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**Mundaring Geophysical Observatory  
Annual Report, 1969**



by

*I. B. Everingham and P. J. Gregson*

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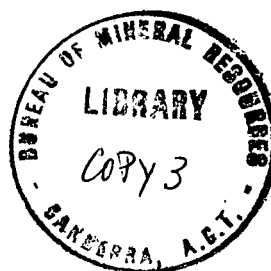
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MUNDARING GEOPHYSICAL OBSERVATORY,

ANNUAL REPORT 1969

By



I.B. EVERINGHAM and P.J. GREGSON

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## SUMMARY

During 1969, basic observatory programmes were continued in geomagnetism, ionospherics, and seismology at the Mundaring Geophysical Observatory, the main instruments being the Eschenhagen normal-run magnetograph, Cossor ionosonde, and a Worldwide Standard Seismograph system.

Seismographs were operated continuously at Kalgoorlie and Meekatharra.

Epicentres of approximately 200 Western Australian earthquakes were determined and annual lists completed. The increase level of seismicity in the Southwest of the State following the 1968 Meckering earthquake continued in 1969.

## 1. INTRODUCTION

The Mundaring Geophysical Observatory opened on 18 March 1959 and now controls operations at Mundaring (seismological and ionospheric recording), Gnangara (magnetic recording), and Kalgoorlie and Meekatharra (seismological recording). Descriptions of the Observatory and an outline of activities there to the end of 1968 have been given in previous Records (e.g. Everingham & Gregson, 1971). This Record summarizes the work during the calendar year 1969. Discussion of non-routine projects is brief, as details are reported separately elsewhere.

## 2. STAFF AND VISITORS

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, and conferences and institutions attended or addresses given, are summarized in Tables 3 and 4.

E. Paull assisted in the New Britain Crustal Study Project from 3 March to 5 May. He also carried out field duties for the first- and third-order regional magnetic surveys between Geraldton and Canberra from 17 October to 19 December. P.J. Gregson acted as Observer-in-Charge of the Port Moresby Observatory from 22 December through the end of the year.

Visitors to the observatory are listed in Table 5.

## 3. GEOMAGNETISM

### Normal magnetograph

The Eschenhagen 20 mm/hour magnetograph continued in operation at Gnangara. Three hours of recording were lost owing to fogging.

The H ordinate was increased by 15 mm on 20 March to reduce the large number of negative ordinates. There were no other abrupt changes in baseline or scale values during the year.

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

<u>Element</u>	<u>Baseline value</u>	<u>Scale value</u>
D	0.24 minutes	-
H	1.7 gammas	0.01 gamma/mm
Z	2.4 gammas	0.02 gamma/mm

An MCO calibrator was installed during March for determination of scale values. The unit was checked before installation, using a digital ammeter. Comparison of current values with the scale-value meter (10923) previously in use showed that the meter had been reading 3 percent too high. Scale values were adjusted from 1 January 1969.

The H and Z scale-value coils were connected in series after tests showed that the field produced by either coil did not affect the other variometer.

#### Magnetograph tests

Temperature co efficient. Least-squares analysis carried out on the 1969 baseline data confirmed co efficient in use, viz.  $Q_H = 1.2 \text{ gammas/}^{\circ}\text{C}$ ,  $Q_Z = 2.5 \text{ gammas/}^{\circ}\text{C}$ .

Parallax tests. Tests during August showed that there was no parallax between the recording trace and time-mark spots for all three components.

#### Magnetometer comparisons and corrections

BMZ 120 was compared through baselines with a proton precession magnetometer Elsec 416 using vector coils to annul H. The magnetometer belonged to the WA Institute of Technology (W.A.I.T.).

Results were:

Apr 16 - May 1	$Z_p = \text{BMZ.120} + 300 \text{ gammas}$	(14 observations)
Jul 2 - Jul 23	$Z_p = \text{BMZ.120} + 294 \text{ gammas}$	(14 observations)
Aug 19 - Aug 21	$Z_p = \text{BMZ.120} + 300 \text{ gammas}$	(4 observations)
Nov 5	$Z_P = \text{BMZ.120} + 299 \text{ gammas}$	(2 observations)

Elsec 416 was compared directly with BMR regional magnetic Elsec 592/424 on 5 November and the two gave identical readings.

QHMs 291, 292, and 293 were compared through baselines with Toolangi QHMs 460, 461, and 462. The Toolangi QHMs were compared at Toolangi on 31 January and had a mean correction of zero. Five observations were made with east QHM. Results were:

Feb 18 to Mar 5	Mean QHM (T00) =	QHM 291	-21 gammas
		QHM 292	-32 gammas
		QHM 293	-10 gammas

From a series of F and Zp readings using Elsec 416 and vector coils, Hp was calculated and compared through baselines with the Gwangara QHMs.

