NUREG/CR-1582
Vol. 3

Seismic Hazard Analysis

Solicitation of Expert Opinion

Manuscript Completed: August 1979
Date Published: August 1980

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Prepared for
Division of Operating Reactors
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN No. A0233

ABSTRACT

This report presents a detailed tabulation of ten experts' answers to a questionnaire on seismicity and ground motion characteristics of the Central and Eastern United States. The goal in eliciting such information was to obtain a subjective representation of parameters that affect seismic hazard in order to supplement the very limited historical data that are available in these regions. Not only was the "most probable value" sought in each case, but also, whenever possible, the entire probability distribution to be used in a probabilistic hazard analysis. The questionnaire was divided into five sections: Source Zone Configuration, Maximum Earthquakes, Earthquake Occurrence, Ground Motion Models and Overall Level of Confidence. The last section was designed to develop a synthesis of opinion, if need be. The questionnaire was designed to contain redundancy to provide cross-checking and establish consistency in the results.

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INTRODUCTION

To obtain subjective data for use in seismic hazard assessment, a questionnaire was prepared to elicit expert opinion about seismicity and attenuation in the Northeastern region of the United States (east of the Rocky Mountains). Because it is difficult, or perhaps impossible, to precisely quantify such factors, given the sparse historical record, expert judgment is crucial to a meaningful hazard assessment.

It was not possible to conduct a Bayesian hazard analysis with these data. A Bayesian analysis would independently consider subjective opinion and available data, and then combine them, each with their corresponding weight, to provide an "a posteriori" input to be used in the analysis. Therefore, a Bayesian analysis requires independence between subjective opinion and data. It was, however, not possible in this case, due to the experts' inherent knowledge of historical seismicity in the East. It was unreasonable to expect the experts to divorce themselves from these data while forming an opinion. Therefore, such expert opinion is necessarily a posterior estimate and cannot be used in a formal Bayesian analysis without double weighting the data.

The experts were supplied with historic seismicity data for various source zones in the East in order to help them answer the questionnaire. These data were based on an integrated catalog of earthquake occurrences generated from various regional catalogs for the East. A listing of all earthquakes having epicentral intensities of IV or greater, and a table giving the number of occurrences of earthquakes of each Modified Mercalli (MM) intensity unit from IV through XII were provided. Part One of this report summarizes objective seismicity data used in the study.

QUESTIONNAIRE FORMAT

Part Two of this report addresses the following five areas into which the questionnaire was divided:

- Source Zone Configuration
- Maximum Earthquakes
- Earthquake Occurrence
- Attenuation
- Self Ranking

In the first section of the questionnaire, Source Zone Configuration, we were concerned with the specification of various areas or regions that appear to be unique in their potential to generate earthquakes. In particular, we were seeking the definition of regions within which the experts felt future earthquake activity would be homogeneous.

In the second section, Maximum Earthquakes, we first addressed the question of determining the size of the largest event that could, in the experts' opinions, be expected to occur in each of the source zones for a given time period in the future. Since extrapolation of results from short time periods to very long ones is controversial, due to possible long-term variations in seismicity and other parameters, we explicitly considered different time periods. The return period for these events was also considered at length in this section.

The third section, Earthquake Occurrence, considered the occurrence of earthquakes within the next 150 years for each source zone.

The section on "Attenuation" provided general information to critique the validity of existing attenuation relationships and develop a new relationship applicable to the Eastern United States. Attenuation data was not specifically provided; rather, each expert was questioned as to his inherent knowledge of Eastern U.S. attenuation and any data available.

At the conclusion of the questionnaire, the experts were asked to rate their overall level of confidence in answers to the different sections of the questionnaire. This input was used to reach a synthesis between all the experts using the method of weighted averages.

In preparing the expert opinion questionnaire, consideration was given to modes of judgment in assessing uncertainty, to biases and to scaling techniques. These issues are discussed in Appendix A of this report. The questionnaire contains purposely redundant material, so as to provide a means of cross-checking and to establish consistency in the results. This approach was chosen to assure that quantification of judgment does, in fact, accurately reflect opinion. The stepwise procedure had the distinct advantages of helping to ensure unbiased overall responses, and of mitigating against overly casual answers.

ANSWERING TECHNIQUES

Though answers to the questions were solicited in several ways, all could be converted to a similar format for analysis. The purpose of allowing the different formats was to obtain answers truly reflecting each expert's opinion, not answers that were easily analyzed. The various formats were:

- A best estimate (fixed quantity)
- A range of values defined by lower and upper bounds and associated with a uniform distribution
- A range of values defined by lower and upper bounds and associated with a non-uniform distribution
- A written discussion

Additionally, if none of these allowed an adequate answer to the questions, the expert was free to choose another format.

Clearly, from the perspective of hazard analysis, a quantitative answer would be preferred. However, several experts provided extremely useful data in written discussion. These written comments can be found in Part Two, "Tabulation of Expert Response," following discussion of the various questions. Further comments of note, from Experts 5 and 7, are summarized in Appendix B.

The following conventions were used to interpret each expert's answers. These conventions were made apparent in the questionaire.

- If he answered with the best estimate only, we assumed that the uncertainty associated with the best estimate can be neglected.
- If he gave only a range of values, we assumed that the distribution over the range was uniform and, therefore, that the best estimate was halfway between the low and high bound of the range.
- If he provided both a best estimate and a range, we assumed a triangular distribution over the range.
- If he provided a best estimate, range and distribution, all the information was given and no assumption was made. (At times, a consistency check between the best estimate and the mean of the distribution was needed.)

NUMERATION

Subsequent sections of this report present the questions asked of the experts and a compilation of their responses. To assure anonymity, the experts were numbered 3, 4, 5, 7, 8, 9, 10, 11, 12, 13 (though thirteen experts were originally contacted, Experts 1, 2, and 6 did not complete the questionnaire). We adhered to the original numbering of the experts throughout this study. The experts who participated in the study are presented in Appendix A.

PRIVATE COMMUNICATIONS

Throughout the duration of the project, continuous communication was maintained with each of the experts, either by mail or phone, to clarify questions or inconsistencies arising from the processing of the answer booklet. This led, at times, to revision or modification of some of their answers. The updated and final versions of their input are tabulated in this report.

PART I

HISTORIC SEISMICITY DATA

PART I HISTORIC SEISMICITY DATA

It is essential for any credible seismic hazard analysis to base the study on an accurate and current seismic data base. This is of course the case with any seismic hazard analysis, but it is particularly true for probabilistic analyses where earthquakes of all sizes contribute to the hazard.

There are several specific ways that uncertainty or unreliability in the seismic data base will influence the results of a probabilistic hazard analysis. First, and most important, is uncertainty in the number of unassociated events that are contained in the host region--that is the source region containing the site. It is generally the case that this so-called background seismicity is a major contributor to the seismic hazard. Second, uncertainty in the location of events, particularly the larger historical events, drives uncertainty in the seismic zonation of the area and this in turn drives the uncertainty in the proximity of nearby active source regions. Third, whether for host regions or for other source regions, the historical record provides the only quantitative basis for assessing the frequency of large events in any given region. At the probabilities relevant to this study (10^{-3} - 10^{-4}), a credible model for the occurrence of these events is most significant. In order to develop as consistent and accurate seismic data base as possible, we have integrated five individual seismic data bases. Emphasis has been given to selected individual bases within certain regions and over certain times. The following sections present the details of the individual bases, the integration criteria and plots illustrating the effect of the integration.

1.0 INDIVIDUAL SEISMIC DATA BASES

We judge that there are five individual catalogs relevant to this study. These have been selected on the basis of the apparent thoroughness with which the catalogs were assembled. The catalogs are summarized in Table I with their respective coverages in time and space, and elaborated upon below.

NEIS DATA BASE

This file contains data on 85,069 earthquakes, known or suspected explosions, associated surface collapse phenomena, coal bumps, rockbursts, quarry blasts, and other earth disturbances recorded by seismographs for the period January 1, 1900, through August 31, 1973. These data include information on the date, origin time, location, focal depth, and magnitude determined as part of the Preliminary Determination of Epicenters (PDE) program of the NOAA National Ocean Survey (formerly Coast and Geodetic Survey). Since July 1971 the Preliminary Determination of Epicenters program has operated within NOAA Environmental Research Laboratories. The National Geophysical Data Center of NOAA's Environmental Data Service makes this information available on punched cards and magnetic tape as well as on microfilm or microfiche. The magnetic tapes are available with data sorted either chronologically or geographically.

The earthquake location program utilizes arrival times from seismograph stations operated by NOAA, other U.S. Government agencies, colleges and universities and many cooperating foreign institutions. About 250 stations report regularly; many of these are part of the Worldwide Standard Seismograph Network (WWSSN).

Since 1961 incoming seismic data have been routinely processed by computer, with external control by a seismologist. A minimum of five stations with compatible data is required for an acceptable solution. These locations are published in the twice-weekly and monthly Preliminary Determination of

TABLE I

SEISMIC DATA BASES FOR THE EASTERN UNITED STATES

Base	Time Coverage	Area Coverage
NEIS	through Dec. 1977	Entire U.S.
Nuttli	through Sept. 1975	Central U.S.
Chiburis	through Dec. 1977	Northeastern U.S.
Canadian	through Dec. 1976	Canada
Algermissen	through Dec. 1974	Entire U.S.

Epicenters (PDE) publication of NOAA as soon as sufficient data have accumulated to ensure a reasonable degree of accuracy. Thus, PDE results may not always agree with later determinations where more extensive network data or new data from critical azimuths and distances are used.

NUTTLI DATA BASE

Nuttli's catalog, which includes earthquakes from 1699 through 1974, contains nearly all felt earthquakes in Central United States. Professor Nuttli personally assigned the epicentral location of the larger historical events after a thorough review of the literature and the intensity reports.

Data sources consulted include Earthquake History of the United States (Coffman and von Hake, 1973), United States Earthquakes (U.S. Department of Commerce) for the years 1928 through 1972, Preliminary Determination of Epicenters (U.S. Geological Survey) for the years 1972 through 1974, Earthquakes of the Stable Interior, with Emphasis on the Midcontinent (Docekal, 1970), A Contribution to the Seismic History of Missouri (Heinrich, 1941), Seismological Notes (Seismological Society of America) for the years 1911 through 1975, Quarterly Seismological Bulletins of Saint Louis University (Stauder, et al., 1974-1976) for the interval June 1974 through March 1976, unpublished lists of earthquakes compiled by J.E. Zollweg of Saint Louis University, a list of earthquakes compiled by M.M. Varma and R.F. Blakely of Indiana University and the Preliminary Safety Analysis Reports for proposed nuclear power plant sites at Marble Hill (Jefferson County, Indiana), Calloway (Calloway County, Missouri), Koshkonong (Jefferson County, Wisconsin), Hartsville (Troudale-Smith Counties, Tennessee), Perry (Lake County, Ohio) and Sterling (Cayuga County, New York).

Nuttli has determined an equivalent earthquake magnitude (m_b) from the intensity data for every earthquake in the catalog. Further, the historical MM Intensity data have been completely and consistently converted to m_b through felt area, epicentral intensity, or intensity fall-off calculations.

CHIBURIS DATA BASE

This catalog, which contains earthquakes in Northeastern United States from 1534 through 1977, represents a careful review and reevaluation of both the historical intensity data and the more current instrumental data. Included in the base are all the very recent earthquakes recorded on the New England Seismic Network.

In compiling the historical data, Chiburis reviewed and integrated the data of several previous investigators including W.E.T. Smith (1962, 1966), E. Brocks (1960), and Mather and Godfrey (1927). Included, and emphasized, were the results of several in-depth investigations into particular earthquakes. For example, P. Pomeroy has investigated the larger historical events in New York State, and these results are given preference over previous less intense studies. Similarly, Weston Geophysical, Inc. has investigated through the original newspaper accounts and other reports, several earthquakes in Massachusetts and surrounding areas, and their results are also given precedence.

At the time this questionnaire was prepared this data base was in the final stages of preparation. Dr. Chiburis kindly made his preliminary version available to us and in the questionnaire we provided plots of the historical data. The preliminary version of the data gave two values of the maximum MM Intensity--the smallest reported and the largest reported epicentral intensity. While data in this form are useful for assessing the uncertainty in maximum MMI reports, a more valuable form would include the "preferred" intensity. Indeed, Chiburis recognized this and included it in his final data base. The maximum reported intensity is presented here for comparison.

The instrumental data in the Chiburis file was integrated from NESA records, LRSM records, the early data (1963-1967) from the New England Seismic Network and Lamart data. Many of the original records were re-scanned and reinterpreted by the Western observatory staff to produce the instrumental local magnitudes contained in the file.

CANADIAN DATA BASE

The basic earthquake data compiled by Basham and others for Eastern Canada are from the two catalogs of Smith (1962, 1966), which cover the periods 1534-1927 and 1928-1959, respectively, and from annual catalogs published by the Earth Physics Branch of their Department of Energy, Mines, and Resources, since 1960. The geographical boundaries selected here to represent the Eastern Canada region are longitudes 56°E and 85°W for the Eastern and Western boundaries, respectively, 51°N latitude for the Northern boundary, and an irregular Southern boundary extending roughly 150 km into the U.S. The extension into U.S. territory is great enough to assess any Canadian zones of earthquake occurrence that may cross the border, and to consider the influence of any significant U.S. earthquakes on Canadian sites. Specifically excluded from consideration by this choice of Southern boundary are the large numbers of earthquakes in the catalogs, particularly in the early years, with epicenters along the Atlantic coast in the Boston-New York area.

The earthquake data, to the end of 1975, have been reassessed for purposes of assigning magnitudes to all earthquakes, both pre- and post-instrumental, which may have been magnitude 4. For the years 1968 to the present, Eastern Canadian earthquake magnitudes have been computed with a standard procedure. Prior to 1968, some of the catalog instrumental magnitudes were biased by the incorrect application of the Richter local magnitude scale to Eastern Canadian earthquakes; see Stevens et al. (1973, Appendix I) and Horner et al. (1973). For purposes of this catalog, all pre-1968 Eastern Canadian earthquake instrumental magnitudes, which may have been magnitude 4, have been recomputed using the original instrumental data and the modern magnitude formulae.

For earthquakes in the range from about M4.0 to M5.5, but without assigned instrumental magnitudes, the felt area is considered to provide a better non-instrumental estimate of magnitude than other macroseismic information. Thus, for earthquakes with reasonable information available on the area of perceptibility, magnitudes have been assigned on the basis of the Nuttli and Zollweg (1974) equation relating felt area to magnitude.

For larger historical earthquakes, the felt area, even if available, does not provide a reliable estimate of magnitude. For these earthquakes, and for some others down to M5, the descriptions of macroseismic effects in the epicentral region are often scarce, exaggerated or unreliable and magnitude estimates can best be made on the basis of intensities assigned at greater distances. The intensity values considered the most reliable are plotted as a function of epicentral distance and a magnitude is selected (to the nearest half-magnitude) on the basis of intensity fall-off relations for Eastern Canada.

For earthquakes that do not fall into one of the above three categories, magnitudes are computed from epicentral intensity (I_o), using the Gutenberg and Richter (1956) formula

$$M = 1 + 2/3\, I_o$$

In both the Canadian (Smith 1962, 1966) and U.S. (Coffman and von Hake, 1973) historical earthquake catalogs the epicentral intensities listed are often "maximum reported intensities". In the review of the macroseismic information available for these earthquakes an intensity more representative of the general macroseismic effects in the epicentral region has been assigned where possible. It is this better estimate of epicentral intensity (I_o) that is used to estimate magnitude.

ALGERMISSEN DATA BASE

Algermissen compiled a catalog of earthquakes for the United States that was based on earthquake data from a variety of sources. Prior to 1966, his major sources are U.S. Earthquakes, Earthquake History of the United States, the Townley and Allen Catalog of Earthquakes on the Pacific Coast, the Reid Catalog, and data for California collected by the California Department of Water Resources. Various published and unpublished catalogs developed for specific states or regions were also reviewed and integrated into the data base. From 1966-1975, Algermissen's data are primarily taken from NOAA's Preliminary Determination of Epicenters and from U.S. earthquakes.

The epicentral intensity data in Algermissen's compilation primarily have been taken from the various sources used in developing the base. However, some new intensity assignments were made on the basis of descriptive information presented in the sources, when no assignment has been previously made. He also re-evaluated intensities when major decrepancies among the various sources were enccuntered.

2.0 DATA BASE INTEGRATION

In order to produce a complete data set for the Eastern United States, the above data bases were combined in the following manner. The regions covered by the Nuttli and Chiburis data bases were first defined based on instrumental coverage and extent of the historical record. Within these regions, described in Figure 1, the respective bases were extended in time, if necessary, to 1977 by the NEIS data. The Canadian data base, although available for all of Eastern Canada, was given preference over NEIS and the Chiburis data in the region indicated in Figure 1 along the Saint Lawrence Seaway. Finally, for Southeastern United States, the Algermissen data base, extended by NEIS up to 1977, was used. We recognize that Professor Bollinger has carefully reviewed the earthquake data in this region and that his data represent a superior data set. However, the data set was not immediately available on computer cards and since this region is several hundred miles from sites under consideration, it was considered most expedient to use the Algermissen data.

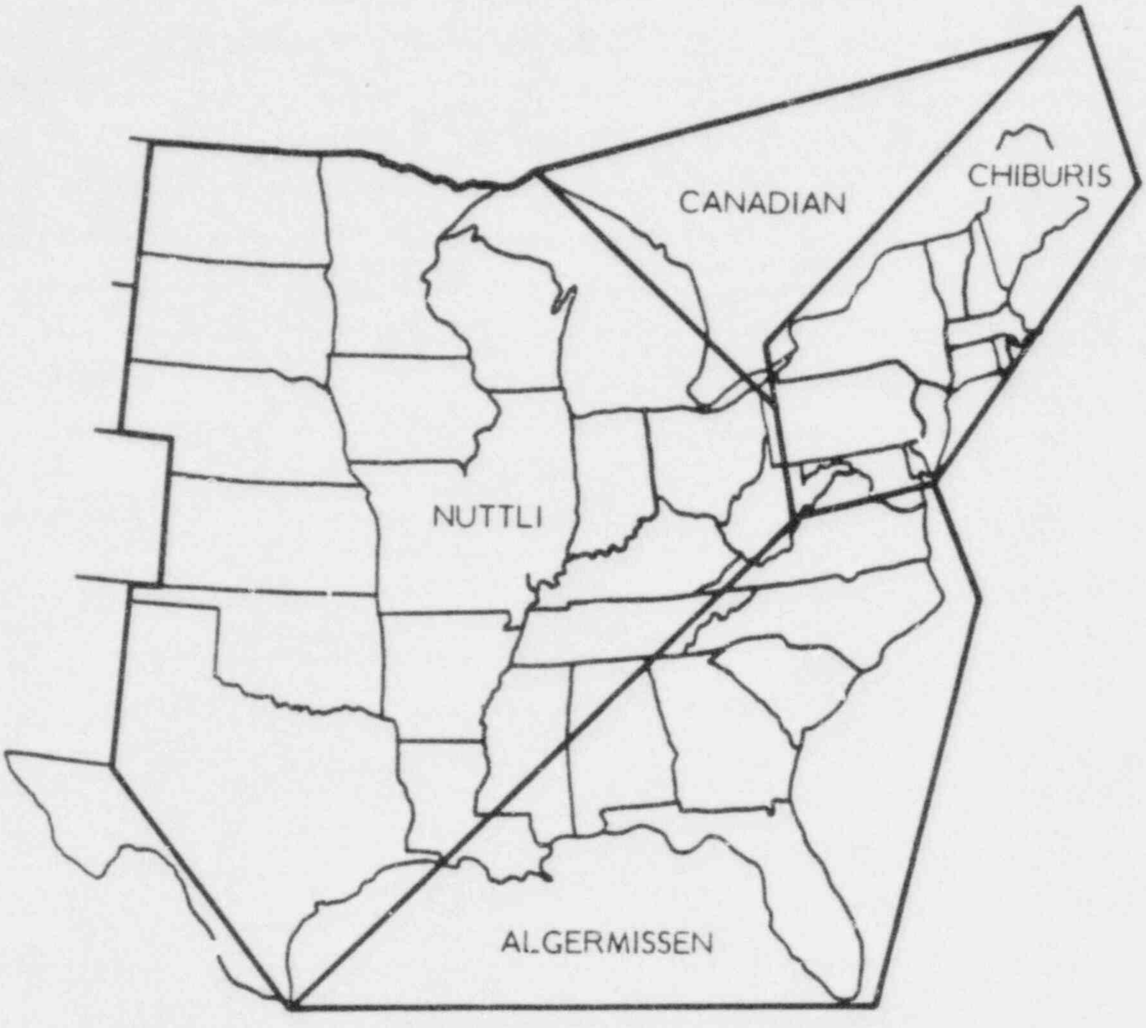


FIGURE 1

SEISMIC DATA BASE REGIONS

3.0 COMMON MAGNITUDE AND INTENSITY SCALE

The above data bases present the size of the earthquake in any of several ways. Intensity could be either Rossi-Forel or Modified Mercalli and magnitude could be m_b, M_s, M_L, or M_{Lg}.

Converting Intensities is not a problem since all the data bases discussed above report Modified Mercalli Intensity and perhaps, secondarily, Rossi-Forel. The Intensity plots presented in the following sections, therefore, will in all cases represent the MM Intensity.

The magnitude scale is more difficult to deal with. All the magnitudes were converted into a single value, and for engineering purposes the local magnitude scale was used. (Of course, reported local magnitudes are not always specifically the Richter local magnitude; there is, therefore, a potential inconsistency within the M_L scale.)

In the plots supplied with the questionnaire, we use the conversion techniques developed by Brazee (1976) for his analysis of earthquake recurrence. His relationships are

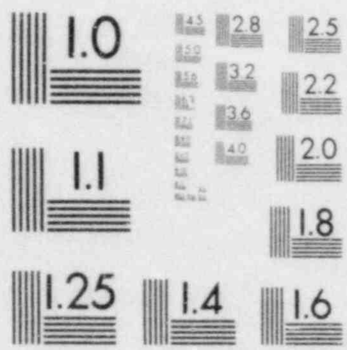
$$M_L = 1.34\, m_b - 1.71$$

$$M_L = 2.20 \left[M_S - 3.80 \right]^{1/2} + 2.97$$

and we here make the implicit assumption that m_b is approximately equal to M_{Lg}.

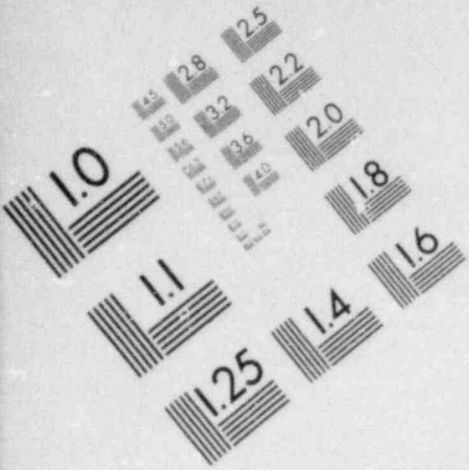
The intensity data and the magnitude data were presented separately to facilitate review.

IMAGE EVALUATION
TEST TARGET (MT-3)



6"

MICROCOPY RESOLUTION TEST CHART



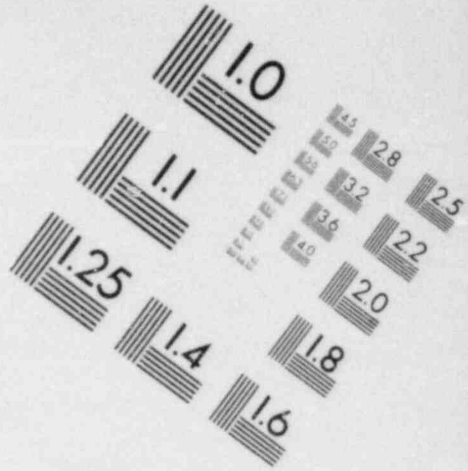
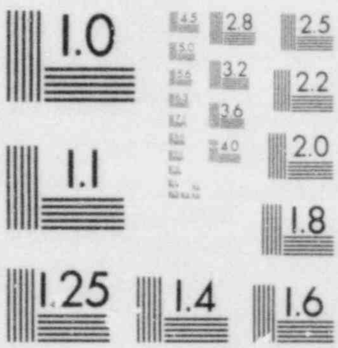
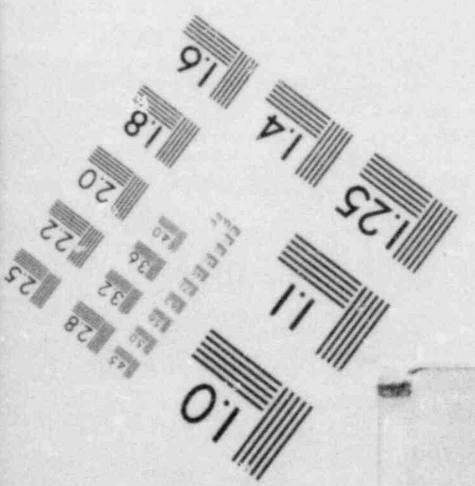


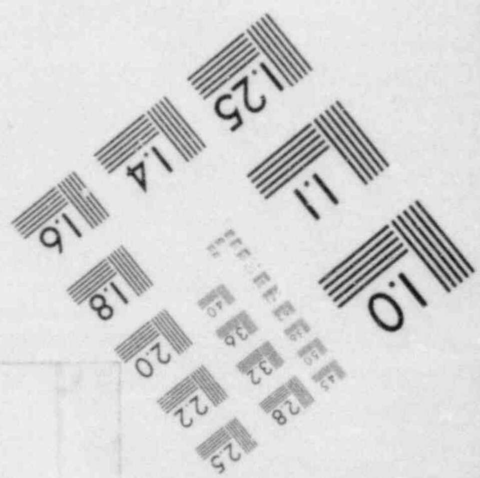
IMAGE EVALUATION
TEST TARGET (MT-3)



6″

MICROCOPY RESOLUTION TEST CHART





4.0 VALIDITY OF THE INTENSITY SCALE

Early records of earthquakes in the United States, with events described by a maximum intensity, are often used for seismicity and seismic risk studies. An implicit assumption, which is difficult or impossible to avoid, is that an intensity VII, say, earthquake in the early catalogs was the same "size" as an intensity VII earthquake of recent history. In earthquake engineering this assumption sometimes takes the form of using records from recent VII earthquakes to estimate the amplitudes of ground motion that the earlier earthquakes of the same intensity may have caused. Thus, it is important to test whether an early event which is classified, again say as a VII, really implies the same amplitudes as recent intensity VII events.

This analysis, which was conducted by John Anderson (USC), attempts to test that assumption by looking for changes with time of the felt areas and the magnitudes of earthquakes at fixed maximum intensity. The test is applied to shocks with maximum Modified Mercalli Intensity (MMI) V, VI, VII and VIII. If the meaning of one of these intensity levels has evolved with time, for example with changes in construction practices, then the amplitudes of shaking needed to cause that intensity level may increase or decrease. Hopefully, these will cause a corresponding increase or decrease in the felt areas and the magnitudes. Reasons for the use of magnitude are obvious, as it supposedly represents an objective measure of the size of the earthquake. The felt area could not be expected to change because it depends on the sensitivity of people to feel the weak earthquake motions at low intensity levels, and there is no reason to assume that the sensitivity of people to weak motions has changed with time. Nuttli (1976) and Nuttli and Zollweg (1974), among others, have suggested that the felt area can be used to estimate the magnitude of the earthquake. It is also relevant that estimates for the felt areas of earthquakes exist for long periods before instrumental magnitude estimates began to be assigned to most earthquakes, thus suggesting the possibility of calibration over a longer time interval.

