DEPARTMENT OF
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# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS



Record 1974/60



## MACQUARIE ISLAND GEOPHYSICAL OBSERVATORY, ANNUAL REPORT 1973

by

P.J. Hill

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## SUMMARY

Geomagnetic and seismological recording was continued at the Macquarie Island Geophysical Observatory throughout 1973. The newly installed seismic system MQI, with the seismometer on the plateau linked by hardwire f.m. telemetry to the recorder in the Geophysics Office, was calibrated and kept functioning throughout the year except for short periods after landline faults developed; when this happened a standby system MCQ in the original vault was brought into operation until repairs had been effected.

Comparisons of microseismic noise at the MQI and MCQ sites indicated that under normal weather conditions noise levels at the new site are not significantly lower than at the old.

Investigation of 1973 earthquakes which produced T phases at the Island confirmed the general epicentral location pattern and the propagation velocity value (1.475 km/s) found in previous years.

## 1. INTRODUCTION

This Record describes the operation of the Macquarie Island Geophysical Observatory from 23 November 1972 to 2 December 1973 when the author was observer-in-charge.

The Bureau of Mineral Resources, Geology and Geophysics (BMR) has carried out seismological and geomagnetic recording at Macquarie Island since 1950 and 1951 respectively, as part of the operations of the Australian National Antarctic Research Expeditions (ANARE); the Antarctic Division (Department of Science) has provided accommodation and logistic support for this work.

The normal term of duty is one year; the author succeeded M. McMullan and was relieved by J. Walsh. During the November 1973 changeover the Observatory was inspected by G. Small, H.Q. Observatory Group, Canberra.

The operation of the Observatory in earlier years is described in BMR Records (e.g. Meath, 1971b; McDowell, 1973; McMullan (in prep.)).

## 2. GEOMAGNETISM

Two sets of continuous recording magnetographs were in operation during 1973:

1. La Cour normal-run (15 mm/h) three-component magnetograph

2. La Cour rapid-run (180 mm/h) three-component magnetograph

Baseline control observations were carried out with absolute instruments as follows:

H: QHMs 177, 178, 179

D: Askania declinometer 640505 and circle 640620

Z: BMZ 236, Elsec PPM 421 (in conjunction with H trace)

Intercomparisons of absolute instruments through the baselines made in November 1973 consisted of:

H: HTM 704 and QHM 172 against QHM 177

D: Dec. 509320 against Dec. 640505

F: Elsec PPM 339 against Elsec PPM 421

Z: Elsec PPM 421 (plus H trace) against BMZ 64 (the latter being checked for use at Casey, Antarctica in 1974)

From baseline value determinations done throughout the year the differances between the QHMs were: 177 - 178 = 7nT

177 - 179 = 6nT

The correction to the BMZ was obtained from Z baseline values derived directly from BMZ observations, and indirectly from PPM 421 values of F and magnetogram values of H (the indirect results are called Zp). The mean difference, with no corrections applied to the QHM data, was:

BMZ 236 - Zp = 147 nT

BMR magnetograph calibrator MCO-1 was used to supply the currents through the Helmholtz coils on each of the 6 variometers for scale-value determinations. Magnetograph parameters are shown in Table 1, and baseline values in Table 2. Normal-run magnetograph control observations were done about 5 times a month and rapid-run magnetograph scale values and parallax corrections (Table 3) were determined once a month. The parallax correction to the normal-run variation time-marks was negligible. Thermometers on the H and Z variometers were read and records changed on both magnetographs daily between 2351 and 2359 UT. At the end of each month, magnetic data (K-indices, preliminary monthly mean values, baseline values, and scale values) was forwarded by telegram to the BMR Office in Melbourne. Preliminary monthly mean values are listed in Table 4; they were determined from the mean of the hourly values of 10 selected quiet days of each month. Table 5 lists the annual mean values 1963-1973.

## Normal-run magnetograph (N/R)

The N/R magnetograph performed well during the year. Only minor record loss resulted owing to sticking of the recording drum. This was rectified by oiling the bearings, adjusting the mass, and lubricating the string of the frictional load for the motor. The prisms and lenses of the recorder were adjusted several times to improve clarity of the traces and to record reserve traces. Correct intensities of the light spots were in part achieved by masking of the lenses.

## Rapid-run magnetograph (R/R)

The mechanics of the magnetograph gave no problems, and the quality of the magnetograms was satisfactory but not perfect, as has been so in previous years. This was due to uneven intensities of the traces, some fogging, and occasional blotchiness. The latter was caused by condensation forming on the paper while on the drum, the variometer hut being unheated. Some improvement was achieved by adjustment of the recorder mirrors (the silvering of which showed signs of corrosion), and fogging was reduced by narrowing the aperture of the recorder, effected by bolting a strip of copper sheeting onto the recorder cover. This considerably reduced fogging during scale value tests.

In July the position of the direct Z trace was shifted, by adjustment of the variometer prism, from the extreme top edge of the record to a more central position.

Orientation tests

Orientation tests on the variometers were performed after disturbance of the magnetographs by earthquakes (see next section) and after adjustments to the variometers. The results of the tests are shown in Table 6.

The N/R H and D variometers each have two sets of orthogonal Helmholtz coils centred on the recording magnets, one for scale values and the other for orientation tests. The R/R H and D variometers each have only one set of coils for scale values, so for orientation tests these have to be turned through 90 i have to be turned through 90 into the prime vertical and meridian directions respectively. The N/R Z and R/R Z variometers have orientation benches, and deflector magnets of known moment (Meath, 1971b) are used for the tests.

Checks were made on the orientation of the N/R coils using the azimuth marks along the north and south walls of the variometer room. Measured orientations of the coils (assuming orthogonality) were 28.4° for D and 118.5° for H. When installed in 1970 the coils were supposedly set at 29.0° and 119.0° respectively (Meath, 1971b), with the footings fixed in plaster. When examined, no cracking or movement of the plaster was evident. McMullan also discovered discrepancies in these values.

When the orientation tests were first carried out, the deflections on the magnetograms of traces from adjacent variometers showed inexplicable behaviour. Subsequently the directions of the orientation currents (which are controlled through the main console in the Geophysics Office) were determined in the variometer building. These were found to be opposite in sense to that indicated by the MCO-1 unit which supplies the R/R current and also to that shown by the MCO-3 which provides the larger current for the N/R coils. This results from the fact that COMMON on the MCO-1 is + ve and that the 12V battery supply in the MCO-3 had been wired internally to give reversed current. Thus there is the possibility that H and D ex-orientation determinations of both N/R and R/R variometers could be in error since 1971. For this reason, and because of variometer adjustments required after earthquake disturbances, no direct correlation between 1972 and 1973 values for H and D ex-orientation angles can be made. N/R and R/R Z ex-orientations for 1973 are in agreement with previous years. The results of the tests are shown in Table 6.

Effect of earthquakes

Macquarie Island lies on an active oceanic ridge and so is subject to seismic disturbance; usually a number of mild tremors are felt at the station each year. Seven such tremors were experienced between December 1972 and November 1973. On the magnetograms the H and D (suspended magnets) traces show large oscillations for the duration of the ground movement, while the Z (pivoted magnet) trace is relatively insensitive to vibration and only small deflections result.

The earthquake on 7 June caused the N/R H ordinate to decrease by about 25 mm and the N/R D trace to disappear off the bottom of the record; the R/R H traces were also displaced. The N/R H trace was returned by a small turn of the torsion head, and the N/R D trace was brought back by turning the variometer body and moving the head an equal amount in the opposite direction to correct the resulting fibre twist. The N/R D baseline mirror was adjusted to restore the baseline trace to its proper position.

