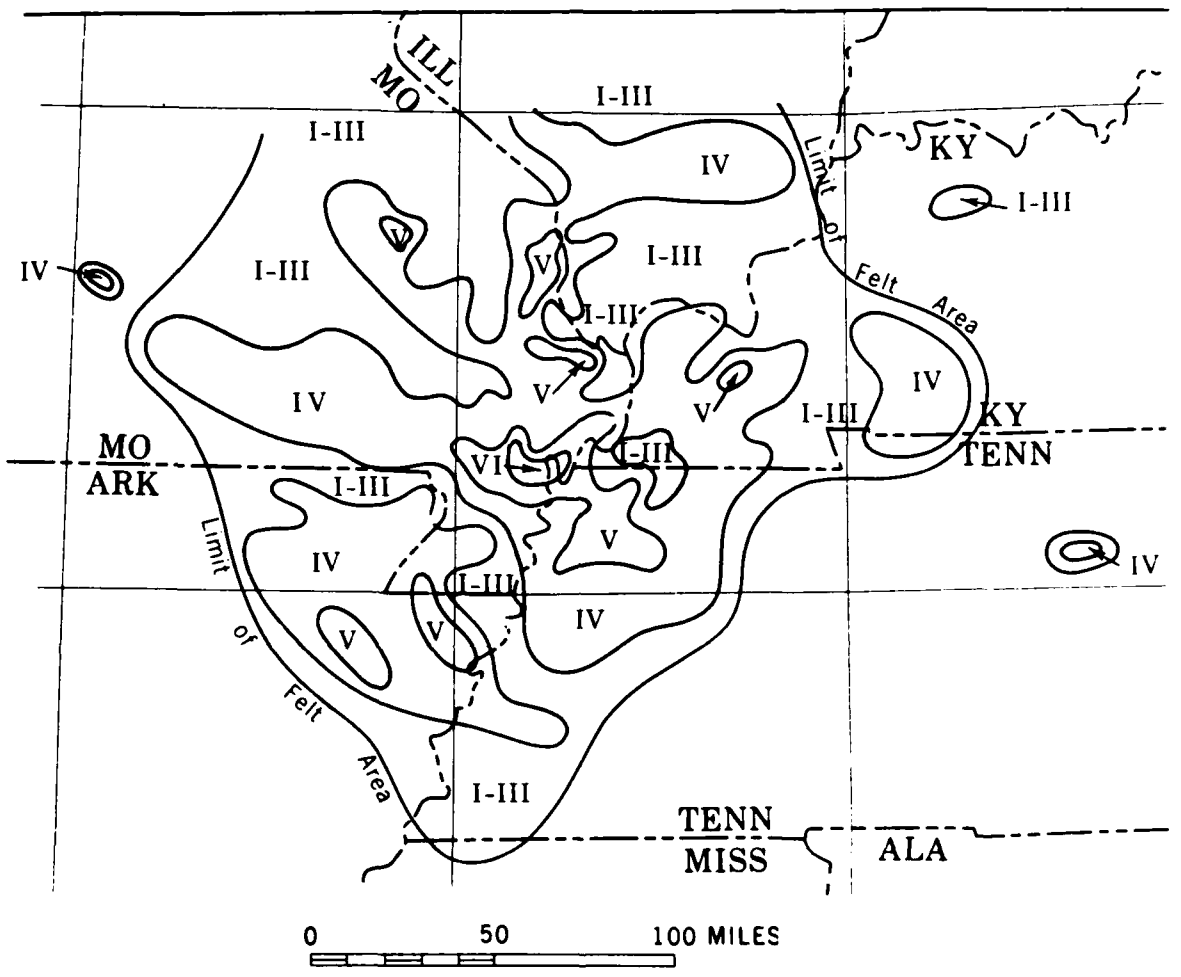


Figure 13 - Isoseismal map for the Catron, Missouri, earthquake of February 2, 1962 (Stearns and Wilson, 1972, Fig. 2.9A-9)

Moderate rumbling earth sounds heard at beginning of earthquake. Rapid onset.

Chaffee - Felt by and awakened many. Buildings creaked; loose objects rattled. Lamp swayed in north-south direction. Faint rattling earth sounds heard during earthquake. Gradual onset; north-south motion; duration 10-15 seconds.

Charleston- Felt by and awakened many. Buildings creaked; loose objects rattled. Rumbling, thunderous sounds heard. Abrupt onset; trembling motion.

Dutchtown - Felt by and awakened nearly all. Buildings creaked, loose objects, windows, and dishes rattled. Loud bumping and rattling earth sounds heard at beginning of earthquake. Abrupt onset; trembling motion.

Falcon - Felt. "Things fell from shelves."

Fredericktown - Felt by and awakened many. Houses shook; bed moved. Deep rumbling sounds heard during earthquake.

Fruitland - Felt by and awakened nearly all. Slight damage. Report of crack in underground cistern. Loose objects rattled; bed rocked. Roaring sounds heard by nearly all. Abrupt onset; undulating motion, east-west; duration, 10-60 seconds.

Gideon - Felt by and awakened many. Buildings creaked; loose objects rattled. Faint roaring earth sounds heard by many at beginning of earthquake. Abrupt onset; trembling motion.

Hollywood - Felt by all. Buildings shook; dishes and windows rattled.

Malden - Felt by and awakened many. Slight damage. Reports of cracked windows. Buildings shook; loose objects and windows rattled. Abrupt onset; trembling motion, southwest-northeast.

Morley - Felt by and awakened many. Abrupt onset; bumping motion.

New Madrid - Felt by and awakened many. Buildings creaked; loose objects rattled. Thunderous earth sounds heard by many at beginning of earthquake. Abrupt onset; trembling motion.

Portageville - Felt by and awakened many. Buildings creaked; loose objects rattled. Roaring earth sounds heard by many at beginning of earthquake. Rapid onset; trembling motion.

Saint Louis - Felt by and awakened many. Police switchboards flooded with calls from alarmed citizens.

Tallapoosa - Felt by and awakened nerly all. General alarm. Buildings creaked; loose objects rattled. Moderately loud roaring sounds heard by nearly all. Gradual onset; trembling motion.

Wolf Island - Felt by and awakened many. Buildings creaked; loose objects and windows rattled; bed shook. Rapid onset.

1962, Feb. 2, cont'd

Intensity (Damage) V in Tennessee

Bogota - Felt by and alarmed many. Buildings creaked; loose objects rattled. Subterranean sounds heard before earthquake. Gradual onset; trembling motion.

Elbridge - Felt by and awakened many; few alarmed. Buildings creaked; loose objects rattled. Thunderous sounds heard by nearly all. Rapid onset; trembling motion from west; duration, 1 minute.

Hornbeak - Felt by many. General alarm. Buildings creaked. Loose objects rattled. Bird knocked off perch. Rapid onset.

Lenox - Felt by nearly all. Doors and windows rattled. Rumbling sounds heard during earthquake.

Obion - Felt by and awakened many; few alarmed. Buildings creaked; loose objects rattled. Disturbed objects observed by many. Trembling motion.

Reelfoot Lake (vicinity of). — "It was reported to have broken water pipes in some places."

Troy - Felt by and awakened many. Slight damage. Buildings creaked; loose objects rattled. Disturbed objects observed by several. Gradual onset; trembling motion.

Union City - Felt by and awakened many; few alarmed. Slight damage. Wall cracked. Buildings creaked; loose objects, windows, and doors rattled. Dishes on north-south wall rattled. Gradual onset; trembling motion.

1962, June 26, 7:29 p.m. V 4.4

Southern Illinois (37.7 88.5)

Focal depth 25 km. Felt in Illinois, Kentucky, and Missouri. Maximum intensity (damage) V. In Williamson and Franklin counties, Illinois, flower pots toppled, pictures fell from walls, and clocks stopped. Slight damage to walls at Johnston City and window damage at West Frankfort was also reported. Questionnaire canvass conducted by Saint Louis University.

Intensity (Damage) V in Illinois

Jacob - Felt by all. Houses shook; "something" rattled on oil burner stove.

Johnston City - Felt. Slight damage to walls reported.

Marion - Felt. Buildings creaked; loose objects rattled. Moderately loud earth sounds heard. Gradual onset; trembling motion.

West Frankfort - Felt. Window damage reported.

1962, June 26, cont'd

Intensity (Damage) V in Kentucky

Paducah - Felt by many. Police, newspaper, and television switchboards flooded with calls from alarmed residents. Buildings shook; windows and doors rattled.

1962, July 13, 8:24 p.m. II-III

Bloomfield, Missouri (36.9 89.9)

Focal depth 18 km. Intensity from Nuttli's 1976 list.

1962, July 23, 12:05 a.m. VI 4.2

Dyersburg, Tennessee (36.1 89.8) 1,100 sq. mi.

Felt in Arkansas, Missouri, and Tennessee. Maximum intensity (damage) VI at Dyersburg, Tenn., where walls and plaster on walls cracked. Stearns and Wilson (1972, Fig. 2.9A-11) present an isoseismal map of this earthquake.

Intensity (Damage) VI in Tennessee

Dyersburg - Felt by nearly all; awakened and alarmed many. Slight damage. Walls and plaster on walls cracked. Police and radio station switchboards swamped with calls. Buildings shook; windows, doors, dishes, and kitchen utensils rattled; bed jumped. Moderately loud thunderous earth sounds heard by several before earthquake.

Intensity (Damage) V in Tennessee

Bogota - Felt by, awakened, and alarmed nearly all. Buildings creaked; loose objects, doors, windows, and dishes rattled. Gradual onset; trembling motion.

Boothspoint - Felt by and awakened many. Doors swung open. Buildings, doors and windows rattled.

Elbridge - Felt by and awakened many. Buildings creaked; windows, doors, dishes and loose objects rattled. Rattling, thunderous earth sounds heard by several at beginning of earthquake. Rapid onset; trembling motion.

Finley - Felt by all; awakened and alarmed many. Furniture shifted; small objects overturned. Buildings creaked; loose objects rattled. Bumping earth sounds heard by several during earthquake. Abrupt onset; trembling motion, north to south.

1962, July 23, Cont'd

Lenox - Felt by and awakened many. Small objects overturned. Buildings creaked; loose objects, windows, doors, and dishes rattled. "Felt like a heavy object hitting the building." Thunderous earth sounds heard. Rapid onset; bumping motion.

Miston - Felt by, awakened, and alarmed many. Slight damage to wall (pulled the wall away from floor in kitchen). Buildings creaked; loose objects rattled. "Felt like a heavy object hitting the building." Bumping, roaring earth sounds heard. Abrupt onset; rolling motion, south to west.

Newbern - Felt by and awakened many; few alarmed. Buildings creaked; loose objects, windows, doors and dishes rattled; doors swung shut. "Felt like a heavy object hitting the house." Abrupt onset; trembling motion.

1963, March 3, 11:30 a.m. VI 4.7 ISOSEISMAL MAP Fig. 14

Southeast Missouri (36.7 90.1) 100,000 sq. mi.

Focal depth about 18 km. Felt over an area of approximately 100,000 square miles in nine states. Maximum intensity (damage) VI in Missouri. Also felt in Arkansas, Illinois, Indiana, Kansas, Kentucky, Mississippi, Oklahoma and Tennessee. Plaster cracked and fell; bricks fell from chimneys; and foundations, walls, sidewalks, chimneys, and windows cracked in various towns. In Poplar Bluff, Mo., water lines were damaged and many basements flooded.

Intensity (Damage) VI in Missouri

Arab - Felt by all. Cracked plaster, concrete floors, and concrete blocks reported. Earth noises heard which sounded like a freight train.

Broseley - Felt by all. General alarm. Cracks appeared in some places around basements and foundations. Light cracks in plaster. Plaster fell in older structures. Merchandise thrown to floor in stores. Water moved in large containers and ponds. "Pumps are going dry since quake." Loud, roaring subterranean sounds heard at beginning of earthquake. Rapid onset; trembling motion. 3 shocks.

Campbell - Felt. Several brick chimneys down. Walls and ceilings cracked. Dishes and other glass items thrown to floor and broken. Dull roar heard moving west-east; became louder as it arrived, and then moved east.

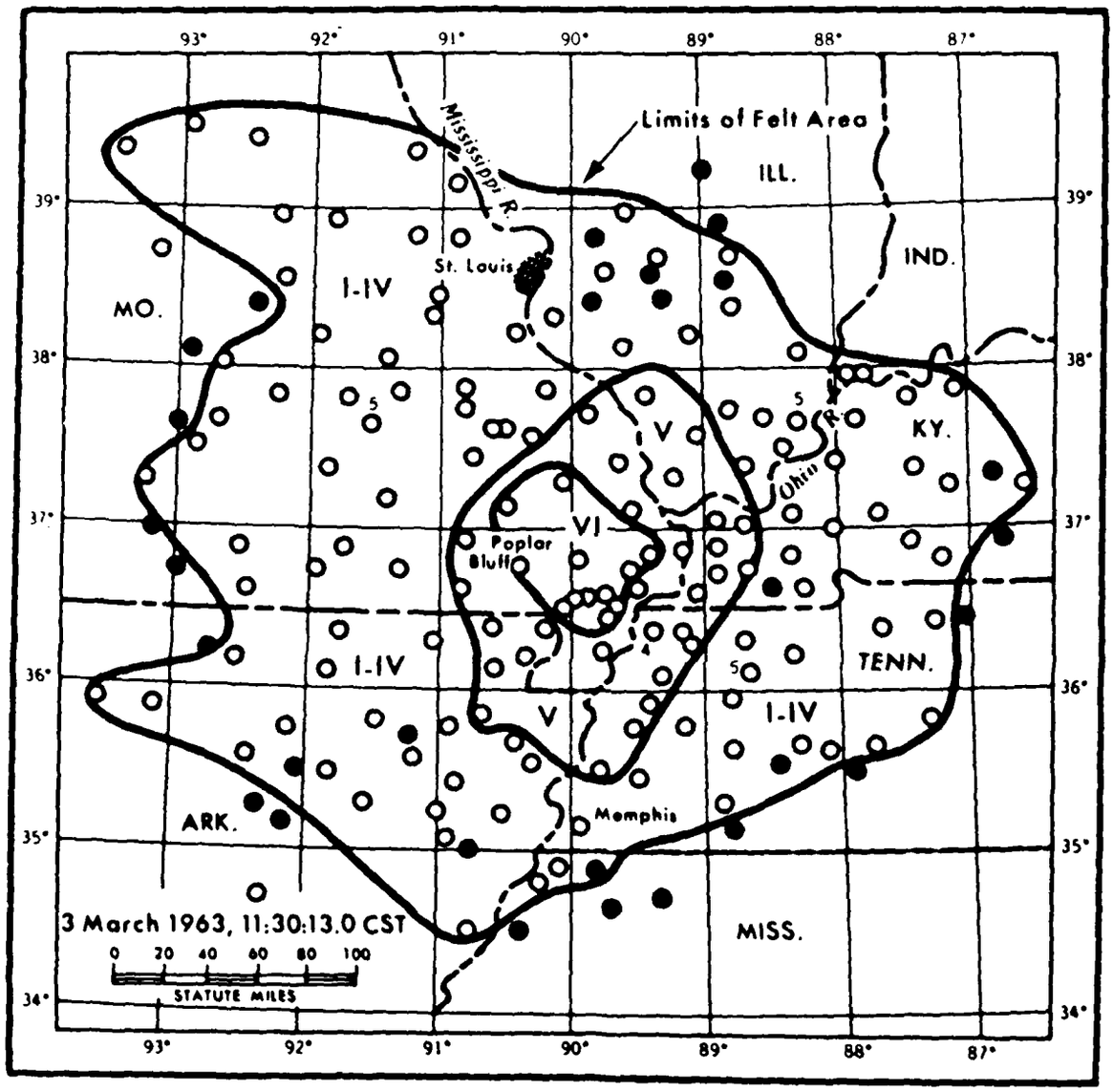


Figure 14 - Isoseismal map for the southeast Missouri earthquake of March 3, 1963 (U.S. Coast and Geodetic Survey, 1963, p. 13, Fig. 4)

Catron - Felt by and alarmed many. Plaster and well constructed brick damaged. Light fixtures swung. Buildings creaked; loose objects rattled. Roaring earth sounds "as approaching train" heard at beginning of earthquake. Rapid onset; swaying motion. 2 shocks.

Conran - Felt by all. Chimney and window panes cracked. Dishes broken; stove damaged. Earth noises "like a train coming" heard.

Dexter - Felt by and alarmed many. Chimneys, plaster and plate glass window cracked; bricks fell from one chimney. Merchandise fell from shelves in stores.

East Prairie - Felt by all. Concrete walk and plaster cracked. Buildings shook. Moderately loud earth sounds heard. Trembling motion.

Leeper - Felt by all. Wall paper and walls cracked. People rushed from homes. Dishes rattled and turned over.

Lilbourn - Felt by and alarmed nearly all. Several reports of cracked plaster and walls. Buildings creaked; loose objects rattled. Moderately loud, rumbling earth sounds heard during and after beginning of earthquake. Abrupt onset; trembling-rocking motion, east-west.

Malden - Felt by nearly all. Many alarmed. Plaster on walls broken and thrown down; pavement cracked. Canned goods thrown from shelves. Chandeliers swung. Buildings creaked; loose objects rattled. Roaring earth sounds heard before and during earthquake. Abrupt onset; rocking-swaying motion, east-west.

Marston - Felt by all. General alarm. Concrete foundation cracked. Chairs displaced. Buildings creaked; loose objects rattled. Loud rumbling earth sounds heard. Abrupt onset; swaying motion.

Poplar Bluff - Felt by many. Plaster cracked. Water lines damaged and flooded many basements. Buildings creaked; loose objects rattled. Roaring earth sound heard during earthquake. Abrupt onset.

Portageville - Felt by nearly all and alarmed several. Walls cracked; items fell from shelves and broke. Electric light poles shook and the lines swayed. Chandeliers swung north-south. Buildings creaked; loose objects rattled. Roaring earth sounds heard by many at beginning of earthquake.

Tallapoosa - Felt by nearly all. Many alarmed. Building cracked slightly. Objects fell from shelves; trees rocked. Buildings creaked; loose objects rattled. Roaring earth sounds heard. Gradual onset; trembling motion.

Intensity (Damage) V in Arkansas

Carryville - Felt. Cracked plaster in church. Buildings creaked. Roaring earth sounds heard.

Corning - Felt. Windows cracked; small cracks appeared in concrete blocks. "Like a distant rumbling noise."

Datto - Felt by all. Buildings vibrated; loose objects rattled. Earth noises heard that sounded like an airplane.

Edmondson - Felt by many. Slight damage to one building. Storage bin with approximately 60,000 pounds of seed slipped off blocks and fell. House swayed east-west; bookcase swayed. Abrupt onset.

Lafe - Felt. Concrete cracked. Windows rattled.

Piggott - Felt. Reports of wall damage, cracks, and leaks. Loud rumbling earth sounds heard. Buildings vibrated.

Rector - Felt by all. Buildings shook. Rumbling earth sounds heard.

State College - Felt by nearly all. Plaster cracked. Some churches evacuated. Buildings shook; light fixtures swayed.

Intensity (Damage) V in Illinois

Cairo - Felt by many. Cracked wall of new educational building. Buildings creaked; loose objects rattled. Abrupt onset; trembling motion.

Carbondale - Felt by and alarmed many. Cracked newly repaired wall. Buildings creaked; loose objects and aluminum door rattled. Rumbling earth sounds heard by many at beginning of earthquake.

Cobden - Felt. Plaster cracked. Noise like dull roar heard.

Gale - Felt by all. "Earth sounds like large flock of birds."

Murphysboro - Felt by several. Plaster cracked on west wall of well-constructed brick church. Thunderous earth sounds heard. Gradual onset; swaying motion, east-west.

Pomona - Felt by several and alarmed many. Moderately loud earth sounds heard. Rapid onset; trembling-rocking motion.

Ridgway - Felt. Plaster cracked. Dishes rattled and pictures moved on walls.

Thebes - Felt by all. General alarm. Buildings creaked; loose objects rattled. Moderately loud, rumbling and shaking sounds heard by all before and at beginning of earthquake. Gradual onset; rumbling-rocking motion.

1963, March 3, cont'd

Intensity (Damage) V in Kentucky

Bandana - Felt. Plaster cracked in several rooms of church. Windows rattled.

Bardwell - Felt by and frightened many. Buildings shook; windows rattled.

Hickman - Felt by all. Wall cracked above and below window casing. Buildings creaked; loud roaring sounds heard before beginning of earthquake. Gradual onset; trembling-swaying motion.

Melber - Felt by and alarmed many. Buildings creaked; loose objects rattled. Abrupt onset; trembling-shaking motion.

Water Valley - Felt. Plaster reported fallen. Landslide at gravel pit 1 mile north. Large chunks of wall fell to floor of pit. Buildings trembled.

Wolf Island - Felt by nearly all and alarmed few. Buildings creaked; loose objects rattled. Low, distant, roaring sounds heard.

Intensity (Damage) V in Missouri

Bernie - Felt by all. Basement wall cracked slightly. Rumbling noise heard.

Bloomfield - Felt by nearly all. Loose plaster fell. Cracks appeard in masonry walls. Rumbling noise heard.

Cape Girardeau - Felt by many. Slight damage to plaster in church. Chandeliers swung and dishes displaced. Buildings creaked; loose objects rattled. Abrupt onset; bumping motion. Several shocks for 2 or 3 minutes.

Chaffee - Felt by many. Plaster cracked. Lamp and rocking chair rocked. Buildings creaked; loose objects rattled. Earth sounds heard. "Could feel vibration, then loud noise and movement." 2 shocks.

Charleston - Felt by nearly all. Plaster cracked at church. Display racks swayed. Abrupt onset. "Felt like my chair moved north-south."

Commerce - Felt. "Bricks from chimney shattered off on top of piano." Buildings popped and creaked. Doors and windows rattled.

Dudley - Felt by nearly all. Plaster cracked. Rumbling noises heard.

Gideon - Felt. Plaster cracked in various buildings. Dishes rattled. Loud explosion and rumble heard.

Hayti - Felt. Window cracked. Very loud rumble like freight train heard.

Hunter - Felt. Three cracks appeared in solid concrete foundation of house. Houses creaked and popped.

Illmo - Felt. Basement wall cracked. Buildings shook and dishes rattled.

Kennett - Felt by many. Minor cracks in plaster and buildings. Buildings creaked; loose objects rattled. Roaring earth sounds heard. Abrupt onset; rocking motion. 2 shocks.

New Madrid - Felt by nearly all. Many alarmed. Buildings creaked; loose objects rattled. Bumping, moderately loud earth noises heard at beginning of earthquake. Gradual onset; trembling motion.

Oran - Felt. Mortar joints cracked in post office.

Oxly - Felt. Sheetrock joints cracked. "Sounded like train at a distance."

Perryville (near) - "Opened a hole and drained a lake. Felt inside a cave." (From newspaper report.)

Ripley - Felt by all. Buildings creaked. Earth sounds were as distant cannon fire or mortar bursts. Steady, vibrating motion which swung doors in and out about a foot.

Risco - Felt. Brick walls cracked. Buildings shook. "Like a strong wind."

Salem - Felt by all. Plaster cracked. Articles on shelves moved. Houses trembled.

Senath - Felt by all. General alarm. Buildings creaked; loose objects rattled. Roaring earth sounds similar to a jet heard before beginning of earthquake. Abrupt onset; trembling motion.

Versailles - Felt. Plaster cracked. Pendulum clock that had not run for years started to run. Earth sounds "as a jet was passing over very high" were heard. Picture window rattled. Gradual onset; trembling motion.

Intensity (Damage) V in Tennessee

Covington - Felt by nearly all. Few reports of cracked plaster. Buildings creaked; loose objects rattled. Abrupt onset; trembling motion.

Elbridge - Felt by all. Slight damage to plaster. Buildings creaked; loose objects rattled. Thunderous earth sounds heard by several after beginning of earthquake. Rapid onset; trembling-swaying motion. 2 shocks.

Finley - Felt by several. Slight damage to poster. Furniture and pictures displaced. "Locked doors were opened." Rattling-bumping earth sounds heard. Gradual onset; swaying motion.

Ridgely - A cracked patio was reported.

1963, March 3 cont'd

Gleason - Felt by many. Slight damage to plaster. Cracks in church enlarged. Chandeliers swung; buildings shook; loose objects rattled. Cracking-scraping earth sounds heard. Rapid onset; trembling motion. 2 shocks.

Hornbeak - Felt by and alarmed many. Displaced mirror on dresser and flowers on shelf. Loose objects rattled. Moderately loud sounds heard at beginning of earthquake. Abrupt onset; rocking motion.

Sharon - Felt by many. Few alarmed. Enlarged crack in one building. Loose objects rattled. Rapid onset; trembling motion.

Troy - Felt by many. Slight roof damage to one building. Chandelier swung approximately 2 feet, east-west. Lamp slid 1 foot on table. Prisms jingled on candelabra. Buildings creaked; loose objects rattled. Abrupt onset; rocking motion.

Woodland Mills - Felt by all. Slight swaying of objects. Trembling motion. 3 shocks.

1963, April 6, time unknown IV

New Madrid, Missouri (36.4 89.4)

(TVA Chronology, 79). Nuttli (1976) lists this earthquake but with no intensity. It may not have been felt.

1963, August 2, 6:38 p.m. V

Illinois-Kentucky border (37.0 88.8)

Depth about 18 km. Maximum intensity (damage) V at Paducah, Ky. In Illinois, the quake was felt with intensity (damage) IV.

Intensity (Damage) V in Kentucky

Paducah - Felt by all. Creaking of buildings and rattling of loose objects heard by all. Windows rattled; disturbed objects observed by several. Television station received many calls. Rapid onset; trembling motion. Duration 30 seconds.

Intensity (Damage) IV in Kentucky

Bardwell - Felt by many. Windows and dishes rattled. Gradual onset; trembling motion.

1963, August 2, cont'd

Boaz - Felt by many. Rattling of loose objects heard by many. Windows rattled violently. "Some friends in country said water wells went dry afterwards." Rapid onset; trembling motion.

