EARTHQUAKES 14

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Australian Seismological Report, 1993

P Gregson, E Paull, G R Small & C Sinadinovski

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

RECORD 1996/13

AUSTRALIAN SEISMOLOGICAL REPORT, 1993

Compiled by

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(AGSO Seismological Centre)

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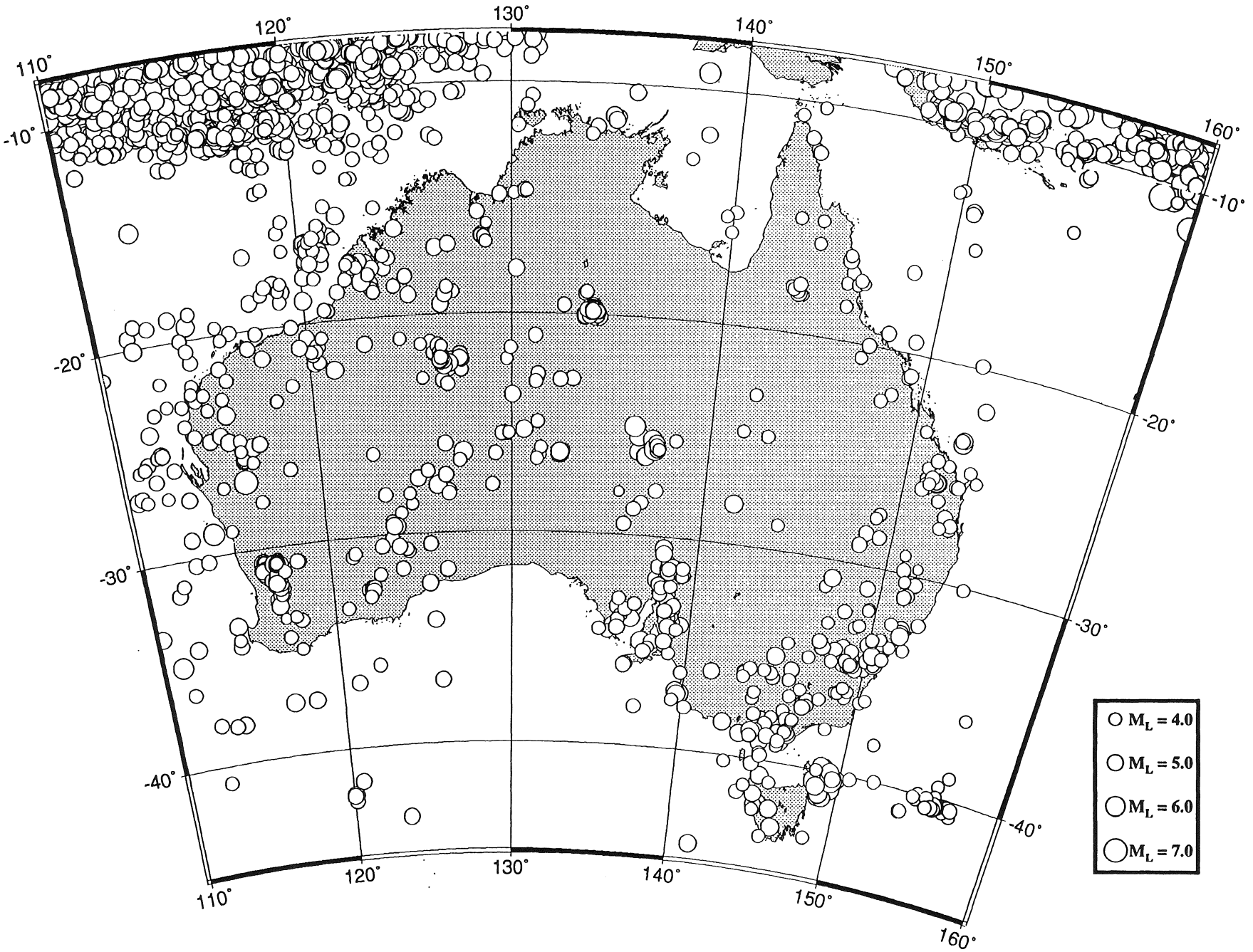

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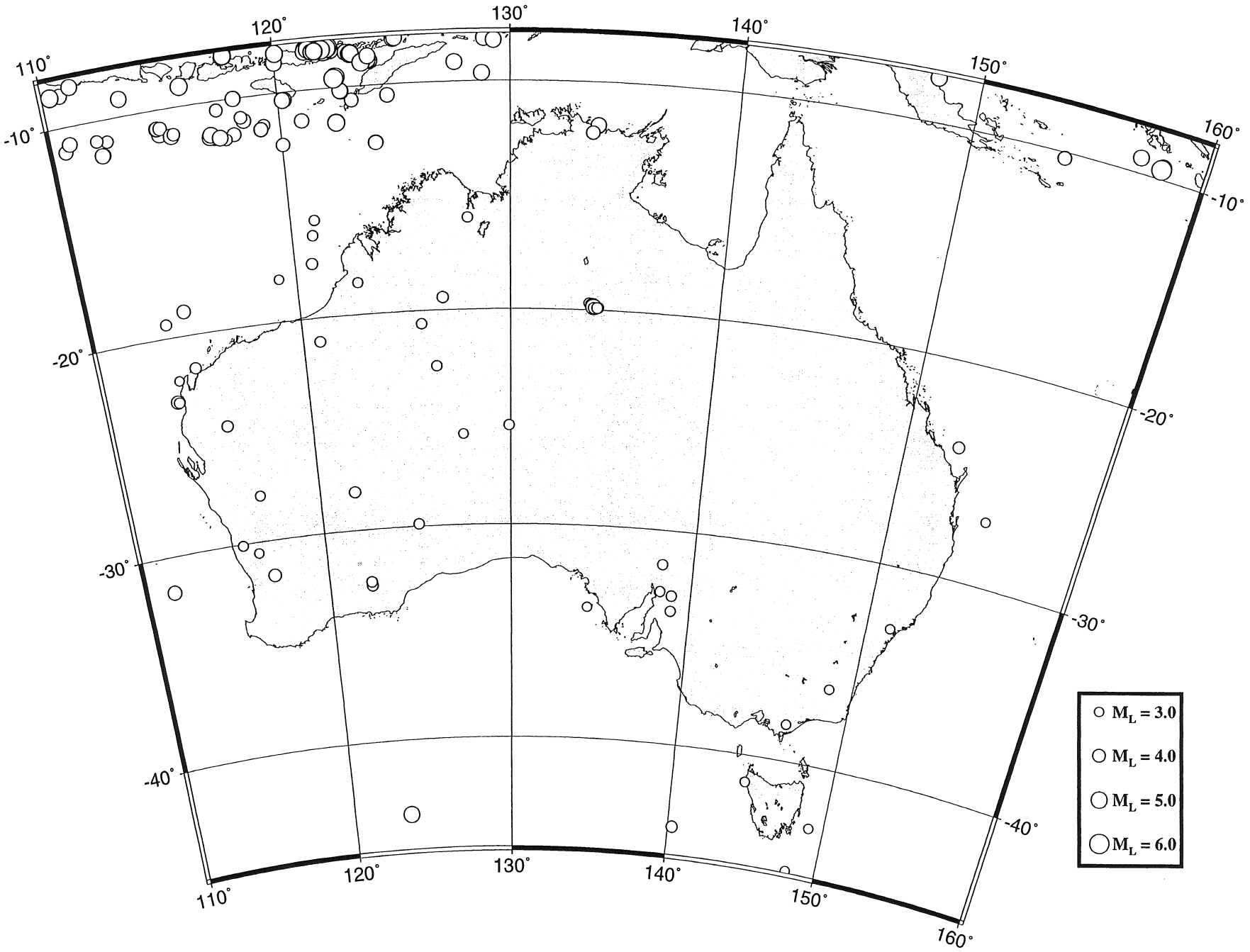


Epicentres of Australian earthquakes, 1993, magnitude $M_L \geq 3.0$

SUMMARY

Nineteen ninety-three was a particularly quiet year for Australian earthquakes, only 59 events had a magnitude of ML 3.0 or more. No damaging earthqakes occurred in Australia and the largest at Tennant Creek in the Northern Territory, had a magnitude of ML 4.8.

The Tennant Creek earthquake sequence which began in 1986 continued its prolific although declining activity.

Intensity questionnaires were distributed for small four earthquakes and isoseismal maps prepared for the events at the Gold Coast, Borumba Reservoir and Lady Elliot Island in Queensland and Willunga in South Australia.

A swarm of small earthquakes occurred near Mukinbudin, 250 km east-north-east of Perth in Western Australia. The swarm was similar to others that have occurred in earlier years throughout the wheatbelt.

Recordings of strong motion data were also sparce and none of them were of direct engineering significamce with only two earthquakes of magnitude ML > 2.9 triggering accelerographs. The highest acceleration recorded was 1260 mm/s/s from a magnitude ML 2.7 earthquake at a distance of 0.5 km.

Worldwide there were 13 major earthquakes, the largest with a magnitude of Ms 8.0 occurred south of the Mariana Islands on 08 August. No one was killed however 48 people were injured on Guam. The most devastating earthquake was an intraplate earthquake of magnitude Ms 6.3, which occurred in peninsula India near Latur and Killari on 29 September killing 9748 people. Several hundred people drowned when a large tsunami swept the Japan Sea following an earthquake in southwest Hokkaido and several other tsunamis were recorded.

World-wide, more than 10 100 people died in earthquakes in 1993, compared with 2880 and 2800 in 1992 and 1991 respectively. The average for the century is about 10 000 per year.

During 1994, a single underground nuclear explosion was detonated; by China at the Lop Nor test site on 7 October. Other nuclear weapons States abided by a self-imposed moratorium on testing in recognition of the changed international political climate.

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 1993. It is the fourteenth 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 1993 seismicity and of large and damaging earthquakes since 1873, a State by State breakdown for 1993 and brief descriptions of the more important earthquakes in that year; **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 1993; **Monitoring of nuclear explosions,** which describes the operation of the AGSO's Nuclear Monitoring Project and lists known underground nuclear explosions and **Isoseismal maps**, describing those that were widely felt.

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

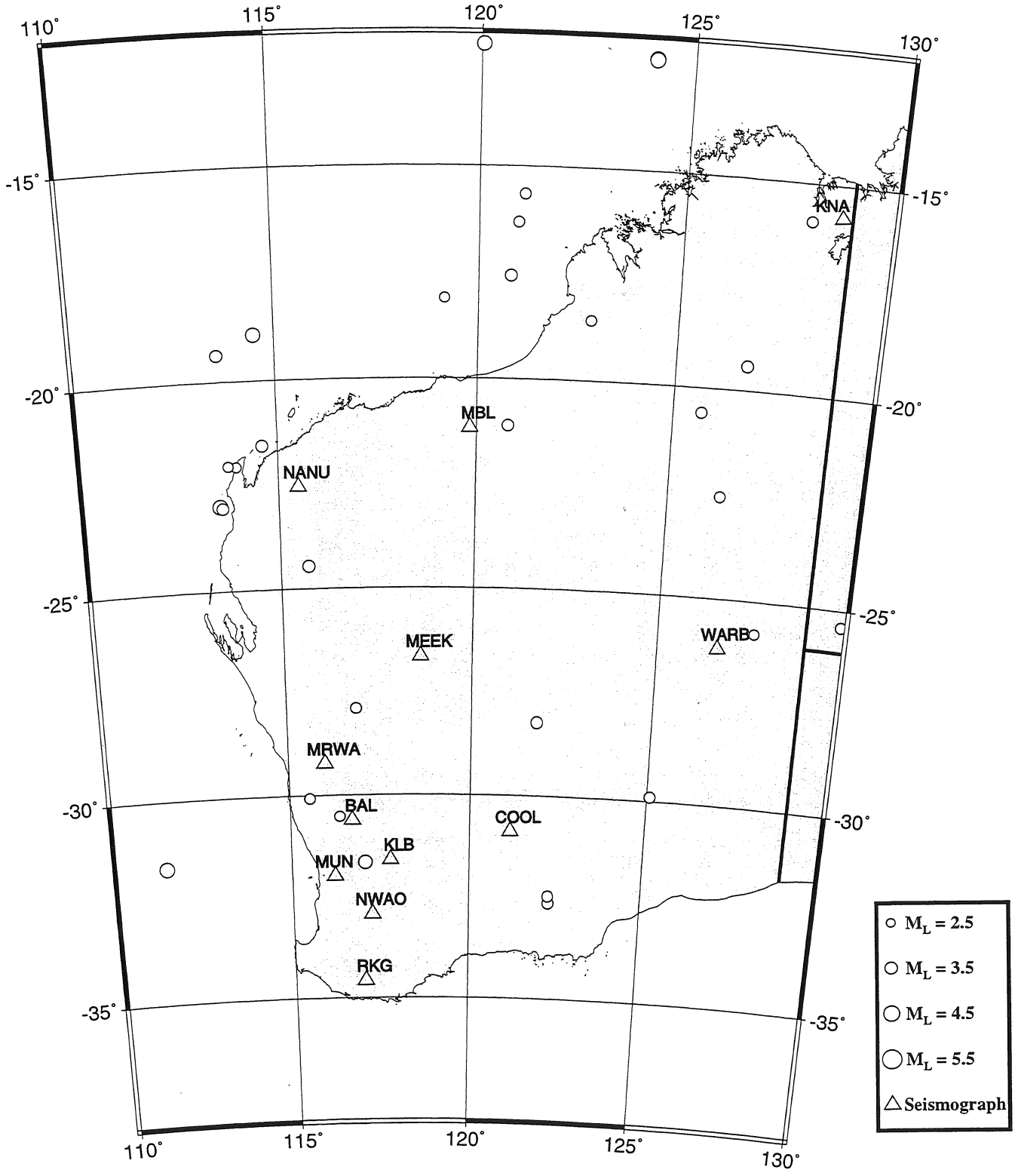
$$\log E = 4.8 + 1.5M$$

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



Earthquake epicentres in Western Australia 1993, magnitude $M_L \geq 2.5$

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.