When magnetic conditions were suitably quiet, orientation tests were done on all variometers (27 June and 8 July). All ex-orientation angles were found to be less than $1^{o}$ except R/R H and N/R D which were respectively W $1.5^{o}$S and N$7.2^{o}$W for the magnets' N pole. The R/R H magnet orientation was adjusted by turning the torsion head. The large ex-orientation of the N/R D magnet indicated that the earthaqake had caused it to spin a number of revolutions, the resulting torsion in the fibre holding the magnet from the meridian. Two turns of the variometer head were required to readjust it; the body was turned, and the baseline mirror adjusted to complete restoration of D traces. Orientation tests were repeated on R/R H, N/R D, and N/R H, and ex-orientation angles determined to be less than $1^{o}$.

On 19 October an earthquake caused a shift downwards in the N/R H trace of about 6 mm, which was restored by turning the variometer torsion head.

Ex-orientation angles of the N/R H and N/R D magnets were checked and found to be almost unaltered.

Pier corrections

Three piers were in use during the year for absolute measurements. In the absolute building, pier E was used for H and D, pier W for Z and F, and only F was measured on the external pier A. Differences in F between the three piers were determined once monthly.

The concrete used in the construction of pier A is magnetic, so it is necessary to position the PPM sensor above the pier out of the magnetic influence of the concrete. Tests were carried out by raising the PPM sensor box to various heights above the pier and measuring F; results are shown in Table 7. With the PPM sensor box 51 cm above the concrete, it was sufficiently high not to be affected by the magnetic concrete. All absolutes and comparisons were done with the box at this height. Initially, wooden blocks were used as support but this proved unstable in windy conditions, so a rigid wooden support was later constructed.

The inter-pier difference (E,W,A) was less than 1nT.

Thermographs

Two temperature traces are provided on the N/R magnetograms, one from the H variometer and the other from the Z variometer. The latter is used for all variometer reductions because it is the more sensitive and because the temperature within the variometer room is fairly uniform.

Temperature scale values (St) and baseline values (bt) for both thermographs are shown in Table 8. Two changes in Zbt can be correlated with times when silica gel was renewed in the variometers (every two months); other changes cannot be explained. The change in Hbt is due to a magnetograph adjustment. The temperature scale values were calculated by a computer least-squares fit to the data obtained from the daily temperature readings and the corresponding ordinates of the temperature traces.

## 3. SEISMOLOGY

In October 1972 a new seismograph system (MQI) was brought into operation to replace the one in the Wireless Hill (MCQ) vault which had been used since recording commenced in 1950. A detailed description of the instruments and an account of the installation of the new system is provided by McMullan (in prep.).

The MQI sensing station is situated on the 250-m high plateau about 3 km from the ANARE base. A fibreglass vaultlet sunk into the bottom of an excavation in weathered volcanics houses a vertical component short-period Willmore MK2 seismometer. It is coupled to a TM 251 telemetry amplifier from which the frequency-modulated seismic signal is fed via a screened six-core cable to the Geophysics Office. Here the original signal is recovered by an FM discriminator, attenuated, and passed through a short-period (0.2 second) galvanometer and is recorded photographically on a 60 mm/minute drum recorder.

As a back-up in the event of landline or other failures, the system in the original value (MCQ) which had been used by McMullan was re-assembled and made operational. This system comprised a Willmore Mk 2 seismometer (replaced in January by a Willmore Mk 1 when the Mk 2 was required in Australia), short-period (0.2 second) galvanometer and BMR 30 mm/minute recording drum.

Seismic data were telegraphed daily to the BMR Office in Melbourne, and thence to the US National Oceanic and Atmospheric Administration (NOAA), Colorado, for preliminary computation of epicentres. Earthquakes listed in the PDE (Preliminary Determination of Epicentres) sheets and recorded at Macquarie Island are shown in Table 9. After final analysis a total of 363 events were reported to the International Seismological Centre at Endinburgh. During the year a number of earthquakes were felt at the ANARE Station; they are listed in Table 10, together with their intensities according to the Modified Mercalli Scale (1956 version).

Tests done during the year on the two systems gave the seismograph constants in Table 11. Until 16 July, MQI was operated as it had been set up (seismometer free period 0.68 seconds, damping ratio about 20:1). The seismometer was then brought to the Geophysics Office, the period adjusted to 1.00 second, and the motor constant (G) of the calibration coil determined by weight lift tests, using the spare amplifier and discriminator as in normal operation. In addition, with the aid of a large screen CRO the damping resistance required to give a damping ratio of 17:1 was determined accurately. The results were:

G = 0.46 N/A

Damping resistance (in each arm of seismometer output)

to give 17.0:1 = 5900 ohms

The vaultlet control board was wired with fixed damping resistors in place of the existing makeshift ganged potentiometers which were unequal in value, easily knocked out of adjustment, and subject to corrosion. The attenuator box was calibrated by applying a sinusoidal signal to the calibration coil and measuring the output on the record for different settings; Table 12 gives the results.

In November the frequency response of MQI was determined, weight lift tests were done (masses used being 20.0 and 41.4 mg) to check G of the calibration coil, and the system magnification was calculated from the deflection produced by a known sinusoidal current through the calibration coil. G was found to be unaltered (0.46 N/A). An exceptionally calm day was chosen for the weight lift tests and the seismometer was set up on a concrete block beside the vaultlet, it being impossible to keep sufficiently still with the seismometer in the vaultlet to prevent the lift pulse being swamped by noise.

The motor constant (G) and magnification (V) are given by the formulae (for derivation see Geotechnical Corporation manual)

$$G = (Xlp/Xlw)\ (980\ Wt \times 10^{-5}/ip).\ 10^{-3}\ N/A$$

$$(V) = Af^2/K \text{ is}$$

$$\text{where } K = G/4\Pi^2 M$$

Xlp : deflection on seismogram from current pulse lp (amperes) through calibration coil

Xlw : deflection from weight lift (Wt grams)

A : trace amplitude (p-p, metres) due to sinusoidal current is (p-p, amperes) of frequency f through calibration coil

M : seismometer mass (kg)

The MQI magnification (with attenuator box setting 42 dB) at 5.0 Hz was 30.3 K; Plate 1 shows the magnification curve.

The attenuator box setting used until 29 July was 38 dB when it was increased to 42 dB and kept there for the rest of the year. The increase was necessary because changing the seismometer period from 0.68 to 1.00 second made the system more sensitive to the ambient noise which has a predominant period of 2 to 3 seconds.

By scaling amplitudes and periods of events recorded on both MQI and MCQ the magnification relation between the two stations in Plate 2 was obtained.

Performance of MQI system

The equipment functioned well throughout the year; the main problem lay in keeping the landline to the vaultlet in service.

On the isthmus the cable had been buried (except for a short section up to the Geophysics Office) to protect it from seals and vehicles, and on the slopes and plateau it was supported above the ground by star-pickets and wooden posts to prevent rabbit damage.

On arrival in November 1972 there were 14 joins in the cable; after it was accidentally severed by a bulldozer, thus requiring another 2 and making a total of 16. In 1972 McMullan had trouble with discontinuities developing in the cable connexions and the same problem was experienced early in 1973 when several faults occurred. The majority of cable failures were due to corrosion of the soldered leads in the connectors; the most vulnerable conductors were those supplying power to the amplifier, i.e. the shielding (OV) and two leads (+12V, -12V). Electrolytic corrosion is greatly accelerated by Macquarie Island's sea air and wet climate.

The cable connexions were housed in wooden boxes and the sleeved, soldered joints were covered with silicone grease to help exclude moisture. Not being completely waterproof, they were not entirely successful. In April and May the cable was thoroughly overhauled - wooden posts were taken to the plateau to replace star-pickets or provide additional support, the deteriorating rubber hose protectors at the metal posts were replaced by tough plastic tubing to prevent further abrasion of the cable, all solder joints were inspected and re-soldered where necessary, and all but five connexions were made permanent by filling the boxes with epoxy resin. These five were left so that the conductors would be accessible for checking with a multimeter so that if a fault occurred it could readily be isolated. Waterproofing was done with silicone grease on the joints, and by painting the boxes with bituminous paint and covering them with layers of plastic sheeting. The cable gave no further trouble throughout the winter until September. From then until departure several faults occurred, mostly due to corrosion; only once was a potted connector at fault.

