

# EARTHQUAKE HAZARD IN NEW ZEALAND: SOME IMPLICATIONS OF THE EDGEKUMBE EARTHQUAKE, MARCH 1987

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## SUMMARY

The intensities experienced near the epicentre of the Edgcumbe earthquake, 1987 March 2, were higher than expected for an earthquake of magnitude 6.3. If this earthquake can be regarded as typical for that part of New Zealand, previous estimates of earthquake hazard must be increased. This has been done by modifying the intensity formula used in an earlier study, and recomputing the hazard figures. Mean return periods of seismic shaking in the Bay of Plenty, Waikato and Northland are reduced in consequence.

## INTRODUCTION

This paper is a sequel to two substantial studies of earthquake hazard in New Zealand. The first (Smith, 1976) examined the known history of large earthquakes in New Zealand and evaluated the spatial variation of their felt effects. On the assumption that the historical record is representative for the purposes of determining earthquake hazard, estimates of mean return periods for Modified Mercalli intensities VI to IX, throughout the country, were then prepared. The full detail of the analysis was presented in two subsequent papers (Smith 1978a,b). This study will be referred to as Study 1.

Although Study 1 provided quantitative estimates of earthquake hazard nationwide, it had several shortcomings, chief among which was the assumption that the short historical period in New Zealand may be regarded as representative of the mean rate of earthquake occurrence. It is well known from countries with much longer recorded histories that there can be quiescent periods in seismicity, often centuries in length.

In order to address the problem, Smith and Berryman (1983) attempted to integrate seismological and geological data. They suggested that in areas of the country where active faulting implies a higher mean rate of earthquake occurrence than has been seen in the last 150 years, this should be recognized in the earthquake hazard estimates. They constructed a seismicity model for the country, and computed mean return periods for intensities MM VI to IX, using the attenuation formula derived in Study 1. The integration procedure was similar to that

proposed by Cornell (1968). The full detail of this analysis (which will be referred to as Study 2) was published in 1986. The new estimates of mean return period were not much changed from those in Study 1, except in Otago and in the northern North Island where they were much reduced.

But the incompleteness of the data for large earthquakes imposed another limitation on the reliability of the results of both studies. The attenuation formula, which gives intensity as a function of the magnitude of the earthquake and the location of the observer with respect to the epicentre, was determined in Study 1 from such intensity estimates as were available, and there are very few of these at short distances (less than 30 km). In constructing the formula, therefore, it was necessary to extrapolate back to shorter distances, in such a way as to provide plausible intensities. This extrapolation was relatively unconstrained by actual observations close to large earthquakes. It is quite feasible, therefore, that there may be parts of the country where the formula misrepresents the ground motion caused by large earthquakes, at least in the region near the epicentre.

This is exactly what happened in the Edgcumbe earthquake, March 1987. Although not a large earthquake (the magnitude was 6.3), it nevertheless caused intensity MM IX in and near the town of Edgcumbe. MM VII or perhaps VIII would have been predicted by the old formula. The isoseismal map is shown in Figure 1. It is the purpose of this paper to modify the intensity formula to take account of high intensities in the Central Volcanic Region, and to recompute the mean return periods accordingly. The seismicity model developed in Study 2 has been retained. The result is that in the northern North Island the mean return periods have decreased, especially at high intensities.