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 contend with this, another scale was devised (Bisztricsany, 1958), based on the recorded duration of the seismic wave train on short-period seismograms

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

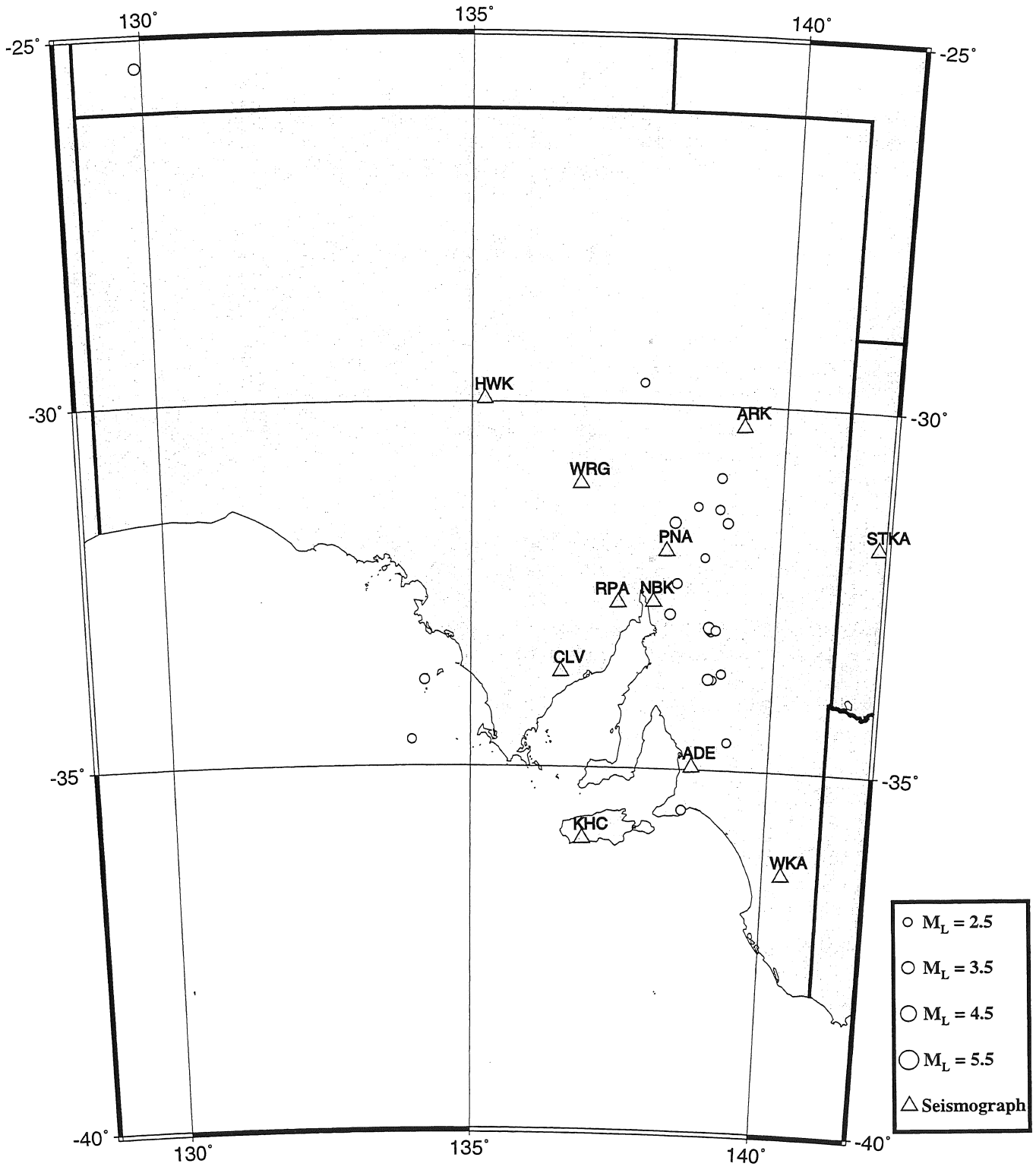
where t is the length of the earthquake coda in seconds (usually from the initial P onset), Δ is the distance from the epicentre, and a, b, and c are constants for a particular recording station. Many other forms of this equation have been used.

Seismic moment magnitude (Mw) Kanamori (1978) defined a world magnitude scale Mw from the seismic moment M_O

$$M_O = \mu A d$$

and

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



Earthquake epicentres in South Australia 1993, magnitude $M_L \geq 2.5$

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:

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

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

Intensity

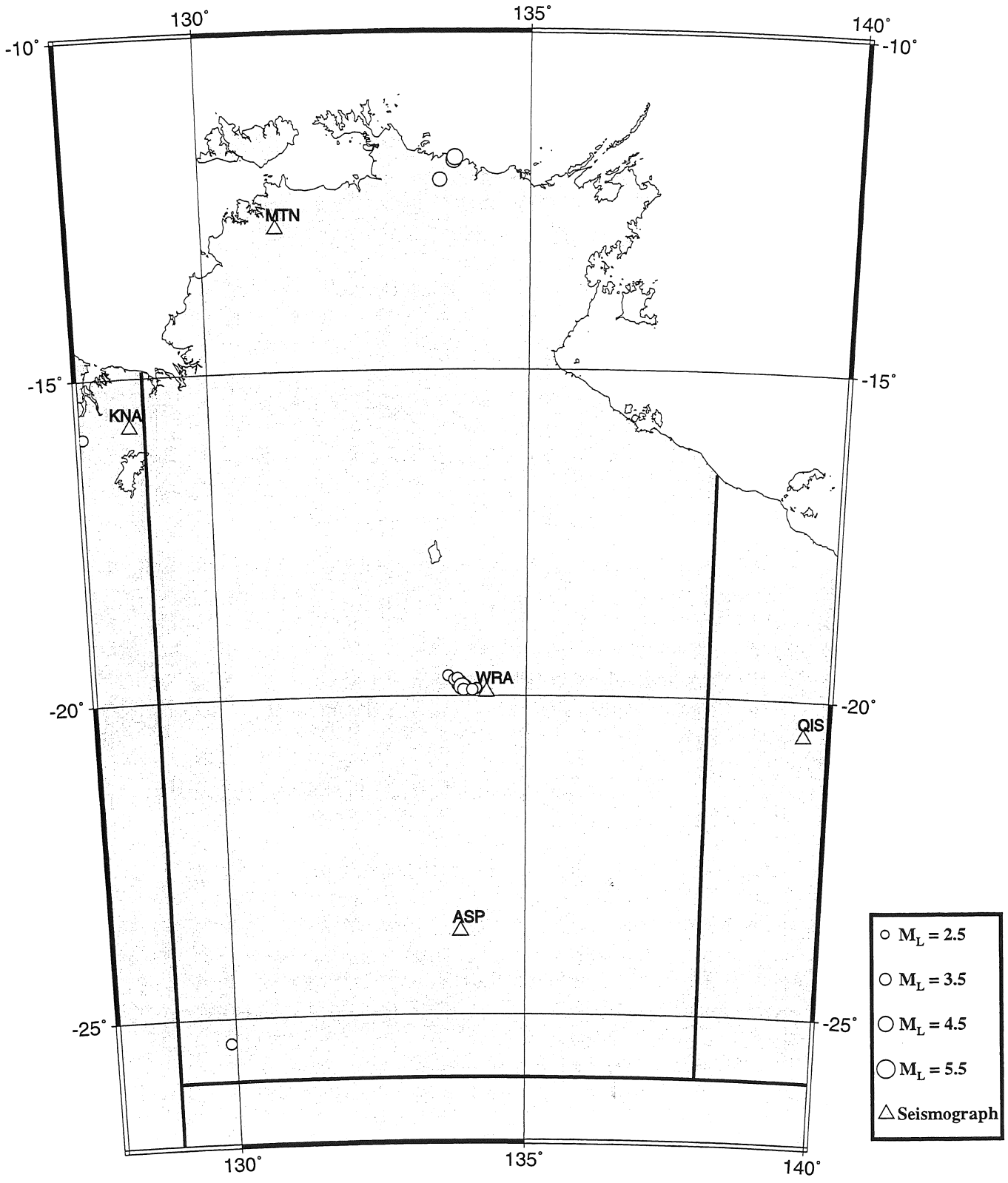
The intensity of an earthquake is a measure of its effects on people and buildings and should not be confused with magnitude which is a measure of the energy release. In this report we use the modified Mercalli (MM) scale as presented by Eiby (1966) for New Zealand. The scale is listed in the Appendix. 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, 1993

All known earthquakes in the Australian region with magnitude ML> 5.9 are shown in Table 1. 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 1856-1993.

Table 2 lists all magnitude ML>2.9 earthquakes which have been located in the Australian region in 1993. The seismicity was lower than average with only 59 events of magnitude ML >2.9 compared with 85 in 1992. Only 6 events had magnitudes ML>3.9 (Figure 1) compared



Earthquake epicentres in Northern Territory 1993, magnitude $M_L \geq 2.5$

with the yearly average of 22 (McCue & Gregson, 1993). The largest earthquake, magnitude ML 4.8, was in the Tennant Creek NT region on 21 October.

Activity continued in the Tennant Creek area, 15 events had a magnitude of ML>2.9 and three of them had a magnitude of ML>3.9. This area has been seismically active since January 1987 when foreshocks of the three large earthquakes in January 1988 (Table 1) commenced.

A swarm of earthquakes occurred near Mukinbudin, Western Australia, concentrated mainly in December 1992 and January 1993. Activity was confined to a small area approximately 2 km in diameter and the largest earthquake was of magnitude ML 2.0. Temporary monitoring equipment was operated there for three months.

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.

Peter Gregson

Western Australia (Figure 3)

Seismic activity in Western Australia in 1993 continued at a relatively low level. One hundred and four events of magnitude ML 2.0 or greater were located (as against 137 in 1992 and 147 in 1991). There were 31 earthquakes with magnitude ML 3.0 or greater and only two with magnitude 4.0 or greater. The largest of these (ML 4.2) occurred well offshore, 300 km NW of Dampier and the other (ML 4.0) occurred just offshore, 136 km SW of Exmouth.

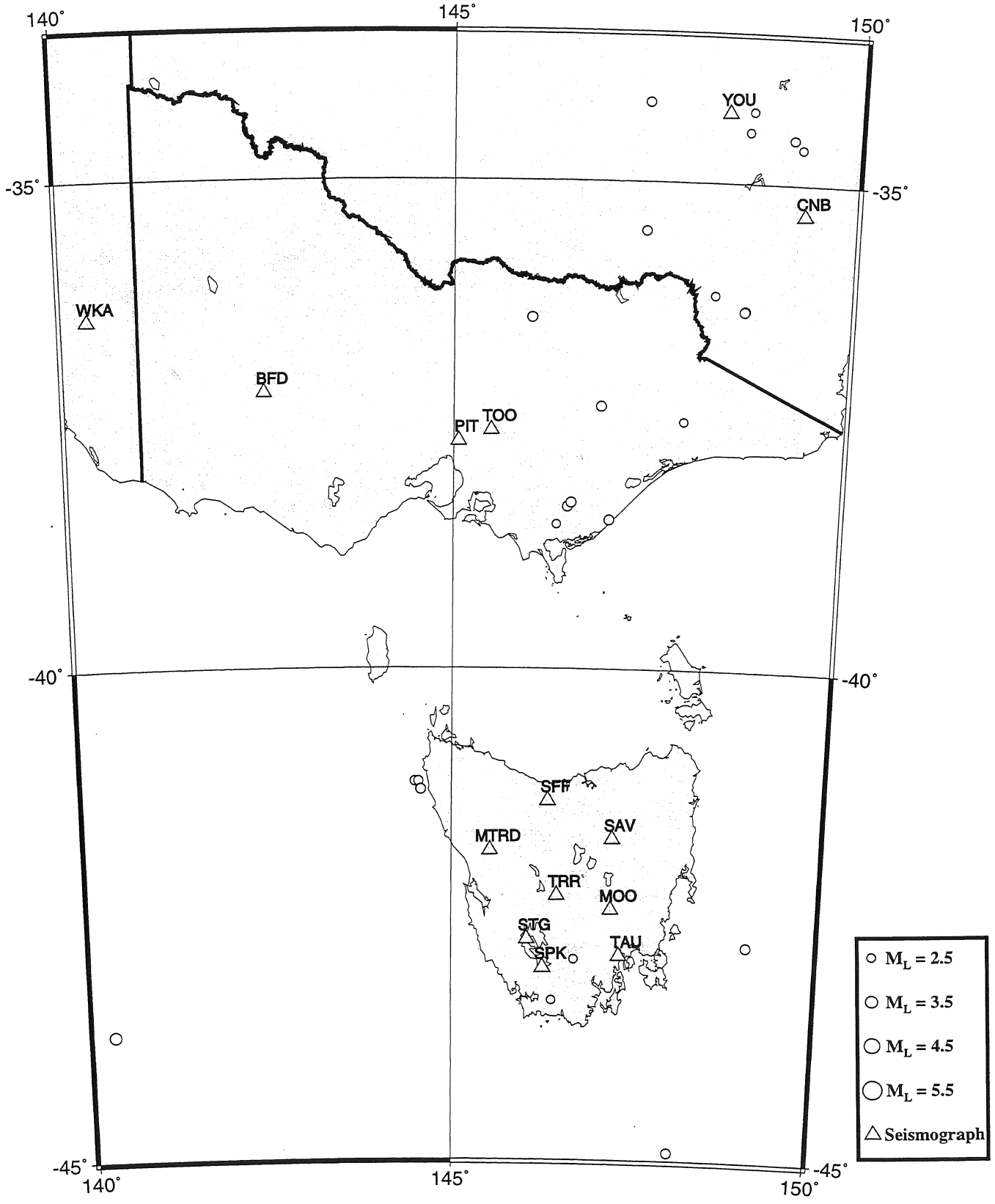
Figure 3 shows earthquakes in Western Australia of magnitude 2.5 or greater, 66 in all. Seven earthquakes occurred in the vicinity of North West Cape including the ML 4.0 event. Seven earthquakes occurred in the Lake Tobin - Lake Mackay region in the Gibson desert, the largest being ML 3.5. Ten occurred in an area offshore from Broome, extending roughly along the edge of the continental shelf and ranging in size from ML 2.5 to 3.5.