Repairing the cable on the plateau and testing of equipment in the vaultlet is made difficult by the cold, wet, windy climatic conditions that prevail on Macquarie Island. Remoteness is another unfavourable factor for all tools and test equipment have to be carried by pack up the arduous plateau climb. Generally soldering is possible only by a large gas flame because of the strong winds, which with the cold prevent any delicate work being carried out. In addition the persistent precipitation saturates any new wiring jobs and aggravates the corrosion problem; even inspection of cable connectors under the usual damp conditions has the same effect, for unless great care is taken moisture will enter them.

It is expected that the cable will have a useful life of a few more years before the task of maintenance becomes too great and the reliability of the seismic system suffers. Deterioration of the cable other than of connectors is already evident - cracks have appeared in the outer PVC owing to hardening by low temperatures and movement by the wind, and also at twists in the cable; abrasion at the posts has left cuts through the PVC and in some places through the shielding; some sections show minor signs of rabbit attack. Wherever the shielding has been exposed, particularly at the joints, oxidation and atmospheric corrosion have worked along the wire for several metres, making it impossible to be soldered properly.

Noise comparison of MQI and MCQ sites

The microseismic noise at Macquarie Island is due primarily to two sources, wind and surf. On the plateau at the MQI vaultlet, wind velocities are generally greater (up to 10 knots according to Meath, 1971a) than on the isthmus; the MCQ valul, being close to the seashore (60 m from the east coast and 140 m from the west coast), is affected by the seismic noise of pounding waves.

On a number of occasions throughout the year MQI and MCQ were run simultaneously, so from the records a comparison of the background noise levels can be made. Noise levels measured from records at time intervals of not less than 12 hours, between 23 July and 11 November are shown in Plate 3. The period of the noise was found to lie mainly in the range 2 to 3 seconds.

The results show no significantly greater (not more than 10%) noise level at MCQ than MQI. The plot does not cover all weather conditions and undoubtedly at times, such as when there is a large easteraly swell, MQI could be a quieter site than MCQ. For most of the year, however, it appears that the noise levels at the two sites are comparable. This is substantiated by McMullan (pers. comm.), but contrasts with Meath's (1971a) conclusion that the noise level on the plateau is about 60 percent less in adverse weather.

Seismometer foundations at the two sites are not identical and could affect the recorded noise levels. At the MCQ vault the seismometer is based on a large concrete pier constructed on bedrock, whereas the MQI seismometer stands in the bottom of a fibreglass box sunk into a medium of soil and weathered rock fragments.

The advantages of having a readily accessible vault (for inspecting and testing seismometers and associated equipment) without a long, failure-vulnerable cable link between seismometer and recorder (thus meaning more reliability and less maintenance) outweigh that of the insignificant decrease in noise by having the vault on the plateau. So it is suggested that MQI be abandoned in favour of the original MCQ vault, or a suitable quieter alternative site near the Geophysics Office. Preliminary noise tests (Connelly, 1971; McCue, 1971) reveal that a number of such sites possibly exist on the isthmus.

T phases

Quite a number of T-phase events appeared on the 1973 records, the associated body waves some times being too small in amplitude to show up on the records. Twenty two which could be correlated with earthquakes listed in the NOAA PDE sheets are given in Table 13. Epicentres of 1973 regional shocks recorded on Macquarie Island and located by NOAA, with and without T phases, are plotted in Plate 4, superimposed on Cooke's (1967) 1961-62 results. The 1973 information shows a similar pattern to that of 1961-62 and indicates that oceanic earthquakes in the region generally produce T waves, except for those occurring on the north-trending Macquarie Ridge as far down as the active area of 62°S. Earthquakes west of Macquarie Island are characterized by large-amplitude surface waves which appear on the Macquarie Island records together with the T waves.

A plot of travel-time against great circle epicentral distance (Plate 5) for the earthquakes of Table 12, yields a velocity of 1.475 km/s for the T waves.

## 4. TIDE GAUGE

The tide gauge on Buckles Bay, belonging to the Horace Lamb Centre for Oceanographic Research, Flinders University, was kept in operation during the year; records were changed weekly and time corrections noted daily.

On 27 July the tide gauge was calibrated; previous to this, the charts provided information only on relative tidal variations, not absolute heights.

WATER LEVEL (RELATIVE TO TOP OF WELL) = 10 x CHART ORDINATE

+ CHART BASELINE (B)

(A gear wheel is emplouey which gives a 1:10 reduction to the pen movement)

A B-value of -381.7 cm was obtained. Checked on 10 November, the calibration gave B as -372.2 cm.

In February there was found to be almost no syphon action; inspection revealed this was caused by blockage of the hose and nozzel by sand and dirt. The whole system was flushed using the station fire hose and pump, and a new syphon head retaining the original nozzle was fitted. Subsequently tests were made monthly by pouring 500 ml of sea water into the well and watching (on the chart) that the water level returned to the normal value within a few minutes. Repair work was necessary on two occasions to the gauge-housing when gigantic seas from easterly gales smashed the fibro walls.

## 5. ADDITIONAL DUTIES

The author acted as stand-in physicist for several weeks. Assistance was given in general station duties. Much time was spent on the ANARE biology program, carrying out bird-banding, checking of bands, and seal and rabbit counts. Buildings were painted and maintained as required during the year.

## 6. ACKNOWLEDGEMENTS

Thanks go to all members of the 1973 expedition for their support and congenial company, in particular A. King (physicist) who looked after the Observatory during the author's absence on field trips and W. Kulikowski (carpenter) who assisted in restoring operation of the tide gauge.

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TABLE 1. MAGNETOGRAPH PARAMETERS

| COMPONENT | MEAN OBSERVED SCALE VALUE | ADOPTED SCALE VALUE | STANDARD DEVIATION Scale Value | STANDARD DEVIATION Baseline | TEMP COEFF nT/°C |
|---|---|---|---|---|---|
| Normal-run | | | | | |
| H | 19.45 | 19.45 | 0.06 | 2 nT | +3.0 |
| D | 2.36 | 2.35 | 0.02 | 0.4 min | - |
| Z | 20.76 | 20.75 | 0.05 | 3 nT | 0 |
| Rapid-runs | | | | | |
| H | 5.43 | 5.40 | 0.08 | - | - |
| D | 0.99 | 0.99 | 0.01 | - | - |
| Z | 6.16 | 6.20 | 0.06 | - | - |

D scale values are in minutes/mm

H and Z scale values are in nT/mm

TABLE 2

OBSERVED BASELINE VALUES, NORMAL-RUN MAGNETOGRAPHS

| Date 1973 | UT h | UT m | Baseline | Remarks |
|---|---|---|---|---|
| Horizontal intensity | | | BHs nT | |
| Jan 01 | 00 | 00 | 12690 | |
| Jun 07 | 02 | 43 | 13175 | Earthquake |
| Jun 08 | 06 | 56 | 12694 | Adjustment |
| Jun 10 | 02 | 06 | 12750 | Adjustment |
| Oct 19 | 00 | 13 | 12858 | Earthquake |
| Oct 20 | 00 | 32 | 12744 | Adjustment |
| Declination | | | BD (E) ° ' | |
| Jan 01 | 00 | 00 | 26 46.8 | |
| Jun 07 | 02 | 43 | 26 28.0 | Earthquake |
| Jun 09 | 10 | 15 | 26 42.2 | Adjustment |
| Jul 13 | 00 | 14 | 26 55.6 | Adjustment |
| Vertical intensity | | | BZs * nT | |
| Jan 01 | 00 | 00 | -63774 | |
| through | | | | |
| Nov 30 | 24 | 00 | | |