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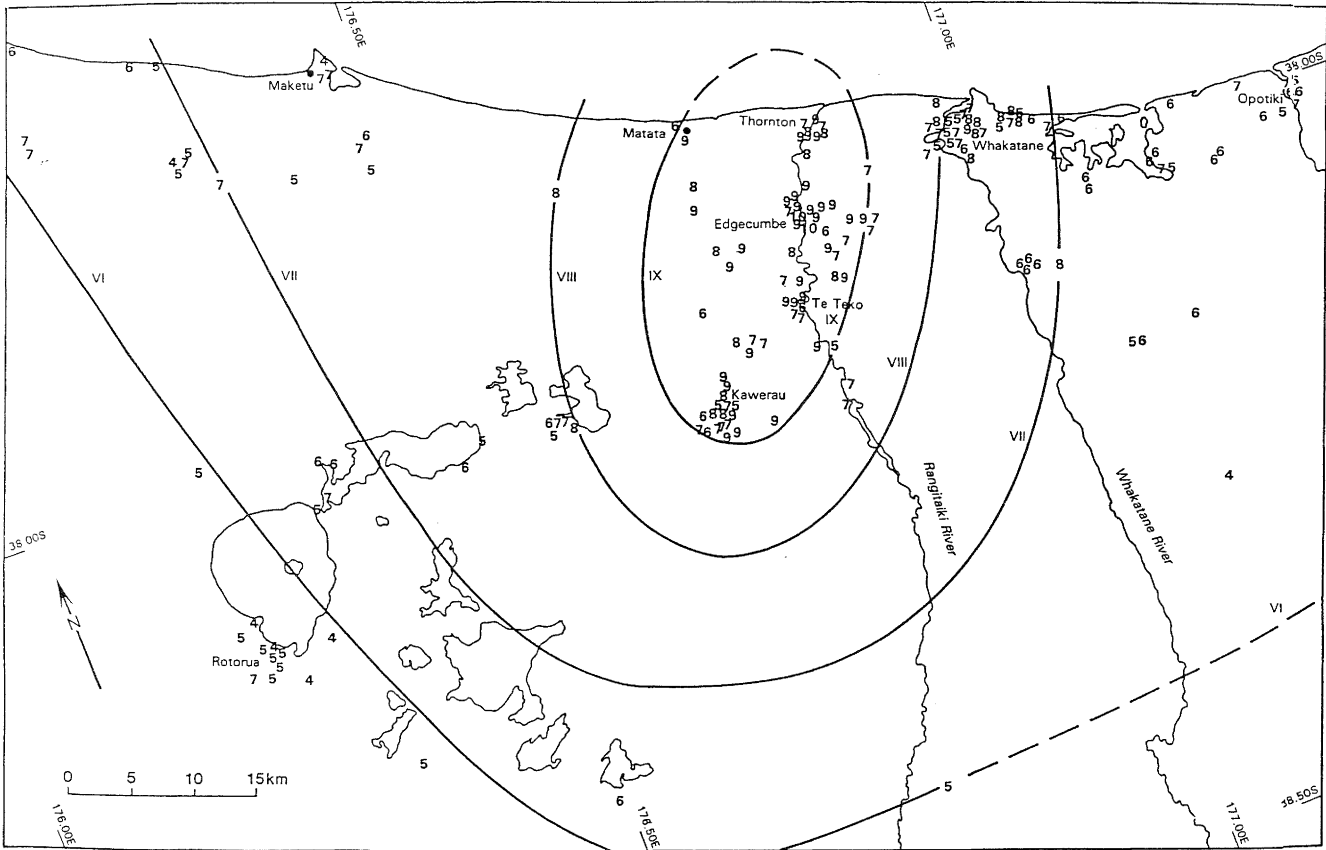


FIGURE 1. ISOSEISMAL MAP FOR THE EDGECCUMBE EARTHQUAKE, 1987 (FROM LOWRY ET AL. 1989).

#### LIKELY INTENSITY AS A MEASURE OF HAZARD

The merits and demerits of intensity scales have often been discussed. It is beyond the purpose of this paper to reproduce this discussion here. Because of the microzoning phenomenon, strong ground motion varies greatly from one location to the next, within quite short distances. This is certainly true of intensities, and is likely to prove true of instrumental measurements of ground motion, if sufficient numbers of instruments could be deployed. This study attempts to evaluate hazard on a regional scale, as earlier studies have done. It uses data from isoseismal maps, which average the available intensity data. No prudent seismologist would regard single estimates of intensity as representative of a region, but their average as shown in isoseismal maps does represent the general effects of the earthquake. It is this regional pattern which is useful for the estimation of earthquake hazard.

#### INTENSITY ATTENUATION FORMULA

The intensity formula developed in Study 1 recognized three different regimes in New Zealand. Figure 2 shows the three geographical regions, for each of which a separate intensity formula was developed. Figure 3 shows the formula for Region B: intensity as a function of magnitude and distance. Note that (i) the curves are

extrapolations at distances of less than 30 km, as indicated by the broken lines; and (ii) the distance scale is logarithmic. This latter fact makes simple extrapolation to zero distance impossible, so further assumptions had to be made, as is shown in Figure 4a.

Because earthquakes occur some kilometres deep in the Earth, it was assumed that intensity does not increase further within a distance of about 10 km. For larger earthquakes, some with source sizes of many tens of kilometres, this cutoff distance will be necessarily greater. So the cutoff distance was defined as a plausible function of magnitude for large earthquakes.

The Edgcumbe earthquake falls geographically in Region B, but the intensity pattern does not fit the curves (Figure 3). This was not too surprising, because other events in that area were known to have been anomalous (Smith 1978a). The fact that this is not an isolated instance of higher intensities experienced than predicted by the curves in Figure 3 suggests that a further region should be defined, with its own attenuation function. The reason appears to be the very shallow depth at which earthquakes generally occur in the Bay of Plenty and the Central Volcanic Region. Smith (1977) speculated on the physical reasons for the difference between Regions A and B, and identified the

