Report 259

Australian seismological report 1981

Compiled by David Denham & Peter J. Gregson

Bureau of Mineral Resources, Geology & Geophysics

Department of Resources & Energy

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 259

AUSTRALIAN SEISMOLOGICAL REPORT 1981

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David Denham & Peter J. Gregson

(Division of Geophysics)

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ABSTRACT

The level of seismicity in Australia during 1981 was close to average. Of the 111 earthquakes of magnitude 3.0 or greater that were located during the year, the largest was the Bass Strait earthquake of 16 June, which was felt throughout central Victoria and had a magnitude of about 5.5 ML.

Isoseismal maps have been prepared for the Tenthill (Qld), Monogorilby (Qld), Bass Strait (Vic), Glen Innes (NSW), Appin (NSW), Suggan Buggan (NSW) and Cadoux (WA) earthquakes. Intensities of 5 on the Modified Mercalli Scale were reported from the Bass Strait, Appin, and Cadoux earthquakes. Nine earthquakes were recorded on strong-motion accelerographs - six were recorded in Western Australia and three in Victoria; the maximum acceleration, 27 cm s^{-2}, was recorded at a site near Meckering from a magnitude 2.0 earthquake which occurred close to the accelerograph.

On a world scale the largest earthquake during 1981 occurred near the Samoa Islands. It had a surface-wave magnitude of 7.7, and generated a local tsunami with a maximum peak-to-peak amplitude of about 24 cm. The most destructive earthquake took place in southern Iran on 11 June, when at least 3000 people were reported killed from a magnitude 6.7 earthquake.in Kerman province.

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INTRODUCTION

This Report provides information on all earthquakes of Richter magnitude 3 or greater that were reported in the Australian region during 1981. It is the second of an annual series compiled by the Bureau of Mineral Resources, Geology and Geophysics (BMR) using data provided by various seismological agencies in Australia. Its purpose is to provide information on Australian earthquakes for the study of seismic risk and to answer inquiries from scientists and the general public.

The Report comprises four main sections: 'Australian earthquakes', which contains a summary of the 1981 seismicity and brief descriptions of the more important earthquakes; 'Network operations', which gives details of the seismographs that operated in Australia during 1981; 'Strong-motion seismograph data', which contains the results of the accelerograph network, and 'Principal world earthquakes 1981', which lists the largest and most damaging earthquakes that took place during 1981.

Throughout the Report we refer to magnitudes of earthquakes and intensities caused by earthquakes. These terms are defined below.

Magnitudes

The magnitude of an earthquake is a measure of its size, and is related to the energy released at its focus. The magnitude scale is logarithmic; thus a magnitude 6 earthquake produces ground amplitudes 10 times as large, and an energy release about 30 times as large, as a magnitude 5 earthquake. A rule-of-thumb relation between magnitude and energy is:

$$\log E = 4.8 + 1.5M$$

where E is in joules. A shock of magnitude 2 is the smallest normally felt by humans, and earthquakes of magnitude 5 or more can cause major damage if they are shallow and close to buildings.

Several magnitude scales are in common usage. Those used in this publication are defined below.

Richter magnitude (ML)

$$ML = \log A - \log Ao$$

as defined by Richter (1958, p. 340), where A is the maximum trace amplitude in millimetres on a standard Wood-Anderson seismogram, and log Ao is a standard value given as a function of distance (0-600 km). Richter's reference earthquake of ML = 3.0 produces a trace amplitude of 1 mm, 100 km from the epicentre.

If standard Wood-Anderson instruments are not available an equivalent Richter magnitude can be determined by correcting for the differences in magnification (see Willmore, 1979, para. 3.1.1).

Surface-wave magnitude (MS)

The surface-wave magnitude is normally applicable only to shallow earthquakes in the distance range 20-160 degrees, and in the period range $T = 20 \pm 3$s. When these conditions hold, MS values are calculated from the IASPEI 1967 formula (see Båth, 1981):

$$MS = \log (A/T) + 1.66\Delta + 3.3$$

where A is the ground amplitude in micrometers, T is seconds, and Δ the epicentral distance in degrees (see Båth, 1981).

Body-wave magnitude (mb)

$$mb = \log (A/T) + Q (\Delta,h)$$

where A is the maximum mean-to-peak ground amplitude in microns of the P, PP, or S-wave trains, T the corresponding wave-period (seconds), and Q (Δ,h) a depth/distance factor. The Q factors were derived by Gutenberg (1945) and are given by Richter (1958, pages 688-689).

Duration magnitude (MD)

$$MD = a \log t + b\Delta + c$$

where t is the length of the earthquake coda in seconds, Δ the distance from the epicentre, and a, b, and c are constants for a particular recording station.

Seismic-moment magnitude (Mw)

$$Mw = (\log Mo/1.5) - 6.0 \text{ (Mo in N-m)}$$

where Mo is the seismic moment based on the physics of the earthquake source.

$$Mo = \mu AD$$

where μ is the rigidity, A is the surface area displaced, and D is the average displacement on that surface. This magnitude scale was proposed by Kanamori (1978).

Further information on magnitudes is available in McGregor & Ripper (1976), Båth (1981), and Denham (1982).

Intensity

Intensity, as applied to earthquakes, represents a quantity determined from the effects on people, buildings, and the Earth's surface. In this Report we use the Modified Mercalli Scale (MM) as presented by Eiby (1966) and listed in the Appendix. Essentially the MM scale is a subjective assessment of how severely the earthquake was felt and the damage that was caused at a particular place. Some earthquakes are large enough to be felt over a wide area, and an isoseismal map can be prepared. These maps indicate in detail the extent of the shaking. They are prepared mainly from information compiled from questionnaire canvasses, newspaper reports, and personal interviews and inspections.

During 1981 seven earthquakes were large enough for isoseismal maps to be prepared (Figs. 3 to 10).

AUSTRALIAN EARTHQUAKES 1981

The level of earthquake activity in the Australian region during 1981 was about the same as in 1980 (Denham & Gregson, 1984), when it was below average. Figure 1 shows the distribution of all known earthquakes having a magnitude of 3 or greater that occurred during 1981, and, for comparison with longer-term seismicity patterns, Figure 2 shows the distribution of magnitude 4 and greater earthquakes between 1873 and 1980. Table 1 lists the hypocentral parameters for the 1981 earthquakes.

The Southwest Seismic Zone of Western Australia remained one of the most active parts of Australia, and 81 earthquakes were located there during 1981. Only one was greater than magnitude 4.

Four earthquakes were located in a zone between 100 and 300 km northwest of Broome (near 17°S, 120°E), the largest having a magnitude of 4.4. A magnitude 5.0 earthquake occurred 80 km northeast of Broome, and five others with magnitudes greater than 3.6 took place onshore and within 140 km of Broome.

South Australia was seismically quiet. Only one earthquake there had a magnitude of 4 during the year and only five were located with magnitudes of 3 or greater.

In eastern Australia the level of seismic activity was close to average. The largest earthquake occurred in Bass Strait and had a Richter magnitude of 5.5. It was felt in Melbourne, and isoseismal maps for it are shown in Figures 5 and 6. Elsewhere in eastern Australia, significant earthquakes took place near Appin, Glen Innes, and Suggan Buggan (NSW). Brief descriptions of these earthquakes and others for which isoseismal maps were prepared are given below.

Tenthill

The Tenthill earthquake took place on 24 March. The felt area was about 500 km^2, and the maximum intensity of MM IV was reported from Tenthill. The main shock had a magnitude of 3.1 (ML); it was accompanied by a foreshock (ML 2.0) and an aftershock (MD 0.6) which were large enough to be located (Rynn, 1984). The isoseismal map is shown in Figure 3.

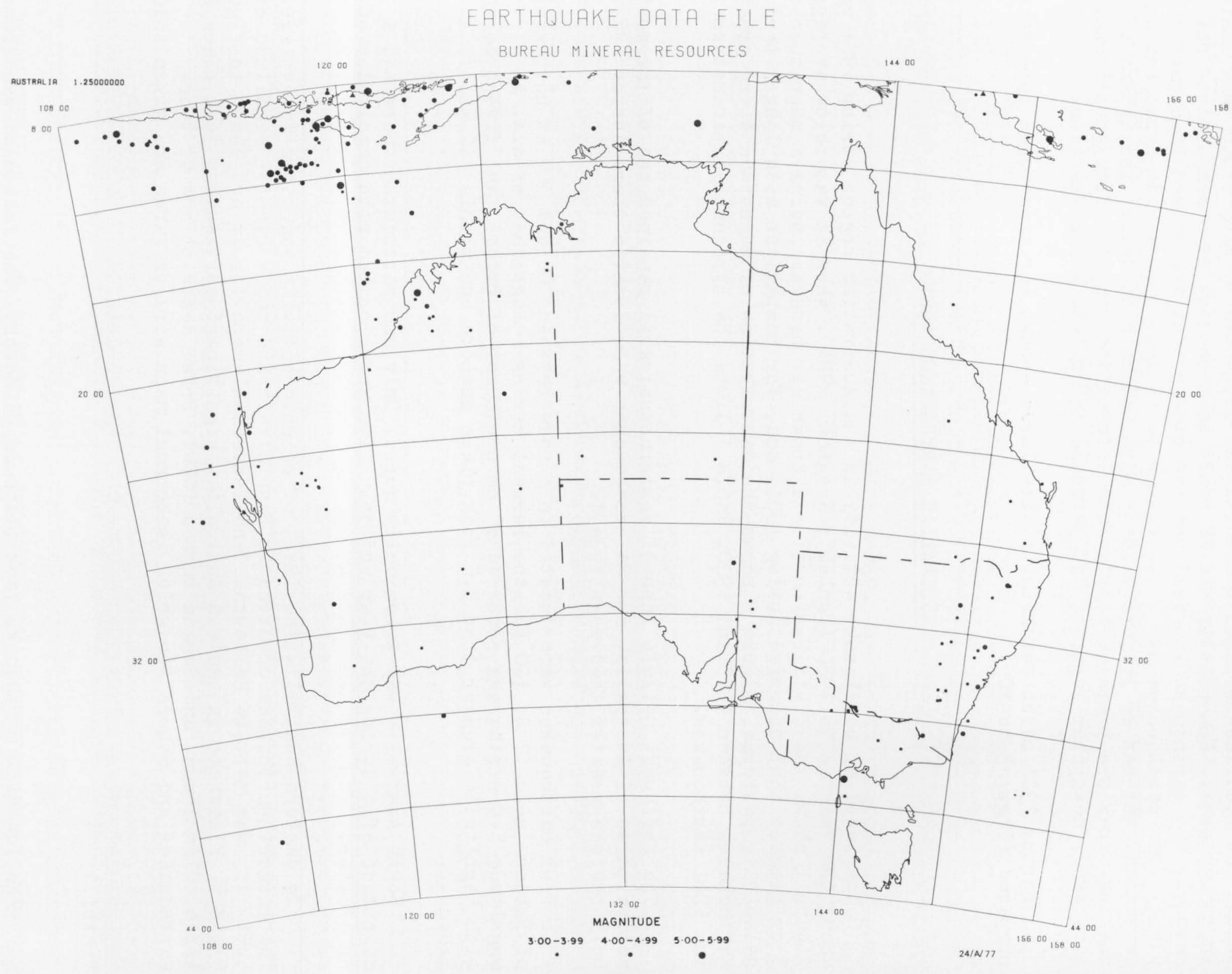


Fig. 1. Australian earthquakes with magnitudes of 3.0 or greater in 1981.