* Derived from H and F (PPM 421)

## TABLE 3

## RAPID-RUN PARALLAX CORRECTIONS (SECONDS)

| | CORRECTION | STANDARD DEVIATION |
|---|---|---|
| D | + 05 | 2 |
| H | + 24 | 2 |
| Z | + 30 | 3 |

## TABLE 4

## PRELIMINARY MONTHLY MEAN VALUES, 1973

| MONTH 1973 | H nT | D East ° | ' | Z nT |
|---|---|---|---|---|
| Jan | 12922 | 27 | 24.0 | -63985 |
| Feb | 12915 | 27 | 25.5 | -63986 |
| Mar | 12911 | 27 | 26.2 | -63990 |
| Apr | 12905 | 27 | 27.2 | -63996 |
| May | 12908 | 27 | 27.3 | -63992 |
| Jun | 12905 | 27 | 27.5 | -63997 |
| Jul | 12905 | 27 | 28.2 | -63990 |
| Aug | 12903 | 27 | 28.4 | -63979 |
| Sep | 12897 | 27 | 29.5 | -63985 |
| Oct | 12897 | 27 | 29.7 | -63978 |
| Nov | 12896 | 27 | 28.6 | -63967 |
| Dec | 12895 | 27 | 28.8 | -63972 |
| Mean | 12905 | 27 | 27.6 | -63985 |

## TABLE 5

## GEOMAGNETIC ANNUAL MEAN VALUES 1963-1973

| YEAR | D | I | H | X | Y | Z | F | NOTES |
|---|---|---|---|---|---|---|---|---|
| | ° ' | ° ' | nT | nT | nT | nT | nT | |
| 1963 | 26.08.5 | -78 24.2 | 13193. | 11843 | 5813 | -64294. | 65634 | |
| 1964 | 26.17.0 | -78 24.7 | 13174. | 11812 | 5834 | -64249. | 65586 | |
| 1965 | 26.28.6 | -78 25.5 | 13152. | 11773 | 5864 | -64214. | 65547 | |
| 1966 | 26.37.6 | -78 26.7 | 13121. | 11729 | 5881 | -64175. | 65503 | |
| 1967 | 26.46.5 | -78 28.5 | 13084. | 11681 | 5894 | -64166. | 65486 | |
| 1968 | 26.54.7 | -78 29.7 | 13053. | 11639 | 5908 | -64132. | 65447 | |
| 1969 | 27.02.3 | -78 30.8 | 13026. | 11602 | 5921 | -64099. | 65409 | |
| 1970 | 27.09.6 | -78 32.1 | 12996. | 11563 | 5932 | -64078. | 65383 | |
| 1971 | 27.13.3 | -78 33.3 | 12963. | 11527 | 5930 | -64032. | 65331 | |
| 1972 | 27.22.1 | -78 34.4 | 12937. | 11489 | 5947 | -64008. | 65302 | |
| 1973 | 27.27.6 | -78 35.8 | 12905. | 11451 | 5951 | -63985. | 65273 | |
| Mean annual change | +07.91 | -01.16 | -28.8 | -39.2 | +13.8 | +30.9 | -36.1 | |

## TABLE 6

## ORIENTATIONS OF VARIOMETER MAGNETS

| COMPONENT | | REFERENCE FIELD | DATE | MAGNET ORIENTATION | N POLE |
|---|---|---|---|---|---|
| Normal-Run | H | 12903 nT | 27-06-73 | E 0.3° N | |
| | | 12898 nT | 25-10-73 | E 0.3 N | |
| | D | 27.5°E | 08-07-73 | N 7.2° W | |
| | | 27.5°E | 13-07-73 | N 0.3° E | |
| | | 27.6°E | 24-10-73 | N 0.2° E | |
| | Z | 63994 nT | 27-06-73 | 0.2° | Down |
| Rapid-Run | H | 12907 nT | 27-06-73 | W 1.5° S | |
| | | 12907 nT | 13-07-73 | W 0.05°S | |
| | D | 27.45°E | 27-06-73 | N 0.2°E | |
| | Z | 63994 nT | 27-06-73 | 0.7° | Down |

## TABLE 7

## F VARIATION ABOVE PIER A

| Height Above Pier A* cm | F FIELD nT |
|---|---|
| 0 | 65362 |
| 11 | 65317 |
| 21 | 65303 |
| 31 | 65294 |
| 41 | 65291 |
| 51 | 65289 |

* Height is measured from base of sensor box to top of pier. Lower edge of sensor is 20 cm above base of box.

TABLE 8

NORMAL-RUN THERMOGRAPHS 1973

| FROM | TO | St | ADOPTED (a) St | bt |
|---|---|---|---|---|
| | | °C/mm | °C/mm | °C |
| Z THERMOGRAPH | | | | |
| 01-01-73 | 07-01-73 | 1.28 | 1.4 | -64.0 |
| 08-01-73 | 29-01-73 | 1.31 | | -63.8 |
| 30-01-73 | 18-02-73 | 1.41 | | -63.5 |
| 19-02-73 | 03-03-73 | 1.38 | | -63.2 |
| 04-03-73 | 02-04-73 | 1.35 | | -64.5 |
| 03-04-73 | 17-05-73 | 1.42 | | -64.2 |
| 18-05-73 | 30-11-73 | 1.40 | | -64.8 |
| H THERMOGRAPH | | | | |
| 01-01-73 | 08-06-73 | 5.66 | 6.0 | -240.8 |
| 09-06-73 | 30-11-73 | 6.33 | | -218.5 |