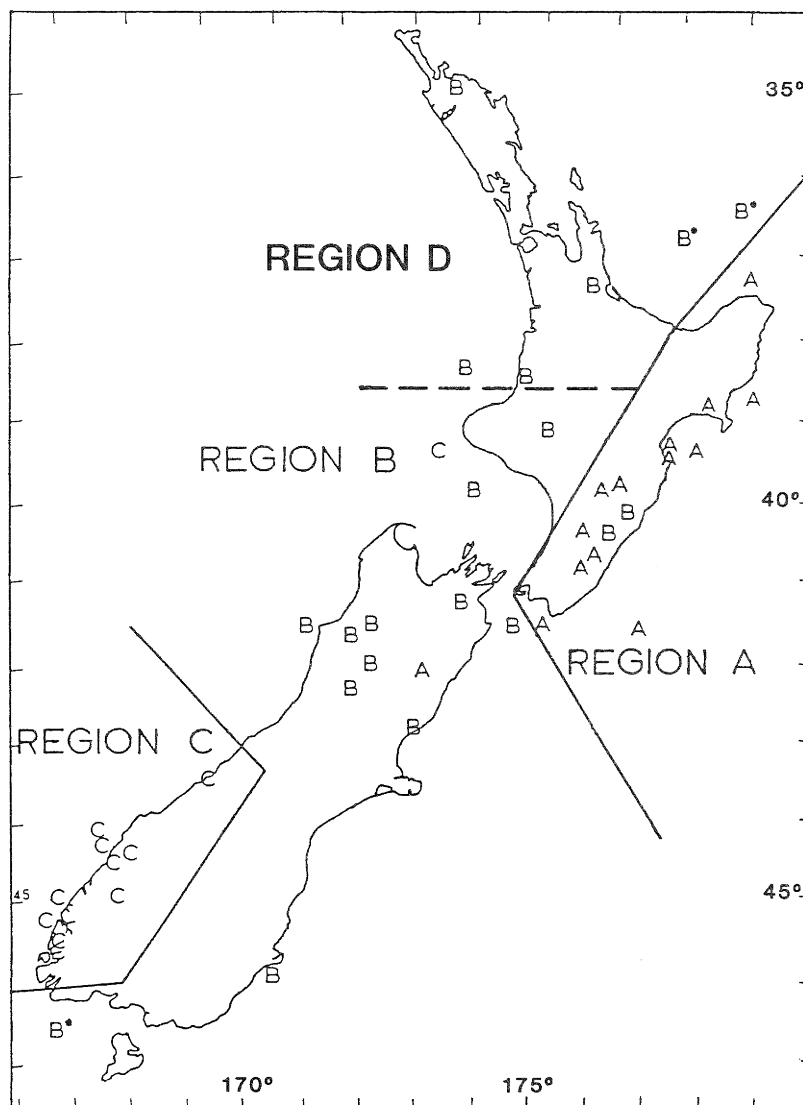


FIGURE 2. GEOGRAPHICAL REGIONS A, B AND C AS DEFINED BY SMITH (1978A) WITH THE ISOSEISMAL PATTERN TYPES ON WHICH THEY WERE BASED. THE BROKEN LINE (LATITUDE 38.60S) DEFINES THE SOUTHERN BOUNDARY OF THE NEW REGION D.

Regions A and B, and identified the predominant focal depths in each as a likely candidate. The Edgcombe earthquake had a focal depth of 8 km. Others have also had very shallow depths, and high epicentral intensities, e.g. Te Aroha (Adams, Muir and Kean, 1972), Korakonui (Eiby, 1977), Waiotapu (Smith, Scott & Latter, 1984), Matata (Richardson, 1989). These intensities are shown in Figure 4. It should of course be recognised that other factors, such as the physical properties of surface rocks, can contribute to the ground motion. The situation is clearly complex.

A new region has been defined, Region D, to the north of the broken line in Figure 2. It includes the whole of the Central Volcanic Region, Waikato, Coromandel and the Northland peninsula, not because there are good data justifying an intensity function with high epicentral intensities in all these places, but because focal depths are known to be very shallow there. Such intensity data as are available from Region D are commensurate with an enhanced intensity function.

There are still inadequate data to define fully an intensity function for the whole range of magnitudes and distances, for Region D. A plausible function is shown in Figure 4b. The cutoff criterion at 10 km (greater for larger magnitudes) has been retained, but the epicentral intensities have been increased by 1.5 intensity units. These new curves join the old ones smoothly at a distance of 50 km. They are constrained chiefly by the Edgcombe intensity data, and therefore take account not only of the high epicentral intensities but also of the rapid attenuation with epicentral distance (Dowrick, 1989) experienced in the Edgcombe earthquake. But it is important to note that the data control for all the curves in Figure 4 is very weak at distances less than 30 km, as is indicated by the broken lines. It is not claimed that the curves in Figure 4b represent Bay of Plenty, Central Volcanic Region, Waikato, Coromandel or Northland intensities accurately, but only that they approximate such intensities as have been observed in Region D, and are therefore likely to be more appropriate than the curves

