copy 3

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1966/162

PENDULUM GRAVITY MEASUREMENTS IN AUSTRALIA, 1964

by

J.E. SHIRLEY

RECORD No. 1966/162

PENDULUM GRAVITY MEASUREMENTS IN AUSTRALIA, 1964

by

J.E. SHIRLEY

CONTENTS

ILLUSTRATIONS

1966/162

SUMMARY

Six pendulum stations along the east coast of Australia were reoccupied during 1964 with a GSI Pendulum apparatus. The gravity intervals obtained differ considerably from the currently accepted values but each determination has a low mean error. Although there are unsatisfactory features of the equipment the results indicate that the timing and other electronic sections of the equipment operate satisfactorily, but there is some alteration, from station to station, in the operating characteristics of the pendulums. It appears that the operating characteristics of the individual pendulums may vary without relation to each other. This suggests that the prime cause of the gravity discrepancies is some anomalous behaviour associated with the pendulums themselves or with the knife edges and supports.

1. INTRODUCTION

From June to December 1964 the Bureau of Mineral Resources (BMR) made gravity measurements along the east coast of Australia using a set of GSI Pendulum equipment. Gravity observations were made at Melbourne, Sydney, Brisbane, Mackay, Townsville, and Cairns.

The GSI Pendulum equipment was purchased by the BMR in 1962 and used to measure the gravity interval between Tokyo and Melbourne (Langron, 1966). The value of the interval determined by Langron differs by about 3 mgal from that determined by Inoue and Seto (1961), whose interval of 202.1 ± 0.2 mgal is thought to be reliable. The value of 205.3 ± 0.9 mgal obtained by Langron indicates either:

(a) incorrect scaling or reduction of results,

(b) an operational malfunction of the equipment, or

(c) an error in the constants used in the reduction of the results.

The possibility of incorrect scaling or reduction of results was, after careful examination of the data, eliminated (Langron, 1966). The measurements described in this Record were designed to further investigate the cause of the discrepancy.

The Isogal Survey of 1964 (Barlow, in prep.) established a gravity network across Australia. This network consists of twelve east-west lines with permanently marked stations at intervals of about 150 miles. North-south control is required to establish the datum for each of these lines. This has been done by using existing data and also by the preliminary measurements along the Western Pacific Calibration Line (Shirley, 1966). It was also intended to use the pendulum gravity observations to provide control if the reliability of the equipment could be established. The north-south gravity control of the Isogal survey includes stations of the Western Pacific Calibration Line as proposed by the International Union of Geodesy and Geophysics.

2. SURVEY OPERATIONS

The survey consisted of two traverses along the east coast of Australia. On each traverse gravity observations were made in the following order - Melbourne, Brisbane, Cairns, Townsville, Mackay, Sydney, and Melbourne (Plate 1). The station descriptions are shown in Plates 2 to 7 and short station descriptions are given in Appendix A. The survey statistics are given in Appendix B.

3. DESCRIPTION OF GSI PENDULUM APPARATUS

The GSI Pendulum equipment purchased by the BMR is similar to that described by Inoue (1961). It consists of a Vening Meinesz arrangement of three minimum quartz pendulums, which are swung in an evacuated chamber. The pendulums have steel knife-edges and are supported on agate plates. The two outer pendulums are swung in antiphase, and the centre pendulum, in the absence of any flexure of the support or ground motion, remains stationary. The amplitude of a pendulum swing is measured by means of a light-spot reflected by both the inner pendulum and one outer pendulum. Thus the movement recorded is that of the difference between the inner and outer pendulums and this reduces the error due to motion of the support. A photomultiplier detects each light-spot as it passes over a slit when the pendulum is in its mean position. For each complete swing of the pendulum two pulses are produced by the detector, i.e. one pulse on the forward swing and one on the backward swing.

The timing of the pendulum is accomplished by the simultaneous recording on a spark chronograph of the pulses from the detector and a standard frequency pulse obtained from a 100 kc/s GT cut quartz crystal oscillator. Plate 8 is a block diagram of the apparatus.

4. OPERATION OF PENDULUM APPARATUS

At each station the pendulum apparatus was assembled and allowed to warm up and stabilise at operating temperature (40°C for the pendulums and 45°C for the crystal oscillator) for a period of at least 24 hours.

Prior to the commencement of swinging operations the frequency of the crystal oscillator was checked against a suitable standard. The Postmaster-General's Department (PMG) provided an accurate (1 part in 10^{10}) 1-kc/s tone, which was used as a standard at the BMR Laboratories in Melbourne. National Standards Laboratories (NSL) provided access to a 1-kc/s standard in Sydney. At all other locations the 10-Mc/s time signals broadcast by WWV-H (Hawaii) or the 5475-kc/s and 7465-kc/s signals broadcast by Weapons Research Establishment (WRE) were used as calibration standards. From 24th September 1964, the PMG time-signal service, VNG, on 5425 kc/s was used for calibration in preference to time signals from WWV-H or WRE.

After the electronics had been tested and the crystal oscillator frequency checked, pendulum swinging operations were commenced. The records were analysed and the pendulum period was calculated before the apparatus was switched off. The apparatus was allowed to cool for at least 24 hours before being dismantled for transport.

5. REDUCTION OF THE DATA

Plate 9 shows some typical records obtained during the survey. The period is obtained by timing about 1000 swings of the pendulum. Each period has an arc (or amplitude) correction and a temperature correction applied to it (Browne, 1959) and the two semi-independent determinations obtained on a record are averaged. About twelve independent determinations of the period are made at each pendulum station.

Because the pressure within the swinging chamber is kept below 0.1 millimetres of mercury no pressure correction is necessary (Inoue & Seto, 1961). Sway effect or flexure of the pendulum support is detected by the centre pendulum, which hangs at rest at the start of a measurement. If there is any flexure of the support or other disturbance the centre pendulum will begin to oscillate. If the oscillation of the centre pendulum exceeds a specified limit the measurement is discarded.

For each station the mean period and the standard deviation of the observations from the mean are obtained. These are listed in Table 1. The standard deviation σ was calculated using

$$\sigma = \left[\frac{\sum(T_i-\bar{T})^2}{n-1}\right]^{\frac{1}{2}}$$

where T_i is the i^{th} period

$\bar{T}$ is the average period for n determinations

n is the number of period measurements.

From the expression $T = 2\pi\sqrt{l/g}$

it can be shown that the gravity interval Δg between two points is

$$\Delta g = -\alpha\Delta T + \beta\Delta T^2 - \ldots\ldots\ldots$$

where ΔT is the difference between the periods of the pendulum at the two points and α and β are constants for a particular pendulum and depend on the value of gravity and the pendulum period at the base station.

For the observations of this survey the base station is the National Gravity Base Station, Melbourne (Station No. 5099.9901), where the gravity value is 979,979.0 mgal (Dooley et al., 1961). The pendulum periods used for the base reading were those obtained in January 1964 (Langron, 1966) and these are shown in Table 1.

The pendulum periods obtained at all stations during 1964 were converted to gravity intervals using the above relation for Δg. The gravity intervals obtained in this way together with the standard error of the observations are shown in Table 2. Also shown in Table 2 are the currently accepted best values for the pendulum stations and the difference between the observed and accepted values.

6. DISCUSSION OF RESULTS

Plate 10 is a plot of the differences in Table 2 and is called the pendulum 'drift'. This 'drift' is composed of long-term creep, i.e. regular change of effective length of the pendulum, and tares. It may also have components due to other causes such as irregular behaviour of the knife edges. It can be seen that the 'drift' shown in Plate 10 is most irregular and cannot be explained satisfactorily. The variations in behaviour of pendulum No. 2 are more pronounced than those of pendulum No. 3.

Plate 11 shows a possible interpretation of the drift curve for pendulums Nos. 2 and 3. In each case there is a difference between the two observations in Melbourne in August and September. The August observation is not of high reliability owing to some ground vibrations, but the difference appears to be real. This may be related to modifications to the vacuum equipment used to evacuate the swinging chamber. The apparatus as supplied relied on a Geisler tube to provide pressure measurements. This was calibrated by the author at NSL, Sydney, in August and the calibration curve is shown in Plate 12. The calibration indicated that the pressure in the chamber for the first traverse had been between 0.06 and 0.11 millimetres of mercury and consequently the equipment was modified and a harder vacuum (0.04 to 0.1 millimetres of mercury) obtained for the second traverse. The difference between the two Melbourne observations in August and September is thought to be related to the harder vacuum obtained for the September observation. On the data obtained during the survey there is no sound basis for the analysis of the results in terms of drift and tares as shown in Plate 11.

The gravity intervals measured during the survey (Table 2) could not be reconciled with the established gravity intervals (Dooley, 1965) nor do they agree with later values obtained using five La Coste and Romberg gravity meters (Shirley, 1966). Consequently the equipment was critically examined to determine the cause of the poor results. It can be seen from the survey results (Table 2) that the intervals obtained using pendulum No. 2 do not agree with the intervals obtained using pendulum No. 3; hence at least part of the cause of the discrepancy must be one that will not affect both pendulums simultaneously.

The possibility of timing errors is negligible as also is any error due to temperature effects. The amplitude corrections supplied by the manufacturer were examined and found to be accurate.

An analysis of the individual pendulum periods at any one station also indicates that the cause of the anomalous pendulum behavious is inherent in each pendulum.

Plate 13 shows the individual periods for the series of pendulum observations in Sydney. The mean errors for these results are :

pendulum 2 : 0.2 mgal
pendulum 3 : 0.1 mgal

These low mean errors show that the results are a consistent set and appear to indicate that the equipment is operating in a satisfactory manner.

Equivalent data for a series of observations at Mackay are shown in Plate 14 and the mean error for both sets of results is 0.1 mgal.

A comparison of Plates 13 and 14 shows that the difference in period between the two pendulums at each station has changed significantly. The differences are :

Mackay	400×10^{-8} second
Sydney	800×10^{-8} second

The maximum gravity interval on the survey - from Cairns to Melbourne - is approximately 1500 mgal and the change in the difference between the periods of the pendulums for this interval may be calculated from

$$\Delta T - \Delta T' = 2\pi(\sqrt{l_2} - \sqrt{l_3})(\sqrt{\tfrac{1}{g}} - \sqrt{\tfrac{1}{g'}})$$

where $T = T_2 - T_3$

subscripts 2 and 3 refering to pendulums Nos. 2 and 3, respectively, and the primed and unprimed symbols refering to values at the base station and the field station, respectively. It is assumed that the effective length l is constant. The maximum differences of $\Delta T - \Delta T'$ should be of the order of 0.3×10^{-8} second for a gravity interval of 1500 mgal. In fact this difference varies from 79×10^{-8} to 196×10^{-8} second and the variation has no relation to the value of gravity.

It appears therefore that part of the cause of the anomalous gravity intervals is inherent in the pendulums.

