AGSO

Australian Seismological Report, 1992

By M. Michael-Leiba & V. Dent

Record 1994/69

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Department of Primary Industries and Energy

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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AUSTRALIAN SEISMOLOGICAL REPORT, 1992

Compiled by
Marion Michael-Leiba & Vic Dent

(Australian Seismological Centre)

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CONTENTS

Tables

Figures

SUMMARY

The seismicity of Australia was below average in 1992. Only 85 magnitude ML>2.9 earthquakes were located and of these only 10 had magnitudes ML>3.9. The largest event occurred off Arnhem Land (NT) on 30 September and had magnitude ML 5.1. Its focal depth was 39 km, making it the deepest known Australian earthquake.

Isoseismal maps were drawn for eleven earthquakes felt in Australia. Four were in Queensland, three in South Australia and one in each of New South Wales, Victoria, the Northern Territory and the Banda Sea. Minor damage was caused by two of these, both in South Australia.

The first ever accelerogram in South Australia was recorded on 8 February 1992. It was of an earthquake in an unusual swarm of hundreds of events during the period November 1991 to February 1992.

Nuclear monitoring continued at AGSO's Australian Seismological Centre. Eight presumed underground nuclear explosions occurred during the year. Six were at the Nevada (USA) test site and two at Lop Nor in China.

INTRODUCTION

Earthquakes are a threat to life and property in Australia as demonstrated by the 1989 Newcastle earthquake (McCue & others, 1990). This report contains information on earthquakes of Richter magnitude 3 or greater that were reported in the Australian region during 1992. It is the thirteenth of an annual series compiled by the Australian Geological Survey Organisation, using data from AGSO and contributing seismological agencies in Australia. Its purposes are to aid the study of earthquake risk in Australia, and to provide information on Australian and world earthquakes for scientists, engineers and the general public.

The report has six main sections: **Australian region earthquakes**, which contains a summary of the 1992 seismicity and of large and damaging earthquakes since 1873, a State by State breakdown for 1992 and brief descriptions of the more important earthquakes in that year; **Isoseismal maps**, describing those that were widely felt; **Network operations**, which gives details of the seismographs that operated in Australia during the year; **Accelerograph data,** which tabulates recordings from the accelerograph network; **Principal world earthquakes,** which lists the largest and most damaging earthquakes that took place world-wide during 1992; and **Monitoring of nuclear explosions,** which describes the operation of the Nuclear Monitoring Section and lists known underground nuclear explosions.

In the report we refer to the *magnitude* of an earthquake and *intensity* caused by an earthquake. These terms are defined below.

Magnitude

The magnitude of an earthquake is a measure of its size and is related to the energy released at its focus. It is calculated from the amplitude and period of seismic waves recorded on seismograms. The magnitude scale is logarithmic: 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 M and energy E (joules) is

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

A shock of magnitude 2 is the smallest normally felt by humans, whereas earthquakes of magnitude 5 or more can cause significant damage if they are shallow and close to buildings. Great, major, large, and moderate are terms used to describe earthquakes above magnitude 8, 7, 6 and 5 respectively whilst small and micro-earthquake are for magnitudes below 4 and 3 respectively. The following magnitude scales are in common use.

Richter magnitude (ML)

Richter (1958) defined a scale to determine the relative size of local earthquakes in California

$$ML = \log A - \log A_0$$

where A is the maximum trace amplitude (zero-to-peak) in millimetres on a standard Wood-Anderson seismogram, and A_0 is the attenuation of amplitude with distance out to 600 km. In California, Richter's reference earthquake, magnitude ML 3.0, causes a trace amplitude of 1 mm on the Wood-Anderson seismogram, 100 km from the epicentre.

If standard, horizontal Wood-Anderson instruments (Anderson & Wood, 1925) are not available, an equivalent Richter magnitude can be determined by correcting for the difference in magnification (see Willmore, 1979, para. 3.1.1) between the seismometer used and the Wood-Anderson, and for a seismometer mounted vertically, rather than horizontally. Allowance must also be made for differences in attenuation from that in California.

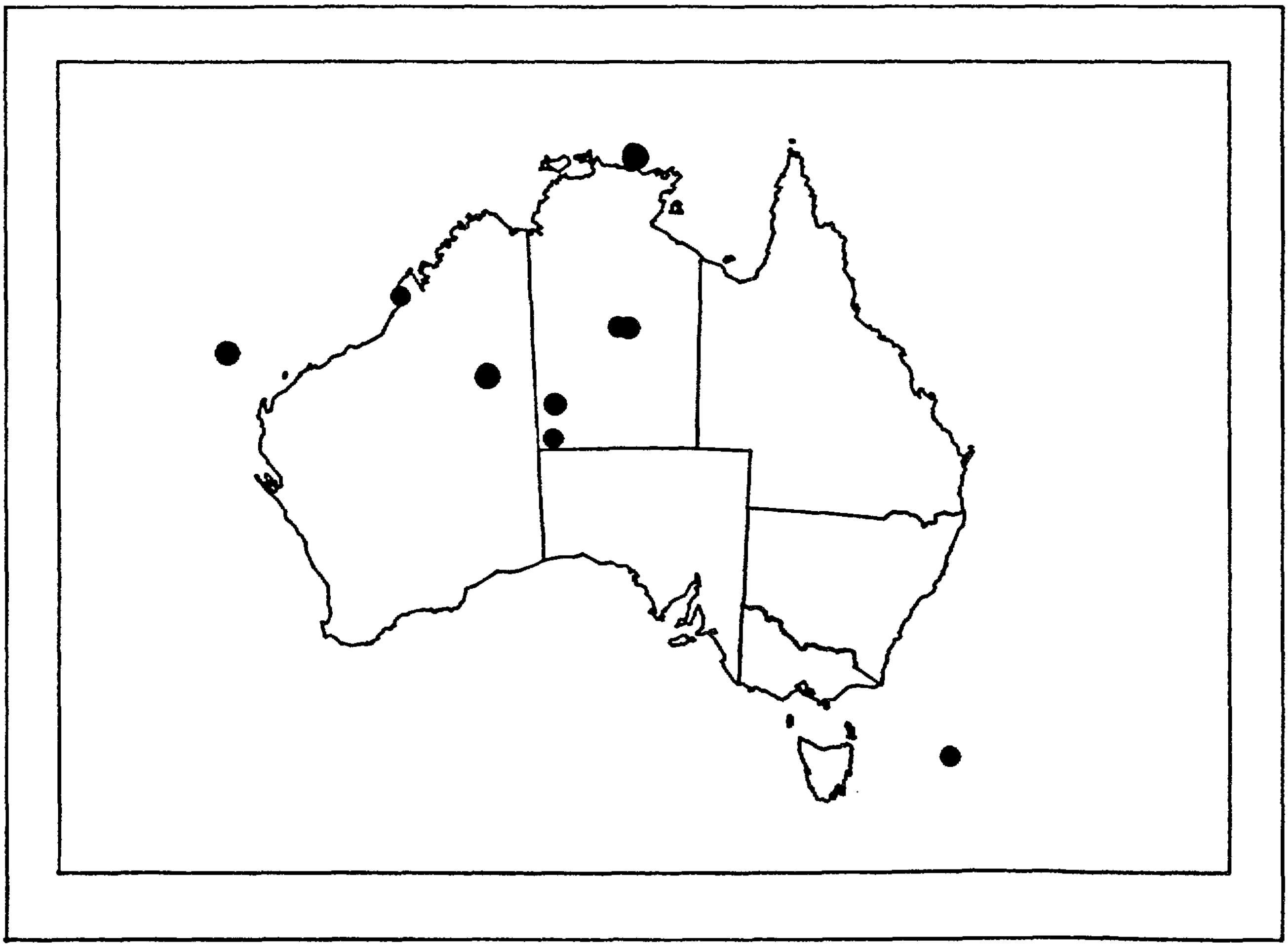


Figure 1 Epicentres of Australian earthquakes, 1992, magnitude ML>3.9.

Surface-wave magnitude (Ms)

The surface-wave magnitude was originally defined for shallow earthquakes in the distance range 20–160°, and in the period range $T = 17–23$ s. When these conditions hold, Ms values are calculated from the 1967 IASPEI formula (see Båth, 1981)

$$Ms = \log A/T + 1.66\log\Delta + 3.3$$

where A is the ground amplitude in micrometers (10^{-6} m), T is in seconds and Δ is the epicentral distance in degrees. Marshall & Basham (1973) extended this formula to distances as close as 1°, and periods as short as 10 s.

Body-wave magnitude (mb)

For deeper earthquakes with negligible surface waves, or shallow earthquakes outside the distance range defined for ML or Ms, Gutenberg (1945) defined a body-wave scale

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

where A is the maximum mean-to-peak ground amplitude in microns of the P, PP, or S-wave train, T is the corresponding wave-period (seconds), and Q is a function of focal depth h and distance Δ. The Q factors were derived by Gutenberg (1945) and are listed in Richter (1958). This definition was subsequently modified to limit the amplitude measurement to the first 20 s of the P or S phase for moderate sized earthquakes and the first 60 s for large earthquakes.

Duration magnitude (MD)

When an earthquake is close to the seismograph, the wave amplitude on the seismogram may be clipped, in which case no measure of magnitude is possible. To counteract this, another scale was devised (Bisztricsany, 1958), based on the recorded duration of the seismic wave train on short-period seismograms

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

where t is the length of the earthquake coda in seconds (usually from the initial P onset), Δ is the distance from the epicentre, and a, b, and c are constants for a particular recording station. Many other forms of this equation have been used.

Seismic moment magnitude (Mw)

Kanamori (1978) defined another magnitude scale from the seismic moment M_o

$$Mw = (\log M_o) / 1.5 - 6.0$$

and $$M_o = \mu A d$$

where μ is the rigidity of the bedrock, A the fault area displaced, and d the average slip on the fault. M_o is proportional to the amplitude of the far-field ground displacement at low frequencies.

Magnitude from isoseismals

In some cases, where reliable magnitudes or moments cannot be determined from seismograms, it is possible to estimate magnitudes from macroseismic data. In this report, the formula of McCue (1980) is used

$$M(Rp) = 1.01\ln(Rp) + 0.13$$

where Rp is the radius of perceptibility (km), the distance equal to the radius of a circle with an area equal to that enclosed by the MM(III) isoseismal, and ln is the natural logarithm. $M(Rp)$ is approximately equivalent to ML below magnitude 6, and to Ms above magnitude 6. The formulae of Michael-Leiba (1989a and b) have been used for historic earthquakes in the Tasmanian region. Greenhalgh & others (1989) modified McCue's equation using a larger data set and extended the method to other intensities, but at the expense of simplicity in application:

$$M(Rp) = 0.35\ (\pm 0.12)(\log Rp)^2 + 0.63\ (\pm 0.41)(\log Rp) + 1.87\ (\pm 0.36)$$

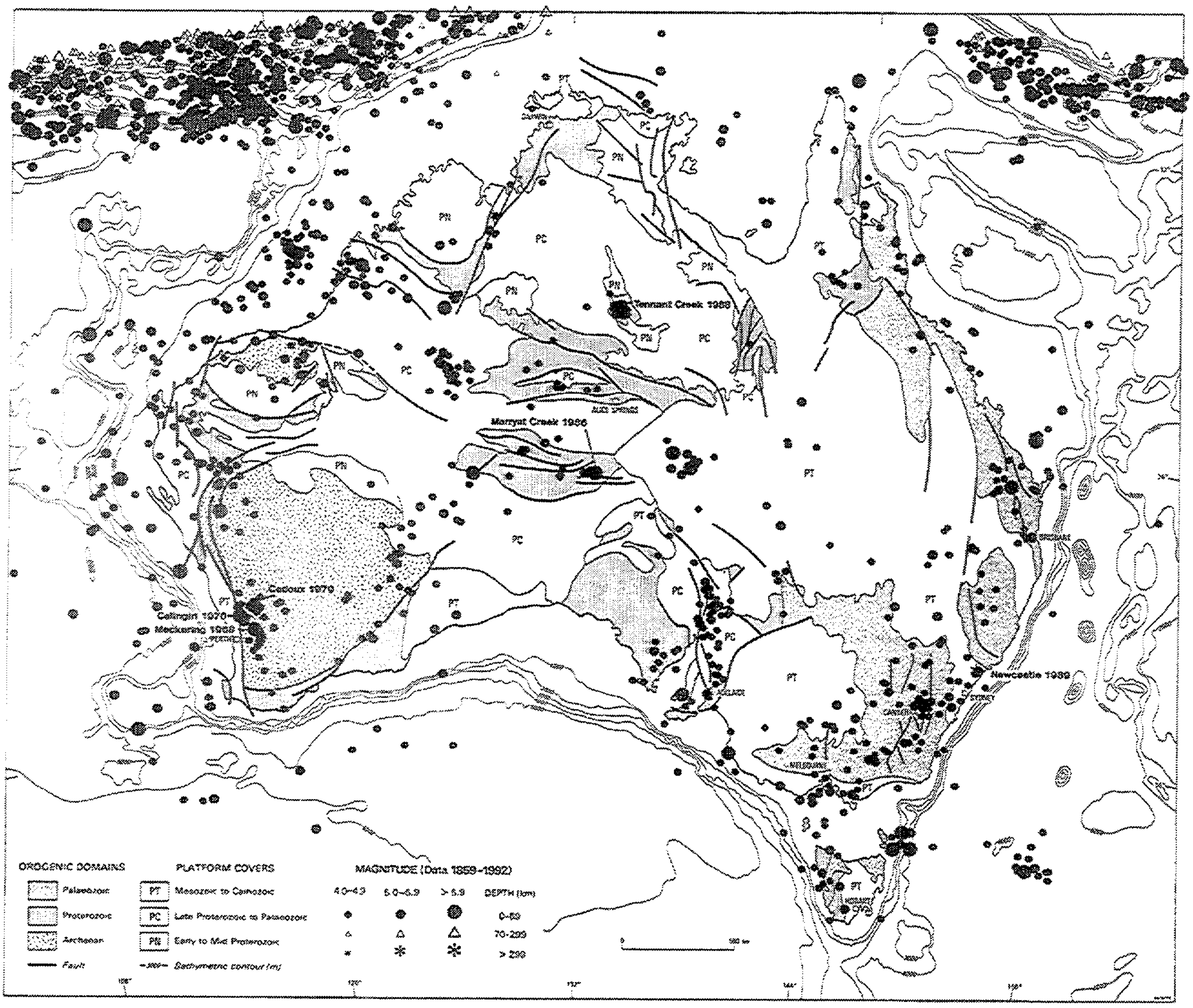


Figure 2 Epicentres of known magnitude ML>3.9 Australian region earthquakes, 1859-1992.

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

Intensity

The intensity of an earthquake is a measure of its effects on people and buildings and should not be confused with magnitude which is a measure of the energy release. In this report we use the modified Mercalli (MM) scale as presented by Eiby (1966) for New Zealand. The scale is listed in the Appendix. Essentially the MM scale is an assessment of how severely the earthquake was felt and of the degree of damage caused at a particular place. Some earthquakes are felt over a sufficiently wide area that an isoseismal map can be prepared using information compiled from questionnaires, newspaper reports, and personal interviews and inspections.

David Denham, Peter Gregson & Kevin McCue

AUSTRALIAN REGION EARTHQUAKES, 1992

Table 1 lists all magnitude ML>2.9 earthquakes which have been located in the Australian region in 1992. The seismicity was lower than average, only 10 events having magnitudes ML>3.9 (Figure 1) compared with the yearly average of 22 (McCue & Gregson, 1993). The only ML>4.9 earthquake was the offshore Arnhem Land event of 30 September. Its magnitude was ML 5.1 and its focal depth 39 km, making it the deepest known Australian earthquake (McCue & Michael-Leiba, 1993).

Activity continued in the Tennant Creek (NT) area with 15 events with magnitude ML>2.9 of which two had magnitude ML>3.9. This area has been seismically active since January 1987 when foreshocks of the three large earthquakes in January 1988 (Table 2) commenced.

Table 2 lists all known earthquakes in the Australian region with magnitude ML>5.9. There are 26 in all, giving an average recurrence rate of one every five years but, if foreshocks and aftershocks are excluded, the recurrence interval increases to six years. If the three events (in 1906, 1920 and 1983) occurring in oceanic crust away from the continental margin are excluded, there are a total of 23 events associated with Australia and its continental shelf, giving an average recurrence rate of one every five years. If foreshocks and aftershocks are excluded, the mean recurrence interval for main shocks associated with Australia and its continental shelf is seven years. Figure 2 shows the epicentres of magnitude ML>3.9 earthquakes in the Australian region including some of the very active northern plate margin during the period 1856-1992.

Table 3 (D. Denham, written communication, 1993) lists some damaging Australian earthquakes during the period 1950-1992. Those for which there are no dollar estimates of the damage bill are not included. By far the most damaging event was the 1989 Newcastle earthquake.

For a comparison of seismic activity by State, epicentres of magnitude ML>2.4 events are plotted in Figures 3 to 8. It should be noted that coverage down to this magnitude is probably complete only in Tasmania, Victoria, southeastern New South Wales and the Australian Capital Territory, southwestern Western Australia and southeastern South Australia.

Marion Michael-Leiba

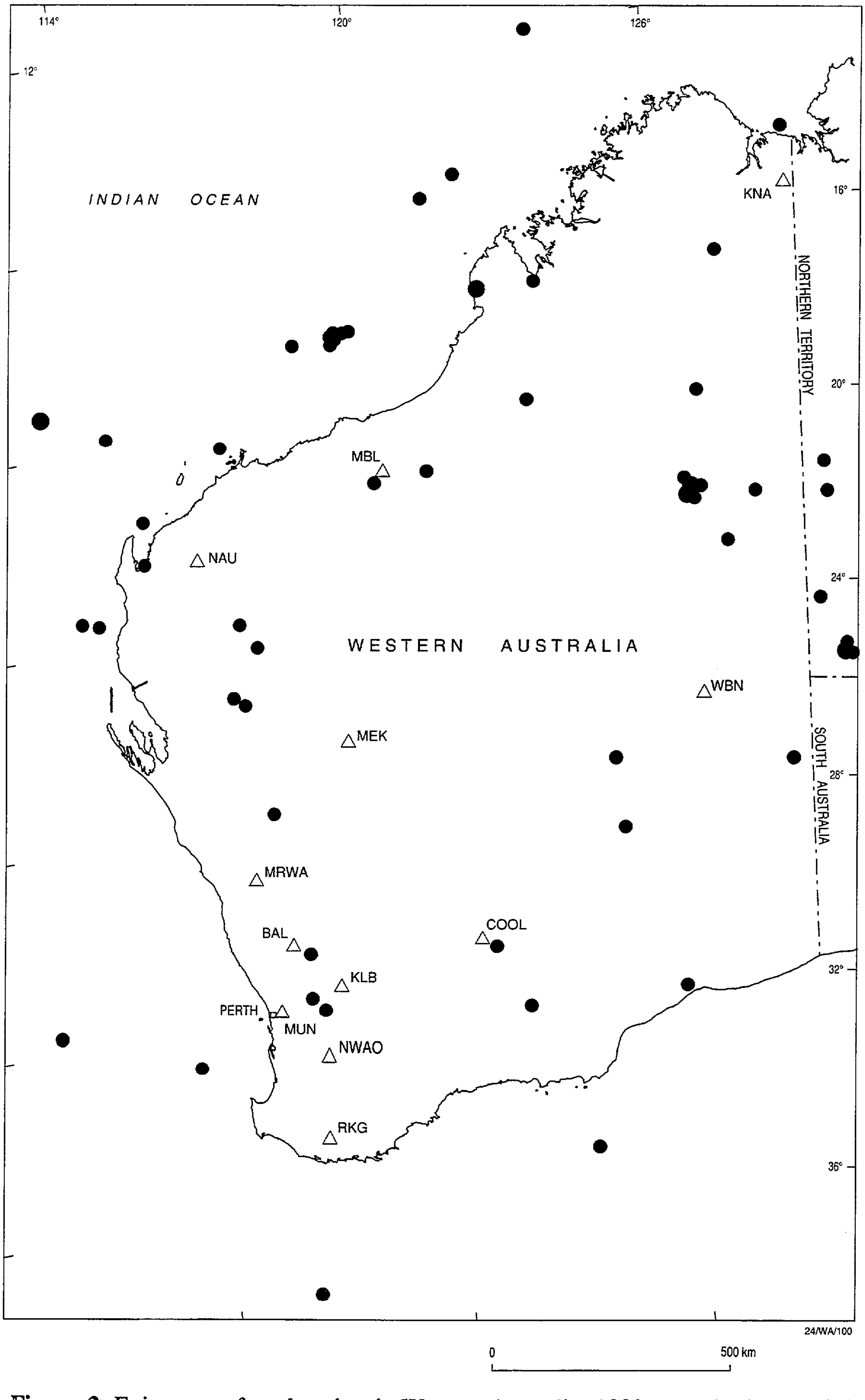


Figure 3 Epicentres of earthquakes in Western Australia, 1992, magnitude ML>2.4. In Figures 3 to 8, the smaller dots are epicentres of events with magnitude ML≤3.9, the larger dots are epicentres of earthquakes with magnitude ML>3.9, and the triangles are seismographs.