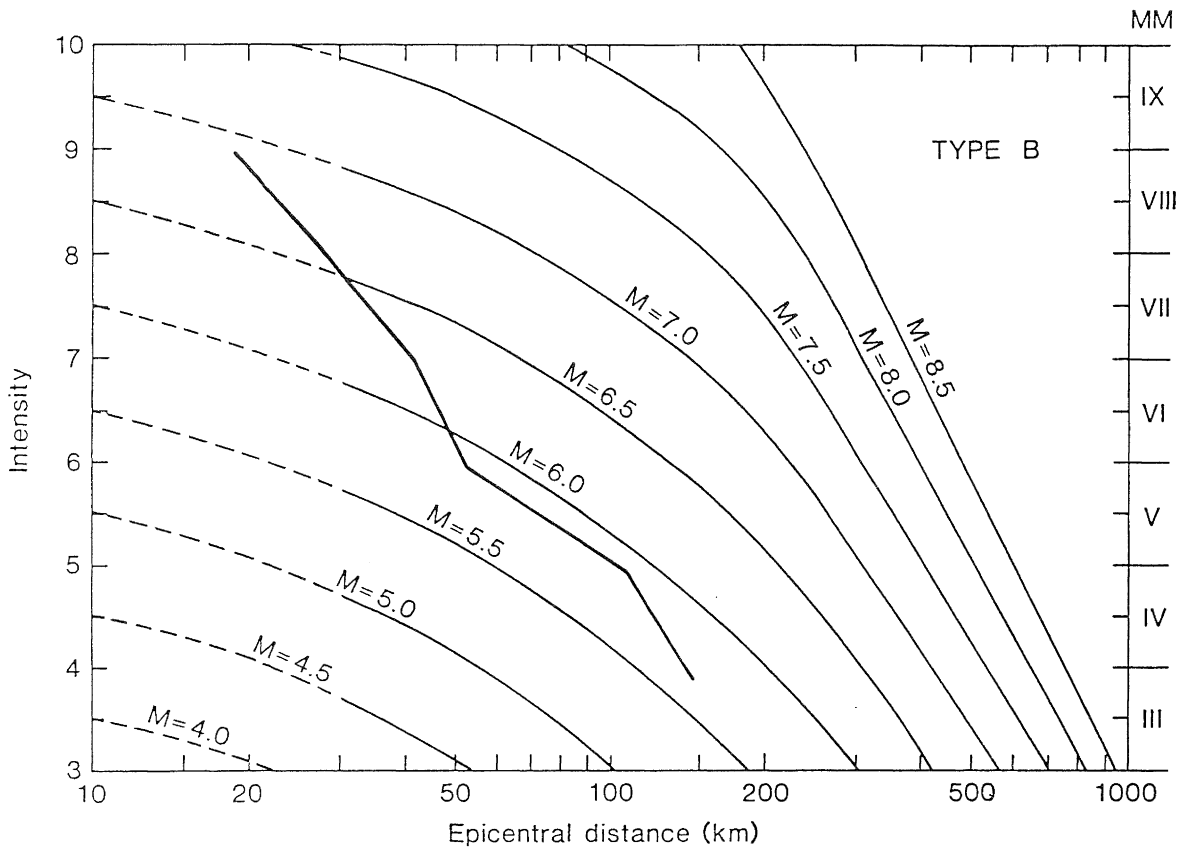


FIGURE 3. INTENSITY CURVES FOR REGION B (FROM SMITH 1978A) WITH THE INTENSITIES FOR THE EDGECUMBE EARTHQUAKE.

