DEPARTMENT OF
MINERALS AND ENERGY

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1975/106

# DETERMINATION OF GRAVITY ACCELERATION AT PORT MORESBY (PAPUA NEW GUINEA) AND HOBART (AUSTRALIA) WITH OVM PENDULUM APPARATUS



by N.A. Gusev

The Chief Administration of Geodesy and Cartography
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## SUMMARY

In late 1974 the Central Research Institute of Geodesy, Aerial Surveying and Cartography of USSR used a set of five OVM pendulums to make two gravity ties. The gravity intervals determined were Moscow (Ledovo) - Port Moresby D = 3349.183± 0.055 mGal and Port Moresby D - Hobart B = 2215.655 ± 0.054 mGal on the IGSN-71 System. The gravity interval Port Moresby - Hobart, as determined by pendulums, is the same within experimental error as that determined by GAG-2 gravity meters in 1973. This confirms that the scale on the Australian Calibration Line is known to about 2 parts in $10^5$. Using the same set of pendulums the gravity interval Moscow (Ledovo) - Sydney A was determined in 1972 to be 1879.519 ± 0.062 mGal on the IGSN-71 System. The gravity interval Sydney-Hobart of 745.988 mGal derived from the pendulum measurements is within experimental error of the GAG-2 gravity meter result.

## 1. INTRODUCTION

In accordance with the obligations undertaken by the Soviet Union within the framework of the International Association of Geodesy (IAG) and by agreement with the Australian Bureau of Mineral Resources, Geology and Geophysics (BMR), the Central Research Institute of Geodesy, Aerial Survey and Cartography (TZNIIGAiK) sent an expedition to Australia and Papua New Guinea in October 1974 to determine the gravity interval Port Moresby-Hobart.

The expedition included the following specialists:

1. Boulanger, J.D. - President of the International Association of Geodesy
   Corresponding Member of the Academy of Science in the USSR
   General leader of the expedition
2. Gusev, N.A. - Head of Laboratory at the TZNIIGAiK
   Practical supervisor of the expedition operations
3. Barzdel, V. Ya. - Senior Engineer
4. Gojdysheva, A.G. - Engineer
5. Korolev, M.N. - Senior Engineer
6. Lokhov, V.V. - Senior Engineer
7. Metlin, A.P. - Engineer

The expedition determined the gravity intervals Moscow (Ledovo) to Port Moresby and Port Moresby to Hobart, with OVM pendulum apparatus. The interval Moscow (Ledovo) to Sydney had been determined with the same apparatus in 1972 (Gusev, 1973).

The measurements were made on the following days:

| | |
|---|---|
| Moscow (Ledovo) I | - 1-5 October 1974 |
| Port Moresby I | - 9-14 October 1974 |
| Hobart | - 17-22 October 1974 |
| Port Moresby II | - 26-31 October 1974 |
| Moscow (Ledovo) II | - 5- 9 November 1974 |

In order to improve the accuracy of measurements of the gravity interval Port Moresby - Hobart a large number of observations were made at these two places.

The equipment was transported by regular aircraft of several airline companies. To obviate reloading the equipment at Melbourne, and to minimise the time of travel between Port Moresby and Hobart, the equipment was transported between Sydney and Hobart in a chartered jet-prop twin-engined aircraft. From the airports to the Observation points the equipment was transported by truck. During flights the apparatus was connected to accumulators and placed in the passenger cabin of the aircraft. The thermostats were not switched off from the first observation at Ledovo to the last observation at Ledovo.

In Port Moresby the observations were carried out at the Geophysical Observatory of BMR, on the concrete ground floor of the library. The temperature in the room was kept constant with the help of an air-conditioner. However, the temperature gradients at the level of the apparatus were rather high (up to $3^{\circ}/m$), and below them closer to the floor the gradients were still higher.

In Hobart the observations were carried out in a vault cut into rock and specially built for these observations. The apparatus was placed on the concrete floor and it was damp in the room, because the concrete had not yet hardened properly. Temperature gradients at the level of the apparatus were up to $3^{\circ}/m$, the temperature being lower nearer the floor. In order to maintain 24-26°C (the temperature of observations at Port Moresby) two powerful electric radiators and a fan to mix the air were used.

## 2. RESULTS OF MEASUREMENTS

All the measurements were made using a set of five OVM pendulum apparatus (each apparatus has two quartz-metal pendulums). The apparatus was designed at TZNIIGAiK and is described by Gusev (1973).

The oscillation period of the pendulums, obtained with the help of a photoelectronic recorder, was corrected for amplitude and temperature of the pendulums, pressure in the container, frequency of the quartz oscillator, and for the tidal influences of the Moon and the Sun. The correction for 'the lack of symmetry' (Slivin, 1964, 1969) was checked during each measurement, and was not permitted to exceed $\pm 0.2\times10^{-8}$s; no correction was applied for it in the data processing. The correction for non-isochronism appeared to be very minor, and was not taken into account.

