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Record No. 1969 / 96

Mundaring Geophysical Observatory, Annual Report 1967

by

I.B. Everingham and P.J. Gregson

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SUMMARY

During 1967, basic observatory programmes were continued in geomagnetism, ionospherics, and seismology at the Mundaring Geophysical Observatory, the main instruments being the Eschenhagen normal-run magnetograph, a Cossor ionosonde, and a Worldwide Standarised Seismograph System.

A seismograph was operated continuously at Kalgoorlie and another was installed at Meekatharra in October.

Annual lists of Western Australian and larger Australian earthquakes were compiled, and a seismicity map of Western Australia was drawn.

In the course of the year crustal structure and upper-mantle investigations proceeded with the gathering of travel-time data from explosion recordings as opportunities arose.

Gnangara geomagnetic secular variation curves are presented.

1. INTRODUCTION

The Mundaring Geophysical Observatory came into being on 18 March 1959 and now controls operations at Mundaring (seismological and ionospheric recording), Gnangara (magnetic recording), Kalgoorlie (seismological recording), and Meekatharra (seismological recording, since 26 October 1967). Descriptions of the Observatory and an outline of activities there to the end of 1966 have been given in previous Records (Everingham, 1968). The present Record summarises the work during the calendar year 1967. Discussion of non-routine projects is brief, as details are reported separately elsewhere.

2. STAFF AND VISITORS

Staff

Observatory staff are listed in Table 1 and others associated with the observatory's operations in Table 2. Staff absences, for other than recreation leave, are summarised in Table 3.

Everingham attended the ANZAAS Congress in Melbourne from 16 to 20 January, and presented a paper entitled "The crustal structure of the oldest region of the Australian Shield." He then attended the Australian Institute of Physics Summer School in Canberra (23 - 27 January). He also addressed the local Geological Society on "Crustal structure work in W.A." (12 June) and visited Head Office for a programme meeting of Observers-in-charge (24 - 29 September). Visits were made to HMAS "Diamantina" (1 and 9 Feb.) to arrange shipboard procedures for the Fremantle Region Upper Mantle Project (FRUMP).

Gregson attended a four-day "Fortran" Introductory Course at the University of W.A. (May). He visited Kununurra (25 - 27 July) to improve the seismograph, and took part in the Rabaul Crustal Structure Project (12 October to 22 November).

Everingham, Gregson, Woad, and Finlayson (Canberra) carried out the FRUMP work (13 - 21 February) and McGregor (Canberra) co-ordinated field work from the Observatory. Everingham recorded WAPET explosions near Dongara (17 - 25 August).

Visitors

Visitors to the Observatory included C. Gran; J. Zebro of the Worldwide Standarised Seismograph Network (WWSSN) maintenance team; S. Gunson (W.A. Institute of Technology); A.J. Flavelle (BMR); Dr A. Trandall (W.A. Geological Survey); A. Williams (W.A. Public Works); Dr J. Heirtzler (Lamont Geological Observatory); D. Falney (University of NSW); Dr R. Giovanelli (CSIRO); Dr J. Harris and five staff (Perth Observatory); scientists from the USSR Research Ship "ZARYA" and Takeo Seto, S. Kakinuma, M. Yoshicla, K. Kikuchi of the Japanse Antarctic Research Expedition ship "Fuji".

3. GEOMAGNETISM

Normal magnetograph

The Eschenhagen 20-mm/hour magnetograph continued in operation. Four and a half days of recording were lost because the recorder aperture was left closed, and sixteen hours owing to recorder drive stopage.

The H ordinate was increased on 17 July to reduce the large number of negative ordinates. The baseline value drifted 10 gammas during April; otherwise changes were small. H scale values were consistent throughout the year.

Two unusual effects on D baseline values were noted. Firstly an unexplained drift of 1.5 minutes occurred in May. Secondly, during September and October, values were widely scattered. Particular care was taken to ensure that the D coil was left in the same position after D scale value tests, to avoid effects due to magnetism in the coils (McGregor, 1967) so it seems likely that the D baseline scatter was due to mechanical vibration of the variometer. (Note: the D baseline value changed 2 minutes after the Meckering earthquake of 14 October 1968).

Abrupt changes did not occur in the Z baseline value. The Z scale value increased by 0.1 gammas/mm in July and decreased to its earlier value in October, but was otherwise consistent.

The standard deviations of observed values from adopted values were:

Element	Baseline Value	Scale Value
D	0.21 minutes	0.03 minutes/mm
H	1.5 gammas	0.01 gammas/mm
Z	1.6 "	0.02 gammas/mm

A thirteen-pair cable was installed during March between the vault and the control hut. The magnetograph control panel was removed from the vault during May and a new panel was installed in the control hut. Time marking for absolute observations was simplified by increasing the brilliance of the time-mark lamp by means of a delayed-release relay operated by the absolute-house foot switches. Tests and modifications were made on a one-hour time-mark unit during December.

The Gnangara magnetograph circuitry will be shown by Gregson and Woad (in preparation).

Magnetograph tests

Orientation. Tests made on the Eschenhagen magnetograph on 6 September indicated that the Z-variometer magnet was accurately levelled. The H-variometer magnet and D-variometer magnet orientations were found to be E 1.1° N and 0.5° W respectively. The reference meridian was 002.9°T, and the value of H was 23,865 gammas. No adjustments were made.

On checking azimuths prior to the tests it was discovered that the 0 - 180° axis of the D coil was aligned 1.2°E of true north. (The revised July 1966 orientation angle is N 1.3°W).

D scale-value. Observations using a Helmholtz coil were made on a weekly basis from July to November. Eighteen observations gave a mean scale value of 1.07 ± 0.03 minutes/mm. Observations were discontinued because it was suspected that the rotating of the D coil each week caused erratic D baseline values (see above).