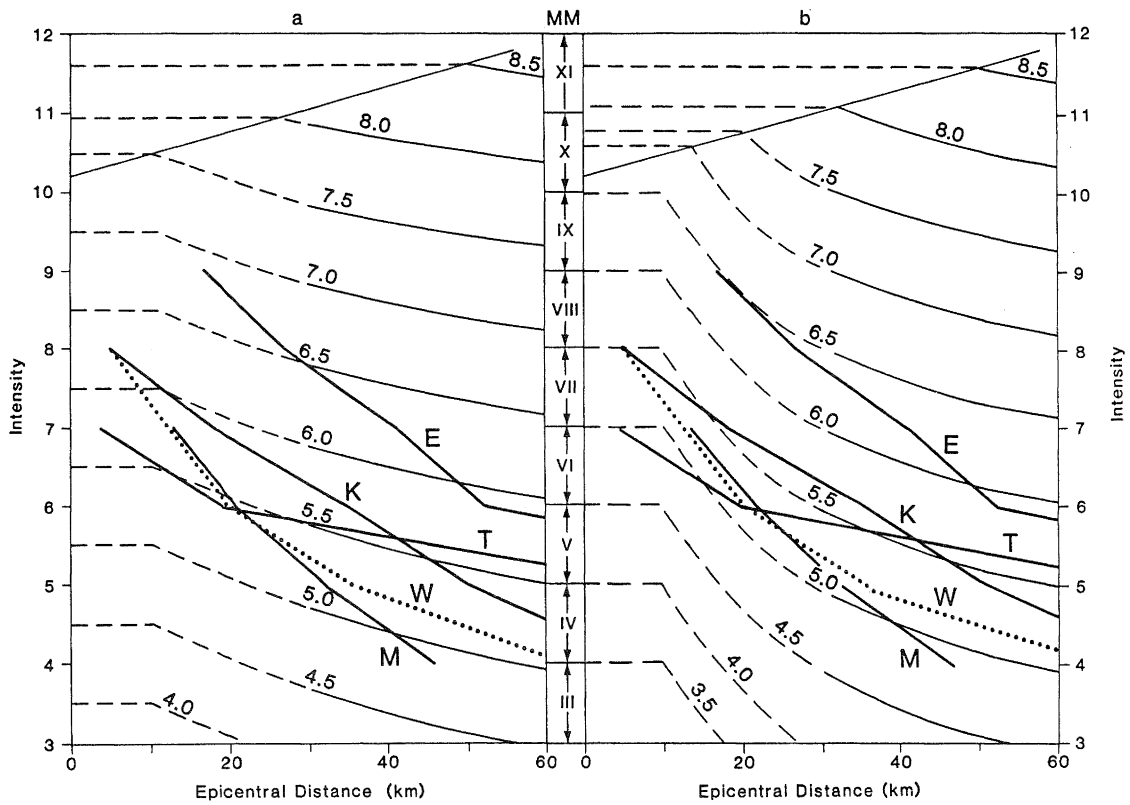


FIGURE 4. INTENSITY FORMULAE AT SHORT DISTANCES FOR (A) REGION B AND (B) THE NEW REGION D. THE BROKEN LINES INDICATE VERY WEAK DATA CONTROL AT DISTANCES LESS THAN 30 KM, AS IN FIGURE 3. ALSO SHOWN ARE INTENSITIES FOR EARTHQUAKES WITHIN OR CLOSE TO THE CENTRAL VOLCANIC REGION. THE EARTHQUAKES ARE:  
 E - EDGECUMBE 1987, M = 6.3; K - KORAKONUI 1976, M = 5.1;  
 M - MATATA 1977, M = 5.4; T - TE AROHA 1972, M = 5.3;  
 W - WAIOTAPU 1983, M = 5.1.

in Figure 4a. They do retain the characteristic which was observed in Study 1, that at any given distance the intensity is a linear function of magnitude. This has only been contravened for high intensities near the epicentre, as it was in Study 1.

#### ESTIMATES OF HAZARD

Computation of hazard has used the same procedures as in Study 2, with (i) the addition of Region D with its characteristic attenuation function shown in Figure 4b; and (ii) a higher order integration formula to take account of the greater variation of intensity at short distances. The results are shown in Figures 5 to 10, in which the broken lines indicate the results of Study 2. Table 1 gives the actual figures for selected cities and towns as were given in Studies 1 and 2 (with the addition of Gisborne, inadvertently omitted from both these studies).

There is essentially no change to the estimates for locations outside Region D, as might be expected. The locations which are affected have the biggest reduction in return period at the higher intensities. At Auckland, for instance, the reduction is 23% at MM VI, 29% at MM VIII.

#### LIMITATIONS OF THE STUDY

There are two limitations of this study which need to be stressed. The first is that the intensity function used is not well constrained by data, but is a plausible function which is an approximate representation of the Edgumbe intensities. It moderate earthquakes in northern New Zealand. The differences between these results and those of Study 2 must therefore be regarded as indicating the uncertainties in these calculations, although the new results are to be preferred.

The second limitation, also present in Studies 1 and 2, is that the results represent regional estimates of hazard. No fine geographical detail has been included in the seismicity model, so none is represented in the results. It is fully expected that, in a large earthquake anywhere in the country, the strong ground motion will vary by at least a factor of two over distances of a few kilometres, whether measured on the intensity scale or on an instrumental scale such as peak acceleration. The hazard estimates developed here are on a regional scale.

#### CONCLUSIONS

The intensities experienced in the Edgumbe earthquake, because they were higher than predicted by the 1978 formula, indicate that the estimates of hazard developed in Study 2 may be too low. By modifying the intensity formula to give enhanced intensities near the epicentre, and assuming that this applies for the Bay of Plenty, Central Volcanic Region, Waikato, Coromandel and Northland, new hazard estimates have been produced for these areas.

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TABLE 1. MEAN RETURN PERIODS (YEARS) FOR MODIFIED MERCALLI INTENSITIES VI TO IX AT SELECTED LOCATIONS.