Before making the observations, the pendulums were test swung to determine the operating conditions. During the expedition the frequency of the quartz oscillators was kept constant to within 2 parts in $10^9$.

Table 1 gives, for each set of observations and each pendulum set, the mean values of oscillation amplitudes together with the applied amplitude corrections, and the values of temperature and residual pressure within the apparatus. During the observations the amplitude, pressure, and temperature were maintained constant, and minor deviations from the values given in Table 1 were taken into account by corrections. It should be noted that within the apparatus the error of measurement of temperature was $m_t = \pm 0.02^\circ C$, and of pressure $m_B = \pm 0.02$ mm of mercury.

The corrected periods of pendulum oscillations for each apparatus and each observation site are given in Table 2, together with the mean period, the standard deviation, and the standard error of the mean period (M). The values of M are within the range $\pm 0.20\times10^{-8}$ to $\pm 0.64\times10^{-8}$s, except instrument No. 6102 which had a higher range of $\pm 0.44\times10^{-8}$ to $\pm 1.27\times10^{-8}$ s because of a high temperature coefficient.

To reduce the influence of microseisms and other vibrations, 6-8 sets of pendulum periods were normally measured in each program of pendulum observations. The time interval between two successive observations on each instrument was generally not less than 6 hours. Between measurements the pendulums were clamped. In some of the programs the number of observations was increased to 9-11 so as to increase the accuracy of the mean-period determination; this is desirable as the instruments have different constants and different temperature sensitivities.

Table 3 gives mean gravity intervals ($\Delta g$) for each instrument in the IGSN-71 system; the corresponding standard errors of the means have been determined by a method developed in TZNIIGAiK (Haifetz, 1962). The method takes into account all the data found by testing the apparatus in the laboratory, the experimental errors in the determination of the periods at each site, the influence of environment conditions, and the effect of possible systematic and partly systematic errors. The arithmetic means of the gravity intervals and their standard errors are shown in the second last column of Table 3.

The last column of Table 3 gives the weighted mean gravity intervals, and these are adopted as the final values. The weights used were the inverse squares of the standard errors of the means for each instrument.

The Honkasalo correction (Honkasalo, 1964) was not introduced during calculation of $\Delta g$.

Plate 4 is a diagram of the gravimetric connections determined by pendulum apparatus. Sydney A ($g_0$ = 979 671.860 mGal) was taken as the initial point. The gravity interval Moscow (Ledovo) to Sydney A, determined using OVM pendulums in 1972 (Gusev, 1973), has been corrected to the IGSN-71 system and becomes 1879.519 ± 0.062 mGal.

The pendulum sites were tied to the gravity meter network using La Coste & Romberg gravity meters (LCR) Wellman et al., 1974; Wellman, 1975). The Sydney A to Hobart B and the Port Moresby D to Hobart B gravity differences are given separately for the GAG-2 gravity meters, and for La Coste & Romberg meters calibrated using the GAG-2 Australian Calibration Line scale (Wellman et al., 1974).

Plate 4 shows the Sydney-Moscow-Port Moresby-Hobart polygon, and gravity values are given in Table 4. The misclosure with La Coste & Romberg measurements is 0.006 mGal, and with GAG-2 measurements 0.050

mGal. Along the Australian Calibration Line between Port Moresby and Hobart the OVM pendulum results differ from the La Coste & Romberg results by 0.006 mGal and from the GAG-2 results by 0.044 mGal. These differences are very small, so the gravity meter scale coefficients must be correct.

The relative error of the OVM pendulum tie Port Moresby to Hobart is 2.4 in $10^5$. This high accuracy of gravity difference can be used as a basis to solve many theoretical and practical problems.

## 3. CONCLUSIONS

1. The difference of gravity between Moscow and Port Moresby was determined with the accuracy of ± 0.055 mGal.

2. The part of the Australian Calibration Line between Port Moresby and Hobart ($\Delta g$ = 2 215 mGal) was determined with a standard error of the mean of ± 0.054 mGal, which corresponds to a relative error of 2.4 parts in $10^5$.

## 4. ACKNOWLEDGEMENTS

A BMR representative, Dr P. Wellman, was responsible for all the organizational details in Australia and Papua New Guinea (Wellman, 1975). During the aeroplane change in Sydney two other members of the BMR staff assisted. Assistance with observationa at Port Moresby was rendered by Ian Ripper, Acting Observer-in-Charge of the Observatory, and by Brian Gaull; and at Hobart by John Shirley of the Geology Department, University of Tasmania. The author would like to express his thanks for this assistance with the organization of the work, and his deep gratitude to the management of the Bureau of Mineral Resources for its part in supporting the work.

