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INTRAPLATE RECORDING OF STRONG MOTION IN SOUTHEASTERN AUSTRALIA

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SUMMARY

This study of peak ground accelerations recorded during earthquakes in southeastern Australia shows that acceleration attenuates very differently with distance than it does in the western USA. Seismic risk maps in the current Australian building code were based on the US data.

INTRODUCTION

Earthquakes can and do occur in Australia and more often perhaps than is generally realised. The earthquake datafile compiled by the Australian Bureau of Mineral Resources for the region 10°S to 90°S and 130°E to 163°E and the period 1883 to 1986, contains details of 36 000 earthquakes. Of these only 3 100 span the period 1900-1962 with a mere 44 prior to 1900. Seventeen large earthquakes, those with magnitudes of 6.0 or more, have occurred since 1900 and are listed in Table 1. Five of these produced surface faulting; at Meckering Western Australia in 1968 (Ref.1), Calingiri Western Australia in 1970 (Ref.2), Cadoux Western Australia in 1979 (Ref.3), Marryat Creek South Australia in 1986 (Ref.4) and Tennant Creek, Northern Territory in 1988 (Ref.5). Other scarps have been recognised in both Western Australia and New South Wales but the causative earthquakes predate recorded history (Ref.6,7,8). Damage measured in millions of dollars has resulted from earthquakes at Adelaide South Australia in 1954, Robertson NSW in 1961, Picton NSW in 1973, Meckering and Cadoux, Western Australia (Ref.9,3) and Tennant Creek Northern Territory (Ref.5).

In recognition of this non-negligable earthquake risk a building code incorporating seismic design coefficients and an earthquake risk map was introduced in 1979 by the Standards Association of Australia (Ref.10). Four zones, 0,A, 1 and 2 were therein defined with a suitable lateral force coefficient chosen for each zone in an attempt to equalise the risk of structural failure throughout the country. Furthermore zones 0, 1 and 2 were defined in such a way as to be comparable with those of the Uniform Building Code of the United States (Ref.11).

At the time the Building Code was introduced no strong motion data had been recorded in Australia. Attenuation formulae relating the ground motion, as measured by intensity, peak ground velocity or acceleration, to focal distance and earthquake magnitude were adopted from western US data (Ref.12) and used as the basis for the Australian earthquake risk studies. After normalisation, such formulae take the form:

$$A=ag(\exp(bM))(R/R_o+c)^{-d}$$

where A is the peak ground acceleration, velocity or ln (intensity)
M is the earthquake magnitude
R is the hypocentral distance
g is the acceleration due to gravity (same units as A)
a,b,c,d and R_o (same units as R) are constants.

In the meantime the Australian Bureau of Mineral Resources (BMR) initiated a strong motion recording program in southeast and southwest Australia which has recently been augmented in Victoria by a similar program at the Seismology Research Centre, PIT. The combined effort has resulted in the collection of a surprisingly large number of accelerograms, most of them digital recordings.

SOUTHEAST AUSTRALIAN ACCELEROGRAPH NETWORK

The first operational accelerograph in Australia was an analogue Kinemetrics type SMA-1 which was installed by BMR in October 1974 in a chicken coop at Hillcrest homestead near Gunning NSW. By December 1987 there were 28 assorted recorders deployed throughout southeastern Australia, most of them in dams or important buildings. Figure 1 shows their distribution in December 1987. Ten accelerographs are networked in two sets of 5 at the Hume Dam, NSW and Dartmouth Dam in Victoria. Three interconnected accelerographs are installed at the Australian National Animal Health Laboratory in Geelong, Victoria and two digital accelerographs were set up at Googong Dam, NSW in 1986. Few of the remainder are free-field instruments, most are in dams or special structures.

Despite the paucity of free-field accelerographs, sufficient data has been obtained in New South Wales and Victoria over the last few years to compare the recorded peak ground accelerations (Fig. 2) with those predicted from the US attenuation relationship. Integration of the records to enable comparision of the observed and predicted peak ground velocities has not yet been completed. Peak ground velocity may correlate better with building damage (or intensity) than peak ground acceleration, due to the high frequency of the acceleration pulses recorded near the southeast Australian epicentres.