Apr 16 - May 1	Hp =	QHM 291	-22 gammas	(6 observations)
		292	-31 gammas	(6 observations)
		293	-6 gammas	(6 observations)

Jul 2 - Jul 23	Hp =	QHM 291	-20 gammas	(8 observations)
		292	-30 gammas	(8 observations)
		293	-5 gammas	(8 observations)

Mean observed differences for 1969 were:

QHM 291 - QHM 293 = 15 gammas  
QHM 292 - QHM 293 = 24 gammas

Preliminary corrections: Those used throughout the year were:

- (a) QHM 291, -14 gammas; QHM 292, -20 gammas; QHM 293, +1 gammas.
- (b) BMZ 120, +302 gammas.
- (c) Askania declinometer 509319, (circle 508135), + 0.5 minutes.

These corrections were carried on from 1968. It was not until May that proton comparison results confirmed the QHM comparisons carried out in February.

#### Data reduction and publications

Data distribution and mean hourly value reduction data continued as for 1968. In addition weekly K-indices and storm data letters were distributed to a further eleven exploration companies, making a total of fifteen.

Monthly and annual mean values of H, D, and Z at Gwangara for 1969 are listed in Table 6. The values are derived from magnetogram ordinates on the five local quiet days of each month.

Recent trends in secular variation for H and D continued with H decreasing by about 20 gammas per year and D becoming more westerly by about 1.7 minutes per year. Z appears to be decreasing numerically by about 5 gammas per year over the last two years.

Miscellaneous requests attended to were primarily for magnetogram copies (Science Research Council, Radio and Space Research, England; Carpentaria Exploration Co., Kalgoorlie; Geomagnetisches Institute, Potsdam) and information on the geomagnetic field in Western Australia.

#### Accessory equipment

The Mundaring Askania visual recorder continued to operate throughout the year.

An AFMAG recording instrument was operated for the Metalliferous Group, throughout the year at Mundaring Weir.

### 4. IONOSPHERICS

#### Equipment

The quarter-hourly sounding schedule was continued using the Cossor 7562C Ionosonde. The performance of the ionosonde deteriorated during the year. Thirty-two days' (26 from October to December) record were lost owing to breakdown of components, including the h.t. transformer on two occasions. Other record losses were due to power failure (73 hours), camera shutter jamming (36 hours), film jamming (50 hours), and operator error (24 hours). Two days' records were lost in January when an attempt was made to install a crystal-controlled variable-frequency oscillator. The attempt was unsuccessful and the original v.f.c. was modified and reinstalled.

#### Publications

Scaling procedures were altered from February, at the request of the Ionospheric Prediction Service Division. Hourly values of  $f_{min}$ ,  $fEs$ ,  $fbEs$ ,  $foF2$ ,  $M(3000)F2$ ,  $FxI$ , and  $M(3000)I$  are now published for BMR in the form of the IPS-D series.

In addition monthly medians and  $f$ -plots of  $F2$  and  $M(3000)F2$  are currently being published by the U.S. Department of Commerce in their Ionospheric Data series CRPL-FA: the median and  $f$ -plot for  $foE$  were discontinued after March.



## 5. SEISMOLOGY

Extraction of MUN, MEK, and KLG data continued without changes.

### Instruments

A log of more significant modifications, installations, faults, and maintenance of equipment follows.

February. The Kalgoorlie (KLG) vertical seismograph required adjustment (12th). The seismometer was buried 30 yards from the seismograph housing to ascertain whether the situation was quieter. There was no marked difference.

The 30-day film recorder was received and repairs and installation in the portable field seismograph cabin commenced. The galvanometer was found to be damaged and was sent to the makers in USA for repairs. Instruments for the New Britain Crustal Project and for a ground noise survey for the proposed Kimberley seismograph were prepared.

March. After the monthly systems test it was necessary to adjust the WWSSN short-period N, E, and Z seismometer periods. The KLG Z galvanometer gave further defocusing trouble and was exchanged with the NW one. Two days' Meekatharra (MEK) records (27th, 29th) were lost owing to a blown globe and a power failure. Maintenance was carried out and advice given to the operator at the PWD Kununurra (KNA) station (3rd).

The galvanometer for the 30-day recorder was installed after being in the USA, and tests show the instrument to be in reasonable working order.

April. MEK records were without timing control, 11-16th. The 30-day recorder was installed in the MUN vault for more prolonged testing; the record was excellent. A calibration coil was installed in the Benioff seismometer used with the Benimore seismograph (MUN).

May. The Willmore recorder was returned from Rabaul and overhauled and reinstalled at MUN. A temporary control and emergency power unit was made for the 30-day film recorder. Work started on control units for the proposed Broome seismograph and for MEK when the crystal clock was installed.

June. Control units for Broome (proposed BME) and MEK were completed.

July. The WWSSN short-period recorder was overhauled. Intermittent trouble with the KLG Z recorder translation clutch occurred. One KLG horizontal component remained out of service because of a faulty galvanometer. An internal calibration unit was designed and installed in a Willmore MkII seismometer. It was necessary to replace one card in one of the newly received EMI crystal clocks.

The MEK control module was replaced and a crystal clock installed (3rd, 4th).

A Willmore seismograph (MkI seismo. and 0.25-sec. galvo. gain on 1/10th) was installed at Broome (7th) in the main meteorological Bureau building at the airport.