The test was applied for four regions of the United States and for maximum intensities of V, VI, VII, and VIII. The most frequent result is that an earthquake with some selected intensity tended to have larger felt areas and larger magnitudes before 1945 than for the time period from 1946 to the present. However, the changes are statistically significant in only a few of the cases considered. The result suggests that some of the older events could be under-rated in currently used catalogs of United States seismicity; this could lead to systematic underestimation of seismic risk when the seismicity is derived from these listings of earthquakes by maximum intensity.

PART II

TABULATION OF EXPERT RESPONSE

I.0 SOURCE ZONE CONFIGURATIONS

In this section of the questionnaire we were concerned with the specification of various areas or regions that appear to be unique in their potential to generate earthquakes. In particular, we were seeking in this section the definition of regions within which future earthquake activity should be homogeneous. The experts were provided with two possible seismic zonations of the Eastern United States with zones numbered one to nineteen. Although the western boundary of these maps is at 96°W, our region of interest extends to the Rocky Mountain front, or roughly 104°W. They were asked to carefully review these figures and to indicate where they thought they might be inadequate. The experts were further asked, for the purpose of analysis, to specify integer labels for the zones they postulated as modifications to the base map, and the credibility (in terms of percent) for these zones. For the purpose of cross-reference between the experts we created a common numbering system for these new zones by lumping similar zones under one integer (e.g., all modifications of the Attica zone are labeled "zone 48" in the common numbering system). Table I-1 matches our numbering code to that of the individual experts, along with the respective zones' credibilities. Appendix C contains the maps drawn by the experts describing the alternatives they preferred for source zone configuration.

In addition to this macrozonal analysis, the experts were asked in question I-5 to consider microzones relevant to the sites, such as tectonic structures, which could be active or otherwise serve to localize activity. The map created by each expert is presented in Appendix C along with the two base maps provided.

QUESTION I-1

The experts were asked to carefully review the source zones specified in the base maps "Figures 1 and 2" of the answer booklet. They should feel free to modify, combine, add or delete zones where necessary, and to indicate only those regions that in their minds are very reasonable.

In following questions they were asked to speculate on less likely source regions and local tectonic structures.

They were further asked to summarize their zonation and to assign, as a percentage, their "degree of belief" in all of the seismic source regions, both theirs and the zones in Figures 1 and 2. Zero credibility or "degree of belief" corresponds to zero percent.

The following table summarizes the experts' response. Our own numbering code, found in the left hand column preceding the zone names, is matched to the experts' own numeration of zones, found in parenthesis. The experts are ordered according to those answering in MMI (3, 4, 5, 10, 13) and in those answering in m_b (7, 8, 9, 11, 12).

NEW MADRID AND WESTERN ZONES ZONE CREDIBILITY % EXPERT'S OWN ZONE NUMERATION ( )

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.
1	NEW MADRID	75	70	50	30	95	20	10	50	60	30
2	NEW MADRID	90	30	10	70	60	30	50	90	85	70
20	NEW MADRID	90 - (28)					80 - (23)	90 - (29)			
21	WABASH								80 - (20)		75 - (24)
22	OZARK UPLIFT								80 - (21)		60 - (23)
23	MISSISSIPPI				80 - (21)		80 - (24)	85 - (30)		80 - (23)	
10	UPPER KENEENAW	50	20	5	20	20	10	80	50	20	0
11	ANNA, OHIO	90	60	5	50	30	70	95	80	80	50
30	ANNA, OHIO						70 - (27)				
18	CENTRAL STABLE REG.	75	90	50	40	90	30	5	50	50	80
19	CENTRAL STABLE REG.	90	90	50	80	90	30	5	50	50	100
27	CENTRAL STABLE REG.	90 - (19)					80 - (26)	80 - (32)		75 - (28)	
28	S. ILLINOIS	80 - (29)		60 - (21)							
29	N. ILLINOIS						80 - (22)		60 - (22)		
24	OUACHITA						80 - (20)		90 - (23)		25 - (22)
25	NEMAHA RIDGE				60 - (24)		80 - (21)		75 - (24)	50 - (29)	
26	N. GREAT PLAINS						80 - (25)		70 - (25)		

QUESTION I-1

NORTH EASTERN ZONES — ZONE CREDIBILITY % — EXPERTS' OWN ZONE NUMERATION ( )

NO.	ZONE NAME	3 % Exp. Zone No.	4 % Exp. Zone No.	5 % Exp. Zone No.	10 % Exp. Zone No.	13 % Exp. Zone No.	7 % Exp. Zone No.	8 % Exp. Zone No.	9 % Exp. Zone No.	11 % Exp. Zone No.	12 % Exp. Zone No.
3	ATTICA	90	30	5	20	60	40	85	60	50	20
4	ATTICA	60	80	10	50	60	75	20	70	90	80
48	ATTICA				75 - (22)			75 - (28)			
5	S.ST.LAWRENCE	50	80	20	40	95	70	0	65	40	100
33	S.ST.LAWRENCE		80 - (5)							90 - (21)	
6	N.ST.LAWRENCE	75	100	20	90	90	70	0	75	75	20
31	N.ST.LAWRENCE	75 - (26)	100 - (6)			90 - (6)		100 - (21)		90 - (22)	90 - (21)
32	N.ST.LAWRENCE				90 - (20)	95 - (22)		90 - (20)			
8	CAPE ANN	70	90	30	30	95	60	40	50	80	40
45	S. NEW ENGLAND		90 - (25)			80 - (21)		80 - (27)			
46	N.E.MASS. THRUST COMPLEX							90 - (25)			
47	CAPE ANN							85 - (33)			
50	N. APPALACHIANS	75 - (23)								60 - (20)	

QUESTION I-1

NORTH EASTERN ZONES (CONT.) ZONE CREDIBILITY % EXPERTS' OWN ZONE NUMERATION ( )

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.	% Exp. Zone No.
7	BOSTON-OTTAWA	70	0	20	10	60	50	0	40	0	0
39	BOSTON-OTTAWA	80 - (24)				30 - (20)					
9	ADIRONDACK	75	50	30	40	80	60	85	60	30	50
34	ADIRONDACK	75 - (25)									
35	W. NEW ENGLAND							90 - (22)			
36	GREEN MT. BELT			60 - (23)		70 - (23)					
37	OSSIPPE INTRUSIVE							85 - (34)			
38	OTHER WHITE MT. INTRUSIVE							80 - (35)			
40	MAINE	60 - (27)	90 - (20)		70 - (23)			85 - (23)		50 - (27)	75 - (20)
41	WEST CENTRAL NEW BRUNSWICK		50 - (23)								
42	PASSAMAQUODDY		100 - (22)								
43	BELFAST DOVER FOXCRAFT		80 - (21)								
44	COASTAL ANTICLINORIUM							60 - (24)			

QUESTION I-1

SOUTH EASTERN U.S. ZONE CREDIBILITY % EXPERTS' OWN ZONE NUMERATION ( )

NO.	ZONE NAME	1		4		5		10		13		7		8		9		11		12	
		%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.	%	Exp. Zone No.
56	E. STABLE PLATFORM													80 - (31)							
12	S. APPALACHIA	75		50		10		50		60		60		85		80		0		90	
51	S. APPALACHIA	90 - (22)																			
13	PIEDMONT	30		60		30		80		80		60		10		80		0		90	
52	PIEDMONT	75 - (21)				70 - (20)								80 - (26)				75 - (26)			
53	CENTRAL VIRGINIA	75 - (21A)																75 - (25)			
14	NORTHERN VALLEY AND RIDGE	50		60		10		50		0		60		60		50		0		90	
15	APPALACHIAN PLATEAU	20		80		20		30		20		20		70		70		0		90	
16	CHARLESTON	30		100		10		30		90		90		75		80		70		75	
55	CHARLESTON	90 - (20)																			
17	ATLANTIC COASTAL PLAIN	30		80		20		80		80		40		60		70		0		75	
49	ATLANTIC COASTAL PLAIN	0 - (17)																			
54	WILMINGTON																	75 - (24)			
57	GULF COASTAL PLAIN															60 - (26)					

QUESTION I-1

QUESTION I-2

To what factor(s) do you attribute the somewhat uniformly spread seismicity over large regions in the Eastern United States? If you feel that several factors are responsible for this situation, rank them on a scale of 0 to 100 (100 being the most important).

THE SEISMICITY IN THE EASTERN U. S. IS	#3	#4	#5	#7	#8	#9	#10	#11	#12	#13
The manifestation of truly random seismicity capable of occurring anywhere.				90		75	50		yes	yes
An artifact resulting from inadequate instrumental or population coverage.		25			20	30				
Likely to be associated with unidentified features	yes	50	100	50	40	60	70	33		
Other (see below)		50*			60*			100*		

THIS ANSWER APPLIES	#3	#4	#5	#7	#8	#9	#10	#11	#12	#13
Only to the so-called background seismicity in, for example, the central stable region.				yes		yes			yes	yes
Over the whole eastern U. S.	yes	yes	yes		yes		yes	yes		

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* OTHER FACTORS

Respondent 4. Intraplate mechanisms presently poorly understood.

Respondent 8. Associated with TECTONIC structures identified through geophysical/geological studies.

Respondent 11.
a. Significant seismicity is related to pre-existing features.
b. Orientation and magnitude of principal stresses WRT pre-existing faults controls locations of earthquakes.
c. The uniform spread of seismicity at first glance implies a uniform distribution of faults and uniform stress field (see comment).

QUESTION I-2

COMMENTS

Respondent 4

In the northeastern U. S., the seismicity, both current and historical, is not all random. Whether it is truly recurrent or temporarily well-behaved is presently under study.

Respondent 8

A TECTONIC structure is understood here to comprise:

a. Geological features of limited extent: faults, intrusions, etc.

b. Broad crustal zones of inhomogeneity, structural or lithological in nature.

Respondent 9

I believe that earthquakes of $m_b \leq 5$ can occur anywhere in the eastern U. S., including the central stable region.

Large earthquakes, on the other hand, are most likely associated with structural features, some or perhaps the majority of which are not presently identified.

I believe that every earthquake, even the small ones, must be associated with some structural feature where stress can concentrate. Most of these minor structural features will probably remain unidentified.

Concerning the genesis of the larger earthquakes, the most difficult problem is to distinguish between inactive and active major structural features.

Respondent 11

In detail, neither the stress field nor the distribution of pre-existing faults is uniform. I believe (and some data suggests) that the stress field varies radically over short distances (100 km) in some areas, such as along the northeast coast of the U. S. In other areas it varies more gradually. There may be a reduction in the deviatoric stress from east to west (highly speculative).

Large faults are needed for large earthquakes. These only exist in a few places, localizing major earthquakes.

QUESTION I-2

COMMENTS (Cont.)

Respondent 12

Within the remainder of eastern U. S., it is my opinion that there exist areas of larger and potentially more damaging seismicity due to localized stress anomalies.

Respondent 13

Other seismic zones may be correlated with some identified features and some unidentified features.

QUESTION I-3

Focus now specifically on zones 18 and 19, representing two models of the Central Stable Region. These regions extend to the Rocky Mountain front even though it is not shown on the map. Do you believe that the seismicity can be considered homogeneous over this whole region or should it be divided in subzones. For example, some investigators have suggested that the Michigan Basin or Northern Illinois should be considered as independent subzones. Be sure to consider possible zones that might lie to the west of the map boundary, such as the Nemaha uplift. In case you decide to add subzones, draw them on the map, number them, and add them to Table I-I. They will be considered as independent zones in the rest of the questionnaire.

Respondent 3

Zone 19 (as modified) seems reasonable to me. However, minor zones should be added (off of Figures 1 and 2) for:

1. SW South Dakota - NW Nebraska
2. Nemaha in Oklahoma
3. NW Missouri - E Kansas - SE Nebraska

Zones that I do not feel as necessary are in:

1. No. Illinois,
2. Western Ohio (more than your zone 11).

While there have been historic events in these areas, they were extremely sporadic and separated by long time intervals. Modern levels of instrumental monitoring have not detected current activity from those areas.

Respondent 4

Homogeneous seismicity in these zones, with the possibility of microzones being included, s[illegible] as zones 10 and 11.

Respondent 5

I do not believe that the seismicity in this area is uniform or homogeneous. However, I do not think it can adequately be represented by subzones either. The rate of earthquake occurrence may be somewhat higher in certain localities, but I think the same basic process is going on everywhere.

Respondent 7

Use subzones 24(20), 25(21), 26(25), 27(26), 29(23), 30(27)

Respondent 8

Division into subzones preferred.

Respondent 9

As I have indicated on the maps and in Table I-1, I believe zones 18 and 19 are not homogeneous over their entire extent, and that there should be subzones included in them.

I do not feel too comfortable about identifying the upper Keweenaw (zone 10) region as a separate source zone. Some of the events reported as earthquakes may have been rockbursts associated with mining activity.

Respondent 10

The Nemaha Uplift region could be a separate seismic zone.

Respondent 11

These localized spots of activity should be singled out. The chance of repeated activity in these areas is higher than in the largeness of 18 and 19. I suspect that other small zones may be identified in the future.

Respondent 12

--

Respondent 13

Not enough data to divide into subzones.

QUESTION I-4

Please list in the answer booklet more speculative source regions and indicate your degree of belief in each. One example of this is a postulated connection between the St. Lawrence, Ohio and New Madrid source zones (frequently referred to as Woollard's Line). If your degree of belief in these sources is high, you may decide to consider them as independent zones throughout the questionnaire.

SPECULATIVE SOURCE REGIONS

#	ZONE NAME	RESPONDENT NO.	CREDIBILITY (PERCENT)
53	CENTRAL VIRGINIA (NORFOLK FRACTURE)	3	75
52	PIEDMONT APPALACHIA	5	70
41	W. CENTRAL NEW BRUNSWICK	4	50
25	NEMAHA RIDGE IN OKLAHOMA	3	40
	S.W. SOUTH DAKOTA - N.W. NEBRASKA	3	40
	N.W. MISSOURI - E. KANSAS - S.E. NEBRASKA	3	40
	N. NEW HAMPSHIRE - E. MAINE - S. MOST QUEBEC	11	30
24	OUACHITA FOLDBELT AND TECTONIC FRONT	12	25
29	N. ILLINOIS	3	20
30	W. OHIO (ANNA)	3	20
	CHARLESTON CUMBERLAND	3	20
7	BOSTON-OTTAWA TREND	5	20
	WOOLARDS LINE	3	10
	WOOLARDS LINE	5	10
	WOOLARDS LINE	10	10
	WOOLARDS LINE	12	0
	NEW MADRID TO GULF COAST	7	10
	MIDCONTINENTAL GEOPHYSICAL ANOMALY	7	10
	ROUGH CREEK - COTTAGE GROVE FAULT ZONE	7	0
	KENTUCKY RIVER FAULT ZONE	7	0

QUESTION I-5

Now consider tectonic features that are local to the sites. Please list any features which could be generators or localizers of earthquakes. What, in your judgment, is the probability that these features are active or serve to localize seismicity.

TECTONIC FEATURES LOCAL TO SITES

Zone No.	Name of Feature or of Zone	Respondent	Probability of Being Active %	Uncertainty In This Probability (± %)
	NEW MADRID AND WESTERN ZONES			
1,2	NEW MADRID FAULT ZONE	9	100	0
20(28)**	NEW MADRID FAULT ZONE	3	100	10
20(27)	NEW MADRID FAULT ZONE	8	85	10
2	FAULT IN SUBSURFACE (NEW MADRID)	11	100	10
2	MISSISSIPPI EMBAYMENT (NEW MADRID)	12	90	10
19	COTTAGE GROVE - ROUGH CREEK FAULT	9	10	30
28(29)	ST. GENEVIEVE - COTTAGE GROVE - ROUGH CREEK	3	90	10
22(21)	ST. GENEVIEVE FAULT	9	30	50
21(20)	WABASH VALLEY FAULT ZONE	9	80	20
24(23)	OUACHITA	9	70	20
25(24)	NEMAHA	9	60	30
29(22)	SANDWICH FAULT	7	30	20
29(22)	SANDWICH FAULT - PLUM RIVER FAULT	9	50	30
27(26)	KANKAKEE ARCH	7	10	20
11	ANNA	8	95	10
	NORTH EASTERN ZONES			
4	CLARENDON LINDEN FAULT	3	90	10
3,4	CLARENDON LINDEN FAULT	4	70	30
3	CLARENDON LINDEN FAULT	7	20	20
4	CLARENDON LINDEN FAULT	9	60	30
4	CLARENDON LINDEN FAULT	10	95	20
4	CLARENDON LINDEN FAULT	11	100	0

QUESTION I-5

(CONT.)

Zone No.	Name of Feature or of Zone	Respondent	Probability of Being Active %	Uncertainty In This Probability (± %)
	NORTH EASTERN ZONES (cont'd)			
3	ATTICA	8	85	10
33(21)	N-S TO NW TRENDING FAULTS (S. ST. LAWRENCE)	11	50	25
6	CHARLEVOIX METEORITE IMPACT CRATER (N.St.Lawrence)	11	100	10
5	ADIRONDACK UPLIFT	12	50	25
39(20),36(23)	POST GLACIAL UPLIFTING (NEW ENGLAND)	13	50	20
37(34)	OSSIPPE INTRUSIVE	8	85	10
38(35)	OTHER WHITE MOUNTAIN INTRUSIVE	8	80	10
40(20)	PLUTONS (MAINE)	12	50	25
8	PLUTONS (CAPE ANN)	12	50	25
8	INTRUSIONS (CRUSTAL WEAKNESS)	13	60	20
47(33)	CAPE ANN STRUCTURE	8	85	10
45(21)	INTRUSIONS (S. NEW ENGLAND)	13	50	50
36(23)	SOUTH CENTRAL CONN.	5	*(See Comment)	
13	CONN. TRIASIC BASIN BORDER FAULT	10	60	30
	SOUTH EASTERN U.S.			
50(20)	NORTH EAST TRENDING FAULTS (NORTH APPALACHIA)	11	50	25
12,13	UPLIFTING (APPALACHIA)	13	60	30
53(21A),50(23)	TRIASIC BASINS (APPALACHIA - W. VA.)	3	60	30
13	RAMAPO FAULT (PIEDMONT)	10	75	20
16	FAULT IN SUBSURFACE NEAR SUMMERVILLE	11	100	10
16	INTRUSIONS (CHARLESTON)	13	50	20

* Stress concentrator(s) exist in S. Central Conn. The location and strength of these is not well known.

** The numbers in parentheses are the experts' own zone numbers.

2.0 MAXIMUM EARTHQUAKES

In this section, we addressed the question of determining the size of the largest event that could be expected to occur in each of the source zones for a given time period in the future. Since extrapolation of results from short time periods to very long ones is controversial due to possible long term variations in seismicity and other parameters, we explicitly considered two distinct time periods. The first one was chosen to be 150 years since it is generally on the order of our time period of interest and approximately equivalent to the length of recorded history in the East. The second time period was chosen to be 1,000 years since such a period covers most non-catastrophic perturbations in seismic activity and leaves out the uncertainties associated with the extremely long-term geological variations which are outside the scope of this questionnaire. Also considered was the largest event that could be expected to occur within the current tectonic framework in each source zone without any specification of time.

The experts were asked to base their answers not only on the recorded data, but also on their feelings as to whether the past history is a good estimator of the true state of nature and whether the future activity is likely to be similar or different from the past. This feeling could be based on any external source of information such as tectonics, theoretical studies, similarity with other regions in the world, or simply educated judgment. The experts could answer either in terms of magnitude or MMI.

This section is divided into two parts. In the first part (questions 2-1 through 2-5), we considered the size of the largest event expected to occur in a zone. In other words, knowing that a certain number of earthquakes will occur, we are interested in determining the size of the largest one and the uncertainty associated with that size. In the second part (questions 2-6 through 2-10), we considered the return period of the largest event.

QUESTION 2-1

What measure of the earthquake size are you going to use throughout this questionnaire?

Respondents 3, 4, 5, 10 and 13 chose to answer in terms of MMI.

Respondents 7, 8, 9, 11 and 12 chose to answer in terms of m_b.

QUESTIONS 2-2 TO 2-5

2-2 In the current tectonic framework and independent of the period of time ("unconstrained time period") what is the size of the largest earthquake that you expect to occur within each zone?

2-3 For each of the two time periods, 150 years and 1,000 years, what is the size of the largest earthquake that you expect to occur within each zone?

2-4 For each of the two time periods, 150 years and 1,000 years, assume that within the next 10 years your lower bound estimate of the largest event actually occurs in a zone. How would this change your answers to 2-3? If you answered question 2-3 with a best estimate only, skip this question.

2-5 For each of the two time periods, 150 years and 1,000 years, assume that within the next 10 years the upper bound estimate of the largest event actually occurs in a zone. How would this change your previous answer to 2-3?

- The following tables are a compilation of the answers given to these questions. The zones have been divided for easier reference into three regions: New Madrid and Western Zones, Northeastern Zones, and South Eastern U. S.

  The answers were given as either a best estimate (in which case only one value is shown in the table for a given expert in a given zone), or as a spread of values, lower bound estimate - best estimate - upper bound estimate. Where the expert gave no answer for a zone from the base map a dash (-) was inserted to indicate "no answer." Where there is a blank space it indicates that the given zone was not even considered by the expert (e.g., zonal modifications not postulated by the expert).

- Please refer to Appendix B for further comments of experts five and seven, and explanation of their response to this section.

NEW MADRID AND WESTERN ZONES

NO.	ZONE NAME	3	4	5	10		7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
1	NEW MADRID	X-XI-XII	VI-VIII-X	XII	XII	XI-XII-XII	7.3-7.5-7.7				7.5
2	NEW MADRID	X-XI-XII		XII	XII		7.3-7.5-7.7				7.5
20	NEW MADRID	X-XI-XII					7.4-7.5-7.7	7.5	7.5-7.6-7.7	7.5-7.5-7.75	
21	WABASH								5.7-6.7-7.0		5.5
22	OZARK UPLIFT								5.7-6.8-7.0		5.5
23	MISSISSIPPI				XII		6.4-6.6-6.8	6.4		5.5-6.0-6.5	
10	UPPER KENEENAW	VII-VIII-IX	V-VI-VIII	XII	VIII	-	6.0-6.3-6.3	4.5	5.5-6.2-6.5	5.0-5.5-6.0	
11	ANNA, OHIO	VI-VII-VIII			VIII		6.2-6.4-6.6	6.0	5.5-6.7-7.0	5.0-5.75-6.0	5.0-5.5
30	ANNA, OHIO						6.2-6.4-6.6				
18	CENTRAL STABLE REG.	VI-VII-VIII	V-VI-VIII	XII	-	-	6.3-6.5-6.8	-	5.2-5.5-5.7	-	4.5 - 5.0
19	CENTRAL STABLE REG.	VI-VII-VIII		XII	-	-	6.3-6.5-6.7	-	5.5-5.7-6.0	-	4.5 - 5.0
27	CENTRAL STABLE REG.						5.0-5.3-5.5	4.5		5.0-5.5-6.0	
28	S. ILLINOIS	VIII-IX-X		XII							
29	N. ILLINOIS								5.8-6.2-6.4		
24	OUACHITA						6.1-6.3-6.5		5.7-6.4-6.7		4.5-5.0
25	NEMAHA RIDGE				VIII-IX-X		6.2-6.4-6.6		5.8-6.5-6.7		
26	N. GREAT PLAINS						5.8-6.0-6.2		5.5-6.2-6.5		

(See appendix)

QUESTION 2-2

NORTH EASTERN ZONES

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
3	ATTICA	VII-VIII-IX		XII	VIII-X-XI		6.0-6.3-6.4	5.6			5.0 - 5.5
4	ATTICA	VII-VIII-IX	VI-VIII-X	XII	VIII-X-XI		6.0-6.3-6.4		5.7-6.7-7.2	6.0-7.0-7.0	5.0 - 5.5
48	ATTICA				VIII-X-XI			4.5			
5	S.ST.LAWRENCE	VIII-IX-X		XII	IX-X-XI	IX-X-XI	6.8-7.0-7.2		6.2-7.2-7.7		6.5 - 7.0
33	S.ST.LAWRENCE		VIII-X-XII							5.75-6.5-7.0	
6	N.ST.LAWRENCE	IX-X-XI		XII	XII		7.1-7.3-7.5		6.7-7.2-7.7		6.5 - 7.0
31	N.ST.LAWRENCE	IX-X-XI	VIII-X-XII			-		7.3		7.0-7.25-7.5	6.5 - 7.0
32	N.ST.LAWRENCE				X	IX-X-XI		6.5			
8	CAPE ANN	IX-X-XI	VI-VIII-X	XII	VII-VIII-XI	IX-X-XI	6.2-6.4-6.7		5.7-6.2-6.7	6.0-6.5-7.0	5.75 - 6.25
45	S. NEW ENGLAND		VI-VIII-IX			VII-IX-X		4.5			
46	N.E.MASS. THRUST COMPLEX							5.0			
47	CAPE ANN							6.0			
50	N. APPALACHIANS	VI-VII-VIII								5.5-6.0-5.5	

(See appendix)

QUESTION 2-2

NORTH EASTERN ZONES (Cont.)