DATA

A summary of the data set showing the frequency or number of recordings in the various magnitude, distance and peak ground acceleration ranges are shown in Figure 3. Values of the extreme parameters are; magnitude M_S 5.9, epicentral distance 833 km and peak ground acceleration $3.05 m/s^2$. With only 62 data points and 5 unknown constants to evaluate, two of the constants were assumed; c=0 and R_o=1 km. Furthermore a piecewise analytical approach was adopted; first determine 'b' from a subset of the data, then 'a', and 'd' using the complete data set.

RESULTS

The latter step was taken to minimise bias in any least squares estimation program due to the non uniform distribution of focal distances; nearly 1/4 of the data were recorded at the same hypocentral distance as measured from the

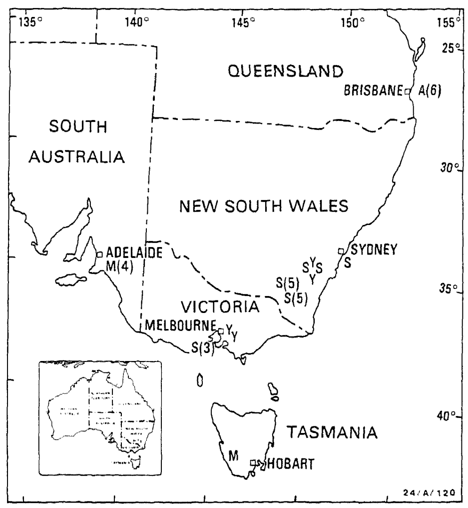

Fig. 1 Accelerograph distribution

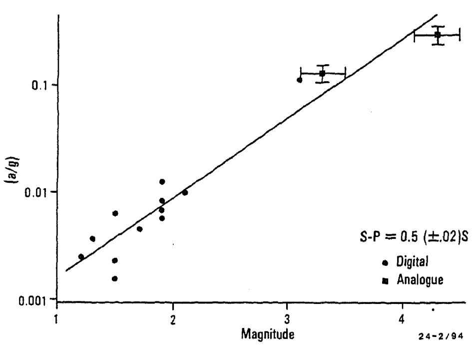

Fig. 4 Acceleration vs. Magnitude

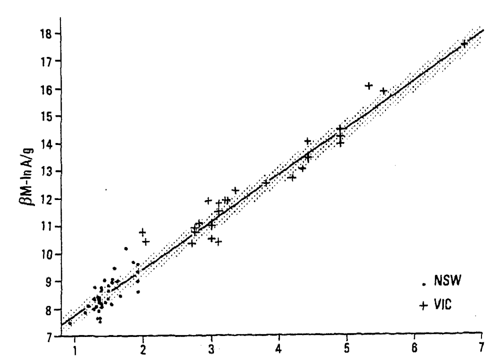

Fig. 5 BM-ln(a/g) vs. Distance

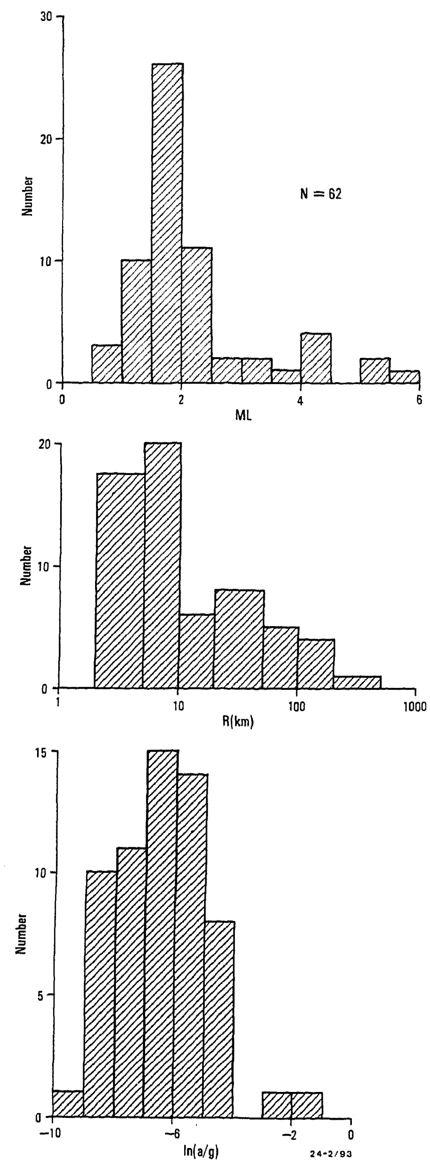

Fig. 3 Data ranges

difference in arrival time between the longitudinal (P) and shear (S) waves (S-P=0.50($\pm$0.02). Since R is constant for this unique data set, a plot of A/g against magnitude yielded a value for 'b', the slope of the line (Fig. 4). The data range over three magnitude units and three orders of magnitude in the dimensionless ratio A/g although most of the data are at the low end of each range. The resultant value of 'b' is 1.72$\pm$0.16 which is much higher than Esteva (Ref.12) obtained in his study of western US earthquakes.

We next plotted the quantity 'bM-ln(A/g)' against 'ln(R/R_o)' as shown in Figure 5 and obtained, using least squares: 'ln a'=-5.75$\pm$.09 and 'd' = 1.69$\pm$.16. The final attenuation relation is plotted in Figure 6 with that of Esteva (Ref.12) for the two magnitudes ML 4.3 and ML 5.4 for which there is local data.

DISCUSSION

