DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/73

MUNDARING GEOPHYSICAL OBSERVATORY
ANNUAL REPORT 1977

by

P.J. Gregson

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SUMMARY

Basic programs in geomagnetism, ionospherics, and seismology were continued at the Mundaring Geophysical Observatory during 1977. The main instruments were an Eschenhagen normal-run magnetograph, an IPSD Type 3E ionosonde, and a Worldwide Standard Seismograph.

Seismographs were operated at Swan View, Kalgoorlie, Meekatharra, Marble Bar, Giles, Kununurra, and Narrogin (Seismic Research Observatory). The Kununurra seismograph is operated in conjunction with the WA Government. Accelerographs were operated at Meckering and Kununurra.

The annual earthquake list shows details of 60 Western Australian earthquakes, 28 of which occurred in the southwest zone.

Analysis of explosion recordings at seismograph stations indicates an apparent Pn velocity of 8.11 km/s in the southwest of Western Australia in a southerly direction.

Isoseismal maps for earthquakes that occurred near Albany and in Indonesia were prepared.

1. INTRODUCTION

The Mundaring Geophysical Observatory opened on 18 March 1959 and now controls operations at Mundaring (seismological and ionospheric recording), Gnangara (magnetic recording), Kalgoorlie, Meekatharra, Marble Bar, Giles, Kununurra, Swan View, and Christmas Island (seismological recording). In co-operation with the United States Geological Survey, a Seismic Research Observatory (SRO) is operated with the sensor at Narrogin and digital and visual recording at the Mundaring office. Descriptions of the observatory and an outline of activity there to the end of 1976 have been given in previous records (e.g. Gregson, 1977); and principal events in the observatory's history are given in Appendix 1. Discussion of non-routine projects is brief, as details will be reported separately.

2. STAFF AND VISITORS

Observatory staff are listed in Table 1, and other personnel associated with the observatory's operations in Table 2. Staff absences, for reasons other than recreation leave, are summarised in Table 3, and conferences and training sessions attended, or addresses given, in Table 4.

Mr P.M. Davies (Geophysicist Class 1) was given training in observatory practice from June to September in preparation for Antarctic duty in 1978.

Visitors to the observatory are listed in Table 5.

3. GEOMAGNETISM

Normal magnetograph

The Eschenhagen 20 mm/h magnetograph continued in operation at Gnangara. Six hours of record was lost while cables were installed in the recording vault on 20 April. Another eight hours was lost during variometer adjustments on 1 and 4 November.

All control equipment operated well throughout the year with the exception of the time-mark control unit. Counting of minute pulses to provide five-minute marks became erratic during May. Adjustment of the spring tension in the mechanical ratchet relay corrected the fault. This unit will be

replaced with an electronic counter in 1978. In February normal time-marks were changed from every ten minutes to every five minutes.

No unexplained changes in baseline or scale values occurred during 1977.

The Z variometer was apparently bumped when new cables were installed in the vault on 20 April. This resulted in a change in the Z temperature compensation.

Adjustments were made to the Z variometer on 23 August. The temperature compensation magnet was lowered 5 mm to reduce the Z temperature coefficient. The poise on the recording magnet was also adjusted to re-level the magnet. Optical adjustments were made to reduce the Z ordinate from 45 mm to 20 mm. This was necessary as the Z time-marks were lost when ordinates increased by only 3 mm (15 nT) above the mean value.

The Z scale value drifted from 5.70 nT/mm to 6.06 nT/mm over the period April to July. The adjustments on 23 August reduced the scale value to 5.70 nT/mm.

Adjustments were made on 1 and 4 November to increase the H ordinate by about 25 mm, in order to reduce the time for which the H ordinate was negative. To reduce the ordinate it was necessary to adjust the magnet-mirror angle. Poor adjustment on 1 November resulted in an ex-orientation of E8.4°N and a gross reduction in the scale value to 1.8 nT/mm. More adjustments on 4 November gave finally an ordinate of about 20 mm, an orientation of E0.2°N, and a scale value of about 2.5 nT/mm.

The standard deviations of the observed baseline and scale values were:

Element	Baseline value	Scale value
D	0.26 min	-
H	2.2 nT	0.01 nT/mm
Z	2.6 nT	0.04 nT/mm

Magnetograph tests

Temperature coefficients. A value of qH = 0.0 nT/°C was used throughout the year. Least-squares analysis on Z baseline values at temperature gave values of:

qZ = 1.7 nT/°C 31 August 1976 to 20 April 1977
qZ = 3.6 nT/°C 20 April 1977 to 23 August 1977

The adjustment to the Z temperature compensating magnet on 23 August improved the temperature coefficient considerably. A preliminary value of 0.0 nT/^{o}C was used for the remainder of the year.

Orientation. Orientation tests were carried out on several occasions. Orientations of the recording magnets in the mean magnetic fields were:

23 August - H: E1.0^{o}N
D: N0.3^{o}W
Z: N0.0^{o} (before and after adjustment)
1 November- H: E8.4^{o}N
4 November- H: E0.2^{o}N

These values are similar to those of previous years.

Parallax. No tests were performed during 1977 and it was assumed that the parallax remained unchanged from previous years. During 1973 it had been found that the parallax on variation trace time-mark spots (but not on baseline spots or hour lines) was zero on all components. The parallax for other time-marks can be measured from the trace time-marks.

Scale values. A magnetograph calibrator MC02 was used in conjunction with Helmholtz coils to determine H and Z scale values once weekly.

The D scale value was determined to be 1.09'/mm on 26 July using the Helmholtz coil method.

Magnetometers

Instruments used during the year for weekly observations were Askania declinometer 509319 and PVM B/116/B. The latter comprised Elsec vector coil set B, Elsec proton-precession magnetometer S/N 116, and sensor set B.

The vector coils were serviced in February. Two steel dowels were removed from the coil base and nine small steel grub screws in the coil levelling knobs were replaced with brass screws. One of the three feet was broken and was replaced. Three perspex rings were made for the coil feet to lock the feet in position after the coils are levelled. The coil bearings were cleaned and lubricated with light machine oil.

The circuit for the 'by half' switch in the constant current supply was adjusted in February so that the current was halved exactly.

Throughout 1977, values of H and Z were determined in a combined set of observations proposed by McGregor (1976, Appendix 1).

Comparisons. No comparisons were made during the year.

Preliminary corrections used throughout the year were:

(a) PVM B/116/B: H nil

(b) Askania declinometer 509319 (circle 508135): + 0.5 minutes

(c) PVM B/116/B: Z nil.

Accessory equipment

The Askania horizontal-intensity visual recorder at the Mundaring office was operated throughout the year apart from two days in June when the clockwork drive was overhauled.

Magnetic pulsation tape-recording equipment was operated at the Weir site for the University of Newcastle. Apart from minor losses, recording was continuous.

Data reduction and publication

Mean hourly value reduction data were prepared in monthly batches about three months after recording. Magnetograms and reduction data were sent to Canberra headquarters for derivation of hourly values. As a check on these values, the first and thirteenth hours of H, D, and Z were hand scaled and mean values calculated at Mundaring for direct comparison.

Monthly and annual mean values of H, D, Z, F, and mean K-index values at Gnangara for 1977, are listed in Table 6. The field values were derived from the ten local quiet days of each month by scaling a mean ordinate for each component from each magnetogram. Annual values for all components since 1967 are shown in Table 7. Recent trends in secular variation continued with H decreasing by about 61 nT; D became more westerly by 1.2 minutes, and Z increased in magnitude by about 29 nT. The mean value for F rose by about 11 nT during 1977.

The distribution and publication of data continued as previously (for details see Record 1975/143).

Miscellaneous requests were attended to, mainly for magnetogram copies and information on the geomagnetic field in Western Australia. On 22 November an aircraft of the US Naval Oceanographic Office's Project Magnet, flew over Gnangara in order to calibrate its equipment. Copies of relevant magnetograms and control data were given to them.

4. IONOSPHERICS

Equipment

The quarter-hourly sounding schedule was continued throughout the year using a model IIIE ionosonde; the ionosonde and components and circuit boards were supplied by the Ionospheric Prediction Service (IPS), Department of Science. 235 hours (2.7%) of record was lost during the year. Losses were due to component failure (100 hours), delays in repairs because technical staff were not available (96 hours), film jamming or running out (23 hours), and the installation of a new mast (16 hours).

The wooden mast of the transmitting and receiving aerial was replaced with a steel telescopic mast in January, because it had been riddled by termites.

Data distribution and publication

The scaling, distribution, and publication of data continued as previously (for details see Record 1976/48).

5. SEISMOLOGY

Sismograph stations

Permanent stations were operated throughout 1977 at Mundaring (MUN), Kalgoorlie (KLG), Meekatharra (MEK), Kununurra (KNA), Marble Bar (MBL), Swan View (SWV), Giles (GLS), and Narrogin (NWAO). A seismograph installed at Christmas Island (XMI) in September 1976 was operated from Mundaring Observatory during the year until 27 November, when the equipment was returned to Mundaring for field use.

The number of events reported from each station in 1977 was:

MUN 835; KLG 364; MEK 718; KNA 1081; MBL 1097; SWV 536; GLS 775; NWAO 1048; and XMI 232. TOTAL 6686.

A summary of record losses from all seismograph stations is given in Table 8. All stations show an improvement over 1976 with the exception of NWAO, GLS, and MEK. The reasons for increased losses at these stations are included in the following summaries.

Mundaring. The WWSS seismograph continued to be very reliable. Apart from repairs to the inverter in March and the replacement of the power supply module in October, only minor repairs were needed. The station stand-by lead-acid batteries were replaced by Nicad batteries in February.

The optics of all components for both the WWSS and supplementary seismographs were cleaned and adjusted in September.

Kalgoorlie. This seismograph operated with little record loss throughout the year. The helicorder pen broke on 19 August while recording a large Indonesian earthquake.

Meekatharra. The seismograph was upgraded from a photographic to a visual recording station on 13 May. The response characteristic changed and Plate 3 shows the calibration curve of the new system.

One side of the ± 12-V dual power supply (PS 112) went high voltage in June. This resulted in several transistors in the preamplifier (EA310) burning out. There was no recording for eighteen days.

Back-to-back zener diodes (3.3 V) were fitted across the helicorder pen drive in August to limit the pen movement to prevent damage from large ground movement.

Marble Bar. The telemetry system installed in June 1976 operated well except for the solar cell charger at the remote seismometer site. The charging capacity of a single panel was insufficient to keep the lead-acid battery charged. A second cell was installed in March. This has proved satisfactory after initial problems which arose from a defective cell in one of the solar panels.

Details of the Marble Bar seismograph will be given by Gregson, Page, & Smith (in prep.).

Kununurra. This station continued to operate exceptionally well with only minor record losses. Part of the success can be attributed to the fact that the operator has several years' experience.

The 0.75 second galvanometer of the vertical component was replaced in October by a 0.25 second galvanometer. This enabled the magnification of short periods to be increased while keeping about the same magnification at periods of one second and more. The new calibration curve is shown in Plate 4. These response characteristics should make the seismograph more useful in detecting local earthquakes.

Swan View. Several days of record was lost in July when the sensitivity of the seismograph dropped for an unexplained reason. Battery boxes with polarised Cannon plugs were constructed to facilitate battery changing and prevent equipment damage at the remote end.

Giles. The operation of this station was extremely difficult for three reasons:

(a) Faults in recording may not come to the attention of experienced operators until two or three weeks after they occur because of the remoteness of the station and fortnightly mail deliveries.

(b) Inexperienced operators. No training in the operation of seismographs has been given to Bureau of Meteorology observers.

(c) Observers are stationed at Giles only for short terms of six months or less. This doesn't allow them to gain experience in seismograph operation.

Consequently the amount of time the seismograph was not operating during the year was considerable (see Table 8, Miscellaneous). The above problems were compounded by the fact that the seismograph was not operational when the observers were changed in September. It took some time to get the seismograph operational.

Service visits were made by headquarters staff in April and Mundaring staff in November.

Christmas Island. A portable Sprengnether (MEQ-800) single-component short-period vertical seismograph was installed at Christmas Island on 27 September 1976, for a trial period in co-operation with the British Phosphate Commissioners.

The station details are:

Latitude:	$10^{o}27.3'$S
Longitude:	$105^{o}41.4'$E
Height:	240 m
Foundation:	Limestone with phosphate deposits
Code:	XMI
Magnification:	8.1 K at 1 s, 20.5 K at 0.6 s

Site plans and a calibration curve are shown in Plates 9 and 10 respectively.

The control of this seismograph was transferred from Canberra headquarters to Mundaring Observatory early in the year. Data were analysed routinely from 1 January.

Although the seismograph is well placed for recording Indonesian earthquakes, it is of little use for recording Australian earthquakes. Therefore because of a general shortage of funds for the purchase of equipment, recording was concluded on 27 November and the equipment was returned to Mundaring where it could be put to better use.

Narrogin. A technical description of the Seismic Research Observatory (SRO) in operation at Narrogin is given by Peterson & others (1967) and by Woad (1977). Station details are given in Table 10, and locality maps and calibration curves are shown in Plates 5 to 8.