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
7	BOSTON-OTTAWA	IX-X-XI		XII	IX-X-XI		6.8-7.0-7.2		6.2-6.7-7.0		5.75-6.25
29	BOSTON-OTTAWA	IX-X-XI				VIII-IX-X					
9	ADIRONDACK	VI-VII-VIII		XII	VIII-IX-X		6.1-6.3-6.5	5.5	5.2-6.0-6.2		5.75-6.25
34	ADIRONDACK	VI-VII-VIII									
35	W. NEW ENGLAND							4.5			
36	GREEN MT. BELT			XII		VIII-IX-X					
37	OSSIPPE INTRUSIVE							6.0			
38	OTHER WHITE MT. INTRUSIVE							5.5			
40	MAINE	VI-VII-VIII	VII-VIII-IX		VIII-IX-X			5.0	-		5.75-6.25
41	WEST CENTRAL NEW BRUNSWICK		V-VI-VIII								
42	PASSAMAQUODDY		VI-VIII-IX								
43	BELFAST DOVER FOXCRAFT		VII-VIII-IX								
44	COASTAL ANTICLINORIUM							5.0			

(See appendix)

QUESTION 2-2

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
56	E. STABLE PLATFORM							4.5			
12	S. APPALACHIA	VIII-IX-X	V-VI-VIII	XII	IX	VIII-IX-X	6.3-6.5-6.8	5.6	5.7-6.5-6.7	-	5.5-6.0
51	S. APPALACHIA	VIII-IX-X									
13	PIEDMONT	VII-VIII-IX	VI-VIII-IX	XII		VII-IX-X	6.3-6.5-6.7		5.2-6.0-6.5		5.0-5.5
52	PIEDMONT	VII-VIII-IX		XII	-			5.0		-	
53	CENTRAL VIRGINIA	VI-VII-VIII								-	
14	NORTHERN VALLEY AND RIDGE	VI-VII-VIII	V-VI-VIII	XII	-	-	5.6-5.8-6.2	4.5	4.7-5.7-6.0	-	5.0-5.5
15	APPALACHIAN PLATEAU	VI-VII-VIII	V-VI-VIII	XII	-	VII-VIII-VII	6.1-6.3-6.5	4.5	5.2-6.0-6.2	-	4.5-5.0
16	CHARLESTON	IX-X-XI	VI-VIII-X	XII	X-XI-XII	X-X-XI	6.7-6.8-7.0	7.3	7.0-7.2-7.5	6.0-6.75-7.0	6.5-7.0
55	CHARLESTON	IX-X-XI			-						
17	ATLANTIC COASTAL PLAIN		V-VI-VIII	XII	-	VII-VIII-VII	6.1-6.3-6.5	5.0	5.7-6.2-6.5	-	4.5-5.0
49	ATLANTIC COASTAL PLAIN	VI-VII-VIII									
54	WILMINGTON									-	
57	GULF COASTAL PLAIN								5.0-5.5-5.7		

(See appendix)

QUESTION 2-2

NEW MADRID + WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
1	NEW MADRID	1 2	IX XI	VI-VIII-X VI-VIII-X		- XII	- XI-XII-XII	6.3-6.5-6.7 7.3-7.5-7.7				6.25-6.5-6.75 7.5
2	NEW MADRID	1 2	IX XI		-	- XII		6.2-6.4-6.6 7.3-7.5-7.7				6.25-6.25-6.75 7.5
20	NEW MADRID	1 2	IX XI					6.5-6.7-6.9 7.4-7.5-7.7	6.7 7.2	6.0-6.6-7.0 7.4-7.5-7.7	5.5-6.0-7.75 7.5-7.5-7.75	
21	WABASH	1 2								5.5-5.7-6.0 5.7-6.6-6.8		4.5-5.25 5.5
22	OZARK UPLIFT	1 2								5.6-5.8-6.1 5.7-6.7-6.9		4.5-5.25 5.5
23	MISSISSIPPI	1 2				XII		6.0-6.3-6.4 6.4-6.6-6.8	5.6 6.0		5.0-5.5-6.0 5.9-6.0-6.5	
10	UPPER KENEENAW	1 2	VII VIII	V-VI-VII V-VI-VIII	-	- IX	-	5.5-5.7-5.9 6.0-6.3-6.3	3.5 4.0	5.1-5.3-5.4 5.5-6.2-6.3	5.0-5.0-6.0 5.0-5.25-6.0	
11	ANNA, OHIO	1 2	VI VII		-	- IX	-	5.4-5.6-5.8 6.2-6.4-6.6	5.2 5.5	5.4-5.5-5.7 5.5-6.4-6.7	5.0-5.25-6.0 5.0-5.5-6.0	5.0-5.5 5.5
30	ANNA, OHIO	1 2						5.3-5.5-5.7 6.2-6.4-6.6				
18	CENTRAL STABLE REG.	1 2	VII VIII	V-VI-VII V-VI-VIII	-	- IX	-	5.6-5.9-6.1 6.3-6.5-6.8	-	4.2-4.4-4.7 5.0-5.3-5.5	-	4.5-5.0 5.0
19	CENTRAL STABLE REG.	1 2	VII VIII		-	- IX	-	5.6-5.9-6.1 6.3-6.5-6.7	-	4.3-4.6-5.0 5.4-5.6-5.9	-	4.5-5.0 5.0
27	CENTRAL STABLE REG.	1 2						4.7-4.9-5.1 5.0-5.3-5.5	3.5 4.0		4.0-4.5-5.0 5.0-5.5-6.0	
28	S. ILLINOIS	1 2	VIII IX		-							
29	N. ILLINOIS	1 2						5.2-5.4-5.6 5.9-6.1-6.3		5.0-5.2-5.5 5.5-6.1-6.2		
24	OUACHITA	1 2						5.6-5.9-6.0 6.1-6.3-6.5		5.7-6.3-6.6		5.0
25	NEMAHA RIDGE	1 2				IX		5.7-6.0-6.1 6.2-6.4-6.6		5.4-5.5-5.6 5.8-6.4-6.5		
26	N. GREAT PLAINS	1 2						5.3-5.5-5.7 5.8-6.0-6.2		4.8-5.1-5.5 5.5-6.0-6.3		

1 - 150 yrs, 2 - 1000 yrs

QUESTION 2-3

NORTH EASTERN ZONES

NO.	ZONE NAME		1 MMI	4 MMI	5 MMI	10 MMI	13 MMI	7 m_b	8 m_b	9 m_b	11 m_b	12 m_b
3	ATTICA	1	VII		-	X	-	5.3-5.5-5.7	5.2			5.0---5.5
		2	VIII				IX	6.0-6.3-6.4	5.4			5.5
4	ATTICA	1	VII	VI-VIII-X	-	X	-	5.3-5.5-5.7		5.5-5.7-5.8	5.0-5.5-7.0	5.0---5.5
		2	VIII				IX	6.0-6.3-6.4		5.7-6.7-7.2	6.0-6.75-7.0	5.5
4a	ATTICA	1				X			3.7			
		2							4.0			
5	S.ST.LAWRENCE	1	VII		-	X	-	5.6-5.8-6.0		5.8-6.0-6.2		6.0
		2	IX				IX-X-XI	6.8-7.0-7.2		6.2-7.0-7.2		7.0
33	S.ST.LAWRENCE	1		VII-IX-XI							5.0-6.0-6.0	
		2		VIII-X-XII							5.75-6.5-7.0	
6	N.ST.LAWRENCE	1	VIII		-	XII	-	5.6-5.8-6.0		6.0-6.2-6.8		6.0
		2	X				XI	7.1-7.3-7.5		6.7-7.2-7.5		7.0
31	N.ST.LAWRENCE	1	VIII	VII-IX-XI			-		6.7		6.0-6.5-7.5	6.0
		2	X	VIII-X-XII					7.0		7.0-7.25-7.5	7.0
32	N.ST.LAWRENCE	1				X	-		6.0			
		2					IX-X-XI		6.3			
8	CAPE ANN	1	VIII	VI-VIII-X	-	VIII	VIII-VIII-IX	5.7-5.8-6.1		5.2-5.3-5.4	5.0-5.5-7.0	5.0-5.25-5.5
		2	X				IX-X-XI	6.2-6.4-6.7		5.7-6.2-6.3	6.0-6.5-7.0	6.25
45	S. NEW ENGLAND	1		VI-VII-IX			VII-VIII-IX		3.7			
		2					VII-IX-X		4.0			
46	N.E.MASS. THRUST COMPLEX	1							4.5			
		2							4.7			
47	CAPE ANN	1							5.5			
		2							5.7			
50	N. APPALACHIANS	1	VII								4.0-4.5-5.0	
		2	VIII								5.0-6.0-6.0	

[1] 150 years [2] 1000 years

QUESTION 2-3

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
7	BOSTON-OTTAWA 1 2	VIII X		- 	X	– X	6.2-6.4-6.6 6.8-7.0-7.2		5.8-6.0-6.1 6.2-6.7-6.8	-	5.0-5.25-5.[illegible] 6.25
39	BOSTON-OTTAWA 1 2	VIII X				VII-VIII-VIII VIII-IX-X					
9	ADIRONDACK 1 2	VII VIII		-	– X	– VIII	5.7-5.9-6.1 6.1-6.3-6.5	5.0 5.3	5.0-5.2-5.7 5.2-5.9-6.2	-	5.0-5.25-5.5 6.25
34	ADIRONDACK 1 2	VII VIII									
35	W. NEW ENGLAND 1 2							3.5 4.0			
36	GREEN MT. BELT 1 2			-		VII-VIII-IX VIII-IX-X					
37	OSSIPPE INTRUSIVE 1 2							5.5 5.7			
38	OTHER WHITE MT. INTRUSIVE 1 2							4.8 5.2			
40	MAINE 1 2	VII VIII	VI-VI-VIII VII-VIII-IX		IX			4.5 4.7		5.75	5.0-5.25-5.5 6.25
41	WEST CENTRAL NEW BRUNSWICK 1 2		V-VI-VII V-VI-VIII								
42	PASSAMAQUODDY 1 2		VI-VII-VIII VI-VIII-IX								
43	BELFAST DOVER FOXCRAFT 1 2		VI-VI-VIII VII-VIII-IX								
44	COASTAL ANTICLINORIUM 1 2							4.5 4.7			

1 150 years 2 1000 years

QUESTION 2-3

SOUTH EASTERN U.S.

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
56	E STABLE PLATFORM	1							3.5			
		2							4.0			
12	S. APPALACHIA	1	VII	V-VI-VII	-	-	-	6.0-6.2-6.4	5.0	5.6-5.7-5.8	-	[illegible]
		2	IX	V-VI-VIII		IX-X	VIII-IX-X	6.3-6.5-6.8	5.4	5.7-6.4-6.5		[illegible]
5[illegible]	S. APPALACHIA	1	VII									
		2	IX									
13	PIEDMONT	1	VII	VI-VII-IX	-	-	-	6.2-6.4-6.6		5.1-5.2-5.3		[illegible]
		2	VIII	VI-VII-IX		IX	VII-IX-X	6.3-6.5-6.7		5.2-6.0-6.1		[illegible]
52	PIEDMONT	1	VII		-				4.5		-	
		2	VIII						4.7			
53	CENTRAL VIRGINIA	1	VII								-	
		2	VIII									
14	NORTHERN VALLEY AND RIDGE	1	VII	V-VI-VII	-	-	-	5.0-5.2-5.4	3.5	4.6-4.8-5.2	-	5.0-5.5
		2	VIII	V-VI-VIII		IX	-	5.6-5.8-6.2	4.0	4.7-5.5-5.7		5.5
15	APPALACHIAN PLATEAU	1	VII	V-VI-VII	-	-	-	5.3-5.7-5.9	3.5	4.7-5.0-5.3	-	4.5-5.0
		2	VIII	V-VI-VIII		IX	VII-VIII-VIII	6.1-6.3-6.5	4.0	5.2-5.7-6.0		5.0
16	CHARLESTON	1	VIII	VI-VIII-X	-		-	5.5-5.7-5.9	5.8	6.0-6.2-6.6	5.0	6.0
		2	X	VI-VIII-X		XI	X-X-XI	6.7-6.8-7.0	6.5	7.0-7.2-7.4	6.0-6.75-7.0	7.0
55	CHARLESTON	1	VIII									
		2	X									
17	ATLANTIC COASTAL PLAIN	1		V-VI-VII	-	-	-	5.6-5.9-6.0	4.5	5.0-5.2-5.5	5.25-525-6.25	4.5-5.0
		2		V-VI-VIII		XI	VII-VIII-VIII	6.1-6.3-6.5	4.7	5.7-6.0-6.5		5.0
49	ATLANTIC COASTAL PLAIN	1	VII									
		2	VIII									
54	WILMINGTON	1									-	
		2										
57	GULF COASTAL PLAIN	1								4.2-4.5-4.7		
		2								5.0-5.4-5.5		

1 - 150 Years 2 - 1000 Years

QUESTION 2-3

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			m_b	m_b	m_b	m_b	m_b	m_b	m_b	m_b	m_b	m_b
1	NEW MADRID	1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *				
2	NEW MADRID	1 2	-		-	-		NO CHANGE *				
20	NEW MADRID	1 2	-					NO CHANGE *	-	6.3-6.8-7.1 NO CHANGE	NO CHANGE	
21	WABASH	1 2								5.6-5.8-6.1 5.7-6.7-6.9		5.25-5.5-5.75 -
22	OZARK UPLIFT	1 2								NO CHANGE 5.7-6.8-7.0		5.25-5.5-5.75 -
23	MISSISSIPPI	1 2				-		NO CHANGE *	-		NO CHANGE	
10	UPPER KENEENAW	1 2	-	NO CHANGE	-	-		NO CHANGE *	-	5.2-5.5-5.7 5.5-6.5-6.8	NO CHANGE	
11	ANNA, OHIO	1 2	-		-	-		NO CHANGE *	-	5.5-5.7-5.9 5.5-6.6-6.8	NO CHANGE	
30	ANNA, OHIO	1 2						NO CHANGE *				
18	CENTRAL STABLE REG.	1 2	-	NO CHANGE	-	-		NO CHANGE *		NO CHANGE		NO CHANGE
19	CENTRAL STABLE REG.	1 2	-		-	-		NO CHANGE *	-	NO CHANGE	NO CHANGE	NO CHANGE
27	CENTRAL STABLE REG.	1 2						NO CHANGE *	-		NO CHANGE	
28	S. ILLINOIS		-		-							
29	N. ILLINOIS	1 2						NO CHANGE *		5.1-5.3-5.6 NO CHANGE		
24	OUACHITA	1 2						NO CHANGE *		NO CHANGE 5.7-6.4-6.7		NO CHANGE
25	NEMAHA RIDGE	1 2				-		NO CHANGE *		5.5-5.6-5.7 5.8-6.6-6.8		
26	N. GREAT PLAINS	1 2						NO CHANGE *		4.9-5.2-5.5 NO CHANGE		

1- 150 yrs, 2- 1000 yrs

* For 1,000 years could change estimates in some low activity areas.

NORTH EASTERN ZONES

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
3	ATTICA [1] [2]	-		-	-		NO CHANGE *	-			-
4	ATTICA [1] [2]	-	NO CHANGE	-	-		NO CHANGE *		NO CHANGE 5.7-6.9-7.3	NO CHANGE	-
4d	ATTICA				-			-			
5	S.ST.LAWRENCE [1] [2]	-		-	-	NO CHANGE	NO CHANGE *		NO CHANGE- 6.2-7.2-7.4		-
33	S.ST.LAWRENCE		NO CHANGE	-						NO CHANGE	
6	N.ST.LAWRENCE [1] [2]	-			-		NO CHANGE *		6.2-6.4-6.8 6.7-7.3-7.5		-
31	N.ST.LAWRENCE	-	NO CHANGE					-		NO CHANGE	-
32	N.ST.LAWRENCE				-	NO CHANGE		-			
8	CAPE ANN [1] [2]	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *		5.3-5.4-5.5 5.7-6.4-6.6	NO CHANGE	NO CHANGE -
45	S. NEW ENGLAND		NO CHANGE			NO CHANGE		-			
46	N.E.MASS. THRUST COMPLEX							-			
47	CAPE ANN							-			
50	N. APPALACHIANS	-								NO CHANGE	

[1] 150 years [2] 1000 years

* For 1,000 years could change estimates in some low activity areas.

QUESTION 2-4

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3 MMI	4 MMI	5 MMI	10 MMI	13 MMI	7 m_b	8 m_b	9 m_b	11 m_b	12 m_b
7	BOSTON-OTTAWA 1 2	-		-	-		NO CHANGE *		NO CHANGE 6.2-6.9-7.2		NO CHANGE -
39	BOSTON-OTTAWA 1 2	-				NO CHANGE					
9	ADIRONDACK 1 2	-		-	-		NO CHANGE *	-	5.1-5.3-5.7 5.2-6.1-6.3		NO CHANGE -
34	ADIRONDACK 1 2	-									
35	W. NEW ENGLAND 1 2							-			
36	GREEN MT. BELT 1 2			-		NO CHANGE					
37	OSSIPPE INTRUSIVE 1 2							-			
38	OTHER WHITE MT. INTRUSIVE 1 2							-			
40	MAINE 1 2	-	NO CHANGE		-			-			NO CHANGE -
41	WEST CENTRAL NEW BRUNSWICK 1 2		NO CHANGE								
42	PASSAMAQUODDY 1 2		NO CHANGE								
43	BELFAST DOVER FOXCRAFT 1 2		NO CHANGE								
44	COASTAL ANTICLINORIUM 1 2							-			

[1] 150 years [2] 1000 years

* For 1,000 years could change estimates in some low activity areas.

QUESTION 2-4

SOUTH EASTERN U.S.

NO.	ZONE NAME	3 MMI	4 MMI	5 MMI	10 MMI	13 MMI	7 m_s	8 m_b	9 m_b	11 m_b	12 m_b
56	E. STABLE PLATFORM							-			
12	S. APPALACHIA	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	-	5.6-5.8-5.9 5.7-6.6-6.8		-
51	S. APPALACHIA	-									
13	PIEDMONT	-	NO CHANGE	-	-	NO CHANGE	[illegible]HANGE		NO CHANGE 5.2-6.2-6.4		-
52	PIEDMONT	-		-				-			
53	CENTRAL VIRGINIA	-									
14	NORTHERN VALLEY AND RIDGE	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	-	NO CHANGE 4.7-5.6-5.8		-
15	APPALACHIAN PLATEAU	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	-	NO CHANGE 5.2-5.9-6.1		NO CHANGE -
16	CHARLESTON	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	-	NO CHANGE 7.4-7.2-7.6	NO CHANGE	-
55	CHARLESTON	-									
17	ATLANTIC COASTAL PLAIN		NO CHANGE	-	-	NO CHANGE	NO CHANGE *	-	NO CHANGE 5.7-6.2-6.6		NO CHANGE -
49	ATLANTIC COASTAL PLAIN	-									
54	WILMINGTON										
57	GULF COASTAL PLAIN								NO CHANGE		

1 150 YEARS 2 1000 YEARS

* For 1,000 years could change estimates in some low activity areas.

QUESTION 2-4

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
1	NEW MADRID 1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *				NO CHANGE
2	NEW MADRID 1 2	-		-	-		NO CHANGE *				NO CHANGE
20	NEW MADRID 1 2	-					NO CHANGE *	NO CHANGE	6.2-6.8-7.2 NO CHANGE	5.5-6.0-7.75 NO CHANGE	
21	WABASH 1 2								5.7-5.9-6.2 6.7-7.0-7.2		5.0-5.5 NO CHANGE
22	OZARK UPLIFT 1 2								5.8-6.0-6.3 6.7-6.9-7.2		5.0-5.5 NO CHANGE
23	MISSISSIPPI 1 2				X NO CHANGE		NO CHANGE *	NO CHANGE		NO CHANGE	
10	UPPER KENEENAW 1 2	-	NO CHANGE	-	-		NO CHANGE *	NO CHANGE	5.5-5.7-5.9 6.2-6.7-7.2	NO CHANGE	
11	ANNA, OHIO 1 2	-		-	-		NO CHANGE *	NO CHANGE	5.5-5.7-5.9 6.4-6.7-7.2	NO CHANGE	NO CHANGE
30	ANNA, OHIO 1 2						NO CHANGE *				
18	CENTRAL STABLE REG. 1 2	-	NO CHANGE	-	-		NO CHANGE *		NO CHANGE 5.3-5.5-5.7		NO CHANGE
19	CENTRAL STABLE REG. 1 2	-		-	-		NO CHANGE *		NO CHANGE 5.6-5.8-6.1		NO CHANGE
27	CENTRAL STABLE REG. 1 2						NO CHANGE *	NO CHANGE		NO CHANGE	
28	S. ILLINOIS 1 2	-		-							
29	N. ILLINOIS 1 2						NO CHANGE *		5.2-5.4-5.7 6.1-6.5-6.7		
24	OUACHITA 1 2						*		NO CHANGE 6.5-6.7-7.0		NO CHANGE
25	NEMAHA RIDGE 1 2				VIII NO CHANGE		NO CHANGE *		5.6-5.7-5.8 6.7-6.9-7.1		
26	N. GREAT PLAINS 1 2						NO CHANGE *		NO CHANGE 6.3-6.5-6.7		

1- 150 yrs, 2- 1000 yrs.

*The aftershocks may define a new source zone

NORTH EASTERN ZONES

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
3	ATTICA [1] [2]	-		-	VIII NO CHANGE		NO CHANGE *	NO CHANGE			NO CHANGE
4	ATTICA [1] [2]	-	NO CHANGE	-	VIII NO CHANGE		NO CHANGE *		5.7-5.9-6.4 6.8-7.2-7.4	5.0-5.5-7.0 NO CHANGE	NO CHANGE
48	ATTICA [1] [2]				VIII NO CHANGE			NO CHANGE			
5	S.ST.LAWRENCE [1] [2]	-		-	IX NO CHANGE	NO CHANGE	NO CHANGE *		5.9-6.1-6.3 7.0-7.3-7.5		MAX.= 6.5 NO CHANGE
33	S.ST.LAWRENCE		NO CHANGE							NO CHANGE	
6	N.ST.LAWRENCE [1] [2]	-		-	X NO CHANGE		NO CHANGE *		6.2-6.5-6.9 7.2-7.5-7.7		MAX. = 6.5 NO CHANGE
31	N.ST.LAWRENCE [1] [2]	-	NO CHANGE					NO CHANGE		NO CHANGE	MAX. = 6.5 NO CHANGE
32	N.ST.LAWRENCE [1] [2]				IX NO CHANGE	NO CHANGE		NO CHANGE			
8	CAPE ANN [1] [2]	-	NO CHANGE	-	VII NO CHANGE	NO CHANGE	NO CHANGE *		5.3-5.4-5.5 6.2-6.5-7.0	5.0-5.5-7.0 NO CHANGE	NO CHANGE
45	S. NEW ENGLAND		NO CHANGE			NO CHANGE		NO CHANGE			
46	N.E.MASS. THRUST COMPLEX							NO CHANGE			
47	CAPE ANN							NO CHANGE			
50	N. APPALACHIANS [1] [2]									4.5-5.0-5.5 NO CHANGE	

[1] 150 years [2] 1000 years

* The aftershocks may define a new source zone.

QUESTION 2-5

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3 MMI	4 MMI	5 MMI	10 MMI	13 MMI	7 m_b	8 m_b	9 m_b	11 m_b	12 m_b
7	BOSTON-OTTAWA [1] [2]	-		-	VIII NO CHANGE		NO CHANGE *		5.8-6.0-6.2 6.7-7.0-7.2		NO CHANGE
39	BOSTON-OTTAWA [1] [2]	-				NO CHANGE					
9	ADIRONDACK [1] [2]	-		-	-		NO CHANGE *	NO CHANGE	5.2-5.5-5.7 6.2-6.7-7.0		NO CHANGE
34	ADIRONDACK [1] [2]	-									
35	W. NEW ENGLAND [1] [2]							NO CHANGE			
36	GREEN MT. BELT [1] [2]			-		NO CHANGE					
37	OSSIPPE INTRUSIVE [1] [2]							NO CHANGE			
38	OTHER WHITE MT. INTRUSIVE [1] [2]							NO CHANGE			
40	MAINE [1] [2]	-	NO CHANGE		VIII NO CHANGE			NO CHANGE			NO CHANGE
41	WEST CENTRAL NEW BRUNSWICK [1] [2]		NO CHANGE								
42	PASSAMAQUODDY [1] [2]		NO CHANGE								
43	BELFAST DOVER FOXCRAFT [1] [2]		NO CHANGE								
44	COASTAL ANTICLINORIUM [1] [2]							NO CHANGE			

[1] 150 years [2] 1000 years

* The aftershocks may define a new source zone.

QUESTION 2-5

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI	MMI	MMI	MMI	MMI	m_b	m_b	m_b	m_b	m_b
56	E. STABLE PLATFORM 1 2							NO CHANGE			
12	S. APPALACHIA 1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	NO CHANGE	5.7-5.9-6.1 6.4-6.9-7.2		NO CHANGE
51	S. APPALACHIA 1 2	-									
13	PIEDMONT 1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *		NO CHANGE 6.0-6.2-6.4		NO CHANGE
52	PIEDMONT 1 2	-		-				NO CHANGE			
53	CENTRAL VIRGINIA 1 2	-									
14	NORTHERN VALLEY AND RIDGE 1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	NO CHANGE	4.8-5.0-5.3 5.7-6.5-6.8		NO CHANGE
15	APPALACHIAN PLATEAU 1 2	-	NO CHANGE	-	-	NO CHANGE	NO CHANGE *	NO CHANGE	4.9-5.2-5.4 6.0-6.4-6.6		NO CHANGE
16	CHARLESTON 1 2	-	NO CHANGE	-	IX NO CHANGE	NO CHANGE	NO CHANGE *	NO CHANGE	6.2-6.4-6.7 7.3-7.5-7.7	4.5-5.0-5.5 NO CHANGE	MAX. = 6.5 NO CHANGE
55	CHARLESTON 1 2	-									
17	ATLANTIC COASTAL PLAIN 1 2		NO CHANGE	-	-	NO CHANGE	NO CHANGE *	NO CHANGE	5.1-5.2-5.5 6.3-6.5-6.7		NO CHANGE
49	ATLANTIC COASTAL PLAIN 1 2	-									
54	WILMINGTON 1 2										
57	GULF COASTAL PLAIN 1 2								NO CHANGE 5.4-5.6-5.9		

1 150 years 2 1000 years

* The aftershocks may define a new source zone.

QUESTION 2-5

QUESTION 2-6

For each of the two time periods, 150 and 1,000 years, do you think that there is a better chance for the lower bound than for the upper bound estimate of the largest event to occur?

The experts were further requested to specify how many times greater the chance was for the lower bound estimate to occur than it was for the upper bound estimate or if the chances were the same.

Those experts who estimated the upper magnitude with a best estimate only, did not answer this question(-).

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			HOW MANY TIMES GREATER					HOW MANY TIMES GREATER				
1	NEW MADRID	1 2	3 -	SAME	-	-	SAME	2				-
2	NEW MADRID	1 2	3 -		-	-		2				-
20	NEW MADRID	1 2	3 -					2	-	10 SAME	~300 *	
21	WABASH	1 2								3 9		10 -
22	OZARK UPLIFT	1 2								3 10		10 -
23	MISSISSIPPI	1 2				- SAME		2	-		10 *	
10	UPPER KENEENAW	1 2	3 -	SAME	-	-	-	2	-	2 5	~10 *	-
11	ANNA, OHIO	1 2	3 -		-	-	-	2	-	2 8	~10 *	-
30	ANNA, OHIO	1 2						2				
18	CENTRAL STABLE REG.	1 2	3 -	SAME	-	-	-	2	-	3 3	- *	25 -
19	CENTRAL STABLE REG.	1 2	3 -		-	-	-	2	-	6 3	- *	25 -
27	CENTRAL STABLE REG.	1 2						2	-		10 *	
28	S. ILLINOIS	1 2	3 -		-							
29	N. ILLINOIS	1 2						2		3 5		
24	OUACHITA	1 2						2		8 4		25 -
25	NEMAHA RIDGE	1 2				10 SAME		2		1-2 4		
26	N. GREAT PLAINS	1 2						2		3 5		

1- 150 years, 2- 1000 years

*smaller diff. in probability for 1000 yrs.

QUESTION 2-6

NORTH EASTERN ZONES

NO.	ZONE NAME		1	4	5	10	13	7	8	9	11	12
			HOW MANY TIMES GREATER					HOW MANY TIMES GREATER				
3	ATTICA	1 2	3 -		-	10 Same		2	-			-
4	ATTICA	1 2	3 -	Same	-	10 Same		2		2 7	~ 100 *	-
48	ATTICA	1 2				10 Same			-			
5	S.ST.LAWRENCE	1 2	3 -		-	5 Same	- 10	2		3 5		-
33	S.ST.LAWRENCE	1 2		≃ 1.5 Same							~ 10 *	
6	N.ST.LAWRENCE		3 -		-	Same		2		4		-
31	N.ST.LAWRENCE	1 2	3 -	≃ 1.5 Same			-		-		~ 20 *	-
32	N.ST.LAWRENCE					-	- 10		-			
8	CAPE ANN	1 2	3 -	Same	-	10 Same	10 -	2		2 3	~ 100 *	5 -
45	S. NEW ENGLAND	1 2		2 Same			10 10		-			
46	N.E.MASS. THRUST COMPLEX								-			
47	CAPE ANN								-			
50	N. APPALACHIANS	1 2	3 -								10 *	

* Smaller difference in probability for 1,000 years.

QUESTION 2-6

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			HOW MANY TIMES GREATER					HOW MANY TIMES GREATER				
7	BOSTON-OTTAWA	1	3		-	5		2		2	-	5
		2	-			SAME				3		-
39	BOSTON-OTTAWA	1	3				10					
		2	-									
5	ADIRONDACK	1	3		-	-		2	-	10	-	5
		2	-							10		-
34	ADIRONDACK	1	3								-	
		2	-									
35	W. NEW ENGLAND	1							-			
		2										
36	GREEN MT. BELT	1			-		10					
		2										
37	OSSIPPE INTRUSIVE	1							-			
		2										
38	OTHER WHITE MT. INTRUSIVE	1							-			
		2										
40	MAINE	1	3	> 3		10			-		-	5
		2	-	SAME		SAME						-
[illegible]1	WEST CENTRAL NEW BRUNSWICK	1		SAME								
		2										
42	PASSAMAQUODDY	1		SAME								
		2										
43	BELFAST DOVER FOXCRAFT	1		> 3								
		2		SAME								
44	COASTAL ANTICLINORIUM	1							-			
		2										

[1] 150 years [2] 1000 years

* Smaller difference in probability for 1,000 years.