Temperature co-efficients. A least-squares analysis was carried out on data for the period August 1966 to March 1967 to determine the H temperature co-efficient of 1.2 gammas/°C. This was adopted from 7 July 1966, when the temperature magnet of the H variometer was last adjusted. (Note: this adjustment was not reported in the Annual Report for 1966). The Z temperature co-efficient was 2.5 gammas/°C, the same as for 1966.

Magnetometer comparisons

Because the proton precession magnetometer (MNZ-1) was inoperable when required, comparisons were not carried out.

Preliminary corrections used throughout the year were:

QHM 291, -14 gammas; QHM 282, -20 gammas; QHM 293, +1 gammas;

BMZ 120, +303 gammas; Askania declinometer 509319 (circle 508135), +0.5 minutes

Data reduction and publications

Data distribution continued as for 1966; in addition, storm warnings and weekly storm data letters were sent to Carpentaria Exploration Company from August.

Mean-hourly-value reduction programme sheets for 1965 and programme sheets and magnetograms for 1963, 1964, and 1966 were sent with magnetograms to Head Office. A routine monthly processing schedule for current data commenced in March with the sending of January 1967 magnetograms and programme sheets to Head Office.

Monthly and annual mean values of H, D, and Z at Gnangara for 1967 are listed in Table 4. The values are derived from magnetogram ordinates on the five local quiet days of each month.

Recent trends in secular variations continued, with H decreasing, D becoming increasingly more westerly, and Z not changing significantly. Plate 1 shows the secular variation curves since 1919; these are continuations of those given by Mcgregor (1966).

Miscellaneous requests attended to were primarily for magnetogram copies (S. Pinter, Czechoslovakia; D.G. McDonald; Imperial College London; Professor S. Akasofu of University of Alaska; Dr F. Jacka of Mawson Institute, University of Adelaide); and information on the geomagnetic field in Western Australia.

Accessory equipment

The Mundaring visual recorder power supply was modified (May) by the addition of a storm switch, by means of which the sensitivity could be halved during disturbed periods. Daily recordings on the induction loop continued to the end of March, after which recordings were made only on Regular World Days.

Effects of O.T.C. transmitters, Gnangara

A geomagnetic-total-force traverse was made (June) between the Observatory site and the transmitting area of the newly installed Overseas Telecommunications Commission Station at Gnangara to test effects of transmitters on the proton-precession magnetometer. Results are shown in Plate 2, and indicate that the magnetometer was unaffected by r.f. interference at distances greater than about 0.5 miles from the aerial array. The test was requested by Head Office because such interference had been postulated as the cause of failure of proton magnetometers at Port Moresby Observatory.

4. IONOSPHERICS

Equipment

The quarter-hourly sounding schedule was continued using the Cossor 7562C ionosonde. The performance of the ionosonde was good apart from repeated detuning of the fixed-frequency oscillator which spoilt recordings for over two weeks in October and caused the loss of 60 hours' record in December. Difficulty in setting the start-of-run frequency was experienced in July. A defective CRO display-tube was replaced in October.

Publications

The hourly values of f min, foE, foEs, foFs and M (3000)F2 were published by the Ionospheric Prediction Service for BMR in the same form as the IPS-D series.

In addition monthly medians and f-plots of E, F2, and M(3000)F2 are currently being published by the U.S. Department of Commerce in its Ionospheric Data series CRPL-FA.

5. SEISMOLOGY

Installations

Vault extension at Mundaring. A 14' x 8' extension to the seismic vault was completed in February. Plate 3 shows the modified vault and the revised instrument layout.

The extension improved operating conditions in that:

(a) The Benimore recorder became easily accessible.

(b) It was not necessary to enter the seismometer room daily to change records.

(c) The control room was enlarged, making access to the control and timing equipment easier and diminishing overheating from electrical gear.

(d) There was room for testing seismographs.

As a result of the construction of the extension a total of two weeks of WWSSN recordings was lost during January and February. The Benimore ran continuously.

Meekatharra outstation. A permanent outstation was established at the Meekatharra airport on 26 October in a 12' x 12' hut built for the purpose. The seismometer was located in an 18" deep pit, thirty yards away.

Details of the station are:

Symbol:	MEK
Location:	Lat. 26° 36' 46" S Long. 118° 32' 42" E
Elevation:	515 metres
Foundation:	Archaean sedimentary rock
Instrument:	Willmore recorder, 0.25-sec. and galvanometer, 1.0-sec. and MK 11 Willmore seismometer. Normal paper speed 53 mm/min. Timing from Mercer chronometer and about two hourly radio (Eddystone) time comparisons. 250V power from Department of Civil Aviation generators.

Routine publication of the MEK data commenced on 1 January 1967.

Ground noise at the site has been satisfactorily low. Artificial vibrations of the seismometer have been absent except when severe storms have occurred and on occasions when a vehicle has passed within a few yards of the seismometer pit.

Modifications and maintenance

A log of more significant features follows:

January. Willmore field seismograph repairs and minor modifications were carried out in preparation for Fremantle region Upper Mantle Project (FRUMP).

February. The Benimore recorder was shifted to the vault extension on 23. A new module was built to supply continuous one-minute pulses from the WWSSN 60-Hz output to drive clocks and the ionosonde programmer.

March. Seven days of KLG record were without accurate timing owing to a radio breakdown. The MUN WWSSN SP-Z galvanometer insert was replaced becuase of a broken suspension (cause unknown).

May. The WWSSN long-period recorder speed was changed from 30 mm/min to the new standard 15 mm/min, in accordance with a request from USGGS. The SP-N galvanometer was replaced when it developed an open circuit.

Routine 120-min/mm Benimore recordings were commenced, using (a) the permanent Benimore and (b) a field recorder when not employed in the field. The recorders operated for alternate 12-hour periods and the seismograms improved resolution of the shortest-period earthquake phases.

June. The safety light system in the vault was improved. The Watts DC amplifier was used to increase the gain of the MUN rapid-run Benimore in order to improve the recordings of P-phase from distant explosions.