Peak ground acceleration data measured during earthquakes in southeastern Australia has been analysed to produce an attenuation equation appropriate for use in eastern Australia. The data span three orders of magnitude in acceleration and four magnitude ranges. For earthquakes up to magnitude ML 5.4, the attenuation seems to be quite different to that obtained in the western United States on which the seismic zoning map of Australia was based.

Close to the epicentre, acceleration are higher than expected from Esteva's data but in the far field they are lower. Esteva used a high value for 'c' to eliminate the singularity in ln A as R decreases to zero. It effectively introduces an acceleration asymptote close to the epicentre which does not seem to occur in eastern Australia, at least close to the small earthquakes we have so far recorded. The lower accelerations in eastern Australia at larger distances could be attributed to a frequency dependent Q, the frequencies close in are high, upwards of 13 Hz whilst at larger distances the predominant frequency in the accelerograms is about 5Hz.

And at a particular distance the difference in peak ground acceleration for a unit increase in magnitude is much greater in eastern Australia than in the western USA although the eastern Australia data set is very limited as yet.

The effect of changing the attenuation relation in the seismic risk evaluation from Esteva's to ours would be to bring the zone boundary closer in to the source zone edge but increase the risk of exceeding a particular ground acceleration within the source zone. Delineating the source zone boundary then becomes a very critical exercise.

Peak ground accelerations probably don't correlate very well with structural damage potential in Eastern Australia because of the high frequency of the seismic waves close to the source. In the next stage of this study the velocity and energy flux will be analysed in an attempt to find a parameter than can be used to scale accelerograms for dynamic design studies and code formulation. Scaling of response spectra directly with magnitude and distance may prove to be the best way of upgrading the current risk map and building code.

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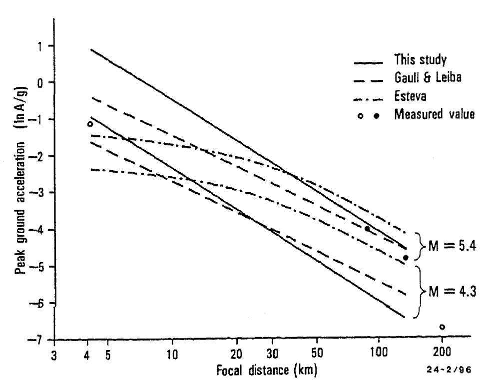