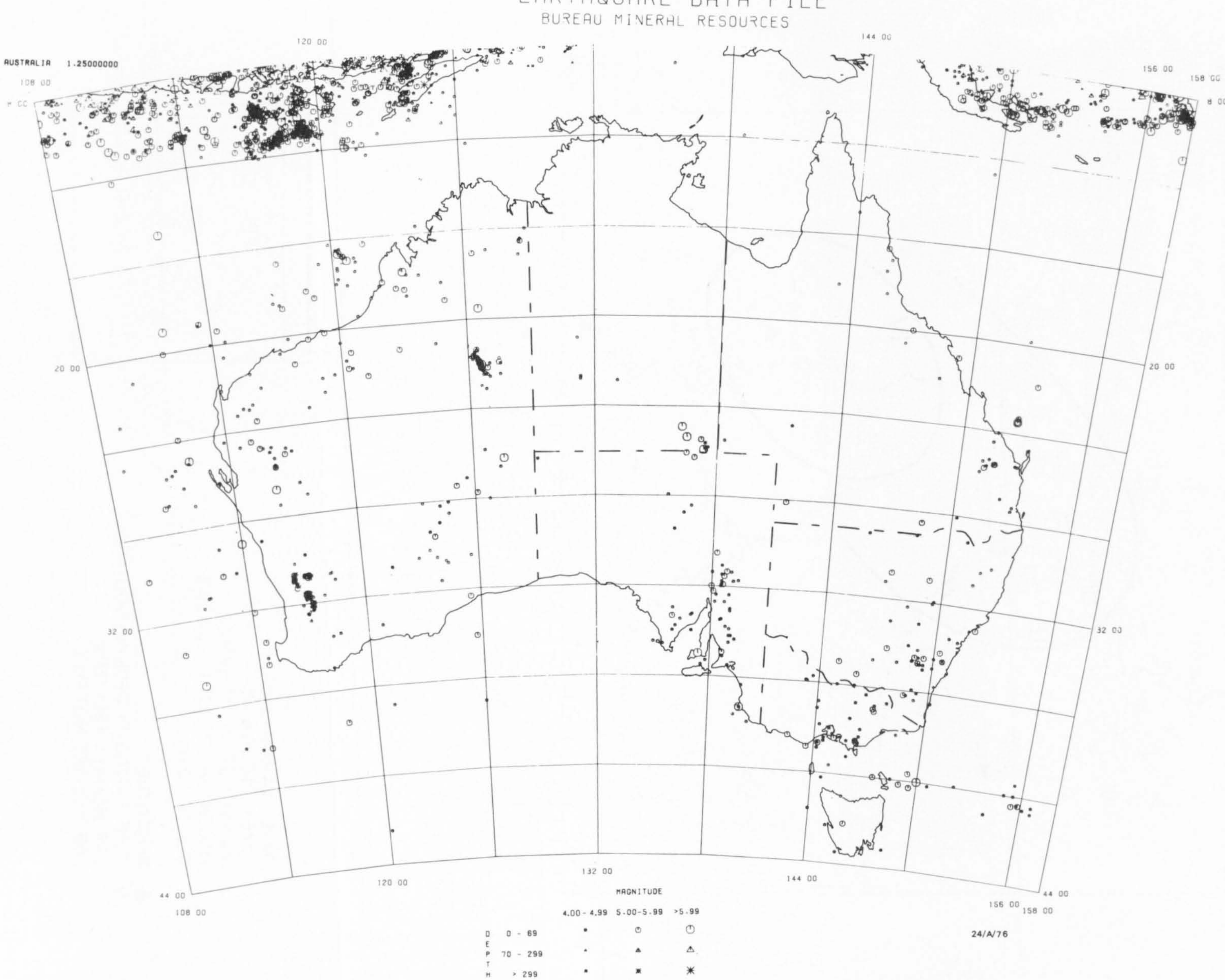


Fig. 2. Australian earthquakes with magnitudes of 4.0 or greater between 1873 and 1980.

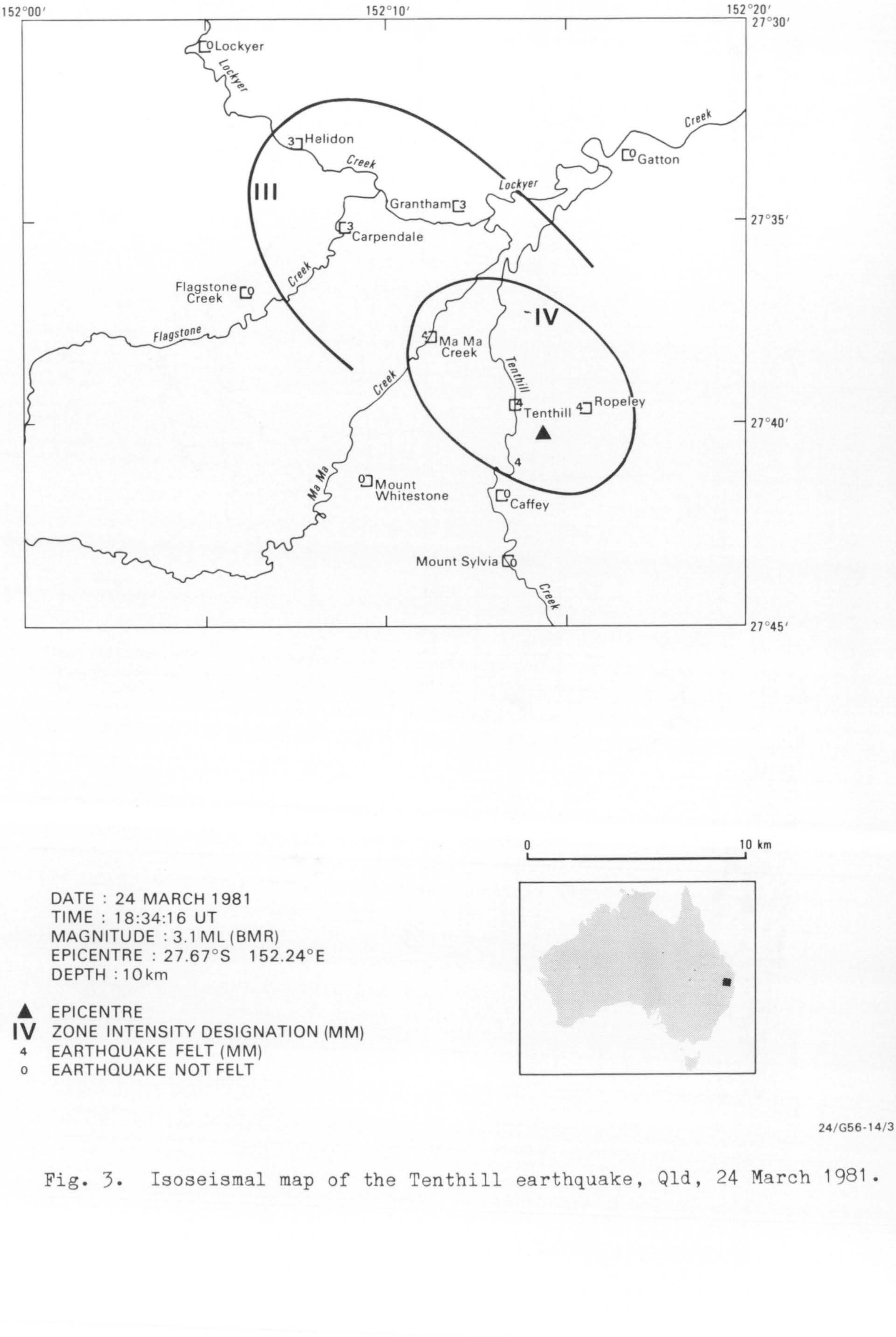


Fig. 3. Isoseismal map of the Tenthill earthquake, Qld, 24 March 1981.

Cadoux

The Cadoux earthquake took place on 7 April. It had a magnitude of 4.5 ML and was located 8 km southeast of Cadoux. The felt area covered about 80 000 km^2, and had a radius of 110 km to the MM IV isoseismal. The maximum intensity experienced was MM V at Cadoux and the surrounding area of 6000 km^2 where small objects on shelves moved. Isolated reports of MM III were received from the Perth metropolitan area, 180 km from the epicentre. The isoseismal map is shown in Figure 4.

Monogorilby

This earthquake took place on 10 May, and was felt over an area of about 6000 km^2 with a maximum intensity of MM IV. The isoseismal map is shown in Figure 5.

Bass Strait

The Bass Strait earthquake of 17 June (local time) was felt in Victoria at distances up to 250 km from the epicentre. The maximum intensity was MM V, too low to cause significant damage. Intensity in the Melbourne suburban area was MM III-IV. South of the epicentre the earthquake was felt at Currie (King Island), but was not felt in northwestern Tasmania. Figures 6 and 7 show the extent and intensity of the shaking.

Glen Innes

The Glen Innes earthquake took place on 11 October. It had a magnitude of only about 3.0 ML, but because of its proximity to Glenn Innes nearly 200 felt reports of the earthquake were obtained. The felt area covered about 1400 km^2, and a maximum intensity of MM V was assigned to a small area near Matheson (15 km west of Glenn Innes), where reports were obtained of tall and small objects on shelves being shifted. The majority of the reports from Glen Innes indicated an intensity of MM IV in the town. The isoseismal map is shown in Figure 8.

Appin

The earthquake that occurred near Appin, New South Wales, on 15 November 1981, and its aftershock of 19 November, were both associated with thrust-faulting in the middle crust (10-20 km), caused by east-west compressive forces (Denham & others, 1982). The magnitudes of the main earthquake were estimated to be 3.9 MS, 4.3 mb, 4.6 ML, and 4.1 Mw, and a seismic moment of about 1.4 x 10^{15} N-m was estimated.

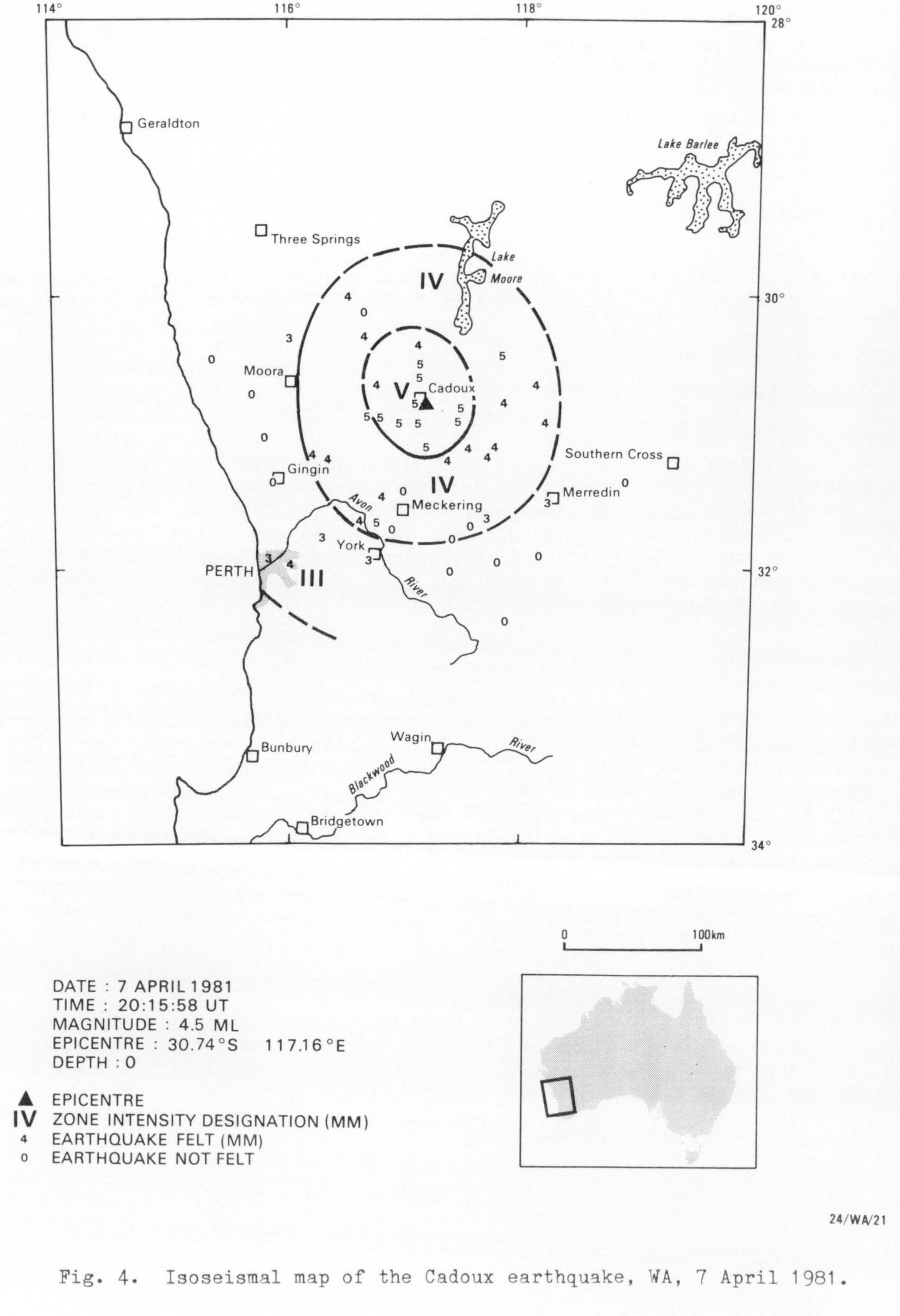


Fig. 4. Isoseismal map of the Cadoux earthquake, WA, 7 April 1981.