August. The Broome seismograph was not running reliably owing to operator inefficiency.

A new galvanometer (period 0.75 seconds) was tested at KLG.

The 30-day film recorder was installed at a temporary site at Southern Cross to record phases from the seismic party explosions in the Kambalda area.

September. The Broome seismograph ran erratically during the month. Recording was stopped on 23rd so that the chronometer could be returned to Mundaring for repairs.

No recordings were made on the 30-day recorder at Southern Cross (SXC) as a bearing in the drum drive seized up. Repairs were made subsequently.

Nine Geotraverse explosions at the Boorabbin Probe were recorded at twelve field sites using a Willmore seismograph operated by observatory staff and a Moseley recorder operated by the seismic party. Records from the latter were inferior. These explosions were also recorded on the Mundaring and Kalgoorlie seismographs.

October. Recordings at Broome were suspended (3rd) and the seismograph returned to Mundaring for use in the Geotraverse refraction work. The 30-day film recorder was reinstalled at Southern Cross (7th). Two of the EMI crystal clocks required transistor replacements in their time pulse output circuit.

Twelve refraction recordings of Seismic Party No. 2 shots were obtained on the portable seismographs operated by observatory staff. KLG and MUN also recorded the shots.

November. The timing card (No. 3) was replaced in the EMI clock at MEK (25th). Some trouble was experienced with the WWSSN recorder power supply (14th, 30th).

December. The 30-day film recorder was reinstalled at Southern Cross (18th) after repairs to the film transport mechanism. Non-critical faults at MEK (time-mark relay) and KLG (fogged records) were corrected by local operators.

### Seismicity

Earthquake lists. 1969 Western Australian earthquakes are listed in Tables 7 and 8 in the same form as for 1968 (Everingham & Gregson, 1971).

The division between the larger and minor earthquakes (i.e. those in Table 7 and those in Table 8) was made on the basis that minor earthquakes were well recorded at only one station. Generally an event in the southern part of the state with  $M_L = 3.0$  or greater would be recorded at more than one station. For northern areas of the State earthquakes would need a magnitude of at least  $M_L = 4.0$  or greater to be well recorded at more than one station.

All larger W.A. earthquakes are plotted in Plates 1 and 2.

The Mundaring observatory annual listings of USCGS data for Australia was discontinued after 1968 as this service was transferred to the BMR Head Office, Canberra. However, two Northern Territory events which occurred on 27 October are listed in Table 7 because they were not shown on CGS PDE cards and would not appear on any other known listing.

Earthquakes felt. A log of the main felt events follows.

February. Numerous tremors with magnitude ( $M_L$ ) as high as 4.0 occurred in a very localized area at Mawson (40 km SSE of Meckering) during the period 28 Jan-3 Feb. The area was visited in order to inspect damage, to advise residents about the tremors, and to obtain Willmore seismograph recordings.

June. The press and radio news services were given data on tremors felt at Cunderdin (10th), Gwambygine (12th), Landor (17th), Cadoux (26th), and Meckering (29th). Another interesting felt event occurred in the Carnarvon Basin near Middalya H.S. (19th).

July. Press and radio news services were given data on felt tremors at Meckering (1st and 30th) and at Cadoux (27th).

October. The public and news services were given information on felt tremors located near Meckering (9th) and Cadoux (23rd).

November. The public and news services were given information on felt tremors located near Bolgart (5th), Pingelly (22nd), and Cunderdin (26th). The Bolgart event was recorded on a field seismograph at Tammin.

The majority of tremors were felt over very restricted areas, suggesting very shallow hypocentres. A field recording of two extremely small events at Mawson indicated depths of less than 2 km, and a depth of 15 km was calculated for an event at Bolgart recorded at a field station.

The Landor earthquake of 17 June was felt over a wide area, and an isoseismal survey was carried out. The maximum intensity reported was MM5. Results were presented by Everingham & Parkes (in prep.).

Earthquakes in the south-western part of the State. 1969 events for this region are plotted in Plate 3.

As in 1968 (Everingham & Gregson, 1971) the central part of the Yandanooka-Cape Riche zone of seismicity was unusually active and almost all felt reports were from this region. Apparently the regional stress distribution has changed as a result of the relatively large Meckering earthquake of 14 October, 1968, and readjustments are taking place over an area of about 25,000 km<sup>2</sup> (see Plate 3).

#### Explosion seismology

During September, October, and November a BMR seismic party made six reflection probes of the WA Precambrian shield between the Fraser Range and Mundaring as a contribution to the International Upper Mantle Project. Larger explosions in this project were also recorded by one or two mobile stations and by permanent observatory stations (KLG, MUN, MEK), for seismic refraction studies of the areas.

Full details of operations, instruments, and data are reported by Gregson & Paull (1971).

Preliminary interpretations suggest that the crust beneath the southwestern shield is different from that beneath the more central areas in that the former is thicker and denser. A shallow intermediate crustal layer with P-velocity 7.25 km/sec (reversed) was proven in the southwest part of the State. Provisional interpretations indicate the following crustal structures.

