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2-E SEISMOLOGY

APPENDIX 2E

SEISMOLOGY

2.E.3.2 DESCRIPTIONS OF LESSER EARTHQUAKES PROBABLY FELT AT THE SITE

<u>1843, January 4</u>; severe in Memphis, Tennessee, where walls were cracked and chimneys fell. "Generally felt throughout Arkansas with three shocks reported at Van Buren" (60 miles west of London) but "not confirmed." (See Reference 2, page 2E-5)

<u>1867, April 24</u>; Lawrence, Kansas, where objects were thrown from shelves and plaster was cracked. Walls were cracked in Manhattan, Kansas, "felt in Arkansas, Illinois, Indiana, Missouri, Nebraska and Kentucky." (See Reference 2, page 2E-5)

<u>1878, November 18</u>; felt in Little Rock, Arkansas (and Cairo, Illinois, Memphis, Tennessee), severe along the Missouri River. (Reference 2)

<u>1882, October 22</u>; At Sherman, Texas, bricks were thrown from chimneys, and objects were overturned. Houses were shaken at Fort Smith, Arkansas, 50 miles west of the site. (Reference 2)

<u>1883, December 5</u>; Slides in railway cut at Melbourne, about 90 miles northeast of site. (Reference 2)

<u>1895, October 31</u>; Heaviest near Charleston, Missouri, where land sank. At Cairo, Illinois, chimneys were demolished. Felt from Canada to Mississippi and from Georgia to Kansas. (Reference 2)

<u>1903, November 4</u>; "St. Louis. Felt in southern Illinois, Kentucky, Mississippi, Arkansas, Missouri, and Tennessee with intensity of VI to VII." (Reference 2)

<u>1917, April 9</u>; Epicentral region between St. Louis and New Madrid, Missouri, where windows were broken and plaster cracked. Felt in Kansas to Ohio and from Wisconsin to Mississippi. (Reference 2)

<u>1918, October 4</u>; Center 20 to 30 miles southeast of Little Rock. Felt in Blackrock, 120 miles northeast of Little Rock, and in Memphis, Tennessee. (Reference 2)

<u>1923, October 28</u>; "Marked Tree, Arkansas. Felt in Arkansas, Kentucky, Illinois, Missouri, Tennessee. Windows shattered, several old chimneys were razed and wall cracked (presumably in Marked Tree)." Marked Tree is about 150 miles east of the site. (Reference 2)

<u>1938, September 17</u>; Epicenter about 32 miles southwest of Jonesboro (which is about 100 miles east of the site). IV at epicenter. Probably I at the site. (Paper by E. J. Walter, References 2, 3 and 4)

<u>1952, April 9</u>; Center near El Reno, Oklahoma, where chimneys fell and walls were cracked. Felt in western Arkansas (I-III) at Clarkesville and Dardanelle (within 20 miles of site). (Reference 3)

0292

1962, July 23; Plaster cracked in Dyersberg, Tennessee. Site area just on edge of felt area according to map but not reported felt by towns near the site area which lies at the limit of perceptibility. (Reference 3)

1965, August 15; Centered in east central Missouri, IV at St. Louis. Not reported felt in towns near site area which lies at the limit of perceptibility. (Reference 3)

2.E.4 SEISMIC REGIONALIZATION AND PROBABILITY MAPS

Plate 2E2 is the "Seismic Regionalization Map of the United States" prepared by C. F. Richter which appears in the Bulletin of the Seismological Society of America, Volume 49, No. 2 (p. 31), April 1959. This map is a very general evaluation of probable maximum intensity, at the existing ground surface, which may be expected in any given area in the United States. The site area is located near the boundary between zones VIII and IX (on this map) and the maximum probable intensity for this area is rated as IX on the Modified Mercalli Scale. However, as pointed out above, this map relates primarily to the anticipated effect at the ground surface in areas of thick deposits of soft, unconsolidated foundation materials. In addition, this map has generally been criticized by some seismologists as being too conservative in areas of low seismic activity. The previous detailed evaluations of historic earthquakes, regional geology, and the results of the bedrock foundation exploration for the critical structures indicates this zone IX assignment should be significantly reduced.

Plate 2E3, the seismic probability map, was prepared as a guideline for building design by the United States Coast and Geodetic Survey. This map shows that the site is not in an area considered as hazardous as the zone IX Richter assignment would indicate. On this map the site is located in a zone of predicted "minor" damage. It is important to note also that the probability map clearly shows the "moderate/major" damage zone associated with the New Madrid epicentral area is confined to the Mississippi Valley area.

2.E.5 FOUNDATION VS SITE INTENSITY

The historical data indicates that Arkansas is not an area of earthquake centers; however, the effects of distant shocks should be considered, in particular those along the Mississippi River north and south of New Madrid. The New Madrid shock which occurred over 150 years ago therefore has been considered when evaluating the seismic design of sensitive structures at the site. In this evaluation, the site has several recognized and distinct advantages.