The short-period vertical SRO response was unsatisfactory for recording local earthquakes at periods 0.2 to 0.3 s. The ratio of magnifications between 0.3 and 2.0 s was 6:1 and as most of the microseismic noise has a period of about 2 to 3 s, the peak magnification at 0.3 s was low. Modifications were made at installation (19 March 1976) and again on 3 March 1977 to increase the magnification ratio between 0.3 s and 2.0 s. To achieve this a

filter was placed in the input to the helicorder amplifier. Hence the data recorded on magnetic tape remain standard, while data recorded on the helicorder are modified by the filter. The effect of the modifications is as follows:

Magnification ratio	Standard	From 19 March 1976	From 3 March 1977
0.3 to 1.0 s	2:1	2.2:1	5.2:1
0.3 to 2.0 s	6:1	16:1	80:1

The magnifications of the three long-period analog seismographs were reduced from 10 K to 5 K on 1 November. This was necessary as considerable data losses arose from the physical limit of helicorder recording.

An Albuquerque Seismological Laboratory maintenance team visited the observatory during November to make checks and modifications to the SRO. The seismograph was not recording for 21 days during tests. The main problems that had occurred during the year were:

(a) Tape unit '0' frequently giving fatal read and write errors.
(b) Data dropouts appearing on both tape and analog records.
(c) Charger/inverter malfunction, particularly after mains power failures. Numerous failures of components.

Work carried out by the maintenance team or associated with them included:

Remote site

(a) Replacement of anti-aliasing filter box and systems controller. Rewiring to make access easier.
(b) 24-V and 5-V d.c. power supplies mounted extermally to reduce heat.
(c) Systems controller drawer, filter box and ADC mounted at the top of the console to improve airflow.
(d) Inverter/charger modification kit installed.

Recording site

(e) Telecom tests on data line (Mundaring-Narrogin) over ten days indicated that noise levels and data errors are well within specifications.

(f) Charger/inverter checks. The problem with this unit occurs at all SRO stations and requires design modifications. These were subsequently made in December by Mundaring staff after instructions from ASL.

(g) Tape units thoroughly checked. Problems experienced were apparently due to a poorly soldered joint.

(h) Dropouts, although they record on both SP and LP analogue records, occur only on the LP tapes. This is because the SP event detector doesn't detect them. The cause of the problem was finally located in the systems controller board. 'Sync' pulses from Mundaring end were occasionally interpreted as two pulses. The controller design is being checked for ways to eliminate the problem. Changes to the computer program in December after advice from the maintenance team in Christchurch drastically reduced the effect of data dropouts. Although they still occur they show only as small single spikes on the SP-Z analogue record and rarely on the LP analogue records.

Field stations. A field seismograph was operated at Walpole to monitor aftershocks following the Albany earthquake of 15 May. Two field seismographs were installed in the Meckering area to monitor minor activity in the area.

Details of the seismographs are given in Table 12.

Site tests were made at Nanutarra, Nyang, and Minnie Creek, in the Gascoyne region with a view to installing a seismograph in 1978. Nanutarra proved to be the most suitable site.

Accelerographs

Four MO2 accelerographs were in operation throughout the year except in January when they were serviced. Two were at Kununurra and two at Meckering, sites B and C. The Meckering accelerographs were used to record an exposion at Meekatharra in August (see below). A third MO2 accelerograph

was installed in the Meckering area at latitude 31.730°S and longitude 116.968°E on 28 November. No earthquakes were recorded.

It appears that the Meckering accelerographs are not triggered by the relatively high frequencies associated with local earthquakes. High frequency geophones coupled to simple amplifiers are being investigated as a trigger mechanism for events which have sufficient acceleration to record but at present are failing to trigger the accelerographs.

Explosion seismology

Seismic waves from mining explosions at Newman, Tom Price, Goldsworthy, Shay Gap, Sunrise Hill, Paraburdoo, and Koolyanobbing were recorded regularly by some Western Australian seismographs. The mining companies involved continued to co-operate by supplying monthly summaries of explosion times. A catalogue of signatures of the explosions recorded at various seismograph stations was prepared to assist observers in differentiating between explosions and local or regional earthquakes.

An 11.3 tonne explosion was exploded about 7 km north of Meekatharra on 15 August as part of the Pilbara project carried out by BMR's Crustal Studies Group. The estimated magnitude of the explosion was ML = 3.0 using seismograms from MUN, NWAO, and MBL. The observatory recorded waves from the explosion at six of its permanent recording stations and three field stations. Two accelerographs were used to record ground acceleration at distances of 500 m and 1000 m from the explosion. Station co-ordinates, shot details, travel times, and amplitude data are summarised in Table 11.

Plate 11 shows a Pn velocity of 8.11 km/s in a southerly direction between Paynes Find and Narrogin. This is consistent with the Pn velocity determined by Mathur, Moss, & Branson (1977) from Geotraverse data. The arrival at Marble Bar (MBL) was 1.3 s early compared with the southern travel time.

Recorded maximum amplutides compare closely with the theoretical values (see Plate 12). The latter were based on data recorded during the Kunanalling and Geotraverse explosions (see Gregson & Smith, 1973; Gregson & Paull, 1971).

Maximum ground accelerations recorded were 0.54 m/s^2 and 0.29 m/s^2 distances of 500 m and 1000 m respectively.

Observatory staff, with the co-operation of the State Mines Department, selected the site for the explosion and assisted with the supervision of transporting the explosives to Meekatharra and loading them into the shaft.

Stress measurements

Temperature measurements were made in February in the seven holes in which (in situ) stress measurements were made in early 1976. Temperatures for holes 1-7 were:

22.63, 24.54, 22.33, 22.83, 22.17, 22.21 and 21.33 $\pm$ 0.21°C.

Seismicity

Table 9 lists 60 Western Australian earthquakes of magnitude ML = 2.0 or greater which occurred during 1977 and for which locations are available; 28 of them occurred in the southwest seismic zone.

Epicentres were determined graphically. With the greater capabilities of the seismograph network in Western Australia (MUN, SWV, NWAO, KLB, and MEK) more accurate epicentres and allowances for depth could be obtained. Travel-time tables based on Geotraverse data (Gregson & Paull, 1971) did not always give good solutions. New tables for the southwest of Western Australia incorporating depth factors based on a two-layer model (see Plate 14) were used from January 1977. The new tables are reasonably similar to, but more consistent than, the previous tables up to distances of 400 km.

Plates 1 and 2 show epicentres of Western Australian earthquakes (with magnitudes mB = 4 or greater) and those in the southwest seismic zone respectively.

Southwest zone. Activity in this zone was at about the same level as for 1976. A magnitude ML = 4.5 earthquake and 13 aftershocks occurred near Albany. These are probably in the southern extension of the zone. Two earthquakes about 100 km west of Kalbarri may be on the northern extension of the zone.

Kununurra. Six earthquakes occurred in this area, all within 120 km south to southwest of Kununurra. The largest, ML = 3.5, occurred on 27 July 118 km SSW of Kununurra. It was felt with an intensity of MM V.

Other areas. Several isolated earthquakes with magnitude mB greater than 4 occurred during the year. Of interest is a magnitude ML = 4.9 earthquake which occurred on 30 December, 200 km NW of Meekatharra. This is at about the same place as a magnitude 5.7 earthquake that occurred in 1969 (Everingham & Parkes, 1971).

Earthquake intensities

Questionnaires were distributed for three earthquakes which were felt in Western Australia. In two cases about two hundred questionnaries were distributed, of which about 75 percent were returned.

The first earthquake occurred near Albany on 15 May. An isoseismal map eas prepared and is shown in Plate 13. The maximum intensity was MM V at Albany, the radius of the isoseismal for intensity IV was 85 km, and the earthquake was felt up to 300 km from the epicentre.

The second earthquake occurred about 900 km northwest of Broome on 19 August. An isoseismal map was prepared by Gregson, Paull & Gaull (1978). The maximum ground intensity reported in Western Australia was MM V at northwest towns, about 900 km from the epicentre. The radius of the isoseismal for intensity IV was about 1150 km, and the earthquake was felt at distances over 2500 km from the epicentre.

Only twenty questionnaires were distributed for the earthquake 200 km northwest of Meekatharra as it is an isolated area. Twelve were returned, and the maximum intensity deduced from them was MM IV to V.

Magnitudes

Magnitudes quoted in this report are in accordance with those recommended by McGregor & Ripper (1976). Magnitudes reported in some previous observatory annual reports differ from their recommendations. Appendix 2 summarises how the magnitudes reported in previous years were derived.

Data distribution and publication

Seismic data were distributed as previously (for details see Record 1975/143), with the exception that preliminary bulletins were distributed monthly through headquarters as either computer printout or on microfiche.

Miscellaneous requests for seismogram copies, phase data, and information on WA seismic activity were attended to.

6. NOTES ON WORKS PROJECTS

Minor repairs and maintenance were carried out on the observatory buildings. A carport was erected for the residence in May, and two air conditioners were installed in the office in August.

7. ACKNOWLEDGEMENTS

The assistance of the daily attendants listed in Table 2 is hereby acknowledged. The co-operation of the Marble Bar Post Office for housing the Marble Bar seismograph is also acknowledged. Punching of ISC cards was carried out by the Australian Bureau of Statistics (Perth) by arrangment with the Deputy Commonwealth Statistician. We also thank Hamersley Iron Pty Ltd, Mount Newman Mining Co. Pty Ltd, and Goldsworthy Mining Ltd for preparing monthly summaries of explosion times for their mining operations.

8. REFERENCES

EVERINGHAM, I.B., & PARKES, A., 1971 - Intensity data for earthquakes at Landor (17 June 1969) and Calingiri (10 March 1970) and their relationship to previous Western Australian observations. Bureau of Mineral Resources, Australia, Record 1971/80

GREGSON, P.J., 1977 - Mundaring Geophysical Observatory Annual Report 1976. Bureau of Mineral Resources, Australia, Record 1977/7.

GREGSON, P.J., PAGE, B.J., & SMITH, R.S., 1978 - Installation of Marble Bar seismograph. Bureau of Mineral Resources, Australia, Record (in prep.)

GREGSON, P.J., & PAULL, E.P., 1971 - Refraction recording of Geotraverse explosions 1969, Operational Report. Bureau of Mineral Resources, Australia, Record 1971/45.

GREGSON, P.J., PAULL, E.P., & GAULL, B.A., 1978 - Indonesian earthquake 19 August, 1977. Bureau of Mineral Resources, Australia, Record 1978/19.

GREGSON, P.J., & SMITH, R.S., 1973 - Mundaring Geophysical Observatory Annual Report 1972. Bureau of Mineral Resources, Australia, Record 1973/174.

MATHUR, S.P., MOSS, F.J., & BRANSON, J.C., 1977 - Seismic and gravity investigation along the Geotraverse, Western Australia, 1969. Bureau of Mineral Resources, Australia, Bulletin 191.

McGREGOR, P.M., 1976 - The adjustment and use of the Proton Vector Magnetometer. Bureau of Mineral Resources, Australia, Record 1976/83.

McGREGOR, P.M., & RIPPER, I.D., 1976 - Notes on earthquake magnitude scales. Bureau of Mineral Resources, Australia, Record 1976/56.

PETERSON, J., BUTLER, H.M., HOLCOMB, L.G., & HUTT, C.R., - The Seismic Research Observatory. Bull. seism. soc. Amer., 6, 66.

WOAD, G., 1977 - Seismic Research Observatory, Western Australia. Science and Technology. May 1977, 20-23.