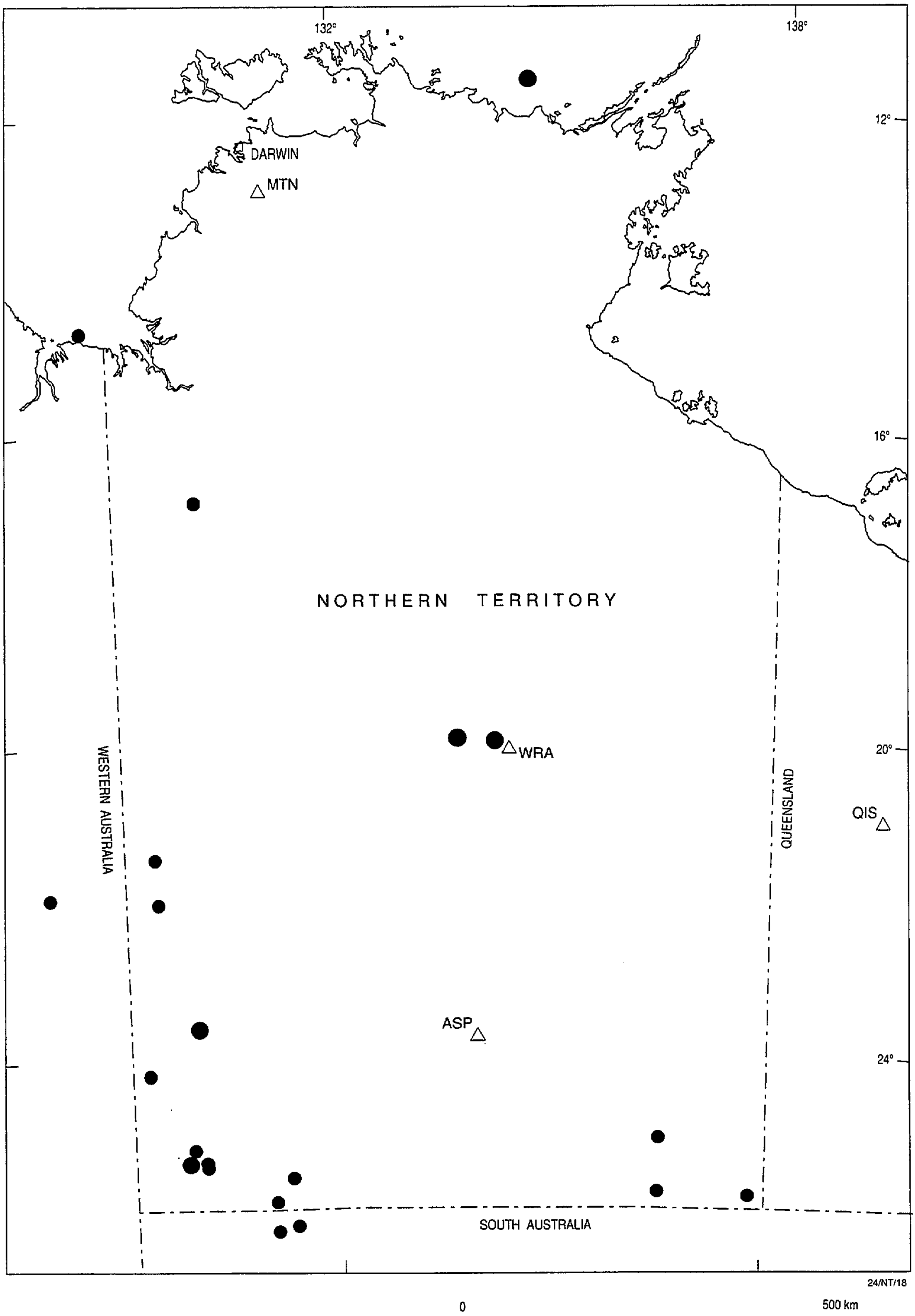


Figure 4 Epicentres of earthquakes in the Northern Territory, 1992, magnitude ML>2.4.

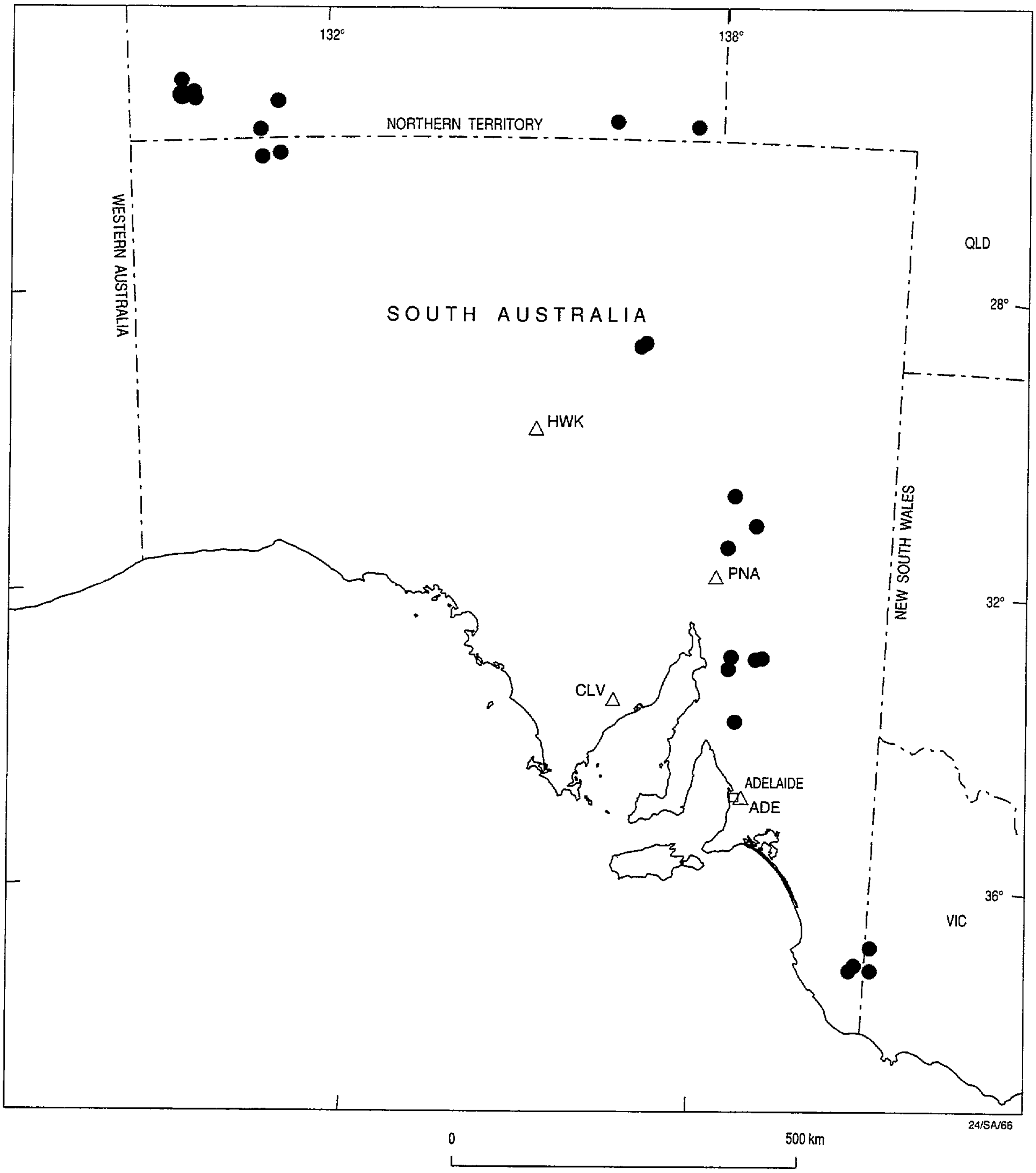


Figure 5 Epicentres of earthquakes in South Australia, 1992, magnitude ML>2.4.

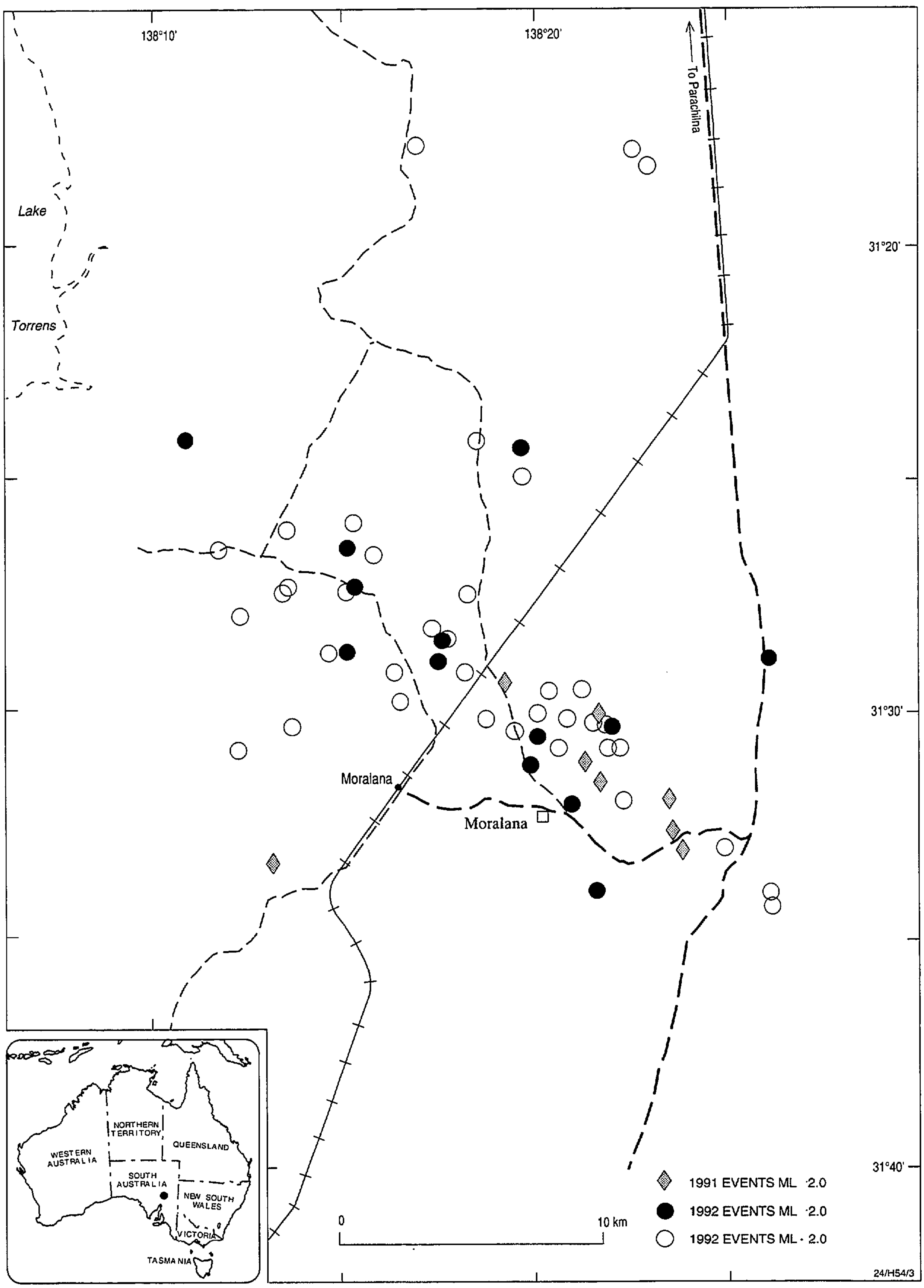


Figure 5b Epicentres of the Moralana SA earthquake swarm.

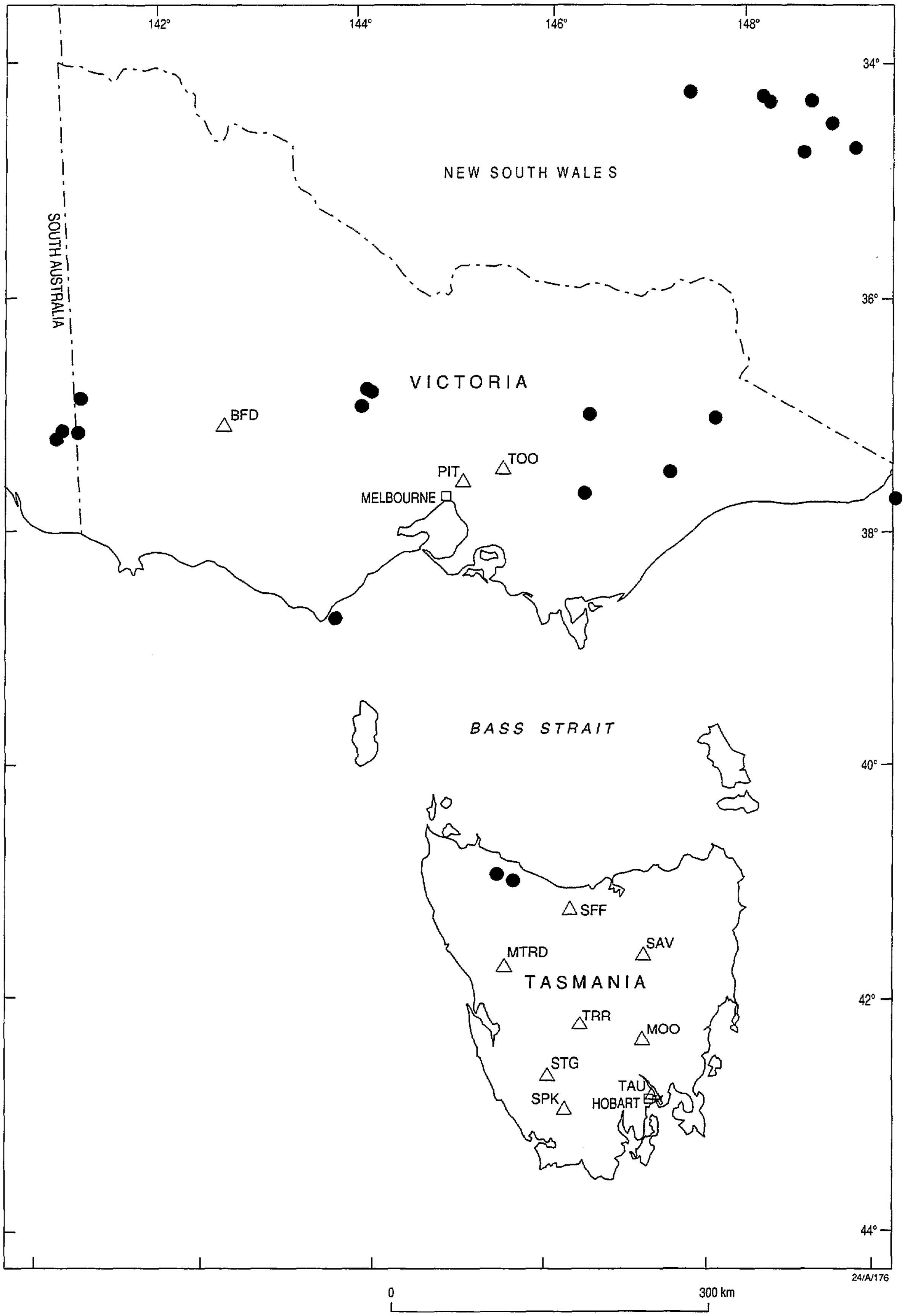


Figure 6 Epicentres of earthquakes in Victoria & Tasmania, 1992, magnitude ML>2.4.

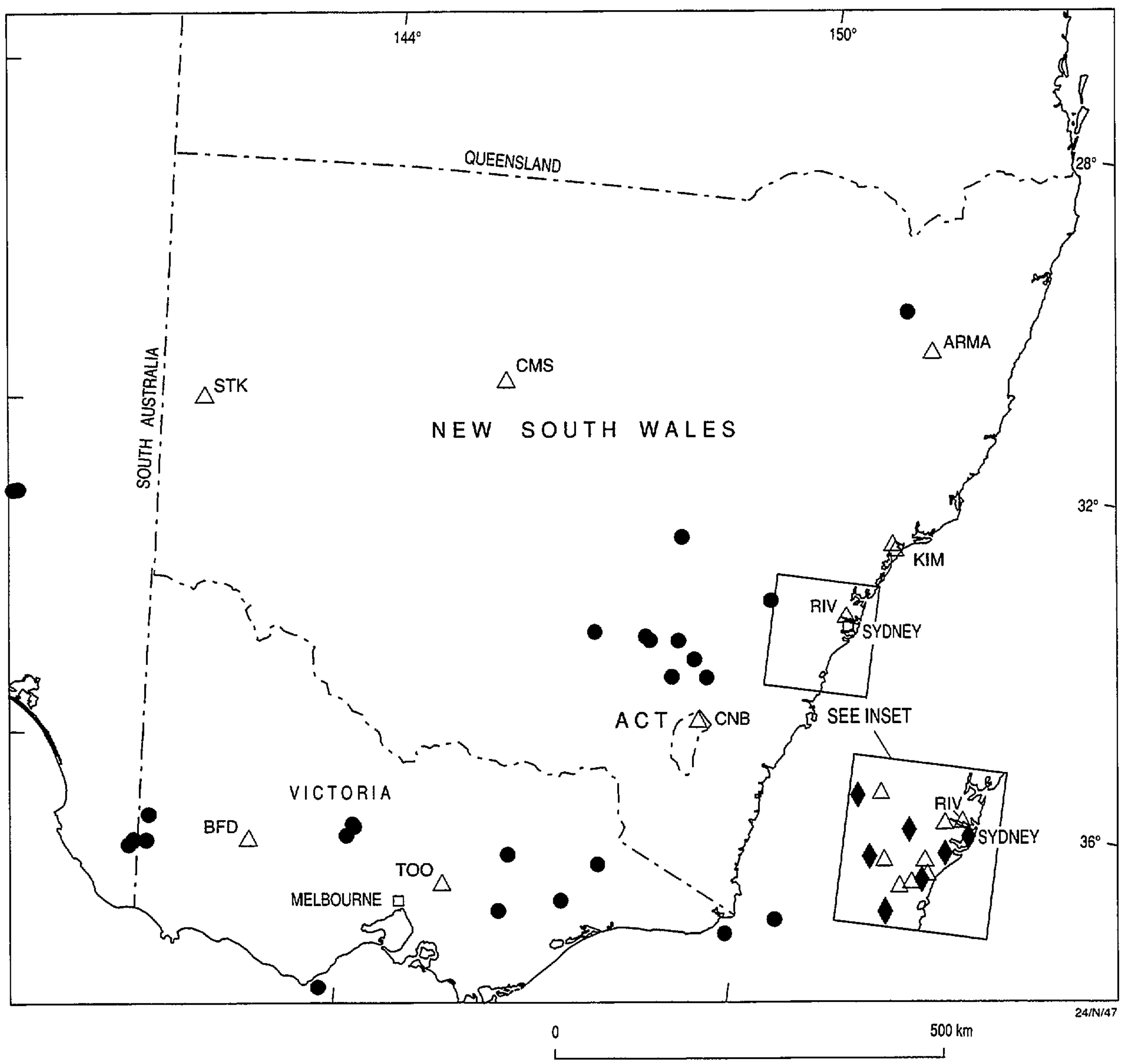


Figure 7 Epicentres of earthquakes in New South Wales, 1992, magnitude ML>2.4. The inset shows seismographs (triangles) and accelerographs (diamonds) in the Sydney region.

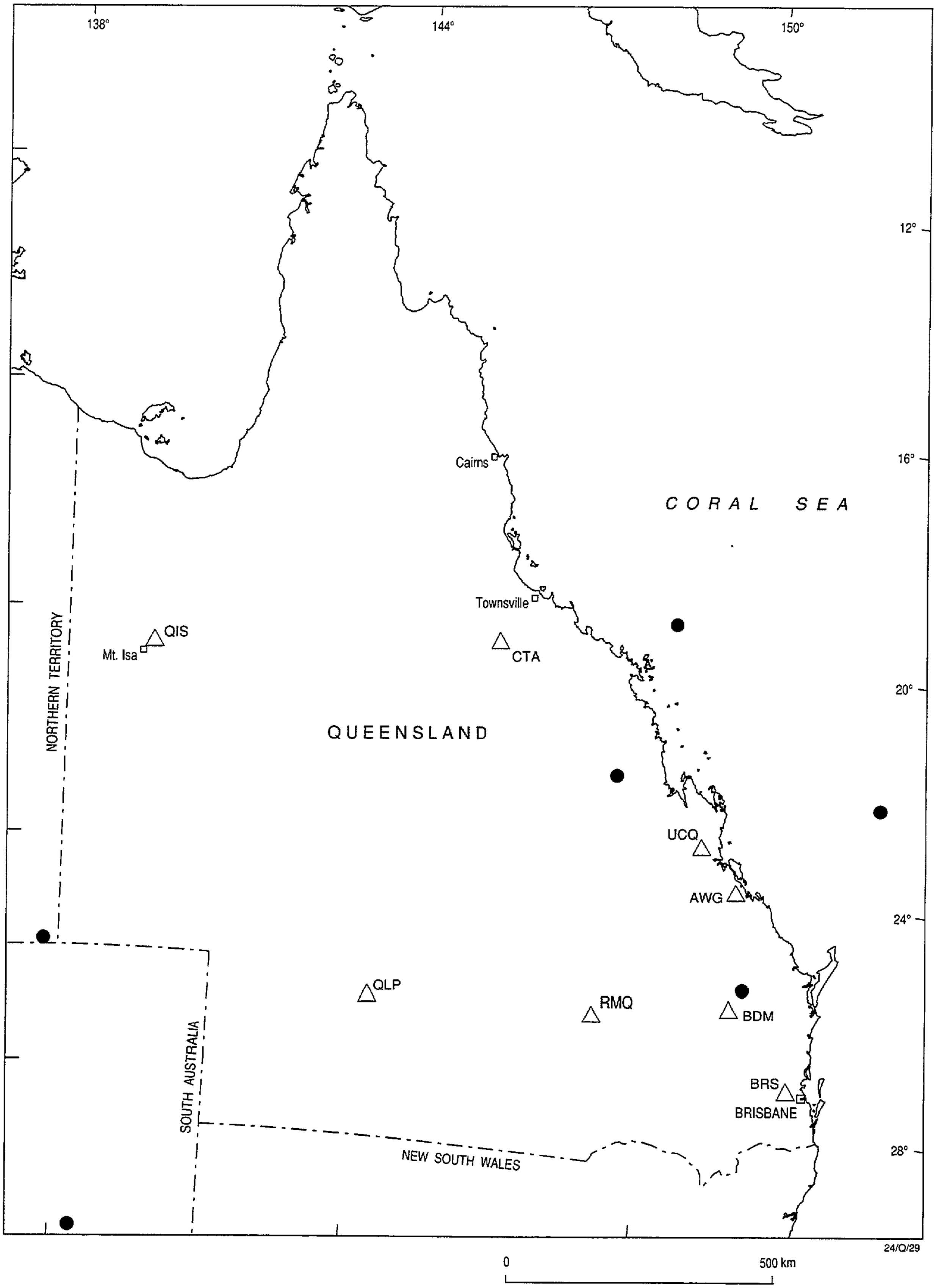


Figure 8 Epicentres of earthquakes in Queensland, 1992, magnitude ML>2.4.