During regular inspections of the pendulums the formation and development of small tension cracks was noticed. In one case a crack occurred in pendulum No. 1 and this crack developed until a small piece of the pendulum close to the knife edge fell off. This was not noticed during operations as this is the centre pendulum and is normally at rest.

In an attempt to isolate the cause of the irregular behaviour of the pendulums, the knife edges and agate supporting plates were examined for flatness (Shirley, in preparation). Optical tests showed that the knife edges were in a fair condition, with the exception of pendulum No. 1, whose knife edge was extensively flattened. The agate plates were not flat nor were the two sides of the plates coplanar. On the agate plate of pendulum No. 1, the departure from coplanarity was one ten thousandth of an inch. The departure from flatness prevented any measurement of the departure from parallelism of the top and bottom surfaces of the agate plates.

7. CONCLUSIONS

The main conclusion is that the GSI Pendulum equipment does not operate in a satisfactory manner. The results obtained at any one station have the appearance of a consistent set and the standard deviations of the observations is small. The results at this stage indicate that the equipment appears to be operating satisfactorily. However, the gravity intervals measured between individual sets of observations are in error by up to 20 mgal. The discrepancies are due to causes as yet undetermined, inherent in the pendulums. Preliminary tests have indicated that the agate plates on which the pendulums are supported are not flat and this may be the cause or part of the cause of the anomalous behaviour of the equipment.

8. REFERENCES

BARLOW, B. C. — Australian Isogal Gravity Survey, 1964. Bur. Min. Resour. Aust. Rec. (in preparation)

BROWNE, B. C. 1959 Draft memorandum on the technique of measuring relative gravity values by means of pendulums. (Unpublished manuscript).

DOOLEY, J. C. 1965 Australian gravity network adjustment, 1962. Bur. Min. Resour. Aust. Rep. 72.

DOOLEY, J. C., McCARTHY, E., KEATING, W. D., MADDERN, C. A., and WILLIAMS, L. W. 1961 Pendulum measurements of gravity in Australia 1950-51. Bur. Min. Resour. Aust. Bull. 46.

INOUE, E. 1961 A new GSI Pendulum apparatus. Bull. Geograph. Surv. Inst. Japan, 6(4), 167-200.

INOUE, E. and SETO, T. 1961 Pendulum determinations of the gravity difference between Tokyo and Melbourne. Bull. Geograph. Surv. Inst. Japan, 6(4), 201-211.

LANGRON, W. J. 1966 Pendulum gravity ties between Tokyo and Melbourne, 1962-1964. Bur. Min. Resour. Aust. Rec. 1966/109.

SHIRLEY, J. E. 1966 Gravity meter measurements in connection with Western Pacific Calibration Line, (Australian Segment), 1965. Bur. Min. Resour. Aust. Rec. 1966/160.

SHIRLEY, J. E. — Modifications and tests of the GSI Pendulum apparatus. Bur. Min. Resour. Aust. Rec. (in preparation).

APPENDIX A

Short descriptions of 1964 pendulum stations

5099.9901 Melbourne	In the 'pendulum room', former BMR Geophysical Laboratory, Gordon Street, Footscray. Marked by painted rectangle on the concrete floor. (Now occupied by Department of Supply Ammunition Factory).
5099.9905 Sydney	In room B37(1) National Standards Laboratory, University Grounds, Chippendale. Marked by painted rectangle and BMR gravity station marker disc.
6499.0147 Brisbane	In the X-ray Laboratory (old seismic vault), Geology School, University of Queensland. Marked by painted rectangle and BMR gravity station marker disc.
6499.9961 Mackay	In the plant room (garage) of the Queensland Ambulance Transportation Board at Mackay. Marked by painted rectangle.
6499.0151 Townsville	In the Materials Test Lqboratory of the Townsville Technical College, Stanley Street. Marked by painted rectangle.
5099.9952 Cairns	In a store room in the workshop of the Ansett-ANA hangar, Cairns aerodrome.

APPENDIX B

Survey statistics

Survey commenced	:	8th June 1964
Survey terminated	:	9th December 1964
Survey personnel	:	J. E. Shirley (Party leader) K. W. Kirby (Field assistant) W. J. Langron (supervised party operations for the first four weeks).

No. of pendulum gravity observations : 14

Equipment	:	GSI Pendulum apparatus as modified by the BMR
Transport	:	2 x 1-ton 4 x 4 trucks (1 truck only for period June to August)

Days observation and testing	:	58
Days computing	:	38
Days travelling	:	38
Days repairs to equipment	:	14
Days unserviceability	:	4

TABLE 1

Pendulum periods and standard deviations

Pendulum No. 2

Pendulum Station	Station number	Date	Period (seconds)	Stand.Dev. (sec x 10^{-8})	No. of swings (n)
Melbourne	5099.9901	Jan.	1.00545753	193	17
Melbourne	5099.9901	May	545624	55	8
Brisbane	6499.0147	June	587207	75	12
Cairns	5099.9952	"	621619	71	15
Townsville	6499.0151	July	615340	196	12
Mackay	6499.9961	"	609228	33	13
Sydney	5099.9905	Aug.	559795	50	13
Melbourne(I)	5099.9901	"	545532	106	12
Melbourne(II)	5099.9901	Sep.	545048	60	12
Brisbane	6499.0147	"	586673	147	14
Cairns	5099.9952	Oct.	620938	163	18
Townsville	6499.0151	"	614334	37	14
Mackay	6499.9961	Nov.	608635	48	13
Sydney	5099.9905	"	559699	22	13
Melbourne	5099.9901	Dec.	544726	20	13

Pendulum No. 3

Pendulum Station	Station number	Date	Period (seconds)	Stand.Dev. (sec x 10^{-8})	No.of swings (n)
Melbourne	5099.9901	Jan.	1.00546054	27	17
Melbourne	5099.9901	May	546043	75	8
Brisbane	6499.0147	June	587548	29	12
Cairns	5099.9952	"	621903	33	15
Townsville	6499.0151	July	615419	20	12
Mackay	6499.9961	"	609622	8	13
Sydney	5099.9905	Aug.	560791	36	13
Melbourne(I)	5099.9901	"	545896	198	12
Melbourne(II)	5099.9901	Sep.	545583	31	12
Brisbane	6499.0147	"	587352	92	14
Cairns	5099.9952	Oct.	621686	86	18
Townsville	6499.0151	Oct.	615164	54	14
Mackay	6499.9961	Nov.	609475	86	13
Sydney	5099.9905	"	560495	40	13
Melbourne	5099.9901	Dec.	545436	27	13

Note : All periods are corrected to 35°C.

TABLE 2

Gravity intervals and mean errors

Pendulum No. 2

Pendulum Station	Station number	Date	Gravity interval from NGBS (mgal)	Mean error* (mgal)	Accepted interval** from NGBS (mgal)
Melbourne	5099.9901	Jan.	0	±0.7	0
Melbourne	5099.9901	May	+2.5	0.4	0
Brisbane	6499.0147	June	-807.6	0.4	-809.2
Cairns	5099.9952	"	-1477.2	0.3	-1478.3
Townsville	6499.0151	July	-1355.1	0.8	-1355.0
Mackay	6499.9961	"	-1236.2	0.1	-1244.0
Sydney	5099.9905	Aug.	-273.7	0.2	-293.3
Melbourne (I)	5099.9901	"	+4.3	0.4	0
Melbourne (II)	5099.9901	Sep.	+13.7	0.2	0
Brisbane	6499.0147	"	-797.2	0.6	-809.2
Cairns	5099.9952	Oct.	-1464.0	0.6	-1478.3
Townsville	6499.0151	"	-1335.5	0.1	-1355.0
Mackay	6499.9961	Nov.	-1224.6	0.2	-1244.0
Sydney	5099.9905	"	-271.8	0.1	-293.3
Melbourne	5099.9901	Dec.	+20.0	0.1	0

Pendulum No. 3

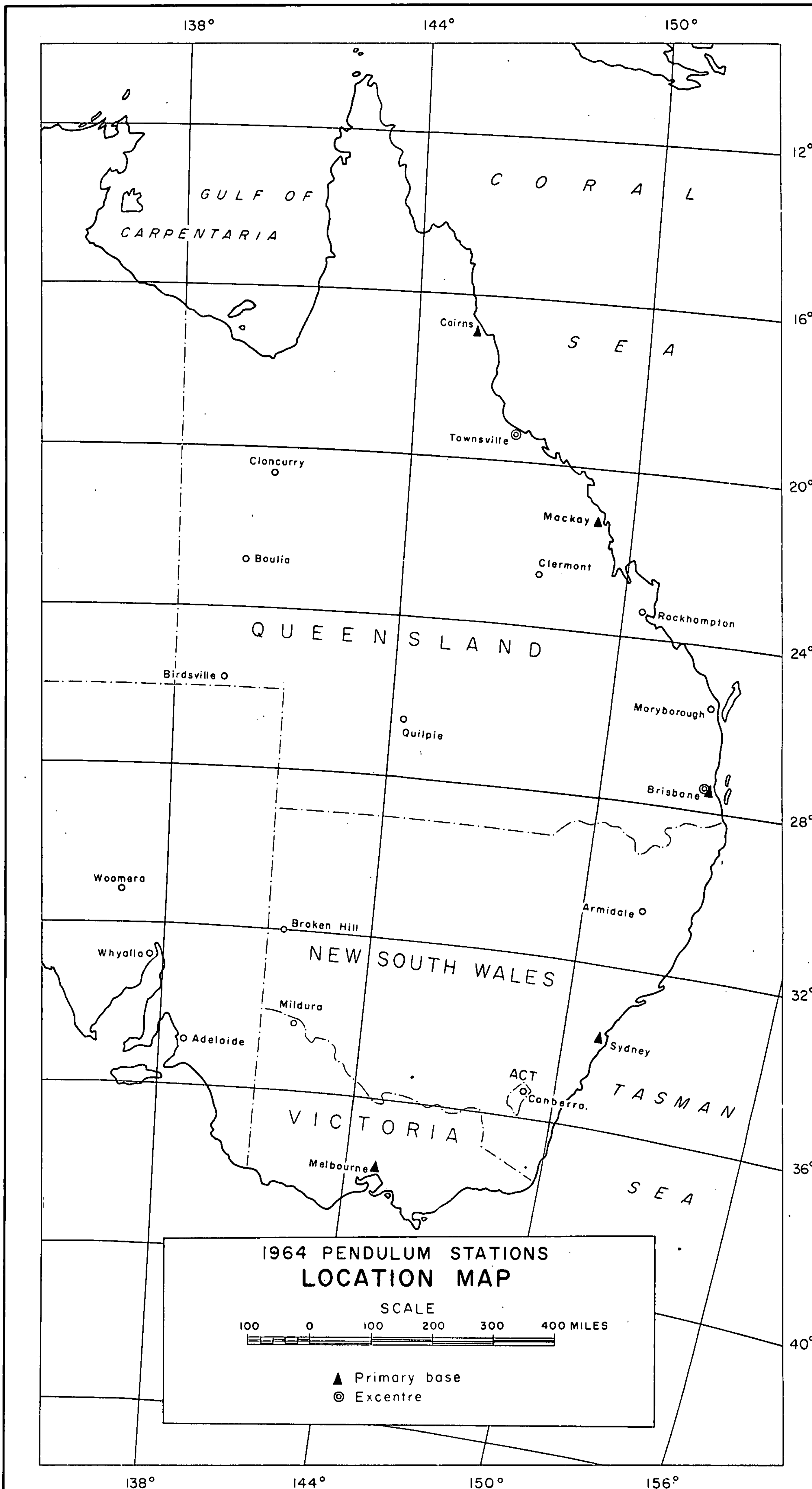
Pendulum Station	Station number	Date	Gravity interval from NGBS (mgal)	Mean error* (mgal)	Accepted interval** from NGBS (mgal)
Melbourne	5099.9901	Jan.	0	±0.1	0
Melbourne	5099.9901	May	+0.2	0.4	0
Brisbane	6499.0147	June	-808.4	0.1	-809.2
Cairns	5099.9952	"	-1476.9	0.1	-1478.3
Townsville	6499.0151	July	-1350.7	0.1	-1355.0
Mackay	6499.9961	"	-1238.0	0.1	-1244.0
Sydney	5099.9905	Aug.	-287.2	0.1	-293.3
Melbourne (I)	5099.9901	"	+3.1	0.8	0
Melbourne (II)	5099.9901	Sep.	+9.4	0.1	0
Brisbane	6499.0147	"	-804.5	0.4	-809.2
Cairns	5099.9952	Oct.	-1472.7	0.3	-1478.3
Townsville	6499.0151	Oct.	-1345.8	0.2	-1355.0
Mackay	6499.9961	Nov.	-1235.1	0.4	-1244.0
Sydney	5099.9905	"	-281.4	0.2	-293.3
Melbourne	5099.9901	Dec.	+12.1	0.1	0