TABLE 1

OBSERVATORY STAFF 1977

Officer	Designation
P.J. Gregson	Geophysicist Class 3
E.P. Paull	Geophysicist Class 2
B.Z. Gaull	Geophysicist Class 1
G. Woad	Technical Officer Grade 2
B.J. Page	Technical Officer Grade 1
Y.M. Moiler (Mrs)	Clerical Assistant Grade 3 (formerly Typist Grade 1)
T.E. Creaser	Assistant Grade 1

TABLE 2

ASSOCIATED PERSONNEL 1977

Name	Nature of duties
P.M. Davies	Antarctic trainee (6 June-2 September)
B. Carline	Daily attendant, Gnangara
R. Kruger	Daily attendant, Kalgoorlie (until 11 May)
P. Maddren	Daily attendant, Kalgoorlie (from 12 May)
B. Harvey	Daily attendant, Meekatharra
J. Bailey	Daily attendant, Marble Bar
J. Roberts	Daily attendant, Kununurra
Observer-in-Charge Weather Station	Daily attendant, Giles

TABLE 3

OBSERVATORY STAFF ABSENCES 1977

Nature of absence	No. of man-days
Sick leave	17
Military leave	16
Attendance at outstations and field operations	30
Furlough	30
Paternity	5
	98

TABLE 4

CONFERENCES, ADDRESSES AND TRAINING

Officer	Date	Address
P.J. Gregson	14 June	Public meeting in Albany
P.J. Gregson	22-26 August	OIC's meeting, Canberra
B.A. Gaull	11 October	WA Petroleum Club
P.J. Gregson	27 October	W.A. Insurance Discussion Group

TABLE 5
VISITORS

Visitors	Institute
E. Masterson	Department of Administrative Services (Perth)
J. Mather	Department of Administrative Services (Perth)
J. Hinge	Department of Administrative Services (Perth)
P. Metha	BMR Review Team
P. Smith	BMR Review Tean
K. Kraitsowits	BMR Review Team
Students	University of WA
J. De Laeter	W.A.I.T.
D. Blair	W.A.I.T.
Student Members	Australia Institute of Physics
J.C. Dooley	BMR
D. Lenson	National Resources (Canberra)
C. Gunn	US Naval Oceanographic Office
B. Brizzell	Albiquerque Seismological Laboratory Maintenance Team
C. Vlatas	Albuquerque Seismological Laboratory Maintenance Team
E. Dimarco	State Public Works Department
J. Denny	State Public Works Department
B. Carling	Gnangara magnetograph operator

TABLE 6

PRELIMINARY MONTHLY MEAN GEOMAGNETIC VALUES AND K-INDEX

1977

Month	D(West)	H, nT	Z, nT	F, nT	K
January	03° 13.1	23549	53545	58495	2.02
February	13.3	543	543	490	2.03
March	13.0	542	546	493	1.88
April	13.3	529	549	490	2.22
May	13.2	532	553	495	1.62
June	13.4	531	555	497	1.36
July	13.8	524	558	496	1.92
August	14.1	516	562	497	2.07
September	13.5	522	561	498	1.95
October	14.3	513	567	500	1.86
November	14.1	520	571	507	1.68
December	14.2	514	573	506	1.71
Mean	03° 13.6	23528	53557	58497	1.86

TABLE 7

GEOMAGNETIC ANNUAL MEAN VALUES 1967-1977

Year	D	I	H, nT	X, nT	Y, nT	Z, nT	F, nT	Notes
1967	-2°54.2'	-65°57.3'	23869	23838	-1209	-53499	58582	2B
1968	55.7	59.0	846	815	1217	494	568	2B
1969	57.6	59.6	822	790	1230	487	552	2B
1970	59.6	-66°01.0'	790	758	1242	474	527	2B
1971	-3°02.3'	02.0	764	730	1260	459	503	2B
1972	05.2	04.0	726	692	1278	454	483	2C
1973	07.8	06.2	686	651	1292	460	472	2C
1974	09.9	09.0	642	606	1304	477	470	2C
1975	11.5	11.3	608	571	1314	496	474	2C
1976	12.4	14.2	567	530	1318	528	486	2C
1977	13.6	17.0	528	491	1324	557	497	2C
Mean Annual Change	-1.94	-1.97	34.1	34.7	-11.5	-5.8	-8.5	

Notes: Preliminary value B. Mean of hourly values, 5 IQ days

C. Mean of daily values, 10 Q days

TABLE 8

1977 SEISMOGRAPH RECORD LOSSES

HOURS

Cause	MUN WWSSN SP Z	MUN WWSSN SP N	MUN WWSSN SP E	MUN WWSSN LP Z	MUN WWSSN LP N	MUN WWSSN LP E	MUN SUP Z	MUN SUP N	MUN SUP E	NWAO SP Z	NWAO LP Z	NWAO LP N	NWAO LP E	SWV	KLG	MEK	MBL	KNA Z	KNA N	KNA E	GLS
OPERATOR																					
Late change															1	30	19	19	19	19	33
Drum not reset											3						6				
Paper reversed							23														
Poorly loaded							24	9													
POWER FAILURES																					
Mains										3	3	3	3		14		6				
Battery/DC										2	2	2	2	3		25	66	23	23	23	233
RECORDER FAULTS																					
Lamp blown	59	21	53				19											31	2	19	
Helicorder												2		4		68					
Optics																		120			
CONTROL EQUIPMENT																					
Clock																		63	63	63	2
Discriminator														52							
Preamplifier																435					
Attenuator					22																
SRO remote																					
SRO local																					
Equipment elsewhere																					
LINE FAILURE																	22				
MAINTENANCE										515	515	515	515			4	10	7	7	7	
MISCELLANEOUS (see text)																					2496
TOTAL	59	21	53	-	22	-	66	9	-	523	526	525	523	59	15	562	131	263	114	131	2764
Percentage	0.7	0.2	0.6		0.3		0.8	0.1		6.0	6.1	6.1	6.0	0.7	0.2	6.4	1.5	3.0	1.3	1.5	31.6
Mean percentage			0.3%					0.3%			6.0%								1.9%		

TABLE 9
WESTERN AUSTRALIAN EARTHQUAKES 1977

Date 1977	Origin Time U.T.	Lat. °S	Long. °E	ML(MUN)	mB(MUN)	Remarks	No. of Stations
Jan 10	08 34 20.5	29.5	115.1	3.9		30 km SSE Dongara.	8
29	21 06 41.3	32.02	117.23	2.2		17 km W of Quairading.	3
Feb 07	09 32 13.6	34.09	117.35	2.9		25 km W Tambellup.	5
26	05 49 53.2	16.50	128.36	2.7		94 km SW Kununurra.	1
26	06 03 05	16.50	128.36	2.4		94 km SW Kununurra.	1
Mar 01	20 08 27.0	33.48	117.69	3.6		15 km S Dumbleyung, felt MM IV.	7
08	17 02 25.5	31.17	117.48	2.5		10 km E Wyalkatchem, felt.	5
08	17 02 36.0	31.25	117.44	2.2		10 km E Wyalkatchem,	3
21	15 09 30.9	31.70	117.08	3.0		7 km SSE Meckering.	5
Apr 01	20 20 56.2	31.7	117.1	2.0		7 km SSE Meckering.	3
06	01 22 42.8	16.53	129.05	2.3		91 km S Kununurra.	1
06	22 06 03.2	16.53	129.05	2.3		91 km S Kununurra.	1
06	22 07 36.0	16.53	129.05	2.1		91 km S Kununurra.	1
09	09 47 57.0	34.44	117.44	3.5		20 km SSW Cranbrook.	6
10	10 18 44.0	30.51	122.92	4.6		130 km E Kalgoorlie.	9
16	15 20 29.1	30.7	121.5	3.6		Kalgoorlie rockburst?	5
18	12 33 27.8	31.93	116.37	2.9		1 km N Yericoin, felt MM IV.	7
23	20 43 31.0	21.65	114.68	3.9		40 km W Onslow.	4
May 10	10 38 50.3	30.75	116.88	2.3		22 km NW Manmanning.	3
10	12 52 28.5	30.75	116.88	2.0		22 km NW Manmanning.	3
15	19 16 07.6	35.00	117.95	4.5		Albany, felt MM V.	10
15	19 21 16.7	35.00	117.95	2.5		Albany.	3
15	19 24 07.0	35.00	117.95	2.1		Albany.	3
15	19 26 46.7	35.00	117.95	2.4		Albany.	3
15	19 59 56.4	35.00	117.95	2.9		Albany, felt.	4
15	22 38 48.9	35.00	117.95	1.9		Albany.	3
16	20 15 41.7	35.00	117.95	2.3		Albany.	3
16	21 27 56.0	28.0	122.9	3.0		Cosmo Newberry	3
18	06 11 41.0	17.5	126.7	3.6		200 km ENE Fitzroy Crossing.	2
19	20 48 58.2	35.00	117.95	2.3		Albany.	3
19	21 36 25.0	35.00	117.95	2.3		Albany, felt.	3
26	08 52 34.0	35.00	117.95	3.4		Albany.	5
26	09 10 27.6	35.00	117.95	3.2		Albany.	5
Jun 02	13 32	35.00	117.95	2.0		Albany.	3
02	13 37 33.0	35.00	117.95	4.0		Albany, felt MM IV.	8
02	21 28	35.00	117.95	2.1		Albany.	3
04	15 13 53.0	31.65	116.97	2.4		4 km SW Meckering.	3
12	09 34 06.0	31.70	117.00	3.9		7 km S Meckering, felt MM V.	7
12	10 17 14.4	31.70	117.00	2.4		7 km S Meckering.	3
15	21 48 30.7	31.70	117.00	2.2		7 km S Meckering.	3
17	03 36 24.4	31.70	117.00	2.1		7 km S Meckering.	3
21	06 11 08.7	32.30	117.20	2.0		20 km NE Brookton.	3
Jul 04	02 22 34.5	31.70	117.12	2.1		13 km SE Meckering.	3
04	19 14 43.2	31.00	117.95	2.9		25 km SSE Bencubbin, depth 7 km felt MM = IV.	5
20	12 19 14.0	17.3	120.2	4.1		220 km W Broome.	9
27	20 09 59.4	116.87	128.52	3.4		118 km SSW Kununurra, felt MM = V.	11

Table 9 (Continued)

Date 1977	Origin Time U.T.	Lat. °S	Long. °E	ML(MUN)	mB(MUN)	Remarks	No. of
Aug 15	19 34 57.2	27.5	112.92	3.5		125 km W Kalbarri.	7
17	21 16 52	30.5	125.6	4.6		390 km E Kalgoorlie.	5
Sep 30	11 48 13.7	30.5	117.2	2.2		30 km N Cadoux.	3
Oct 24	12 20 10.0	23.86	124.51	3.6		180 km ESE Lake Disapointment.	5
Nov 03	03 56 38.5	22.6	127.0		4.0	Lake McKay.	3
07	19 05 09.3	18.00	119.25	3.7		310 km W Broome.	5
12	18 53 38.7	27.8	113.2	3.8		100 km W Kalbarri.	3
17	17 56 32.0	30.59	123.67	4.6		30 km NE Cundeelee, felt.	8
22	08 00 09.0	19.6	120.4	4.3		180 km NE Marble Bar, felt.	6
30	05 44 08.9	31.82	116.98	2.0		21 km S Meckering, felt.	3
30	07 30 12.5	33.59	117.31	3.0		25 km NW Katanning.	3
Dec 26	17 40 03.0	(30.6)	(123.7)	3.5		30 km NE Cundeelee.	5
30	10 09 37.0	25.16	117.08	4.9		200 km NW Meekatharra, felt MM = IV^{+}.	10
30	17 31 12	(25.16)	(117.08)	3.8		Aftershock.	

TABLE 10

NARROGIN (NWAO) SEISMOGRAPH DATA

CODE

NWAO

CO-ORDINATES

Seismometer site (Narrogin)

Latitude: $32^{o}55.6'S$

Longitude: $117^{o}14.0'E$

Elevation: 365 m (at surface) seismometer depth 100 m

Foundation: Precambrian granite

Recording site (Mundaring)

Latitude: $31^{o}54.2'S$

Longitude: $116^{o}09.9'E$

Elevation: 290 m

INSTRUMENTATION

Seismic Research Observatory using Telecom lines to telemeter digital data from Narrogin to Mundaring.

One short period vertical and three long period components recorded on both digitally on magnetic tape and visually on helicorder recorders. Helicorder recording speeds 60 mm/min and 15 mm/min for short and long periodrcomponents respectively.

Magnifications

See Plates 7 and 8 for magnification curves.

TABLE 11

MEEKATHARRA EXPLOSION 15 AUGUST 1977

EXPLOSION DETAILS

Shot instant: 02 10 00.5 UT

Co-ordinates: Lat. 26.532°S Long. 118.538°E

Shot size: 11.3 tonnes

STATION DETAILS

Station	Code	Latitude	Longitude
Meekatharra	MEK	26.61°S	118.54°E
*Paynes Find	PFD	29.297	117.740
*Frank's Rock	FRK	31.035	116.982
Kalgoorlie	KLG	30.78	121.46
*Meckering quarry	MQY	31.636	116.973
Marble Bar	MBL	21.16	119.83
Swan View	SWV	31.88	116.06
Mundaring	MUN	31.98	116.21
Narrogin	NWAO	32.928	117.236

*Field stations

TRAVEL TIME DATA

Station	Distance(km)	P Arrival	P Travel time	S Arrival
MEK	8.6	021002.0	1.5	
PFD	317.4	1045.96	45.45	
FRK	523.4	1111.3	70.8	021205.6
KLG	551.9	11(14.8)	74.3	
MQY	587.8	1119.10	78.6	
MBL	611.8	1121.0	80.5	1321
SWV	641.7	11(26.1)	85.6	1228
MUN	646.7	1126.5	86.0	12(30)
NWAO	722.5	1135.9	95.4	1246

AMPLITUDE DATA

Station	P Period	P Amplitude	Maximum Period	Maximum Amplitude	Theoretical Maximum
	(Seconds)	(Trace mm)			(mm)
MEK		55			87
PFD	0.25	0.3	0.2	16.5	32
FRK	0.2	1.2	0.4	8.0	8
KLG					
MQY	0.25	1.0	0.25	5.5	11
MBL	0.3	1.5		1.5	
SWV	0.35	0.3	0.4	2.7	
MUN (HG)	0.3	0.8	0.3	2.0	
NWAO	(0.3)	0.2	0.3	1.5	