Mayfield - Felt by many. Rattling of loose objects heard. Moderately loud, subterranean sounds heard by many at beginning of quake. Rapid onset; trembling-bumping motion. Duration, 30 seconds.

Water Valley - Felt. Creaking of buildings and rattling of loose objects heard. Subterranean sounds heard before quake began.

Intensity (Damage) IV in Illinois

Cairo - Felt by many. Buildings creaked; loose objects rattled. Rumbling noises heard. Abrupt onset.

Metroplis (3 miles northeast of) - Felt by several. Windows rattled. "Heard a slight rumbling noise during first tremor which appeared to come from south." 2 shocks.

1963, November 14, p.m.

Nashville, Tennessee (36.15 86.8)

A tremor visited downtown Nashville and the Vanderbilt area. It was not determined whether the shock was of seismic or nonseismic origin.

1963, December 5, 12:51 a.m. II-III

Drakesboro, Kentucky (37.2 87.0)

(TVA Chronology, 79) Time is from Nuttli's 1976 list.

1963, December 14, 11:31 p.m. III

Beechmont, Kentucky (37.5 87.0)

Disturbed objects observed. Rapid onset; swaying motion. (U.S. Earthquakes, 1963, p. 16)

1964, March 16, 8:15 p.m. IV

Caruthersville, Missouri (36.2 89.7)

One report was received which stated that a slight shock was felt by several at this time. Buildings creaked and loose objects rattled. Disturbed objects observed; gradual onset; trembling motion. Felt in Lake County, Tennessee.

1964, May 23, 5:25 a.m. IV-V 4.5

New Madrid, Missouri (36.6 89.9)

Focal depth 18 km. (TVA Chronology, 99)

1965, February 10, 9:40 p.m. III 3.3

Portageville, Missouri (36.4 89.7)

(Nuttli's 1976 list)

1965, March 6, 3:09 p.m. III 4.1

Fletcher (Jefferson County), Missouri (37.4 91.1)

Focal depth about 18 km. Felt in Fletcher. Location and intensity are from Nuttli's 1976 list.

1965, March 25, 7:00 a.m. III 3.7

Tennessee-Missouri boundary (36.4 89.5)

A light earthquake centered near the Tennessee-Missouri boundary 130 miles south of St. Louis, near the mouth of the Ohio River. Felt as far to the north as St. Louis. By some the time was given as 7:30 a.m. CST. The shock was not generally noticed, and informers quoted St. Louis information rather than local information. Therefore, the size and approximate limits of the "felt area" could not be determined. Nuttli's 1976 list has no intensity value. Perhaps it was not actually reported to be felt.

1965, August 13, 14, and 15

A series of at least five earthquakes occurred in southwestern Illinois during these three days. Center of the tremors was apparently in the vicinity of Tamms. The following summary of these shocks is based on the descriptions by McClain and Myers (1970), U.S. Coast & Geodetic Survey, and the Seismological Society of America.

1965, August 13, 11:46 p.m. IV 3.2

Southwestern Illinois (37.2 89.3)

Felt at Tamms and Unity, Illinois. Earth noises were heard.

1965, August 14, 7:14 a.m. VII 3.8

Southwestern Illinois (37.2 89.3)

Focal depth about 38 km. At Tamms chimneys fell, basements and walls cracked, water supplies were muddied, and groceries fell from shelves. Thunderous earth noises accompanied the shock. Rapid onset; swaying motion, northwest-southeast. At Unity many were alarmed, buildings creaked, and loose objects rattled (V). Faint, bumping earth sounds were heard. Dishes rattled at Olive Branch. Also felt at Elco and Olmsted. The magnitude and intensity values are from Nuttli's 1976 list.

1965, August 14, 10:19 p.m. V 3.4

Southwestern Illinois (37.4 89.5)

1965, August 15, 12:07 a.m. V 3.4

Southwestern Illinois (37.4 89.5)

Focal depth about 16 km.

1965, October 20, 8:05 p.m. VI 4.9 ISOSEISMAL MAP Fig. 15

Near Centerville, Missouri (37.5 91.1) 160,000 sq. mi.

Focal depth 5-10 km. The earthquake was felt in most part of Missouri, and in the adjoining portions of Iowa, Illinois, Arkansas, Kansas and Oklahoma. It was also felt at a few places in western Tennessee and Kentucky, and in southeastern Nebraska. The region in which the tremor was felt was elliptical, with the major portion lying to the northwest of the epicenter. The epicenter, in Reynolds County on the edge of the exposed Precambrian igneous core of the Ozark uplift, falls near the Paleozoic Black Fault. No evidence of surface movement on this fault has been found.

Damage, reported at 14 locations was mostly minor, including cracked plaster, broken windows, and a muddied well. Several reports of cracks in foundations were made and bricks were knocked off a chimney at the epicenter. The maximum M.M. intensity assigned was six. The main region within which damage was reported lies to the northwest of the epicenter. At nine locations to the southeast, within 175 km, the earthquake was not felt at all, even though it was felt at over 550 km to the northwest. These locations of low intensity were on the alluvial plain between the Ozark uplift and the Mississippi River. Sounds were widely reported. Most observers described them as similar to a sonic boom or they "thought the furnace had exploded." Several made the comment that though the noise was like a sonic boom they were aware that it was coming from below.

Four aftershocks were recorded, with approximate origin time of 8:30 p.m., 8:54 p.m., 10:07 p.m., and 10:11 p.m. (personal communication from C. Kisslinger, Saint Louis). The results of a questionnaire canvass conducted by Saint Louis University are given below.

Intensity VI in Missouri

Augusta - Cistern cracked and water leaked out. Dishes and windows rattled.

Illmo - Felt by many. Basement floor cracked. Rapid onset. Rocking motion.

Pacific - Sewer ventline cracked in house. Windows and dishes rattled.

Reynolds - Bricks fell from flue. House shook.

Saint Louis - Press reported that plaster cracked and fell and chairs rocked.

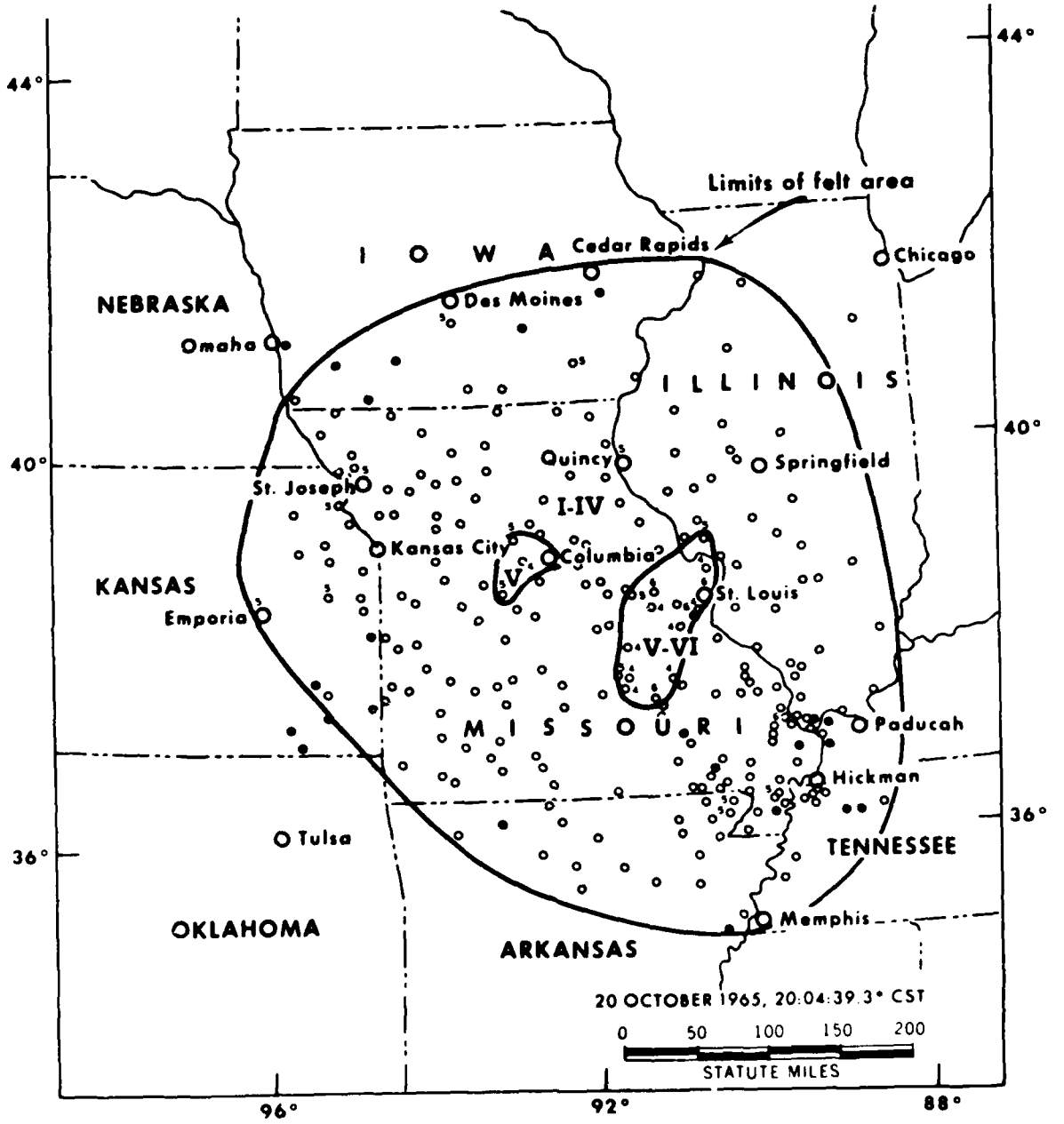


Figure 15 - Isoseismal map for the Centerville, Missouri, earthquake of October 20, 1965 (U.S. Coast and Geodetic Survey, 1965, p. 9, Fig. 3)

1965, Oct. 20 cont'd

Intensity V in Arkansas

Piggott - Felt by and alarmed many. Buildings creaked; loose objects rattled; chairs and beds shook. Earth sounds heard. Rapid onset; trembling-swaying motion.

Rector - Felt by nearly all. Buildings creaked; loose objects rattled. Lamp almost fell from table. Thunderous earth sounds. Gradual onset; trembling motion. "Alarmed residents only for a short time."

Intensity V in Illinois

Jerseyville - Window cracked (press).

Quincy - Press reported that furniture moved, doors slammed, and dishes rattled. Low rumbling noise; slight vibration.

Intensity V in Missouri

Bismarck - Plaster was damaged on second floor of brick building. Low rumble heard.

Columbia - Cracks in solid tile house. Low noises.

Conran - Felt by nearly all. Buildings creaked; loose objects rattled; chair moved. Rumbling earth sounds heard before shock began. Abrupt onset; swaying motion. "People were surprised and startled."

Fayette - Press reported 13 stained-glass windows broke in a church.

New Haven - Plaster cracked in brick and frame homes. Picture fell.

St. Joseph - Felt by several. Wall cracked in corner of room. Houses shook, door rattled, and stairway popped and creaked.

Salem - Felt by and alarmed many. Buildings creaked; loose objects rattled. Thunderous earth sounds heard before shock began. Rapid onset; swaying motion.

Syracuse - Plaster cracked in four rooms of house. Loose objects rattled; rumbling heard.

1966, February 13, 5:19 p.m. IV 3.1

Eastern Missouri (37.1 91.0)

(TVA Chronology, 93, 99)

1967, July 21, 3:15 a.m. V 4.2

Poplar Bluff, Missouri (37.5 90.6)

Focal depth about 10 km (Nuttli and Zollweg, 1974). Felt over a considerable area of southeastern Missouri and southern Illinois. Plaster fell from ceiling of court house at Poplar Bluff, Mo.; some plaster cracked at Elvins and Fredericktown, Mo. (Intensity and magnitude from Nuttli and Zollweg, 1974 who present an isoseismal map on Figure 4).

1968, February 9, 7:35 p.m. III 3.5

New Madrid, Missouri (36.5 89.9)

Focal depth about 33 km. Felt at Malden. (Intensity and magnitude from Nuttli, 1976).

1968, November 9, 11:02 a.m. VII 5.5 ISOSEISMAL MAP Fig. 16

Hamilton County, Illinois (38.0 88.5) 500,000 sq. mi. (approx.)

Focal depth about 19 km. restricted (USCGS). Seismic waves generated by this earthquake were felt in an area of approximately 500,000 square miles in the central United States, including all or portions of 23 states. It was the strongest shock in this region since 1895.

Maximum intensity VII is assigned to the epicentral area roughly bounded by the villages of Dale, Walpole, and Broughton in south Hamilton County, Illinois. Damage included twisted and thrown chimneys, toppled parapets, cracked windows and plaster, toppled television antennae, and overturned tombstones. Sounds described as sonic booms, waves on ponds, and wildly swaying power lines accompanied the earthquake. Approximately 40 percent of the chimneys in the epicentral area were damaged. In every observed instance of chimney damage, the building affected appeared to be from 30 to more than 50 years old. At McLeansboro shear cracks formed in brick exterior walls and cornices toppled from the tower at the Methodist Church, and plaster cracked at the Hamilton County Courthouse. At Eldorado a parapet atop the First State Bank was left in a dangerous condition, and bricks were loosened above the entrance to the Adult Education Center. A survey of cemeteries revealed

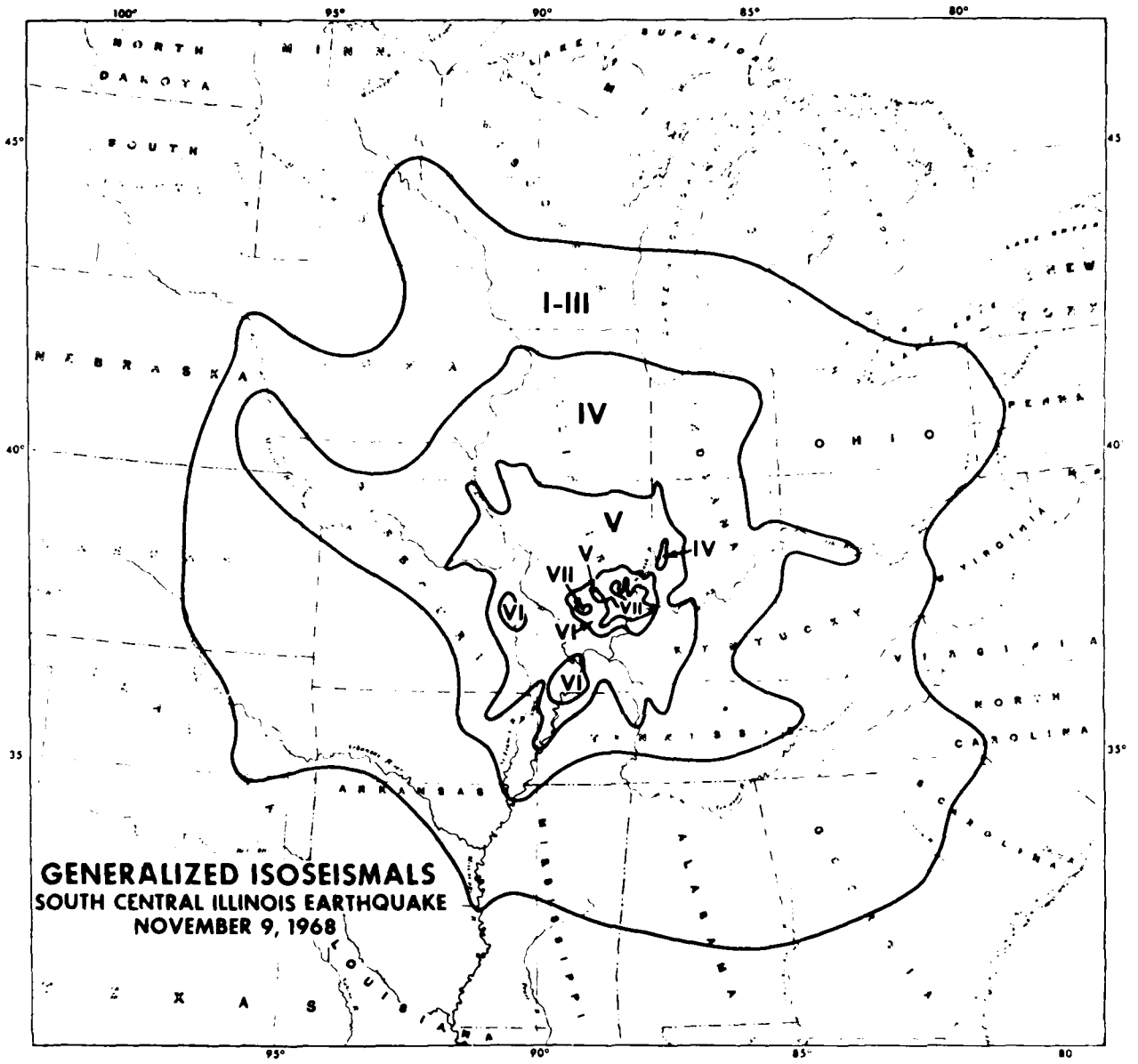


Figure 16 - Isoseismal map for the Hamilton County, Illinois earthquake of November 9, 1968 (Gordon and others, 1968, p. 958)

that many tombstones had been rotated slightly, and a few had been thrown down. All of the overturned tombstones were found west of the epicenter at cemeteries on terraces overlooking Hogg Creek, Rector Creek, and the Middle Fork of the Saline River.

The earthquake also caused minor damage in the nearest metropolitan centers--Evansville, 50 miles east; Chicago over 270 miles north; and St. Louis, about 110 miles to the northwest. Considerable masonry damage was sustained at the City Building in Henderson, Kentucky, 50 miles east-southeast of the epicenter. There were isolated felt reports from people in tall buildings at more distant localities such as Boston, Mobile, and southern Ontario.

A portion of the survey of damage is presented in detail as follows.

Intensity VII in Illinois

Broughton - Felt by and frightened all in community. At the post office, marks in the asphalt flooring indicated a steel desk rotated about 1 degree counterclockwise. About 40 percent of the chimneys in town were damaged. Diagonal tension cracks were observed in exterior east and west walls of a 1-story brick building. Plaster fell. Small objects shifted and fell. Trees and bushes shook. Loud earth noises. Damage slight. "I ran outside and saw others that had run out of their homes too. Another slight tremor was felt about 10 minutes later. Church bells rang here. One of them had not rung for years, having been lodged in the belfry." At the Mt. Oval Cemetery, 5½ miles east of Broughton, tombstones were disturbed.

Dale - Felt by all and rrightened many. Chimneys cracked and twisted. Hamilton County Courthouse and library were damaged. At the service station, X-cracking occurred in south and east walls. In east side of station, a vertical crack about 1/2 inch wide formed between the office section and a later addition. Windows cracked; plaster cracked and fell. Trees and bushes shook. Big, booming earth noises. At the Texaco Flood Station, a two-story sheet-steel and reinforced concrete structure, abrasions on freshly-painted 2½-inch pipes gave an estimate of the relative movement between individual elements of the building. A scar 5 centimeters long was formed

by a wall bracket rubbing against a horozontal pipe. In the northwest corner of the building, the action of a bracket 6½ feet above ground level formed a scar 9 centimeters long on a vertical pipe. On the second floor, a wooden desk was translated 1½ centimeters and rotated clockwise. During the shock, a reinforced concrete ground-level tank opened along pre-existing hairline cracks, sending a jet of water 50 feet into the adjacent parking area. The cylinder, which had walls 1 foot thick and 12 inches high, and an outside diameter of 52 feet, was bound with five 3/4-inch bands that probably prevented complete failure. When examined 1 week later, the tank had been repaired by caulking 1-centimeter vertical cracks in the south and west walls.

A large two-story brick house, 3½ miles west of Dale, sustained several thousand dollars in damage. Cracks occurred along the seams of all interior walls, and plaster fell where chimneys were broken and leaning, and the front porch pulled several inches away from the house. In the basement, a trace of powdered cement and chipped paint, 4½ feet above the concrete floor, marked the junction between the foundation and upper walls of the structure.

At Tuckers Corners, 6 miles west of Dale, merchant reported violent shaking tumbled one-third of his merchandise off shelves. Two fluorescent lights, which had hung from the ceiling by a hook and eyelet device were found hanging by one hook and electric wiring. Shear cracks occurred in southwest corner of the store, and bricks in the chimney were loosened above the roofline. A concrete and brick cistern collapsed at a residence 1/2 mile north of Tuckers Corners.

At Braden, 7 miles west of Dale, a television antenna toppled from the roof of a house. Plaster cracked, and extensive china and glassware breakage occurred. An older home nearby lost its chimney. During the shock, waves with crests moving east to west were observed on Lake Jay, an artificial lake 1/4 mile wide and adjacent to Braden.

At Little Springs Cemetery, 8½ miles west of Dale, tombstone was thrown to west from its pedestal.

Eldorado - Felt by all and frightened many. Many chimneys fell. Plaster cracked. Furniture shifted. Heavy, thunderous earth sounds. Quake loosened parapet wall in

front of two-story bank; in rear, window broke and diagonal X-crack appeared. Bricks loosened above entrance to Education Center. Debris dislodged from upper portion of twin, 150-foot-high, brick chimneys at abandoned mine, 2 miles southwest of Eldorado. Several monuments were thrown down; several rotated in cemetery.

Galatia - Felt by and frightened all. Chimneys torn down. Plaster cracked and fell. Windows broke. Dishes fell from cabinets. Cracked chimneys rotated counterclockwise. "At the time of the quake I was in the city cemetery 1 mile east of town. The earth trembled and tombstones shook." Loud earth noises.

Harrisburg - Felt by and frightened many. Chimneys were wrecked. Walls, windows, and plaster cracked. Furniture shifted. Loose objects fell. Bricks fell from exterior wall of automobile agency. Damage moderate. "I could hardly stand on my feet it was so strong."

McLeansboro - Felt by all and frightened many. Plaster cracked on second and third floors of Hamilton County Courthouse. Spalling scar 2 inches deep, 8 inches long, on reinforced concrete beam of courthouse. At Methodist Church, masonry fell from tower and top of rear wall. Diagonal X-cracks in rear wall of church. Ornate chimney damaged beyond repair at Memorial Library. Nineteen windows broke at high school gym. Chimneys and tombstones cracked, twisted, and overturned. Some sidewalks cracked. Furniture shifted. Trees and bushes shook; vehicles rocked. Damage slight.

Ridgway - Felt by and frightened all. Bricks thrown from 35-foot section of parapet over 1½-story, W. M. Speckt Building. Tall chimney cracked above roofline on church. Knickknacks overturned. "I ran into next room of trailer and our tropical goldfish aquariums were rocking, and water was sloshing all over the floor." Windows cracked. Plaster cracked and fell. Furniture shifted somewhat. Trees and bushes shook. Loud earth noises. Damage slight.

1968, November 9 cont'd

Intensity VII in Kentucky

Henderson - Felt by and frightened all. Four or five chimneys toppled on old houses. Two old buildings cracked. Considerable masonry damage at the City Building. Plaster fell. Door came open. Pictures fell. Trees and bushes shook. Moderate earth noises. Damage very slight.

Poole - Felt by and frightened all. Chimneys cracked; some fell. Trees and bushes shook; vehicles rocked. Loud rumbling earth noises. Observer also reported "no damage."

Smith Mills - Felt by and frightened all. A few chimneys toppled. Plaster cracked. Furniture shifted. Small objects fell. Trees and bushes shook. "People who were moving in cars felt it only slightly, but drivers of large trucks felt it with such severity that they had to pull off to side of road." Moderate earth noises. Damage slight.

Uniontown - Felt by all and frightened few. Chimneys fell or bricks broke off. Some objects shifted. Vehicles shook. Moderate earth noises. Damage slight.

Intensity VII in Missouri

Herman - Felt by many in community. Some chimneys fell on old buildings. Plaster cracked. Furniture and small objects shifted. Vehicles rocked. Damage slight.

St. Charles - Felt by and frightened all. Chimneys knocked down. Overhang above service counter in post office knocked loose; one light fixture loose. Moderate earth noises.

Sikeston - Felt by many and frightened few. One or two chimneys fell. Small objects shifted. Trees and bushes shook; vehicles rocked. "Shock was very brief."

St. Louis - Press reported: Several injured by falling debris. Walls cracked, chimneys fell, and windows broke. A 15-by 20-foot section of southwest wall at Mid-American Metal Company collapsed. Civil War Museum at Jefferson Barracks closed due to a large crack opening in museum wall, causing bricks and plaster to fall. Many objects crashed to floors.

Intensity VI in Kentucky

Benton - Felt by all and frightened many. Plaster cracked. Small objects shifted. Trees and bushes shook; vehicles rocked.

Cadiz - Felt by and frightened many. Some bricks fell from chimneys. Plaster cracked. Small objects fell. Trees and bushes shook; vehicles rocked. Terrific noises. Damage slight.

Clay - Felt by all and frightened many. Articles fell from shelves. Pots and pans rattled. Loud earth noises.

Clinton - Felt by all and frightened many. One chimney fell. Dishes fell from shelves. Plaster and windows cracked. Trees and bushes shook. Faint earth noises. Damage slight.

Corydon - Felt by and frightened all. Plaster cracked. Small objects shifted. Trees and bushes shook. Loud earth noises. Damage slight.

Crofton (Post Office Building) - Felt by and frightened many. Some bricks fell from chimney tops. Furniture shifted. Small objects fell. Faint earth noises.

Dawson Springs (near) - Press reported several bricks fell from chimneys and a new school building cracked. Items fell from shelves.

Hampton - Felt by and frightened all. Some chimneys damaged. Waterlines broke. Small objects shifted. Trees and bushes shook. Loud earth noises.

Hartford - Felt by all and frightened few. Plaster cracked. Small objects shifted. Trees and bushes shook. Damage moderate.

Hickman - Bricks fell from courthouse walls (press).

Paducah - Few bricks fell from chimneys (press).

Sebree - Bricks fell from chimneys (press).