		<u>SW AUST. SHIELD</u>		<u>CENTRAL (KALGOORLIE) SHIELD</u>	
		P-wave velocity (km/sec)	Thickness (km)	P-wave velocity (km/sec)	Thickness (km)
CRUST LAYER	1	6.2	17	6.2	28
CRUST LAYER	2	7.25	29	7.25	3
UPPER MANTLE		8.4		8.4	
MOHO DEPTH			46km		31 km

The crustal structure beneath the Perth Basin area appears to be much the same as for the SW Shield, and not thicker as suggested by Everingham (1965).

#### Ground noise tests

To investigate the suitability of sites for a seismograph at Broome a portable visual-recording seismograph was constructed.

Tests carried out at Mundaring area showed that large variations in ground noise occurred in regions of differing geology. It was found that the instrument could be operated at full gain on quiet shield areas, whereas on areas covered by thick sand, unconsolidated rock, or alluvium the instrument could be operated at only one-tenth full gain because of the increase in noise level. Suitability of recording sites could be categorized as good, fair, or poor on the basis of ground noise level.

During field trips, tests were made at various towns in Western Australia (see Plate 3) and the following classifications made:

Derby	-	very poor	Dampier	-	good
Broome	-	poor	Geraldton	-	fair
Port Hedland	-	fair	Perth	-	poor
Mount Newman	-	fair	Mundaring	-	good
Carnarvon	-	poor			

#### Reports and publications

Reports with 1969 seismological content were prepared by Everingham, Gregson & Doyle (1969), Everingham & Gregson (1969), Everingham & Gregson (1971), and Gregson & Woad (1970).

### 6. NOTES ON OPERATIONS

#### Department of Works

Repairs and maintenance and alterations were:

- (a) The weir site entry road was sealed (February, March).
- (b) No. 2 engine at the Weir site was completely overhauled (February).
- (c) No. 1. engine at the Weir site was completely overhauled (June).
- (d) The seismic vault was treated for white ants (July).

- (e) The office was painted (December).
- (f) A safety ladder was installed on the ionosonde mast.

## 7. ACKNOWLEDGEMENTS

The assistance of the Regional Director and staff of the Department of Supply, Perth, Mr S. Gunson, Western Australian Institute of Technology (for the loan of a proton magnetometer), and officers of the Department of Civil Aviation at Meekatharra and Kalgoorlie for outstation servicing, is hereby acknowledged.

8. REFERENCES

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TABLE 1  
OBSERVATORY STAFF, 1969

<u>Officer</u>	<u>Designation</u>
I.B. Everingham	Geophysicist Class 3.
P.J. Gregson	Geophysicist Class 2.
E.P. Paull	Geophysicist Class 1.
A. Parkes	Technical Officer Grade 2.
G. Woad	Technical Officer Grade 1.
T.D. Pustkuchen (Mrs)	Clerical Assistant Grade 1.
C. Cowling (Miss)	Clerical Assistant Grade 1. (from 8 Sept. to 19 Dec.).
T. Creaser	Assistant Grade 1.

TABLE 2  
ASSOCIATED PERSONNEL, 1969

A.S. Murray	University student, vacation 1968/69.
P. Simonds	University student, vacation 1968/69.
J. Murray	University student, vacation 1969/70.
L. Tilbury	University student, vacation 1969/70.
M. Robertson	Geophysicist Class 1, Antarctic trainee. (21 April-26 Sep.).
J.R. Meath	Geophysicist Class 1, Antarctic trainee. (3 Feb-16 Sep.).
P. Jonannsen	Daily attendant, Gwangara magnetograph.
D.C. Allen	Daily attendant, Kalgoorlie seismograph.
S.J. Morrison	Daily attendant, Meekatharra seismograph. (to 10 Mar).
B. Wharton	Daily attendant, Meekatharra seismograph. (from 10 Mar to Sep).
B. Page	Daily attendant, Meekatharra seismograph. (from Sep).



TABLE 3

OBSERVATORY STAFF ABSENCES, 1969

Nature of absences	No. of man-days
Sick, special, repatriation	94
Furlough	65
Military	16
Attendance at outstations & field operations	45
Participation in other Geophysical Branch surveys	99
Conferences	38
	<u>357</u>

TABLE 4

CONFERENCES, INSTITUTIONS VISITED AND ADDRESSES

Officer	Date	Conference or institution
I.B. Everingham	Sep 1-13	Madrid - Attended General Scientific Assemblies of the International Association of Seismology and Physics of the Earth's Interior (I.A.S.P.E.I.), the International Association of Geomagnetism and Aeronomy (I.A.G.A.), and the Upper Mantle Committee (U.M.C.).
	Sep 15	Blacknest - Visited United Kingdom Atomic Energy Authority (U.K.E.A.).seismological array centre.
	Sep 16	London - Visited Imperial College, Department of Civil Engineering.
	Sep 17	Edinburgh - Visited International Seismological Centre (I.S.C.).