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## TABLE I. CONDITIONS OF OBSERVATION

| Pendulum Station | Amplitude (min.of asc.) Starting | Amplitude (min.of asc.) Initial | Amplitude (min.of asc.) Final | Corr.for amplitude $1 \times 10^{-8}$s | Temp. (°C) | Pressure mm Hg |
|---|---|---|---|---|---|---|
| **INSTRUMENT 6101** | | | | | | |
| Ledovo I | 47.5 | 47.0 | 43.1 | -527.8 | 40.00 | 0.89 |
| Port Moresby I | 47.6 | 47.1 | 43.1 | -527.6 | 40.24 | 0.91 |
| Hobart | 47.5 | 47.0 | 43.1 | -526.7 | 40.07 | 0.82 |
| Port Moresby II | 47.6 | 47.0 | 43.1 | -526.7 | 40.10 | 0.86 |
| Ledovo II | 47.5 | 47.0 | 43.1 | -526.6 | 40.19 | 0.92 |
| **INSTRUMENT 6102** | | | | | | |
| Ledovo I | 34.0 | 34.4 | 30.8 | -270.9 | 39.70 | 0.90 |
| Port Moresby I | 33.9 | 34.4 | 30.8 | -270.9 | 39.82 | 0.91 |
| Hobart | 34.0 | 34.4 | 30.8 | -271.1 | 39.86 | 0.92 |
| Port Moresby II | 33.8 | 34.4 | 30.8 | -271.0 | 39.84 | 0.91 |
| Ledovo II | 33.9 | 34.4 | 30.8 | -270.8 | 39.93 | 0.95 |
| **INSTRUMENT 6301** | | | | | | |
| Ledovo I | 44.8 | 44.3 | 39.7 | -452.0 | 40.13 | 0.91 |
| Port Moresby I | 44.7 | 44.4 | 39.6 | -452.4 | 40.30 | 0.87 |
| Hobart | 44.8 | 44.3 | 39.7 | -452.1 | 40.20 | 0.89 |
| Port Moresby II | 44.7 | 44.4 | 39.6 | -451.9 | 40.34 | 0.93 |
| Ledovo II | 44.8 | 44.3 | 39.7 | -451.8 | 40.32 | 0.92 |
| **INSTRUMENT 6302** | | | | | | |
| Ledovo I | 25.9 | 25.6 | 21.0 | -214.9 | 40.50 | 0.82 |
| Port Moresby I | 25.9 | 25.7 | 20.9 | -213.9 | 40.57 | 0.92 |
| Hobart | 25.9 | 25.7 | 20.9 | -214.2 | 40.48 | 0.91 |
| Port Moresby II | 25.9 | 25.7 | 20.9 | -214.1 | 40.50 | 0.86 |
| Ledovo II | 25.9 | 25.6 | 20.9 | -213.7 | 40.54 | 0.94 |
| **INSTRUMENT 6303** | | | | | | |
| Ledovo I | 49.3 | 48.3 | 43.4 | -478.0 | 40.28 | 0.92 |
| Port Moresby I | 49.2 | 48.3 | 43.4 | -477.6 | 40.47 | 0.91 |
| Hobart | 49.0 | 48.3 | 43.5 | -477.6 | 40.32 | 0.90 |
| Port Moresby II | 48.8 | 48.3 | 43.4 | -477.7 | 40.47 | 0.90 |
| Ledovo II | 49.1 | 48.3 | 43.2 | -477.0 | 40.42 | 0.93 |

## TABLE 2. OSCILLATION PERIODS (Seconds)

Instruments

| | 6101 | 6102 | 6301 | 6302 | 6303 |
|---|---|---|---|---|---|
| | | | **Ledovo I.** | | |
| | 0.4915+ | 0.4949+ | 0.4830+ | 0.7393+ | 0.4853+ |
| | 43757 | 30812 | 35470 | 96344 | 88134 |
| | 43753 | 30818 | 35480 | 96340 | 88159 |
| | 43748 | 30788 | 35472 | 96358 | 88146 |
| | 43746 | 30788 | 35434 | 96365 | 88132 |
| | 43748 | 30736 | 35452 | 96354 | 88146 |
| | 43755 | 30790 | 35445 | 96347 | 88145 |
| | 43765 | 30790 | 35462 | 96372 | |
| Mean | 0.4915 43753 | 0.4949 30789 | 0.4830 35459 | 0.7393 96354 | 0.4853 88144 |
| M | 0.25 | 1.00 | 0.62 | 0.44 | 0.40 |
| m | 0.66 | 2.64 | 1.64 | 1.16 | 0.98 |
| | | | **Port Moresby I** | | |
| | 0.4923+ | 0.4957+ | 0.4838+ | 0.7406+ | 0.4862+ |
| | 84506 | 77210 | 61670 | 61041 | 18336 |
| | 84498 | 77224 | 61670 | 61060 | 18294 |
| | 84502 | 77228 | 61690 | 61066 | 18327 |
| | 84488 | 77210 | 61680 | 61052 | 18302 |
| | 84502 | 77202 | 61710 | 61099 | 18322 |
| | 84506 | 77235 | 61660 | 61070 | 18348 |
| | 84508 | 77219 | 61684 | 61082 | 18324 |
| | | | 61688 | 61079 | 18306 |
| Mean | 0.4923 84501 | 0.4957 77218 | 0.4838 61682 | 0.7406 61069 | 0.4862 18320 |
| M | 0.26 | 0.44 | 0.54 | 0.65 | 0.64 |
| m | 0.68 | 1.16 | 1.54 | 1.83 | 1.81 |