The southwest seismic zone was the most active region of Western Australia with 74 earthquakes of ML 1.5 or greater and 11 of ML 2.5 or greater. The Meckering area had 18 earthquakes including an event of ML 3.5, the largest for the zone. Fourteen earthquakes occurred in the Quairading area and 15 in the region of Cadoux.

An earthquake of magnitude ML 2.6 occurred 10 km east of Margaret River on 15 December. This is the same location as a magnitude ML 3.0 earthquake that occurred in 1978 (Gregson, 1980) and is close to the Dunsborough Fault.

The ML 3.7 earthquake near Laverton at 1503 UTC (11.03 p.m. WST) on 28 May caused some interest both locally and in the Perth press. A bright light, assumed to be a meteorite, was observed by travellers on the Laverton - Leonora road at about the same time as the earthquake occurred. No impact crater has been found. Later an article appeared in the West Australian newspaper of 16 March 1996, speculating on the possible coincidence of the meteorite and earthquake but in the absence of other evidence, we assume the recording is that of a normal tectonic earthquake.

Edward Paull & Peter Gregson



Earthquake epicentres in Victoria and Tasmania 1993, magnitude $M_L \geq 2.5$

Micro-earthquakes near Mukinbudin. In December 1992 reports were received of frequent tremors from a farm 20 km north of Mukinbudin, a small wheatbelt town 250 km ENE of Perth. These events were of small magnitude, as they were not recorded at Kellerberrin (KLB), the nearest permanent seismograph, 60 km to the south. Three portable recorders were taken to the area and operated between 22 December 1992 and 18 March 1993. Kelunji seismographs were operated from 2 sites, and a Kelunji accelerograph operated at a third site for 8 weeks in the closing stages of the activity. An MO2 accelerograph and an A700 accelerograph were also deployed, but were not triggered by the small events. Approximately 50 small earthquakes were recorded during the survey, only 16 of them were recorded by more than one instrument. Up to 9 events were recorded on any one day. The largest event, ML 2.0, was recorded on 19 January 1993. The activity declined significantly after January.

Although the events were generally small and hence difficult to locate, the S-P times recorded showed very little variation, indicating a quite small epicentral area, probably of the order of 2 km in diameter. The very small S-P times also required the events to be very shallow, probably less than 2 km in depth. Only 3 accelerograms were recorded, the maximum acceleration being 180 mm/s/s at a distance of about 1.5 km from an event of ML approx 1.0. The Mundaring Observatory earthquake data catalogue shows that 5 events of ML between 2.3 and 4.0 were recorded approx 7 km south of the epicentral zone on 21 June 1968 and 22/23 April 1972. However, because of the poor seismograph coverage at the time the errors in these locations are of the order of ± 10 km. Since in other wheatbelt areas, seismicity seems to return to the same location after long periods of inactivity, the earlier events could have been in the same area.

Vic Dent

Northern Territory (Figure 4)

Seventeen earthquakes with magnitude ML>2.9 occurred in the Northern Territory in 1993 and three of these had ML >3.9. Two of the latter were in the Tennant Creek area and included a magnitude ML 4.8 event which was the largest Australian earthquake for the year. The remaining event, ML 4.2, was off the coast of Arnhem Land. One earthquake, ML 3.2, occurred 130 km west of Uluru and all the others were in the Tennant Creek area with three off the coast of Arnhem Land.

Peter Gregson

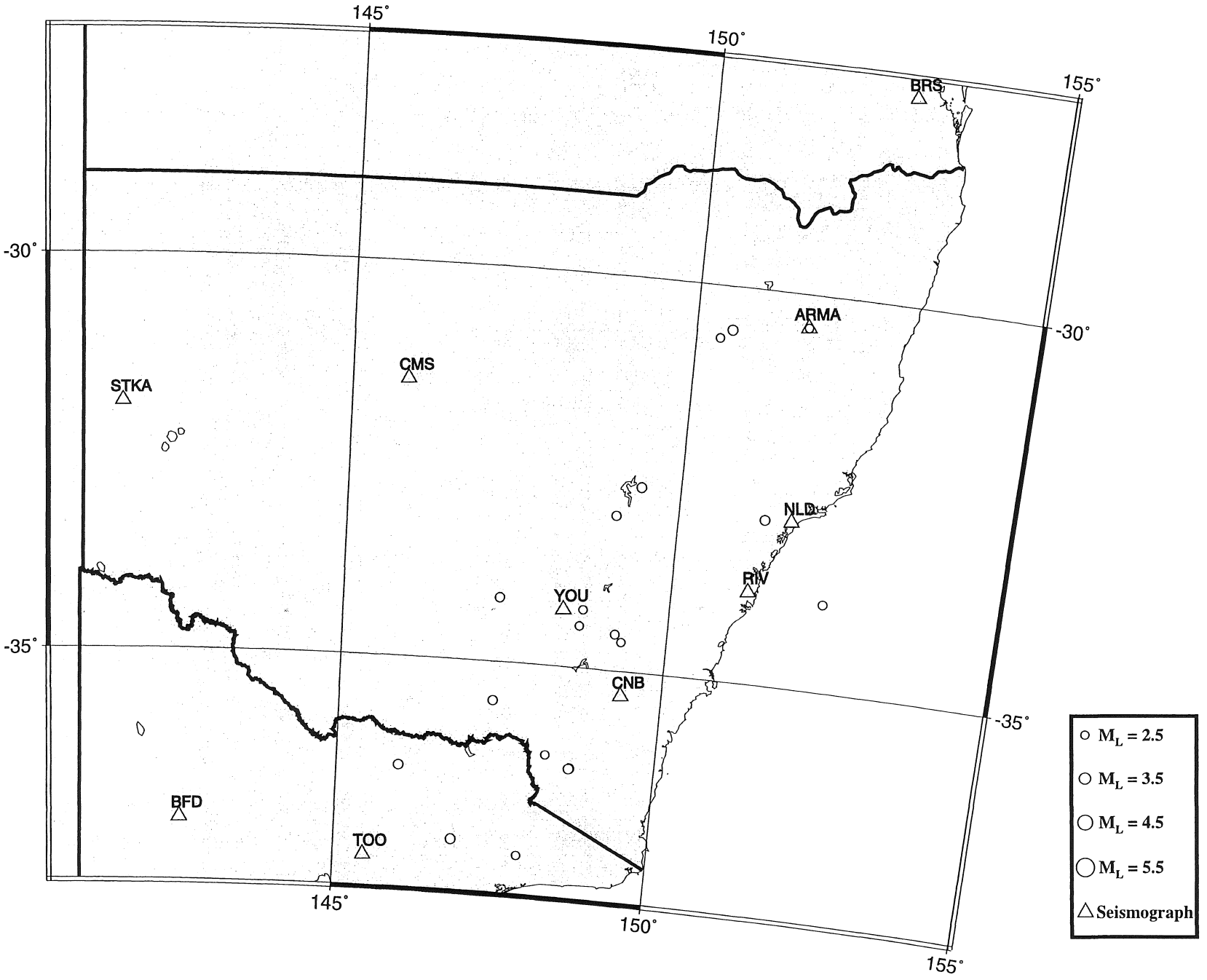
South Australia (Figure 5)

Activity in South Australia was slightly lower than average in 1993 with 288 events recorded, and only three over magnitude 3. The largest event had a magnitude of ML 3.3 and occurred at Peterborough. There were 19 events reported felt. Only one isoseismal map was attempted for a small earthquake at Willunga, and the result was hardly worthwhile. There were more earthquakes within 80 km of Adelaide this year.

David Love

Victoria (Figure 6)

The year was very quiet in terms of seismicity for Victoria. On July 24 an earthquake of magnitude ML 2.9 near Churchill in the Latrobe Valley was felt with a maximum intensity of MM 3. On September 25 an earthquake of magnitude ML 3.0 occurred at Traralgon South



Earthquake epicentres in NSW and ACT 1993, magnitude $M_L \geq 2.5$

followed by an aftershock of magnitude ML 1.8 the next day. On October 11 an earthquake of magnitude ML 2.9 occurred near Wonnangatta, close to the site of the 1982 magnitude ML 5.6 earthquake. An earthquake of magnitude ML 2.9 near Goorambat, 20 km NW from Benalla was reported felt on 17 December.

Two small earthquakes occurred in the Melbourne suburbs, one of magnitude ML 1.5 occurred on 28 February, 12 km below Glenhuntly and the secondof magnitude ML 0.8, below Camberwell on 20 June. There were no reports of either being felt.

Wayne Peck

Tasmania (Figure 6)

Of a total of 56 events located in the Tasmania region in 1993, 3 had a magnitude greater than ML 2.9. The largest earthquake was a magnitude ML 3.5 event on 10 September located about 500 km WSW of Hobart. An ML 3.0 event on 10 November was located about 200 km S of Hobart. Another ML 3.0 event occurred on 17 December, 40 km W of Temma (NW Tasmania) and was felt in Temma by a National Parks and Wildlife Service Ranger.

June Pongratz

New South Wales and ACT (Figure 7)

Only five events with magnitude ML >2.9 occurred in New South Wales in 1993. Two of these, both ML 3.1 and felt, were associated with mine collapses at the Ellalong Colliery on 22 and 24 May. Two occurred near the north end of Lake Jindayne and one 10 km south-west of Cessnock.

In the Dalton-Oolong area (Leiba, 1994), activity was lower than average with 68 events in the latter 6 months ranging in magnitude form ML 0.1 to 2.7 of which 17 were located. Only two earthquakes had magnitudes ML >1.9, both within 15 km of Dalton, the largest with ML 2.7 occurred on 18 August.

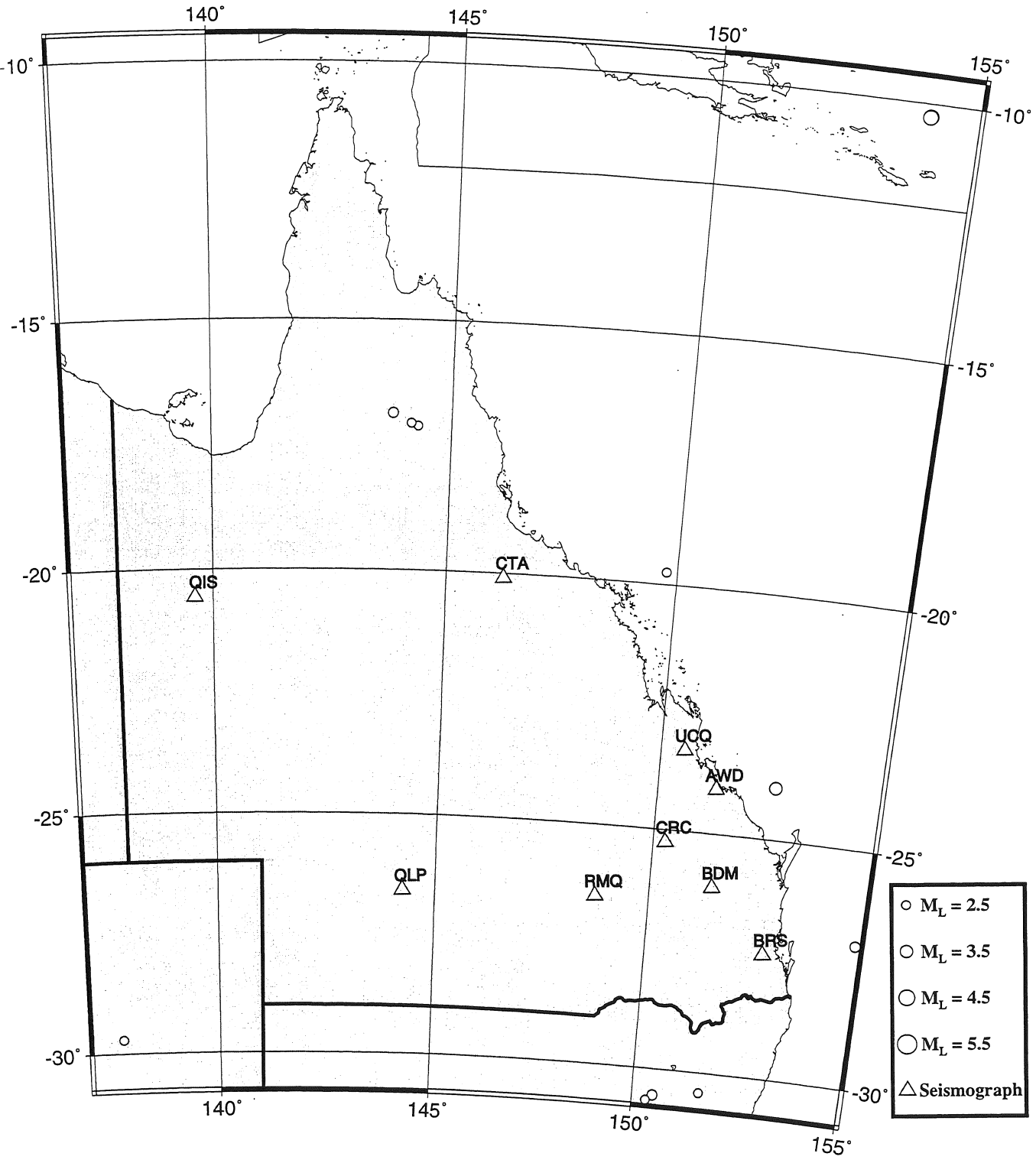
Three small earthquakes occurred in Canberra suburbs. Two of magnitude MD 1.3 and MD 1.4, were under the suburb of Hawker on 28 July. The first was heard as a muffled explosion and the second shook houses and rattled things. The third of magnitude MD 1.2, occurred on 13 August near Sutton but there were no felt reports. In addition there were two earthquakes near Murrumbateman, 31 km NW of Canberra, ML 1.2 and 1.6 and a third of magnitude MD 2.0, near the Lake George fault 32 km NE of Canberra. (Michael-Leiba, 1996)