* Mean error calculated from :

$$\text{Mean error} = \text{Standard deviation}/\sqrt{n}$$

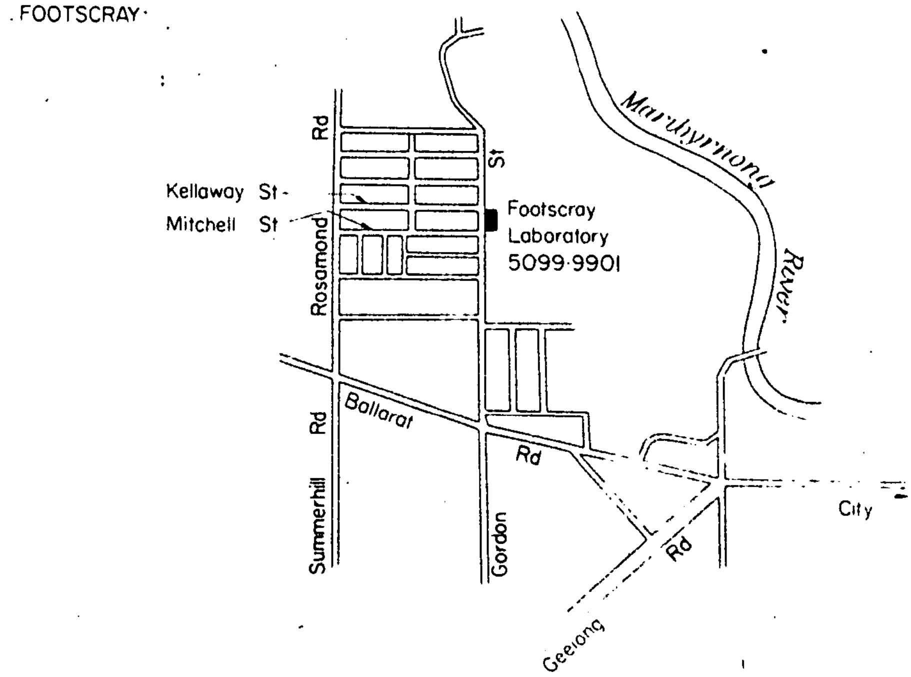
** From Dooley (1965)

PLATE I

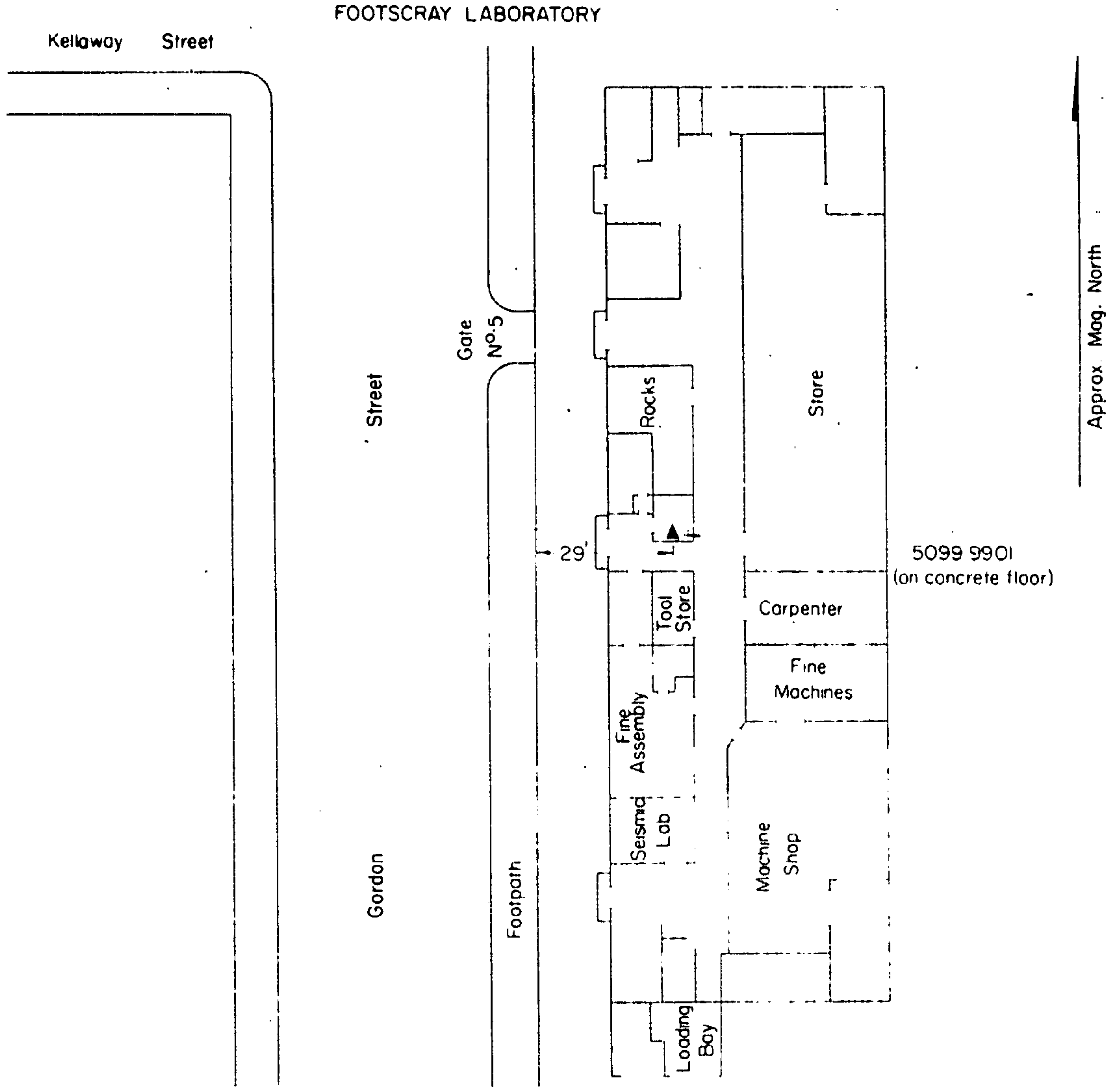


GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS A/B2-14

TO ACCOMPANY RECORD No. 1966/162



FOOTSCRAY LABORATORY



PENDULUM STATION 5099·9901

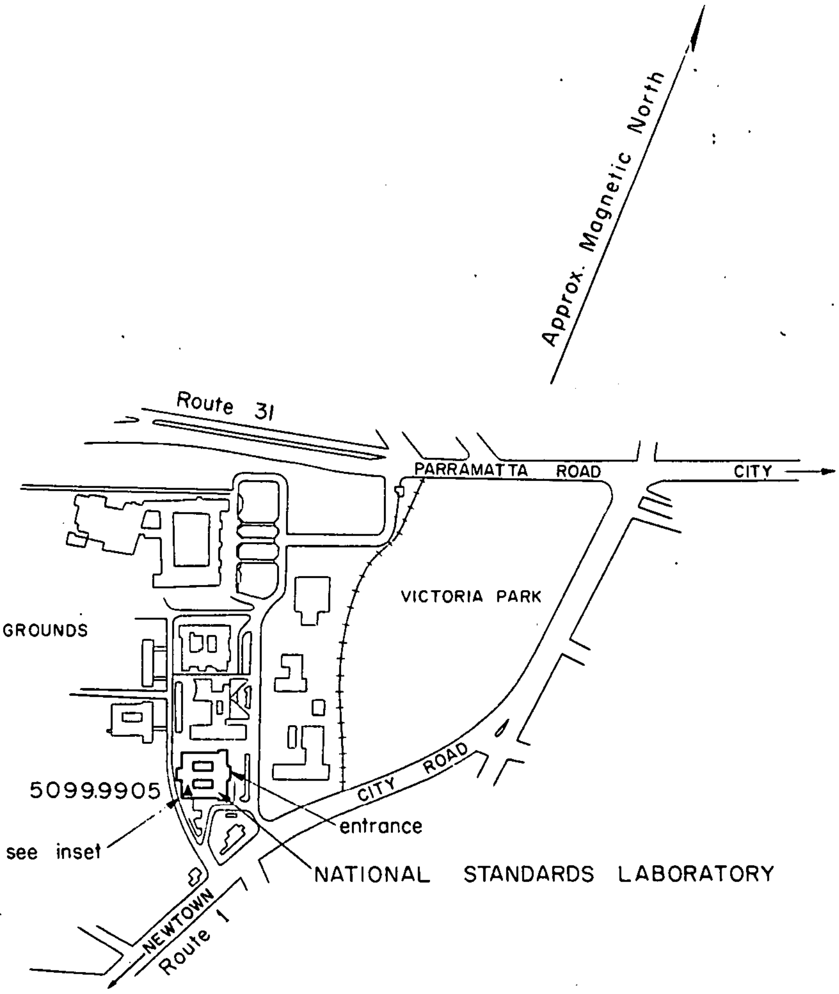
MELBOURNE

▲ Primary base

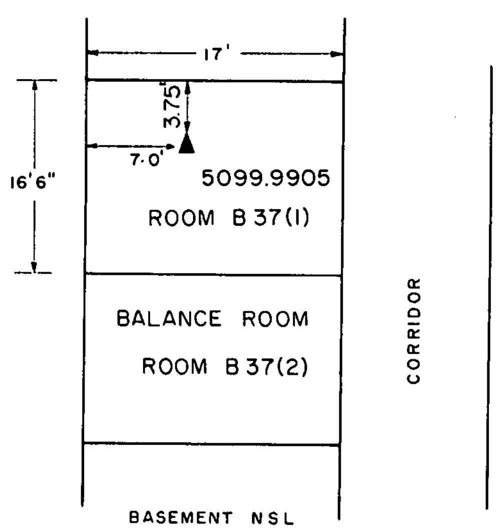
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics J55/B2-71-1