	Sep 18	Eskdalemuir - Visited Institute of Geological Sciences (I.G.S.) seismological and geomagnetic observatory and U.K.E.A. seismological array station.
	Sep 19	Edinburgh - Visited I.G.S. seismological array station, and geomagnetic division.
	Sep 22-26	Ottawa - Visited Dominion Observatory.
	Oct 15-19	Melbourne - Earthquake Engineering Symposium.
	Oct 20-24	Canberra - Observers'-in-Charge meeting.
P.J. Gregson	Aug 15	Adelaide - Geophysics Group, A.I.P., Crustal Study Symposium.
	Aug 18-22	Adelaide - A.N.Z.A.A.S.

Officer	Date	Addresses
I.B. Everingham	May 22-23	I.E.A. Symposium Meckering Earthquake on Meckering earthquake effects.
	Jun 11	Bunbury Group Institute of Engineers on W.A. seismicity.
	June 20	Senior geography and architecture students U.W.A. on the effects of the Meckering earthquake.
P.J. Gregson	May 2	Physics seminar, U.W.A. on the work of the M.G.O.
	May 12	Astronomical Society W.A. on the Meckering earthquake.

TABLE 5

VISITORS

Visitors	Institution
W. Shaw, R. Hargraves	AMAX
P.M. McGregor, N.G. Chamberlain,	BMR
J.A. Brooks, K. Kennedy,	
J.C. Branson, B. Williams	
L.S. Prior, E.R. Smith	
W. Fraser	BMR (Darwin)
J.R. Bennett, A. Crebbin,	National Development
B. Dockery	Sharp instruments
J. Shearer	University of W.A.
G.A. Eiby	Seismological Observatory Wellington N.Z.
E. Bettenay	C.S.I.R.O. (soils)
J. Harris, T. Turtle	Perth Observatory

TABLE 6

PRELIMINARY 1969 MONTHLY AND ANNUAL MEAN VALUES  
OF GEOMAGNETIC ELEMENTS AT GNANGARA

Month	H, gammas	D (W)	Z, gammas	F, gammas
Jan	23833	2°56.9	53498	58566
Feb	830	57.3	492	560
Mar	814	57.1	494	555
Apr	810	57.4	498	557
May	815	57.0	494	556
Jun	819	57.2	489	552
Jul	821	57.5	483	548
Aug	820	57.7	487	551
Sep	823	58.1	480	546
Oct	819	57.8	483	547
Nov	819	57.9	479	543
Dec	821	58.5	482	547
Year	23820	2°57.5	53488	58552

TABLE 7

## LARGER EARTHQUAKES IN THE WESTERN AUSTRALIA REGION, 1969

Date 1969	H. (U.T.)	Lat. °S	Long. °E	Dist. (MUN) km	Magnitude (see footnotes)					Recording stations and remarks (see footnotes also)
					ML	m'	mb		m	
							(a)	(b)		
Jan 11	06 59 47.8	31.62	117.01	84	3.5	4.4	3.7	5.1	4.4	Meckering.
16	14 24 42.8	31.81	116.90	68	3.2	4.1	3.9	4.6	4.1	Quellington.
20	02 27 00.7	31.9	117.1	94	2.9	3.9	4.2		3.9	Meckering.
20	23 30 51.1	32.13	117.23	98	3.7	4.5	4.9	5.3	4.5	Dangin.
22	09 16 51.4	32.20	117.15	94	3.0	4.0	4.2		4.2	25 km SE of Beverley.
29	14 32 54.8	32.03	117.18	89	3.0	4.0	4.3	4.6	4.0	Mawson.
29	16 00 45.8	31.85	116.81	59	3.0	4.0	3.7	4.5	4.0	Quellington.
30	06 15 43.0	31.96	117.15	89	3.7	4.5	4.8	5.2	4.6	Mawson.
30	06 16 31.5	(32.2)	(117.3)	103	3.0	4.0	4.1		4.0	Dangin.
31	09 47 44.5	32.17	117.28	102	3.3	4.2	4.1	4.9	4.3	Dangin.
Feb 01	02 39 35.6	31.96	117.15	89	3.5	4.4	4.7	4.8	4.5	Mawson.
01	03 29 57.7	31.96	117.15	89	4.0	4.7	5.2	5.4	4.9	Felt Mawson. MM5 radius. 3km.
01	04 52 02.5	31.96	117.15	89	3.7	4.5	5.2	5.0	4.6	Mawson.
01	04 54 53.6	31.96	117.15	89	3.8	4.6	4.8	5.3	4.7	Mawson.
01	07 22 11.7	31.96	117.15	88	3.6	4.4	4.8	4.9	4.5	Mawson.
01	07 35 22.3	31.96	117.15	88	3.0	4.0	4.2	4.9	4.2	Mawson.
01	08 51 29.3	31.96	117.15	88	3.3	4.2	4.5	4.8	4.3	Mawson.
01	16 54 33.3	32.53	116.93	89	3.0	4.0	4.1		4.0	15km W of Pingelly.