(a) Adopted scale values apply for the entire interval 1 Jan through 30 Nov 1973

TABLE 9

EARTHQUAKES RECORDED AT MACQUARIE ISLAND AND LISTED IN NOAA PDE SHEETS

| Date 1973 | Station | Arrival Time UT hms | Geographic Co-ords Lat. | Geographic Co-ords Long. | Depth km | Magnitude MB | Region |
|---|---|---|---|---|---|---|---|
| | | | | | DATA FROM PDE SHEETS | | |
| Jan 04 | MQI | 04 09 19.4 | 49.7S | 155.1E | N | - | North of Macquarie Island |
| Jan 05 | MQI | 13 58 43.0 | 39.0S | 175.2E | 150 | 6.2 | North Island, New Zealand |
| Jan 06 | MQI | 16 00 17.0 | 14.7S | 166.4E | 36 | 6.1 | New Hebrides Islands |
| Jan 18 | MQI | 09 36 51.1 | 6.9S | 150.0E | 43 | 6.3 | New Britain Region |
| Jan 23 | MQI | 04 57 37.0 | 12.1S | 166.5E | 97 | 5.8 | Santa Cruz Islands |
| Jan 24 | MQI | 20 15 26.3 | 1.0N | 126.3E | 53 | 5.1 | Molucca Passage |
| Feb 13 | MQI | 15 29 50.5 | 17.5S | 178.5W | 541 | 5.5 | Fiji Islands Region |
| Feb 21 | MQI | 12 23 31.4 | 5.3S | 151.5E | 90 | 5.3 | New Britain Region |
| Mar 10 | MQI | 19 47 22.0 | 0.1N | 123.4E | 173 | 5.0 | Northern Celebes |
| Mar 13 | MQI | 01 51 15.8 | 5.4S | 154.2E | 170 | 5.5 | Solomon Islands |
| Mar 14 | MQI | 06 09 27.0 | 62.5S | 165.3E | 36 | 5.5 | Balleny Islands Region |
| Mar 14 | MQI | 11 34 31.8 | 5.3S | 152.2E | 64 | 5.8 | New Britain Region |
| Mar 16 | MQI | 01 02 11.0 | 2.1N | 126.6E | 18 | 6.0 | Molucca Passage |
| Mar 17 | MQI | 05 03 55.0 | 19.4S | 169.4E | 194 | 6.0 | New Hebrides Islands |
| Mar 17 | MQI | 08 42 40.0 | 13.4N | 122.8E | N | 5.6 | Luzon, Philippine Islands |
| Mar 19 | MCQ | 06 42 46.1 | 53.2S | 159.2E | N | 5.5 | Macquarie Islands Region |
| Mar 20 | MCQ | 19 18 35.8 | 8.3S | 117.4E | 162 | 5.7 | Sumbawa Island Region |
| Apr 28 | MQI | 08 14 05.2 | 55.9S | 158.7E | 22 | - | Macquarie Islands Region |
| May 02 | MQI | 01 34 36.0 | 10.0S | 150.2E | 29 | 5.6 | East New Guinea Region |
| May 04 | MQI | 11 37 37.6 | 2.3N | 126.7E | N | 5.9 | Molucca Passage |
| May 04 | MQI | 19 43 52.5 | 6.0S | 129.7E | 175 | 5.3 | Banda Sea |
| May 11 | MQI | 10 55 44.0 | 1.0N | 126.0E | 24 | 5.4 | Molucca Passage |
| May 12 | MQI | 16 29 13.0 | 3.7S | 152.1E | 13 | 5.5 | New Ireland Region |
| May 22 | MQI | 22 13 15.1 | 10.0S | 150.3E | 13 | 5.5 | East New Guinea Region |
| Jun 01 | MQI | 07 30 05.0 | 47.8S | 99.7E | N | 5.8 | Southeast Indian Rise |
| Jun 07 | MQI | 02 43 38.1 | 53.9S | 159.4E | N | 5.8 | Macquarie Islands Region |
| Jun 09 | MQI | 08 29 30.7 | 10.3S | 161.4E | 70 | 6.3 | Solomon Islands |
| Jun 14 | MQI | 11 11 31.6 | 7.3S | 120.4E | 631 | 5.8 | Flores Sea |
| Jun 15 | MQI | 21 35 38.0 | 61.1S | 154.2E | N | 4.9 | Balleny Islands Region |
| Jun 25 | MQI | 07 31 54.8 | 19.1N | 121.2E | 50 | 5.7 | Philippine Islands Region |
| Jul 09 | MQI | 16 32 21.0 | 10.7N | 92.6E | 46 | 5.7 | Andaman Islands Region |
| Jul 20 | MQI | 08 02 51.8 | 56.3S | 146.9E | N | 5.2 | West of Macquarie Island |
| Jul 21 | MQI | 04 25 24.3 | 24.8S | 179.2W | 411 | 5.9 | South of Fiji Islands |
| Jul 23 | MQI | 01 41 57.7 | 50.0N | 78.9E | 0 | 6.3 | Eastern Kazakh SSR |
| Jul 23 | MQI | 08 43 12.8 | 5.4S | 146.9E | 221 | 5.1 | East New Guinea Region |
| Jul 29 | MQI | 21 43 56.3 | 56.3S | 147.4E | N | 5.3 | West of Macquarie Island |
| Aug 01 | MQI | 01 38 53.2 | 14.35 | 167.3E | 200 | 6.1 | New Hebrides Islands |
| Aug 04 | MQI | 22 01 45.0 | 2.0N | 126.7E | 40 | 5.6 | Molucca Passage |
| Aug 05 | MQI | 15 55 40.3 | 16.2S | 173.1W | N | 6.1 | Tonga Islands |
| Aug 09 | MQI | 13 08 08.6 | 56.3S | 147.4E | N | 5.6 | West of Macquarie Island |
| Aug 13 | MQI | 08 37 14.7 | 4.5S | 144.0E | 112 | 6.0 | Near North Coast of New Guinea |

TABLE 9 (cont)

| Date 1973 | Station | Arrival Time UT hms | Geographic Co-ords Lat. | Long. | Depth km | Magnitude MB | Region |
|---|---|---|---|---|---|---|---|
| | | | | | DATA FROM PDE SHEETS | | |
| Aug 30 | MQI | 20 02 47.2 | 7.1N | 84.3E | N | 5.9 | Bay of Bengal |
| Sep 03 | MQI | 19 10 05.6 | 54.6S | 146.3E | N | - | West of Macquarie Island |
| Sep 05 | MQI | 03 51 12.0 | 19.7S | 177.9W | 402 | 5.0 | Fiji Islands Region |
| Sep 12 | MCQ | 07 19 33.6 | 73.3N | 55.2E | 0 | 6.8 | Novaya Zemlya |
| Sep 24 | MQI | 23 31 36.8 | 52.3S | 160.7E | 10 | 5.6 | Macquarie Islands Region |
| Sep 25 | MQI | 16 19 07.0 | 54.8S | 145.8E | N | 5.9 | West of Macquarie Island |
| Sep 26 | MQI | 16 29 26.1 | 55.4S | 146.3E | N | 5.5 | " " " |
| Sep 28 | MQI | 23 53 27.0 | 55.4S | 146.0E | N | 5.1 | " " " |
| Sep 29 | MQI | 03 06 05.0 | 60.3S | 150.0E | N | 4.8 | " " " |
| Sep 29 | MQI | 11 19 41.0 | 49.8S | 164.1E | N | - | Auckland Islands Region |
| Oct 19 | MCQ | 00 13 03.9 | 54.7S | 158.5E | N | 5.8 | Macquarie Islands Region |
| Oct 27 | MCQ | 07 19 34.9 | 70.8N | 54.2E | 0 | 6.9 | Novaya Zemlya |
| Nov 06 | MQI | 05 25 19.0 | 23.8S | 179.1E | 546 | 5.5 | South of Fiji Islands |
| Nov 12 | MQI | 04 02 22.9 | 6.2S | 154.5E | 50 | 5.6 | Solomon Islands |
| Nov 30 | MQI | 08 17 17.0 | 15.2S | 167.4E | 124 | 6.0 | New Hebrides Islands |

## TABLE 10

## INTENSITIES OF LOCAL EARTHQUAKES

| DATE | ARRIVAL TIME (UT) AT RECORDING STATION hms | MM INTENSITY AT ANARE STATION |
|---|---|---|
| 1972 Dec 24 | 20 31 31.4 | II |
| 1972 Dec 26 | 15 09 28.7 | II - III |
| 1973 Jun 07 | 02 43 38.1 | III - IV |
| 1973 Oct 19 | 00 13 03.9 | IV |
| 1973 Oct 19 | 14 19 30.5 | II |
| 1973 Nov 19 | 18 18 54.7 | II |
| 1973 Nov 20 | 22 32 15.3 | II |

TABLE 11

SEISMOGRAPH CONSTANTS

| DATE 1973 | SEISMOMETER | SEISM. F.P. (SEC) | GALVO. F.P. (SEC) | GALVO. DAMPING | SYSTEM DAMPING | DEFLECTION ON SEISMOGRAM FOR GROUND MOTION UP |
|---|---|---|---|---|---|---|
| | | MCQ (LAT. 54° 29.9'S LONG. 158°57.4'E) | | | | |
| Jan 31 | Willmore Mk 2 | 0.97 | 0.2 | 3.4:1 | Critical | Down |
| Feb 21 | Willmore Mk 1 | 0.86 | 0.2 | 11:1 | 3.1:1 | Up |
| Oct 24 | Willmore Mk 1 | 0.87 | 0.2 | 13:1 | 3.6:1 | Up |
| | | MQI (LAT. 54°31.2'S LONG. 158°55.9'E) | | | | |
| Jul 02 | Willmore Mk 2 | 0.68 | 0.2 | 18:1 | - | - |
| Jul 18 | Willmore Mk 2 | 1.00 | 0.2 | 18:1 | Seism. damping set at 17.0:1 | Up |
| Aug 29 | Willmore Mk 2 | 0.99 | 0.2 | 18:1 | - | - |
| Nov 05 | Willmore Mk 2 | 0.99 | 0.2 | 17:1 | - | Up |