1. The sensitive structures will be founded on unweathered firm shale bedrock.

2. The site is about 220 miles from the New Madrid epicentral zone. According to a mathematical formula, relating distance to earthquake shock attenuation, developed by H. Kawasumi of the Earthquake Research Institute in Tokyo, a site intensity of about VI could be anticipated from a New Madrid area earthquake of intensity XII.

3. From Myron Fuller's report (Reference 1) it may be estimated that St. Louis, Missouri, experienced an intensity of VII during the New Madrid shock. St. Louis is about 60 miles closer to New Madrid than the site and is founded, in part, on thick alluvial deposits overlying shale and limestone bedrock.

4. The above discussion and the previous sections of this Appendix have demonstrated that a maximum probable intensity assignment of VII for this site is warranted.

2.E.6 STRONG MOTION ACCELEROGRAPH

One Strong Motion Accelerograph supplemented by three Peak-Recording Accelerometers will be installed. The Strong Motion Accelerograph will be mounted outside the containment but in an area which will be representative of ground accelerations on rock level at the plant site. One Peak Recording Accelerometer will be installed within the reactor building near to the top, another near or on the reactor and a third on the reactor building base slab.

Selection criteria for accelerograph and accelerometers include:

1. Simplicity of operation and maintenance.

2. Reliability and accuracy.

3. Wide range of sensitivity.

4. Economy.

5. Acceptability by the U. S. Coast and Geodetic Survey's Earthquake Research Center. 13

After reviewing several accelerograph specifications and discussing the equipment with personnel from the U.S.C. & G.S. Consultants, University of California, California Institute of Technology specialists and manufacturers, it has been concluded that Model RFT-250 Strong Motion Accelerograph and PRA-100 Peak Recording Accelerometers manufactured by Teledyne Corporation, Pasadena, California, are most appropriate.

The RFT-250 has been approved and used by the U.S.C. & G.S. for several years. The advantages of this new model include a wide film width (70 mm) that produce good resolution and a simple design that allows unskilled personnel to calibrate and maintain the equipment. Other favorable features include battery operation to eliminate the possibility of lost records due to a power failure during an earthquake, a film pack cartridge to enable changing in daylight, a trigger sensitivity to tilt or horizontal displacement, and rapid (0.1 second) operation when triggered.

The PRA-100 Peak-Recording Accelerographs detect and record peak amplitudes of low-frequency acceleration resulting from strong local earthquakes. This type of recorder can be installed within the containment building and a record can be kept on a small piece of magnetic tape without the danger of excessive background radiation destroying the trace as with photographic film. Here again, advantages include simplicity of operation and maintenance and positive recording ability. The PRA-100 is less than three inches square and requires no power. 13

Following an earthquake the resulting measurements will be evaluated by qualified seismology and engineering personnel. If the analysis indicates the shock may have caused stresses exceeding design limits to components or system, specific action will be taken as recommended by the evaluating personnel.

2.E.7 REFERENCES 13

1. Fuller, M. L. "The New Madrid Earthquake", U.S. Geological Survey, Bull. 494, pp. 115, 1912.

2. Epply, R. A. "Earthquake History of the United States" Part 1, U.S. Coast and Geodetic Survey Publ. No. 41-1, Washington, 1965.

3. "United States Earthquakes", Annual Publication of the U.S. Coast and Geodetic Survey.

4. Walter, E. J. "The Arkansas Earthquake of September 17, 1938", Bull. Seism. Scc. Amer., 29, 497-503, 1939.

2.E.8 CONSULTANT'S REPORT 13

On the following page.

Perry Byerly
6037 Contra Costa Road
Oakland, California 94618

Phone 654-6893

September 5, 1967

Mr. Cole R. McClure, Jr.
Bechtel Corporation
220 Bush Street
San Francisco, California 94104

Dear Mr. McClure:

I have reviewed the report section on seismology for the Russellville site submitted to me by Bechtel Corporation and agree with their conclusions.

A careful study of the seismic history of the area shows that the area is not one in which earthquakes have their centers, if you wish it is not an area of active faults. We face here the difficulty met for many parts of the central United States—that of a region which experienced one great shock a long time ago and only trivial shaking since that time.

Considering the conditions listed in the report: the firm bedrock (the McAlester shale), the distance from New Madrid, and the comparison to the probable intensity of VII at St. Louis, Missouri, the conclusions in the report are quite valid. I might add an additional advantage in the high seismic velocities of 11,000 fps to 14,500 fps of the foundation rock.

It seems reasonable to anticipate the effects on a Class 1 structure of an earthquake producing an intensity of between VI and VII at the site. This would correspond to a design spectrum of 0.1 g and a safe shut-down factor of 0.2 g.