MK1 Willmore galvanometers were made less sensitive to 50-Hz interference by insulating them from the recorder frame by means of nylon wheels and a perspex base for the translation wedge. Larger galvanometer mirrors were also added to make adjustments to the light beam less critical.

July. Sensitivities of the Benimore and field seismographs were compared by means of simultaneous recordings at MUN. Willmore recorder seismometer plugs and leads were standarised.

The ORD seismograph was maintained and a semi-automatic radio time-marking device appended (26th). To that date the station timing has been based on aural comparisons of radio and chronometer times.

August. Three days (3rd - 5th) KLG records were without accurate time marks because of radio-programme trouble.

October. The 30 mm/min Benioff recorder was returned from The Lake View and Star site for preparation for use at Meekatharra.

November. A new lead-screw was installed in a Benioff recorder to change the drum-speed from 30 to 60 mm/min.

December. Crystals were replaced in receivers because of VHG's frequency change (12.005 to 12.00 and 7.515 to 7.500 MHz).

Notes on seismicity

Australian earthquakes. Three events (listed in Table 5) were positioned by USGGS. One of these was on the continental shelf north of the Kimberleys.

Western Australian earthquakes. 1967 earthquakes are listed in Table 6 and 7, and larger ones are plotted in Plate 4. Lists are a continuation of previous ones (McGregor, 1967; Everingham, 1968) and give similar data. The division between "minor" (Table 7) and "larger" (Table 6) earthquakes was made on the basis that "minor" earthquakes were well recorded at only one station. Generally an event with magnitude M_L = 3 would be recorded at more than one station whilst one with M_L = 2.5 would not.

During the latter part of 1967 the Meekatharra station considerably improved the detection of earthquakes throughout the State. The Kununurra station (ORD) provided useful data for northern earthquakes.

Seven 1967 earthquakes were located offshore along what could be an ill-defined meridional zone of seismicity at about 112°E between the Banda Arc and about 38°S. This would include the major 1906 earthquake with M=7. (See Plate 4, which includes Stover's (1966) recalculated epicentre for this event).

Other events, with the exception of Nos. 81 and 84 in Table 6, occurred in previously recognised zones of activity. Those two events, with epicentres about 350 miles north-east of Kalgoorlie, were of interest because they were located near the epicentre of a small 1965 event, which was the first known within an extensive otherwise aseismic Shield area in central Western Australia.

Smaller tremors listed in Table 7 were all within the Yandanooka-Cape Riche active zone.

Kalgoorlie events

During 1967, 88 events believed to be rock-bursts were recorded from the mining area of Kalgoorlie. Eighteen of these caused damage in the mines, and over half of them were felt.

Events are not listed as in previous annual reports becuase they will be available in a Record describing results from November 1964 to end of 1967. (Gregson, in preparation).

The release of strain continued steadily at about the same rate as in past years.

Explosion seismology

During 1967, observatory and field recordings were made of explosions at iron-ore quarries, marine explosions by oil prospectors, local quarry blasts, and explosions especially designed for crustal and upper-mantle studies. A brief description of the work is given below. Localities are shown in Plate 5. Data and interpretation will be given in separate reports.

The Fremantle region upper mantle project (FRUMP ONE). During February (13 - 21) the Observatory, in conjunction with the Royal Australian Navy, conducted an offshore seismic experiment designed for the investigation of the deep structure and thickness of the Earth's crust in south Western Australia.

The Navy exploded seventeen 300lb depth charges in the ocean near Fremantle and along the south coast. Three Willmore field seismographs and the permanent seismographs at Mundaring and Kalgoorlie detected the seismic phase from the explosions, which were recorded weakly at distances in excess of 400 kilometres. Ninety-one percent of first arrivals were successfully recorded.

The operational aspects of the project are described by Gregson and Woad (1968).

Preliminary interpretations of the results pointed to a very high Pn velocity (8.9 km/s) in the upper mantle at a depth of roughly 55 km beneath a lower crustal region with P velocity of about 7.5 km/s.

Kwinana explosions. During the closing stages of a habour deepening project at Kwinana, smaller and less frequent explosions than in 1966 were used to soften the ocean bed. However, the Observatory made occasional field recordings of the explosions in the manner outlined by Everingham (1968).

During March an accurate travel-time from MUN to Kwinana blasting area was established, and in March-April fourteen field recordings were obtained at distances less than 70 kilometres.

WAPET marine survey explosions. During the period 28 July to 5 August, over three thousand 66-pound high explosive marine seismic reflection shots were exploded at a depth of six feet at 40-second intervals during firing runs by West Australian Petroleum Pty Ltd in the offshore region between Rottnest Island and Yanchep. Most of the explosions were recorded on the MUN Benimore seismograph at distances in the range 50-110 kilometres, and about three thousand

shot-instant times were recorded on a commercial tape recorder on land via two-way radios. It is proposed to use these travel-time data for a detailed refraction study of the Perth Basin deep structure.

During August, shot instants of marine seismic refraction shots at three points off the west coast at Lat. 29°S (near Geraldton) were recorded at a land base as before. Charges ranged from 100 to 2000 pounds in weight. Seismic recordings were obtained at Walkaway, MUN, near Williams, and KLG, at distances of approximately 30, 350, 460, and 680 kilometres respectively. Ground amplitudes recorded at Walkaway indicated that amplitude of ground motion was about directly proportional to charge size (changes were at a depth of about 130 feet).

The results of the more distant recordings (from MUN to the south-east) gave a reversed Pn velocity which tended to confirm the high velocity in the upper mantle indicated by the FRUMP work.

Quarry blasts. During routine seismograph interpretation it was deduced that events recorded at MUN and KLG were blasts at the Koolyanobbing Iron-Ore quarry. To investigate their potential for crustal structure work, seismic travel-times feom one three-ton blast (28 June) were measured. Recordings were made at KLG (186 km), in the field (170 km) and at MUN (340 km). It was concluded that such explosions could be used to provide reliable travel-times at distances up to 250 km.

