A new seismic risk map of the United States is presented, along with strain release and maximum Modified Mercalli intesity maps of the country. Frequency of occurrence of damaging earthquakes was not considered in zone ratings, but included frequency studies may aid interpretation. Discussion of methods is included with review of calculations. (MH)

Presented at the Fourth World Conference on
Earthquake Engineering, Santiago, Chile

January 14, 1969 /

This preprint of the paper "Seismic Risk Studies
in the United States," by S. T. Algermissen is
being made available in limited quantity be-
cause of the unusually high number of requests
for it following its presentation at the Fourth
World Conference on Earthquake Engineering on
January 14, at Santiago, Chile. The paper,
with appropriate revisions, will be printed as
a part of the Proceedings of the Fourth World
Conference on Earthquake Engineering. This
preprint is tentative and subject to revision
before its final publication.

SEISMIC RISK STUDIES IN THE UNITED STATES

S. T. Algermissen[1]

Synopsis

A new Seismic Risk Map of the United States is presented,
together with strain release and maximum Modified Mercalli
intensity maps of the country. Frequency of occurrence of
damaging earthquakes was not considered in assigning ratings to
the various zones on the.risk map, but studies of earthquake
frequency are included as an aid in using the risk map. The
Seismic Risk Map is suggested as a revision of the Seismic
Probability Map prepared by the Coast and Geodetic Survey in
1947 and withdrawn in 1952.

Introduction

The zoning of the United States for seismic risk has not
received the attention in the earthquake engineering literature
that the subject has enjoyed in other parts of the world, notably
in countries such as Japan, the. U.S.S.R. and New Zealand. Risk
studies in the United States have been limited by the relatively
short historical record of seismicity available for the country
as compared with such countries as Japan, the difficulty in
correlating known seismicity with geological evidence of tectonic
activity in many areas and the general scarcity of pertinent
geodetic data that might bear on the problem.

Materials Used

The historical record of earthquakes in the conterminous
United States consists of data on approximately 28,000 shocks.
Within the past two years the Coast and Geodetic Survey has
catalogued all of the pertinent seismicity information on
punched cards and magnetic tape. All earthquakes have been
assigned a reference number and origin times and hypocenters
have been recorded if available from instrumental data. Hypocenters

---

[1] Chief, Geophysics Research Group, Coast and Geodetic Survey, ESSA,
U. S. Department of Commerce, Rockville, Maryland, U. S. A.

are estimated from accounts of the shock and isoseismal data
if no instrumental data are available. Magnitudes and reported
intensities are also keypunched into each card. Sources of the
information, availability of strong motion records, and other
related data are also catalogued. A more complete description
of the format of the data stored on punched cards and magnetic
tape has been given by Algermissen (1). It is possible to
prepare quite a number of different statistical presentations
and maps of the various parameters of seismicity using the
basic data retained on magnetic tape and punched cards. Two
types of maps were prepared which, it is believed, are particu-
larly useful in estimating seismic risk. These two maps show
the distribution of maximum Modified Mercalli (M.M.) intensities
and strain release in the United States.

Maximum Modified Mercalli Intensity

The maximum M.M. intensities reported throughout the United
States from the first recorded earthquake in 1534 through 1965
are shown in Figure 1. Isoseismal maps were prepared for sig-
nificant earthquakes not previously mapped by using whatever
data were available. Figure 1 shows clearly that high M.M.
intensities have been reported throughout a large portion of the
country, even though the frequency of occurrence of high inten-
sities in many areas may be quite low.

Strain Release

The cumulative strain release resulting from earthquakes
in the time span 1900-1965 is plotted in Figure 2. Using the
concept developed by Benioff (2), the strain release of an
earthquake is taken to be proportional to the square root of
its energy release. The energy, E, was related to earthquake
magnitude, M, using the formula $\log E = 11.8 + 1.5 M$ (3). The
magnitudes of earthquakes below six are known only for shocks
occurring during approximately the past five years. Earthquakes
whose magnitudes are six and above are known from about 1900.
When magnitude values were not available, they were estimated
from maximum M.M. intensity using the relation $M = 1 + 2/3 I$,
where 1 is M.M. intensity (4). The above empirical relationship
between magnitude and intensity is only an approximation and
possibly subject to considerable error. The error, however, is
not large in this calculation of strain release since it was
necessary to use this conversion from maximum intensity to magnitude
only for small shocks for which the strain release is small. The
entire United States was divided into squares of 10,000 square
kilometers and the strain release associated with earthquakes within
each square was summed. The strain was represented as the equivalent

-2-

number of magnitude four earthquakes in each block. The
equivalent number of magnitude four earthquakes is then obtained
by dividing the sum of the strain release associated with earth-
quakes in a particular block by the strain release associated
with a magnitude four earthquake.

The strain release map is useful in that it shows the
current relative rate of tectonic activity in various parts
of the United States. Areas of the country with a continuing,
but a low level of seismic activity are revealed. These areas
do not normally show up on a maximum intensity map. The exact
shape and pattern of the areas shown in Figure 2 are not signifi-
cant since the size of the block over which the strain energy is
summed is somewhat arbitrary. A comparison of the relative strain
release throughout the United States is, however, interesting and
informative, as it is an index of current tectonic activity.
Inspection of Figure 2 shows that the United States may be divided
roughly into four areas that have different rates of strain release
during the 66 year period considered. The four areas are:

Pacific West	- west of 114° W. longitude
Rocky Mountains	- 106° - 114° W. longitude
Central Plains	- 92° - 106° W. longitude
Eastern U. S.	- east of 92° W. longitude

Dividing the total equivalent number of magnitude four earth-
quakes in each area by the total area we obtain the following
rates:

Area	No. of Equivalent Magnitude 4 earthquakes/1000 km^2/66 years
Pacific West	12
Rocky Mountains	2.0
Central Plains	.14
Eastern U. S.	.74

Another calculation of the relative strain release in the four
areas was made considering only those portions of each area in
which more than 0.25 equivalent magnitude four earthquakes
occurred. The strain release per unit area was computed
considering only the shaded portions of figure 2. The results are:

Area	No. of Equivalent Magnitude 4 earthquakes/1000 km^2/66 years
Pacific West	13
Rocky Mountains	2.6
Central Plains	.38
Eastern U. S.	1.1

Using the first set of data on the preceding page, the strain release during the past 66 years in the Pacific West has been approximately six times greater than in the Rocky Mountain area, 86 times greater than in the Central Plains and 16 times greater than in the Eastern United States. Using the second set of data on the preceding page, the strain release in the Pacific West has been, respectively, five, 34 and 12 times greater than the other areas.

Earthquake Frequency

The difficulties encountered in any analysis of the recurrence rates of damaging earthquakes are very great. It has been stated repeatedly in the literature that the historical record of seismicity in the United States is inadequate to estimate recurrence rates. It is believed, however, that the historical record of seismicity in the United States does provide some guidelines to the relative seismicity of various areas of the country.