1968, Nov. 9 cont'd

Smithland - Felt by and frightened many. Bricks fell from chimney. Small objects shifted. Trees and bushes shook. Loud earth noises.

Sturgis - Felt by all and frightened many. Few chimneys damaged. Bushes shook. Rumbling sound, explosive at onset.

Intensity VI in Missouri

Bonne Terre - Felt by all and frightened some. Plaster cracked, broke, and fell. One light was damaged. Moderate earth noises.

Broseley - Felt by all and frightened many. Plaster cracked and fell. Small objects fell. Damage slight.

Cape Girardeau - Felt by all in restaurant; few frightened. Chimneys damaged. Few cases of cracked windows, fallen plaster, and fallen objects. Trees and bushes shook. Loud earth noises. Damage slight.

Charleston - Press reported concrete floor of new brick home was cracked. Numerous foundation cracks in churches. Plaster damaged at one church.

Crosstown - Press reported chimney lost several bricks, and that plaster cracked throughout Perry County.

De Soto - Felt by many and frightened few. Plaster cracked and fell. Small objects shifted, overturned, and fell. Trees and bushes shook. Loud earth noises. "Damage slight, if any."

Elsberry - Felt by many and frightened few. Two chimneys damaged on one home. Plaster cracked. Furniture and small objects shifted. Trees and bushes shook. Roaring earth noises. Press reported several rows of brick and the iron rim of chimney were torn off and scattered on the ground. Guy rod bent; chimney twisted.

Festus - Felt by and frightened all. Furniture and small objects shifted. Trees and bushes shook. Faint earth noises.

Illmo - Press reported machinery visibly moved, walls cracked, and that the whole community was frightened. Groceries fell from market shelves.

Jamesport - Press reported furniture moved considerably and desks and chairs swayed. Plaster fell in some places.

Linn - Felt by several; few frightened. Heavy safe moved. Damage slight. "Thought building would collapse."

Louisiana - Press reported one chimney collapsed. Few loose bricks fell in scattered portions of city. Several reports of cracked walls in business district. Many swarmed into streets.

Marshall - Felt by all; few frightened. Small objects shifted and fell. Car rocked rather violently.

Oregon - Frightened all. Plaster broke. Small objects fell. Furniture shifted. Trees and bushes shook. Damage slight.

Troy - Felt by all. Stock fell from store shelves. Trees and bushes shook. Damage slight.

Unionville - Felt by and frightened many. Furniture and small objects shifted. Trees shook.

Weston - Press reported that plaster fell, desk moved, doors banged, and light fixtures danced. Loud earth noises.

Intensity VI in Tennessee

Dyersburg - Felt by many and frightened few. Furniture and small objects shifted. Hanging objects swung moderately.

Erin - Felt by many. Water muddy after earthquake. Small objects shifted. Hanging objects swung. Moderate earth noises. No damage.

Hartsville - Felt by many and frightened few. One city water main burst. "Sounds like a loud wind." No observable damage.

Huntingdon - Felt by many and frightened few. Furniture and small objects shifted. Hanging objects swung. Moderate earth noises. Trees and bushes shook.

End of Nov. 9, 1968 Earthquake

1969, January 20, 1:25 p.m. III

Farmington, Missouri (37.8 90.4)

1970, March 26, 9:44 p.m. IV 3.5

New Madrid, Missouri (36.5 89.7)

Focal depth about 5 km. Felt at New Madrid, Missouri; reported without macroseismic information.

1970, November 29, 10:46 p.m. III-IV 2.8

New Madrid Area (36.3 89.5)

Only felt over 10 km^2 according to Nuttli and Zollweg (1974).

1970, December 24, 4:18 a.m. IV 3.5

New Madrid Area, Missouri (36.8 89.7)

Also felt at Poplar Bluff. Focal depth 12 km. An isoseismal map is presented by Nuttli and Zollweg (1974, p. 79, Fig. 28A, Seismo. Soc. America Bull., v. 61, p. 1105, 1971).

1972, January 31, 11:42 p.m. V-VI 4.2

Randolph County, Arkansas (36.4 90.8)

Int. V. At Delaplaine, Ark., cracks appeared in Foundation of a building. Concrete wall cracked at Biggers, Ark. The questionnaire canvass was conducted by the Jesuit Seismological Association, Saint Louis University, Saint Louis, Mo. (U.S. Earthquakes, 1972, p. 16). The intensity and magnitude from Nuttli and Zollweg (1974) where an isoseismal map is presented.

Intensity V in Arkansas

Biggers - Walls cracked in concrete block building. Loud, explosivelike noise.

1972, Jan. 31, cont'd.

Delaplaine - "Caused one end of house to settle. Caused foundation to crack under a concrete floor and caused cracks between building blocks."

Knobel - Felt by all in area. "Sounded like an explosion with pronounced reverberation."

Maynard - Felt by all. Loud explosion.

1972, March 29, 2:38 p.m. V 3.7

Southeast Missouri and northeast Arkansas (36.20 89.61)

Focal depth 10 km. Epicenter between Blytheville, Arkansas, and Hayti, Missouri. Windows broken and floors buckled in Cooter, Missouri. Police and fire departments in the region were flooded by telephone calls. Felt in Arkansas, Missouri, Mississippi, Tennessee, and Kentucky.

(Followill, Arkansas newspaper; and U.S. Dept. Commerce, Oceanic and Atmospheric Adm.)

The press reported broken windows and buckled floors at Cooter, Mo. Plaster cracked at Newman, Ky. The NEIC questionnaire canvass was supplemented by data from the Jesuit Seismological Association, Saint Louis University, Saint Louis, Mo. (U.S. Earthquakes, 1972, p. 16-18).

Intensity V in Kentucky

Newman - Felt by many. Windows rattled. Loud earth noises. Plaster cracked. Damage slight.

Intensity V in Missouri

Broseley - Felt by several; frightened many. Windows, doors, and dishes rattled; building creaked slightly. Earth noises, like sonic boom. Hanging objects swung slightly. Some small objects shifted, overturned, and fell.

Cooter - Felt by several in community. Windows, doors, and dishes rattled; building cracked. Moderate earth noises. Small objects shifted and fell. The Springfield, Ill., Register (dated Mar. 30, 1972) reported broken

1972, Mar. 29, cont'd.

windows and buckled floors in this town. "Sounded like an explosion or thunder in the distance."

Deering - Felt by all in community. Building shook slightly. Moderate earth noises.

Kennett - Felt by several. Windows, doors, and dishes rattled. Small objects shifted, overturned, and fell.

Steele - Felt by all in community; frightened many. Metal cabinets rattled. Loud earth noises. Small objects fell.

Intensity V in Tennessee

Miston - Felt by many in community. Windows, doors, and dishes rattled. Loud earth noises, like logs rolling under the building. Small objects shifted, overturned, and fell; standing pictures fell. "I knew it was an earthquake when I heard it coming. Not as hard as the one we had a year ago."

1972, June 9, 1:15 p.m. IV 3.0

Eastern Missouri (37.70 90.41)

Focal depth 18 km. (U.S. Earthquakes, 1973, p. 18).

1972, June 18, 11:46 p.m. IV 3.3

Cape Girardeau, Missouri (37.00 89.08)

Focal depth 13 km. Intensity IV at Wickliffe, Ky., also felt at Kevil, Ky. (U.S. Earthquakes, 1972, p. 18).

1972, September 5, 8:28 p.m. 2½

Eastern Missouri (36.4 89.9)

"Magnitude about 2½ (Poor epicenter)". One person called and said he felt the earthquake, but the location was not given. (U.S. Earthquakes, 1972, p. 18). The magnitude is too low to be on Nuttli's 1976 list.

1973, January 7, 4:56 p.m. IV 3.2

Madisonville, Kentucky 37.4 87.3

(TVA Chronology, 99) No intensity is listed by Nuttli(1976).

1973, January 12, 6:56 a.m. IV 3.2

Eastern Missouri 37.93 90.52

"Things shook a bit and glass rattled in windows at Farmington" (press report). (U.S. Earthquakes, 1973, p. 24). The magnitude is from Nuttli's 1976 list.

1973, October 9, 2:15 p.m. IV 3.8

New Madrid, Missouri area (36.4 89.2)

The shock affected a small area in Lake County, Tennessee, and Fulton County, Kentucky, but full extent of area was not determined. (Reported by B. C. Moneymaker in U.S. Earthquakes, 1973, p. 25).

1973, December 20, 4:45 a.m. III 3.4

Southeast Missouri (36.157 89.580)

Focal depth 10 km. Felt in Caruthersville, Hayti and Gobler. (U.S. Earthquakes, 1973, p. 25).

1974, January 7, 7:12 p.m. V 4.3

Northwest Tennessee (36.20 89.39)

Focal depth 1 km. Felt over a small area of western Tennessee, southern Missouri, and at a few towns in southern Illinois and northeastern Arkansas. No damage occurred, but small objects shifted at Burfordville, Mo., and Dyersburg and Elbridge, Tenn. Dishes rolled off kitchen cabinet at Miston, Tenn. The USGS canvassed 500 towns in the region for intensity data. Of these 400 reported the earthquake was not felt and 81 did not return the questionnaire.

On Mar. 29, 1972, an earthquake located a few kilometers west of this epicenter (36.20°N., 89.61°W.) and with the same magnitude was felt over 171,000 km^2 of six states and caused minor damage in Missouri and Kentucky. (U.S. Earthquakes, 1974, p. 56-57).

U.S.G.S. reports (Circular 723-A, p A-17) that loud noises frightened many at Bogota, and at Miston there were "loud noises like logs rolling under house." They also present an isoseismal map (Fig. 12).

1974, May 13, 12:52 a.m. VI 4.1

East Prairie, Missouri (36.71 89.39)

Depth of 1 km. Felt in Kentucky, Missouri, and Tennessee. At East Prairie, Mo., the city swimming pool was "badly damaged," and plaster cracked in several buildings. Many were awakened at one home by loud earth noises. (U.S. Earthquakes, 1974, p. 63).

1974, August 11, 8:29 a.m. V 3.6

Fremont, Missouri (36.92 91.17)

At Fremont, all in community felt the shock, which was accompanied by moderate earth noises. Windows, doors and dishes rattled; hanging objects swung moderately northwest-southeast. (U.S. Earthquakes, 1974, p. 63).

1974, December 13, 4:13 a.m. III 2.8

West Plains, Missouri (36.7 91.6)

(TVA Chronology, 99).

1975, February 13, 1:43 p.m. V 3.3

Conran, Mo. (36.53 89.56)

(St. Louis Univ. Net) Reported by U.S.GS.(Circular 749-A) Reported to have been V in Conran and Marston; IV in Portageville, and Union City, Tenn.

1975, June 13, 4:40 p.m. V 4.3

Marston, Missouri (36.54 89.68)

Felt over southeast Missouri. (St. Louis Univ. Net)

1975, July 6, 2:48 a.m. II 2.9

New Madrid, Missouri (36.2 89.5)

(TVA Chronology, 99)

1975, December 2, 9:00 p.m. V 2.8

New Madrid, Missouri (36.54 89.57)

Felt. Cracked plaster at New Madrid, Mo. (St. Louis Univ. Net)

1976, March 24, 6:41 p.m. & 7:00 p.m. VI 5.0, 4.5 ISOSEISMAL MAP Fig.17

Northeastern Arkansas (35.59 90.48)

Aftershock at 7 p.m.

U.S.G.S. (Circular 766-A, p A-18 to A-20) reports on this earthquake in detail from which the following data are abstracted:

> The quake was felt over an area of approximately 280,000 sq. km. This earthquake triggered seven accelerographs located at four stations, Arkabutla dam, Mississippi; Wappapelo dam, Missouri; Tiptonville, Tenn.; and New Madrid, Mo. The maximum recorded acceleration was 0.04g (C. F. Porcella, written commun., 1977).
>
> Intensity VI
>
> Arkansas--Decatur (unconfirmed reports of minor property damage; ceiling tiles fell and some roof damage--press report), Jonesboro (power blackout, telephone lines down; ceilings, walls, floors shook violently at state police headquarters, which is 7.6 m. underground--press report). Paragould (windows broken; $700 damage estimated -- Press report).
> Mississippi--Abbeville, Arkabutla, De Soto County (press report), Faulkner, Lafayette County (press report), Lee County (press report), Michigan City, Monroe County (press report), Panola County (press report), Quitman County (press report), Tate County (press report), Tunica County (press report), Tupelo (cracked masonry -- press report).
> Tennessee--Memphis (minor damage at nine stations of Memphis Fire Department; books shaken from shelves in 11-story library tower at Memphis State University -- press report). Union City (damage to telephone circuits -- press report).

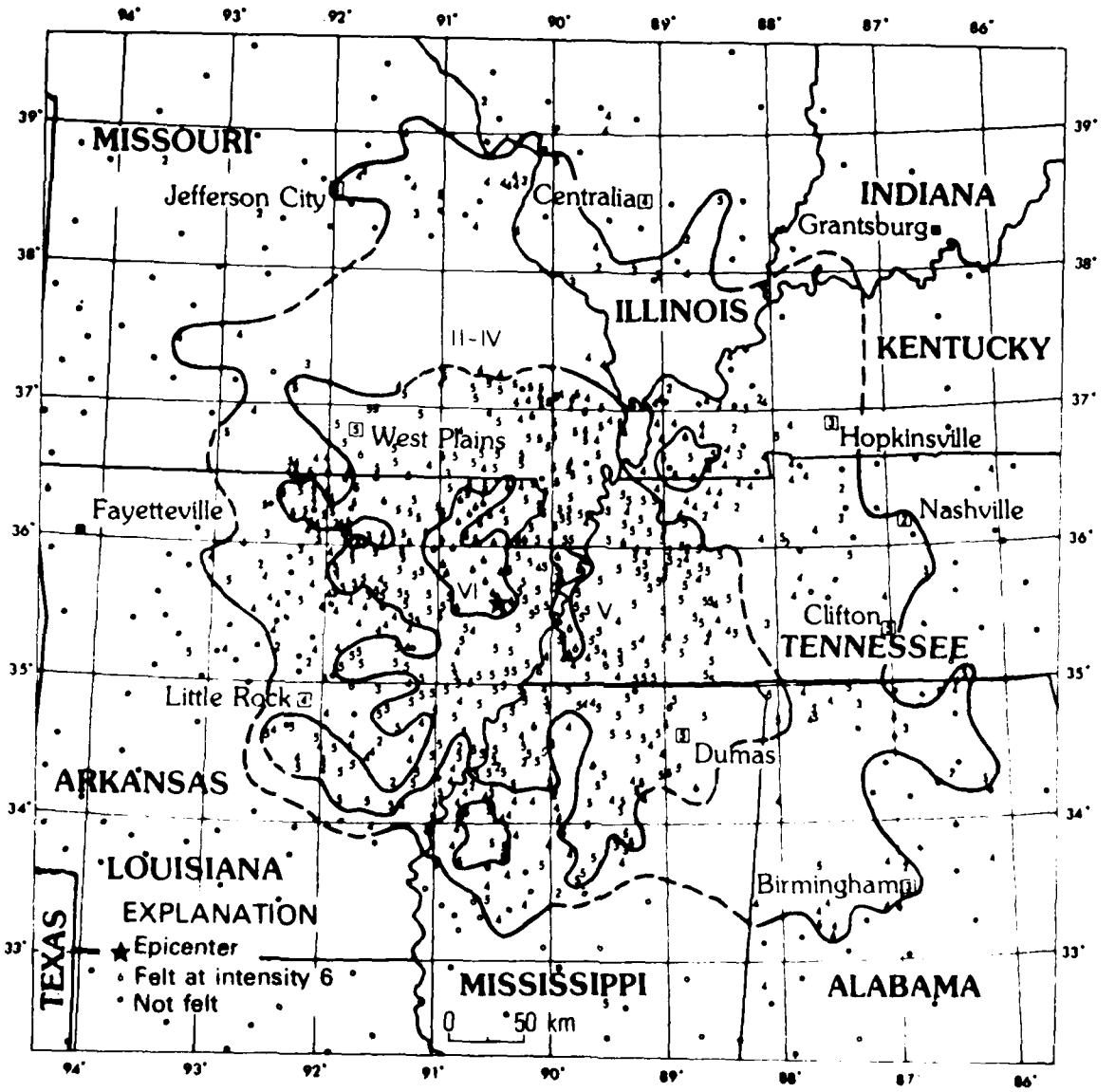


Figure 17 - Isoseismal map for the northeastern Arkansas earthquake of March 24, 1976 (U. S. Geological Survey, Circular 766-A, p. A-18)

1976, March 24, cont'd

Intensity V

Alabama--Florence (furniture moved--press report).
Lawrence County (some downed powerlines--press report).
Arkansas--Batesville (powerlines down -- press report).
Mississippi--Batesville (powerlines down -- press report).
Holly Springs (all residents alarmed -- press report).
Missouri--Malden (telephone service disrupted -- press report).

1976, April 15, 1:03 a.m. V 3.3

Hopkinsville, Kentucky (37.41 87.31)

Depth 15 km. (USGS circular 766-B, 1978)

1976, May 22, 1:40 a.m. V 3.2

Cooter and Steele, Missouri (36.04 89.84)

Depth 10 km. (USGS Circular 766-B, 1978)

Intensity is from Nuttli's 1976 list.

1976, December 13, 2:35 a.m. IV 3.5

Farmington, Missouri (37.80 90.24)

Felt at Farmington (St. Louis Net) Intensity from Nuttli's list (1976).

1977, January 3, 4:57 p.m. 3.3

Appleton, Missouri (37.55 89.79)

(St. Louis Net)

1977, March 29, 05:17 a.m. (Felt) 2.5

(36.5 89.5)

(St. Louis Net)

1977, May 6, 11:34 a.m. (no magnitude given)

Fordsville, Kentucky (37.62 86.74)

(St. Louis Net)

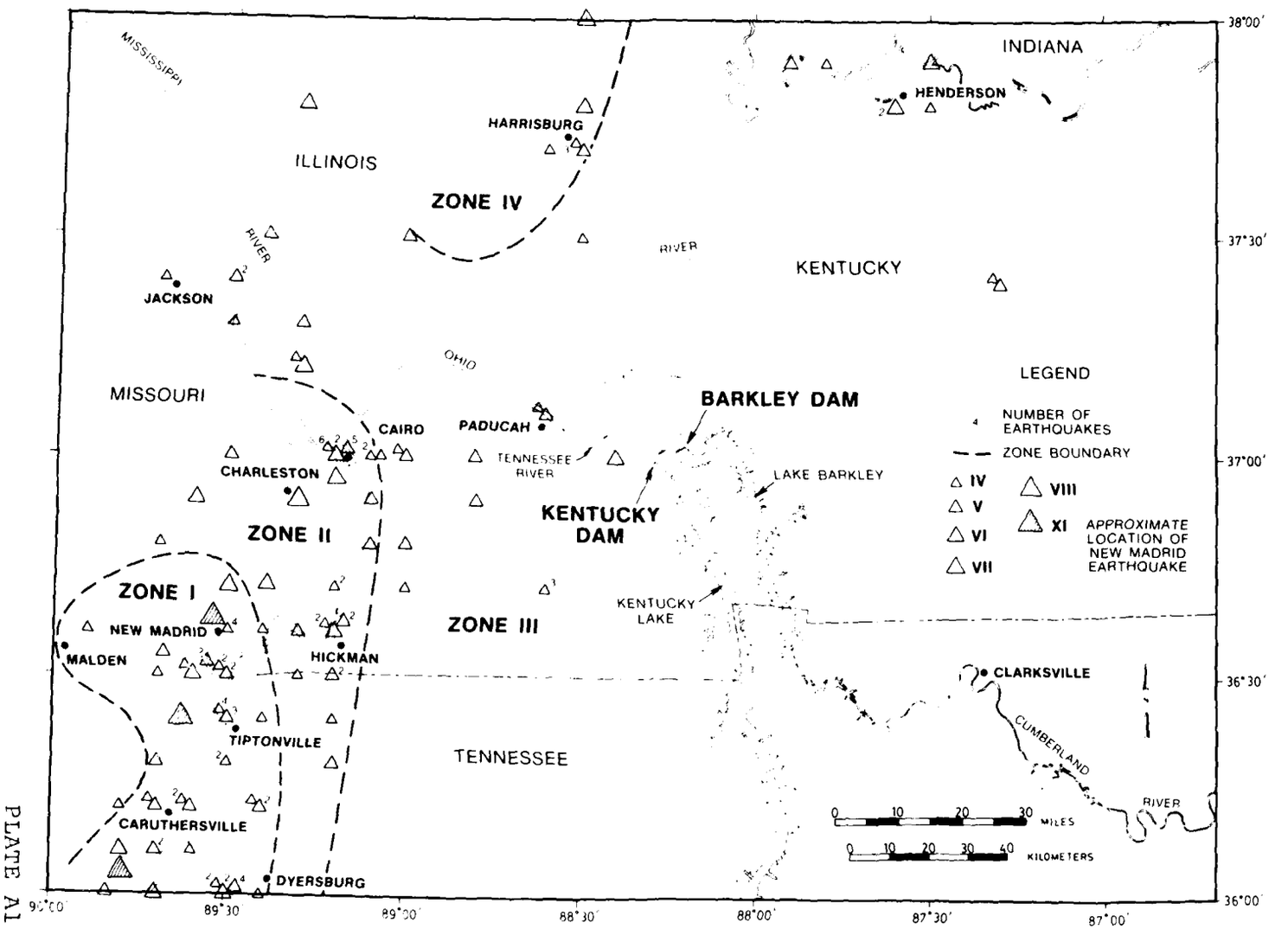

MISSISSIPPI
ILLINOIS
INDIANA
KENTUCKY
TENNESSEE
MISSOURI
OHIO
RIVER
HARRISBURG
HENDERSON
JACKSON
CAIRO
PADUCAH
CHARLESTON
TENNESSEE RIVER
BARKLEY DAM
LAKE BARKLEY
KENTUCKY DAM
KENTUCKY LAKE
ZONE I
ZONE II
ZONE III
ZONE IV
NEW MADRID
MALDEN
HICKMAN
TIPTONVILLE
CARUTHERSVILLE
DYERSBURG
CLARKSVILLE
CUMBERLAND RIVER
LEGEND
NUMBER OF EARTHQUAKES
ZONE BOUNDARY
IV
V
VI
VII
VIII
XI
APPROXIMATE LOCATION OF NEW MADRID EARTHQUAKE
0 10 20 30 MILES
0 10 20 30 40 KILOMETERS
38°00′
37°30′
37°00′
36°30′
36°00′
90°00′
89°30′
89°00′
88°30′
88°00′
87°30′
87°00′