Peter Gregson

Queensland (Figure 8)

It was a very quiet year with only two events exceeding magnitude ML 2.9. The largest of magnitude ML(I) 4.2 occurred near Lady Elliot Is off Central Queensland and was felt along the coast SE of Gladstone. A novel location was done by Jenny Hafner of CQU using a single triaxial seismograph recording (see isoseismal map). A series of small earthquakes were recorded on the Tully-Millstream network and located near Chillagoe in northern Queensland.

Russell Cuthbertson and Kevin McCue



Earthquake epicentres in Queensland 1993, magnitude $M_L \geq$ 2.5

NETWORK OPERATIONS 1993

Details of seismographs and accelerographs operated in Australia during the year are shown in Tables 3 and 4 respectively.

In New South Wales three new recorders were installed around Hume reservoir on either side of the Victoria-New South Wales border. The Hume network comprises one triaxial accelerograph, one triaxial seismograph and one combined six channel seismograph/accelerograph. In addition in October 1993 two accelerographs were installed in suburban Melbourne as part of the Urban monitoring project.

In South Australia two accelerographs were installed in suburban Adelaide as part of the urban monitoring project. The station GEX remained non-operational throughout the year.

The Tully-Millstream network in north Queensland, comprising two accelerographs and the following 6 sites; BLP, CCQ, DPT, HRD, RVH and SCY, was removed during 1993. In addition, the NWL and WLR sites were also removed. The responsibility for network operations transferred during the year from the Geological Survey of Queensland (GSQ) to Queensland University (UQ) with financial support maintained by the State Government.

There were no changes to the Northern Territory or Tasmanian networks in 1993.

In Western Australia, an accelerograph was installed at Trinity College (TRI), Perth as part of urban monitoring project. The Kelunji accelerograph was shifted from Dowerin (DOW) to Cadoux (CAA) and the MO2 from CAA was relocated at Quairading (QUW).

Edward Paull

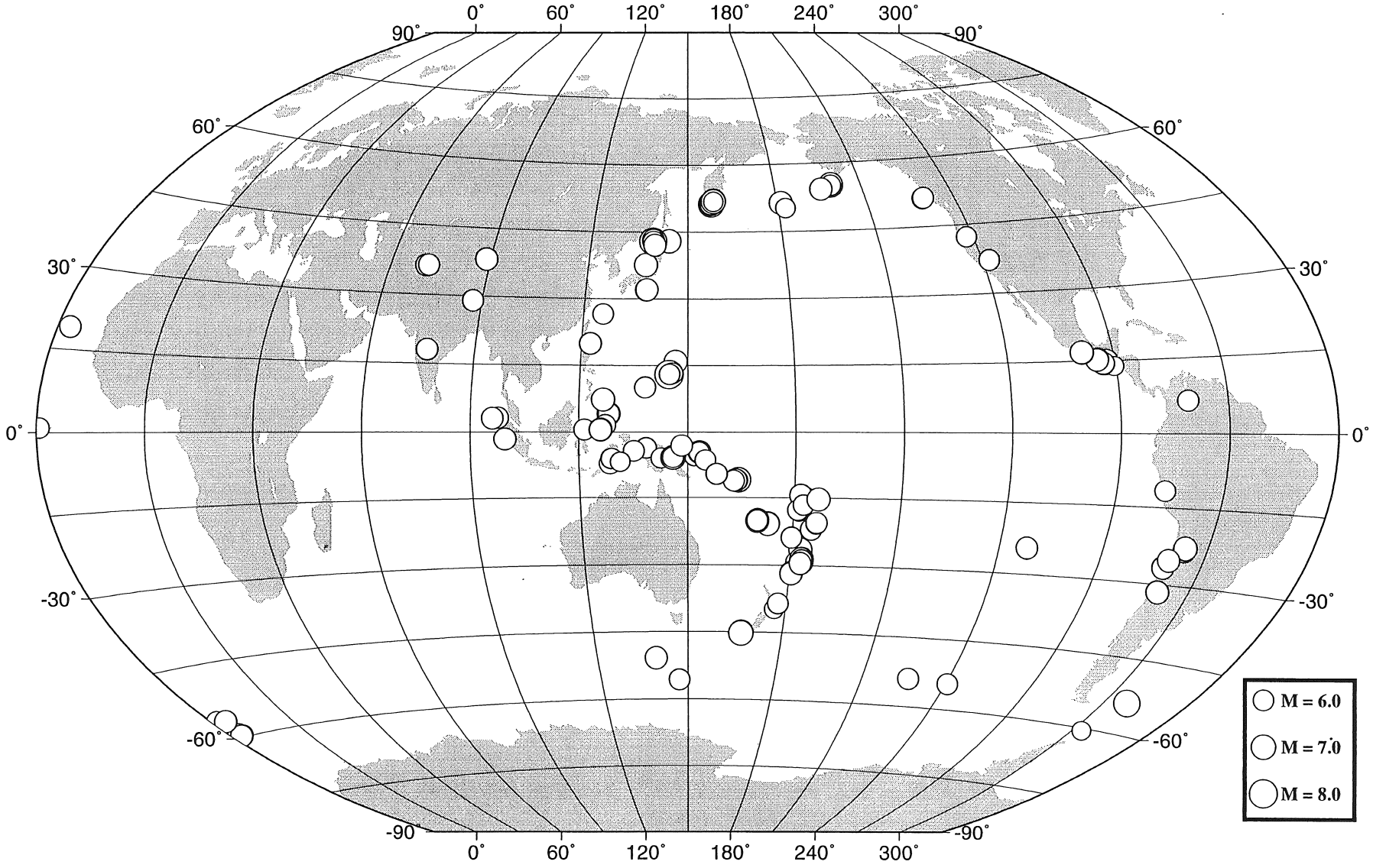
ACCELEROGRAPH DATA

Accelerograms were obtained from 35 individual earthquakes in Western Australia. An earthquake of magnitude ML 3.5 near Meckering was recorded at Goomalling (GOO) 35 km away with an acceleration of 86 mm/s/s. A second earthquake of magnitude ML 3.9, offshore from Kalbarri recorded an acceleration of 0.7 mm/s/s at the Lakes (LAK), 887 km from the epicentre.

There were 12 analogue film recordings from an MO2 accelerograph at Quairading, which was placed near the centre of an area that was active in 1992 and 1993. The largest of these recordings was from an ML 2.7 event and the others were all from events of ML>2.0. The peak acceleration of 1260 mm/s/s recorded at an epicentral distance of approximately 0.5 km from the ML 2.7 event was the highest recorded in Australia in 1993.

Thirteen accelerograms were recorded in the Cadoux area, most of which were from events of magnitude ML<2.0. The magnitude ML 2.6 event was recorded at the 2 stations in the area (CAA and CAS) with accelerations of 37 mm/s/s and 6 mm/s/s at distances of 6 and 13 km respectively.

There were 3 recordings from small events near Mukinbudin, in the central wheatbelt of WA which are referred to earlier in the report.



Principal world earthquakes, 1993, magnitude 6.0 or greater

The highest acceleration recorded by any Seismology Research Centre instrument during the year was 25 mm/s/s. This acceleration was recorded by a combined six channel seismograph/accelerograph located near Jenolan Caves NSW as a result of an earthquake of magnitude ML 2.4 that occurred 29 kilometres away, not far from Katoomba in the Blue Mountains on 22 March at 0806 UTC.

Within Victoria the highest acceleration was 5 mm/s/s, recorded on the Plane Track accelerograph after an earthquake of magnitude ML 2.9 that occurred 55 kilometres away, near Churchill in the Latrobe Valley on 24 July at 1333 UTC.

One accelerogram was recorded at Canberra in the basement of the AGSO building, 70 km from the epicentre of a magnitude ML 2.7 earthquake near Bevendale NSW.

Some of the details of recorded accelerograms including peak accelerations are given in Table 5.

Vic Dent and Wayne Peck

MONITORING OF NUCLEAR EXPLOSIONS

A list of presumed underground nuclear explosions detonated during 1993 is shown in Table 6. Only one explosion was believed to have occurred during the year, detonated at the Chinese test site at Lop Nor. The United States, Russia and France were observing a moratorium on testing put into place in 1992. Consequently the number of explosions is well down on previous years.

Spiro Spiliopoulos

TSUNAMIS

A devastating tsunami more than 30 m high in places swept the Japan Sea following a major earthquake off southwest Hokkaido on 12 July. The island of Okushiri bore the brunt of damage, harbours were destroyed and many fishing boats from Japan, Russia and South Korea were sunk.

Two small Pacific-wide tsunamis were generated by earthquakes in Kamchatka and Guam on 8 June and 8 August respectively but no damage was reported.

Kevin McCue

PRINCIPAL WORLD EARTHQUAKES, 1993

Table 7 lists earthquakes that occurred throughout the world in 1993 of magnitude 7.0 or greater, or that caused fatalities or substantial damage. There was only one great earthquake, a magnitude MS 8.0 event south of Mariana Islands on 08 August. No one was killed however 48 people were injured on Guam and there was extensive damage to hotels in the Tumon Bay area. A small tsunami was generated. Of the 27 earthquakes listed, 20 occurred around the Pacific rim, 2 were associated with mining activity in South Africa and 3 were intraplate earthquakes. One of the latter caused the most deaths. On 29 September a magnitude Ms 6.3 earthquake occurred in India. A total of 9748 people were killed in the Latur-Osmanabad area

and the village of Killari was almost totally destroyed. The earthquake was felt over large parts of central and southern India including Bangalore, Bombay, Hyderabad and Madras.

World-wide, more than 10,100 people died in earthquakes in 1993, compared with 2880 and 2800 in 1992 and 1991 respectively. The average for the century is about 10 000 per year.

The abovementioned 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, 1993).

Edward Paull and Yvonne Moiler

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ISOSEISMAL MAPS

Four small earthquakes during 1993 were sufficiently widely felt or in strategic or unusual locations that questionnaires were distributed and the returned forms collated to draw up isoseismal maps; three in Queensland and one in South Australia.

The format of these maps is the same as those printed in the three volumes of the AGSO (BMR) Isoseismal Atlas.

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.

