SEISMIC HAZARD IN AUSTRALIA AND NEW ZEALAND

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ABSTRACT

As a prelude to the planned harmonization of building codes in Australia and New Zealand, this paper illustrates the seismic hazard in the two countries for discussion purposes. Hazard maps for peak ground acceleration for a 475 year return period are presented, and also for 2500 year return period in New Zealand, along with typical response spectra. It is shown that the hazard in the least seismic parts of New Zealand is similar to that of the more seismically active parts of Australia. The eventual harmonized loadings code would accommodate regional differences in hazard by using different response spectra and zone factors appropriate to the different regions of the two countries.

INTRODUCTION

This paper is a discussion document intended to familiarize engineers and seismologists in New Zealand and Australia with the overall picture of seismic hazard in the two countries. It is hoped that this will help in the process of harmonization of the building codes which is planned between Australia and New Zealand. At the time of writing, it just happened that each country was independently in the process of issuing a revision of its national earthquake loadings code [Standards New Zealand, 1992; Standards Australia, 1993]. It has been proposed that harmonizing documents should be issued by 1995. By presenting a broad comparison of the seismic hazard in the two countries, this paper should help some of the main technical issues of harmonization to be identified and then resolved. In order to facilitate the discussion process this paper is to be published in both Australia and New Zealand.

This paper is one of the outcomes of initial deliberations of a joint Australia/New Zealand Working Group, a collaboration of the National Committee on Structural Engineering (Aust) and the Structural Engineering Society (NZ). This Working Group has been reporting to the Standards Associations of our two countries.

For the purposes of discussion the hazard has been estimated in terms of two return periods, i.e. 475 and 2500 years. The 475 year value (10% probability in 50 years) was chosen because the basic design loads in both the Australian and New Zealand codes [Standards New Zealand, 1992; Standards Australia, 1993] are related to this hazard level. The 2500 year return period was chosen because it represents a hazard level which is appropriate for collapse control of normal use structures in regions of low seismicity [Dowrick, 1992].

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SEISMICITY OF AUSTRALIA

The first written account of an earthquake in Australia was penned by Governor Phillip only months after the new British colony of New South Wales was established in 1788. He wrote "The 22nd of this month (June) we had a slight shock of an earthquake; it did not last more than 2 or 3 seconds. I felt the ground shake under me, and heard a noise that came from the southward, which I at first took for the report of guns fired at a great distance". The experiences of the early colonisers of Victoria, South Australia and Western Australia were similar.

We now know that Australia is wholly intraplate with no major active fault systems like the Alpine fault and its northern splays, but the early historical accounts of felt events, the occurrence of more recent instrumentally recorded earthquakes, and discovery of as yet undated Recent fault scarps show that large earthquakes do occur in Australia and they are indeed a threat to life and limb.

The largest known earthquake this century occurred offshore WA in 1906 and had a magnitude estimated at 7.2 [Gregson and Everingham, 1992]. The largest onshore earthquake was also in WA, on 29 April 1941, and its magnitude was about 7.0. Since 1960, 5 earthquake sequences have produced surface faulting; at Meckering WA (1968), Calingiri WA (1970), Cadoux WA (1979), Marryat Creek SA (1986) and Tennant Creek NT (1988).

The record of Australian earthquakes is relatively short. Probably all the magnitude 6 or greater earthquakes since 1890 are known, all above magnitude 5 since 1950 will have been recorded and only since 1980 are we confident that all the magnitude 4 events have been detected. The Australian Geological Survey Organisation's (AGSO) goal is to be able to locate all the magnitude 3 or greater earthquakes in Australia but that is not yet possible. The historical seismicity of Australia is illustrated by the map of epicentres (Figure 1).