Western Australia (Figure 3)

Seismic activity in Western Australia in 1992 continued at the relatively low level seen in 1991. No earthquakes were significant enough to warrant the preparation of an isoseismal map. One hundred and thirty events of magnitude ML>1.9 were located (as against 147 in 1991). The largest earthquake recorded was of magnitude ML 4.8 in the Lake Tobin region, whereas the largest 1991 event was ML 4.3. There were a total of four earthquakes of magnitude 4.0 or greater, the same as in 1991.

Lake Tobin , in the remote Gibson Desert region of Western Australia, was the most active locality during the year, with 10 events being located there. The series started on 14 July, when two foreshocks of the ML 4.8 earthquake of 15 July were recorded. This is the same area in which an ML 6.7 event occurred on 24 March 1970, and many smaller earthquakes have been recorded in this area since then.

In the southwest seismic zone, the most significant activity occurred near Quairading, where 24 events were recorded. Most of these were in January, following a magnitude ML 3.3 earthquake on 4 January. The largest aftershock was ML 3.0, on 21 January.

Twenty-two events were recorded in the Cadoux region and 12 from Meckering during the year, with the largest having magnitudes of ML 2.7 and ML 2.5 respectively.

A swarm of small but felt earthquakes occurred about 12 km north of Mukinbudin, a small wheatbelt town approximately 300 km eastnortheast of Perth. The swarm commenced in December 1992 and continued until March 1993. The largest event in the series was of magnitude ML 1.8. In many respects, the swarm was similar to a swarm experienced near Ongerup in early 1991 (McCue & Gregson, 1994). A network of temporary seismographs and strong motion recorders was established in the area to record some of these microearthquakes. The life of this network was December 1992 to March 1993, and its results will be included in the 1993 Australian Seismological Report.

Vic Dent

Northern Territory (Figure 4)

Twenty-five earthquakes with magnitude ML>2.9 occurred in the Northern Territory in 1992 and of these, four had ML>3.9. They included a magnitude ML 5.1 event off the coast of Arnhem Land (Figure 16). This was the largest Australian earthquake for the year. It is also the deepest-known Australian earthquake, with a depth of 39 km determined from pP-P and sP-P times (McCue and Michael-Leiba,1993).

Of the remaining three ML>3.9 events, one of magnitude ML 4.5 occurred north of Lake Neal and had many aftershocks, the largest being ML 3.1. The other two were Tennant Creek aftershocks and had magnitudes ML 4 .4 and 4.2. An additional 13 Tennant Creek aftershocks with magnitudes ML 3.0 - 3.9 occurred in 1992.

A large (Ms 7.0) earthquake occurred in the Banda Sea, 650 km north of Darwin, on 20 December. This was felt widely throughout Northern Australia, including Darwin and Katherine in the Northern Territory, and Kununurra in Western Australia. An isoseismal map was prepared for this event (Figure 19).

Marion Michael-Leiba

South Australia (Figure 5)

An unusual swarm of hundreds of small events occurred near Moralana, in the Flinders Ranges region of South Australia (Figure 5b) from November 1991 until February 1992. The largest events in the swarm (ML 3.3 and ML 3.5) occurred on 29 November, 1991. During 1992 only a few of these events were above magnitude 2. More than 155 local events were recorded by the permanent network during January, of which 61 were located. (The previous monthly record was 43). This was the longest swarm to occur in the last eight years. An aftershock survey was carried out for three weeks during February. On 8 February at 16:33 the first ever accelerogram was recorded in South Australia. In all 22 small accelerograms were recorded at close range for small magnitude (0.2-1.6) events, the highest acceleration being only 0.0033g at 7 km from a magnitude ML 1.6. The events were scattered over a small (5x3 km) area and from the eight best located events it was possible to produce a remarkably consistent focal mechanism which is discussed later.

Apart from this, activity during the year was normal with 320 events being located, the largest being magnitude ML 3.7 south of Blinman on 28 July. A number of felt events were reported from Peterborough in November and December, and from Naracoorte in November. Three isoseismal maps were produced during the year. There were a few more small events than usual in the area south and east of Adelaide with a number of felt reports.

David Love

Victoria (Figure 6)

The Bradford Hills region experienced a renewed level of seismic activity early in 1992, 11months after the original swarm. On 1 January at 15:37 UTC an earthquake of magnitude ML 2.2 occurred at Bradford Hills, followed on 2 January at 06:15 UTC by a magnitude ML 2.0 event. On 26 January at 14:54 UTC there was an earthquake of magnitude ML 2.8 at Bradford Hills, and a magnitude ML 2.1 on 28 March at 08:49 UTC.

On 9 February at 10:43 UTC a magnitude ML 2.6 earthquake occurred near Mt Buller. This event was felt with an intensity of III on the Modified Mercalli scale in the Mt Buller village and surrounding areas.

Two earthquakes occurred at Bradford Hills within a few days of each other, both of magnitude ML 2.8. The first was on 28 April at 21:02 UTC and was felt with an intensity of MM III. The second event on 1 May at 00:22 UTC was assigned a maximum intensity of MM IV.

On 11 July at 10:03 UTC an earthquake of magnitude ML 2.7 occurred at Wonwron in Gippsland. This event was reported felt at Carrajung Lower and was assigned a maximum intensity of MM III. Two accelerograms were recorded from this event.

A magnitude ML 3.8 earthquake occurred on 22 August south of Mallacoota. This event is described in more detail under Isoseismal Maps (Figure 15).

On 24 October at 10:15 UTC an earthquake of magnitude ML 2.2 occurred beneath the Melbourne suburb of Croydon. This event was felt widely throughout the outer eastern suburbs and was assigned a maximum intensity of MM III.

On 8 November at 01:40 UTC an earthquake of magnitude ML 3.4 was felt with an intensity of MM III by the lighthouse keeper at Cape Otway.

Wayne Peck

Tasmania (Figure 6)

A total of 55 Tasmanian region events were located by the Tasmanian network in 1992, a very quiet year. Only seven had magnitude ML>2.4 and most of these were in the Tasman Sea, well to the east of Tasmania. There were three on shore events in 1992, as against only one in 1991. Many very small events were recorded on Mt Read (MTRD) only.

June Pongratz

New South Wales and ACT (Figure 7)

Only four earthquakes with magnitudes ML 3.0 or greater occurred in New South Wales in 1992. The largest, of magnitude ML 3.7, was near Temora on 11 October. It was felt widely and an isoseismal map was drawn (Figure 17). The other three were at Dalton on 2 July (ML 3.0, felt MM V), 33 km northwest of Armidale on 19 August (MD 3.3, felt MM IV), and 9 km north of Boorowa on 12 December (ML 3.5, felt MM III).

Several microearthquakes in the Dalton-Oolong area were reported felt during the year as was a magnitude ML 2.9 event at Young on 10 May and a magnitude ML 2.8 earthquake in the Jenolan Caves area on 2 September.

Two microearthquakes recorded at Newcastle (ML 2.1 on 16 June and ML 1.3 on 15 July) were not felt.

No earthquakes were felt or recorded in the ACT, but two small events (magnitude MD 1.0 and 1.3) occurred in January on the part of the Lake George Fault beside the western side of Lake George, a prominent geomorphological feature northeast of Canberra. No events had been recorded previously on this part of the fault.

Marion Michael-Leiba

Queensland (Figure 8)

Some of the largest events in Queensland for 1992 were large blasts from the Bowen Basin. Several of these had magnitudes in excess of ML 3. Of the five earthquakes with magnitudes over ML 3 recorded on the Queensland network, only two were from Queensland, and three were from northern New South Wales. There were eight events recorded with magnitudes over ML 2.4. Isoseismal maps were prepared for three ML 2.4 events, at Proston, Widgee and Mundubbera.

Russell Cuthbertson

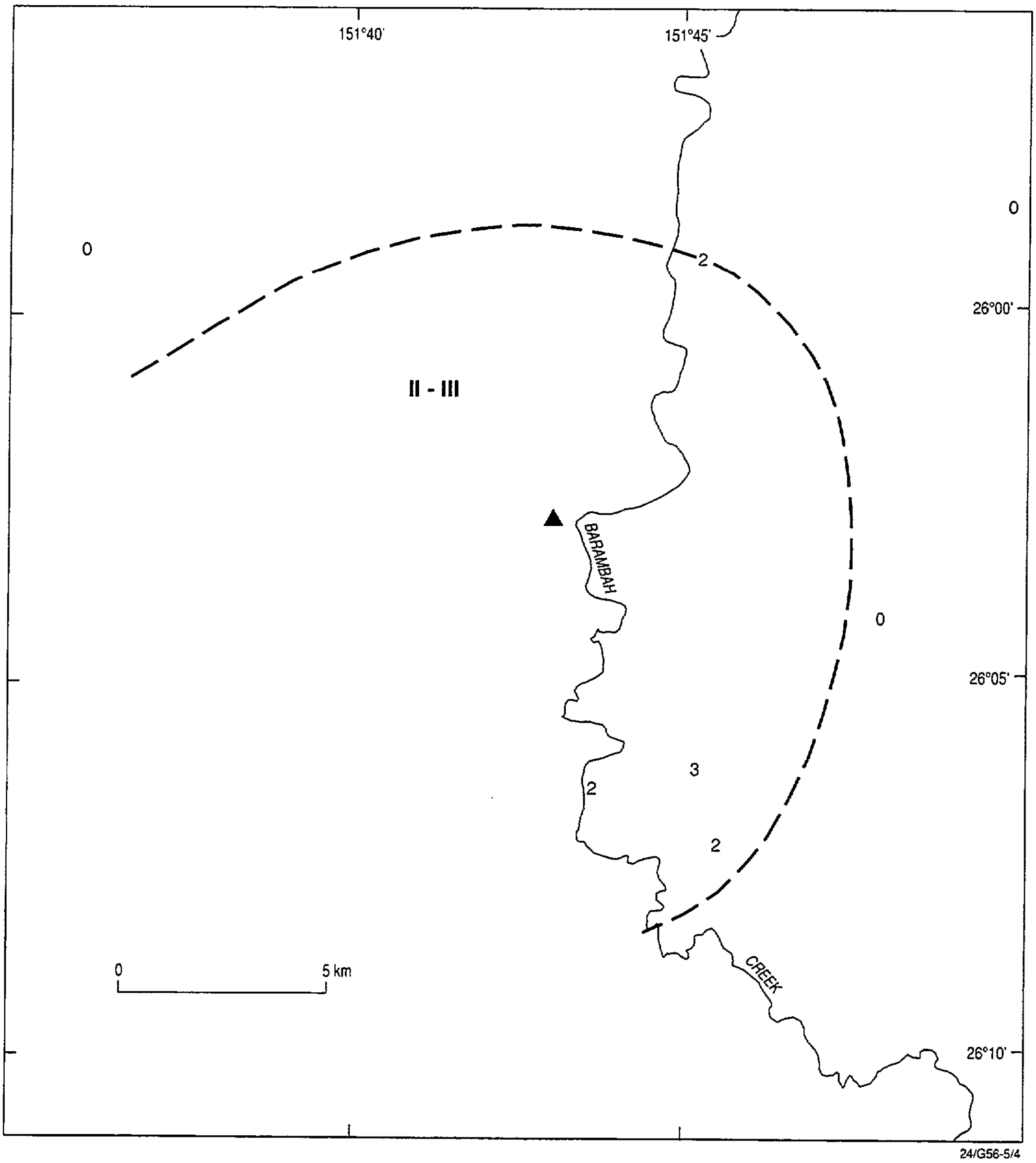
ISOSEISMAL MAPS

Proston Qld, 11 January, 21:31 UTC (Figure 9)

A small (ML 2.4) earth tremor was felt in the early morning (7:31 AEST on 12 January) in the rural community to the northeast of Proston. The event had similar felt effects to an earthquake (ML 2.7) on 22 November 1991 in a similar location.

Russell Cuthbertson and Col Lynam

ISOSEISMAL MAP OF THE PROSTON EARTHQUAKE, QUEENSLAND
11 JANUARY 1992



DATE: 11 JANUARY 1992
TIME: 21:31:22.6 UTC
MAGNITUDE: 2.4 ML
EPICENTRE: 26.047°S 151.717°E
DEPTH: 7 KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

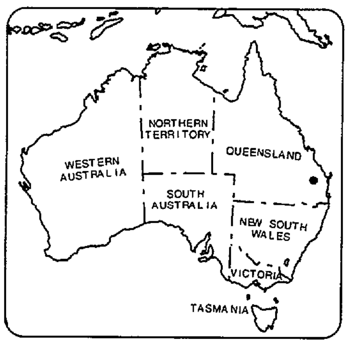
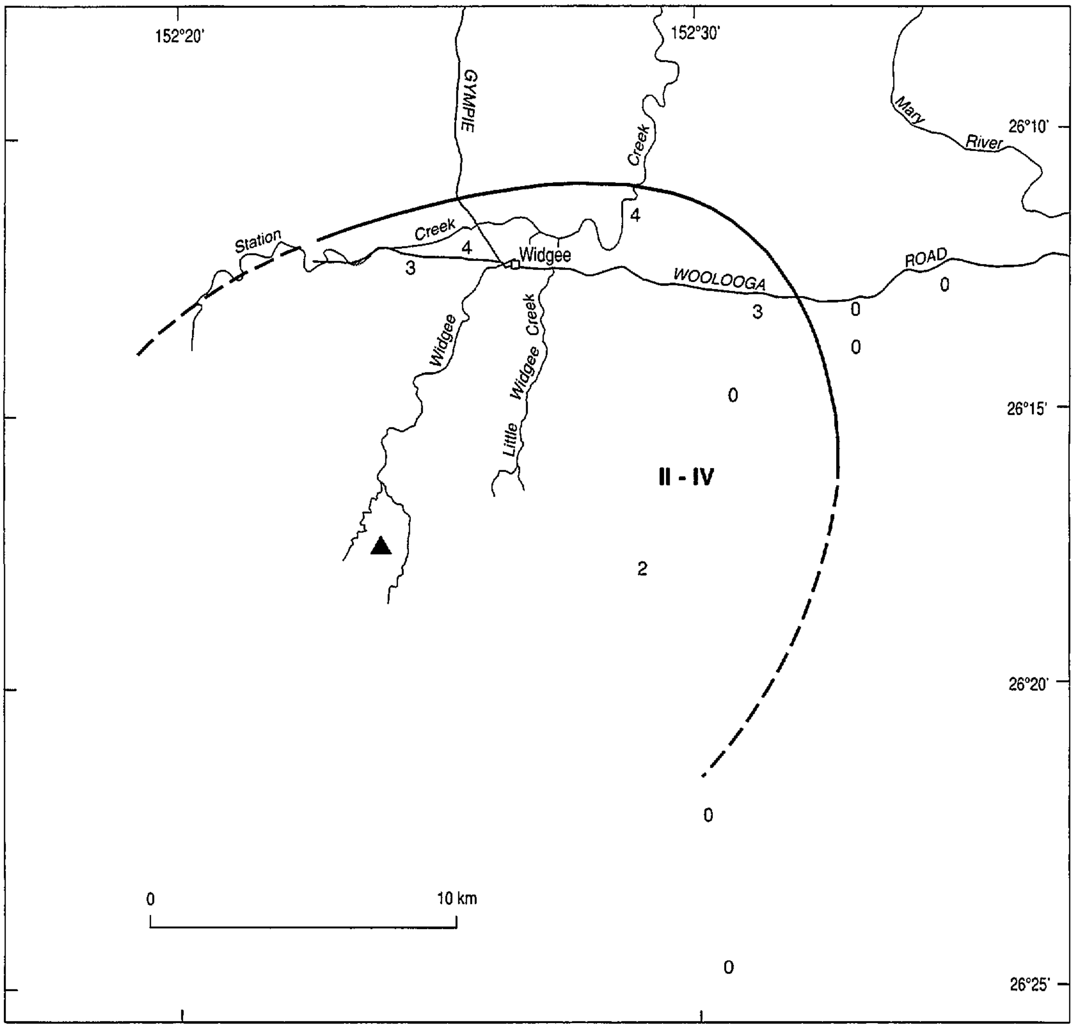


Figure 9

ISOSEISMAL MAP OF THE WIDGEE EARTHQUAKE, QUEENSLAND
3 MARCH 1992



DATE: 3 MARCH 1992
TIME: 03:35:20.9 UTC
MAGNITUDE: 2.3 ML
EPICENTRE: 26.290°S 152.400°E
DEPTH: 9 KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

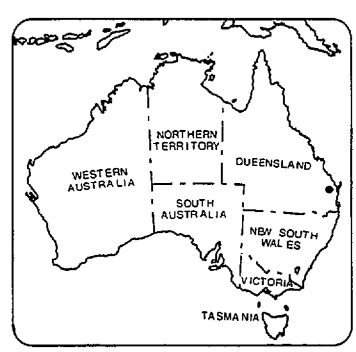
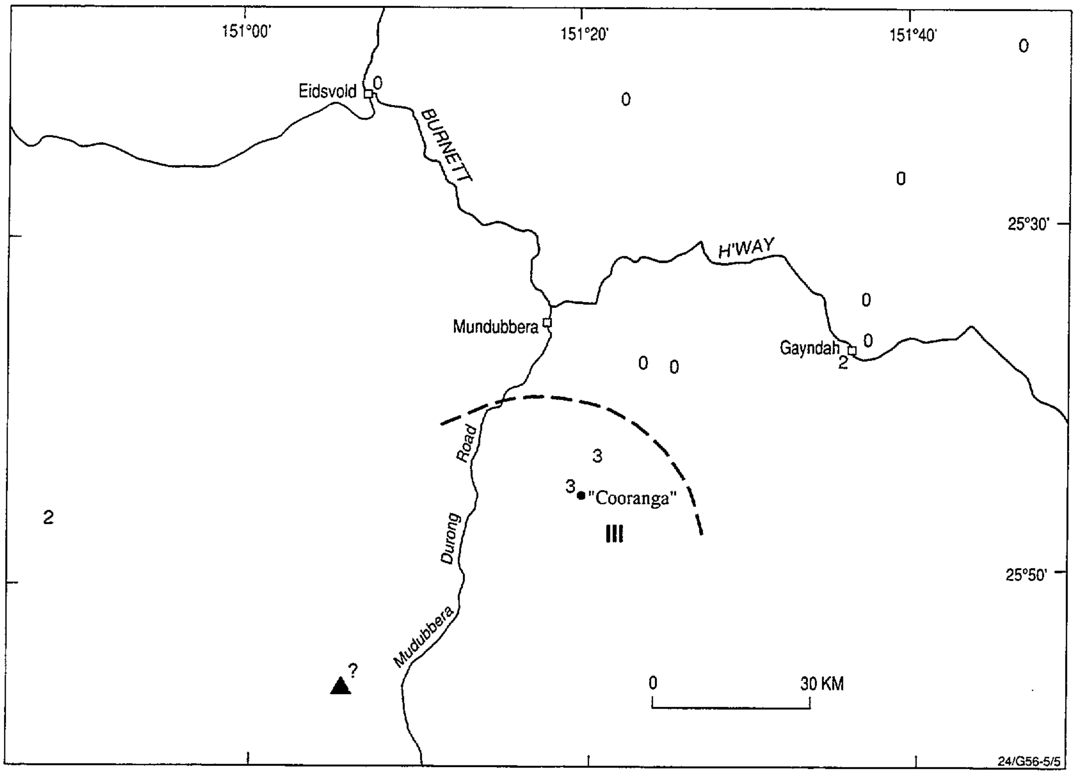


Figure 10

ISOSEISMAL MAP OF THE MUNDUBBERA EARTHQUAKE,QUEENSLAND
11 MARCH 1992



DATE: 11 MARCH 1992
TIME: 00:35:50.3 UTC
MAGNITUDE: 2.4 ML
EPICENTRE: 25.941°S 151.092°E
DEPTH: 3 KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

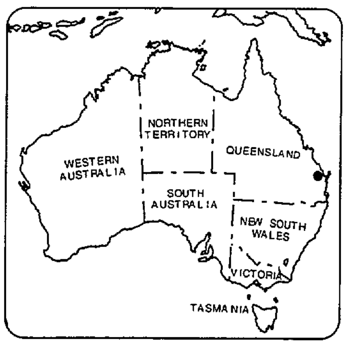
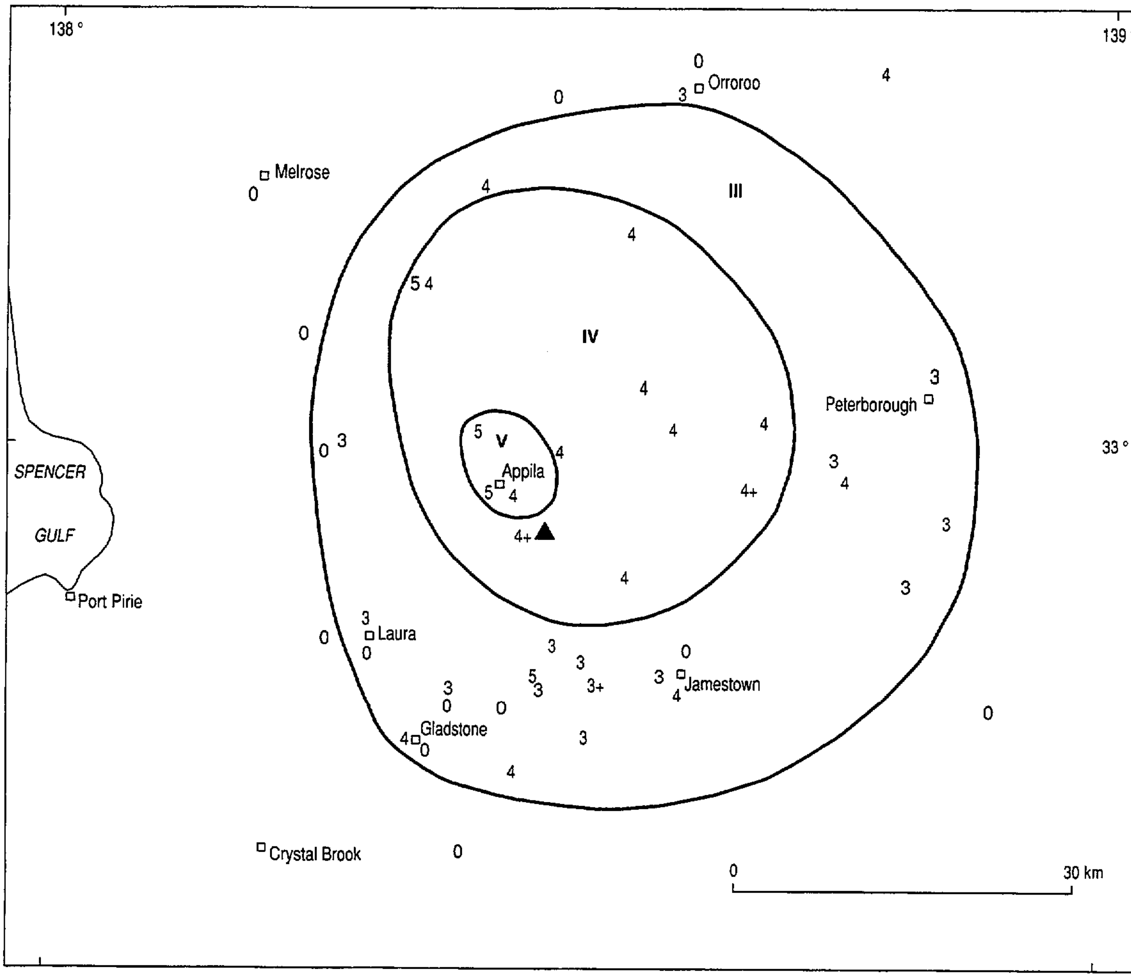


