Reports

Earthquake Hazard in New England

Abstract. *The earthquake return periods (the mean interoccurrence time) and the probability of earthquake occurrences for southern New England are calculated from the available seismic data for the period 1725 through 1974. For this region the occurrence of larger earthquakes varied with time and the seismic activity was higher in the period 1725 through 1824 than in the next 100 years (1825 through 1924). This variation introduces large uncertainties into calculations of the earthquake hazard. The estimated return period, based on data covering the time period 1725 through 1974, for earthquakes in the southern New England area of intensity VI or greater is 25 years and for intensity VIII or greater is 130 years.*

The New England area has the longest record of reported earthquakes in the United States. On the basis of the historic record and some large earthquakes, parts of southern New England have been classified as zones of high seismic hazard (*1*). We present here the results of a detailed statistical study of the earthquake data in order to quantify the hazard estimates in the densely populated southern New England region.

The seismic activity of the New England area since 1700 is shown in Fig. 1a. The population of southern New England has been sufficiently high to provide a reasonably complete record of its seismic history for about the last 250 years. Although the earthquake epicenters are more diffuse in New England than in a plate boundary region, there is some evidence that the seismic activity along a southeast-northwest zone, referred to as the Boston-Ottawa seismic zone, may define a tectonic trend (*2*). We investigated the seismicity of the southern portion of this subregion separately. The geographical boundaries of the southern New England region and the southern portion of the Boston-Ottawa subregion are indicated in Fig. 1a by dashed and solid lines, respectively.

The principal compilation of seismicity data for the northeastern United States was done by Smith (*3*), who listed earthquakes since the early 1600's. Because the completeness and reliability of the earliest data are questionable, we began our analysis at 1725, correlating Smith's catalog with other compilations of New England seismicity (*4*). Because all the historical data are given in terms of intensities, we used epicentral intensities (modified Mercalli) rather than magnitudes. To obtain the best estimate of the intensity, we took a weighted average of the intensities given by the four compilations. The estimates of Smith (*3*) and the U.S. Department of Commerce [see (*4*)], considered more reliable, were given twice the weight of the other estimates.