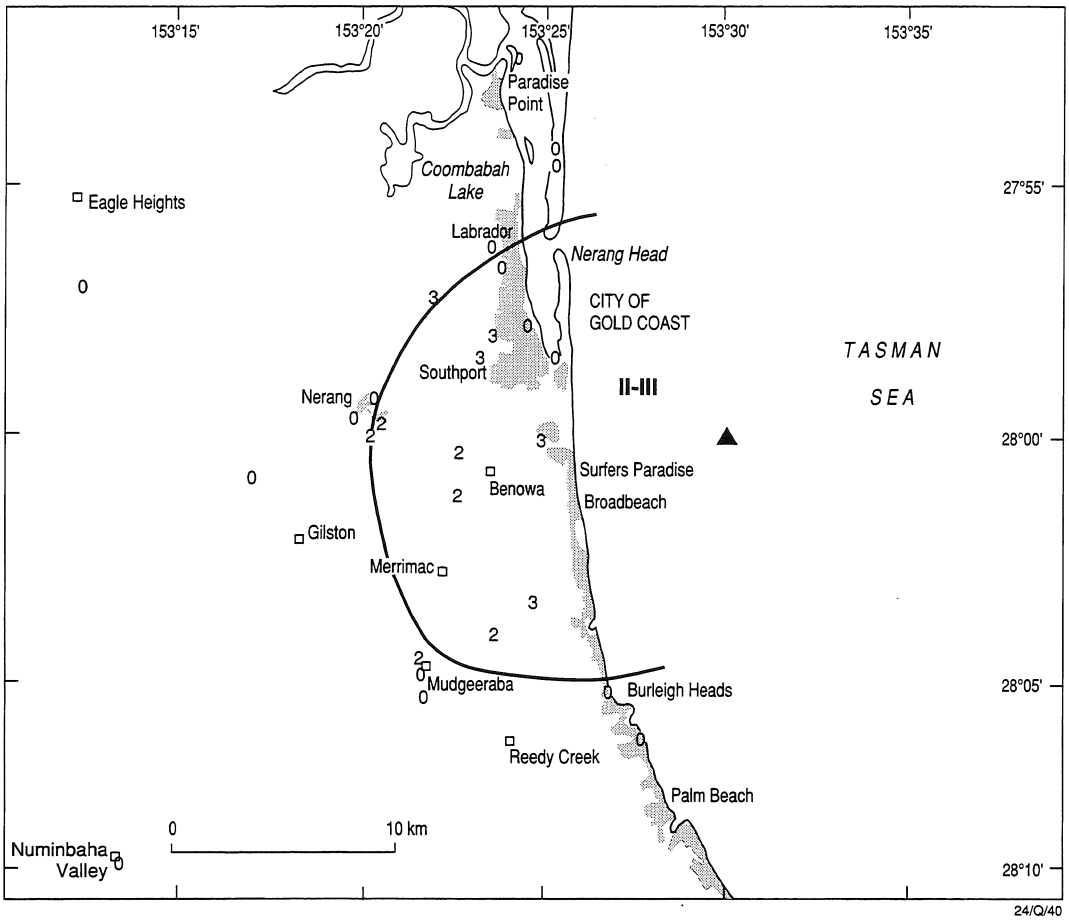
The `domestic water tanks' listed under MM VII are of the cylindrical corrugated-iron type common in New Zealand rural areas. If these are only partly full, movement of the water may burst soldered and riveted seams. Hot-water cylinders constrained only by supply and delivery pipes may move sufficiently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

Isoseismal map of the Gold Coast Queensland earthquake 25 April 1993

A magnitude ML 1.8 micro-earthquake was felt in the early morning (4:02 am AEST) by people along the Gold Coast of south-east Queensland. The calculated epicentre has considerable uncertainty because the seismographs used were all over 90 km to the northwest.

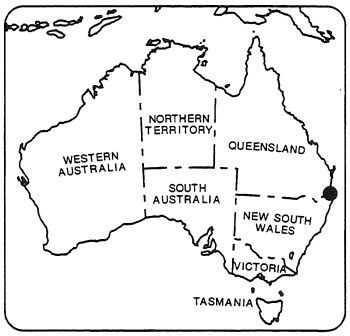
Contributor: This map was compiled by Russell Cuthbertson from the Department of Earth Sciences at the University of Queensland, Brisbane

ISOSEISMAL MAP OF A GOLD COAST EARTHQUAKE, QUEENSLAND
25 APRIL 1993



DATE: 25 APRIL 1993
TIME: 18:02:48 UTC
MAGNITUDE: 1.8 ML (UQ)
EPICENTRE: 27.873°S, 153.592°E

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

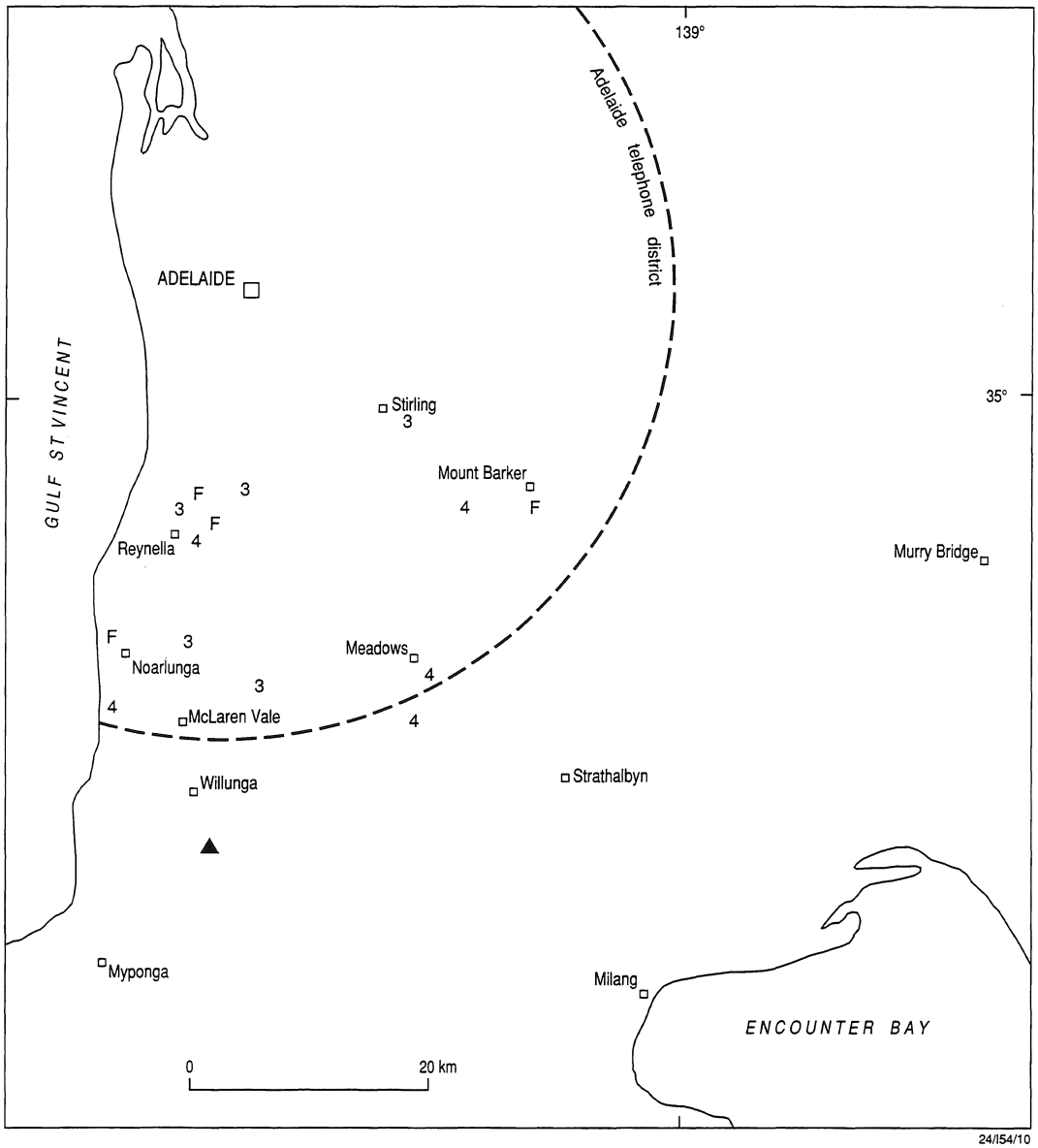


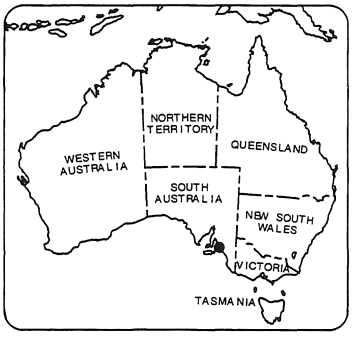
Isoseismal map of the Willunga South Australia earthquake 8 May 1993

A micro-earthquake of Richter magnitude ML 2.3 occurred near Willunga south of Adelaide on Sunday morning (9 May 1994 local time) at 1.30 a.m. A number of people felt the event and rang the department. The replies were plotted, however when the event was later located it was found to be outside the area covered by the replies. The controlling factor in the calls appears to have been the boundary of the Adelaide telephone district.

Contributor: This map of spot intensities was compiled by David Love of the South Australian Department of Mines and Energy (MESA).

ISOSEISMAL MAP OF THE WILLUNGA EARTHQUAKE, SOUTH AUSTRALIA
8 MAY 1993





DATE: 8 MAY 1993
TIME: 16:00:30.5 UTC
MAGNITUDE: 2.3 ML
EPICENTRE: 35.296°S 138.572°E
DEPTH: 5 km

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

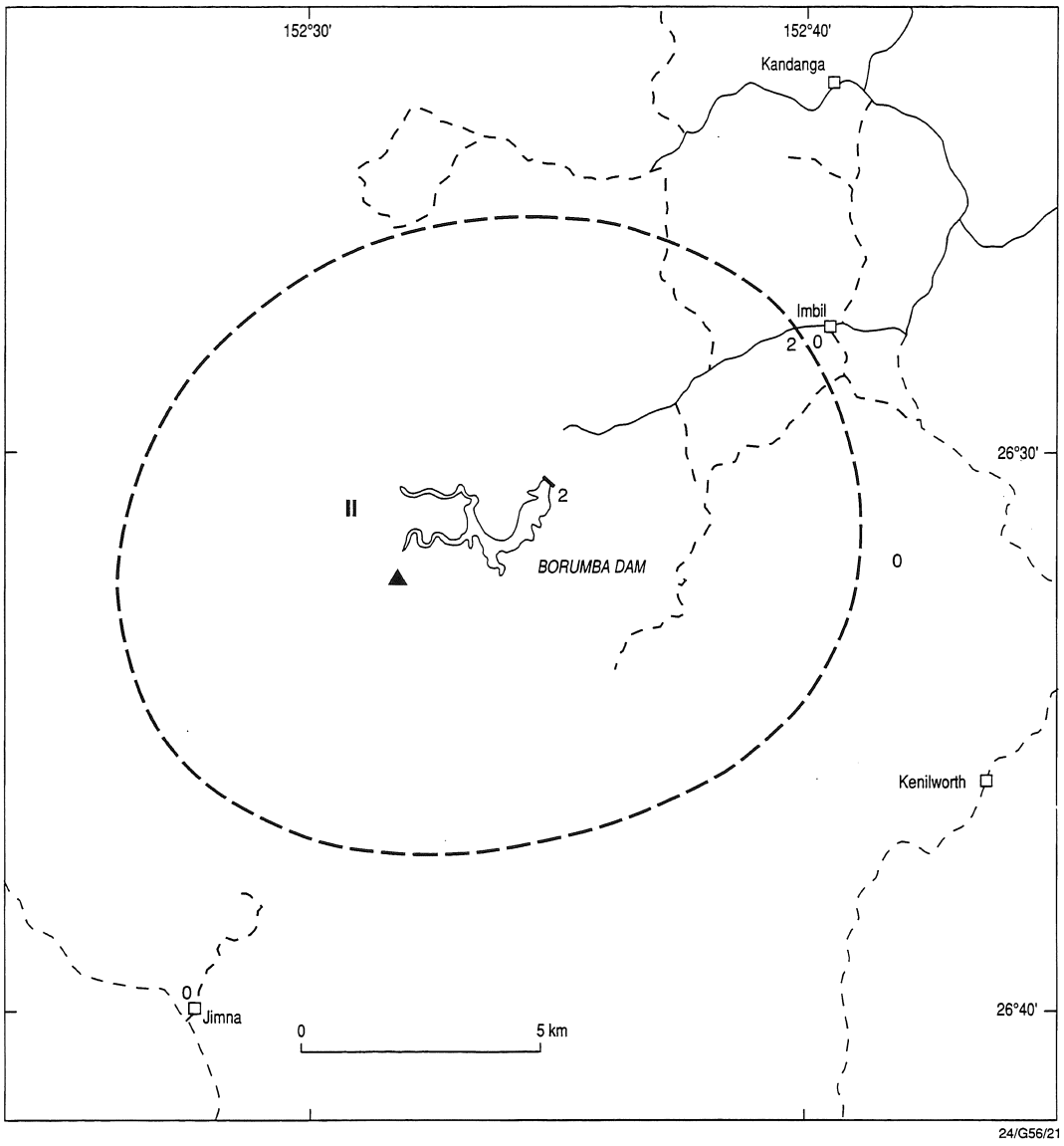
Isoseismal map of the Borumba Reservoir Queensland earthquakes 22 August 1993

A micro-earthquake of magnitude ML 2.0 was felt by several people near Borumba Dam. The calculated epicentre and felt area suggest this event occurred in the same location as the magnitude 3.6 earthquake of 6 December 1991.

Contributor: This map was compiled by Russell Cuthbertson from the Department of Earth Sciences at the University of Queensland, Brisbane

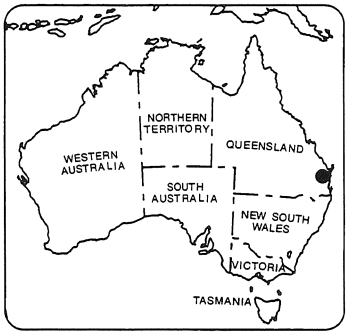
ISOSEISMAL MAP OF THE BORUMBA DAM EARTHQUAKE, QUEENSLAND

22 AUGUST 1993



DATE: 22 AUGUST 1993
TIME: 09:56:23.1 UTC
MAGNITUDE: 2.0 ML
EPICENTRE: 26.55°S,152.535°E
DEPTH: 8 km

▲ *Epicentre*
II *Zone intensity designation*
2 *Earthquake felt (MM)*
0 *Earthquake not felt*



Isoseismal map of the Lady Elliot Island Queensland earthquake 25 November 1993

The following report about the earthquake appeared in the Rockhampton Morning Bulletin of Saturday 27 November 1993.