M = Standard error of the mean

m = Standard deviation

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| Instruments | 6101 | 6102 | 6301 | 6302 | 6303 |
|---|---|---|---|---|---|
| | | | **Hobart** | | |
| | 0.4918+ | 0.4952+ | 0.4833+ | 0.73 98+ | 0.4856+ |
| | 27776 | 16631 | 14604 | 23744 | 68653 |
| | 27752 | 16716 | 14612 | 23730 | 68644 |
| | 27769 | 16676 | 14635 | 23698 | 68656 |
| | 27776 | 16718 | 14614 | 23709 | 68670 |
| | 27792 | 16704 | 14620 | 23727 | 68648 |
| | 27782 | 16644 | 14620 | 23713 | 68675 |
| | 27769 | 16662 | 14612 | 23706 | 68654 |
| | 27771 | 16634 | | | 68677 |
| | 27768 | | | | 68658 |
| | 27774 | | | | 68678 |
| | | | | | 68648 |
| Mean | 0.4918 27773 | 0.4952 16673 | 0.4833 14167 | 0.7398 23718 | 0.4856 68660 |
| M | 0.33 | 1.27 | 0.37 | 0.61 | 0.38 |
| m | 1.03 | 3.60 | 0.97 | 1.61 | 1.26 |
| | | | **Port Moresby II** | | |
| | 0.4923+ | 0.4957+ | 0.4838+ | 0.7406+ | 0.4862+ |
| | 84496 | 77170 | 61672 | 61064 | 18377 |
| | 84500 | 77148 | 61668 | 61083 | 18359 |
| | 84502 | 77126 | 61684 | 61079 | 18341 |
| | 84494 | 77161 | 61680 | 61083 | 18351 |
| | 84500 | 77200 | 61682 | 61067 | 18361 |
| | 84488 | 77154 | 61673 | 61082 | 18349 |
| | 84509 | 77142 | 61692 | 61082 | 18350 |
| | 84506 | 77130 | 61688 | 61101 | 18348 |
| | 84496 | 77166 | 61680 | 61094 | 18368 |
| | | 77127 | | | 18356 |
| Mean | 0.4923 84499 | 0.4957 77152 | 0.4838 61680 | 0.7406 61082 | 0.4852 18356 |
| M | 0.21 | 0.73 | 0.26 | 0.38 | 0.34 |
| m | 0.64 | 2.31 | 0.78 | 1.15 | 1.06 |

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| Instruments | 6101 | 6102 | 6301 | 6302 | 6303 |
|---|---|---|---|---|---|
| | | | Ledovo II | | |
| | 0.4915+ | 0.4949+ | 0.4830+ | 0.7393+ | 0.4853+ |
| | 43714 | 30624 | 35444 | 96380 | 88114 |
| | 43704 | 30598 | 35456 | 96394 | 88112 |
| | 43700 | 30607 | 35450 | 96396 | 88114 |
| | 43705 | 30610 | 35465 | 96382 | 88116 |
| | 43714 | 30620 | 35466 | 96382 | 88116 |
| | 43710 | 30616 | 35456 | 96392 | 88095 |
| | 43709 | 30614 | 35477 | 96394 | 88110 |
| | | 30579 | | 96399 | 88104 |
| Mean | 0.4915 43708 | 0.4949 30609 | 0.4830 35459 | 0.7393 96390 | 0.4853 88110 |
| M | 0.20 | 0.51 | 0.42 | 0.26 | 0.26 |
| m | 0.53 | 1.44 | 1.11 | 0.74 | 0.73 |

TABLE 3. GRAVITY INTERVALS IN THE IGSN-71 SYSTEM (mGal).