An examination of the number of

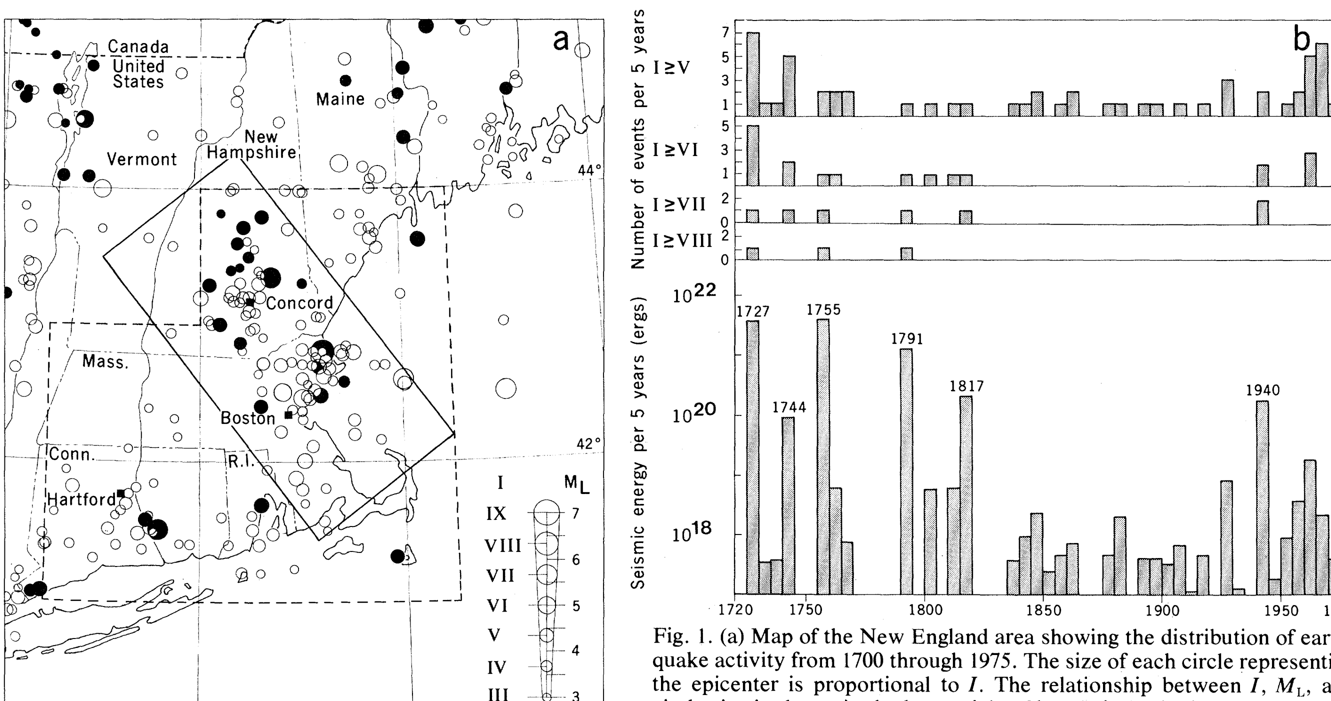

Fig. 1. (a) Map of the New England area showing the distribution of earthquake activity from 1700 through 1975. The size of each circle representing the epicenter is proportional to *I*. The relationship between *I*, M_L, and circle size is shown in the lower right. Closed circles indicate the most reliable epicentral locations. Enclosed areas designate the two regions where statistical analyses of earthquake activity were carried out: southern New England (dashed line) and Boston–New Hampshire (solid line), representing the southern portion of the Boston-Ottawa trend. (b) Southern New England seismic activity over time, between 1725 and 1975: (top) number of events per 5-year interval as a function of *I*; (bottom) seismic energy released by earthquakes of *I* = IV and above over 5-year intervals. Numbers in columns indicate the years in which large earthquakes occurred.

Table 1. Variation of earthquake hazard estimates with observation period.

Time period	Return period (years)			Probability of occurrence in 100 years (%)		
	$I \geq$ VI	$I \geq$ VII	$I \geq$ VIII	$I \geq$ VI	$I \geq$ VII	$I \geq$ VIII
			Southern New England area			
1725 to 1974	25	55	130	99	86	55
1850 to 1974	45	180		90	44	
			Boston–New Hampshire area			
1725 to 1974	30	65	140	97	80	52
1850 to 1974	50	180		88	44	

earthquakes as a function of time for this region, especially for larger earthquakes, indicates an apparent variation of frequency with time. This nonstationarity is shown in Fig. 1b as a plot of the number of earthquakes and the total seismic energy released as a function of 5-year segments between 1725 and 1974. The seismic energy released is calculated from the relationship

$$\log E_s = 11.18 + 1.33I - 0.011I^2 \quad (1)$$

obtained by combining the standard empirical relationships between intensity (I), seismic energy (E_s), and local magnitude (M_L) (*5*). The data in Fib. 1b suggest that there were more high-intensity events and that the seismic energy release was greater between 1725 and 1824 than in the next 100 years (1825 through 1924). The questions then arise: can the variations be accounted for by normal statistical fluctuations, and are the data biased?

The occurrences of earthquakes (excluding aftershocks) can generally be represented by a Poisson process (*6*). If we assume a Poisson process with a mean rate corresponding to that during the period 1725 through 1849, we can test whether the activity since then is part of the same process. Taking events of $I \geq$ VI and the mean rate of occurrence as that between 1725 and 1849, we find the probability that there would be no more than five such events observed in the next 125 years is $P \simeq .01$. This is well below the usual 5 percent rejection level. Relaxing the assumption of a Poisson distribution, we can use the χ^2 contingency test to examine whether the occurrence distribution during the first 125-year period is not different from that during the second 125-year period (*7*), and again this hypothesis is rejected ($P \simeq .03$). Therefore, it is clear that either the intensities of the early events were substantially and consistently overestimated, which seems unlikely, or the earthquake occurrences did not follow a stationary random process in the period examined.