TABLE 12

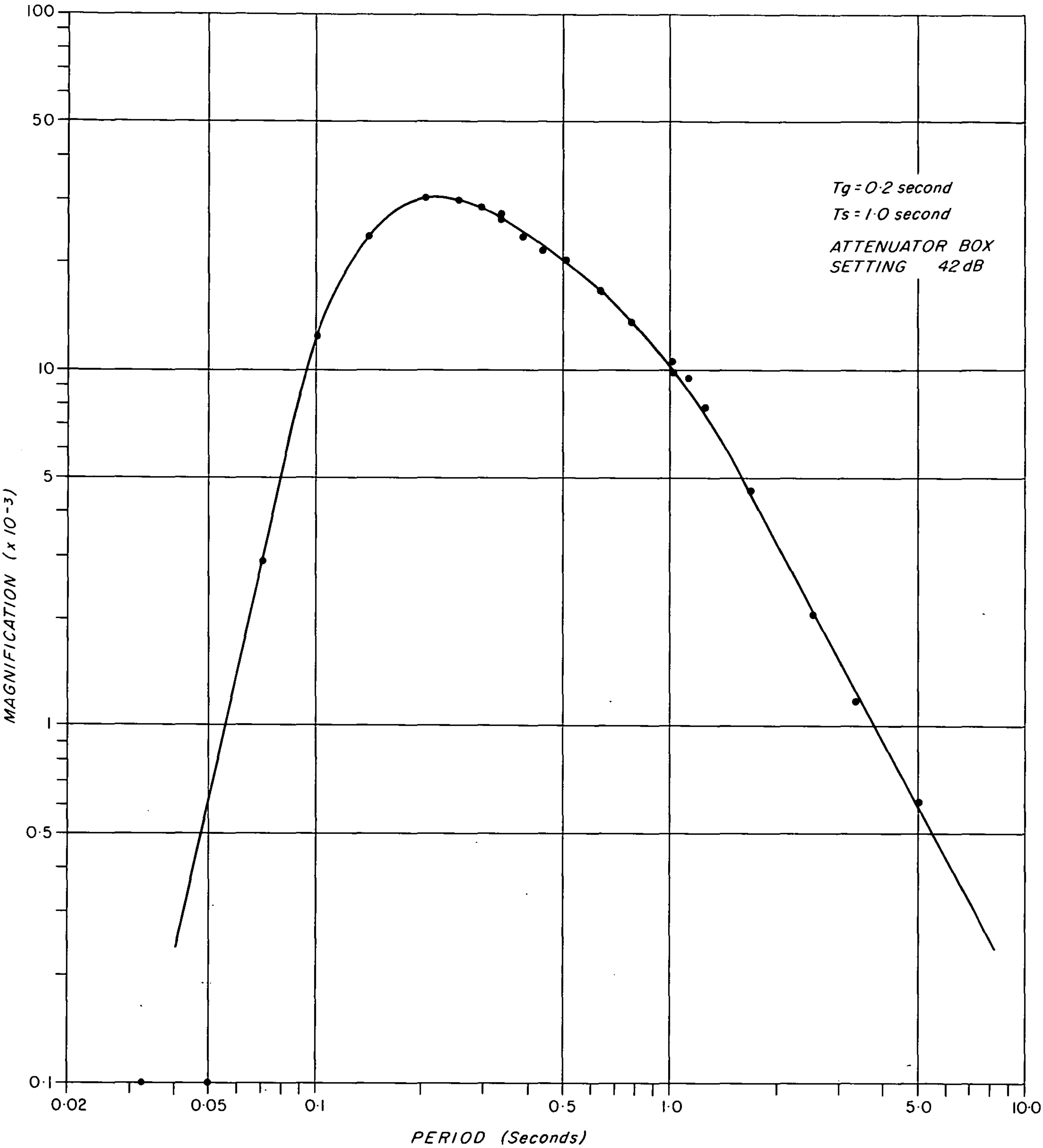
MQI ATTENUATOR SETTINGS

| | | | | | |
|---|---|---|---|---|---|
| Attenuator Box Setting | | 42 dB | 38 dB | 34 dB | 30 dB |
| Relative Magnification | Observed | 1.0 | 1.55 | 2.5 | 3.95 |
| | Calculated | 1.0 | 1.58 | 2.51 | 3.98 |

