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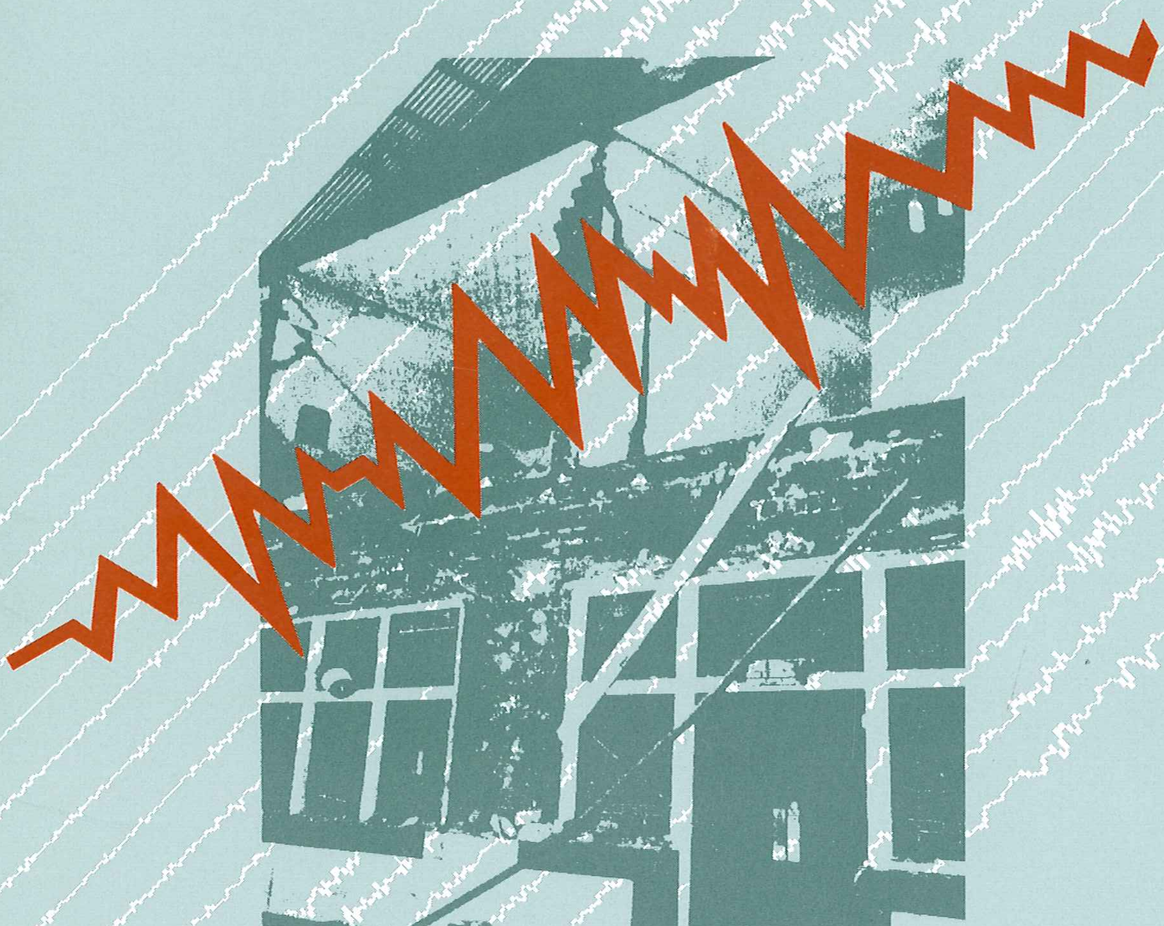
Australian Seismological Report, 1995

Kevin McCue and Peter Gregson



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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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AUSTRALIAN SEISMOLOGICAL REPORT, 1995

Compiled by

Kevin McCue and Peter Gregson

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY
CANBERRA

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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Minister for Resources and Energy: Senator the Hon. W.R. Parer
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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

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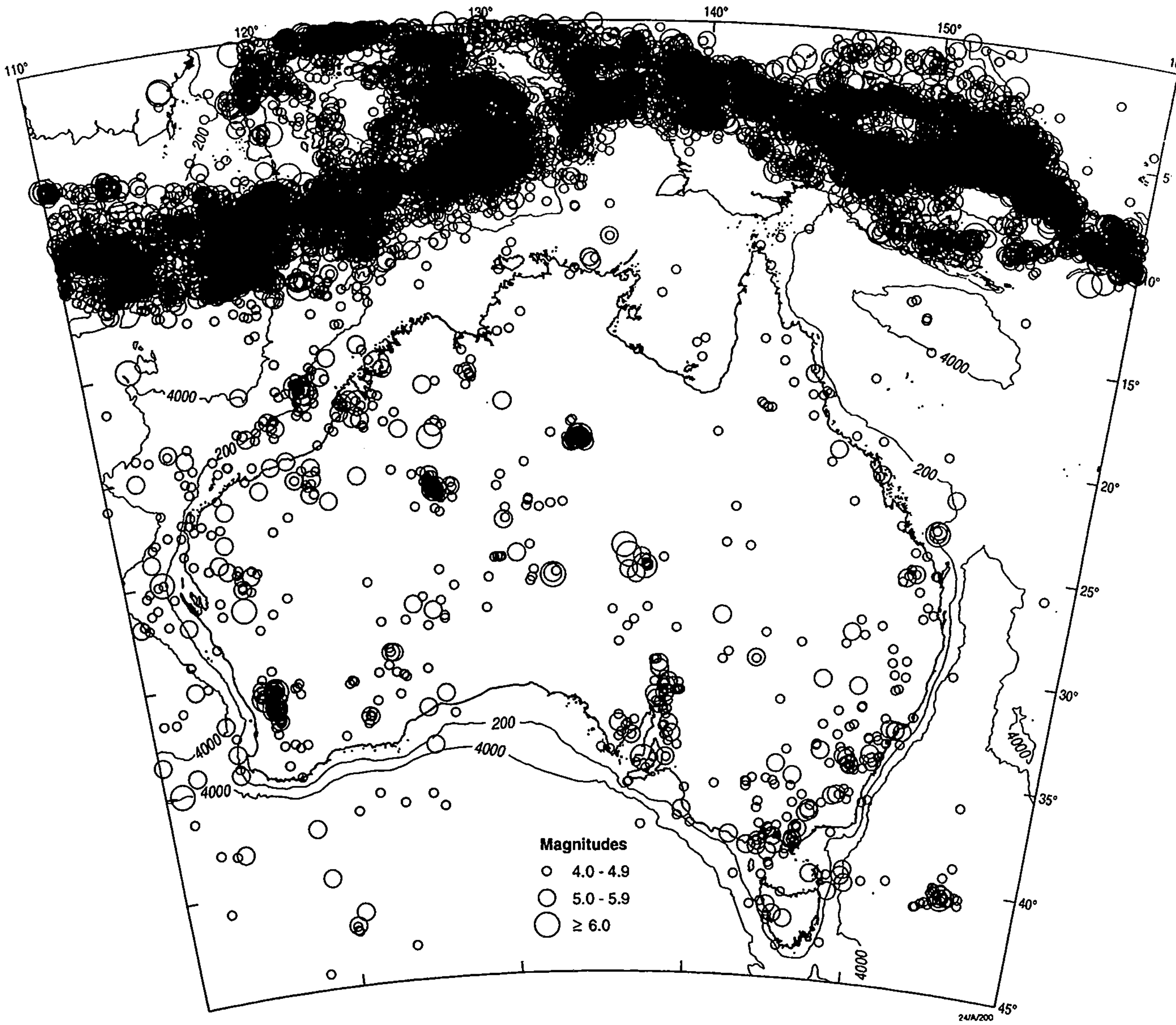

Figure 1 Epicentres of Australian earthquakes, post - 1788, magnitude ML ≥ 4.0.

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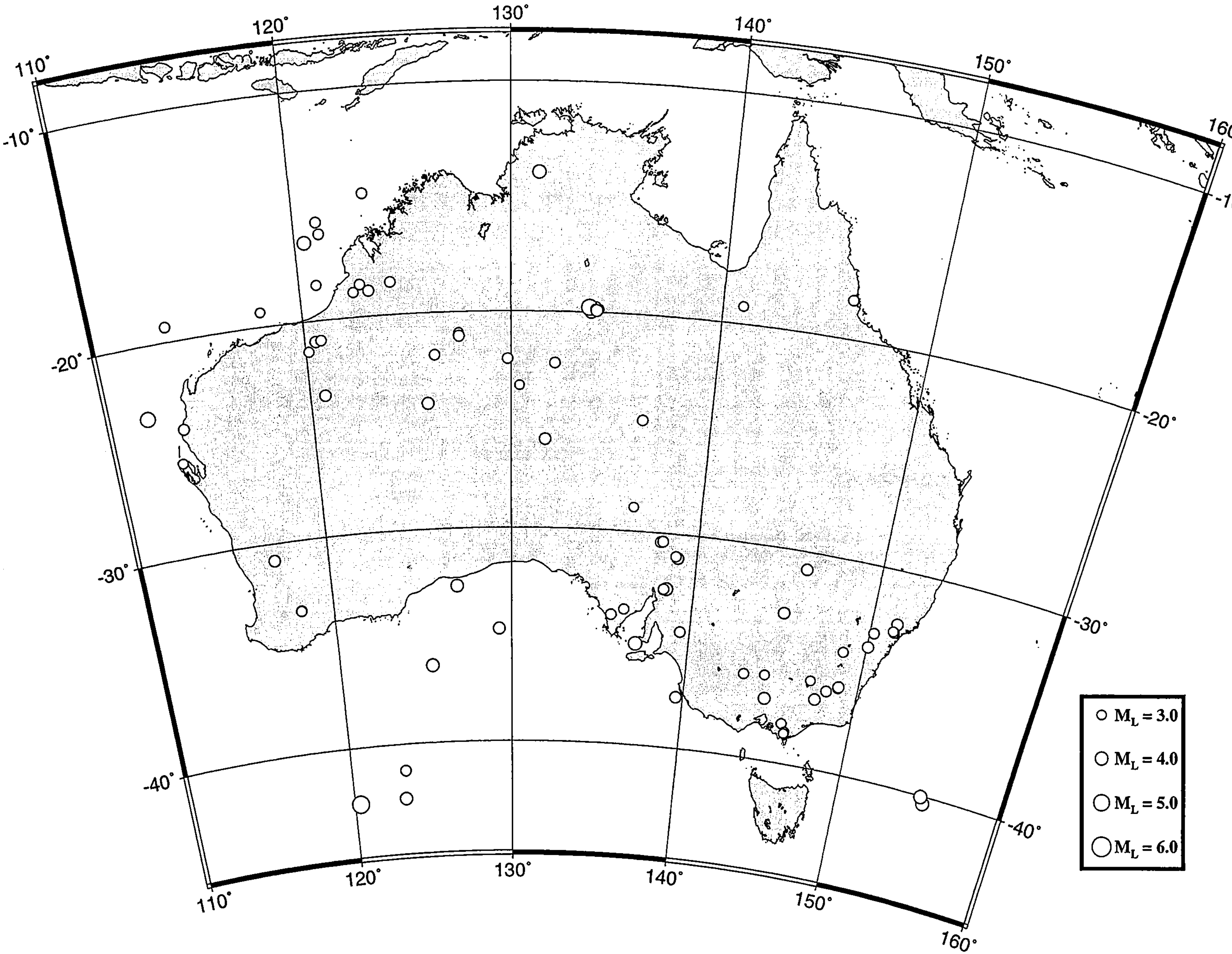

Figure 2 Epicentres of Australian earthquakes, 1995, magnitude $M_L \geq 3.0$

SUMMARY

The year was another average one with respect to the frequency and magnitude of earthquakes in Australia, though a very active year for major earthquakes worldwide. The largest earthquake in the Australian region in 1995 had a focus in oceanic crust in the Southern Ocean 800 km south of Esperance WA, its magnitude was Mw 5.4. The largest onshore earthquake was a magnitude ML 4.9 aftershock of the January 1988 sequence at Tennant Creek in the Northern Territory. None of the 86 earthquakes of magnitude ML 3 or more caused significant damage and there were no injuries reported. That most strongly and widely felt event was the Banda Sea earthquake on Christmas Day which rocked the Top End where the intensity in Darwin was rated as MMV by seismologists at AGSO's Mundaring Office who investigated the effects.

Intensity questionnaires were distributed and isoseismal maps compiled for four earthquakes that were widely felt; their epicentres were at Caldwell Qld, Stenhouse Bay and Orroroo SA, and in the Banda Sea. Several earthquakes were felt by ANARE personnel at Macquarie Island during the year.

Under the joint Federal and State Government's 3-year Urban Monitoring Program, pairs of accelerographs continued to be installed in urban areas. Both of the Darwin instruments were triggered by the large Banda Sea earthquake on Christmas Day, and the Adelaide instruments were triggered by an earthquake in Stenhouse Bay off Yorke Peninsula. In Canberra, an accelerograph in the AGSO building was triggered by three small regional earthquakes and one of the Telecom Tower instruments triggered on a fourth. Purchase and installation of the instruments has proven very successful, their longterm maintenance is essential to ensure that useful data are collected.

Worldwide there were 3 great earthquakes of magnitude 8 or more in 1995 and at least 7874 people died during the year compared with the average number of earthquake fatalities of about 10 000 per year since 1900.

During 1995, AGSO detected seven underground nuclear explosion, five were detonated by France at Mururoa in the Pacific and two by China at their Lop Nor test site. Other nuclear weapons States abided by a self-imposed moratorium on testing in recognition of the changed international political climate.

INTRODUCTION

Each year in Australia there are on average about 200 earthquakes of magnitude 3 or more and one earthquake of at least magnitude 5.3. The larger ones are a threat to life and property as was so tragically demonstrated by the 1989 Newcastle earthquake. Analysis of the small ones will yield clues to the cause, location and style of future large ones. This report contains information on the 1995 earthquakes and is the sixteenth compiled by the Australian Geological Survey Organisation (and its predecessor BMR) since 1980. 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: the **Australian region earthquakes** section contains a summary of the 1995 seismicity with a State by State breakdown and a brief description of the more important earthquakes; **Isoseismal maps** describing those that were widely felt; **Network operations** which gives details of the seismographs that operated in Australia during the year and calibration details; **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 1995; and **Monitoring of nuclear explosions** which describes the operation of the Nuclear Monitoring Section and lists known underground nuclear explosions.

In this 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 as a magnitude 5 earthquake, but an energy release about 30 times greater.

A rule of thumb relation between magnitude M and energy E (joules) is

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

Shocks as small as magnitude 1.0 are reported felt, whereas earthquakes of magnitude 5 or more may 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 terms used for magnitudes below 5 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 Wood-Anderson instruments (Anderson & Wood, 1925) are not available, an equivalent Richter magnitude can be determined using other instruments by correcting for the difference in magnification (Willmore, 1979) 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 $\Delta = 20\text{–}160°$, and in the period range $T = 17\text{–}23$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. This is a most convnient way to measure magnitude and many other forms of this equation have been used. It is usually calibrated against Richter magnitude.

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

$$M_o = \mu A\, d$$

and

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

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

Magnitude from isoseismals (M (Rp)) 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. Greenhalgh & others (1989) modified the equation using a larger data set and extended the method to other intensities, but at the expense of simplicity in application. They derived the expression:

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

Additional information on magnitudes is available in McGregor & Ripper (1976), Båth (1981), Denham (1982), Everingham & others (1987), and Ambraseys and Free (1997).

Intensity

The intensity of an earthquake is a subjective estimate of its effects on people and buildings and should not be confused with magnitude which is a measure of the amplitude of seismic waves recorded on a seismogram. In this report we use the modified Mercalli (MM) scale (Eiby, 1966) 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, 1995

Earthquakes of magnitude ML 3 or more recorded in 1995 on AGSO's National Seismographic Network and State and regional networks are listed in Table 1, and those of magnitude ML 4 or more since 1788 are plotted from the AGSO earthquake database in Figure 2. The pattern of activity is similar to that of the previous year, a broad NW/SE swathe of activity across the continent with few earthquakes in Queensland or southwestern Australia.

The only earthquake of magnitude 5 or more occurred in oceanic crust between the continent and the mid-ocean ridge south of Esperance WA. It was not felt onshore. There were four earthquakes onshore of magnitude ML 4 or more, two in South Australia and three in the Northern Territory, and another six offshore as shown in Figure 2.

None of the earthquakes in 1995 caused serious damage or injuries but many of them were felt locally, especially those in the more densely populated southeast of the continent. There was no repeat of the earthquake swarm near Eugowra in 1994 (Gibson and others, 1995).

Compared with a post-1980 yearly average of one earthquake of magnitude 5.3 or more, 21 of magnitude 4 or more and more than 200 of magnitude 3.0 or more, there were 1, 9 (2) and 78 (8) respectively in 1995 - very similar to the respective numbers in 1994. The numbers in brackets are aftershocks at Tennant Creek, the annual totals are the sums of the two numbers. The year's seismicity was like that in 1994, slightly below average.

Kevin McCue

Western Australia (Figure 3)

The level of seismic activity in Western Australia was slightly higher than for 1994. Two hundred and four earthquakes of magnitude greater than ML 1.9 were located (as against 191 in 1994). Ninety percent of these located were located within or just adjacent to recognised zones.

Five earthquakes of magnitude ML 4 or greater were located during the year (one more than in 1994). The largest at ML 4.6 occurred on 25 August, 250 km NW of Carnarvon. A magnitude ML 4.3 earthquake occurred on 27 December, 250 km NW of Broome and there were two off the south coast, 421 km SE of Esperance (ML 4.0) on 29 April and 850 km S of Albany

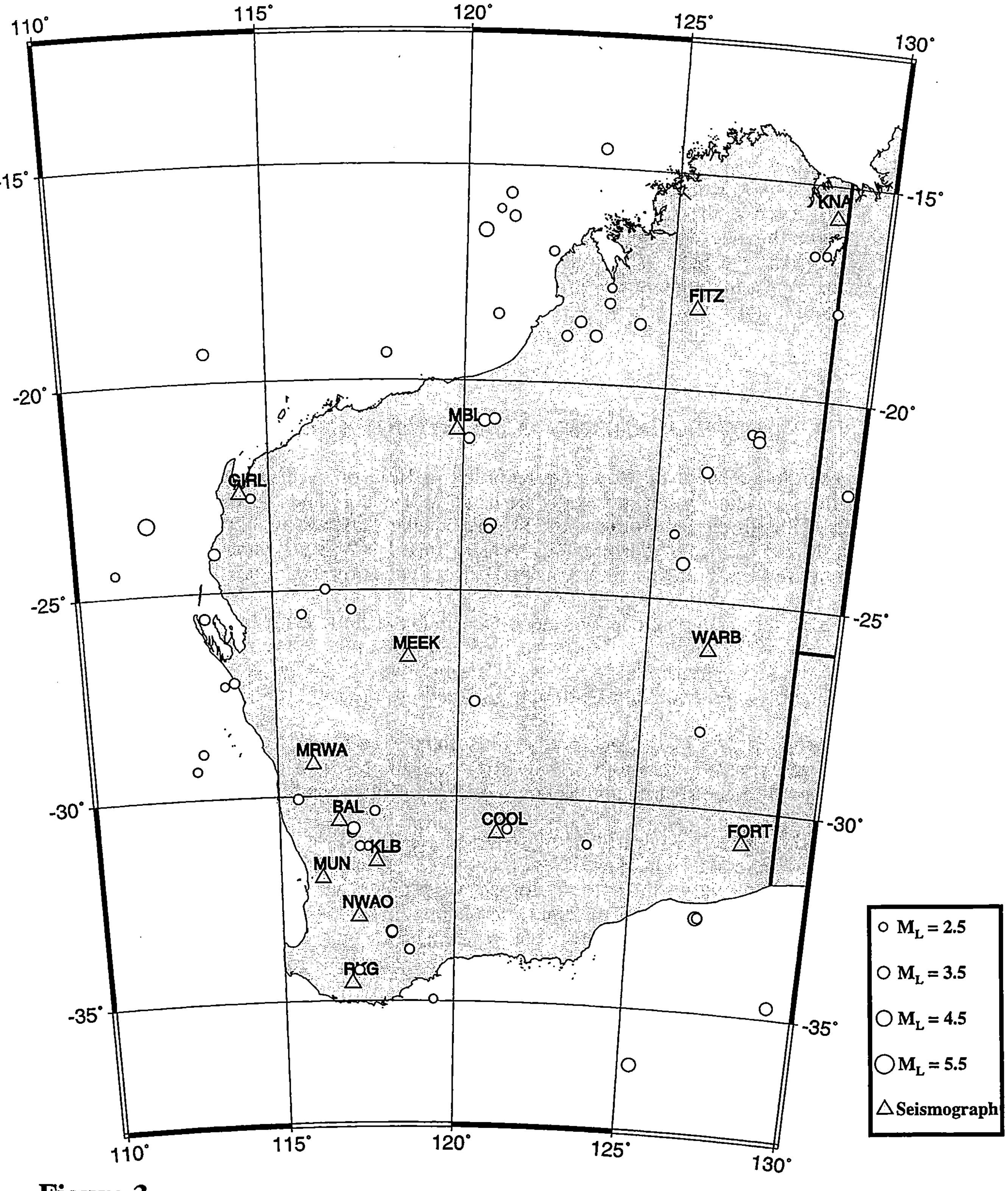

Figure 3

Earthquake epicentres in Western Australia 1995, magnitude $M_L \geq 2.5$

(MW 5.4) on 15 May. A magnitude ML 4.0 event on 5 April was located 106 km SE of Cocklebiddy and was well outside a recognised zone.

Other earthquakes occurring outside recognised zones were located near Jiggalong, 250 km SSE of Marble Bar, (ML 3.0 and 2.6), 119 km NNW of Port Hedland (ML 3.0), 245 km NNW of Warburton (ML 3.7), 120 km ENE Sandstone (ML 2.9), the north end of Shark Bay (ML 3.1) and approximately 70 km N Kalbarri (ML 2.9 and 2.5). Two events occurred 36 km SE Eneabba, to the west of the South West Seismic Zone (ML 2.5 and 2.9).

The South West Seismic Zone was the most active zone where 142 earthquakes were located compared with 104 in 1994. The largest (ML 3.5) occurred near Cadoux where 19 earthquakes were located. The most active area was approximately 28 km N of Nyabing where 27 earthquakes up to magnitude 3.3 occurred, the majority of them in April. Sixteen earthquakes were located in both the Meckering and Wyalkatchem areas, and there were fourteen earthquakes approximately 18 km NW Beacon. Other active areas were Brookton, Talbot Brook and Gnowangerup (6 each), Kellerberrin and Calingiri (4 each), Quairading, Wagin and Ongerup (3 each), Wongan Hills and Katanning (2 each). One event was located at Mt Barker, east of Albany, Tambellup, Pingrup, Lake Grace, Dumbleyung, Narrogin, Harvey, Corrigin and Dowerin.

Three micro-earthquakes, all less than magnitude 3, were located in the south-east of the State compared with 7 in 1994. Six earthquakes were located in the Carnarvon Basin, the largest magnitude, ML 3.4 occurring on 4 June, 93 km north of Carnarvon; four ranging in magnitude from 2.8 to 3.3 in the Tobin Lake area (the same as 1994), and eight in the Halls Creek Mobile Belt, six of them approximately 80 to 100 km south of Kununurra. Offshore, four earthquakes ranging in magnitude from 3.0 to 3.3 were located towards the northern end of the north-west shelf and five earthquakes offshore from Carnarvon, Geraldton and Dampier and south-east of Esperance.

The NEIC computed a centroid moment tensor solution and AGSO a mechanism from first motions on Australian stations (McCue, unpublished), of the MW 5.4 intraplate earthquake in the Southern Ocean on 15 May. The mechanisms are very similar but the first motions from Central Australian stations, Alice Springs, Kakadu, Fitzroy Crossing and Warramunga do not fit the NEIC solution, arrivals at WA stations MUN and NWAO were emergent ie near nodal and those from a group of Antarctic stations including Mawson but excluding Casey and South Pole do not fit either. The earthquake had a thrust mechanism reflecting a near horizontal north-south oriented principal stress direction, parallel to the plate motion but perpendicular to the stress orientation in the closest continental crust east of Perth.

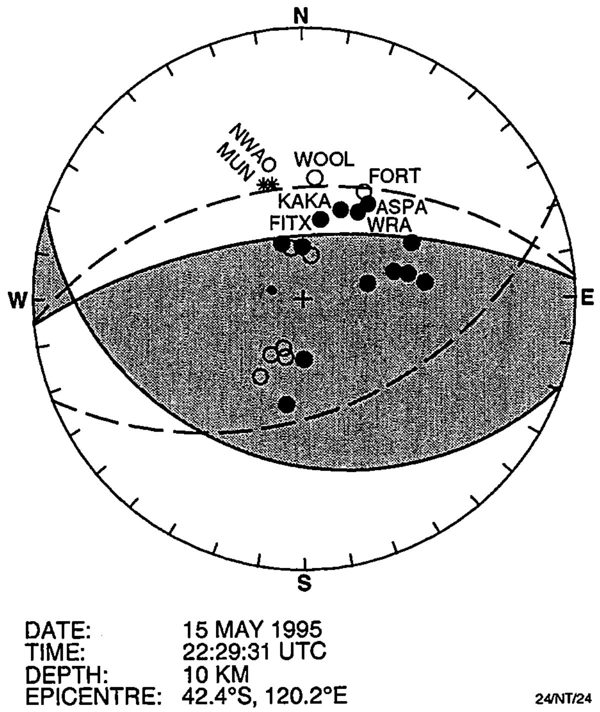

FIGURE 15 Fault Plane Solution (see text)

At 1:57 a.m. WST on 1 May, many Perth residents were awoken by the sound of an explosion and by their house shaking. Others simultaneously observed a meteorite travelling over the city from SW to NE then disintegrating. The sonic boom was recorded

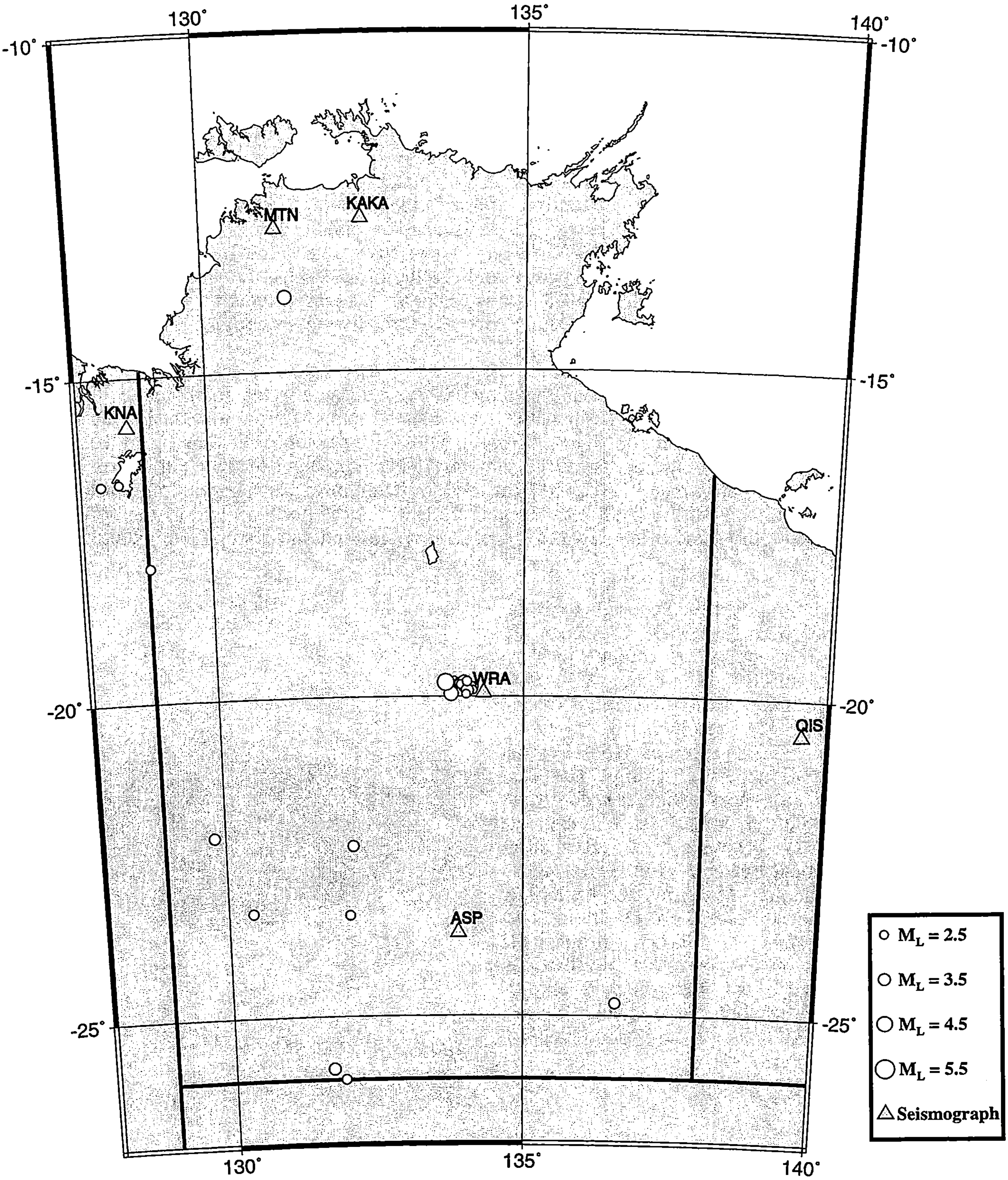

Figure 4

Earthquake epicentres in Northern Territory 1995, magnitude $M_L \geq 2.5$

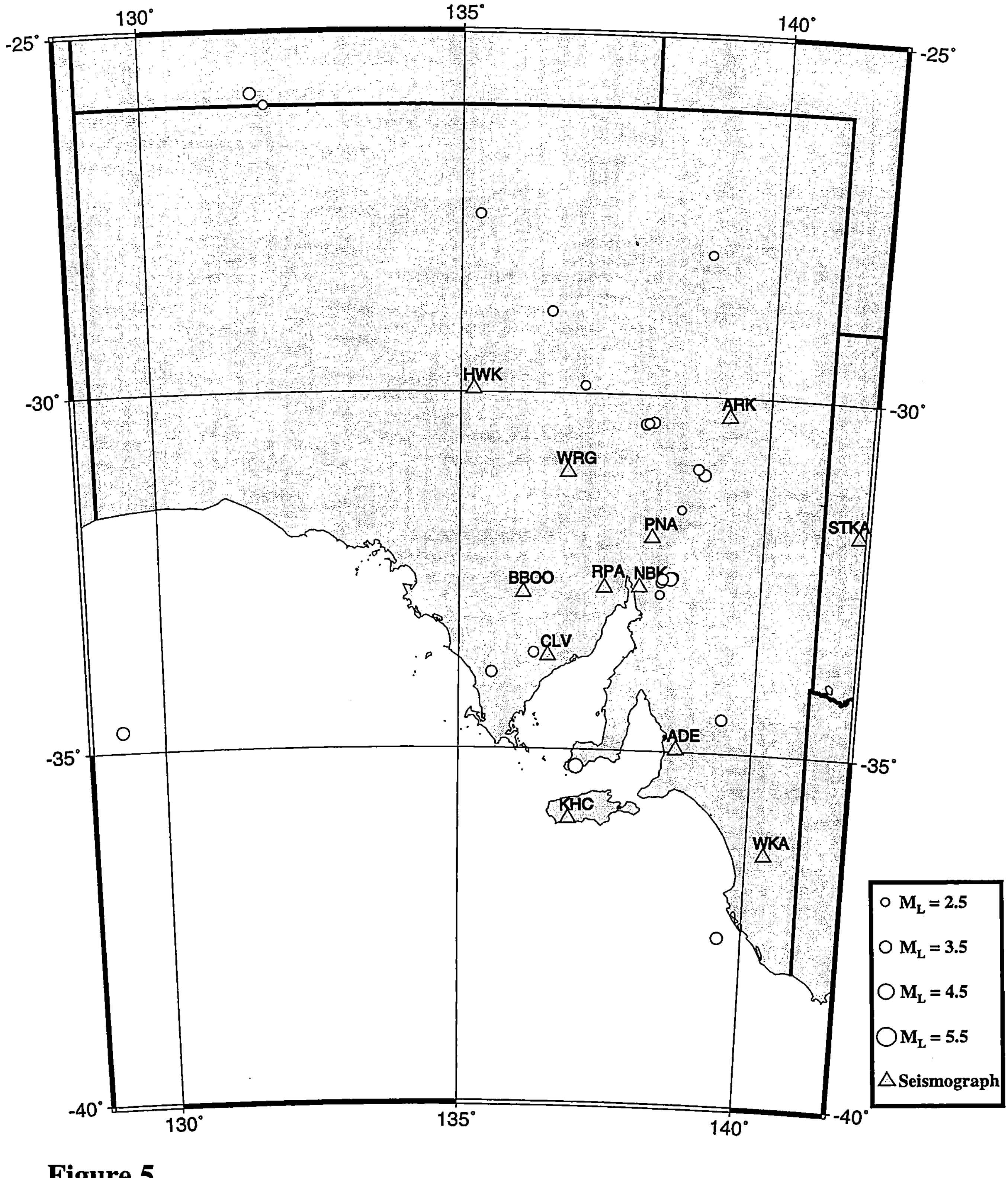

Figure 5

Earthquake epicentres in South Australia 1995, magnitude $M_L \geq 2.5$

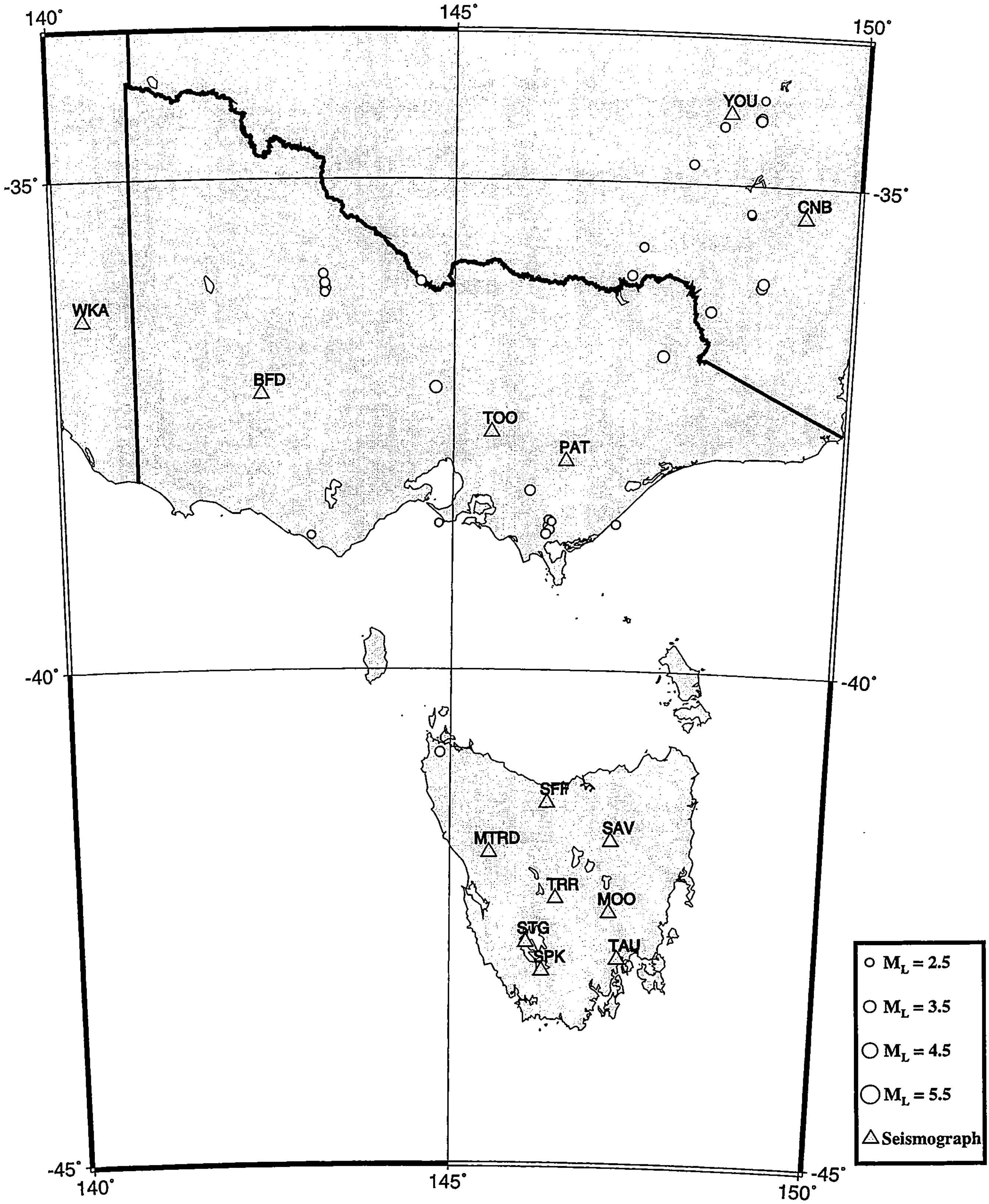

Figure 6

Earthquake epicentres in Victoria and Tasmania 1995, magnitude $M_L \geq 2.5$

for 40 sec on the Mundaring seismograph but not on the Ballidu, Kellerberrin and Narrogin seismographs about 130 km to the north, east and southeast of Perth. This is the first confirmed recording of a meteorite by the Mundaring Observatory.

Peter Gregson and Edward Paull

Northern Territory (Figure 4)

The largest earthquake onshore was another in the aftershock sequence near Tennant Creek that has continued since January 1988. It had a magnitude of 4.9 and occurred on 14 June. Its epicentre was at the western end of the mapped fault scarp that ruptured in 1988 (Jones & others; 1991). The remaining seven aftershocks of magnitude 3 or more were scattered along the length of the 1988 surface rupture.