One approach to the problem to determining the relative seismicity of various regions is to plot earthquake magnitude versus frequency of occurrence for the areas considered. The magnitudes of earthquakes are known for shocks of magnitude six and greater since about 1900 but for small shocks the records are far less complete. In contrast, M.M. intensities have been assigned by the Coast and Geodetic Survey and other investigators to nearly all significant earthquakes known to have occurred within the United States. In order to make use of the complete historical earthquake record, maximum M.M. intensity was plotted versus earthquake frequency. A number of assumptions are necessary when the maximum intensity is used in a study of earthquake frequency. The principal assumptions are that all of the earthquakes in the area considered occurred at approximately the same focal depth and that the maximum intensity for each earthquake has been, in fact, reported. Earthquakes in the United States are nearly all of normal focal depth, although California and Nevada shocks are somewhat shallower (averaging about 10-15 km) than in the remainder of the country (about 30-60 km). It is possible to select geographic areas for study such that the earthquakes within each area are of approximately the same depth. The adequacy of earthquake reporting is also a significant variable and this point will be discussed in greater detail.

In 1860, all states in the western portion of the country, with the exception of California, had an average population density of less than one person per square mile. All states had population densities greater than one per square mile by 1910 with the exception of Nevada. It is clear that the low population density in the western United States prior to 1900 adversely affects the completeness of intensity data in that area, particularly for intensities less than VI or VII.

Reasonably complete records of great earthquakes will
obviously be available for a longer span of years than for
earthquakes of small or moderate maximum intensity. Accord-
ingly, the intensity data were examined and an estimate was made
of the total span of years for which maximum intensity data at
each level of the intensity scale are nearly complete. To
illustrate the technique further, Figure 3 shows the number of
maximum intensity VI earthquakes reported for a north-south
trending zone of seismicity through western Montana, eastern
Idaho, central Utah and Arizona (region 4 of Figure 5). The
data seem relatively complete from 1900 to present. To obtain
the frequency of intensity VI earthquakes in this particular
zone, the number of intensity VI shocks was simply divided by the
time span, 1900-1967, or 68 years. Similarly, for all areas
considered, the average number of earthquakes at each intensity
level was determined and plotted against intensity.

The recurrence relationship for all intensity data in the
United States is shown in Figure 4. It was assumed, in plotting
the data, that a relationshup of the form log N (per year) $= a + b\,I$
exists, where N is the number of earthquakes of intensity 1.
Two conclusions can be drawn for this plot: 1. maximum in-
tensities of V and below in general have not been completely
reported for United States earthquakes and 2. the occurrence
of great earthquakes (M.M. intensity XI and XII) is erratic
over the time span considered. The recurrence curve for all
United States earthquakes obviously combines data from areas
of different geologic structure and tectonic activity. Accord-
ingly, the country was divided into nine areas (Figure 5) in
an attempt to obtain recurrence curves for areas that seem to
be related to more or less definite trends or regions of seismic
activity and are somewhat geologically similar throughout.

Figure 6 shows the recurrence intensities for California,
based on approximately 16,000 earthquakes. The slope of the least
squares line, log N $= a + b\,I$, is 0.54 and corresponds to a value
of b of 0.83 in the equation log N $= a + b\,M$ where M is the
magnitude and the conversion $M = 1 + 2/3\,I$ is used. For the
equation log N = a+b (8-M), Gutenberg and Richter (5) obtained
a value of 0.88 for Southern California and Allen, et al. (3)
obtained a value of 0.86. Both of these slopes are in close
agreement with the value obtained from the data in Figure 6.
The curve for Nevada shows a similar slope.

Area 8 (Figure 5) includes the southeast Missouri area
where great earthquakes occurred during 1811-12 together with
the St. Lawrence Valley region. The recurrence relationship
is shown in Figure 7. The 1811-12 New Madrid earthquakes (maximum
intensity =XII) were not used in computing the least squares line.
There is considerable question as to the validity of considering
these two active seismic regions as one area for statistical purposes.

-5-

Recurrence curves were constructed for the regions separately, but there were only slight differences in the slopes of the lines.

A summary of recurrence relationships are shown in Table 1. The areas are arranged in order of decreasing V11 M.M. activity. The seismic risk zones associated approximately with the areas used in the frequency studies are also indicated. Table 11 shows the frequency of occurrence of earthquakes of various maximum intensity levels per 100 years per 100,000 km^2. The frequencies in Table 1 have been divided by the area of each region. Assuming that the recurrence relationship has some validity, these tables are measures of the relative seismicity of each area and could be used on a broad scale for planning purposes. The results shown must be used with many qualifications and reservations. The numbers in parentheses are recurrence rates based on the least squares lines only, that is, earthquakes with the indicated maximum intensity are not known to have occurred in that particular area. It should be stated again that the above results depend upon the assumption that a relationship of the type $\log N = a + b\,I$ is valid for these data and that the decisions made regarding the completeness of the data sample were reasonably correct.

Seismic Risk Map

A Seismic Probability Map of the United States was prepared in 1948 by F. P. Ulrich with the advice of seismologists through-out the United States (6) and was issued by the Coast and Geodetic Survey in 1948. In 1949, the Seismic Probability Map was revised such that the Charleston, South Carolina area was changed from Zone 3 to Zone 2 and a Zone 3 was set up for the Puget Sound region of Washington which had formerly been included in Zone 2 (7). The revised map was adopted by the Pacific Coast Building Officials Conference for inclusion in the 1952 edition of the Uniform Building Code. Subsequent editions of the Uniform Building Code have included this map with no changes (8).

The map was withdrawn by the Coast and Geodetic Survey in 1952 as "subject to misinterpretation and too general to satisfy the requirements of many users." The annual publication United States Earthquakes has included a map showing locations of destructive and near destructive earthquakes throughout the United States, but the Coast and Geodetic Survey has offered no other probability map.

The Seismic Probability Map has been most useful as part of the criteria in the establishment of lateral force requirements for buildings but it does, however, have several obvious limitations.

As pointed out by Richter (9), the circular spot numbered 3 in
Montana corresponds to damaging earthquakes in 1935, but the map
ignores other earthquakes and known active structures in the same
geological province. Along many zone boundaries, Zone 3 borders
Zone 1 and Zone 2 borders Zone 0. If a major earthquake is
considered possible in Zone 3, the normal distribution of in-
tensities would suggest that an area of Zone 2 should surround it,
the same reasoning being true for the peripheries of Zone 2
areas. The original Seismic Probability Map describes Zones 0
through 3 only in terms of "no damage, minor damage, moderate
damage and major damage" respectively. No attempt was made to
correlate the zones with intensity.

The map presented in Figure 8, which will be termed a
"Seismic Risk Map," is meant to be an interim revision of the
original Coast and Geodetic Survey Seismic Probability Map.
The map in Figure 8 is actually more than a revision of the
old map in that the factors used in constructing the new risk
map are somewhat different from those considered in the original
map.

The Seismic Risk Map presented here is based on the following
factors:

1. the distribution of M.M. intensities associated
    with the known seismic history of the United States,

2. strain release in the United States since 1900, and

3. the association of strain release patterns with
    large scale geologic features believed to be
    related to recent seismic activity.