Later (24 August) travel-times to MUN (309 km) and Walkaway (137 km) from a similar iron-ore quarry blast at Koolanooka were measured.

Several recordings of Australian Blue Metal quarry blasts at Kelmscott were made at distances less than 50 km.

Explosions in a water-filled quarry, Byford. Three explosions (maximum 150 lb of ammonium nitrate and dieselene) were fired at a depth of about 35 feet in a water-filled quarry on the Shield close to the Darling Fault near Byford. They were only weakly recorded at MUN (30 km) and two closer stations. Unless the explosive was incorrectly mixed, results indicate that one-ton charges would be needed here for recordings at distances up to about 200 km and such explosions would therefore have little advantage over large quarry blasts at Kelmscott.

Data and publications

Changes in procedures did not occur during 1967 (see Mcgregor, 1966, p.8).

6. NOTES ON OPERATIONS

Department of Works jobs

Repairs and maintenance and alterations were:-

(a) Extension to seismic vault completed (February).

(b) Repairs and paving of the seismic vault turning circle (March).

(c) Drains installed in the office darkroom and from the office building to the adjacent road (April).

(d) Seismic hut at Meekatharra built (July-October).

(e) Linoleum titles laid in seismic vault (August).

(F) Access road to weir site maintained (October).

(g) Annual fire precautions carried out including fire-breaks at Gnangara and rotary hoeing at the office.

Routine inspection of fire-fighting equipment was organised (November).

(h) Office entrance and parking area re-surfaced (December).

7. ACKNOWLEDGEMENTS

The assistance of the Regional Director and staff of the Department of Supply, Perth, and Messrs D.H. Eggleston and D. Gorton of Kalgoorlie, and Mr. S. Morrisson of Meekatharra (for outstanding servicing) is hereby acknowledged. The co-operation of the Royal Australian Navy and the Crew of the Diamantina, West Australian Petroleum Pty Ltd, Western Mining Corporation Ltd (Koolanooka), Hamersley Iron Pty Ltd (Mount Tom Price), and Dampier Mining Company Ltd (Koolyanobbing), was essential for successful recording of their explosions, and was greatly appreciated.

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TABLE 1

Observatory Staff 1967

Officer	Designation
I.B. Everingham	Geophysicist Acting Cl. 3
P.J. Gregson	Geophysicist Acting Cl. 2
M.F. Barbetti	Geophysicist Cl. 1 (7 March to 14 July)
A. Parkes	Technical Officer Gr. 2
G. Woad	Technical Officer Gr. 1
T.D. Dunning (Miss)	Clerical Assistant Gr. 1
N. Keating	Assistant Gr. 1 (to 14 July)
J.D. Cochrane	Assistant Gr.1 (from 7 August)

TABLE 2

Associated personnel 1967

R.M. Kerr	University Student, vacation 1966/67
G. Eichinski	University Student, vacation 1966/67
A.S. Murray	University Student, vacation 1967/68
R.S. Smith	University Student, vacation 1967/68
J.B. Connelly	Geophysicist Cl. 1, Antarctic trainee (to 12 June)
R.S. Smith	Geophysicist Cl. 1, Antarctic trainee (26 June to 6 November)
D.H. Eggleston	Daily attendant, Kalgoorlie seismograph (to August)
D. Gorton	Daily attendant, Kalgoorlie seismograph (from August)
S.J. Morrison	Daily attendant, Meekatharra seismograph (from 25 October)
E. Wormall	Daily attendant, Gnangara magnetograph (to December)
P. Johannsen	Daily attendant, Gnangara magnetograph (from December)

TABLE 3

Observatory staff absences 1967

Nature of absence	No. of man-days
Sick, special, repatriation leave	35
Military leave	33
Attendance at outstations, local field work	48
Conferences and interstate travel	61
Total	177

Table 4

Provisional 1967 monthly and annual mean values of geomagnetic elements

	H, gammas	D (W)	Z, gammas
Jan	23 879	2°53.7'	-53 503
Feb	873	53.5	502
Mar	877	53.5	497
Apr	874	53.6	499
May	865	53.8	502
Jun	585	54.1	507
Jul	862	54.1	502
Aug	865	54.3	497
Sep	866	54.4	493
Oct	867	54.5	490
Nov	870	54.9	493
Dec	859	55.2	498
Year	23 868	2°54.1'	-53499

TABLE 5

USCGS PDE data for Australia (1967)

	H (U T)	Lat. °S	Long. °E	PDE Card	Depth km	mb
	h m s					
Jan 14	11 32 57	29.2	145.9	8/67	33R	
15	02 28 41	38.9	144.6	8/67	33R	
Apr 03	04 40 42.2	12.2	126.3	34/67	33R	5.1

TABLE 6

Large earthquakes in the region of Western Australia, 1967

No.	Date 1967	H (U.T)	Lat. °S	Long °E	Dist. (MUN) km	Magnitude M_L	Magnitude m'	Magnitude m_b MUN	Magnitude m_b KLG	Magnitude m	Remarks (see footnotes)
67	Jan 31	06 25 42	17.4	120.2	1680			3.9		4.3	Recorded DAR, WRA
68	Mar 02	07 04 53	26.8	110.7	780			4.2	4.6	4.8	
69	Mar 12	13 37 10	36.4	111.4	660			3.9	4.1	4.4	Oceanic crust
70	Apr 03	04 40 42.4	12.2	126.3	2140			5.2	5.1	5.6	See Table 5. Clear Lg.
71	Apr 03	08 01 07	30.7	116.5	145	3.0	4.0	3.1		3.7	
72	Apr 04	05 58 02	38.2	114.0	720			4.8	4.8	5.2	Oceanic crust
73	Jul 17	09 14 14	32.0	117.3	103	2.8	3.9	3.7		4.0	
74	Aug 29	11 02 22	31.9	117.3	103	3.2	4.2	4.2	4.0	4.4	
75	Aug 29	21 09 26	31.9	117.3	103	3.4	4.3	4.3	4.1	4.5	
76	Sep 18	13 33 57	32.0	117.3	102	3.4	4.3	3.7	3.9	4.2	
77	Oct 12	10 31 04	17.9	123.9	1770			4.1		4.5	
78	Oct 22	10 38 15	32.0	117.3	99	3.5	4.4	4.6	3.8	4.4	
79	Nov 12	05 05 24	17.8	120.2	1615			3.9		4.3	Recorded MEK, ORD, WRA
80	Nov 21	10 37 16	28.6	124.6	900	3.1*	4.1	3.4	3.8	4.0	*KLG S2, recorded MEK