Figure 11

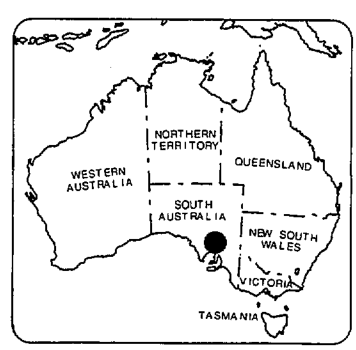
ISOSEISMAL MAP OF THE APPILA EARTHQUAKE, SOUTH AUSTRALIA

27th MAY 1992



DATE:	27 MAY 1992
TIME:	10:17:11.6 UT
MAGNITUDE:	2.9 ML [ADE]
EPICENTRE:	33.076°S 138.487°E
DEPTH:	2 km

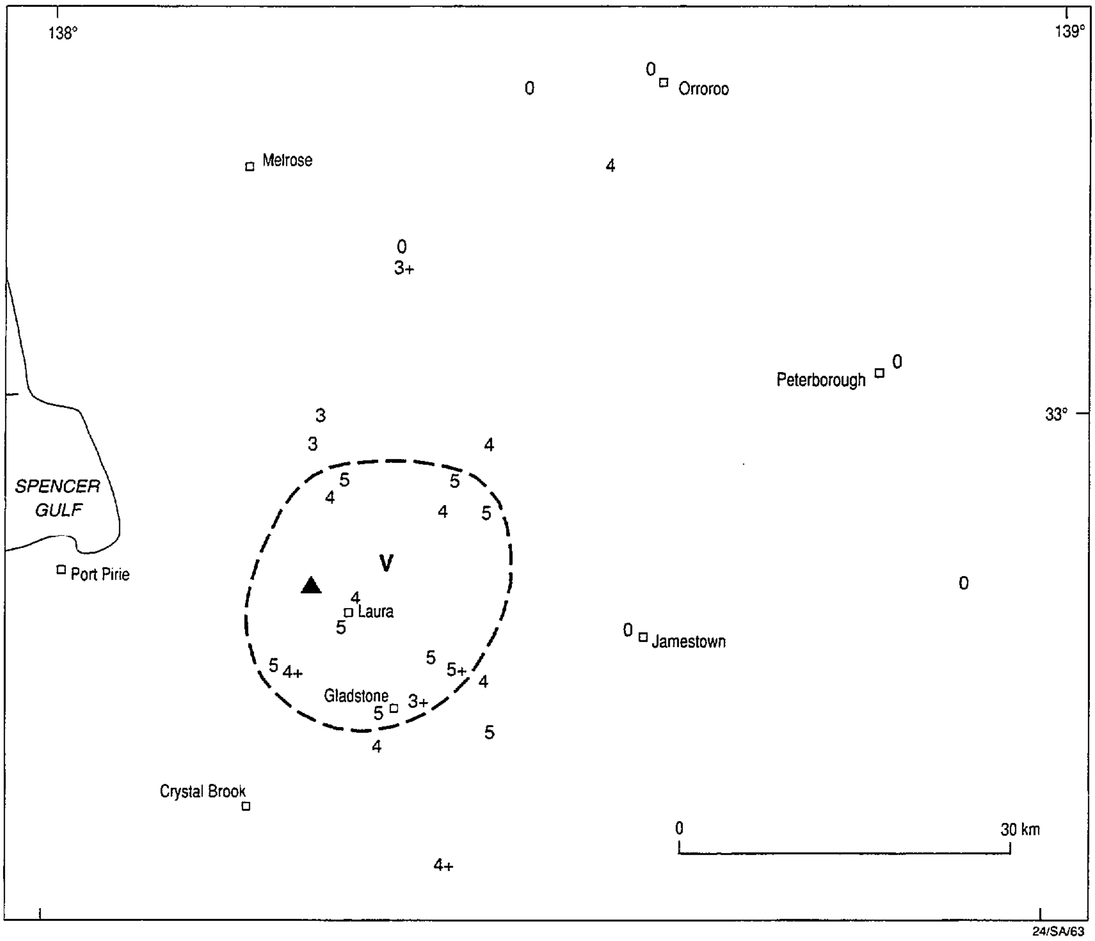
▲	*Epicentre*
IV	*Zone intensity designation*
4	*Earthquake felt (MM)*
0	*Earthquake not felt*



24/SA/62

Figure 12

ISOSEISMAL MAP OF THE LAURA EARTHQUAKE,SOUTH AUSTRALIA
11 JUNE 1992



DATE: 11 JUNE 1992
TIME: 19:14:4.8 UTC
MAGNITUDE: 3.1 ML (ADE)
EPICENTRE: 33.167°S 138.267°E
DEPTH: 5KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

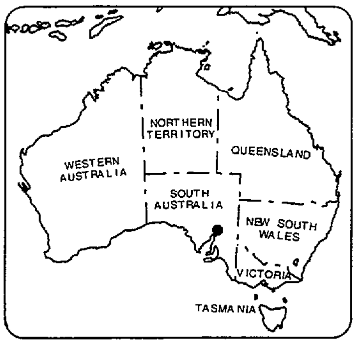
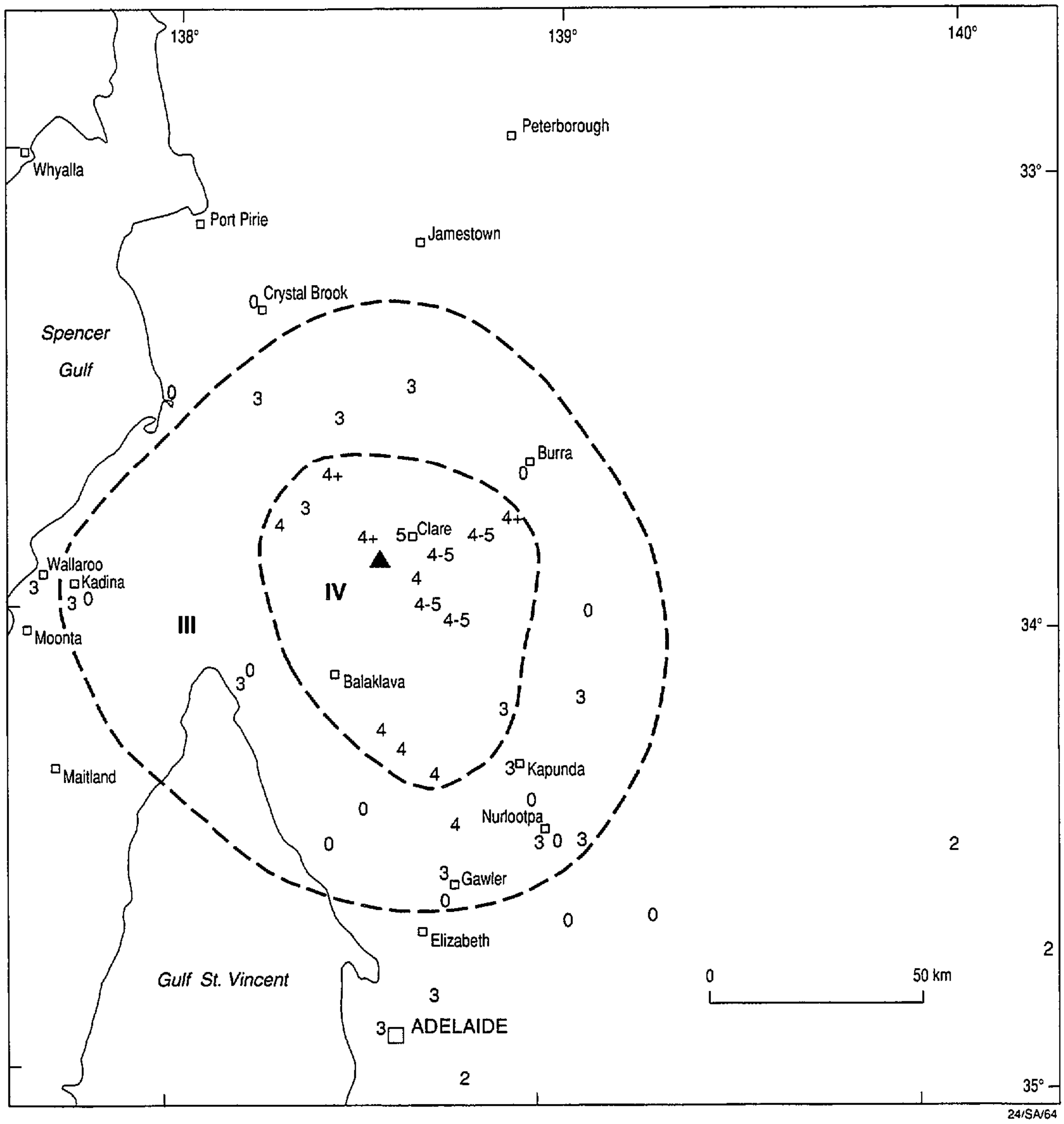
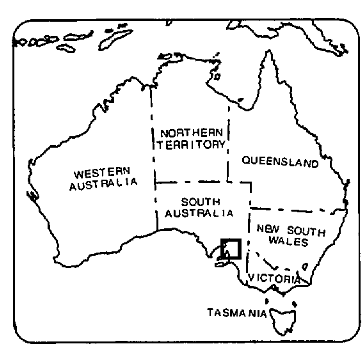


Figure 13

ISOSEISMAL MAP OF THE CLARE EARTHQUAKE, SOUTH AUSTRALIA
17 AUGUST 1992

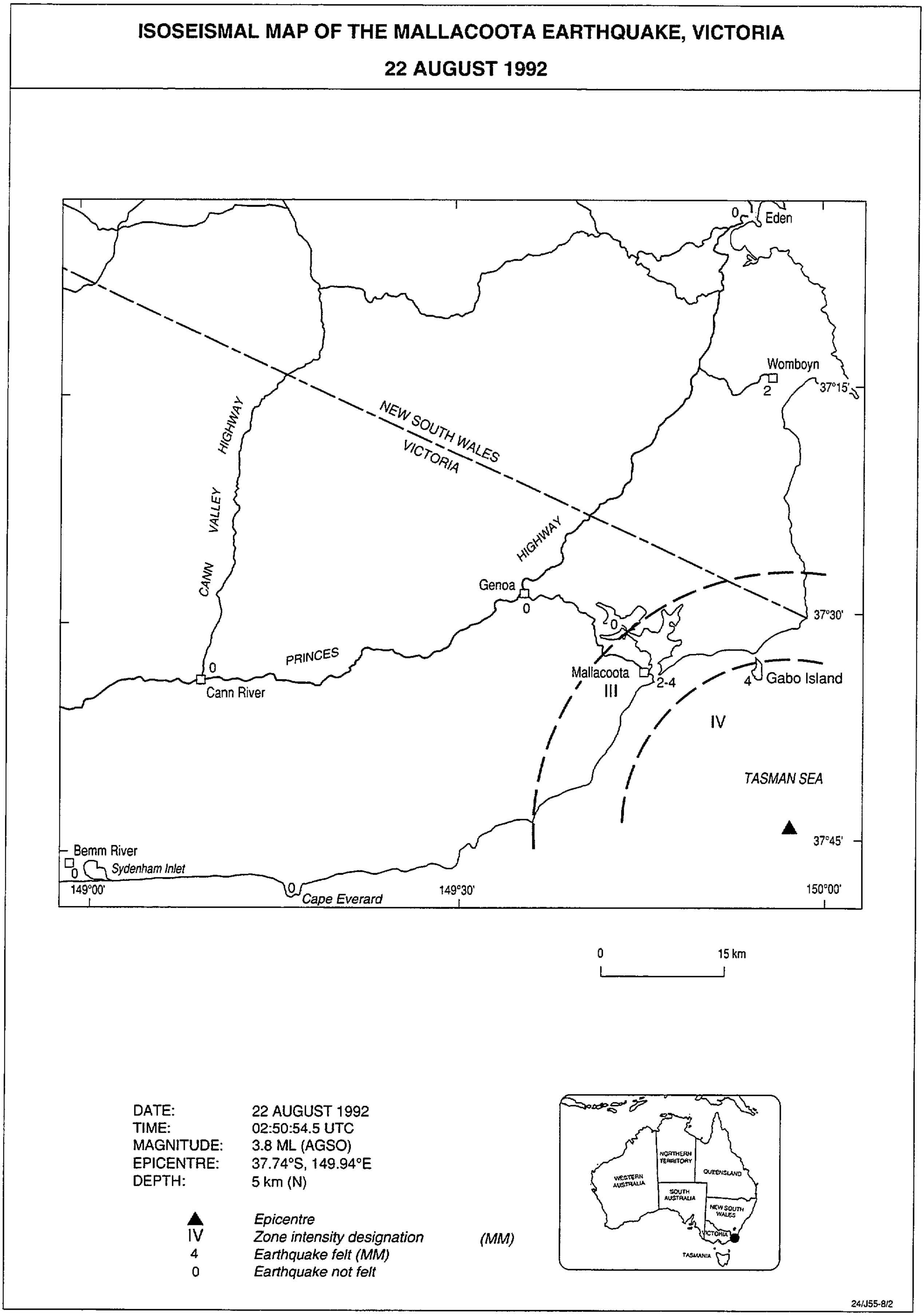




DATE: 17 AUGUST 1992
TIME: 20:33 UTC
MAGNITUDE: 3.2 ML (ADE)
EPICENTRE: 33.905°S 138.556°E
DEPTH: 11 KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

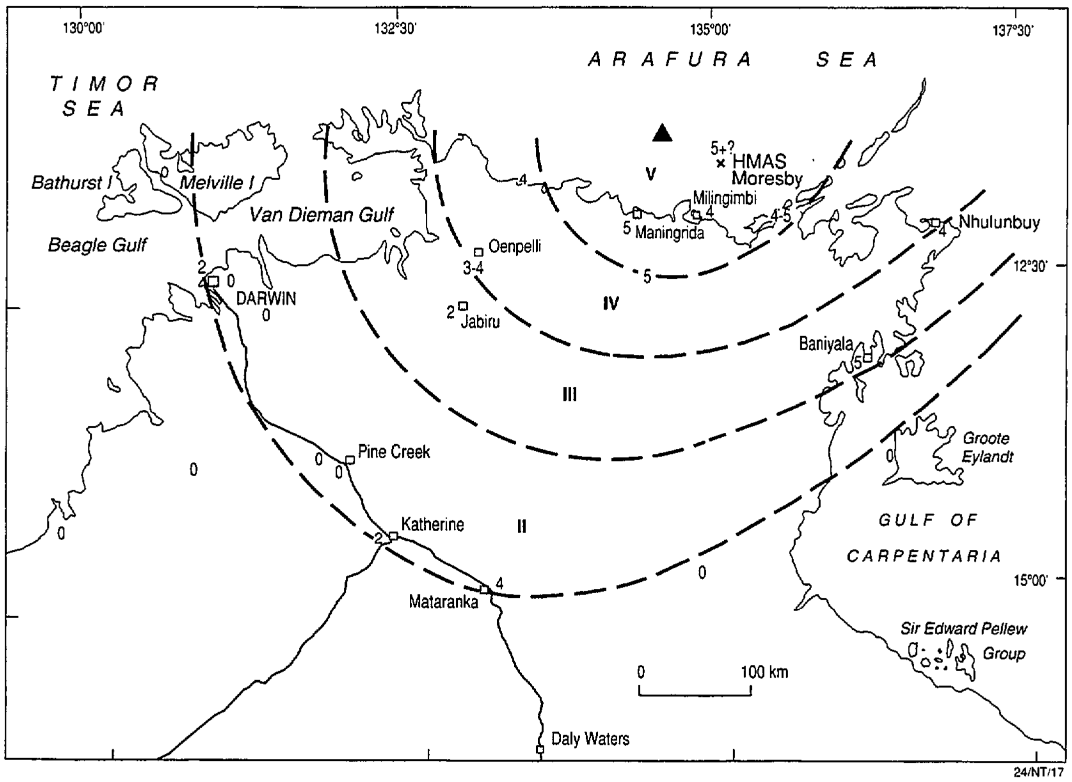
Figure 14



ISOSEISMAL MAP OF THE MALLACOOTA EARTHQUAKE, VICTORIA
22 AUGUST 1992
Eden
Womboyn
NEW SOUTH WALES
VICTORIA
CANN VALLEY HIGHWAY
HIGHWAY
PRINCES
Genoa
Mallacoota
Cann River
Gabo Island
III
IV
TASMAN SEA
Bemm River
Sydenham Inlet
Cape Everard
37°15'
37°30'
37°45'
149°00'
149°30'
150°00'
0 15 km
DATE: 22 AUGUST 1992
TIME: 02:50:54.5 UTC
MAGNITUDE: 3.8 ML (AGSO)
EPICENTRE: 37.74°S, 149.94°E
DEPTH: 5 km (N)
Epicentre
IV Zone intensity designation (MM)
4 Earthquake felt (MM)
0 Earthquake not felt
24/J55-8/2

Figure 15

ISOSEISMAL MAP OF THE ARNHEM LAND EARTHQUAKE, NT
30 SEPTEMBER 1992



DATE: 30 SEPTEMBER 1992
TIME: 11:18:07 UTC
MAGNITUDE: 5.1 ML
EPICENTRE: 11.35°S 134.57°E
DEPTH: 38.8±2.5 KM

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

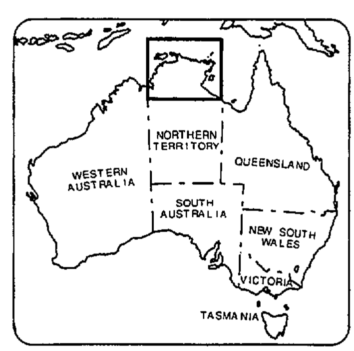
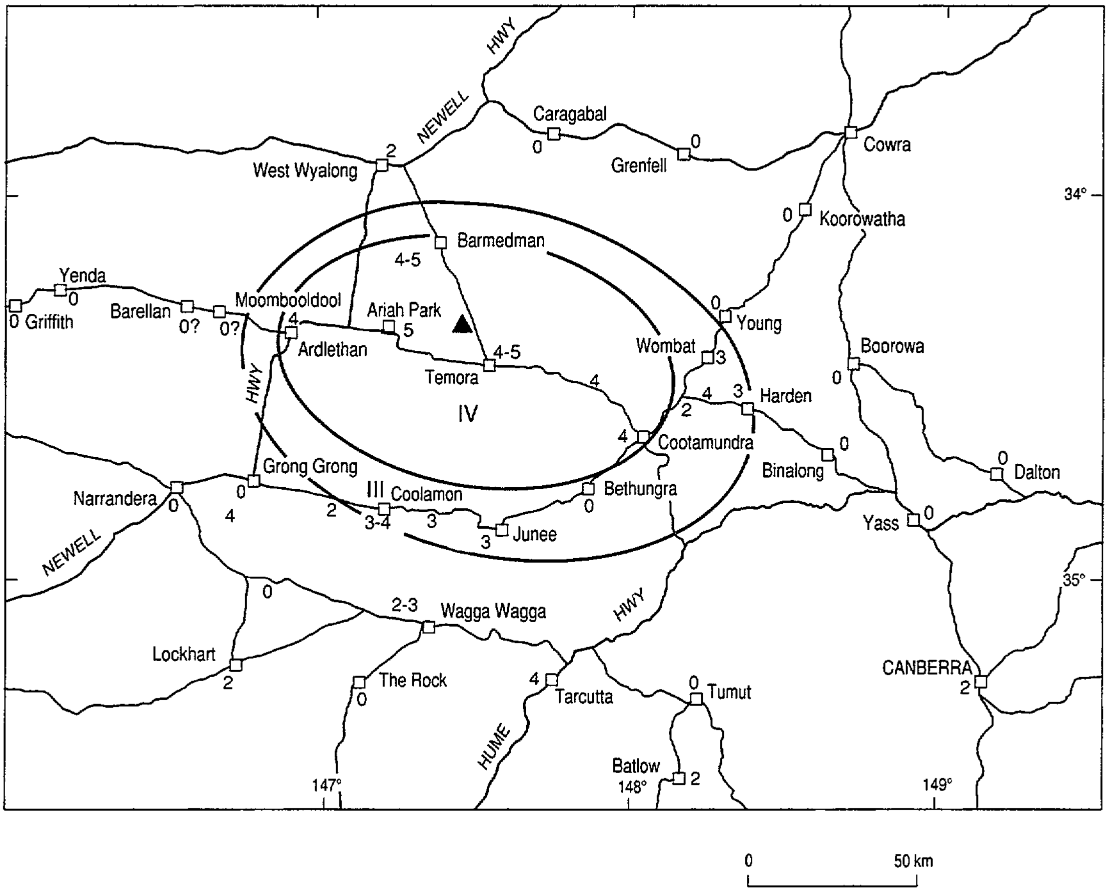