Date 1969.	H. (U.T.)			Lat. °S	Long. °E	Dist. (MUN) km	Magnitude (see footnotes)					Recording stations and remarks (see footnotes also)
							ML	m <sup>o</sup>	mb		m	
							(a)	(b)				
Feb 01	20 25	57.1	32.01	117.15	88	3.2	4.1	4.3	4.7	4.2		Mawson.
01	23 12	18.8	31.88	117.10	84	3.0	4.0	4.0	4.7	4.1		NE of Mawson.
01	23 51	52.5	32.59	116.87	89	2.0	3.9	4.0		3.9		21km W of Pingelly.
02	03 03	30.8	32.05	117.12	87	3.4	4.3	4.1	5.0	4.6		Mawson.
15	12 14	31.1	31.75	117.10	85	3.2	4.1	3.9	5.0	4.3		17km SE of Meckering.
Mar 11	12 00	41.3	30.64	116.57	152	3.5	4.4	4.2	4.3	4.4		Ballidu.
15	09 24	33.4	31.61	117.03	87	3.3	4.2	4.1	4.7	4.3		Meckering, Felt MM3 Northam.
18	05 41	28.9	31.77	116.88	67	3.6	4.4	4.1	5.0	4.5		Quellington, Felt MM3 Toodyay.
21	19 50	50.0	32.15	117.25	102	3.0	4.0	3.9		4.0		Dangin.
25	13 56	17.7	31.14	116.38	94	3.5	4.4	4.2	5.3	4.4		Calingiri, Felt.
25	15 19	16.9	31.13	116.36	94	3.4	4.3	4.0	5.1	4.4		Calingiri.
26	19 33	32.8	32.35	117.15	98	2.9	3.9	4.1		3.9		15km E of Brookton.
28	03 33	09.4	25.4	116.2	750	(3.3)*	4.2	4.7		4.7		*MEK value. Felt Berringarra
Apr 02	22 12	57.7	32.40	117.00	89	3.2	4.1	4.4	4.7	4.2		Brookton.
May 09	11 20	28.5	32.00	117.30	102	3.5	4.4	4.4	4.9	4.4		Quairading.
16	04 22	47.9	30.9	117.2	155	3.7	4.5	4.4	4.4	4.5		Manmanning.
Jun 17	19 54	32.1	25.0	116.8	785	5.6		6.0	5.7	5.9		WRA, DAR, KNA, ADE, CTA, Felt MM5 around Landor. MM3 radius about 180.km. Depth 15km.
19	21 01	07.5	23.3	114.7	965	(2.8)*		4.2		4.2		*MEK value. Felt Middalya.

Date 1969	H. (U.T.)	Lat. °S	Long. °E	Dist. (MUN) km	Magnitude (see footnotes)					Recording stations and remarks (see footnotes also)
					ML	m <sup>v</sup>	mb		m	
							(a)	(b)		
Jun 23	14 14 44.4	17.6	123.1	1722			5.1	4.7	4.9	WRA, KNA. SW of Derby.
26	00 38 09.2	30.76	117.18	163	3.4	4.3	4.2	5.3	4.3	Felt Cadoux, MM5.
30	17 38 35.9	18.0	120.1	1580			5.0	4.9	4.9	KNA, WRA. W of Broome.
Jul 01	00 19 11.3	31.60	117.00	87	3.1	4.1	3.4	4.7	4.2	3km N of Meckering. Felt.
27	09 17 03.1	30.86	117.10	150	3.0	4.6	4.8	4.4	4.6	2km E of Moonijin.
27	09 20 47.3	30.95	117.10	144	4.2	4.9	4.7	4.8	4.8	4km E of Moonijin. Felt.
Aug 01	08 48 32.0	31.2	116.6	89	2.8	3.8	3.7	4.4	4.0	12km NE of Bolgart.
08	12 09 23	25.5	111.1	875				4.3*(4.3)		MUN, MEK, * (MEK mb) W of Carnarvon.
11	08 55 30	24.9	115.7	795			4.4	3.7	4.0	13km WNW of Mooloo Downs.
14	06 13 52.0	31.20	116.57	95	2.6	3.7	3.9	4.2*	3.9	MUN, MEK, * (MEK mb) 12km NNE of Bolgart.
17	17 55 29	25.1	116.0	750				4.2	4.2	(MEK mb 4.3) Mt Dalgety.
21	23 57 04.0	30.75	117.16	163	3.2	4.1	3.5	4.7	4.3	Felt Cadoux. OOR.
Sep 07	01 16 23.0	31.69	116.83	68	3.1	4.1	2.8	4.9	4.0	Quellington.
14	22 58 48	17.9	123.1	1650			4.7	5.0	4.8	WRA, KNA, DAR, Broome No Lg.
24	23 39 07	21.7	118.2	1155				5.1*	5.1	*MUN, MEK, WRA, *(MEK mb) 50km N of Wittenoom.
Oct 05	12 15 50.3	31.72	116.90	72	3.0	4.0	3.8	3.9*	3.9	MUN, MEK* (MEK mb) 15km SW of Meckering. OR.
08	20 26 56.6	31.80	116.90	68	3.4	4.3	5.0	4.4	4.5	WRA, Quellington. Felt.
09	01 29 11	19.1	117.1	1425			5.2	4.9*	5.0	WRA *(MEK mb) 190km NW of Port Hedland. No. Lg.