QUESTION 2-6

SOUTH EASTERN U.S.

NO.	ZONE	1	4	5	10	13	7	8	9	11	12
		HOW MANY TIMES GREATER					HOW MANY TIMES GREATER				
56	E. STABLE PLATFORM 1 2							-			
12	S. APPALACHIA 1 2	3 -	SAME	-	-	- 10	2	-	2 7		-
51	S. APPALACHIA 1 2	3 -									
13	PIEDMONT 1 2	3 -	2 SAME	-	-	- 10	2		1-2 8		-
52	PIEDMONT 1 2	3 -		-				-			
53	CENTRAL VIRGINIA 1 2	3 -									
14	NORTHERN VALLEY AND RIDGE 1 2	3 -	SAME	-	-	-	2	-	5 10		-
15	APPALACHIAN PLATEAU 1 2	3 -	SAME	-	-	-	2	-	4 5		25 -
16	CHARLESTON 1 2	3 -	SAME	-	10 SAME	- 10	2	-	3 2	YES (NO ESTIMATE) *	-
55	CHARLESTON 1 2	3 -									
17	ATLANTIC COASTAL PLAIN 1 2		SAME	-					3 3		25 -
49	ATLANTIC COASTAL PLAIN 1 2	3 -			-	-	2	-			
54	WILMINGTON										
57	GULF COASTAL PLAIN 1 2								3 3		

1 - 150 Years 2 - 1000 Years

(see recurence relation)

*smaller diff. in probability for 1000 yrs.

QUESTION 2-6

QUESTIONS 2-7 TO 2-9

2-7 What in your opinion is the return period of the lower bound estimate of the largest event for 150 years, 1,000 years and also an unconstrained time period?

2-8 What in your opinion is the return period of the upper bound estimate of the largest event for 150 years, 1,000 years, and also an unconstrained time period?

2-9 What in your opinion is the return period of the best estimate of the largest event for 150 years, 1,000 years and also an unconstrained time period?

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE				
1	NEW MADRID	1 2 3	150 1900 1900	1-3-15 yrs " "	-	-	-	-				-
2	NEW MADRID	1 2 3	150 1900 1900		-	-		-				-
20	NEW MADRID	1 2 3	150 1900 1900					-	-	40 900 1000	-	
21	WABASH	1 2 3								100 150 165		10 - -
22	OZARK UPLIFT	1 2 3								100 130 125		10 - -
23	MISSISSIPPI	1 2 3				-		-	-		-	
10	UPPER KENEENAW	1 2 3	-	3-10-15 " "	-	-	-	-	-	100 230 230	-	
11	ANNA, OHIO	1 2 3	-	3-10-15 3-10-15 3-10-15	-	-	-	-		120 170 160	-	- - 300
30	ANNA, OHIO							-				
18	CENTRAL STABLE REG.	1 2 3	-	3-10-15 3-10-15 3-10-15	-	-	-	-	-	100 650 1000	-	10 - 5-10
19	CENTRAL STABLE REG.	1 2 3	-		-	-	-	-	-	100 550 1000	-	10 - 5-10
27	CENTRAL STABLE REG.							-	-		-	
28	S. ILLINOIS	1 2 3	50 150 "		-							
29	N. ILLINOIS							-		100 250 300		
24	OUACHITA	2 3						-		75 300 330		- 5-10
25	NEMAHA RIDGE	1 2 3				100-150-200 " "		-		120 300 300		
26	N. GREAT PLAINS	1 2 3						-		100 300 400		

1- 150 yrs, 2- 1000 yrs, 3- UNCONST.

QUESTION 2-7

NORTH EASTERN ZONES

NO.	ZONE NAME		1	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE				
3	ATTICA	1 2 3	-		-	-		-	-			- - 300
4	ATTICA	1 2 3	-	1-3-15 " "	-	100-130-200		-		100 140 "	75 - -	- - 300
48	ATTICA	1 2 3				100-130-200			-	-		
5	S.ST.LAWRENCE	1 2 3	-		-	100-140-200	-	-		160 250 "		- 150
33	S.ST.LAWRENCE	1 2 3		3-5-20 5-15-40 "							25 - -	
6	N.ST.LAWRENCE	1 2 3	-		-	-		-		100 350 "		- - 150
37	N.ST.LAWRENCE	1 2 3	-	3-5-20 5-15-40 "			-		-		25 - -	- - 150
32	N.ST.LAWRENCE	1 2 3				-	-		-			
8	CAPE ANN	1 2 3	300 4500 "	1-3-15 " "	-	50-75-150	80-140-400 150-300-900 "	-		125 350 "	100 - -	150 - 300
45	S. NEW ENGLAND	1 2 3		5-10-15 " "			-		-			
46	N.E.MASS. THRUST COMPLEX	1 2 3							-			
47	CAPE ANN	1 2 3							-			
50	N. APPALACHIANS	1 2 3	50 120 "									

1 150 years 2 1000 years 3 UNCONST.

QUESTION 2-7

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE				
7	BOSTON-OTTAWA	1 2 3	-		-	100-150-200		-		100 300 300	-	150 - 300
39	BOSTON-OTTAWA	1 2 3	-				-					
9	ADIRONDACK	1 2 3	-		-	100-150-200		-	-	65 140 140	-	150 - 300
34	ADIRONDACK	1 2 3	-									
35	W. NEW ENGLAND	1 2 3							-			
36	GREEN MT. BELT	1 2 3			-		-					
37	OSSIPPE INTRUSIVE	1 2 3							-			
38	OTHER WHITE MT. INTRUSIVE	1 2 3							-			
40	MAINE	1 2 3	-	15-30-40 15-40-100 "		50-100-150			-		-	150 - 300
41	WEST CENTRAL NEW BRUNSWICK	1 2 3		3-10-15 " "								
42	PASSAMAQUODDY	1 2 3		5-8-20 " "								
43	BELFAST DOVER FOXCRAFT	1 2 3		15-30-40 1[illegible]-40-100 "								
44	COASTAL ANTICLINORIUM	1 2 3							-			

[1] 150 years [2] 1000 years [3] UNCONST.

QUESTION 2-7

SOUTH EASTERN U.S.

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE LOWER BOUND ESTIMATE				
56	E. STABLE PLATFORM	1 2 3							-			
12	S. APPALACHIA	1 2 3	20 200 "	3-10-15 " "	-	-	-	-	-	100 150 145	-	- - 500
51	S. APPALACHIA	1 2 3	20 200 "									
13	PIEDMONT	1 2 3	-	5-10-15 " "	-	-	-	-	-	130 170 165		- - 300
52	PIEDMONT	1 2 3	50 120 "		-				-		- -	
53	CENTRAL VIRGINIA	1 2 3	50 120 "								-	
14	NORTHERN VALLEY AND RIDGE	1 2 3	-	3-10-15 " "	-	-	-	-	-	100 130 130	-	- - 300
15	APPALACHIAN PLATEAU	1 2 3	-	3-10-15 " "	-	-	-	-	-	60 250 250		10 - 5-10
16	CHARLESTON	1 2 3	50 800 "	1-3-15 " "	-	100-150-200	-	-	-	100 500 450	-	- - 150
55	CHARLESTON	1 2 3	50 800 "									
17	ATLANTIC COASTAL PLAIN	1 2 3		3-10-15 " "	-	-	-	-	-	100 500 500	-	10 - 5-10
49	ATLANTIC COASTAL PLAIN	1 2 3	-									
54	WILMINGTON	1 2 3									-	
57	GULF COASTAL PLAIN	1 2 3								100 600 650		

1 150 years 2 1000 years 3 UNCONST.

QUESTION 2-7

NEW MADRID AND WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE				
1	NEW MADRID	1 2 3	-	>150 300-1000->1000 "	-	-	-	-	-			500 - -
2	NEW MADRID	1 2 3	-		-	-		-				500 - -
20	NEW MADRID	1 2 3	-					-	-	350 1200 "	-	
21	WABASH	1 2 3								300 1100 1600		250 - -
22	OZARK UPLIFT	1 2 3								330 1050 1200		250 - -
23	MISSISSIPPI	1 2 3				-		-	-		-	
10	UPPER KENEENAW	1 2 3	-	>150 300->1000 "	-	-	-	-	-	180 1050 1100	-	-
11	ANNA, OHIO	1 2 3	-		-	-	-	-	-	220 1300 2000	-	500 - -
30	ANNA, OHIO	1 2 3						-				
18	CENTRAL STABLE REG.	1 2 3	-	>150 300->1000 "	-		-	-	-	330 1800 2000	-	250 - -
19	CENTRAL STABLE REG.	1 2 3	-		-	-	-	-	-	330 1800 5000	-	250 - -
27	CENTRAL STABLE REG.	1 2 3				-		-	-		-	
28	S. ILLINOIS	1 2 3	-		-							
29	N. ILLINOIS	1 2 3						-		275 1050 1400		
24	OUACHITA							-		600 1200 1800		250 - -
25	NEMAHA RIDGE	1 2 3				400-800-1200 " "		-		200 1050 1100		
26	N. GREAT PLAINS	1 2 3						-		350 1200 2000		

1 - 150 Years
2 - 1000 Years
3 - UNCONST

QUESTION 2-8

NORTH EASTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE				
3	ATTICA	1 2 3	-		-	-		-	-			500 - -
4	ATTICA	1 2 3	-	>150 300-1000->1000 "	-	400-600-800		-		150 1100 "	-	500 - -
48	ATTICA	1 2 3				400-600-800			-			
5	S.ST.LAWRENCE	1 2 3	-		-	200-500-800	-	-		250 1250 2000	-	500 - -
33	S.ST.LAWRENCE	1 2 3		>150 >1000 "								
6	N.ST.LAWRENCE	1 2 3	-		-	-		-		360 1200 1600		500 - -
31	N.ST.LAWRENCE	1 2 3	-	>150 >1000 "			-		-		-	500 - -
32	N.ST.LAWRENCE	1 2 3				-	-		-			
8	CAPE ANN	1 2 3	-	>150 300-1000->1000 "	-	400-600-1000	150-300-900 14000 "	-		140 1100 3000	-	600 - -
45	S. NEW ENGLAND	1 2 3		>150 200-500->1000 "			-		-			
46	N.E.MASS. THRUST COMPLEX	1 2 3							-			
47	CAPE ANN	1 2 3							-			
50	N. APPALACHIANS	1 2 3	-								-	

1 - 150 Years 2 - 1000 Years 3 - UNCON

QUESTION 2-8

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE				
7	BOSTON-OTTAWA 1 2 3	-		-	300-600-900		-		240 1050 1400	-	600 - -
39	BOSTON-OTTAWA 1 2 3	-				-					
9	ADIRONDACK 1 2 3	-		-	200-350-500		-	-	650 2000 1500	-	600 - -
34	ADIRONDACK 1 2 3	-							-		
35	W. NEW ENGLAND 1 2 3							-			
36	GREEN MT. BELT 1 2 3			-		-					
37	OSSIPPE INTRUSIVE 1 2 3							-			
38	OTHER WHITE MT. INTRUSIVE 1 2 3							-			
40	MAINE 1 2 3	-	> 150 300- ≥ 1000 -		300-500-800			-		-	600 - -
41	WEST CENTRAL NEW BRUNSWICK 1 2 3		150 300- > 1000 -								
42	PASSAMAQUODDY 1 2 3		> 150 300- > 1000 -								
43	BELFAST DOVER FOXCRAFT 1 2 3		> 150 300- > 1000 -								
44	COASTAL ANTICLINORIUM 1 2 3							-			

[1] 150 years [2] 1000 years [3] UNCON.

QUESTION 2-8

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE					RETURN PERIOD IN YEARS FOR THE UPPER BOUND ESTIMATE				
56	E. STABLE PLATFORM 1 2 3							-			
12	S. APPALACHIA 1 2 3	-	>150 300->1000 *	-	-	-	-	-	155 1200 2000	-	500 - -
51	S. APPALACHIA 1 2 3	-									
13	PIEDMONT 1 2 3	-	>150 200-500->1000 *	-	-	-	-	-	185 1100 3000		500 - -
52	PIEDMONT 1 2 3	-		-				-		-	
53	CENTRAL VIRGINIA 1 2 3	-								-	
14	NORTHERN VALLEY AND RIDGE 1 2 3	-	>150 300->1000 *	-	-	-	-	-	550 1300 2500	-	500 - -
15	APPALACHIAN PLATEAU 1 2 3	-	>150 300->1000	-	-	-	-	-	250 1300 2500	-	250 - -
16	CHARLESTON 1 2 3	-	>150 300-1000->1000 *	-	500-800-1100	-	-	-	270 1050 1100	-	500 - -
55	CHARLESTON 1 2 3	-									
17	ATLANTIC COASTAL PLAIN 1 2 3		>150 300->1000 *	-	-	-	-	-	300 1500 1700	-	250 - -
49	ATLANTIC COASTAL PLAIN 1 2 3	-									
54	WILMINGTON 1 2 3									-	
57	GULF COASTAL PLAIN 1 2 3								330 1800 2500		

1 150 YEARS 2 1000 YEARS 3 UNCONS.

QUESTION 2-8

NEW MADRID AND WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE BEST ESTIMATE					RETURN PERIOD IN YEARS FOR THE BEST ESTIMATE				
1	NEW MADRID	1 2 3	-	50-80-300 " "	-	-	-	-	*			-
2	NEW MADRID	1 2 3	-		-	-		-				-
20	NEW MADRID	1 2 3	-					-	-	150 1000 1100	-	
21	WABASH	1 2 3								150 1000 "		-
22	OZARK UPLIFT	1 2 3								150 1000 "		-
23	MISSISSIPPI	1 2 3				-		-	-		- -	
10	UPPER KENEENAW	1 2 3	-	10-20-30 10-30-50 "	-	-	-	-	-	150 1000 "	-	
11	ANNA, OHIO	1 2 3	-		-	-	-	-	-	150 1000 1200	-	-
30	ANNA, OHIO	1 2 3										
18	CENTRAL STABLE REG.	1 2 3	-	10-20-30 10-30-50 "	-	-	-	-	-	150 1000 2000	-	-
19	CENTRAL STABLE REG.	1 2 3	-		-	-	-	-	-	150 1000 3000	-	-
27	CENTRAL STABLE REG.	1 2 3						-	-		-	
28	S. ILLINOIS	1 2 3	-		-							
29	N. ILLINOIS	1 2 3						-		150 1000 1200		
24	OUACHITA	1 2 3					-			1000 "		-
25	NEMAHA RIDGE	1 2 3				200-300-400 " "	-			150 1000 "		
26	N. GREAT PLAINS	1 2 3					-			150 1000 2000		

1 - 150 Years
2 - 1000 Years
3 - UNCONST.

* An answer would not be meaningful because of short length of the available historical data

NORTH EASTERN ZONES

NO.	ZONE NAME		1	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE BEST ESTIMATE					RETURN PERIOD IN YEARS FOR THE BEST ESTIMATE				
3	ATTICA	1 2 3	-		-	-		-	* -			-
4	ATTICA	1 2 3	-	50-80-300 " "	-	100-300-500		-		150 1000 "	-	-
48	ATTICA	1 2 3				200-350-500			-			
5	S.ST.LAWRENCE	1 2 3	-		-	200-300-400	-	-		150 1000 1200		-
33	S.ST.LAWRENCE	1 2 3		20-100-150 200-600-1000 "							-	
6	N.ST.LAWRENCE	1 2 3	-		-	-		-		150 1000 "		-
31	N.ST.LAWRENCE	1 2 3	-	20-100-150 200-600-1000 "			-		-		-	-
32	N.ST.LAWRENCE	1 2 3				-	-		-			
8	CAPE ANN	1 2 3	-	50-80-300 " "	-	100-150-200	80-140-400 1K-4K-10K "	-		150 1000 "	-	-
45	S. NEW ENGLAND	1 2 3		30-50-400 100-150-400 "			-		-			
46	N.E.MASS. THRUST COMPLEX	1 2 3							-			
47	CAPE ANN	1 2 3							-			
50	N. APPALACHIANS	1 2 3	-								-	

1 - 150 Years 2 - 1000 Years 3 - UNCON

* An answer would not be meaningful because of the short length of the available historical data.

QUESTION 2-9

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			RETURN PERIOD IN YEARS FOR THE BEST ESTIMATE					RETURN PERIOD IN YEARS FOR THE BEST E TIMATE				
7	BOSTON-OTTAWA	1 2 3	-		-	200-300-400		-	*	150 1000 "	-	-
39	BOSTON-OTTAWA	1 2 3	-				-					
9	ADIRONDACK	1 2 3	-		-	200-250-300		-	-	150 1000 1100	-	-
34	ADIRONDACK	1 2 3	-							-		
35	W. NEW ENGLAND	1 2 3							-			
36	GREEN MT. BELT	1 2 3			-				-			
37	OSSIPPE INTRUSIVE	1 2 3							-			
38	OTHER WHITE MT. INTRUSIVE	1 2 3							-			
40	MAINE	1 2 3	-	15-20-40 100-200-300 "		150-250-350			-		-	-
41	WEST CENTRAL NEW BRUNSWICK	1 2 3		10-20-30 10-30-50 "								
42	PASSAMAQUODDY	1 2 3		80-100-300 150-200-500 "								
43	BELFAST DOVER FOXCRAFT	1 2 3		15-20-40 100-200-300 "								
44	COASTAL ANTICLINORIUM	1 2 3							-			

1 150 years 2 1000 years 3 UNCONST.

* An answer would not be meaningful because of the short length of the available historical data.

QUESTION 2-9

QUESTION 2-10

If in the next 150 years you were told that among the several events that occurred the two largest ones were of the same size, what size would you guess they were?

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI					m_b				
1	NEW MADRID	IX	VI-VII-VIII	-	-	-	6.0-6.2-6.4	*			6.0
2	NEW MADRID	IX		-	-		6.1-5.9-6.3				6.0
20	NEW MADRID	IX					6.2-6.4-6.6	6.2	6.2	5.5-6.0-6.5	
21	WABASH								5.5		5.5
22	OZARK UPLIFT								5.6		5.5
23	MISSISSIPPI				IX		5.8-6.0-6.0	5.1		5.0-5.5-[illegible]	
10	UPPER KENEENAW	VII	V-VI-VII	-	-	-	5.2-5.4-5.6	3.1	5.1	4.5-5.0-5.5	
11	ANNA, OHIO	VI		-	-	-	5.2-5.4-5.6	4.7	5.3	4.5-5.0-5.5	4.75
30	ANNA, OHIO						5.0-5.2-5.4				
18	CENTRAL STABLE RE[illegible]	VI	V-VI-VII	-	-	-		-	4.2	-	5.0
19	CENTRAL STABLE REG.	VI		-	-	-	5.4-5.6-5.8	-	4.4	-	5.0
27	CENTRA[illegible]BLE REG.						4.6-4.4-4.8	3.[illegible]		4.0-4.5-5.0	
28	S. ILLINOIS	VII		-							
29	N. ILLINOIS						4.9-5.1-5.3		5.0		
24	OUACHITA						5.4-5.6-5.[illegible]		5.2		5.0
25	NEMAHA RIDGE				VII		5.5-5.7-5.9		5.3		
26	N. GREAT PLAINS						5.0-5.2-5.4		4.9		

* All zones $-0.5m_b$ of upper bound 150 years earthquake.

QUESTION 2-10

NORTH EASTERN ZONES

NO.	ZONE NAME	1	4	5	10	13	7	8	9	11	12
		MMI					m_b				
3	ATTICA	VI		-	VIII		5.0-5.2-5.4	* 4.7			4.75
4	ATTICA	VI	VI-VII-VIII	-	VIII		5.0-5.2-5.4		5.4	5.0-5.5-5.75	4.75
48	ATTICA				VIII			3.2			
5	S.ST.LAWRENCE	VII		-	VIII	-	5.3-5.5-5.7		5.7		5.5
33	S.ST.LAWRENCE		VIII-IX-X							5.5-5.75-6.0	
6	N.ST.LAWRENCE	VIII		-	X		5.3-5.5-5.7		5.8		5.5
31	N.ST.LAWRENCE	VIII	VIII-IX-X			-		6.2		6.0-6.25-6.5	5.5
32	N.ST.LAWRENCE				IX	-		5.5			
8	CAPE ANN	VII	VI-VII-VIII	-	VII	VII	5.4-5.6-5.8		5.1	5.0-5.5-6.0	5.25
45	S. NEW ENGLAND		VI-VII-VII			-		3.2			
46	N.E.MASS. THRUST COMPLEX							4.0			
47	CAPE ANN							5.0			
50	N. APPALACHIANS	VI								4.0-4.5-5.0	

* All zones -0.5m_b of upper bound 150 years earthquake.

QUESTION 2-10

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI					m_b				
7	BOSTON-OTTAWA	VII		-	VIII		5.9-6.1-6.3	*	5.7	-	5.25
39	BOSTON-OTTAWA	VII				-					
9	ADIRONDACK	VI		-	-		5.4-5.6-5.8	4.5	5.0	-	5.25
34	ADIRONDACK	VI									
35	W. NEW ENGLAND							3.0			
36	GREEN MT. BELT			-		-					
37	OSSIPPE INTRUSIVE							5.0			
38	OTHER WHITE MT. INTRUSIVE							4.3			
40	MAINE	VI	VI-VI-VII		VII			4.0		-	5.25
41	WEST CENTRAL NEW BRUNSWICK		V-VI-VII								
42	PASSAMAQUODDY		VI-VII-VII								
43	BELFAST DOVER FOXCRAFT		VI-VI-VII								
44	COASTAL ANTICLINORIUM							4.0			

* All zones $-0.5m_b$ of upper bound 150 years earthquake.

QUESTION 2-10

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		MMI					m_b				
56	E. STABLE PLATFORM							* 3.0			
12	S. APPALACHIA	VIII	V-VI-VII	-	-	-	5.7-5.9-6.1	4.5	5.5	-	5.0
51	S. APPALACHIA	VIII									
13	PIEDMONT	VII	VI-VII-VII	-	-	-	-		5.0		4.75
52	PIEDMONT	VII		-				4.0		-	
53	CENTRAL VIRGINIA	VI		-						-	
14	NORTHERN VALLEY AND RIDGE	VI	V-VI-VII	-	-	-	-	3.0	4.6	-	4.75
15	APPALACHIAN PLATEAU	VI	V-VI-VII	-	-	-	-	3.0	4.8	-	5.0
16	CHARLESTON	VIII	VI-VII-VIII	-	IX	-	-	5.3	5.9	5.0	5.5
55	CHARLESTON	VIII									
17	ATLANTIC COASTAL PLAIN		V-VI-VII	-	-	-	-	4.0	5.0	-	5.0
49	ATLANTIC COASTAL PLAIN	VI									
54	WILMINGTON									-	
57	GULF COASTAL PLAIN								4.3		

* All zones $-0.5 m_b$ of upper bound 150 years earthquake.

QUESTION 2-10

3.0 EARTHQUAKE OCCURRENCE

The following questions considered the occurrence of earthquakes within the next 150 years. Occurrences are either expressed in terms of the number of earthquakes (n) expected to occur within that period (for example: 47 in 150 years) or as the mean rate of occurrence per year (i.e., 0.313 per year). In most cases, the experts were given the choice to express their opinion in terms of a best estimate and/or as a range defined by its lower and upper bounds. Again, they had the opportunity to express their level of confidence over the range in terms of a distribution (either discrete or continuous).

The linear relationship

$$\text{Log } N_c = a + bS$$

where S = size of earthquakes (Magnitude or MMI)

N_c = cumulative number of events greater or equal to size S

a, b = regression parameters, respectively intercept and slope of straight line,

which was usually obtained from regression analysis on the data, was often used to represent the seismicity of a region. The regression parameters "a" and "b" are occasionally referred to in the following questions.

QUESTION 3-1

Do you think that a linear relation is acceptable to describe the seismicity of seismic source zones? If not, what should the form be?

Six of the ten respondents thought the linear recurrence relationship should be used without modification.

Respondents 3, 9 and 10:	"acceptable"
Respondent 5:	Appears to be approximately linear - over the modest range of adequate data (V-VIII) in most regions.
Respondent 7:	for lack of anything demonstrably better
Respondent 11:	A more complex relationship is not warranted by either theory or data.

Four respondents suggested improvement.

Respondent 4 said that the data seemed to be showing a bi-linear or tri-linear relationship (i.e., a lower slope for $I \leq V$ than for $I \geq VI$. Also, there may be an even steeper slope for $I \geq X$).

Respondent 8 wanted the relationship qualified by an upper bound to prevent the extrapolation of extreme events, as not all regions appear capable of producing such events. Thus, the upper bound should be determined regionally by investigation of such deterministic factors as fault dimensions, rock properties, and the stress regime.

Respondent 12 thought the relationship should be quadratic.

Respondent 13 thought the relationship is valid where the data set is complete. Otherwise, it is necessary to make a correction for "detection capability" as a function of time.

QUESTION 3-2

Do you think that the slope or shape of the recurrence relationship should be zone-independent and that only the intercept "a" should vary from region to region? If so, and if you believe that a linear recurrence relation is valid, what in your opinion is the value of "b" appropriate for the East?

Respondent		"b"-value
3	Region independent	0.57 (MMI)
4	Region independent for N.E. U.S. and E. Canada "b"-value very preliminary for: I ≤ VII I > VII	 0.417 (MMI) 1.586 (MMI)
5	Region independent best to assume a "b"-value of about and fit this to the best data.	0.55 - 0.6 (MMI)
7	Region independent (except possibly New England) (except near Charleston, S.C. "b" = 0.70)	0.90 ± .05 (m_b)
8	Region independent	0.8 ± .1 (m_b)
12	Region independent - the "state-of-the-art" does not justify region dependence (with the possible exception of zone 2)	0.8 - 1.0 (m_b)
13	Region independent for large regions	0.55 ± .1 (MMI)
9	Region dependent	
10	Region dependent	
11	Region dependent Because of insufficient data, this expert could not determine "b"-values for the individual zones. He, therefore, assigned a common "b"-value of 0.5 ± 0.1 for all the zones. He notes, however, that when the data base becomes sufficient, separate "b"-values should be determined for the separate zones.	0.5 ± 0.1 (MMI)

QUESTION 3-3

Consider a local tectonic feature which in recorded history has had a few earthquakes of relatively large size associated with it. Do you believe that the classical recurrence relationship is appropriate to describe potential activity of this feature or is another type of recurrence biased toward the large size events more appropriate?

The majority of respondents found the classical relation appropriate, although most appended comments of one form or another. The respondents finding the classical relation inappropriate did so because there may be question on how well one can predict large events from small ones, because direct deterministic predictions may prove better, and because of the scarcity of data on large events.

Respondent

3 Classical recurrence relationship appropriate

4 Classical approach okay with modification for a bi-linear or tri-linear recurrence

5 Consider only those events with a return priod of less than the period of observation

7 If the data is not sufficient to determine "a" and "b," then assume "b" and adjust the line with due consideration to the data set.

8 Because of the shortness in time of the historical data base, our assessment of the earthquake potential might favor a more deterministic approach (i.e., local rock properties, structural dimensions, and the regional stress field)

9 For the New Madrid Fault Zone, the classical recurrence relation, when fitted to the large earthquakes, gives essentially the same recurrence equation as the micro-earthquake and the minor earthquake data.