Yours sincerely,

Perry Byerly

Perry Byerly

0296

GEORGE W. HOUSNER
1201 EAST CALIFORNIA BLVD.
PASADENA, CALIFORNIA 91109

3 November 1967

Bechtel Corporation
Power and Industrial Division
220 Bush Street
San Francisco, California 94119

Attn: D. W. Halligan

Subject: Arkansas Power and Light Company, Russelville Nuclear Unit, Preliminary Safety Report.

At your request, I have examined Sections 2, 5, Appendices 2E, 2D, 5A of the Preliminary Safety Report that you sent me under cover of your letter of October 6, 1967, giving particular attention to those parts dealing with earthquake criteria and design. In general, those parts dealing with the earthquake problem appear satisfactory to me. My particular comments are as follows:

1. I consider the use of a 10%g design spectrum (20%g no loss of function) to be appropriate for the site.

2. The damping values to be used in the seismic analysis are appropriate.

Yours truly,

GEORGE W. HOUSNER

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MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

1. Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel scale.)

2. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale.)

3. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)

4. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel scale.)

5. Felt by nearly everyone, many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale.)

6. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)

7. 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 motorcars. (VIII Rossi-Forel scale.)

8. 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. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel scale.)

9. 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. (IX+ Rossi-Forel scale.)

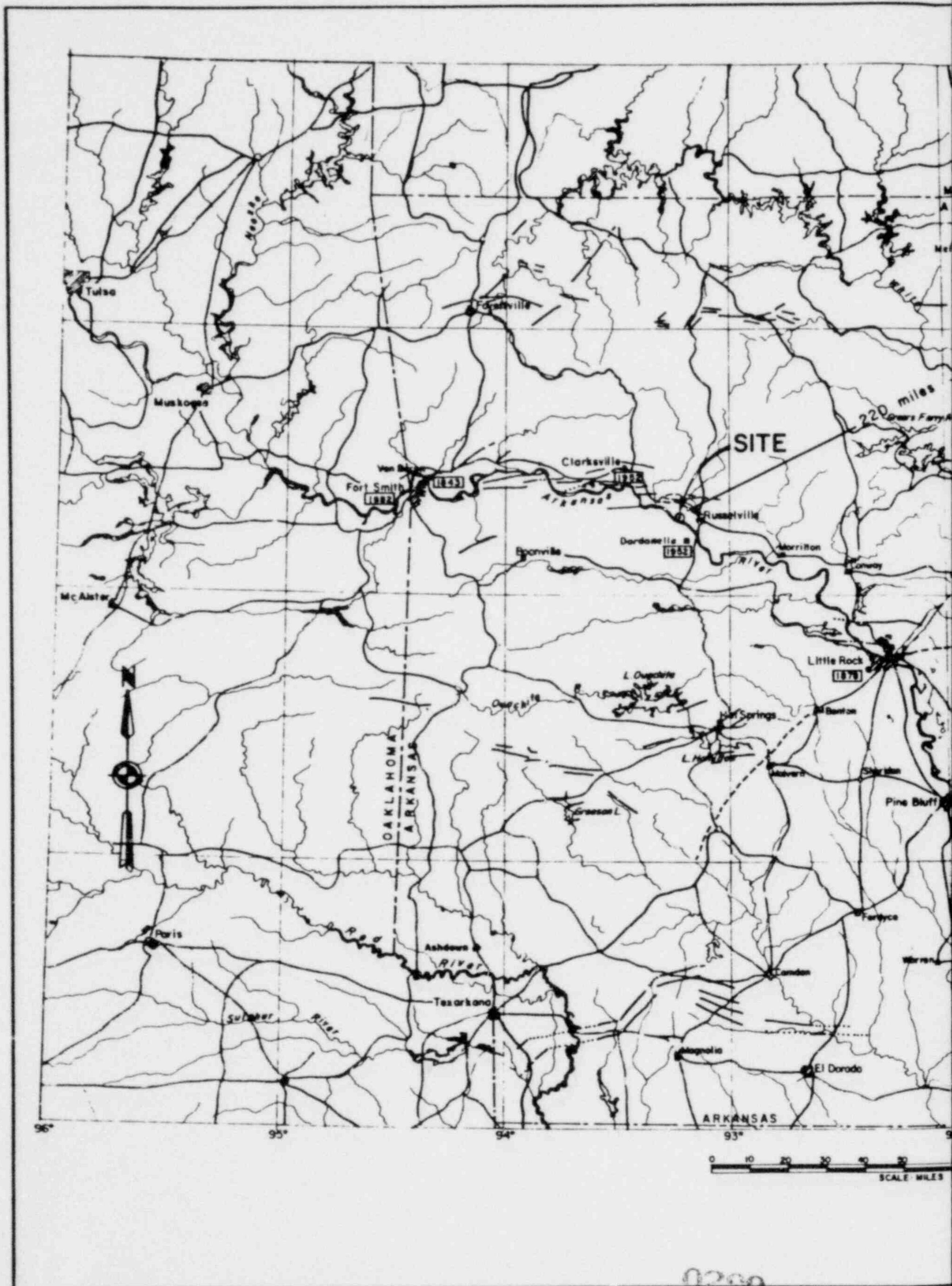
10. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel scale.)