Where seismic activity has occurred intermittently along a
recognizable geologic trend, it has been, in general, assumed
that seismic activity could occur with equal likelihood anywhere
along that trend or structure. In areas where the relations
between seismicity and geologic structure are not clear or where
only limited geologic information is available, the risk zones
are based on the distribution of M.M. intensities and strain
release. In all cases, the size and shape of the zones have been
heavily influenced by the historical distribution of intensities
(Figure 1). It is realized that it would be desirable to relate
risk to a measurable quantity less subjective than M.M. intensity,
but the available strong motion and other data appear to be in-
sufficient to attempt this at present. No special corrections
are presented for types of surficial geology and soils that
may increase or decrease the intensity of shaking. It should be
remarked, however, that the M.M. intensities reported for an
earthquake are usually the maximum effects observed on the
worst ground.

The risk zones in the northeast portion of the United States are not greatly changed from the original risk map. The St. Lawrence Valley continues to be Zone 3 because of the great earthquakes in 1663 and 1925 and lesser shocks near Attica, N. Y. in 1929 and near Massena, N. Y. in 1944. The Boston, Massachusetts area was zoned 3 in consequence of the earthquake east of Cape Ann in 1755 and many other lesser earthquakes in the area. The Zone 3 rating in the Charleston, South Carolina area is a consequence of the 1886 earthquake. Zone 2 has been extended to include the main structures of the Appalachian area from Pennsylvania to Alabama which are associated with numerous moderate earthquakes. Zone 3 and Zone 2 in the Mississippi Valley have been very much enlarged over those zones on the old Seismic Probability Map. The new zone more nearly reflects the probable distribution of intensities in any repetition of the 1811-12 series near New Madrid, Missouri. Zone 2 has been extended northeast across a zone of relatively minor seismicity in Indiana to southwestern Ohio. Although earthquakes with maximum M.M. intensities of V11 are known in western Ohio (10), connection of Zone 2 in Ohio with the Zone 2 surrounding the New Madrid, Missouri area is a matter of interpretation. This zone is based on the apparent alignment of epicenters from the St. Lawrence Valley to southeast Missouri. There is no conclusive geologic evidence at present for the alignment, and other interpretations are possible (10).

A Zone 2 area has been drawn along the Nemaha Ridge structure in Nebraska, Kansas and Oklahoma which includes the 1952 earthquake near El Reno, Oklahoma and numerous other shocks along the Nemaha Ridge. The north-central plains states have been, for the most part, rated in Zone 1 because of the lack of data relating seismicity with geologic structure and because of the rather widespread and erratic distribution of moderate earthquake activity. North Dakota is a good example. No earthquakes (11) are known to have occurred in the state until July 8, 1968 when a magnitude 4.4 earthquake shook the Bismarck area (12). The Zone 3 area restricted to southeastern Montana on the old map has been extended southward through Idaho and Utah. The large earthquake near Hebgen Lake, Montana in 1959, the Kosmo, Utah shock of 1934, the series of shocks in 1920 and 1921 near Elsinore, in southern Utah and the related north-south trending faults amply justify the zoning.

Only minor changes have been made from the original map in the states bordering the Pacific. The original Zone 1 rating in Oregon has been slightly changed. Other minor changes have been made in the shape of the Zone 3 area in Washington at the south end of Zone 2 in the Great Valley of California.

Discussion and Summary

The Seismic Risk Map presented is offered as a revision
of the Seismic Probability Map originally prepared by the Coast
and Geodetic Survey in 1947. The new map is only an interim one
and does not represent the final form of a risk map for the
United States. It does not consider the frequency of occurrence
of the seismic events in each zone. An estimate of the relative
rates of occurrence of earthquakes of various maximum M.M.
intensity in different zones has been made in this paper
using strain release and earthquake recurrence data.

It is suggested that eventually it may be possible to
estimate seismic risk in the United States using three separate
maps: one map would be geological in nature, showing all geological
structure thought to be related to seismic activity, with assign-
ment of relative risk to each of the structures; a second map
would estimate the frequency of occurrence of earthquakes of
various magnitudes or maximum intensities throughout the United
States; and a third map would show the distribution of maximum
M.M. intensity in the United States such as is shown in Figure 1
of this paper. If proper coefficients are assigned to each area
or feature of each of the three maps, it would be possible to
obtain both the long term (risk over a very long time) and short
term (risk over 25-50 years) risks in the following manner:
The short term risk at a particular site could be obtained by
a weighted consideration of coefficients from maps 1, 2 and 3.
Long term risk could be obtained from a similar integration
of data from maps 1 and 3. Much additional work remains to
be done, particularly with regard to the relationship between
geologic structure and earthquake occurrence. It is hoped that
the data and maps presented will be useful in developing future
seismic risk maps for the United States.

Acknowledgements

The author has benefited greatly from numerous discussions
with engineers and seismologists throughout the United States
that are interested in the seismic risk problem. Mr. L. M.
Murphy provided many helpful suggestions for the preparation
of the risk map. J. C. Stepp and R. L. Rothman compiled and
edited much of the seismicity and related data used in the
preparation of the various maps.

References

1. Algermissen, S. T., "A Seismic Risk Map for the United States:
A Progress Report," Proceedings of the Third Symposium on
Earthquake Engineering, Roorkee, India, pp. 389-398, 1966.

2. Benioff, H., "Earthquakes and Rock Creep," Bull. Seis. Soc. Amer., Vol. 41, pp. 31-62, 1951.

3. Allen, C. R., St. Amand, P., Richter, C. F., and Nordquist, J. M., "Relationship Between Seismicity and Geologic Structure in the Southern California Region," Bull. Seis. Soc. Amer., Vol. 55, pp. 753-797, 1965.

4. Richter, C. F., "Elementary Seismology," W. H. Freeman and Company, San Francisco, California, 1958.

5. Gutenberg, B. and Richter, C. F., "Seismicity of the Earth," 2nd ed., Princeton University Press, Princeton, N. J., 1954.

6. Roberts, E. B., and Ulrich, F. P., "Seismological Activities of the U. S. Coast and Geodetic Survey in 1948," Bull. Seis. Soc. Amer., Vol. 40, pp. 195-216, 1950.

7. Roberts, E. B. and Ulrich, F. P., "Seismological Activities of the U. S. Coast and Geodetic Survey in 1949," Bull. Seis. Soc. Amer., Vol. 41, pp. 205-220, 1951.

8. "Uniform Building Code," Vol. 1, 1964 Edition, International Conference on Building Officials, Pasadena, California, 503 pp., 1964.

9. Richter, C. F., "Seismic Regionalization," Bull. Seis. Soc. Amer., Vol. 49, pp. 123-162, 1959.

10. Bradley, E. A. and Bennett, T. J., "Earthquake History of Ohio," Bull. Seis. Soc. Amer., Vol. 55, pp. 745-752, 1965.

11. Eppley, R. A., "Earthquake History of the United States," Coast and Geodetic Survey, ESSA, U. S. Government Printing Office, 120 pp., 1965.