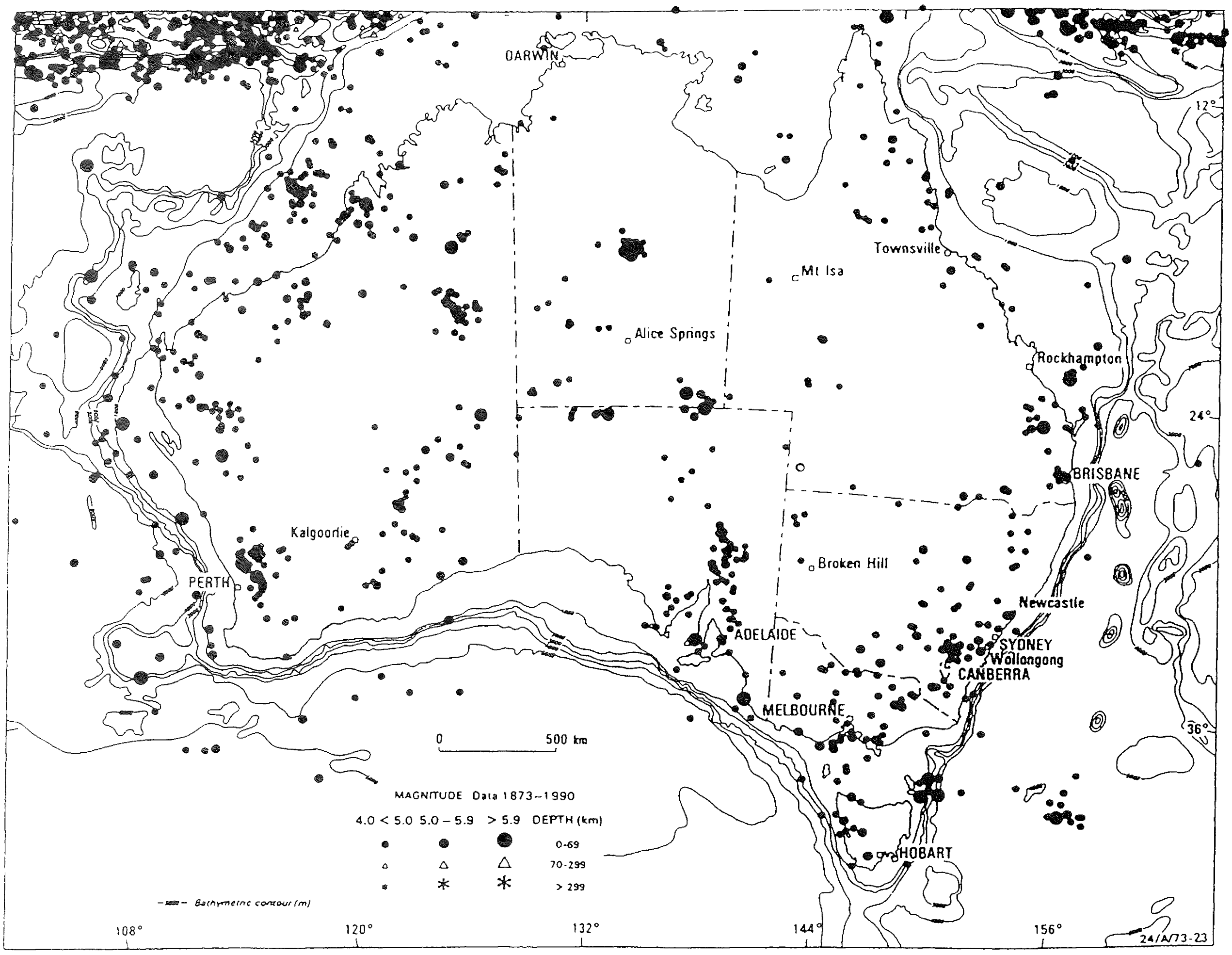

FIGURE 1 Seismicity of Australia, 1856 - 1990

From this limited data set the observed apparent annual frequencies are 0.2, 1.0 and 21 for magnitudes ≥ 6, ≥ 5.3 and ≥ 4.0 respectively. Where the earthquakes are most likely to happen is another matter. The large 1988 Tennant Creek earthquakes were in an area where very few had been observed prior to the foreshock sequence in 1987. The 1986 earthquakes at Marryat Creek were the first recorded there although the Meckering, Cadoux and Calingiri earthquakes were in a well recognised seismic zone. Newcastle NSW has an earthquake history dating back to 1837 though this was not widely known until after the December 1989 earthquake there. Other large cities including Sydney, Melbourne and Brisbane are within the East Coast Seismic Zone, a 500 km wide zone straddling the east coast of Australia.

No model of intraplate seismicity exists to explain why these earthquakes occurred where they did nor where they are most likely to occur in the future. They rupture cratons, relict mobile zones and basins indiscriminately. It must be assumed that earthquakes can and will occur anywhere but there is some evidence that they are more likely to occur in some areas than others. During the last 100 years, more earthquakes occurred in Western Australia than Central Australia and more in Central Australia than in the East, paralleling the crustal age which decreases from Archaean in the west to Tertiary in the east.

The most damaging earthquake in Australia since European settlement was that at Newcastle NSW in December 1989. At magnitude M_L 5.6 it was about the once-per- year earthquake for the continent. Its proximity to a major population centre which is on the seashore and by a major steel works, with old buildings, poorly maintained and underlain in part by alluvium, were factors which contributed to the extensive damage, estimated at about A$1200 million. An earthquake of similar size occurred near Adelaide SA on 28 February 1954. No one was killed and the damage there was about A$100 million (in 1992 dollars).

Among the contributing factors to the anomalously high damage during moderate earthquake in Australia are two source factors, the shallow focal depth of most of the earthquakes and their thrust mechanism. Although some events have occurred in the lower crust, all of the recent large earthquakes and that at Newcastle were in the upper crust at depths less than 15 km. The upper crust seems to be everywhere in compression, and following rupture high accelerations are recorded close to even small earthquakes.

SEISMICITY OF NEW ZEALAND

New Zealand is a country of moderate seismicity on a world scale. Its seismic activity results from its location at the boundary of the Pacific and Indian-Australian tectonic plates (Figure 2), with the Pacific plate subducting beneath the east coast of the North Island and the northern part of the South

Island, and the Australian plate subducting beneath the south-west corner of the South Island. The crustal strain caused by these two actions has resulted in about 30 shallow earthquakes (h ≤ 45 km) of magnitude ≥ 6.5 occurring under or within 50 km of the New Zealand land mass since 1840. Of these events, probably 16 were of magnitude 7 or more (Figure 2). The magnitudes of most of the pre-1900 events are not well determined, so that the preceding numbers of events are somewhat approximate.

The historical seismicity and the geology of New Zealand have been interpreted into a seismicity model [Smith and Berryman, 1986, 1992] which divides the country into 15 regions, the most active of which (East coast North Island) is about 30 times as active as the least seismic region (Auckland and Northland).

The latter region is over two hundred kilometres from the interplate zone, and c.190 km from the active back-arc spreading region (Central Volcanic Region); hence it is firmly on the seismically less active intraplate crust (i.e. the Australian plate).