Figure 16

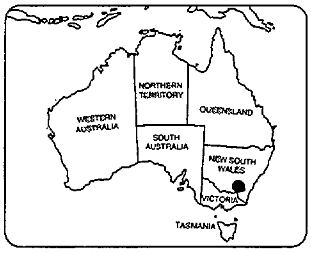
ISOSEISMAL MAP OF THE TEMORA EARTHQUAKE, NEW SOUTH WALES

11 OCTOBER 1992



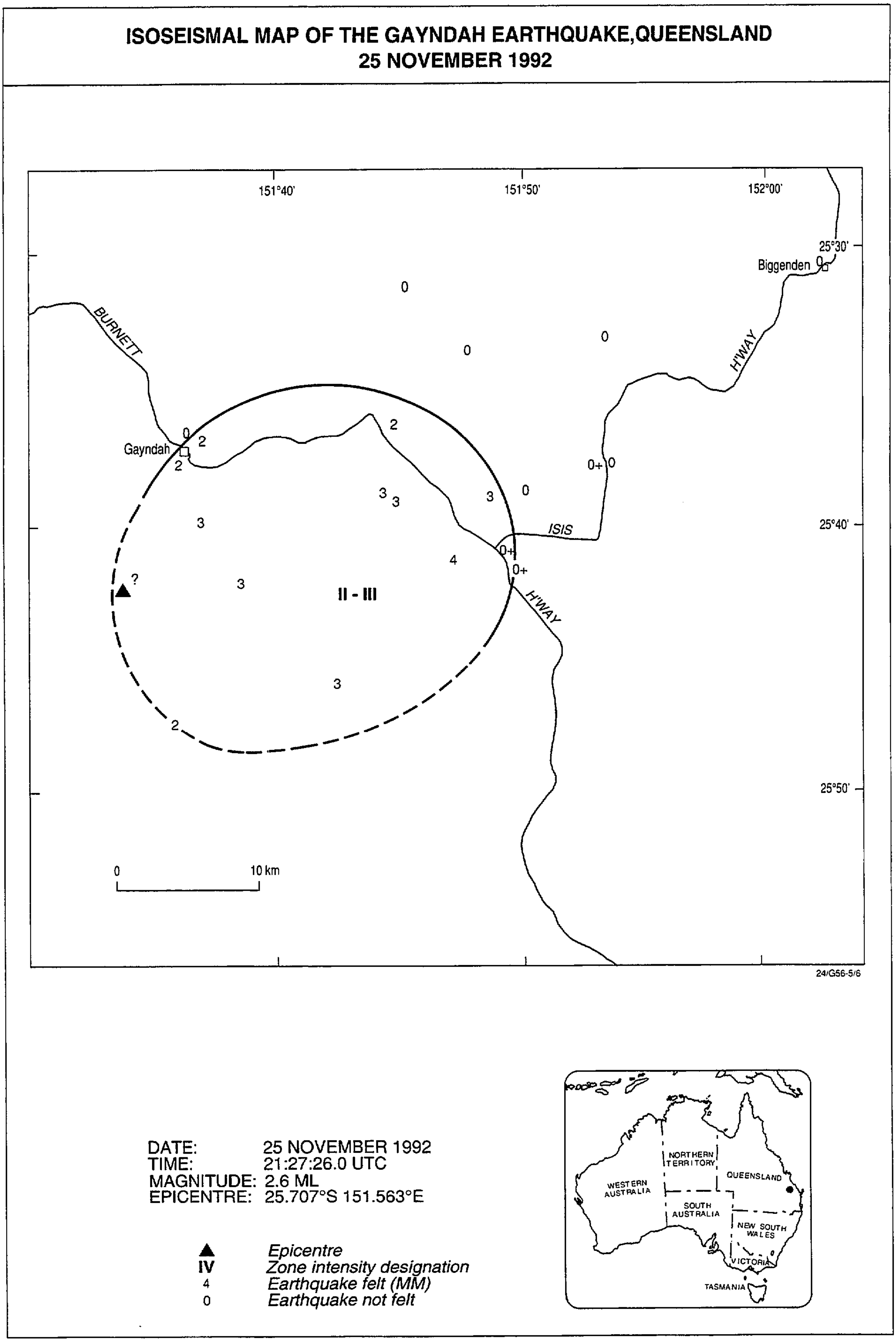
DATE: 11 OCTOBER 1992
TIME: 02:03:27 UTC
MAGNITUDE: 3.7 ML (AGSO), 3.7 MD (AGSO)
EPICENTRE: 34.35°S, 147.46°E

▲ *Epicentre*
IV *Zone intensity designation (MM)*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*



24/155/32

Figure 17



ISOSEISMAL MAP OF THE GAYNDAH EARTHQUAKE,QUEENSLAND
25 NOVEMBER 1992
151°40'
151°50'
152°00'
25°30'
25°40'
25°50'
Biggenden
Gayndah
BURNETT
H'WAY
ISIS
II - III
0
10 km
24/G56-5/6
DATE: 25 NOVEMBER 1992
TIME: 21:27:26.0 UTC
MAGNITUDE: 2.6 ML
EPICENTRE: 25.707°S 151.563°E
Epicentre
IV Zone intensity designation
4 Earthquake felt (MM)
0 Earthquake not felt
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA

Figure 18

ISOSEISMAL MAP OF THE BANDA SEA EARTHQUAKE, 20 DECEMBER 1992

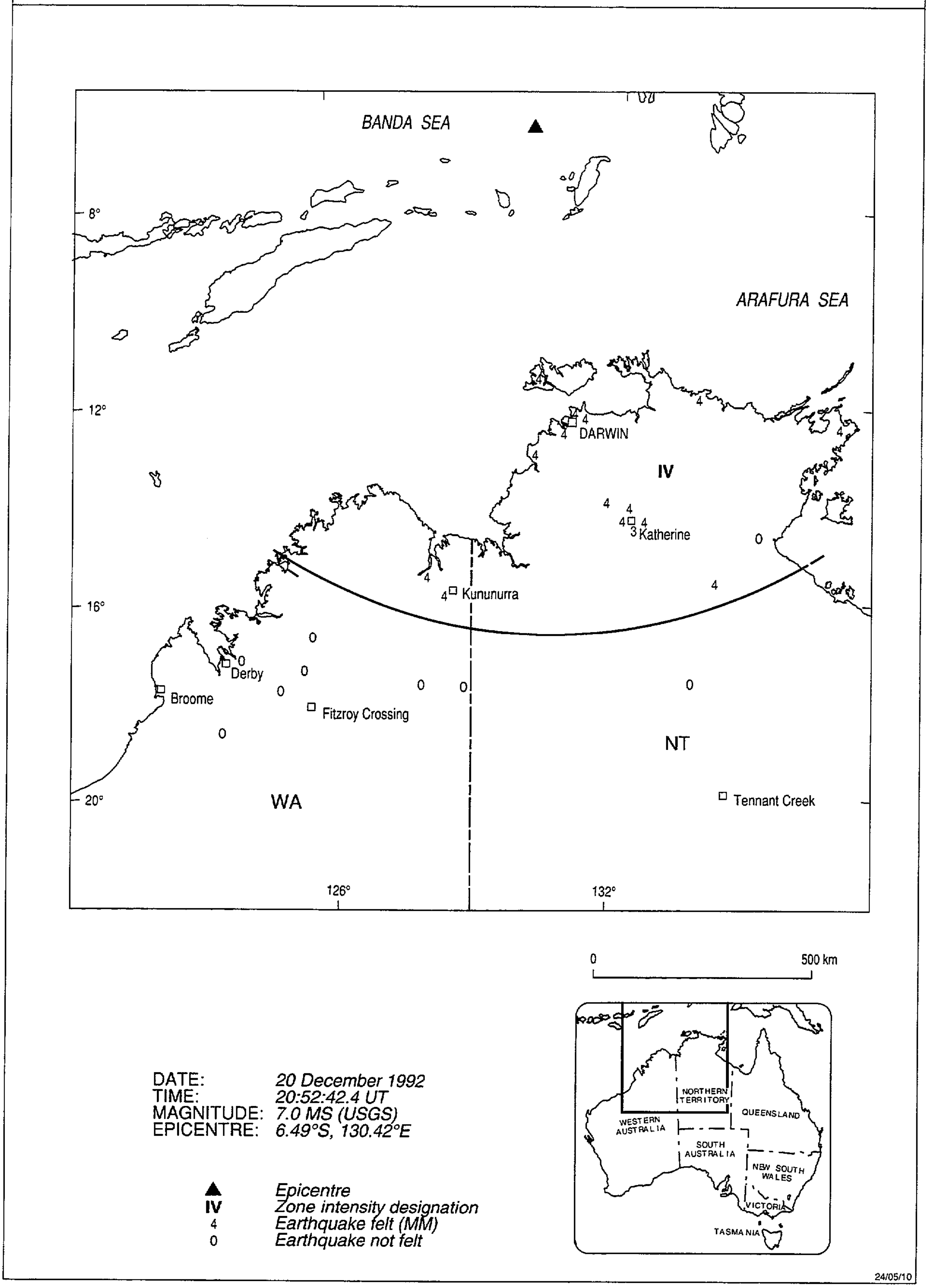


Figure 19

Widgee Qld, 3 March, 03:35 UTC (Figure 10)

Numerous reports were received of this event being felt in the tiny community of Upper Widgee, to the east of Gympie in southeast Queensland. The isoseismal map for this event suffers from the lack of reports to the southwest.

Russell Cuthbertson and Col Lynam

Mundubbera Qld, 11 March, 00:35 UTC (Figure 11)

This event was felt in a limited area with several reports of high intensities being received from the area near Cooranga homestead, 17 km south of Mundubberra. One observer reported a flock of ibis being startled into flight. An isolated report was received from Hawkwood to the southwest of Mundubbera.

This event (ML 2.4) produced similar intensity reports, from similar locations, as the Mundubbera tremor of 13 July 1991 (ML 2.3). The computed location for the 1991 event was just 2 km south of Mundubbera while the computed location for this event, which suffers from not having being recorded on the nearby Boondooma Dam seismograph, was approximately 40 km SSW of Mundubbera.

If the computed location for this event is correct then this would indicate a radius of perceptibility of over 30km. This compares with measurements of approximately 10 km from similar sized events (Proston, 11 January 1992, ML 2.4 and Widgee, 3 March 1992, ML 2.4). The high intensities at Cooranga homestead indicate that the epicentre for this event and the 1991 event were close to the homestead.

Russell Cuthbertson and Col Lynam

Appila SA, 27 May, 10:17 UTC (Figure 12)

A small earthquake occurred at 7.47 pm (local time), and was felt from Gladstone to Orroroo. Effects were only minor, although a few people near the epicentre reported a sudden explosion, with small objects being displaced. A questionnaire was distributed and 42 replies were received from 83 posted. From these and telephone calls the map was produced.

David Love

Laura SA, 11 June, 19:14 UTC (Figure 13)

Only two weeks after the Appila earthquake, another slightly larger event hit the area. At 4.44 am (12 June local time) many people around Laura were suddenly awakened.

A questionnaire was sent out using the previous earthquake's distribution list. As this epicentre was 25 km further to the southeast, the distribution was not wide enough. The early hour also meant that a MM III line could not be drawn, and other isoseismal lines are not clear.

From 61 questionnaires sent, 31 replies were received. A number of these mentioned slight cracking to plaster and small objects being moved or upset. A small foreshock (ML 1.3) at 4.36 am was also felt.

David Love

Clare SA, 17 August, 20:33 UTC (Figure 14)

A small earthquake of Richter magnitude 3.2 occurred at 5.31 am (18 August local time) near Clare. The earthquake was very widely felt, so 75 questionnaires were distributed. From 58 replies and a few phone calls, the isoseismal map was produced.

Given the early hour, when it was dark and quiet but many people were nearly awake, intensities were difficult to assign and contours were difficult to draw. Although eight people reported some minor cracking, the total descriptions did not warrant an intensity of MM VI. The highest intensity assigned was MM V at Clare. Of interest were a considerable number of felt reports near Adelaide and two reports from the Murray Mallee. One respondent at 190 km from the epicentre identified two weak arrivals a short time apart.

David Love

Mallacoota Vic, 22 August, 02:51 UTC (Figure 15)

At 12.51 pm (local time) a magnitude ML 3.8 earthquake occurred about 28 km southeast of Mallacoota. It was the largest earthquake on record to have occurred within 50 km of that township.

A phone survey of nine population centres in this sparsely populated part of Australia was conducted. In addition, Richard Routh, Editor of the Mallacoota Mouth, the weekly newspaper of Mallacoota P-12 College, sent a student journalist to survey a few people in the community about the event. The Mallacoota Mouth reported seven people's experiences, and an additional three phoned the Australian Seismological Centre as a result of a request from the newspaper.

There were 12 felt reports from Mallacoota where the assessed intensities ranged from MM II -IV. It was variously described as like thunder but not felt; a vibration; a roar; an explosion; or strong and making things rattle. The duration was estimated as being frm 2-10 seconds.

The earthquake was felt most strongly at Gabo Island, 20 km north of the epicentre, where the lighthouse keeper's household experienced it as rolling in from the east. It sounded like a roar and made things rattle.

The only other place where it was reported felt was at Womboyn, NSW, 55 km north of the epicentre. At least one household there heard a little roar, marginally felt a vibration, and saw a tall ornament rock.

Because of the low population density of the area and the few felt reports, the contours on the isoseismal map are very poorly constrained.

Marion Michael-Leiba

Arnhem Land NT, 30 September, 11:18 UTC (Figure 16)

At 8.48 pm (local time) a magnitude ML 5.1 earthquake occurred off the coast of Arnhem Land. It is the largest Australian earthquake in 1992 and, with a focal depth of 39 km, is Australia's deepest known earthquake (McCue and Michael-Leiba, 1993).

From questionnaires, and telephone and newspaper reports, an isoseismal map was compiled. The earthquake was felt most strongly at Nhulunbuy, Milingimbi and Maningrida. At Nhulunbuy assessed intensities varied between III and VI on the modified Mercalli scale; one reliable observer reported seeing waves ripple a concrete pavement and there was a single report that plaster was cracked. At Milingimbi and Maningrida, household objects rattled and some people were frightened, but not because the sensation was new as large earthquakes in the Banda Sea Arc are felt in northwestern Australia about once per year. The HMAS Moresby, an Australian naval vessel, was anchored off Maningrida in calm water at the time of the earthquake. One of the ship's officers reported that the ship shook violently and that the shaking was apparently transmitted up the anchor chain. Very few people felt or heard the earthquake in Darwin. The isoseismal map has been published in McCue and Michael-Leiba, 1993.

Marion Michael-Leiba and Kevin McCue

Temora NSW, 11 October, 02:03 UTC (Figure 17)

At 12.03 pm local time on 11 October a magnitude ML 3.7 earthquake occurred 13 km northwest of Temora. Its isoseismal map was compiled from interviews of residents from 38 localities.

The earthquake was felt most strongly and outdoors at Temora, Ariah Park and Barmedman. At Temora, some people were frightened and video cassettes fell off shelves in the video shop. Everyone in Barmedman felt it. This included a man walking, and at least one person inside was very frightened. In Cootamundra, the event made things rattle and was described as a big bang and as producing the sensation of a semi trailer running into the house.

The most distant felt reports were from Tarcutta, Lockhart, Batlow and Canberra, 110, 120, 150 and 190 km respectively from the epicentre. In Tarcutta, things rattled as though a large truck was passing. In Lockhart, one person felt the earthquake through her body, but nothing in the room rattled. A couple of people in Batlow felt it and saw pot plants shaking. In Canberra, three people reported feeling the earthquake, while another heard the event and things rattling, but did not feel it. Two accelerograms for the event were recorded in Canberra.

Marion Michael-Leiba

Gayndah Qld, 25 November, 21:27 UTC (Figure 18)

This event, at 7:27 am AEST on 26 November 1992, was felt in an area southeast of Gayndah. The limited number of reports to the south is due to the sparse population. There was some uncertainty in the computed location, with initial estimates being to the east of Gayndah. The final location, which is still not considered reliable is to the south of Gayndah, on the edge of the felt area.

Russell Cuthbertson and Col Lynam

Banda Sea, 20 December, 20:52 UTC (Figure 19)

A magnitude Ms 7.0 earthquake occurred in the Banda Sea at 6.22 am CST on 21 December. Although located 650 km north of Darwin, it was felt strongly in the northern part of Australia.

No damage was reported and generally the intensity experienced was MM IV over an area of 350,000 km^2 up to 1100 km from the epicentre. The earthquake was felt as far as Nhulumbuy in the east, Kununurra in the west and Katherine in the south.

In Darwin it was estimated that the earthquake was felt for longer than a minute with trembling and rumbling sounds. Water in swimming pools slopped and one observer in a lift experienced the lift cage bouncing around in the lift well. Because the earthquake occurred early in the morning there were no reports received of intensities less than MM IV. Six aftershocks were recorded in Darwin at 15 to 20 minute intervals following the main shock.

Peter Gregson

NETWORK OPERATIONS 1992

The only significant changes made to the Australian seismological net (Table 4), in 1992 were in NSW, where 24 new stations (seismographs and/or accelerographs) were added by the Seismology Research Centre (RMIT). These stations (see inset to Figure 7) were installed in the Sydney Water Catchment area, as part of a contract undertaken with the Sydney Water Board. Much of these data are telemetered back to the Research Centre's Headquarters in Melbourne.

In Western Australia, no additions were made to the permanent network, but the seismographs at Forrest and Meekatharra were each relocated several kilometres, in order to lessen the effects of local seismic noise (trains and blasts respectively). The Mundaring three component seismograph was connected to a PC so that digital data could be obtained for significant local events. Temporary stations were set up in the Quairading and Mukinbudin areas of the central Wheat Belt, to monitor swarms of small events which were being felt in these areas.

In South Australia, no changes were made to the South Australian permanent network during the year. The station GEX remained unoperational throughout 1992. However, a number of temporary stations, including some accelerographs, were set up in the Moralana area of the Flinders Ranges in February. These were to study in detail a swarm of events which had commenced in November 1991. The first accelerograms to be recorded in South Australia were made during this survey, although the accelerations were only small.

In central Queensland, a new station was opened at Maryvale (MRVQ) while a station at Byfield (BYFQ) was closed. There were no changes to the Tasmanian or Northern Territory networks in 1992.

Vic Dent

ACCELEROGRAPH DATA

The locations of permanent accelerographs in 1992 are given in Table 5.

During 1992 there was a significant increase in the number of accelerographs in southeast Australia when the Seismology Research Centre, RMIT, received a contract from the Water Board of Sydney, Illawarra and the Blue Mountains to monitor seismicity in their catchment area. Seven combined seismograph/accelerographs and six accelerographs were installed for the dual purposes of determining local attenuation and monitoring the response of significant Water Board structures to earthquakes and other sources of vibration.

During 1992, no accelerograph within Victoria triggered on any earthquake greater than magnitude ML 2.7. The highest acceleration recorded was 0.000879 g by the Plane Track accelerograph (PTA) from an earthquake of magnitude ML 2.7 that occurred near Mt Selma on 26 September, at a distance of 23 km. This same event triggered the accelerograph mounted on the crest of Upper Yarra dam (UYC) where an acceleration of 0.000488 g was recorded.

On 11 July at 10:03 UTC an earthquake of magnitude ML 2.7 at Wonwron triggered the PTA accelerograph. Peak acceleration at PTA from this event was 0.000180 g. The accelerograph at Jeeralang Junction (JNA) was also triggered by this event and recorded a peak acceleration of 0.000175 g.

In the ACT, two accelerograms were recorded from the magnitude ML 3.7 event at Temora, NSW, at a distance of about 200 km. The recording from PHB, in the basement of the new Parliament House, is shown in Figure 21. The peak acceleration recorded there was 0.000386g. That from ASC, in the basement of Jamieson House in Reid, was 0.000614g.

In Western Australia, only eight accelerograms were recorded, representing five small Meckering events (largest ML 2.4) recorded at Goomalling, approximately 40 km to the northwest, and three small events from Quairading, recorded at a distance of approximately 0.5 km. The largest of these events was magnitude ML 2.0

In South Australia, the South Australian Department of Mines and Energy borrowed a Kelunji recorder and accelerometer for temporary use to monitor some of the Moralana aftershock activity. In all, 22 accelerograms were recorded from events which ranged in magnitude from 0.2 to 1.6. The largest acceleration recorded was 0.0033 g at 7 km from the magnitude ML 1.6 event (Figure 20).

Acceleration recorded at one magnitude can be converted (normalised) to acceleration at another magnitude using a derivation of Kanai's (1961) magnitude/acceleration relationship

$$A(ML_a) = A(ML_b) * \exp(0.8*(ML_a - ML_b))$$

Acceleration data recorded in 1992 have been normalised to ML 3.0 by this method, and plotted in Figure 22. These data will help to define the acceleration vs distance (attenuation) relationship in Australia.

Vic Dent and Wayne Peck

AUSTRALIAN EARTHQUAKE FOCAL MECHANISMS

Moralana (Figure 23)

The events of the Moralana SA swarm were scattered over a small (5x3 km) area and from the eight best located events it was possible to produce a remarkably consistent focal mechanism with upper hemisphere arrivals. It shows clear compression in a NW-SE direction, parallel to the edge of the Flinders Ranges at that point. From other geological evidence the SE dipping plane is the preferred fault plane.

David Love

George V Fracture Zone (Figure 24)

On 2 February 1992 at 00:31 UTC a magnitude Ms 6.2 earthquake occurred on the George V fracture zone, a major strike slip fault crossing the southeast Indian rift, south of Australia. The focal mechanism is consistent with the north-striking sinistral faulting suggested by the tectonics.

Kevin McCue and Marion Michael-Leiba

PRINCIPAL WORLD EARTHQUAKES, 1992

Table 6 lists earthquakes that occurred throughout the world in 1992 of magnitude 7.0 or greater, or that caused fatalities or substantial damage. There were no great earthquakes, and 12 of the 15 earthquakes of magnitude Ms 7 or more occurred around the Pacific rim. The other three were in the Asian region, Indonesia and the Cuban region. The largest at magnitude Ms 7.6 occurred on 28 June in Southern California. The most destructive earthquake was in the Flores region of Indonesia on 12 December. There were at least 2200 people killed, more than 500 injured and 40 000 left homeless. Ninety percent of the buildings were destroyed at Maumere by the earthquake and resulting tsunami. Figure 25 shows the location of the earthquakes of magnitude 6.0 or more in 1992. Moderate intraplate earthquakes in The Netherlands on 13 April and Egypt on 12 October caused fatalities, injuries and damage.

World-wide, more than 2880 people died in earthquakes in 1992, compared with 2800 and 52 000 in 1991 and 1990 respectively, and the average for the century of 10 000 per year.