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

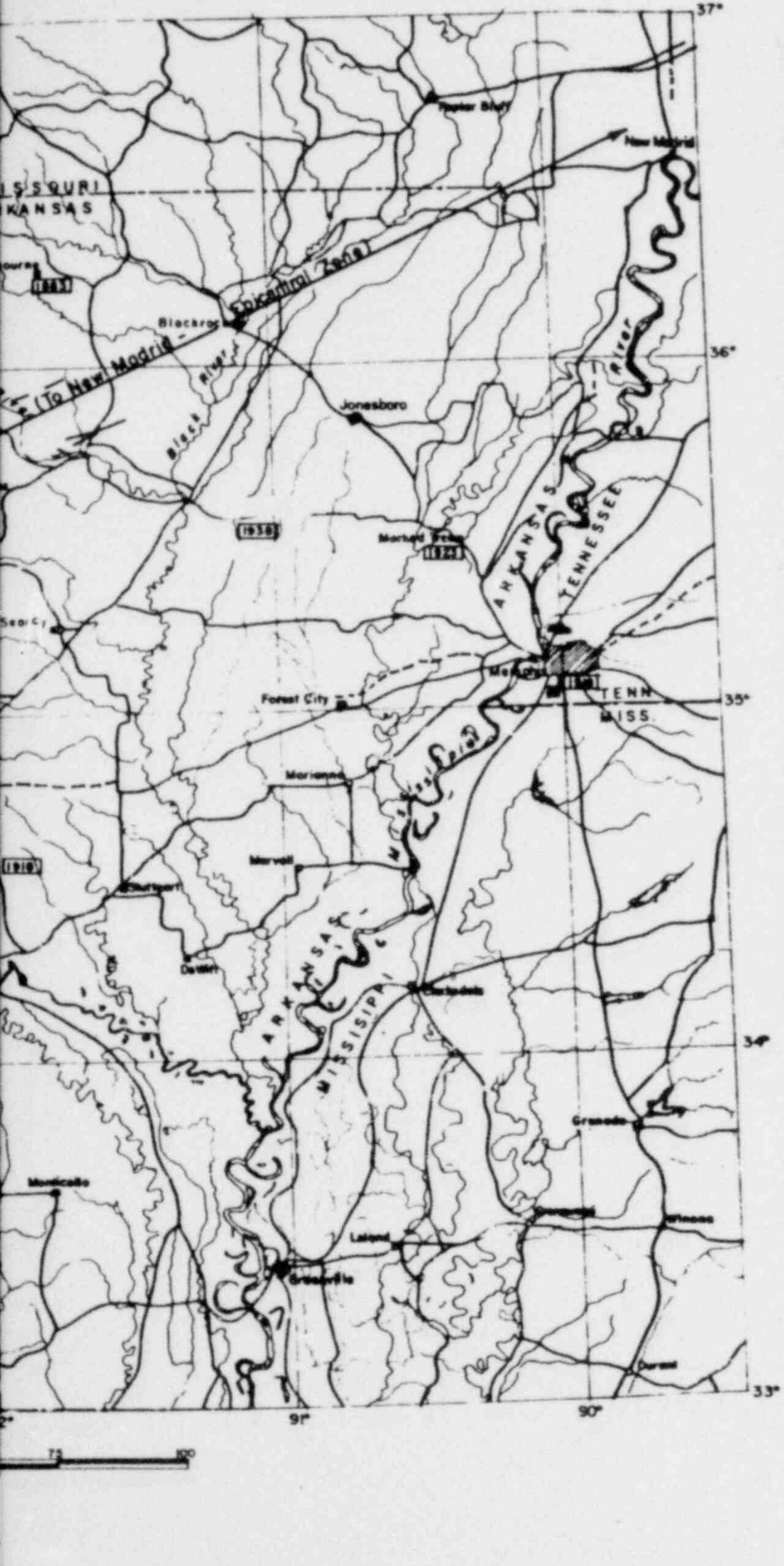
12. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

0298

"Modified Mercalli Intensity Scale of 1931", by Harry O. Wood and Frank Neumann, Bulletin of the Seismological Society of America, Vol. 12, No. 4, December 1931.