Other isolated earthquakes occurred in the Territory; one near Katherine on 3 January was reported felt, the others were in isolated areas west of Alice Springs and in the Simpson Desert.

Kevin McCue

South Australia (Figure 5)

Activity was relatively normal for the year, occurring at about the usual levels in the usual zones. In all 305 events were located, 11 of which were over magnitude 3, and 21 of which were reported felt.

The activity at Myrtle Springs continued during January, but there were few earthquakes during the remainder of the year. The equal largest event of the year was a magnitude ML 3.7 (ADE) earthquake in the Great Australian Bight on 27 October. It was followed only 6 hours later by the most significant event of the year, a magnitude ML 3.6 (ADE) earthquake at Stenhouse Bay on Yorke Peninsula which was weakly felt in Adelaide (assessed as ML 4.2 by AGSO). An isoseismal map was produced (see below). Only 2 weeks later a magnitude ML 3.7 earthquake occurred near Orroroo which was the largest event in a cycle of activity that included foreshocks and aftershocks. An isoseismal map was produced for the mainshock. Portable instruments were deployed, but owing to the rapid decay of the sequence and some equipment problems, little useful information was recorded. The Stenhouse Bay and main Orroroo events triggered the Seismology Research Centre's real-time detection system in Victoria, and approximate, but useful epicentres and magnitudes were calculated in a very short time.

A small earthquake which occurred on Christmas Day morning, just offshore from Port Noarlunga, was felt in Adelaide by a few people and the intensity was assessed as MMIII.

David Love

Victoria & Tasmania (Figure 6)

On 18 April a magnitude ML 4.1 earthquake occurred in the East Bass Strait Seismic Zone near 40°S, 155°E, where there is a large guyot or submarine volcano in the Tasman Sea. A magnitude Ms 6.3 earthquake occurred there in 1983 (Denham, 1985) and small earthquakes are relatively frequent. None of the onshore Tasmanian earthquakes were reported felt in 1995.

In Victoria the largest earthquake was a magnitude ML 3.7 earthquake at Benambra in the northeast on 30 July where the maximum intensity was MMIV. This event was also felt at Omeo, Dartmouth, Falls Creek and Mt Bogong but an isoseismal map was not drawn.
Microearthquakes occurred near the main metropolitan areas of Melbourne, Geelong and Albury.

Gary Gibson, Wayne Peck & Kevin McCue

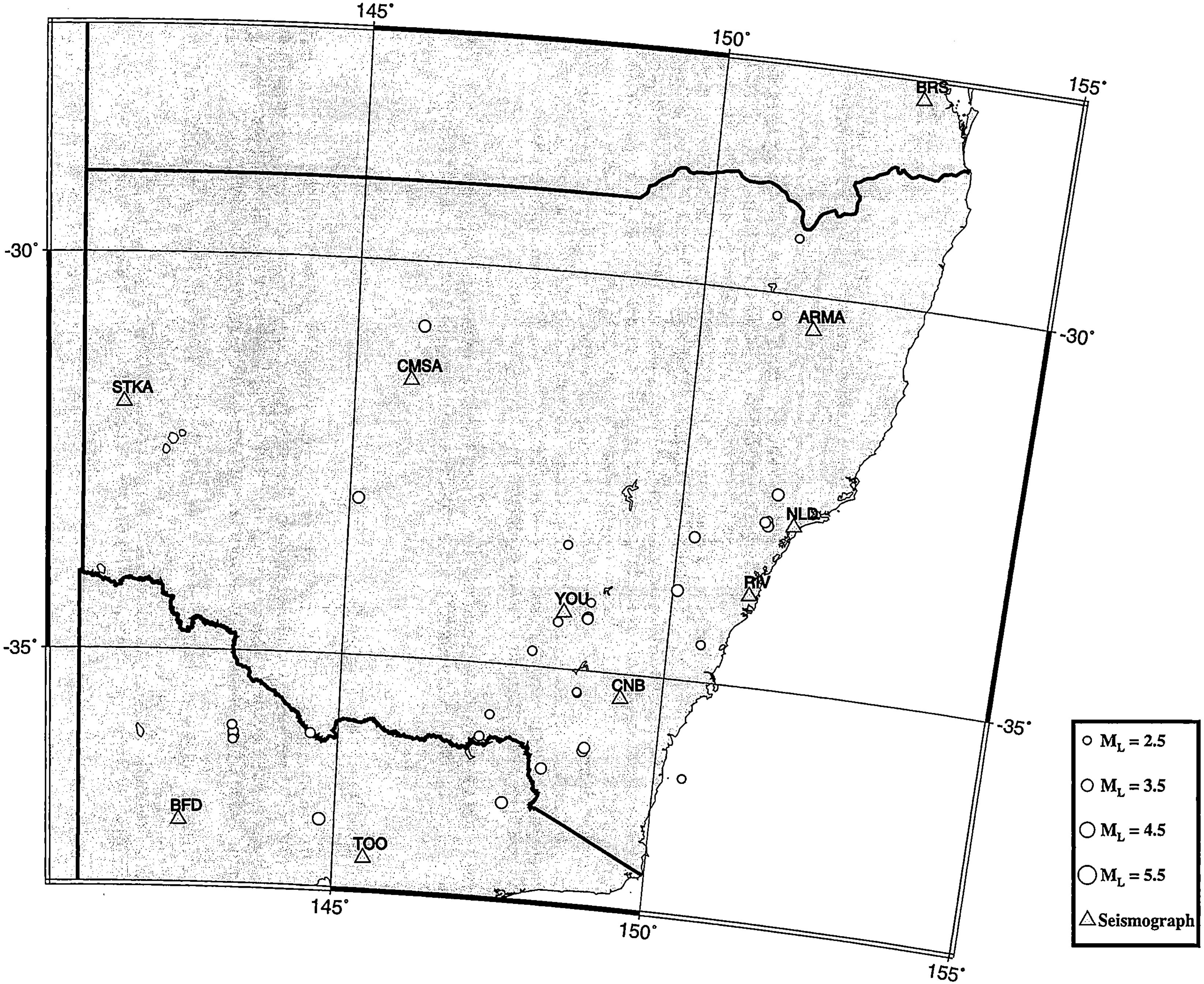

Figure 7 Earthquake epicentres in NSW and ACT 1995, magnitude $M_L \geq$ 2.5

New South Wales and ACT (Figure 7)

The largest earthquake in NSW in 1995 was the ML 3.6 event near Jenolan Caves west of Sydney on 20 May. It was widely felt and reported. In the Ellalong area west of Newcastle, a coal mining area struck by a magnitude ML 5.3 earthquake in August 1994 (Jones and others, 1994), there were four events in July, all with magnitude below ML 3.0, another one in September, one in October and another two in November.

Most of the earthquakes occurred in the coastal zone between Newcastle and the Snowy Mountains, one near Adaminaby on 21 July was felt there and in Cooma and Berridale. The Dalton-Gunning Seismic Zone was very quiet throughout the year with not a single earthquake of magnitude 3 or more.

In the ACT several people reported feeling a microearthquake that occurred in NSW about 23 km SSW of Canberra on 10 October. A number of such microearthquakes have been felt or recorded in the Capital over recent years (AGSO, 1996).

Kevin McCue

Queensland (Figure 8)

There were only two earthquakes in Queensland of magnitude 3 or more in 1995. That near Cardwell north of Townsville was felt and an isoseismal map was compiled at the University of Queensland from the telephone reports and returned questionnaires. The other was near Mt Isa in Western Queensland.

Russell Cuthbertson

NETWORK OPERATIONS 1995

In South Australia, a station was installed jointly by AGSO and MESA on the Eyre Peninsula at Buckleboo (BBOO) on 7 December. It was equipped with a vertical, broadband sensor and sited on a moderate sized granite outcrop approximately 130 km from the sea. The new station at Port Pirie (PTP), a six channel Kelunji, was installed by MESA as part of the joint Urban Monitoring Project (JUMP) and began operating on 9 May. It is on soft sediments at the edge of the town, about 1 km from the tall smoke stack.

In Western Australia, the station at Nanutarra (NANU) was closed in March and a new station established at Giralia (GIRL) in September, the data telemetered to Canberra via satellite.

In the Northern Territory, the station at Manton Dam (MTN) was closed and a new station opened at Kakadu (KAKA) in March. The relocation was to improve the signal to noise ratio, to enable telemetry of the data to Canberra and to combine the operation with a newly established magnetic observatory there.

Calibration curves for many of the digital stations of the Australian National Seismograph Network are presented in Appendix 2. Corresponding curves for many of the analogue stations were presented in the 1990 report as separate figures for Eastern and Western Australian networks.

Graeme Small, Peter Gregson, David Love, Kevin McCue and Russell Cuthbertson

Urban Monitoring

This was the third and final year of funding by the Commonwealth for the joint Urban Monitoring project coordinated by AGSO with the States and Territories. The project was funded by the Commonwealth to purchase two accelerographs for installation in all urban area with more than 50 000 people, the State and Territory Governments role being to install and

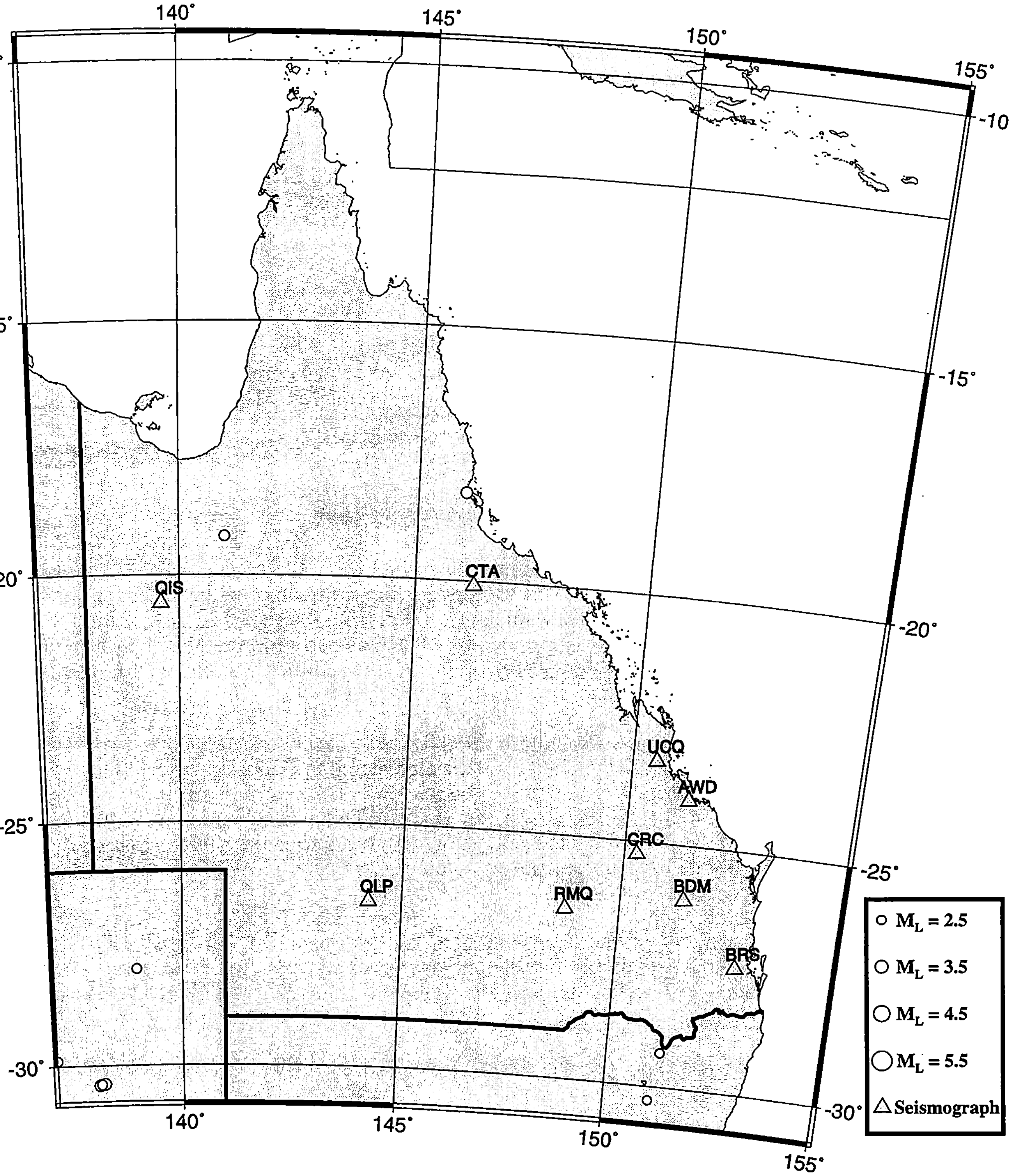

Figure 8

Earthquake epicentres in Queensland 1995, magnitude $M_L \geq$ 2.5

maintain the instruments. Many of the chosen sites have been equipped with triaxial accelerometers, GPS clocks and digital Kelungi recorders which can be interrogated by telephone and already many of these instruments have recorded earthquakes.

Trevor Jones, Victor Dent and Peter Gregson

ACCELEROGRAPH DATA & ATTENUATION

The locations of permanent accelerographs in 1995 are given in Table 5.

In Western Australia and the Northern Territory Urban Monitoring accelerographs continued operation in Perth and two new instruments were installed in Darwin in March, one at Parliament House and the second at the Department of Mines and Energy rock store. The two Darwin accelerographs were triggered during the Christmas Day earthquake in the Banda Sea. This major earthquake had a focal depth of 150 km and a magnitude of Mw 7.1 (GS). Its epicentre was about 650 km NW of Darwin where the intensity was MMV (see Gregson's isoseismal map this report). The maximum accelerations were 211 mms^{-2} and 112 mms^{-2} on the accelerograph at Parliament House and the rock store respectively (Figure 23). Altogether ten records from nine earthquakes were obtained on the Darwin accelerographs.

In WA the accelerograph at Beverley (BEM) was closed and a new site established in the Cadoux area (CAM). Some of the accelerographs in the South West Seismic Zone in Western Australia were relocated as shown in Table 5. In all, twenty six accelerograms were recorded, nineteen of these from small earthquakes (ML<2.1) at distances of less than 10 km with accelerations generally less than 50 mms^{-2}. A magnitude ML 2.9 Cadoux earthquake on 5 February was recorded at a distance of 60 km with an acceleration of 2 mms^{-2}. One of the records obtained, on an A700 recorder, was of a magnitude ML 3.5 earthquake near Manmanning on 27 May. The focal distance was only 1 km or so (<0.1 s S-P time) and the peak acceleration about 0.15g which is typical for close-in recordings of small Australian earthquakes.

Peter Gregson and Victor Dent

In South Australia Accelerographs were triggered by a number of small events, but no strong motion was recorded. There were a number of small events on portable recorders from the tail end of the Myrtle Springs activity (see the 1994 ASC Report), and recordings were obtained on the Adelaide joint urban monitoring project (JUMP) instruments of the Sedan earthquake on 9 February and the Stenhouse Bay earthquake on 27 October.

David Love

In Eastern Australia A number of accelerograms of small earthquakes were recorded. In Canberra a magnitude 3.4 earthquake near Adaminaby NSW on 21 July was felt in Cooma, Berridale and Jindabyne and triggered an accelerograph at mid-height in the Telecom Tower 75 km north of the epicentre. Fourier analysis of the east-west component of the tower response (in the direction of the S-wave maximum) showed a prominent peak at 2.5 s, the natural period of the Tower (identical to that measured from microtremors). The strongest shaking was surprisingly in the vertical direction with a strong spectral peak in the 5 to 6 Hz range.

The accelerograph in the basement of the AGSO building triggered during the two magnitude ML 3.1 earthquakes near Boorowa NSW on 12 September and 14 October at a distance of 120 km from Canberra. The ground motion under the AGSO basement was a mere 0.1 mg showing the wide dynamic range of these modern instruments. A micro-earthquake of magnitude ML 2.0, centred 23 km SSW of Canberra on 10 October also triggered the accelerograph and the ground motion was again about 0.1mg.

P Gregson, K McCue, T Jones & D Love

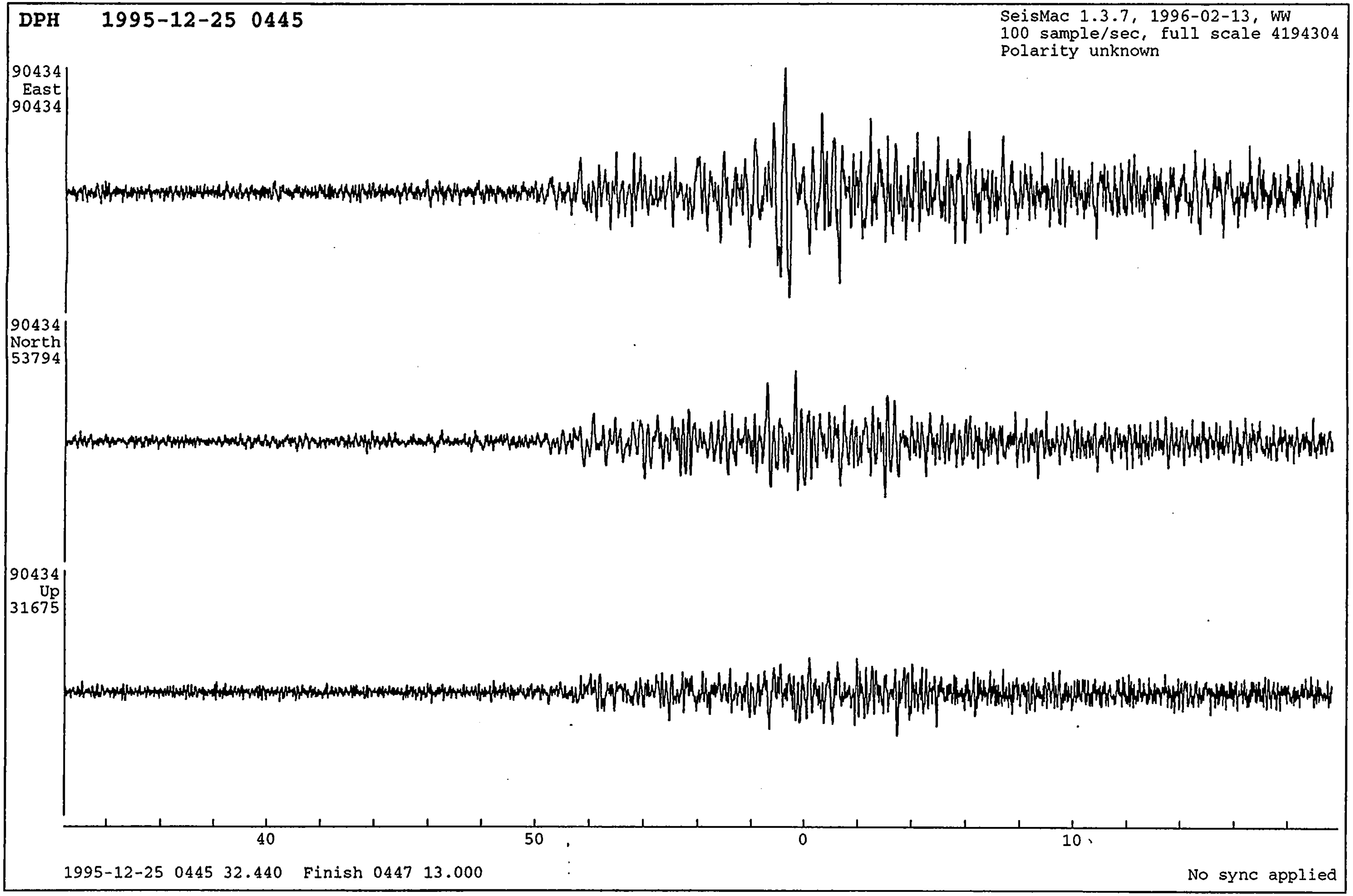

Figure 13 Accelerogram recorded in the grounds of Parliament House Northern Territory

SYDNEY PILOT EARTHQUAKE MICROZONATION PROJECT

A Pilot Earthquake Microzonation Study was undertaken in the Homebush Bay area in 1995 for the New South Wales State Emergency Management Committee. The aims of the Pilot Study were to:

- demonstrate a technique which zones the likely ground shaking response to potential earthquake activity; and
- determine the utility of the technique as an aid to Emergency Response Planning in the Sydney region.

Four earthquake microzonation maps were prepared. Triassic Ashfield Shale is mantled over the 14-square km area by combinations of sediments and landfill with a maximum thickness of 23 m. The first map was based on the Site Factors described in AS1170.4-1993. The other maps, one for each of low-rise, medium-rise and high-rise structures, modified this zonation to account for the period-dependent response of rock, sediments and reclaimed land observed in 'background' (microtremor) ground shaking in the Pilot area.

The lowest level of earthquake hazard is associated with the Ashfield Shale. All structures at the Sydney 2000 Olympics site are, or will be, built on these shales.

The microzonation maps and various geological, spatial, cultural and infrastructure data were assembled into an Arc/Info© Geographical Information System (GIS) and a presentation was developed in ArcView©. The presentation highlighted key vulnerable infrastructure elements in the region.

Trevor Jones and Michael Neville

TSUNAMIS

No destructive tsunamis occurred during the year but several were observed or recorded. The Loyalty Islands earthquake of 16 May generated a small tsunami which was recorded in the Southwest Pacific and along the eastern coast of Australia. The Tonga earthquake of 7 April and the other two great earthquakes in Chile and the Kurile Islands also generated small tsunamis.

The largest tsunami with a maximum runup of 0.2m was from the destructive Jalisco Mexico earthquake of 9 October but it seems to have caused no extra damage in Mexico.

TIME ZONES IN AUSTRALIA

The Standard Time Act of 1895 introduced Greenwich Mean Time (GMT) to Australia and standardised time zones within the States; Eastern, Central and Western Standard Time, 10, 9:30 and 8 hours ahead of GMT. According to Paul Payne of the Sydney Observatory; prior to 1895 the times of the capital cities for noon in Sydney were: Brisbane 12:07 pm, Melbourne 11:45 am, Hobart 11:45 am, Adelaide 11:10 am, Perth 9:39 am, which times correspond closely to the difference in longitude from Sydney. Towns near the capital cities probably adopted the same time but what standard was adopted in isolated towns is not known.

GMT is a measure of Earth rotation relative to the Sun at the longitude of Greenwich UK. The Coordinated Universal Time (UTC) scale, synonymous with GMT since 1970, is derived from the US National Bureau of Standards atomic frequency standard which emulates the Caesium resonance frequency to within a few parts in 10^{13}. Integral second corrections are applied to UTC as required so that it never differs from UT (the Earth rotation time with respect to the sun and corrected for polar motion) by more than 0.7s (NBS, 1972; J. McK. Luck, 1991).

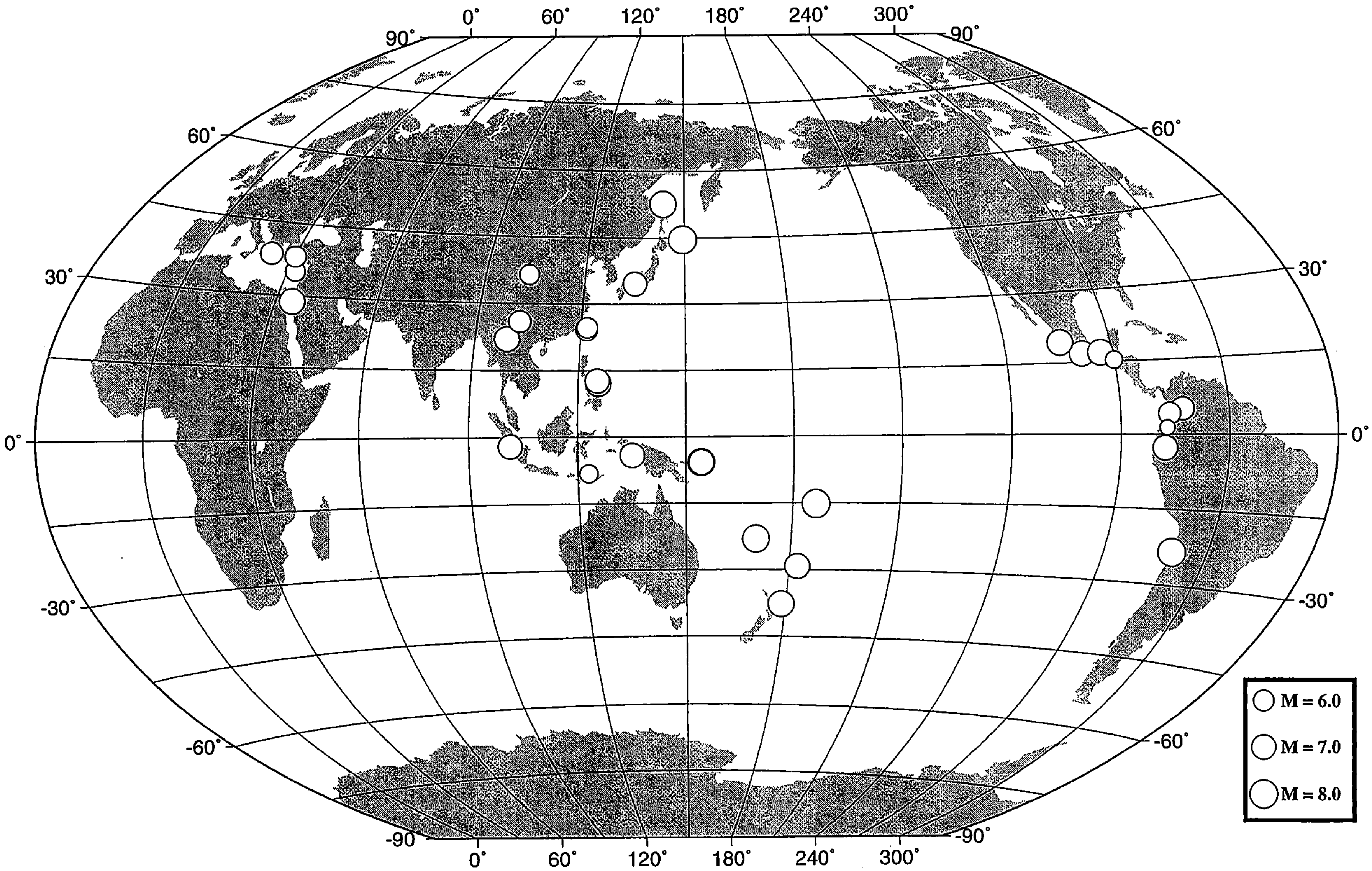

Figure 14 Principal world earthquakes, 1995, magnitude 6.0 or greater

PRINCIPAL WORLD EARTHQUAKES, 1995

Table 7 lists earthquakes that occurred throughout the world in 1995 of magnitude 7.0 or greater, or that caused fatalities or stubstantial damage. There were three great earthquakes of magnitude 8.0 or more, and all three generated small non-destructive tsunamis; the first near Tonga caused no injuries, the second struck northern Chile where three people were killed and many were injured, and the third was in the Kuril Islands with no casualties. A further 16 earthquakes were recorded with magnitudes of 7 or more. All of these occurred around the Pacific rim except for one near the Myanmar-China border and another in Egypt.

The most destructive earthquake was on 16 January near the south coast of Western Honshu, Japan. Dubbed the Kobe or great Hanshin earthquake, at least 5502 people were killed and approximately 37 000 injured, most of them in the collapse of old, traditional styled masonry houses with heavy, tiled roofs. Nearly 310 000 people were evacuated with over 200 000 buildings damaged or destroyed. Few of the high-rise buildings designed to the latest Japanese Building Code sustained structural damage. The port area and overhead railways and roads fared badly and gas, electricity and water mains were cut for long periods. Fires raged through the city for several days after the earthquake.

This earthquake occurred almost one year to the day after the similar sized Northridge earthquake near Los Angeles, California, its magnitude Ms 6.8 or ML 7.2 (JMA), not much larger than the 1968 Meckering or 1988 Tennant Creek earthquakes in Australia. Limited surface faulting was observed on Awaji Island, south of Kobe but faulting is assumed to have propagated towards and under Kobe city. This earthquake was neither strictly interplate nor intraplate so the lessons for Australia are limited though it demonstrates just how destructive an earthquake can be close to a major urban area when rupture focussing occurs and foundation conditions are poor.

Representing the Australian Earthquake Engineering Society and his sponsor Alexander Howden Reinsurance Brokers (Aust) Ltd, Dr George Walker joined the New Zealand National Society for Earthquake Engineering reconnaissance team to Kobe and compiled a sobering report of the earthquake and its effects (Walker, 1995). The NZNSEE team compiled a report focussing on lifelines (Brunsdon & others, 1996). Drs Mike Griffith (Adelaide Uni) and Lam Pham (CSIRO) also visited the stricken city and Dr Griffith prepared a reported on the effects and their consequences for Australia (Griffith, 1995).

Worldwide more than 7874 people died in earthquakes in 1995, compared with 10 044 and 2880 in 1994 and 1993 respectively, and the average for the century of about 10 000. Fewer than the average number of people were killed despite a remarkably active year.

This information is from the 'Earthquake Data Reports' published by the United States Geological Survey and the SEAN Bulletin of the Smithsonian Institution (SEAN, 1995).

Peter Gregson, Yvonne Moiler and Kevin McCue

CONSULTANCIES

As a result of the Richards review, AGSO projects are is now required to attract funding through consultancies. To help achieve this goal, the Earthquake Hazards Project hired Dr Malcolm Somerville, an engineering seismologist/geophysicist with extensive experience in earthquake risk assessments to bid for and undertake a range of consultancy projects.

MONITORING OF NUCLEAR EXPLOSIONS

China and France detonated underground nuclear explosions in 1995, two at China's Lop Nor testing site and five at France's Pacific testing site in the Mururoa and Fangataufa atolls (Table 8). All other Nuclear Weapons States abided by an agreed moritorium on testing.

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ISOSEISMAL MAPS

Four of the earthquakes during 1995 were sufficiently widely that questionnaires were distributed and the returned forms collated to draw up isoseismal maps; one in Western Australia, one in Queensland and two in South Australia.

The format of these maps is the same as those printed in the three volumes of the AGSO (BMR) Isoseismal Atlas (Everingham and others, 1982; Rynn and others, 1987; McCue, 1995).

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.

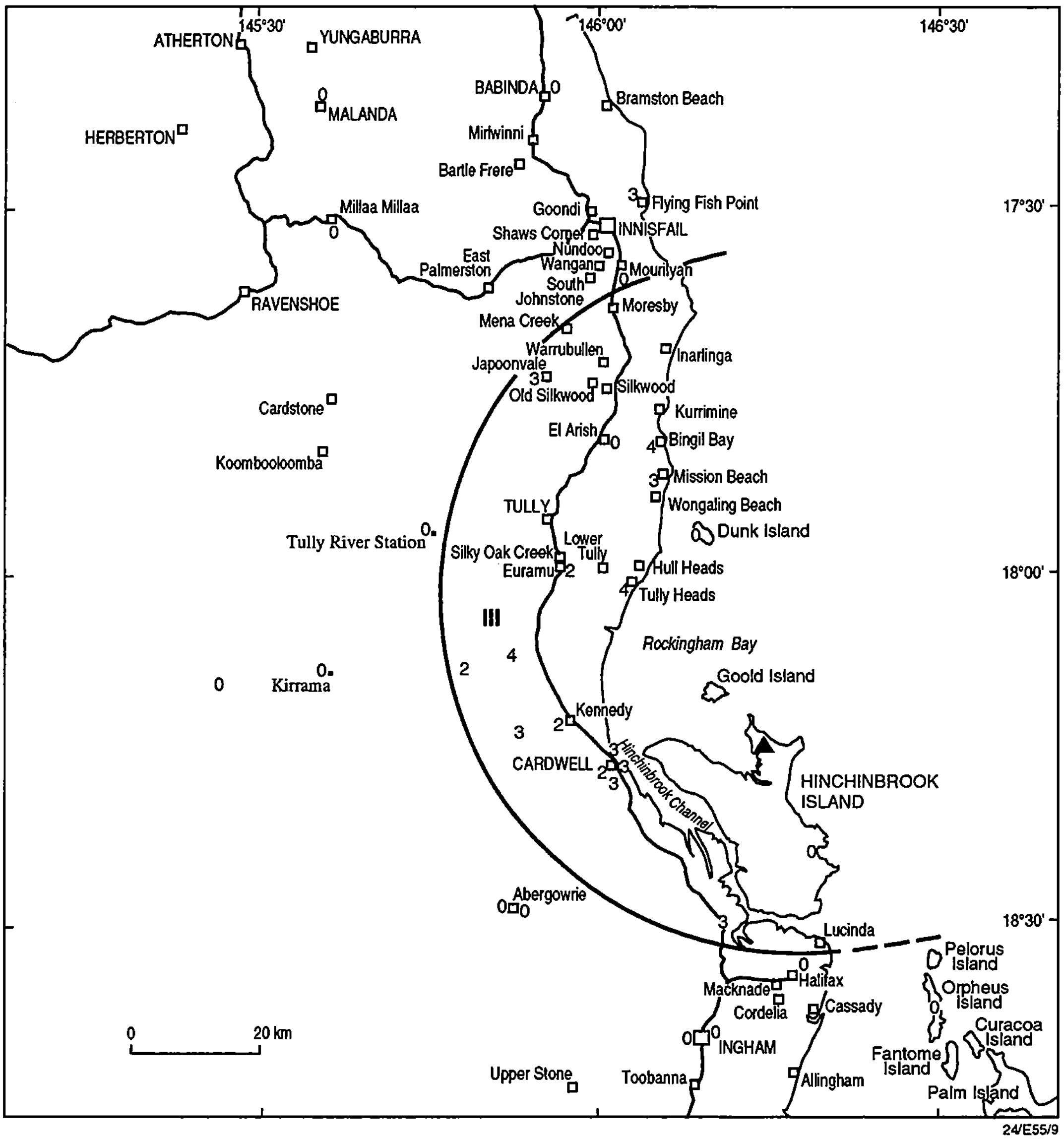
Notes

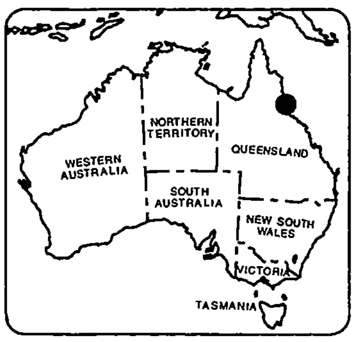
Window breakage depends greatly upon the nature of the frame and its orientation with respect to the earthquake source. Windows cracked at MM V are usually either large display windows, or windows tightly fitted to metal frames.

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 CARDWELL EARTHQUAKE, QUEENSLAND
17 MARCH 1995





DATE: 17 MARCH 1995
TIME: 17:41:14 UTC
MAGNITUDE: 3.2 ML
EPICENTRE: 18.25°S, 146.25°E

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

Figure 9

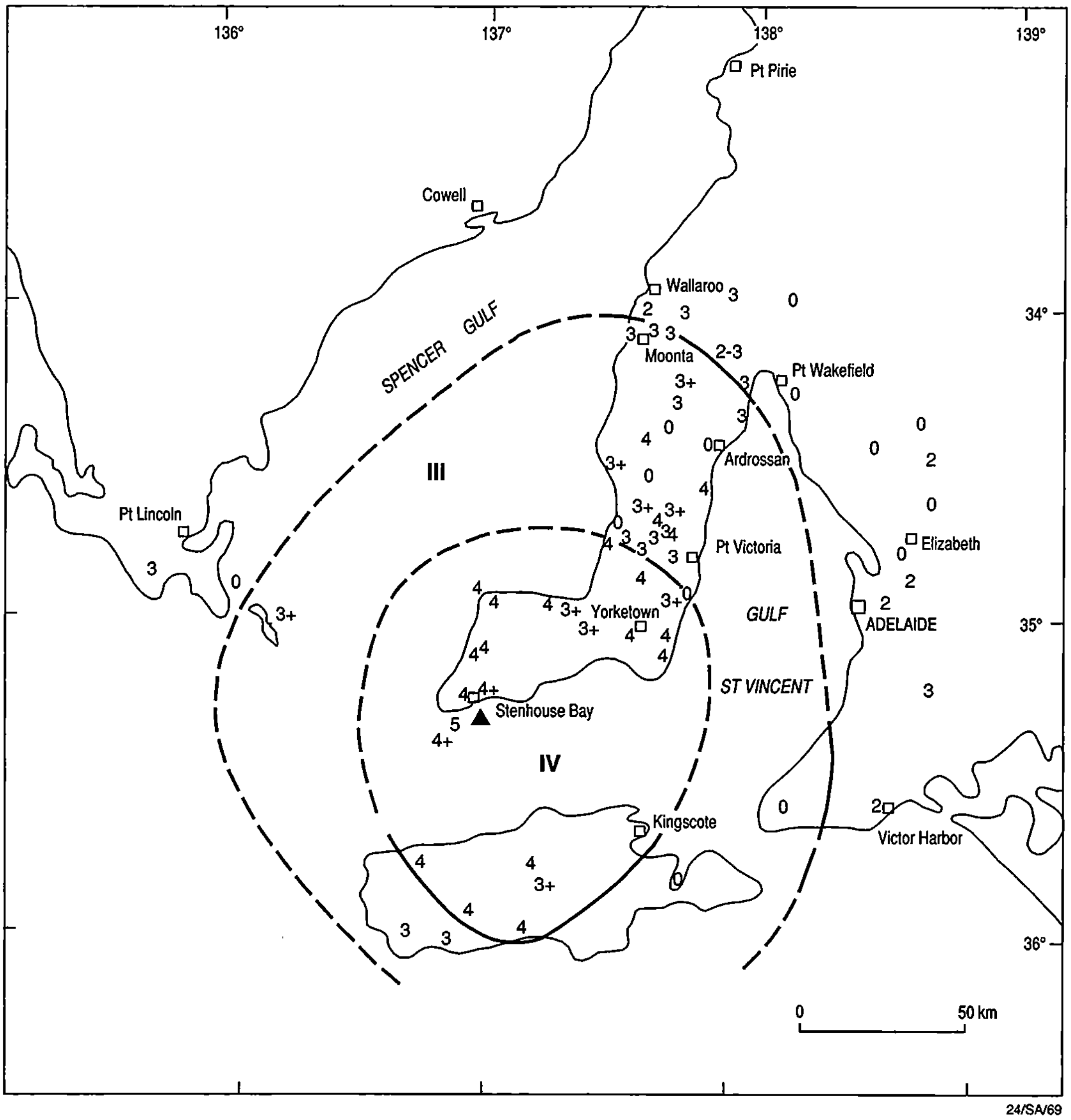
Isoseismal map of the Cardwell Earthquake Qld 17 March 1995

The earthquake occurred on a Friday evening and was felt along the north Queensland coast from just north of Ingham to Innisfail. The nearest seismographs (Charters Towers and the Burdekin Falls Dam network) were all over 200 km to the south and so the location has poor control in the east-west direction. The extension of the intensities along the coast indicate the epicentre was probably just offshore.