TABLE 12

FIELD SEISMOGRAPH DETAILS

Walpole	
Equipment:	Sprengnether MEQ 800.
Co-ordinates:	Latitude 34.887°S
	Longitude 116.697°E
Dates of operation:	1 June to 14 June 1977
Meckering (McKenzies farm)	
Equipment:	Transportable 70 mm film recorder
Co-ordinates:	Latitude 31.716°S
	Longitude 116.968°E
Dates of operation:	28 November 1977 (continuing)
Meckering (Richardson's farm)	
Equipment:	Sprengnether MEQ 800
Co-ordinates	Latitude 31.608°S
	Longitude 117.002°E
Dates of operation:	6 December 1977 (continuing)

APPENDIX 1
PRINCIPAL EVENTS
MUNDARING GEOPHYSICAL OBSERVATORY 1957-1977

1957 May	Geomagnetic recording commenced at Gnangara (La Cour).
1959 Mar 18	Transfer of Observatory from Watheroo to Mundaring.
1959 Apr 3	Ionospheric recording commenced (Type 2 ionosonde).
1959 Jul 30	MUN seismograph recording commenced (Benioff).
1960 Mar-1960 Oct	Atmospheric noise recording (for CSIRO).
1960 Apr 30	Eschenhagen normal magnetograph replaced La Cour at Gnangara.
1960 May 1	Cossor ionosonde replaced Type 2.
1960 Jun 22	Absolute magnetic observations commenced in new absolute house.
1962 Jun	WWSS system commenced operation at MUN.
1963 Apr 19-1963 Dec 17	GRV seismograph operation.
1963 May 30-1963 Dec 19	NGN seismograph operation.
1964 Nov 6	KLG SP seismograph recording commenced.
1965 Nov 29-1966 Aug 24	LVS seismograph operation.
1965 Nov	KNA SP-Z seismograph recording commenced; operation intermittent till Feb 1972.
1967 Feb	Fremantle Region Upper Mantle Project.
1967 Oct 26	MEK SP-Z seismograph recording commenced.
1968 Oct-1968 Nov 26	Field seismograph operation at Meckering.
1968 Nov 16-1971 Dec 31	AFMAG recording at Mundaring.
1970 Jan 1	Routine analysis of KNA seismograms commenced.
1970 Feb 26	IPS IIIE ionosonde replaced Cossor.
1971 Feb 10-1972 Jul 31	KAA SP-Z seismograph operation.
1971 Nov 30	Two MO2 accelerographs installed at Meckering.
1972 Feb 29	KNA seismograph upgraded to 3 components.
1972 Mar 1	MO2 accelerograph (PWD) installed at Kununurra.
1972 Jun 27	Proton scalar magnetometer introduced for Z baseline control.
1972 Oct 12-1975 Feb	MBT SP-Z seismograph recording.
1972 Nov 16	MO2 accelerograph (PWD) installed at Kununurra.
1973 Jan 31	Mobile SP-Z recording at various sites in SW seismic zone started.
1973 Mar 30	KLG - reduced to SP-Z.
1973 May 1	MEK - increased to 3-component SP.
1973 May 23	MUN - 2 Wood Andersons installed.
1973 May 25	MUN - Benimore SP-Z withdrawn; Benioff SP-Z started.
1974 Apr 1	Proton vector coils introduced for Z baseline control.
1974 May 1	Proton vector coils introduced for H baseline control.
1974 Jun 17-31	Riometer recording at Mundaring during solar eclipse.
1974 Sep	GLS - SP-Z recording commenced.
1975 Jul 18-Nov 19	Earthtide recording at Mundaring.
1975 Mar 19-Aug 15, Dec 18	SWV - SP-Z recording.

Appendix 1 (Continued)

1975 Sep 2-1976 Feb 5	NWA - SP-Z recording.
1976 Mar 27	NWAO - Seismic Research Observatory commenced.
1976 Jun	MBL SP-Z recording commenced.
1976 Sep-1977 Nov 27	XMI SP-Z recording commenced.
1976 Oct	Special ionospheric sounding, solar eclipse (23 Oct).
1977 Nov 28	A third MO2 accelerograph installed at Meckering.

APPENDIX 2

MAGNITUDES REPORTED IN ANNUAL REPORTS

Year	Record Number	Table	Magnitude	Recommended Symbol	Remarks
1965	1967/29	6	M_L	ML(MUN)	As for Richter magnitude but using MUN(WWSSN) horizontal amplitudes.
			m_L	m	Derived m_L = 1.8 + 0.73 ML.
			M_S	MS	MS = log (A/T) + 1.66 log Δ + 3.3 using surface waves in 18-22 s period.
			m_S	M	Derived M = 0.63 M_S + 2.5
			m_b	mB(MUN)	mB = log (A/T) + Ao. Ao is distance factor taken from Everingham 1968/97 curve A.
			unified m		Weighted mean of all listed values of m_L, m_S and m_b.
		7	M_L	ML(MUN)	As in Table 6 (above).
		8	m_B	mB(MUN)	As in Table 6 (above).
1966	1968/97	2	M_L	ML(MUN)	As for 1965.
			m_L	m	As for 1965.
			m_b(a)	mB(MUN)	As for 1965 (curve A).
			m_b(b)	mB(MUN)	As for 1965 (curbe B).
			m		Weighted mean of all m_L and m_b values except m_b(a).
		3	M_L	ML(MUN)	As for 1965.
		4	M_S	MS	External sources.
		5	m_b	mB(CGS)	USCCGS, PDE.
1967	1967/96	5	mb	mB(CGS)	USCGS, PDE.
		6	M_L	ML(MUN)	As for 1965.
			m'	m	Derived m' = 1.8 + 0.73 ML.
			m_b	mB(MUN)	As for 1966 (curve B) either from MUN or KLG.
		7	M_L	ML(MUN)	As for Table 6 (above).
			m_b	mB(MUN)	As for Table 6 (above).
1968	1971/12	5	mb(USCGS)	mB(CGS)	From USCGS, PDE.
			mb(MUN) + 0.4	mB(MUN)	From curve B + 0.4. This value used from 1968 onwards except table 6 and below.
			m		See table 6.
		6	ML	ML(MUN)	As for 1965.

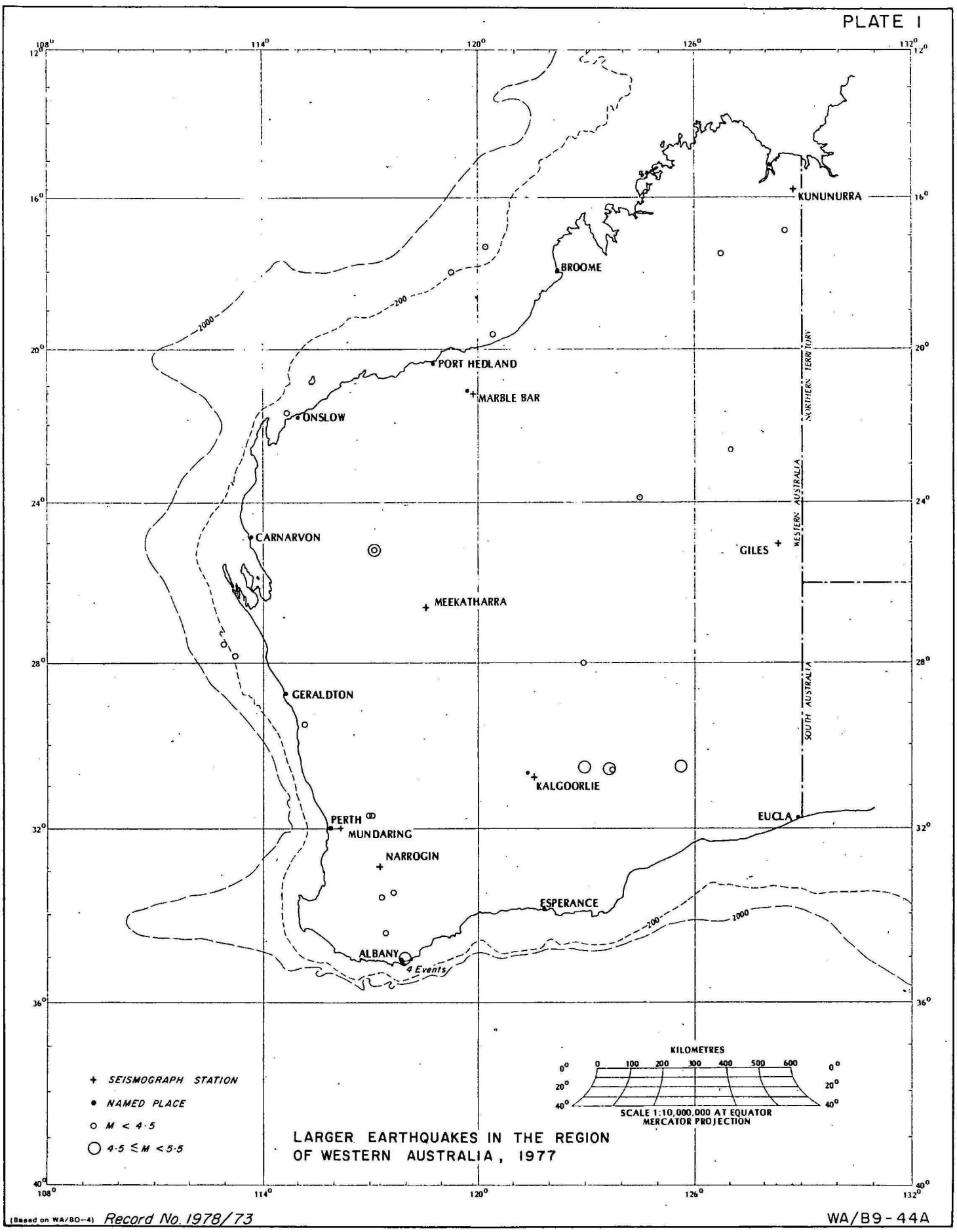
Appendix 2 (Continued)

Year	Record Number	Table	Magnitude	Recommended Symbol	Remarks
1968	1971/12	6	m'	m	Derived m = 1.8 + 0.73 ML.
			mb(MUN)(a)		Curve B, MUN data.
			mb(MUN)(b)		Curve B, KLG data.
			m		Weighted mean m' and mB(MUN) + 0.4.
		7	ML		As for Table 6.
			m'		As for Table 6.
			mb(MUN)(a)		As for Table 6.
			mb(MUN)(b)		As for Table 6.
		8	ML	ML(MUN)	As above.
			mb(MUN)	mB(MUN)	MUN data or if *KLG (curve B).
		9			As for Table 8.
1969	1971/76	7	ML	ML(MUN)	Weighted mean of MUN, KLG data. Determined as for 1965.
			m'	m	Derived m' = 1.8 + 0.73 ML.
			mb(a)	mB(MUN)	Curve B + 0.4, MUN data.
			mb(b)	mB(MUN)	Curve B + 0.4, KLG data.
			m		Weighted mb and m' values.
		8			As for Table 7.
1970	1971/77	12	ML	ML(MUN)	As for 1969.
		13	m'	m	Derived.
			mb(MUN)		Curve B + 0.4, MUN data
			mb(KLG)		Curve B + 0.4, KLG data.
			mb(MEK)		Curve B + 0.4, MEK data.
			m		Weighted mb and m' values.
		14	ML		As avobe MUN data.
			mb		As above MUN data.
1971	1971/48	11	ML(MUN)	ML(MUN)	As for 1969.
			m'(MUN)	m	Derived m' = 1.8 + 0.73 ML.
			mB(MUN)		Curve B + 0.4, MUN data.
			mB(KLG)		Curve B + 0.4, KLG data.
			mB(MEK)		Curve B + 0.4, MEK data.
			mB(KAA)		Curve B + 0.4, KAA data.