TABLE 6 (continued)

No.	Date 1967	H (U T)	Lat. °S	Long. °E	Dist. (MUN) km	Magnitude M_L	m'	m_o MUN	KLG	m	Remarks
81	Nov 27	16 32 52	25.6	110.8	880			3.6	3.5	4.0	recorded MEK
82	Nov 28	08 30 14	19.0	113.5	1460			4.7		5.1	recorded MEK, not KLG
83	Dec 14	14 17 18	(29.0)	(124.1)	815	2.8*	3.9		3.9	4.1	*KLG 52, recorded MEK
84	Dec 17	03 30 56	25.3	111.3	880			4.3		4.7	recorded MEK, not KLG
85	Dec 27	06 10 20	29.1	112.8	460	4.1	4.8	4.1	5.0	4.9	recorded MEK

Notes

DAR - Darwin, WRA - Warramunga, ORD - Kununurra

M_L - determined from MUN records unless designated

m' - derived from M_L via $m = 1.8 + 0.73\ M_L$

m_b - determined using Everingham's (1968) curve B for attenuation function

m - Unified magnitude (weighted mean of m' and (m_b + 0.4) values for MUN & KLG)

() - less accurate value

All events recorded at MUN and KLG unless designated.

TABLE 7

Minor local earthquakes 1967

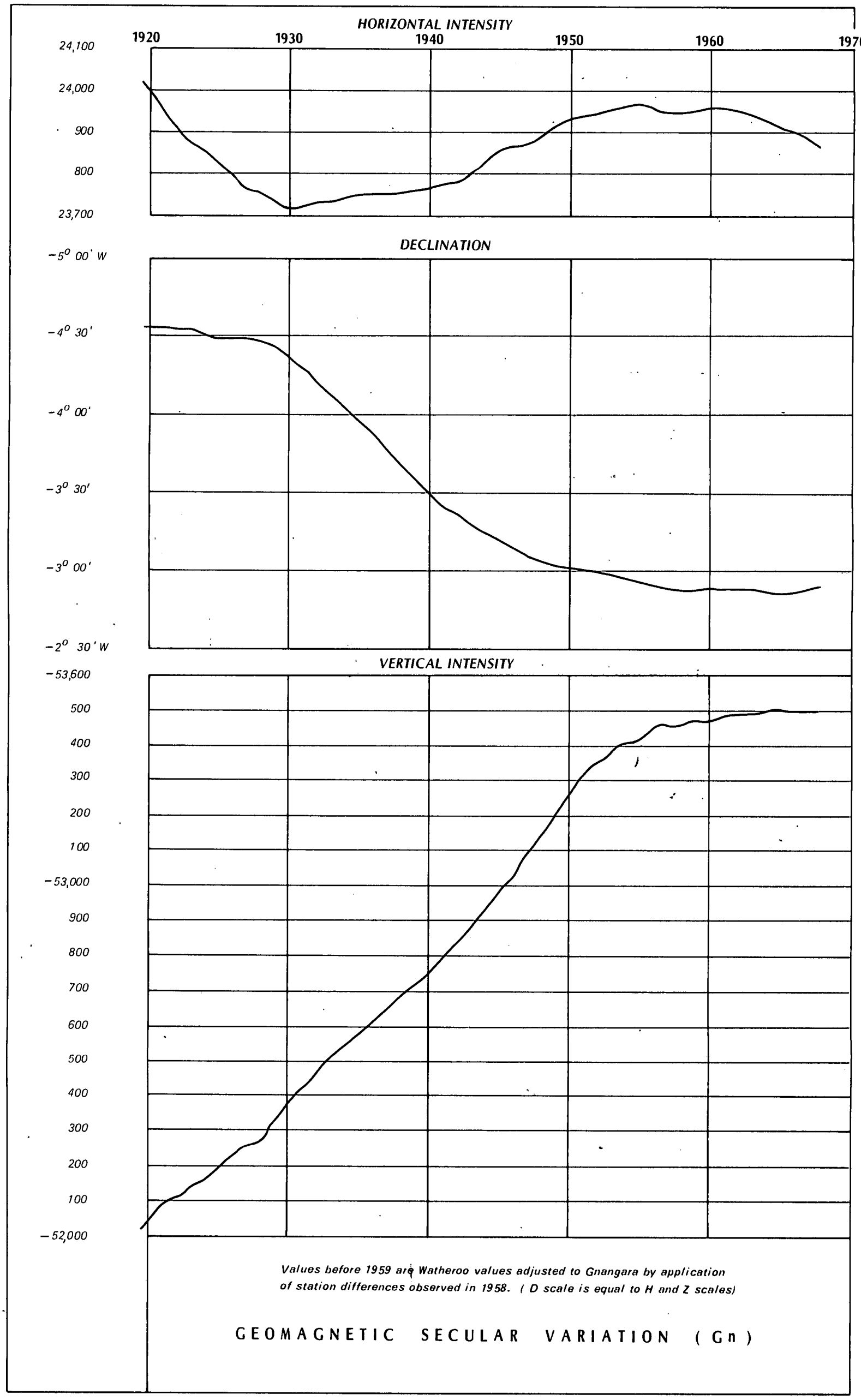
Date 1967	P-arrival Time U T	M_L	m_b	Dist. km	Bearing ^oT	Remarks
	h m s					
Mar 14	21 25 11	1.7		73	076	Bearings and distances
24	04 50 43	2.6	2.8	145	009	and from MUN unless
29	16 19 15	2.3		145	009	stipulated
Apr 10	17 54 04	1.9	2.9	67	109	
10	19 52 17	2.1	2.7	98	072	
10	20 38 29	1.8		96	068	
14	04 14 04	1.7		65	107	
May 02	15 02 51	1.9	3.3	99	109	
07	11 15 09	1.7		99	109	
Jul 16	19 58 51	2.3		102	(090)	
18	00 17 06	2.2		103	(090)	
27	12 24 30	2.4		103	(090)	
Aug 04	13 00 32	2.0	2.7	95	012	
19	23 47 30	1.7		100	(090)	
25	05 42 44	2.3	3.0	98	(090)	
29	11 05 12	1.9	3.4	103	084	
29	11 07 36	2.0	3.3	101	084	
29	11 12 06	2.1	3.6	103	(090)	
29	21 59 59	2.0		102	087	
Sep 01	07 56 57	2.4	3.6	102	(090)	
01	19 07 46	1.9		103	(000)	
08	23 36 34	2.1		102	(090)	
09	00 26 44	2.3		102	085	
10	15 01 19	1.7	2.7	101	(090)	
10	19 56 51	2.1	3.0	101	(090)	
13	21 36 53	2.0	2.5	102	(090)	
28	12 05 12.5	1.4	3.1	68	116	
Oct 20	22 33 30	2.0	3.5	70	108	
30	05 17 24	1.9	3.0	99	(090)	