The largest earthquake to have occurred in New Zealand since European settlement was the 1855 Wairarapa earthquake of magnitude 8.1 to 8.3, while the two next largest were of magnitude 7.8 (Murchison 1929, and Hawke's Bay 1931). The 1848 Marlborough event may have been as large as M = 7.9 [Dowrick, 1991]. The earthquake to cause the most damage was the 1931 Hawke's Bay event which produced intensity X on the Modified Mercalli scale over an area containing a population of c.30,000 people, and resulted in damage costs a total of about £7 million at 1931 values or about NZ$450 million at 1992 values.

Since 1840 eight of New Zealand's larger earthquakes (M ≥ 7) are known to have occurred on surface rupturing faults, and many other active faults have been found. Many moderate sized events have occurred which were too deep to rupture the surface, but still caused significant damage, e.g. Events Nos 4-7, 9, 10, 14-17, in Table 1.

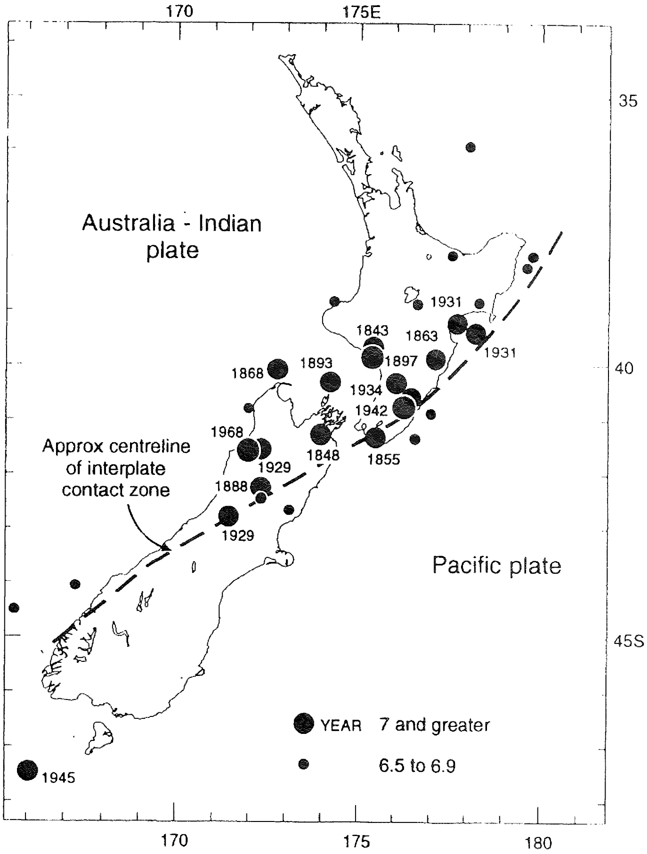

FIGURE 2 Shallow (h ≤ 45 km) seismicity of New Zealand, M ≥ 6.5, 1840-1992. Also shown is the approximate centreline of the tectonic interplate contact zone.

COMPARATIVE SEISMICITY

Since 1900 New Zealand has experienced perhaps 20 earthquakes that have caused more than NZ$2 million damage (in 1992 values), compared with 8 earthquakes in Australia causing more than A$50,000 damage. In this period the total earthquake damage in New Zealand has been approximately NZ$1000 million (Table 1), and in Australia A$1344 million (Table 2).

It is seen that to date losses in Australia have been higher than in New Zealand although far few damaging events have occurred. This surprising fact is accounted for by the Newcastle event, in which a city with a population of 430,000 without earthquake resistant construction was directly hit by a moderate sized earthquake; no parallel situation has arisen in New Zealand, as most construction is reasonably earthquake resistant and the largest urban centre to receive a direct hit was Napier/Hastings with a population of c.30,000.

Epicentre distribution

When considering smaller events than those shown in Figure 2, epicentres are fairly uniformly distributed over about two thirds of New Zealand, with much quieter regions in the north west of the North Island and the central and south-eastern South Island.

Australian earthquakes are not uniformly distributed but cluster in space and time, and even within a seismic zone cluster in discrete areas rather than along lines. Because of the low level of activity and the short monitoring record, no pattern has yet been discerned in this clustering.

Focal depths

In a given interval of time there are many more earthquakes per unit area in New Zealand than in Australia. New Zealand earthquakes occur over a great depth range, about half having focal depths greater than 40 km. Damage of course reduces with depth, but events with magnitudes up to about M = 8 could occur in the subducting plates, and even at 100 km depth such an event could produce damaging intensities (in this case c.MM8). Events of depth ≤ 40 km are nominally termed *shallow* in New Zealand.

In Australia focal depths of 2 km or less are common, especially in areas of granite outcrop. Earthquakes are considered shallow if they are within about 5 km of the surface, medium if they are between 5 km and 15 km, and deep if they are below 15 km. The deepest was at 38 km in western Australia and 20 km in eastern Australia. When they occur within urban areas, shallow earthquakes smaller than magnitude 1.0 are felt and reported in the media.