The bias in the data as a function of time is difficult to determine quantitatively. Since during the period of the analysis the population was increasing as a function of time, one would expect the number of earthquakes detected and reported to increase. This type of bias will give the opposite effect from that observed. Another possibility would be a systematic overestimation of the earthquake intensities prior to 1825. Chinnery and Rogers (*8*) considered this unlikely. Furthermore, any overestimation of the intensities of the early events would have to be quite substantial to change our conclusions based on the Poisson and χ^2 test results. Thus one must conclude that the earthquake activity level was in fact higher in the time period 1725 through 1849 than in the next 125 years. This difference in the earthquake activity level must be taken into account in estimating the earthquake hazard.

To estimate earthquake occurrence probabilities and return periods we use the extreme-value method (*9*), which requires data on only the largest earthquake in each of a number of equal time intervals. Since the largest events are the most reliable when dealing with historical data, the extreme-value method is very appropriate. In our analysis, earthquake data are blocked into 5-year sampling intervals, and the set of largest earthquakes in each of these intervals is used for calculating return periods. Because of the apparent nonstationarity, these data are analyzed in three separate time spans: 1725 through 1974, 1725 through 1849, and 1850 through 1974. A subset of the southern New England region corresponding to the southern portion of the Boston-Ottawa trend (referred to as the Boston–New Hampshire region) is analyzed separately.

The resulting distribution of extremes for the southern New England area, for 1850 through 1974, is shown in Fig. 2a, along with the fitted least-squares line, plotted on extremal probability paper. For these data, the earthquake return period (the mean interoccurrence time) of an event with $I \geq$ VII is about 180 years, and there is a probability of about two chances in three of the interoccurrence

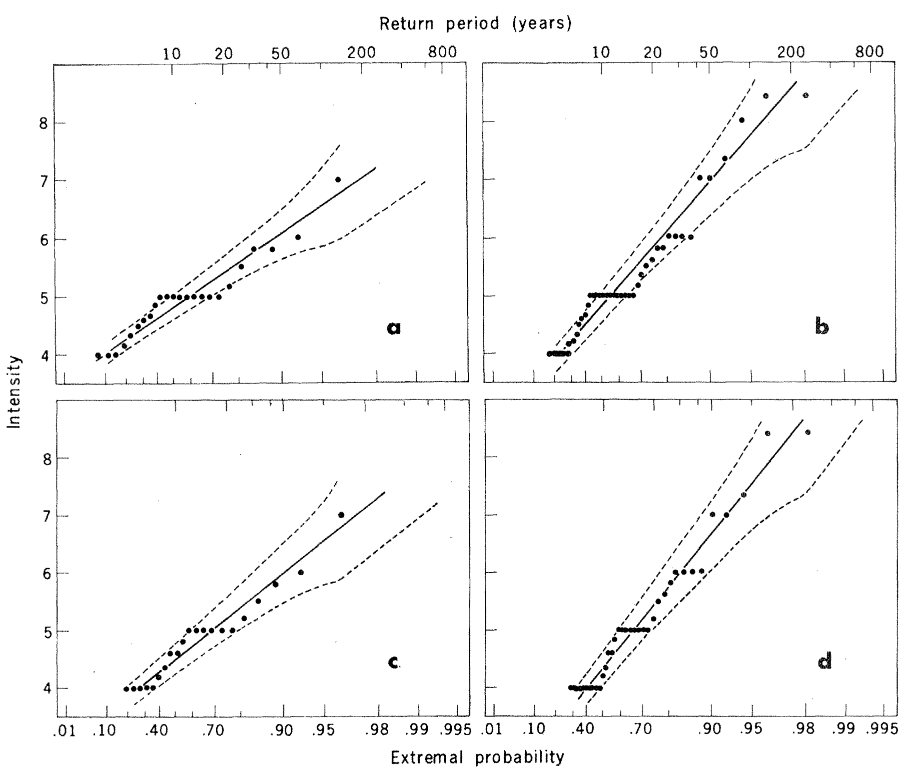

Fig. 2. The fitted least-squares line (solid line) and confidence bands (dashed lines) for determining earthquake probabilities and return periods. (a) Southern New England area, 1850 through 1974; (b) southern New England area, 1725 through 1974; (c) Boston–New Hampshire area, 1850 through 1974; (d) Boston–New Hampshire area, 1725 through 1974.