TABLE 7 (cont.).

Minor local earthquakes 1967

Date 1967	P-arrival Time U T	M_L	m_b	Dist. km	Bearing ^oT	Remarks
	h m s					
Nov 03	10 08 37	1.5	3.1	90	104	
09	00 44 48	2.4	3.5	112	010	
19	08 23 53	1.9	3.2	66	108	
Nov 24	23 44 53	1.7		60	108	
Dec 04	06 44 07	1.8	3.2	86	097	
12	15 39 53	14	2.9	65	097	
14	17 27 44	2.5	3.2	135	010	KLG m = 3.1
20	21 35 37	1.9		76	061	
22	17 13 37	1.7		76	059	
23	10 12 09	2.1		76	059	
26	12 17 38	2.3	3.2	99	(090)	
30	06 10 16	2.3		103	(090)	

BINDING



Values before 1959 are Watheroo values adjusted to Gnangara by application of station differences observed in 1958. (D scale is equal to H and Z scales)

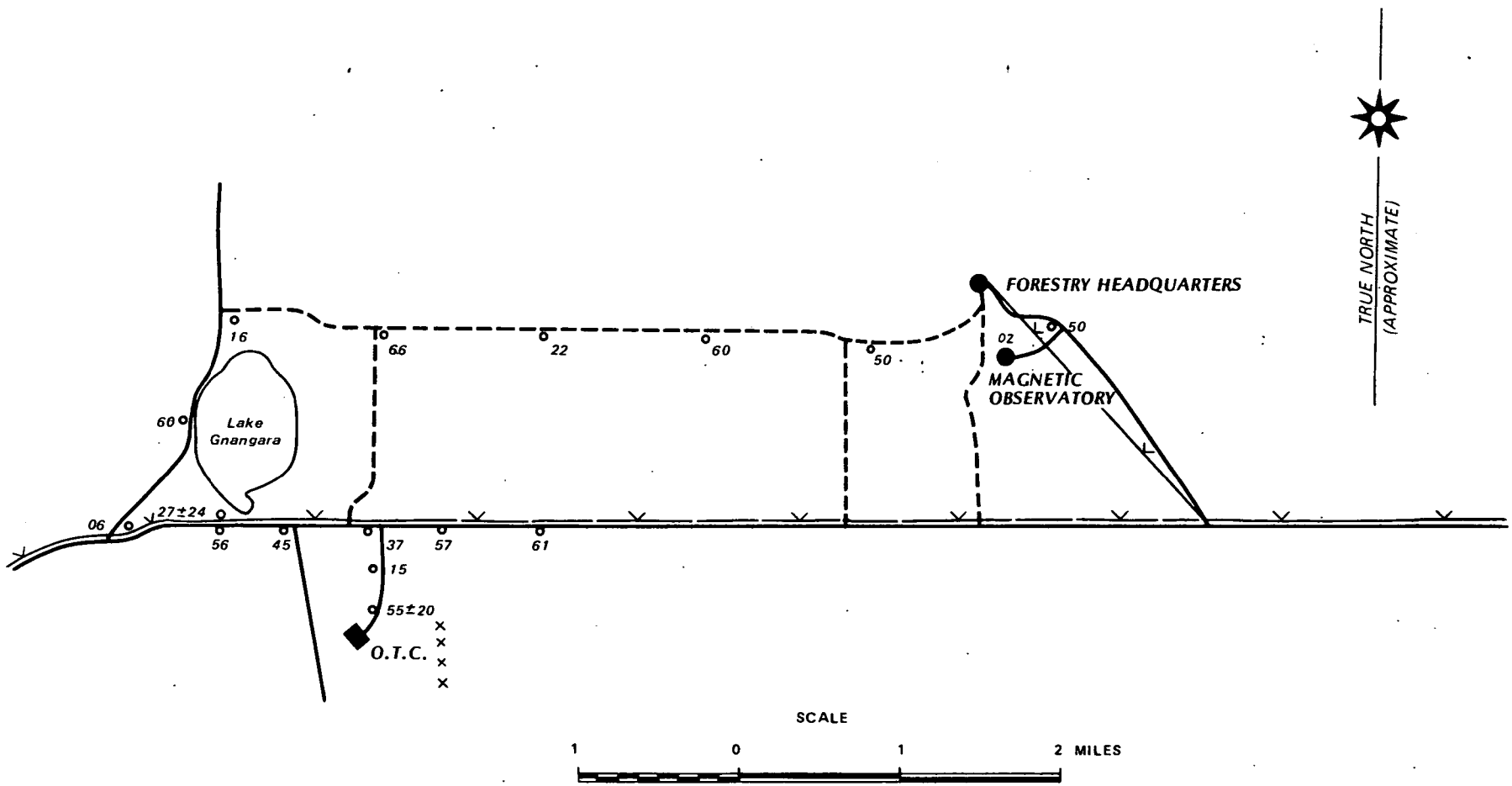
GEOMAGNETIC SECULAR VARIATION (Gn)