Date 1969	H. (U.T.)	Lat. °S	Long. °E	Dist. (MUN) km	Magnitude (see footnotes)					Recording stations and remarks (see footnotes also)
					ML	m <sup>o</sup>	mb		m	
							(a)	(b)		
Oct 11	16 40 46.6	31.65	116.94	79	3.0	4.0	3.9	3.8	4.0	6km SW of Meckering. OOR.
23	12 05 16.7	30.88	117.13	151	2.7	3.8	4.2	4.3	4.0	6km SE OF Manmanning.
27	11 39 36	23.1	130.8	1770			4.3	4.6	4.5	WRA, KNA, ADE, W of Alice Springs.
27	12 22 07	23.1	130.8	1770			4.3	4.6	4.5	WRA, KNA, W of Alice Springs.
Nov 05	07 06 39.8	31.26	116.50	85	2.8	3.8	3.5	4.4	4.0	Felt Bolgart. Depth 15km. Recorded Tammin field station.
13	01 35 16.4	32.53	116.93	90	3.0	4.0	4.2	4.0	4.0	10km W of Pingelly. Depth OOR
14	01 36 19	32.5	116.9	90	2.9	3.9	4.0		3.9	" " " " "
20	05 23 25.4	32.53	116.93	90	3.0	4.0	4.2		4.0	" " " " "
20	19 54 16.9	32.53	116.93	90	3.1	4.1	4.1		4.1	" " " " "
20	19 54 23.5	32.53	116.93	90	3.4	4.3	4.5		4.3	" " " " "
22	15 05 33.2	32.53	116.93	90	3.6	4.4	4.9	(5.0)*	4.6	" " " " "
										*MEK value. Felt Pingelly MM4. Pn at KLG extremely small amplitude.
22	15 07 58	32.6	116.9	90	2.7	3.8	4.1		3.8	18km SW of Pingelly Depth OOR
22	16 02 16.3	32.53	116.93	90	2.7	3.8	4.0		3.8	" " " " "
23	07 20 25.2	32.53	116.93	90	3.1	4.1	4.5		4.1	" " " " "
23	10 50 54.7	32.59	116.87	90	2.6	3.7	4.1		3.7	" " " " "
24	20 36 26.6	32.59	116.87	90	2.9	3.9	4.0		3.9	" " " " "
Dec 31	10 05 25.4	32.53	116.93	90	3.3	4.2	3.5	4.0	4.1	" " " " "

# NOTES

\* Recording stations - MUN, MEK and KLG all recorded event unless signified otherwise.

DAR - Darwin, WRA - Warramunga, KNA - Kununurra.

ML - Weighted mean of MUN and KLG.

$m^{\circ}$  - derived from ML via  $m^{\circ} = 1.8 + 0.73 \text{ ML}$ .

mb - derived from  $mb = \log A/T + A_0 + 0.4 = mb(\text{MUN}) + 0.4$ .

m - Unified magnitude (weighted mean of  $m^{\circ}$  and mb) values for MUN and KLG or MEK.

() - Less accurate value.

depth - 7km depth assumed unless noted in remarks.

3OR - depth assumed from limited evidence.



TABLE 8

MINOR EARTHQUAKES IN SOUTHWESTERN AUSTRALIA, 1969

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing ° T	Remarks
Jan 07	0449	2.7	3.8	68	116	Values relate to MUN unless stipulated.
08	2317	2.7	3.7	68	073	
10	0608	2.8	3.9	81	062	
Feb 01	0333	2.8	3.9	89	(090)	Mawson )
01	0359	2.7	3.6	89	(090)	" )
01	0502	2.2	3.5	87	(090)	" )
01	0530	2.3	3.5	88	(090)	" ) Many felt all heard.
01	0734	2.5	3.8	88	(090)	" )
01	0744	2.2	3.5	88	(090)	" )
01	0909	2.8	4.0	88	(090)	" )
01	2154	2.7	3.8	89	130	
01	2157	2.6	3.7	89	135	
01	2206	2.5	3.6	89	135	
01	2243	2.4	3.3	85	090	
01	2355	2.7	3.8	89	135	
02	0001	2.4	3.7	89	135	
03	0859	2.9	3.6	72	(070)	
04	0541	2.6	3.8	88	090	
11	1835	2.8	3.8	89	135	
13	1101	2.4	3.2	68	(105)	
17	1930	2.4	3.5	85	(090)	