PLATE A1

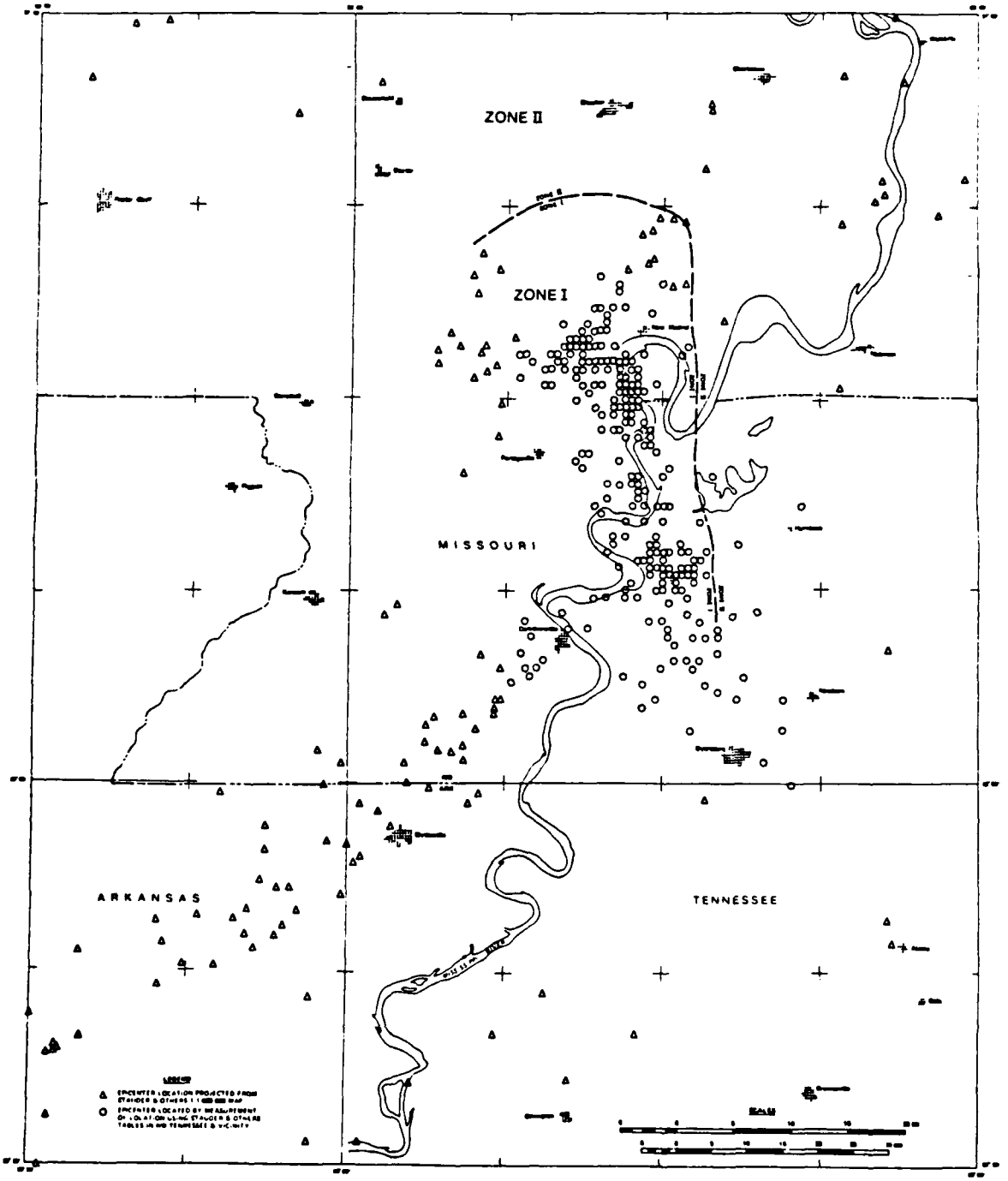
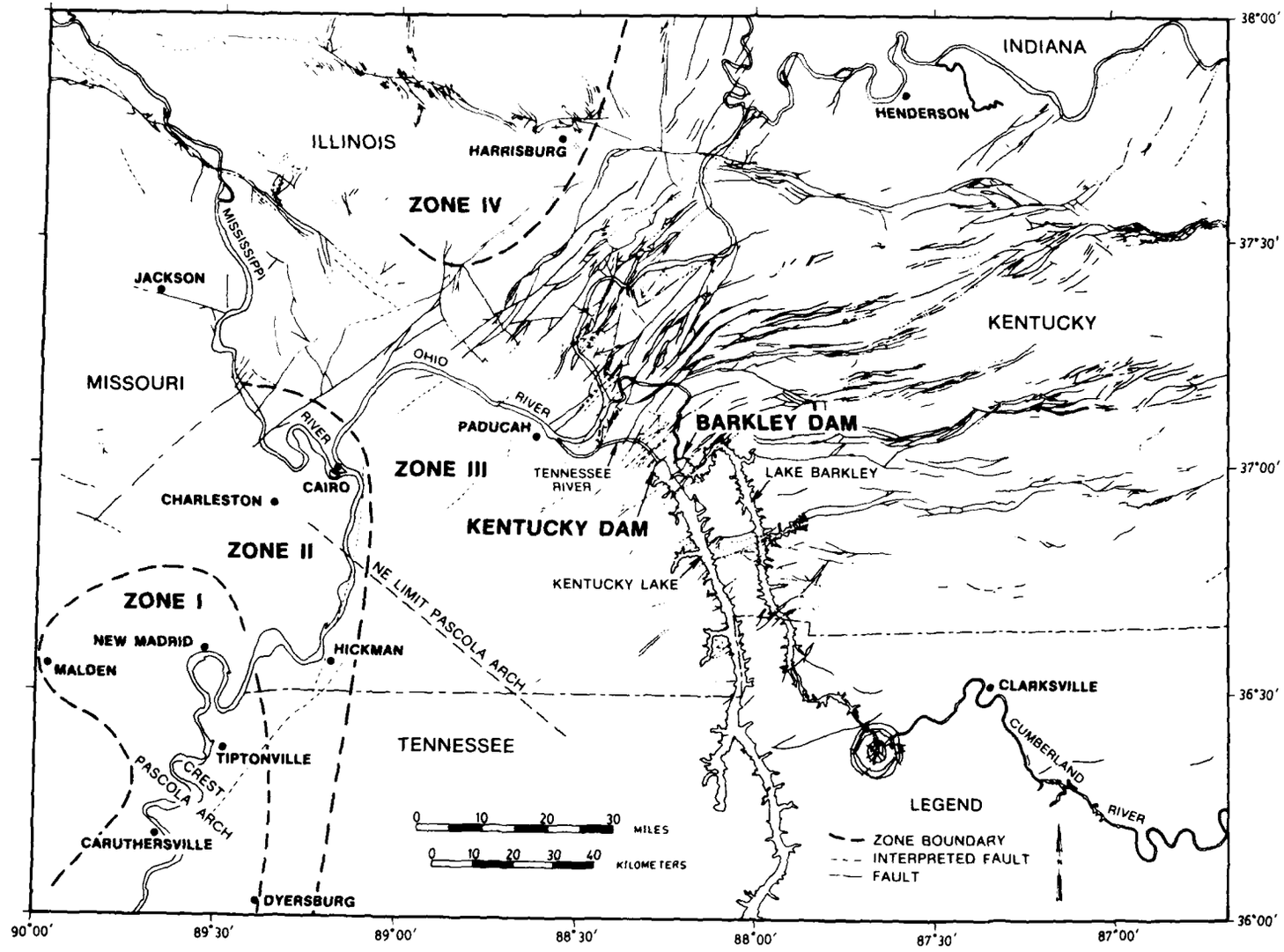


PLATE A2


INDIANA
HENDERSON
ILLINOIS
HARRISBURG
ZONE IV
MISSISSIPPI
JACKSON
KENTUCKY
MISSOURI
OHIO
RIVER
PADUCAH
BARKLEY DAM
ZONE III
TENNESSEE RIVER
LAKE BARKLEY
CAIRO
CHARLESTON
KENTUCKY DAM
ZONE II
KENTUCKY LAKE
NE LIMIT PASCOLA ARCH
ZONE I
NEW MADRID
HICKMAN
MALDEN
CLARKSVILLE
CUMBERLAND
RIVER
TENNESSEE
TIPTONVILLE
PASCOLA ARCH
CREST
CARUTHERSVILLE
DYERSBURG
0 10 20 30 MILES
0 10 20 30 40 KILOMETERS
LEGEND
ZONE BOUNDARY
INTERPRETED FAULT
FAULT
38°00′
37°30′
37°00′
36°30′
36°00′
90°00′
89°30′
89°00′
88°30′
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87°30′
87°00′

PLATE A3

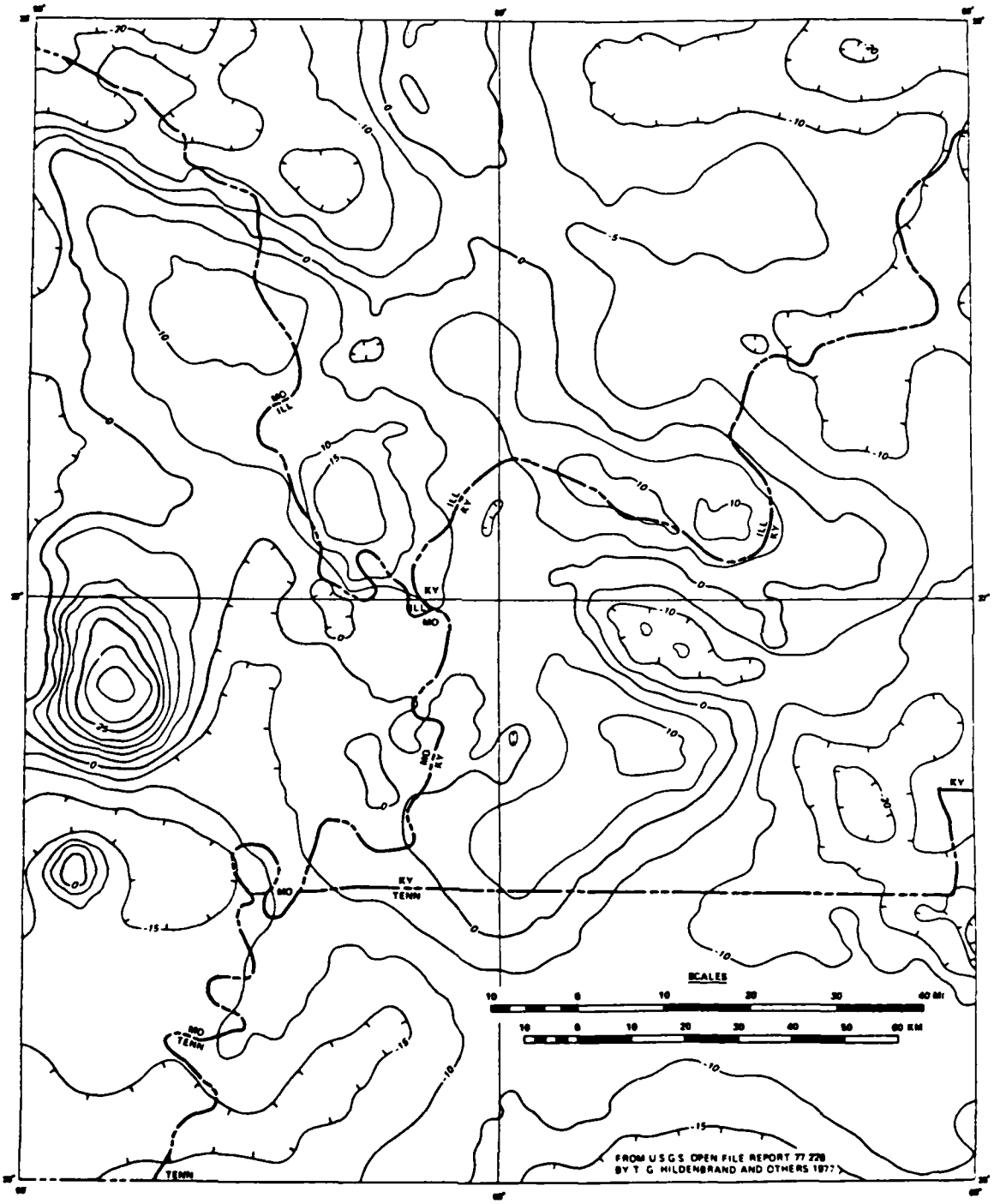

KY
ILL
MO
TENN
SCALES
10 0 10 20 30 40 MI
10 0 10 20 30 40 50 60 KM
FROM U.S.G.S. OPEN FILE REPORT 77-228
BY T. G. HILDENBRAND AND OTHERS 1977

PLATE A4

APPENDIX A

SUPPLEMENT 1
SUPPLEMENTARY EARTHQUAKES IN THE BARKLEY DAM AREA IN RELATION TO THE NEW MADRID REGION, MAY 1977 TO DECEMBER 1981

by

Dale L. Barefoot

DATE	LOCATION	LAT.	LONG.	M.M. INT.	MAG.
1978 Aug. 31	New Madrid, Mo., Region	36.1	89.4	V	3.5*
1980 Mar. 13	Southern Illinois	37.93	88.45	IV	3.3*
1980 Mar. 23	Central Kentucky	37.63	86.69	IV	3.3 M_N (S)
1980 Mar. 29	Illinois	37.21	89.06	IV	3.3 M_N (S)
1980 July 5	New Madrid Area	36.60	89.58	IV	3.6 M_N (S)
1980 July 12	Western Kentucky	37.26	86.99	III	3.1 M_N (G)
1980 Oct. 31	Missouri	36.52	89.59		2.6 (S)
1980 Dec. 2	Northwestern Tennessee	36.2	89.4	VI	3.8*
1981 Jan. 2	Northwestern Tennessee	36.36	89.51	IV	2.3 M_D (K)
1981 Jan. 3	Northwestern Tennessee	36.29	89.49		1.8 M_D (K)
1981 Feb. 11	Kentucky-Ill. Border Region	37.05	89.13	IV	2.7 M_N (S)
1981 Apr. 25	Tennessee	36.24	89.59		2.6 (S)
1981 May 29	Northwestern Tennessee	36.28	89.49		2.3 M_N (S)
1981 June 9	Southern Illinois	37.82	89.02	V	3.4 M_N (S)
1981 Sep. 30	Missouri	36.56	89.65		2.5 (S)
1981 Oct. 22	Northwestern Tennessee	36.30	89.44		2.5 M_D (K)
1981 Nov. 8	Northwestern Tennessee	36.10	89.30	IV	3.0 M_N (G)
1981 Dec. 27	Illinois	37.17	89.32		2.6 (K)

(G) = U. S. Geological Survey, National Earthquake Information Service, Golden, Colorado, or Network Operations Branch, Menlo Park, California

(K) = Tennessee Earthquake Information Center, Memphis

(S) = St. Louis University, St. Louis, Missouri

M_D = Duration or Coda Length Magnitude

M_N = Nuttli

* = Type of Magnitude not Specified

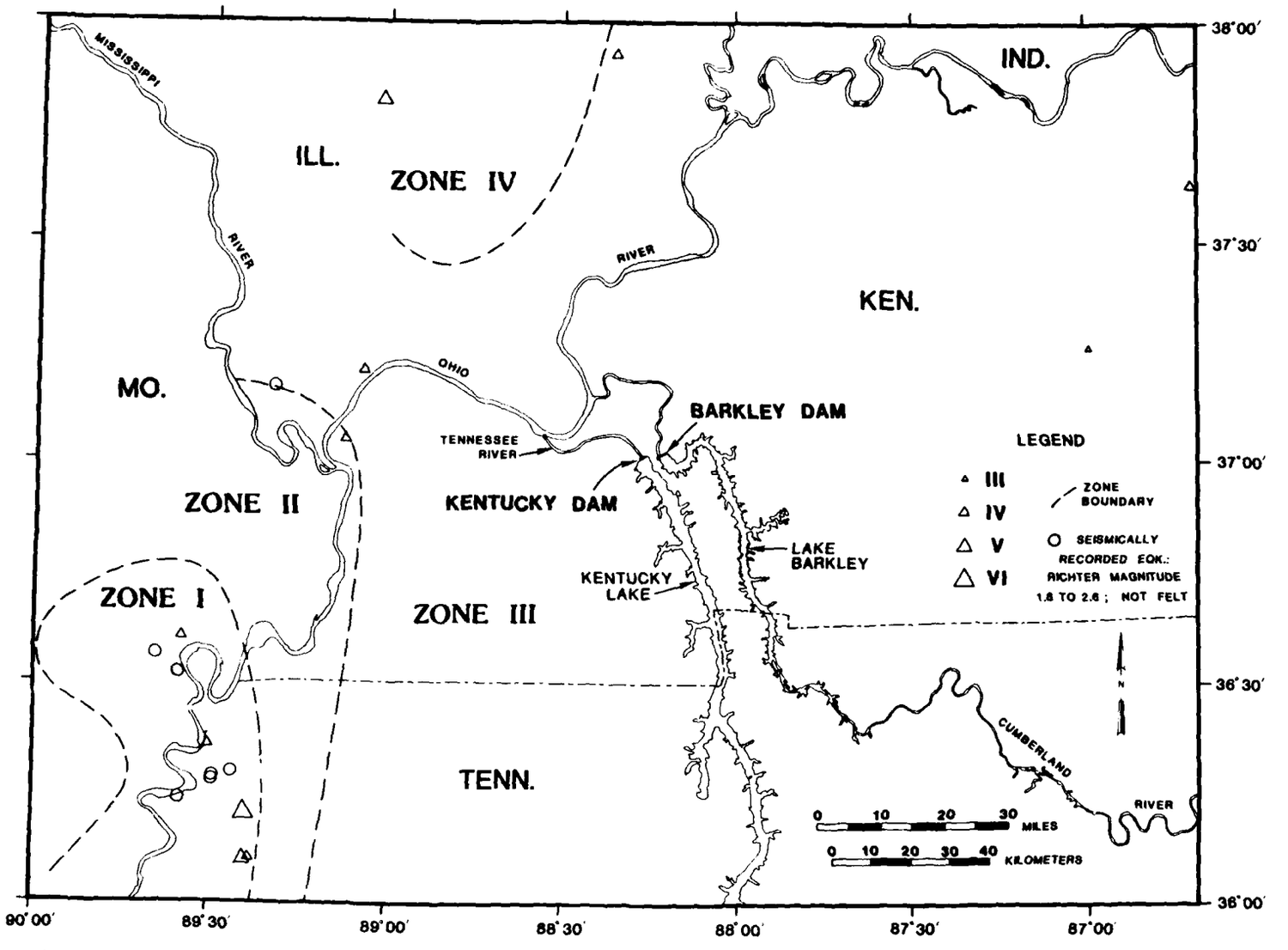


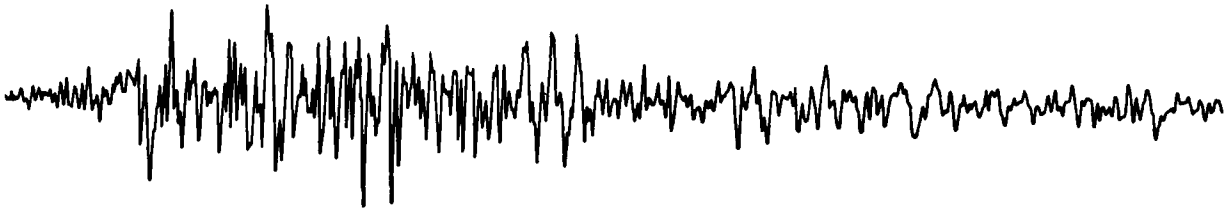
Figure A - Supplement 1. Locations of earthquakes in the Barkley Dam - New Madrid region, May 1977 to December 1981

APPENDIX B

EARTHQUAKE MOTIONS AND RECOMMENDED ACCELEROGRAMS *FOR THE BARKLEY DAMSITE, BASED ON* ZONES I, II, AND III

by

David J. Leeds
Los Angeles, California



DAVID J. LEEDS AND ASSOCIATES

Consultants in Engineering Seismology/Geology/Geophysics

11972 Chalon Road
Los Angeles, CA 90049
(213) 472-0282

15 January 1978

Dr. Ellis L. Krinitzsky
Soils and Pavements Laboratory
U.S. Army Engineer Waterways Experiment Station
P.O. Box 631, Vicksburg, MS 39190

Re: Seismic Criteria
Alben Barkley Dam
Near Paducah, Kentucky

Dear Dr. Krinitzsky:

This letter confirms my meeting with you and Dr. Richard G. Stearns and our discussions of seismic criteria for the Alben Barkley Dam, resulting in our mutual concurrence on the following conclusions.

Seismic ground motion at the damsite should be considered from three source areas, as follows:

Source I: The area of highest historical seismicity, characterized by magnitude m_b = 7.5, Intensity XI, the epicentral region of the 1811-1812 earthquakes, and the area of recent microearthquake activity. This area is defined on the east by folding on the west side of Reelfoot Lake and follows the eastern limit of current microearthquakes. The north side encloses the closely spaced microearthquakes. (Note: Dr. Stearns will submit a plate showing the area described.)

Source II: The area characterized by the most recent faults, that may be active, with a level of magnitude m_b = 6.5 and Intensity IX. The eastern margin follows the most recent faults. The northeast is based on faulting extending to 20 miles north of the Kentucky border. Northwestward, it follows the north edge of the Pascola Arch (-2000 foot contour on top of the Knox Dolomite). The area includes the epicenter of the 1895 Charleston earthquake. (See Dr. Stearns' map.)

Source III: A random, far-field area outside the New Madrid Zone, characterized by magnitude m_b = 5.5 and Intensity VII, in which the dam is located.

The following table presents representative ground motions at the damsite from the three source areas discussed above:

Source	Max. m_b	I_o	Distance to Site, km (mi.)	Site				
				I_{site}	Accel., g	Velocity, cm/sec	Displ., cm	Duration at 0.05 g, sec
I	7.5	XI	118 (74)	IX	0.28	40	22	10
II	6.5	IX	85 (53)	VIII	0.23	32	18	10
III	5.5	VII	-- --	VII	0.18	25	15	10

Copies of accelerograms and response spectra are attached which may be scaled for representative ground motions. The Taft and Santa Barbara 1952 Kern County, California records probably best represent Source I ground motion. Lake Hughes #1 and Castaic records of the 1971 San Fernando earthquake may be used for Source II motion. The Logan, Utah earthquake of 1962 appears applicable for use in Source III, random far-field, if it is necessary to run a lower level test. The accelerogram has not been digitized to present day standards; however, an unpublished version is attached.

Thank you the opportunity of working with you and Dr. Stearns on this interesting project. If there are any questions or if my remarks need further amplification, please contact me.

Very truly yours,

David J. Leeds

DJL:z

Encl: Accelerograms
Response spectra

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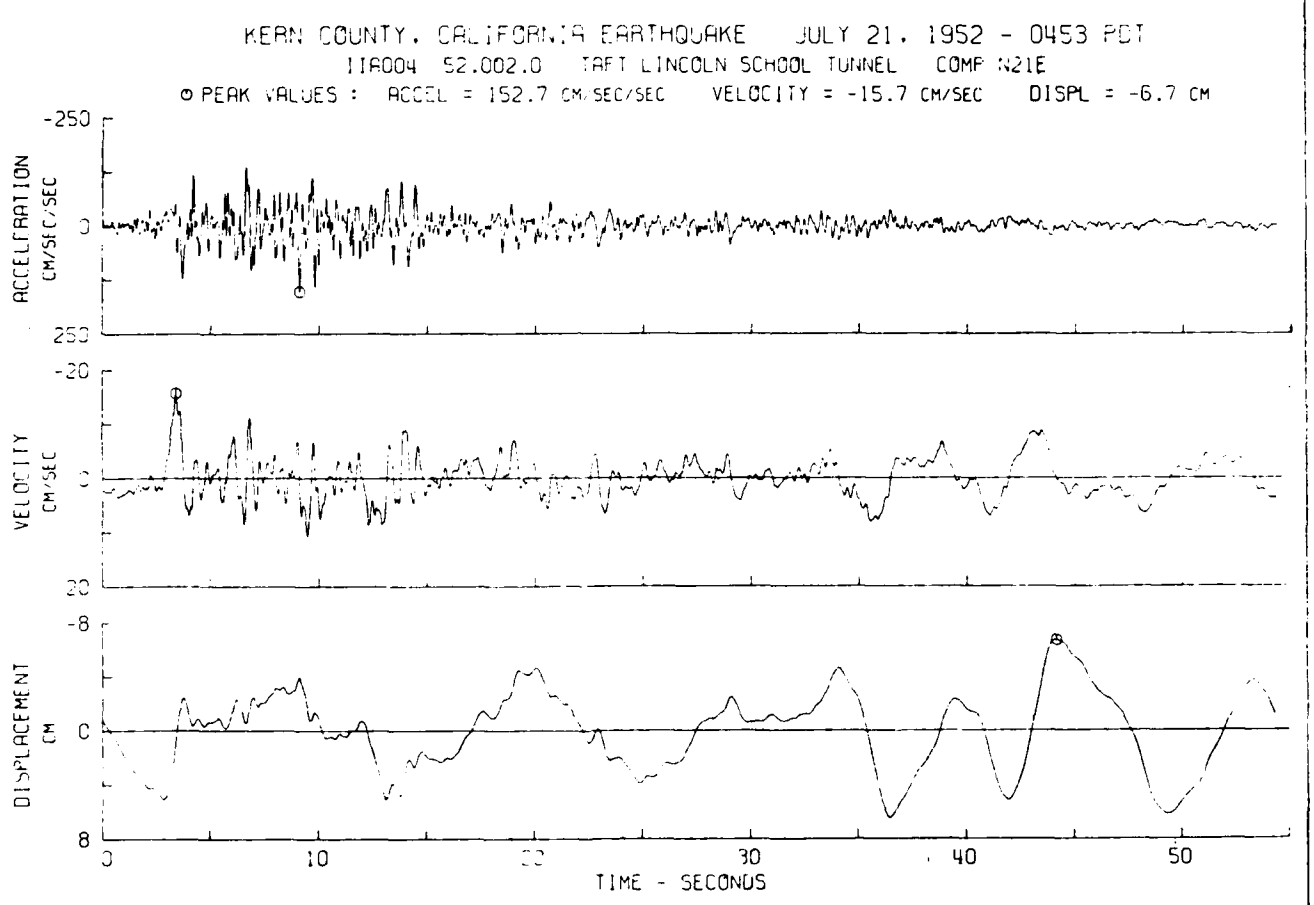
DAVID J. LEEDS AND ASSOCIATES

C.I.T. EERL 71-50, p.41



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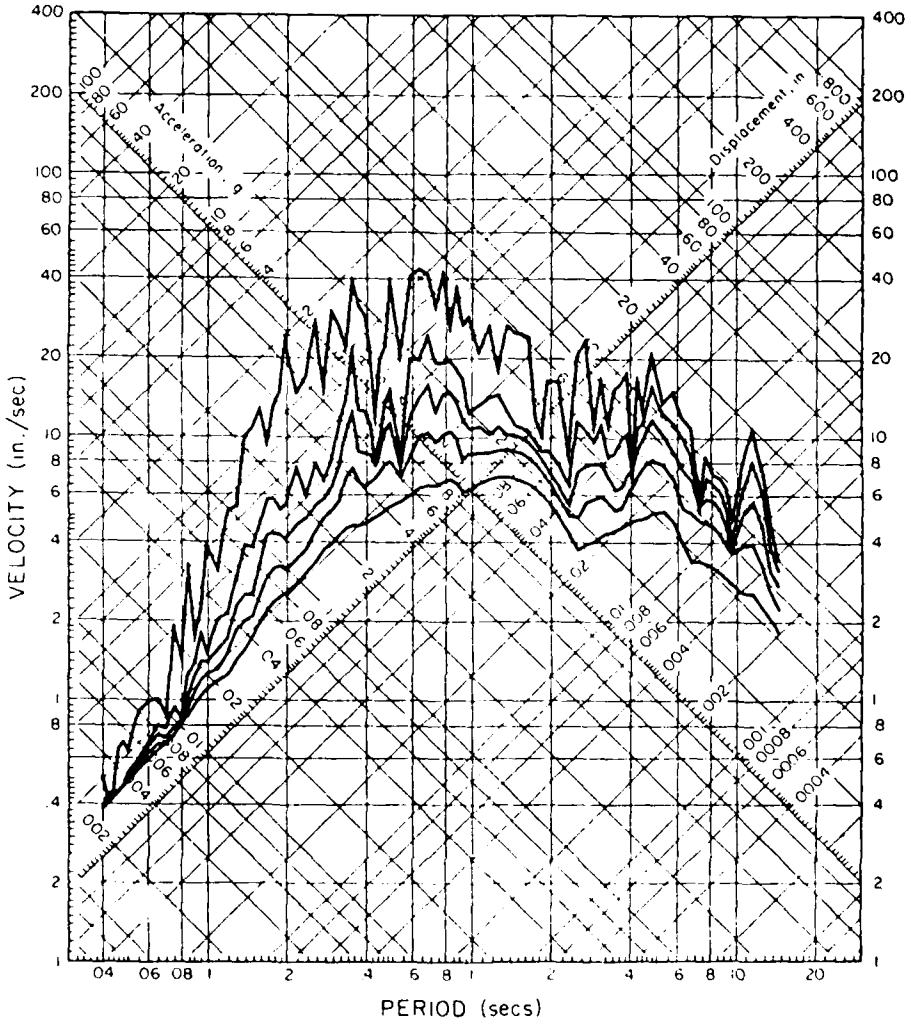
RESPONSE SPECTRUM

KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT

1111A004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP N21E

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL



C. I. T. EERL 72-80, p. 69

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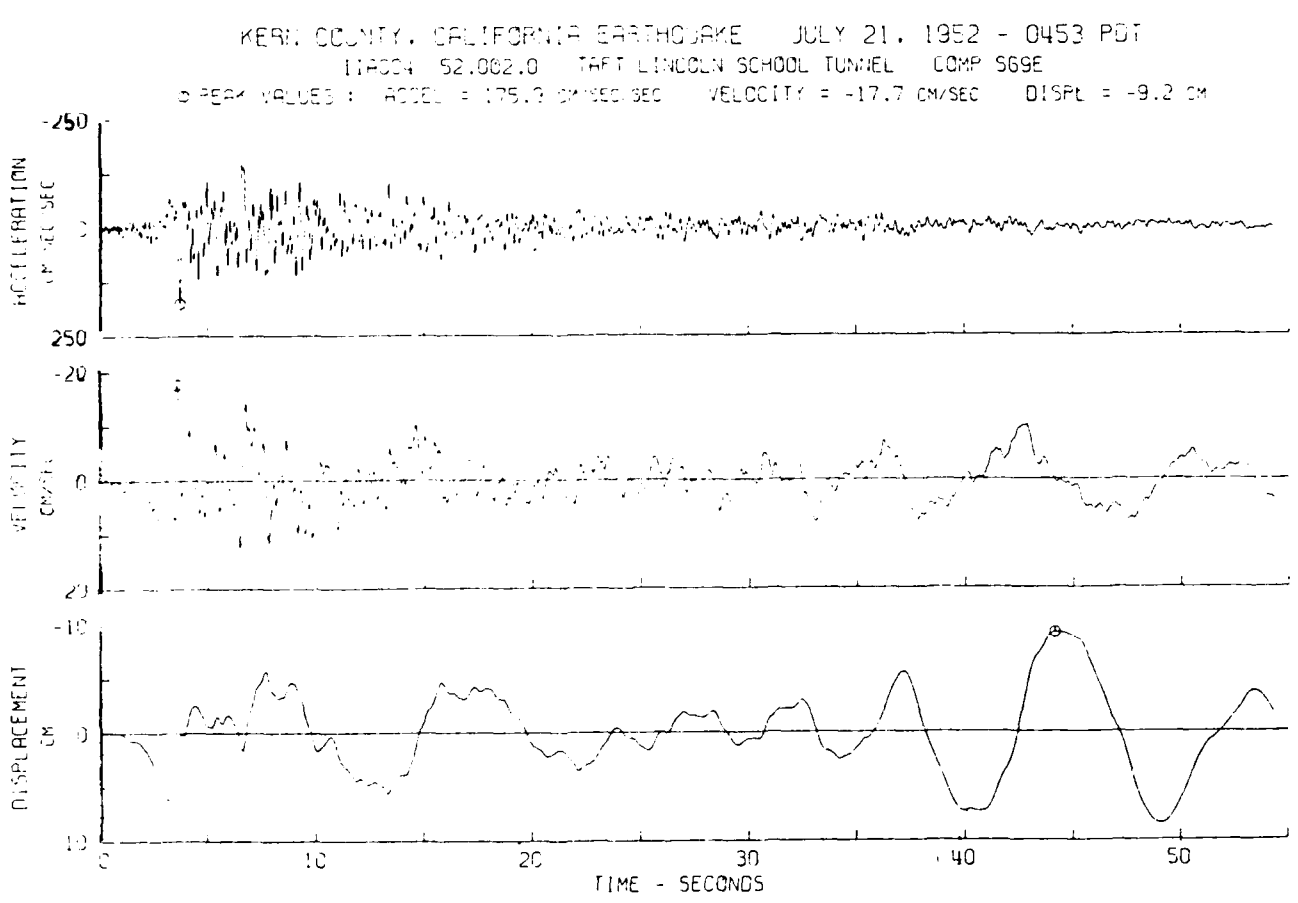
C.I.T. EERL 71-50, p.42



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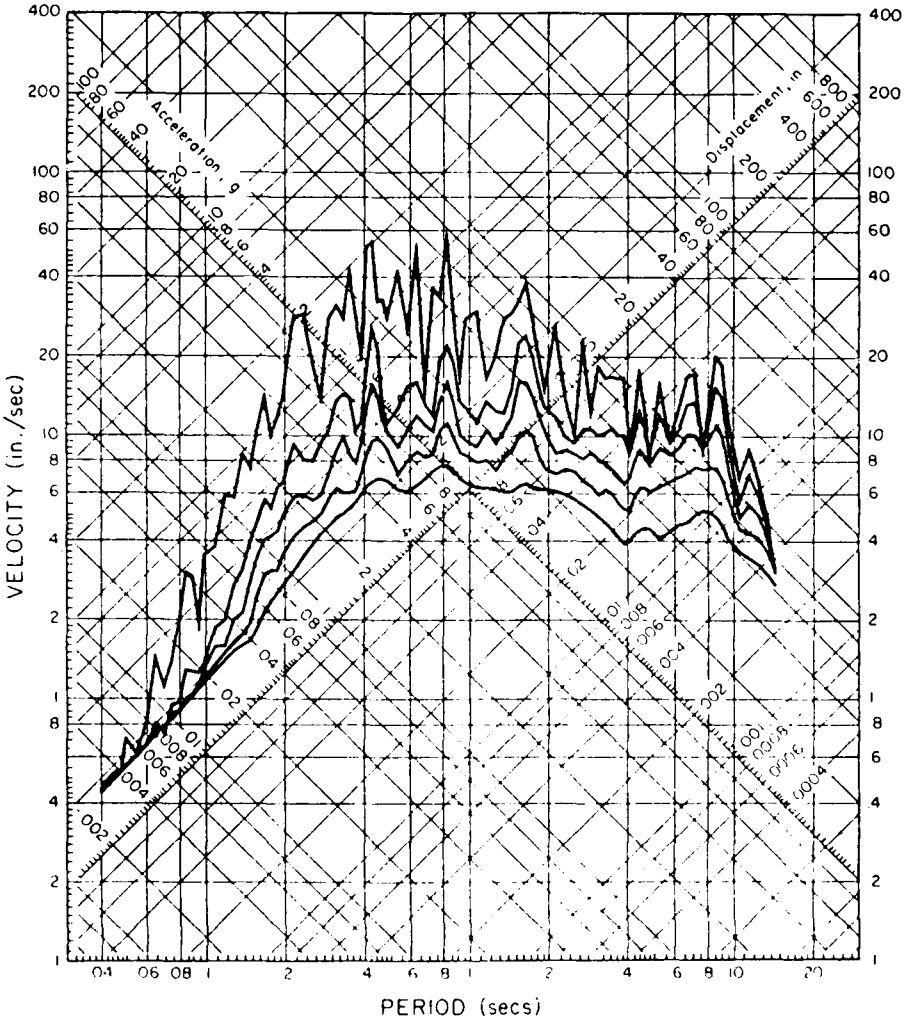
DAVID J. LEEDS AND ASSOCIATES

RESPONSE SPECTRUM

KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT

IIIA004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP S69E

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL



C. I. T. E ERL 72-80, p. 73

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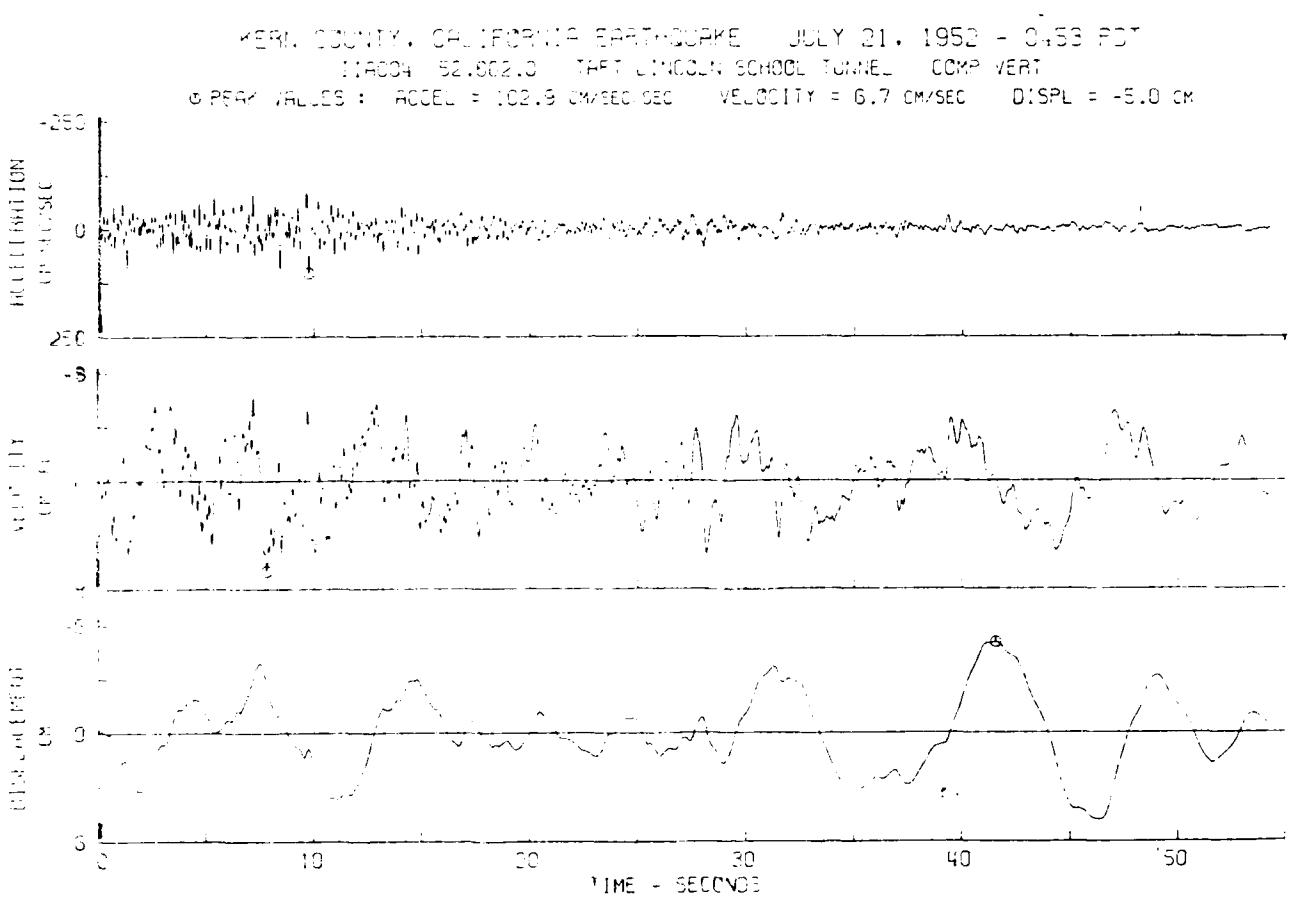
DAVID J. LEEDS AND ASSOCIATES

C.I.T. EERL 71-50, p.43



REVISIONS
BY _____ DATE _____

BY _____ DATE _____
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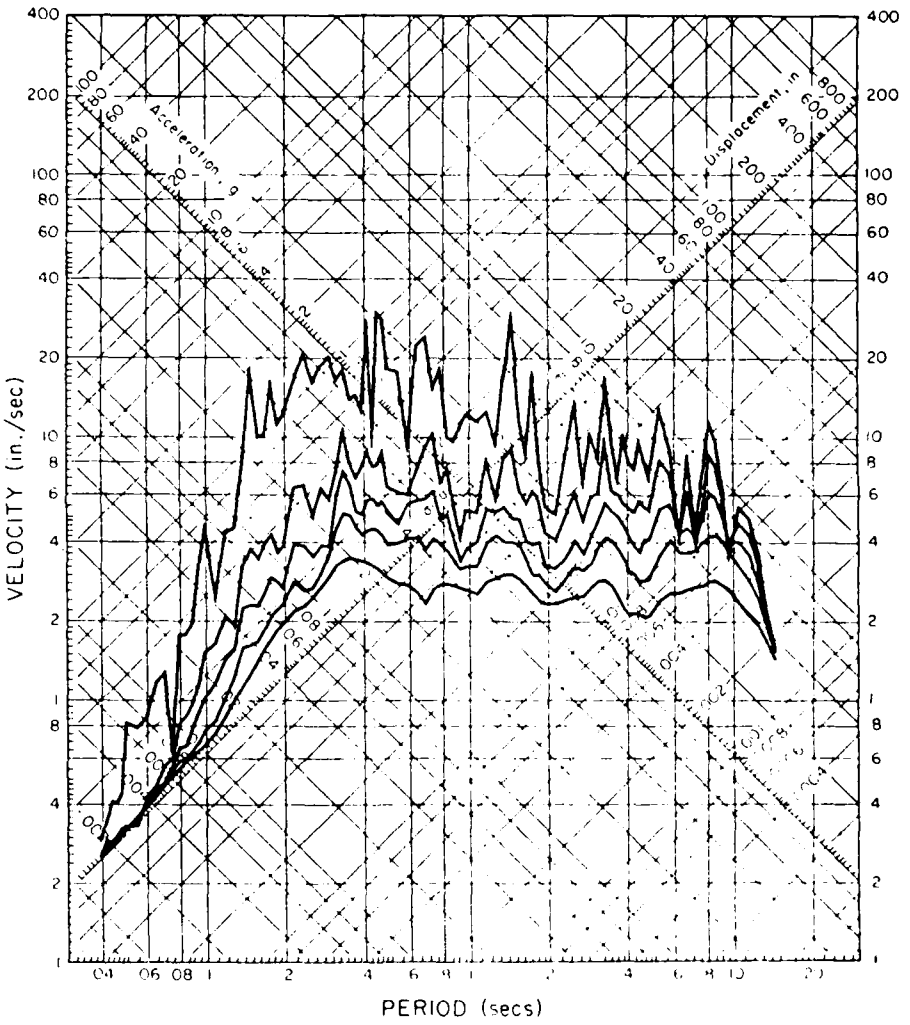
DAVID J. LEEDS AND ASSOCIATES

RESPONSE SPECTRUM

KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT

1111A004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP VERT

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL



C.I.T. EERL 72-80, p.77

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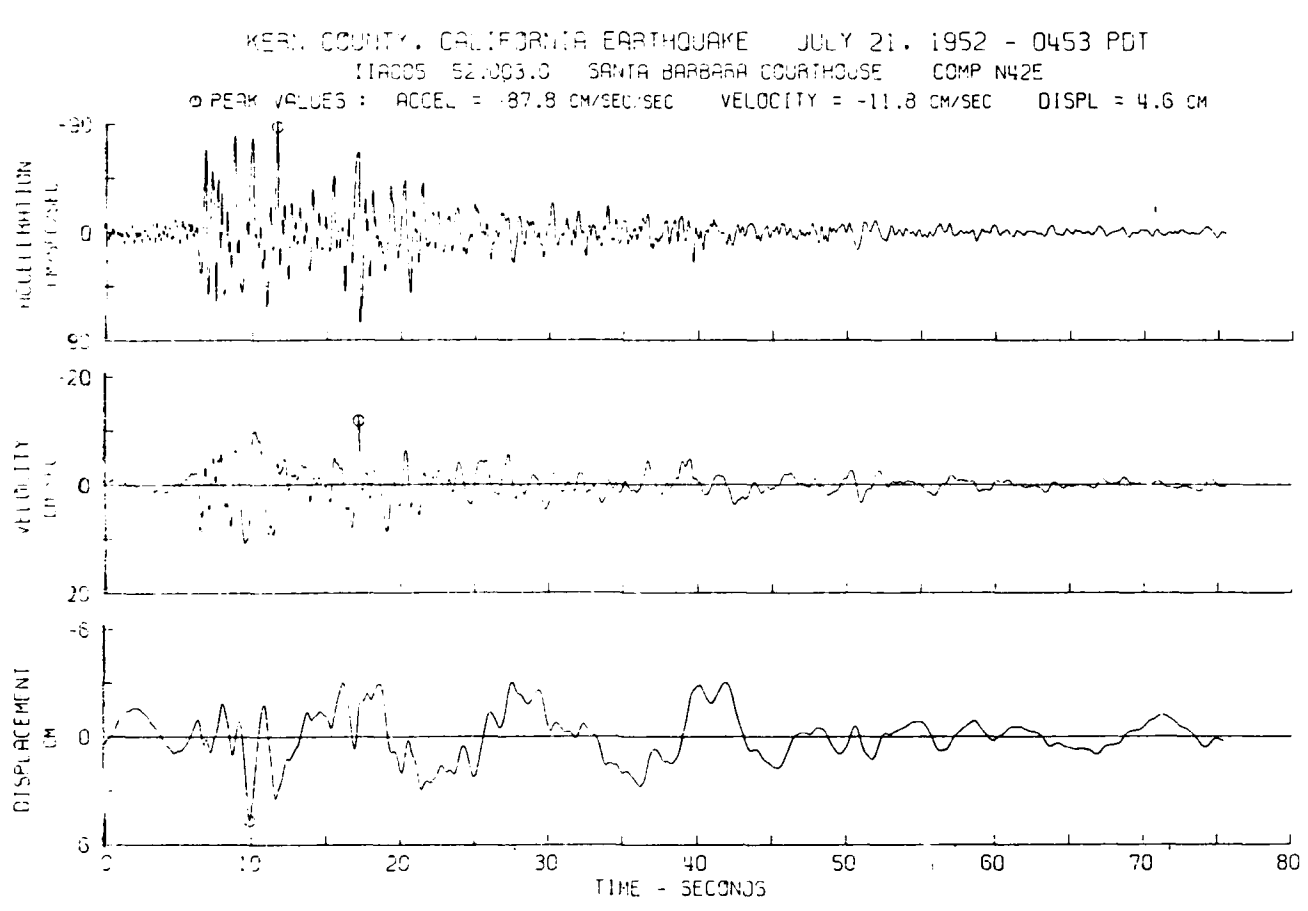
C.I.T. EERL 71-50, p.44



RESPONSE SPECTRUM

KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT

1111005 52.003.0 SANTA BARBARA COURTHOUSE COMP N42E

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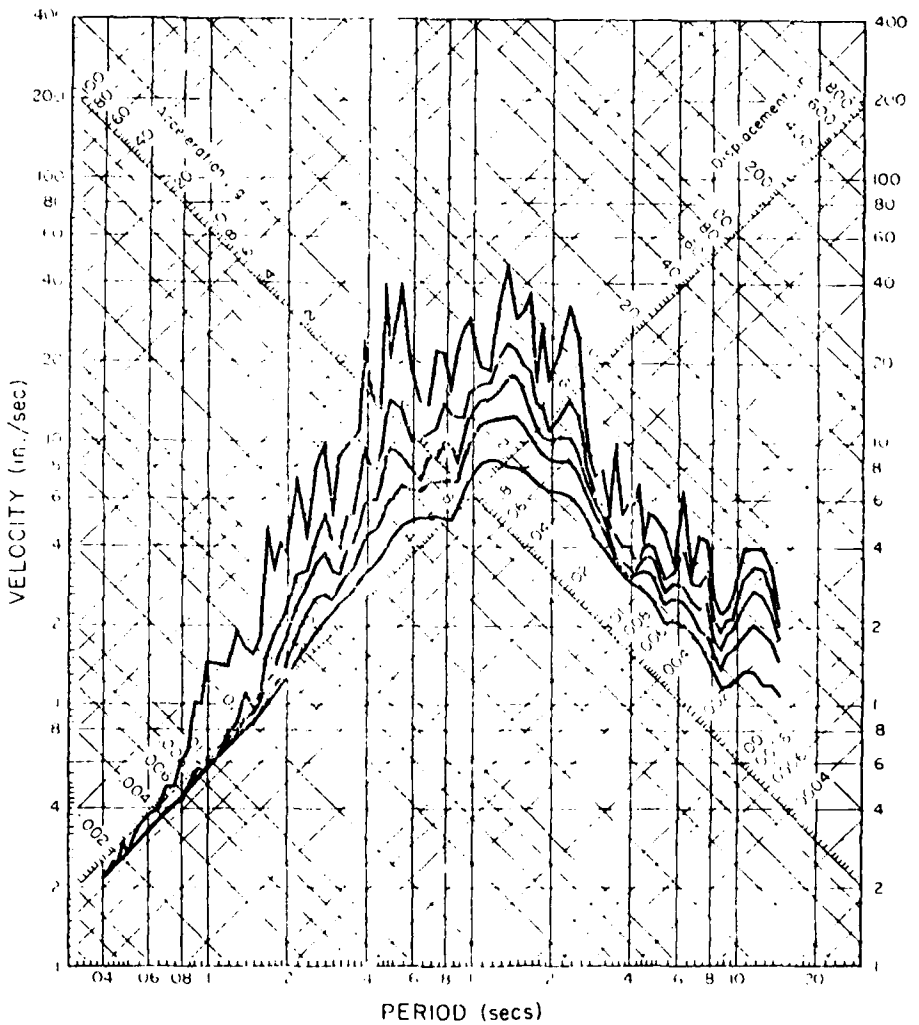

C.I.T. EERL 72-80, p.81

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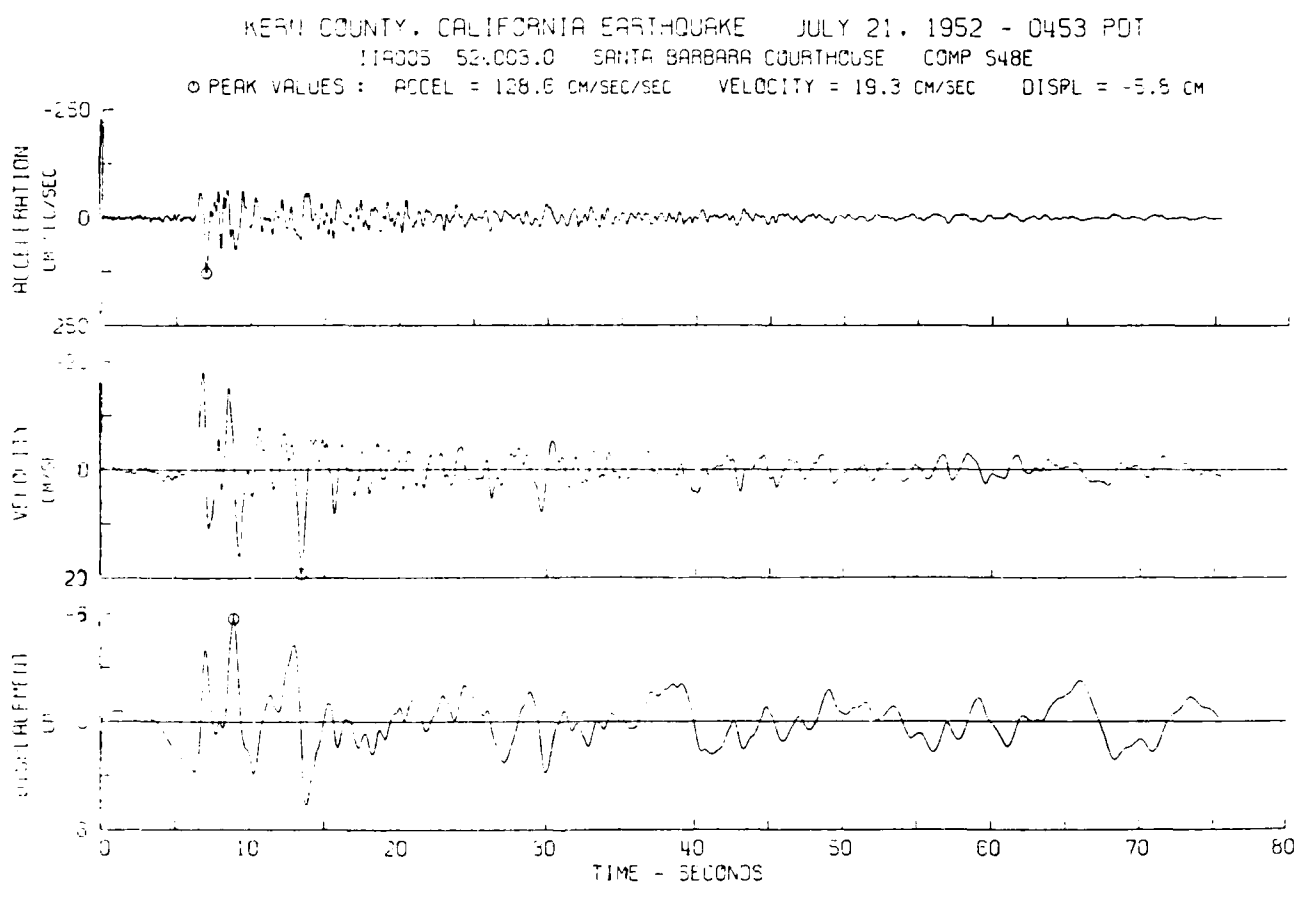
C.I.T. EERL 71-50, p.45