TO ACCOMPANY RECORD No. 1966/162

PLATE 3



INSET



NOTE : NSL should be notified of impending arrival

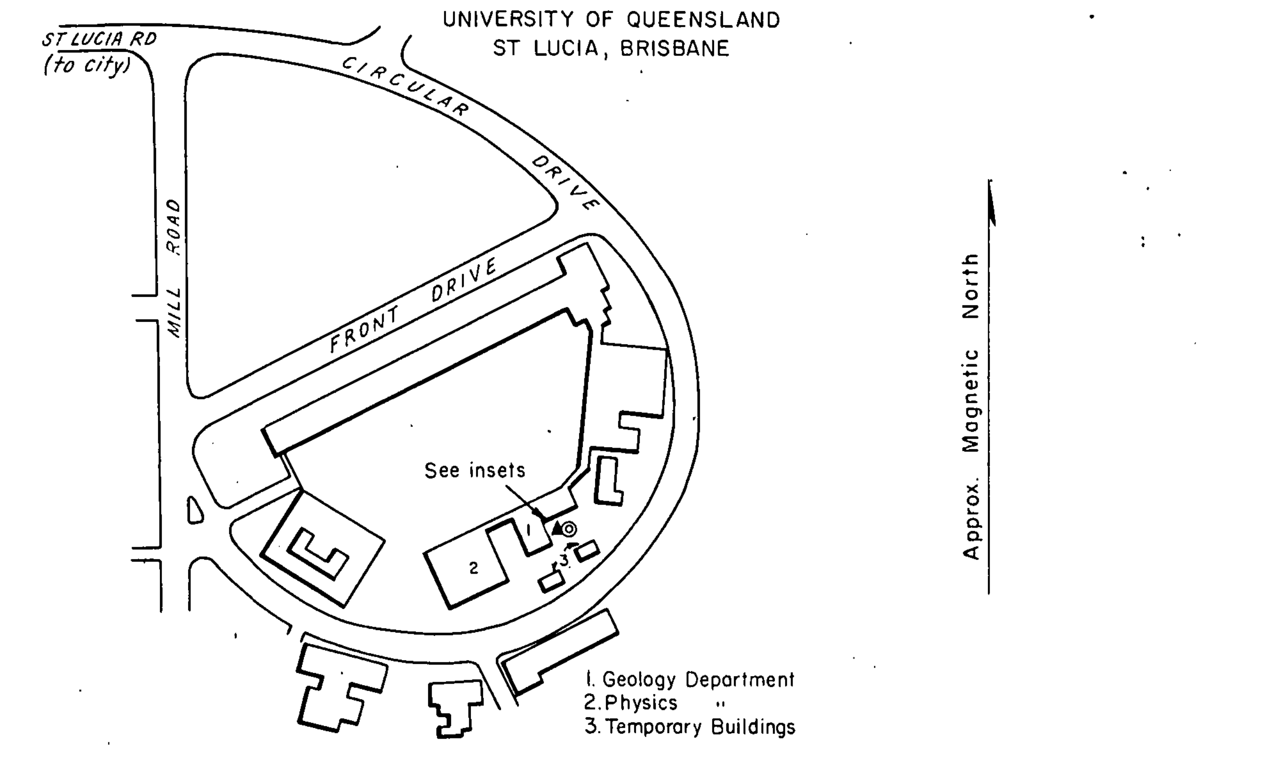
PENDULUM STATION 5099.9905
NATIONAL STANDARDS LABORATORY
SYDNEY NSW

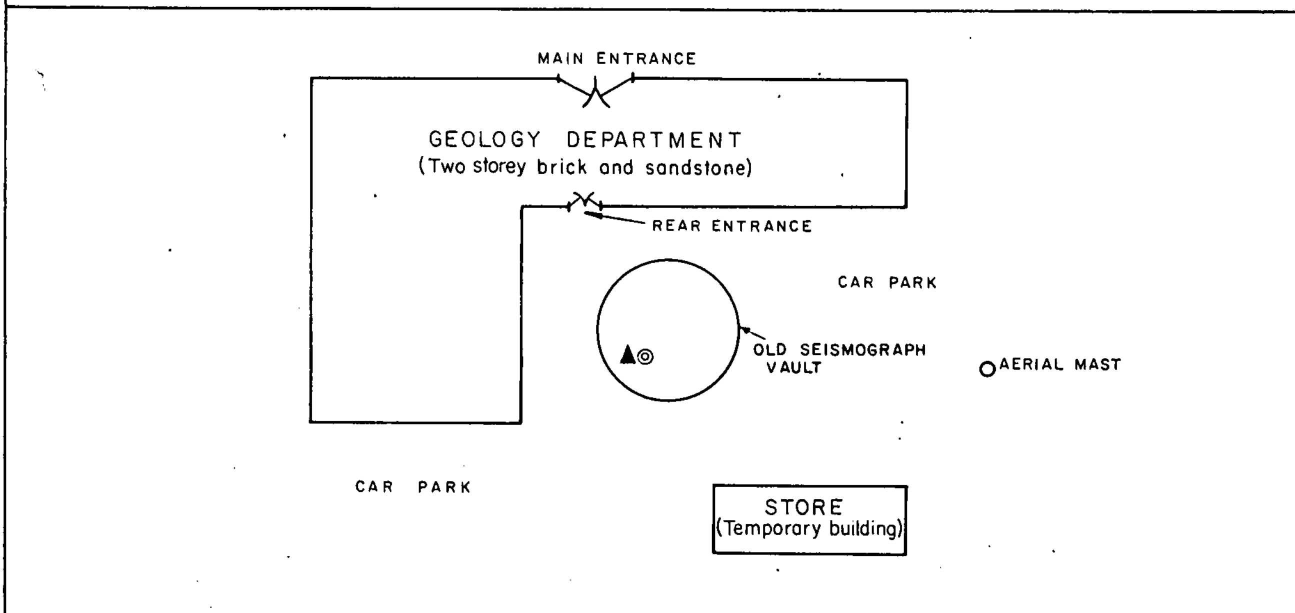
▲ Primary base

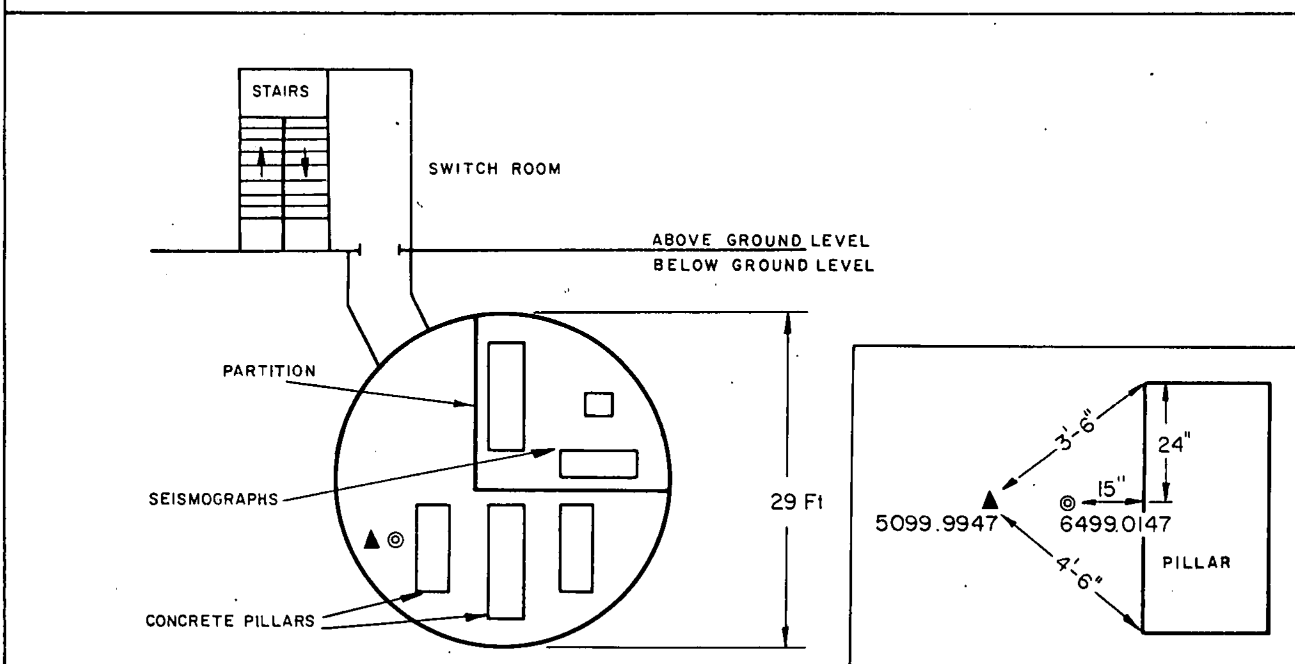
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics I56/B2-18-1