12. "Preliminary Determination of Epicenters," Card No. 50-68, U. S. Department of Commerce, ESSA, Coast and Geodetic Survey, 1968.

TABLE 1

SUMMARY OF EARTHQUAKE RECURRENCE FORMULAS

AREA	RISK ZONE	LOG N = a + b l (per year)		EARTHQUAKES PER 100 YEARS			
		a	b	V	V1	V11	V111
1. 2. California, Nevada	3,2	4.11	-0.55	2290	646	182	51.3
1. California	3,2	3.92	-0.54	1660	479	138	39.8
2. Nevada	3,2	3.98	-0.56	1510	417	115	31.6
4. Montana, Idaho Utah, Arizona	3,2	3.41	-0.56	407	112	30.9	8.5
8. Mississippi Valley, St. Lawrence Valley	3,2,1	2.71	-0.50	162	51.3	16.2	5.1
3. Puget Sound, Washington	3,2	3.45	-0.62	224	53.7	12.9	3.1
9. East Coast	3,2,1	3.02	-0.58	132	34.7	9.1	2.4
5. Wyoming, Colorado, New Mexico	3,2,1	3.66	-0.68	182	38.0	7.9	1.7
7. Nebraska, Kansas, Oklahoma	2,1	1.99	-0.49	34.7	11.2	3.6	1.2
6. Oklahoma, North Texas	2,1	2.10	-0.55	22.4	6.3	1.8	(0.5)

TABLE 11

SUMMARY OF EARTHQUAKE RECURRENCE FORMULAS

AREA	RISK ZONE	EARTHQUAKES PER 100 YEARS PER 100,000 KM.²			
		V	V1	V11	V111
1. 2. California, Nevada	3,2	300	84.6	23.8	6.72
4. Montana, Idaho, Utah, Arizona	3,2	64.4	17.7	4.89	1.35
3. Puget Sound, Washington	3,2	68.0	16.3	3.92	0.94
8. Mississippi Valley, St. Lawrence Valley	3,2,1	24.2	7.65	2.42	0.76
7. Nebraska, Kansas, Oklahoma	2,1	13.0	4.20	1.35	0.45
5. Wyoming, Colorado, New Mexico	3,2,1	32.8	6.85	1.42	0.31
6. Oklahoma, North Texas	2,1	13.3	3.73	1.07	0.30
9. East Coast	3,2,1	12.8	3.39	0.88	0.23

MAXIMUM INTENSITIES

THROUGH 1965

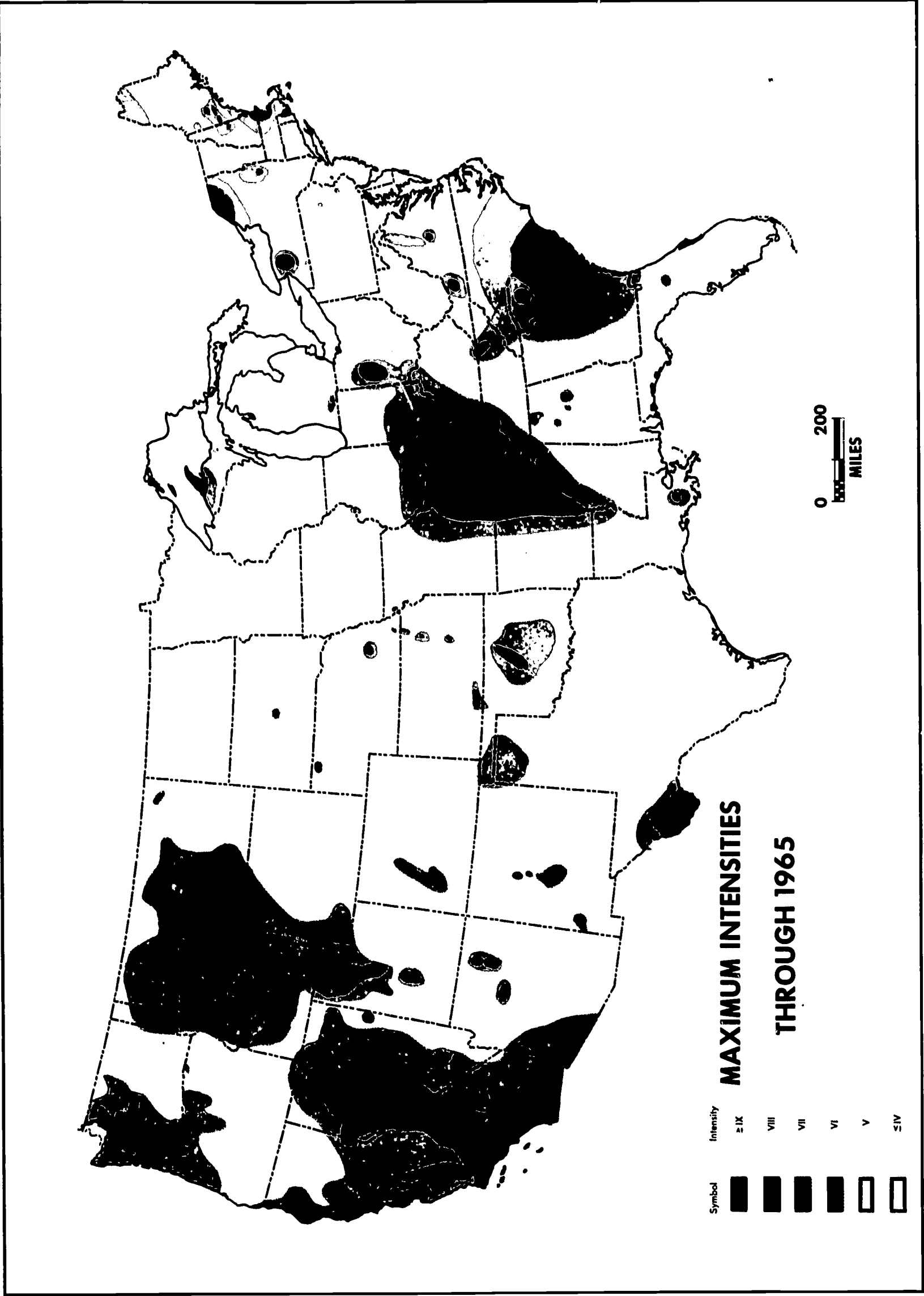| Symbol	Intensity
■	≥ IX
■	VIII
■	VII
■	VI
□	V
□	≤ IV