Table 1: New Zealand earthquakes, 1900-1992, with damage costs exceeding NZ$2 million

No	Date UT	Epicentre °S	°E	h_e (km)	M	Damage Cost NZ$ million (1992 Values)	Location
1	1901 11 15	43	173	c.10	6.0s	5?	Cheviot, SI
2	1929 06 16	41.7	172.2	c.8	7.8s	c.120	Murchison, SI
3	1931 02 02	39.3	177	c.17	7.8s	c.450	Hawkes Bay, NI
4	1932 09 15	38.9	177.6	c.17	6.9s	5?	Wairoa, NI
5	1934 03 05	40_?	175?	40?	7.6s	3?	Pahiatua, NI
6	1942 06 24	40.9	175.9	8	7.2s	5?	Wairarapa, NI
7	1942 08 01	41.0	175.8	43	7.0s	2?	Wairarapa, NI
8	1962 05 10	41.7	171.5	8	5.9s	4	Westport, SI
9	1966 03 04	38.8	178.1	18	5.8w	4?	Gisborne, NI
10	1966 04 23	41.8	174.7	19	5.8w	3	Seddon, SI
11	1968 05 23	41.8	172.0	10	7.4s	35	Inangahua, SI
12	1974 04 09	46.0	170.5	6	4.9L	4	Dunedin, SI
13	1987 03 02	37. 9	176.8	4	6.4w	280	Edgecumbe, NI
14	1990 02 19	40.4	176.4	28	6.3w	4	Weber I, NI
15	1990 05 13	40.3	176.3	13	6.4w	9	Weber II, NI
16	1991 01 28	41.9	171.6	10	5.8w	2	Hawks Crag I, SI
17	1991 01 28	41.9	171.6	12	6.0w	2	Hawks Crag II, SI

Note: h_e is depth to centroid of fault rupture
S indicates surface wave magnitude M_S
L indicates local (Richter) magnitude M_L
w indicates moment magnitude M_W
? indicates costs are educated guesses

Table 2: Australian earthquakes, 1900 - 1992, with damage costs exceeding A$50,000

No	Date UT	Time UT	Epicentre °S	°E	ML	MS	Damage Cost A$ million, 1992 values	Location
1	1954 02 28	1809 52	34.95	138.69	5.4	4.9	100	Adelaide, SA
2	1961 05 21	2140 03	34.55	150.50	5.6		3	Bowral, NSW
3	1968 10 14	0258 50	31.62	116.98	6.9	6.8	29	Meckering, WA
4	1973 03 09	1909 15	34.17	150.32	5.6	5.3	2	Picton, NSW
5	1979 06 02	0947 59	30.83	117.17	6.2	6.1	9	Cadoux, WA
6	1985 02 13	0801 23	33.49	150.18	4.3		0.09	Lithgow, NSW
7	1988 01 22	0035 57	19.84	133.99		6.7	1.2	Tennant Ck, NT
8	1989 12 27	2326 58	32.95	151.61	5.6	4.6	1200	Newcastle, NSW

Magnitude Distribution

An area with low seismicity and under horizontal compression is likely to have earthquakes with stress drops which are above the average for interplate regions, and such areas are likely to have a lower than average proportion of earthquake strain energy released in small earthquakes compared with that released in larger earthquakes. This results in the Gutenberg-Richter b-value being less than 1.0 for local areas in Australia although a current study indicates that for the continent as a whole, the b-value is very close to 1.0. In contrast, for New Zealand the b-value is 1.1 to 1.2.

Earthquake swarms and very long aftershock sequences seem to be associated with shallow earthquakes in areas of low seismicity, and both are common in Australia. The Tennant Creek aftershock sequence has continued through May 1994, more than 6 years after the mainshocks. Swarms are also common in the much more active Central Volcanic Zone of New Zealand.

The New Zealand interplate region provides the potential for earthquake rupture areas corresponding to magnitudes of up to M_S 8.5. In New Zealand's complex tectonic environment, the maximum magnitude varies from 7.5 to 8.5 in different regions, as given in the seismicity model [Smith and Berryman, 1986, 1992]. Because there are no large active faults within Australia, and larger earthquakes seem to be constrained to the relatively thin upper crust, the maximum credible magnitude for an earthquake is probably about M_S 7.5. Assuming that the depth and width of the rupture are constrained, larger earthquakes would require an unrealistically long fault.

The earthquake hazard in Australia is primarily from the more frequent shallow nearby events with magnitudes from 5.5 to 6.5. Larger events are so infrequent that their effect will be significant only when very long return periods are considered.

The same is true for the least seismic parts of New Zealand, but in the most seismic areas earthquakes approaching the maximum credible magnitude will occur relatively frequently. For example, Wellington can expect a local event of magnitude 7.5 at intervals of about 500 years on average.

Attenuation

The attenuation of seismic waves with distance is lower in Australia, especially in the western Archaean shield areas, so earthquakes will be felt over larger distances than in New Zealand. Attenuation on a lithospheric scale appears to be related to the thermal state.

Earthquake Intensities

In the more seismic parts of New Zealand earthquakes are felt quite often, for example in Wairoa events felt by a majority of people (i.e. intensity MM5) occur about once a year on average. In contrast Auckland has experienced intensity >MM4 only once (actually MM6) since 1840 (i.e. once in 150 years).

Like the Auckland/Northland area of New Zealand, because of the low level of earthquake activity and the wide distribution of epicentres, earthquakes are rarely felt in Australia. In most areas the interval between felt events can be 5 to 10 years or more, and most of these will be from a distant moderate magnitude event. However because of the shallow depth of all Australian earthquakes, a larger proportion of Australian events of a given magnitude are capable of causing damage than is the case in New Zealand.

Very shallow Australian earthquakes (within one or two kilometres of the surface) as small as magnitude 1.5 can be felt with surprising intensity within a kilometre or two of the epicentre. In 1986, an earthquake of magnitude 3.8 at Mathoura in southern NSW produced floor to ceiling cracks in an old masonry structure with the top of one wall moving out by 50 mm. It has been reported that insurance claims for minor damage have been paid following an earthquake of magnitude 1.5.

Australian buildings will suffer more than New Zealand buildings for a given intensity because few have been designed for lateral seismic loads, unreinforced masonry is common, and because their condition deteriorates more in the longer interval between earthquakes.