10 Sparse data in Eastern U. S. If there is reasonably complete data at small sizes, the relationship may be valid at intermediate sizes, but not for the larger magnitudes.

QUESTION 3-3

(CONT.)

11 The classical approach seems to work in areas where there is a more complete data set. My first approach would be to try it in less active areas. I cannot suggest a different model.

12 Given the "state-of-the-art" the classical recurrence relationship is the most appropriate

13 The extreme value method (i.e., Gumbel).

QUESTION 3-4

> At what depth would you locate the energy release in each source zone? Use several depths or depth ranges if you believe that distinct source mechanisms or other factors generate parallel activities at different depths. If you use several depths or depth ranges, comment on the reason for doing so and assign the percentage of activity attributable to each.

The consensus of the experts was that the focal depth for most eastern earthquakes lies in the 5 to 15 km range, though the table of responses should be referred to for more detail.

Respondent eight, while stressing the sparcity of data, replied that most focal depths in the East lie between 5 and 17 km, with some small magnitude quakes shallower than 5 km. Respondent nine postulated 1 to 20 km with a median depth of 5 to 10 km. Respondent seven commented that, according to his focal depth study based on surface waves, in general focal depth lies between 1 and 25 km deep in the East. He found that most source regions have a mean depth of 12 $\pm$ 5 km, with only a few exceptions: Charleston, Attica, and New York would all be less than 5 km, while Wabash would be 15 to 25 km. Shallow depth means a higher intensity for a given magnitude, but the same felt area.

The following table lists the experts' answers to Question 3-4 in detail.

NEW MADRID AND WESTERN ZONES

NO.	ZONE NAME	3 %	3 DEPTH IN KM	4 %	4 DEPTH IN KM	5 %	5 DEPTH IN KM	10 %	10 DEPTH IN KM	13 %	13 DEPTH IN KM	7 %	7 DEPTH IN KM	8 %	8 DEPTH IN KM	9 %	9 DEPTH IN KM	11 %	11 DEPTH IN KM	12 %	12 DEPTH IN KM
1	NEW MADRID		-		3-10-25	100	5-30		-		3-30	70 30	5-12-15 0-3-5								+
2	NEW MADRID		-			100	5-30		-			70 30	5-12-15 0-3-5								+
20	NEW MADRID		-									70 30	5-12-15 0-3-5		*		*	100	0-10		.
21	WABASH																*				+
22	OZARK UPLIFT																*				+
23	MISSISSIPPI							100	0-10-20			70 30	5-12-15 0-3-5		*			95 5	0-10 0-25		
10	UPPER KENEENAW		-		3-10-25	100	5-30		-		3-30		1-10-20		*		*		* ~Zones 31 + 33		
11	ANNA, OHIO		-			100	5-30		-		3-30		1-10-20		*		*		* ~ Zone 4		+
30	ANNA, OHIO												1-10-20								
18	CENTRAL STABLE REG.		-		3-10-25	100	5-30		-		3-30		1-10-20		*		*		-		+
19	CENTRAL STABLE REG.		-						-		3-30		1-10-20		*		*		-		+
27	CENTRAL STABLE REG.												1-10-20		*			75 25	0 - 10 10 - 20		
28	S. ILLINOIS		-			100	5-30														
29	N. ILLINOIS												7-12-17				*				
24	OUACHITA												7-12-17								+
25	NEMAHA RIDGE							100	0-10-20				7-12-17				*				
26	N. GREAT PLAINS												7-12-17				*				

* Insufficient data. (8)

* Insufficient data. (9)

\+ Beyond my knowledge. (12)

QUESTION 3-4

NORTH EASTERN ZONES

NO.	ZONE NAME	3		4		5		10		1[illegible]		7		8		9		11		12	
		%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM	%	Depth in kM
3	ATTICA		-			100	5-30	100	0-10-20				1-3-5		•						•
4	ATTICA		-		3-10-25	100	5-30	100	0-10-20				1-3-5				•	90% 10	+0-5 5-1C ?		•
4d	ATTICA							100	0-10-20						•						
5	S.ST.LAWRENCE		-			100	5-30	100	0-10-20		3-30		1-10-20				•				•
33	S.ST.LAWRENCE				3-10-25													75 25	0-10 10-20		
6	N.ST.LAWRENCE					100	5-30	100	0-10-20				1-10-20				•				•
31	N.ST LAWRENCE		-		3-10-25						3-30				•			75-80 20-25	0-10 10-20		•
32	N.ST.LAWRENCE							100	0-10-[illegible]		3-30				•						
8	CAPE ANN		-		3-10-25	100	5-30	100	[illegible]-10-20		3-30		1-10-20				•		~ TO ZONES 31 + 33		•
45	S. NEW ENGLAND				3-10-25						3-30				•						
46	N.E.MASS. THRUST COMPLEX														•						
47	CAPE ANN														•						
50	N. APPALACHIANS		-															100	0-10		

1 DEPTH 1 2 DEPTH 2

• Insufficient data.

• Insufficient data.

• Beyond my knowledge.

QUESTION 3-4

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3		4		5		10		13		7		8		9		11		12	
		%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM	%	DEPTH IN KM
7	BOSTON-OTTAWA 1 / 2		-			100	5-30	100	0-10-20				1-10-20				*		-		+
39	BOSTON-OTTAWA 1 / 2		-								3-30										+
9	ADIRONDACK 1 / 2		-			100	5-30		-				1-10-20		*		*		-		
34	ADIRONDACK 1 / 2		-																		
35	W. NEW ENGLAND 1 / 2														*						
36	GREEN MT. BELT 1 / 2					100	5-30				3-30										
37	OSSIPPE INTRUSIVE 1 / 2														*						
38	OTHER WHITE MT. INTRUSIVE 1 / 2														*						
40	MAINE 1 / 2		-		3-10-25			100	0-10-20						*				-		+
41	WEST CENTRAL NEW BRUNSWICK 1 / 2				3-10-25																
42	PASSAMAQUODDY 1 / 2				3-10-25																
43	BELFAST DOVER FOXCRAFT 1 / 2				3-10-25																
44	COASTAL ANTICLIORIUM 1 / 2														*						

1 - DEPTH 1 2 - DEPTH 2

* Insufficient data.

* Insufficient data.

\+ Beyond my knowledge.

QUESTION 3-4

SOUTH EASTERN U.S.

NO.	ZONE NAME		3 %	3 DEPTH IN KM	4 %	4 DEPTH IN KM	5 %	5 DEPTH IN KM	10 %	10 DEPTH IN KM	13 %	13 DEPTH IN KM	7 %	7 DEPTH IN KM	8 %	8 DEPTH IN KM	9 %	9 DEPTH IN KM	11 %	11 DEPTH IN KM	12 %	12 DEPTH IN KM
56	E. STABLE PLATFORM	1														*						
		2																				
12	S. APPALACHIA	1	90	3 - 10		3-10-25	100	5-30		-		3-30		1-10-20		*		*		-		+
		2	10	* < 3																		
51	S. APPALACHIA	1	90	3 - 10																		
		2	10	* < 3																		
13	PIEDMONT	1	90	3-15		3-10-25	100	5-30		-		3-30		1-10-20		*		*		-		+
		2	10	* < 3																		
52	PIEDMONT	1		3-15												*				-		
		2		* < 3																		
53	CENTRAL VIRGINIA	1		-																-		
		2																				
14	NORTHERN VALLEY AND RIDGE	1		-		3-10-25	100	5-30		-		3-30		1-10-20		*		*		-		+
		2																				
15	APPALACHIAN PLATEAU	1		-		3-10-25	100	5-30		-		3-30		1-10-20		*		*		-		+
		2																				
16	CHARLESTON	1	90	3 -15		3-10-25	100	5-30	100	0-10-20		3-30		1-10-20		*		*	100	0-10		+
		2	10	* < 3															1	10†		
55	CHARLESTON	1	90	3-15																		
		2	10	* < 3																		
7	ATLANTIC COASTAL PLAIN	1				3-10-25	100	5-30		-		3-30		1-10-20		*		*				+
		2																				
9	ATLANTIC COASTAL PLAIN	1																				
		2																				
54	WILMINGTON	1																				
		2																				
57	GULF COASTAL PLAIN	1																*				
		2																				

1 - DEPTH 1   2 - DEPTH 2

* The shallow activity is microquakes - primarily a "skin" effect.

* Insufficient data.

* Insufficient data.

† Based on accurate depths.

\+ Beyond my knowledge.

QUESTION 3-4

QUESTION 3-5

Consider the historical seismic data as, for example, presented in the seismicity booklet. In general, is this data by itself adequate to define seismicity models of future activity? Express your answer as a percentage difference between the actual data and the appropriate model.

There does not seem to be consensus on this question, and some respondents found it ambiguous. Four of the eight answering respondents answered that no difference should be ascribed either because the data are adequate for small zones, or because the data are inadequate, yet nothing else can be reasonably done. Three respondents answered by zone, one by range for all zones. These answers cluster about 70 to 70 percent "lower" for the small range, and about 80 percent "lower" for intermediate range. There were few responses for the large range. The following table lists the answers in detail.

Respondent 5 * "I firmly believe that there are rather substantial changes in seismicity with time. I suspect that these changes are strongly region-dependent. However, apart from hinting that they exist, actual data is not adequate to define these changes.

"In the absence of information about these changes, there are in my opinion two options. One would be to accept the historical data at face value, using the argument that we are not sure whether the region is in a period of high or low seismicity. The other is to attempt to be extremely conservative, and to use a larger rate of seismicity for future estimation than observed in the historical record.

"I tend towards the first of these options."

Respondent 10 * Data not adequate, but seismicity models of future activity must be based on it until better methodology is available. Meanwhile, all zones 0%.

QUESTION 3-5

(CONT.)

Respondent 13	* Insufficient data. For all zones (except 3 & 4): Small Range-data is 75% lower than needed. Medium Range-data is 50% lower in more active zones, and 80% lower in other zones. Large Range-data is 95% incomplete (totally inadequate).
Respondent 9	* Insufficient data.
Respondent 11	+ Cannot quantify the error. Data is adequate for small range, but not for medium and large range.

NEW MADRID + WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			(-) LOWER BY % (+) HIGHER BY %					(-) LOWER BY % (+) HIGHER BY %				
1	NEW MADRID	SM. RG M. RG LG. RG	-	20 - 40% 10 - 30% 30 - 50%	* 0%	* 0%	*	0%				0%
2	NEW MADRID	1 2 3	-			* 0%		0%				0%
20	NEW MADRID	1 2 3	-					0%	-20%	0 +100% 0	+	
21	WABASH	1 2 3								0 50 *		0%
22	OZARK UPLIFT	1 2 3								0 50 *		0%
23	MISSISSIPPI	1 2 3			* 0%	* 0%		- -	-30		+	
10	UPPER KENEENAW	1 2 3	-	70 - 90 40 - 60 70 - 90	* 0%	* 0%	*	-	-70	0 0 *	+	
11	ANNA, OHIO	1 2 3	-		* 0%	* 0%	*	-	-60	0 -100 *	+	0%
30	ANNA, OHIO	1 2 3										
18	CENTRAL STABLE REG.	1 2 3	-	70 - 90 40 - 60 70 - 90	* 0%	* 0%	*	-	-	-25 +100 *	+	0%
19	CENTRAL STABLE REG.	1 2 3	-		* 0%	* 0%	*	-	-	-25 +100 *	+	0%
27	CENTRAL STABLE REG.	1 2 3						-	-50		+	
28	S. ILLINOIS	1 2 3	-		* 0%			-				
29	N. ILLINOIS	1 2 3								0 50 *		
24	OUACHITA	1 2 3						-		+300 *		0%
25	NEMAHA RIDGE	1 2 3				* 0%		-		0 0 *		
26	N. GREAT PLAINS	1 2 3						-		-20 +500 *		

QUESTION 3-5

NEW MADRID + WESTERN ZONES

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			(-) LOWER BY % (+) HIGHER BY %							(-) LOWER BY % (+) HIGHER BY %		
1	NEW MADRID	SM. RG M. RG LG. RG	-	20 - 40% 10 - 30% 30 - 50%	* 0%	* 0%	*	0%				0%
2	NEW MADRID	1 2 3	-			* 0%		0%				0%
20	NEW MADRID	1 2 3	-					0%	-20%	0 +100% 0	+	
21	WABASH	1 2 3								0 50 *		0%
22	OZARK UPLIFT	1 2 3								0 50 *		0%
23	MISSISSIPPI	1 2 3			* 0%	* 0%		-	-30		+	
10	UPPER KENEENAW	1 2 3	-	70 - 90 40 - 60 70 - 90	* 0%	* 0%	*	-	-70	0 0 *	+	
11	ANNA, OHIO	1 2 3	-		* 0%	* 0%	*	-	-60	0 -100 *	+	0%
30	ANNA, OHIO	1 2 3										
18	CENTRAL STABLE REG.	1 2 3	-	70 - 90 40 - 60 70 - 90	* 0%	* 0%	*	-	-	-25 +100 *	+	0%
19	CENTRAL STABLE REG.	1 2 3	-		* 0%	* 0%	*	-	-	-25 +100 *	+	0%
27	CENTRAL STAPLE REG.	1 2 3						-	-50			
28	S. ILLINOIS	1 2 3	-		* 0%			-				
29	N. ILLINOIS	1 2 3								0 50 *		
24	OUACHITA	1 2 3						-		+300 *		0%
25	NEMAHA RIDGE	1 2 3				* 0%		-		0 0 *		
26	N. GREAT PLAINS	1 2 3						-		-20 +500 *		

1 SM. RANGE 2 M. RANGE 3 LG. RANGE

QUESTION 3-5

NORTH EASTERN ZONES

NO.	ZONE NAME	Range	1	4	5	10	13	7	8	9	11	12
			(-) LOWER BY % (+) HIGHER BY %					(-) LOWER BY % (+) HIGHER BY %				
3	ATTICA	1 2 3	-		• 0%	• 0%		-	-70%			0%
4	ATTICA	1 2 3	-	20-40% 10-30 70-90	• 0%	• 0%		-		0% 100 •	•	0%
48	ATTICA	1 2 3				• 0%			-50			
5	S.ST.LAWRENCE	1 2 3	-		• 0%	• 0%	•	-		0 0 •		0%
33	S.ST.LAWRENCE	1 2 3		70-90 40-60 70-90							+	
6	N.ST.LAWRENCE	1 2 3	-		• 0%	• 0%		-		+50 -50-100 +30		0%
31	N.ST.LAWRENCE	1 2 3	-	70-90 40-60 70-90			•		-20		+	0%
32	N.ST.LAWRENCE	1 2 3				• 0%	•		-30			
8	CAPE ANN	1 2 3	-	20-40 10-30 70-90	• 0%	• 0%	•	-		0 0 •	+	0%
45	S. NEW ENGLAND	1 2 3		20-40 10-30 70-90			•		-30			
46	N.E.MASS. THRUST COMPLEX	1 2 3							-20			
47	CAPE ANN	1 2 3							30			
50	N. APPALACHIANS	1 2 3	-								+	

1 - SM RANGE   2 - M. RANGE   3 - LG RANGE

QUESTION 3-5

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		(-) LOWER BY % (+) HIGHER BY %					(-) LOWER BY % (+) HIGHER BY %				
7	BOSTON-OTTAWA 1 2 3	-		* 0%	* 0%				0% 0 *	+	0%
39	BOSTON-OTTAWA 1 2 3	-				*					
9	ADIRONDACK 1 2 3	-		* 0%	* 0%		-	-70%	0 0 *	+	0%
34	ADIRONDACK 1 2 3	-									
35	W. NEW ENGLAND 1 2 3							30			
36	GREEN MT. BELT 1 2 3			* 0%		*					
37	OSSIPPE INTRUSIVE 1 2 3							-30			
38	OTHER WHITE MT. INTRUSIVE 1 2 3							50			
40	MAINE 1 2 3	-	20-40 10-30 70-90		* 0%			-30		+	0%
41	WEST CENTRAL NEW BRUNSWICK 1 2 3		20-40 10-30 70-90								
42	PASSAMAQUODDY 1 2 3		20-40 10-30 70-90								
43	BELFAST DOVER FOXCRAFT 1 2 3		20-40 10-30 70-90								
44	COASTAL ANTICLINORIUM 1 2 3							50%			

[1] SM. RANGE [2] M. RANGE [3] LG. RANGE

QUESTION 3-5

SOUTH EASTERN U.S.

NO.	ZONE NAME		3	4	5	10	13	7	8	9	11	12
			(-) LOWER BY % (+) HIGHER BY %					(-) LOWER BY % (+) HIGHER BY %				
56	E. STABLE PLATFORM	1 3							- 50%			
12	S. APPALACHIA	1 2 3	-	60-80% 20-40 70-90	* 0%	* 0%	*	-	- 35	0% 0 *	+	0%
51	S. APPALACHIA	1 2 3	-									
13	PIEDMONT	1 2 3	-	60-80 20-40 70-90	* 0%	* 0%	*	-		0 0 *	+	0%
52	PIEDMONT	1 2 3	-		* 0%				- 40		+	
53	CENTRAL VIRGINIA	1 2 3	-								+	
14	NORTHERN VALLEY AND RIDGE	1 2 3	-	60-80 20-40 70-90	* 0%	* 0%	*	-	- 45	0 * *	+	0%
15	APPALACHIAN PLATEAU	1 2 3	-	60-80 20-40 70-90	* 0%	* 0%	*	-	- 50	0 0 *	+	0%
16	CHARLESTON	1 2 3	-	60-80 20-40 70-90	* 0%	* 0%	NO ANS.	-	-	0 0 -200%	+	0%
55	CHARLESTON	1 2 3	-									
17	ATLANTIC COASTAL PLAIN	1 2 3		60-80 20-40 70-90	* 0%	* 0%	*	-	- 30	+50 -50 *	+	0%
49	ATLANTIC COASTAL PLAIN	1 2 3	-									
54	WILMINGTON	1 2 3									+	
57	GULF COASTAL PLAIN	1 2 3								-25 +100 *		

1 SM. RANGE 2 M. RANGE 3 LG. RANGE

QUESTION 3-5

QUESTION 3-6

If you feel that the "b"-value should be zone-dependent, what values would you recommend?

The following table lists the "b"-values given by the experts in both Question 3-2 and Question 3-6.

NEW MADRID & WESTERN ZONES

NO.	ZONE NAME	3	4	5	11	13	7	8	9	10	12
		"b" - MMI					"b" - m_b				
1	NEW MADRID	+ 0.57	* ≤ VII: 0.417 > VII: 1.586	+ .55-0.6	+ .5 ± .10	+ 0.55 ± .1	+ * 0.90 ± .05	+ 0.8 ± .1		.8 ± .3	+ 0.8-1.0
2	NEW MADRID									.8 ± .3	
20	NEW MADRID								0.7-0.92-1.0		
21	WABASH								0.7-0.92-1.1		
22	OZARK UPLIFT								0.7-0.92-1.1		
23	MISSISSIPPI									.6 ± .2	
10	UPPER KENEENAW					NO ANS			0.7-0.78-0.9	.4 ± .3	
11	ANNA, OHIO					NO ANS			0.7-0.92-1.0	.5 ± .3	
30	ANNA, OHIO										
18	CENTRAL STABLE REG.								0.7-0.92-1.2	1.0 ± .2	
19	CENTRAL STABLE REG.								0.7-0.92-1.2	1.0 ± .2	
27	CENTRAL STABLE REG.										
28	S. ILLINOIS										
29	N. ILLINOIS								0.7-0.92-1.1		
24	OUACHITA								0.5-0.92-1.3		
25	NEMAHA RIDGE								0.8-0.92-1.0		
26	N. GREAT PLAINS								0.7-0.92-1.2		

+ Zone Independent

* Also in New England enough data may exist to establish an estimate of "b".

QUESTION 3-6

NORTH EASTERN ZONES

NO.	ZONE NAME	1	4	5	11	13	7	8	9	10	12
		"b" - MMI					"b" - m_b				
3	ATTICA	+ 0.57	≤ VII: 0.417; > VII: 1.586	+ 0.55 - 0.6	+ .5 ± .1	NO ANS.	+ 0.90 ± .05	+ 0.8 ± .1		.6 ± .2	+ 0.8 - 1.0
4	ATTICA					NO ANS.			0.6-0.69-0.8	.5 ± .2	
48	ATTICA									.7 ± .3	
5	S.ST.LAWRENCE					+ 0.55 ± .1			.65-.75-.85	.7 ± .2	
33	S.ST.LAWRENCE										
6	N.ST.LAWRENCE								0.6-0.735-1.0	.6 ± .2	
31	N.ST.LAWRENCE										
32	N.ST.LAWRENCE									.9 ± .1	
8	CAPE ANN								.85-.945-.95	.7 ± .3	
45	S. NEW ENGLAND										
46	N.E.MASS. THRUST COMPLEX										
47	CAPE ANN										
50	N. APPALACHIANS										

+ Zone independent.

QUESTION 3-6

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3	4	5	11	13	7	8	9	10	12
		"b" - MMI					"b" - m_b				
7	BOSTON-OTTAWA								0.9-0.975-1.1	.9 ± .1	
39	BOSTON-OTTAWA										
9	ADIRONDACK								1.0-1.325-1.4	.9 ± .1	
34	ADIRONDACK										
35	W. NEW ENGLAND										
36	GREEN MT. BELT										
37	OSSIPPE INTRUSIVE										
38	OTHER WHITE MT. INTRUSIVE										
40	MAINE									.9 ± .2	
41	WEST CENTRAL NEW BRUNSWICK										
42	PASSAMAQUODDY										
43	BELFAST DOVER FOXCRAFT										
44	COASTAL ANTICLINORIUM										

QUESTION 3-6

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	11	13	7	8	9	10	12
		"b" - MMI					"b" - m_b				
56	E. STABLE PLATFORM										
12	S. APPALACHIA	+ 0.57	+ ≤VII: 0.417 >VII: 1.586	+ 0.55-0.6	+ .5 ± .1	+ 0.55 ± .1	+ 0.90 ± .05	+ 0.8 ± .1	0.7-0.78-0.9	.9 ± .3	+ 0.8-1.0
51	S. APPALACHIA										
13	PIEDMONT								0.9-1.02-1.1	1.0 ± .2	
52	PIEDMONT										
53	CENTRAL VIRGINIA										
14	NORTHERN VALLEY AND RIDGE								1.0-1.20-1.30	.6 ± .3	
15	APPALACHIAN PLATEAU								1.0-1.175-1.3	.6 ± .3	
16	CHARLESTON					NO ANS.	* 0.7 ± .05		0.6-0.69-0.9	.4 ± .2	
55	CHARLESTON										
17	ATLANTIC COASTAL PLAIN								0.7-0.91-1.1	.6 ± .2	
49	ATLANTIC COASTAL PLAIN										
54	WILMINGTON										
57	GULF COASTAL PLAIN								0.7-0.92-1.2		

+ Zone independent.

* Only exception.

QUESTION 3-6

QUESTION 3-7

What values for the intercept "a" would you recommend for each source zone? Assume N_c represents annual cumulative numbers of earthquakes in each zone (not normalized by area) and the intercept occurs at a "size" zero. If you prefer to provide N_c for a normalized area, explicitly note the unit area that you are using.

The following table lists the answers to this question.

There were no responses from the experts to questions 3-8 to 3-15.

NEW MADRID AND WESTERN ZONES

NO.	ZONE NAME	3 "a"	4 "a"	5 "a"	10 "a"	13 "a"	7 "a"	8 "a"	9 "a"	11 "a"	12 "a"
1	NEW MADRID	-	-	-	-	-	3.68±.3	*			-
2	NEW MADRID	-		-	-		3.57±.3				-
20	NEW MADRID	-					3.9±.53		3.4-3.9-4.4	-	
21	WABASH								2.95-3.1-3.25		-
22	OZARK UPLIFT			-					3.1-3.2-3.3		-
23	MISSISSIPPI			-	-		3.58±.2			-	
10	UPPER KENEENAW	-	-	-	-	-	2.95±.18		1.8-2.0-2.2	-	
11	ANNA, OHIO	-			-	-	2.82±.18		2.7-2.8-2.9	-	-
30	ANNA, OHIO						2.82±.12				
18	CENTRAL STABLE REG.	-	-	-	-	-	4.08±.18		†1.6-1.8-2.0	-	-
19	CENTRAL STABLE REG.	-		-	-	-	3.85±.18		†1.6-1.8-2.0	-	-
27	CENTRAL STABLE REG.						1.83±.21			-	
28	S. ILLINOIS	-		-							
29	N. ILLINOIS						2.64±.14		2.45-2.6-2.75		
24	OUACHITA						3.21±.47		†2.3-2.8-3.3		-
25	NEMAHA RIDGE				-		3.22±.12		†2.8-2.9-3.0		
26	N. GREAT PLAINS						3.16±.31		†2.2-2.5-2.8		

(See Appendix)

* We would not recommend "a" values at this time.

† Normalized to an area of 100,000 km^2.

QUESTION 3-7

QUESTION 3-7

NORTH EASTERN ZONES

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		"a"	"a"	"a"	"a"	"a"	"a"	"a"	"a"	"a"	"a"
3	ATTICA	-		-	-		2.77+.12	*			-
4	ATTICA	-	I≥VI a=5.089 I≤V a=2.613	-	-		2.77+ .18		1.6-1.8-2.0	-	-
48	ATTICA				-						
5	S.ST.LAWRENCE	-		-	-	-	3.37 ±.18		2.2-2.3-2.4		-
33	S.ST.LAWRENCE		5.089 2.613							-	
6	N.ST.LAWRENCE	-		-	-		3.07 ±.18		2.1-2.4-2.7		-
31	N.ST.LAWRENCE	-	5.089 2.613			-				-	-
32	N.ST.LAWRENCE				-	-					
8	CAPE ANN	-	"	-	-	1.6-2.1-2.5	3.02 ±.18		2.7-2.8-2.9	-	-
45	S. NEW ENGLAND		"			-					
46	N.E.MASS. THRUST COMPLEX										
47	CAPE ANN										
50	N. APPALACHIANS	2.10									

(See Appendix)

* We would not recommend "a" values at this time.

+ Normalized to an area of 100,000 km^2.

QUESTION 3-7

NORTH EASTERN ZONES (CONT.)

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		"a"					"a"				
7	BOSTON-OTTAWA	-		-	-	1.8-2.3-2.6	3.59 ± .18		3.5-3.6-3.7	-	-
39	BOSTON-OTTAWA	-				-					
9	ADIRONDACK	-		-	-		3.12 ± .18		4.6-4.8-5.0	-	-
34	ADIRONDACK	-									
35	W. NEW ENGLAND										
36	GREEN MT. BELT			-		-					
37	OSSIPPE INTRUSIVE										
38	OTHER WHITE MT. INTRUSIVE										
40	MAINE	2.10	5.089 2.613		-					-	-
41	WEST CENTRAL NEW BRUNSWICK		"								
42	PASSAMAQUODDY		"								
43	BELFAST DOVER FOXCRAFT		"								
44	COASTAL ANTICLINORIUM										

(See Appendix)

QUESTION 3-7

QUESTION 3-7

SOUTH EASTERN U.S.