0   200
MILES

Figure 1   Maximum Modified Mercalli intensities throughout the United
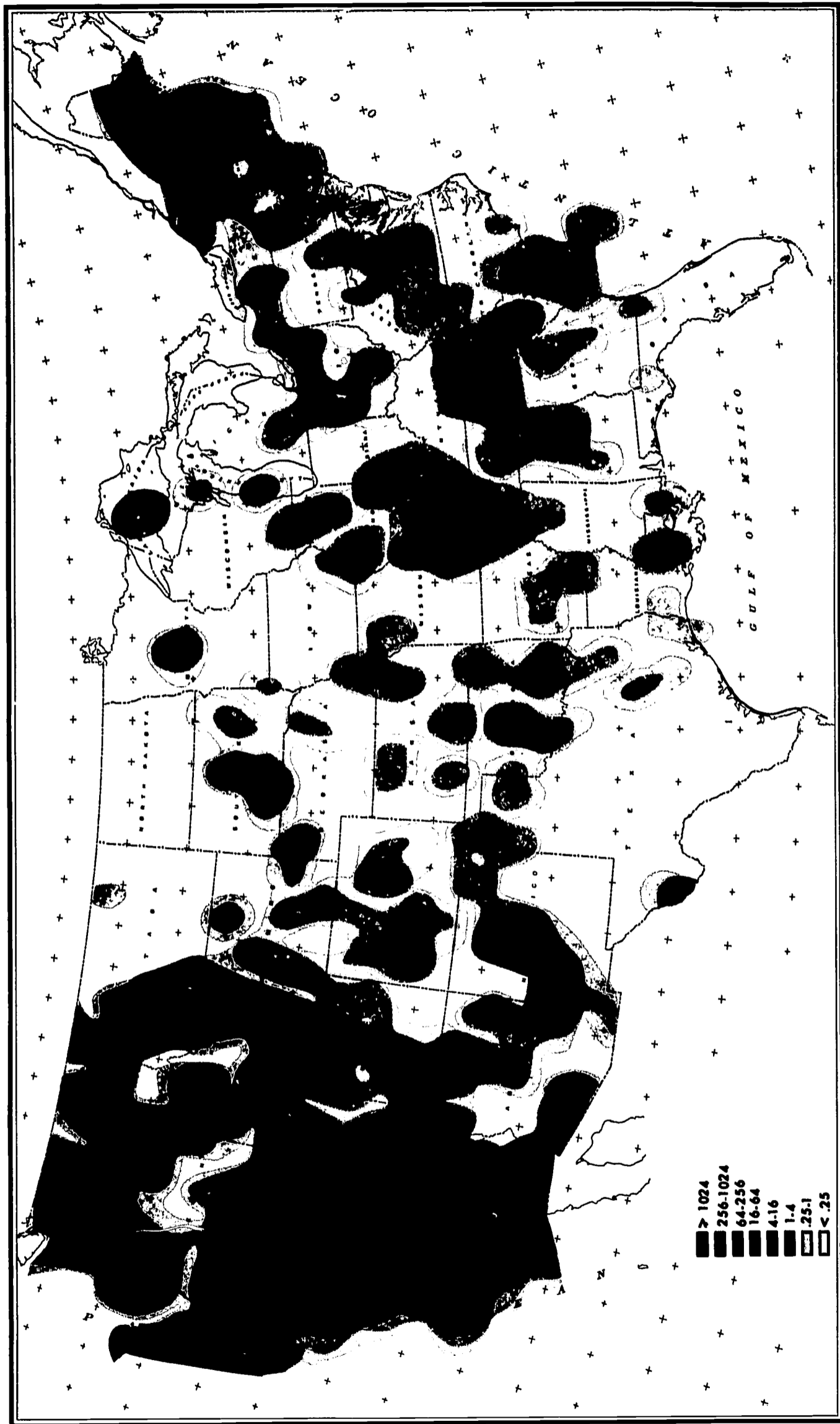States – all historical data through 1965

Figure 2   Strain release in the United States, 1900 to 1965, expressed as the
equivalent number of magnitude four earthquakes

> 1024
256-1024
64-256
16-64
4-16
1-4
.25-1
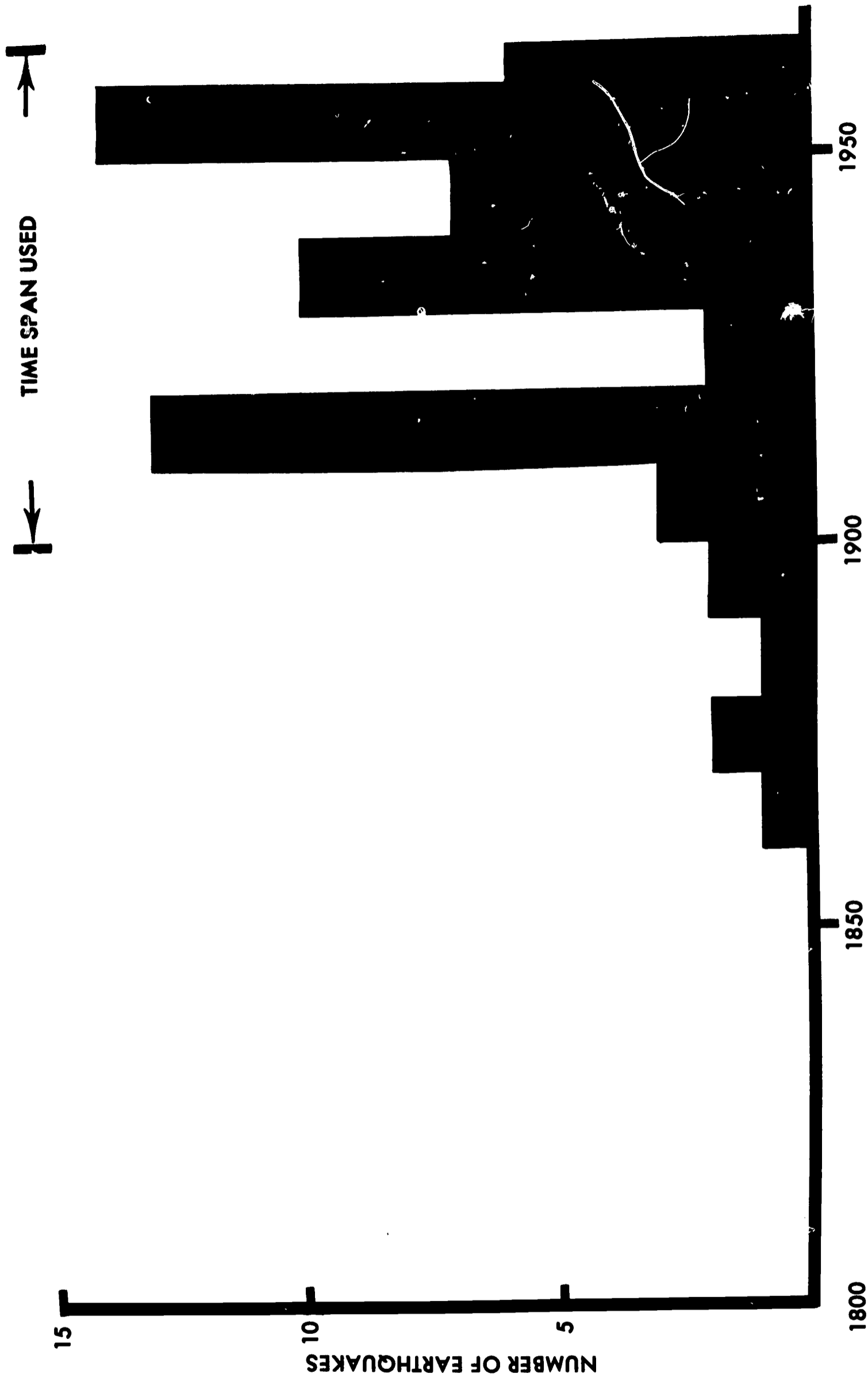< .25