Because New Zealand earthquakes tend to be larger and deeper than Australian earthquakes, they usually have more low frequency seismic wave energy (selectively affecting larger structures), and the duration of motion is longer.

Because Australian earthquakes are mostly shallower and probably have higher stress drops than most New Zealand earthquakes, the seismic wave frequencies experienced will tend to be higher (affecting small or rigid structures), and the peak ground acceleration values will tend to be high, but the duration of strong motion will be relatively short. Figure 3 shows an Australian accelerogram from an earthquake of magnitude only M_L 4.9 at a distance of about 10 km, but the peak horizontal acceleration exceeds 0.4g and the vertical exceeds 0.5g.

THE NEW ZEALAND SEISMIC HAZARD MAPS

The principal steps in deriving the New Zealand seismic hazard map in terms of peak ground accelerations (PGA) were:
(1) Derive a seismicity model for the whole country.
(2) Derive a model for attenuation of response spectrum accelerations.
(3) Use (1) and (2) to derive maps of response spectrum accelerations for given return periods.
(4) Convert the spectral acceleration maps (3) to PGA terms.

The above steps are now briefly described.
(1) The seismicity model used [Smith and Berryman, 1986, 1992] divided the country into 15 regions for which the seismicity levels were described in terms of annual frequency of occurrence, per $1000km^2$, of earthquakes of magnitude M or greater, and the likely maximum magnitude M_{max}.
(2) The attenuation model for spectral acceleration was derived by tuning a Japanese model with the very sparse New Zealand data [McVerry, 1986].
(3) Hazards maps for New Zealand were derived using (1) and (2) above by a subcommittee [Matuschka et al, 1985] working on a revision of the loadings code. The four maps were in terms of 5% damped spectral acceleration at a period of T = 0.2s, and were for return periods of 50, 150, 450 and 1000 years. The patterns of these maps were all quite similar, and a single simplified version of these patterns was adopted for code zoning purposes in the loadings code revision [Standards New Zealand, 1992].
(4) Hazard maps in PGA terms for 475 and 2500 year return periods were derived from the spectral acceleration maps

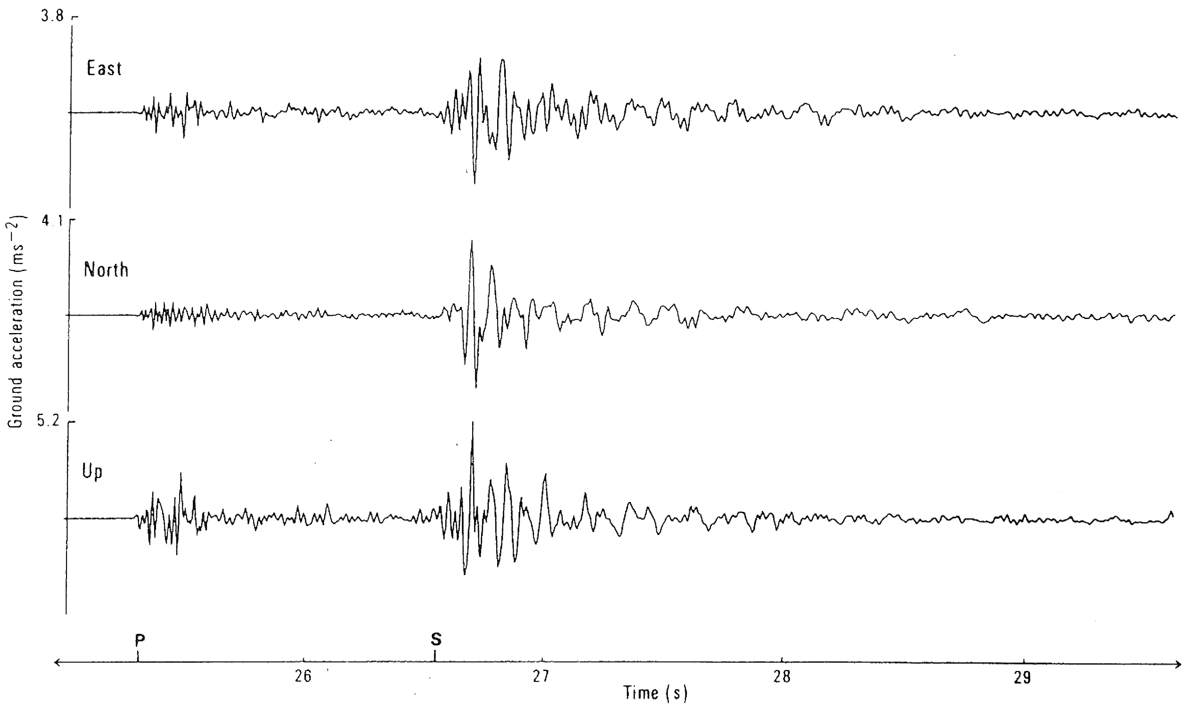

FIGURE 3 Accelerogram recorded at Tennant Creek, Northern Territory during an M_L 4.9 aftershock at a focal distance of about 10 km.