PLATE 1

(BASED ON G82/1 47)

To accompany Record No. 1969/96

G82/1–48



GEOMAGNETIC TOTAL FORCE TRAVERSE

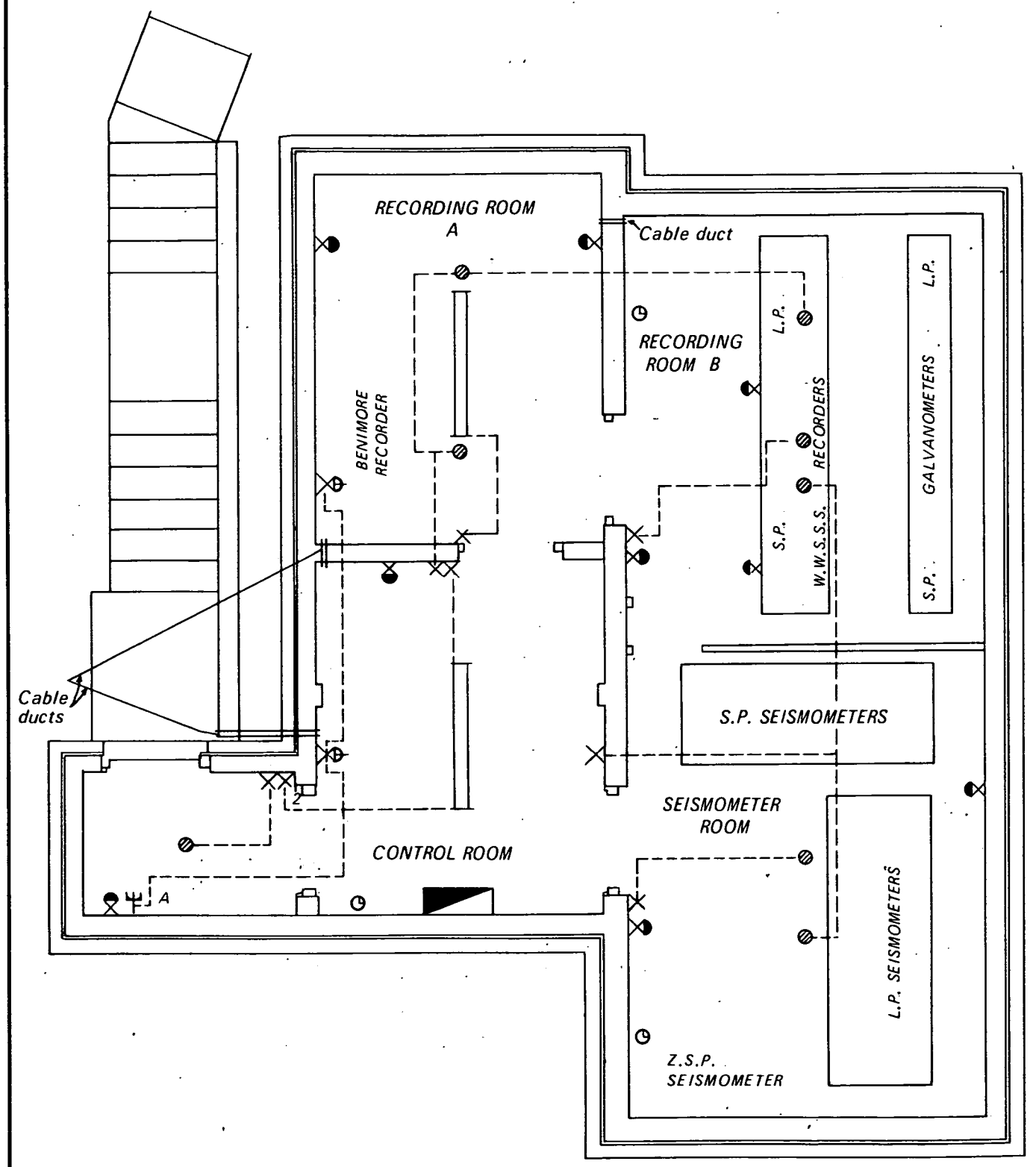
GNANGARA

To Accompany Record No. 1969/96

PLATE 2

G82/1-49

PLATE 3



LEGEND

- Clock
- Incandescent
- Fluorescent
- Reversed inlet socket
- Power outlet special purpose switched
- Power outlet
- Switchwire
- Distribution board
- Wall switch