Only 14 of the 31 intensities questionnaires returned a positive report. Most of these reported minor shaking and noises. There was one second hand report of cups falling of a shelf.

Russell Cuthbertson

ISOSEISMAL MAP OF THE STENHOUSE BAY EARTHQUAKE, SOUTH AUSTRALIA
27 OCTOBER 1995



DATE: 27 OCTOBER 1995
TIME: 10:28:57.7 UTC
MAGNITUDE: ML (SA) 3.6
EPICENTRE: 35.239°S, 137.017°E
DEPTH: 15 km

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

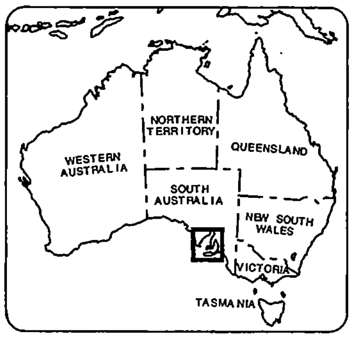


Figure 10

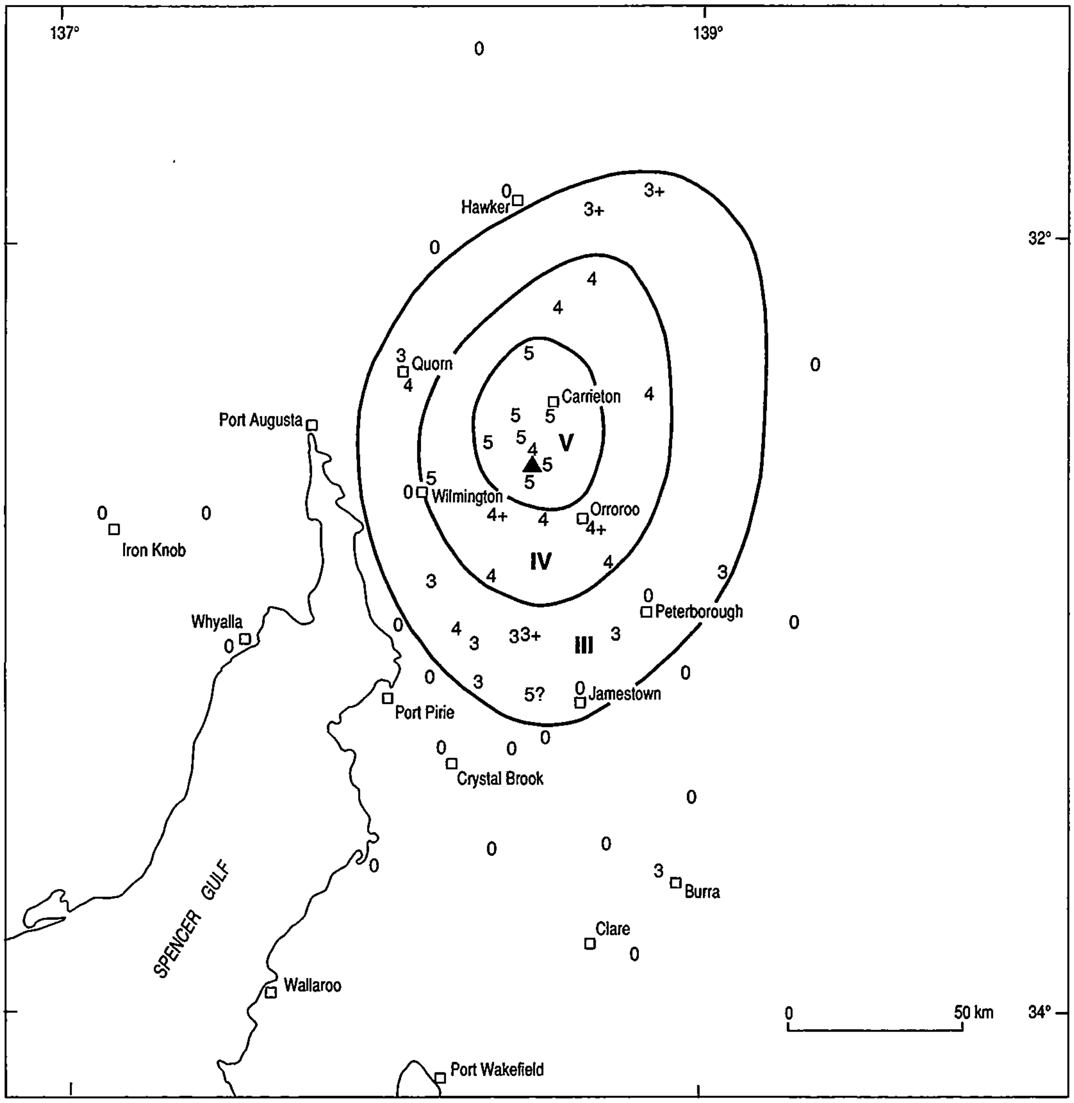
Isoseismal Map of the Stenhouse Bay Earthquake
South Australia, 27 October 1995

An earthquake occurred near Stenhouse Bay on Friday 27th October 1995 at 7:59pm (CST). It was widely felt throughout Yorke Peninsula, as well as on Kangaroo Island and by a small percentage of people around Adelaide. Near the epicentre the vibrations were quite strong with one lady reporting a loud crack along with the shaking. A few small objects were upset. On the northern cliffs of Kangaroo Island there was a small rockfall into the sea. The vibrations in Adelaide were much milder, mostly reported as a slight rumbling or slight vibration, although a few people had furniture shake or doors move. The furthest felt report came from about 200 km from the epicentre.

The magnitude on the current ML(SA) scale was 3.6. This is the largest earthquake in the general area since a magnitude 4.3 event at the western end of Kangaroo Island on 16 December 1986.

David Love

ISOSEISMAL MAP OF THE ORROROO EARTHQUAKE, SOUTH AUSTRALIA
13 NOVEMBER 1995



24/SA/70

DATE: 13 NOVEMBER 1995
TIME: 04:00:17.3 UTC
MAGNITUDE: ML (SA) 3.7
EPICENTRE: 32.584°S, 138.466°E
DEPTH: 7 km

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

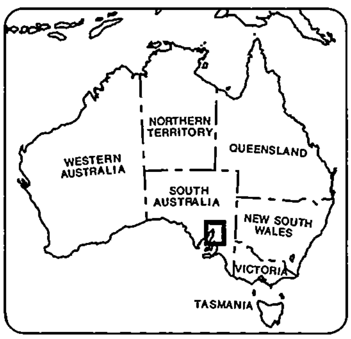


Figure 11

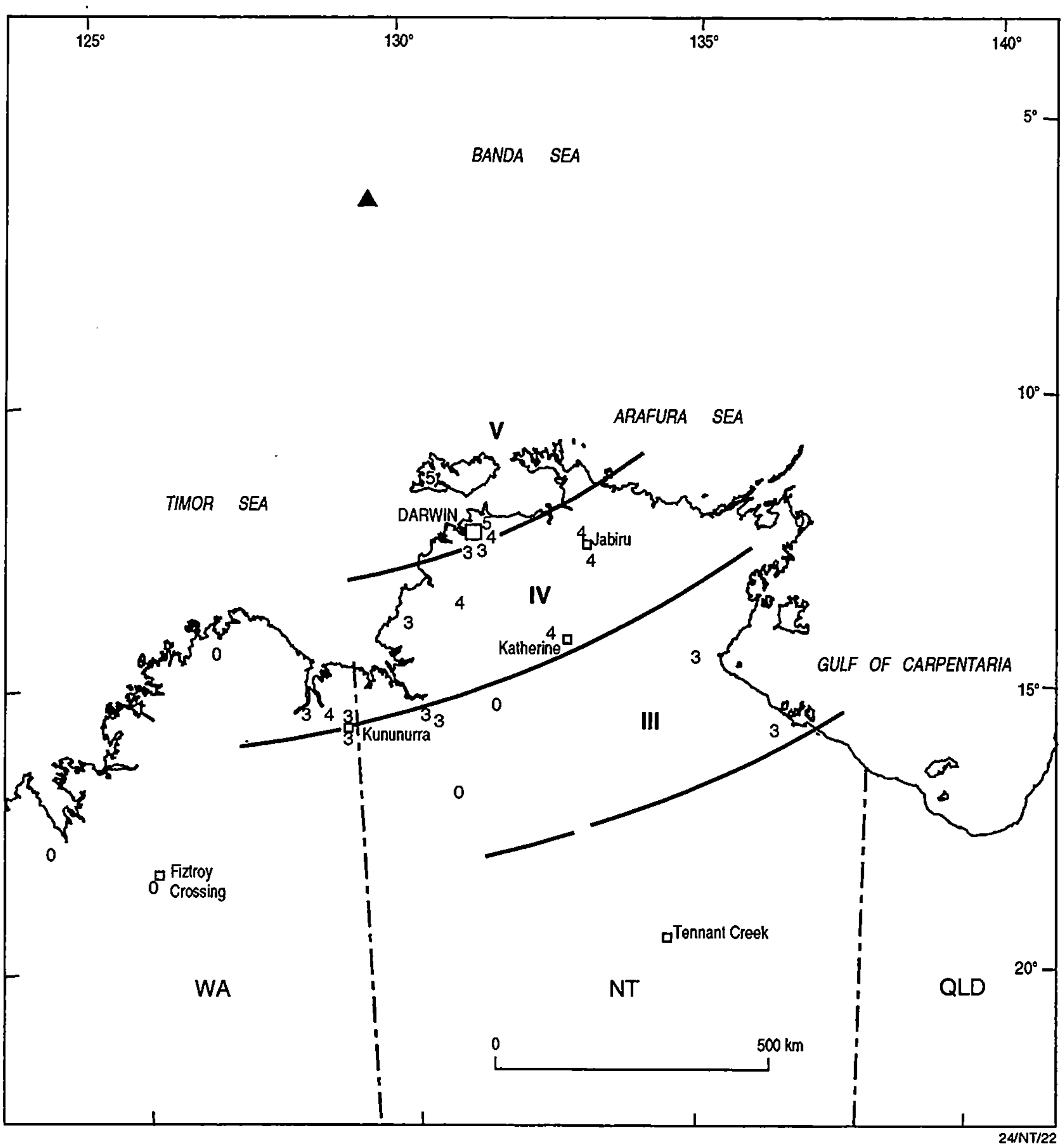
Isoseismal Map of the Orroroo Earthquake South Australia, 13 November 1995

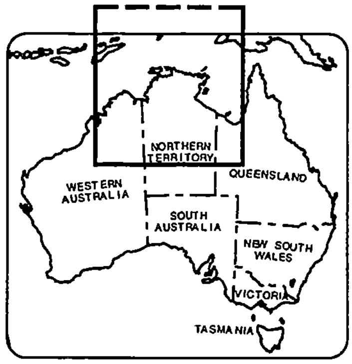
At 04:00 UTC (2:30pm local time) an earthquake approaching magnitude 4 rattled the area around Orroroo. It was felt from Jamestown to Hawker. People in the epicentral area reported small objects shifting or being upset, small cracks and plaster falls occurring, pictures falling off walls, and a mirror falling off a dressing table. The vibrations were well recorded by the South Australian seismic network, and by many stations interstate. The epicentre was quickly located and portable instruments were despatched to the area. A number of aftershocks were recorded. In all 140 questionnaires were posted out and this map was produced from the 75 replies. In the previous few months there were a number of shocks in this area, including one of magnitude ML 3.0 on the 1 November.

David Love

ISOSEISMAL MAP OF THE BANDA SEA EARTHQUAKE,

25 DECEMBER 1995





DATE: 25 DECEMBER 1995
TIME: 04:43:24.9 UTC
MAGNITUDE: 6.2 mB, 7.1 Mw (USGS)
EPICENTRE: 6.94°S, 129.18°E

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

Isoseismal map of the Banda Sea earthquake 25 December 1995

An earthquake occurred in the Banda Sea (6.94°S, 129.18°E) on Christmas Day, 25 December at 04:43 UT (2:15 p.m. CSST). The USGS reported the magnitude as mB 6.2 and Mw 7.1.

An intensity of MM VI was reported from Saumlaki and MM IV fom Ambon and Tuai in Indonesia. The earthquake was felt strongly in Australia with a maximum intensity of MM V on Bathurst Island and Darwin in the Northern Territory. In Darwin, windows and crockery rattled and small objects on shelves moved. Some people moved outside of buildings. At Nguiu on Bathurst Island, many people were woken up and windows rattled.

Two strong motion recorders in Darwin, 638 km from the epicentre, were triggered and recorded peak ground accelerations in an E-W direction of 211 mms^{-2} and 112 mms^{-2} at Parliament House and the Department of Mines and Energy rock store in Winnellie respectively.

The radius of the MM IV isoseismal was 950 km with no felt reports beyond 1250 km.

Peter Gregson

Table 1 Australian epicentres, 1995, ML ≥ 3.0

Date	*Time*	*Latitude*	*Long*	*mb*	*ML*	*Ms*	*Mw*	*Place*
1- 1	1227 54.2	-28.510	136.170		3.2			Oodnadatta SA
1- 2	2308 22.5	-19.960	133.810	4.1	4.2			Tennant Creek NT
1- 3	0633 16.6	-13.868	131.268		4.1			Katherine NT
1- 9	0533 56.6	-20.936	120.526		3.5			Marble Bar WA
1-11	0711 37.8	-38.178	145.999		3.1			Warragul Vic
1-20	0804 49.4	-20.890	120.780		3.2			Shay Gap WA
1-23	1744 53.1	-30.409	138.005		3.2			Myrtle Creek SA
1-24	0826 0.4	-19.865	134.160		3.2			Tennant Creek NT
1-27	1914 34.3	-18.860	123.230		3.4			Broome WA
1-28	0536 16.2	-19.863	134.128		3.3			Tennant Creek NT
1-31	0845 10.8	-28.860	136.446		3.0			Lake Eyre SA
2- 1	1021 20.2	-38.531	146.238		3.0			Boolarra South Vic
2- 9	0410 59.4	-34.527	139.467		3.2			Sedan SA
2-21	0126 13.9	-18.886	122.512		3.1			Broome WA
2-23	0403 48.9	-21.905	126.226		3.3			Tobin Lake SA
3- 6	1056 22.3	-22.129	129.814		3.3			Lake McKay NT
3- 6	1242 44.4	-33.933	135.543		3.2			Tooligie SA
3-12	1136 55.0	-32.626	138.343		3.0			Pt Augusta SA
3-16	1231 54.9	-36.293	148.232		3.2			Khancoban NSW
3-16	2301 5.1	-23.347	130.406		3.0			L Mckay NT
3-17	1741 14.4	-18.250	146.000		3.2			Cardwell Qld
3-26	0653 30.0	-35.947	147.229		3.0			Hume Reservoir NSW
3-27	0444 12.2	-30.383	138.125		3.3			Myrtle Creek SA
4- 5	2338 49.5	-32.670	126.950		4.0			Cocklebiddy WA
4- 6	1807 9.0	-32.692	127.100		3.0			Cocklebiddy WA
4- 6	1932 9.6	-19.809	133.949		3.0			Tennant Creek NT
4- 6	2324 50.8	-33.300	118.190		3.0			Nyabing WA
4-11	1549 5.0	-31.095	138.981		3.5			Blinman SA
4-17	0533 7.0	-33.290	118.170		3.0			Nyabing WA
4-18	1431 59.3	-40.328	155.324	4.0	4.1			Tasman Sea
4-20	1204 20.7	-33.290	118.200		3.0			Nyabing WA
4-20	1311 30.1	-33.280	118.180		3.3			Nyabing WA
4-20	1316 53.8	-33.310	118.190		3.1			Nyabing WA
4-29	0712 3.0	-36.380	125.360		4.0			SE Esperance WA
5- 3	0424 23.0	-33.170	150.240		3.2			N Lithgow NSW
5- 3	1748 23.5	-38.610	146.210		3.0			Boodarra Vic
5-11	0006 0.5	-19.220	140.960		3.0			Mt Isa Qld
5-14	0206 32.8	-19.770	134.020		3.4			Tennant Creek NT
5-15	2229 31.4	-42.570	120.350	5.3	5.6	4.9	5.4	Southern Ocean WA
5-19	1942 50.2	-16.160	121.140		3.3			NNW Broome WA
5-20	1129 11.8	-33.860	150.070		3.6			Jenolan NSW
5-25	1351 36.5	-33.650	136.250		3.1			Cleve SA
5-28	2312 58.4	-32.518	151.408		3.5			Glendon Brook NSW
5-29	2033 53.8	-24.800	136.600		3.2			Simpson Desert NT
6- 3	1820 31.0	-36.073	143.392		3.1			Glenloth Vic
6- 4	2036 9.0	-24.119	125.796		3.7			NNW Warburton WA
6-14	1641 54.3	-19.782	133.718	4.8	4.9			Tennant Creek NT
6-25	2023 41.5	-15.635	121.046		3.3			NNW Broome WA
7- 1	1843 31.7	-17.483	122.416		3.2			NNE Broome WA
7- 7	0653 24.5	-32.928	151.318		3.2			Ellalong NSW
7-10	1225 27.0	-22.313	132.129		3.2			Yuendumu NT
7-14	1928 14.6	-42.473	123.256		3.8			Southern Ocean WA
7-21	1426 3.7	-35.988	148.878		3.4			Adaminaby NSW
7-29	0424 14.8	-19.851	134.011		3.1			Tennant Creek NT
7-30	0441 3.3	-36.766	147.639		3.7			Benambra Vic
7-31	1548 56.0	-30.786	117.103		3.5			Cadoux WA
8- 5	0734 52.0	-19.317	113.495		3.2			NNW Exmouth WA
8- 7	0030 18.0	-21.362	120.146		3.1			ESE Marble Bar WA

Table 1 (cont.)

8-15	0157 11.2	-18.414	120.813		3.1	WSW Broome WA
8-17	1336 17.0	-25.618	113.199		3.1	SW Carnarvon WA
8-25	1150 11.6	-23.313	111.860	4.6	4.6	Indian Ocean
8-29	0049 31.4	-41.210	123.347		3.3	Southern Ocean
9-12	1023 55.6	-34.333	148.750		3.1	Boorowa NSW
9-15	0440 18.3	-19.350	118.050		3.0	NNW Pt Hedland WA
10-14	0411 1.5	-34.336	148.756		3.1	Boorowa NSW
10-19	0355 47.6	-18.550	122.830		3.3	SE Brooma WA
10-19	1944 3.0	-23.420	120.730		3.5	Jiggalong WA
10-27	0420 41.2	-34.713	129.276		3.7	Gt Australian Bight SA
10-27	1028 57.7	-35.239	137.017		4.2	Stenhouse Bay SA
10-29	0655 39.7	-24.060	113.530		3.4	N Carnarvon WA
11- 1	0601 7.9	-32.552	138.543		3.0	Orroroo SA
11-11	2026 59.7	-20.939	127.447		3.0	Tobin Lake WA
11-13	0400 17.8	-32.573	138.498		4.0	Orroroo SA
11-16	1623 32.4	-32.583	138.367		3.2	Orroroo SA
11-17	1243 25.9	-36.031	144.570		3.0	N Echuca NSW
11-17	1301 19.5	-33.010	145.131		3.5	Hillston NSW
11-18	0932 16.9	-36.999	144.741		3.4	Tooborac Vic
11-18	1325 22.4	-31.014	138.875		3.1	Blinman SA
11-20	0101 34.3	-19.912	134.074		3.7	Tennant Creek NT
11-20	1116 28.6	-25.829	131.706		3.5	Mulga Park NT
11-21	1702 14.1	-32.884	151.269		3.1	Millfield NSW
12-10	1252 2.6	-14.560	123.240		3.2	N Derby WA
12-12	2211 17.4	-18.530	124.280		3.3	W Fitzroy Criossing WA
12-16	0156 32.6	-21.080	127.450		3.4	NE Tobin Lake WA
12-18	1644 51.0	-37.600	139.590		3.5	Beachport SA
12-27	0505 52.2	-16.490	120.440		4.3	NW Broome WA

Table 2. Large or damaging Australian earthquakes, 1788 - 1995

Date UTC	*Time*	*Lat °S*	*Long °E*	*ML*	*Ms*	*$AUS loss (1994$)*	*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 3. Australian Seismographic Stations, 1995

Code#	*Name*	*Lat °S*	*Long °E*	*Elev.m*	*Operator*	*Type**
Queensland						
AWD	Awoonga Dam	24.078	151.316	110	QLD	1
BDM	Boondooma Dam	26.112	151.444	320	QLD	1
BGD	Biggenden	25.530	152.094	180	QLD	8
BLO	Burdekin Lookout	20.625	147.121	234	QLD	1,8
BNB+		25.6862	151.7872	150	QLD	8
BRS	Mt Nebo Brisbane	27.392	152.775	525	QLD	5
BWN+		20.022	148.126	40	QLD	1
CTAO	Charters Towers	20.088	146.255	357	QLD/AGSO	2/7
DLB	Dalbeg	20.151	147.264	70	QLD	1
DNG	Doongara	20.555	146.475	280	QLD	1
DRG-	Durong	26.286	151.292	340	QLD	8
EDV	Eidsvold	25.438	151.292	220	QLD	8
GC1+		27.9504	153.3607	60	QLD	8
GLD	Glenlyon Dam	28.969	151.480	48	QLD	1
MCP	Mt Cooper	20.552	146.806	300	QLD	1
MNT	Monto	24.855	151.141	250	QLD	8
MPR	Mount Perry	25.198	151.731	370	QLD	8
MRVQ	Maryvale Break	22.955	150.675	75	UCQ	1
MTMQ	Mt Morgan	23.763	150.390	170	CQU/AGSO	8
PFD	Peter Faust Dam	20.386	148.375	12	QLD	1
QIS	Mount Isa	20.556	139.605	330	AGSO	7
QLP	Quilpie	26.584	144.235	210	AGSO	1
RMQ	Roma	26.489	148.755	360	AGSO	1
UCQ2	CQU Campus	23.329	150.524	27	CQU	1
UKA	Ukalunda	20.899	147.127	200	QLD	1
WBA	Buaraba	27.353	152.308	100	QLD	1
WMB	Mt Brisbane	27.115	152.550	160	QLD	1
WPM	Pine Mountain	27.536	152.735	35	QLD	1
WRC	Reedy Creek	27.187	152.663	190	QLD	1
WTG	Toogoolawah	27.146	152.333	130	QLD	1
WWH	Wivenhoe Hill	27.370	152.587	190	QLD	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						
ARG	Argyle Diamond	16.7092	128.427	230	SRC	8
BAL	Ballidu	30.607	116.707	300	MUN	1
COOL-	Coolgardie	30.884	121.145	500	MUN	1
FITX+	Fitzroy Crossing	18.109	125.642	110	MUN	1
FITZ	Fitzroy Crossing	18.102	125.639	110	MUN	7
FORT+	Forrest	30.779	128.059	165	MUN	7
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
MGO	Mundaring Office	31.9033	116.165	250	MUN	1

Table 3 (cont.)

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	7
WOOL+	Woolibar	31.073	121.678	325	MUN	7
NSW & ACT						
APN	Appin	34.171	150.823	277	SRC	8
ARMA+	Armidale	30.4198	151.628	1130	AGSO	7
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
CAV	Cavalon	29.6495	151.6227	96	SRC	8
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
COP	Copeland Dam	29.9194	150.9336	62	SRC	8
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
PIN	Pindari Dam	29.3977	151.2407	53	SRC	8
QFS	Quorrobolong	32.933	151.396	14	ASC	8
RIV	Riverview	33.829	151.159	21	RIV	2
STKA	Stephens Creek	31.8769	141.5952	213	AGSO	7
WER	Werombi	33.950	150.580	226	CAN	1
YOU	Young	34.278	148.382	503	AGSO	1
South Australia						
ADE/ADT	Adelaide	34.967	138.714	655	ADE	2/1
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	8
HTT	Hallett	33.430	138.921	708	ADE	1
HWK	Hawksnest	29.958	135.203	180	ADE/AGSO	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	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	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/AGSO	1

Table 3 (Cont.)

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	36.9906	143.9722	230	SRC	8
DRO	Dromana	38.360	144.997	170	SRC	1
DTM/DTT	Dartmouth	36.5293	147.4686	436	SRC	8
FRT	Forrest	38.534	144.997	210	SRC	1
FSK	Fish Creek	38.753	145.994	45	SRC	8
GOG	North Grampians	36.888	142.400	265	SRC	8
GVL	Greenvale	37.6186	144.9006	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	37.6346	145.2709	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	7
TOS	Thomson PABX	37.8243	146.4057	68	SRC	8
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

Notes +/- Opened/closed this year
This list does not include stations or temporary networks installed during the year

Table 4. Focal Mechanism of the Southern Ocean earthquake 15 May 1995 (CMT from NEIC)

	Strike	*Dip*	*Slip*	*Azimuth*	*Plunge*
Nodal Plane	109	28	111		
Nodal Plane	266	64	79		
P-axis				004	18
T-axis				154	70
N-axis				271	10

Table 5. Australian accelerographs, 1994

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	ACTEW
Lower Cotter Dam	35.308	148.908	535	Basalt	SRC	ACTEW
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	ACTEW
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 5 (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 (CAA)	30.746	117.151	320	Laterite/ Granite	A700	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	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

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
Perth Kings Park KPK	31.960	115.842	60	Limestone	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
Victoria Dam VID	32.04	116.06		Granite	A700	WAWA
Wall SEW	32.40	116.10		Earthfill	A700	WAWA
York (Temporary)	31.968	116.717	380	Granite	SRC	MUN

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; ACTEW 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 6 Australian accelerograph data, 1995

Date UTC	*Time*	*Lat°S*	*Long°E*	*ML*	*Site*	*H/E km*	*Comp*	*T Sec*	*Acc* mms^{-2}
01 02	16:20	35.28	148.68	2.6	ASC	41/41	PZ	0.01	2.8
							SN	0.01	1.6
							SE	0.01	1.6
					BMC	40/40	SZ	0.02	3.0
							SN	2.57	1.0
							SE	2.57	1.0
02 05	1614	30.88	117.06	2.9	CAA	17/17	SZ	0.09	6
							SN	0.06	8
							SE	0.06	12
					GOO	60/60	SZ	0.045	1
							SN	0.045	2
							SE	0.045	2
2 6	648	30.88	117.05	1.8	CAA	17/17	SZ	0.08	1
							SN	0.06	1
							SE	0.06	2
02 18	1359	30.74	117.12	1.7	CAA	4/3.3	SZ	0.035	23
							SN	0.025	82
							SE	0.02	89
03 09	1101	30.81	117.07	2.1	CAA	10/10	SZ	0.04	23
							SN	0.02	95
							SE	0.04	96
03 09	2339	30.77	117.07	2.1	CAA	4/3.5	SZ	0.05	5
							SN	0.04	5
							SE	0.05	6
03 19	23:53	4.18	135.11	mB 6.2	DPH	1030	SZ	0.37	3
						33	SN	0.40	2
							SE	0.40	2
04 02	05:21	7.5	129.6	mB 4.8	DPH	572	SZ	0.14	2
						33	SN	0.20	2
							SE	0.20	3
04 25	16:11	6.76	129.87	mB 4.1	DPH	640	SZ	0.18	1
						132	SN	0.18	1
							SE	0.18	1
05 10	18:41	7.25	129.27	mB 4.5	DPH	592	SZ	0.16	2
						167	SN	0.22	3
							SE	0.22	5
05 14	1136	8.38	125.13	mB 6.9	DPH	774	SZ	0.26	2
						11	SN	0.26	4
							SE	0.27	3
05 19	17:09	6.10	130.40	mB 5.5	DPH	706	SZ	0.14	5
						140	SN	0.14	5
							SE	0.14	7
05 27	04:54	30.83	117.06	2.7	CAM	2/2	SZ	0.03	1622
							SN	0.03	960
							SE	0.03	1235
					CAA	13/13	SZ	0.06	24
							SN	0.04	41
							SE	0.03	33
					GOO	65/65	SZ	0.04	6
							SN	0.036	7
							SE	0.038	8

07 31	15:48	30.79	117.1	3.5	CAS	4/04	PZ	0.033	122
							PN	-	-
							PE	0.027	88
							SZ	0.045	265
							SN	-	-
							SE	0.045	388
					CAA	6/06	PZ	0.035	122
							PN	0.035	55
							PE	0.04	71
							SZ	0.04	157
							SN	0.03	170
							SE	0.04	484
					CAM	7/07	SZ	0.03	565
							SN	0.03	378
							SE	0.03	674
07 31	17:33	30.79	117.09	1.7	CAA	7/07	SZ	0.02	4
							SN	0.02	13
							SE	0.025	10
08 01	02:39	30.79	117.09	1.9	CAA	7/07	SZ	0.02	9
							SN	0.02	27
							SE	0.03	30
10 10	09:10	35.44	148.97	2.0	ASC	23/23	SZ	0.1	0.6
							SN	0.1	1.0
							SE	0.1	.75
10 14	04:11	34.34	148.76	3.1	ASC	112/112	SZ	0.1	0.8
							SN	0.1	0.8
							SE	0.1	0.8
10 27	10:29	35.24	137.02	4.2	TUK	170/170	SZ	0.1	2.8
							SN	0.1	4.9
							SE	0.1	3.9
					GHS	170/170	SZ	0.1	13.8
							SN	0.1	22.0
							SE	0.1	22.0
12 19	23:28	3.69	140.27	mB 6.2	DPH	1420	SZ	0.18	2
				70			SN	0.26	2
							SE	0.26	5
12 25	04:43	6.94	129.18	mB 6.2	DPH	638	SZ	0.34	74
						150	SN	0.40	126
							SE	0.35	211
					DRS	638	PZ	0.14	31
							PN	0.14	2
							PE	0.14	23
					DRS	638	SZ	0.22	70
							SN	0.19	85
							SE	0.26	112
12 31	22:23	7.23	128.60	mB 4.7	DRS	629	SZ	0.23	1
						127	SN	0.25	2
							SE	0.25	2

H/E is hypocetral/Epicentral depth in km <u>or</u> distance over focal depth km

Table 7. Principal world earthquakes, 1995

(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
16 Jan	20 46 52.1	Near S Coast of Western Honshu	34.583 N	135.018 E	6.3mB, 6.8Ms 6.8Mw (GS) 6.9Ms (HRV)

Depth 22 km. Over 5,502 people confirmed killed, 36,896 injured and extensive damage (VII JMA) in the Kobe area and on Awaji-shima. Over 90 percent of the casualties occurred along the southern coast of Honshu between Kobe and Nishinomiya. At least 28 people were killed by a landslide at Nishinomiya. Nearly 310,000 people were evacuated to temporary shelters. Over 200,000 buildings were damaged or destroyed. Numerous fires, gas and water main breaks and power outages occurred in the epicentral area. Felt (VII JMA) along a coastal strip extending from Suma Ward, Kobe to Nishinomiya and in the Ichinomiya area on Awaji-shima; (V JMA) at Hikone Kyoto and Toyooka; (IV JMA) at Nara, Okayama Osaka and Wakayama; (V) at Iwakuni. Also felt (IV JMA) at Takamatsu, Shikoku. Right lateral surface faulting was observed for 9 kilometers with horizontal displacement of 1.2 to 1.5 meters in the northern part of Awaji-shima. Liquefaction also occurred in the epicentral region.

19 Jan	15 05 03.4	Colombia	5.050 N	72.916 W	6.3mB, 6.6Ms 6.5Mw (GS) 6.5Mw (HRV) 6.5Ms (BRK)

Depth 17 km. Five people killed, several injured and at least 20 major buildings damaged in the Bogota area. One person also killed at Manizales and another at Miraflores. More than 500 houses were damaged or destroyed in Boyaca Department and 12 others were destroyed in Casanare Department. Landslides blocked several rivers and streams in Colombia. Felt in much of Colombia and western Venezuela as far as Caracas, Venezuela.

03 Feb	15 26 10.6	Wyoming	41.529 N	109.640 W	5.3mB, 4.6Ms

Depth 1 km. Possible implosion in a trona mine west of Green River. One miner killed and ten injured. Slight damage at Green River and Little America. Felt (V) at Rock Springs; (III) at Eden and Reliance. Also felt at Ogden and Salt Lake City, Utah. Up to 1 meter of surface subsidence occurred in about a 1 by 2 km area above the mine.

05 Feb	22 51 05.1	Off E. Coast of N. Island, New Zealand	37.759 S	178.752 E	6.5mB, 7.5Ms 7.0Mw (GS) 7.1Mw (HRV) 7.5Ms (BRK)

Depth 21 km. Felt overmuch of the North Island and as far south as Christchurch on the South Island. Also felt on the Chatham Islands.

08 Feb	18 40 25.3	Colombia	4.104 N	76.622 W	6.3mB 6.4 Mw (GS) 6.4Mw (HRV) 6.0MD (UPA)

Depth 74 km. Forty two people killed, nearly 400 injured and over 2,000 buildings damaged or destroyed in the Cali-Pereira area. Landslides blocked two roads in the epicentral area. Damage occurred at Armenia, Calarca, Cali, La Union, Manizales, Pereira, Trujillo and in many other areas of western Colombia. Felt throughout Colombia.

Table 7 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
Feb 23	05 19 01.9	Taiwan	24.137 N	121.614 E	5.9mB, 6.2Ms 6.2Mw (HRV)

Depth 41 km. Two people killed and 14 injured on a bus struck by a landslide in the epicentral region. Felt (IV JMA) at Hua-lien, Hsin-chu and Su-ao; (III JMA) at I-lan, Tai-chung and Tai-pei. Felt in Fujian, Jiangxi and Zhejiang Provinces, China.

Feb 23	21 03 01.3	Cyprus Region	35.046 N	32.279 E	5.8mB, 5.7Ms 5.9Mw (GS) 5.9Mw (HRV) 5.8Ms (BRK)

Depth 10 km. Two people killed and five injured in the Paphos area. Fifty houses destroyed, 70 seriously damaged and 500 slightly damaged in the Paphos and Nicosia areas. Twenty masonry houses were destroyed at Arodhes. Felt (VII) at Arodhes, Peristerona and Polis; (VI) at Kathikas, Peyia and Stroumbi; (V) at Kykkou Monastery; (IV) at Larnaca, Limassol and Nicosia; (III) at Paralimni. Felt throughout Cyprus. Also felt in northern Israel and Lebanon.

04 Mar	23 23 40.6	Colombia	1.282 N	77.307 W	4.4mB

Depth 5 km. At least 8 people killed, ten injured and houses damaged in the Pasto area.

19 Mar	23 53 14.9	Irian Jaya Region, Indonesia	4.183 S	135.109 E	6.2mB, 7.1Ms 6.8Mw (GS) 6.9Mw (HRV) 7.1Ms (BRK)

Depth 33 km. Some minor damage to buildings in Ayam, Nabire and Fakfak areas. Felt in much of Irian Jaya.

07 Apr	22 06 56.8	Tonga Islands	15.199 S	173.529 W	6.8mB, 8.0Ms 7.4Mw (GS) 7.4Mw (HRV) 8.1Ms (BRK)

Depth 21 km. Felt at Apia, Western Samoa. Local tsunami generated with recorded maximum wave heights (peak-to-trough) of about 30 cm at Pago Pago, American Samoa and about 5 cm on Niue Island.

21 Apr	00 30 10.8	Samar, Philippine Islands	11.925 N	125.564 E	6.3mB,7.2Ms 6.8Mw (HRV)

Depth 17 km.

21 Apr	00 34 46.0	Samar, Philippine Islands	12.059 N	125.580 E	6.3mB,7.3Ms 7.1Mw (GS) 7.2Mw (HRV)

Depth 21 km. Some damage occurred at Borongan and Sulat. Felt (IV RF) at Butuan, Mindanao; (III RF) on Masbate; (II RF) on Cebu and at Cagayan de Oro, Mindanao. Also felt at Davao, Mindanao. Local tsunami generated with maximum wave heights (peak-to-trough) of 10 cm recorded at Legaspi, Luzon.

Table 7 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
05 May	03 53 45.0	Samar, Philippine Islands	12.626 N	125.297 E	6.2mB,7.0Ms 7.0Mw (GS) 7.1Mw (HRV) 7.1Ms (BRK)

Depth 16 km. Felt on Catanduanes, Leyte and Masbate. Also felt in southern Luzon.