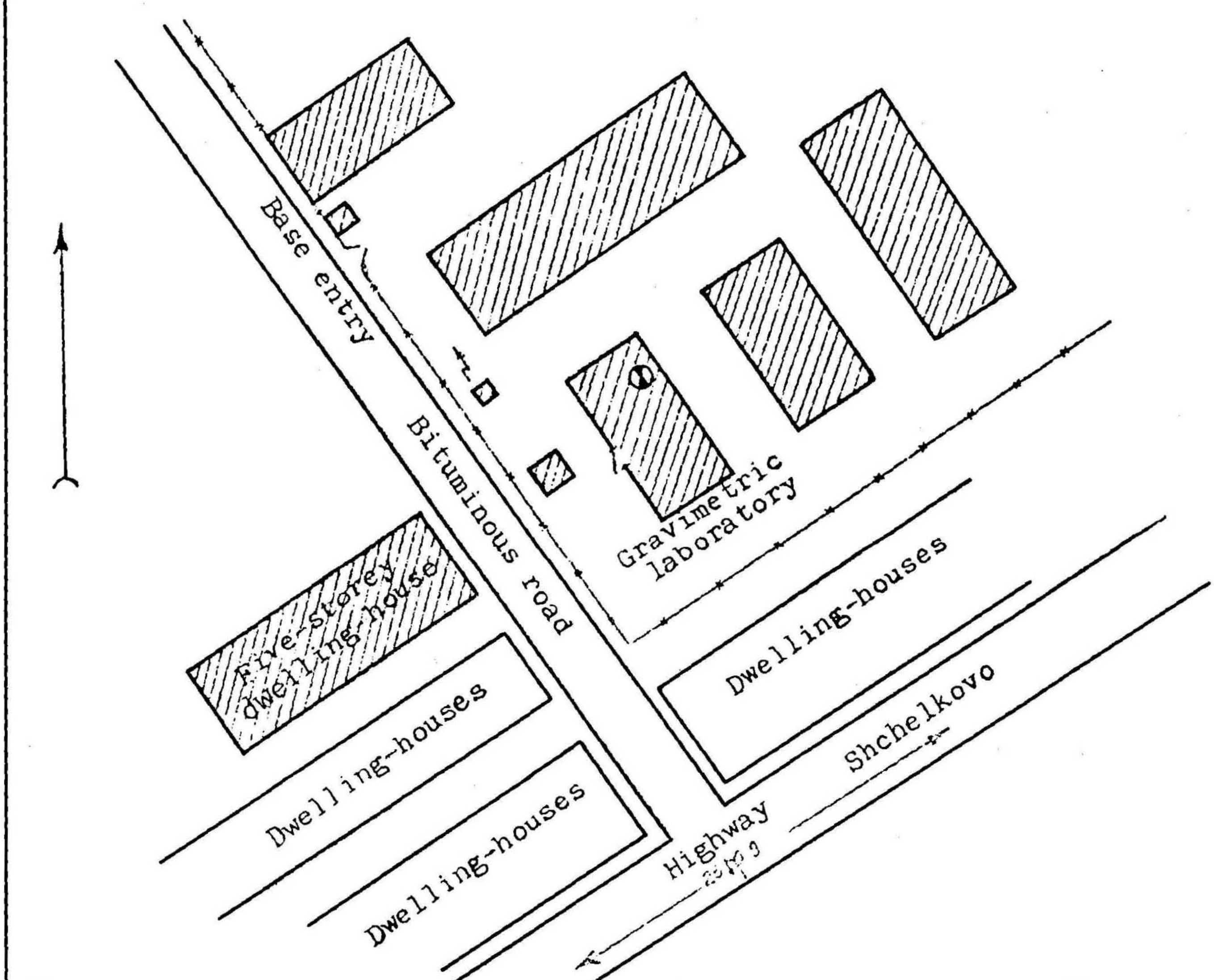
| Gravity interval | OVM Pendulum Number | | | | | Mean value and standard error of mean | Weighed mean value and standard error of mean |
|---|---|---|---|---|---|---|---|
| | 6101 | 6102 | 6301 | 6302 | 6303 | | |
| Moscow (Ledovo) - Port Moresby D | 3349.21 ± 0.13 | 3348.91 ± 0.26 | 3349.23 ± 0.09 | 3349.18 ± 0.10 | 3349.09 ± 0.17 | 3349.12 ± 0.06 | 3349.183 ± 0.055 |
| Port Moresby D - Hobart P | 2215.81 ± 0.11 | 2215.61 ± 0.20 | 2215.70 ± 0.10 | 2215.57 ± 0.11 | 2215.50 ± 0.13 | 2215.64 ± 0.05 | 2215.655 ± 0.054 |

TABLE 4. GRAVITY VALUES IN IGSN-71 SYSTEM (mGal).