RESPONSE SPECTRUM

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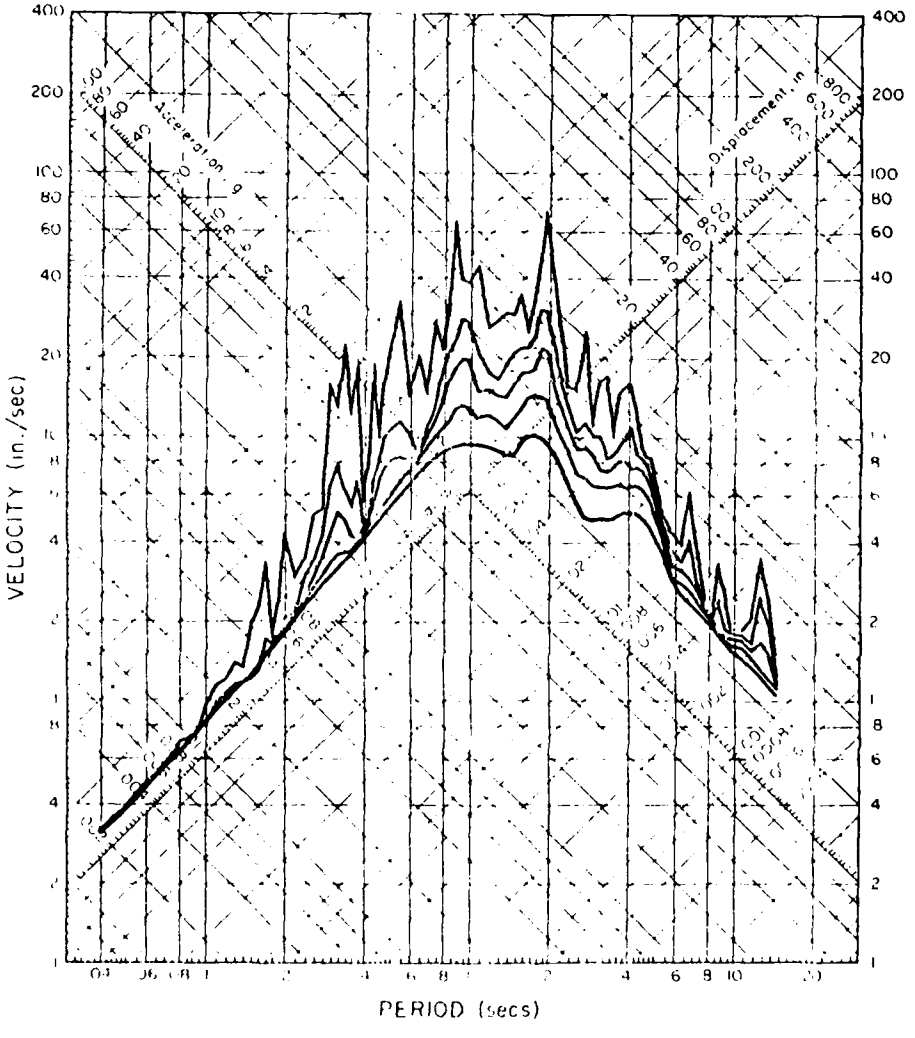

C.I.T. EERL 72-80, p.85

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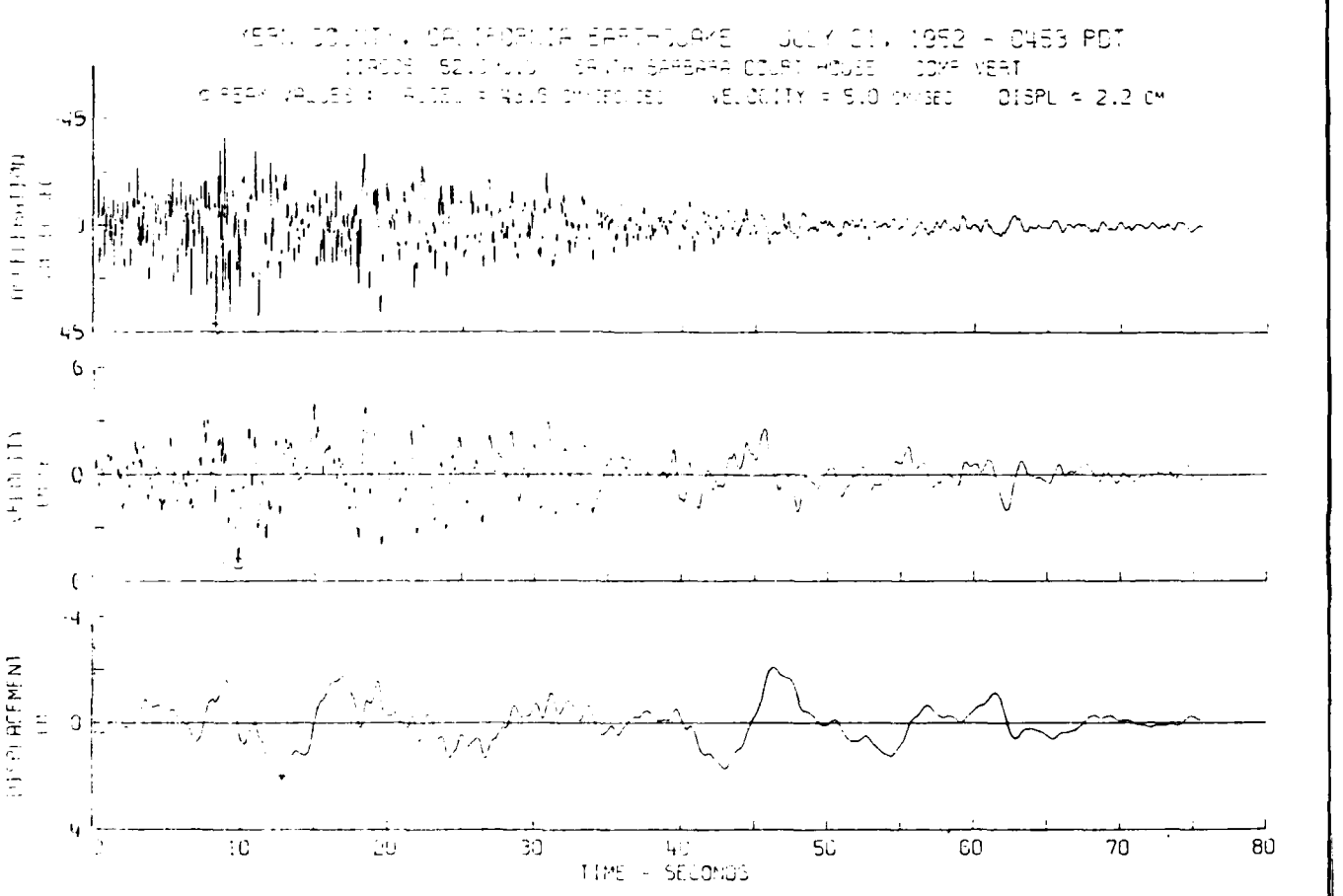
C.I.T. FERL 71-50, p.46



RESPONSE SPECTRUM

KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT

111A005 S2.003.0 SANTA BARBARA COURT HOUSE COMP VERT

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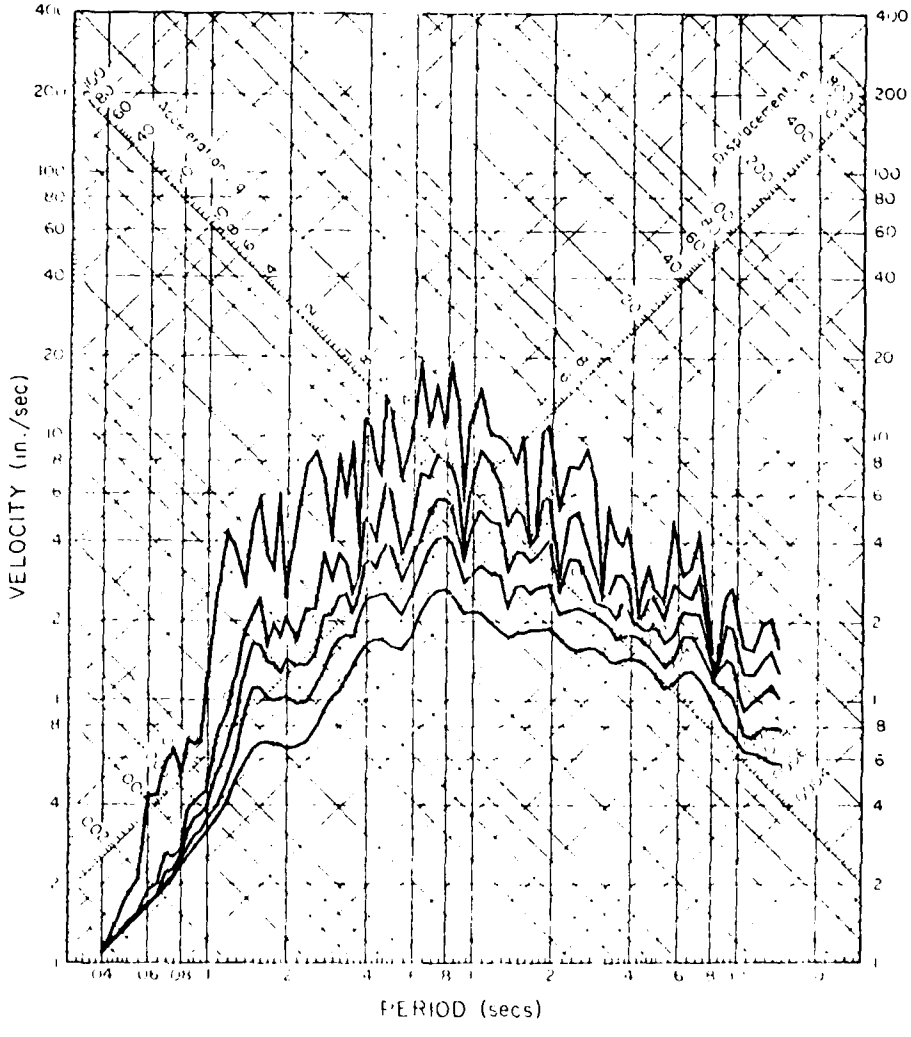

C. I. T. EERL 72-80, p. 89

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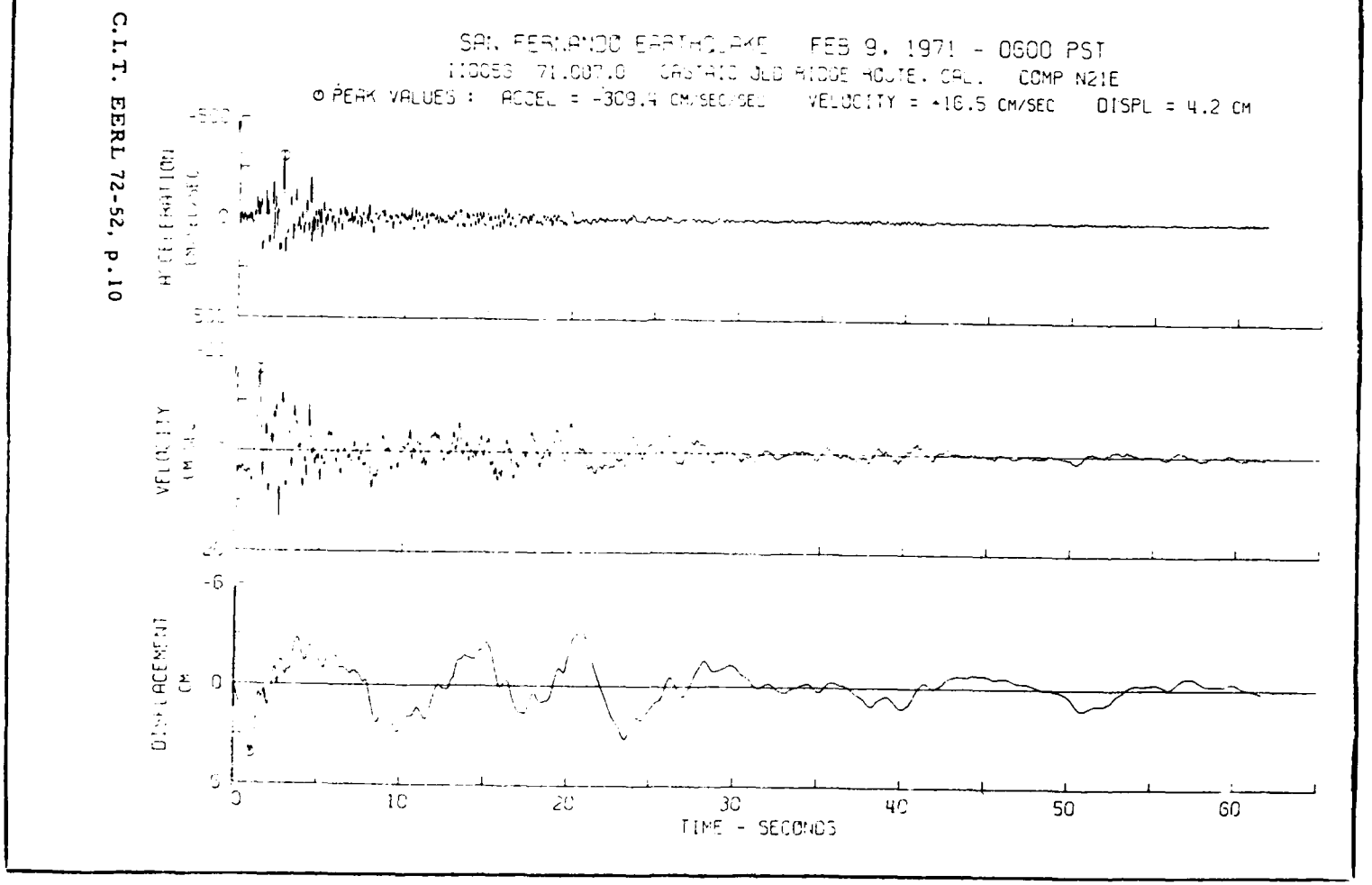
C.I.T. EERL 72-52, p.10



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RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

1110056 71.007.0 CASTAIC OLD RIDGE ROUTE, CAL. COMP N21E

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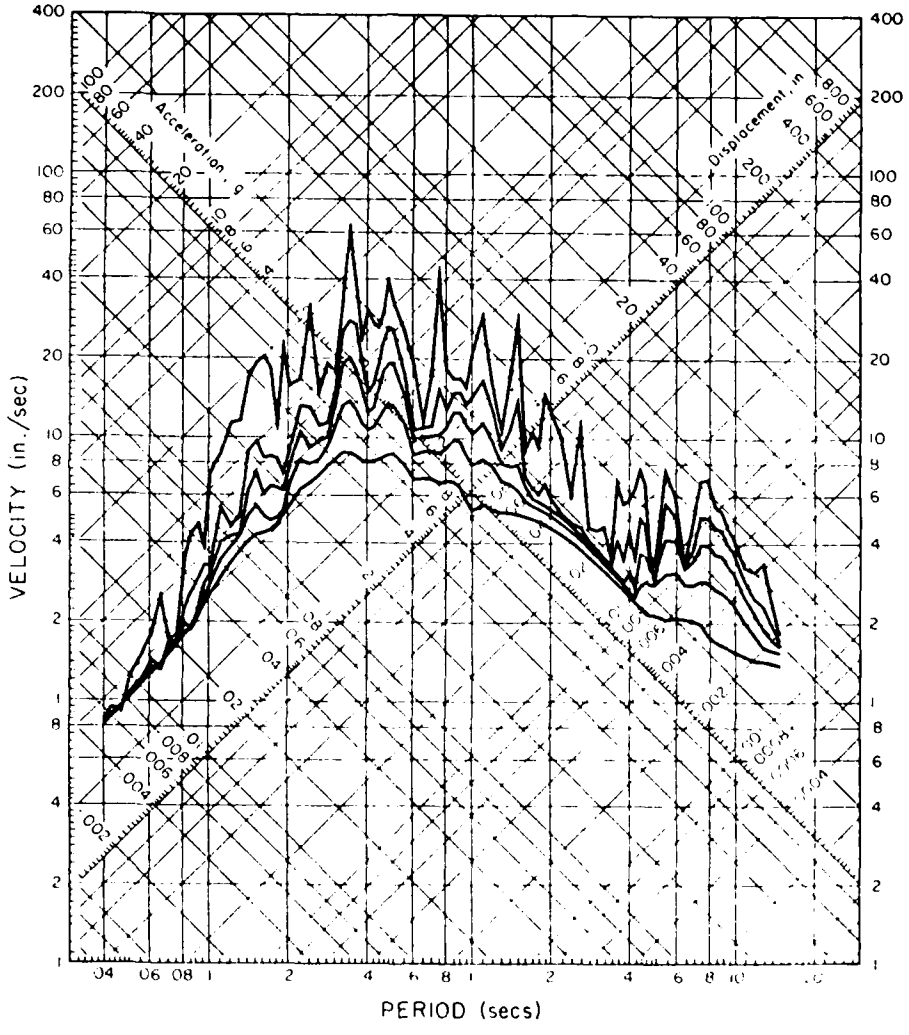

C.I.T. EERL 73-82, p.11

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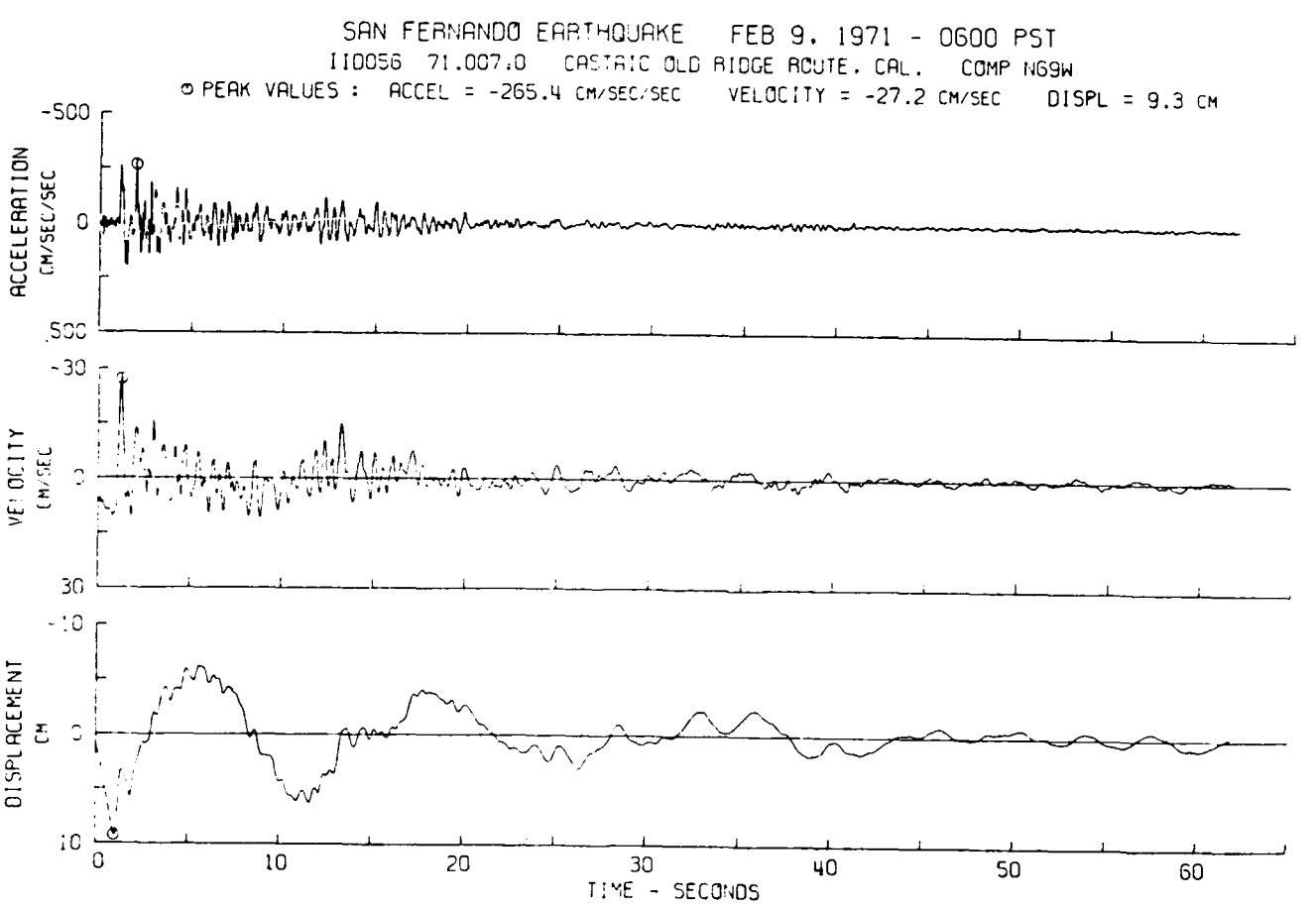
C.I.T. EERL 72-52, p.11



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RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

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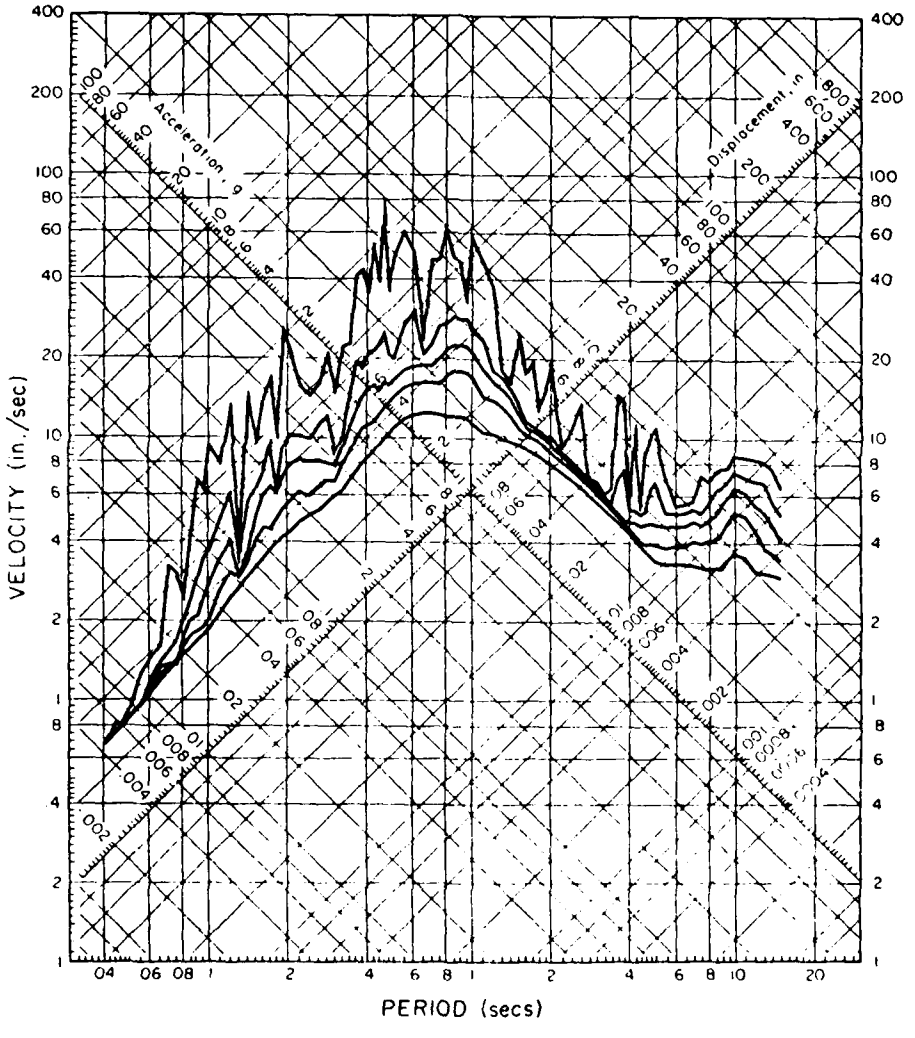

C.I.T. EERL 73-82, p.15

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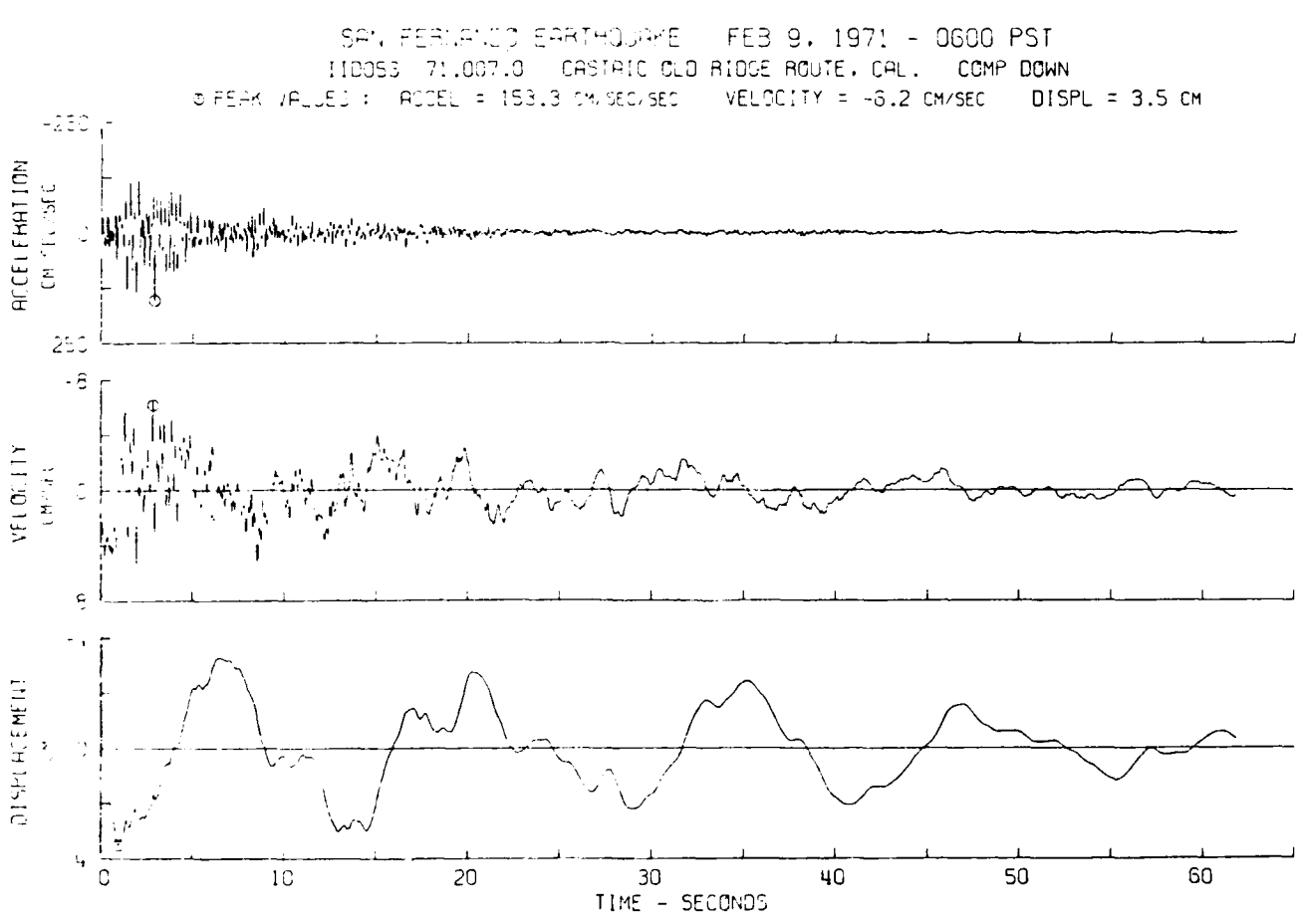
C.I.T. EERL 72-52, p.12