Fig.6 Attenuation of ground motion

Table 1 Large Australian Earthquakes, 1900-1988

Date			Time h m	s	Lat °S	Long °E	Depth km	Magnitude mb	Ms	ML
1902	9	19	1035	0.0	35.00	137.40	14			6.0
1906	11	19	0718	41.0	19.10	111.80	33	7.4	7.2	
1918	6	6	1814	24.0	23.50	152.50	15		5.7	6.0
1920	2	8	0524	30.0	35.00	111.00	33		6.0	
1929	8	16	2128	23.4	16.99	120.66	33		6.8	
1935	4	12	0132	24	26.00	151.10	0		5.4	6.1
1941	4	29	1354	41.0	26.80	116.10	33	7.3	6.5	7.2
1941	6	27	0755	49.0	25.95	137.34	0		6.5	
1968	10	14	0258	50.6	31.62	116.98	10	6.0	6.8	6.9
1970	3	24	1035	17.6	22.05	126.61	0	6.2	5.9	6.4
1972	8	28	0218	56.2	24.95	136.26	10	6.3		6.2
1979	4	23	0545	10.8	16.66	120.27	39	5.9	5.7	6.6
1979	6	2	0947	59.3	30.82	117.17	6	6.0		6.2
1986	3	30	0853	48.4	26.33	132.51	5	5.8	5.8	6.0
1988	1	22	0035	57.4	19.79	133.93	3		6.3	
1988	1	22	0357	24.3	19.88	133.84	3		6.4	
1988	1	22	1204	55.8	19.94	133.74	3		6.8	

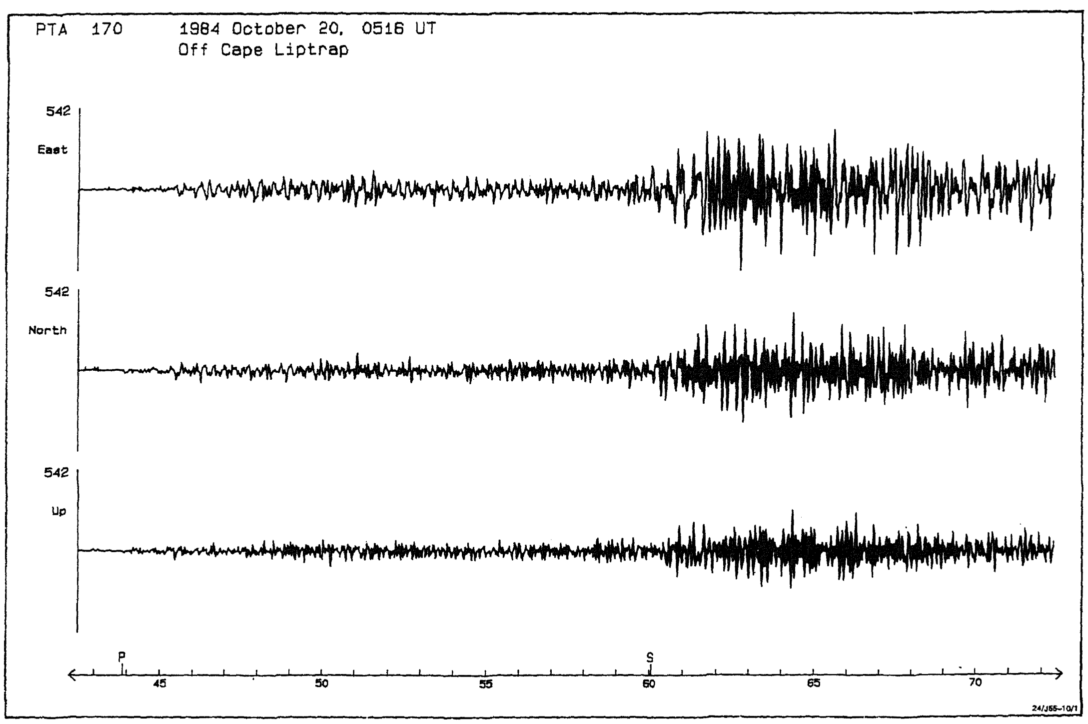

Fig. 2 Accelerogram of an ML 4.3 earthquake at 133 km.