16 May	20 12 44.2	Loyalty Islands Region	23.008 S	169.900 E	6.9mB,7.7Ms 7.3Mw (GS) 7.7Mw (HRV) 7.8Ms (BRK)

Depth 20 km. Felt (III) on the Loyalty Islands and at Noumea, New Caledonia. Tsunami generated with maximum wave heights (peak-to-trough) at the following locations: 40 cm at Port-Vila, Vanuatu; 10 cm at Pago Pago, American Samoa; 6 cm at Lautoka and 5 cm at Suva, Fiji; 3 cm at Apia, Western Samoa; 3 cm at Nukualofa, Tonga; 3 cm at Rarotonga, Cook Islands. The tsunami was also recorded along the coast of New South Wales, Australia.

21 May	06 13 11.8	Flores Region, Indonesia	8.265 S	122.977 E	5.2mB,4.6Ms 5.2Mw (HRV)

Depth 28 km. One person killed, 5 injured and several buildings destroyed on Adonara.

27 May	13 03 52.6	Sakhalin Island	52.629 N	142.827 E	6.7mB,7.5Ms 7.1Mw (GS) 7.1Mw (HRV) 7.3Ms (BRK)

Depth 11 km. As many as 1,989 people killed, about 750 injured and severe damage (IX) in the Neftegorsk area. Some damage (VII) occurred at Okha. Felt (VI) at Moskalvo; (V) at Nikolayevsk-na-Amure and Nyvrovo; (IV) at Aleksandrovsk-Sakhalinskiy and Nysh.

15 Jun	00 15 48.6	Greece	38.401 N	22.269 E	6.0mB,6.5Ms 6.3Mw (GS) 6.5Mw (HRV) 5.7ML (THE)

Depth 14 km. Twenty six people killed and 60 injured in theAiyion area. Extensive damage occurred at Aiyion and Eratini. Damage also occurred at Corinth, Patras and Pirgos. Preliminary estimate of damage was placed at 660 million US dollars. Felt at Athens, Ioannina, Kalamata, Kardhitsa and Kozani. Also felt on Kefallina.

25 Jun	06 59 04.9	Taiwan	24.598 N	121.725 E	5.8mB,5.5Ms 6.0Mw (GS) 6.0Mw (HRV)

Depth 41 km. One person was killed, 3 injured and 6 houses damaged by landslides in the epicentral area. Felt throughout Taiwan. Also felt (II JMA) on Kin-men and Peng-hu.

03 Jul	19 50 50.1	Kermadec Islands, New Zealand	29.198 S	177.612 W	6.5mB,7.2Ms 7.2Mw (GS) 7.2Mw (HRV) 7.2Ms (BRK)

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

Table 7 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
11 Jul	21 46 39.7	Myanmar-China Border Region	21.933 N	99.162 E	6.1mB,7.2Ms 6.8Mw (GS) 6.8Mw (HRV) 6.9Ms (BRK)

Depth 13 km. Six people killed, 99 injured, more than 100,000 houses destroyed and 42,000 damaged in the Lancang-Menglian-Ximeng area, China. Some buildings were also damaged in Chiang Mai and Chiang Rai Provinces, Thailand.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
21 Jul	22 44 07.6	Gansu, China	36.443 N	103.105 E	5.7mB,5.4Ms 5.6Mw (GS) 5.6Mw (HRV)

Depth 33 km. Fourteen people killed, at least 60 injured, 5,000 left homeless, 4,500 houses destroyed and 5,000 houses damaged in the Yongdeng area. Felt at Baiyin, Dingxi, Jingtai, Lanzhou, Tianzhu and Wuwei. Also felt at Xining, Qinghai.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
30 Jul	05 11 23.5	Near Coast of Northern Chile	23.364 S	70.312 W	6.6mB,7.3Ms 7.5Mw (GS) 8.1Mw (HRV) 7.2Ms (BRK)

Depth 47 km. Three people were killed, 58 injured, 630 left homeless and 115 houses destroyed (VII) in the Antofagasta area. Landslides blocked several roads in the Antofagasta area. One person was injured at Mejillones. Several houses were damaged at Calama, Mejillones, San Pedro de Atacama, Taltal and Tocopilla. Felt (VI) at Baquedano, Chuquicamata, Copiapo, Diego de Almagro, Inca de Oro, Iquique, Mejillones, Peine, Sierra Gorda, Taltal, Tierra Amarilla and Tocopilla; (V) at Chanaral, El Salvador, Huasco and Vallenar; (IV) at Arica, Caldera and La Serena. Felt in Buenos Aires, Cordoba, Jujuy, La Rioja, Mendoza, Salta and San Juan Provinces and as far away as Buenos Aires, Argentina. Also felt in southern Peru and (III) at La Paz, Bolivia. Tsunami generated with maximum wave heights (peak-to-trough, in cm) recorded at the following selected tide stations: 55 at Valparaiso, Chile; 10 on Easter Island; 75 at Hilo, 70 at Kahului, 15 at Honolulu and 12 at Mawiliwili, Hawaii; 27 at Crescent City, 25 at Santa Monica, 11 at San Diego and 10 at Los Angeles, California; 30 at Adak, 21 at Sand Point, 20 on Shemya, 10 at Kodiak and 9 at Seward, Alaska; 25 at Pago Pago, American Samoa; 9 at Papeete, Tahiti; 29 at Miyako and 26 at Hachinohe, Japan.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
16 Aug	10 27 26.4	Solomon Islands	5.809 S	154.212 E	6.4mB,7.8Ms 7.4Mw (GS) 7.8Mw (HRV) 7.8Ms (BRK)

Depth 16 km. Minor damage occurred in the epicentral area. Landslides blocked road between Rabaul and Kokopo, New Britain.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
16 Aug	23 10 28.9	Solomon Islands	5.782 S	154.256 E	6.1mB,7.2Ms 6.9Mw (GS) 7.2Mw (HRV) 7.2Ms (BRK)

Depth 74 km.

Table 7 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
14 Sep	14 04 31.5	Near Coast of Guerrero, Mexico	16.808 N	98.648 W	6.4mB, 7.2Ms 7.5Mw (GS) 7.5Mw (HRV)

Depth 21 km. Three people killed, nearly 100 injured, 500 homeless and extensive damage in Guerrero. Several people injured, 400 homeless and considerable damage in Oaxaca. Some minor damage occurred in Puebla and at Mexico City. Felt strongly along the Pacific Coast of Mexico from Michoacan to Chiapas.

01 Oct	15 57 16.0	Turkey	38.099 N	30.175 E	5.7mB,6.1Ms 6.0Mw (GS) 6.3Mw (HRV)

Depth 33 km. One hundred and one people killed, 348 injured, 50,000 homeless and 4,500 houses and buildings damaged or destroyed in the Dinar area. About 600 buildings were destroyed at Evciler. Felt in much of western Turkey as far west as Izmir and as far north as Bursa and Yalova.

03 Oct	01 51 24.1	Peru-Ecuador Border Region	2.774 S	77.884 W	6.5mB,7.0Ms 6.8Mw (GS) 7.0Mw (HRV) 6.9Ms (BRK)

Depth 27 km. Two people killed, 5 injured and at least 83 homes damaged or destroyed in Ecuador. Some damage at Archidona, Canelos, Limon, Macas, Mendez, Patuca, Puyo, Santiago, Sucua and Tena, Ecuador. Slight damage (V) at Quito, Ecuador. Felt (V) at Ayabaca; (IV) at Chachapoyas and Moyobamba; (III) at Chulucanas, Jaen and Tumbes; (II) at Tarapota, Peru. Felt in many parts of Ecuador, Peru and in Colombia as far north as Bogota. Two events about 2.6 seconds apart.

06 Oct	18 09 45.9	Southern Sumatera, Indonesia	2.089 S	101.414 E	5.8mB, 6.9Ms 6.8Mw (GS) 6.8Mw (HRV)

Depth 33 km. Eighty four people killed, 2,178 injured, nearly 65,000 homeless and over 18,900 homes and buildings damaged or destroyed in Jambi Province. Landslides occurred in the epicentral area. Felt in many parts of central Sumatera and as far as southern Malaysia and Singapore.

09 Oct	15 35 54.6	Near Coast of Jalisco, Mexico	19.245 N	104.188 W	6.5mB,7.3Ms 7.6Mw (GS) 7.9Mw (HRV)

Depth 33 km. At least 38 people killed, 200 injured, nearly 1,000 homeless and substantial damage in the Chihuatlan-Manzanillo area. Ten other people were killed in the state of Jalisco and one person was injured at Puerto Vallarta. Damage occurred in the states of Colima, Guerrero, Jalisco and Michoacan. Felt strongly at Mexico City. Felt as far as Dallas and Houston, Texas and Oklahoma City, Oklahoma. Tsunami generated with maximum wave heights (peak-to-trough) recorded at the following tide stations: 200 cm at Manzanillo, 50 cm at Cabo San Lucas, 20 cm on Isla Socorro and 12 cm at Kahului, Hawaii. Complex event with major subevent occurring about 35 seconds after onset observed on broadband displacement seismograms.

21 Oct	02 38 57.5	Chiapas, Mexico	16.890 N	93.451 W	6.2mB 7.3Mw (GS) 7.3Mw (HRV)

Depth 161 km. Several houses damaged at San Andres Larrainzar. Felt strongly in many parts of southern Mexico and at Mexico City. Also felt in many parts of Guatemala. Felt (II) at Metapan El Salvador.

Table 7 (Cont'd)

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
23 Oct	22 46 54.1	Yunnan, China	25.923 N	102.227 E	5.8mB,6.4Ms 6.1Mw (GS) 6.2Mw (HRV)

Depth 33 km. At least 36 people killed, 200 injured and more than 100 houses collapsed in the Wuding area. Felt in Sichuan Province and in northern Vietnam.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
22 Nov	04 15 11.7	Egypt	28.818 N	34.861 E	6.2mB,7.3Ms 7.0Mw (GS) 7.2Mw (HRV)

Depth 10 km. At least 8 people killed and 30 injured in the epicentral region, including 2 killed and 11 injured at Nuwaybi. Damage occurred in many parts of northeastern Egypt as far away as Cairo. One person was killed and two slightly injured at Al Bad, Saudi Arabia. Some damage occurred at Al Bad, Al Ula and Haql, Saudi Arabia. One person died of a heart attack, several people were injured and substantial damage with power outages and liquefaction occurred at Elat, Israel. Some damage also occurred at Jerusalem, Israel and Agaba, Jordan. Felt from Sudan to Lebanon. High waves were reported along the coast at Agaba, Jordan.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
03 Dec	18 01 08.7	Kuril Islands	44.660 N	149.380 E	6.8mB,8.0Mw 7.8Mw (GS) 7.9Mw (HRV)

Depth 33 km. Felt (V) on Iturup, (IV) on Matua and (III) on Kunashir. Felt (II JMA) at Akkeshi, Kushiro and Urakawa, Hokkaido. Also felt (II JMA) at Aomora and Mutsu, Honshu. Local tsunami generated with maximum wave heights (peak-to-trough) recorded at the following tide stations: 17 cm at Nemuro and 10 cm at Kushiro, Hokkaido; 13 cm at Hachinohe and 6 cm at Ayukawa, Honshu.

Date	Origin Time (UTC)	Region	Lat.	Long.	Magnitude
19 Dec	20 56 06.1	Guatemala	15.274 N	90.060 W	5.0mB,4.8Ms

Depth 10 km. One person killed and one person injured by rockslides. Some houses damaged at San Miguel Tucuro and Tamahu. Landslides occurred in the epicentral area. Felt (IV) at Coban and (III) at Guatemala City.

Table 8 Nuclear explosions detected*, 1995

Date	Time UTC	mb	Ms	Yield kton	Lat	Long	Site	Source
05 15	040557.86.1		5.0	75	41.603N	88.820E	LopN	PDE
08 17	005957.86.0			40	41.587N	88.782E	LopN	PDE
09 05	212958.34.8			9	21.858S	138.837W	Mur	PDE
10 01	232957.95.4			85	22.248S	138.781W	Mur	PDE
10 27	215957.05.5			45	21.950S	139.190W	Mur	QED
11 21	212958.04.8			10	21.876S	139.036W	Mur	PDE
12 27	212957.75.1			20	21.922S	139.001W	Mur	PDE

Site:
LopN: Lop Nor China
Mur: French Polynesia

Source:
¤ PDE Preliminary Determination of Epicentres; QED Quick Epicentre Determination

* from: AGSO Nuclear Explosions Database

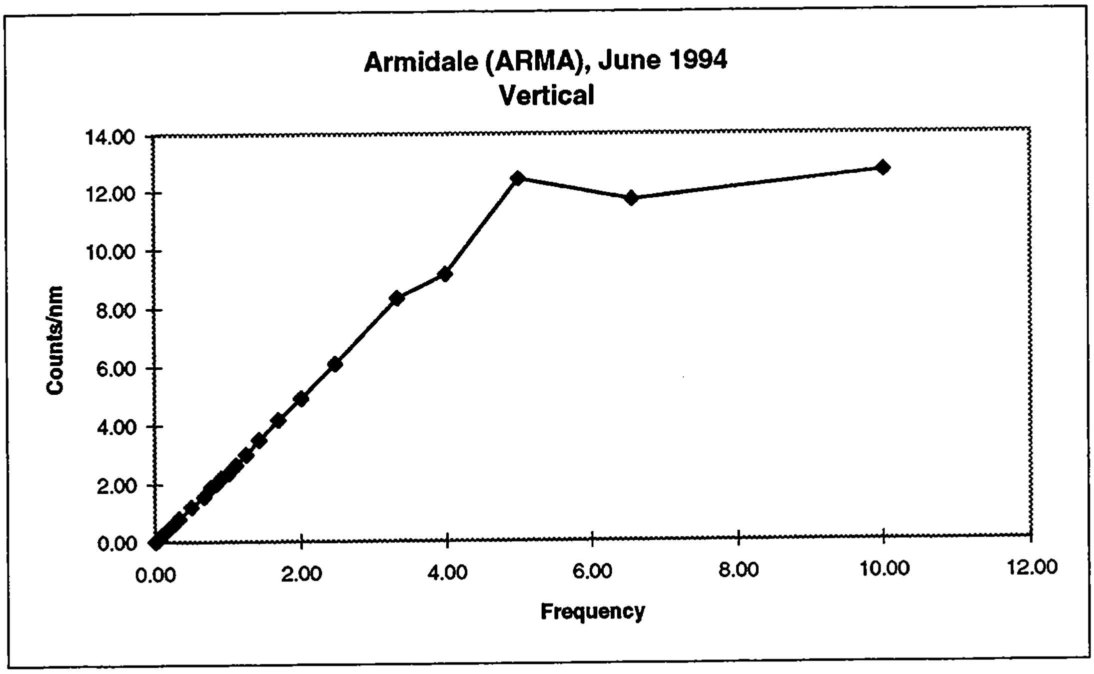
Table 9. Yield versus magnitude for underground nuclear explosions

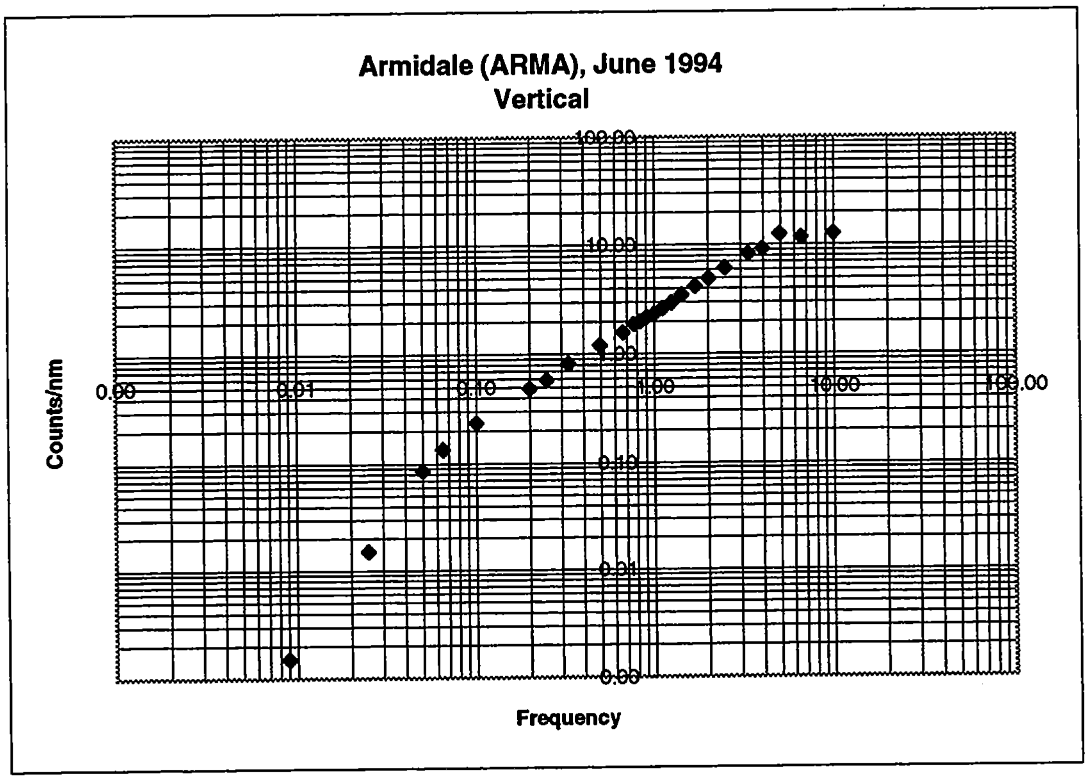
Magnitude mb Test site: Nevada	*Magnitude mb* Test site: Other	*Yield ktons*
0.0 - 4.5	0.0 - 4.8	< 10
4.6 - 4.8	4.9 - 5.1	5 - 20
4.9 - 5.0	5.2 - 5.4	10 - 40
5.1 - 5.3	5.5 - 5.7	20 - 80
5.4 - 5.6	5.8 - 6.0	40 - 150
> 5.6	> 6.0	>80

APPENDIX 2

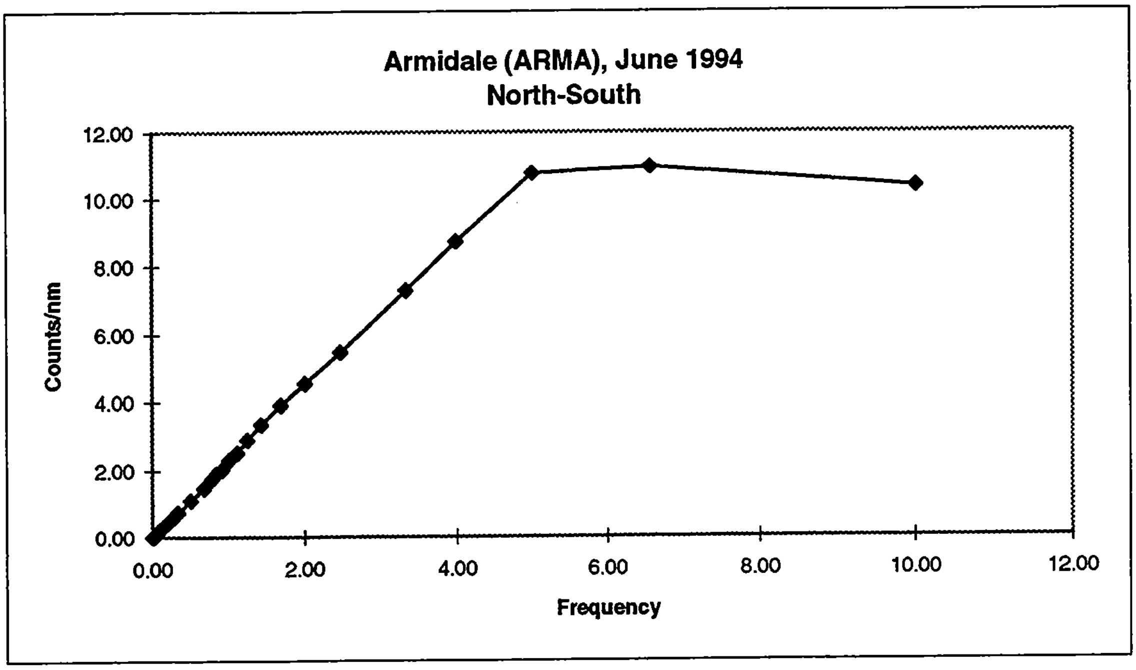
CALIBRATION CURVES

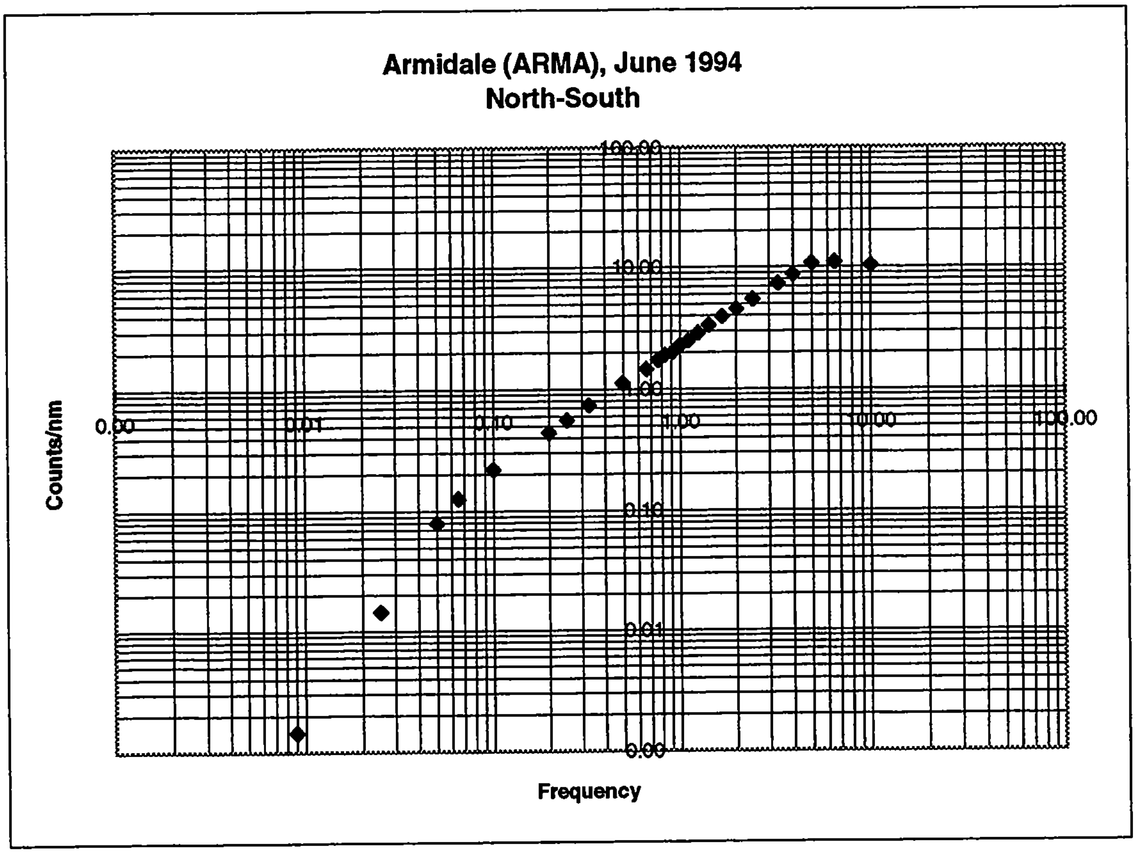
Calibration curves for analogue stations of the Australian *National Seismograph Network were published in the 1990 Report by McCue and Gregson (1993). Revised data and corresponding curves for most of the digital stations of the Network were compiled by Graeme Small and are included in the following pages.

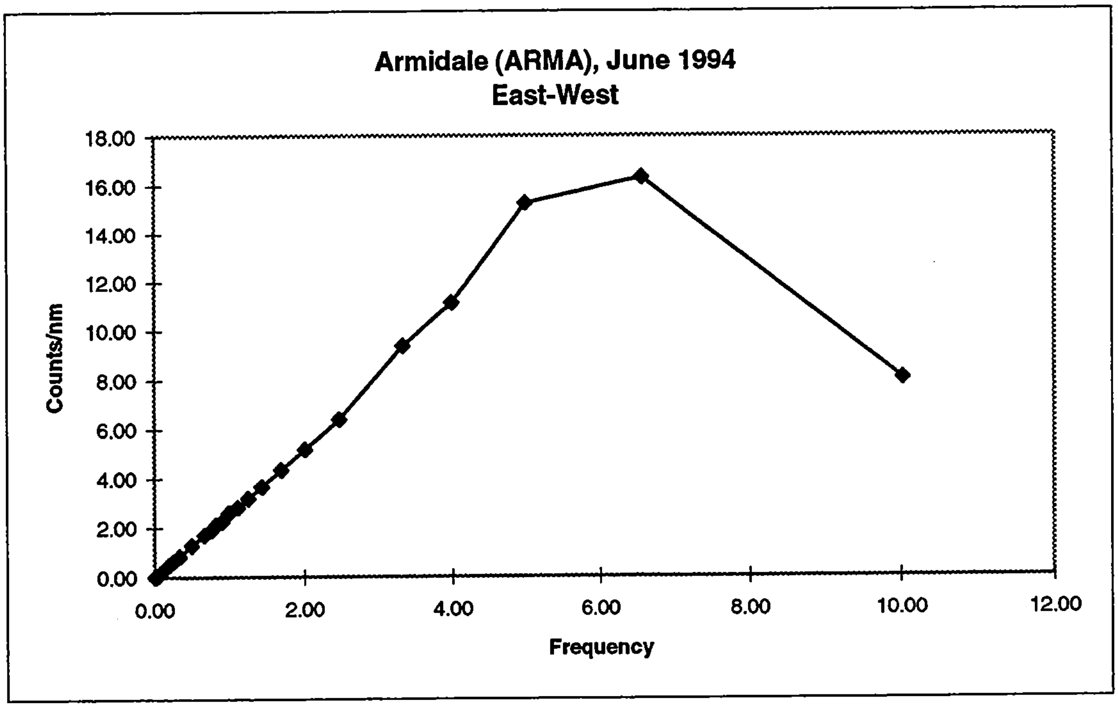

Armidale (ARMA), June 1994
Vertical
Counts/nm
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Frequency

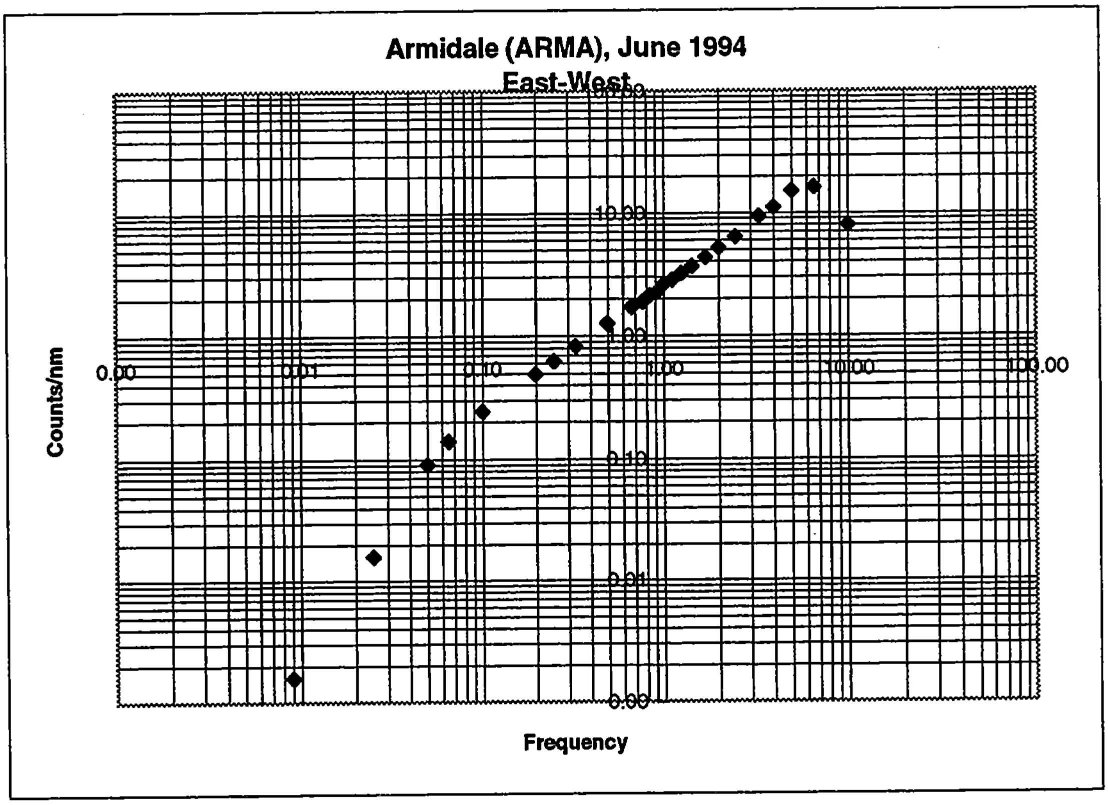

Armidale (ARMA), June 1994
Vertical
Counts/nm
100.00
10.00
1.00
0.10
0.01
0.00
0.00
0.01
0.10
1.00
10.00
100.00
Frequency

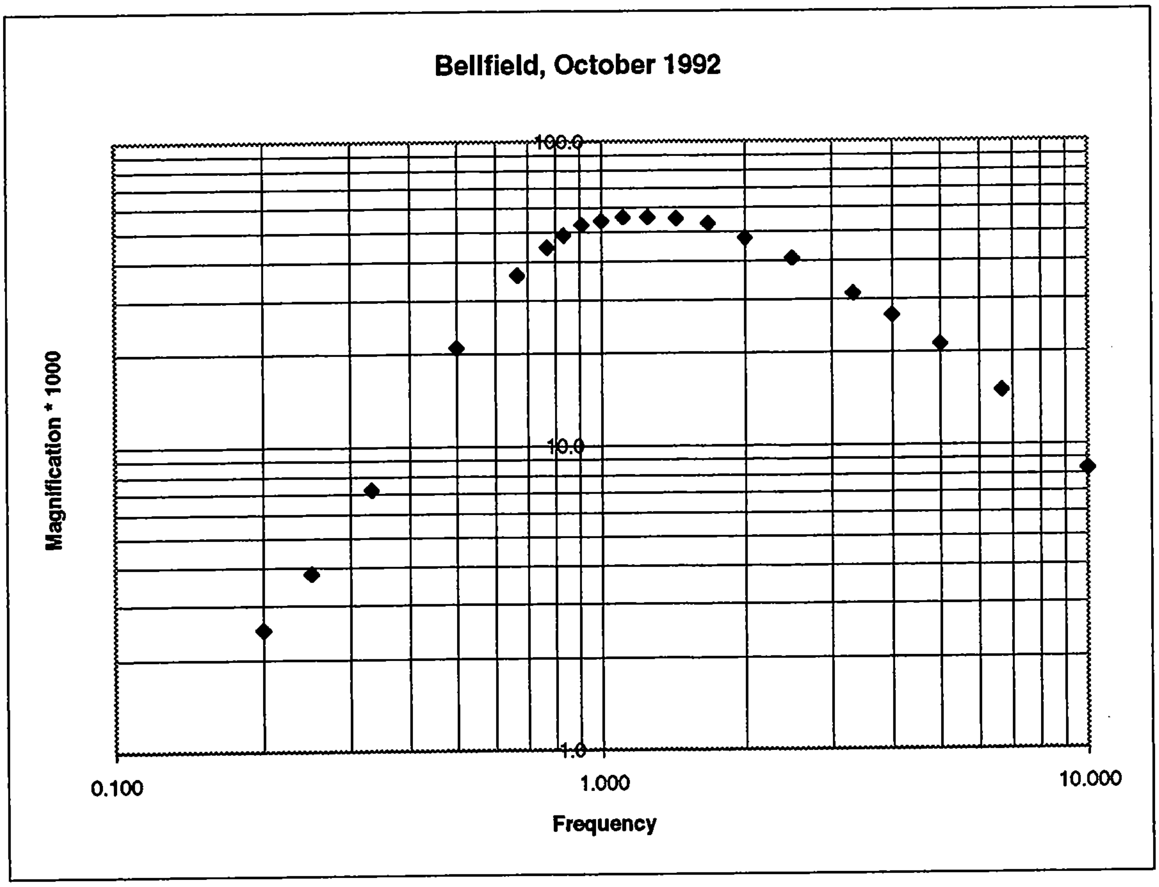
Seismograph Calibrations



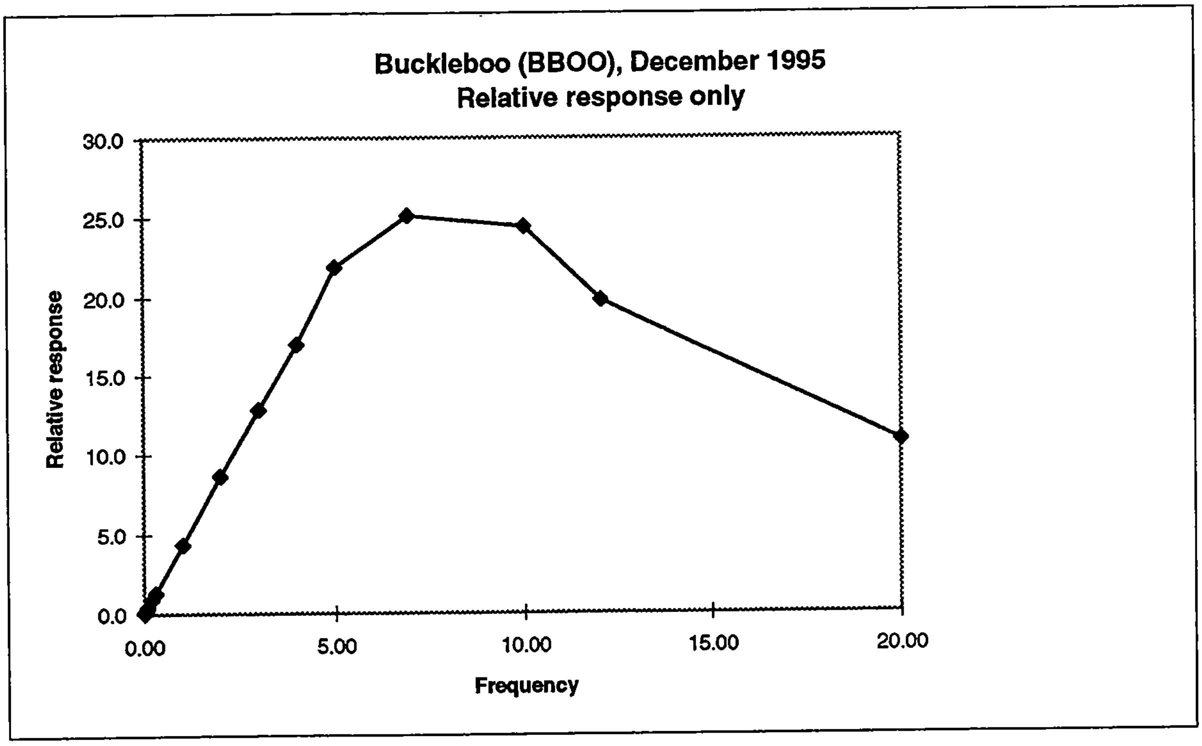



Armidale (ARMA), June 1994
East-West
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Counts/nm
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Frequency

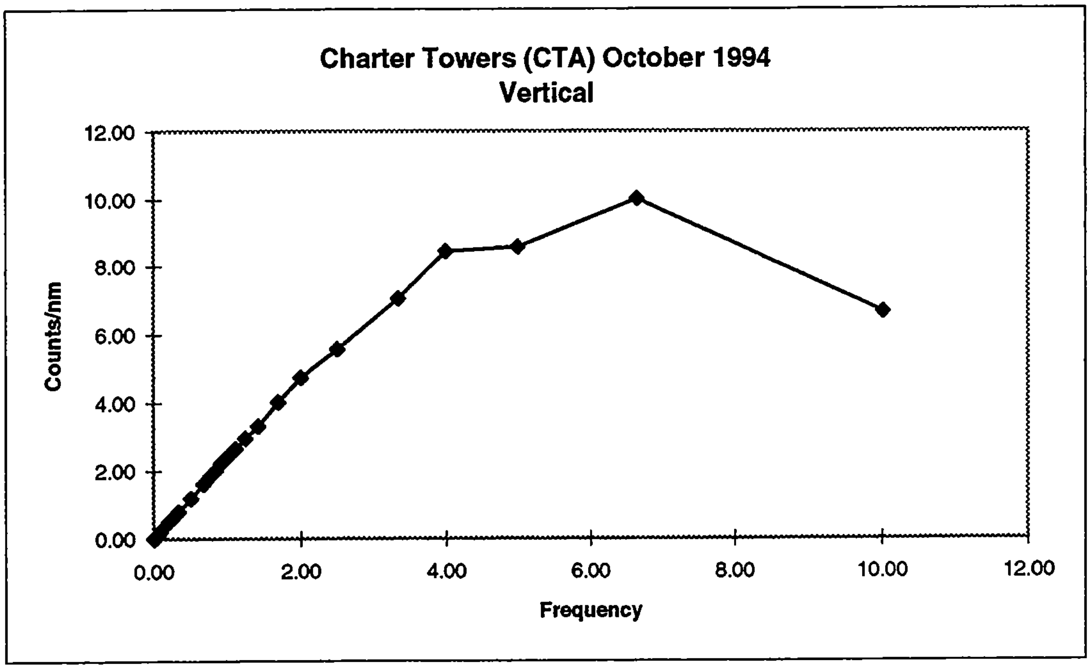

Armidale (ARMA), June 1994
East-West
10.00
1.00
0.10
0.01
0.00
Counts/nm
0.00
0.01
0.10
1.00
10.00
100.00
Frequency