	MM	VI	VII	VIII	IX
Kaitaia		150	600		
Whangarei		81	350	1500	
Auckland		48	200	990	
Tauranga		6	25	110	480
Hamilton		17	68	290	1500
Whakatane		4	21	83	320
Rotorua		5	25	100	480
Gisborne		9	45	140	410
Taupo		5	40	170	870
New Plymouth		8	29	110	400
Napier/Hastings		8	42	140	430
Wanganui		4	17	72	270
Palmerston North		5	23	71	210
Masterton		8	26	79	240
Wellington/Hutt Valley		6	21	67	220
Nelson		5	16	56	200
Blenheim		5	17	58	210
Westport		8	26	91	330
Kaikoura		6	20	70	250
Greymouth		10	34	110	410
Christchurch		14	48	160	600
Mt Cook		14	48	170	600
Timaru		25	88	310	1200
Milford Sound		12	62	330	1800
Queenstown		12	54	250	1100
Oamaru		27	100	380	1600
Dunedin		31	130	500	2200
Invercargill		14	50	170	650

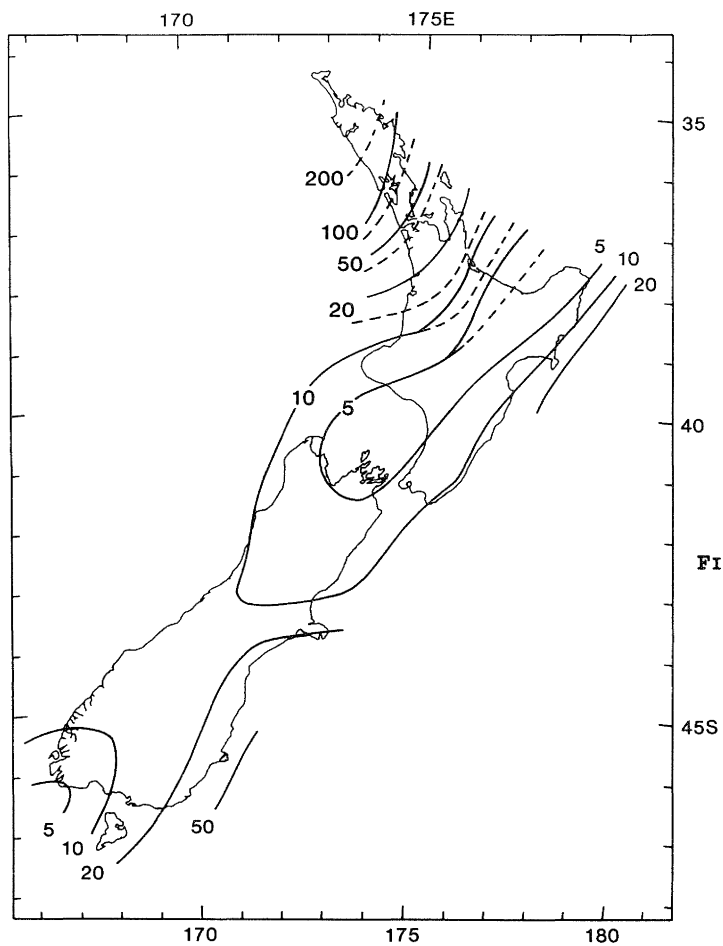


FIGURE 5. MEAN RETURN PERIODS (YEARS) FOR MODIFIED MERCALLI INTENSITY MM VI. THE SMITH & BERRYMAN (1983) RESULTS ARE INDICATED BY THE BROKEN CURVES.

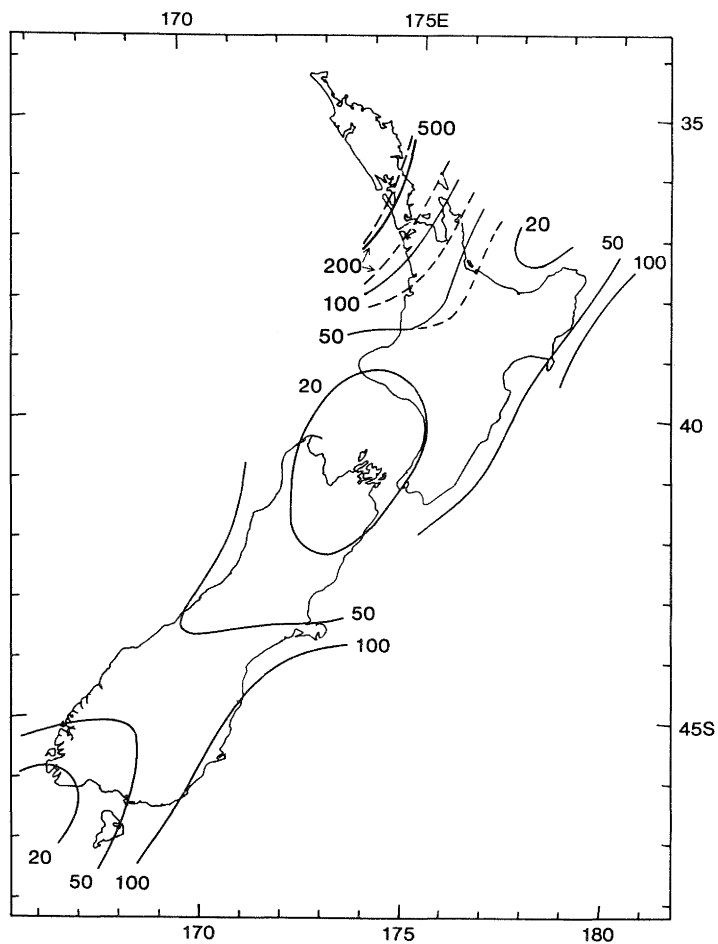


FIGURE 6. MEAN RETURN PERIODS, AS IN FIGURE 5, FOR MM VII.