Figure 3   The number of maximum Modified Mercalli intensity VI earthquakes
            reported in each ten year period through 1965 (region 4 of
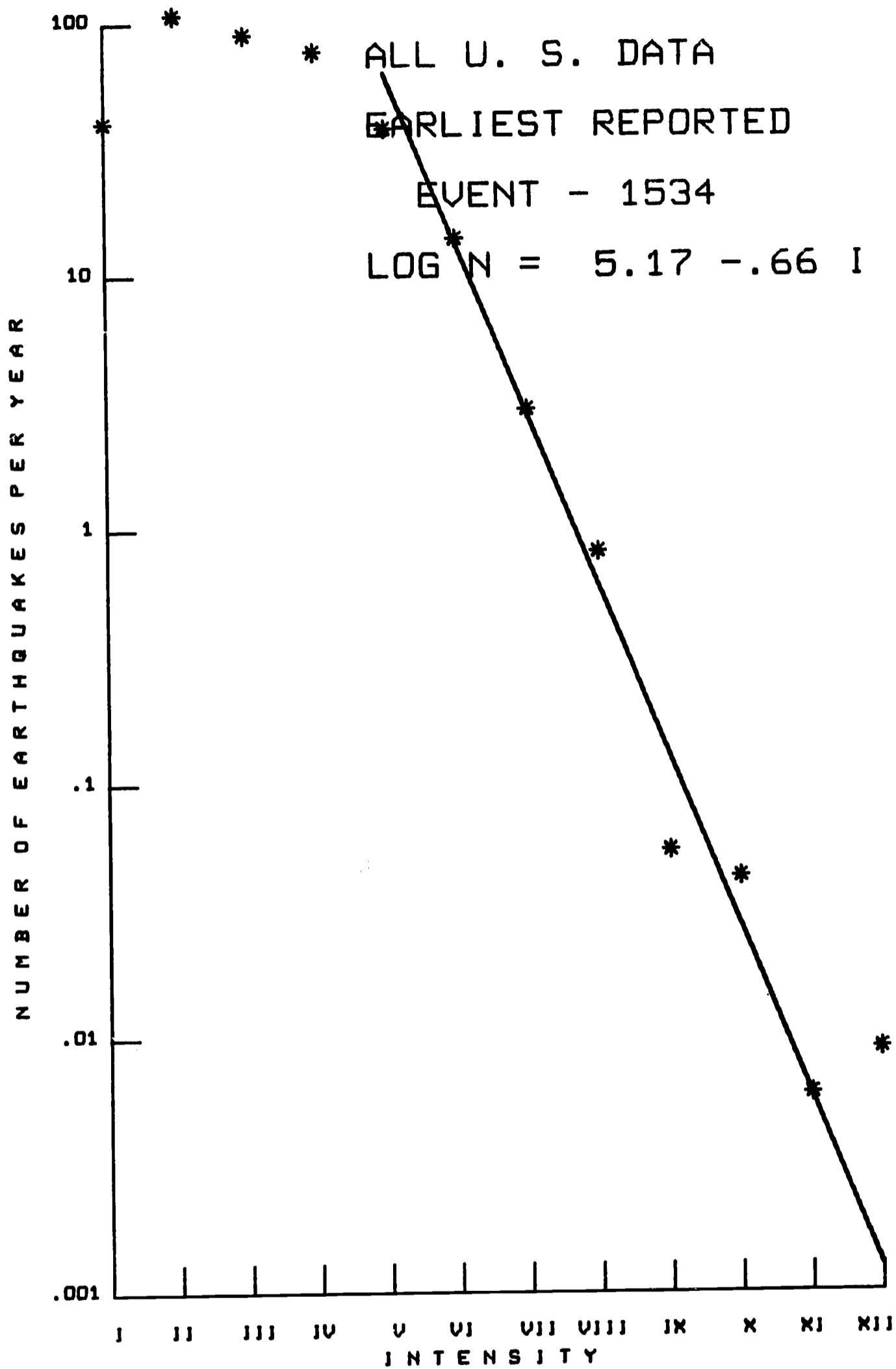   Figure 5)

Figure 4   Frequency of earthquake occurrence
(per year) vs. maximum M.M. intensity -
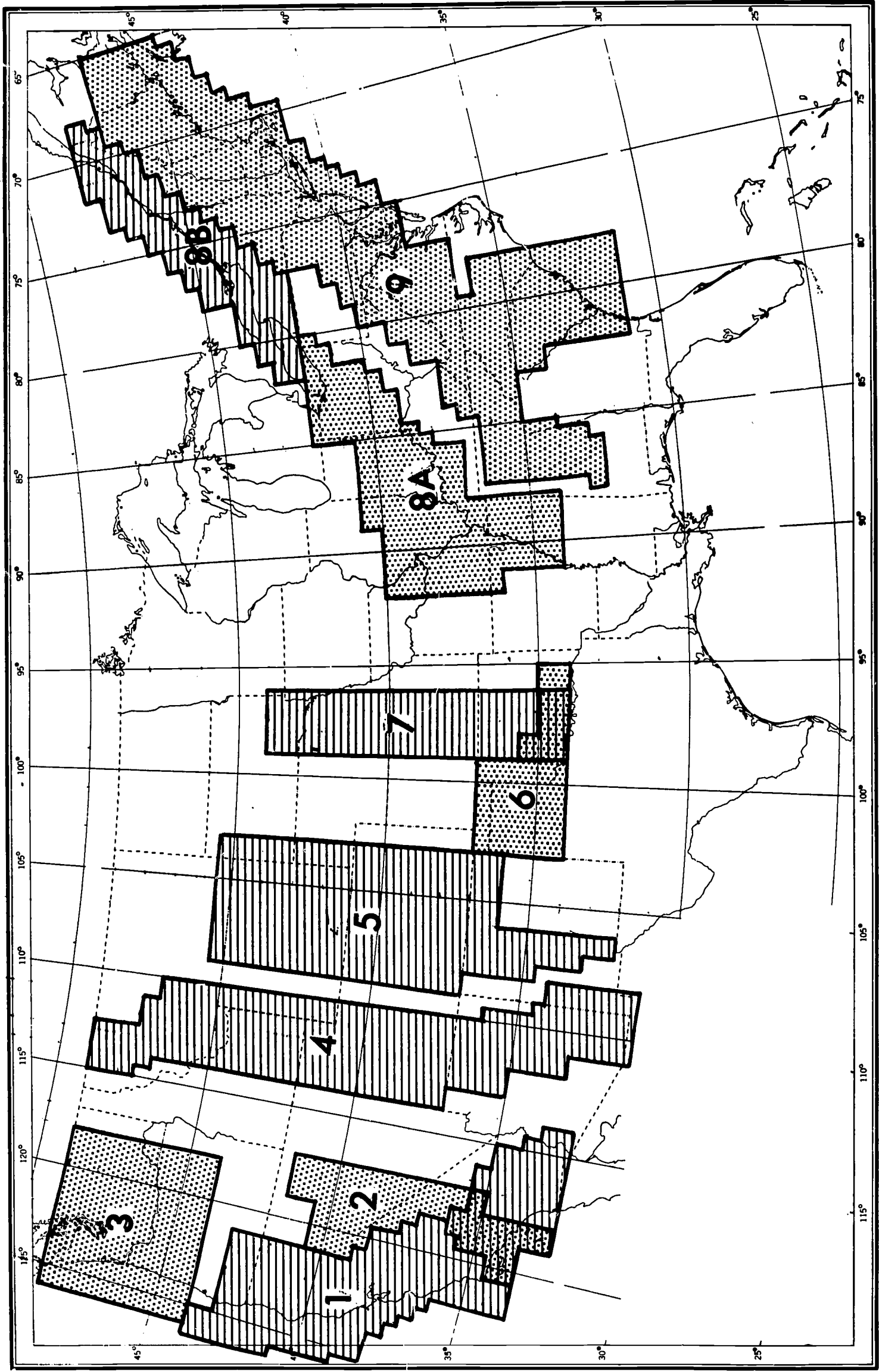all U. S. data 1534-1965