| Gravity station | OVM pendulum | La Coste & Romberg gravity meter | GAG-2 gravity meter |
|---|---|---|---|
| Sydney A | 979 671.860 | 979 671.860 | 979 671.860 |
| Moscow (Ledovo) | 981 551.376 | | |
| Port Moresby D | 978 202.193 | 978 202.184 | 978 202.202 |
| Hobart B | 980 417.848 | 980 417.845 | 980 417.901 |

code IGB : 213 57

# MOSCOW PENDULUM STATION (LEDOVA)

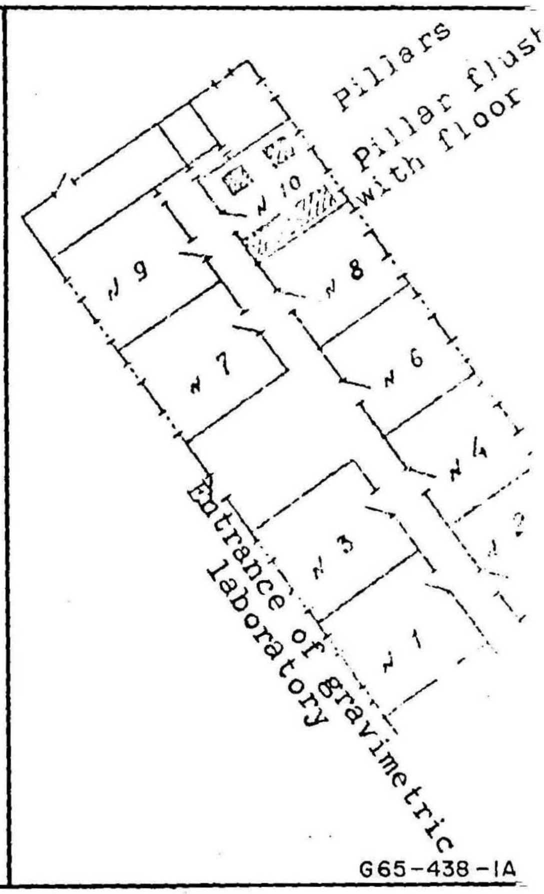



The station is situated at the area of the Ledovo-test base of the Institute of Earth's Physics (IFZ) of the Academy of Sciences of the USSR near Moscow (village Dolgoe-Ledovo, district Shchelkovo, IFZ base Ledovo).

Measurements were made on the concrete pillar in room No. 10 of the gravimetric laboratory of the IFZ. The pillar is provided with mark No. 5035.

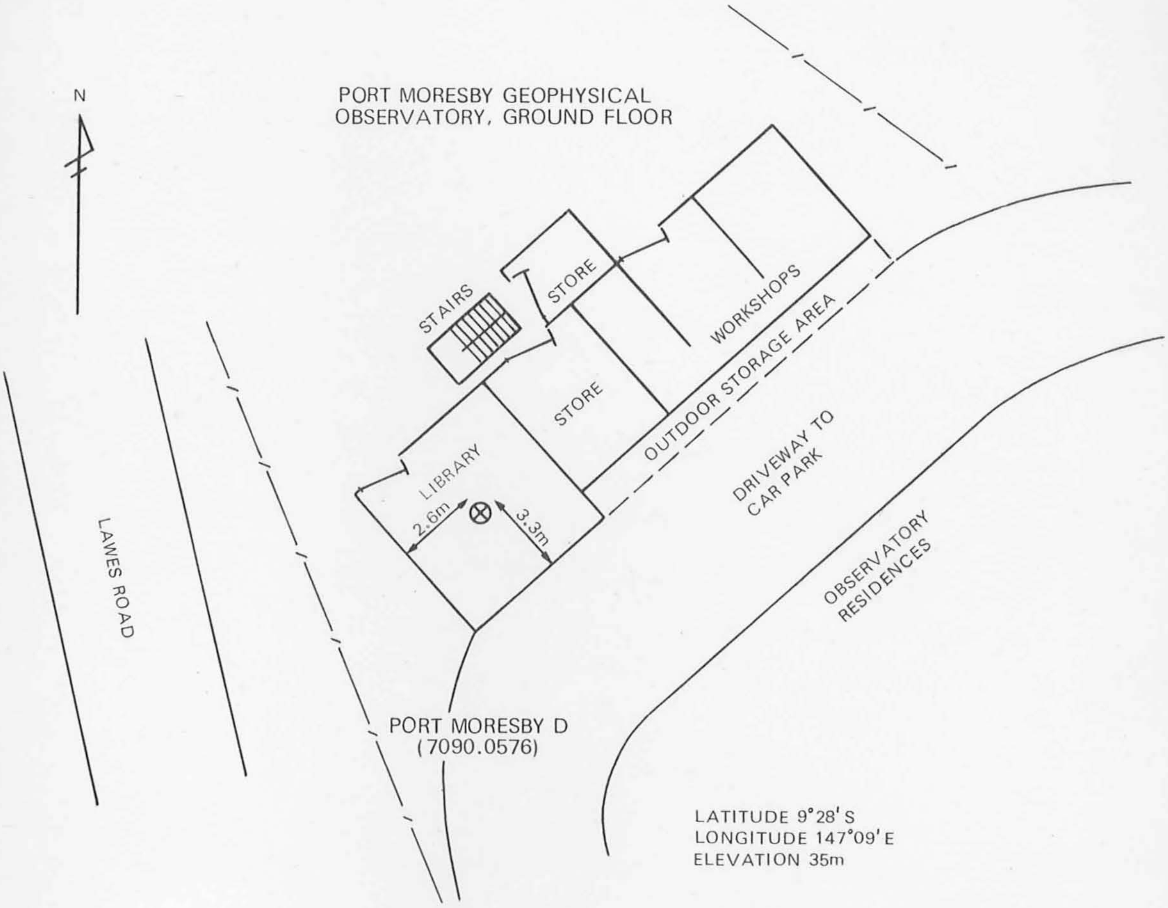
Approximetely :