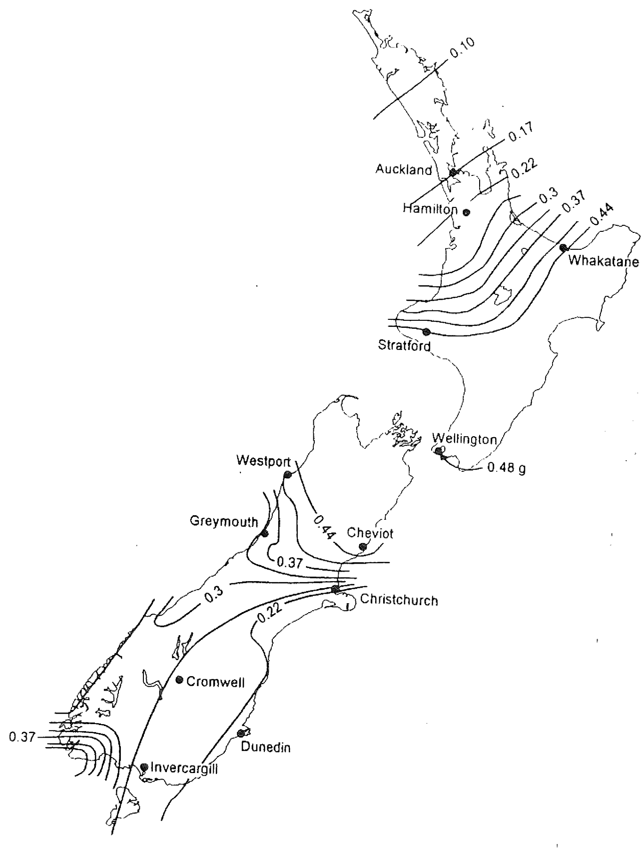

FIGURE 4 Seismic hazard of New Zealand in terms of the 475 year return period peak ground accelerations.

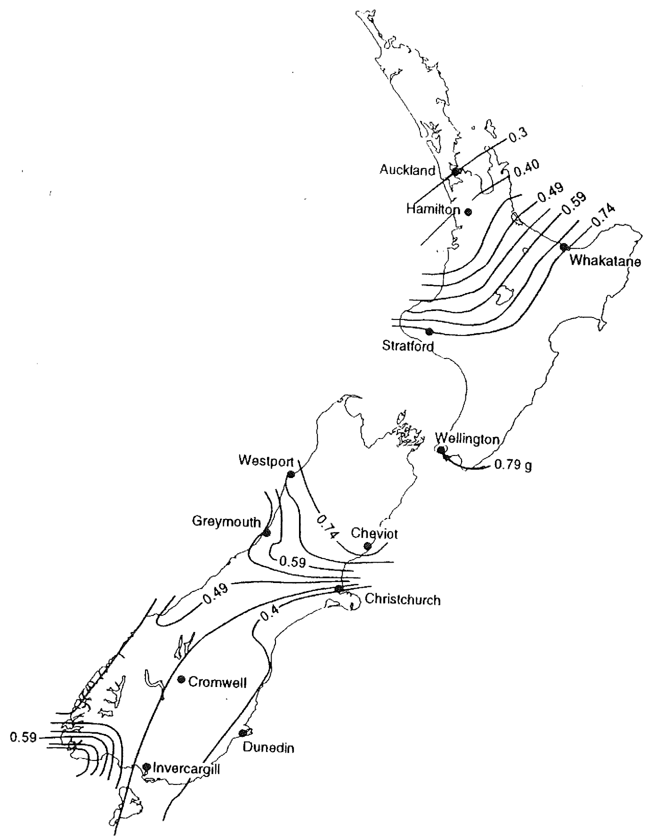

FIGURE 5 Seismic hazard of New Zealand in terms of the 2500 year return period peak ground accelerations.

of McVerry [1986] using:

$$PGA = \frac{PeakSpectralAcceleration(T = 0.2s)}{2.75}$$

For finding the 475 and 2500 year PGA's, the 450 and 1000 year values were multiplied by 1.018 and 1.36 respectively. These factors derive from the expression:

$$\log\left[\frac{a(T_1)}{a(T_2)}\right] = \frac{\log(T_1/T_2)}{k}$$

where T_1 and T_2 are the relevant return periods, and k is an empirical constant. The value k = 3 has been used as an approximate average for New Zealand in the 1992 loadings code, as noted in the Commentary to NZS4203 [Standards New Zealand, 1992]. The resulting hazard maps are shown in Figures 4 and 5. It should be noted that no account is made in these figures of the concentrations of hazard on very active faults.

THE AUSTRALIAN SEISMIC HAZARD MAPS AND RESPONSE SPECTRA

To derive a hazard map, in the absence of a model to explain the cause of Australia's intraplate earthquakes, the country was divided into source zones on the basis of past seismicity and with some guidance from the mapped geology [Gaull et al, 1990]. Recurrence relations and maximum magnitude were derived for each zone, and a Cornell type of analysis [Cornell, 1968] was undertaken using attenuation relations derived from published isoseismal maps. Gaull et al. [1990] then assigned background seismicity for the areas between the gaps.

The intensity was converted to peak ground velocity using Newmark and Rosenblueth's relationship [12], and for the code this was in turn converted to an acceleration coefficient using the ATC's [Appl. Techn. Council, 1978] recommended factor. Conceptually the acceleration coefficient is equivalent to PGA. Although the precise numerical relationship between the acceleration coefficient and PGA has not been determined, they are approximately equal. Very few accelerograms of use to the engineering community have yet been recorded in Australia. It is suspected that recorded PGA values will be higher than the acceleration coefficients, but the effect of this on structural response will be offset by the short duration and high frequency nature of the strong motion.

The resultant map, contoured at the 10% in 50 years level, was then scrutinised by a committee of Standards Australia consisting of seismologists with specialised knowledge of the seismicity of each State. The committee smoothed and modified the Gaull et al map [Matuschka et al, 1985] based on their collective judgment. For example, whilst the area around Tennant Creek is not necessarily considered to be a candidate for the next large earthquake, Meckering suffered an M_L 5.5 earthquake nearly 22 years after the M_S 6.8 mainshock on 10 October 1968, and the Cadoux region has not yet returned to pre-1979 levels of seismicity, so higher risk contours were drawn around Tennant Creek. Peaks around areas such as Dalton/Gunning were lowered correspondingly.