TO ACCOMPANY RECORD No. 1966/162

PLATE 4







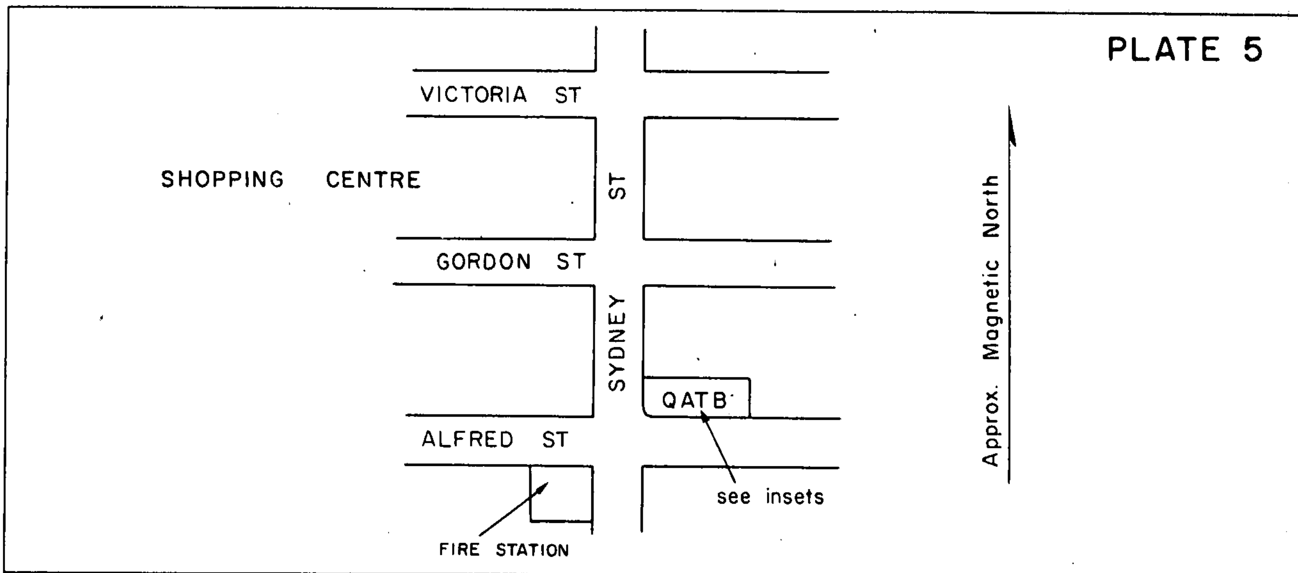
PENDULUM STATIONS, 5099.9947 and 6499.0147
UNIVERSITY, BRISBANE, QLD

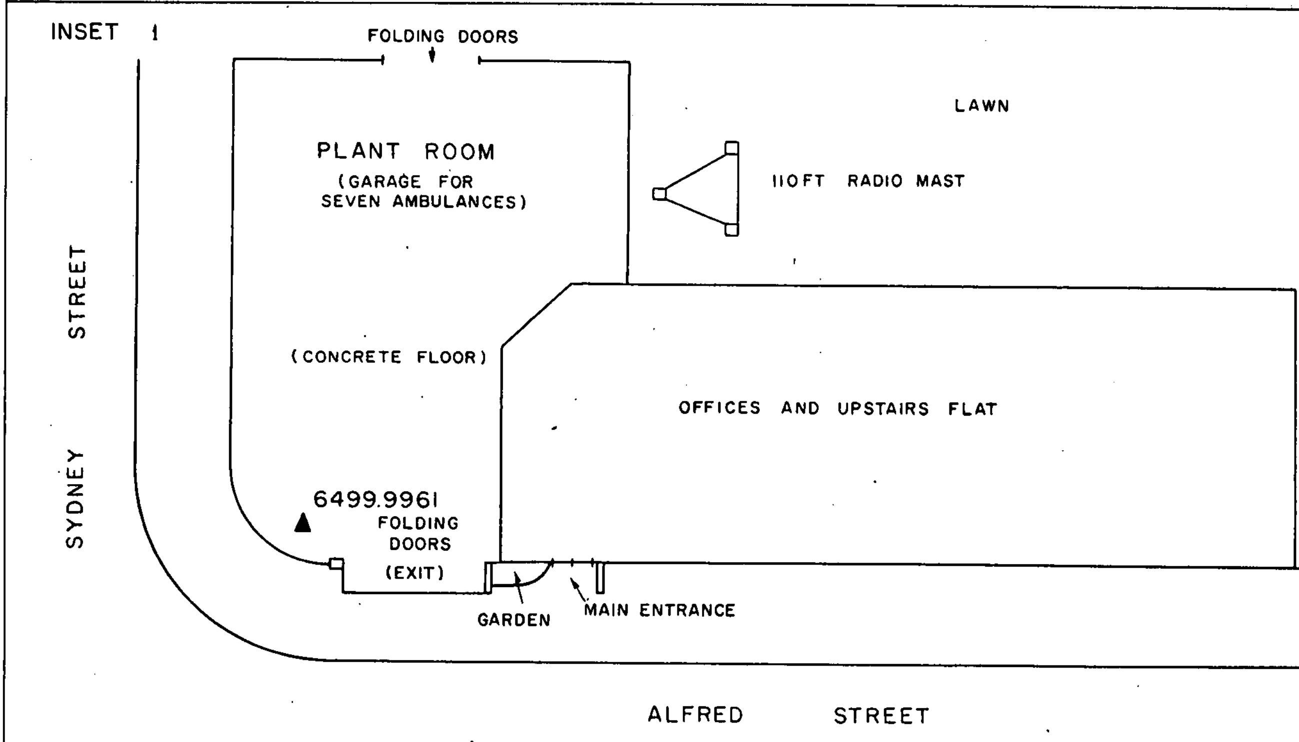
▲ Primary base
◎ Excentre

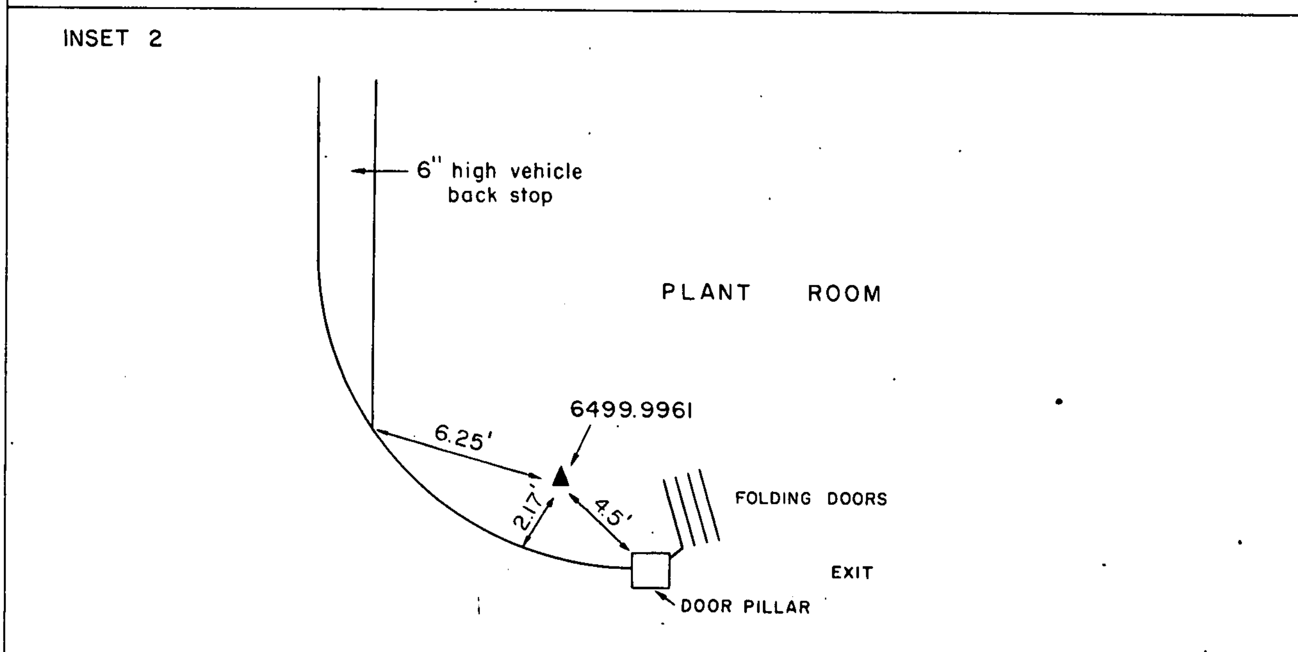
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics G 56/B2-25-1

TO ACCOMPANY RECORD No. 1966/162

PLATE 5







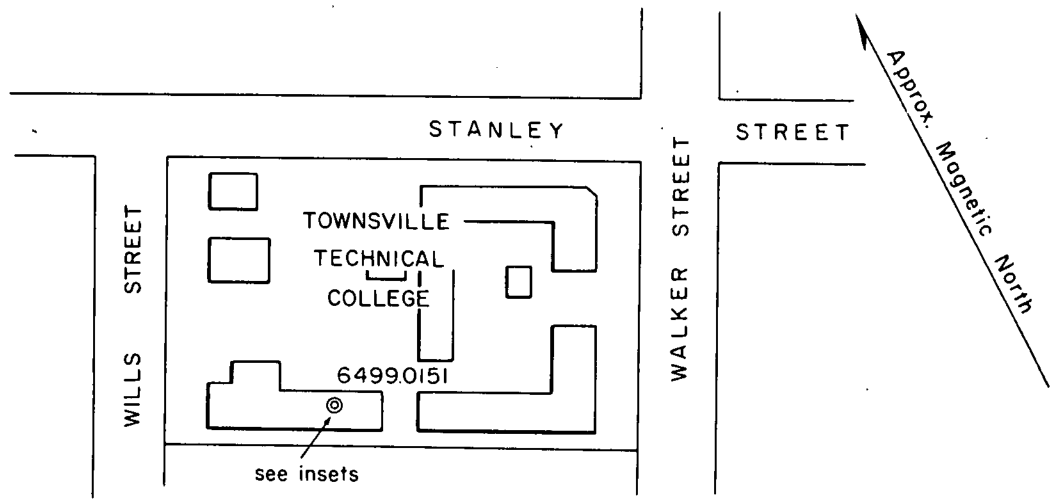
PENDULUM STATION 6499.9961
QUEENSLAND AMBULANCE TRANSPORTATION BOARD
MACKAY, QLD.