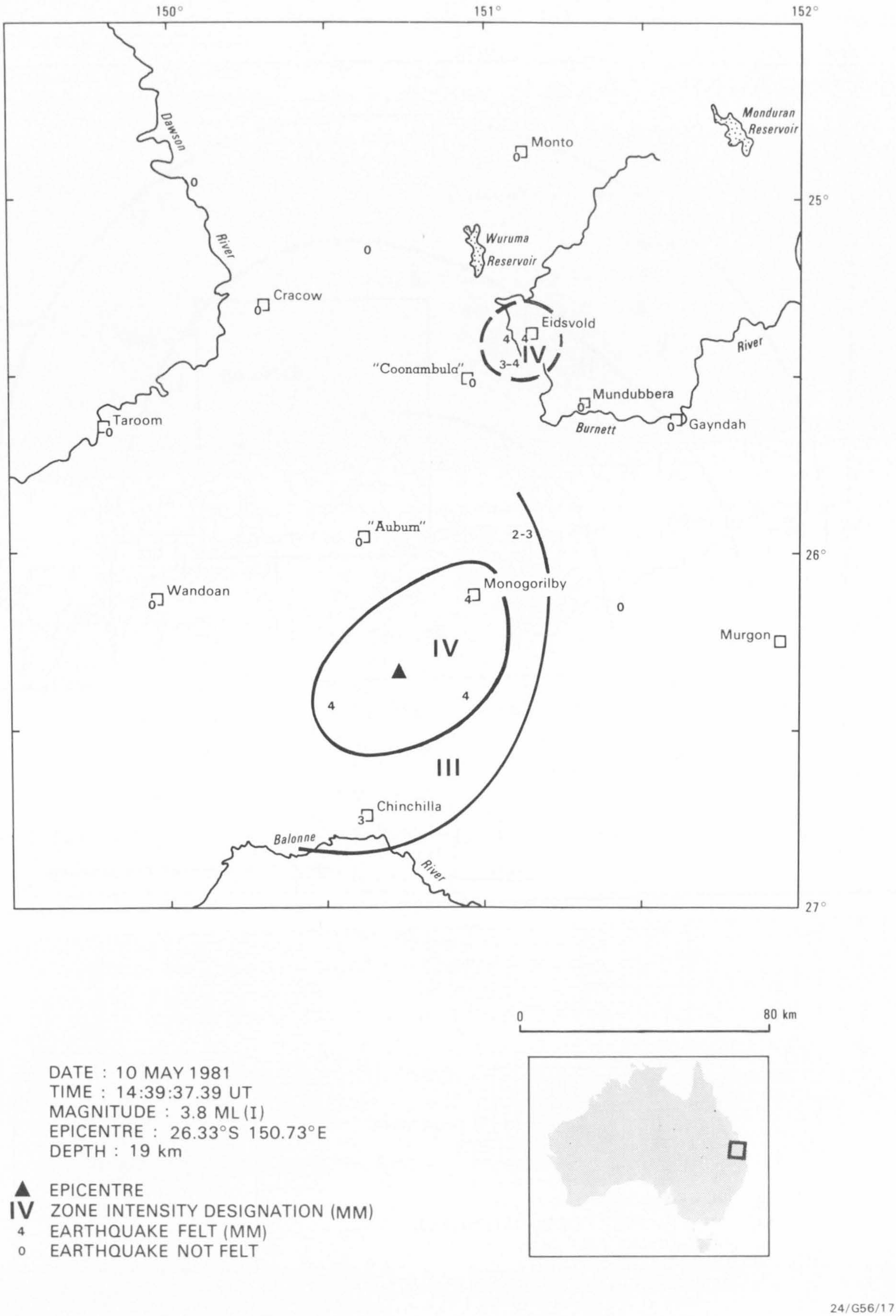


Fig. 5. Isoseismal map of the Monogorilby earthquake, Qld, 10 May 1981.

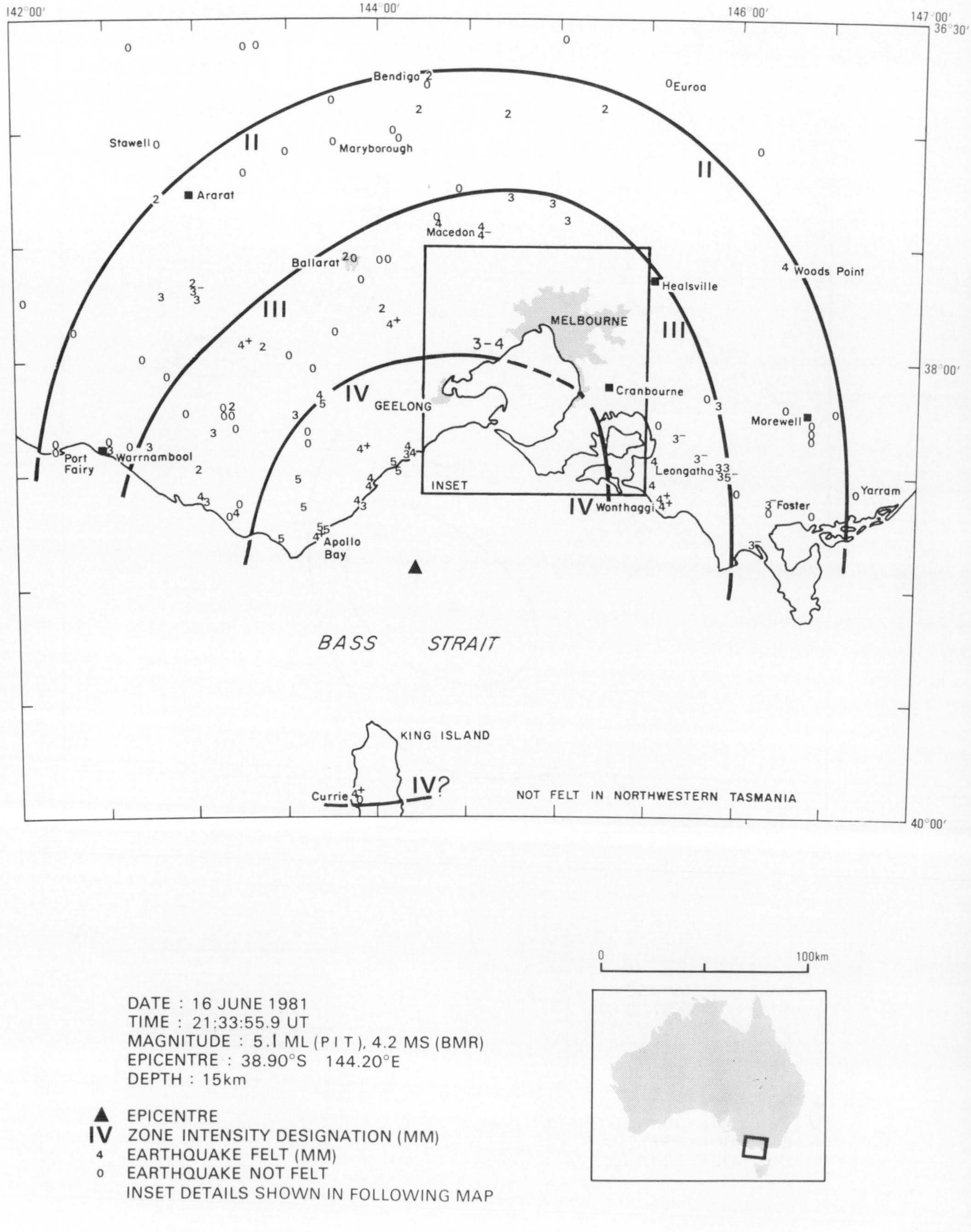
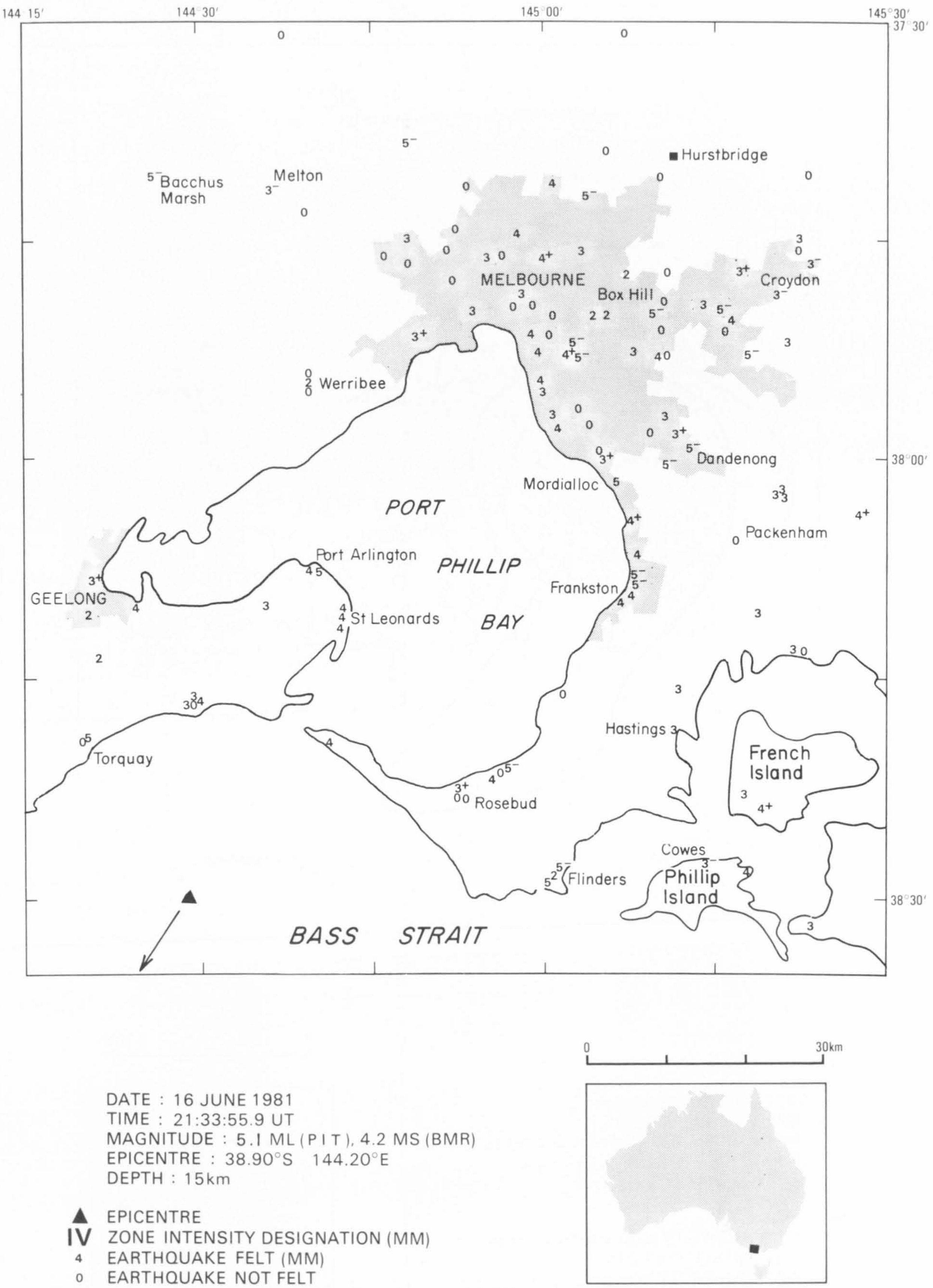
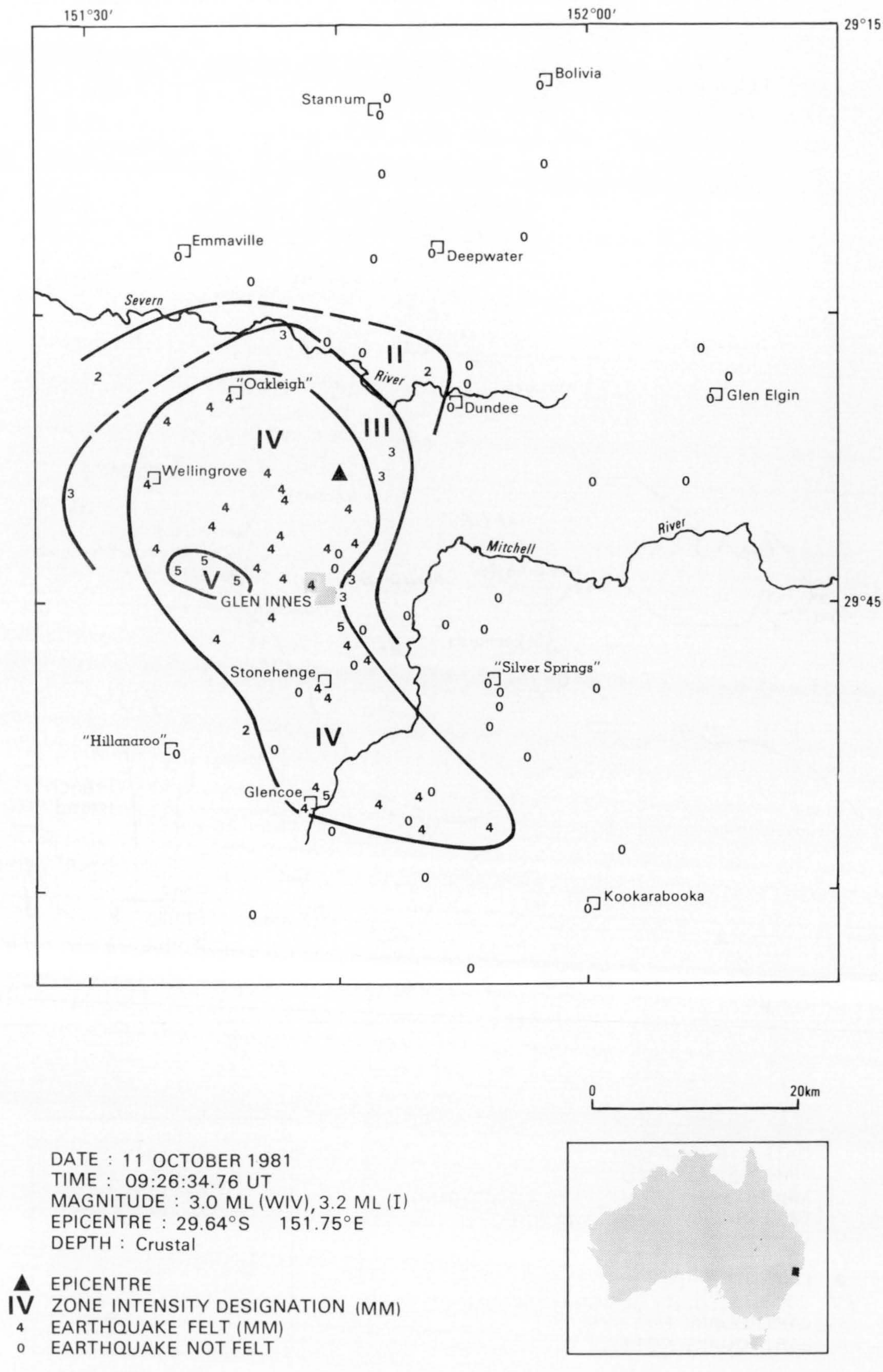