Earth moves for coastal residents

By MELISSA MITCHELL

Central Queensland's coastal residents may have felt the earth move on Thursday afternoon following the recording of a tremor registering 4.5 on the Richter scale.

Seismographs at the University of Central Queensland (UCQ) recorded the tremors at 2.07pm on Thursday. The most intense tremors were felt on Lady Elliot Island, offshore from Town of 1770.

The tremor was in the general area of the 1918 Bundaburg earthquakes which registered six on the Richter scale.

The 1918 earthquakes caused considerable damage in Bundaberg and to a lesser extent, Rockhampton.

Residents between Gladstone and Hervey Bay who felt the tremor have been asked to contact the UCQ.

UCQ Department of Physics spokesman Mr Byron McKavanagh said the tremor was recorded as intensity four on Lady Elliot Island and intensity three at Agnes Water.

"No damage was caused at either location, although island residents were concerned during the shaking of windows, doors and crockery," he said.

"The epicentre of the tremor has been placed at 15kms south of Lady Elliot and 90kms east of Agnes Water."

Mr McKavanagh said coastal residents with information about the tremor could help the UCQ to draw an accurate map of the event.

"Any assistance in the research is appreciated.

"Input will be valuable in helping researchers to understand the effects of these phenomena."

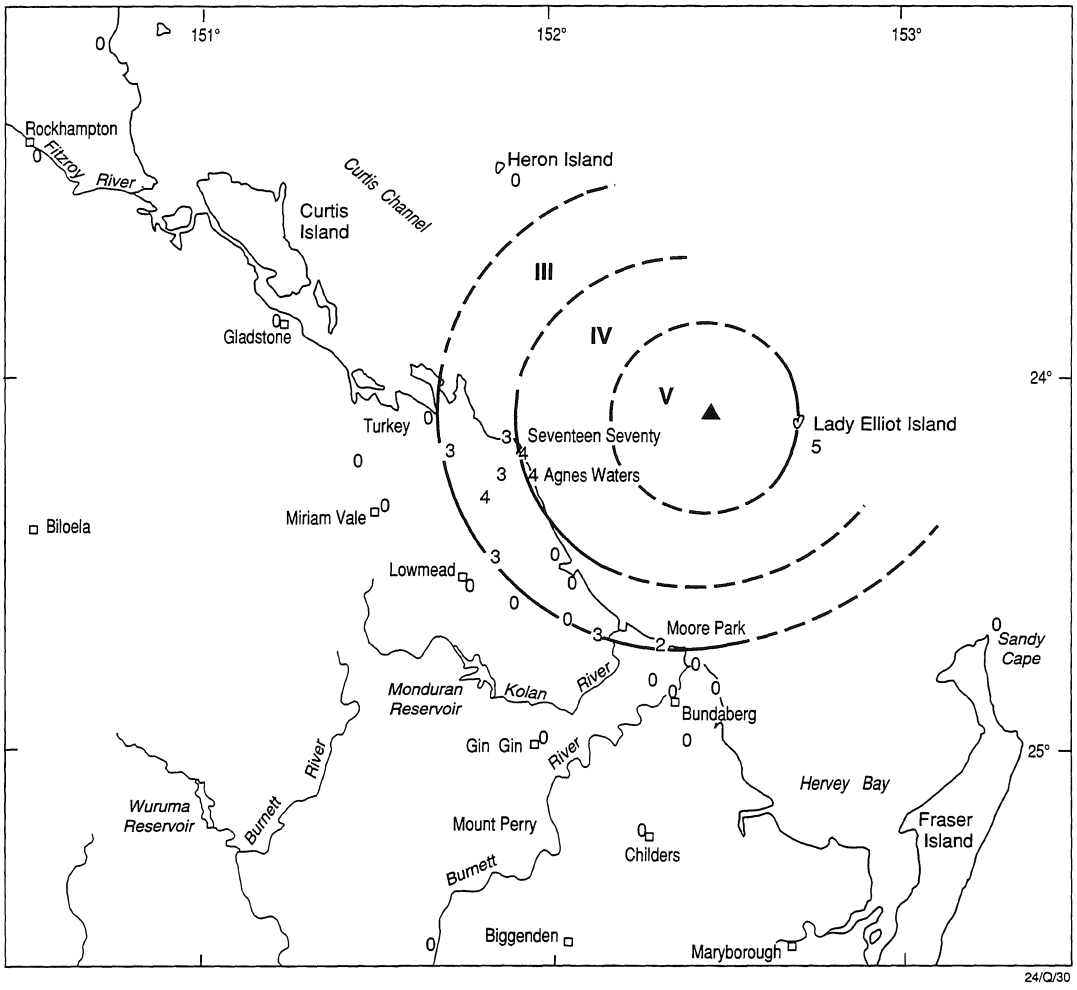
Anyone who felt the tremor can contact Mr McKavanagh on (079) 309625 or by leaving a message on (079) 309777.

ATTLE INDEX: This week: 145.4. Last Week: 142.4. **ALL ORDS:** 2043.1, +1.1

CITY: Fine, mod SE to E wind, 29. COAST: Showers, mod SE to E wind. WEST: Fine, light to mod E to

Contributor: This map was compiled by Jenny Hafner with contributions from Bruce Boreham, Byron McKavanagh and Craig Bugden, all from the Applied Physics Department of the Central Queensland University, Rockhampton.

ISOSEISMAL MAP OF THE LADY ELLIOT IS EARTHQUAKE, QUEENSLAND
25 NOVEMBER 1993



0 80 km

DATE: 25 NOVEMBER 1993
TIME: 04:06:50 UTC
MAGNITUDE: 4.2 ML (I)
EPICENTRE: 24.13°S 152.35°E
DEPTH: 5 km

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

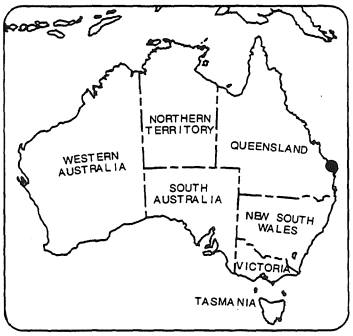


Table 1. Large or damaging Australian earthquakes, 1788 - 1993

Date UTC	*Time*	*Lat °S*	*Long °E*	*ML*	*Ms*	*$AUS loss (1993$)*	*Location*
1873 12 15	0400	26.25	127.5		6.0		SE WA
1884 07 13	0355	40.5	148.5		6.2		NE Tasmania
1885 01 05	1220	29.0	114.0		6.5		Geraldton WA
1885 05 12	2337	39.8	148.8		6.5		NE Tasmania
1892 01 26	1648	40.3	149.5		6.6		NE Tasmania
1897 05 10	0526	37.33	139.75		6.5		Kingston SA
1902 09 19	1035	35.0	137.4		6.0		Warooka SA
1903 04 06	2352	38.43	142.53	4.6			Warrnambool Vic
1903 07 14	1029	38.43	142.53	5.3			Warrnambool Vic
1906 11 19	0718	21.5	104.5		7.3		Offshore WA
1918 06 06	1814 24	23.5	152.5	6.0	5.7		Gladstone Qld
1920 02 08	0524 30	35.0	111.0		6.0		Offshore WA
1929 08 16	2128 23	16.99	120.66		6.6		Broome WA
1935 04 12	0132 24	26.0	151.1	5.2	5.4		Gayndah Qld
1941 04 29	0135 39	26.92	115.80	7.0	6.8		Meeberrie WA
1941 06 27	0755 49	25.95	137.34		6.5		Simpson Desert
1946 09 14	1948 49	40.07	149.30	6.0	5.4		West Tasman Sea
1954 02 28	1809 52	34.93	138.69	5.4	4.9	107M	Adelaide SA
1961 05 21	2140 03	34.55	150.50	5.6		3M	Bowral NSW
1968 10 14	0258 50	31.62	116.98	6.9	6.8	31M	Meckering WA
1970 03 10	1715 11	31.11	116.47	5.1	5.1		Calingiri WA
1970 03 24	1035 17	22.05	126.61	6.7	5.9		L Mckay WA
1972 08 28	0218 56	24.95	136.26		6.2		Simpson Desert
1973 03 09	1909 15	34.17	150.32	5.6	5.3	2M	Picton NSW
1975 10 03	1151 01	22.21	126.58		6.2		L Mckay WA
1978 05 06	1952 19	19.55	126.56		6.2		L Mckay WA
1979 04 23	0545 10	16.66	120.27	6.6	5.7		Broome WA
1979 04 25	2213 57	16.94	120.48		6.1		Broome WA
1979 06 02	0947 59	30.83	117.17	6.2	6.1	10M	Cadoux WA
1983 11 25	1956 07	40.45	155.51	6.0	5.8		Tasman Sea
1985 02 13	0801 23	33.49	150.18	4.3		.09M	Lithgow NSW
1986 03 30	0853 48	26.33	132.52		5.8		Marryat Ck SA
1988 01 22	0035 57	19.79	133.93		6.3	1.3M	Tennant Ck NT
1988 01 22	0357 24	19.88	133.84		6.4		Tennant Ck NT
1988 01 22	1204 55	19.94	133.74		6.7		Tennant Ck NT
1989 12 27	2326 58	32.95	151.61	5.6	4.6	1 270M	Newcastle NSW
1994 08 06	1103 52	32.92	151.29	5.3		34M	Ellalong NSW

Table 2 Australian epicentres 1993, ML ≥3

Date	Time UTC	Lat °S	Long °E	Depth km	ML	Place
1 20	1533 22.6	31.649	117.044	4	3.5	Meckering, WA
1 28	2046 15.0	27.890	116.865	5	3.1	Mt Magnet, WA
2 7	0551 39.4	30.522	116.363	5	3.0	Miling, WA
2 8	2028 44.0	16.303	120.943	5	3.2	Offshore NW WA
2 16	0534 37.8	19.790	133.898	0	3.3	Tennant Ck, NT
2 21	0839 29.3	19.815	133.903	1	4.6	Tennant Ck, NT
2 22	1156 26.6	19.692	133.723	5	3.3	Tennant Ck, NT
2 24	1613 26.0	19.787	133.904	3	4.0	Tennant Ck, NT
2 25	1027 51.1	19.782	133.883	0	3.5	Tennant Ck, NT
2 27	2208 42.6	36.625	122.317	5	3.4	Norseman, WA
3 5	2222 11.9	19.755	133.825	1	3.6	Tennant Ck, NT
3 8	1142 52.6	21.108	120.793	5	3.4	Marble Bar, WA
3 11	2216 32.4	21.552	114.606	5	3.5	Onslow, WA
3 12	1704 33.2	30.075	115.556	9	3.1	Eneabba, WA
3 13	0141 39.2	19.890	134.179	8	3.2	Tennant Ck, NT
3 22	0208 36.9	25.392	129.903	0	3.2	Peterman Ra, NT
3 27	0808 10.1	18.561	122.821	5	3.1	Broome, WA
4 05	1754 39.7	25.768	127.593	5	3.0	Giles, WA
4 15	0005 28.6	15.641	121.082	5	3.3	Offshore NW WA
4 20	1447 00.0	33.035	138.909	9	3.3	Peterborough, SA
5 8	1119 41.5	31.609	138.289	0	3.3	Sth Arkaroola, SA
5 10	0821 58.5	32.865	138.261	18	3.1	Melrose, SA
5 14	2014 39.2	22.978	113.472	5	4.0	Offshore NW WA
5 18	0608 52.5	23.026	113.533	5	3.4	Offshore NW WA
5 23	1103 19.1	17.549	120.784	5	3.5	Offshore NW WA
5 28	1503 42.8	28.218	121.806	1	3.6	Laverton, WA
6 7	1508 04.9	18.093	119.174	5	3.0	E Pt Hedland, WA
6 8	0436 57.5	31.648	111.422	5	3.6	Offshore Perth, WA
6 10	0336 27.6	32.458	122.298	5	3.3	Norseman, WA
6 29	1025 27.0	19.799	133.932	5	3.1	Tennant Ck, NT
6 30	1530 48.3	19.857	134.000	5	3.7	Tennant Ck, NT
7 6	2359 34.7	22.569	126.368	5	3.3	Tobin Lake, WA
7 9	1006 28.0	24.458	115.713	5	3.6	Gascoyne Jn, WA
7 10	1231 07.1	19.368	113.561	5	3.5	Offshore NW WA
7 11	0735 00.3	19.731	133.870	5	3.2	Tennant Ck, NT
8 11	1914 17.8	19.422	126.784	5	3.5	Halls Ck, WA
8 28	1926 24.7	15.885	128.043	5	3.2	Kununurra, WA
9 10	0333 36.7	43.720	140.300	10	3.5	Southern Ocean
9 10	1107 05.1	19.876	133.971	5	3.6	Tennant Ck, NT
9 16	1412 23.2	27.69	109.12	5	3.9	Offshore WA
9 25	0240 07.0	38.311	146.539	10	3.0	Traralgon Vic
10 1	1941 36.3	19.885	134.178	4	3.0	Tennant Ck, NT
10 3	0231 03.3	22.019	113.722	5	3.0	Exmouth, WA
10 21	0527 28.1	19.862	133.944	5	4.8	Tennant Ck, NT
10 23	1232 41.5	32.914	151.299	7	3.0	Ellalong, NSW
10 28	1658 03.3	33.754	138.928	10	3.3	Burra, SA
10 29	0814 13.2	18.904	114.493	5	4.2	Offshore NW WA
11 05	0639 37.2	19.910	133.968	13	3.6	Tennant Ck, NT
11 10	2341 59.4	44.917	148.067	0	3.0	Southern Ocean
11 17	0618 31.4	42.800	149.067	0	3.0	East of Hobart Tas
11 20	0738 19.3	20.590	125.726	5	3.3	Tobin Lake, WA
11 25	0406 50.0	23.922	152.632	2	4.2	Lady Elliot Is Qld
11 30	0051 41.3	29.892	125.087	5	3.2	Rawlina, WA
12 07	0612 48.1	19.908	134.110	11	3.4	Tennant Ck, NT
12 07	2353 58.4	33.816	134.239	4	3.0	Eyre Peninsula, SA
12 13	1623 12.0	26.980	154.890	0	3.0	East Brisbane Qld
12 17	0116 43.3	41.230	144.580	5	3.0	Temma Tas
12 18	1927 36.2	12.160	133.630	20	4.2	Arnhem Land, NT
12 18	2116 20.6	36.307	148.671	6	3.0	Jindabyne, NSW