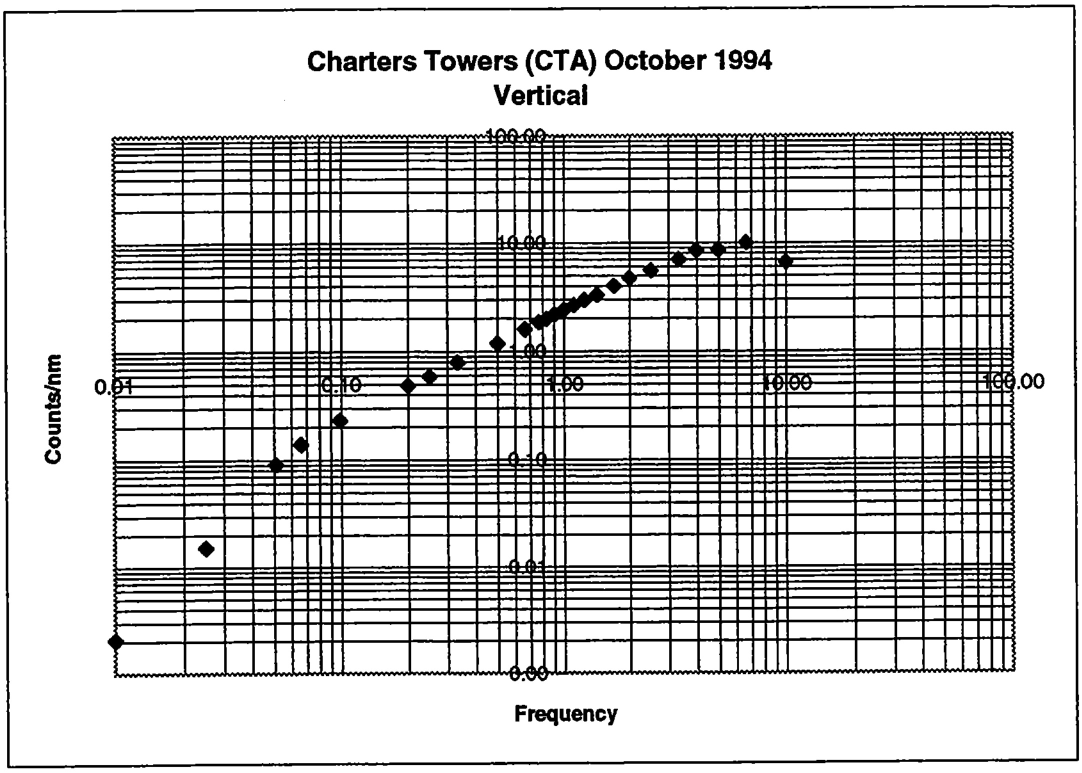


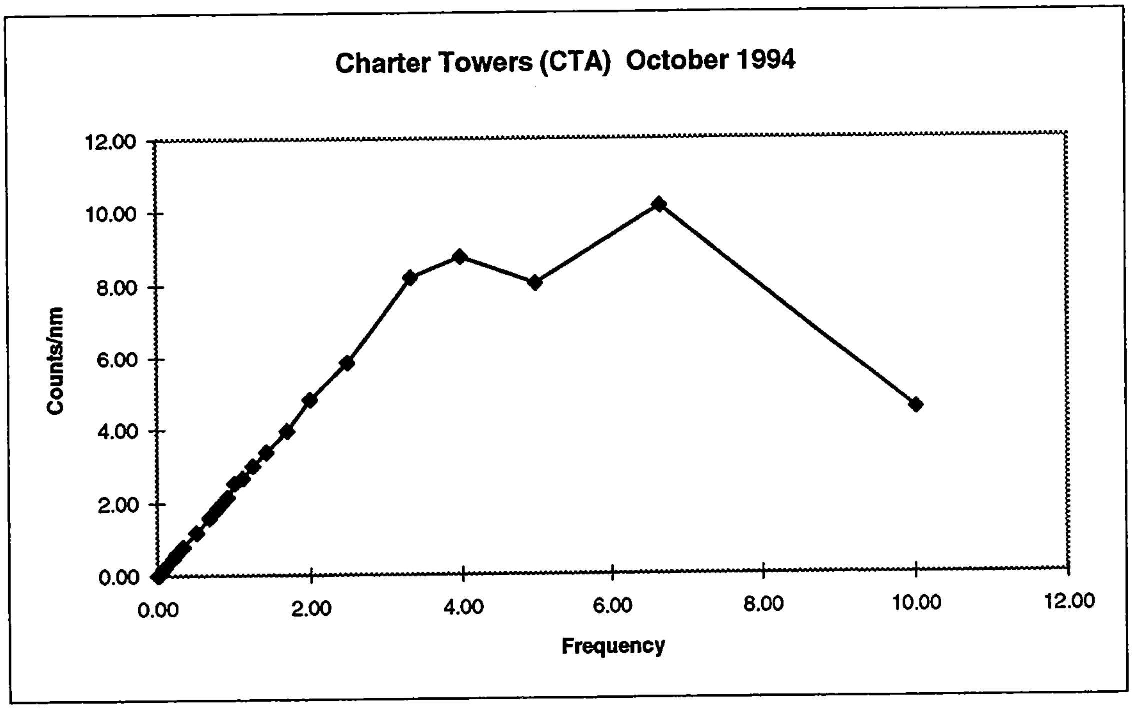
Bellfield, October 1992
100.0
10.0
1.0
Magnification * 1000
0.100
1.000
10.000
Frequency

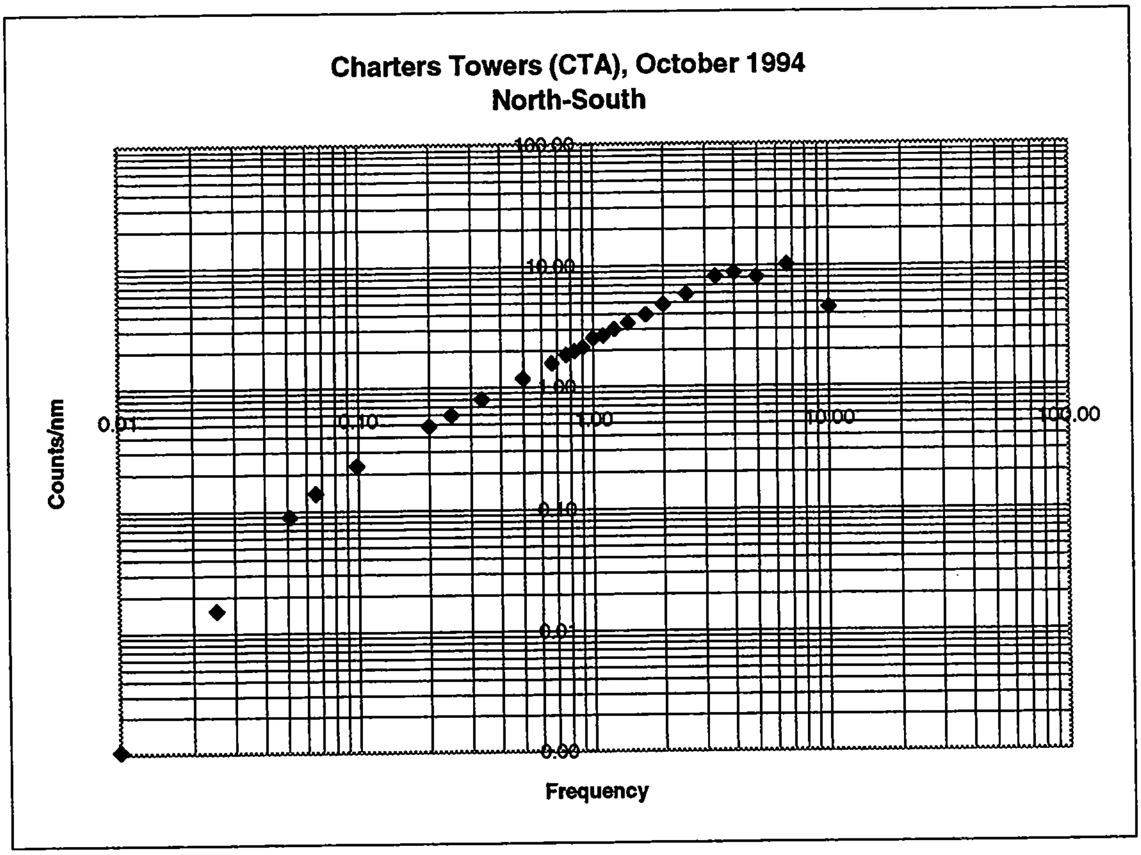


Buckleboo (BBOO), December 1995
Relative response only
Relative response
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
5.00
10.00
15.00
20.00
Frequency

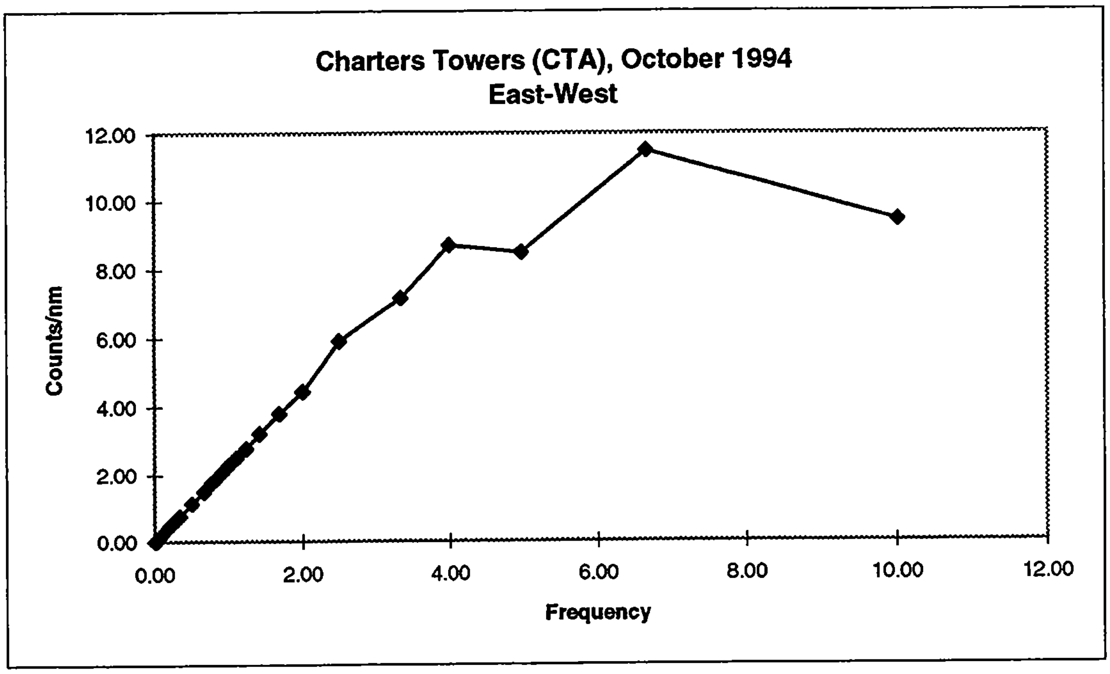

Charter Towers (CTA) October 1994
Vertical
Counts/nm
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Frequency

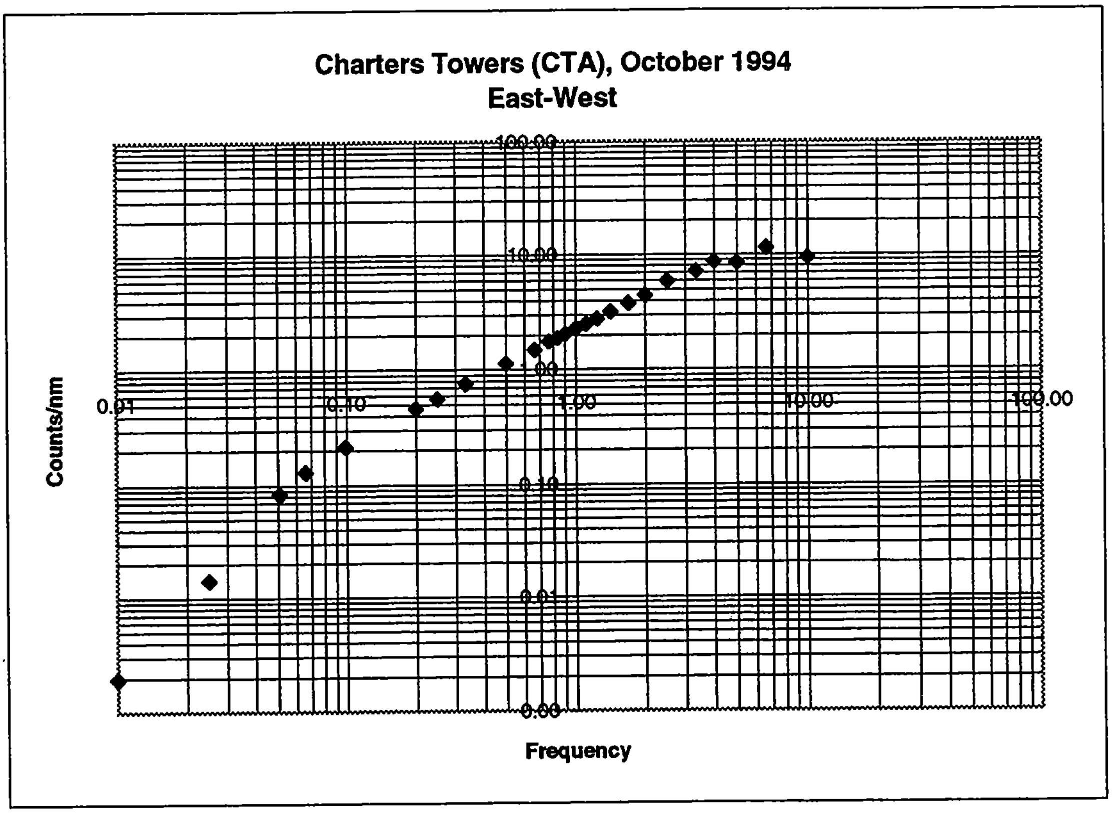

Charters Towers (CTA) October 1994
Vertical
Counts/nm
100.00
10.00
1.00
0.10
0.01
0.00
0.01
0.10
1.00
10.00
100.00
Frequency

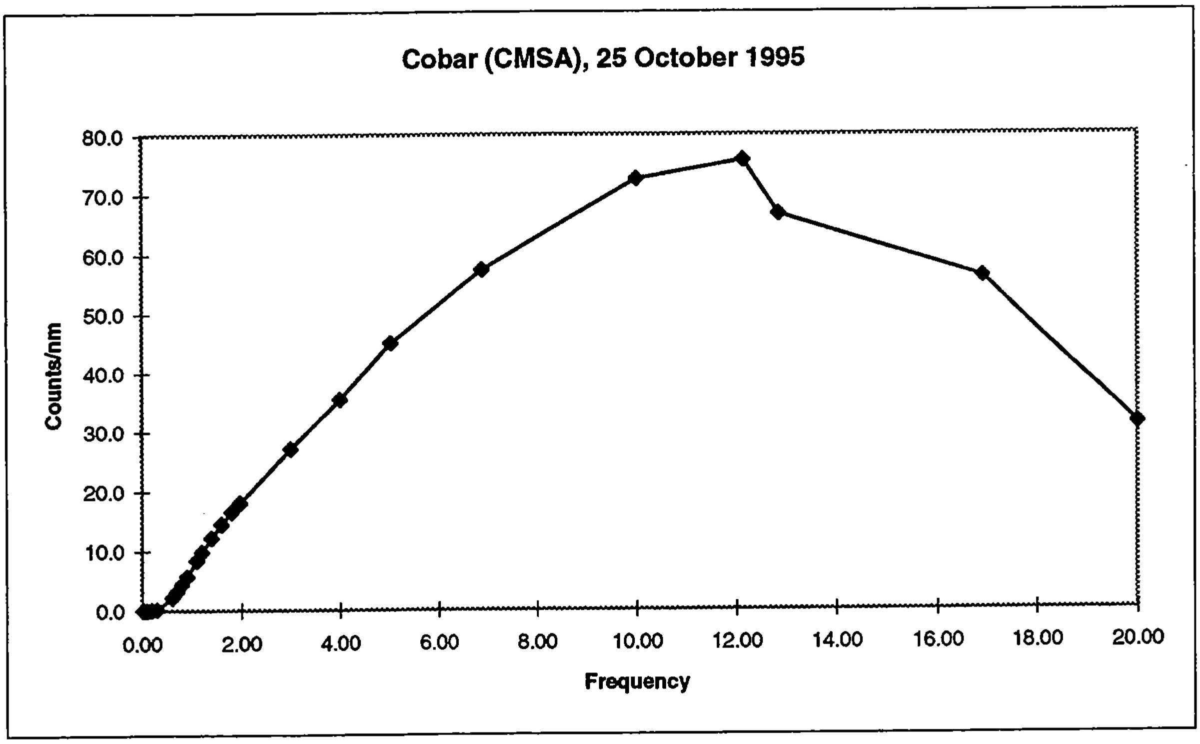

Charter Towers (CTA) October 1994
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Counts/nm
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Frequency

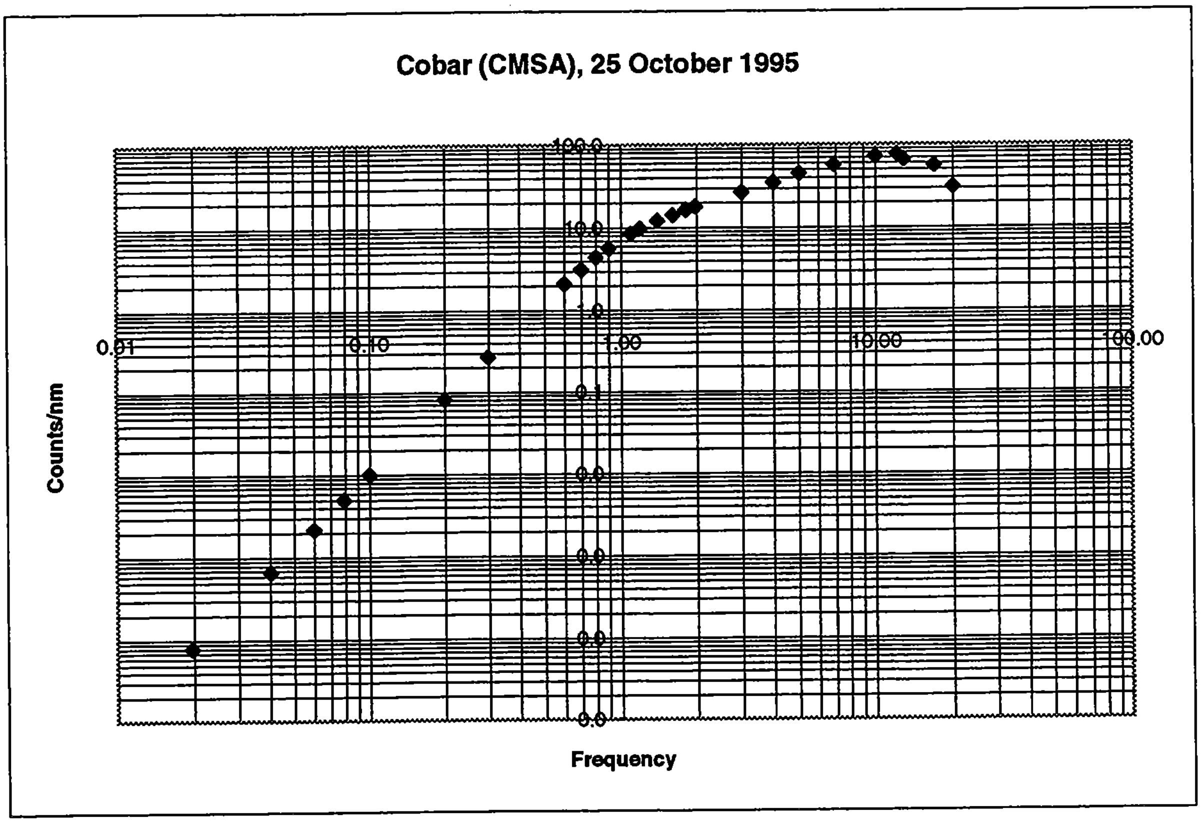

Charters Towers (CTA), October 1994
North-South
100.00
10.00
1.00
0.10
0.01
0.00
0.01
0.10
1.00
10.00
100.00
Counts/nm
Frequency

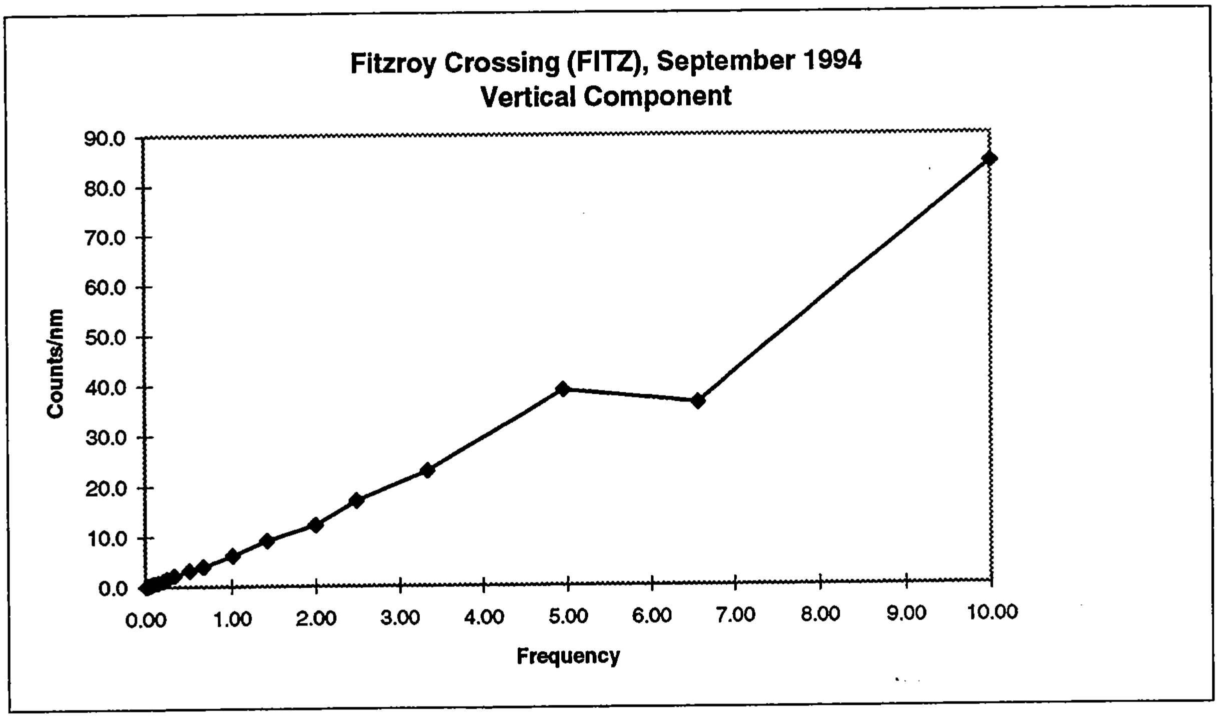
Seismograph Calibrations

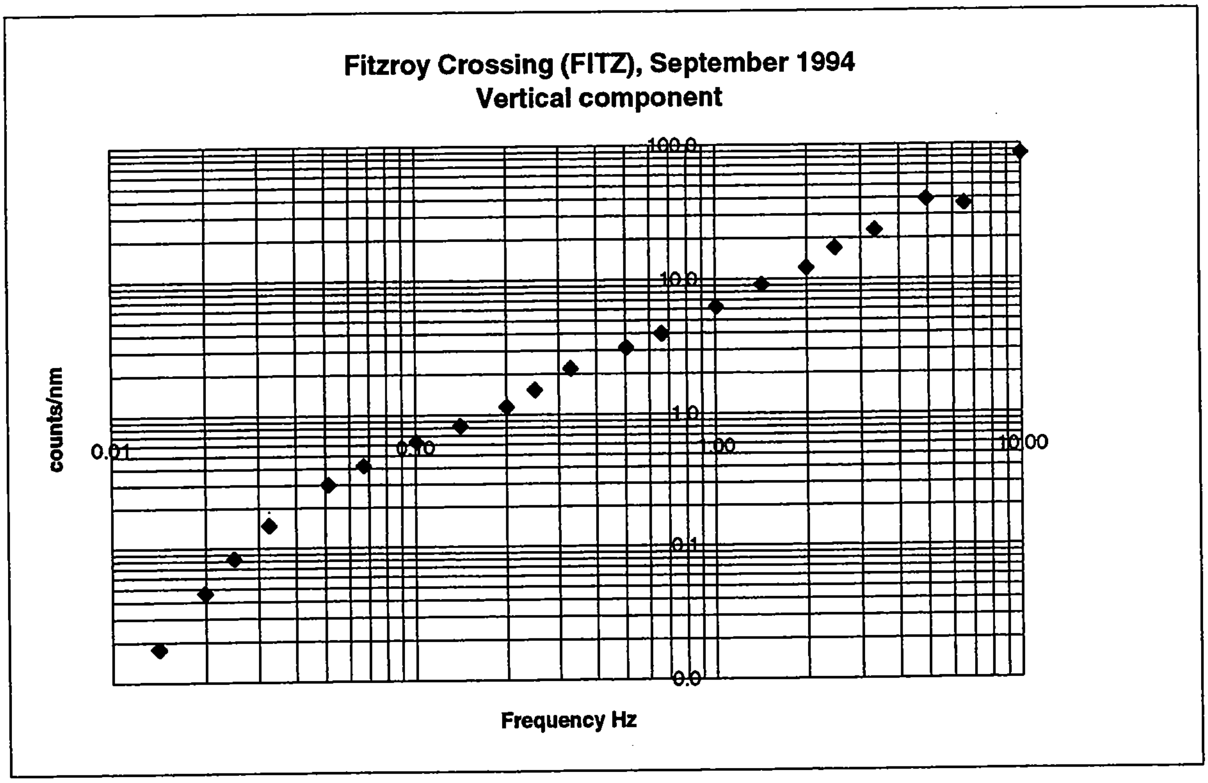


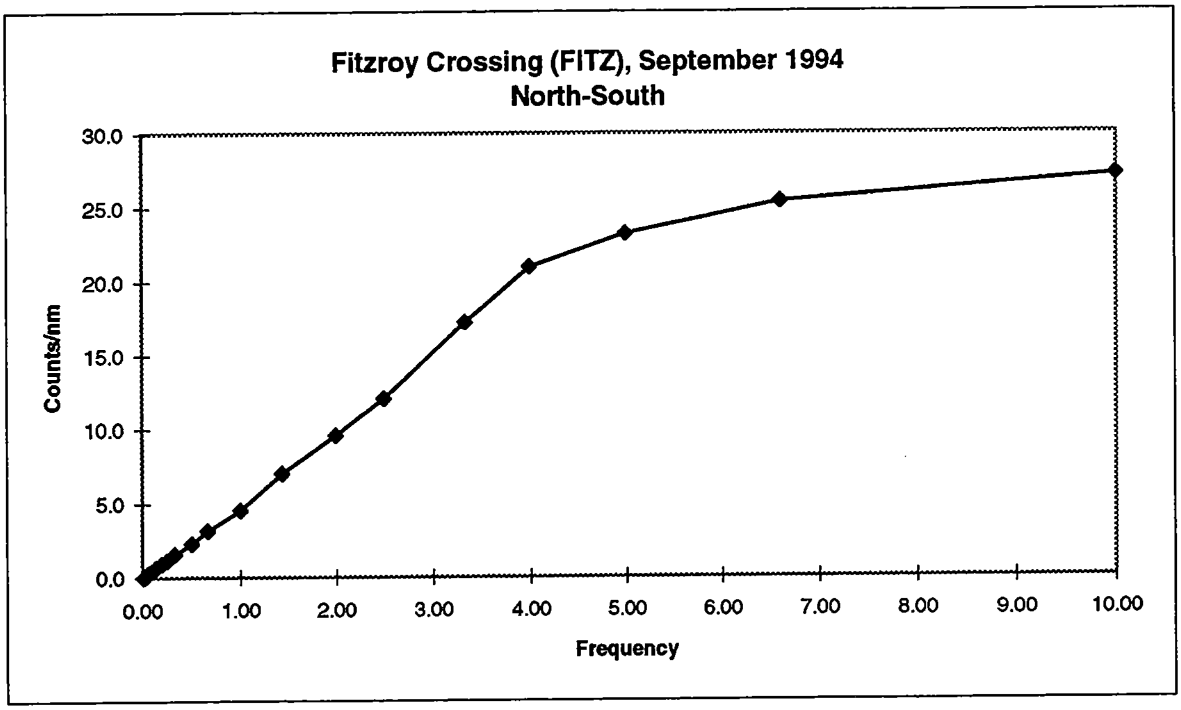



Cobar (CMSA), 25 October 1995
Counts/nm
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Frequency

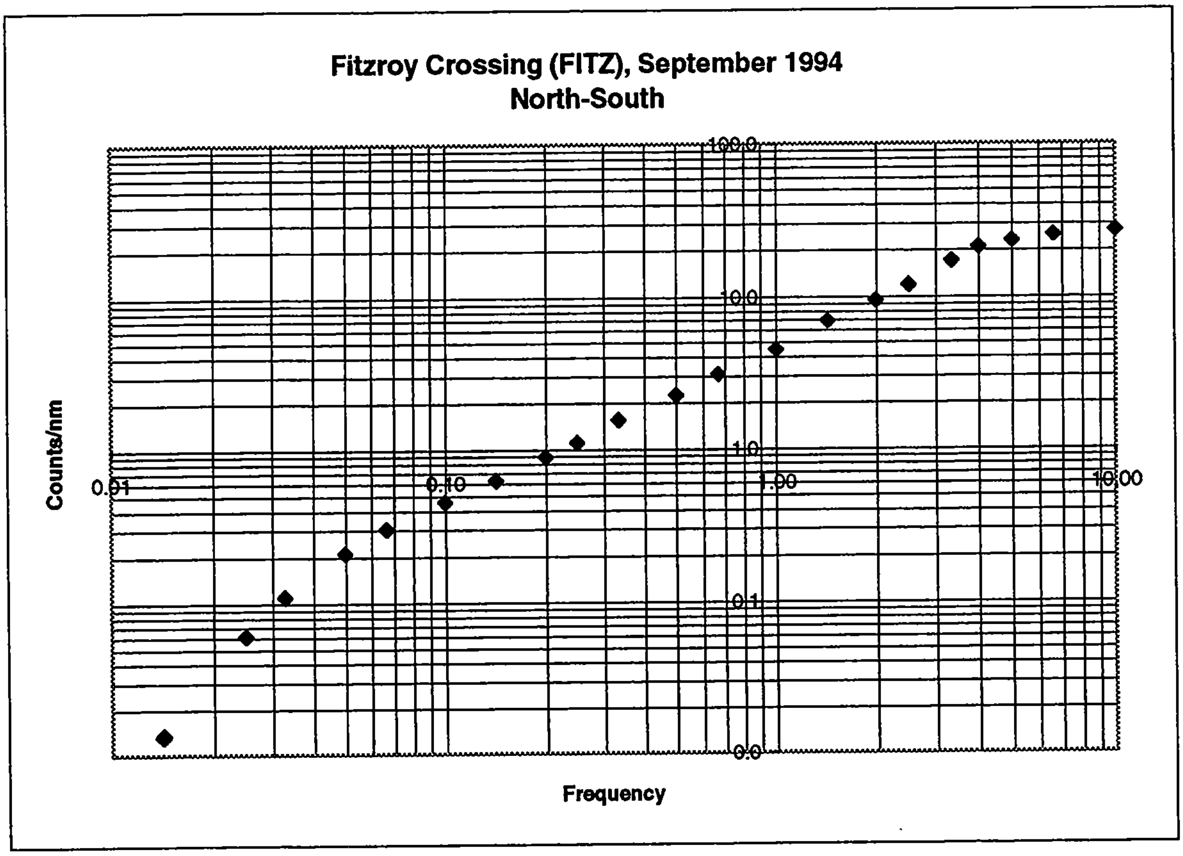

Cobar (CMSA), 25 October 1995
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.0
0.0
0.0
0.01
0.10
1.00
10.00
100.00
Frequency


Fitzroy Crossing (FITZ), September 1994
Vertical Component
Counts/nm
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency

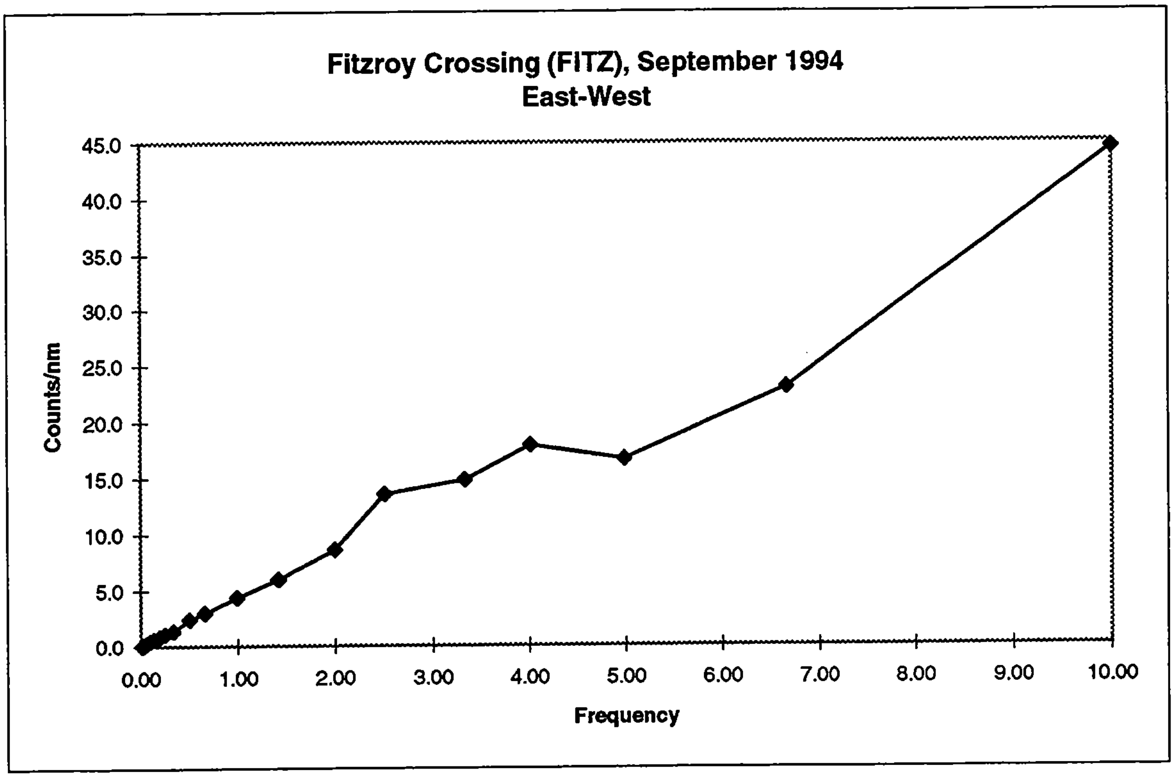

Fitzroy Crossing (FITZ), September 1994
Vertical component
counts/nm
100.0
10.0
1.0
0.1
0.0
0.01
0.10
1.00
10.00
Frequency Hz