This information is from the ISC monthly bulletins, 'Earthquake Data Reports' published by the United States Geological Survey and the SEAN Bulletin of the Smithsonian Institution (SEAN, 1992).

Peter Gregson, Kevin McCue, Yvonne Moiler and Graeme Small

AUSTRALIAN CRUSTAL MODELS

Regional authorities responsible for locating earthquakes have adopted crustal models suitable for their local areas. The closeness of these models to the true geological conditions has a large effect on the accuracy of the earthquake locations. The models currently in use in Australia are shown in Table 7.

Vic Dent

MONITORING OF NUCLEAR EXPLOSIONS

A list of presumed underground nuclear explosions detonated during 1992 is shown in Table 8. In all eight explosions are believed to have been detonated, six at the Nevada Test Site (NTS) in the United States and two at the Chinese test site of Lop Nor. Aside from the two small explosions at NTS all were recorded at Australian stations. No magnitude is available for the explosion labelled "Diamond Fortune" as it was too small to be located by the network of stations contributing data to form the PDE bulletins.

The explosion of 21 May was the largest Chinese explosion detonated to date and is the largest underground nuclear test since one detonated by the USSR at its test site of Novaya Zemlya on 10 October 1975. The yield of the Chinese explosion exceeded the 150 kT limit set by the Threshold Test Ban Treaty (1976) which is observed by the other testing states.

Both France and Russia had put into place moratoria on testing, conseqently the total number of explosions recorded in 1992 is down from previous years.

Spiro Spiliopoulos

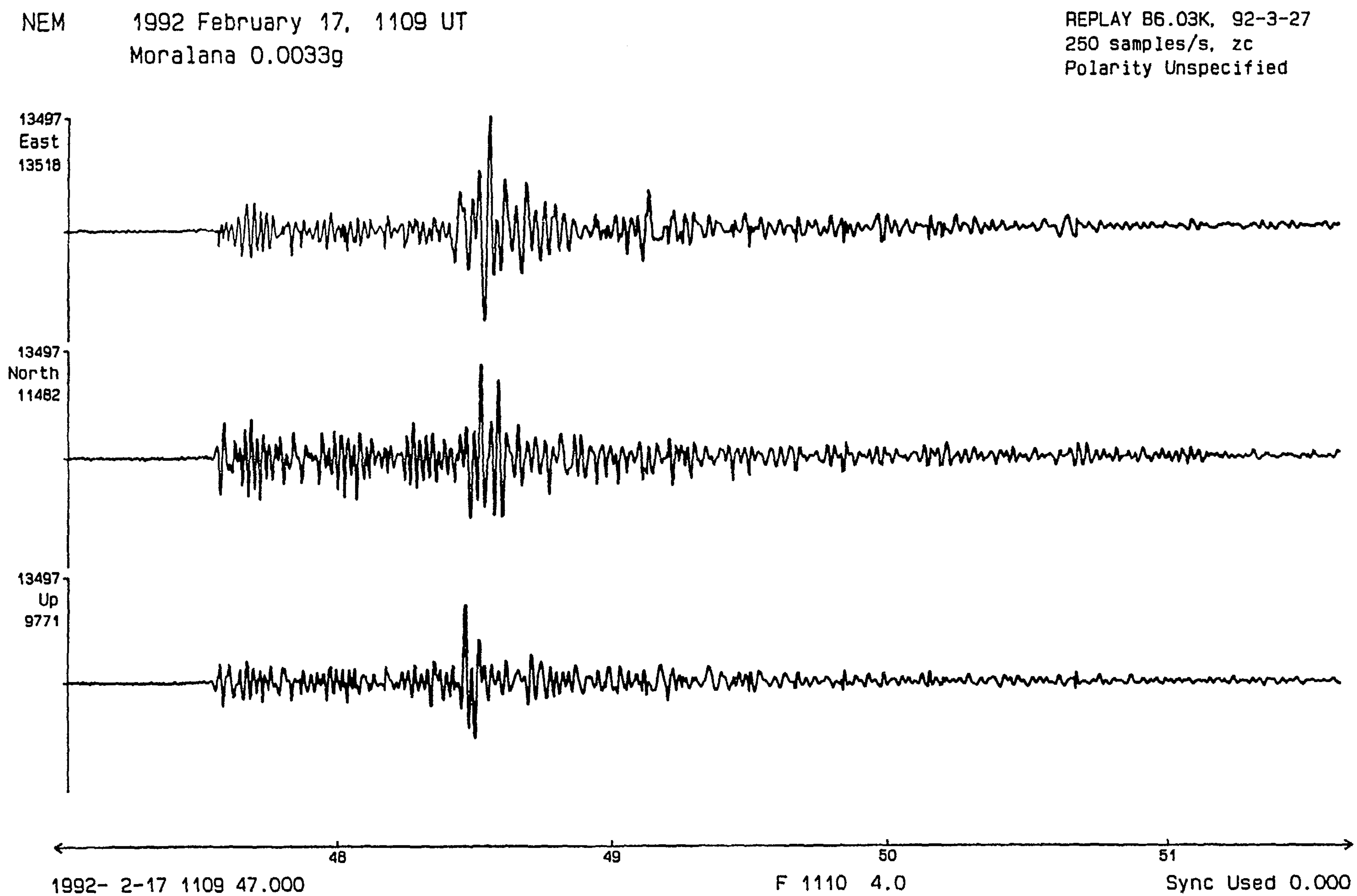


Figure 20 Accelerogram of the Moralana SA earthquake of 17 February 1992 recorded at 7 km from a magnitude ML 1.6 event. The ordinate scale is in counts, with 13497 counts corresponding to 0.0033g.

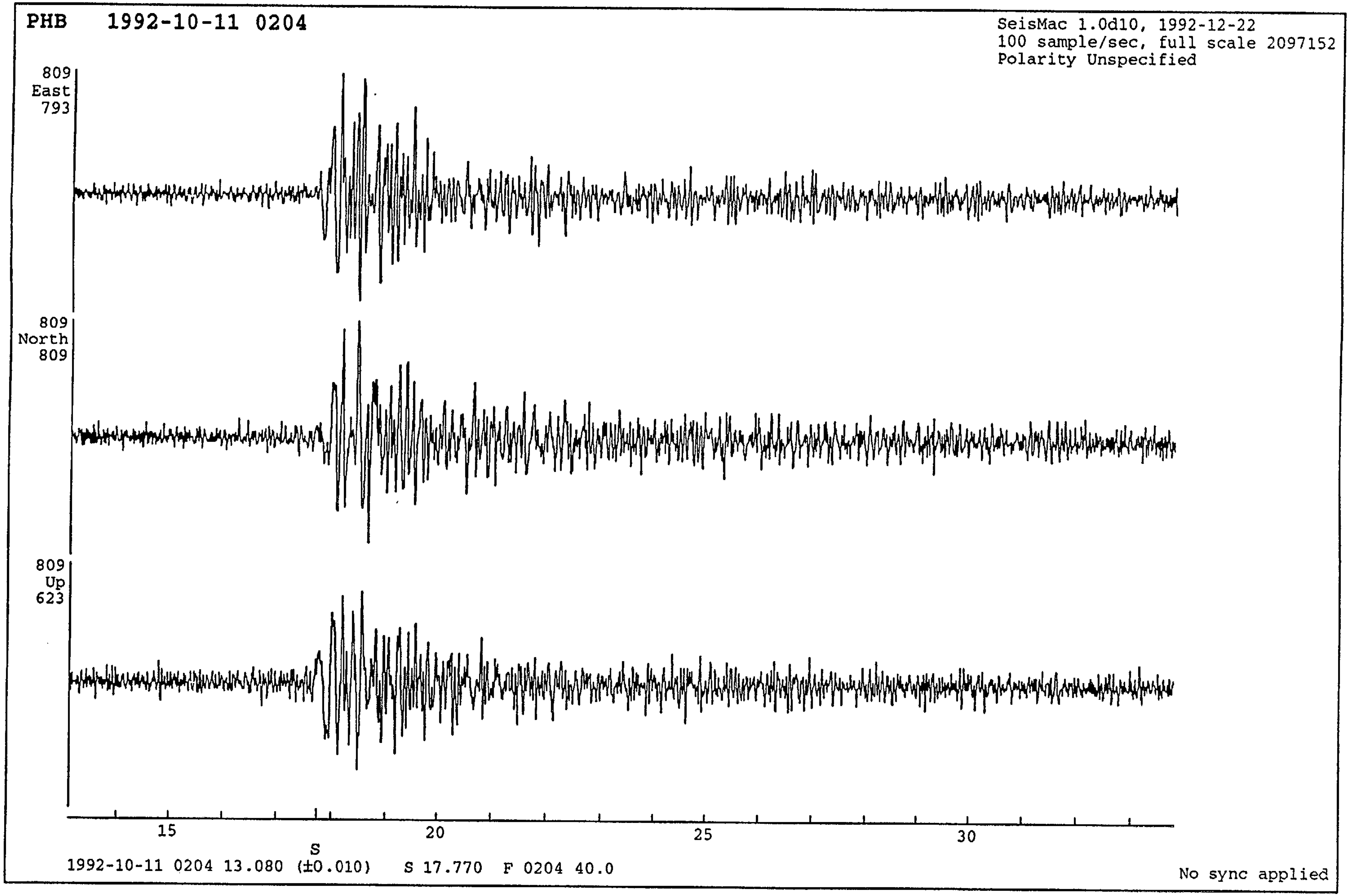


Figure 21 Accelerogram of the magnitude ML 3.7 Temora NSW earthquake of 11 October 1992 recorded in the basement of the new Parliament House in Canberra. The ordinate scale is in counts with 2097152 counts corresponding to 1g.

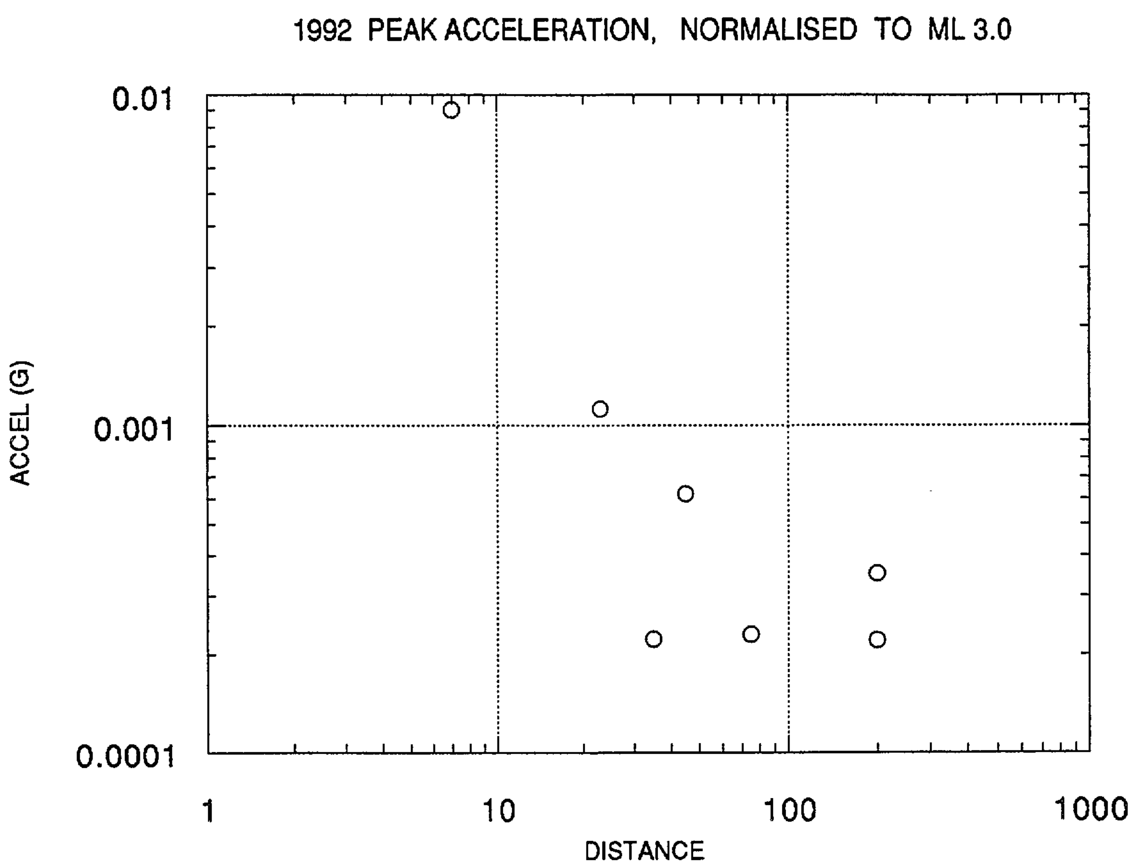


Figure 22 Acceleration data for 1992 normalised to magnitude ML 3.0.

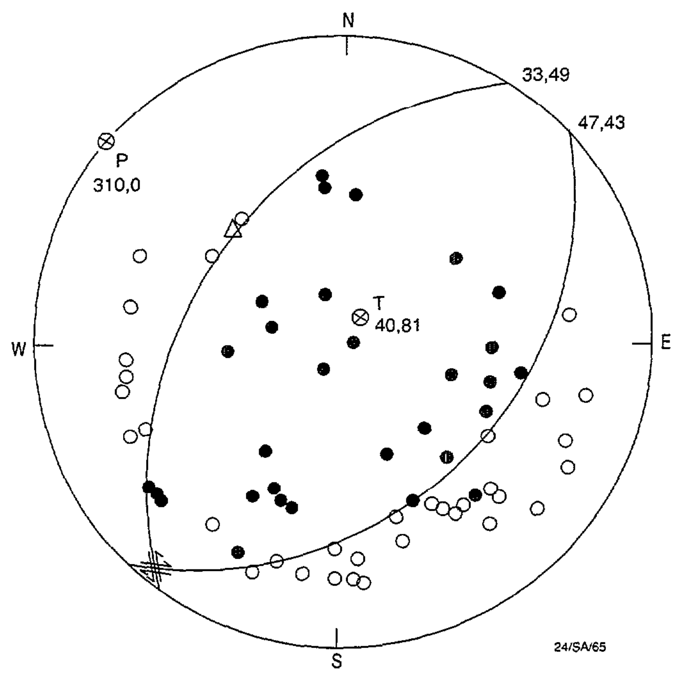


Figure 23 Focal mechanism of the Moralana SA swarm. Solid circles represent compressions and open circles dilatations.

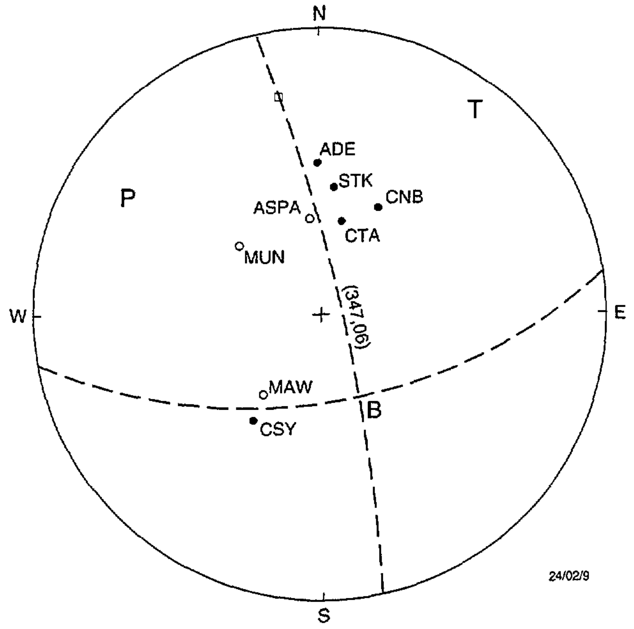


Figure 24 Focal mechanism of the George V fracture zone earthquake. Solid circles are compressions, open circles dilatations.

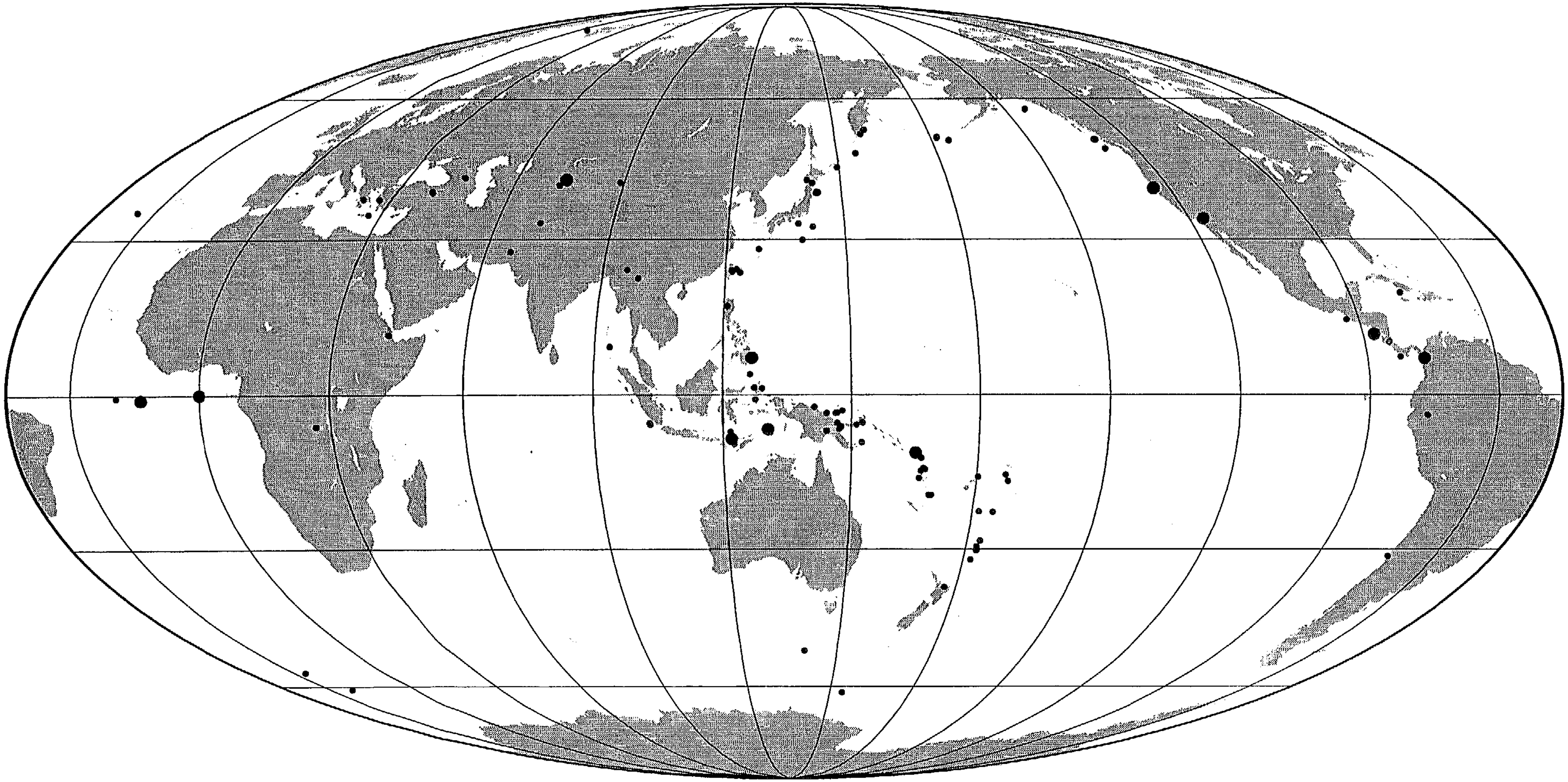


Figure 25 Principal world earthquakes, magnitude 6 or greater in 1992. Data extracted from the AGSO/ISC earthquake database (Lenz & others, 1992).