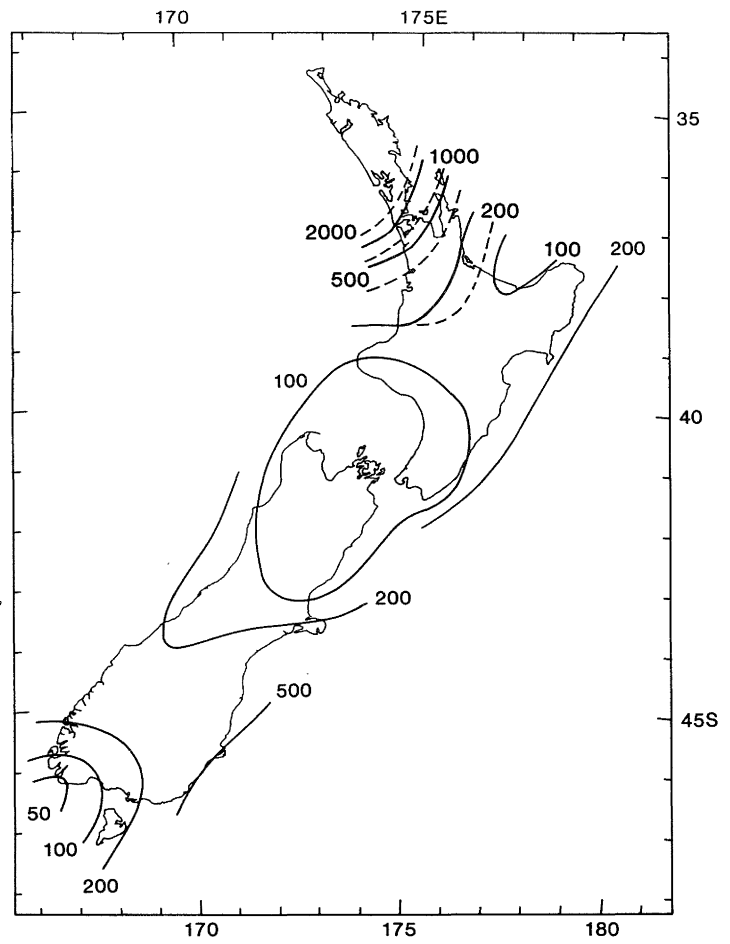


FIGURE 7. MEAN RETURN PERIODS, AS IN FIGURE 5, FOR MM VIII.

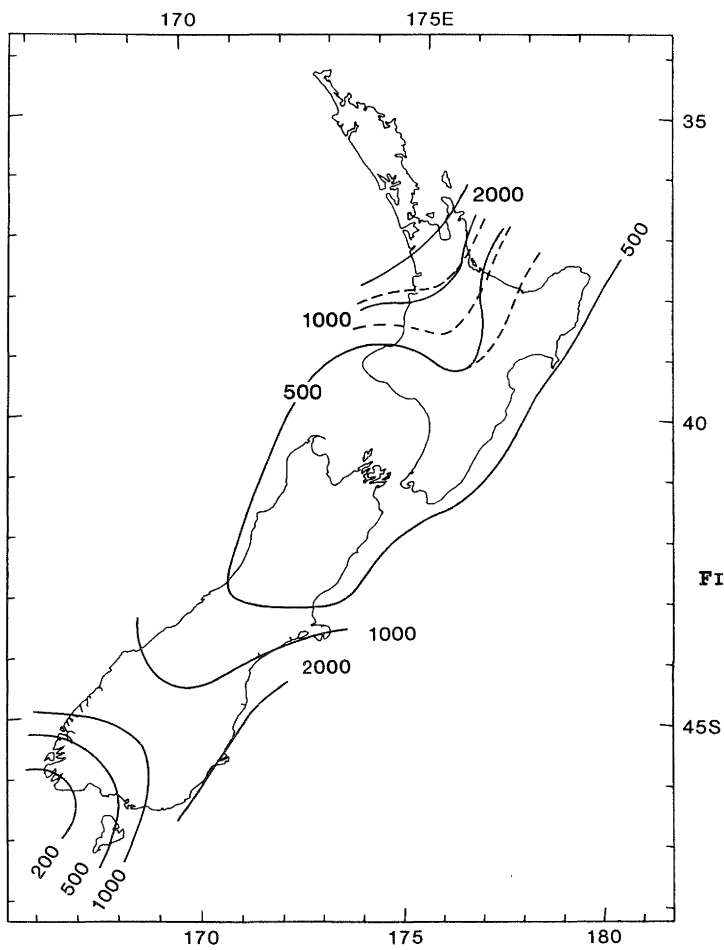


FIGURE 8. MEAN RETURN PERIODS, AS IN FIGURE 5, FOR MM IX.