The draft *committee map* was then circulated for public comment and pertinent changes made where the committee agreed. The map is shown in Figure 6. From this figure we see that the highest hazard in the various States range from about 0.10g to 0.20g. These values overlap with the lowest hazard values New Zealand, for the same probability of occurrence, i.e. as shown on Figure 4 the hazard in the Auckland/Northland area ranges from about 0.10g to 0.22g, and the south-eastern coastal area of the South Island has a value of 0.22g.

Hazard mapping was not undertaken for a 2500 year return period (the Australian database was considered too short), but special studies for sites near Sydney and Adelaide indicated that extrapolation of the results to a 2500 year return period would lead to a doubling of the ground acceleration over the 475 year result. In contrast the New Zealand studies find that over most of that country the 2500 year accelerations are only about 1.7 times the 475 year values, as shown on Figures 4 and 5.

A response spectrum was then derived by another committee of Standards Australia; this was a smoothed 5% damped spectrum from predominantly Californian accelerograms. The accelerograms recorded to date in Australia have a higher amplitude at short periods (<0.3s) and a lower amplitude at longer periods (>0.5s) than this spectrum, but these are all from small to moderate earthquakes at close focal distances. The spectra adopted are shown in Figure 7.

NZ RESPONSE SPECTRA

Earthquake response spectra provide simple and convenient descriptions of ground motions from which design loadings may be derived. Adequate data bases of strong motion recordings do not yet exist for defining reliable response spectrum models for all parts of New Zealand and (particularly) Australia. It is likely that regionally different response spectra will be appropriate, especially for regions near to and far from the boundary between the Pacific and Indian-Australian tectonic plates. The South Island and the eastern part of the North Island of New Zealand lie along the tectonic plate boundary (Figure 2); this is called the *interplate* region. The north of New Zealand (including Auckland northwards) and Australia is an *intraplate* region.

The USA has a tectonic situation analogous to that of Australia and New Zealand, with an interplate region in the western USA and an intraplate region covering middle and eastern USA. Using a reasonably rich data base, it has been shown that these two tectonic regions have quite different characteristic response spectrum shapes [Algermissen and Leyendecker, 1992]. This occurs mainly because of the difference in source characteristics and attenuation rates in the two regions. For example high frequencies attenuate much more slowly in eastern than in western USA. Figure 8 shows the mean 5% damped spectral accelerations, S_A, for the interplate and intraplate regions of the USA for an average return period of 475 years, normalised with respect to S_A for period T = 0.3s. Adapted from Algermissen and Leyendecker [1992], the interplate spectrum is derived from results for San Francisco, Oakland, Los Angeles and San Diego, while the intraplate spectrum represents the mean for Salt Lake City, Memphis, New York, St Louis, Chicago and Charleston.

The Uniform Building Code [ICBO, 1992] of the USA does not yet (1992) acknowledge this regional difference in spectral shapes. The UBC has only one regional set of shapes, dependent only on soil conditions; its intermediate soil (type 2) spectrum is closely similar in shape to that for California derived by Algermissen and Leyendecker, given in Figure 8.

We speculate that the relationship between the Australia/New Zealand interplate and intraplate regions might be similar to