SITE
220 miles
Tulsa
Muskogee
Fayetteville
Fort Smith
Clarksville
Arkansas
River
Russellville
Dardanelle
Morrilton
Conway
Booneville
McAlester
Little Rock
L. Ouachita
Ouachita
Hot Springs
Benton
Malvern
Sheridan
Pine Bluff
OKLAHOMA
ARKANSAS
Paris
Red
River
Ashdown
Texarkana
Sulphur
River
Fordyce
Camden
Magnolia
El Dorado
ARKANSAS
96°
95°
94°
93°
SCALE: MILES



EARTHQUAKES FELT
1843 - 1952

1843	*"Generally felt throughout Arkansas with three shocks reported at Van Buren" but "not confirmed".*
1876	*Felt in Little Rock, Arkansas; severe along the Missouri River.*
1882	*At Sherman, Texas, bricks were thrown from chimneys, and objects were overturned. Houses were shaken at Fort Smith, Arkansas.*
1883	*Slides in railway cut at Melbourne, Arkansas, about 90 miles northeast of site.*
1918	*Center 20 to 30 miles southeast of Little Rock. Felt in Blackrock, 120 miles northeast of Little Rock, and in Memphis, Tennessee.*
1923	*"Marked Tree, Arkansas. Felt in Arkansas, Kentucky, Illinois, Missouri and Tennessee. Windows shattered, several old chimneys were razed and a wall cracked, (presumably in Marked Tree)."*
1938	*Epicenter about 32 miles southwest of Jonesboro, IV at epicenter. Probably I at site, (refer to text).*
1952	*Center near El Reno, Oaklahoma, where chimneys fell and walls were cracked. Felt in western Arkansas, I-III at Clarksville and Dardanelle.*

Major Fault, dashed where inferred, dotted where concealed.

NOTE:
Additional earthquakes without specific reference to Arkansas are listed in the text.

REFERENCES:

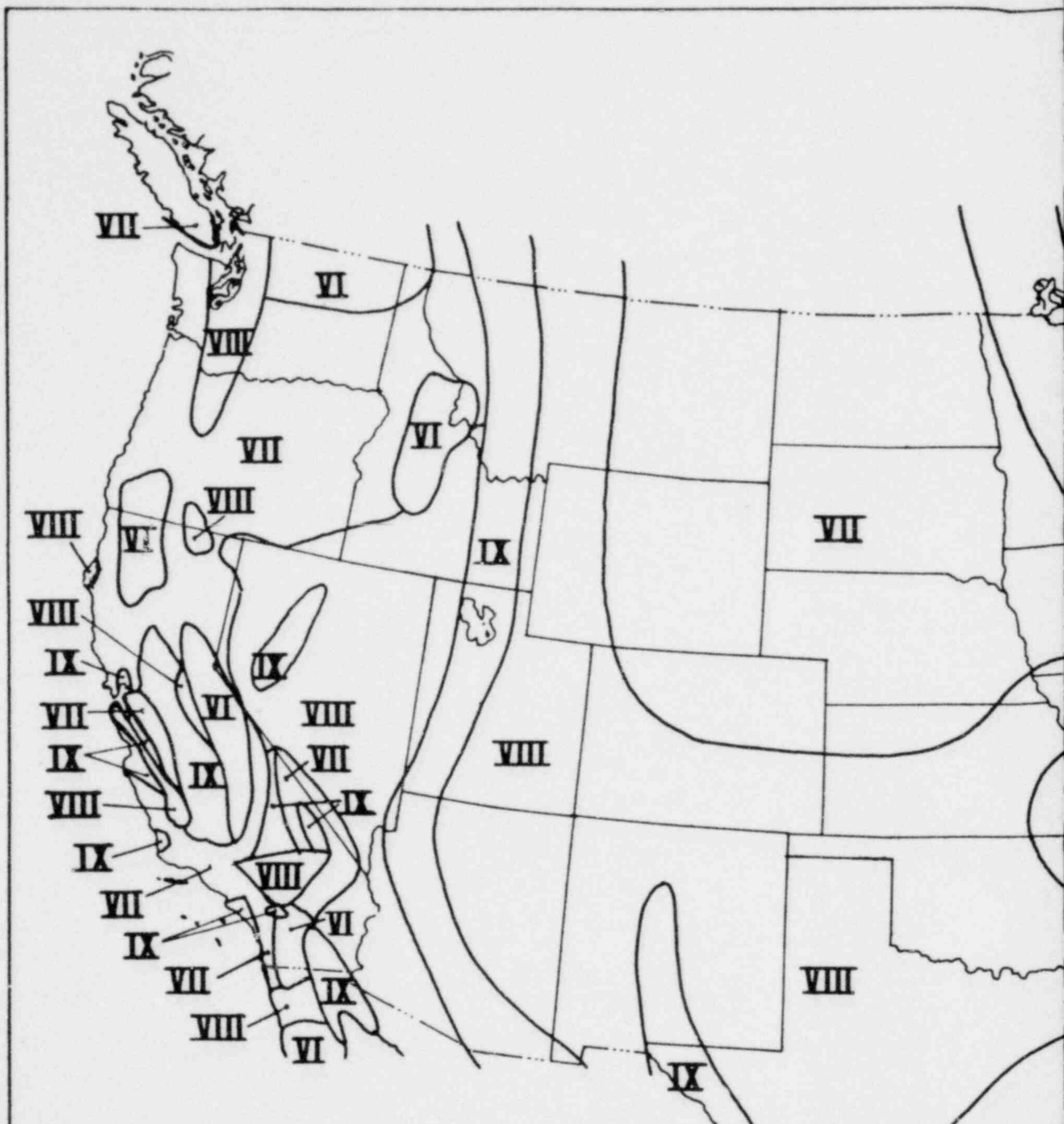
(1) Geologic Map of Arkansas.
(2) Geologic Map of Russellville West Quadrangle, Arkansas, USGS & Arkansas Geological Commission, 1967.
(3) Map of Hartshorne Coal Bed, Keplinger & Wanenmacher, Petroleum Engineers, Tulsa, Oklahoma.