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RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

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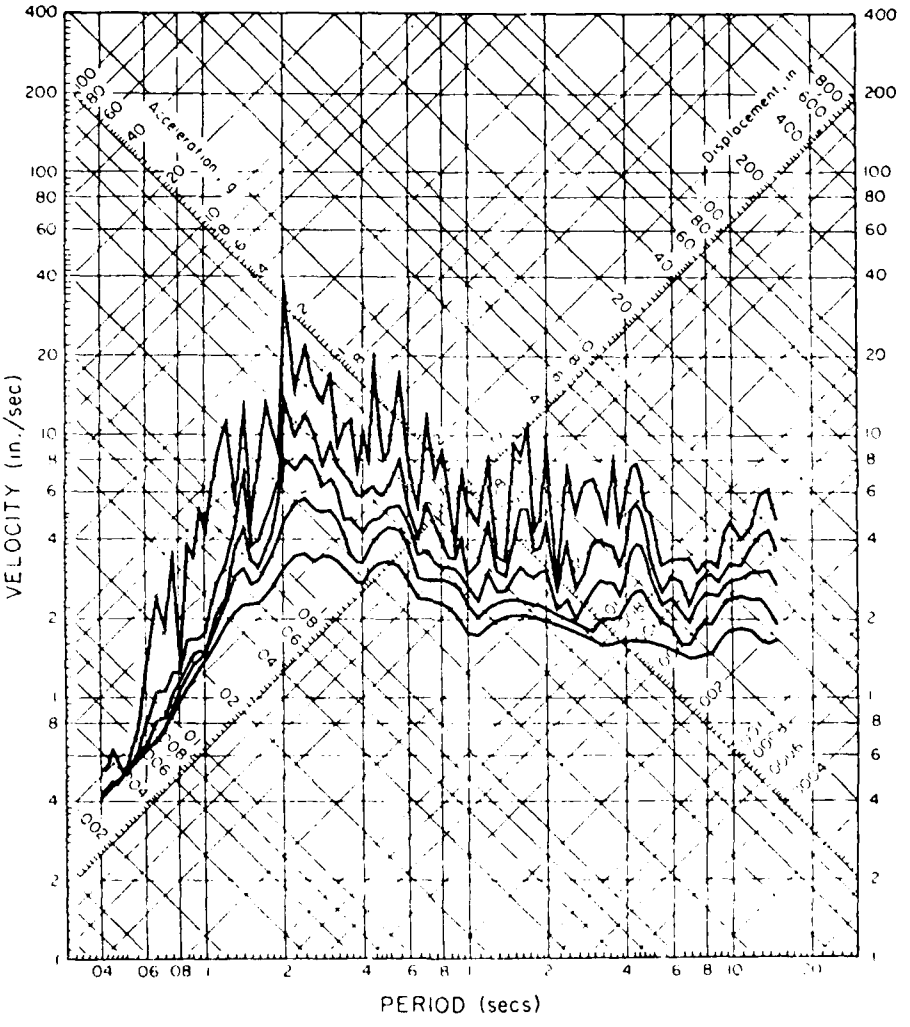

C.I.T. EERL 73-82, p.19

AD-A170 665 SEISMIC STABILITY EVALUATION OF ALBEN BARKLEY DAM AND LAKE PROJECT VOLUME..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTE.. E L KRINITZSKY 3/3

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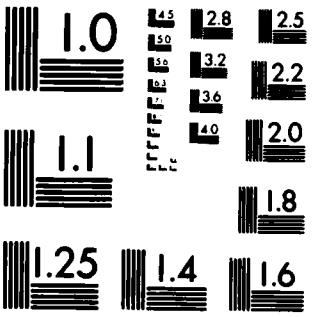

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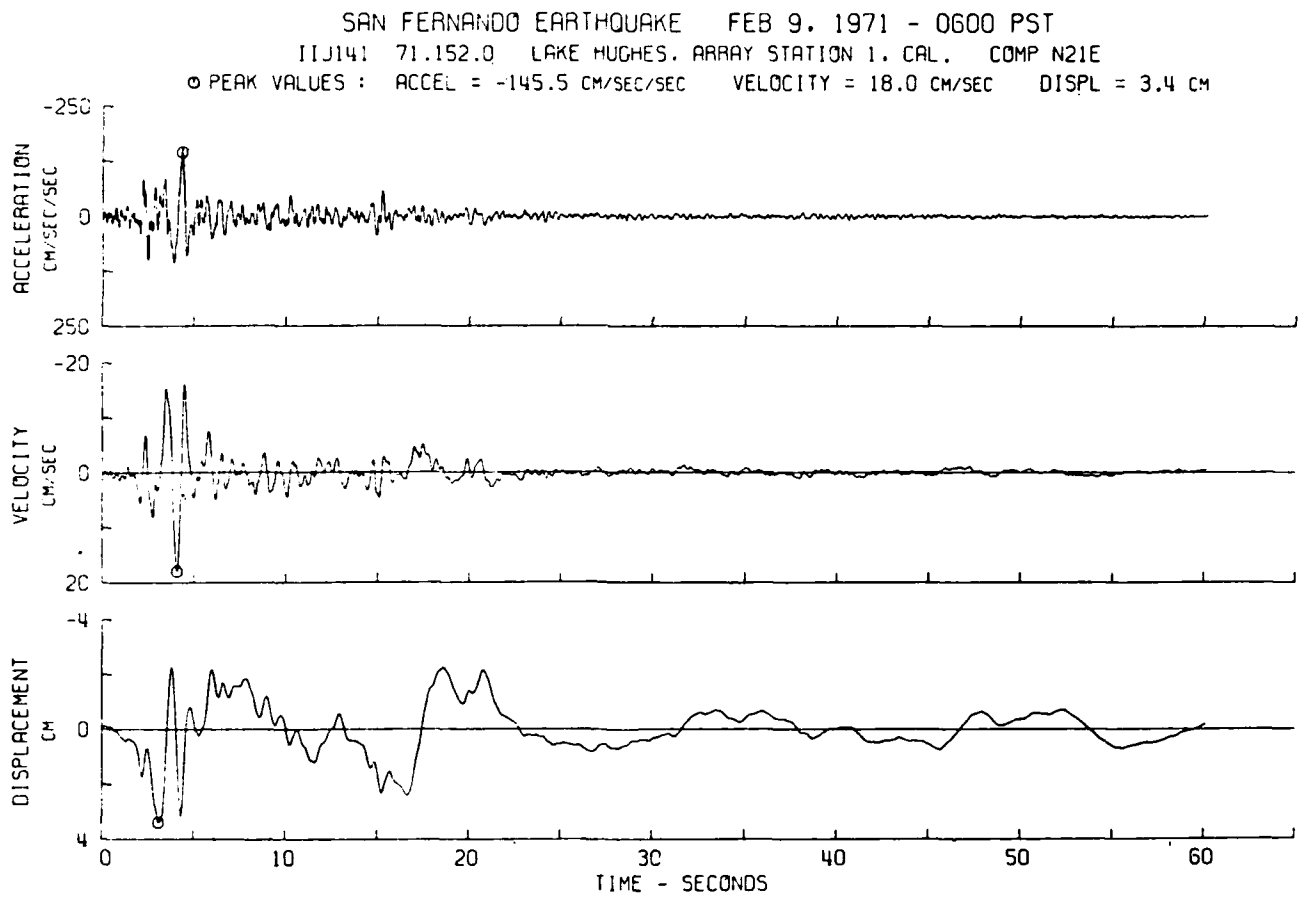
C.I.T. EERL 74-52, p.14



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RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

IIIJ141 71.152.0 LAKE HUGHES, ARRAY STATION 1, CAL. COMP N21E

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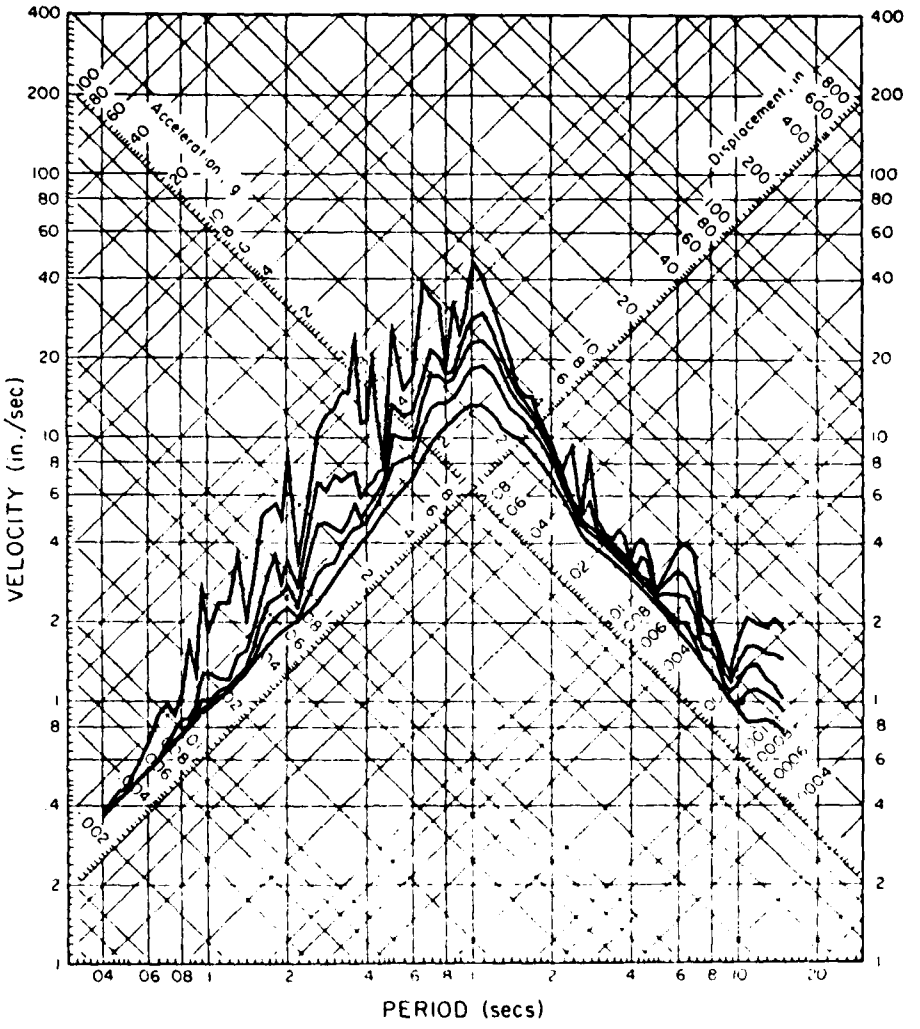

C.I.T. EERL 74-82, p.17

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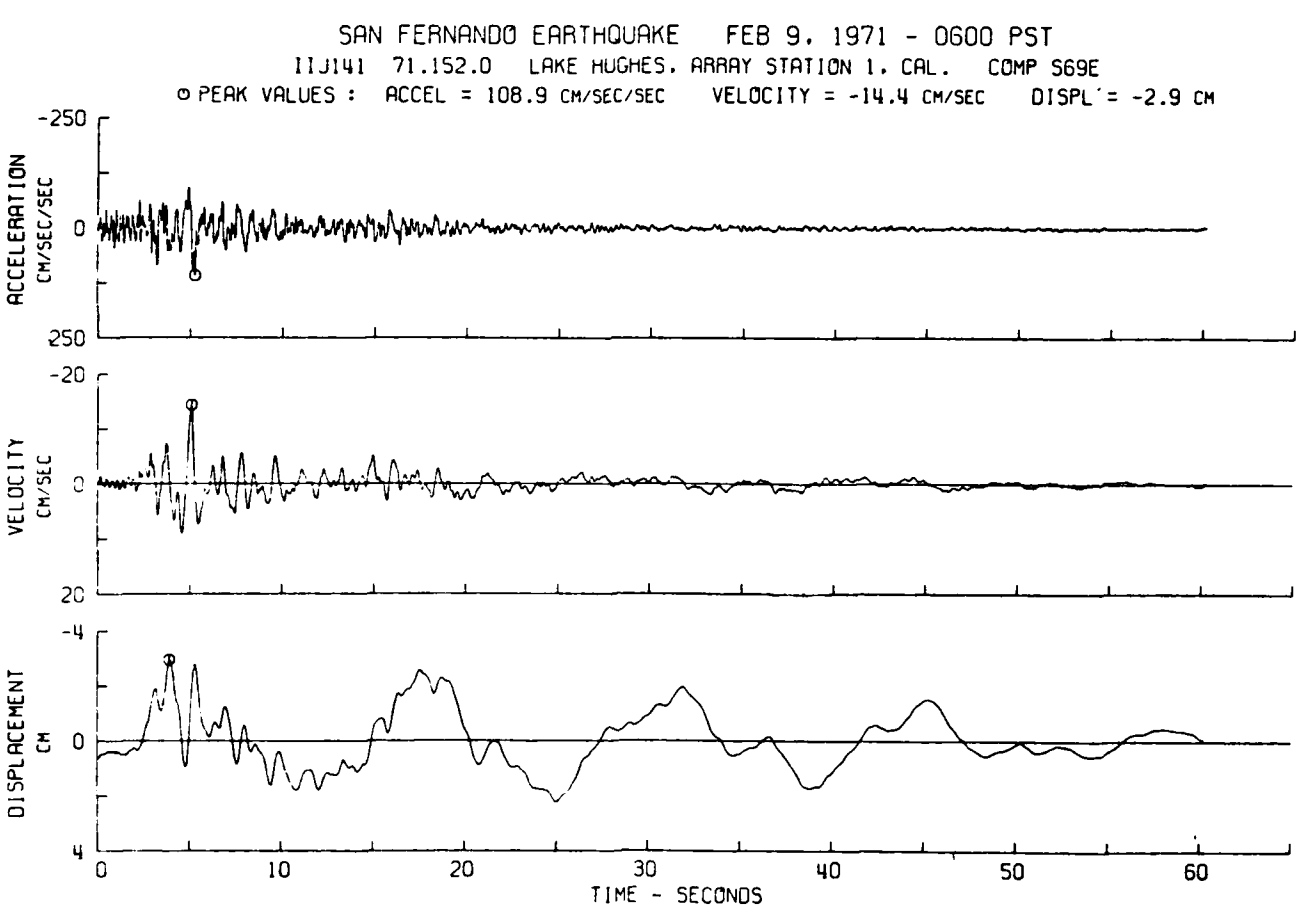
C.I.T. EERL 74-52, p.15



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RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

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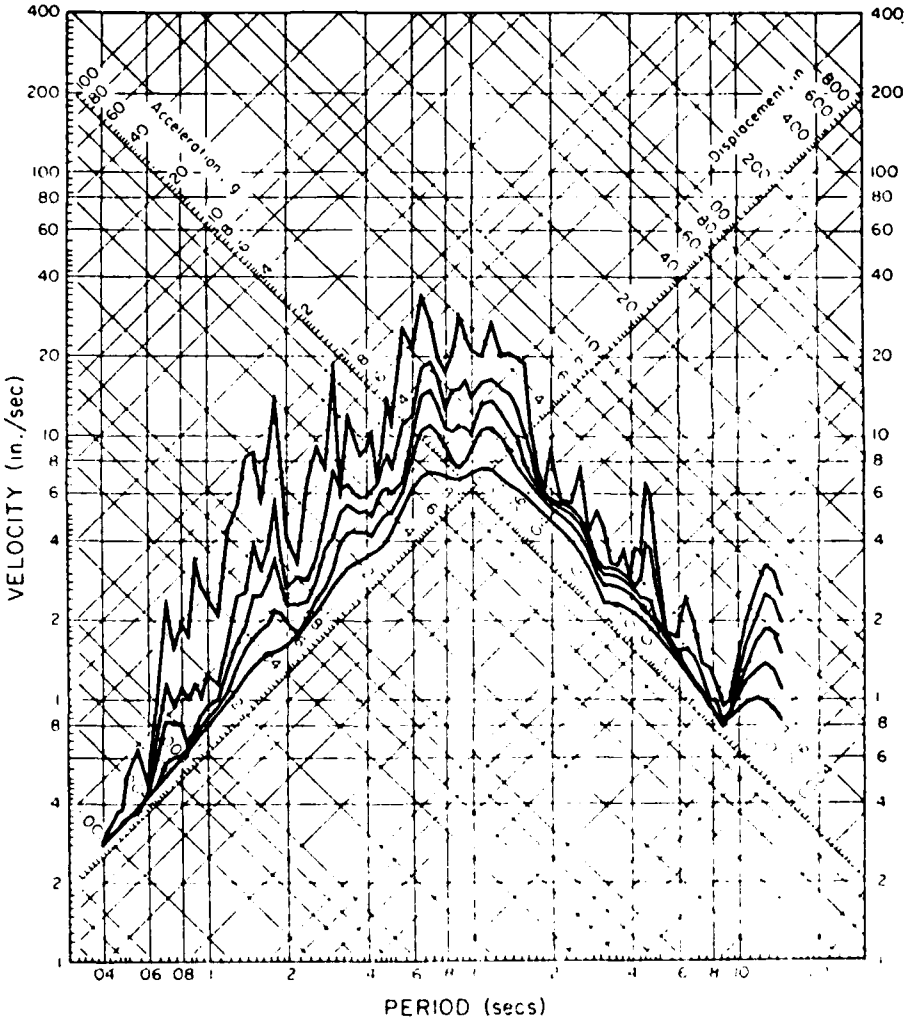

C.I.T. EERL 74-82, p.21

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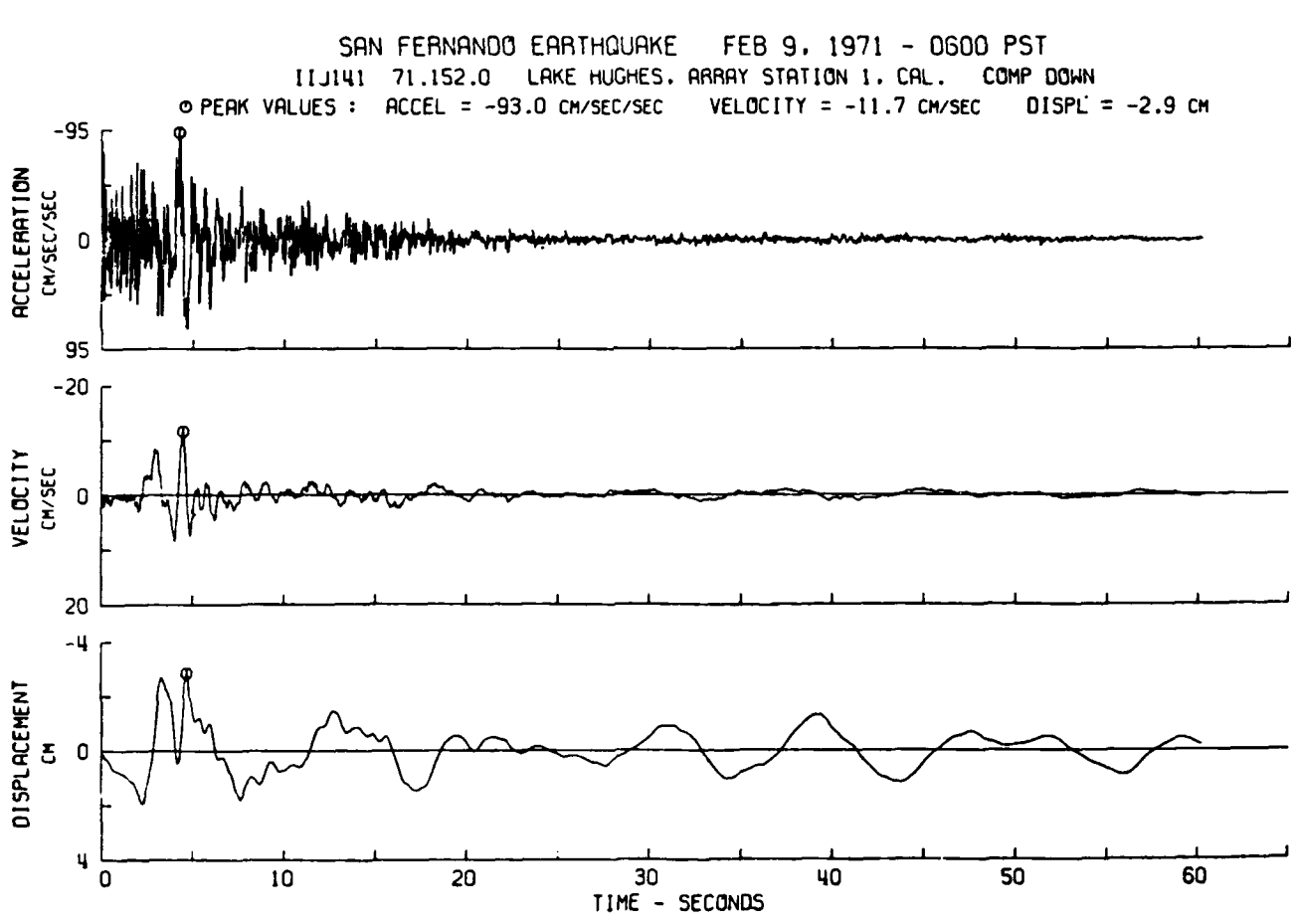
C.I.T. EERL 74-52, p.16



RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

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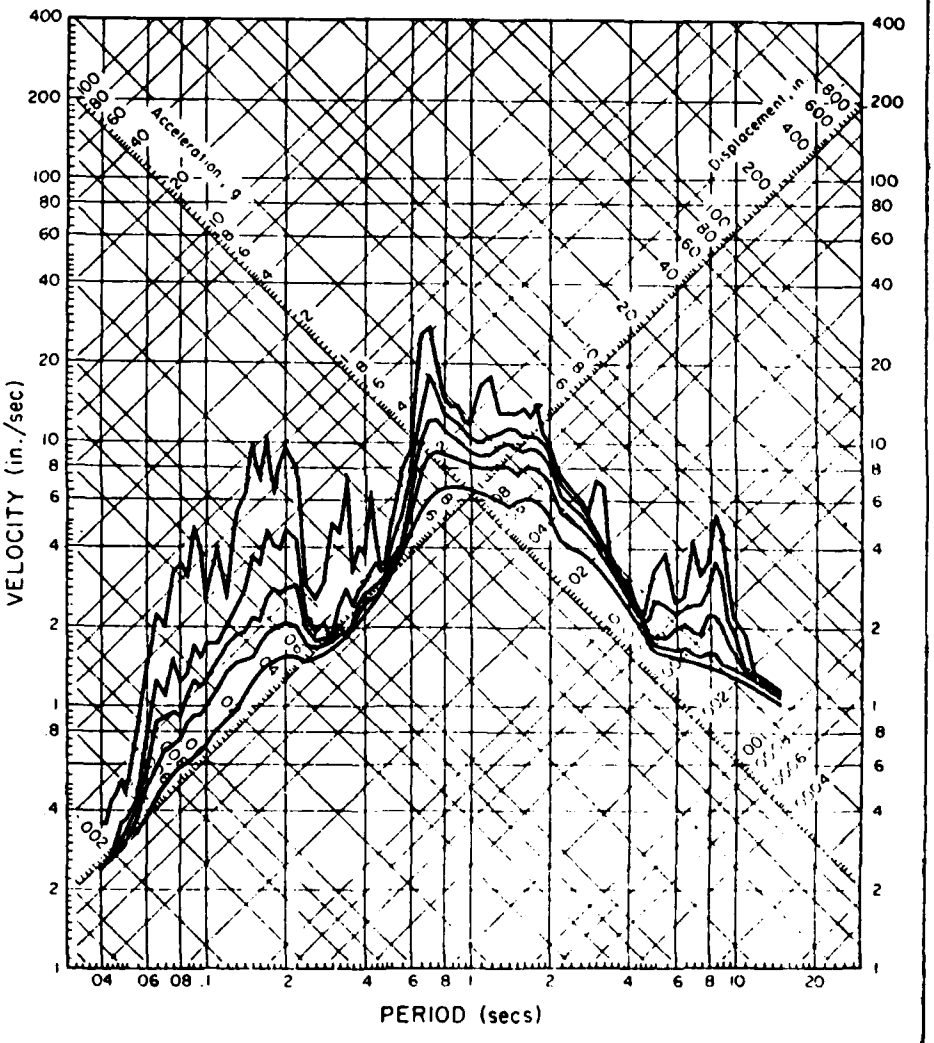