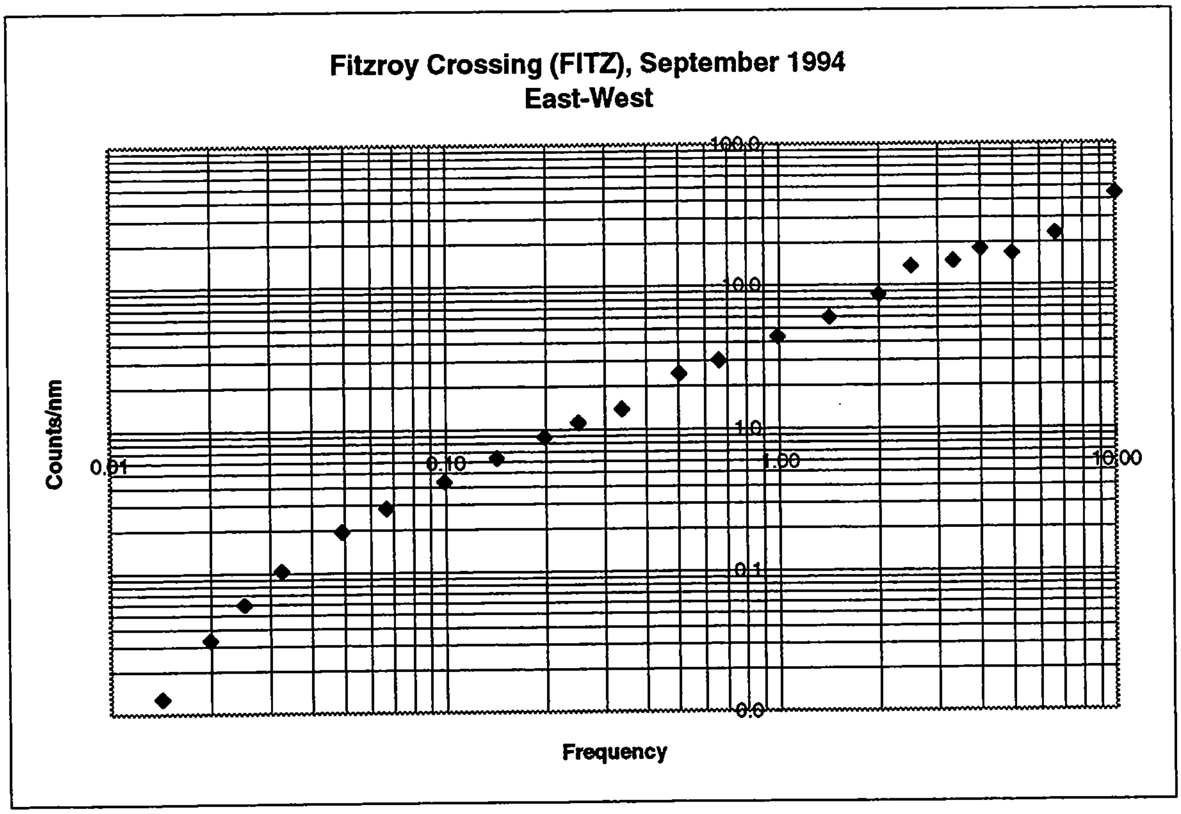


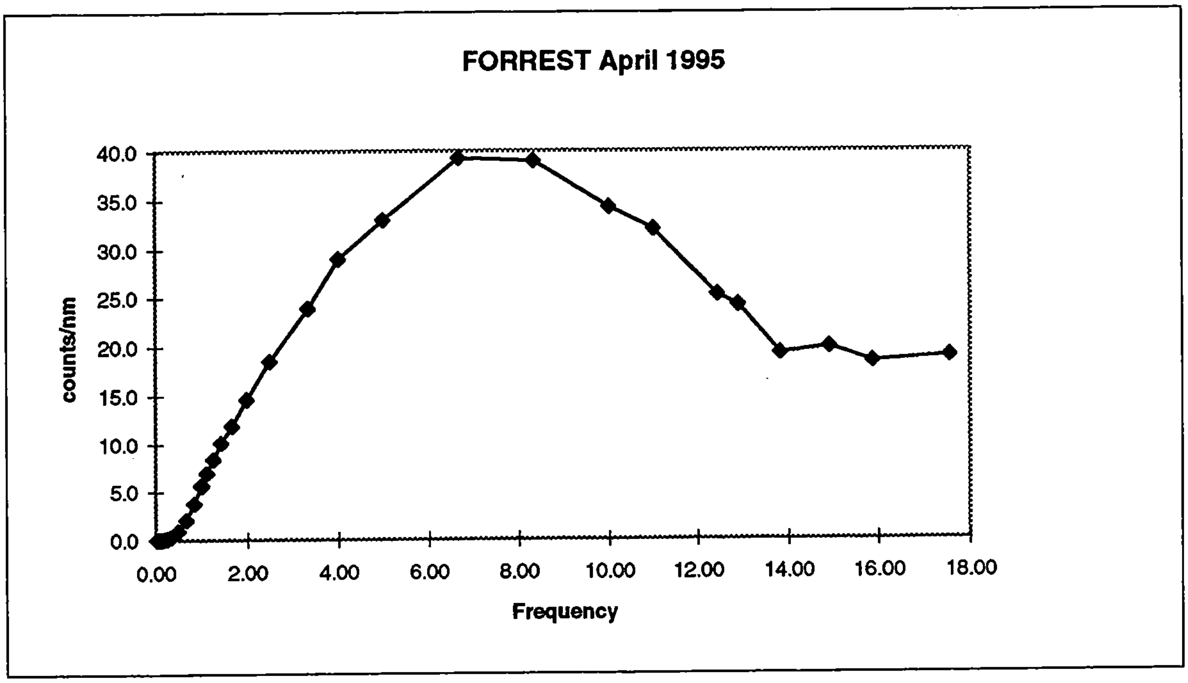
Fitzroy Crossing (FITZ), September 1994
North-South
Counts/nm
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency

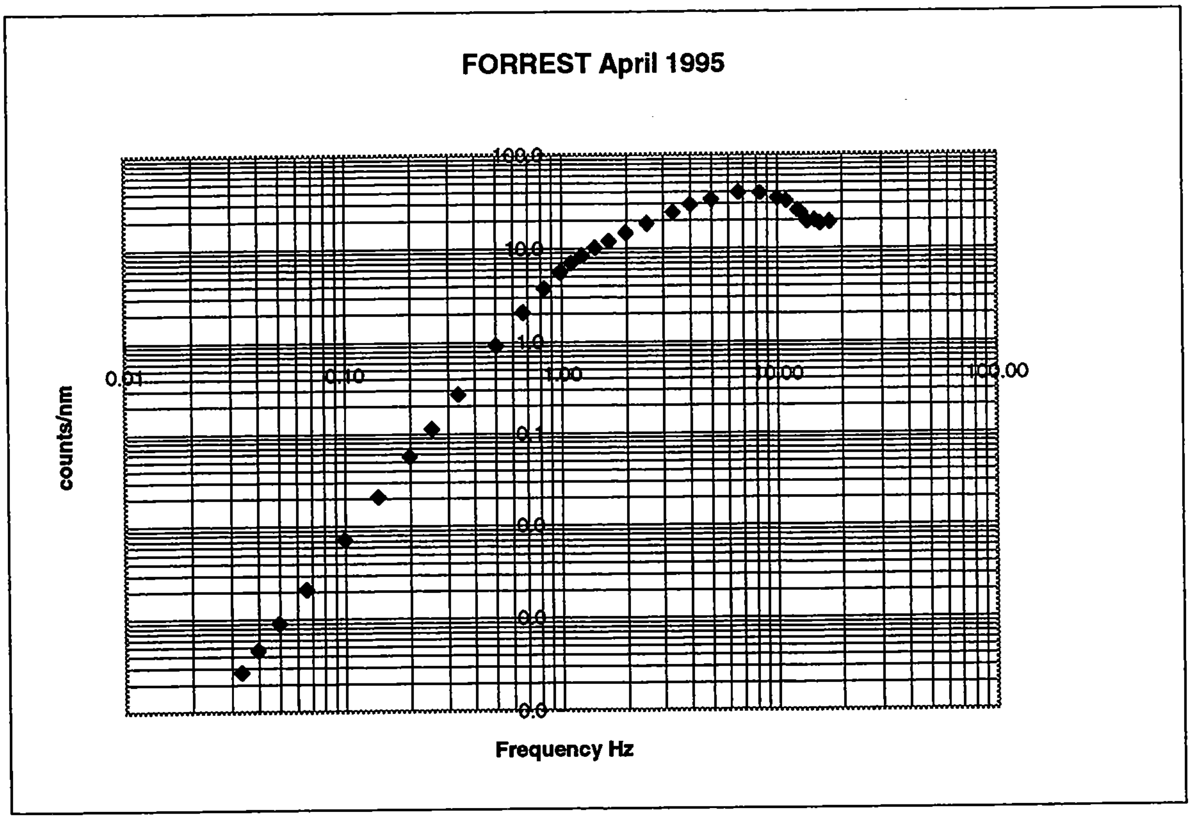


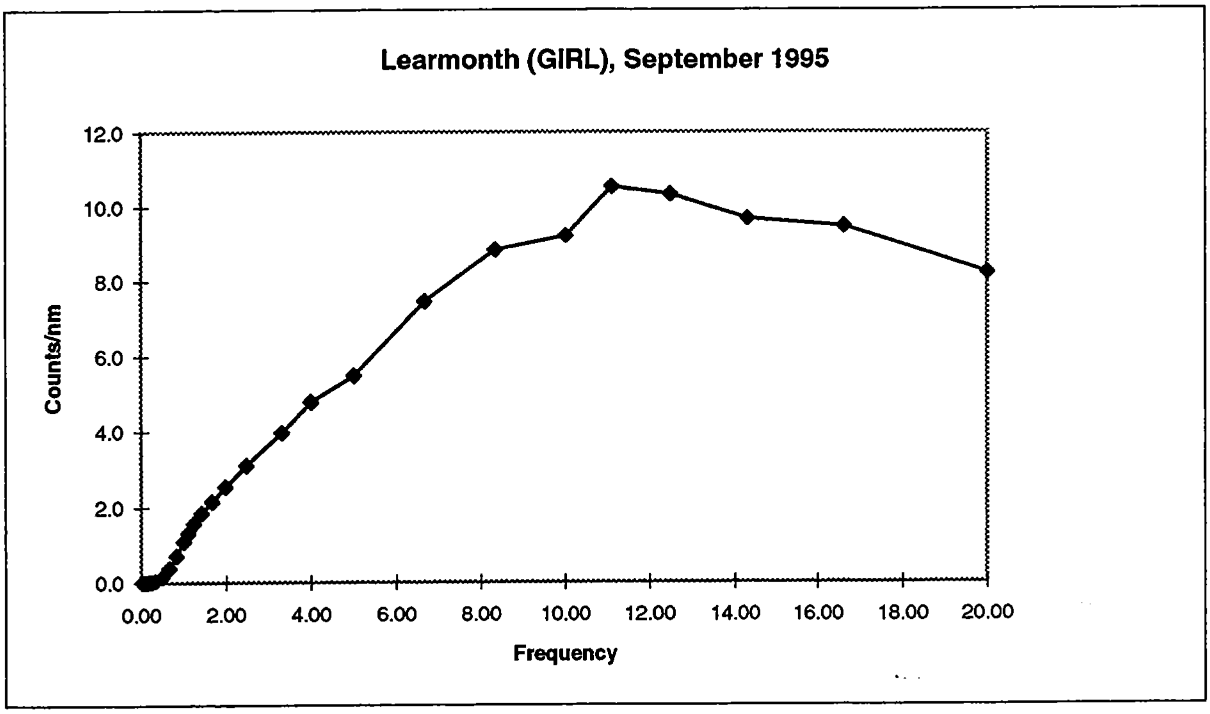
Fitzroy Crossing (FITZ), September 1994
North-South
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.01
0.10
1.00
10.00
Frequency


Fitzroy Crossing (FITZ), September 1994
East-West
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Counts/nm
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency

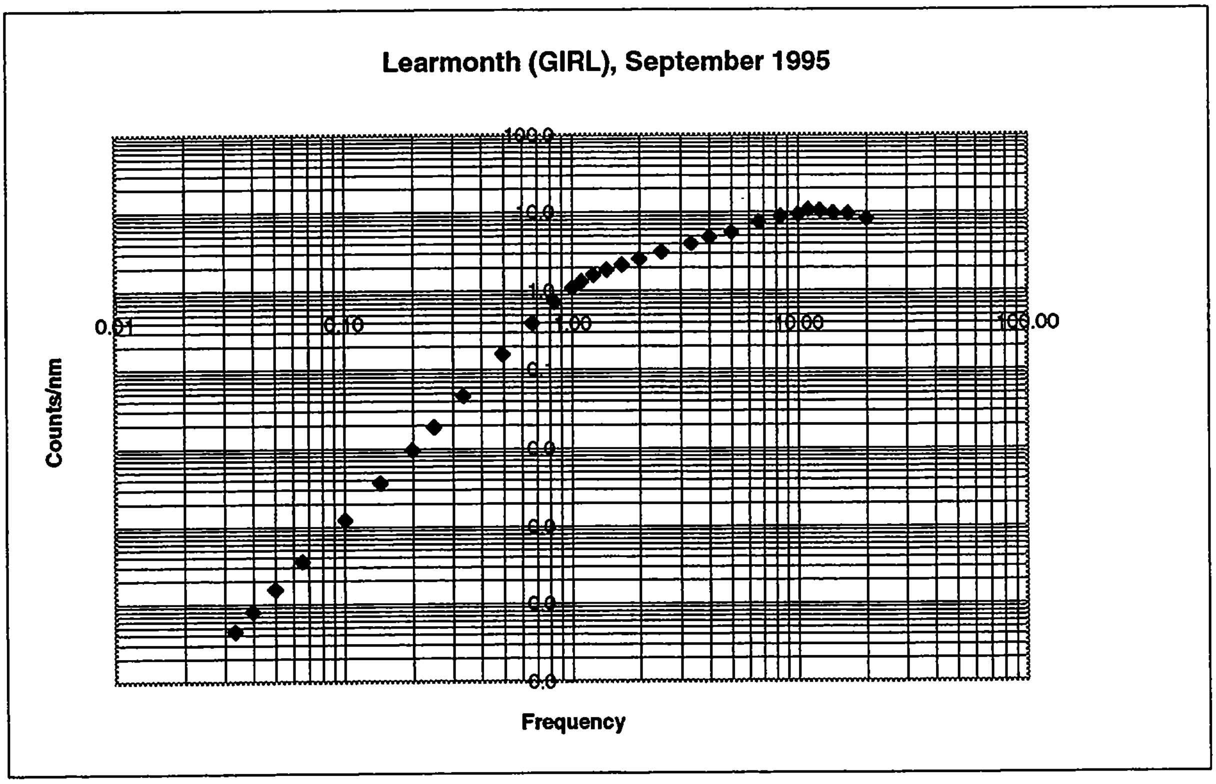

Fitzroy Crossing (FITZ), September 1994
East-West
100.0
10.0
1.0
0.1
0.0
0.01
0.10
1.00
10.00
Counts/nm
Frequency


FORREST April 1995
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
counts/nm
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
Frequency

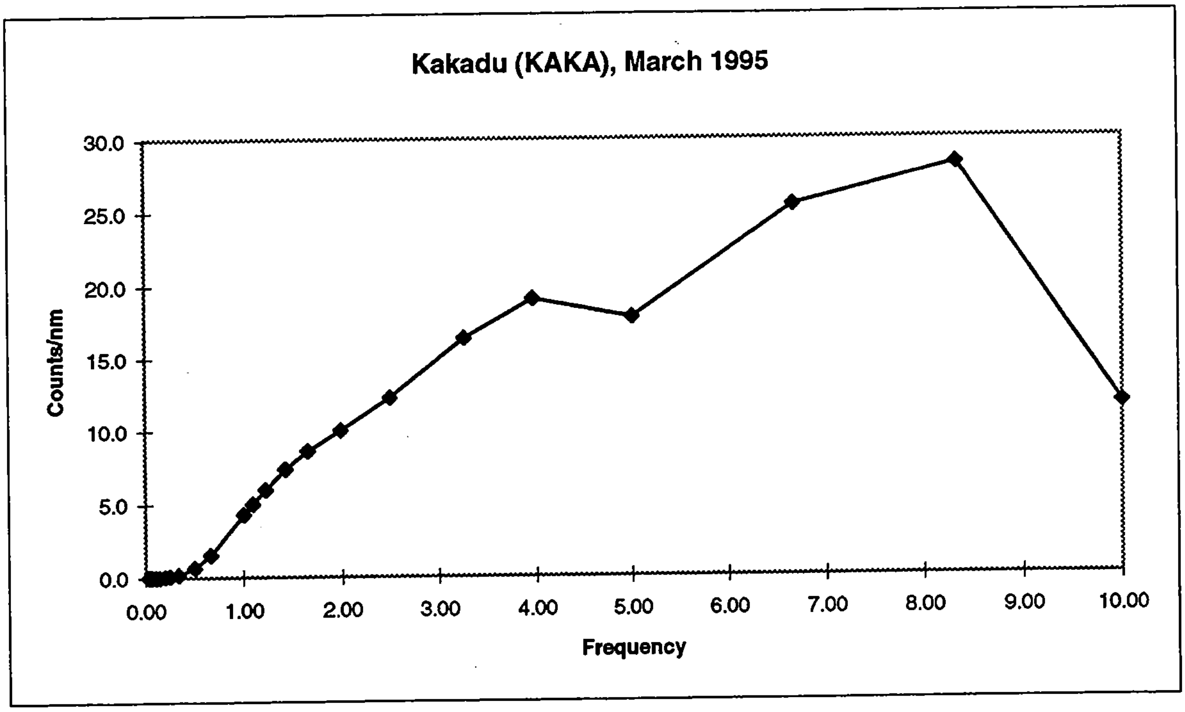

FORREST April 1995
100.0
10.0
1.0
0.01
0.10
1.00
10.00
100.00
0.1
0.0
0.0
0.0
counts/nm
Frequency Hz

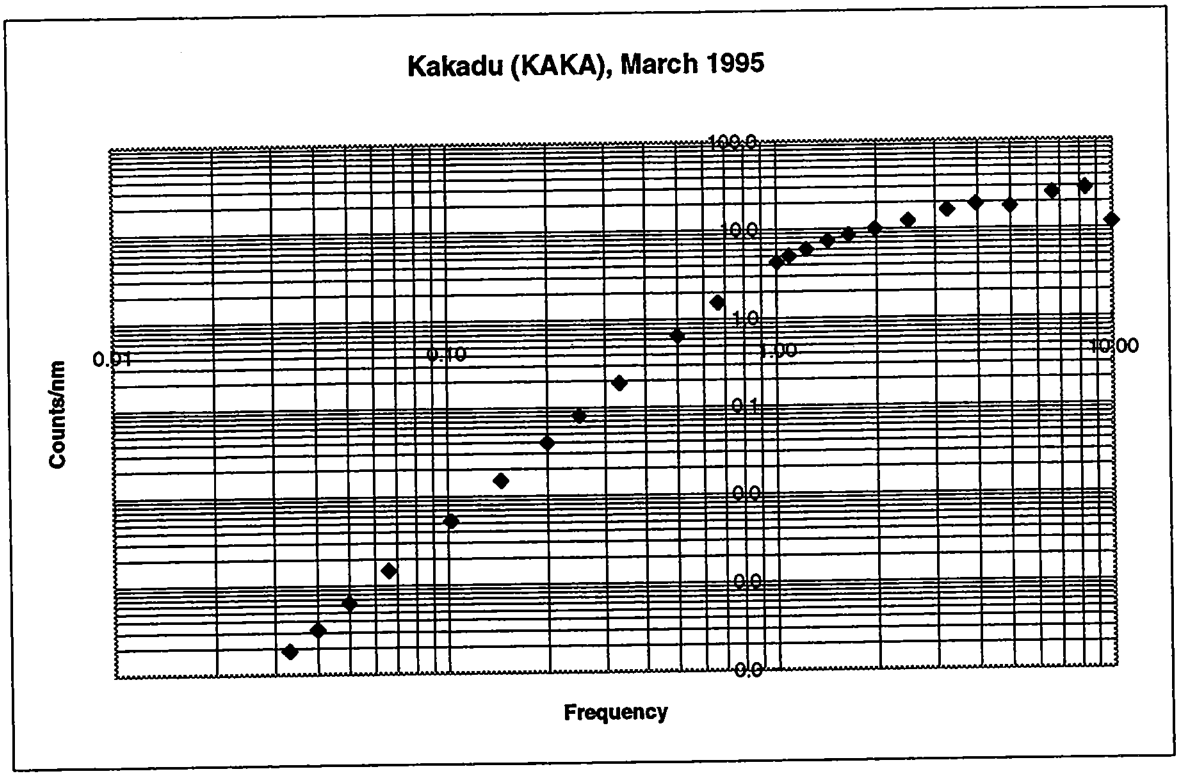


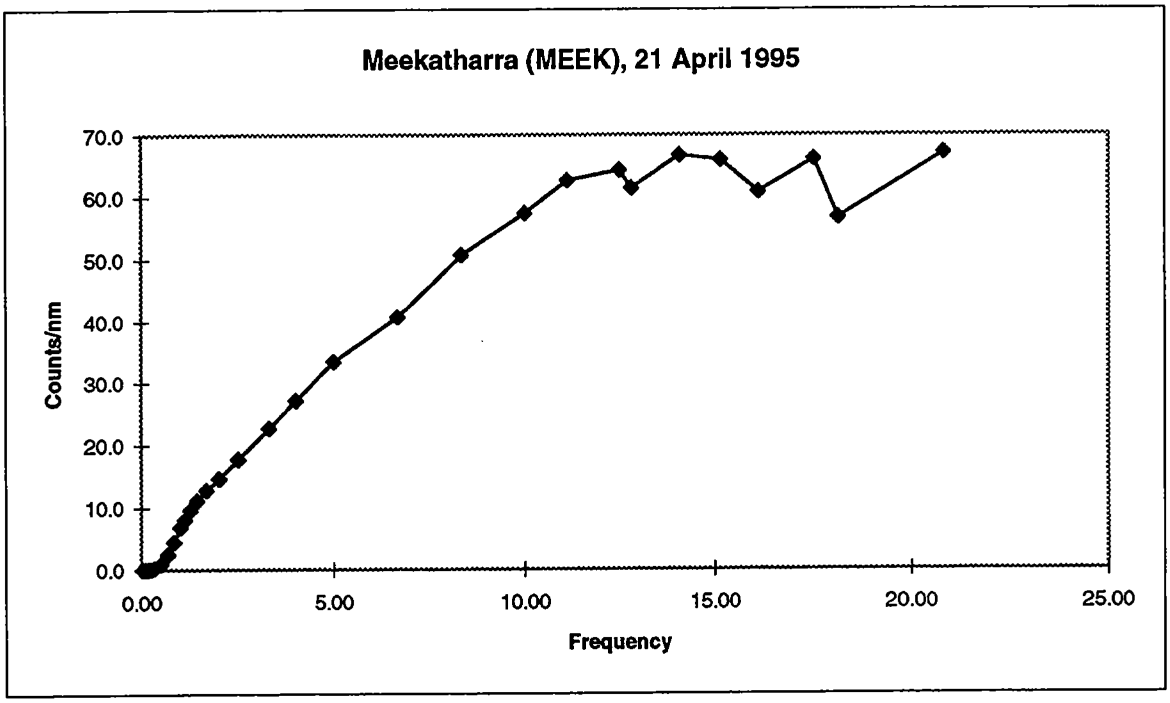
Learmonth (GIRL), September 1995
Counts/nm
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Frequency

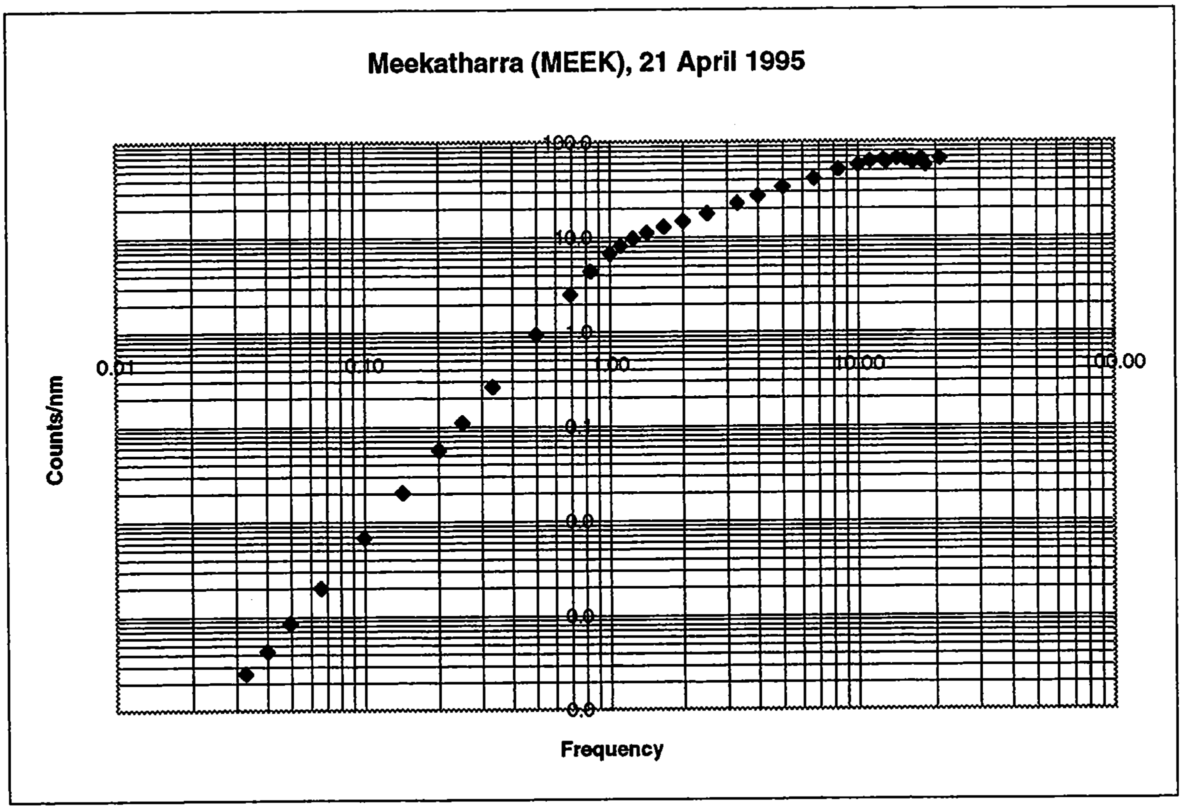


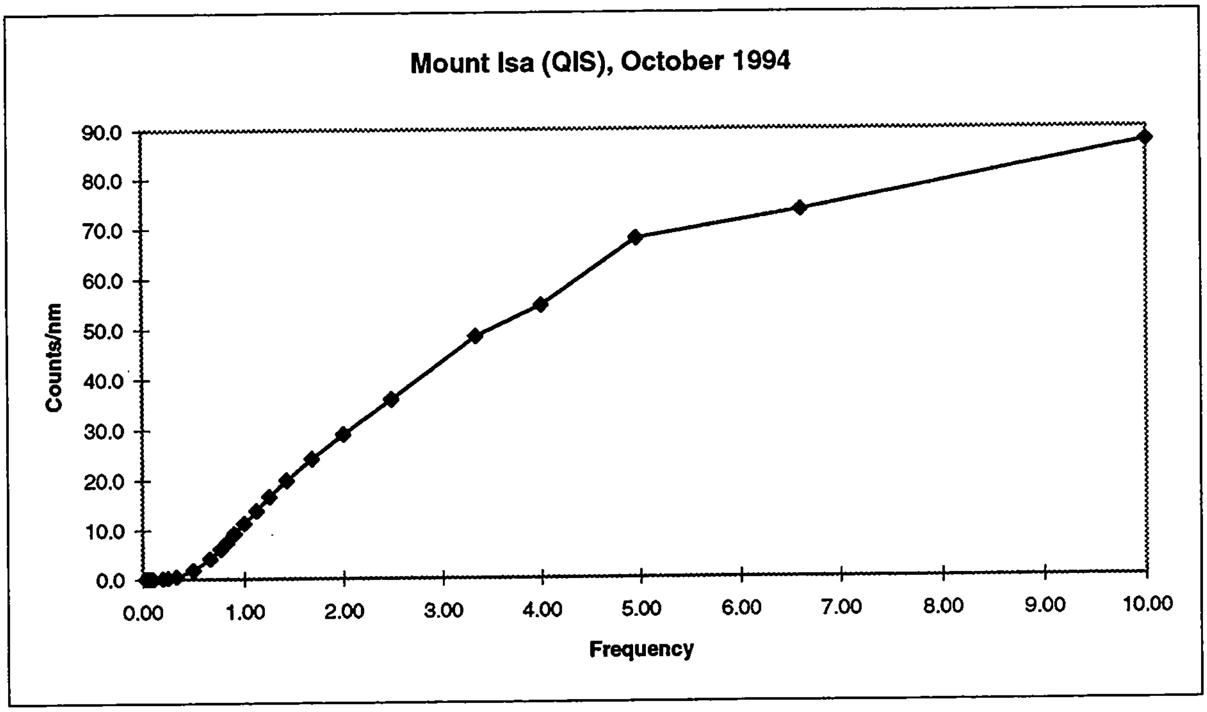
Learmonth (GIRL), September 1995
Counts/nm
100.0
10.0
1.0
0.01
0.10
1.00
10.00
100.00
Frequency

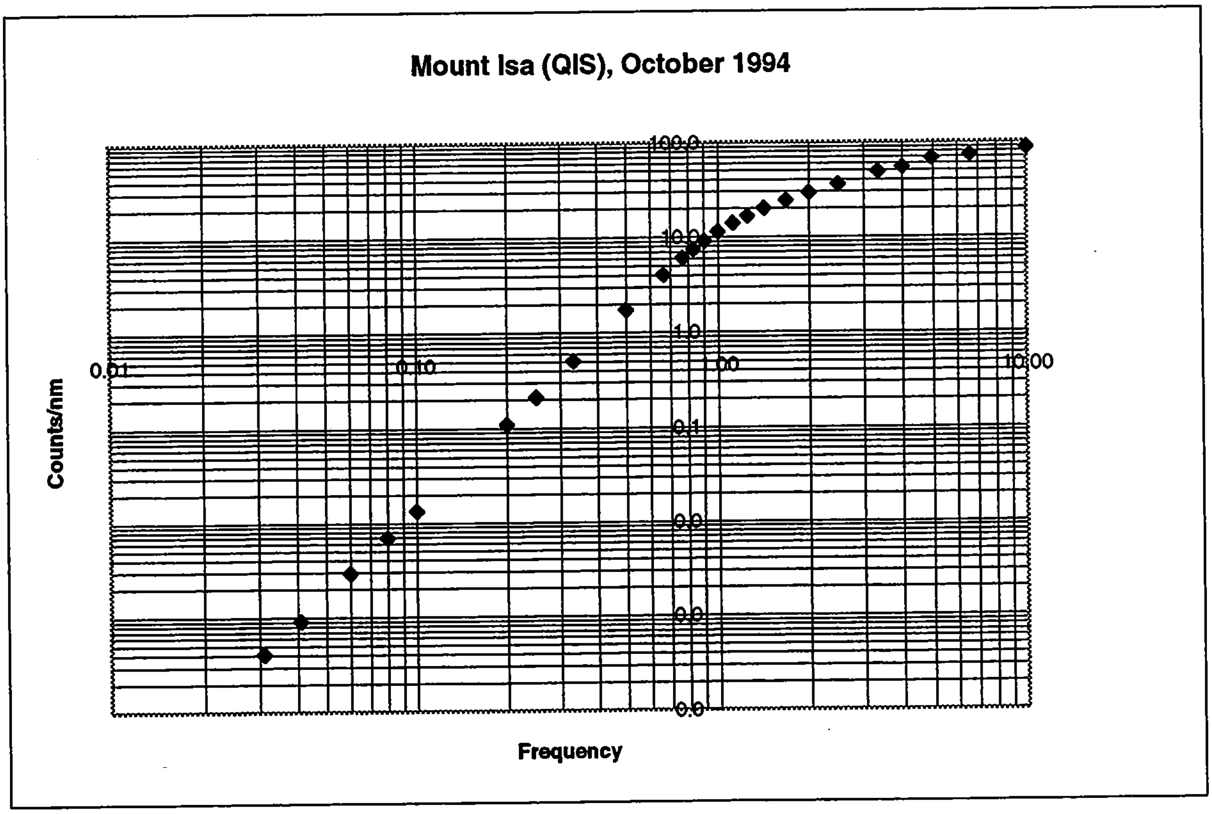

Kakadu (KAKA), March 1995
Counts/nm
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency

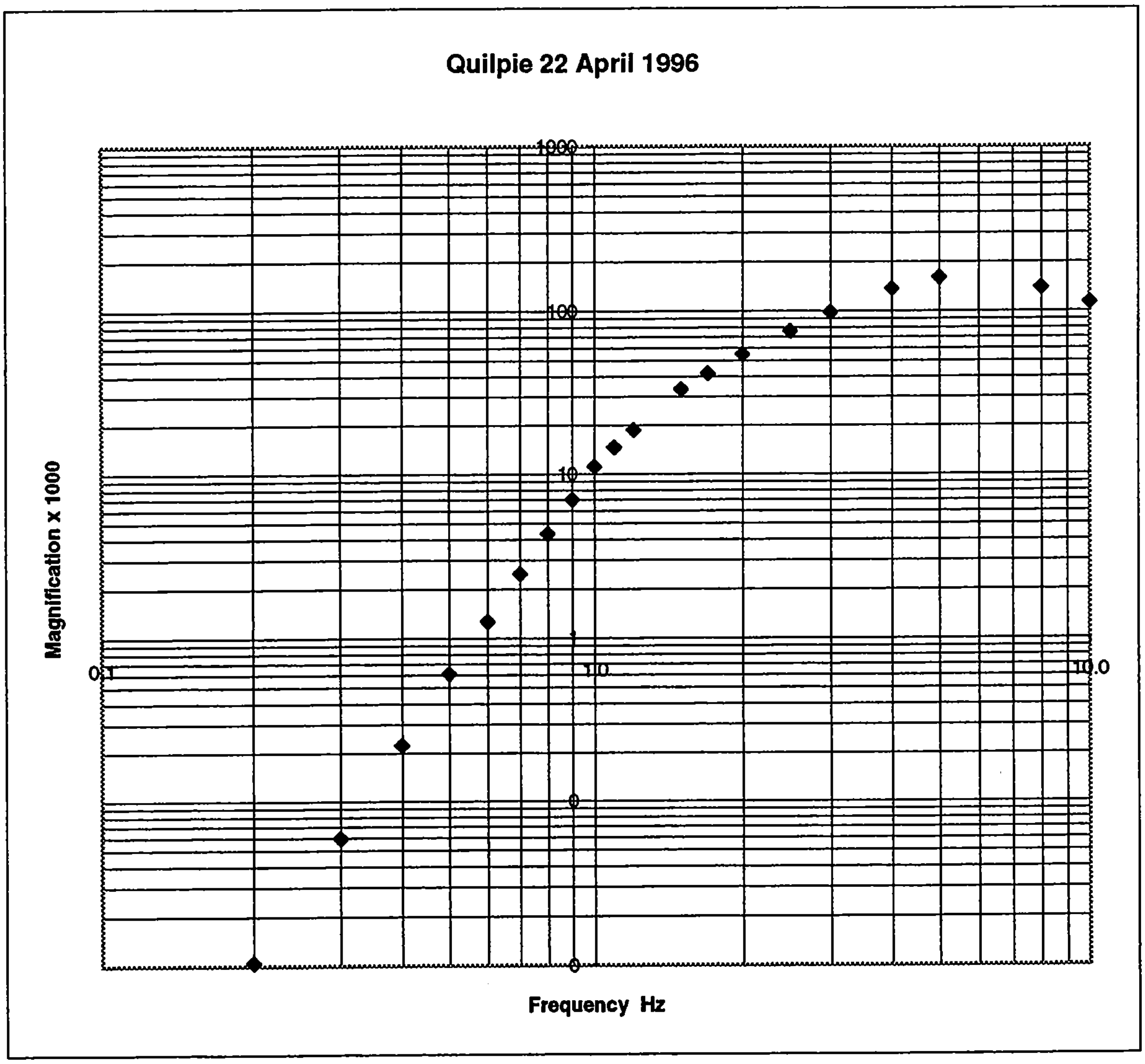

Kakadu (KAKA), March 1995
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.0
0.0
0.01
0.10
1.00
10.00
Frequency

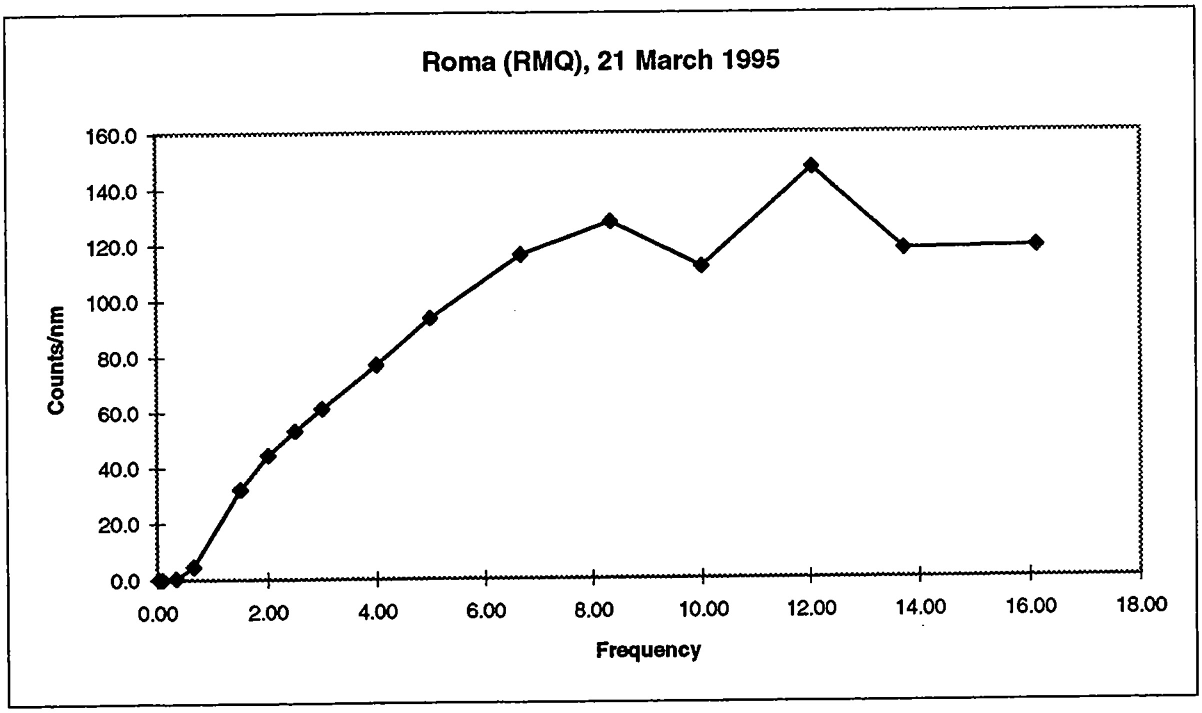

Meekatharra (MEEK), 21 April 1995
Counts/nm
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.00
5.00
10.00
15.00
20.00
25.00
Frequency