Figure 5   Location map showing the areas for which recurrence formulas were computed
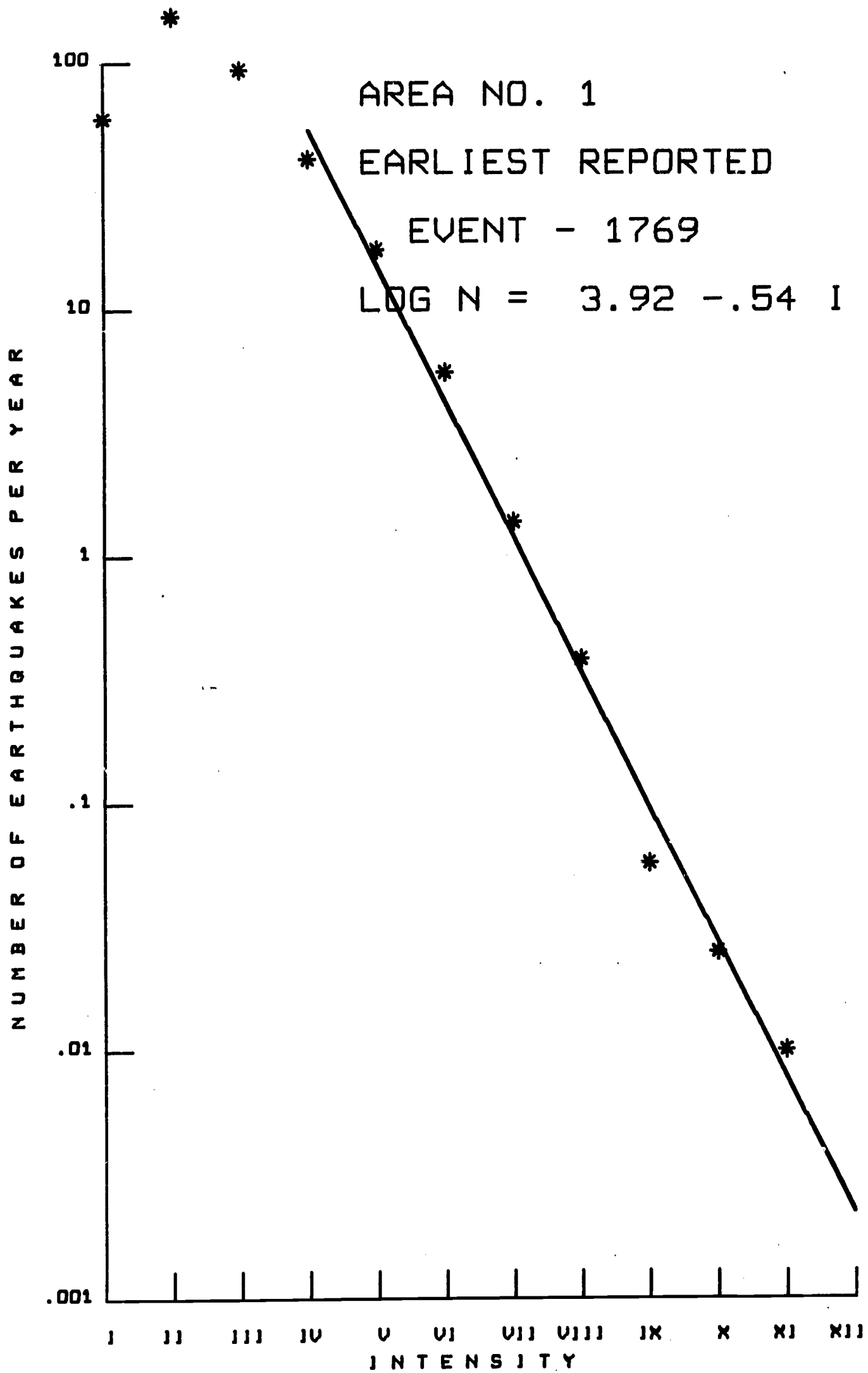
Figure 6   Frequency of earthquake occurrence
            (per year) vs. maximum M.M. intensity -
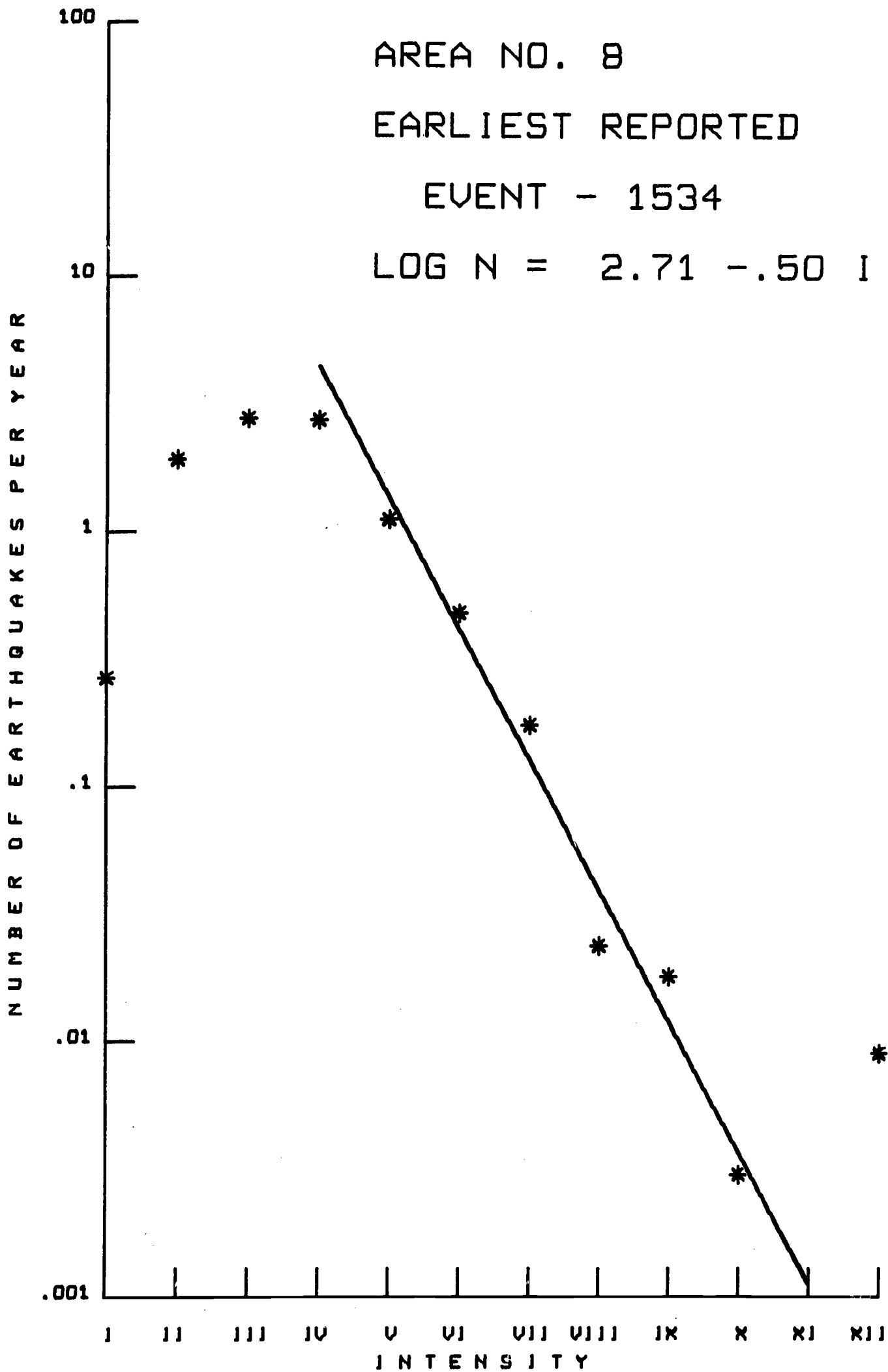   area 1, California