TABLE 13

T PHASES MACQUARIE ISLAND 1973

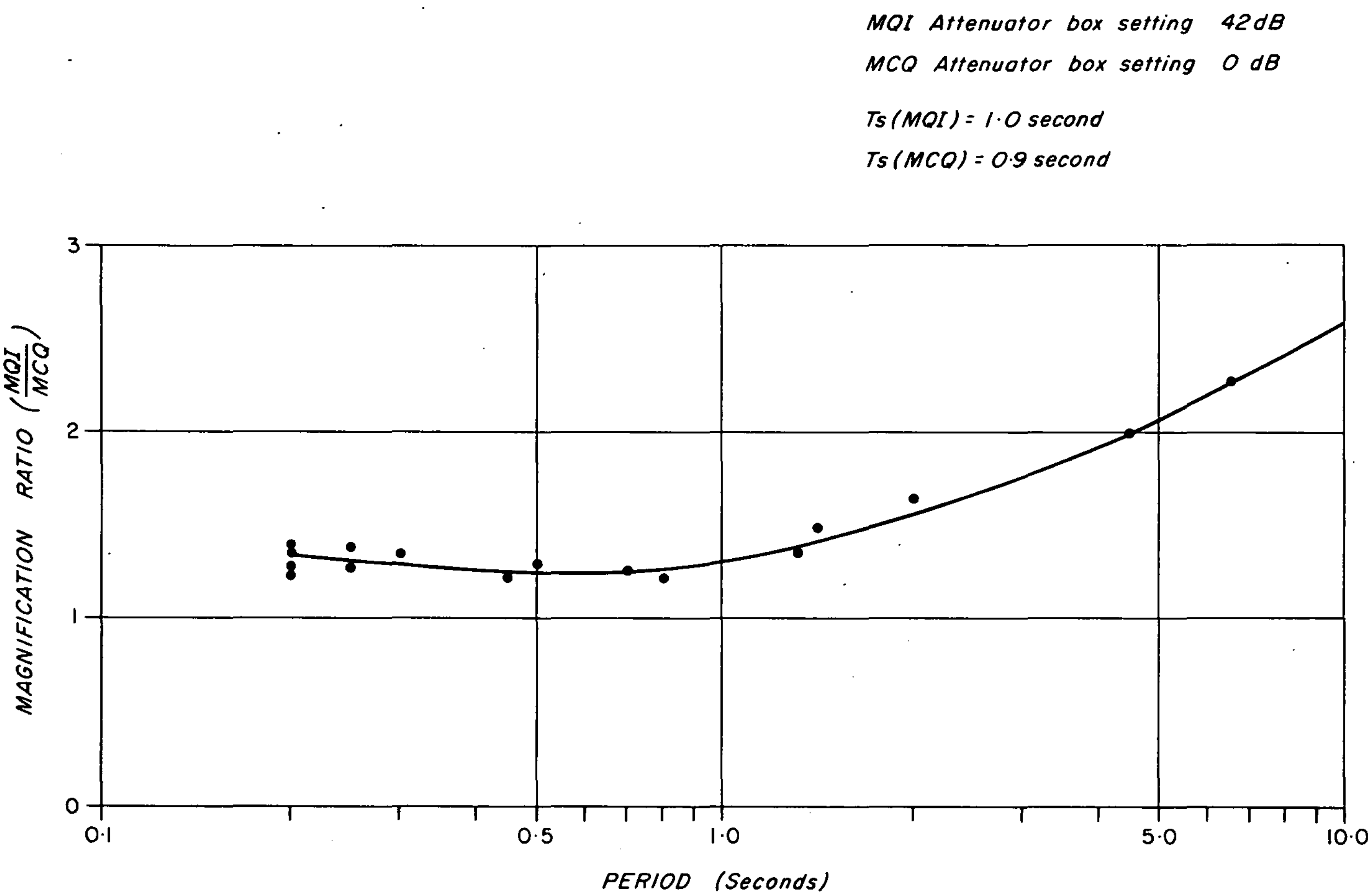
| DATE | ORIGIN TIME UT (hms) | GEOGRAPHIC Co-ords Lat. | Long. | DEPTH KM | REGION | STATION | RECORDED TMAX TIME UT (hms) | GREAT CIRCLE DISTANCE KM |
|---|---|---|---|---|---|---|---|---|
| Jan 04 | 04 08 01.7 | 49.7S | 155.1E | N | North of Macquarie Island | MQI | 04 14 55 | 594 |
| Feb 08 | 10 09 08.3 | 45.5S | 96.3E | N | Southeast Indian Rise | MQI | 10 59 40 | 4452 |
| Feb 19 | 20 07 11.9 | 57.5S | 141.0W | N | South Pacific Cordillera | MQI | 20 49 00 | 3651 |
| Feb 20 | 22 05 19.6 | 62.6S | 167.4E | N | Balleny Islands Region | MQI | 22 17 07 | 836 |
| Mar 14 | 06 07 30.8 | 62.5S | 165.3E | 36 | " " | MQI | 06 18 20 | 965 |
| Apr 25 | 07 27 20.1 | 65.5S | 179.3E | N | " " | MQI | 07 46 30 | 1660 |
| May 19 | 18 18 31.4 | 15.6S | 73.8W | 79 | Southern Peru | MQI | 20 20 22 | 10810 |
| Jun 01 | 07 22 57.0 | 47.8S | 99.7E | N | Southeast Indian Rise | MQI | 08 09 12 | 4092 |
| Jun 10 | 07 16 19.5 | 57.7S | 142.1W | N | South Pacific Cordillera | MQI | 07 57 41 | 3582 |
| Jul 20 | 08 01 16.7 | 56.3S | 146.9E | N | West of Macquarie Island | MQI | 08 09 55 | 786 |
| Jul 29 | 21 42 21.4 | 56.3S | 147.4E | N | " " " | MQI | 21 50 55 | 758 |
| Aug 07 | 06 39 00.8 | 54.4S | 136.6W | N | South Pacific Cordillera | MQI | 07 24 41 | 4044 |
| Aug 09 | 13 06 36.6 | 56.3S | 147.4E | N | West of Macquarie Island | MQI | 13 15 06 | 756 |
| Aug 18 | 09 20 18.4 | 56.0S | 143.8W | N | South Pacific Cordillera | MQI | 10 00 45 | 3552 |
| Sep 03 | 19 08 26.1 | 54.6S | 146.3E | N | West of Macquarie Island | MQI | 19 17 34 | 816 |
| Sep 25 | 16 17 28.3 | 54.8S | 145.8E | N | " " " | MQI | 16 26 35 | 845 |
| Sep 26 | 16 27 47.2 | 55.4S | 146.3E | N | " " " | MQI | 16 36 53 | 818 |
| Sep 28 | 23 51 46.9 | 55.4S | 146.0E | N | " " " | MQI | 24 00 49 | 834 |
| Sep 29 | 11 18 20.7 | 49.8S | 164.1E | N | Auckland Islands Region | MQI | 11 24 51 | 637 |
| Oct 05 | 05 45 27.3 | 33.0S | 71.9W | 14 | Near Coast of Central Chile | MQI | 07 29 07 | 9190 |
| Oct 12 | 18 04 29.3 | 16.0S | 74.0W | 47 | Near Coast of Peru | MCQ | 20 06 10 | 10760 |
| Nov 16 | 23 08 49.0 | 51.2S | 139.5E | N | South of Australia | MQI | 23 24 02 | 1356 |