Fig. 6. Isoseismal map of the Bass Strait earthquake, Vic., 16 June 1981.



24/J55

Fig. 7. Felt-intensity map of the Bass Strait earthquake in the Port Phillip Bay area, 16 June 1981.



24/H56-6/2

Fig. 8. Isoseismal map of the Glen Innes earthquake, NSW, 11 October 1981.

Although no damage was reported, the main earthquake was felt over about 60 000 km^2 of New South Wales. A maximum intensity of V on the Modified Mercalli Scale was felt near the epicentral region and along the coastal plain from Wollongong to Nowra. The radius to the MM IV isoseismal was about 200 km. The isoseismal map is shown in Figure 9.

Suggan Buggan

This earthquake, which occurred on 30 November, was felt over an area of 15 000 km^2. The most intense shaking, MM V, was felt at the Thredbo Ranger Station; it startled several people near the epicentre though no damage was reported. The earthquake had a magnitude of 3.7 ML. The focal mechanism of the earthquake indicated strike-slip faulting associated with the Moyangul River Fault (Bock & Denham, 1983). The isoseismal map is shown in Figure 10.

NETWORK OPERATIONS

Figure 11 shows the locations of all the stations that operated continuously during 1981. Six new stations were commissioned during the year: Camp Site, Glendon Crossing, Mount Graham, Glenroy, and Mount Golengumma in Queensland, and Kellerberrin in Western Australia. Table 2 lists the co-ordinates of the stations and indicates the type of seismograph in operation.

STRONG-MOTION SEISMOGRAPH DATA

Several accelerographs operated in Australia during 1981; these are listed in Table 3, and Table 4 lists the principal facts from the nine triggerings obtained during the year. Six triggerings were obtained in the Southwest Seismic Zone of Western Australia, and three in Victoria. The largest acceleration of 27cm s^{-2} was recorded near Meckering from a 2.0 ML earthquake very close to the accelerograph.

PRINCIPAL WORLD EARTHQUAKES 1981

Table 5 lists earthquakes of magnitude 7 or greater, damaging earthquakes, and earthquakes of particular interest that occurred throughout the world during 1981. The most disastrous earthquake was that of 11 June in southern Iran which killed at least 3000 people. The total world-wide death-toll from earthquakes for 1981 was about 4100 (about half of that for 1980). These data are based on 'Earthquake Data Reports' published by the United States Department of the Interior, Geological Survey, and the SEAN Bulletin of the Smithsonian Intitution (Washington DC, US).

Figure 12 shows the locations of these earthquakes and the numbers of casualties.

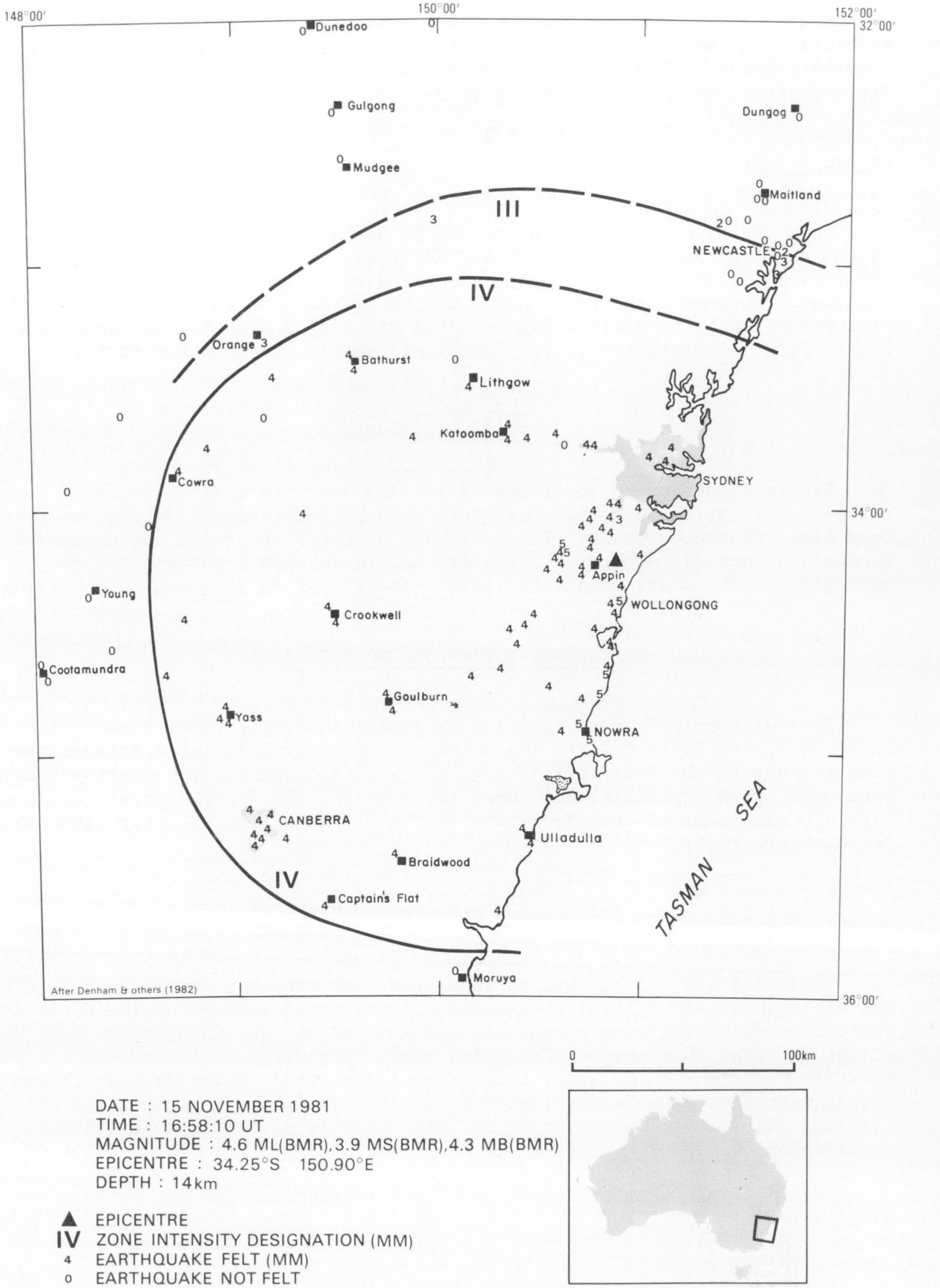
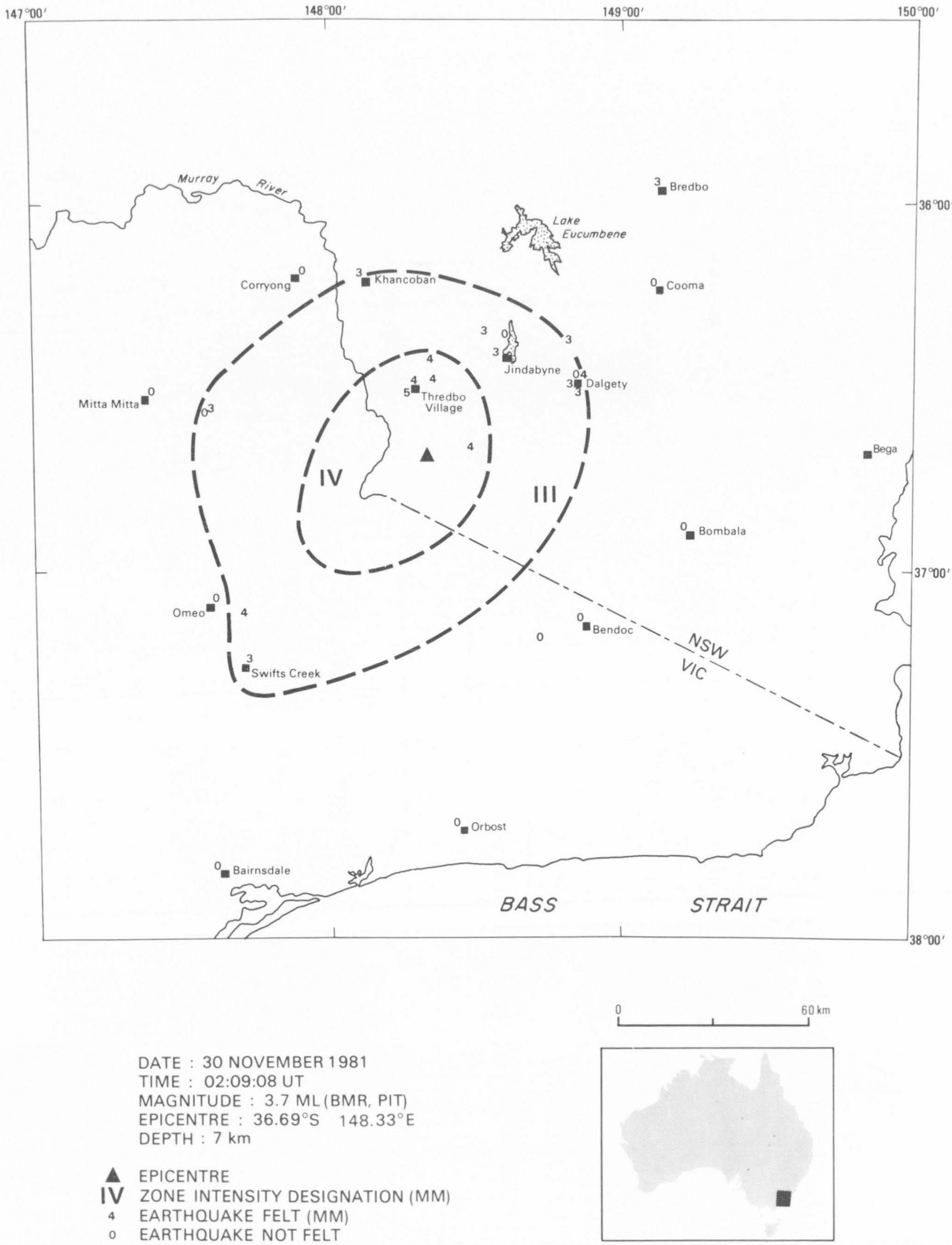