▲ Primary base

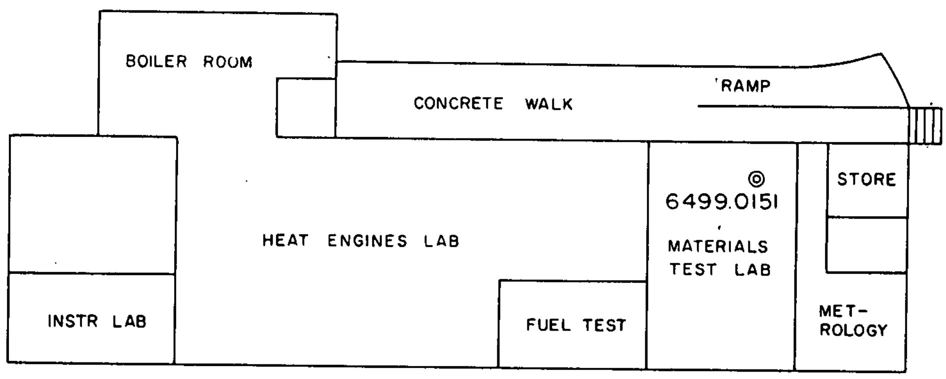
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. F 55/B2-34-1

TO ACCOMPANY RECORD No. 1966/162

PLATE 6

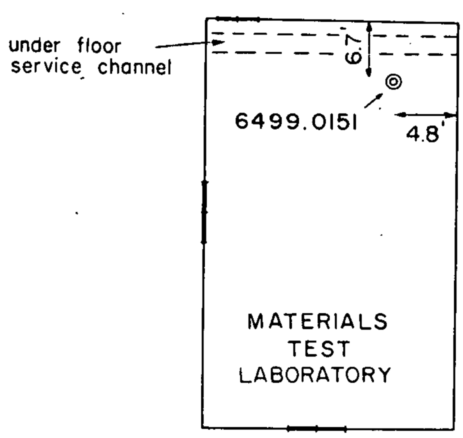


INSET 1



APPLIED HEAT LABORATORY BUILDING

INSET 2



Note
Refer to correspondence with the Bureau of Mineral Resources on College file No. A/20/2 - "Applied Heat Laboratory"

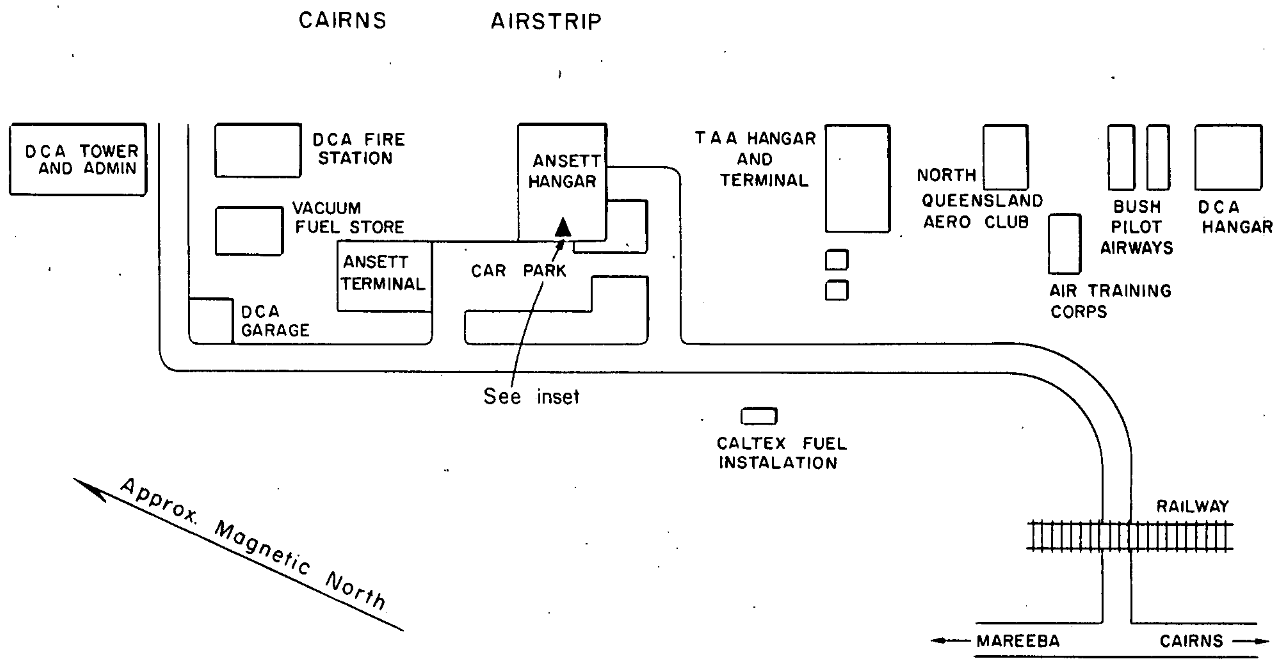
PENDULUM STATION 6499.0151
TOWNSVILLE TECHNICAL COLLEGE
TOWNSVILLE, QLD

◎ Excentre

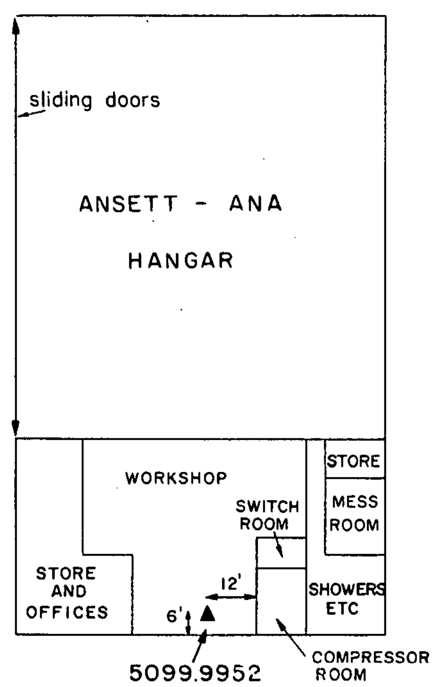
Geophysical Branch, Bureau of Mineral Resources Geology and Geophysics E55/B2-27-1

TO ACCOMPANY RECORD No. 1966/162

PLATE 7



INSET



PENDULUM STATION 5099.9952

CAIRNS AIRPORT

CAIRNS, QLD

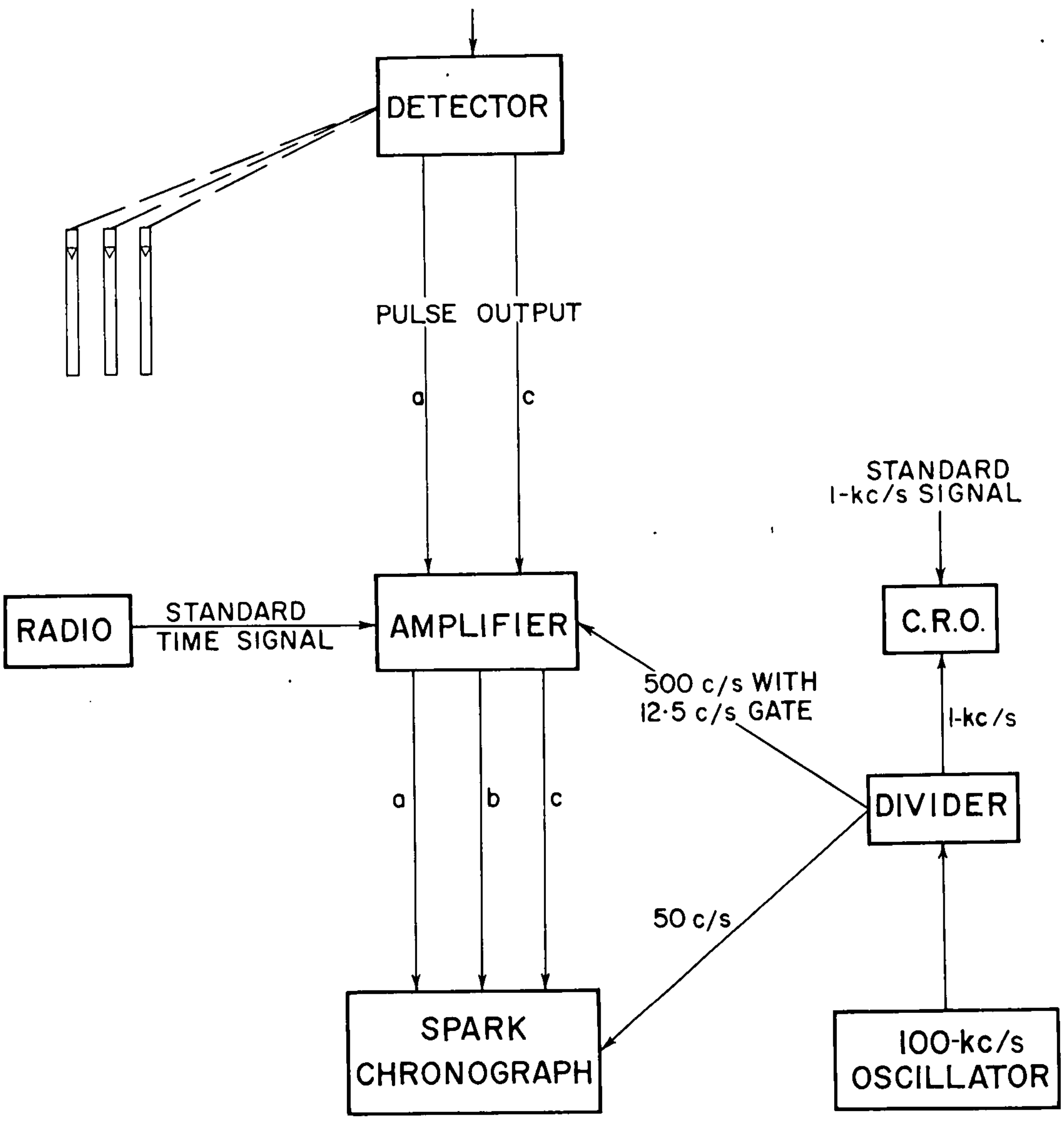
▲ Primary base

Geophysical Branch, Bureau of Mineral Resources Geology and Geophysics E 55/B2-28-1