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		"a"					"a"				
56	E. STABLE PLATFORM							*			
12	S. APPALACHIA	3.01	-	-	-	-	3.4 ±.18		4.9-5.0-5.1	-	-
51	S. APPALACHIA	3.01									
13	PIEDMONT	3.01	-	-	-	-	3.59 ±.18		+ 3.0-3.1-3.2	-	-
52	PIEDMONT	3.01		-						-	
53	CENTRAL VIRGINIA	2.10								-	
14	NORTHERN VALLEY AND RIDGE	2.10	-	-	-	-	2.47 ±.18		3.3-3.6-3.9	-	-
15	APPALACHIAN PLATEAU	2.10	-	-	-	-	2.79 ±.18		+ 3.5-3.8-4.1	-	-
16	CHARLESTON	2.76	-	-	-	-	1.80 ±.18		1.9-2.2-2.5	-	-
55	CHARLESTON	2.76									
17	ATLANTIC COASTAL PLAIN		-	-	-	-	3.17 ±.18		+ 2.1-2.5-2.9	-	-
49	ATLANTIC COASTAL PLAIN	2.10									
54	WILMINGTON									-	
57	GULF COASTAL PLAIN								+ 1.6-1.8-2.0		

(See Appendix)

* We would not recommend "a" values at this time.

\+ Normalized to an area of 100,000 km^2.

QUESTION 3-7

4.0 ATTENUATION

An attractive approach to supplement the limited strong motion data in the East is to infer, based on theoretical or experimental considerations, the difference in peak acceleration and velocity ground motion between the Eastern United States (East) and the Western United States (West) and to modify correspondingly the Western attenuation relations and intensity correlations in order to make them applicable in the East. The following questions address this problem in a qualitative as well as quantitative manner.

The experts were asked to keep in mind when answering the following questions, that we are interested in strong earthquake ground motions that pose a threat to the safety of nuclear power plants. Ground motions roughly corresponding to M.M. site intensities of IV or greater may be considered strong motion for this exercise.

Questions 4-1 to 4-8 addressed the overall ground motion differences between the East and the West without trying to determine their origin. The rest of the section explores several of the possible causes for these differences. Questions 4-9 to 4-15 considered differences in attenuation (travel path and regional geology). Questions 4-16 to 4-18 referred to differences in source characteristics between earthquakes occurring in the East and West.

The data in this section was formed by only seven of the experts. Respondent five did not answer, and three answered only two questions. Respondent eight felt that he could not make a meaningful comparison because the available "strong motion" data in the East was "negligible."

QUESTION 4-1

> To what degree do you feel there is evidence to substantiate the hypothesis that strong ground motion characteristics are different between the East and the West?

There is a general consensus that the characteristics for strong ground motion are different between the East and the West. Only two respondents indicated that the evidence was less than 90 percent convincing. Respondent seven answered with 70 percent, while respondent eight commented that there was not yet sufficient strong-motion data from the East to make a meaningful comparison.

Respondent nine noted in particular that ". . . except for very high frequency waves, absorption does not affect ground motion at distances of less than about 25 to 50 kilometers. Thus, in the nearfield zone the attenuation in the East will be similar to that in the West." Further in this section the opinion of the other experts bore out this conclusion.

QUESTION 4-2

Specify the evidence that supports this hypothesis.

EXPERT NO.	3	4	7	9	10	11	12	13
TYPES OF DATA	IMPORTANCE OF DATA ON A SCALE OF 0 TO 100							
Size of Felt Areas (Intensity Reports)	90	100	60	100	100	100	100	50
Instrumental Strong-Motion Records	0	10	60	0	10	10	25	50
Instrumental Records of Local Non-Damaging Earthquakes	90	80	70	100	--	90	100	80
Instrumental Teleseismic Records	10	10	15	30	50	30	15	70
Measurements Obtained from Nuclear Explosions	10	10	10	30	--	30	0	40
Other areas in the World with Similar Tectonic Setting	0	40	10	50	--	10	0	10

There is a consensus that the size of felt areas and the instrumental records of local non-damaging earthquakes overwhelmingly provide the bulk of the evidence. Some importance was also given to instrumental teleseismic records and some also to instrumental strong-motion records. The other factors were generally considered unimportant.

QUESTION 4-3

Several correlations between epicentral intensity and magnitude have been developed for different regions in the East. What correlation(s) do you think is appropriate for the source regions developed in Section 1.0? Comment in general as to the reliability of these correlations.

The respondents fell into two somewhat similar camps. One group (respondents four, seven, nine and ten) favored either the Nuttli or Street-Turcotte relationships

Nuttli $I_o = 2m_b - 3.5$

S&T $I_o = 2m_b - 3.4$

with respondent ten favoring Aggarwal's formulation for the Northeast. Respondent four favored $m = 1. + 0.6 I_o$ based on one hundred data points in the Northeast, while respondent thirteen favored $m = 1.2 + 0.6 I_o$ (Chinnery) for zones seven and eight. These relations give a slightly greater spread in magnitudes than do Nuttli or Street.

The other group (respondents eleven, twelve and thirteen) emphasized the large scatter in the relevant data and pointed out the need for more work to be done on these relationships. Fundamentally, I_o was thought not to be a good indication of magnitude because of the variance in hypocentral depth, the difficulty in measuring I_o and m_b, the lack of data for specific cases, and the lack of a standard magnitude scale.

The suggestion was made to reanalyze the available data by combining data sources, and possibly searching for other correlations (e.g., m_b vs. log isoseismal area, or the introduction of depth as a variable).

Despite the emphasis on the need for more work, there seems to be a general consensus in favor of the Nuttli or Street-Turcotte formulations as applying generally to the Eastern U. S.

QUESTION 4-4

Considering the possible regional variation of strong ground motion characteristics, how would you zone the entire United States? If you feel that several zonations are acceptable, rank them.

There is some agreement among the respondents on zonation of the entire U. S. Most favored West-East zonation under the opinion that more detailed zonation was not necessary for most purposes or that it awaits either further data or increased understanding. This was the predominant response.

Respondent thirteen, however, repeatedly made the point throughout this section that local variations in strong-motion characteristics can be so great as to overshadow any regional differences.

Respondent eleven mentioned the possibility of an intermediate zone between the Rockies and Sierra Nevadas, and the possibility of the Gulf Coast as a distinct zone. Mention was also made, by respondent nine, that there may be some difference in attenuation between the Southeastern, Northeastern, and Central sections.

QUESTION 4-5

What kind of differences in the correlation between peak ground motion values and intensity would you expect to find in the East as compared to the West? Specify the percent change in the parameters for a given intensity expected in the East relative to the West. Indicate by a minus a decrease in the East relative to the West.

The experts were again divided into two groups on this question. One group said there would be no difference between the East and West. But their reasons differed. Respondent eleven argued the mechanids of attenuation. Respondent thirteen argued that there was such a great variation between neighboring sites within each region (up to 300 percent) that this fact overshadows the difference between the "average" value of the East and West. Respondent four felt there was not enough data.

The following table summarizes the response of those who believed that for a given intensity and distance there would be an incremental percentage difference in peak acceleration and velocity between the East and West (a minus percentage equals a decrease in the East compared to the West).

		For a given intensity distance range (km)			
Parameter	Expert	0-20	20-50	50-100	100-500
	7	20%	50	100	300
Peak Acceleration	9	0	200	500	1,000
	12	0	-10	-25	-100
	7	[illegible]0%	50	100	300
Peak Velocity	9	[illegible]	150	300	600
	12	0	20	50	285

QUESTION 4-6

What kind of differences would you expect in response spectrum amplification factors of ground motion in the East as compared to the West? Specify the percent change for the East relative to the West. Indicate by a minus sign a decrease in the East relative to the West.

Of the three respondents who answered this question respondents seven and twelve answered numerically:

Frequency Range	Expert No.	0-20	20-50	50-100	100-500
		Distance Range (km)			
High Frequencies (Proportional to Acceleration)	7	0-82%	82-346%	346-1,892%	19.2 - 3×10^6%
	12	Same	-10%	-25%	-100%
Moderate Frequencies (Proportional to Velocity)	7	0-6%	6-16%	16-35%	35-39%
	12	Same	20%	50%	285%
Low Frequencies (Proportional to Displacement)	7	Same	0-1.5%	1.5-3%	3-16%
	12	Same	20%	50%	285%

Respondent thirteen argued that amplification depends largely on site geology and structure as opposed to regional characteristics.

QUESTION 4-7

How would you prefer to develop a response spectrum for an Eastern site?

The responses of the five answering experts are summarized in the table below.

Ranked below on a scale of 0 to 100 (with 100 being the highest preference) are several techniques for development of response spectra at a site.

TECHNIQUE I — Calculate or infer a site intensity. Correlate this with a peak acceleration and correlate the peak acceleration with a response spectrum.

TECHNIQUE II — Calculate or infer a site intensity. Correlate this with a peak acceleration and a peak velocity. Correlate these two parameters with a response spectrum.

TECHNIQUE III — Calculate or infer a site intensity and correlate this directly with a response spectrum.

TECHNIQUE IV — Infer a postulated earthquake magnitude and distance from the site. Correlate directly with response spectrum ordinates.

TECHNIQUE V — Infer a postulated earthquake magnitude and distance from the site. Infer a set of representative time histories and thereby postulate a response spectrum.

	Expert No.				
Techniques	4	7	10	12	13
I	50	50	70	10	50
II	60	55	0	50	80
III	100	25	0	30	10
IV	100	60	50	90*	20
V	80	55	80	100*	80
Other	0	70**	0	0	0

* only if magnitude period dependent

** "use magnitude, distance, acceleration, velocity relations to set levels of response spectra." Also, representative time histories might be used. The DELMAR model might also be used, but would require verification.

QUESTION 4-8

What are the factors responsible for the difference in strong ground motion characteristics between the East and the West?

Attenuation was considered to be the most important factor accounting for differences in strong ground motion between the East and West. The importance ascribed to source characteristics and local site effects was mixed, indicating a smaller role. Several other factors were indicated in the comments. Respondents eleven and thirteen noted that site effects in either region could cause greater variations than East-West differences. Respondent thirteen suggested ignorance or lack of good data for the East could account for some of the perceived difference. Respondent twelve remarked that the duration may affect differences in characteristics. Respondent nine noted that faults of western earthquakes sometimes break ground and consequently cause larger ground motions than quakes in the East which are not known to do so. He also said that most of the differences in ground motion can be accounted for by differences in attenuation caused by absorption.

Possible factors controlling differences in strong ground motion characteristics and their percentage weights are specified in the following table:

QUESTION 4-8

(CONT.)

FACTORS	4	7	9	10	11	12	13
				Percentage Distribution			
ATTENUATION (Travel path, Regional Geology, etc.)	50-60-80	40-45-60	70-80-90	20-30-40	70-80-90	25	30
SOURCE CHARACTERISTICS (Earthquake generation mechanism, Depth, etc.)	0-20-30	40-45-60	10-20-30	5-10-15	10-20-30	25	30
LOCAL SITE EFFECTS (Local geology or soil conditions)	10-20-40	5-10	0	50-60-70	0	25	30±100
OTHER -	0	0	0	0	0	25*	10**

* Duration of strong motion

** Poor knowledge, lack of data

QUESTION 4-9

> Are travel path effects regionally variable in the East? If so, can you specify regions of relatively uniform travel path effect?

All seven respondents thought that there is a regional Eastern variation in travel path effects. As a general classification, several identified one or more of the following as uniform zones: Northeast, or Appalachian; the Atlantic Coastal Plain, the Gulf Coast Plain; and the Central U. S. Respondent thirteen remarked that the crust is not uniform even within zones; while respondent nine noted that East/West differences are so much greater than any regional differences within the East, that these Eastern regional differences become insignificant for most studies.

QUESTION 4-10

What form of an intensity attenuation relation do you prefer for the East?

Ranked below on a scale of 0 to 100 (with 100 being the highest preference) are several functional forms for an intensity attenuation relation.

	Expert Number					
	4	7	9	10	11	13
$I_s = I_o + C_1 - C_2R - C_3\log R$	100	90	70		100	80
$I_s = I_o - C_1 - C_2R$	50	20	50			20
$I_s = I_o + C_1 - C_3\log R$	50	75	80	100		60
Other						90

Most respondents favored the more general form of the equation, equation 1, while equation 3 ($C_2 = 0$) was generally thought to be adequate, too. Respondents nine and ten definitely favored this specialized form. Respondent thirteen, however, thought the relatio... ...ould be developed from local network data, and that until that time concentration should be placed on predicting ground motion as a function of distance, site, etc. Respondent twelve thought I_o a poor characterization of an earthquake and therefore recommended that none of the equations be used.

QUESTION 4-11

Given the dependent variables of acceleration and velocity, what is an appropriate set of independent variables for Eastern attenuation relations?

Given the dependent variables of acceleration and velocity, the following independent variables were preferred for Eastern attenuation relations:

- I_s = Site Intensity (usually computed from a relationship of the form: $I_s = I_o - C_1 - C_2R - C_3 \log R$)

  Only Respondent 4 felt that this was sufficient in itself for an Eastern attenuation relation. Most other experts felt I_s could be used as a variable in conjunction with other independent variables. Four correspondents, recorded below, also felt that it wasn't at all necessary for the attenuation relation.

- R = Distance from source to site

  S = Event "size" (e.g., magnitude or epicentral intensity)

  The respondents (except number four) felt that these variables were necessary, though in the differing combinations discussed below.

- I_s, R, S

  The combination of all three independent variables was favored as the best possible alternative by Respondents seven, ten, eleven, and thirteen. Respondent eleven, however, suggested that one could either do without the size of the event (S) and just use I_s and R, or, for peak values, do without R and just use I_s and S. Respondent ten felt that one only had to use I_s and S for all frequencies.

- Four experts suggested using R and S without the independent variable I_s.

  Respondent seven — indicated that, for waves of all frequency, this was sufficient.

  Respondent nine — noted that the coefficient of absorbtion for large waves (1 Hz) is

  0.0006 km^{-1} in the East, and
  0.006 km^{-1} in the West.

  For waves of 10 Hz the coefficient is

  0.006 km^{-1} in the East, and
  0.06 km^{-1} in the West.

  Thus, for various wave frequencies, it is possible to construct attenuation curves for ground motion amplitude vs. distance. However, he saw no way of including site intensity (I_s) in such relations.

  Respondent eleven — felt R, S to be sufficient only for high frequency waves.

  Respondent twelve — suggested a further variation: S (m_b), R, γ, with "γ" being an elastic attenuation coefficient. He also commented that values are available for 0.1 Hz, 1 Hz, and 10 Hz, while values for other waves could be extrapolated.

In summation we can say that most experts favored using the three variables, I_s, R, and S, though some of these experts felt that it is not necessary to use I_s. On the other hand, R and S were generally considered to be indispensable input for an Eastern attenuation relation.

QUESTION 4-12

Are there any specific attenuation relationships that you would recommend for use in the Eastern United States? If so, specify the relationships, references, and applicable regions.

All three respondents answering yes to the question indicated no differentiation among zones. Respondents nine and twelve cited Nuttli's magnitude formulae (published in 1973 and 1979).

$$\log a_H(\text{cm/s}^2) = \begin{cases} -0.36 + 0.52\, m_s & R \le 15 \text{ km} \\ 0.84 + 0.52\, m_b - 1.02 \log R(\text{km}) & R \ge 15 \text{ km} \end{cases}$$

$$\log V_{max}(\text{cm/s}) = -2.92 + m_b - 1.0 \log R(\text{km})$$

Respondent four suggested the conservative $I_s = I_o$ criterion for the Northeast.

QUESTION 4-13

> To your knowledge, is there any evidence to suggest that the rate of intensity attenuation is a function of the epicentral intensity I_o? In other words, is the attenuation gradient $\Delta I / \Delta R$ a function of I_o?

The experts generally agreed that, as for the data available to them indicated, the rate of intensity attenuation was independent of the epicentral intensity, I_o.

There were, however, comments made modifying this consensus. Respondent twelve said there was too much scatter in the I_o to realistically answer. Respondent thirteen noted that in large earthquakes the area of I_o is also usually large, causing a slower attenuation of intensity until greater distances are reached. A large focal depth also causes a slower fall off of intensity. He also noted that above a given value of strain attenuation increases.

QUESTION 4-14

Are there any regions in the world that might have attenuation characteristics similar to those in the East?

Six of the experts made suggestions. The consensus of opinion centered on the bulk of Europe (excluding the Mediterranean countries), the northern and central Russian platforms, and eastern central Latin America. Stable continental masses such as Central Australia, Africa and India were mentioned by half of the respondents. One respondent mentioned Canada and China near Beijing (Peking).

The criteria used fell under:

1. Lithosphere thickness at time of latest progeny
2. Intraplate regions
3. Stable continental areas
4. Shields or old high platform areas

QUESTION 4-15

To what factors can we attribute the differences in attenuation between the East and the West?

The table below summarizes the response of the experts. They indicated by ranking on a scale of 0 to 100 the factors they felt might explain the differences in attenuation between the East and West.

	Expert Numbers							
Factors	4	7	9	10	11	12	13	Ave.
Lower intrinsic damping	100	90	85	30	75	100	50	75
Different crust structures (vertical heterogeneities giving rise to critical angle reflections and wave guide effect)	60	50	0	60	100	0	50	39
Less complex wave path (lateral heterogeneities giving rise to scattering and defocusing)	30	80	15	80	75	0	50	47
Other							50*	

* "Inadequate data to really establish this at short distances."

QUESTION 4-16

Are there any significant differences between Eastern and Western earthquake source characteristics?

There is not a general consensus on this question. Respondents nine and eleven remarked in their comments that they thought there were no intrinsic differences between Eastern and Western sources. There is, however, a general consensus among six respondents including one who did not feel that there were any differences, that "stress drops" and "source dimension" are important factors that distinguish the two regions. Only four respondents specified smaller/larger comparisons; seven and ten thought that the East has smaller "stress drops," twelve and thirteen thought the contrary, and all four thought the "source dimensions" in the East were smaller. The importance rating given source depths and competent rock was somewhat mixed. Rupture time and rupture velocity were considered less important factors. Respondent twelve stated that the Eastern earthquakes were more predictable. Respondent seven commented that the first three factors were lumped together in their calculation of "stress drop," and noted that small Eastern earthquakes are deficient in low frequencies and larger Eastern earthquakes are similar in stress drops to Western ones.

Of the two respondents who saw no intrinsic difference between the Eastern and Western earthquake sources, respondent twelve commented that local site differences overshadow any generalization between Eastern and Western source characteristics. Respondent nine mentioned that the only significant difference in source mechanisms between Eastern and Western earthquakes was that the latter sometimes break the surface.

The following table summarizes the opinion of the experts. They indicated by ranking on a scale of 0 to 100 the factors which they felt distinguished Eastern versus Western earthquake sources.

QUESTION 4-16

(CONT.)

Factors	Expert Numbers 4	7	9	10	11	12	13	Ave.
Longer/shorter rupture time	10	60	30	10	0	0	20	19
Lower/higher rupture velocity	10	50	0	10	0	0	20	13
Smaller/larger source dimensions	70	60	30	50	0	50	60	46
Smaller/larger stress drops	80	90	30	50	0	50	60	53
Deeper/shallower sources	10	10	20	40	100	0	40	31
More/less competent rock	100	40	0	0	0	0	60	29
Other (specify)	--	--	--	--	--	--	100*	--

More predictable

QUESTION 4-17

How, in general, are these differences in earthquake source characteristics between the East and West manifested in ground motion?

Higher "high frequency content" and higher "low frequency content" were thought to be the most important manifestations of the differences. Higher "peak values," (particularly velocity and displacement) and larger "durations" were also considered. Respondent seven commented that the frequency differences in the East will become smaller with increases in earthquake magnitude. Respondent thirteen stated that his answers were guesses because it is necessary to look at data from the East and the West for the same magnitude (I_o) events. Respondent nine suggested that Eastern earthquakes may have higher stress drops for the same seismic movement which would affect the high frequency spectral content. He also stated that this factor is much less important than differences in absorption in explaining differences in ground motion.

The responses are further summarized below. The effects on ground motion are ranked on a scale of zero to one hundred.

	Expert Number						
	4	7	9	10	11	12	13
Longer/shorter duration	10	60	30	--	--	90	--
Higher/lower high frequency content	90	30	50	50	--	0	80
Higher/lower low frequency content	90	80	20	--	--	70	--
No change in frequency content	10	10	70	--	--	0	--
Higher/lower peak values for the same intensity	100	--	0	5	--	--	--
• acceleration	--	30	--	--	--	--	--
• velocity	--	50	--	--	--	50	--
• displacement	--	70	--	--	--	--	--

QUESTION 4-18

Are there any regions in the world that might have earthquake source characteristics similar to those in the East?

There is a general consensus among six respondents that other continental intraplate regions in the world are likely to be similar to the Eastern U. S. Respondent eleven said that probably most of the world was similar to the East because he thought source characteristics other than depth were not regionally dependent. Another respondent stated Central Europe, especially the Upper Rhine of Germany, is similar and also of moderate activity. He suggested reviewing the work of Ahorner and Rosenhauer (1978, and previously in 1975), as they applied Gumbel's extreme value method to estimate risk and maximum magnitude.

Respondents four and twelve did not answer and thirteen, while falling within the consensus, remarked that his answer was just a first guess.

QUESTION 4-19

> Are there any significant differences in site effects between Eastern and Western sites?

Five of the seven respondents answered either that there were no differences, or that differences from site to site overwhelm any East-West regional differences.

Respondent four predicted a difference in the high and low frequency content as well as a difference in peak values. Respondent ten, however, felt that only the high frequency content would be affected.

QUESTION 4-20

In general, what is mechanically the maximum acceleration that various types of deposits could be expected to sustain?

Three respondents answered, in terms of percentage g, what they thought the maximum sustainable acceleration on different earth media would be. They all, however, emphasized the poor quality of data or lack of confidence in their answers.

Type of Ground	Maximum Acceleration in %g. Expert 4	Expert 7	Expert 13
Soft Soils	50-80-100	40	100
Firm Soils	30-60-80	50	100
Soft Sedimentary Rock	40-70-100	60	100
Hard Sedimentary Rock	30-50-80	100	100
Basement Rock	10-30-40	150	100

QUESTION 4-21

Now attempt to integrate your responses on the previous travel path, source characteristics and site effects questions by summarizing the distinction between East and West overall ground motion. Indicate by a minus a decrease in the East relative to the West.

The consensus indicated that the "duration," "high and low frequencies," and "peak values" (especially velocity) are greater in the East for a given magnitude than in the West, and that the differences increase with distance from the source.

The increase in the near-field (0-50 km) for "duration" and "low frequency" content was considered from negligible to small, while "high frequency" content was believed to show a more significant rise. Only one respondent predicted more than a small rise in low frequency content with distance.

"Peak values" close to the source (0-20 km) also showed only a negligible increase in the East over the West, but showed much greater increase with distance.

The following table tabulates the response of the experts. They were asked to indicate by percentage increase how the overall differences in source characteristics, attenuation, and site effects between East and West would affect the following parameters of ground motion:

Effects on Ground Motion	Expert No.	Distance Range (km) 0-20	20-50	50-100	100-500
Longer Duration	4	0	10	20	30
	7	0-20	20-50	50-100	100+
	9	0	50	100	2-500
	10	0	0	0	0
	12	0	25	50	100
Higher/Lower High Frequency	4	20	30	40	50
	7	0-10	20-50	50-100	100+
	9	30	50	100	200
	10	50	50	50	50
	12	--	--	--	--
Higher/Lower Low Frequency	4	10	10	10	10
	7	0-10	30	30	50
	9	20	20	20	20
	10	--	--	--	--
	12	0	20	50	285
Higher/Lower Peak Values	4	10	30	40	50
• Acceleration	7	-30	0	50	200
	9	0	200	500	1,000
• Velocity	7	0	20	60	20
	9	0	150	300	500
	12	0	20	50	285
• Displacement	7	30	40	80	200
	9	0	150	200	300

5.0 SELF RANKING

A synthesis of opinion was reached among the experts through a weighted average procedure based upon self-assigned levels of confidence. In this section the experts were asked to rate on a scale of one to ten (ten being the highest) the confidence they had in their responses to the different sections of the questionnaire: source zone configuration, maximum earthquake estimates, earthquake recurrences, and attenuation.

The following table lists the response of the experts to this question.

NEW MADRID AND WESTERN ZONES

SELF RANKING ON A SCALE OF ZERO TO TEN

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		ZONE CONFIGURATION - MAXIMUM EARTHQUAKE - EARTHQUAKE RECURRENCE - ATTENUATION									
1	NEW MADRID	7-9-9*	8-8-8-8	5-8-8-3	9-10-8-7	3-4-4	3-8-8-9	8-9-9	10-10-10-10	9-8-7-6	8-9-9-9
2	NEW MADRID	7-9-9	8-8-8-8	5-8-8-3	9-10-8-7	3-4-4	3-8-8-9	8-9-9	10-10-10-10	9-8-7-6	8-9-9-9
20	NEW MADRID	9-9-9					9-9-9-9	8-9-9			
21	WABASH								9-8-8-10		8-8-8-9
22	OZARK UPLIFT								8-8-8-10		9-7-7-9
23	MISSISSIPPI				9-10-8-7		9-9-9-9	7-8-9		9-8-7-4	
10	UPPER KENEENAW	5-6-7	4-8-4-4	5-5-5-3	2-7-6-6	4-4-4	2-7-6-9	7-8-9	4-5-5-10	6-6-4-4	9-10-10-8
11	ANNA, OHIO	9-6-6	4-8-4-4	5-5-5-3	6-8-8-9	0-4-4	6-8-8-9	9-8-9	7-8-8-10	9-7-7-6	6-7-9-9
30	ANNA, OHIO						8-8-8-9				
18	CENTRAL STABLE REG.	7-6-5	7-8-8-5	6-5-5-3	9-9-9-9	2-4-4	3-7-6-7	8-8-9	8-8-8-10	9-0-0	6-8-8-10
19	CENTRAL STABLE REG.	9-6-5	7-8-8-5	6-5-5-3	9-9-9-9	2-4-4	3-7-6-7	8-8-9	8-8-8-10	9-0-0-	6-8-8-10
27	CENTRAL STABLE REG.	9-6-5					9-8-7-9	7-8-9		8-6-6-6	
28	S. ILLINOIS	8-7-6									
29	N. ILLINOIS						8-8-8-9		6-8-7-10		
29	N. ILLINOIS										
24	OUACHITA						8-8-8-8		8-7-8-10		5-7-6-6
25	NEMAHA RIDGE				9-9-8-9		9-8-8-9		8-9-8-10		
26	N. GREAT PLAINS						8-8-7-9		7-8-8-10		

* The first, second, and third numbers are the self rankings of the experts for zone configuration, maximum earthquake, and earthquake recurrence, respectively. The fourth entry would be the self ranking for attenuation.

QUESTION 5-0

NORTH EASTERN ZONES

SELF RANKING ON A SCALE OF ZERO TO TEN

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		ZONE CONFIGURATION - MAXIMUM EARTHQUAKE - EARTHQUAKE RECURRENCE - ATTENUATION									
3	ATTICA	9-7-6*	10-10-10-10	3-5-5-3	10-10-10-10	5-6-4	4-8-8-9	8-9-9	7-8-8-10	10-7-6-4	7-8-8-7
4	ATTICA	6-7-6	10-10-10-10	3-5-5-3	10-10-10-10	5-6-4	6-8-8-9	8- -9	7-8-8-10	10-7-6-4	7-8-3-7
48	ATTICA				10-10-10-10			8-8-9			
5	S.ST.LAWRENCE	5-8-7	10-10-10-10	7-8-8-3	9-9-9-9	5-6-7	6-8-6-7	9- -9	8-9-8-10	10-0-0	7-8-7-8
33	S.ST.LAWRENCE		10-10-10-10							10-8-7-4	
6	N.ST.LAWRENCE	7-8-7	10-10-10-10	7-8-8-3	7-9-6-7	5-6-7	6-8-6-7	9- -9	8-9-8-10	10-0-0	8-8-9-8
31	N.ST.LAWRENCE	7-6-5	10-10-10-10					9-9-9		10-8-7-4	8-9-9-9
32	N.ST.LAWRENCE				10-10-10-10	7-7-7		9-8-9			
8	CAPE ANN	7-8-8	10-10-10-10	9-9-9-3	9-10-10-9	8-8-8-6	4-7-6-7	8-7-9	6-8-7-10	9-7-6-4	9-9-10-10
45	S. NEW ENGLAND		10-10-10-10			7-7-7		8-9-9			
46	N.E.MASS. THRUST COMPLEX							9-9-9			
47	CAPE ANN							8-9-9			
50	N. APPALACHIANS	7-7-6								7-8-7	

* The first, second and third numbers are the self rankings of the experts for zone configuration, maximum earthquake, and earthquake recurrence, respectively. The fourth entry would be the self ranking for attenuation.