Fig. 9. Isoseismal map of the Appin earthquake, NSW, 15 November 1981.



DATE : 30 NOVEMBER 1981
TIME : 02:09:08 UT
MAGNITUDE : 3.7 ML (BMR, PIT)
EPICENTRE : 36.69°S 148.33°E
DEPTH : 7 km

▲ EPICENTRE
IV ZONE INTENSITY DESIGNATION (MM)
4 EARTHQUAKE FELT (MM)
o EARTHQUAKE NOT FELT

24/J55/12

Fig. 10. Isoseismal map of the Suggan Buggan earthquake, NSW, 30 November 1981.

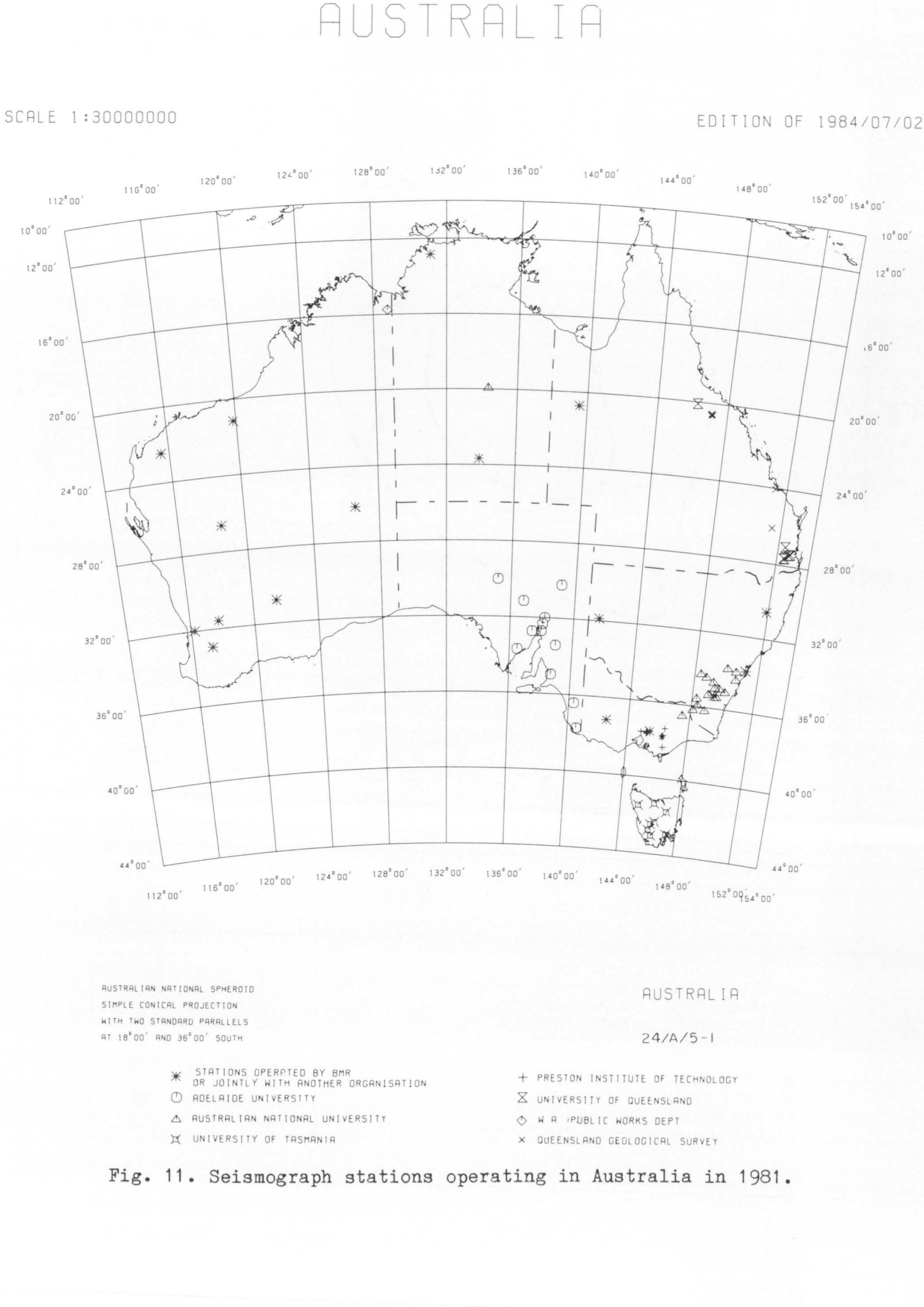


Fig. 11. Seismograph stations operating in Australia in 1981.

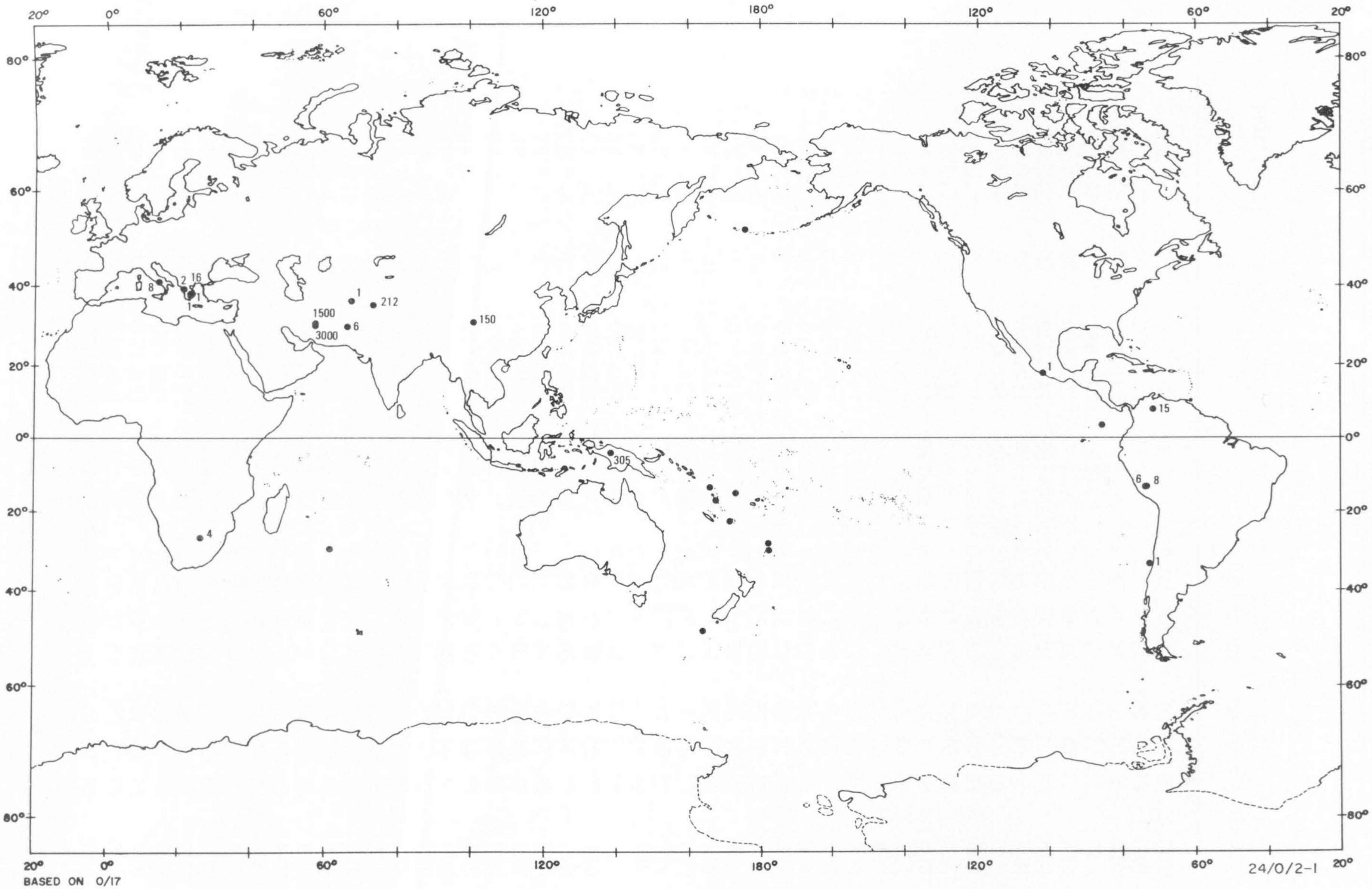


Fig. 12. Principal world earthquakes, 1981, showing numbers of reported deaths.