MUNDARING OBSERVATORY – SEISMOGRAPH VAULT

To Accompany Record No. 1969/96

G82/3–130

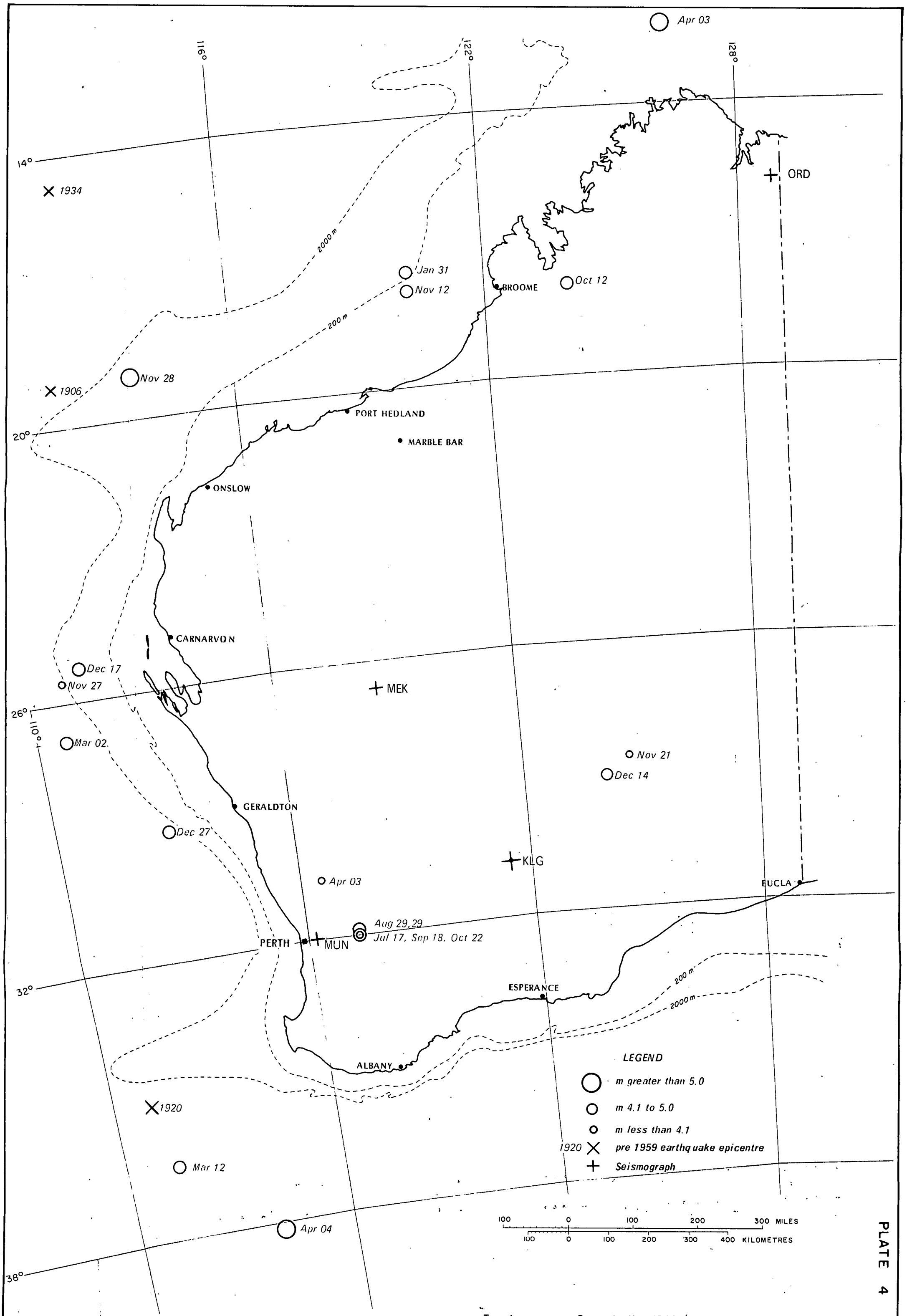

Apr 03
116°
122°
128°
14°
1934
2000 m
Jan 31
Nov 12
BROOME
Oct 12
ORD
200 m
1906
Nov 28
PORT HEDLAND
MARBLE BAR
20°
ONSLOW
CARNARVON
Dec 17
Nov 27
MEK
26°
110°
Mar 02
Nov 21
Dec 14
GERALDTON
Dec 27
KLG
Apr 03
EUCLA
Aug 29,29
Jul 17, Sep 18, Oct 22
PERTH
MUN
32°
ESPERANCE
200 m
2000 m
ALBANY
LEGEND
m greater than 5.0
m 4.1 to 5.0
m less than 4.1
1920
pre 1959 earthquake epicentre
Seismograph
1920
Mar 12
Apr 04
100 0 100 200 300 MILES
100 0 100 200 300 400 KILOMETRES
38°
PLATE 4
To Accompany Record No. 1969/96
G82/4–73

PLATE 5

115° 118° 121° 124° 127°

26° 29° 32°

MUN TO TOM PRICE

TO TOM PRICE

MEK

CUE

Lake Austin

Lake Carnegie

Lake Wells

Lake Gillen

Lake Yeo

Lake Raeson

Salt Lakes

Lake Barlee

Lake Carey

Lake Bullard

Jubilee Lakes

Lake Ell

Plumridge Lakes

GERALDTON

WALKAWAY

WAPET

BY-B

G.F

DONGARA

KOOLANOOKA

Lake Monger

Lake Moore

PRECAMBRIAN SHIELD

Lake Currajong

Lake Rebecca

Mulgabbie Salt Lake

INDIAN OCEAN

PERTH BASIN

KOOLYANOBBING

Lake Seabrook

KALGOORLIE

KLG

COOLGARDIE

RAWLINNA

FORREST

SOUTH AUSTRALIA

BOORABBIN

SOUTHERN CROSS

Lake Lefroy

WIDGIEMOOLTHA

MERREDIN

Lake Cowan

FRUMP B

WAPET REFLECTION SURVEY

MUN

ABM QUARRY

FRUMP A

KWINANA

BYFORD

DARLING FAULT

NORSEMAN

Lake Johnston

Lake Dundas

Lake Hope

EUCLA

EYRE

WILLIAMS

NARROGIN

BUNBURY

KATANNING

ESPERANCE

FRUMP E

NORTHCLIFFE

ALBANY

FRUMP D

FRUMP C

BINDING

LEGEND

+	Seismograph station	MUN Mundaring
●	Shot-point	KLG Kalgoorlie
○	Town	MEK Meekatharra

SCALES

50 0 50 100 150 200 MILES

50 0 50 100 150 200 250 300 KILOMETRES

(BASED ON WA/80-2)

(BASED ON GEOLOGICAL MAP OF WESTERN AUSTRALIA 1966)

To Accompany Record No. 1969/96

112° 115° 118° 121° 124° 127°

G82/1-50