Table 3. Australian Seismographic Stations, 1993

Code#	*Name*	*Lat °S*	*Long °E*	*Elev.m*	*Operator*	*Type**
Queensland						
AWD	Awoonga Dam	24.078	151.316	110	UQ	1
BDM	Boondooma Dam	26.112	151.444	320	UQ	1
BLO	Burdekin Lookout	20.625	147.121	234	UQ	1,8
BLP-	Blunder Park	17.76	145.42	650	UQ	8
BRS	Mt Nebo Brisbane	27.392	152.775	525	UQ	5
CCQ-	Carron Creek	17.85	145.57	740	UQ	8
CRC	Cracow	25.253	150.279	290	UQ	1
CTAO	Charters Towers	20.088	146.255	357	UQ	2
DLB	Dalbeg	20.151	147.264	70	UQ	1
DNG	Doongara	20.555	146.475	280	UQ	1
DPT-	Dingo Pocket	17.913	145.823	100	UQ	1
GCM2	German Ck Mine	22.98	148.55	136	UCQ	1
GLD	Glenlyon Dam	28.969	151.480	48	UQ	1
HRD-	H Road	17.76	145.65	260	UQ	8
MCP	Mt Cooper	20.552	146.806	300	UQ	1
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	UQ	1
PFD	Peter Faust Dam	20.386	148.375	12	UQ	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	UQ	1
SCY-	Sunday Creek	17.88	145.34	690	UQ	8
UCQ2	UCQ Campus	23.329	150.524	27	UCQ	1
UKA	Ukalunda	20.899	147.127	200	UQ	1
WBA	Buaraba	27.353	152.308	100	UQ	1
WCR-	Cricket Road	27.520	152.455	100	UQ	1
WMB	Mt Brisbane	27.115	152.550	160	UQ	1
WPM	Pine Mountain	27.536	152.735	35	UQ	1
WRC	Reedy Creek	27.187	152.663	190	UQ	1
WTG	Toogoolawah	27.146	152.333	130	UQ	1
WWH	Wivenhoe Hill	27.370	152.587	190	UQ	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
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	26.638	118.615	530	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
RKG	Rocky Gully	34.570	117.010	300	MUN	1
WARB	Warburton	26.184	126.643	460	MUN	1

Table 3 (cont.)

NSW & ACT						
APN	Appin	34.171	150.823	277	SRC	8
ARMA	Armidale	30.4198	151.628	1.13	AGSO	1
AVD	Avon	34.376	150.615	532	SRC	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	SRC	8
DAL	Dalton	34.726	149.174	570	AGSO	1
DON	Donald's Castle Ck	34.359	150.713	401	SRC	8
DRA+	Dora Dora	35.965	147.375	230	SRC	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	34.620	150.484	711	SRC	8
GRV	Greaves Creek	33.662	150.309	980	SRC	8
JBD	Jenolan	33.762	150.049	1235	SRC	8
LBX	Letterbox	34.272	150.874	400	SRC	8
MEG	Meangora	35.101	150.037	712	CAN	1
NAT	Nattai	34.206	150.427	632	SRC	8
NLD	North Lambton	32.901	151.701	50	NCC	8
NPSD	Newcastle Police	32.931	151.786	20	ASC	8
PHD	Pipehead Depot	33.847	150.969	90	SRC	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	138.714	655	ADE	2
ARK	Arkaroola	30.276	139.339	520	ADE	1
CLV	Cleve	33.691	136.495	238	ADE	1
GEX	Naracoorte	37.074	140.825	80	ADE	1/8
HTT	Hallett	33.430	138.921	708	ADE	1
HWK	Hawksnest	29.958	135.203	180	ADE/AGSO	1/8
KHC	Kelly Hill Caves	35.983	136.911	100	ADE	1
MGR2	Mt Gambier	37.801	140.686	60	ADE	1
NBK	Nectar Brook	32.701	137.983	180	ADE	1
PDA	Parndana	35.806	137.239	140	ADE	1/8
PNA	Partacoona	32.006	138.165	180	ADE	1
RPA	Roopena	32.725	137.403	95	ADE	1
SDN	Sedan	34.509	139.337	125	ADE	1/8
THS	The Heights HS	34.742	138.773	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	SRC	1
BEL	Bell's Track	37.761	146.389	545	SRC	1
BFD	Bellfield	37.177	142.545	235	AGSO	1
BUC	Bucrabanyule	36.238	143.498	210	SRC	1
CRN	Cairn Curran	36.991	143.972	230	SRC	8

Table 3 (Cont.)

DRO	Dromana	38.360	144.997	170	SRC	1
DTM/DTT	Dartmouth	36.529	147.469	436	SRC	8
FRT	Forrest	38.534	144.997	210	SRC	1
GOG	North Grampians	36.888	142.400	265	SRC	8
GVL	Greenvale	37.619	144.901	188	SRC	1
HOP	Mount Hope	35.995	144.207	300	SRC	1
IVS+	Inverness	36.134	147.068	330	SRC	8
JEN	Jeeralang Junction	38.351	146.420	330	SRC	1
KOWA	Kowarra	35.791	144.521	85	SRC	1
MAL	Marshall Spur	37.749	146.292	1076	SRC	1
MEM	Merrimu	37.637	144.497	160	SRC	1
MCV	McVeigh	37.691	145.899	630	SRC	1
MIC	Mount Erica	37.944	146.359	805	SRC	1
TOT	Thompson Dam	37.843	146.406	680	SRC	8
MLW	Molesworth	37.137	145.510	280	SRC	1
PAT	Plane Track	37.857	146.456	771	SRC	1
PEG	Pegleg	36.985	144.091	340	SRC	1
POL	Poley Tower	37.626	145.801	1200	SRC	1
PNH	Panton Hill	37.635	145.271	180	SRC	1
RUS	Rushworth	36.662	144.947	145	SRC	1
SIN	Swingler Track	37.739	146.292	980	SRC	8
TMD	Thomson Dam	37.810	146.349	941	SRC	1
TOM	Thomson	37.810	146.348	941	SRC	1
TOO	Toolangi	37.572	145.490	604	AGSO	5
TYR	Tyers	38.108	146.435	280	SRC	1
UYB	Upper Yarra	37.673	145.897	300	SRC	1
VPE	Vantage Point	37.642	145.937	650	SRC	1
WSK	Woodstock	36.814	144.055	210	SRC	1
Tasmania						
MOO	Moorlands	42.442	147.190	325	TAU	1
MTRD	Mount Read	41.846	145.544	1090	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
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	66.289	110.529	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 4. Australian accelerographs, 1993

Location	*Lat °S*	*Long °E*	*Elev (m)*	*Foundation*	*Type*	*Owner*
ACT						
ASC-AGSO	35.289	149.139	560	Alluvium	SRC	AGSO
Parliament House	35.310	149.123	600	Sandstone	SRC	AGSO
Corin Dam (2)	35.524	148.812	915	Granite	SRC	ACTE&W
Lower Cotter Dam	35.308	148.908	535	Basalt	SRC	ACTE&W
Telecom Tower (3)	35.275	149.096	810	Sandstone	SRC	TEL
New South Wales						
Avon (AVD)	34.376	150.615	532	Sandstone	SRC	NSWWB
Cataract bedrock CTB	34.265	150.811	322	Sandstone	SRC	NSWWB
Cataract Dam (CTD)	34.267	150.802	294	Concrete dam	SRC	NSWWB
Oolong (OOL)	34.773	149.163	600	Weathered granite	SMA-1	AGSO
Ferndale (FND)	34.745	149.166	580	Granite	SRC	AGSO
Fitzroy Falls (FTZ)	34.625	150.484	711	Sandstone	SRC	NSWWB
Springfield (SPF)	34.765	149.151	580	Granite	SRC	AGSO
Wilton (WIL)	34.800	149.221	660	Granite	SRC	AGSO
Googong Dam (2)	35.425	149.264	620	Meta-sediments	SRC	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	SRC	NSWWB
Lucas Heights LHB	34.052	150.979	80	Sandstone	SRC	ANSTO
Lucas Heights LHR	34.05	150.98	80	Reactor Building	SRC	ANSTO
Newcastle Police Stn NPSD	32.931	151.786	20	Building basement	SRC	AGSO
Pipehead Depot (PHD)	33.847	150.969	90	Sandstone /shale	SRC	NSWWB
Water Board Office	33.876	151.207	90	Multi-storey bldg	SRC	NSWWB
Warragamba dam abutment WDA	33.883	150.593	180	Sandstone	SRC	NSWWB
Warragamba dam base WDB	33.885	150.594	30	Concrete dam	SRC	NSWWB
Warragamba Dam Centre (WDC)	33.885	150.594	60	Concrete dam	SRC	NSWWB
Warragamba Dam Top WDT	33.885	150.594	100	Concrete dam	SRC	NSWWB
Warragamba bedrock WGB	33.866	150.575	254	Concrete dam	SRC	NSWWB
Yerranderie (YER)	34.142	150.232	554	Sandstone	SRC	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 HosSRCal	34.83	138.70	50	Marl & clay	MO2	PWDSA
Admin. Centre	34.925	138.608	50	Alluvium	MO2	PWDSA
Govt House GHS+	34.921	138.599	40	Stiff clay	SRC	AGSO
Tucker's TUK+	34.968	138.659	320	Rock	SRC	AGSO
Tasmania						
Gordon Dam	42.71	145.97	350	Quartzite	MO2	HEC

Table 4 (cont.)						
Victoria						
Hume Dam HUM+	36.111	147.029	190	Dam wall	SRC	DWR
Inverness IVS+	36.1337	147.0618	330	Granite	SRC	DWR
Jeeralang JNA	38.351	146.419	330	Mesozoic sediments	SRC	SRC
Moone Ponds MPD+	37.7684	144.9085	20	Tertiary sediment	SRC	
Plane Track PTA	37.357	146.357	771	Palaeozoic sediments	SRC	SRC
Surrey Hills SHY+	37.826	145.1104	100	Palaeozoic sediments	SRC	
Bradford Hills BRD	36.892	144.099	284	Granite	SRC	SRC
Phillip Institute SRC	37.683	145.061	116	Eocene sediments	SRC	SRC
Dartmouth Dam DDC	36.561	147.524	494	Dam crest	SRC	RWCV
	36.570	147.580	520	Hoist house	SMA-1	RWCV
Dartmouth Dam DDB	36.558	147.511	329	Ordivician meta-sediments	SRC	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	SRC	MMBW
Thomson Abutment TMA	37.8440	146.3972	180	Abutment	SRC	MW
Northern Territory						
Tennant Creek TCTY	19.642	134.183	370	Sediments	SSA-1	SRC
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		SRC	QEC
	17.85	145.57	74		SRC	QEC
Western Australia						
Beverley (BEM)	32.159	117.200	240	Alluvium	A700	AGSO
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
Dowerin (DOW)-	31.010	116.982	300	Granite	SRC	AGSO
Goomalling (GOO)	31.394	116.852	250	Granite	SRC	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/granite	MO2	AGSO
Meckering ME3	31.714	117.054	200	Alluvium/granite	A700	AGSO
Mundaring LAK-	31.86	116.34	310	Alluvium/granite	SRC	AGSO
Mundaring Weir						
Weir MUW	31.958	116.164	140	Concrete wall 42m high	SMA1	WAWA
Mukinbudin MBC-	30.728	118.253	350	Alluvium/granite	MO2	AGSO

Table 4 (Cont.)						
Mukinbudin MBS-	30.740	118.256	360	Laterite	SRC	AGSO
Museum MUC	31.957	116.162	106	Concrete floor	MO2	WAWA
Perth TRI+	31.959	115.878	5	Clay-alluvium	SRC	AGSO
Quairading QUW+	31.987	117.270	300	Weathered granite	MO2	AGSO
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;
SRC 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.
MW Melbourne Water.