QUESTION 5-0

NORTH EASTERN ZONES (CONT.)

SELF RANKING ON A SCALE OF ZERO TO TEN

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		ZONE CONFIGURATION		-	MAXIMUM EARTHQUAKE		-	EARTHQUAKE RECURRENCE		-	ATTENUATION
7	BOSTON-OTTAWA	7-8-8 *	10-10-10-10	9-9-9-3	9-10-10-9	7-8-7-6	4-7-6-7	9- -9	6-7-7-10	10-0-0	9-9-9-9
39	BOSTON-OTTAWA	8-8-5				8-8-7					
9	ADIRONDACK	7-7-7	10-10-10-10	7-5-7-3	10-10-10-10	5-6-4	4-7-6-7	8-8-9	6-7-7-8	10-0-0	7-9-9-9
34	ADIRONDACK	7-7-5									
35	W. NEW ENGLAND							8-8-9			
36	GREEN MT. BELT			6-6-6-3		6-6-7					
37	OSSIPPE INTRUSIVE							8-9-9			
38	OTHER WHITE MT. INTRUSIVE							7-8-9			
40	MAINE	6-6-4	10-10-10-10		10-10-10-10			8-8-9		7-0-0	10-10-10-10
41	WEST CENTRAL NEW BRUNSWICK		10-10-10-10								
42	PASSAMAQUODDY		10-10-10-10								
43	BELFAST DOVER FOXCRAFT		10-10-10-10								
44	COASTAL ANTICLINORIUM							7-8-9			

* The first, second and third numbers are the self rankings of the experts for zone configuration, maximum earthquake, and earthquake recurrence, respectively. The fourth entry would be the self ranking for attenuation.

QUESTION 5-0

SOUTH EASTERN U.S.

SELF RANKING ON A SCALE OF ZERO TO TEN

NO.	ZONE NAME	3	4	5	10	13	7	8	9	11	12
		ZONE CONFIGURATION - MAXIMUM EARTHQUAKE - EARTHQUAKE RECURRENCE - ATTENUATION									
56	E. STABLE PLATFORM							7-8-9			
12	S. APPALACHIA	7-9-8*	6-8-7-5	5-5-5-3	7-9-8-7	1-4-4	6-7-6-7	7-8-9	7-8-7-8	9-0-0-6	3-3-2-5
51	S. APPALACHIA	9-9-6									
13	PIEDMONT	3-9-8	6-8-7-5	5-5-5-3	7-9-8-7	1-4-7	6-7-6-7	8- -9	7-8-7-8	9-0-0	3-3-2-5
52	PIEDMONT	7-9-6		5-7-8-3				8-8-9		7-0-0	
53	CENTRAL VIRGINIA	7-7-6								7-0-0	
14	NORTHERN VALLEY AND RIDGE	5-8-8	6-8-7-5	5-5-5-3	7-9-8-7	1-4-4	6-7-6-7	7-8-9	6-6-6-8	9-0-0	3-3-2-5
15	APPALACHIAN PLATEAU	2-7-8	6-8-7-5	5-5-5-3	7-9-8-8	1-3-7	6-7-6-7	7-8-9	6-6-6-8	9-0-0	3-3-2-5
16	CHARLESTON	3-9-7	6-8-7-5	7-6-8-3	10-10-10-9	2-4-4	8-9-7-7	9-9-9	7-9-8-8	9-7-7-6	3-3-2-5
55	CHARLESTON	9-9-7									
17	ATLANTIC COASTAL PLAIN	3-7-6	6-8-7-5	7-8-8-3	10-10-10-9	3-3-7	6-7-6-7	7-8-9	7-7-7-8	9-0-0	3-3-2-5
49	ATLANTIC COASTAL PLAIN										
54	WILMINGTON									8-0-0	
57	GULF COASTAL PLAIN								6-7-7-8		

* The first, second and third numbers are the self rankings of the experts for zone configuration, maximum earthquake and earthquake recurrence, respectively. The fourth entry would be the self ranking for attenuation.

QUESTION 5-0

6.0 REFERENCES

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APPENDIX A

SOLICITATION OF EXPERT OPINION

APPENDIX A
SOLICITATION OF EXPERT OPINION

A.1 THE EXPERT PANEL

An obvious keystone to any expert opinion solicitation is the selection of the expert panel. The criteria used for this project was simple; employ as many as possible of the best seismologist experts in EUS seismology. Thirteen experts were contacted and their availability determined. Of these, only ten were able to complete the questionnaire. These experts, listed by region, were,

Dr. Robert Herrmann

Dr. Otto Nuttli

Dr. Ronald Street

Dr. Gilbert Bollinger

Dr. Edward Chiburis

Dr. Michael Chinnery

Dr. Richard Holt

Dr. Paul Pomeroy

Dr. Nafi Toksöz

Dr. Marc Sbar

A.2 MODES OF JUDGMENT

Modes of judgment are the methods by which people assess uncertainty. They use intuitive assessment procedures that are often based on cues of limited reliability and validity. Three common features of these modes of judgement noted by Spetzler and von Holstein (1975) are:

- Generally people are not aware of the cues their judgments are based on
- Controlling the cues people base their judgments on is difficult
- People can be made aware of biases and make a conscious attempt to control them

It is convenient to divide the modes of judgments into the four categories of representativeness, availability, adjustment and anchoring, and unstated assumptions.

Representativeness is the tendency to assign the probability of an event according to the degree of similarity it has with a broader group of events from which it is issued. Often a simple event is given more weight than it should because it is well defined and considered representative while the whole population carries more generalized information. The biases resulting from representativeness can often be reduced or eliminated by structuring the problem in more detail (Spetzler and von Holstein, 1975).

Availability refers to how easily occurrences can be brought to mind. For instance, present or recent occurrences or information that made a strong impression at the time it was presented are more available than occurrences from a long time ago or that did not make a strong impression. One may assess the risk of heart attack among middle-aged people by recalling such occurrences among one's acquaintances, and often such information will be given more weight than it should because it is still vivid in one's memory. Such bias can usually be removed by conditioning the subject and forcing him to broadly survey his information base before starting the scaling.

The first or most available piece of information is often used as a basis for answering further questions by adjusting the responses according to this base. Typically the subject's adjustments will be insufficient and lead to a central bias. Such a phenomenon is called anchoring. Anchoring often occurs when the starting point is given to the subject, or when he is first asked a question which he considers very important (such as a mean value) and he bases the remainder of his answers on those. Such biases can be reduced by covering a wide range of values at the beginning, asking questions whose answers are uncorrelated.

If there is room for unstated assumptions, the subject will, consciously or not, restrict himself to particular cases with which he feels more at ease or implicitly disregard situations that he feels are too far-fetched to need consideration. Therefore his probability distribution does not reflect his total uncertainty. This obstacle can be removed by properly structuring the problem and making sure that conditional probabilities are explicitly stated.

A.3 BIASES

Biases are discrepancies between the expert's answers and his real knowledge. Such discrepancies can take several forms and can be either conscious or unconscious.

- Displacement biases consist of a translation of the whole distribution function either upward or downward but with no change in the shape.
- Variability biases consist of a variation in the shape of the distribution function. The bias can result either in a tighter distribution (central bias) or in a broader distribution (more uncertainty) than is justified by the expert's state of knowledge. These discrepancies are often a mixture of both biases unless the subject consciously modifies his answers following a well-defined pattern.

The sources of bias can be divided into two categories--motivational or cognitive--both of which can be either conscious or unconscious.

- When obeying to motivational biases, the subject wants to influence the decision in his favor by modifying his answers. For example, he might reduce the uncertainty beyond what his knowledge would allow him because he feels that an expert in his position is expected to talk about this subject with a high level of confidence. In other cases, an expert might want to broaden the uncertainty to influence the decision one way or another.
- Cognitive biases are systematic adjustments introduced by the way the expert formulates his judgment. For example, one expert may give more weight to the last piece of information he has acquired simply because it is fresher in his mind.

A.4 SCALING TECHNIQUES

The goal of the encoding session is to obtain an accurate representation of the experts' judgment on a well-defined, uncertain parameter. This judgment will be sought not only on the "most probable value" or on the expected value of the distribution, but also, when possible, on the entire probability distribution.

A judgmental probability distribution is encoded in a session between the expert whose judgment is being encoded, and an analyst who conducts the interview. In the present case we recommend that a questionnaire be sent out to each expert and be followed up by a personal interview during which additional questioning will resolve inconsistencies and other problems.

It is convenient to divide the different stages of scaling sessions into three steps.

- Pre-conditioning - the expert is conditioned to think fundamentally about his judgment and to avoid cognitive biases
- Scaling - the judgment is quantified in probabilistic terms
- Verifying - the responses obtained in the scaling are checked for consistency

The purpose of pre-conditioning is to pinpoint biases that might surface during the scaling and to force the subject to think of how he makes his judgment. This step will reveal what information seems to be most available, what anchors are being used and what assumptions are being made.

It is during the scaling session that the subjective probability associated with the quantities of interest are obtained from the expert. Scaling methods can be sorted in different ways since they differ in several aspects, such as in the properties of the scale (ordinal, interval, ratio), the nature of the response (direct, indirect), the nature of the uncertain quantity (probability, value, both: P, V or PV methods), the experimental procedures, etc. Each of these aspects can be used to classify the scaling methods.

For the purpose of this study, we believe it is useful to sort them as follows:

Ordinal Questioning (Indirect or Direct Response Technique)

In the indirect response technique, to be used during interview, the subject is asked to choose between two or more alternatives. The choices are then repeatedly adjusted until he feels indifferent about choosing between them. The level at which indifference is reached can be translated in terms of probabilities (P methods) or values of the variable being scaled (V methods). In the case of the external reference process, one alternative is expressed in terms of the uncertain quantity and the other in terms of a familiar reference event. When the external reference is used, it is important that the expert be familiar and at ease with this external reference. References can be of two types: either a standard list of events of fixed probabilities or graphic displays such as the probability wheel or the probability segment. The internal reference process, on the other hand, uses alternatives defined in terms of the same value scale. For example, the subject is asked to choose between two possible ranges of values of the uncertain quantity.

In the direct response technique, the subject is asked to assign a probability corresponding to a given value (P method) or to assign a value corresponding to a given probability (V method).

Graphs

By graphing his subjective input, the subject provides both the probability and value of the uncertain quantity. He graphs this subjective input either by directly drawing the CDF or by giving a number of pairs of points from which a curve can be drawn.

Semantic Variables

This method requires that the scaling be done in two phases. First, the expert characterizes the event in terms of descriptors he is familiar with (such as "likely," "most probably," "rare," etc.) and then he must encode these descriptors in quantitative terms himself. This last step is necessary because the quantitative meaning of the verbal labels is extremely subjective (Lichtenstein and Newman, 1967). Although this method may be useful when the quantities of interest have no ordinal value scale, it is not thought practical for this project.

Finally, in the verifying phase of the session, judgments are tested for consistency. Since feedback and cross-checking play an important role in the process interviews are highly recommended to complete the procedure.

APPENDIX B

ADDITIONAL COMMENTS FROM EXPERTS 5 AND 7

EXPERT 5

Question 1-1: Comment

He preferred not to have to deal with zones or provinces at all. "The stress field in the Eastern U.S. is extremely complex. It is, by its very nature, continuous. There is, therefore, no unique way to construct discretized 'provinces' or 'zones' that have any meaning. All parts of the Eastern U.S. have the potential to c[illegible]e earthquakes (though at different rates), and no region can be defined which is even approximately homogeneous."

There is "a highly variable and very complex set of stress concentrations throughout the Eastern U.S. Earthquakes will occur in the vicinity of each stress concentrator, and their location and rate will depend on the shape and amplitude of each individual concentrator. The problem can only be studied by statistical methods."

Question 2-2: Comment

"There is no concrete data that leads to an estimate for the maximum possible earthquake in any region of the world. There have been attempts to link the maximum possible earthquake with rate of seismicity, but I think these are very unconvincing . . . . The only thing we really can be sure of is that rates of activity vary very strongly.

"This is not to say that upper bounds do not vary from region to region, but in the absence of definitive data the only way I can answer this question is to say that an intensity XII is possible anywhere."

Questions 2-3 to 2-5: Comments

"Each of these questions uses the phrase 'expect to occur,' and I find this very difficult to interpret. My reason for this is that all the evidence available suggests that earthquake occurrence within any region can only be described on a statistical or probabilistic basis. . .

"I can think of several possible interpretations for your phrase 'the largest earthquake that you expect to occur.' One is the 'largest conceivable earthquake.' This is not, I think, the intent of your question, but my answer for this follows from question 2-2, and is intensity XII for all regions.

"Another possible interpretation is that you want the size of earthquake that has a mean return period of 150 (or 1000) years. I can illustrate the problem here using the data given for region I (New Madrid). Here, using one analysis of the data, earthquakes in the intensity range 8.0 to 8.9 have a mean return period of about 150 years, and those in the range 9.0 to 9.9 have a mean return period of about 1000 years. This means that, within an arbitrary 150 year period, the probability that at least one of the quoted intensity will occur is:

Intensity	Probability
7.0-7.9	99%
8.0-8.9	63%
9.0-9.9	14%

"These are enough to demonstrate that mean return period by itself is a meaningless quantity. I do 'expect' (at the 14% probability level) that an earthquake of intensity IX will occur in a period of 150 years, even though its mean return period is 1000 years.

"This raises another possible interpretation of the question, in which you want me to specify the probability level which corresponds to my definition of 'expected to occur.' I have to change this request around, and ask what is an acceptable error rate. If I said (in the above example) that an intensity VIII was the largest expected in 150 years, the table shows that I would be wrong in more than one out of seven cases. If I quoted similar values for 21 regions, larger values than my estimates should occur in at least 3 cases during any 150 year interval. I have been forced into a situation where my probability level for each region depends on the number of regions. This sounds absurd at first sight, yet this is the nature of the probabilistic approach.

"My only alternative is to reduce my expectation of failure to an extremely low level, say .001. Using the same data as above, this would lead to an intensity XI. If I were to choose .0001, I would have to quote an intensity XII (all of these values are based on a very conservative interpretation of the data).

"I have presented these arguments in some detail to explain why my answer to question 2-2 precludes me from being able to give any satisfactory answers to questions 2-3 to 2-8, as stated."

EXPERT 7

Questions 2-4, 2-5: Comment

"The occurrence of a 150 year earthquake near one of the bounds does not bother me. The 150 year earthquake has about a 28% chance of occurring in a 50 year period, or a 50% chance of occurring in a 100 year period. The particular limits set on the 150 year earthquake magnitude in 2-3 reflect the error associated in the magnitude estimate. I feel that we have a fairly good feel on this earthquake.

"The 1000 year earthquake is another story. Presumably we have experienced that earthquake in New Madrid - Source Zone 23, Charleston - Source Zone 16, and in the St. Lawrence - Zones 5 and 6. The recurrence of such an event there would only give a better estimate of magnitude. The occurrence of the 1000 year earthquake elsewhere may define another source zone, especially if it is large enough to generate an aftershock zone. With respect to zones of low activity, or low 1000 year magnitude, such as Source Zone 26, that earthquake would provide some food for thought or even a good test of our extrapolation methods."

Questions 2-3, 2-4, 2-5: Comment

" . . . the maximum earthquake is defined as the 1000 year earthquake under a certain qualification. It is obvious that, as one makes the source zone larger, the 1000 year earthquake becomes larger due to the increase in the a value of the recurrence relation. In this case, one should look at the largest event that has occurred, e.g., the largest event seems to have occurred at New Madrid, Charleston, and St. Lawrence. The departure from a linear recurrence relation is obvious in many source zones, pointing out this feature. Likewise, in establishing the 150 year earthquake, the recurrence relation may indicate a larger magnitude than for the 1,000 year event chosen. A rule of thumb might be to use the largest event as the 1000 year earthquake, if it is of m_b greater than 6.5, or to add 1.0 m_b unit to the largest event in the 100-150 years."

Question 2-10: Comment

"Fudge this. Convert magnitude to energy, multiply by two, and go back to magnitude. Thus, New Madrid 1811-1812 was a series of three 7.2 events, which would be equivalent to one 7.5 earthquake."

Question 3-6: Comment

"The data are really good for intensity VI to IV. In some cases, it is difficult to establish even a b-value. In other cases, it is conservative to put the line with slope defined by the b-value through the largest event data, only.

"In general, the scatter may be within a factor of 1.5 for 97% confidence, at any intensity level, perhaps log-normal."

Question 3-7: Comment

"In the use of the recurrence curves together with the maximum magnitude limits, I would say that the maximum magnitude given in 2-2 would have a 0.001 probability, with perhaps a zero probability of the upper limit earthquake occurring. E.g., use recurrence relation for magnitudes less than the 1000 year earthquake and set the probability equal to zero for the upper limit earthquake, which I have in general set equal to $m_{1,000\ yr}$ + 0.2 . This is how I would truncate the probability curves."

Question 4-12: Comment

"Use Bollinger (1977) USGS Prof paper 1028. Gupta and Nuttli, 1976 BSSA, 743-751.

$$I_{MM} = \begin{cases} 0.0 + I_0 - 0.0 \log_{10} R & R \text{ less than 20 km} \\ 3.1 + I_0 - 2.46 \log_{10} R & R \text{ greater than 20 km} \end{cases}$$

Gupta also gives a form involving a - C R term."

APPENDIX C

EXPERT MAPS FOR ALTERNATIVE SOURCE ZONE CONFIGURATION

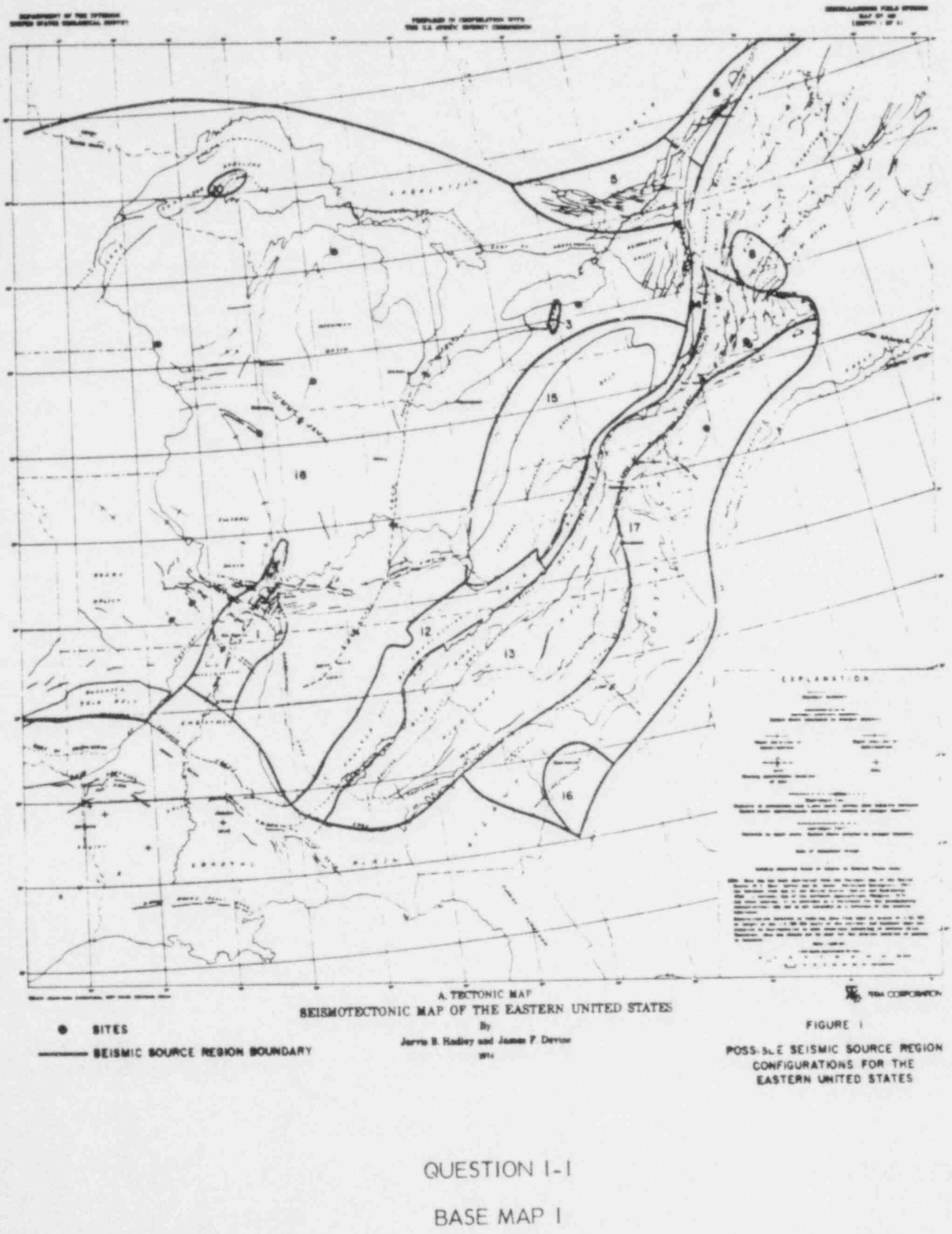


FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

BASE MAP 1

POOR ORIGINAL

● SITES

—— SEISMIC SOURCE REGION BOUNDARY

— — — BOUNDARIES REPEATED FROM FIGURE 1

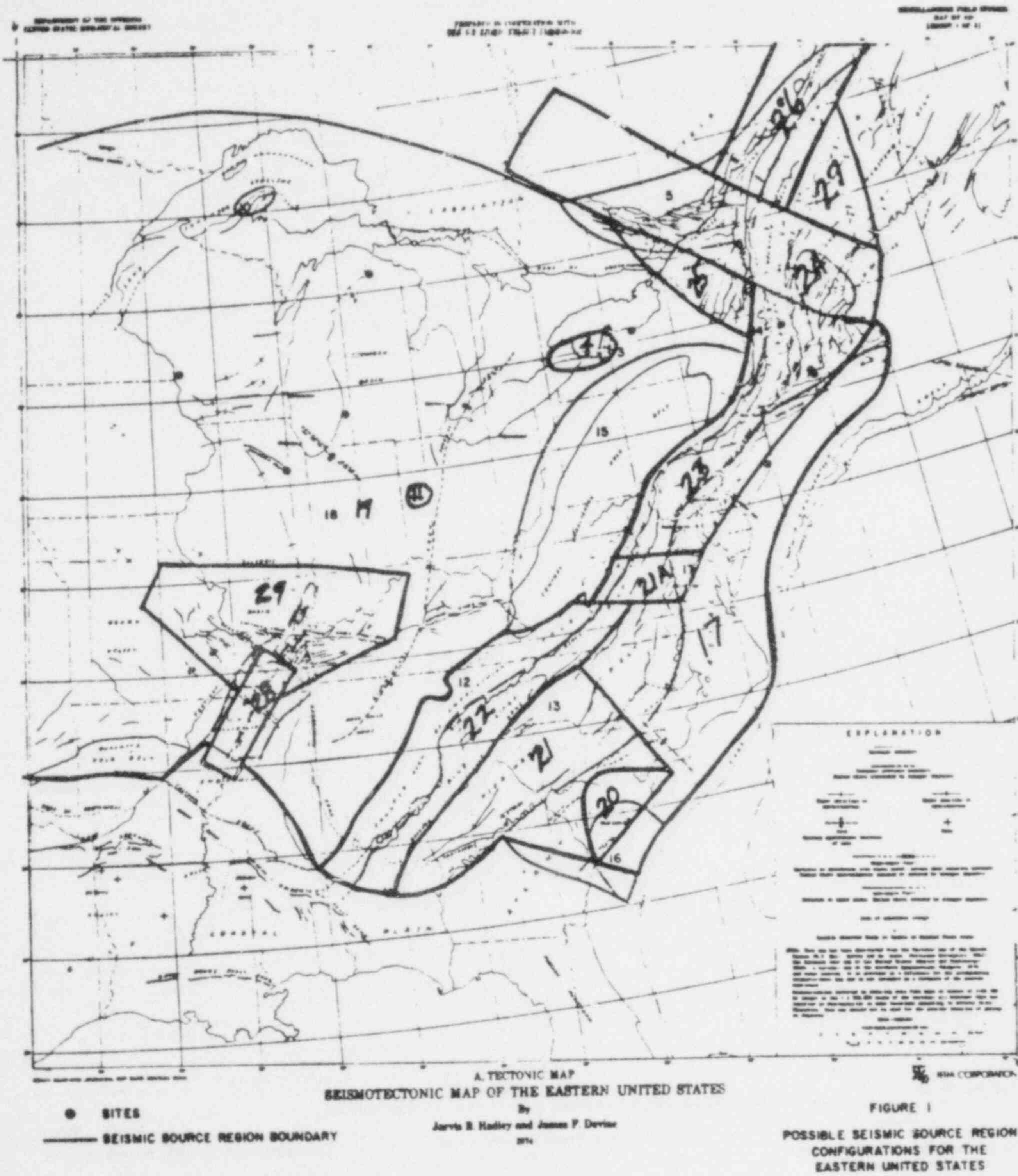
FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