ARKANSAS POWER & LIGHT CO.

EARTHQUAKE HISTORY
1843 - 1952

JOB NO.	DRAWING NO.	REV.
6600	PLATE 2E1	

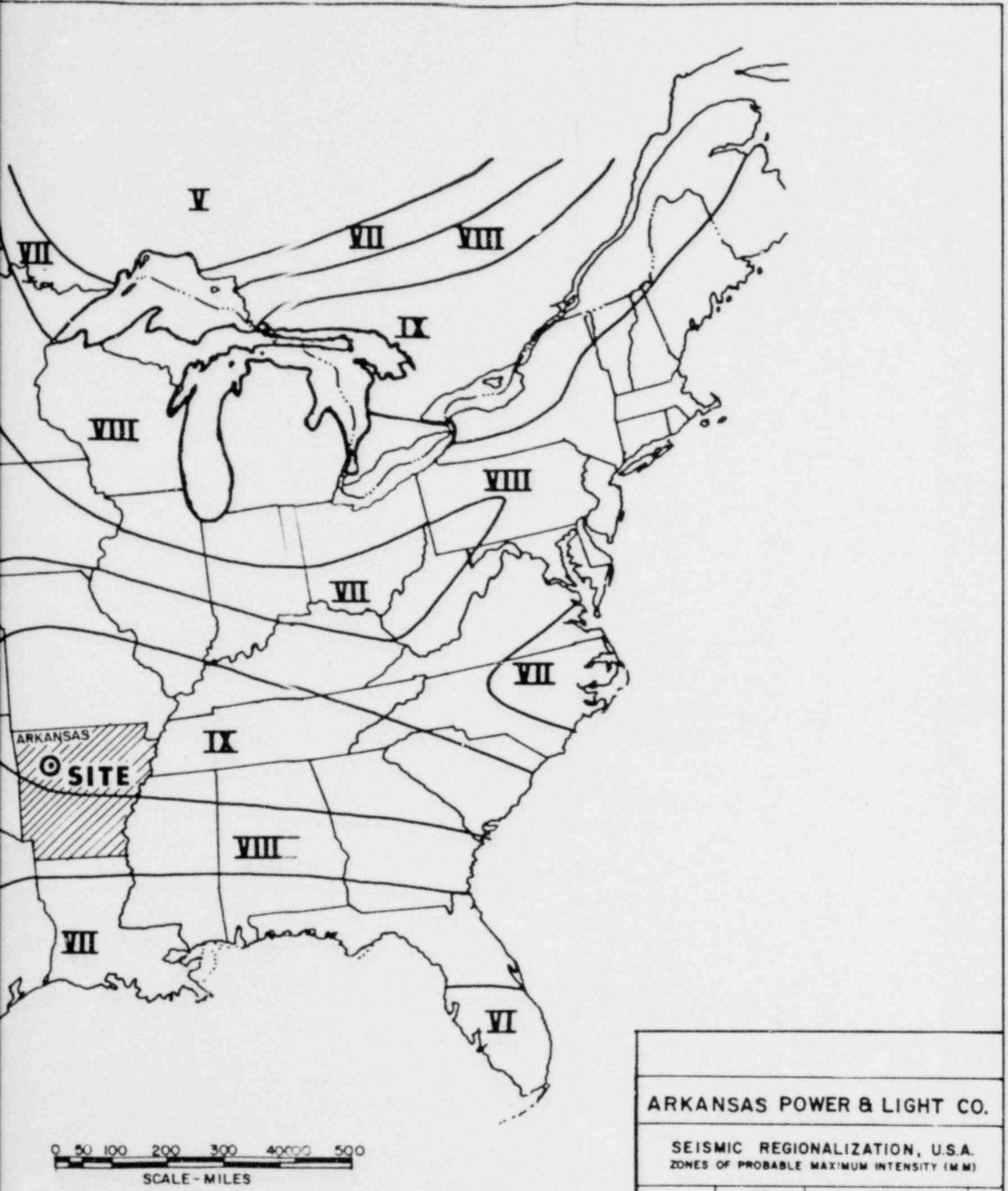
0300



NOTE: THIS IS A SMALL SCALE GENERALIZED MAP. MAXIMUM INTENSITY LEVEL MAY BE LOCALLY HIGHER