time being between 90 and 600 years [as indicated by the 2 σ confidence bands (σ is the standard deviation)]. There is a substantial difference between these results and those for the period extending from 1974 back to 1725 (Fig. 2b). Similar analysis of the data for the Boston–New Hampshire region yields results which also change markedly with the observation period (Fig. 2, c and d). For the period 1725 through 1849 we obtain results for each area (not plotted in Fig. 2) not greatly different from those for 1725 through 1974 (Fig. 2, b and d). In Table 1 the estimates of return periods and probabilities for events of intensity $I \geq$ VI, VII, and VIII are compared for the periods 1725 through 1974 and 1850 through 1974. The actual time intervals between successive earthquakes could vary greatly from those listed in Table 1. To the extent that these results can be compared with those of other studies (which do not include estimations of time variations in the seismic activity, nor do they always consider the same area), there is a general agreement in the estimated return periods (*10*).

Earthquake occurrence rates in other parts of the world have changed with time (*11*). However, these changes have not been permanent; there have been periods of intense activity and periods of relative quiet. It is unlikely that the observed decline in the number of earthquakes in New England since 1825 will continue into the future. Examining Fig. 1b, we notice a marked increase in the seismic energy release since 1940, which could represent the beginning of another episode of increased seismic activity in southern New England. For hazard estimates, then, it is most appropriate to use the return periods and probabilities based on data covering the longest time period. For New England, these are the values for the period 1725 through 1974.

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10. Chinnery and Rogers (*8*), using the frequency-magnitude method, estimated the return period of an event with $I \geq$ VIII as about 180 years for southern New England. Howell [see (*5*)], in a study of regional seismic energies, suggested that an earthquake of I = VI to VII might occur once every 100 years in this area. C. A. Cornell and H. A. Merz [*J. Struct. Div. Proc. Am. Soc. Civil Eng.* **101** (No. ST10), 2027 (1975)], in a site-risk study, estimated that the return period of an event with $I \geq$ V at Boston is about 100 years.
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Synthetic Galactocerebrosides Evoke Myelination-Inhibiting Antibodies

Abstract. *Synthetic galactodihydrocerebrosides with widely different fatty acid components can evoke myelination-inhibiting antibodies in rabbits. Whether these are the only such haptens involved in experimental immunizations of other species or in spontaneous human diseases is not yet known.*

Complement-dependent, central nervous system (CNS)–specific factors associated with immunoglobulins (Ig) of the 7*S* IgG2 type are detectable by their ability to inhibit myelination in unmyelinated CNS cultures or to demyelinate already myelinated cultures (*1–11*). Such factors may be defined as myelination-inhibiting or demyelinating antibodies. They can be detected in cerebrospinal fluid (*12*), and a high proportion of serums (*4, 11*) from patients with multiple sclerosis (MS) and amyotrophic lateral sclerosis (ALS). They are also present in serums from animals with experimental allergic encephalomyelitis (EAE) induced by whole CNS (*1–3*) tissue or by myelin (*9, 10*) but not in serums from animals with EAE induced by encephalitogenic myelin basic protein (*6–11*).

Both types of antibodies have been evoked in rabbits by cerebrosides extracted from CNS (*13*), but similar cerebrosides did not evoke demyelinating antibody in guinea pigs (*10*) or myelination-inhibiting antibody in rats (*9*). Although both types of antibody in rabbit serums can be absorbed out by cerebrosides (*13*), and although demyelinating antibody in guinea pig serums can be absorbed out by purified myelin (*10*), demyelinating antibody from MS serum can be absorbed out not by myelin but by the nonmyelin pellet (*14*).

Since extracts of CNS designed to yield particular lipids or proteins are difficult if not impossible to prepare with absolute purity, and since animals can react immunologically to trace contaminants not otherwise detectable, the resolution of some of the above discrepancies seemed unlikely unless synthetic materials could be shown to be active.

N-Lignoceroyldihydroglucocerebroside (Glu-24), *N*-lignoceroyldihydrogalactocerebroside (Gal-24), and *N*-palmitoyldihydrogalactocerebroside (Gal-16) were obtained from Miles Laboratories, Inc., Kankakee, Ill. These had been prepared by Miles-Yeda, a commercial adjunct of the Weizmann Institute of Science, Rehovot, Israel, by the procedure of D. Shapiro and were certified as 100 percent pure by thin-layer chromatography.

White New Zealand rabbits (2 to 3 kg) were immunized with a total of 1 ml of