POOR ORIGINAL

QUESTION I-1

BASE MAP 2



● SITES

—— SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 3

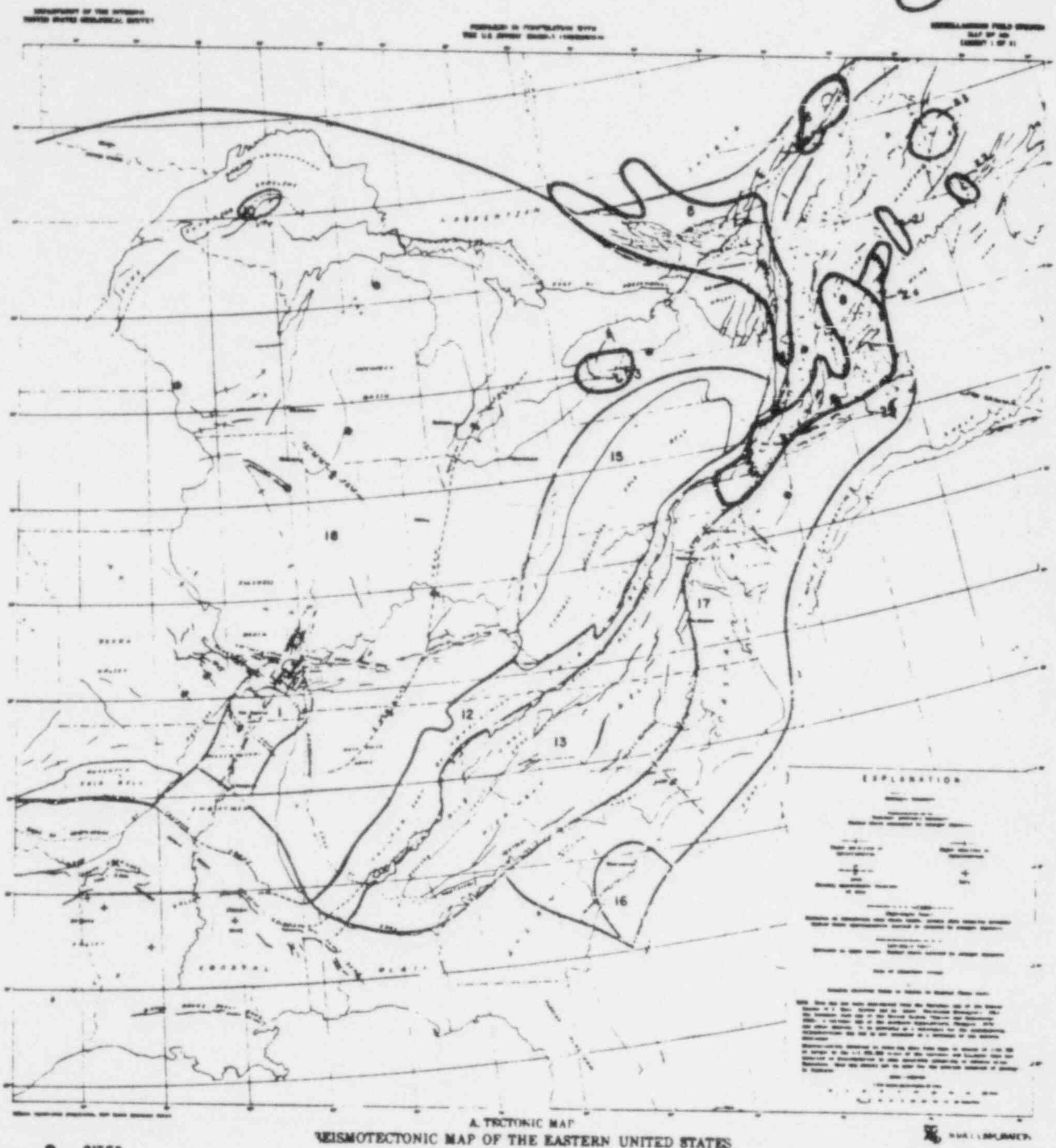


FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 4

POOR ORIGINAL

● SITES

——— SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 5

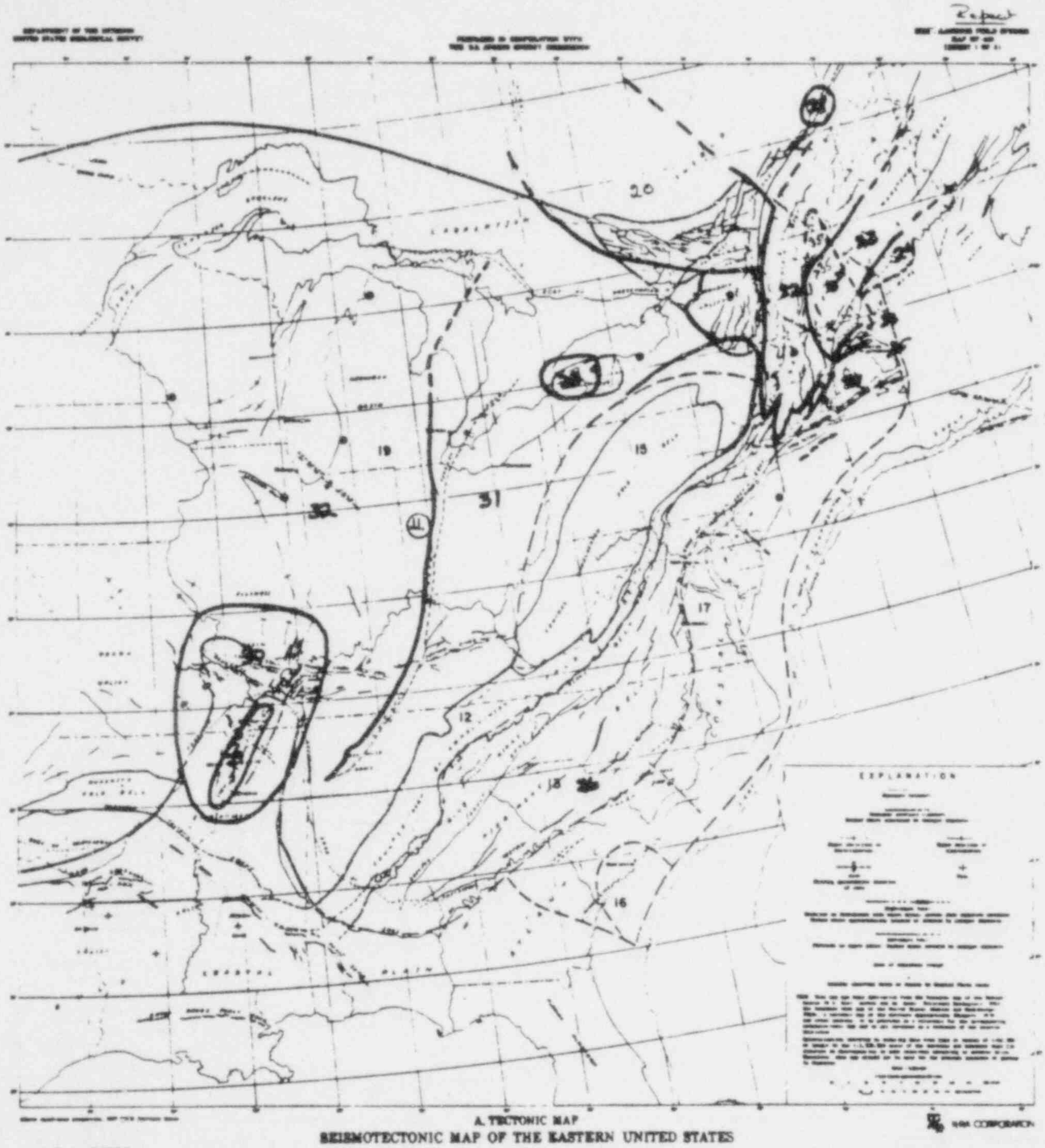
FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-I

EXPERT 7

POOR ORIGINAL



● SITES

——— SEISMIC SOURCE REGION BOUNDARY

— — — BOUNDARIES REPEATED FROM FIGURE I

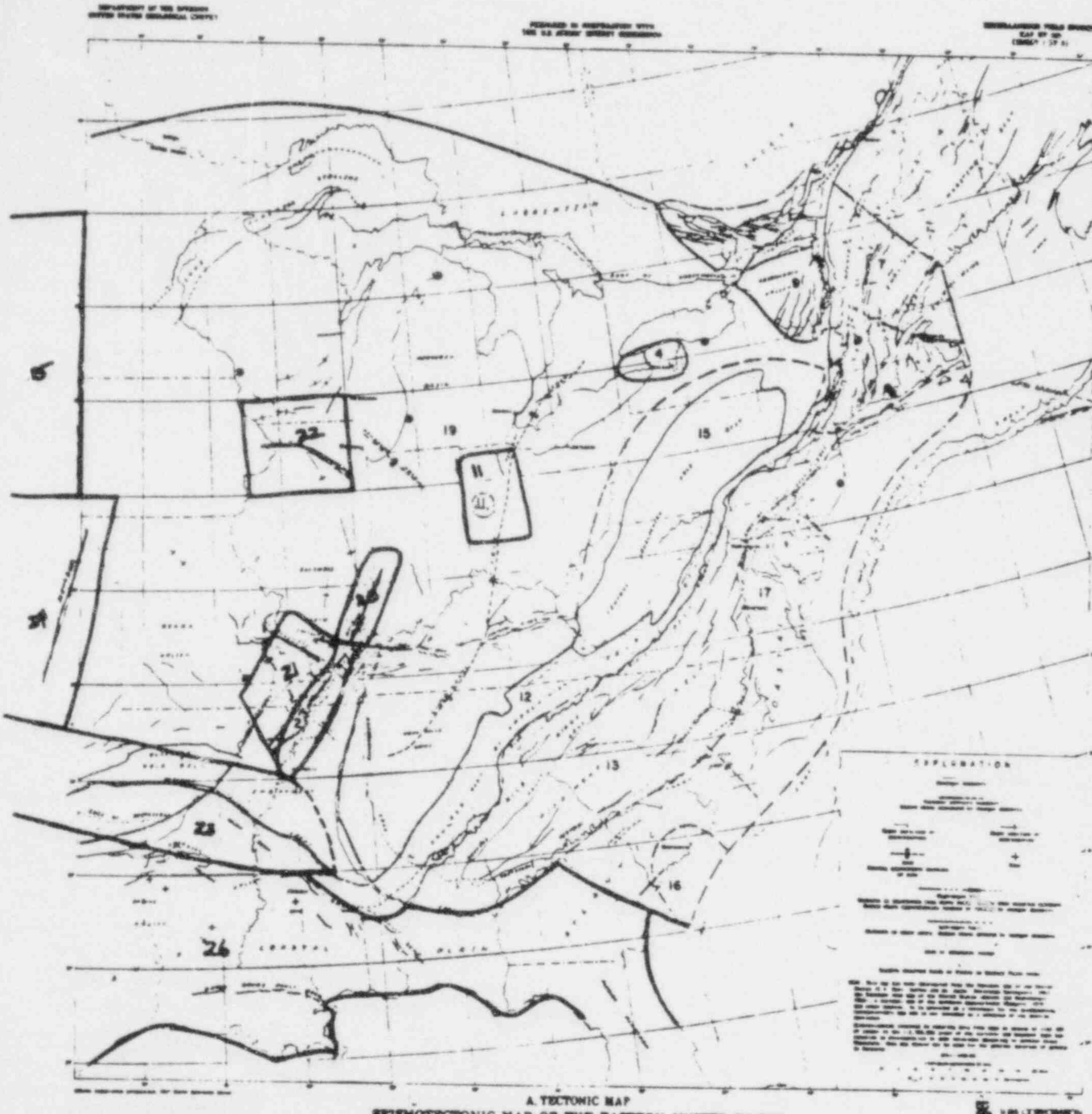
FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 8

POOR ORIGINAL



● SITES

——— SEISMIC SOURCE REGION BOUNDARY

— — — BOUNDARIES REPEATED FROM FIGURE 1

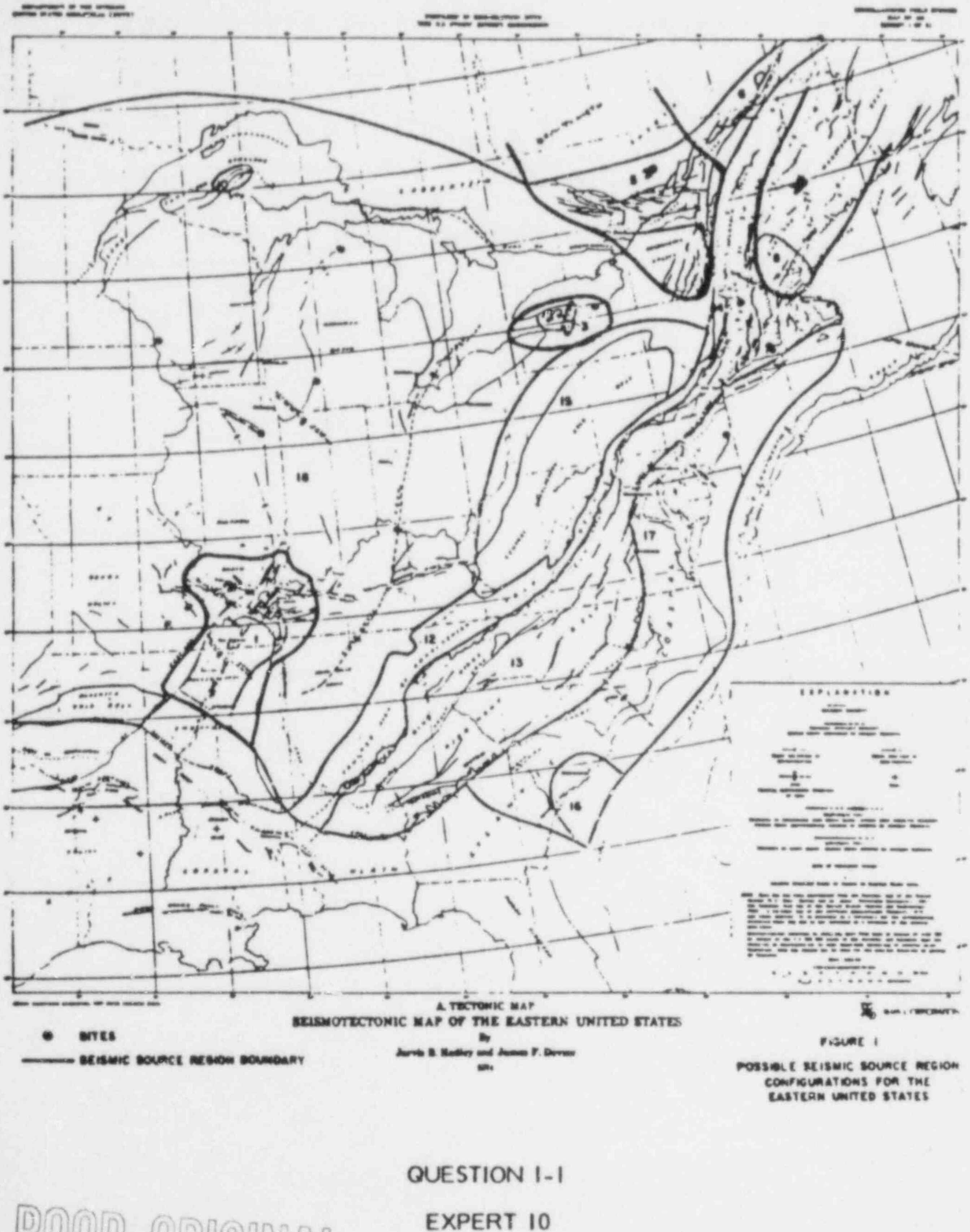
FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

POOR ORIGINAL

QUESTION I-1

EXPERT 9



● SITES

——— SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 10

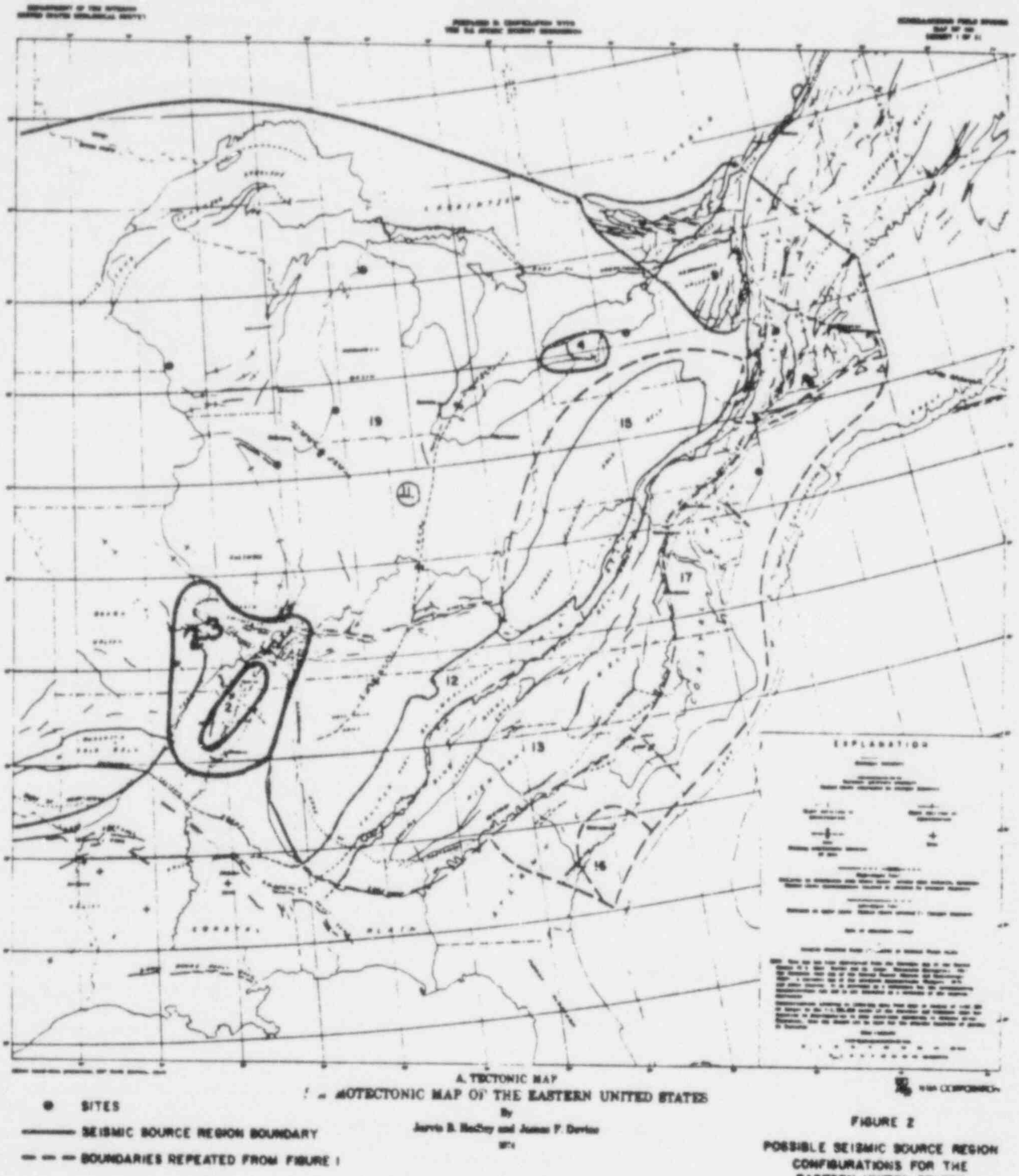


FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT II CENTRAL

A. TECTONIC MAP
SEISMOTECTONIC MAP OF THE EASTERN UNITED STATES
By
Jarvis B. Hadley and James F. Devine
1974

● SITES

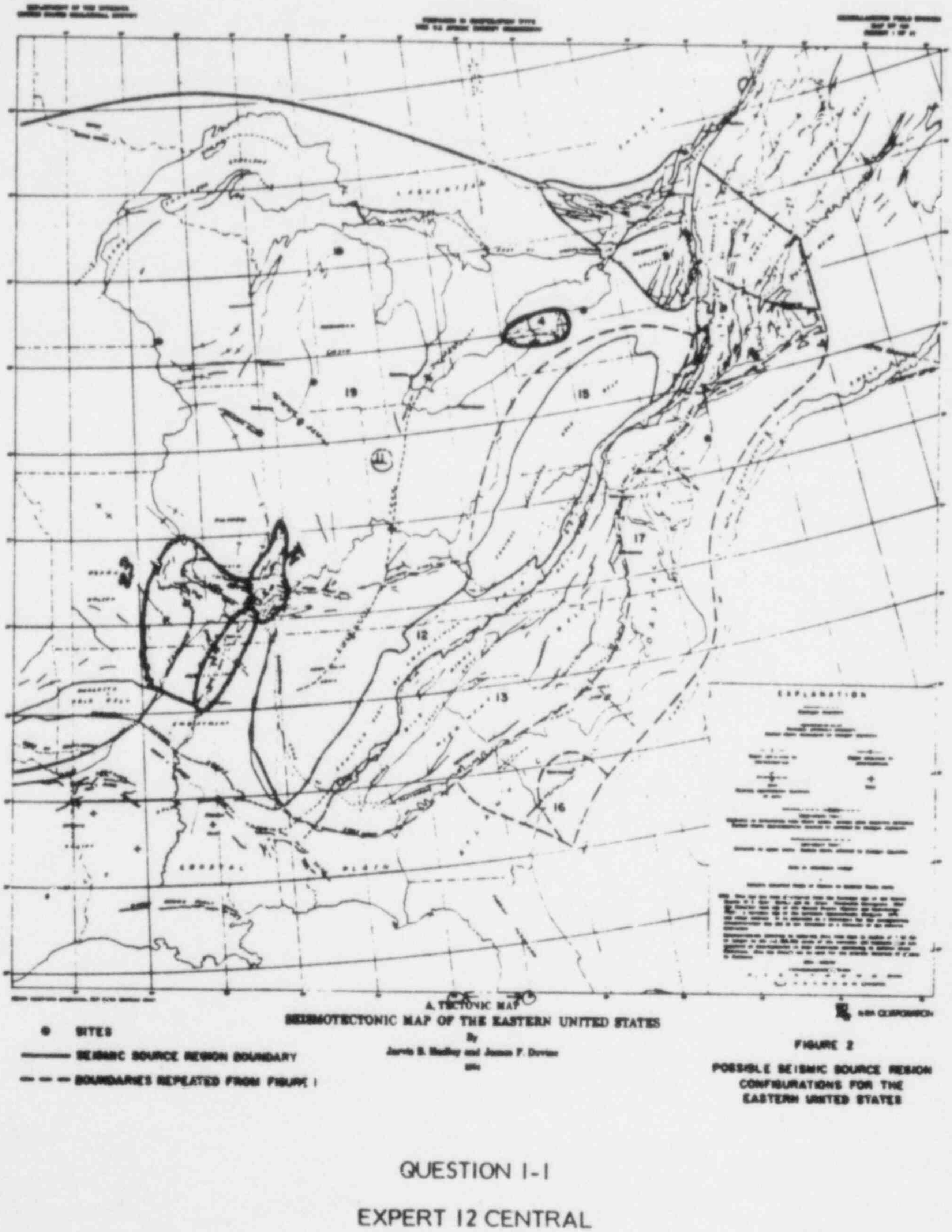
SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 11 EAST



● SITES

—— SEISMIC SOURCE REGION BOUNDARY

— — — BOUNDARIES REPEATED FROM FIGURE 1

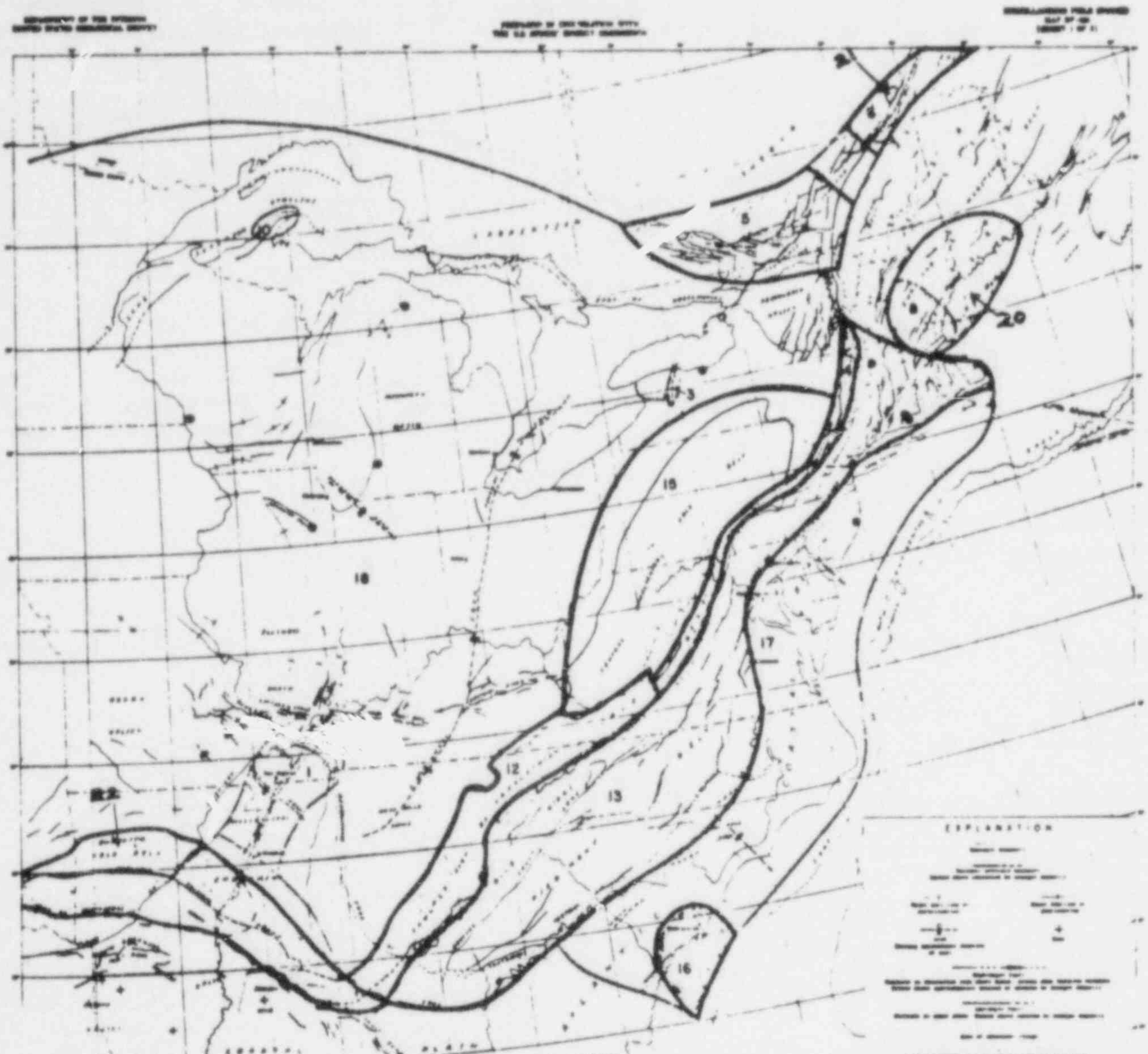
FIGURE 2

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION 1-1

EXPERT 12 CENTRAL

POOR ORIGINAL



A. TECTONIC MAP
SEISMOTECTONIC MAP OF THE EASTERN UNITED STATES
By
Jarvis B. Hadley and James F. Devine
1974

● SITES

—— SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 12 EAST

● SITES

—— SEISMIC SOURCE REGION BOUNDARY

FIGURE 1

POSSIBLE SEISMIC SOURCE REGION CONFIGURATIONS FOR THE EASTERN UNITED STATES

QUESTION I-1

EXPERT 13

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)* Seismic Hazard Analysis Subtitle: Solicitation of Expert Opinion	1. REPORT NUMBER *(Assigned by DDC)* NUREG/CR-1582, Vol. 3
	2. *(Leave blank)*
	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) TERA Corporation	5. DATE REPORT COMPLETED MONTH: July YEAR: 1980
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* Lawrence Livermore Laboratory P. O. Box 808 Livermore, California 94550	DATE REPORT ISSUED MONTH: August YEAR: 1980
	6. *(Leave blank)*
	8. *(Leave blank)*
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* U. S. Nuclear Regulatory Commission Division of Licensing Office of Nuclear Reactor Regulation Washington, D.C. 20555	10. PROJECT/TASK/WORK UNIT NO.
	11. CONTRACT NO. FIN No. A0233
13. TYPE OF REPORT Technical	PERIOD COVERED *(Inclusive dates)*
15. SUPPLEMENTARY NOTES	14. *(Leave blank)*

16. ABSTRACT *(200 words or less)*

This report presents a detailed tabulation of ten experts' answers to a questionnaire on seismicity and ground motion characteristics of the Central and Eastern United States. The goal in eliciting such information was to obtain a subjective representation of parameters that affect seismic hazard in order to supplement the very limited historical data that are available in these regions. Not only was the "most probable value" sought in each case, but also, whenever possible, the entire probability distribution to be used in a probabilistic hazard analysis. The questionnaire was divided into five sections: Source Zone Configuration, Maximum Earthquakes, Earthquake Occurrence, Ground Motion Models and Overall Level of Confidence. The last section was designed to develop a synthesis of opinion, if need be. The questionnaire was designed to contain redundancy to provide cross-checking and establish consistency in the results.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT Unlimited	19. SECURITY CLASS *(This report)* Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)*	22. PRICE S

NRC FORM 335 (7-77)