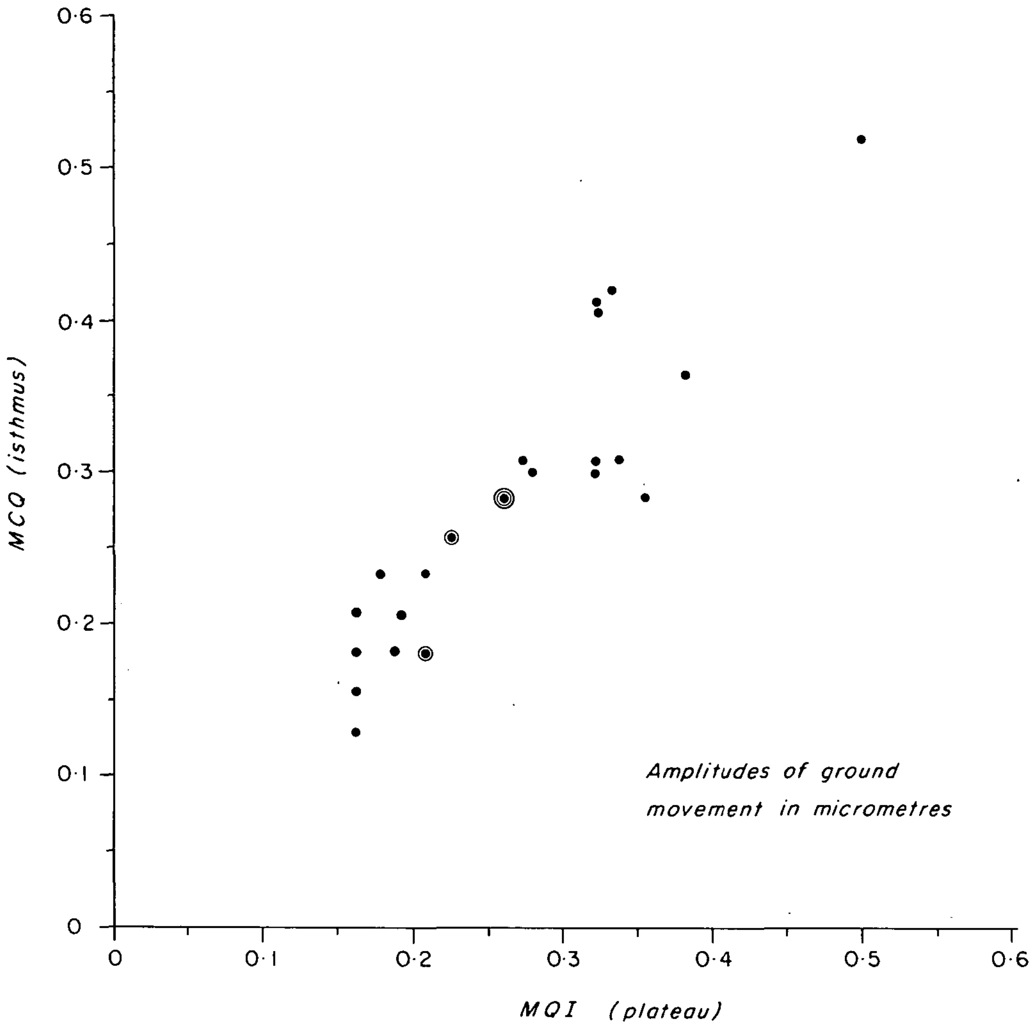

# MQI MAGNIFICATION CURVE 1973

*To accompany Record No. 1974/60*

ANT / B9 - 46 A

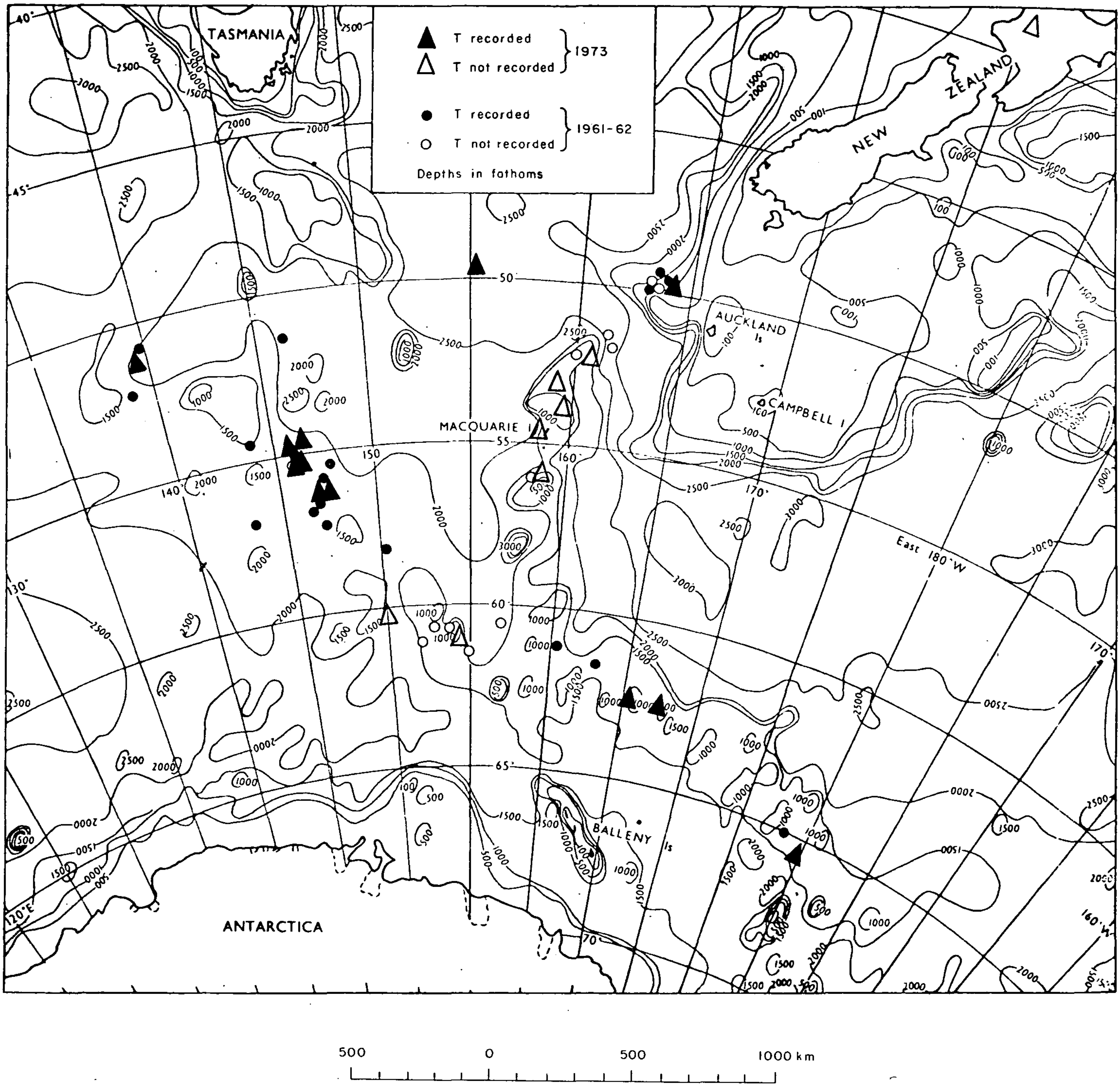



# MQI-MCQ MAGNIFICATION RELATION




# COMPARISON OF MICROSEISMIC NOISE LEVELS IN MQI AND MCQ VAULTS

(Tg = 2 – 3s)

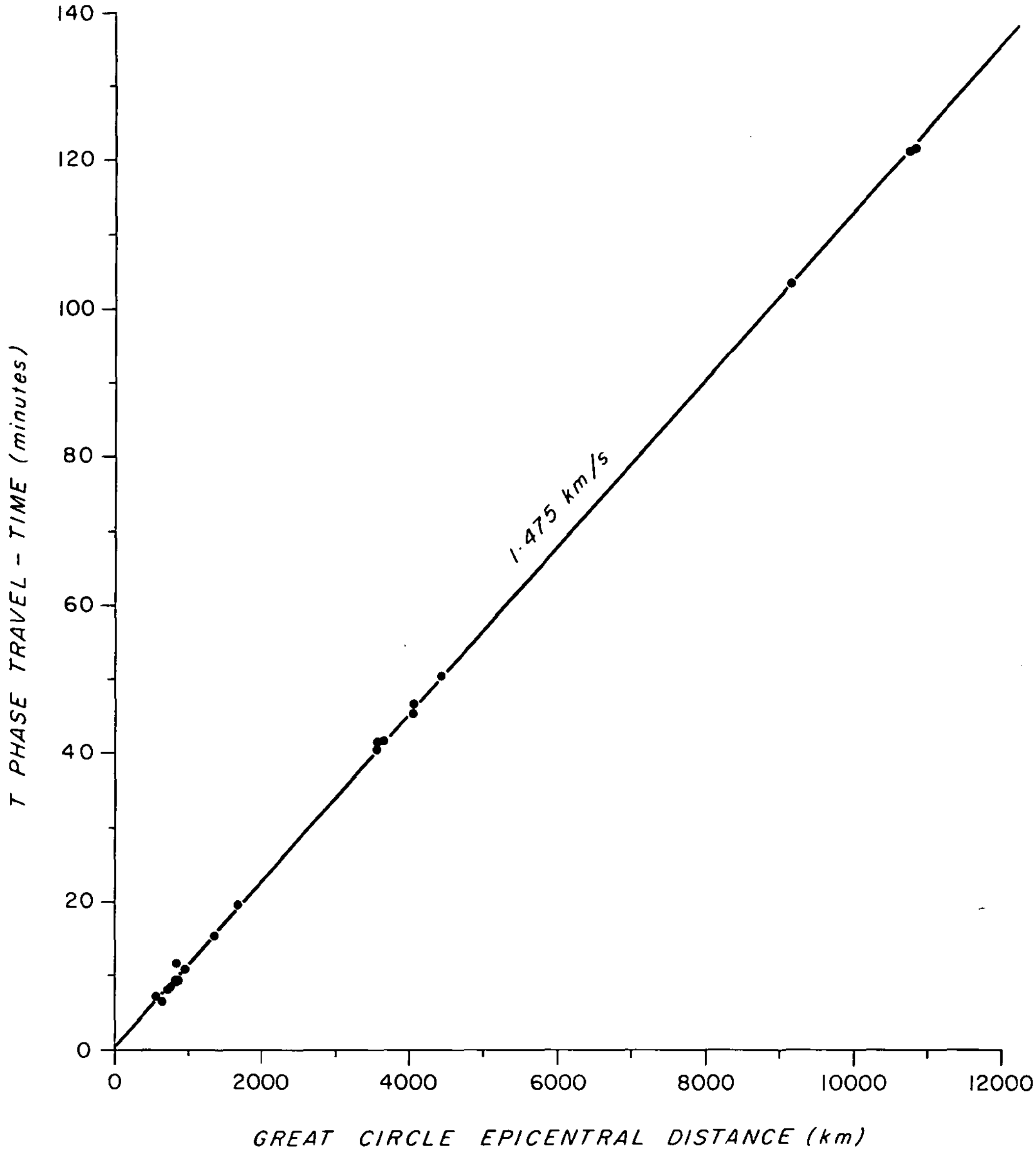



# EPICENTRES MACQUARIE ISLAND REGION 1973 – T PHASE

*To accompany Record No. 1974/60*

ANT/B9-49A

PLATE 5




OBSERVED T PHASE TRAVEL-TIMES
MACQUARIE ISLAND 1973

*To accompany Record No. 1974/60*

ANT/B9-50A