Appendix 2 (Continued)

Year	Record Number	Table	Magnitude	Recommended Symbol	Remarks
1971	1971/48	11	m		Weighted mean of m' and mB.
		12	ML	ML(MUN)	As above Table 11.
			mB	mB(MUN)	As above Table 11.
		13	ML	ML(MUN)	MUN data, *KAA data, ∅ MEK data.
			m'	m	Derived m' = 1.8 + 0.73 ML.
			mB(MUN) etc.		As Table 11.
1972	1973/154	11	ML	ML(MUN)	As 1971 Table 11.
			m'	m	As 1971 Table 11.
			mB(MUN) etc.		As 1971 Table 11.
			m		As 1971 Table 11.
		12	ML	ML(MUN)	As above.
			mB(MUN)	mB(MUN)	As above.
1973	1974/104	11)	ML	ML(MUN)	As above.
1974	1975/143	10)			
1975	1976/48	9)	mB	mB(MUN)	Curve B + 0.4, weighted mean of data available from all WA stations.
1976	1977/7	9)			

PLATE 1

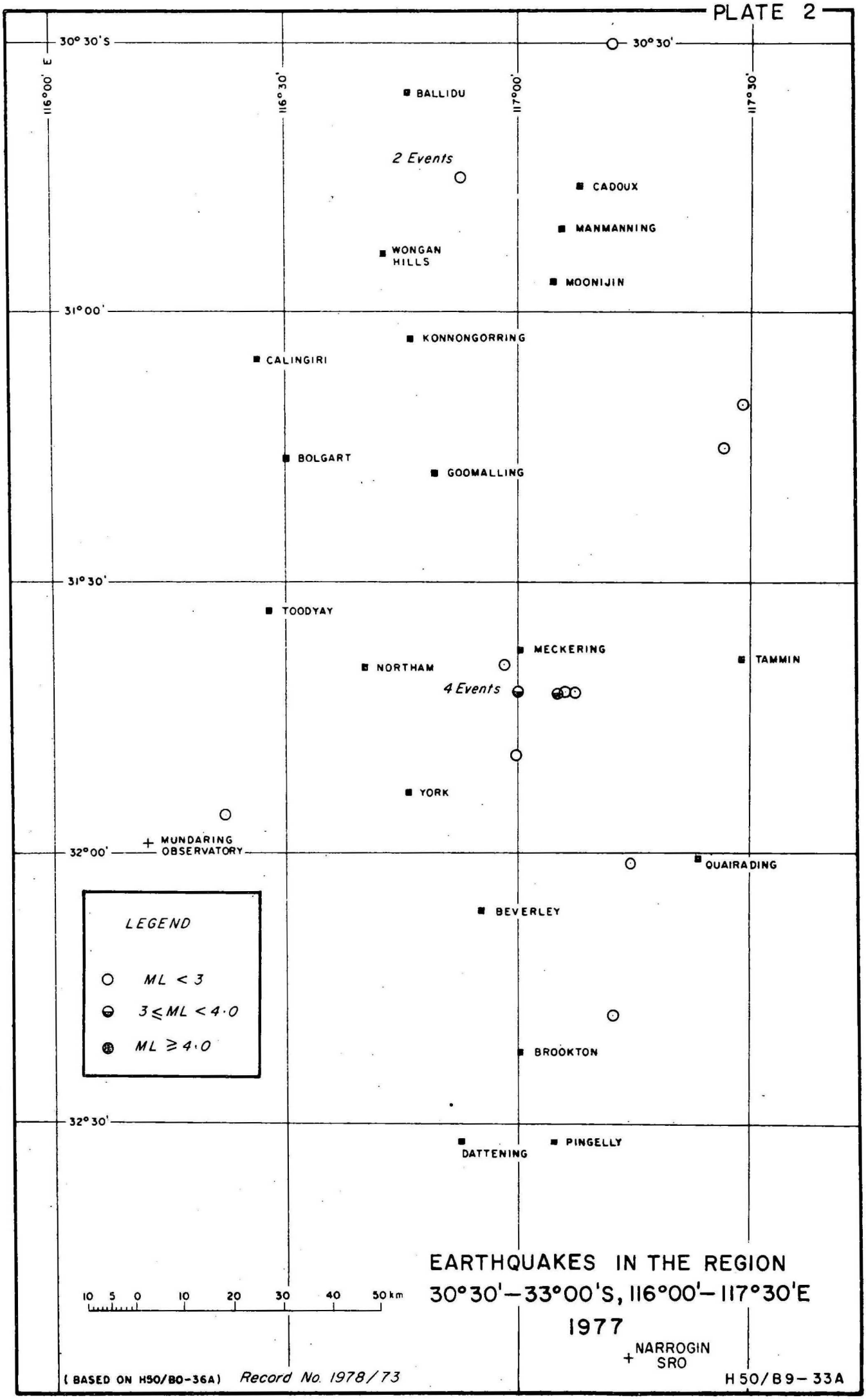


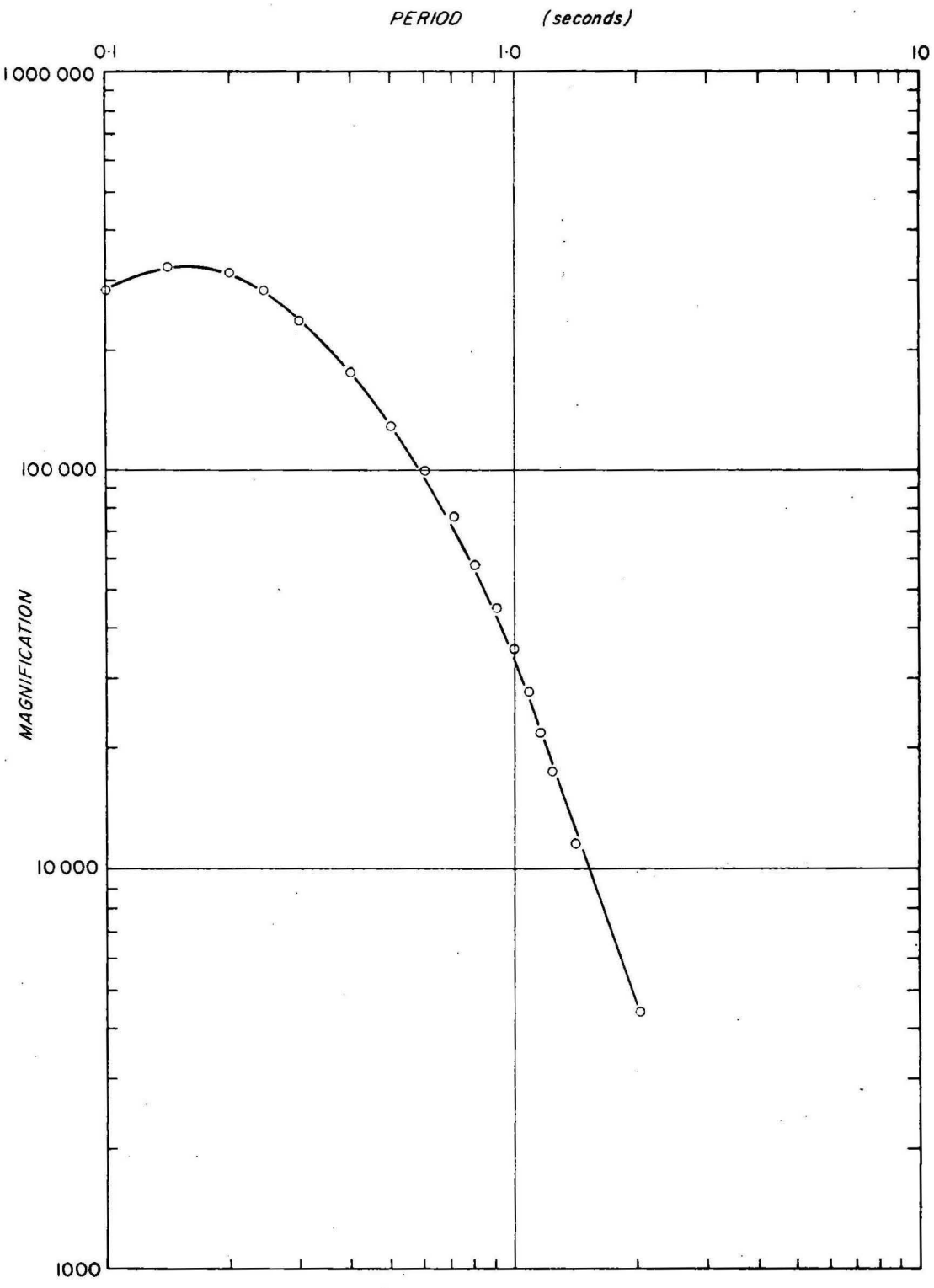
LARGER EARTHQUAKES IN THE REGION OF WESTERN AUSTRALIA, 1977

(Based on WA/80-4) Record No. 1978/73

WA/B9-44A

PLATE 2


30° 30'S
30° 30'
116° 00' E
116° 30'
117° 00'
117° 30'
BALLIDU
2 Events
CADOUX
MANMANNING
WONGAN HILLS
MOONIJIN
31° 00'
KONNONGORRING
CALINGIRI
BOLGART
GOOMALLING
31° 30'
TOODYAY
MECKERING
NORTHAM
TAMMIN
4 Events
YORK
MUNDARING OBSERVATORY
32° 00'
QUAIRADING
BEVERLEY
BROOKTON
32° 30'
DATTENING
PINGELLY
LEGEND
ML < 3
3 ≤ ML < 4·0
ML ≥ 4·0
10 5 0 10 20 30 40 50 km
EARTHQUAKES IN THE REGION
30°30'—33°00'S, 116°00'—117°30'E
1977
NARROGIN SRO
(BASED ON H50/80-36A)
Record No. 1978/73
H50/89-33A