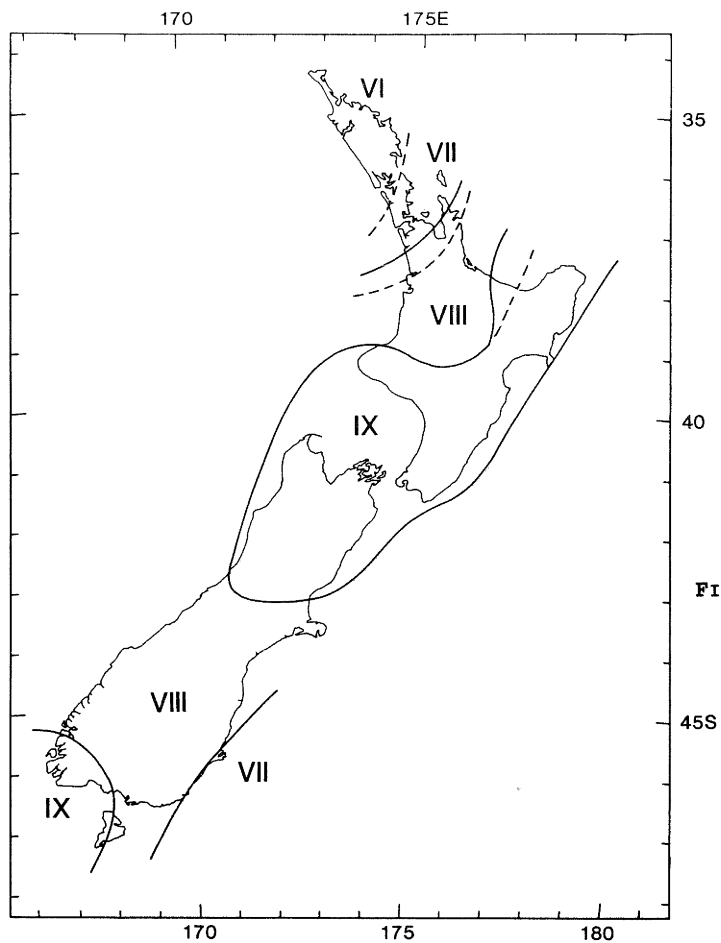


FIGURE 9. INTENSITIES WITH A 10% LIKELIHOOD OF OCCURRENCE WITHIN 50 YEARS.

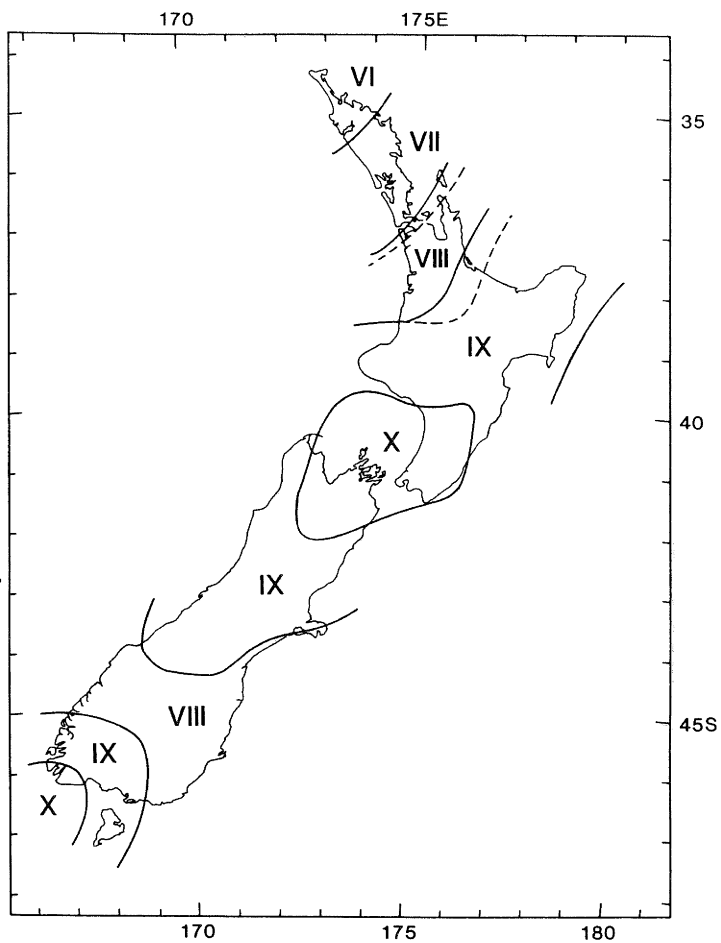


FIGURE 10. INTENSITIES WITH A 5% LIKELIHOOD OF OCCURRENCE WITHIN 50 YEARS.