OR LOWER THAN IS SHOWN. RISK DEPENDS ON FREQUENCY OF OCCURRENCE AS WELL AS MAXIMUM EXPECTED INTENSITY.

AFTER C. F. RICHTER, BULLETIN SEISMOLOGICAL SOCIETY OF AMERICA, VOL. 49, APRIL 1959.

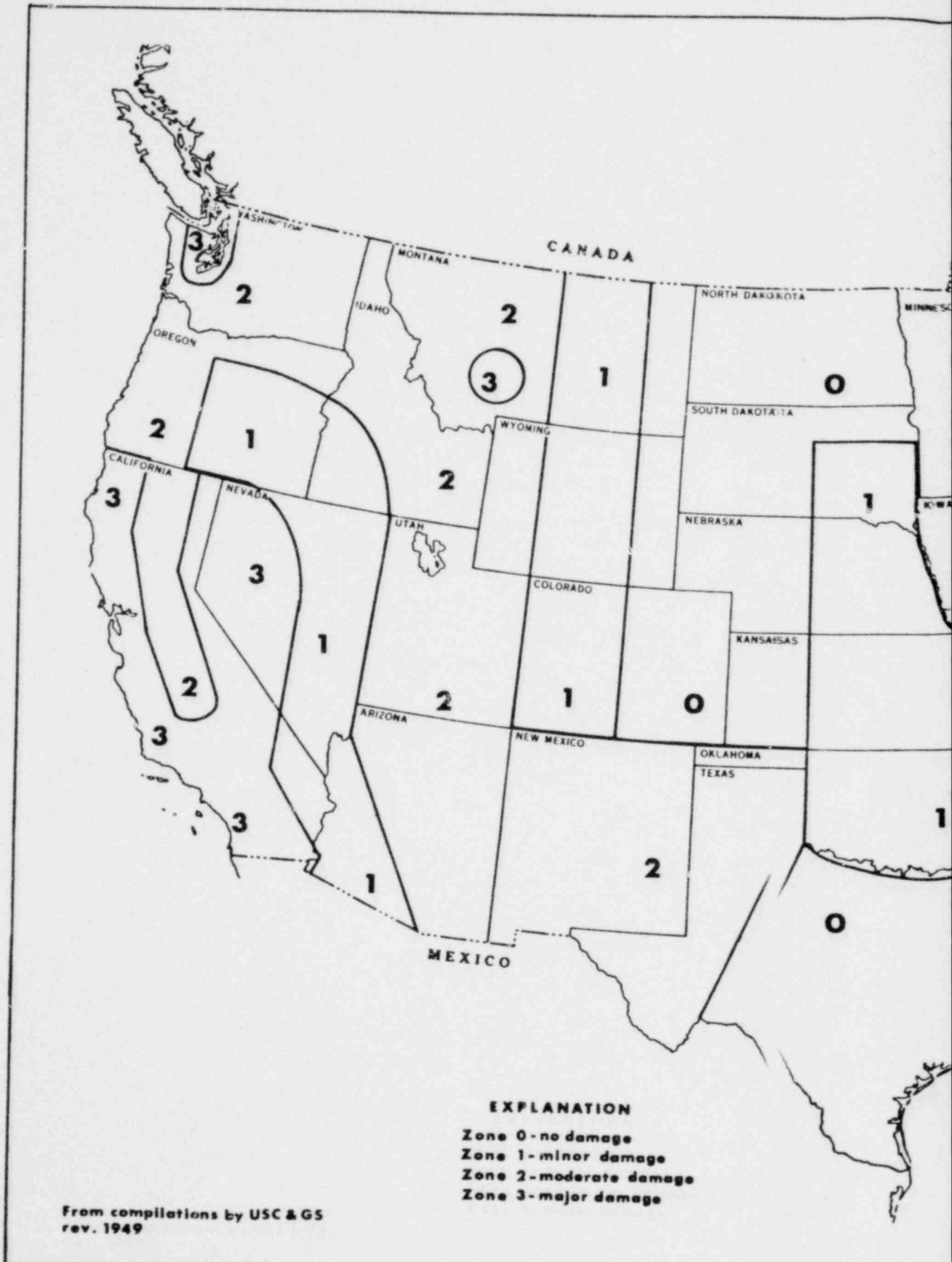
[redacted]