Figure 7   Frequency of earthquake occurrence
(per year) vs. maximum M.M. intensity -
area 8, Southeast Missouri to the
St. Lawrence Valley

SEISMIC RISK MAP OF THE UNITED STATES

ZONE 0 – No damage.

ZONE 1 – Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 seconds; corresponds to intensities V and VI of the M.M.* Scale.

ZONE 2 – Moderate damage; corresponds to intensity VII of the M.M.* Scale.

ZONE 3 – Major damage; corresponds to intensity VIII and higher of the M.M.* Scale.

This map is based on the known distribution of damaging earthquakes and the M.M.* intensities associated with these earthquakes; evidence of strain release; and consideration of major geologic structures and provinces believed to be associated with earthquake activity. The probable frequency of occurrence of damaging earthquakes in each zone was not considered in assigning ratings to the various zones. See accompanying text for discussion of frequency of earthquake occurrence.
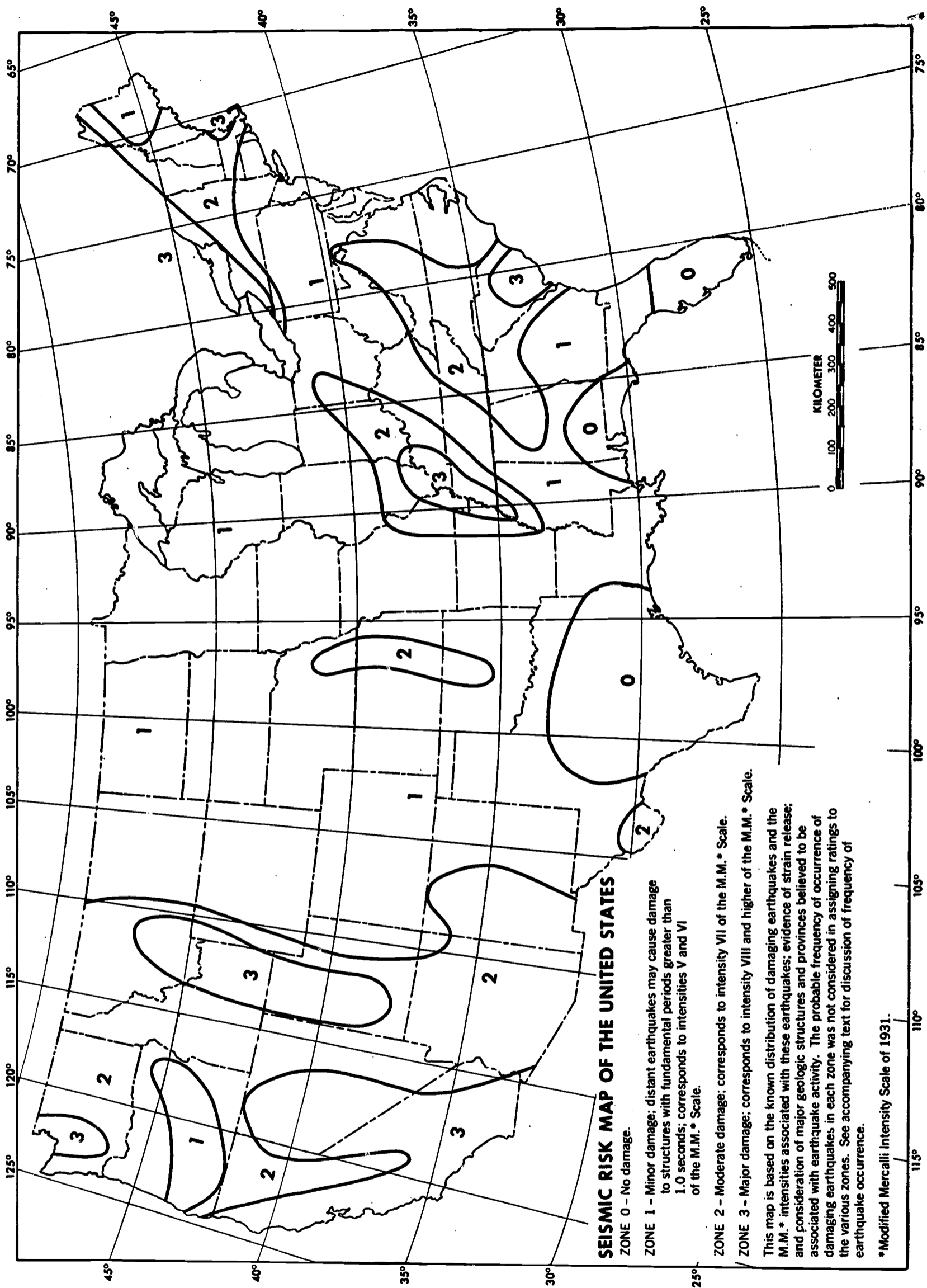
*Modified Mercalli Intensity Scale of 1931.

KILOMETER

Figure 8   Seismic Risk Map of the United States