TO ACCOMPANY RECORD No. 1966/162

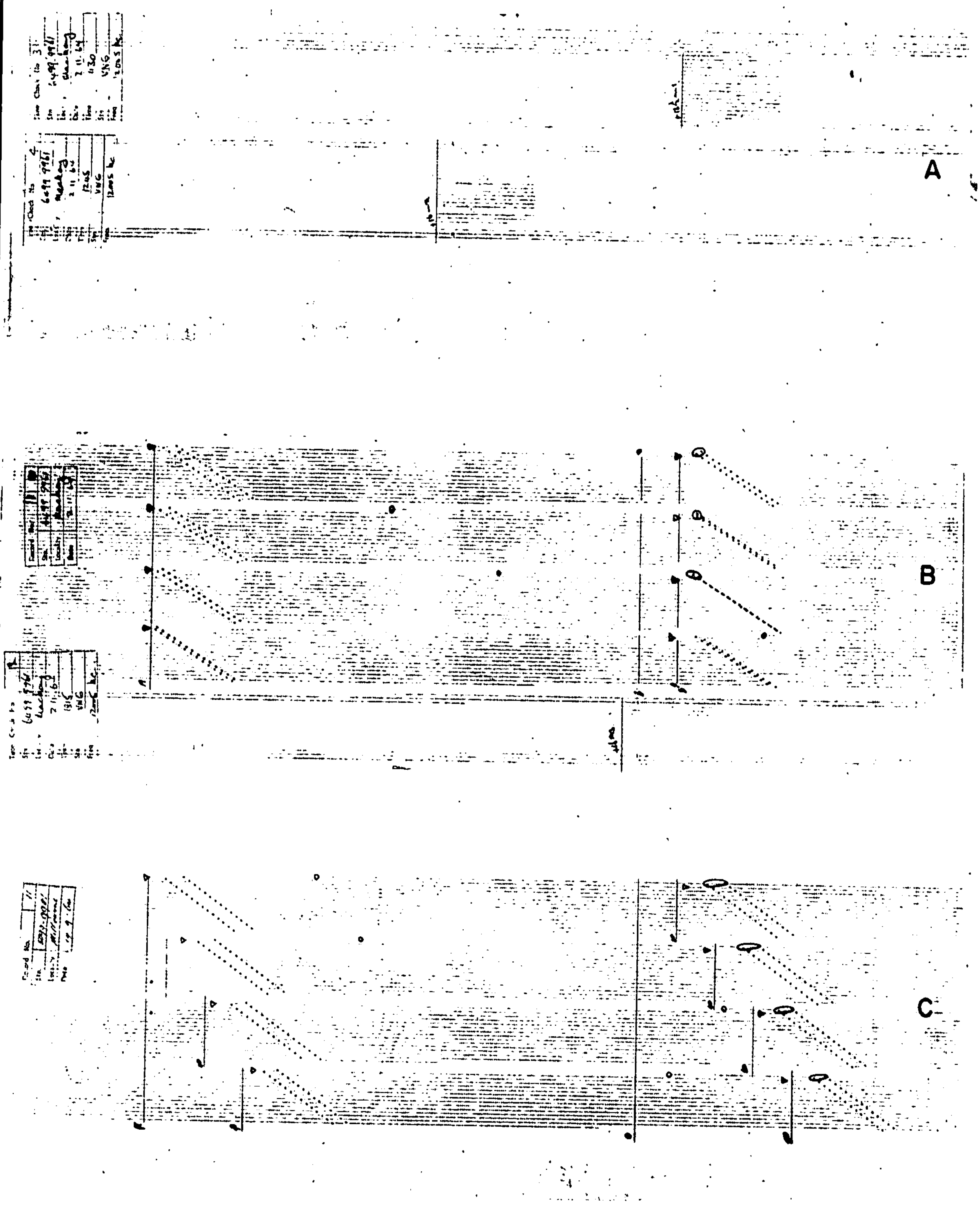
PLATE 8

BLOCK DIAGRAM OF GSI PENDULUM APPARATUS



a..... Left pendulum pulse
b.... 500 c/s with 12·5 c/s gate <u>OR</u>
time signal
c.... Right pendulum pulse