$\varphi$ = 55°45'N $\lambda$ = 37°42'E.G.



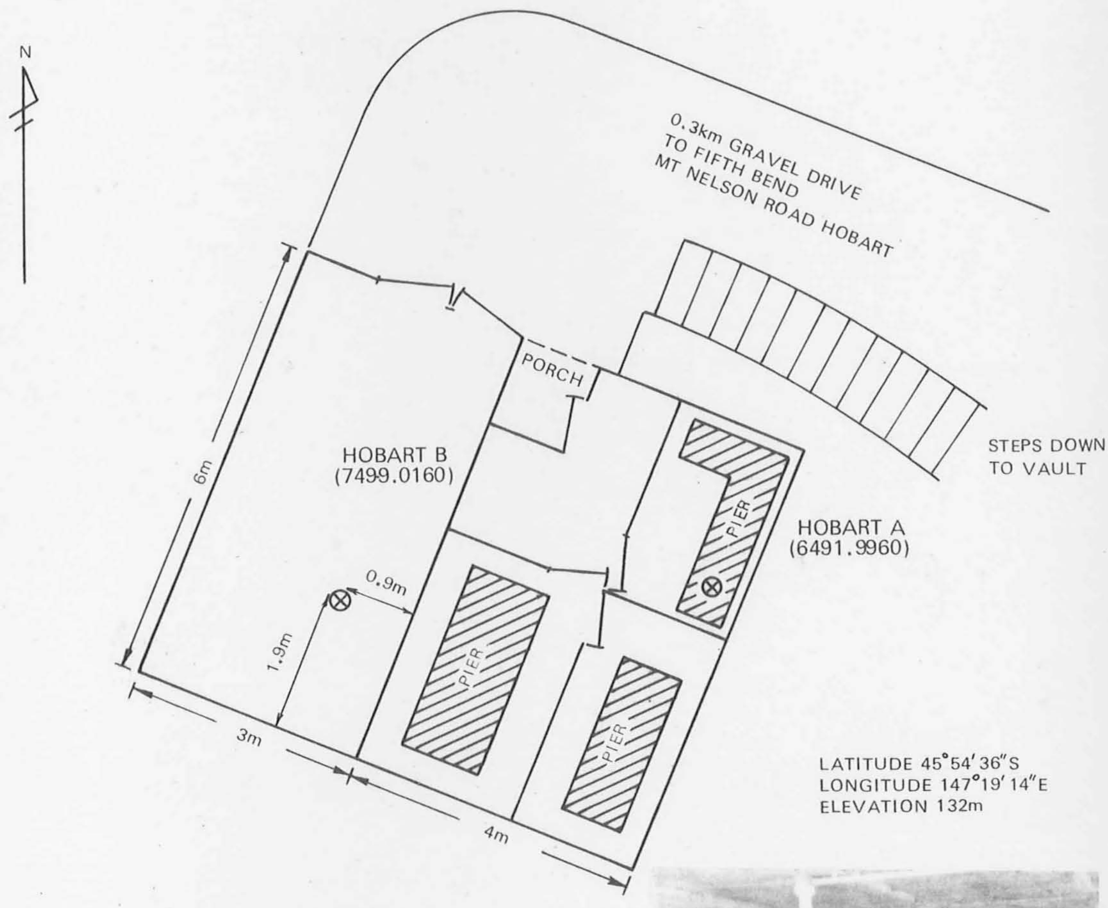
# PORT MORESBY D
## (PNG)

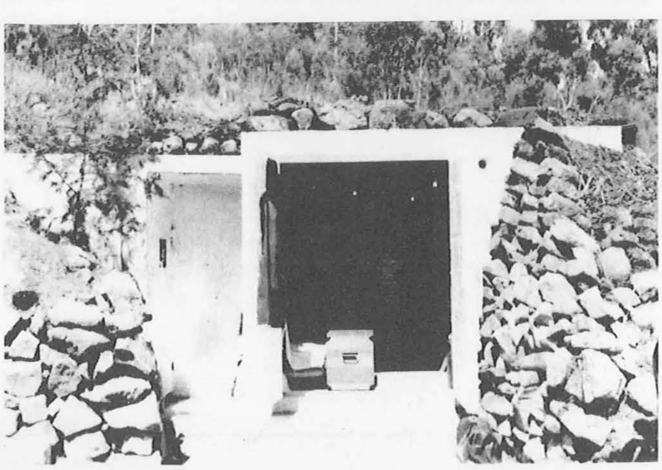
*Port Moresby D (7090.0576) is in the library of the Port Moresby Geophysical Observatory, Lawes Road, Port Moresby, The station is on the concrete floor, 2.6m from the SW wall, 3.3m from the SE wall, and it is marked by a brass disc.*