TABLE 1. AUSTRALIAN EARTHQUAKES 1981 : HYPOCENTRAL PARAMETERS

DATA SOURCE	*	DATE yr mo dy	ORIGIN UT hr mn sec	LAT°S	LONG°E	DEPTH km	MAGNITUDE	N
ISC		81 01 01	09 00 09.3	17.510	122.760	33	5.0 ML	10
CAN		81 01 01	09 00 20.	32.420	149.200	0	3.2 ML	3
QLD		81 01 03	18 49 05.4	25.913	151.240	10	3.0 MD	0
PIT		81 01 07	17 14 07.0	37.093	145.931	3	3.4 MD	32
CAN		81 01 07	21 10 50.9	35.770	150.660	28	3.1 ML	14
CAN		81 01 11	18 13 56.2	34.590	149.240	16	3.0 ML	14
MUN		81 01 12	20 23 21.4	21.780	112.590	10	4.0 ML	7
CAN		81 01 16	09 43 41.	39.350	154.640	0	3.8 ML	13
MUN		81 01 21	03 25 07.0	20.690	120.230	0	3.2 ML	2
CAN		81 01 21	09 19 24.1	34.580	149.230	14	3.0 ML	12
MUN		81 01 22	22 16 52.5	30.790	117.130	0	3.3 ML	6
PIT		81 01 23	16 00 56.2	37.361	147.229	2	3.3 MD	31
CAN		81 01 27	13 06 22.2	36.130	146.950	17	3.3 ML	11
MUN		81 02 07	03 11 04.7	18.830	115.430	37	3.1 ML	3
MUN		81 02 21	06 19 13.0	29.420	114.550	0	3.2 ML	3
CAN		81 02 22	13 12 33.5	32.980	150.510	10	3.4 ML	13
MUN		81 02 23	07 11 38.5	25.430	116.610	0	3.2 ML	3
CAN		81 02 25	05 29 02.3	32.780	151.460	21	3.6 ML	11
MUN		81 02 26	02 58 26.6	33.560	117.810	0	3.2 ML	5
CAN		81 03 03	18 11 33.8	35.820	144.550	21	3.7 ML	10
CAN		81 03 05	14 36 00.7	35.890	144.610	36	3.4 ML	10
ISC		81 03 15	18 29 00.5	18.590	123.410	37	3.9 ML	6
MUN		81 03 17	21 38 20.0	18.660	123.230	37	3.5 ML	4
QLD		81 03 24	18 34 15.9	27.670	152.240	10	3.1 ML	5
QLD		81 03 25	10 09 48.7	24.950	152.650	10	3.0 MD	0
MUN		81 04 03	20 00 41.	18.120	123.150	0	4.3 ML	4
CAN		81 04 05	14 52 56.	35.950	143.240	0	3.9 ML	12
BMR		81 04 07	20 15 55.8	30.744	117.164	0	4.5 ML	10
ADE		81 04 08	17 30 29.3	31.724	138.761	20	3.0 MD	11
MUN		81 04 13	06 40 34.	16.690	120.550	37	3.5 ML	5
MUN		81 04 15	23 14 37.	22.170	126.500	19	4.2 ML	7
MUN		81 04 16	19 13 58.0	33.100	121.460	10	3.3 ML	4
MUN		81 04 21	15 05 06.8	22.410	114.080	10	3.0 ML	3
CAN		81 04 23	09 17 36.6	35.930	144.160	23	3.5 ML	9
MUN		81 04 24	21 03 47.3	26.330	129.100	10	3.6 ML	6
MUN		81 04 29	10 12 32.	16.450	120.580	37	4.4 ML	7
MUN		81 05 05	05 52 12.	18.940	121.840	37	4.0 ML	6
MUN		81 05 06	18 35 42.0	19.230	123.320	10	3.2 ML	5
CAN		81 05 09	14 09 55.	35.900	144.150	0	3.3 ML	6
QLD		81 05 10	14 39 37.4	26.330	150.730	19	3.8 ML	5
CAN		81 05 15	17 07 06.	33.440	148.760	0	3.0 ML	12
MUN		81 06 02	12 13 44.0	18.590	121.630	37	3.7 ML	4
MUN		81 06 07	14 51 26.7	24.330	112.180	10	3.2 ML	2
PIT		81 06 16	21 33 56.4	38.913	144.262	14	5.1 ML	33
CAN		81 06 20	13 08 52.9	34.160	150.340	21	3.5 ML	12
ADE		81 06 27	22 33 02.0	29.748	137.670	42	4.0 MD	5

TABLE 1 (cont.)

DATA SOURCE	*	DATE yr mo dy	ORIGIN UT hr mn sec	LAT°S	LONG°E	DEPTH km	MAGNITUDE	N
ISC		81 06 27	23 33 14.1	17.780	122.650	37	3.8 ML	6
MUN		81 06 28	08 23 10.8	17.880	126.500	17	3.3 ML	4
BMR		81 06 28	20 02 06.4	25.596	117.175	31	3.8 ML	8
ISC		81 06 29	06 39 28.0	26.360	111.200	37	4.4 ML	8
MUN		81 07 01	08 38 37.3	25.550	117.150	10	3.1 ML	3
MUN		81 07 01	08 42 44.4	25.550	117.150	10	3.4 ML	4
MUN		81 07 03	17 39 57.9	16.530	128.760	10	3.0 ML	4
MUN		81 07 03	21 29 22.6	25.010	112.970	10	3.3 ML	2
MUN		81 07 07	18 25 21.0	26.250	110.760	10	3.1 ML	2
CAN		81 07 08	11 43 08.	32.550	148.730	0	3.0 ML	7
MUN		81 07 13	16 51 15.0	36.150	122.300	10	4.2 ML	6
ADE		81 07 15	02 09 09.9	31.366	138.639	24	3.1 MD	12
MUN		81 07 16	12 46 39.0	21.030	114.240	10	4.7 ML	8
MUN		81 07 26	13 24 23.2	26.390	127.060	0	3.2 ML	3
CAN		81 07 26	17 05 41.8	34.590	148.820	15	3.0 ML	10
MUN		81 07 29	04 52 51.	21.670	113.880	10	3.4 ML	4
MUN		81 07 30	16 54 44.6	25.240	117.050	5	3.4 ML	6
GS		81 08 02	14 03 54.5	12.719	119.824	33	3.7 MB	9
MUN		81 08 10	15 42 33.	13.080	120.260	37	3.9 ML	5
QLD		81 08 11	23 34 13.0	28.690	148.880	10	3.6 ML	6
BMR		81 08 15	19 23 24.2	15.956	121.079	0	4.0 ML	6
BMR		81 08 23	19 56 32.3	16.858	120.379	0	4.2 ML	7
ADE		81 09 04	12 27 30.7	25.178	136.628	15	3.0 MD	8
BMR		81 09 06	19 27 34.7	30.777	149.407	0	3.5 ML	23
CAN		81 09 07	02 45 14.0	32.460	150.990	19	4.2 ML	13
MUN		81 09 12	13 20 33.6	30.880	124.090	37	3.0 ML	4
BMR		81 09 21	05 57 50.4	35.707	144.282	0	3.1 ML	10
MUN		81 09 21	07 25 02.3	30.770	117.220	13	3.4 ML	4
BMR		81 09 21	15 26 21.7	35.735	144.445	0	3.4 ML	22
BMR		81 09 21	15 39 17.8	35.717	144.460	3	3.1 ML	20
BMR		81 09 21	16 42 41.1	35.723	144.545	13	3.5 ML	28
MUN		81 09 26	01 27 20.0	23.130	112.060	10	4.3 ML	4
MUN		81 09 26	10 46 06.0	23.940	112.060	10	3.0 ML	3
ADE		81 10 02	17 55 27.8	32.476	138.878	7	3.2 MD	11
MUN		81 10 05	21 01 08.0	24.310	114.370	10	3.2 ML	3
MUN		81 10 11	02 02 41.6	25.290	116.150	10	3.5 ML	7
QLD		81 10 11	09 26 34.8	29.650	151.730	0	4.6 ML	10
MUN		81 10 14	16 29 31.0	40.810	112.540	10	4.3 ML	5
GS		81 10 24	16 39 00.0	12.422	119.765	33	5.4 MB	11
CAN		81 10 25	08 28 04.0	36.340	150.480	24	4.0 ML	12
BMR		81 10 25	10 32 58.0	25.050	130.130	10	3.4 ML	3
BMR		81 11 01	15 46 43.2	26.577	117.392	31	3.2 ML	6
MUN		81 11 04	21 35 38.0	18.500	120.750	37	3.2 ML	5
MUN		81 11 09	16 00 05.0	24.860	116.420	10	3.4 ML	5
BMR		81 11 11	17 49 36.3	30.260	151.020	7	3.6 ML	11
GSQ		81 11 13	19 19 40.4	22.750	147.768	24	3.2 MD	13
MUN		81 11 14	23 13 36.2	29.790	123.920	10	3.6 ML	5
BMR		81 11 15	16 58 10.8	34.249	150.897	14	4.6 ML	26
BMR		81 11 19	12 18 52.8	34.227	150.886	12	3.3 ML	11

TABLE 1 (cont.)

DATA SOURCE	* DATE yr mo dy	ORIGIN UT hr mn sec	LAT°S	LONG°E	DEPTH km	MAGNITUDE	N
CAN	81 11 25	13 10 03.	31.340	149.350	0	3.6 ML	9
BMR	81 11 30	02 09 08.3	36.692	148.329	6	3.7 ML	18
GS	81 12 01	18 36 43.0	12.509	122.253	33	4.4 MB	9
GS	81 12 05	09 52 27.0	12.401	114.283	33	4.6 MB	13
BMR	81 12 06	01 40 48.1	22.785	114.175	0	4.5 ML	10
MUN	81 12 06	12 55 26.3	16.820	128.730	10	3.0 ML	1
CAN	81 12 07	17 55 05.8	32.650	150.650	29	3.4 ML	9
BMR	81 12 08	11 33 24.7	14.808	129.451	0	4.8 ML	15
TAU	81 12 08	22 53 47.9	39.667	144.383	0	3.0 ML	0
ADE	81 12 11	05 17 01.9	32.200	137.963	21	3.1 MD	13
GS	81 12 14	11 59 33.3	13.952	122.788	33	4.1 MB	6
BMR	81 12 15	00 43 30.4	19.311	125.091	0	3.7 ML	8
CAN	81 12 15	05 48 27.5	35.030	149.010	15	3.0 ML	13
GSQ	81 12 22	15 43 26.6	17.617	147.369	9	3.2 MD	16

* Code refers to the contributors listed on p.iii.
N is the number or stations that reported the earthquake.

TABLE 2. AUSTRALIAN SEISMOGRAPH STATIONS 1981

CODE	STATION NAME	LAT°S	LONG°E	ELEV M	OPERATOR*	CATEGORY
QUEENSLAND						
AWMG	MT GOLEGUMMA	24.0462	151.3157	125	QGS	1
BDDM	BOONDOOMA DAM	26.1120	151.4443	320	QGS	1
BFCS	CAMP SITE	20.6198	147.1311	160	QGS	1
BFGC	GLENDON CROSSING	20.6140	147.1609	160	QGS	1
BFGR	GLENROY	20.5492	147.1052	160	QGS	1
BRS	BRISBANE	27.3917	152.7750	525	QLD	5
BFMG	MT GRAHAM	20.6142	147.0608	160	QGS	1
CTAO	CHARTERS TOWERS	20.0883	146.2550	357	QLD	4,2
ISQ	MOUNT ISA	20.7150	139.5533	500	BMR	1
QNN	WIVENHOE DAM	27.3507	152.5404	120	QLD	3
NORTHERN TERRITORY						
ASP	ALICE SPRINGS	23.6786	133.6786	600	BMR	3
MTN	MANTON DAM	12.8467	131.1300	80	BMR	1
WB2	WARRAMUNGA ARRAY	19.9444	134.3525	366	CAN	3
WESTERN AUSTRALIA						
KLG	KALGOORLIE	30.7833	121.4583	360	MUN	1
KLB	KELLERBERRIN	31.5778	117.7600	300	MUN	1
KNA	KUNUNURRA	15.7500	128.7667	150	PWD/MUN	1
MBL	MARBLE BAR	21.1600	119.8333	200	MUN	1
MEK	MEEKATHARRA	26.6133	118.5450	520	MUN	1
MUN	MUNDARING	31.9783	116.2083	253	MUN	2
NAU	NANUTARRA	22.4420	115.5000	80	MUN	1
NWAO	NARROGIN	32.9267	117.2333	265	MUN	4
WBN	WARBURTON	26.1400	126.5780	457	MUN	1
NEW SOUTH WALES AND ACT						
BWA	BOOROWA	34.4250	148.7513	656	CAN	1
AVO	AVON	34.3764	150.6150	532	CAN	1
CAH	CASTLE HILL	34.6467	149.2417	700	CAN	1
CAN	CANBERRA (ANU)	35.3208	148.9986	650	CAN	1
CBR	CABRAMURRA	35.9433	148.3928	1537	CAN	1
IVN	INVERALOCHY	34.9650	149.6667	640	CAN	1
JLN	JENOLAN	33.8258	150.0172	829	CAN	1
KHA	KHANCOBAN	36.2136	148.1288	435	CAN	1
LER	LERIDA	34.9344	149.3642	940	CAN	1

TABLE 2 (cont.)