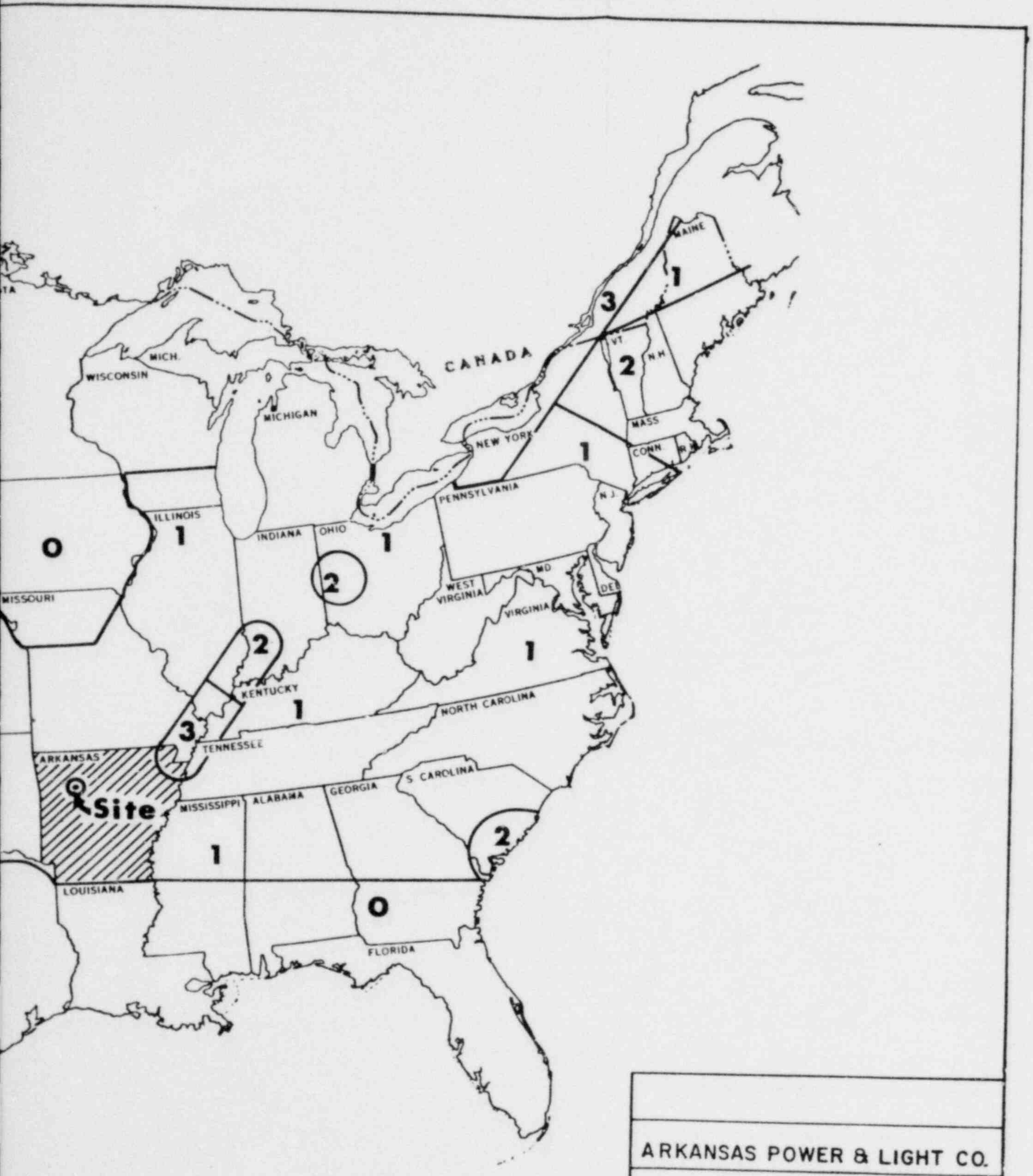
ARKANSAS POWER & LIGHT CO.

SEISMIC REGIONALIZATION, U.S.A.
ZONES OF PROBABLE MAXIMUM INTENSITY (M.M)

6600	PLATE 2E2


CANADA
MONTANA
IDAHO
OREGON
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
EXPLANATION
Zone 0 - no damage
Zone 1 - minor damage
Zone 2 - moderate damage
Zone 3 - major damage
From compilations by USC & GS
rev. 1949

0303



ARKANSAS POWER & LIGHT CO.

SEISMIC PROBABILITY MAP, U.S.A.

6600	PLATE 2E3