C.I.T. EERL 74-82, p.25

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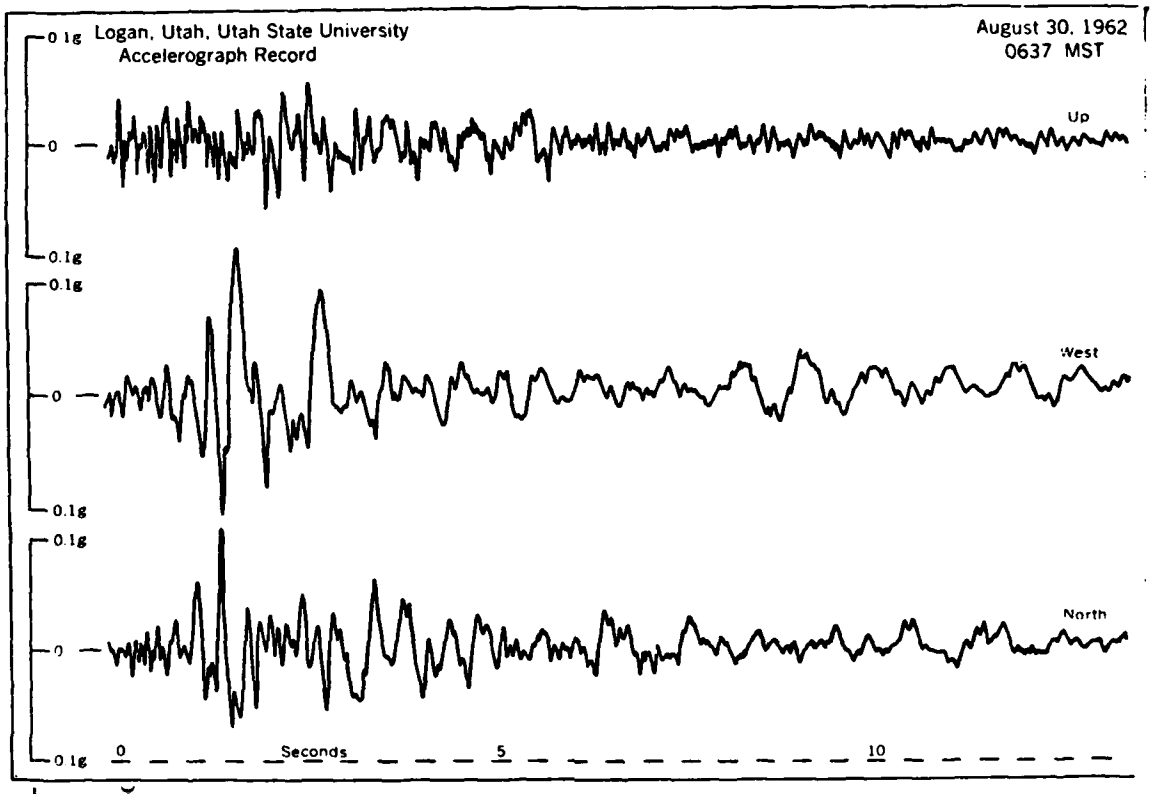

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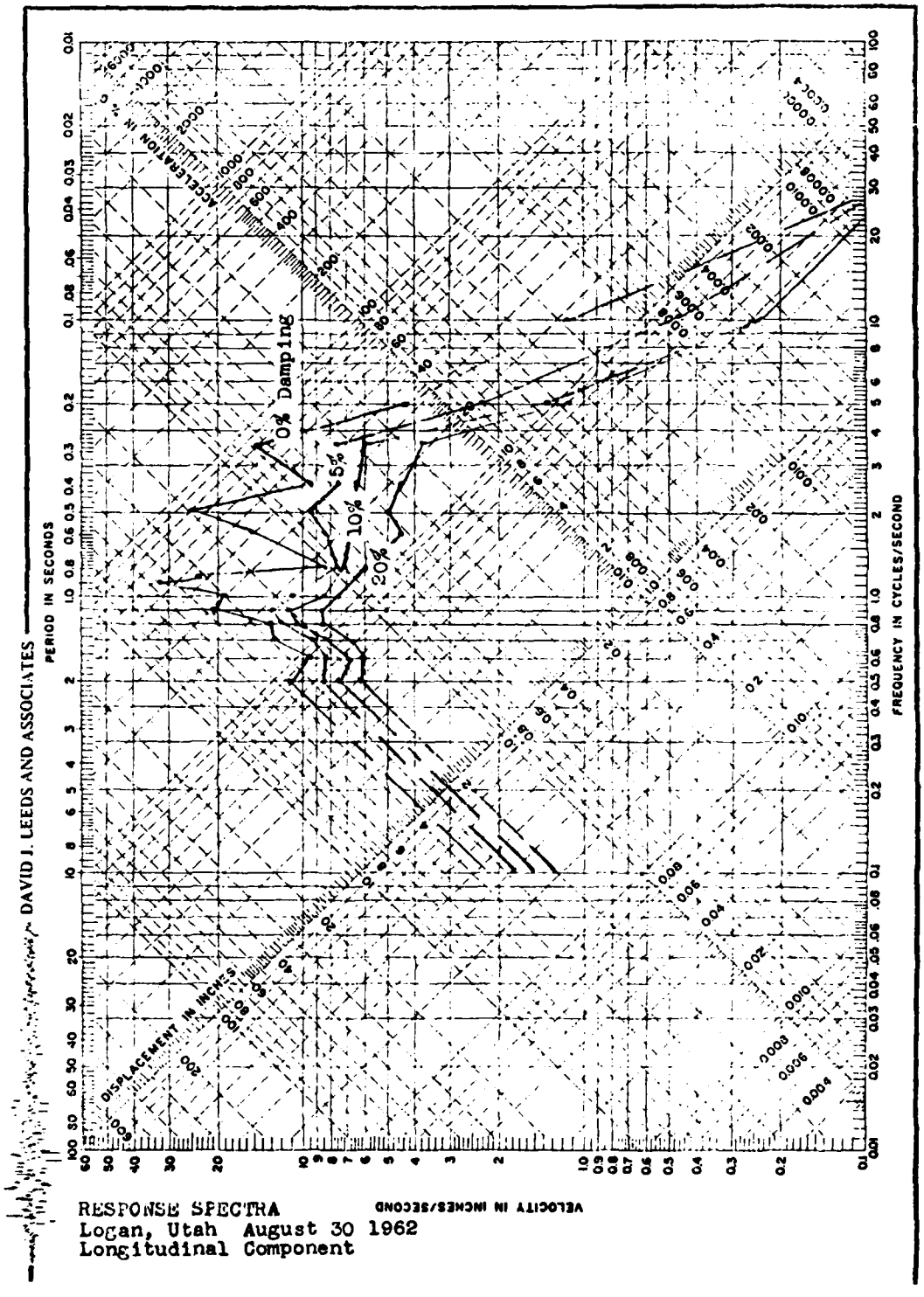
Station and component	Instrument No.	T_0	V	Sensitivity		Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
		sec.		cm/g		sec.	cm/sec.²	sec.	cm	
Logan: Vertical	319	0.0788	125	19.4	9	0.15	41		0.023	0.07 and 0.09 period waves present
West	320	.0798	125	19.9	13	.30	117		.37	Irregular train of 0.8 sec. waves present.
North	321	.0793	125	19.7	9	.19	84		.077	

Epicenter	Recording Station and Distance	Location of Instrument	Intensity†	Acceleration	Displacement*
				cm/sec.²	cm.
41.8°N., 112.0° W., northern Utah, VII°. Mag. 5.7.	Logan, 46 miles	Basement	VII	113	0.37

Utah Earthquake August 30, 1962

Ref: US Earthquakes 1962



RESPONSE SPECTRA
Logan, Utah August 30 1962
Longitudinal Component

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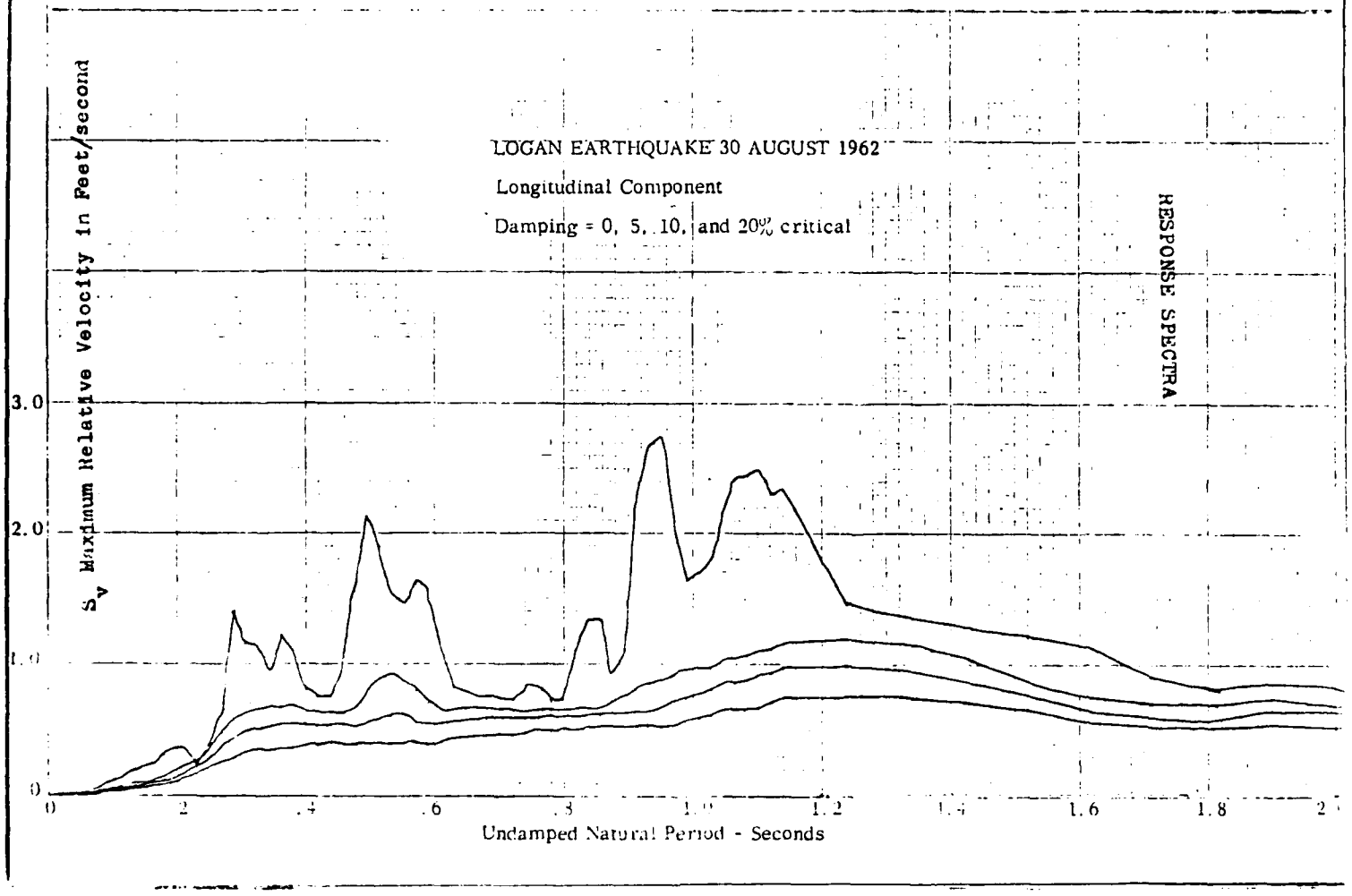

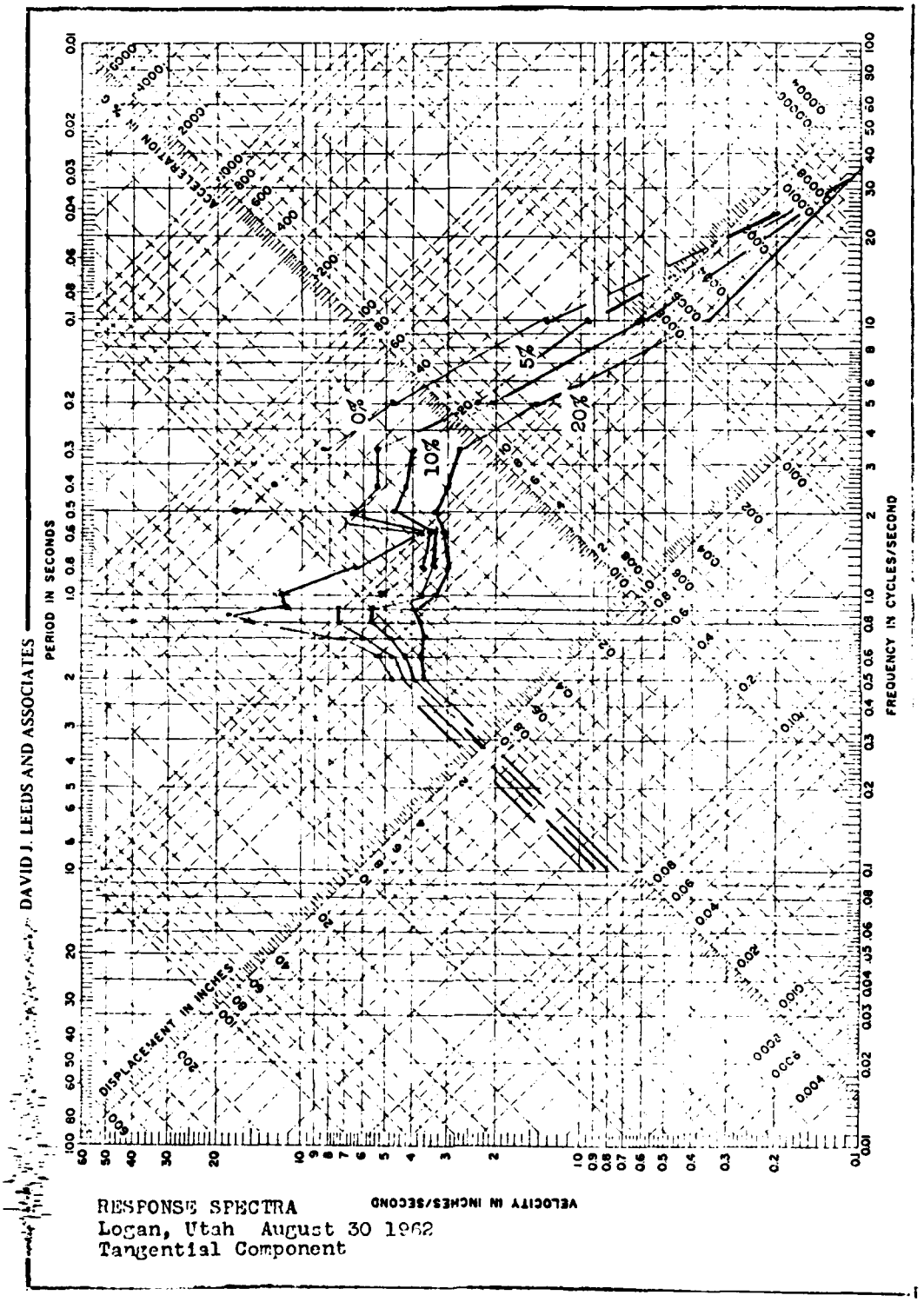

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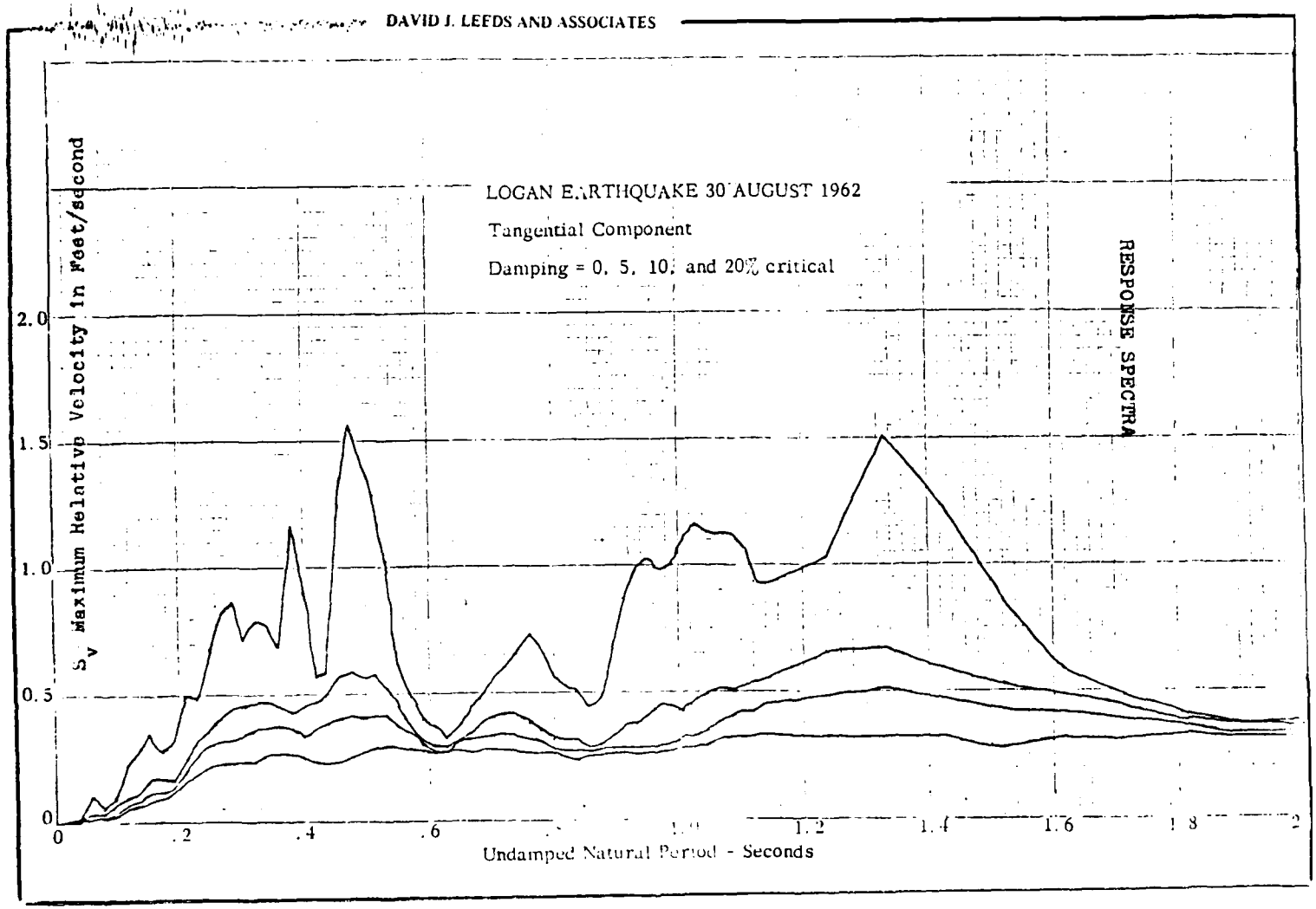

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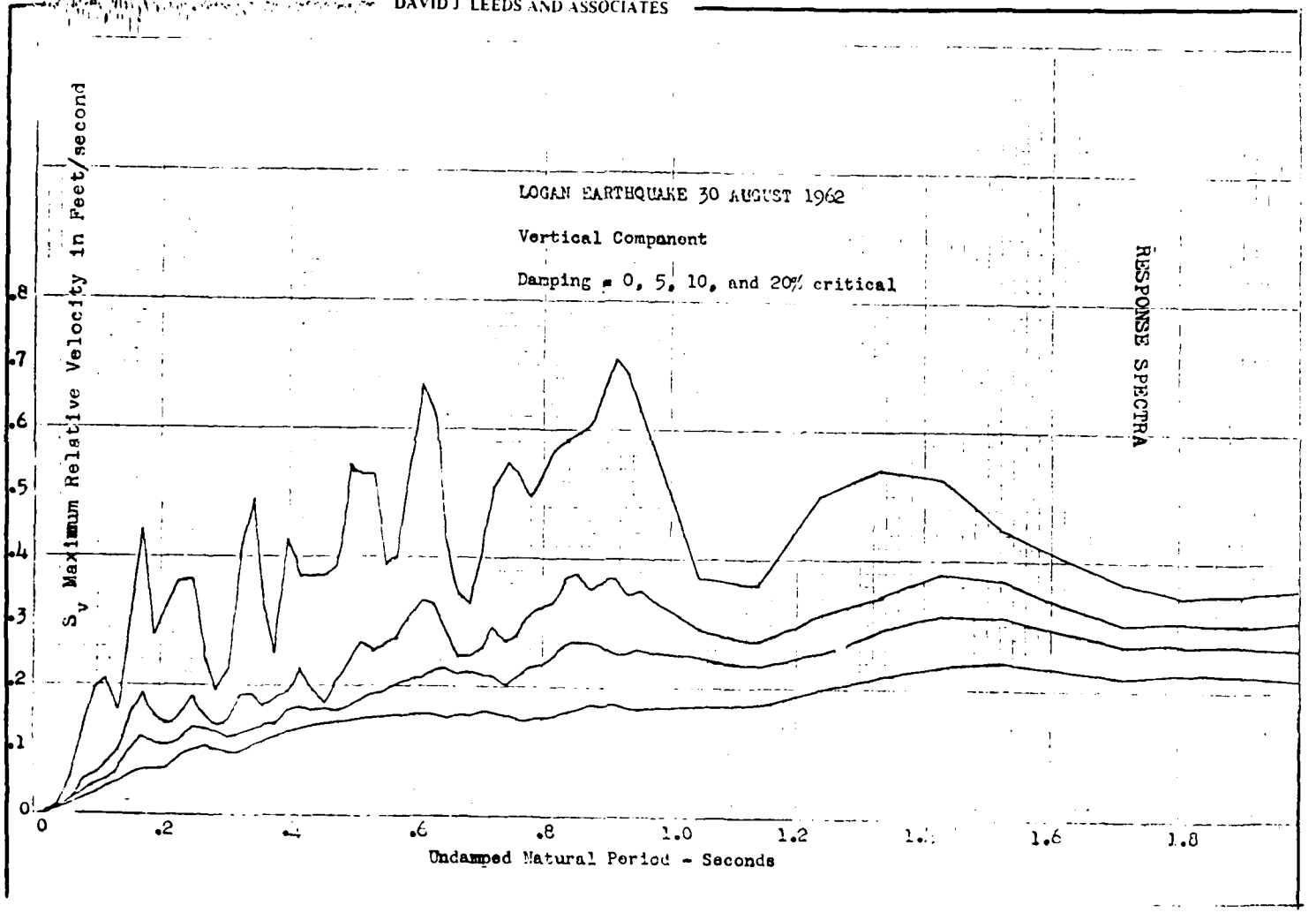


APPENDIX C

EARTHQUAKE MOTIONS FOR THE BARKLEY DAMSITE BASED ON THE WABASH VALLEY ZONE (ZONE IV)

by

Dr. Otto W. Nuttli
St. Louis University
St. Louis, Missouri

OTTO W. NUTTLI
PROFESSOR OF GEOPHYSICS
P.O. BOX 8099, LACLEDE STA.
ST. LOUIS, MISSOURI 63156

(314) ~~XXXXXXX~~ 658-3124

July 19, 1978

Dr. E. L. Krinitzsky
Waterways Experiment Station, CE
P.O. Box 631
Vicksburg, MS 39180

Dear Dr. Krinitzsky:

I am writing with regard to the maximum hard-rock motion expected at the Alben Barkley dam site in Kentucky from an earthquake in the Wabash valley seismic zone of southeastern Illinois and southwestern Indiana.

The Wabash valley zone in historic times has experienced five earthquakes with body-wave magnitude (m_b) greater than or equal to 5.0. They are the events of April 29, 1899 (m_b = 5.0, I_o = VI-VII), September 27, 1909 (m_b = 5.3, I_o = VII), November 26, 1922 (m_b = 5.0, I_o = VI-VII), April 26, 1925 (m_b = 5.0, I_o = VI-VII) and November 9, 1968 (m_b = 5.5, I_o = VII). A conservative estimate of the maximum-magnitude earthquake to be expected for the Wabash valley seismic zone is one with m_b = 6.5, I_o = IX, with the depth no greater than 25 km.

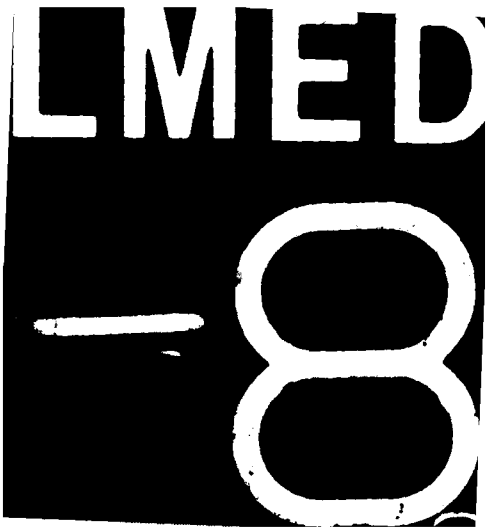
There is some disagreement among geologists and seismologists as to whether or not the Wabash valley seismic zone is continuous with the New Madrid seismic zone. It is my opinion that they are distinct zones, with the Wabash valley zone having its southern terminus near Shawneetown, Illinois, approximately 40 miles or 65 kilometers from the Alben Barkley dam site. This would be the closest distance from the maximum-magnitude earthquake to the dam. According to the table on page 14 of Krinitzsky and Chang (Specifying Peak Motions for Design Earthquakes, Report 7, State of the Art for Assessing Earthquake Hazards in the United States, Misc. Paper S-73-1, Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, December 1977), the motion at the dam site would be of the far-field type.

From Figure 3 of the report by Krinitzsky and Chang (op. cit.), an epicentral intensity of IX would be attenuated to an intensity of VIII at 65 kilometers distance. Thus the site intensity at the Alben Barkley dam is taken to be VIII. The same result is obtained if one uses the curve of Gupta and Nuttli (Figure 1, Spatial Attenuation of Intensities for Central U. S. Earthquakes, Bull. Seismological Society of Amer., vol. 66, 743-751, 1976). From Figures 7, 9, 11 and 14 of the report by Krinitzsky and Chang, the hard-rock site acceleration, velocity, displacement and bracketed duration would be 0.23g, 32 cm/sec, 18 cm and 10 sec, respectively. The above numbers are arrived at by the conservative estimate that they are 70% of the observed maximum ground motion data associated with intensity VIII ground shaking.

Sincerely yours,

Otto W. Nuttli

Otto W. Nuttli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