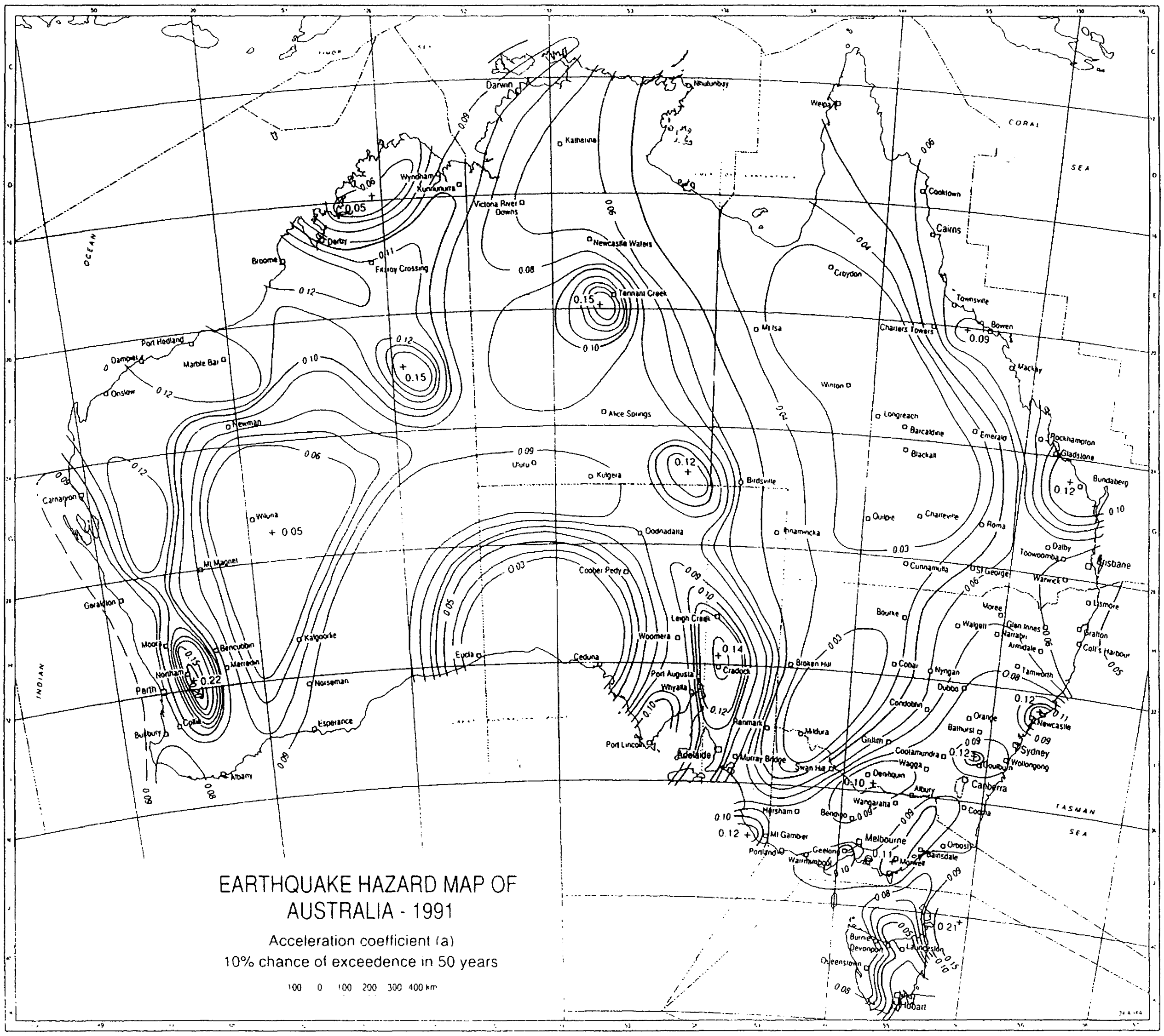

FIGURE 6 Earthquake hazard map of Australia, acceleration coefficient, 10% exceedance probability in 50 years (c.475 years return period).

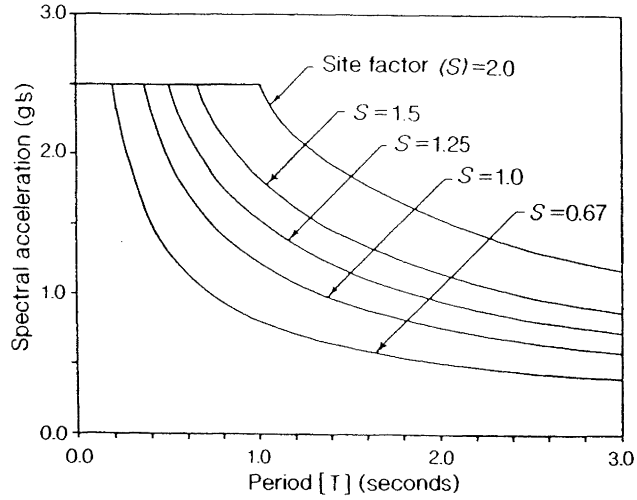

FIGURE 7 Design spectra for Australia, from the loadings code [Standards Australia, 1993], normalised with respect to an acceleration coefficient (effectively peak ground acceleration).

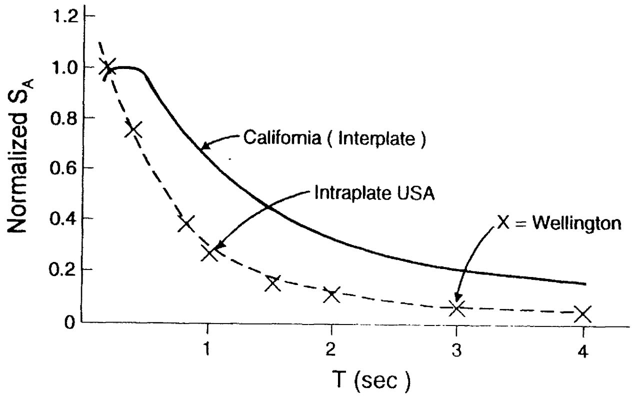

FIGURE 8 Response spectra for the USA [Algermissen and Leyendecker, 1992] and for Wellington, for ground conditions of intermediate stiffness, and return period of 475 years.

those of the USA. In Figure 8, together with the two USA curves, we have plotted the response spectrum for Wellington normalised with respect to S_A for period T = 0.2s, calculated using a program based on the model used for Reference 9. It is striking that the Wellington (interplate) spectrum is closely similar to the USA intraplate spectrum, and not the USA interplate one. As the Wellington spectrum is based largely on Japanese data, this implies that earthquake source mechanisms in Japan are very different from those of California. This situation is also suggested by a recent study of peak ground accelerations in New Zealand [Dowrick and Sritharan, 1993], in which PGA attenuation in New Zealand was shown to be similar to that in Japan and very different from that in the western USA.

As virtually no strong-motion recordings have yet been obtained in the intraplate region of New Zealand, we cannot plot a real New Zealand intraplate spectrum for comparison. Consequently, as for the USA, New Zealand at present has only one regional spectral shape; the elastic response spectrum for intermediate soil conditions of the 1992 code [Standards New Zealand, 1992] has adopted a shape which is between those for Wellington and California Interplate, given in Figure 8.

CONCLUSION

The most seismic parts of Australia have the same hazard as the least seismic parts of New Zealand. This may be explained largely by the similar tectonic setting of Australia and the Auckland/Northland area. The remaining differences between Australia and most parts of New Zealand in the nature and level of seismicity do not prevent development of a common earthquake code. Obviously the proposed code could readily accommodate the differences in the design response spectra by using different response spectra and zone factors for different regions.

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