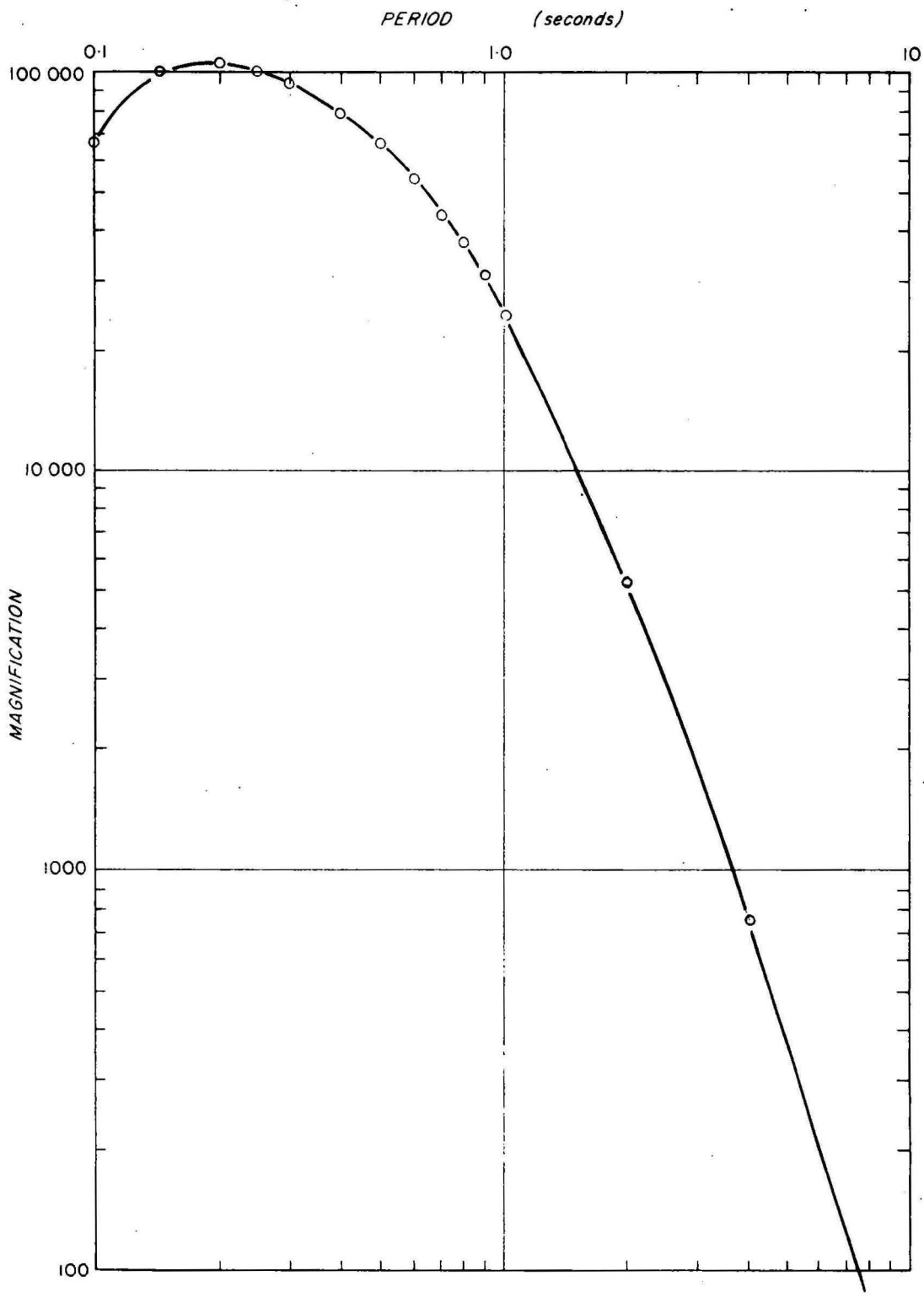


CALIBRATION CURVE MEEKATHARRA

FROM 13 MAY 1977

(Based on G82/2-170A) *Record No. 1978/73*

G50/B9-8A



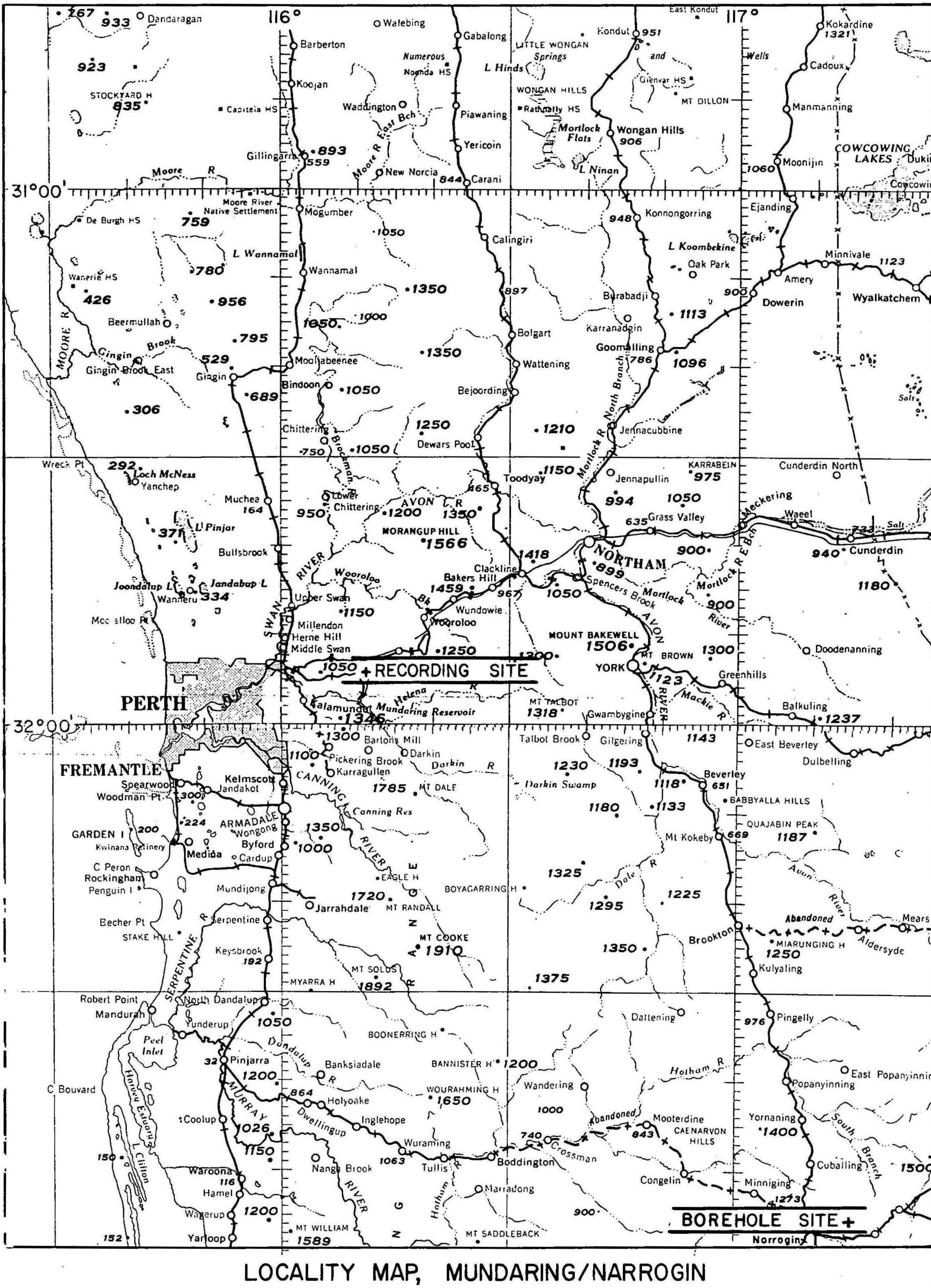
CALIBRATION CURVE, KUNUNURRA

FROM 9 OCTOBER 1977

(Based on G82/2-170A) *Record No. 1978/73*

D52/B9-14A

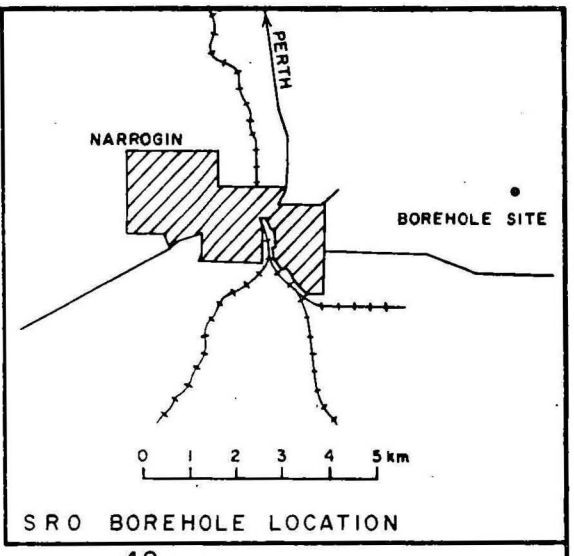
PLATE 5



LOCALITY MAP, MUNDARING/NARROGIN SEISMIC RESEARCH OBSERVATORY

Record No. 1978/73

H50/B9-34A



42

Power line

SRO BOREHOLE

124

125

1620

5046

N

Gate

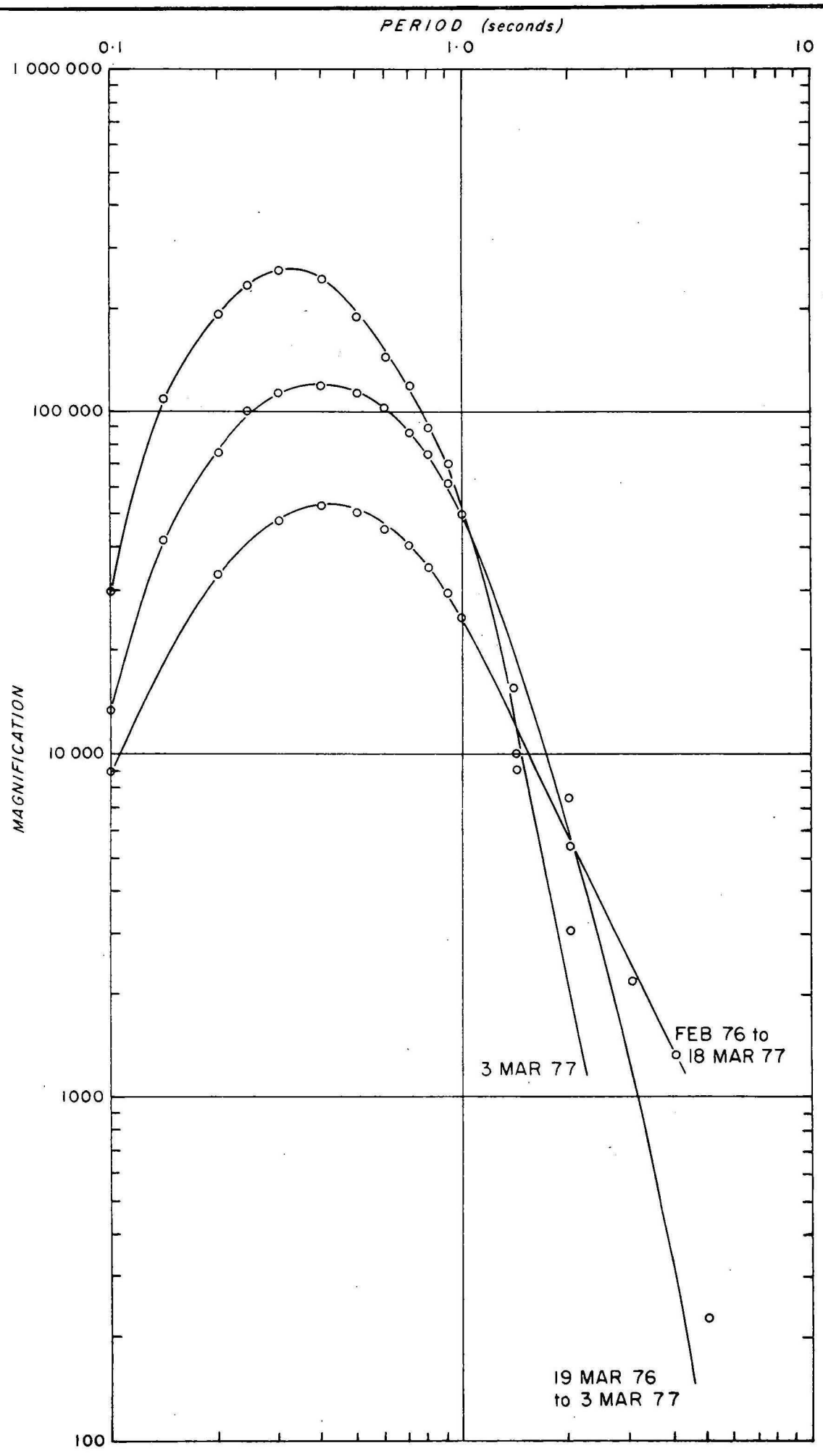
0 100 200 300 400 500 METRES

NARROGIN BOREHOLE SITE
LOCALITY MAP

NARROGIN

YILLIMINNING