# HOBART B
## (AUSTRALIA)

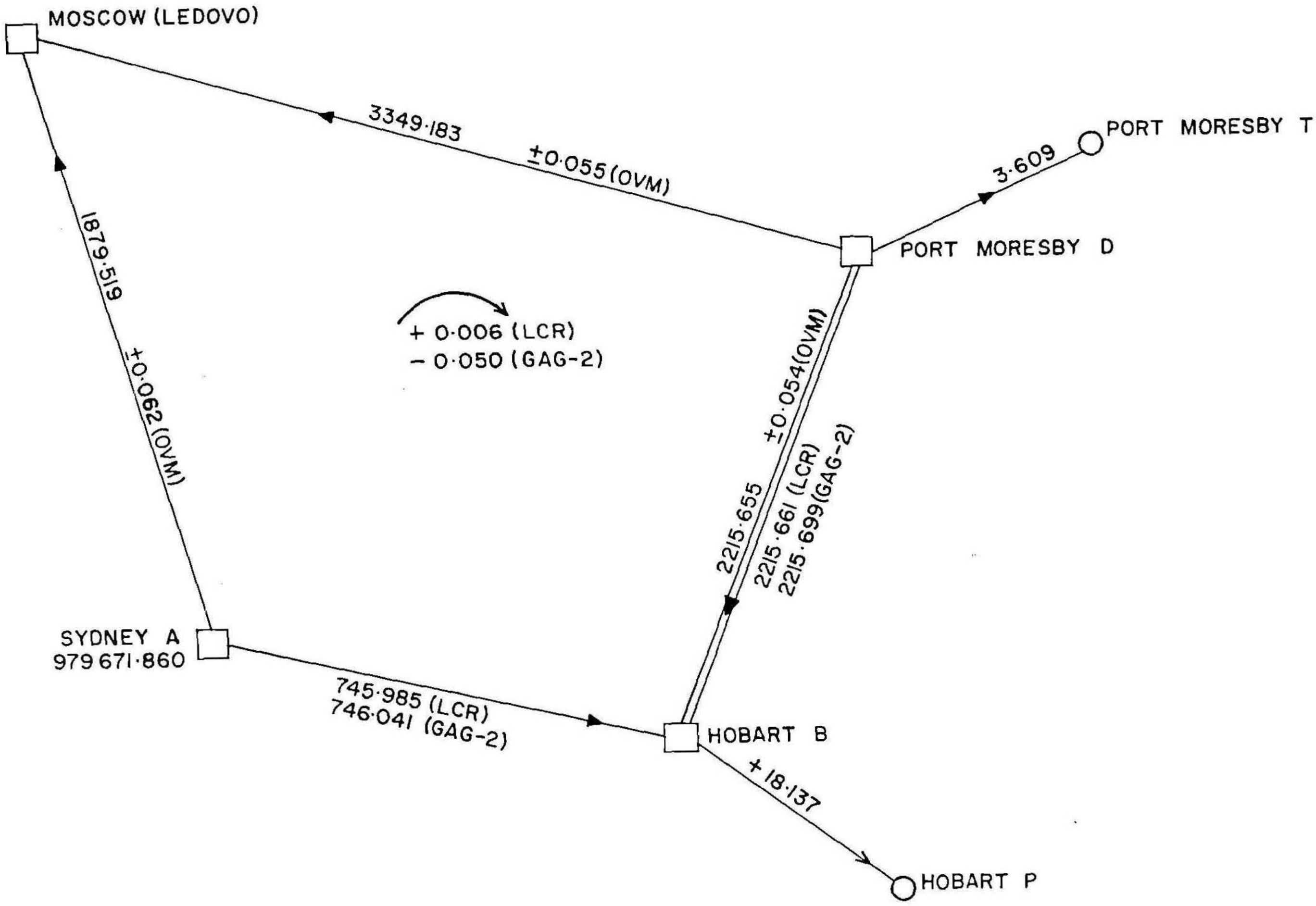
*Hobart B (7499.0160) is in the 1974 extension to the TAU seismic vault in the grounds of the University of Hobart. The site is 1.9m from the back wall and 0.9m from the vault wall.*



*To accompany Record No. 1975/48, 106*

G65-426A




SCHEMA OF GRAVIMETRIC TIES