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TABLE 1. MAGNITUDE ML>2.9 EARTHQUAKES IN THE AUSTRALIAN REGION, 1992

SRCE #	UTC DATE year mo dy	TIME hr mn sec	LAT S	LONG E	DEPTH km		MAGNITUDE ML
MUN	1992- 1- 2	02 33 0.0	31.800	110.820	5		3.0
MUN	1992- 1- 4	07 14 0.0	32.000	117.280	5		3.3
BMR	1992- 1- 4	09 56 57.0	19.900	133.900	5		3.0
BMR	1992- 1-16	09 56 58.0	19.790	133.980	8		3.3
BMR	1992- 1-17	18 00 58.0	40.590	155.080	5		4.1
MUN	1992- 1-21	12 44 49.3	31.711	117.049	5		3.0
PIT	1992- 1-26	14 54 43.2	37.007	143.979	5		3.0
BMR	1992- 2-25	18 46 29.8	19.861	134.177	5		4.4
BMR	1992- 2-29	16 10 27.9	25.393	130.078	5	N	3.0
BMR	1992- 3-10	03 47 22.3	25.449	130.077	5		3.2
BMR	1992- 3-23	06 21 49.7	19.838	134.051	10		3.0
CAN	1992- 3-28	11 22 35.4	37.570	147.335	23		3.1
GSQ	1992- 3-29	22 11 8.4	22.263	153.811	8		3.1
MUN	1992- 4-16	08 01 0.0	24.420	116.690	5		3.2
BMR	1992- 4-17	12 08 10.6	19.804	133.622	12		4.2
MUN	1992- 4-18	20 40 0.0	17.380	123.330	5		3.6
MUN	1992- 4-26	08 21 0.0	25.370	129.910	5		3.0
BMR	1992- 4-28	21 02 26.7	36.862	144.063	3		3.1
MUN	1992- 4-28	21 34 0.0	27.840	116.610	5		3.0
BMR	1992- 5-23	09 19 30.2	19.900	133.800	2	N	3.1
BMR	1992- 5-27	10 17 12.2	33.004	138.467	6		3.2
BMR	1992- 5-29	16 39 12.4	19.900	133.800	2	N	3.1
MUN	1992- 6- 2	01 16 10.9	22.010	127.950	5	N	3.2
BMR	1992- 6- 5	21 29 47.0	37.770	146.390	3	N	3.0
BMR	1992- 6-11	19 14 6.1	33.180	138.430	5	N	3.1
BMR	1992- 6-13	18 05 21.3	23.660	130.050	16		4.5
MUN	1992- 6-14	15 29 4.0	21.470	129.440	5	N	3.1
MUN	1992- 6-25	19 59 19.8	23.550	113.130	5	N	3.2
MUN	1992- 7- 1	04 36 8.6	19.223	112.473	5		4.7
BMR	1992- 7- 2	18 45 50.2	34.759	149.185	4		3.1
MUN	1992- 7- 7	16 10 2.4	21.184	120.834	5		3.2
MUN	1992- 7-12	17 46 36.5	19.903	123.066	5		3.0
MUN	1992- 7-12	21 42 24.9	32.789	114.089	5		3.4
BMR	1992- 7-14	03 42 29.2	22.088	126.573	5		3.7
BMR	1992- 7-14	05 20 60.1	22.053	129.480	5		3.5
BMR	1992- 7-15	00 17 6.5	22.064	126.433	5		4.8
MUN	1992- 7-15	01 56 15.0	21.934	126.506	5		4.4
BMR	1992- 7-15	23 55 53.0	20.000	134.100	5		3.0
MUN	1992- 7-27	09 40 37.4	24.284	129.286	5		3.0
MUN	1992- 7-27	11 59 51.6	17.616	122.139	5		4.0
ADE	1992- 7-28	09 33 17.2	31.220	138.797	16		3.8
MUN	1992- 7-29	04 51 40.8	17.536	122.103	5		3.1
GSQ	1992- 7-30	08 23 0.0	19.444	149.609	5		3.1
MUN	1992- 8- 2	07 34 14.2	19.906	126.730	5		3.2
ADE	1992- 8-17	20 01 50.4	33.905	138.556	11		3.2
BMR	1992- 8-19	11 18 16.5	30.162	151.457	0	G	3.3
BMR	1992- 8-21	20 53 35.4	16.818	130.136	5	N	3.9
BMR	1992- 8-22	02 50 54.5	37.736	149.935	5	N	3.8
TAU	1992- 8-22	02 51 06.0	41.550	141.533			3.0
MUN	1992- 8-22	10 54 17.8	27.556	128.611	5		3.8
MUN	1992- 8-27	19 19 20.4	12.370	123.530	5		3.7
MUN	1992- 8-30	17 40 4.9	18.214	119.064	5		3.1
CAN	1992- 9- 2	10 51 47.4	33.750	150.003	17		3.2
BMR	1992- 9-23	19 26 26.0	19.750	133.490	5	N	3.1
BMR	1992- 9-30	11 18 7.2	11.354	134.573	39	N	5.1
BMR	1992-10- 1	07 47 6.5	19.901	134.004	5		3.1
BMR	1992-10- 5	03 21 43.7	19.866	134.107	0		3.0
ADE	1992-10-10	19 19 28.7	30.839	138.431	14		3.0
BMR	1992-10-11	02 03 26.6	34.352	147.463	17		3.7
MUN	1992-10-11	15 46 42.5	21.912	126.694	5		3.0

TABLE 1 (Continued)

SRCE #	UTC DATE year mo dy	TIME hr mn sec	LAT S	LONG E	DEPTH km	MAGNITUDE ML
MUN	1992-10-16	07 04 35.6	37.576	116.531	5	3.7
BMR	1992-10-17	14 44 47.0	19.800	134.000	5	3.1
BMR	1992-10-20	19 36 39.5	26.300	131.100	5	3.0
MUN	1992-10-21	21 42 43.0	15.170	121.850	5	3.2
BMR	1992-10-22	21 10 51.1	19.810	134.048	11	3.0
BMR	1992-10-24	01 38 21.5	19.876	134.023	4	3.0
MUN	1992-10-27	17 15 8.9	18.270	119.038	5	3.8
MUN	1992-10-31	12 25 18.1	22.015	126.518	5	3.9
ADE	1992-11- 1	21 00 58.5	28.828	136.968	15	3.3
MUN	1992-11- 2	21 19 53.6	14.677	128.644	5	3.2
ADE	1992-11- 4	21 12 46.2	33.037	138.976	6	3.1
BMR	1992-11- 6	06 37 38.6	24.904	136.387	20	3.0
BMR	1992-11- 8	01 40 24.9	38.853	143.699	5	3.3
MUN	1992-11- 9	05 36 18.1	18.202	119.275	5	3.4
BMR	1992-11-10	01 42 57.4	36.883	141.049	5	3.0
MUN	1992-11-16	21 04 56.0	17.034	127.206	5	3.2
BMR	1992-11-18	11 04 41.6	19.900	133.800	2	3.1
TAU	1992-11-19	21 49 23.7	41.000	154.717		3.6
MUN	1992-11-29	15 57 48.4	23.899	116.322	5	3.0
BMR	1992-12- 3	17 38 3.0	25.560	131.310	5	3.6
BMR	1992-12-12	05 02 15.4	34.367	148.725	5	3.5
ADE	1992-12-15	01 35 38.3	31.534	138.347	8	3.2
TAU	1992-12-16	02 13 55.6	41.050	145.467	5	3.0
BMR	1992-12-17	18 03 42.7	33.053	138.919	0	3.8
BMR	1992-12-29	20 20 57.1	25.404	129.870	0	4.0

Codes denote the contributors listed in the text, on page iii.
G,N indicate depth constrained, or set at normal depth, by the locating geophysicist.

TABLE 2. KNOWN LARGE AUSTRALIAN REGION EARTHQUAKES

UTC DATE year mo dy	TIME hr	mn	sec	LAT S	LONG E	DEPTH km	MAGNITUDE ML	Ms
1873-12-15	04	00	0.0	26.250	127.500	0G	6.2*	6.0
1884- 7-13	03	55	0.0	40.500	148.500	0	6.4I	
1884- 9-19	10	27	0.0	40.800	149.500	0	6.4I	
1885- 1- 5	12	20	0.0	29.000	114.000	0G	6.6*	6.5
1885- 5-12	23	37	0.0	39.900	148.900	0	6.8I	
1892- 1-26	16	48	0.0	40.400	149.500	0	6.9I	
1892- 1-26	16	56	0.0	40.400	149.500	0	6.0I	
1897- 5-10	05	26	0.0	37.333	139.750	0G	6.5I	
1902- 9-19	10	35	0.0	35.000	137.400	14G	6.0I	
1906-11-19	07	18	41.0	19.100	111.800	33	7.2*	7.2
1918- 6- 6	18	14	24.0	23.500	152.500	15	6.0	5.8
1920- 2- 8	05	24	30.0	35.000	111.000	33	6.3*	6.2
1929- 8-16	21	28	23.4	16.990	120.660	33	6.7*	6.6
1938- 4-17	08	56	22.0	25.500	137.200	0	6.0*	5.8
1941- 4-29	13	54	41.0	26.800	116.100	33	7.2	6.8
1941- 6-27	07	55	49.0	25.950	137.340	0R	6.0	6.6
1946- 9-14	19	48	50.1	39.970	149.350	0	6.0	5.4
1968-10-14	02	58	50.6	31.620	116.980	10R	6.9	6.8
1970- 3-24	10	35	17.6	22.050	126.610	0R	6.7	5.9
1979- 4-23	05	45	10.8	16.660	120.270	34	6.2I	5.7
1979- 6- 2	09	47	59.3	30.827	117.179	6R	6.2*	6.0
1983-11-25	19	56	7.8	40.451	155.507	19	6.0*	5.8
1986- 3-30	08	53	48.4	26.333	132.517	5	6.0*	5.8
1988- 1-22	00	36	1.1	19.812	133.975	6	6.4*	6.3
1988- 1-22	03	57	28.5	19.826	133.984	4	6.6*	6.4
1988- 1-22	12	05	0.6	19.838	133.994	5	6.8*	6.7

G,R: Depth constrained or set at normal depth by locating geophysicist

I: Magnitude determined by measurements on isoseismal radii

*: Local magnitude estimated from Ms

TABLE 3. SOME DAMAGING AUSTRALIAN EARTHQUAKES, 1950-1992

DATE	*PLACE*	*ML*	*DAMAGE A*	*DAMAGE B*
1954- 1- 3	Adelaide, SA	5.4	$8.8m	$68m
1961- 5-22	Robertson - Bowral, NSW	5.6	$0.5m	$3m
1968-10-14	Meckering, WA	6.9	$5.0m	$30m
1973- 3-10	Picton, NSW	5.5	$0.5m	$2m
1979- 6- 2	Cadoux, WA	6.2	$3.7m	$9m
1985- 2-13	Lithgow, NSW	4.0	$65k	$93k
1988- 1-22	Tennant Creek, NT	6.8	$1.1m	$1.2m
1989-12-28	Newcastle, NSW	5.6	$1.5b	$1.5b

Column 'A' is dollars at the time of the earthquake.
Column 'B' is in 1992 dollars.

Table 4. Australian Seismographic Stations, 1992

Code#	*Name*	*Lat °S*	*Long °E*	*Elev.m*	*Operator*	*Type**
Queensland						
AWD	Awoonga Dam	24.078	151.316	110	GSQ	1
BDM	Boondooma Dam	26.112	151.444	320	GSQ	1
BLO	Burdekin Lookout	20.625	147.121	234	GSQ	1,8
BLP	Blunder Park	17.76	145.42	650	GSQ	8
BRS	Mt Nebo Brisbane	27.392	152.775	525	QLD	5
BYFQ-	Byfield	22.820	150.626	80	UCQ	8
CCQ	Carron Creek	17.85	145.57	740	GSQ	8
CRC	Cracow	25.253	150.279	290	GSQ	1
CTAO	Charters Towers	20.088	146.255	357	QLD	2
DLB	Dalbeg	20.151	147.264	70	GSQ	1
DNG	Doongara	20.555	146.475	280	GSQ	1
DPT+	Dingo Pocket	17.913	145.823	100	GSQ	1
GCM2	German Ck Mine	22.98	148.55	136	UCQ	1
GLD	Glenlyon Dam	28.9694	151.4797	48	GSQ	1
HRD	H Road	17.76	145.65	260	GSQ	8
MCP	Mt Cooper	20.552	146.806	300	GSQ	1
MNH-	Munroe Hill	17.97	145.80	40	GSQ	8
MRVQ+	Maryvale Break	22.955	150.675	75	UCQ	1
MTMQ	Mt Morgan	23.763	150.390	170	UCQ	8
NWL	Newlands	21.221	147.868	290	GSQ	1
PFD	Peter Faust Dam	20.3858	148.3746	12	GSQ	1
QIS	Mount Isa	20.556	139.605	330	AGSO	1
QLP	Quilpie	26.584	144.235	210	AGSO	1
RMQ	Roma	26.489	148.755	360	AGSO	1
RVH	Ravenshoe	17.63	145.48	880	GSQ	1
SCY	Sunday Creek	17.88	145.34	690	GSQ	8
UCQ2	UCQ Campus	23.3287	150.5244	27	UCQ	1
UKA	Ukalunda	20.899	147.127	200	GSQ	1
WBA	Buaraba	27.353	152.308	100	GSQ	1
WCR	Cricket Road	27.520	152.455	100	GSQ	1
WMB	Mt Brisbane	27.115	152.550	160	GSQ	1
WPM	Pine Mountain	27.536	152.735	35	GSQ	1
WRC	Reedy Creek	27.187	152.663	190	GSQ	1
WTG	Toogoolawah	27.146	152.333	130	GSQ	1
WWH	Wivenhoe Hill	27.370	152.587	190	GSQ	1
Northern Territory						
ASPA	Alice Springs	23.667	133.901	600	AGSO	3
MTN	Manton Dam	12.847	131.130	80	AGSO	1
WRA	Warramunga	19.944	134.353	366	CAN	3
Western Australia						
BAL	Ballidu	30.607	116.707	300	MUN	1
COOL	Coolgardie	30.884	121.145	500	MUN	1
FORR-	Forrest	30.799	128.067	165	MUN	1
FORT	Forrest	30.779	128.059	165	MUN	1
KLB	Kellerberrin	31.578	117.760	300	MUN	1
KNA	Kununurra	15.750	128.767	150	PWD/MUN	1
MBL	Marble Bar	21.160	119.833	200	MUN	1
MEEK+	Meekatharra	26.6380	118.6150	530	MUN	1
MEKA-	Meekatharra	26.6150	118.5333	520	MUN	1
MRWA	Morawa	29.218	115.996	300	MUN	1
MUN	Mundaring	31.978	116.208	253	MUN	2
NANU	Nanutarra	22.562	115.529	800	MUN	1
NWAO	Narrogin	32.927	117.233	265	MUN	4

Table 4 (cont.)						
WARB	Warburton	26.184	126.643	460	MUN	1
RKG	Rocky Gully	34.570	117.010	300	MUN	1
NSW & ACT						
APN	Appin	34.171	150.823	277	PIT	8
ARMA	Armidale	30.4198	151.628	1.13	AGSO	1
AVD	Avon	34.376	150.615	532	PIT	8
BWA	Boorowa	34.425	148.751	656	CAN	1
CAH	Castle Hill	34.647	149.242	700	CAN	1
CAN	Canberra (ANU)	35.321	148.999	650	CAN	1
CBR	Cabramurra	35.943	148.393	1537	CAN	1
CMS	Cobar	31.487	145.828	225	AGSO	1
CNB	Canberra (AGSO)	35.314	149.362	855	AGSO	1
CPX	Mt Cotopaxi	34.476	150.625	622	PIT	8
DAL	Dalton	34.726	149.174	570	AGSO	1
DON	Donald's Castle Ck	34.359	150.713	401	PIT	8
IVY	Inveralochy	34.972	149.718	770	CAN	1
JNL	Jenolan	33.826	150.017	829	CAN	1
KBH	Kambah	35.390	149.080	600	AGSO	1
FTZ	Fitzroy Falls	34.625	150.484	711	PIT	8
GRV	Greaves Creek	33.662	150.309	980	PIT	8
JBD	Jenolan	33.762	150.049	1235	PIT	8
LBX	Letterbox	34.272	150.874	400	PIT	8
MEG	Meangora	35.101	150.037	712	CAN	1
NAT	Nattai	34.206	150.427	632	PIT	8
NLD	North Lambton	32.9003	151.7009	50	NCC	8
NPSD	Newcastle Police	32.931	151.786	20	ASC	8
PHD	Pipehead Depot	33.847	150.969	90	PIT	8
QFS	Quorrobolong	32.933	151.396	14	ASC	8
RIV	Riverview	33.829	151.159	21	RIV	2
STK	Stephens Creek	31.882	141.592	213	AGSO	7
WER	Werombi	33.950	150.580	226	CAN	1
YOU	Young	34.278	148.382	503	CAN	1
South Australia						
ADE/ADT	Adelaide	34.967	138.713	655	ADE	2
ARK	Arkaroola	30.276	139.339	520	ADE	1
CLV	Cleve	33.691	136.495	238	ADE	1
GEX	Naracoorte	37.0735	140.8251	80	ADE	1
HTT	Hallett	33.430	138.921	708	ADE	1
HWK	Hawksnest	29.958	135.203	180	ADE/AGSO	1/8
KHC	Kelly Hill Caves	35.9825	136.9111	100	ADE	1
MGR2	Mt Gambier	37.8011	140.6865	60	ADE	1
NBK	Nectar Brook	32.701	137.983	180	ADE	1
PDA+	Parndana	35.8059	137.2389	140	ADE	8
PNA	Partacoona	32.006	138.165	180	ADE	1
RPA	Roopena	32.725	137.403	95	ADE	1
SDN	Sedan	34.5093	139.3374	125	ADE	8
THS	The Heights HS	34.7416	138.7733	340	ADE	1
WKA	Willalooka	36.417	140.321	40	ADE	1
WRG	Woomera	31.105	136.763	168	ADE	1
Victoria						
ABE	Aberfeldy	37.719	146.389	549	PIT	1
BEL	Bell's Track	37.761	146.389	545	PIT	1
BFD	Bellfield	37.177	142.545	235	AGSO	1
BUC	Bucrabanyule	36.238	143.498	210	PIT	1
CRN	Cairn Curran	36.991	143.972	230	PIT	8

Table 4 (Cont.)

DRO	Dromana	38.360	144.997	170	PIT	1
DTM/DTT	Dartmouth	36.529	147.469	436	PIT	8
FRT	Forrest	38.534	144.997	210	PIT	1
GOG	North Grampians	36.888	142.400	265	PIT	8
GVL	Greenvale	37.619	144.901	188	PIT	1
HOP	Mount Hope	35.995	144.207	300	PIT	1
JEN	Jeeralang Junction	38.351	146.420	330	PIT	1
KOWA	Kowarra	35.791	144.521	85	PIT	1
MAL	Marshall Spur	37.749	146.292	1076	PIT	1
MEM	Merrimu	37.637	144.497	160	PIT	1
MCV	McVeigh	37.691	145.899	630	PIT	1
MIC	Mount Erica	37.944	146.359	805	PIT	1
TOT	Thompson Dam	37.8423	146.4057	680	PIT	8
MLW	Molesworth	37.137	145.510	280	PIT	1
PAT	Plane Track	37.857	146.456	771	PIT	1
PEG	Pegleg	36.985	144.091	340	PIT	1
POL	Poley Tower	37.626	145.801	1200	PIT	1
PNH	Panton Hill	37.635	145.271	180	PIT	1
RUS	Rushworth	36.662	144.947	145	PIT	1
SIN	Swingler Track	37.739	146.292	980	PIT	8
TMD	Thomson Dam	37.810	146.349	941	PIT	1
TOM	Thomson	37.810	146.348	941	PIT	1
TOO	Toolangi	37.572	145.490	604	AGSO	5
TYR	Tyers	38.1083	146.4354	280	PIT	1
UYB	Upper Yarra	37.673	145.897	300	PIT	1
VPE	Vantage Point	37.642	145.937	650	PIT	1
WSK	Woodstock	36.814	144.055	210	PIT	1
Tasmania						
MOO	Moorlands	42.442	147.190	325	TAU	1
SAV	Savannah	41.721	147.189	180	TAU	1
SFF	Sheffield	41.337	146.307	213	TAU	1
SPK	Scotts Peak	43.038	146.275	425	TAU	1
STG	Strathgordon	42.751	146.053	350	TAU	1
SVR	Savage River	41.489	145.211	360	TAU	1
TAU	Tasmania Uni	42.910	147.321	132	TAU	2
TRR	Tarraleah	42.304	146.450	579	TAU	1
MCQ	Macquarie Is.	54.498	158.957	14	AGSO	1/6
Antarctica						
CSY	Casey	66.2894	110.5289	56	AGSO	1
MAW	Mawson	67.607	62.872	15	AGSO	5/7
MCQ	(see Tasmania)					

Refers to contributors listed on page iii.

* Type of seismograph
1. Short period (vertical and/or horizontal); 2. World Wide Standardised Seismographic Station (WWSSN); 3. Seismic array; 4. Seismological research observatory (SRO); 5. Long and short period; 6. Broad-band vertical ; 7. Broad-band triaxial; 8 Kelunji digital triaxial triggered.

+/- Opened/closed this year

Table 5. Australian accelerographs, 1992

Location	*Lat °S*	*Long °E*	*Elev (m)*	*Foundation*	*Type*	*Owner*
ACT						
ASC-AGSO	35.289	149.139	560	Soil	PIT	AGSO
Parliament House	35.310	149.123	600	Sandstone	PIT	AGSO
Corin Dam (2)	35.524	148.812	915	Granite	PIT	ACTE&W
Lower Cotter Dam	35.308	148.908	535	Basalt	PIT	ACTE&W
Telecom Tower (3)	35.275	149.096	810	Sandstone	PIT	TEL
New South Wales						
Avon (AVD)	34.376	150.615	532	Sandstone	PIT	NSWWB
Cataract bedrock CTB	34.265	150.811	322	Sandstone	PIT	NSWWB
Cataract Dam (CTD)	34.267	150.802	294	Concrete dam	PIT	NSWWB
Oolong (OOL)	34.773	149.163	600	Weathered granite	SMA-1	AGSO
Ferndale (FND)	34.745	149.166	580	Granite	PIT	AGSO
Fitzroy Falls (FTZ)	34.625	150.484	711	Sandstone	PIT	NSWWB
Springfield (SPF)	34.765	149.151	580	Granite	PIT	AGSO
Wilton (WIL)	34.800	149.221	660	Granite	PIT	AGSO
Googong Dam (2)	35.425	149.264	620	Meta-sediments	PIT	ACTE&W
Hume Weir (3)	36.110	147.043	600	Dam wall	SMA-1	DWR
Hume Weir	36.110	147.043	329	Downstream bank	SMA-1	DWR
Hume Weir	36.110	147.043	600	Left hand abutment	SMA-1	DWR
Jenolan (JBD)	33.672	150.049	1235	Palaeozoic dacite	PIT	NSWWB
Lucas Heights LHB	34.052	150.979	80	Sandstone	PIT	ANSTO
Lucas Heights LHR	34.05	150.98	80	Reactor Building	PIT	ANSTO
Newcastle Police Stn NPSD+	32.931	151.786	20	Building basement	PIT	AGSO
Pipehead Depot (PHD)	33.847	150.969	90	Sandstone /shale	PIT	NSWWB
Water Board Office	33.876	151.207	90	Multi-storey bldg	PIT	NSWWB
Warragamba dam abutment WDA	33.883	150.593	180	Sandstone	PIT	NSWWB
Warragamba dam base WDB	33.885	150.594	30	Concrete dam	PIT	NSWWB
Warragamba Dam Centre (WDC)	33.885	150.594	60	Concrete dam	PIT	NSWWB
Warragamba Dam Top WDT	33.885	150.594	100	Concrete dam	PIT	NSWWB
Warragamba bedrock WGB	33.866	150.575	254	Concrete dam	PIT	NSWWB
Yerranderie (YER)	34.142	150.232	554	Sandstone	PIT	NSWWB
South Australia						
Kangaroo Ck Dam	34.87	138.78	244	Slates/schists	MO2	EWSSA
Little Para Dam	34.75	138.72	102	Dolomite	MO2	EWSSA
Modbury Hospital	34.83	138.70	50	Marl & clay	MO2	PWDSA
Admin. Centre	34.925	138.608	50	Alluvium	MO2	PWDSA
Tasmania						
Gordon Dam	42.71	145.97	350	Quartzite	MO2	HEC
Victoria						
Jeeralang JNA	38.351	146.419	330	Mesozoic sediments	PIT	PIT
Plane Track PTA	37.357	146.357	771	Palaeozoic sediments	PIT	PIT

Table 5 (cont.)