CODE	STATION NAME	LAT°S	LONG°E	ELEV M	OPERATOR*	CATEGORY
NEW SOUTH WALES AND ACT (cont.)						
MEG	MEANGORA	35.1007	150.0367	712	CAN	1
SBR	STH BLACKRANGE	35.4250	149.5333	1265	CAN	1
TAO	TALBINGO	35.5958	148.2900	570	CAN	1
WAM	WAMBROOK	36.1928	148.8833	1290	CAN	1
WER	WEROMBI	33.9503	150.5803	226	CAN	1
YOU	YOUNG	34.2783	148.3817	503	CAN	1
CNB	CANBERRA (BMR)	35.3140	149.3617	855	BMR	1
COO	COONEY	30.5783	151.8917	650	BMR	1
STK	STEPHENS CREEK	31.8817	141.5917	213	BMR	1
RIV	RIVERVIEW	33.8293	151.1585	43	RIV	2
SOUTH AUSTRALIA						
ADE	ADELAIDE	34.9670	138.7136	655	ADE	2
CLV	CLEVE	33.6911	136.4955	238	ADE	1
EDO	ENDILLOE	32.3216	138.0483	300	ADE	1
HKN	HAWKSNEST	30.0120	135.1860	171	ADE	1
HTT	HALLETT	33.4305	138.9217	708	ADE	1
MGR	MT GAMBIER	37.7283	140.5710	190	ADE	1
NBK	NECTAR BROOK	32.7010	137.9830	180	ADE	1
PNA	PARTACOONA	32.0057	138.1647	180	ADE	1
RPA	ROOPENA	32.7250	137.4033	95	ADE	1
UMB	UMBERATANA	30.2400	139.1280	610	ADE	1
WKA	WILLALOOKA	36.4170	140.3210	40	ADE	1
WSA	WOOMERA	31.1444	136.8047	180	ADE	1
VICTORIA						
BFD	BELLFIELD	37.1767	142.5450	235	BMR	1
TOO	TOOLANGI	37.5717	145.4900	604	BMR	5
ABE	ABERFELDY	37.7190	146.3890	549	PIT	1
GVL	GREENVALE	37.6186	144.9006	188	PIT	1
JEN	JEERALANG JNTN	38.3490	146.4140	330	PIT	1
KGD	KANGAROO GROUND	37.6988	145.2694	80	PIT	1
LIL	LILYDALE	37.6936	145.3424	80	PIT	1
MAL	MARSHALL SPUR	37.7483	146.2917	1076	PIT	1
MIC	MOUNT ERICA	37.9030	146.3590	805	PIT	1
PAT	PLANE TRACK	37.3570	146.4560	771	PIT	1
PNH	PANTON HILL	37.6346	145.2709	180	PIT	1
TOM	THOMSON	37.8100	146.3480	941	PIT	1
DRT	DARTMOUTH	36.5833	147.4917	950	CAN	1

TABLE 2 (cont.)

CODE	STATION NAME	LAT°S	LONG°E	ELEV M	OPERATOR*	CATEGORY
TASMANIA						
MOO	MOORLANDS	42.4417	146.1903	325	TAU	1
SAV	SAVANNAH	41.7208	147.1889	180	TAU	1
SFF	SHEFFIELD	41.3375	146.3075	213	TAU	1
STG	STRATHGORDON	42.7508	146.0533	350	TAU	1
SPK	SCOTTS PEAK	43.0383	146.2750	425	TAU	1
SVR	SAVAGE RIVER	41.4888	145.2108	360	TAU	1
TAU	TASMANIA UNIV	42.9097	147.3206	132	TAU	2
TRR	TARRALEAH	42.3042	146.4500	579	TAU	1

* Operator refers to the contributors listed on p.iii.

Category of station

1. Short period (vertical and/or horizontal)
2. World-wide standard seismograph station
3. Array
4. Seismological Research Observatory
5. Long and short-period seismographs

TABLE 3. AUSTRALIAN ACCELEROGRAPHS 1981

LOCALITY	LAT °S	LONG °E	ELEV m	FOUNDATION	INSTRU-MENT	OPER-ATOR
New South Wales						
Oolong	34.773	149.163	600	Firm soil	SMA1	BMR
Yass	34.830	149.043	300	Firm soil	SMA1	BMR
Hume Weir	36.110	147.043	600	Dam Wall	SMA1	WRC
Hume Weir	36.110	147.043	600	Dam Wall	SMA1	WRC
Hume Weir	36.110	147.043	600	Dam Wall	SMA1	WRC
South Australia						
Kangaroo Creek Dam	34.87	138.78		Slates/schists	M02	EWSSA
Modbury Hospital	34.83	138.70		Marl, clay	M02	PWDSA
Admin. Centre	34.925	138.608		Alluvium	M02	PWDSA
Tasmania						
Gordon Dam	42.71	145.97		Quartzite	M02	HEC
Victoria						
Jerralang Junction JENA	38.351	146.419	330	Cretaceous sandstone	PIT	PIT
Plane Track PATA	37.357	146.456	771	Ordovician sandstone	PIT	PIT
Western Australia						
Meckering						
Kelly's ME-K	31.694	116.982	200	Alluvium/granite	M02	BMR
Morrell's ME-K	31.659	117.089	200	Alluvium/granite	M02	BMR
Richardson's ME-R	31.608	117.002	200	Alluvium/granite	M02	BMR
Springbett's ME-S	31.813	116.958	220	Alluvium/granite	M02	BMR
Mundaring Weir MU-W	31.969	116.169	250	Concrete wall	SMA1	PWDWA

TABLE 3 (cont.)

LOCALITY		LAT °S	LONG °E	ELEV m	FOUNDATION	INSTRU-MENT	OPER-ATOR
Ord River Dam							
abutment	KU-A	16.113	128.737	160	Phyllite	M02	PWDWA
wall	KU-W	16.113	128.738	120	Rockfill,3m clay 90m quartzite	M02	PWDWA
Perth							
Telecom)	PT-B	31.953	115.850	10	Basement	SMA1	TEL
Exchange)	PT-M	31.953	115.850	40	Middle floor	SMA1	TEL
Building)	PT-T	31.953	115.850	70	Top floor	SMA1	TEL

Operators

BMR = Bureau of Mineral Resources, Canberra or Mundaring
EWSSA = Enginering and Water Supply Department, South Australia
HEC = Hydro-electric Commission, Tasmania
PIT = Phillip Institute of Technology, Victoria
PWDSA = Public Works Department, South Australia
PWDWA = Public Works Department, Western Australia
TEL = Telecom (Perth)
WRC = Water Resources Commission of New South Wales

TABLE 4. ACCELEROGRAM DATA 1981 : PRINCIPAL FACTS

YR	MO	DY	UT	LAT	LONG	ML	LOC	H/E	COM	T(S)	ACC	R	DUR
81	02	24	0833	31.76	117.01	1.8	ME-K	(9)/(8)	SZ	0.02	1.0		
									N	0.02	4.9	7.7	5.8
									E	0.02	5.9		
81	03	07	0121	31.66	117.09	1.7	ME-M	(3)/(0)	SZ	0.04	2.0		
									N	0.02	2.0	3.5	1.7
									E	0.02	2.0		
81	06	09	0740	31.68	117.14	1.5	ME-M	(5)/(5)	SZ	0.04	1.0		
									N	0.02	1.0	1.7	1.1
									E	0.02	1.0		
81	06	09	0741	31.68	117.13	1.5	ME-M	(4)/(4)	SZ	0.04	1.0		
									N	0.02	2.9	3.7	4.6
									E	0.02	2.0		
81	06	16	2134	38.91	144.26	5.1	PATA	225/225	SZ	0.13	0.20		
									N	0.19	0.51	0.65	
									E	0.15	0.35		
81	07	26	1633	31.69	116.98	2.0	ME-K	3/1	PZ	0.02	0.7		
									N	0.02	3.2	4.7	5.6
									E	0.02	3.4		
									SZ	0.04	6.9		
									N	0.03	26.5	26.8	
									E	0.03	2.9		
81	11	01	1403	31.69	117.07	1.6	ME-K	(8)/(7)	SZ	0.02	2.9		
									N	0.02	3.9	5.7	5.5
									E	0.02	2.9		
							ME-M	(4)/(3)	SZ	0.05	2.0		
									N	0.01	4.9	7.2	5.7
									E	0.01	4.9		
81*	11	30	0209	36.69	148.33	3.7	PATA	209/209	SZ	0.11	0.064		
									N	0.11	0.082	0.132	
									E	0.11	0.082		
81	12	05	2055	37.81	146.58	2.2	PATA	20/12	SZ	0.070	0.69		
									N	0.070	0.46	1.08	0.5
									E	0.070	0.69		

* Triggered on S-wave, maximum acceleration may be significantly larger.

YR = year, MO = month, DY = day, UT = universal time, LAT = latitude (degrees south), LONG = longitude (degrees east), ML = Richter magnitude, LOC = accelerograph location, H/E = hypocentral distance/epicentral distance (km), COM = component, T(S) = ground period in seconds, ACC = peak ground acceleration (cm s^{-2}), R = resultant acceleration (cm s^{-2}), DUR = duration in seconds while ground acceleration remained above 0.5 (cm s^{-2}).

TABLE 5. PRINCIPAL WORLD EARTHQUAKES, 1981

(Magnitude 7.0 or greater, or causing damage or fatalities. PAS - Pasadena. BRK - Berkeley. PMR - Palmer, Alaska. PAL - Palisades, New York. JMA - Japan Meteorological Agency).

Date	Origin time (UT)	Region	Co-ordinates Lat.	Long.	USGS magnitude	Remarks
Jan 19	15 11 01.0	Irian Jaya	4.58S	139.23E	6.0mb 6.7MS 6.7MS(BRK) 6.8MS(PAS) 6.7mb(PAS)	Depth 33 km. 305 people reported killed, some injured, and about 1000 missing. Thrust fault. Moderately well controlled auxiliary plane strikes N 65° W and dips 63° SW; P-axis plunges 18° toward azimuth 205°, T-axis plunges 72° toward azimuth 25°.
Jan 23	21 13 51.7	Sichuan Province, China	30.93N	101.10E	5.7mb 6.8MS 6.6MS(PAS)	Depth 33 km. 150 people killed, 300 injured, and extensive damage in the Dawu area. Strike-slip fault. Moderately well controlled fault plane strikes N 48° W and dips 88° SW; P-axis plunges 1.4° toward azimuth 267°, T-axis plunges 1.4° toward azimuth 357°.
Jan 23	21 54 41.6	Atlantic-Indian Rise	29.68S	60.84E	6.1mb 6.8MS 7.0MS(PAS)	Depth 10 km. Strike-slip fault. Moderately well controlled fault plane strikes N 4° W and dips 90°; P-axis plunges 0.0° toward azimuth 41°, T-axis plunges 0.0° toward azimuth 131°.
Jan 30	08 52 44.1	Rat Islands, Aleutian Islands	51.74N	176.27E	6.3mb 7.0MS 7.1MS(BRK) 7.1ML(PMR)	Depth 41 km. Felt (IV) on Shemya. Thrust fault. Moderately well controlled auxiliary plane strikes N 35° E and dips 52° SE; P-axis plunges 12° toward azimuth 143°, T-axis plunges 65° toward azimuth 259°.
Feb 14	17 27 44.3	Southern Italy	41.05N	14.60E	4.6mb 4.9ML(TRI) 4.7ML(RMP)	Depth 10 km. Eight people reportedly died as a result of heart attacks, four others were killed, and damage (VII) was reported.
Feb 18	08 28 20.0	Republic of South Africa	26.63S	26.61E	4.7mb	Depth 33 km. Four miners killed in a mine near Orkney. Felt in the Klerksdorp area.
Feb 24	20 53 38.4	Greece	38.22N	22.93E	5.9mb 6.7MS 6.7MS(BRK) 6.8MS(PAS)	Depth 33 km. 16 people reported killed, more than 400 injured, and considerable damage in the Athens-Corinth area. Some rockslides were also reported. Normal fault with a component of strike-slip. Moderately well controlled solution with one plane striking N 60°E and dipping 60° SE and the other plane striking N 32° W and dipping 50° NE; P-axis plunges 53° toward azimuth 275°, T-axis plunges 6° toward azimuth 177°.

TABLE 5 (cont.)