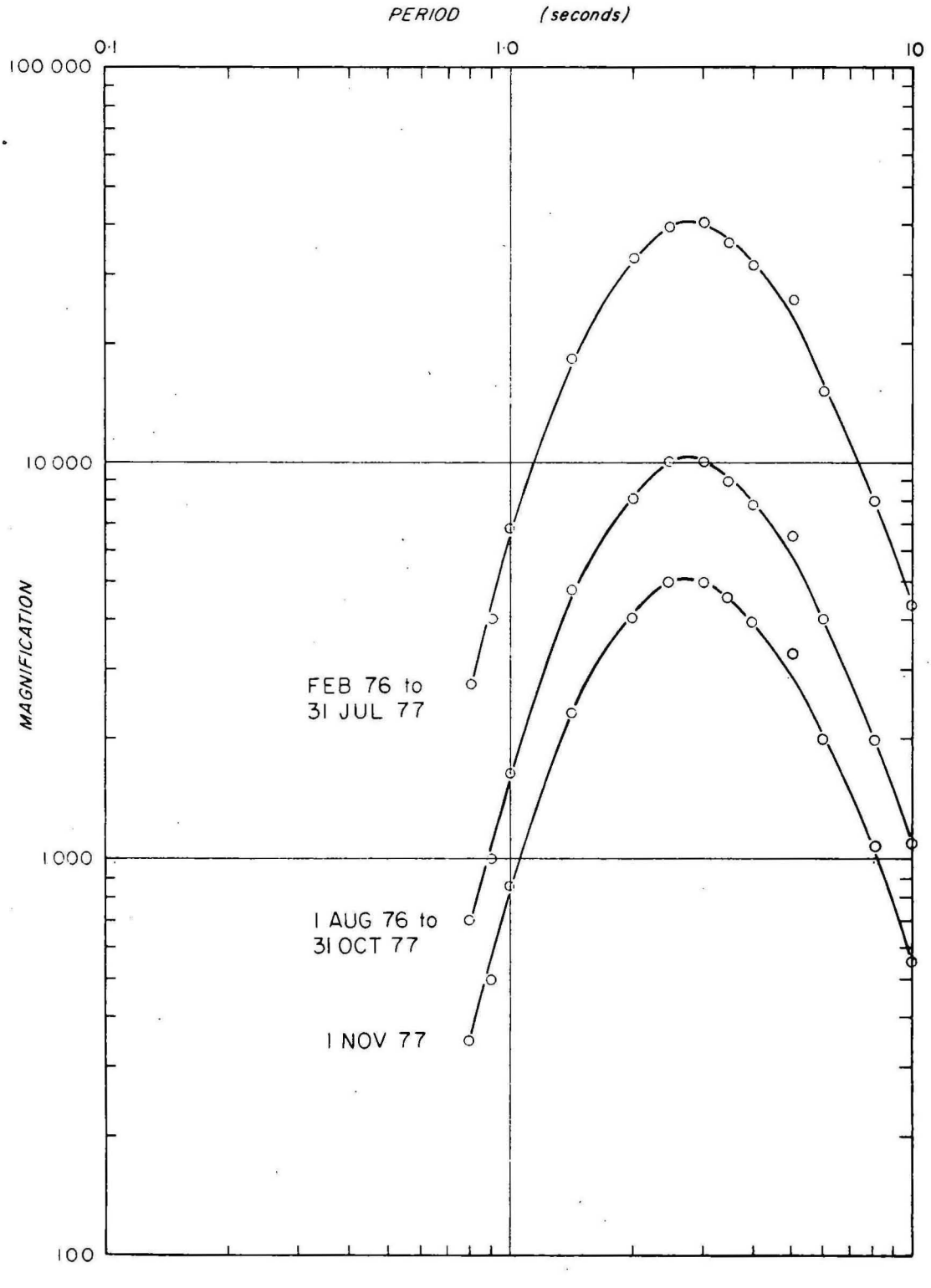
PLATE 7



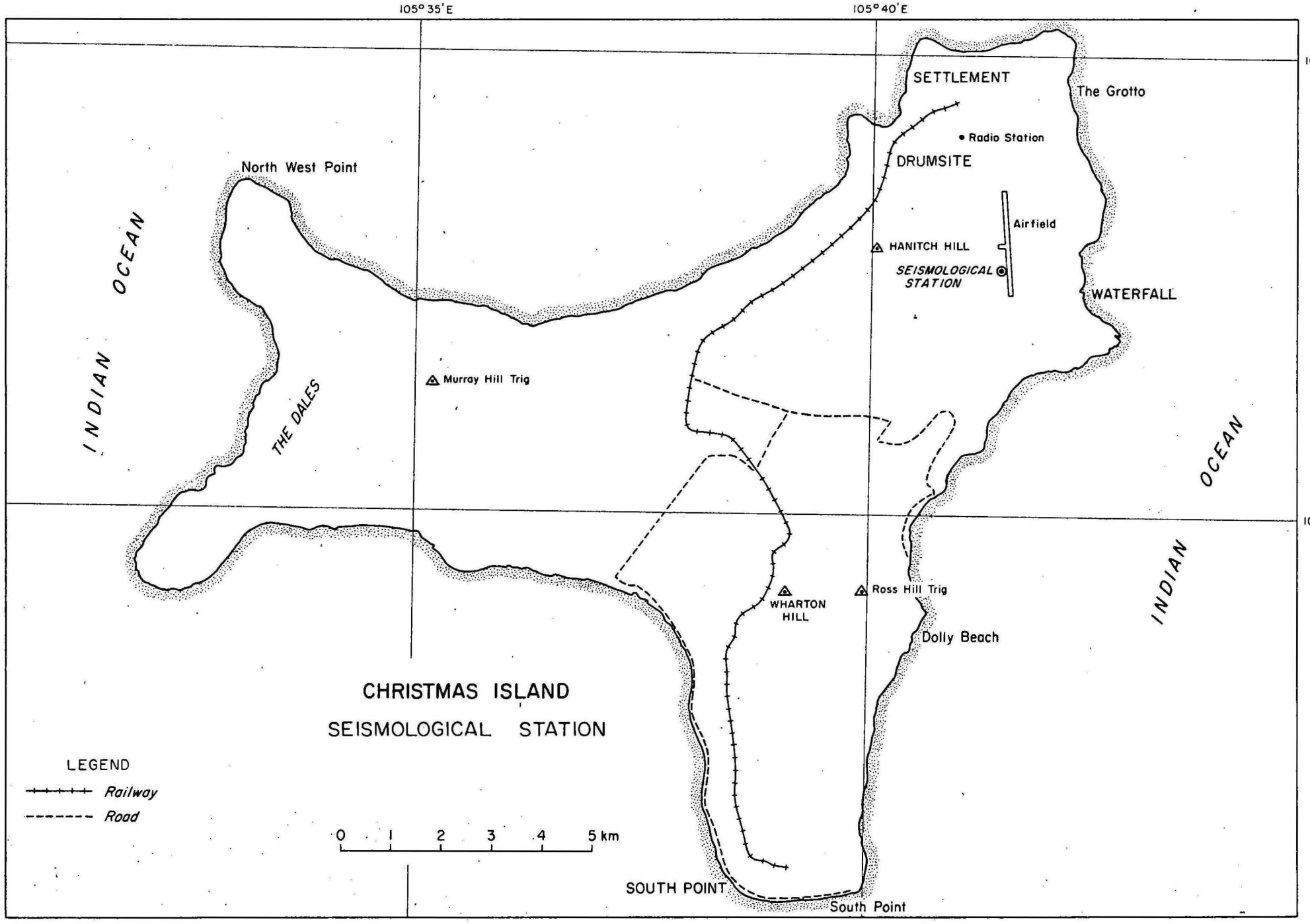
SHORT-PERIOD CALIBRATION CURVES, NARROGIN

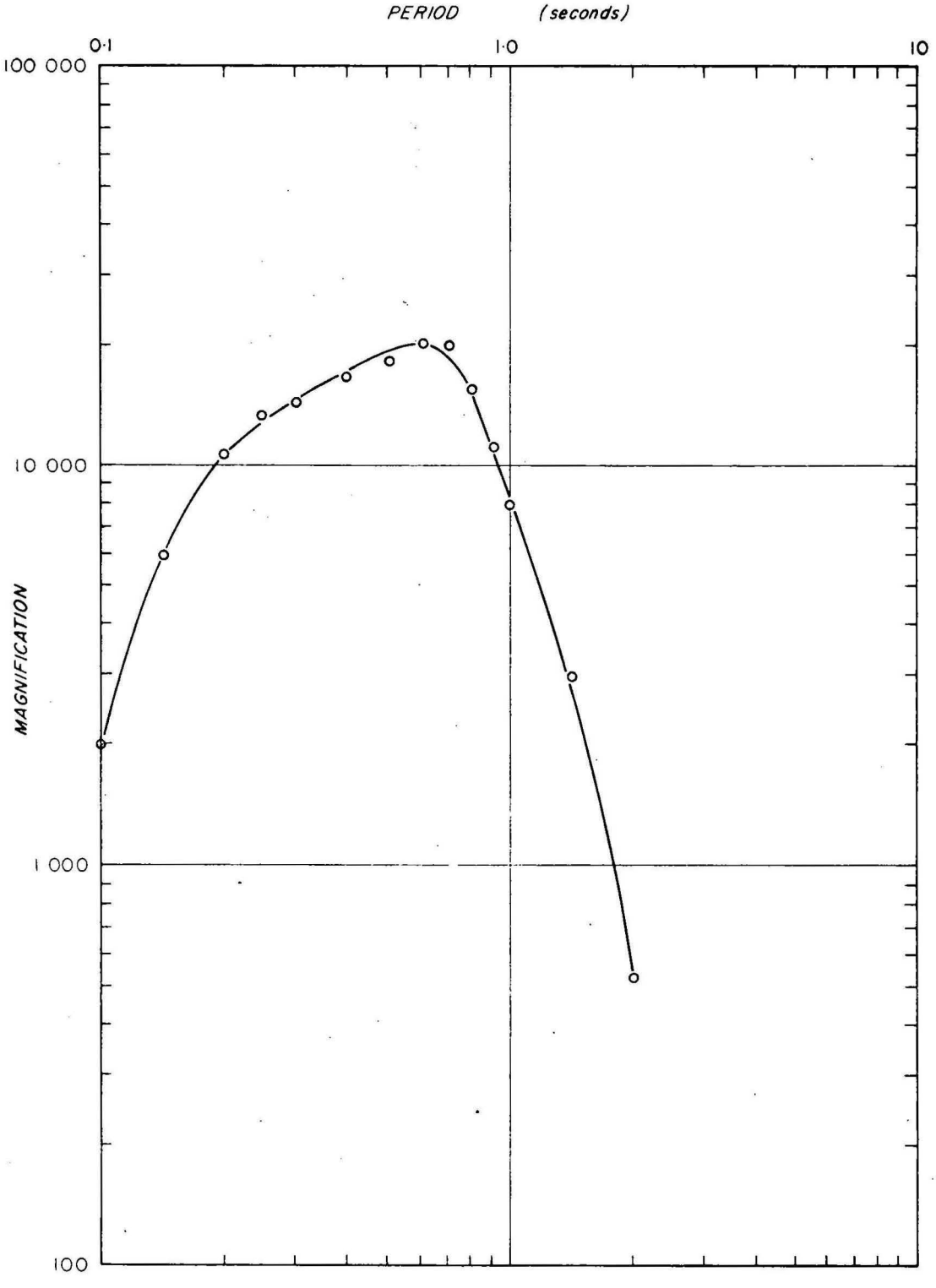
Record No. 1978/73

I50/B9-6A



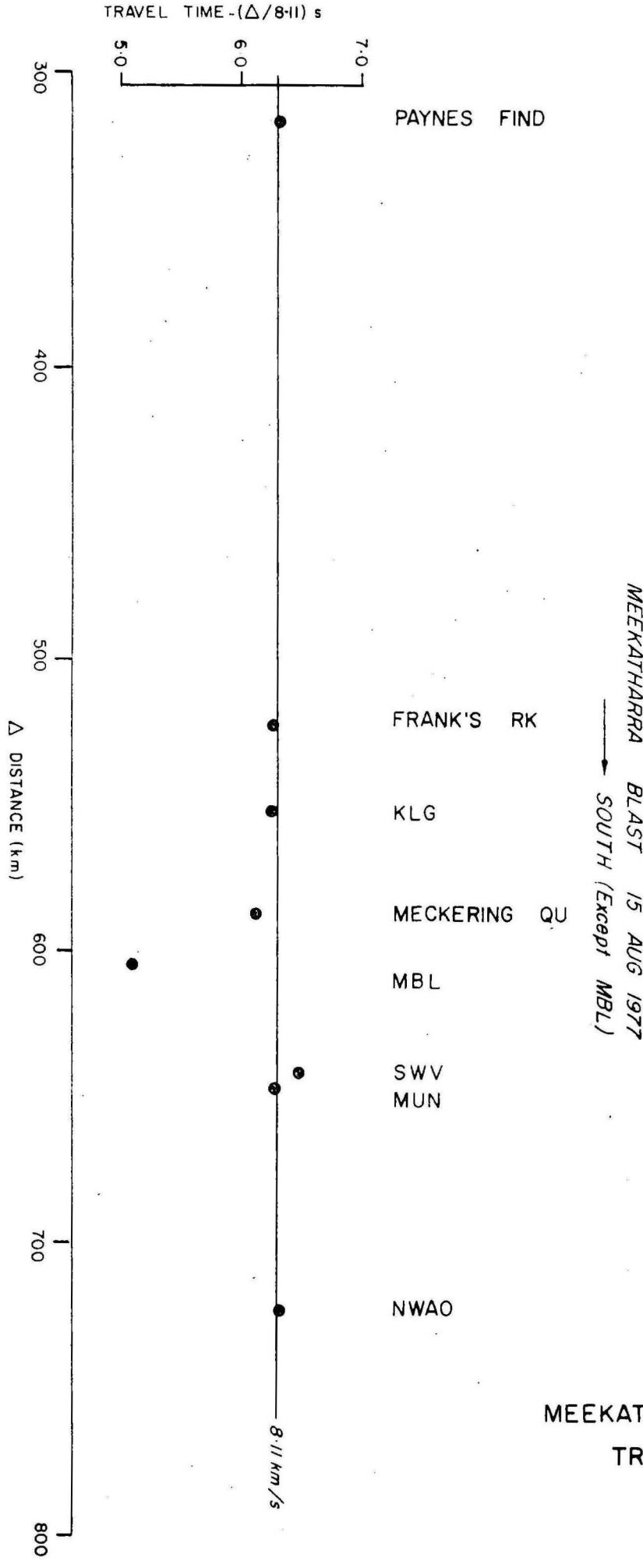
LONG-PERIOD CALIBRATION CURVES, NARROGIN


105° 35' E
105° 40' E
10° 25' S
10° 30' S
SETTLEMENT
The Grotto
Radio Station
DRUMSITE
North West Point
Airfield
HANITCH HILL
SEISMOLOGICAL STATION
WATERFALL
INDIAN OCEAN
Murray Hill Trig
THE DALES
INDIAN OCEAN
WHARTON HILL
Ross Hill Trig
Dolly Beach
CHRISTMAS ISLAND
SEISMOLOGICAL STATION
LEGEND
Railway
Road
0 1 2 3 4 5 km
SOUTH POINT
South Point