Bradford Hills BRD	36.892	144.099	284	Granite	PIT	PIT
Phillip Institute PIT	37.683	145.061	116	Eocene sediments	PIT	PIT
Dartmouth Dam DDC	36.561	147.524	494	Dam crest	PIT	RWCV
	36.570	147.580	520	Hoist house	SMA-1	RWCV
Dartmouth Dam DDB	36.558	147.511	329	Ordivician meta-sediments	PIT	RWCV
	36.570	147.580	420	Downstream face	SMA-1	RWCV
	36.570	147.580	360	Access tunnel	SMA-1	RWCV
Animal Health Lab(3)	38.15	144.39	10		SMA-1	CSIRO
Thomson Dam (TMT)	37.844	146.396	460	Outlet Tower	PIT	MMBW
Northern Territory						
Tennant Creek TCTY	19.642	134.183	370	Sediments	SSA-1	PIT
Queensland						
Wivenhoe Dam	27.394	152.602	80	Crest	A700	BAWB
	27.395	152.603	28	Base	A700	BAWB
	27.347	152.631	78	Power Station	A700	QEC
	27.375	152.631	78	Power Station	A700	QEC
Splityard Ck. Dam	27.379	152.641	170	Dam Wall	A700	QEC
	27.375	152.641	65	Valve room	A700	QEC
Tully Millstream	17.76	145.42	65		PIT	QEC
	17.85	145.57	74		PIT	QEC
Western Australia						
Cadoux (CAK)	30.718	117.141	380	Granite	MO2	AGSO
Cadoux (CAA)	30.746	117.151	320	Laterite/ Granite	A700	AGSO
Cadoux (CAR)	30.781	117.138	360	Weathered granite	MO2	AGSO
Cadoux (CAS)	30.810	117.132	400	Weathered granite	MO2	AGSO
Canning Dam						
Lower gallery (CDL)	32.154	116.126	142	Granite	A700	WAWA
Upper gallery (CDU)	32.154	116.126	202	Granite	A700	WAWA
Goomalling (GOO)	31.394	116.852	250	Granite	PIT	AGSO
Kununurra						
Dam abutment KNA	16.113	128.737		Phyllite	A700	WAWA
Dam wall KNW	16.113	128.738		Rock fill, 3m clay core	A700	WAWA
Meckering MEK	31.694	116.982	200	Alluvium	MO2	AGSO
Mundaring Weir						
Weir MUW	31.958	116.164	140	Concrete wall 42m high	SMA1	WAWA
Museum MUC	31.957	116.162	106	Concrete floor	MO2	WAWA
North Dandalup NDD	32.52	116.01	205	Granite	A700	WAWA
Serpentine Dam						
Basement SEB	32.40	116.10		Granite	A700	WAWA
Wall SEW	32.40	116.10		Earthfill	A700	WAWA
Victoria Dam VID	32.04	116.06		Granite	A700	WAWA

ANSTO Australian Nuclear Science & Technology Organisation; BAWB Brisbane and Area Water Board; AGSO Australian Geological Survey Organisation, Canberra/Mundaring; EWSSA Engineering & Water Supply Department, South Australia; E&W ACT Electricity and Water Authority;
HEC Hydroelectric Commission, Tasmania; MMBW Melbourne & Metropolitan Board of Works;
PIT Seismology Research Centre, RMIT; PWDSA Public Works Department, South Australia;
PWDWA Public Works Department, Western Australia; QEC Queensland Electricity Commission;
TEL Telecom (ACT & Perth); RWCV Rural Water Commission, Victoria;
DWR Department of Water Resources, NSW; WAWA Water Authority of Western Australia.

Table 6. Principal world earthquakes, 1992

(Earthquakes of magnitude 7.0 or greater, or causing fatalities or substantial damage).
PAS Pasadena, BRK Berkeley, PMR Palmer, Alaska, PAL Palisades, New York, JMA Japan Meteorological Agency, TRI Trieste, NEIS US Geological Survey)*.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
13 Feb	01 29 13.1	Vanuatu Islands	15.894 S	166.318 E	6.1 mb, 6.8 Ms 7.1 Ms (BRK)

Depth 10 km. Felt at Port Vila.

14 Feb	17 28 23.0	Republic of Sth Africa	26.420 S	27.430 E	3.4 mblg(BUL)

Depth 5 km. Four people killed and 4 others injured at the Western Deep Levels South Mine near Carltonville.

04 Mar	11 57 53.0	Northern Iran	31.726 N	50.778 E	4.9 mb, 4.6 Ms

Depth 18 km. At least 6 people killed, 50 injured and 300 homes destroyed in the Lordegan-Ardal area. Landslides blocked roads in the epicentral region.

07 Mar	01 53 37.7	Costa Rica	10.210 N	84.323 W	6.2 mb 5.6 MD (SJR) 5.6 MD (UPA)

Depth 79 km. One person died of a heart attack and damage at San Jose. Felt strongly throughout Costa Rica. Felt (III) at Changuinola and David, Panama.

13 Mar	17 18 39.9	Turkey	39.710 N	39.605 E	6.2 mb, 6.8 Ms 6.9 Ms (BRK)

Depth 27 km. At least 498 people killed, 2,000 injured, some missing. 2,200 houses heavily damaged at Erzincan. Landslides and avalanches blocked a number of roads in the epicentral area. Felt strongly in many parts of northeastern Turkey.

13 Apr	01 20 00.8	The Netherlands	51.153 N	5.798 E	5.5 mb, 5.2 Ms 5.9 ML (BNS) 5.9 ML (UCC) 5.8 ML (STR) 5.8 ML (BGS) 5.5 ML (LDG) 5.8 MD (VIE)

Depth 21 km. One person died of a heart attack at Bonn, Germany. Twenty people injured and some buildings damaged (VIII) at Roermond, Netherlands and 25 people injured and some buildings damaged (VII) at Heinsberg, Germany. Damage also reported at Bonn and Koln, Germany and in Limburg Province, Belgium. Felt strongly in many parts of northwestern Germany, eastern Belgium and southern Netherlands. Felt in northeastern France. Also felt throughout much of southeastern England and in the Liverpool-Manchester area, United Kingdom.

25 Apr	18 06 04.2	Nr Coast of Northern California	40.368 N	124.316 W	6.3 mb, 7.1 Ms

Depth 15 km. Ninety eight people injured and considerable damage in southwestern Humboldt County. Preliminary estimate of damage in this area from the series of earthquakes is 66 million U.S. dollars. Maximum intensities (VIII) at Ferndale, Honeydew, Petrolia, Rio Dell and Scotia. (VII) at Fortuna and Loleta. (VI) at Eureka. Landslides and rockfalls occurred in the Honeydew-Petrolia area. Liquefaction was noted in areas of the Eel and Mattole River Valleys. Felt throughout much of northern California as far south as San Francisco and southeast to Carson City and Reno, Nevada. Also felt in many areas of southern Oregon. Strong-motion records indicate peak horizontal accelerations of 1.3g at Cape Mendocino and 0.69g at Petrolia. A tsunami was generated with maximum wave heights (peak-to-trough) of 1.1m at

Table 6 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude

Crescent City, 0.2 m at Arena Cove and 0.17 m at Pt Reyes, California: 0.2 m at Port Orford, Oregon: 0.15 m at Kahului and 0.1 m at Hilo, Hawaii.

12 May	18 05 42.6	Samoa Islands Region	16.524 S	172.367 W	6.4 mb, 6.8 Ms 7.0 Ms (BRK)

Depth 15 km. Felt in American Samoa and Western Samoa.

15 May	07 05 05.3	Eastern New Guinea Region	6.075 S	147.572 E	6.2 mb 7.1 Ms (BRK)

Depth 58 km. Slight damage at Lae.

15 May	08 08 02.9	Kyrgyzstan	41.019 N	72.429 E	5.7 mb, 6.2 Ms

Depth 50 km. Three people killed, 5,500 houses completely destroyed and more than 4,000 houses damaged (VII) in the Osh area. Felt (VI) at Andizan, (V) at Fergana, (IV) at Namangan and (III) at Tashkent. Also felt (III) at Dzhambul and (II) at Chimbent and Alma-Ata. Landslides reported at Uzgen.

17 May	09 49 19.1	Mindanao, Philippine Islands	7.239 N	126.645 E	6.2 mb, 7.1 Ms 7.0 Ms (BRK)

Depth 33 km. Felt (V RF) at Bislig, (IV RF) at Cagayan de Oro, (III RF) at Palo and (II RF) at Mactan.

17 May	10 15 31.3	Mindanao, Philippine Islands	7.191 N	126.762 E	6.4 mb, 7.5 Ms 7.5 Ms (BRK)

Depth 33 km. Some minor damage at Tandag and Bislig. Felt (V RF) at Cagayan de Oro, (III RF) at Palo and (II RF) at Mactan. Small tsunami generated.

20 May	12 20 32.8	Pakistan	33.377 N	71.317 E	6.0 mb, 6.0 Ms

Depth 16 km. At least 36 people killed and 100 injured in the Peshawar and Kohat Districts, including 20 people killed at Shakkar Khel. At least 400 houses destroyed in the Kohat District. Felt at Islamabad and Lahore. Also felt in the Srinagar area, Kashmir and in part of northern India.

25 May	16 55 04.1	Cuba Region	19.613 N	77.872 W	6.3 mb, 6.9 Ms 7.0 Ms (BRK)

Depth 23 km. Forty people injured and more than 820 buildings damaged in the Pilon-Manzanillo area. Felt at Guantanamo and in most of eastern Cuba as far away as Sancti Spiritus. Also felt on Jamaica.

27 May	05 13 38.8	Santa Cruz Islands	11.122 S	165.239 E	6.3 mb, 7.0 Ms 7.3 Ms (BRK)

Depth 19 km. Felt strongly at Lata Station, Santa Cruz. A small tsunami was observed.

28 Jun	11 57 34.1	Southern California	34.201 N	116.436 W	6.2 mb, 7.6 Ms

Depth 1 km. One person was killed at Yucca Valley. Two people died of heart attacks; more than 400 people were injured and substantial damage occurred in the Landers-Yucca Valley area. Maximum intensity IX. Preliminary estimate of damage for this earthquake plus the following magnitude 6.7 event at 1505 UTC is 92 million U.S. dollars. Felt throughout southern California, southern Nevada, western Arizona and southern Utah. Felt in high-rise buildings as far north as Boise, Idaho and as far east as Albuquerque, New Mexico and Denver, Colorado. Surface faulting observed along a 70 kilometer segment from Joshua Tree to near Barstow with as much as 5.5 metres of horizontal displacement and as much as 1.8 meters of vertical displacement. Seiches were reported as far north as Lake Union, Washington and as far east as Aurora, Colorado and Corpus Christi, Texas.

Table 6 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
18 Jul	08 36 58.7	Off East Coast of Honshu, Japan	39.419 N	143.330 E	6.2 mb, 6.9 Ms 7.0 Ms (BRK)

Depth 29 km. Felt (III JMA) at Aomori, Hachinohe, Ishinomaki, Miyako, Sakata and Sendai; (III JMA) at Akita and Fukushima; (I JMA) at Kofu, Tokyo, Tateyama and Utsunomiya, Honshu. Also felt (II JMA) at Kushira, Nemuro and Obihiro, Hokkaido, Japan. Tsunami generated with maximum wave heights (peak-to-trough) 46 cm at Ofunato; 42 cm at Miyako; 28 cm at Aikawa and 24 cm at Hachinohe.

19 Aug	02 04 37.4	Kyrgzstan	42.142 N	73.575 E	6.6 mb, 7.4 Ms 7.5 Ms (BRK)

Depth 27 km. An estimated 75 people killed, including 14 killed by landslides in Toluk. Several villages, including Toluk were destroyed (IX) in the Susamyrtau Mountains and at least 8,200 dwellings were destroyed. Felt (VII) at Andizhan, Chimion and Namangan, Uzbekistan. Structural damage (VI) occurred to buildings at Bishkek, Kyrgzstan. Felt (VI) at Angren, Fergana and Tashkent, Uzbekistan and at Osh, Kyrgyzstan. Also felt (VI) at Alma-Ata, Kazakhstan; (V) at Samarkand and Yangiyul, Uzbekistan and Khodzhent, Tajikistan; (IV) at Dushanbe, Kulyab, Nurek and Pendzhikent, Tajikistan and Naryn, Kyrgyzstan; (III) at Cholpon-Ata and Przhevalsk, Kyrgyzstan. Elevation changes of up to 4 meters observed in the Susamyr Valley. Liquefaction occurred in the epicentral area.

28 Aug	00 50 50.4	Pakistan	29.087 N	66.740 E	5.5 mb, 5.5 Ms

Depth 9 km. At least four people killed, several injured and many houses destroyed in Kalat area. Felt at Khuzdar, Manguchar, Mastung and Quett.

02 Sep	00 15 57.5	Near Coast of Nicaragua	11.761 N	87.419 W	5.3 mb, 7.2 Ms

Depth 10 km. At least 116 people killed and 68 missing, 1,143 houses and 185 fishing boats destroyed along a 250 km strip of the west coast of Nicaragua. Some damage was also reported in Costa Rica. Most of the casualties and damage were caused by a tsunami affecting the west coasts of Nicaragua and Costa Rica, reaching heights of up to 8 meters. Tsunami run-up of 1,000 meters was reported at Masachapa, where at least 15 of the people were killed. Maximum wave heights (in cm. peak-to-trough) at selected tide stations were as follows: 111 at Baltra Island, 83 at Easter Island, 28 at Socorro Island, 18 at La Libertad, Ecuador, 10 at Valparaiso, Chile and 10 at Hilo, Hawaii. Felt in Chinandega and Leon Department, Nicaragua. Also felt at El Crucero, Managua and San Marcos, Nicaragua and at San Jose, Costa Rica.

08 Sep	00 38 14.3	Southern Iran	29.127 N	52.098 E	5.1 mb, 4.6 Ms

Depth 10 km. One person killed and 11 injured in Firuzabad area. Also 200 houses and 3 bridges were destroyed and landslides blocked roads in the epicentral region. Damage reported at Bonu, Darenjan, Giah Zar and Meygoli. Felt at Kazerun and Shiraz.

11 Sep	03 57 26.2	Zaire	6.091 S	26.680 E	6.7 mb, 6.5 Ms

Depth 10 km. Eight people killed, 37 injured and several buildings destroyed at Kabalo. Felt at Bujumbura, Burundi.

12 Oct	13 09 56.3	Egypt	29.888 N	31.223 E	5.9 mb, 5.2 Ms 5.3 MD (HLW)

Depth 25 km. At least 541 people killed, more than 6,500 injured and about 8,300 buildings damaged or destroyed in the Cairo area. Preliminary estimates of damage about 300 million dollars. Felt in much of Egypt from Alexandria to Aswar and in Israel from Elat to Tel Aviv and Jerusalem.

17 Oct	08 32 39.9	Northern Colombia	6.866 N	76.816 W	6.2 mb, 6.7 Ms 7.0 Ms (BRK)

Table 6 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude

Depth 10 km. About 20 people injured and 90 percent of the buildings destroyed in Murindo. Felt throughout northwestern Colombia from Cali and Bogota to Cesar Department.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
18 Oct	15 11 59.3	Northern Colombia	7.123 N	76.887 W	6.6 mb, 7.3 Ms 7.4 Ms (BRK)

Depth 10 km. One person killed, 50 injured and damage in the Murindo-Apartado-Medellin area. At least ten people killed, 65 injured and 1,500 homeless by the explosion of a mud volcano in the San Pedro de Uraba area. Slight damage at Bogota. Felt in much of northwestern Colombia as far south as Cali. Felt strongly in Darien Province, Panama. Also felt (IV) on the Azuero Peninsula and at Panama City, Panama. Felt at Caracas and Valencia, Venezuela. Also felt on Aruba. Landslides occurred in the epicentral area. Liquefaction was observed in the Murindo area and as far north as Apartado. A small island emerged from the Caribbean Sea off San Juan de Uraba.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
22 Oct	09 04 24.9	Kermadec Islands, New Zealand	29.997 S	177.276 W	6.0 mb, 6.6 Ms 7.2 Ms (BRK)

Depth 33 km. Felt (IV) on Raoul Island.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
22 Oct	17 38 58.3	Egypt	29.513 N	31.473 E	4.5 mb, 3.4 Ms 4.2 MD (HLW) 4.1 MD (RYD)

Depth 10 km. Four people killed and at least 50 injured in the Cairo area.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
23 Oct	09 11 08.9	Morocco	31.347 N	4.331 W	5.2 mb, 5.2 Ms 5.2 MD (RBA)

Depth 28 km. At least 2 people killed at Rissani. Felt throughout much of Morocco from Fes to Marrakech.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
23 Oct	23 19 47.2	Eastern Caucasus	42.503 N	45.073 E	6.2 mb, 6.5 Ms 6.8 Ms (BRK)

Depth 33 km. At least one person killed, 10 injured and several houses damaged in the Barisakho, Georgia area. Landslides reported in the epicentral area.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
02 Nov	15 13 25.7	Switzerland	46.739 N	8.316 E	4.2 mb 4.0 ML (GRF) 3.8 ML (LDG) 3.7 ML (VIE) 3.4 ML (ROM)

Depth 0 km. Six people killed by the accidental explosion at an ammunitions cavern.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
12 Dec	05 29 27.1	Flores Region, Indonesia	8.482 S	121.930 E	6.5mb, 7.5 Ms

Depth 36 km. At least 2,200 people killed or missing in the Flores region, including 1,490 at Maumere and 700 on Babi. More than 500 people were injured and 40,000 left homeless. 19 people were killed and 130 houses destroyed on Kalaotoa. Severe damage, with approximately 90 percent of the buildings destroyed at Maumere by the earthquake and tsunami: 50 to 80 percent of the structures on Flores were damaged or destroyed. Damage also occurred on Sumba and Alor. Tsunami run-up of 300 meters with wave heights of 25 meters was reported on Flores along with landslides and ground cracks at several locations around the island. Felt (V) at Larantuka, Flores: (IV) at Waingapu, Sumba and Ujung Pandang, Sulawesi: (III) at Kupang, Timor.

TABLE 7. **Crustal Models used in Australia**

QUEENSLAND NEQ

Depth	Vp	Vs
	4.5	2.9
1		
	5.94	3.4
17		
	6.62	3.6
40		
	7.82	3.95

QUEENSLAND SEQ

Depth	Vp	Vs
	5.85	3.3
17.0		
	6.67	3.8
37.0		
	7.95	4.6

QUEENSLAND BFQ

Depth	Vp	Vs
	5.0	2.85
4		
	6.0	3.4
19		
	6.7	3.8
35		
	8.1	4.6

VICTORIA VIC5A

Depth	Vp	Vs
	5.12	3.13
3.63		
	6.01	3.57
8.46		
	6.04	3.59
17.17		
	6.45	3.69
35.61		
	7.81	4.46

NSW DAL1A

Depth	Vp	Vs
	5.80	3.35
10.5		
	6.30	3.64
26.5		
	6.90	3.98
31.0		
	7.35	4.24
50.0		
	8.08	4.66

NT TC1A

Depth	Vp	Vs
	5.47	3.34
2.8		
	6.06	3.56
6.0		
	6.20	3.65
21.0		
	6.85	3.96
27.0		
	7.30	4.22
50.5		
	8.70	4.61

SOUTH AUSTRALIA SA1A

Depth	Vp	Vs
	6.23	3.58
38.0		
	8.05	4.60

TASMANIA

Depth	Vp	Vs
	5.95	3.48
38.0		
	8.05	4.60

WESTERN AUSTRALIA WA2

Depth	Vp	Vs
	6.13	3.62
19.0		
	7.14	3.96
36.5		
	8.27	4.75

NEQ NORTH EAST QUEENSLAND
SEQ SOUTH EAST QUEENSLAND
BFQ BURDEKIN FALLS QUEENSLAND

VP P WAVE VELOCITY, KM/SEC
VS S WAVE VELOCITY, KM/SEC

TABLE 8. PRESUMED UNDERGROUND NUCLEAR EXPLOSIONS, 1992

Origin Time	*Magnitude (m)*	*Yield (kT)*	*Site*	*Comments+*
1992 03 26 16:30:00.0	5.5	40-150	Nevada Test Site, USA	Junction (PDE)
1992 04 30 16:30:00.0	--	0-10	Nevada Test Site, USA	Diamond Fortune (APTA)
1992 05 21 04:59:57.0	6.5	200-800	Lop Nor, China	(PDE)
1992 06 19 16:45:00.0	M_L 3.0	0-10	Nevada Test Site, USA	Victoria(PDE)
1992 06 23 15:00:00.0	M_L 3.9	0-10	Nevada Test Site, USA	Galena (PDE)
1992 09 18 17:00:00.0	4.4	0-10	Nevada Test Site, USA	Hunters Trophy (PDE)
1992 09 23 15:04:00.0	4.4	0-10	Nevada Test Site, USA	Divider (PDE)
1992 09 25 07:59:58.3	5.0	0-10	Lop Nor, China	(PDE)

+PDE - Preliminary Determination of Epicentres
APTA - American Peace Tests Alert

APPENDIX 1 Modified Mercalli (MM) Scale of Earthquake Intensity (after Eiby, 1966)

MMI 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 ten 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.

MMII 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.

MMIII 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.

MMIV 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 building 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.

MMV 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. Glassware and crockery may be broken. Some windows crack. A few earthenware toilet fixtures crack. Hanging pictures move. Doors and shutters swing. Pendulum clocks stop, start, or change rate.

MMVI 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 and crockery broken. Objects fall from shelves, and pictures from walls. Heavy furniture moves. Unstable furniture overturns. Small school bells ring. Trees and bushes shake, or are heard to rustle. Material may be dislodged from existing slips, talus slopes, or slides.

MMVII 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.

MMVIII Alarm may approach panic. Steering of motor cars 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.

MMIX 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 broken. Serious damage to reservoirs.

MMX 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.

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

MMXII Damage virtually total. Practically all works of construction destroyed or greatly damaged. Large rock masses displaced. Lines of slight 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 By-law, 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 are good. Few buildings erected prior to 1935 can be regarded as Masonry A.

Masonry B Reinforced buildings of good workmanship and with sound 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 Buildings with low standards of workmanship, poor mortar, or constructed of weak materials like mud brick and rammed earth. Weak horizontally.

Notes

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.

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

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 pipes at about the same intensity.