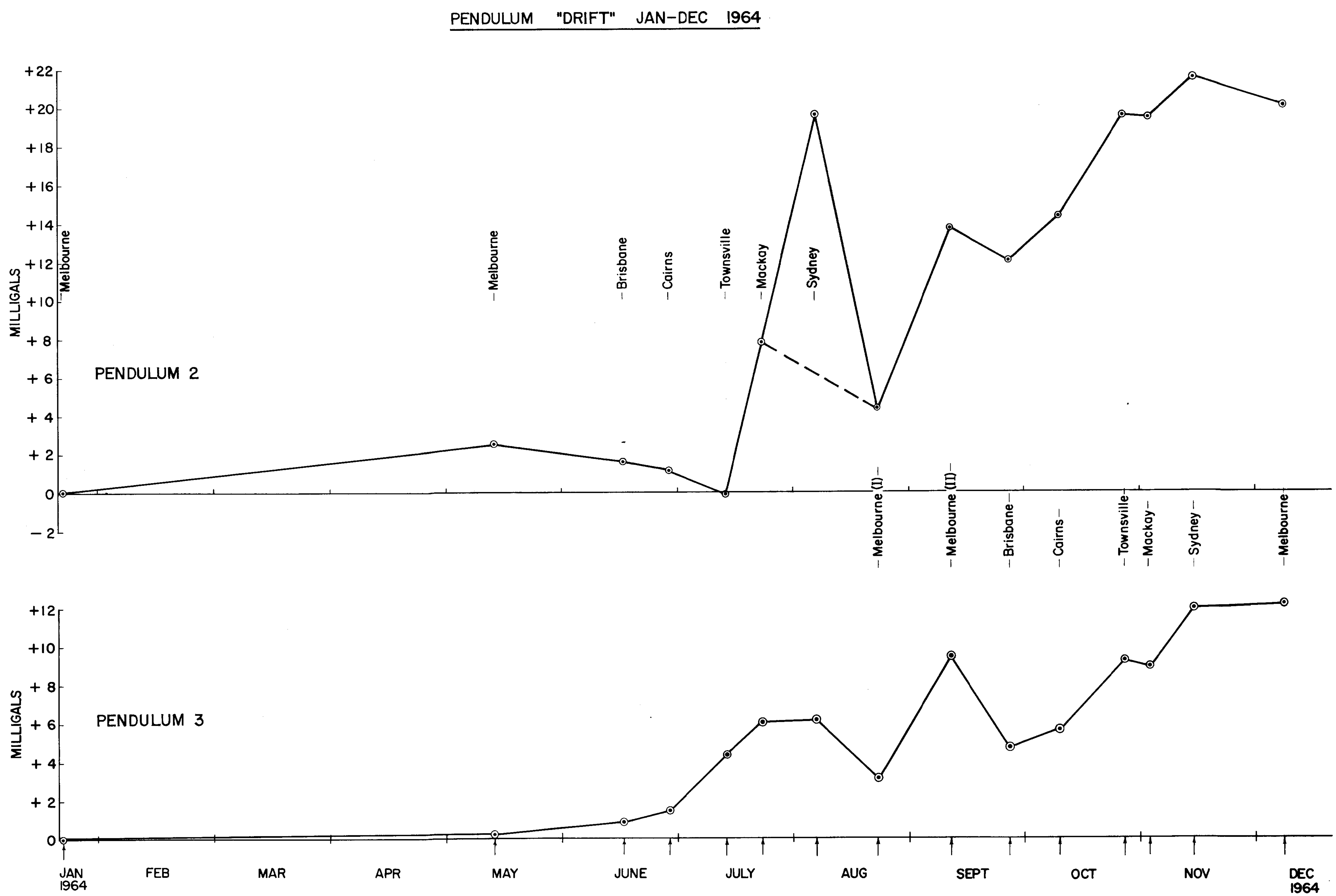
G 65-148



SAMPLE RECORDS OBTAINED FROM GSI PENDULUM APPARATUS

A Record of time signals
B,C Normal records showing pendulum marks

PLATE 10

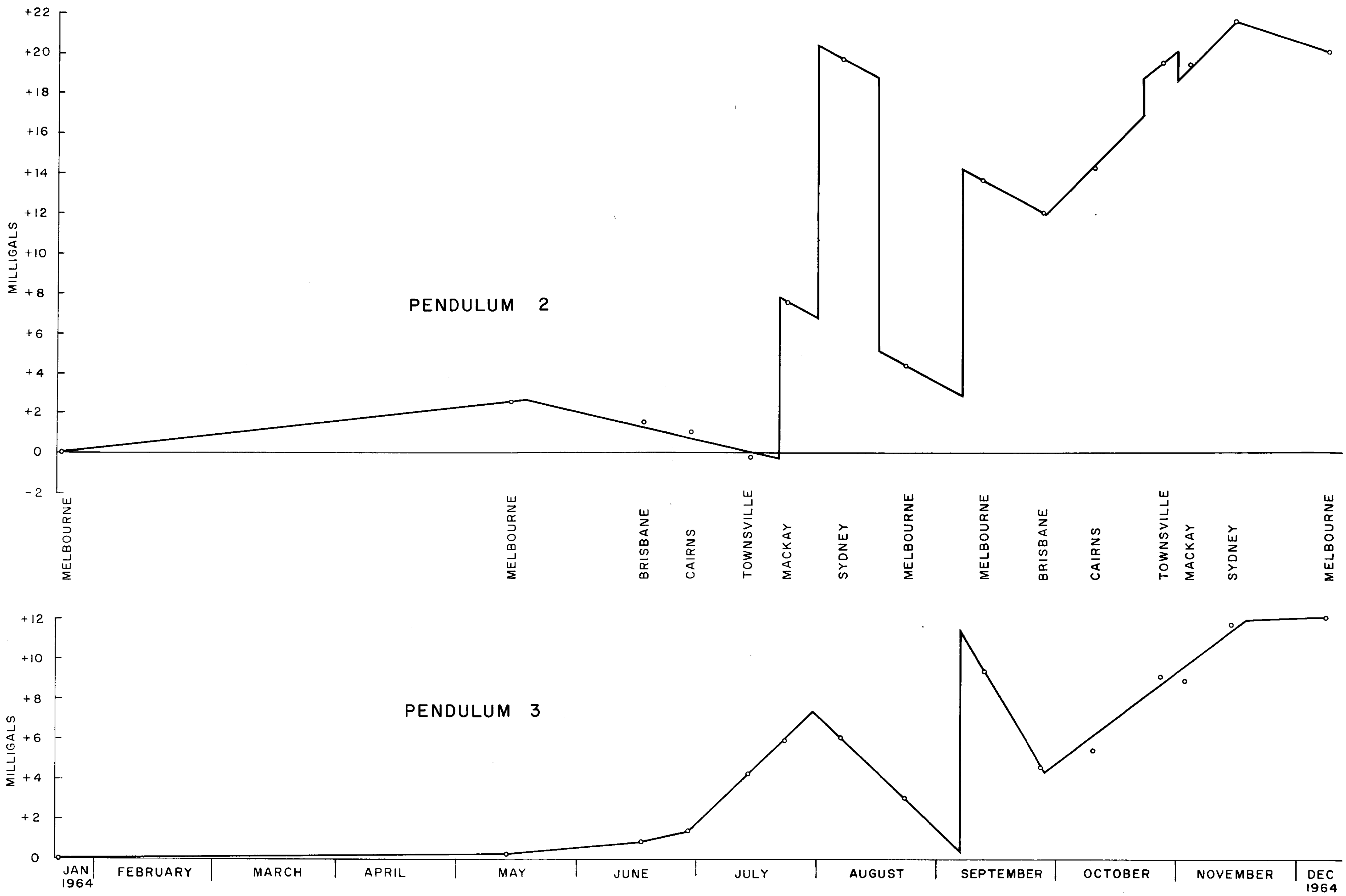


TO ACCOMPANY RECORD No. 1966/162

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

G 65-149

PLATE II



POSSIBLE PENDULUM "DRIFT" ANALYSIS

G65-161

TO ACCOMPANY RECORD No. 1966/162

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

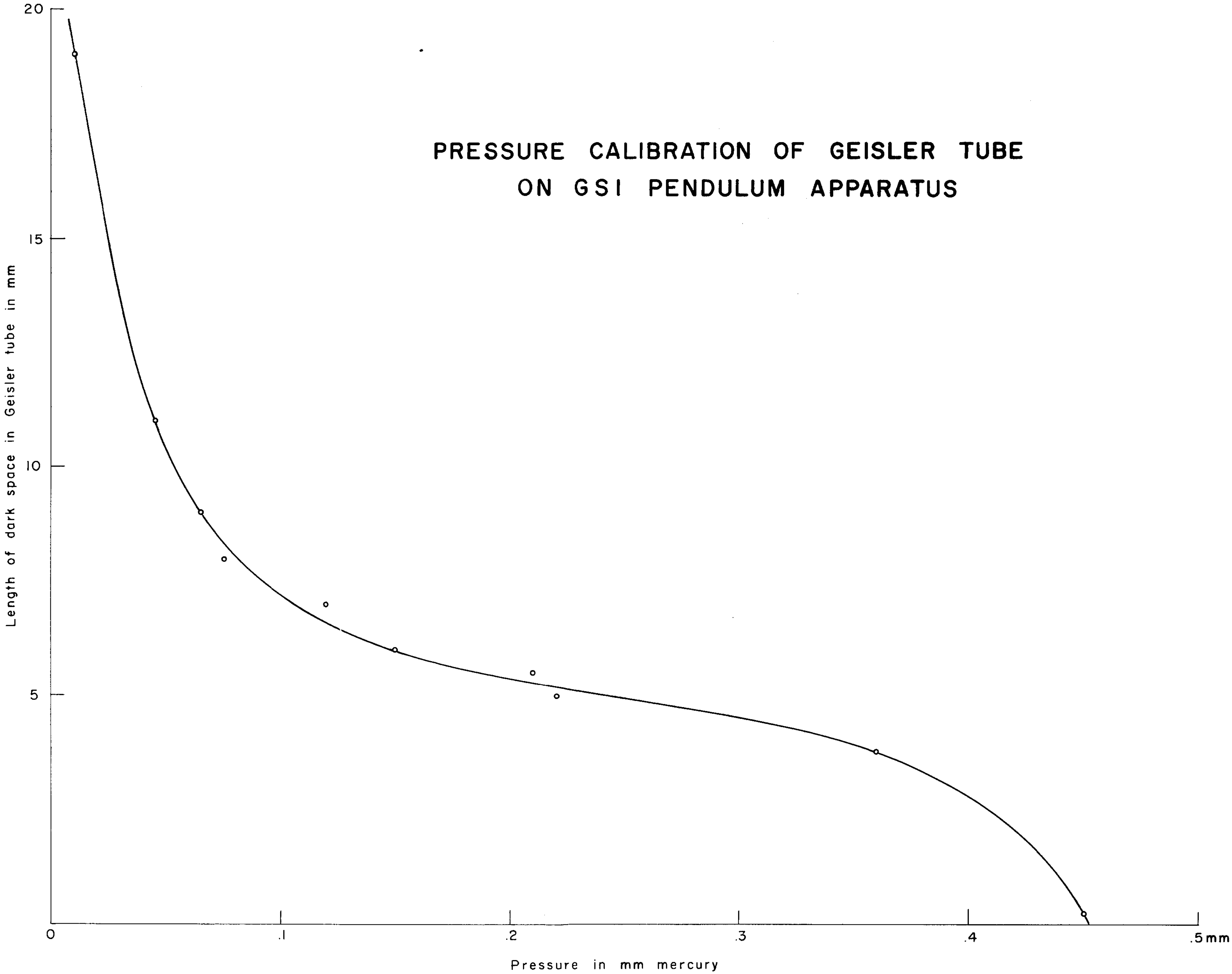
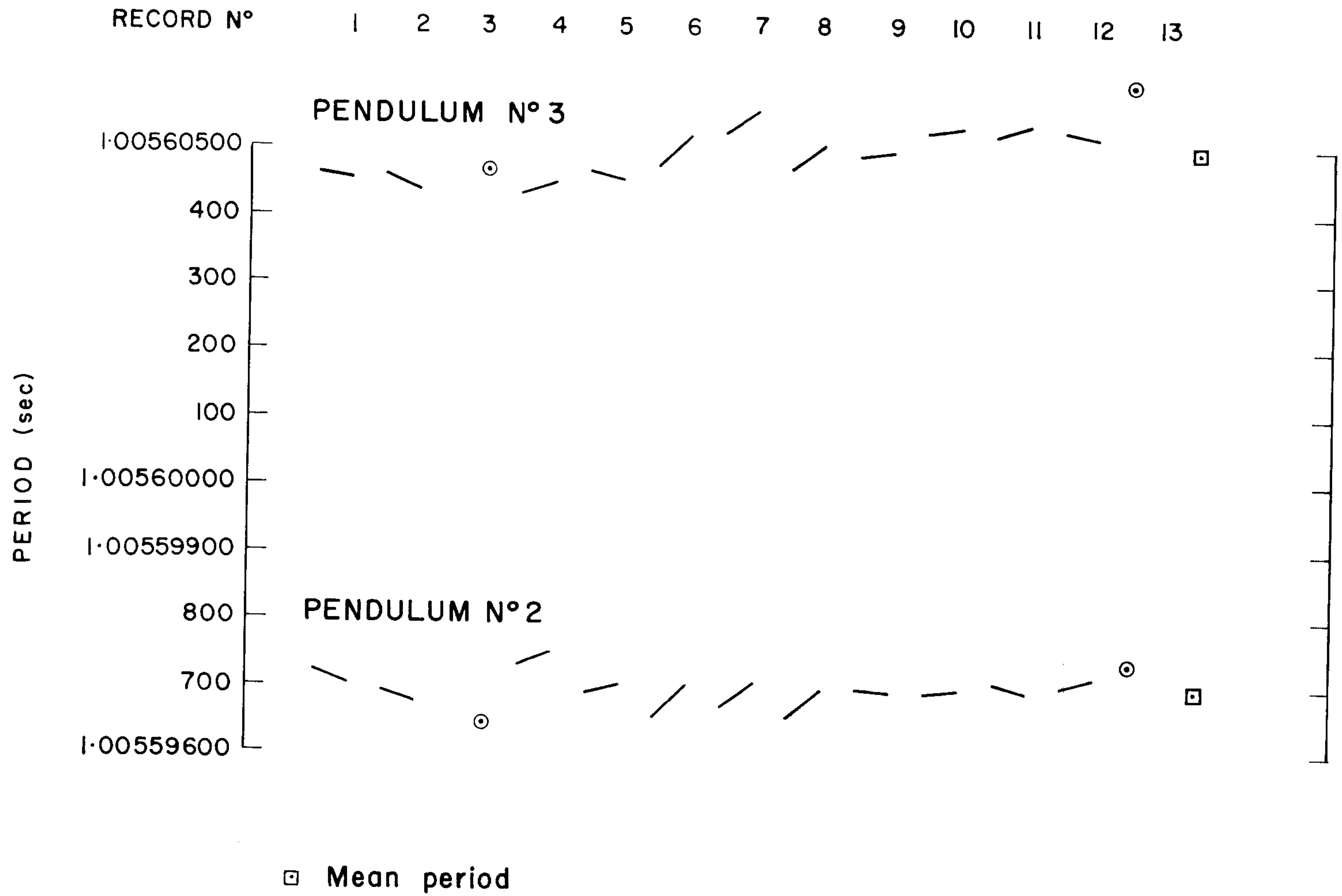

PRESSURE CALIBRATION OF GEISLER TUBE
ON GSI PENDULUM APPARATUS
20
15
10
5
0
.1
.2
.3
.4
.5 mm
Length of dark space in Geisler tube in mm
Pressure in mm mercury

PLATE 13

PENDULUM PERIODS SYDNEY

STATION : 5099.9905 (SYDNEY) NOV 1964



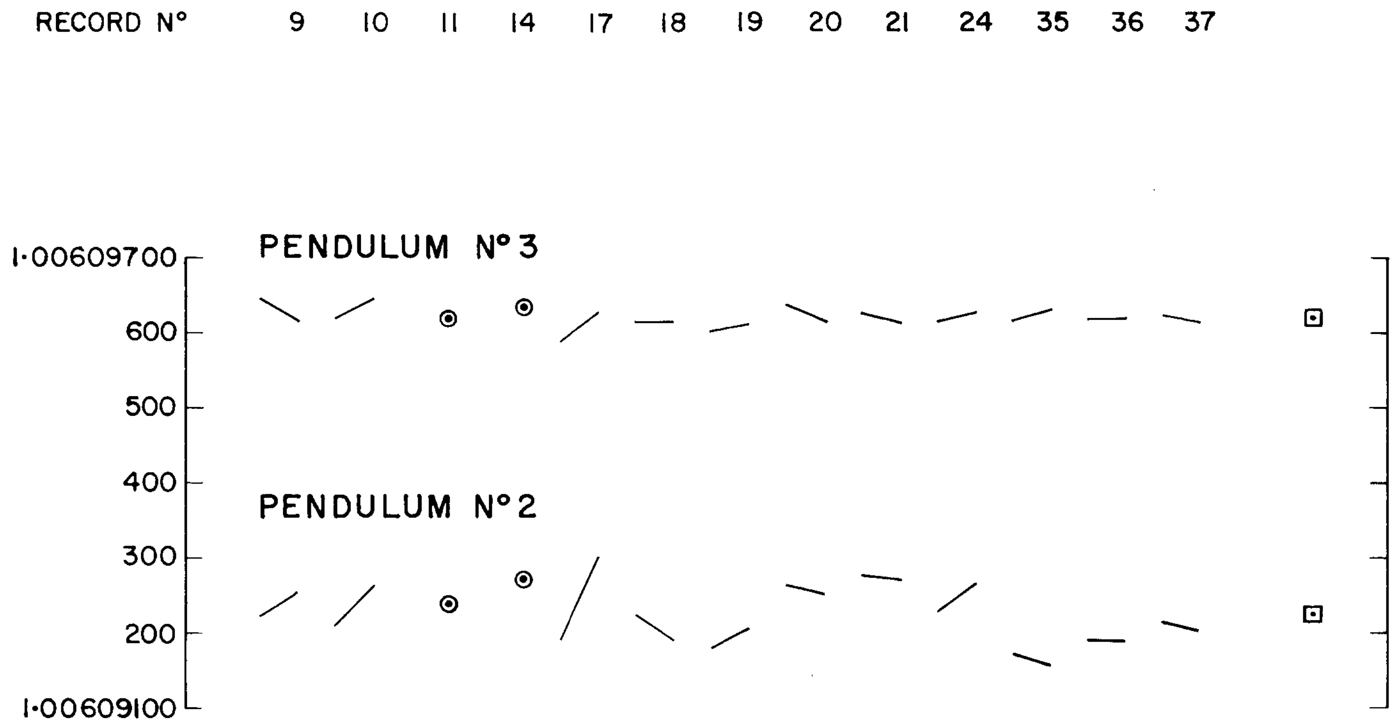
TO ACCOMPANY RECORD No. 1966/162

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 65-146

STATION : 6499.9961 (MACKAY) JULY 1964

PENDULUM PERIODS
MACKAY



⊡ Mean period

TO ACCOMPANY RECORD No. 1966/162

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 65-147

PLATE 14