Table 5. Accelerogram data, 1993

Mn Dy	*Tine*	*Lat ^{o} S*	*Long ^{o} E*	*ML*	*Loc*	*H/E*	*Com*	*T(S)*	*Acc*
01 20	1533	31.65	117.04	3.5	GOO	34/33	SZ	0.040	40
							SN	0.030	86
							SE	0.050	85
08 03	0744	34.53	149.19	2.7	ASC	70/70	SZ	0.17	2.0
							SN	0.08	3.0
							SE	0.13	1.9
09 06	1412	27.69	109.12	3.9	LAK	887/887	PZ	0.090	.7
							PN	0.130	.3
							PE	0.130	.4

Acc = peak ground acceleration in millimetres per second squared

Table 6. Presumed underground nuclear explosions, 1993

Origin Time UTC	*Magnitude mb*	*Yield (kT)*	*Site*	*Comments*
1993 10 05 01:59.56.5	5.9	10-40	Lop Nor, China	PDE*

*PDE - USGS Preliminary Determination of Epicentres

Table 7. Principal world earthquakes, 1993

(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
08 Jan	06 57 51.8	Republic of South Africa	28.028 S	26.800 E	2.7 ML (PRE)

Depth 5 km. Six people killed and seven injured in a mine near Welkom.

13 Jan	17 11 07.5	Jamaica Region	17.955 N	76.583 W	5.5 mb, 4.8 Ms 5.5 Mw (HRV) 5.7 MD (UPA) 5.4 MD (HOJ)

Depth 16 km. One person killed and some damage (VII) in the Kingston area. Felt strongly throughout much of Jamaica.

15 Jan	11 06 05.9	Hokkaido, Japan Region	43.300 N	143.691 E	6.9 mb, 7.1 Ms 7.5 Mw (GS) 7.6 Mw (HRV) 6.7 Ms (BRK)

Depth 102 km. Two people killed, 614 injured and substantial damage (VI JMA) at Kushiro, Hokkaido and Hachinohe, Honshu. Felt (V JMA) at Hiroo, Nemuro, Obihiro, Otaru and Urakawa; (IV JMA) at Hakadate and Tomakomai; (III JMA) at Sapporo, Hokkaido. Felt (IV JMA) at Aomori and Morioka; (III JMA) at Akita, Fukushima, Sendai, Tokyo and Yokahama, Honshu. Also felt (VII) on Shikotan and (VI) at Kurilsk, Kuril Islands. Landslides and subsidence occurred in the epicentral area.

31 Jan	19 33 34.4	Yunnan, China	25.905 N	101.535 E	4.9 mb, 4.5 Ms 4.7 ML (BJI)

Depth 33 km. Two people were killed and some houses were slightly damaged in Dayoo County.

06 Mar	03 05 49.8	Santa Cruz Islands Region	10.972 S	164.181 E	6.1 mb, 7.1 Ms 7.1 Mw (GS) 7.1 Mw (HRV) 7.2 Ms (BRK)

Depth 20 km. Felt (III) at Honiara, Guadalcanal.

12 Mar	14 01 35.4	Fiji Islands Region	14.385 S	178.252 W	6.0 mb, 6.4 Ms 6.4 Mw (GS) 6.4 Mw (HRV) 6.5 Ms (BRK)

Depth 10 km. Five people killed, more than 20 seriously injured and damage on Futuna Island.

20 Mar	14 51 59.7	Xizang	29.084 N	87.333 E	5.8 mb, 6.0 Ms 6.2 Mw (HRV) 5.8 Ms (BRK)

Depth 12 km. At least 2 people killed, 3 seriously injured and damage in Ngamring County. Felt at Xigaze. Also felt at Kathmandu, Nepal.

18 April	09 16 23.2	Central Peru	11.652 S	76.530 W	6.0 mb 6.3 Mw (GS) 6.3 Mw (HRV) 5.8 mb (BRK)

Depth 106 km. Six people killed, including 3 killed by earthquake induced landslides at Lima. Thirty houses destroyed (VI) at Lima. Felt (V) at Chimbote and Huacho; (IV) at Ica and Trujillo; (III) at Huancayo and Huaraz; (II) at Chiclayo.

Table 7 (Cont.)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
11 May	18 26 51.3	Mindanao, Philippine Islands	7.219 N	126.570 E	6.1 mb, 6.6 Ms 7.0 Mw (GS) 7.0 Mw (HRV) 6.5 Ms (BRK)

Depth 59 km. Felt (V RF) at Bislig and Davao; (IV RF) at Cagayan de Oro and Kidapawan; (III RF) at Cotabato. Also felt (III RF) at Palo, Leyte and (II RF) at Camiguin Island.

14 May	13 37 24.2	Republic of South Africa	26.834 S	26.666 E	3.8 ML (PRE)

Depth 5 km. Some people possibly killed in a mine explosion.

24 May	23 51 28.2	Jujuy Province, Argentina	22.67 S	66.54 W	6.6 mb 7.0 Mw (GS) 7.0 Mw (HRV) 6.6 mb (BRK)

Depth 221 km. Felt in Jujuy, Salta and Tucman Provinces. Also felt (V) in the Antofagasta-Taital-Calama area; (IV) at Mejillones, San Pedro and Tocopilla; (III) at Iquique and (II) at Copiapo, Chile. Felt (III) at Arequipa, Peru.

08 Jun	13 03 36.4	Nr East Coast of Kamchatka	51.218 N	157.829 E	6.4 mb, 7.3 Ms 7.1 Mw (GS) 7.5 Mw (HRV) 7.2 Ms (BRK)

Depth 71 km. Damage (VII) at Severo-Kurilsk. Felt (VI) at Petropavlovsk-Kamchatskiy. Maximum tsunami wave heights (peak-to-trough) recorded at selected tide stations were as follows: 12 cm at Hilo, 10 cm on Shemya, 8 cm on Midway Island and 5 cm at Haleiwa, Hawaii.

10 Jul	20 40 58.9	Costa Rica	9.821 N	83.622 W	5.3 mb, 5.6 Ms 5.8 Mw (HRV) 5.2 MD (HDC)

Depth 20 km. One person was killed, another died of a heart attack and at least nine people were injured in the Turrialba area. Damage occurred to homes and buildings at Cartago and Turrialba. Landslides blocked roads in the epicentral area. Felt throughout Costa Rica.

12 Jul	13 17 11.9	Hokkaido, Japan Region	42.851 N	139.197 E	6.6 mb, 7.6 Ms 7.3 Mw (GS) 7.7 Mw (HRV) 7.3 Ms (BRK)

Depth 17 km. At least 200 people were killed and 39 missing in the Hokkaido region, including at least 165 killed on Okushiri. One person on a fishing boat was killed off Aomori, Honshu. Three people were missing from the southeast coast of Russia. Severe damage (V JMA) was caused by the earthquake and accompanying fires, landslides and tsunami in southwestern Hokkaido. 540 houses were destroyed and 1,834 others were damaged. Approximately 600 fishing boats were damaged or lost off Western Japan, southeastern Russia and South Korea. Tsunami wave heights as high as 30.6 meters was reported along the southwest coast of Okushiri Island, 10 meters along the west coast of Hokkaido, 3 meters at Nakhodka, Russia, 2 meters along the northeast coast of South Korea and nearly 1 meter at Aomori, Honshu. The tsunami affected much of the southeastern coast of Russia and also caused damage to a factory at Kamenka, Sakhalin Island.

22 Jul	04 57 07.0	Northern Colombia	6.470 N	71.210 W	6.1 mb, 5.9 Ms 6.1 Mw (GS) 6.0 Mw (HRV) 5.6 Ms (BRK)

Table 7 (Cont.)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
Depth 20 km. Two people killed, some injured and many houses destroyed at Puerto Rondon, Puerto Colombia. Felt strongly in northeastern Colombia and Western Venezuela. Also felt at Bogota, Colombia and Caracas, Venezuela.					
01 Aug	00 20 40.0	Sudan	15.400 N	31.669 E	5.2 mb, 5.2 Ms
Depth 10 km. At least two people killed, nine injured and damage in the Khartoum area.					
08 Aug	08 34 25.0	South of Mariana Islands	12.964 N	144.766 E	7.2 mb, 8.1 Ms 7.5 Mw (GS) 7.8 Mw (HRV) 8.2 Ms (BRK)
Depth 61 km. Forty-eight people injured on Guam. Extensive damage (IX) to hotels in the Tumon Bay area. Cracks, tens of meters long and 25-50 cm wide, caused by liquefaction in the underlying soil, damaged facilities at the commercial port and naval base at Apra Harbor. Damage (VII) occurred at several locations in the northern half of the island. One end of the approach to a bridge at Pago Bay fell more than 35 cm. Many landslides and rockslides were reported, mainly in the southern half of the island. The preliminary estimate of loss from damage to commercial buildings is placed at 112 million U.S. dollars and loss from damage to private residences is estimated at several million U.S. dollars. Slight damage (V) on Saipan. Felt (VI) on Rota and (V) on Tinian. Tsunami generated with maximum wave heights at selected tide stations as follows: 98 cm at Muroto-Misaki, Shikoku; 68 cm on Chichi-Shima, Bonin Islands; 58 cm at Tosashimizu, Shikoku; 56 cm at Aburatsu, Kyushu; 46 cm at Mera and Owase, Honshu; 44 cm at Ayukawahama, Honshu; 42 cm at Omae-zaki, Honshu; 34 cm at Hanasaki and Kushimoto, Honshu, 34 cm at Hirara, Ryukyu Islands; 28 cm at Ofunato, Honshu; 24 cm at Kochi Shikoku; 19 cm Port Allen, Kauai; 15 cm at Lahaina, Maui; 14 cm at Haleiwa, Oahu: 12 cm at Hachinohe, Honshu and Kahului, Maui; 7 cm at Kapoho, Hawaii and Nowiliwili, Kauai; 5 cm at Honokohau, Hawaii.					
10 Aug	00 51 54.7	Off W. Coast of S. Island, NZ	45.140 S	166.954 E	6.2 mb, 7.1 Ms 7.1 Mw (GS) 7.0 Mw (HRV)
Depth 33 km. Felt (VI) on South Island within 150 km of the epicentre. Power outages reported in the Te Anau area. Felt throughout South Island. Also felt in southern North Island.					
10 Sep	19 12 54.8	Nr Coast of Chiapas, Mexico	14.734 N	92.675 W	6.3 mb, 7.3 Ms 7.2 Mw (GS) 7.2 Mw (HRV) 7.2 Ms (BRK)
Depth 34 km. One person killed, 3 injured and considerable damage in southwestern Guatemala. Rockslides blocked some roads in Guatemala. Some damage in parts of Chiapas, Mexico. Felt strongly in southern Mexico and as far away as Mexico City. Felt in much of Central America.					
21 Sep	03 28 55.6	Oregon	42.312 N	122.005W	5.8 mb, 5.8 Ms 5.9 Mw (GS) 5.9 Mw (HRV) 5.9 ML (BRK) 5.9 MD (SEA)
Depth 11 km. One person was killed by an earthquake-induced landslide along U.S. highway 97 north of Klamath Falls. Another person died of a heart attack. Maximum intensity (VII) in parts of Klamath Falls and in rural areas northwest of that city. Approximately 700 homes and commercial buildings were damaged. Three highways leading to Klamath Falls were temporarily closed because of rockfalls or concern about possible damage to bridges. Felt in southern Oregan and parts of northern California.					

Table 7 (Cont.)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
29 Sep	22 25 48.5	Southern India	18.055 N	76.424 E	6.3 mb, 6.3 Ms 6.1 Mw (GS) 6.1 Mw (HRV)

Depth 6 km. Nine thousand seven hundred forty-eight people killed, about 30,000 injured and extreme devastation in the Latur-Osmanabad area. Nearly all buildings were destroyed in the village of Killari. Felt in large parts of central and southern India, including Bangalore, Bombay, Hyderabad and Madras.

11 Oct	15 54 22.4	South of Honshu	32.003 N	137.852 E	6.5 mb 6.8 Mw (GS) 6.9 Mw (HRV) 6.8 mb (BRK)

Depth 365 km. One person died of a heart attack and four other people were injured in the Tokyo area. Felt (IV JMA) at Tokyo and Yokohoma; (III JMA) at Chiba, Fukushima and Utsunomiya; (II JMA) at Kushiro, Morioka and Sendai.

13 Oct	02 06 00.1	Eastern New Guinea Region, Papua New Guinea	5.929 S	146.029 E	6.4 mb, 7.1 Ms 6.7 Mw (GS) 6.7 Mw (HRV) 7.1 ML (PMG)

Depth 24 km. Sixty people were killed and several injured in the Upper Markham Valley. Large landslides blocked the Ume River and contributed to many of the casualties.

16 Oct	03 05 31.0	Eastern New Guinea Region, Papua New Guinea	5.944 S	146.201 E	6.2 mb, 6.4 Ms 6.3 Mw (GS) 6.3 Mw (HRV) 6.5 Ms (BRK) 6.5 ML (PMG)

Depth 33 km. Three people killed and additional damage in the Upper Markham Valley.

25 Oct	10 27 01.5	Eastern New Guinea Region, Papua New Guinea	5.892 S	146.001 E	6.4 mb, 7.1 Ms 6.7 Mw (GS) 6.7 Mw (HRV) 7.1 Ms (BRK)

Depth 10 km.

13 Nov	01 18 04.2	Near East Coast of Kamchatka	51.919 N	158.704 E	6.5 mb, 7.1 Ms 6.9 Mw (GS)

Depth 34 km. Felt (VI) at Petropavlavosk-Kamchatkskiy and (IV) at Severo-Kurilsk.

29 Dec	07 48 14.4	Vanuatu Islands	20.175 S	169.764 E	6.1 mb, 6.8 Ms 6.9 Mw (GS) 7.0 Mw (HRV) 6.8 Ms (BRK)

Depth 33 km.