Date	Origin time (UT)	Region	Co-ordinates Lat.	Long.	USGS magnitude	Remarks
Mar 04	21 58 05.9	Greece	38.21N	23.29E	6.0mb 6.4MS 6.6MS(PAS) 6.2ML(ATH)	Depth 29 km. One person died from a heart attack, 9 people injured, and additional damage in the Athens-Corinth-Khalkis area. Normal fault with a component of strike-slip. Moderately well controlled solution with one plane striking N 30° E and dipping 45° SE and the other plane striking S 62° W and dipping 47° NW; P-axis plunges 79.4° toward azimuth 227°, T-axis plunges 1.0° toward azimuth 132°.
Mar 06	19 42 59.5	Off coast of Central America	3.89N	85.92W	6.1mb 6.4MS 6.2MS(BRK) 6.3MS(PAS) 6.7mb(PAS)	Depth 33 km.
Mar 07	11 34 43.9	Greece	38.19N	23.32E	5.5mb 4.8MS 5.7ML(ATH)	Depth 33 km. One person killed and additional damage in the Athens area.
Mar 10	15 16 19.8	Greece-Albania border region	39.48N	20.70E	5.6mb 5.2ML(ATH)	Depth 31 km. Two people killed from a rockfall and about 150 houses damaged in western Greece.
Apr 18	00 32 39.8	Peru	13.14S	74.38W	5.3mb 4.8MS	Depth 38 km. Eight people killed, 15 injured, and damage in the Ayacucho area.
Apr 24	21 50 06.0	Vanuatu Islands	13.43S	166.42E	6.1mb 6.9MS 7.3MS(BRK) 6.5MS(PAS) 6.8mb(PAS)	Depth 33 km. The preferred fault-plane solution from P-wave first motions corresponds to a reverse fault type mechanism with a left-lateral strike-slip component. This nodal plane strikes N 53° W and dips 55° NE; P-axis plunges 5.5° toward azimuth 57.8°, T-axis plunges 65.1° toward azimuth 259.8°, and slip vector rakes 60° SE.
May 25	05 25 14.4	Off west coast of South Island, New Zealand	48.79S	164.36E	6.1mb 7.6MS 7.6MS(BRK) 7.6MS(PAS)	Depth 33 km. Felt throughout southern South Island. The preferred fault-plane solution from P-wave first motions corresponds to a reverse fault type mechanism. Well controlled auxiliary plane strikes N 38° W and dips 71.3° SW; P-axis plunges 26.8° toward azimuth 228°, T-axis plunges 62.7° toward azimuth 59.7°.
Jun 11	07 24 25.2	Southern Iran	29.91N	57.72E	6.1mb 6.7MS 6.9MS(BRK) 6.7MS(PAS)	At least 3000 people reported killed, many injured, and extensive damage in Kerman Province.

TABLE 5 (cont.)

Date	Origin time (UT)	Region	Co-ordinates Lat.	Long.	USGS magnitude	Remarks
Jun 13	07 29 10.8	Hindu Kush	36.18N	67.83E	5.5mb 5.4MS	Depth 24 km. One person killed, two injured in the Jozjan Province, Afghanistan. Felt (IV) in the Ayvadzh-Termex area, USSR.
Jun 22	17 53 21.3	Peru	13.17S	74.52W	5.1mb 5.2MS	Depth 24 km. At least six people killed, some injured, and damage in the Ayacucho area.
Jul 06	03 08 24.1	Loyalty Islands	22.29S	171.74E	6.9mb 7.0MS 7.0MS(BRK) 6.6MS(PAS)	Depth 33 km. The preferred fault-plane solution from P-wave first motions corresponds to a reverse fault type mechanism. The moderately well controlled auxiliary plane strikes N 78.0°E and dips 72.0°SSE, the poorly controlled fault plane strikes N 78.0°E and dips 18.0°NNW; P-axis plunges 27.0° toward azimuth 168.0°, T-axis plunges 63.0° toward azimuth 348.0°.
Jul 15	07 59 08.4	Vanuatu Islands	17.26S	167.60E	5.6mb 7.0MS 7.1MS(BRK) 6.9MS(PAS)	Depth 30 km. Minor damage in the Shepherd Islands area. Felt at Port-Vila. The preferred fault-plane solution from P-wave first motions corresponds to a reverse fault type mechanism. The moderately well controlled auxiliary plane strikes N 11.0°W and dips 79.0°WSW, the poorly controlled fault plane strikes N 11.0°W and dips 11.0°ENE; P-axis plunges 34.0° toward azimuth 259.0°, T-axis plunges 56.0° toward azimuth 79.0°.
Jul 28	17 22 24.6	Southern Iran	30.01N	57.79E	5.7mb 7.1MS 7.3MS(BRK) 7.3MS(PAS)	Depth 33 km. 1500 people killed, 1000 injured, 50 000 homeless, and extensive damage in the Kerman region. The preferred fault-plane solution from P-wave first motions corresponds to a fairly well controlled reverse fault type mechanism with a small component of strike-slip. One nodal plane strikes N 57.0°E and dips 53.0°SE, the other nodal plane strikes N 86.0°E and dips 37.0°N; P-axis plunges 6.4° toward azimuth 159.7°, T-axis plunges 74.3° toward azimuth 273.2°.
Sep 01	09 29 32.4	Samoa Islands	14.99S	173.17W	7.0mb 7.7MS 7.9MS(BRK) 7.7MS(PAS)	Depth 33 km. Local tsunami (24 cm peak-to-peak) recorded at Pago Pago.

TABLE 5 (cont.)

Date	Origin time (UT)	Region	Co-ordinates Lat.	Long.	USGS magnitude	Remarks
Sep 12	07 15 54.1	Northwestern Kashmir	35.67N	73.55E	6.1mb 5.9MS	Depth 33 km. 212 people killed, 17 missing, 2000 injured, and extensive damage in the Gilgit area. Felt at Peshawar and Rawalpindi, Pakistan.
Oct 16	03 25 42.1	Off coast of central Chile	33.13S	73.07W	6.1mb 7.2MS 7.5MS(BRK) 7.2MS(PAS)	Depth 32 km. One person killed in an auto accident caused by a panicked driver. Felt throughout central Chile. Maximum intensity (VI) at Las Cruces.
Oct 18	04 31 02.8	Venezuela	8.10N	72.47W	5.4mb	Depth 56 km. Eight people killed and damage reported in San Cristobal. Also seven people killed and damage reported in Cucuta, Colombia. At least 100 people were reported injured in the two cities.
Oct 25	03 22 15.4	Michoacan, Mexico	18.01N	102.11W	6.1mb 7.3MS 7.4MS(BRK) 7.2MS(PAS)	Depth 33 km. One person killed, 11 injured, and damage at Mexico City. Two people killed, 17 injured, and extensive damage in Michoacan. Felt throughout southern Mexico.
Dec 12	20 26 46.7	Pakistan	29.87N	66.95E	4.7mb	Depth 33 km. Six people killed, 12 injured in the Karak area.
Dec 24	05 33 21.5	Kermadec Islands	29.96S	177.70W	6.1mb 6.8MS 7.0MS(BRK) 6.6MS(PAS)	Depth 33 km.
Dec 26	17 05 32.8	Kermadec Islands	29.81S	177.85W	6.3mb 7.1MS 6.6MS(PAS)	Depth 33 km.

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APPENDIX

MODIFIED MERCALLI (MM) SCALE OF EARTHQUAKE INTENSITY

(New Zealand version, 1965, from Eiby, 1966*)

MM I — Not felt by humans, except in especially favourable circumstances, but birds and animals may be disturbed. Reported mainly from the upper floors of buildings more than 10 storeys high. Dizziness or nausea may be experienced. Branches of trees, chandeliers, doors, and other suspended systems of long natural period may be seen to move slowly. Water in ponds, lakes, reservoirs, etc., may be set into seiche oscillation.

MM II — Felt by a few persons at rest indoors, especially by those on upper floors or otherwise favourably placed. The long-period effects listed under MM I may be more noticeable.

MM III — Felt indoors, but not identified as an earthquake by everyone. Vibrations may be likened to the passing of light traffic. It may be possible to estimate the duration, but not the direction. Hanging objects may swing slightly. Standing motorcars may rock slightly.

MM IV — Generally noticed indoors, but not outside. Very light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. Walls and frame of buildings are heard to creak. Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock, and the shock can be felt by their occupants.

MM V — Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people frightened. Direction of motion can be estimated. Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Some windows crack. A few earthenware toilet fixtures crack. Hanging pictures move. Doors and shutters may swing. Pendulum clocks stop, start, or change rate.

MM VI — Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. Slight damage to Masonry D. Some plaster cracks or falls. Isolated cases of chimney damage. Windows, glassware, and crockery break. Objects fall from shelves, and pictures from walls. Heavy furniture moves. Unstable furniture overturns. Small church and school bells ring. Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from existing slips, talus slopes, or shingle slides.

MM VII — General alarm. Difficulty experienced in standing. Noticed by drivers of motorcars. Trees and bushes strongly shaken. Large bells ring. Masonry D cracked and damaged. A few instances of damage to Masonry C. Loose brickwork and tiles dislodged. Unbraced parapets and architectural ornaments may fall. Stone walls crack. Weak chimneys break, usually at the roof-line. Domestic water tanks burst. Concrete irrigation ditches damaged. Waves seen on ponds and lakes. Water made turbid by stirred-up mud. Small slips, and caving-in of sand and gravel banks.

MM VIII — Alarm may approach panic. Steering of motorcars affected. Masonry C damaged, with partial collapse. Masonry B damaged in some cases. Masonry A undamaged. Chimneys, factory stacks, monuments, towers, and elevated tanks twisted or brought down. Panel walls thrown out of frame structures. Some brick veneers damaged. Decayed wooden piles break. Frame houses not secured to the foundation may move. Cracks appear on steep slopes and in wet ground. Landslips in roadside cuttings and unsupported excavations. Some tree branches may be broken off. Changes in the flow or temperature of springs and wells may occur. Small earthquake fountains.

MM IX — General panic. Masonry D destroyed. Masonry C heavily damaged, sometimes collapsing completely. Masonry B seriously damaged. Frame structures racked and distorted. Damage to foundations general. Frame houses not secured to the foundations shift off. Brick veneers fall and expose frames. Cracking of the ground conspicuous. Minor damage to paths and roadways. Sand and mud ejected in alluviated areas, with the formation of earthquake fountains and sand craters. Underground pipes break. Serious damage to reservoirs.

MM X — Most masonry structures destroyed, together with their foundations. Some well-built wooden buildings and bridges seriously damaged. Dams, dykes, and embankments seriously damaged. Railway lines slightly bent. Cement and asphalt roads and pavements badly cracked or thrown into waves. Large landslides on river banks and steep coasts. Sand and mud on beaches and flat land moved horizontally. Large and spectacular sand and mud fountains. Water from rivers, lakes, and canals thrown up on the banks.

MM XI Wooden frame structures destroyed. Great damage to railway lines. Great damage to underground pipes.

MM XII Damage virtually total. Practically all works of construction destroyed or greatly damaged. Large rock masses displaced. Lines of sight and level distorted. Visible wave-motion of the ground surface reported. Objects thrown upwards into the air.

Categories of non-wooden construction

Masonry A

Structures designed to resist lateral forces of about 0.1 g, such as those satisfying the New Zealand Model Building Bylaw, 1955. Typical buildings of this kind are well reinforced by means of steel or ferro-concrete bands, or are wholly of ferro-concrete construction. All mortar is of good quality, and the design and workmanship is good. Few buildings erected before 1935 can be regarded as Masonry A.

Masonry B

Reinforced buildings of good workmanship and with some mortar, but not designed in detail to resist lateral forces.

Masonry C

Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces.

Masonry D

Building with low standards of workmanship, poor mortar, or constructed of weak materials like mud brick and rammed earth. Weak horizontally.

Windows

Window breakage depends greatly upon the nature of the frame and its orientation with respect to the earthquake source. Windows cracked at MM V are usually either large display windows, or windows tightly fitted to metal frames.

Chimneys

The 'weak chimneys' listed under MM VII are unreinforced domestic chimneys of brick, concrete block, or poured concrete.

Water tanks

The 'domestic water tanks' listed under MM VII are of the cylindrical corrugated-iron type common in New Zealand rural areas. If these are only partly full, movement of the water may burst soldered and riveted seams. Hot-water cylinders constrained only by supply and delivery pipes may move sufficiently to break the pipes at about the same intensity.

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