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing °T	Remarks
Mar 03	2143	2.8	3.5	98	(095)	Dulbelling.
07	1432	2.6	3.5	99	(095)	"
07	2203	2.7	3.5	99	(095)	"
07	2208	2.3	3.2	100	(095)	"
10	0553	2.4	3.4	98	(095)	"
11	1123	2.3	3.2	98	(095)	"
12	1910	2.3	3.2	66	(070)	
13	1723	2.3	3.3	98	(095)	
15	1232	2.3	3.4	97	(095)	
15	1941	2.3	3.4	97	(095)	
16	1311	2.6	3.4	98	(095)	
19	1310	2.4	3.4	89	135	
20	0100	2.7	3.8	104	(095)	Dangin.
20	1803	2.5	3.7	100	(095)	"
20	1941	2.9	3.9	102	095	"
23	0926	2.4	3.6	102	(095)	
28	0237	2.3	3.3	98	120	
28	0418	2.6	3.6	88	(090)	Mawson.
29	0037	2.6	3.6	71	078	
Apr 18	0856	2.3	3.2	68	079	
20	1025	2.7	3.7	77	063	
27	0003	2.5	3.5	70	071	
27	0007	2.5	3.6	70	071	
27	0041	2.3	3.3	70	071	

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing °T	Remarks
Apr 27	1755	2.7	3.8	83	064	
28	0345	2.3	3.1	81	064	
28	0422	2.2	3.1	81	064	
30	2149	2.2	3.1	91	(090)	
May 19	1529	2.7	3.2	152	040	Manmanning.
Jun 04	1211	2.2	3.2	74	063	
07	1225	2.6	3.6	105	079	Felt Cunderdin.
07	1225	2.1	2.9	105	079	
09	1757	2.6	2.9	164	027	
09	2209	2.1	2.4	164	027	
10	0049	2.5	3.4	104	(063)	Felt Cunderdin.
12	1427	2.1	3.1	57	090	Felt Gwambygine.
12	1428	1.6	2.6	57	090	" "
12	1516	1.6	2.6	57	090	" "
12	1850	1.9	2.8	57	090	" "
12	2139	2.1	3.1	57	090	" "
22	0627	2.7	3.8	89	062	
23	2144	2.8	3.6	144	027	
24	2304	2.7	3.6	74	053	Felt Northam.
24	2304	2.8	3.7	74	053	" "
25	0608	3.2	1.8	59	110	
26	0037	2.9	3.6	160	039	Felt Cadoux.
26	0645	2.6	3.6	160	039	" "
28	2057	2.6	3.4	86	058	Felt Meckering.
Jul 06	1413	2.4	3.5	115	(150)	W of Narrogin.

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing $\begin{smallmatrix} O \\ T \end{smallmatrix}$	Remarks
Jul 17	1335	2.6	3.5	144	037	
24	1017	1.9	3.0	86	068	
27	0837	2.9	3.2	149	030	
27	1246	2.9	3.6	151	039	
27	1254	2.9	3.6	146	040	
27	1315	1.5	2.7	81	063	
27	1404	2.4	3.4	147	031	
30	0233	2.6	3.2	88	062	
Aug 05	1737	1.8	3.0	94	027	
14	0611	1.9	3.3	92	023	
14	0638	1.7	3.2	96	022	
22	0243	2.9	3.9	71	070	
24	0104	2.1	3.4	94	030	
25	1620	1.8	3.0	90	101	
29	0031	1.8	2.4	80	057	
29	0040	1.5	3.1	81	063	
Sep 26	1948	2.2	3.8	70	073	
Oct 03	1225	2.7	3.2	258		Epicentre 30.05°S, 117.75°E, origin time 12 24 34.
08	1938	2.3	3.7	68	072	
08	2359	2.8	3.6	68	072	
09	0059	2.7	3.6	68	072	
09	1922	2.4	3.9	68	072	
12	0416	2.7	3.6	68	069	

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing OT	Remarks
Oct 14	0803	2.7	3.9	68	074	
14	1009	2.2	3.6	68	072	
16	0634	2.4	3.8	68	073	
16	0636	1.9	3.3	68	064	
16	0721	1.7	3.5	68	070	
16	0924	2.5	3.4	68	068	
22	2017	2.9	3.8	150	034	
22	2026	2.8	3.6	150	034	
23	1213	2.8	3.8	151	036	
Nov 01	0553	2.7	3.2	151	033	Felt Manmanning.
01	0740*			139*	((315))*	(*MEK values)
08	0846	2.5	2.9	152	038	Manmanning.
12	0501	2.3	3.4	89	135	W of Pingelly.
14	0439	1.7	3.1	88	130	
14	0842	2.6	3.3	88	135	
22	0214	2.4	3.5	89	072	Meckering.
22	1727	1.8	2.8	91	131	
23	0102	1.7	3.0	89	126	
23	0102	2.0	3.3	89	126	
23	0805	2.3	3.5	89	126	
24	2214	2.3	3.7	92	127	
25	1624	2.5	2.6	85	064	
25	2252	1.6	3.1	89	127	
26	1343	2.5	3.8	93	127	

Date 1969	P-time U.T.	ML	mb	Dist. km	Bearing °T	Remarks
Nov 26	1540	2.3	3.0	85	064	
26	2257	2.8	3.6	84	074	
Dec 03	0813	2.7	2.8	90	064	Meckering - large S wave
05	1302	2.2	3.1	89	133	
05	1546	2.2	3.1	89	133	
28	2255	2.8	3.9	90	065	