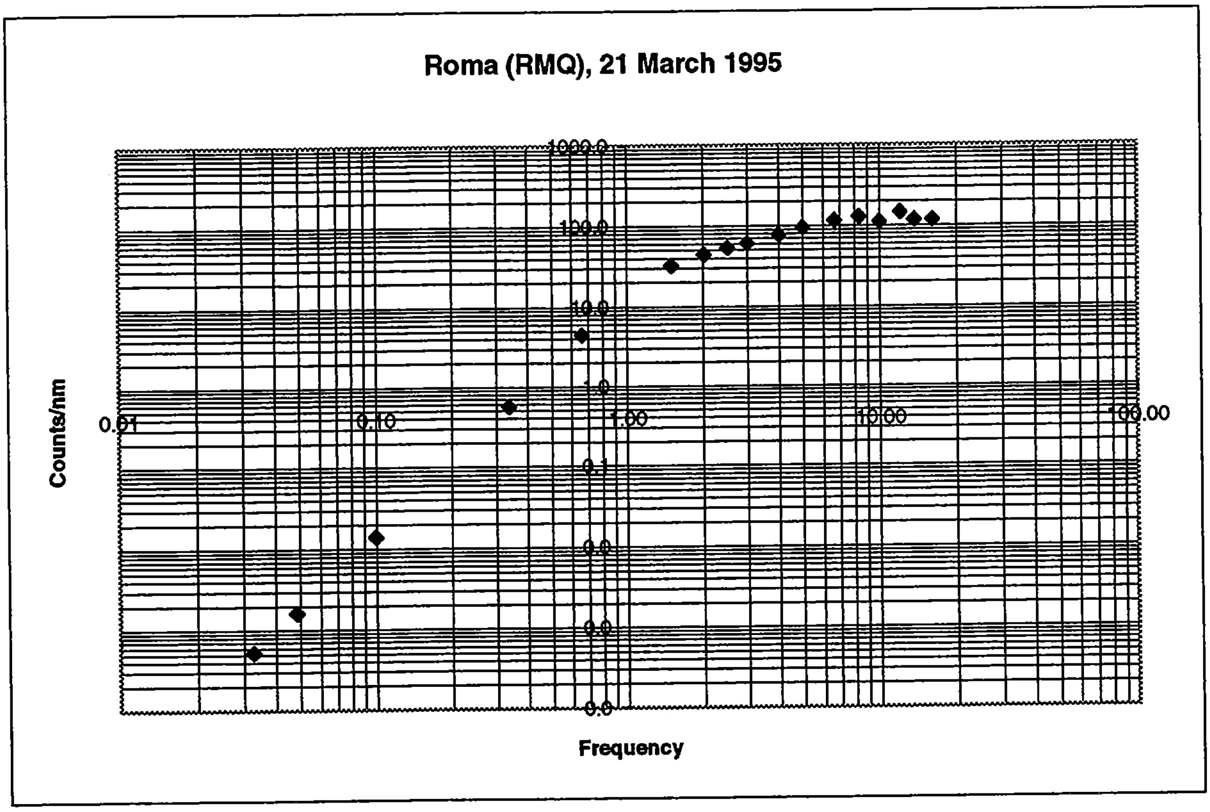

Meekatharra (MEEK), 21 April 1995
Counts/nm
100.0
10.0
1.0
0.1
0.01
0.10
1.00
10.00
100.00
Frequency

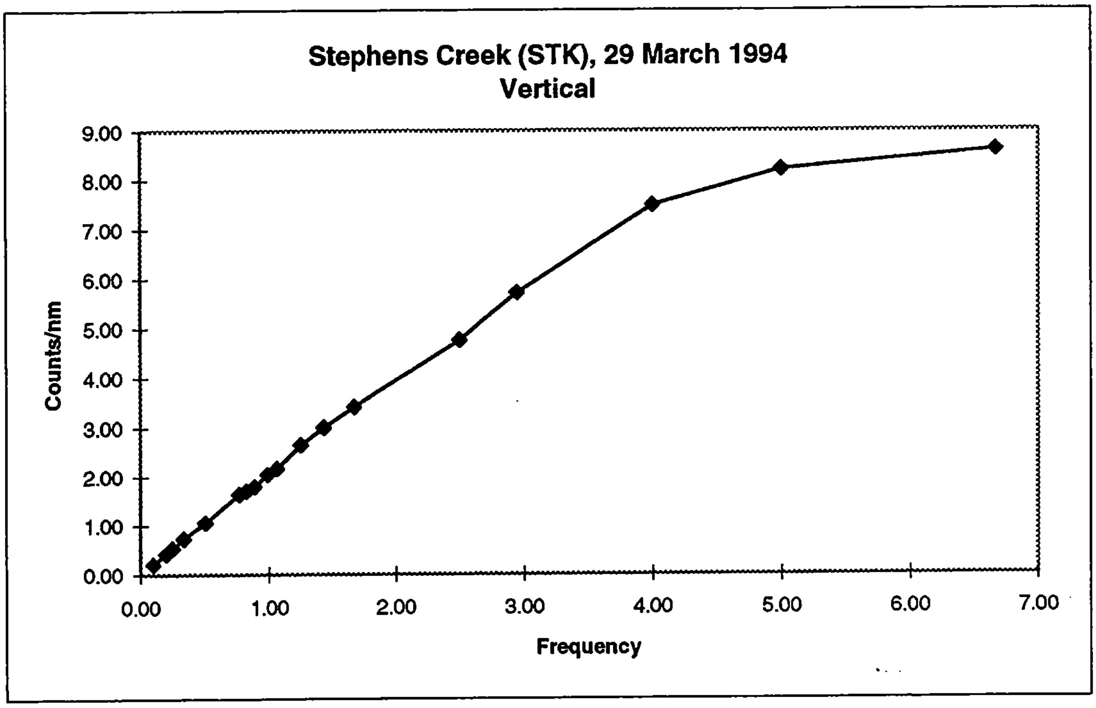

Mount Isa (QIS), October 1994
Counts/nm
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency

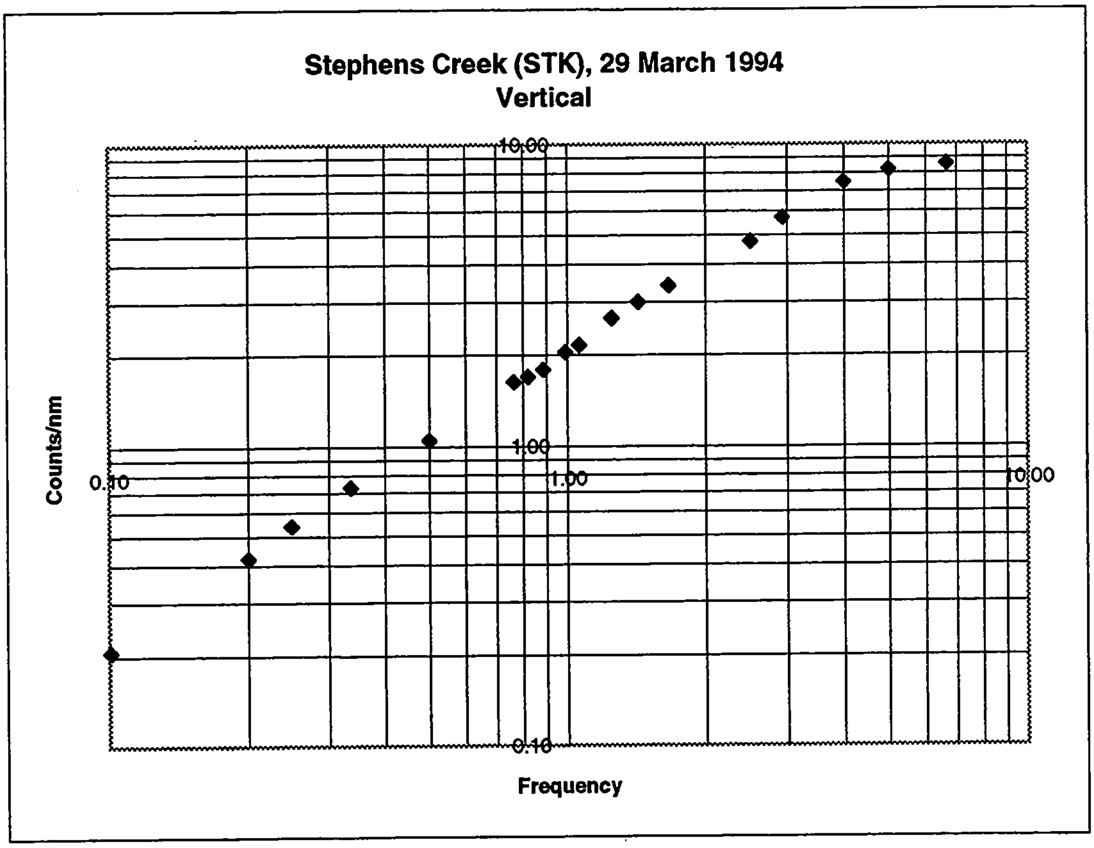

Mount Isa (QIS), October 1994
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.0
0.0
0.01
0.10
10.00
Frequency

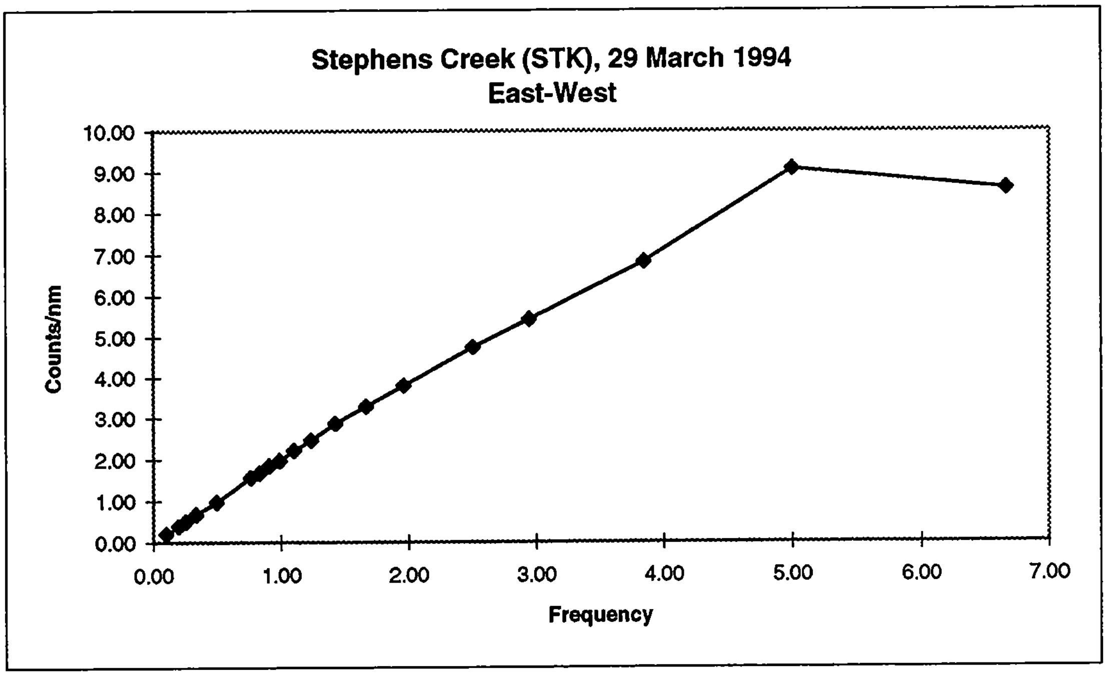

Quilpie 22 April 1996
1000
100
10
1
0
0
0.1
1.0
10.0
Magnification x 1000
Frequency Hz

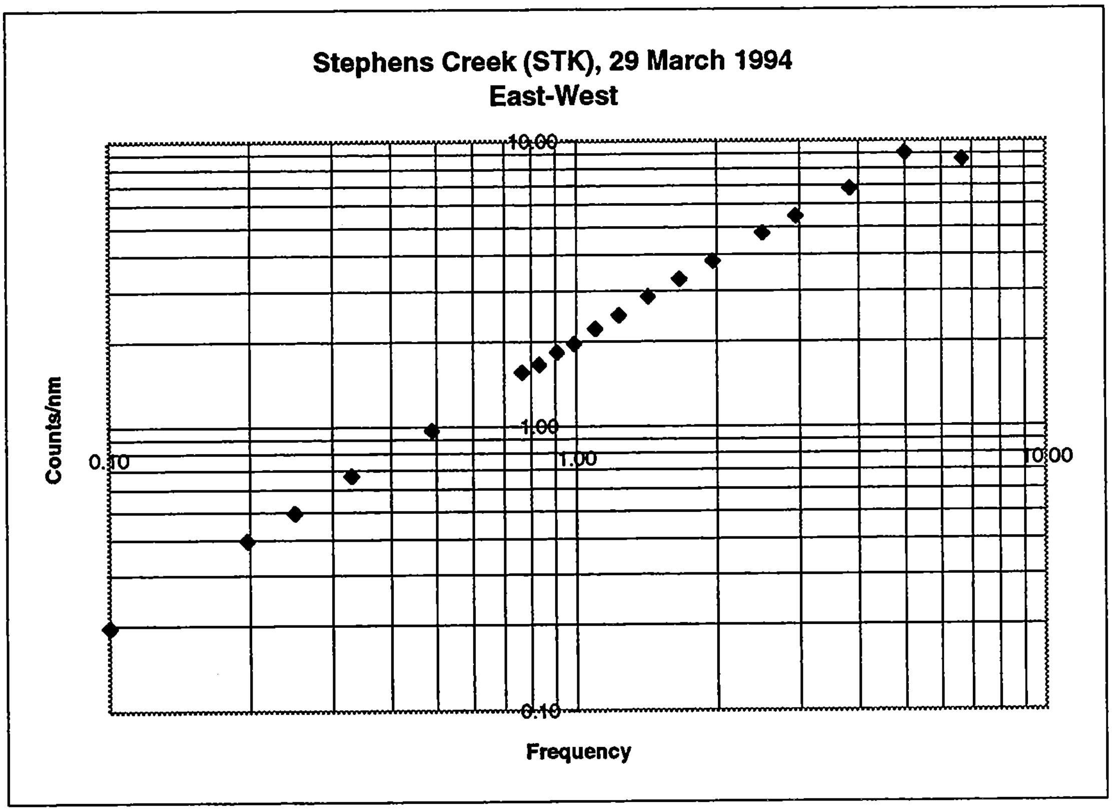

Roma (RMQ), 21 March 1995
Counts/nm
Frequency
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00

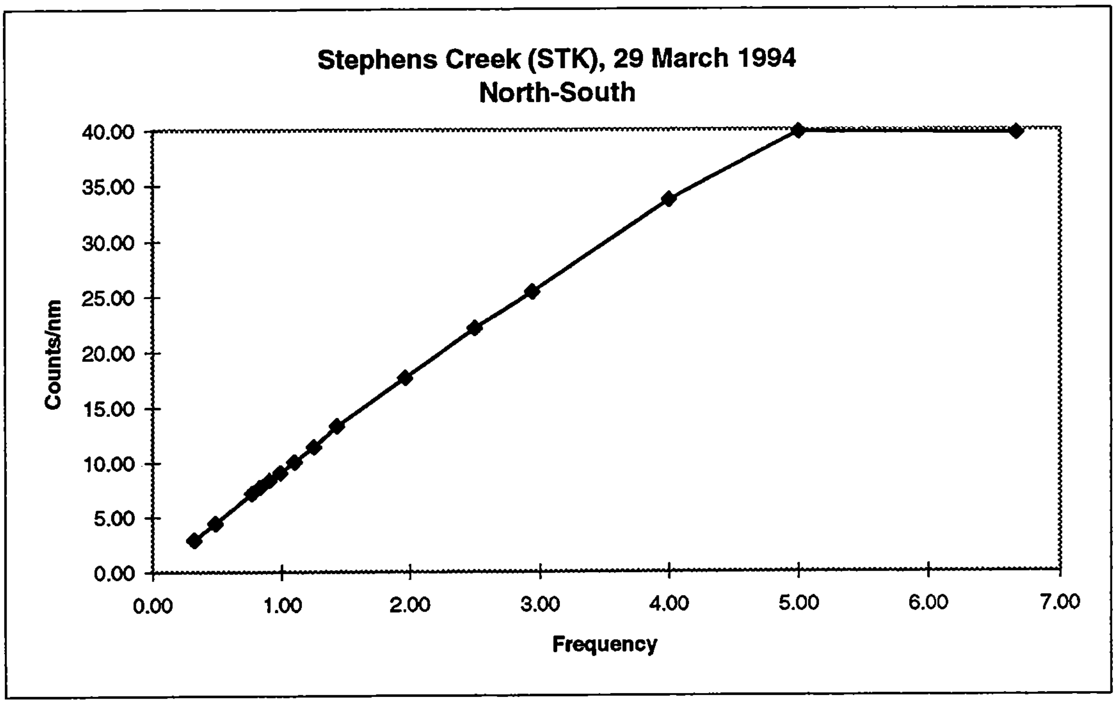

Roma (RMQ), 21 March 1995
Counts/nm
Frequency
1000.0
100.0
10.0
1.0
0.1
0.0
0.0
0.0
0.01
0.10
1.00
10.00
100.00

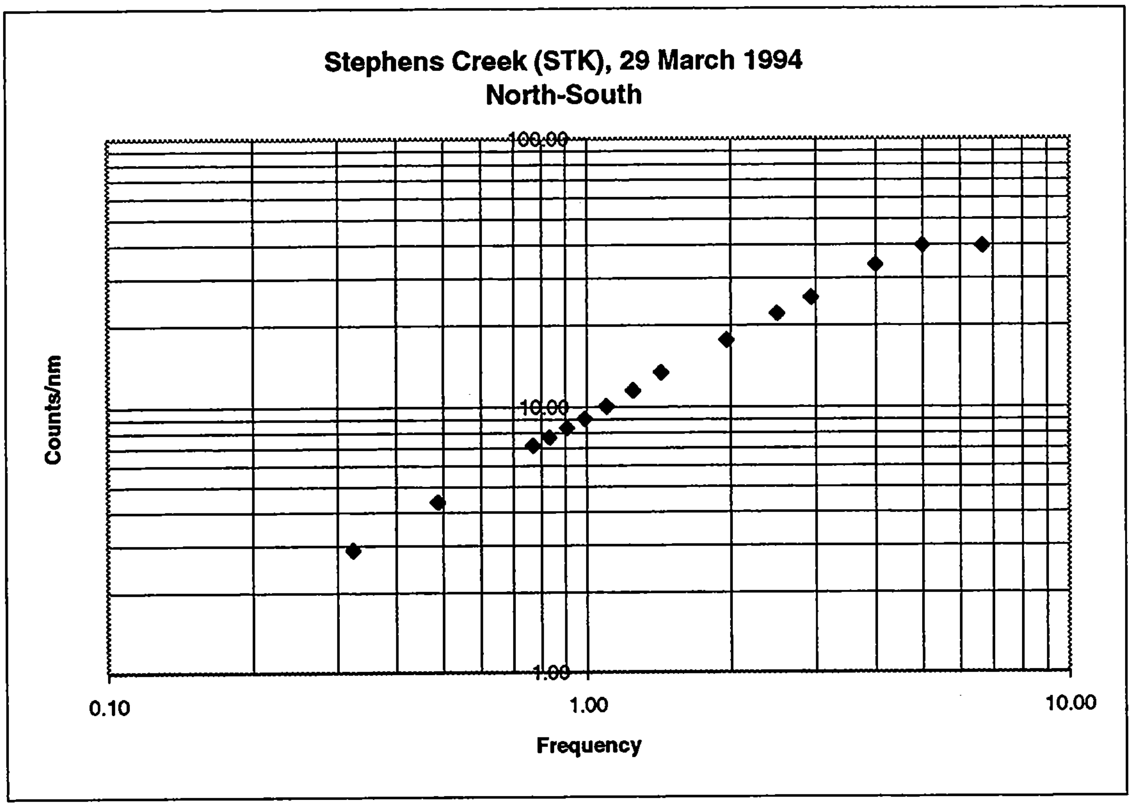

Stephens Creek (STK), 29 March 1994
Vertical
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Counts/nm
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Frequency

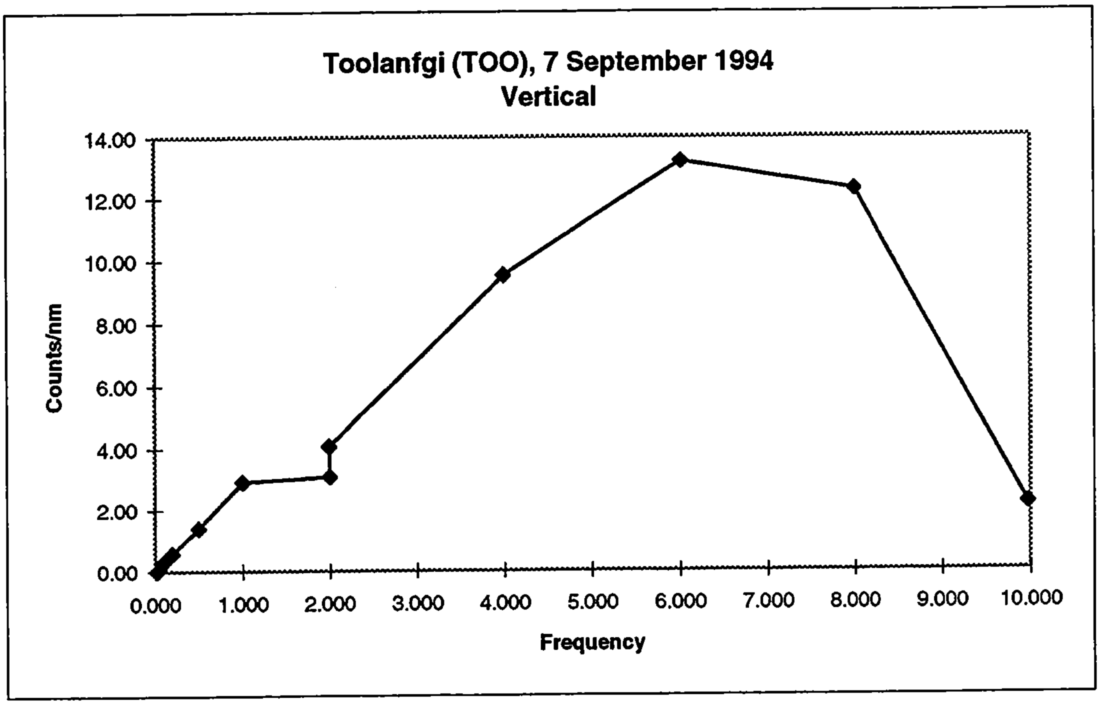

Stephens Creek (STK), 29 March 1994
Vertical
10.00
1.00
0.10
Counts/nm
0.10
1.00
10.00
Frequency

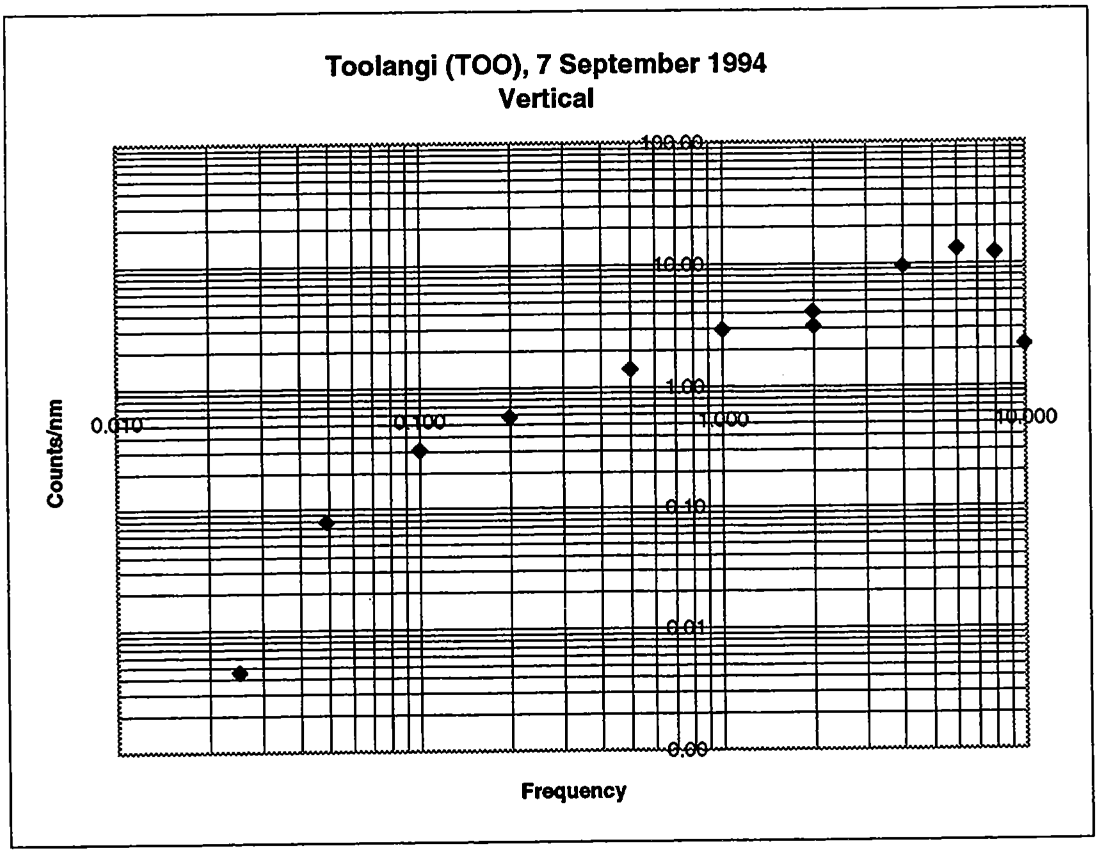

Stephens Creek (STK), 29 March 1994
East-West
Counts/nm
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Frequency

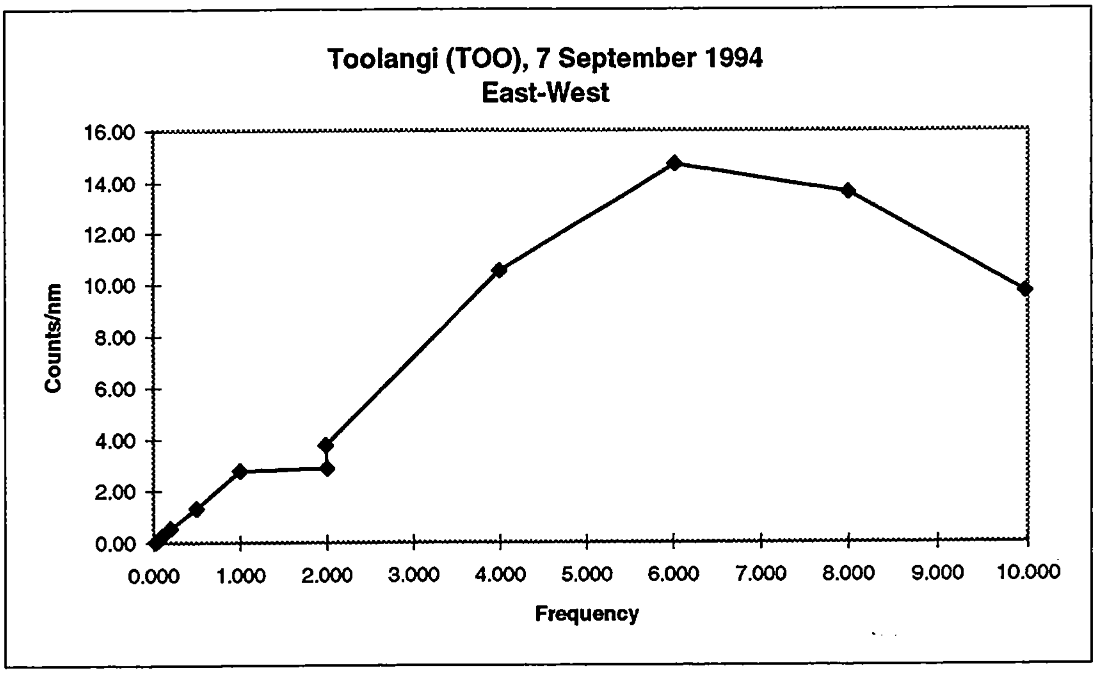

Stephens Creek (STK), 29 March 1994
East-West
Counts/nm
10.00
1.00
0.10
0.10
1.00
10.00
Frequency

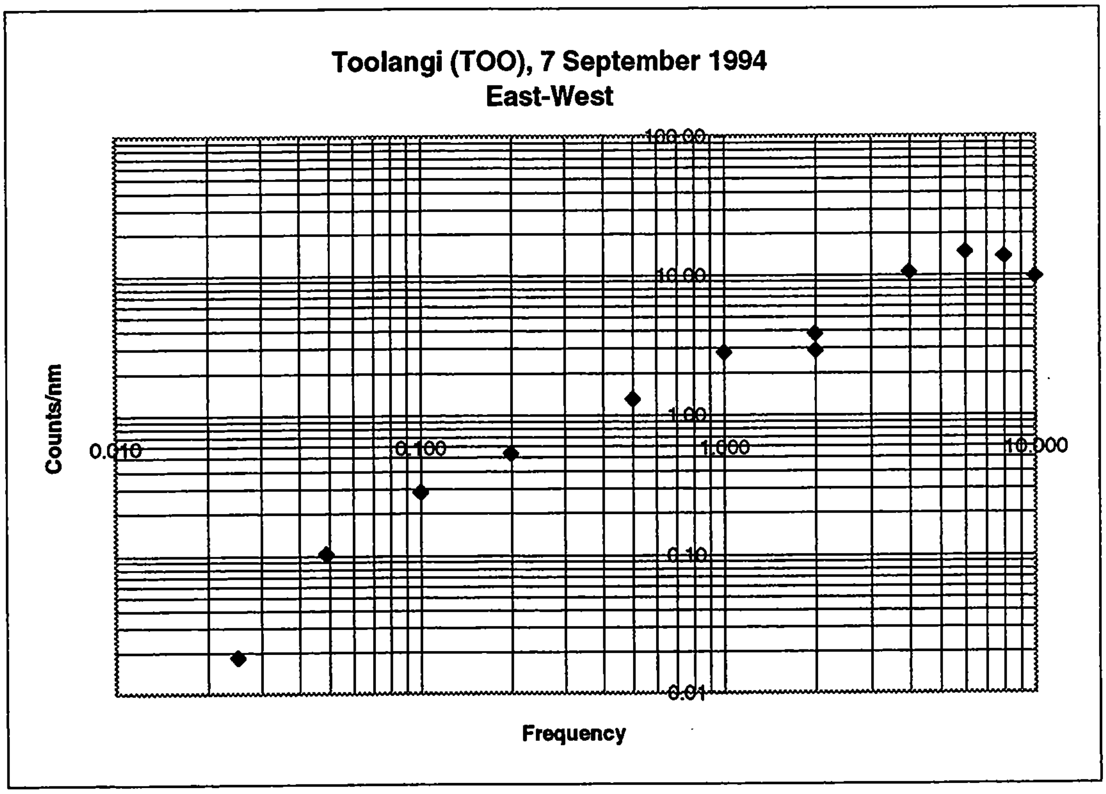

Stephens Creek (STK), 29 March 1994
North-South
Counts/nm
Frequency
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00

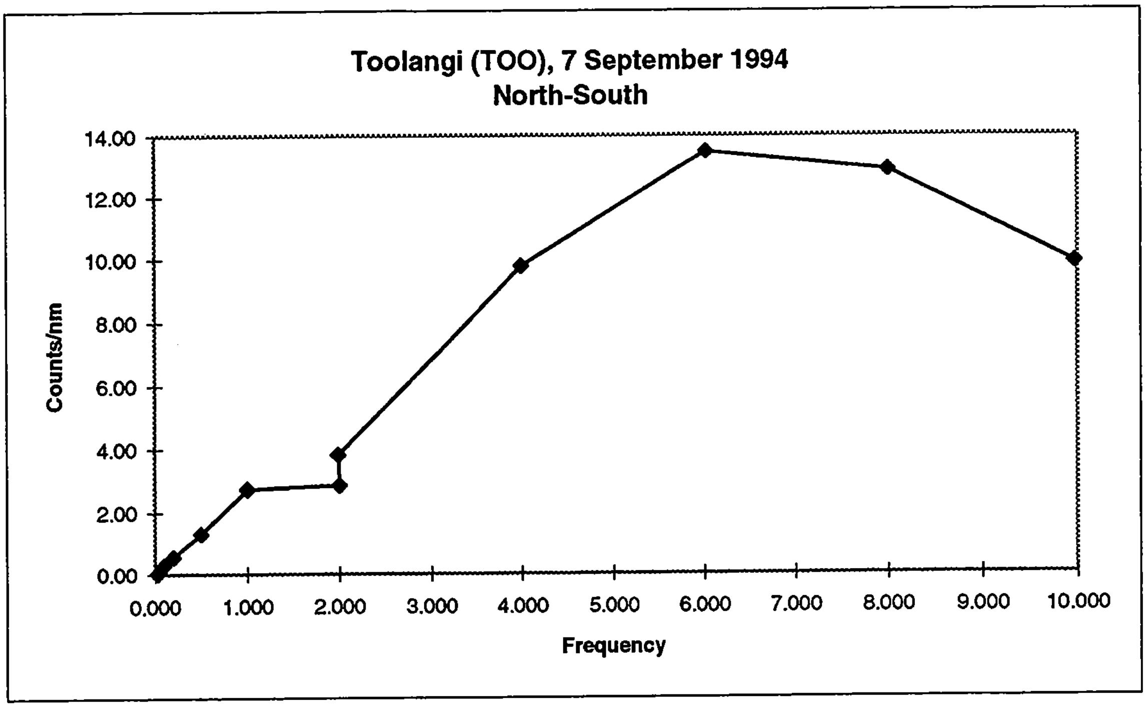

Stephens Creek (STK), 29 March 1994
North-South
Counts/nm
Frequency
100.00
10.00
1.00
0.10
1.00
10.00

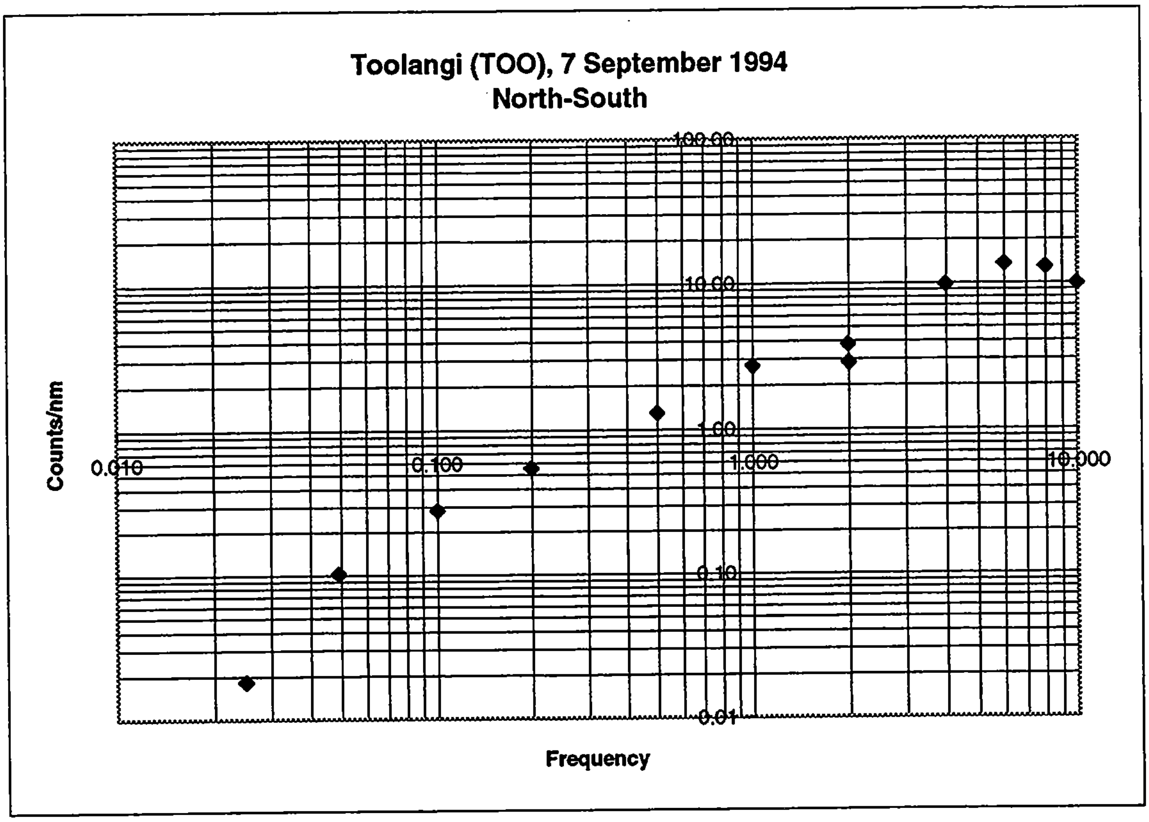

Toolanfgi (TOO), 7 September 1994
Vertical
Counts/nm
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
Frequency

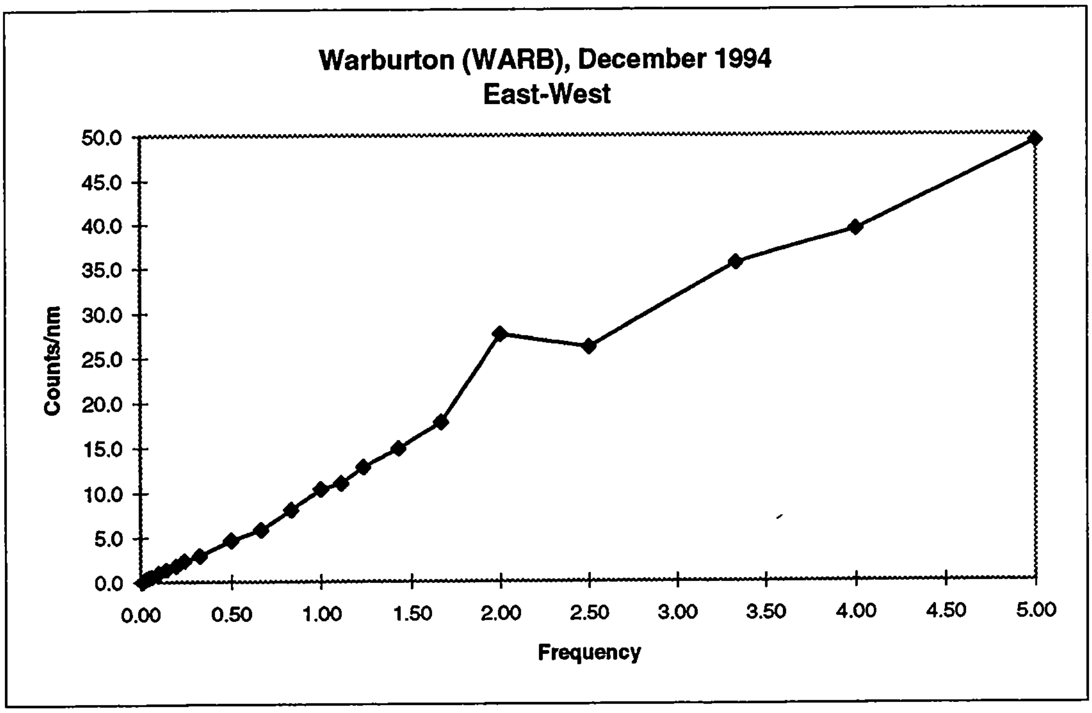

Toolangi (TOO), 7 September 1994
Vertical
Counts/nm
100.00
10.00
1.00
0.10
0.01
0.00
0.010
0.100
1.000
10.000
Frequency