CALIBRATION CURVE, CHRISTMAS ISLAND
FROM OCTOBER 1976 TO 27 NOVEMBER 1977

PLATE II

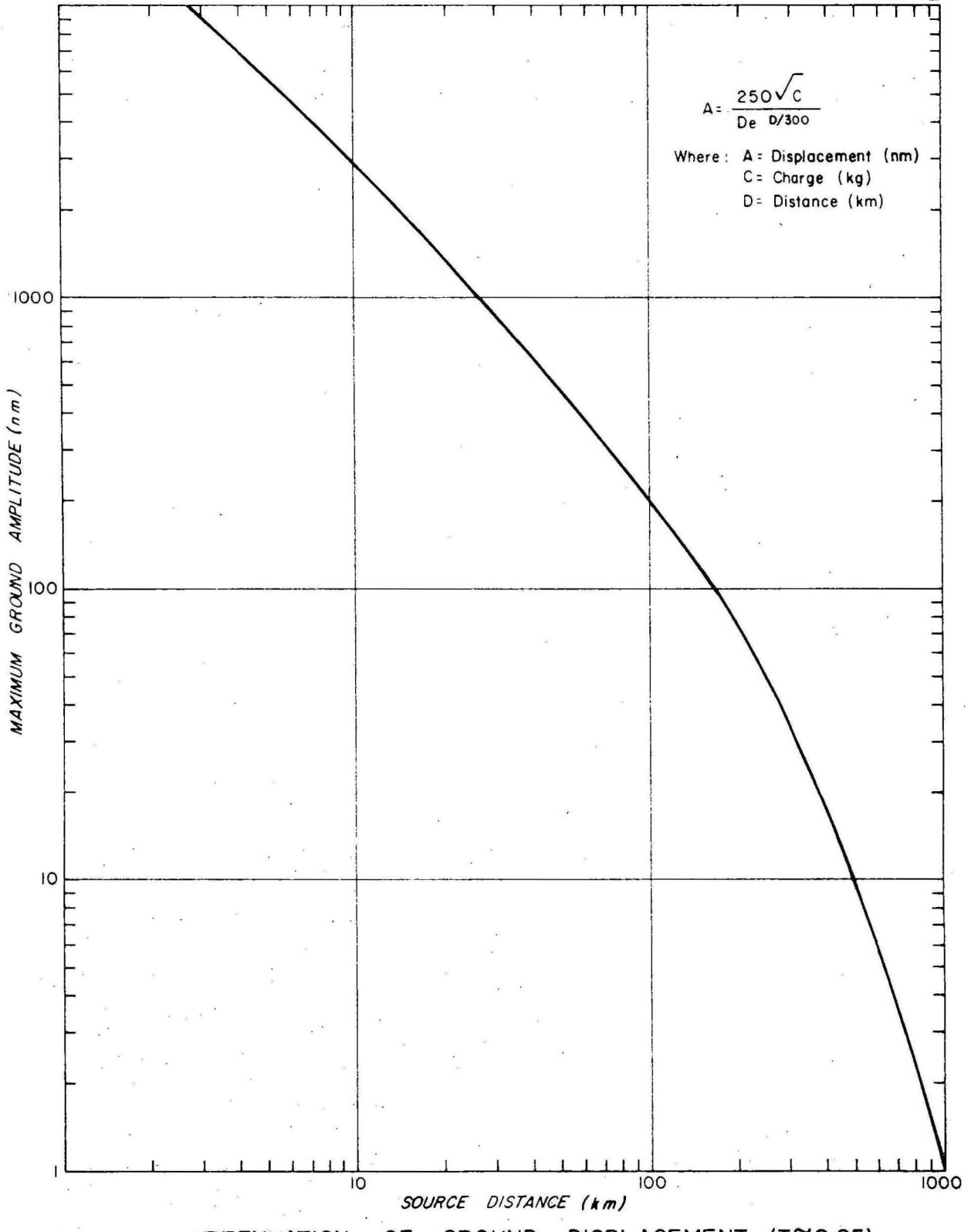


MEEKATHARRA EXPLOSION
TRAVEL TIMES

Record No. 1978/73

G50/B9-9A

PLATE 12

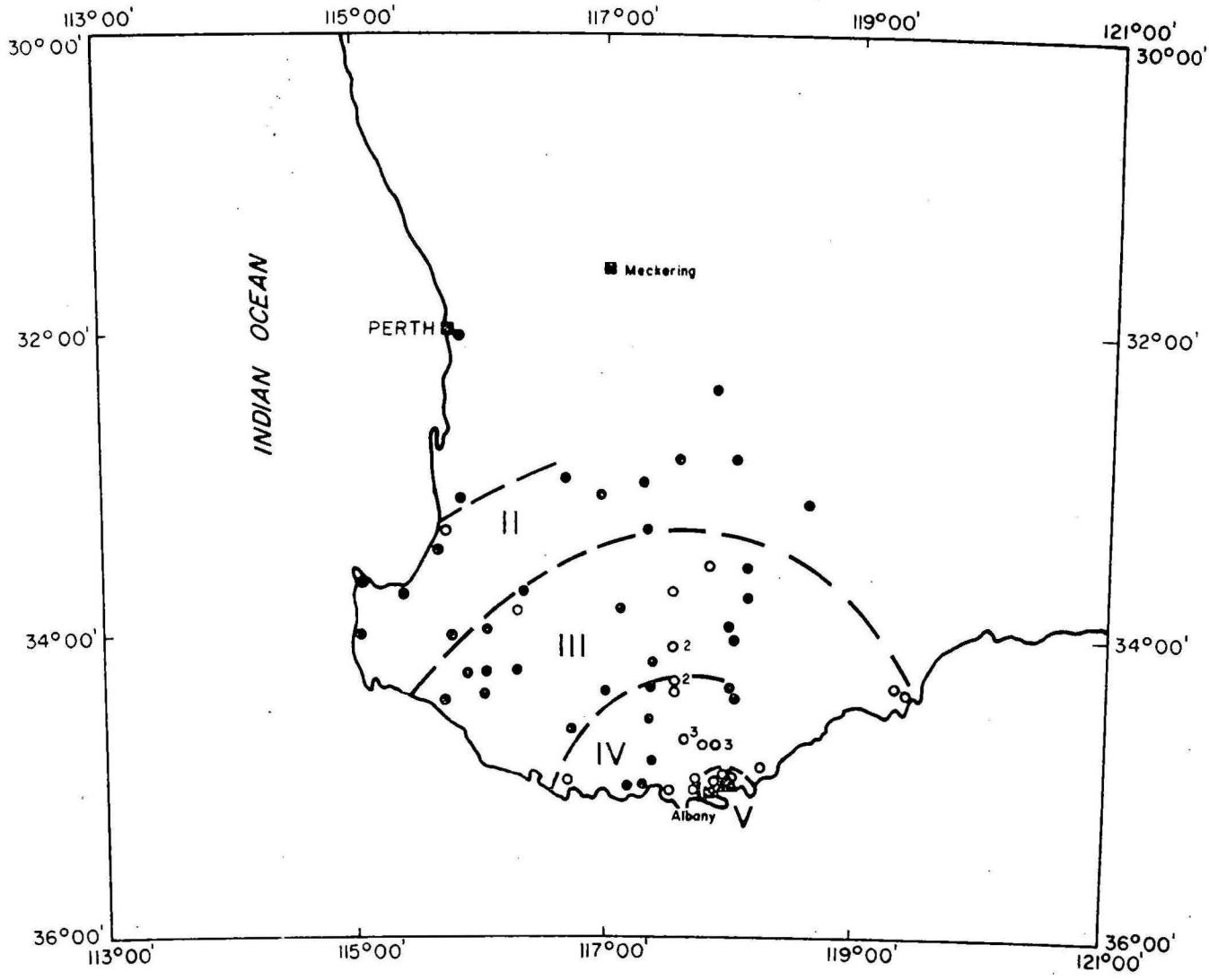


ATTENUATION OF GROUND DISPLACEMENT ($T \simeq 0{\cdot}25$)
FOR MEEKATHARRA BLAST OF AUGUST 1977
(13 TONNES)

Record No. 1978/73

G50/89-10A

ISOSEISMAL MAP OF ALBANY EARTHQUAKE 15 MAY 1977

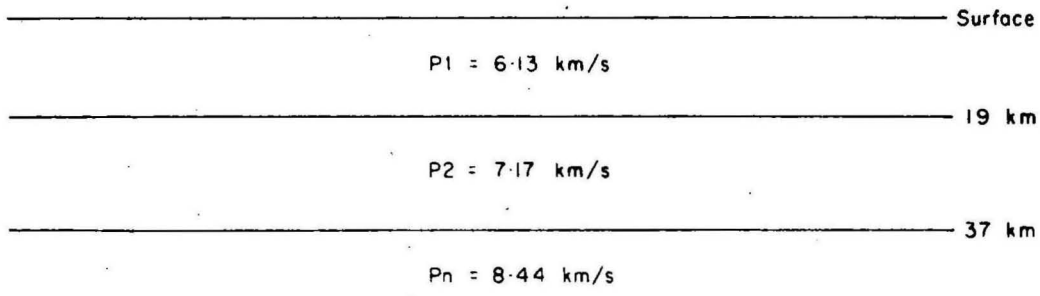


KILOMETRES

100 0 100 200 300 400

DATE	: 15 MAY 1977	▲	EPICENTRE
TIME	: 19:16:07·6 UTC	o	EARTHQUAKE WAS FELT
MAGNITUDE:	4·5ML	•	EARTHQUAKE WAS NOT FELT
EPICENTRE:	35·00°S 117·95°E	IV	ZONE INTENSITY DESIGNATION (MM)
DEPTH:		■	NAMED PLACE

Small figure beside open circle indicates intensity is different from zone designation



TRAVEL TIMES

Surface focus

P1 Travel time $= \frac{D}{6 \cdot 13}$

P2 Travel time $= \frac{D}{7 \cdot 17} + 3 \cdot 22$

Pn Travel time $= \frac{D}{8 \cdot 44} + 6 \cdot 91$

First layer

P1 Travel time $= \frac{(D^2+d^2)^{\frac{1}{2}}}{6 \cdot 13}$

P2 Travel time $= \frac{D}{7 \cdot 17} + 3 \cdot 22 - 0 \cdot 085d$

Pn Travel time $= \frac{D}{8 \cdot 44} + 6 \cdot 91 - 0 \cdot 112\,d$

Second layer

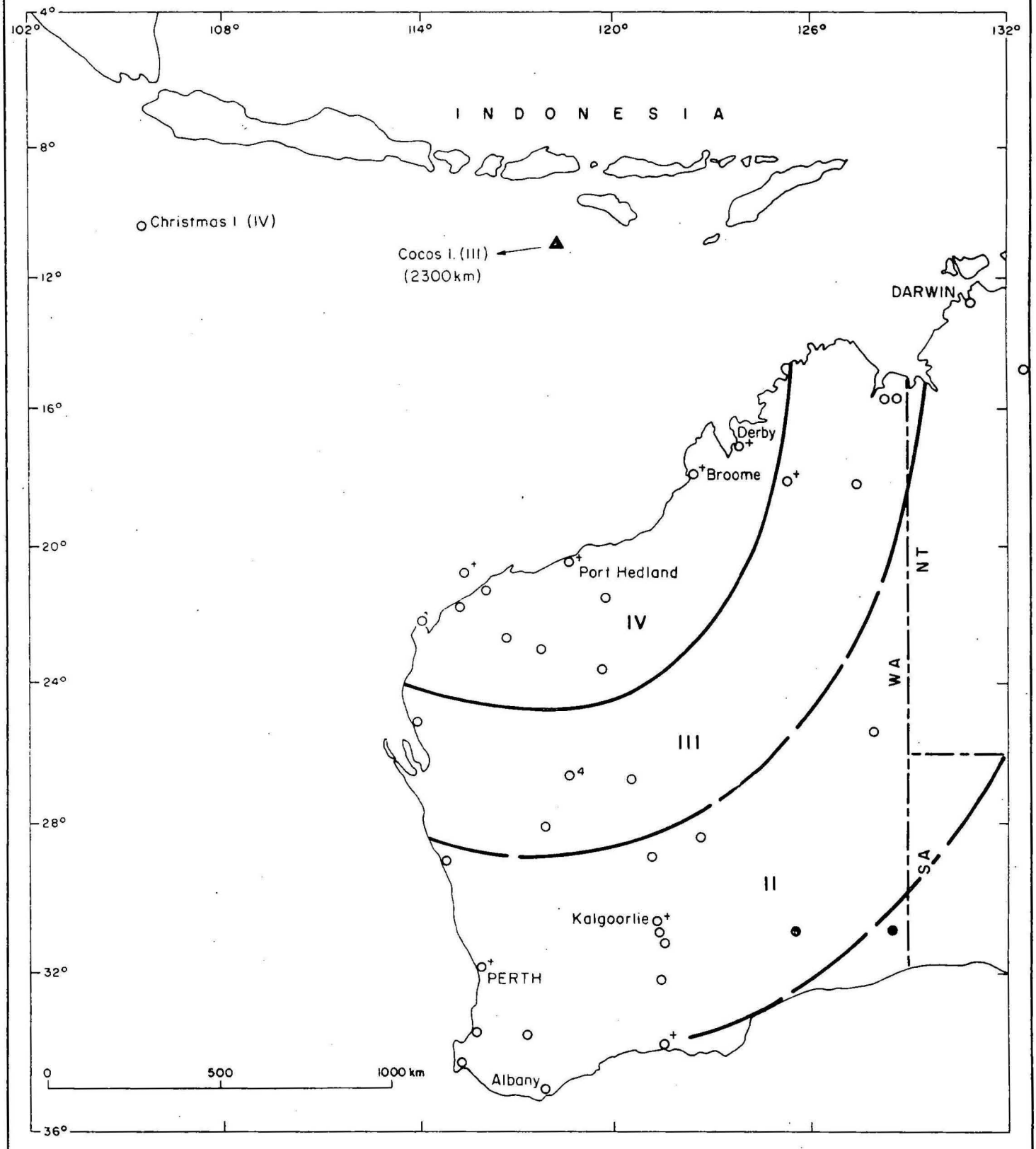
Pn Travel time $= \frac{D}{8 \cdot 44} + 6 \cdot 18 - 0 \cdot 074\,d$

Where D = epicentral distance, kilometres

d = depth, kilometres

CRUSTAL MODEL FOR TRAVEL TIMES IN SOUTHWEST OF WESTERN AUSTRALIA

ISOSEISMAL MAP OF THE INDONESIAN EARTHQUAKE 19 AUGUST 1977



DATE : 19 AUGUST 1977

TIME : 06:08:51 UT

MAGNITUDE : 8·4 M

EPICENTRE : 11·0°S 118·2°E

DEPTH : SHALLOW

▲ EPICENTRE

○ EARTHQUAKE WAS FELT

● EARTHQUAKE WAS NOT FELT

IV ZONE INTENSITY DESIGNATION (MM)

Small figure beside open circle indicates intensity is different from zone designation

Small cross beside open circle indicates intensity is approaching higher zone