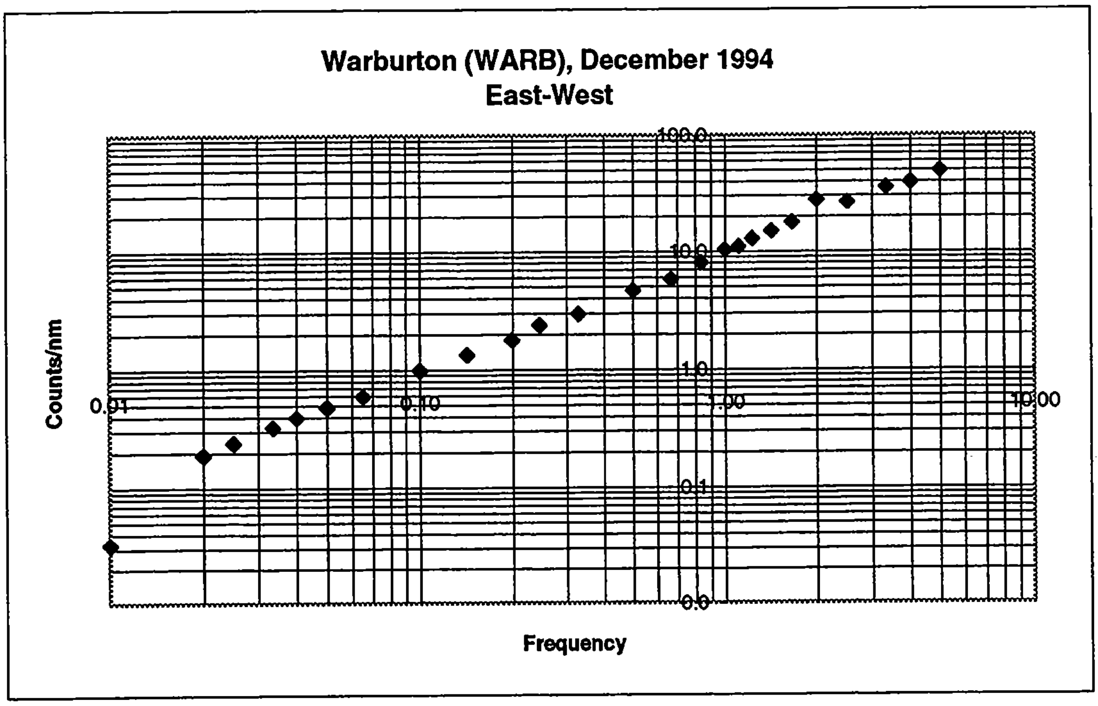

Toolangi (TOO), 7 September 1994
East-West
Counts/nm
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
Frequency

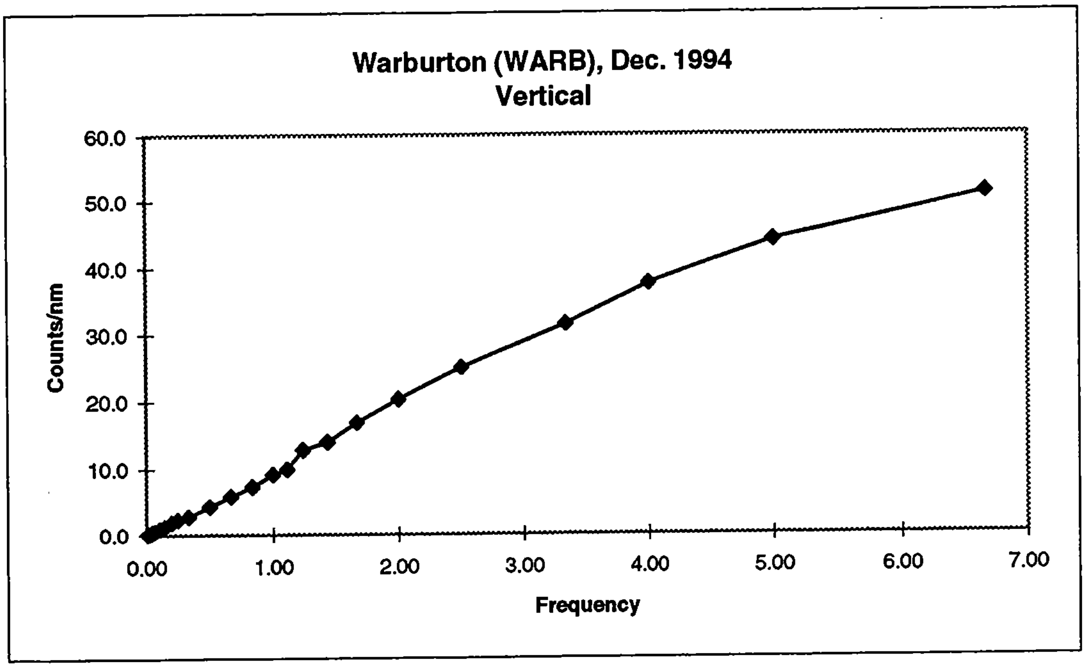

Toolangi (TOO), 7 September 1994
East-West
Counts/nm
100.00
10.00
1.00
0.10
0.01
0.010
0.100
1.000
10.000
Frequency

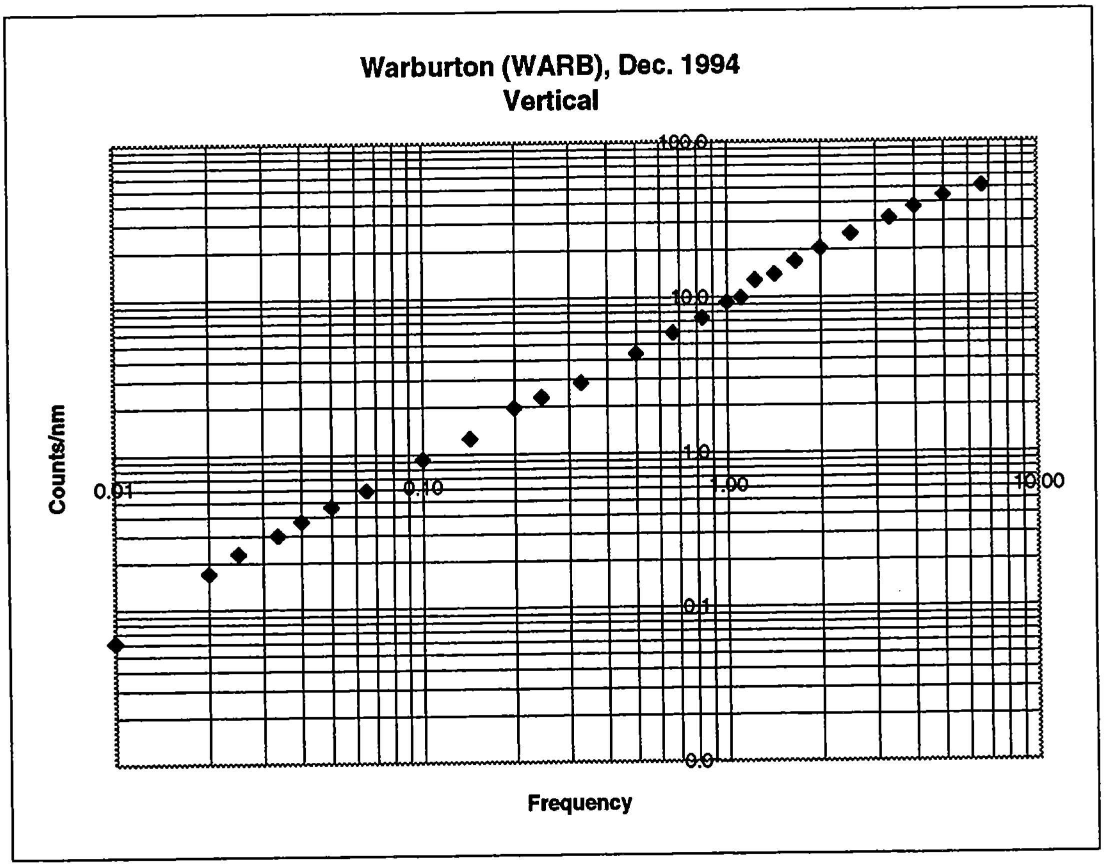

Toolangi (TOO), 7 September 1994
North-South
Counts/nm
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
Frequency

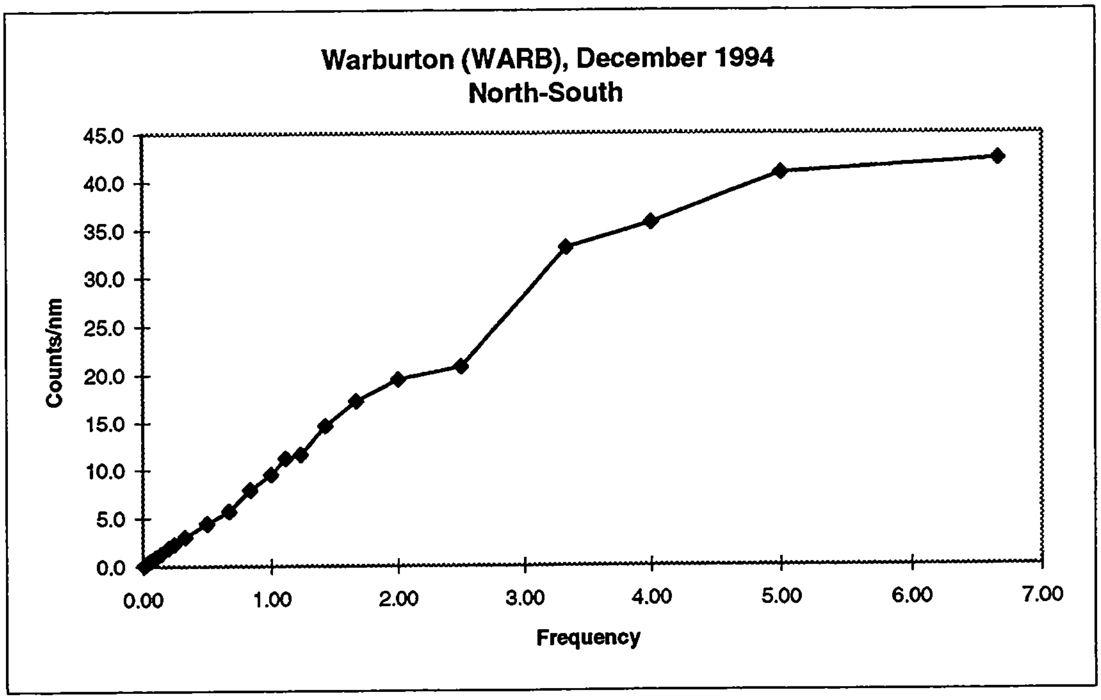

Toolangi (TOO), 7 September 1994
North-South
Counts/nm
100.00
10.00
1.00
0.10
0.01
0.010
0.100
1.000
10.000
Frequency

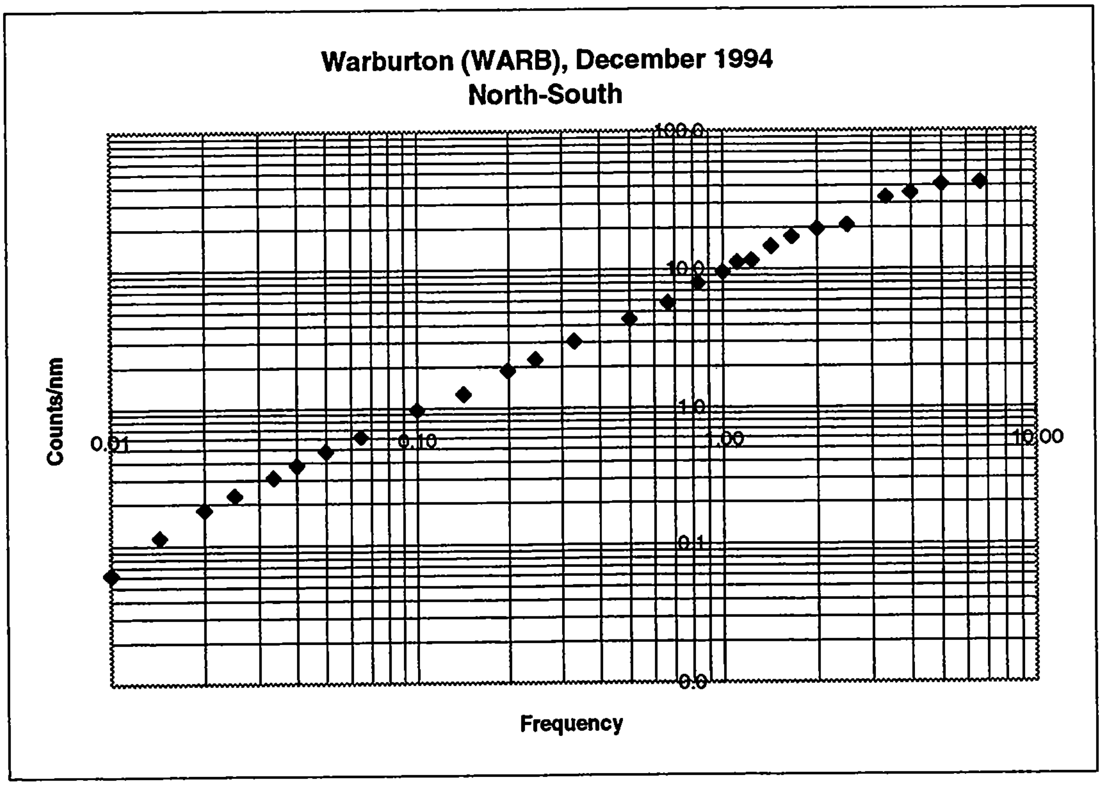

Warburton (WARB), December 1994
East-West
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Counts/nm
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Frequency

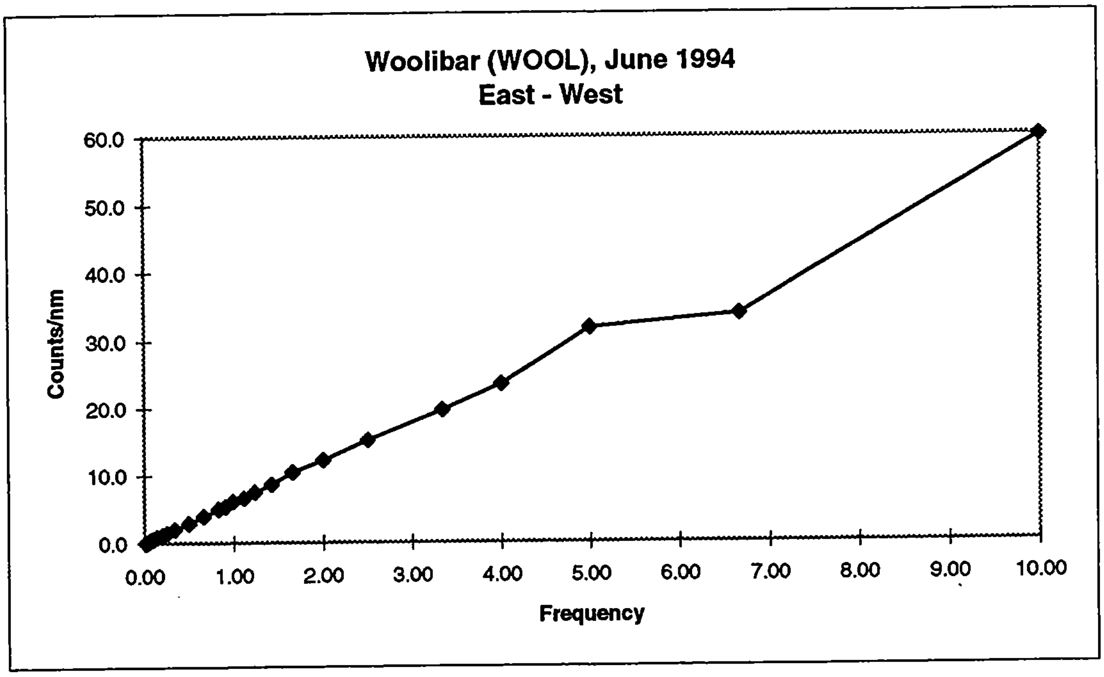

Warburton (WARB), December 1994
East-West
100.0
10.0
1.0
0.1
0.0
Counts/nm
0.01
0.10
1.00
10.00
Frequency


Warburton (WARB), Dec. 1994
Vertical
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Counts/nm
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Frequency

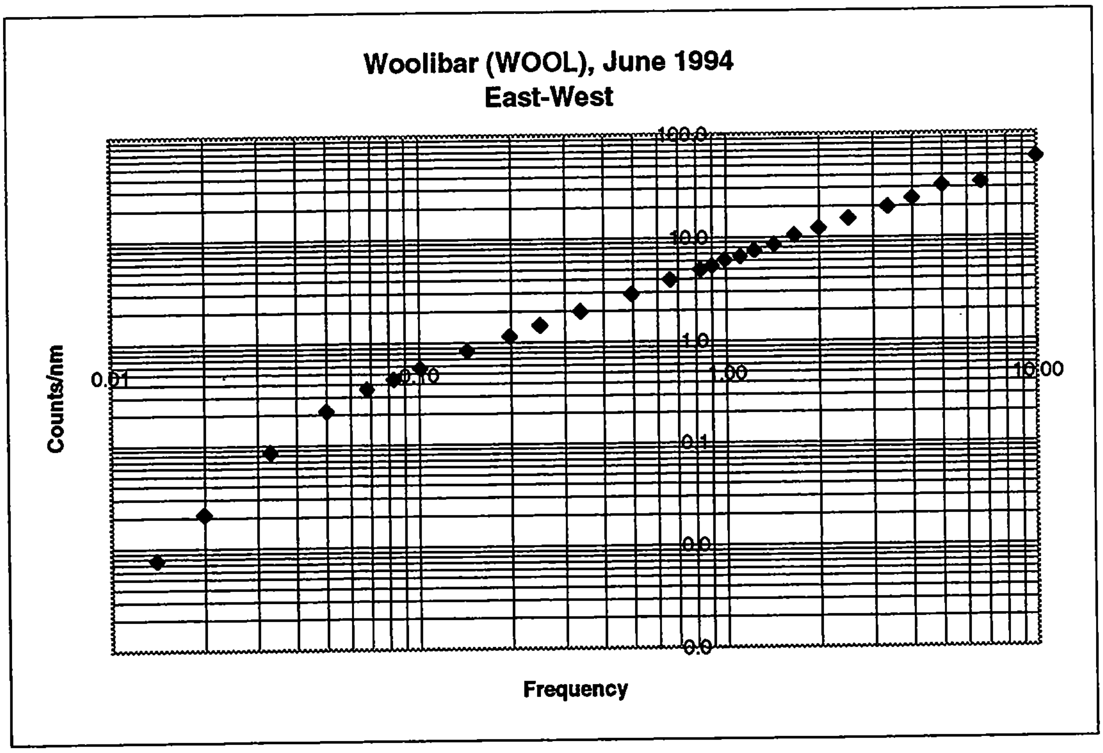

Warburton (WARB), Dec. 1994
Vertical
100.0
10.0
1.0
0.1
0.0
Counts/nm
0.01
0.10
1.00
10.00
Frequency


Warburton (WARB), December 1994
North-South
Counts/nm
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Frequency

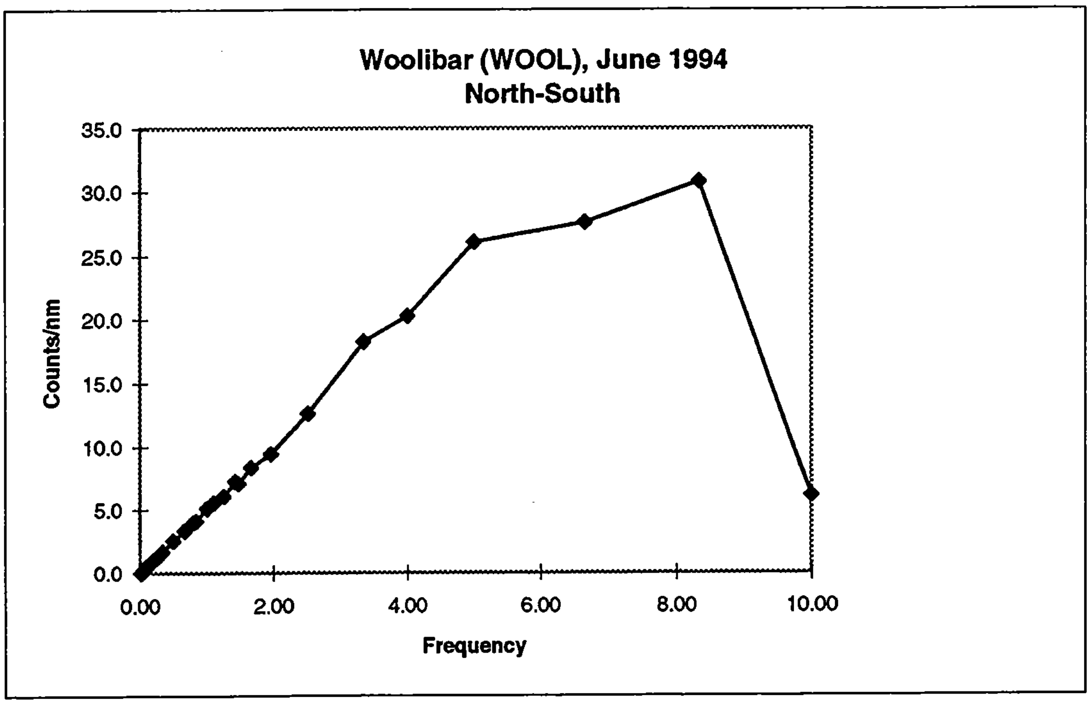

Warburton (WARB), December 1994
North-South
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.01
0.10
1.00
10.00
Frequency

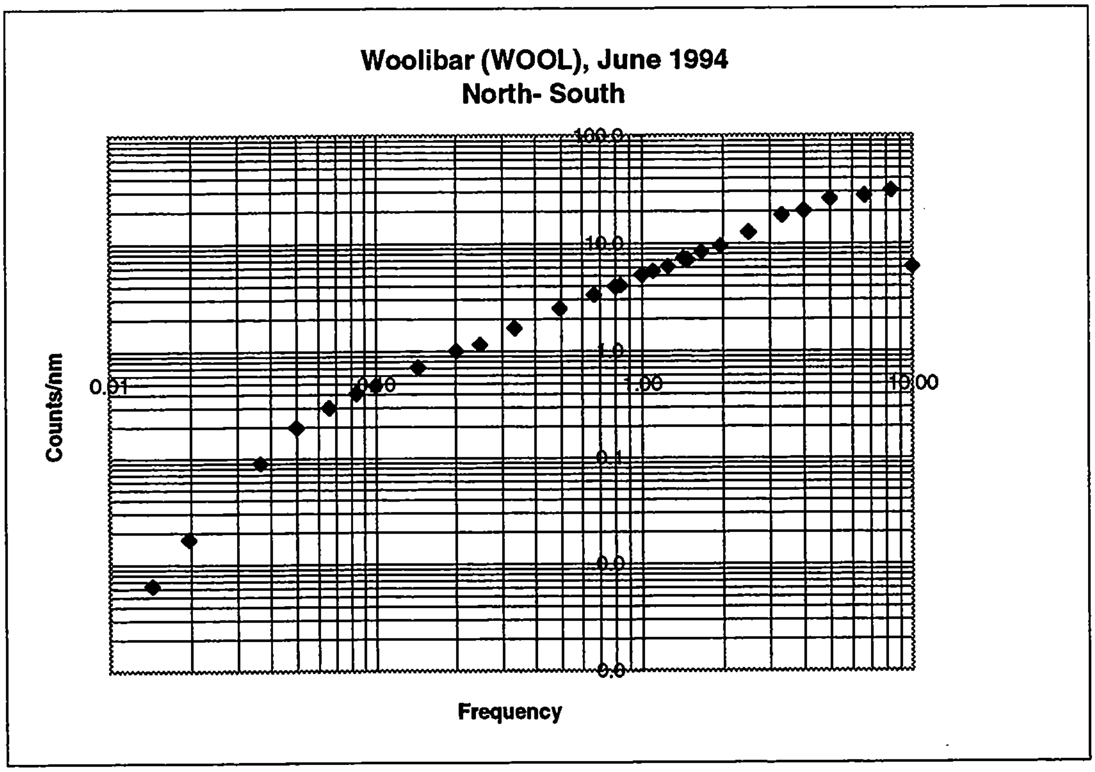


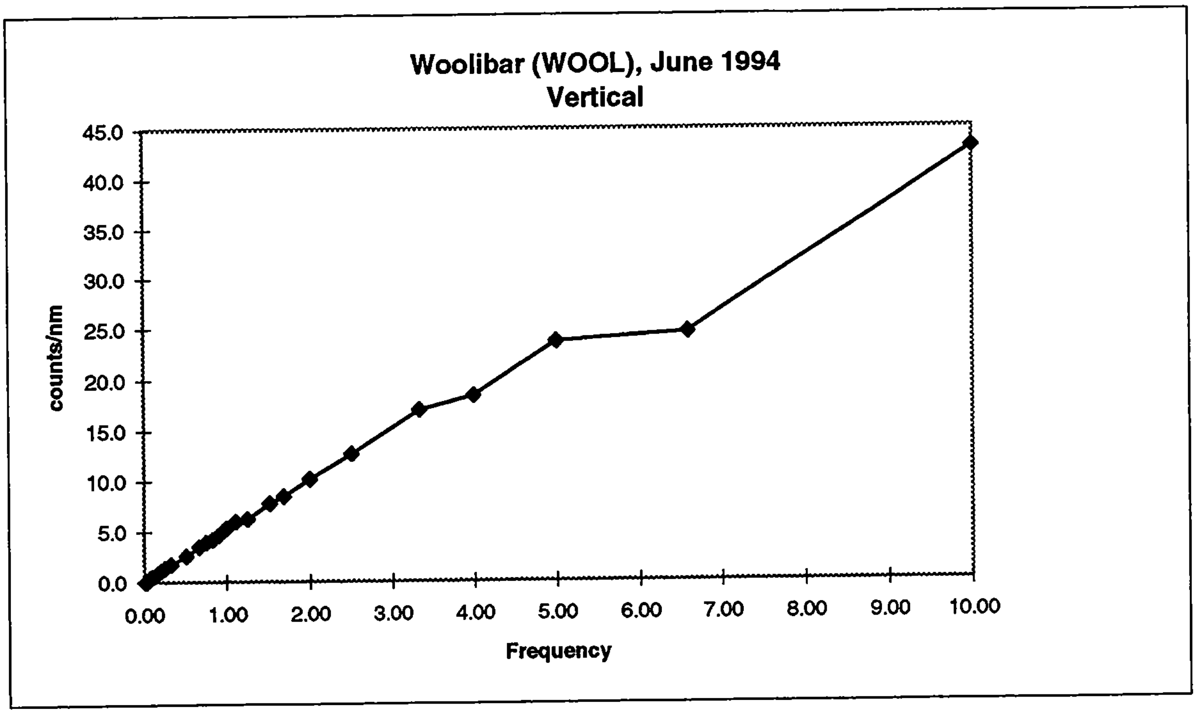
Woolibar (WOOL), June 1994
East - West
Counts/nm
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency



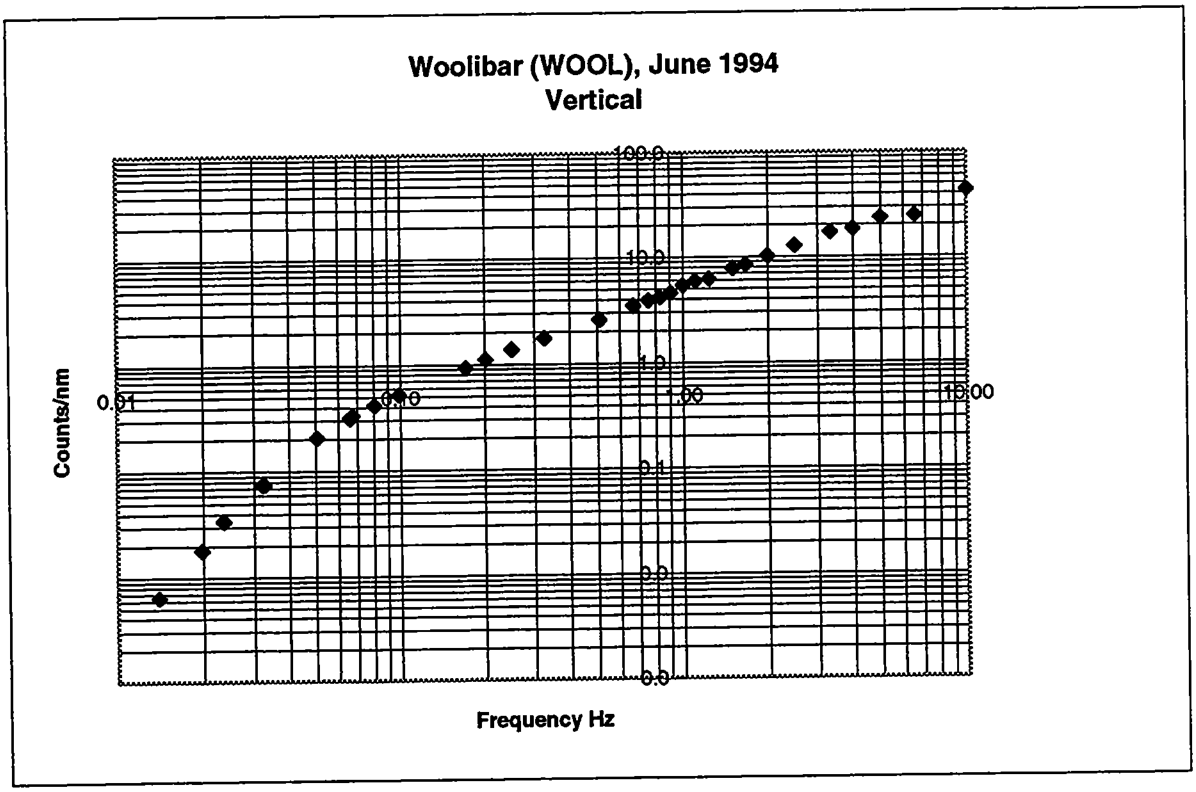
Woolibar (WOOL), June 1994
East-West
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.0
0.01
0.10
1.00
10.00
Frequency


Woolibar (WOOL), June 1994
North-South
Counts/nm
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
2.00
4.00
6.00
8.00
10.00
Frequency

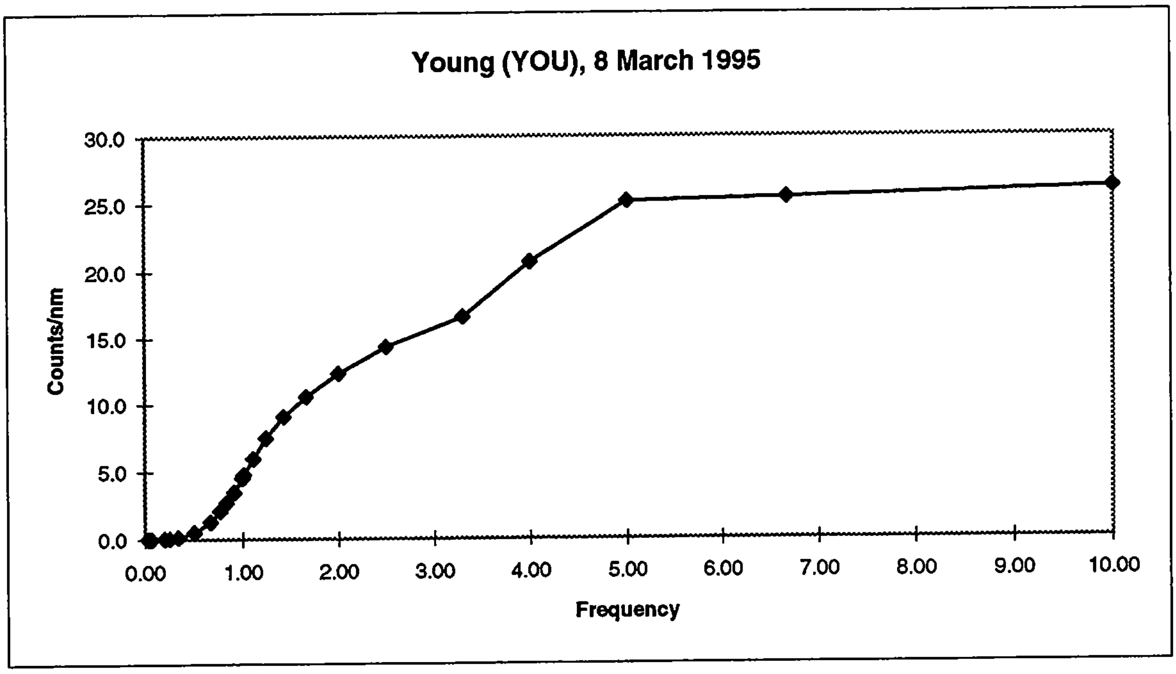

Woolibar (WOOL), June 1994
North- South
Counts/nm
100.0
10.0
1.0
0.01
0.10
1.00
10.00
0.1
0.0
0.0
Frequency

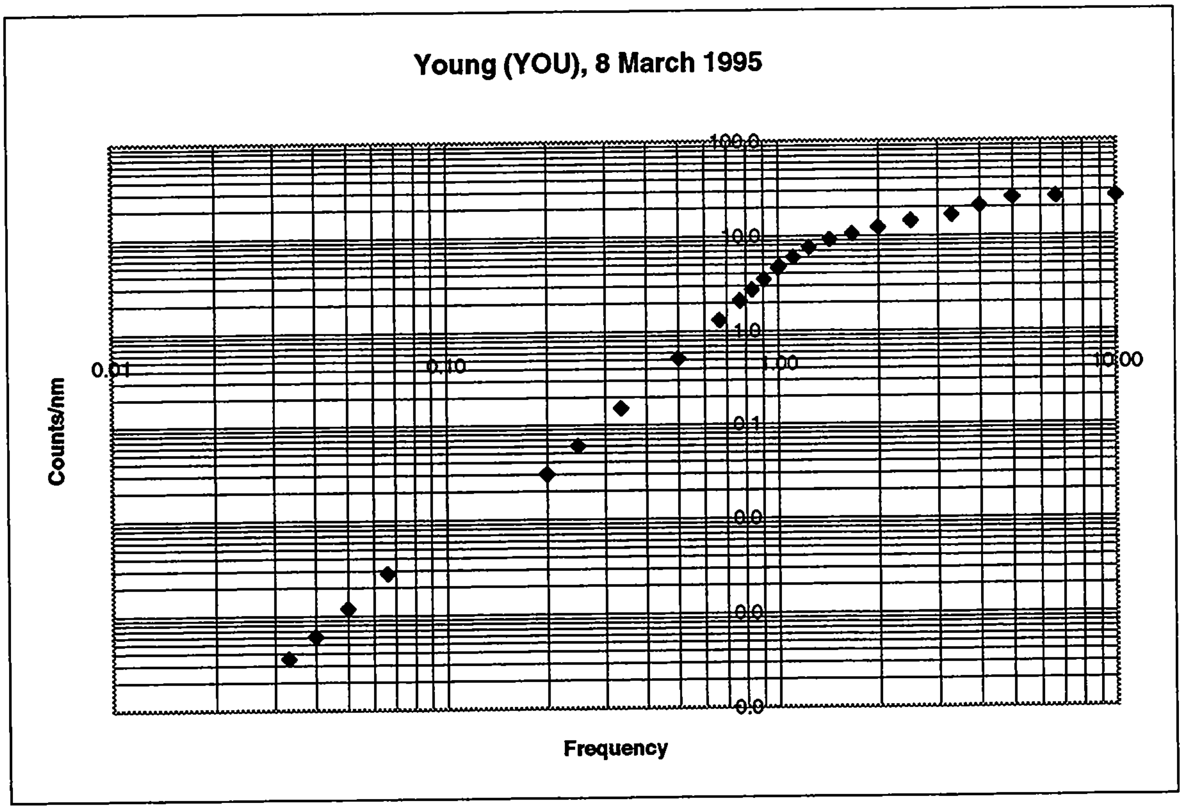


Woolibar (WOOL), June 1994
Vertical
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
counts/nm
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency



Woolibar (WOOL), June 1994
Vertical
100.0
10.0
1.0
0.1
0.0
0.0
0.01
0.10
1.00
10.00
Counts/nm
Frequency Hz


Young (YOU), 8 March 1995
Counts/nm
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequency


Young (YOU), 8 March 1995
Counts/nm
100.0
10.0
1.0
0.1
0.0
0.0
0.0
0.01
0.10
1.00
10.00
Frequency