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Pendulum Doternination of the Gravity Differences between Tokyo, Mowbray and Syowa Base

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第6次南極地域観測隊重力部門報告

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要　旨

1956年の南極会議及び国際重力会議の両会議において採択された決議により，第2次南極観測の際に計画された目黒（当時千葉）と Mowbray・昭和基地の重力振子による接続のうち，当時氷状不良のために実施できなかった Mowbray・昭和基地間の接続が，今回計画実施された．これは，再度採択された 1960 年の南極会議及び国際地球物理学・測地学連合総会の決議にも基づくものである．また，宗谷の往復航海を利用して目黒・Mowbray 間の接続が再度行なわれた．

今回は南極観測用として設計製作された装置と，特に重力振子は安全を期して2組使用された．各観測点における測定のうち，1 組の振子の観測は昭和基地において時計の不調のために失敗したが，目黒・Mowbray では良い結果が得られた．他方の振子の組については順調に観測を終了できた．

各測点の位置は次の通りである．

目　黒　$\varphi = 35°38'.6$　N
$\lambda = 139°41'.3$　E
$h = 28.04$ m

Mowbray $\varphi = 33°57'.1$　S
$\lambda = 18°28'.1$　E
$h = 38.4$ m

昭和基地 $\varphi = 69°00'.3$　S
$\lambda = 39°35'.4$　E
$h = 14.0$ m

測定結果は次の通りである．

$g_{\mathrm{Megro}} = 979.7770\ gal$ を基準にした場合

$g_{\mathrm{Mowbray}} = 979.6471 \pm 0.0005\ gal$（振子セットAによる）

$g_{\mathrm{Mowbray}} = 979.6463 \pm 0.0004\ gal$（振子セットDによる）

$g_{\mathrm{Syowa\ Base}} = 982.5394 \pm 0.0005\ gal$（振子セットDによる）

g_{Mowbray} の値は第2次観測の際の結果とも良く一致している．

特に昭和基地重力点については，南極地域には振子による重力観測の例が少ないので，同点は重力基準点として充分利用し得る点であると考えられる．同点には金属標識を設置して今後の使用の便をはかった．

なお，Worden 重力計を使用して，オングル島内及び宗谷の Singapore 停泊中，Singapore・Kuala Lumpur 間の接続が行なわれた．

Introduction

In accordance with the resolutions adopted at the meetings of SCAR 1956 and also of the International Gravity Commission 1956, the establishment of a fundamental

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gravity station in Antarctica with a pendulum apparatus during the second Japanese Antarctic Research Expedition was planned. In carrying out this plan, observations at Chiba (Japan), Singapore and Mowbray (Cape Town) were performed successfully. However, the connection of Syowa Base (Antarctica) with Mowbray, which composed the most important part of this plan, could not be executed because of the disadvantageous transportation condition due to the heavy ice state[3),4)].

Afterward, the resolutions that pendulum gravity stations should be established along the coasts of Antarctica have been adopted at the fourth meeting of SCAR and of the International Union of Geodesy and Geopysics, in view of the importance of the fundamental gravity stations in Antarctica[8)].

Since the sixth Japanese Antarctic Research Expedition 1962 was the last chance for this purpose in this series of expeditions, the connection between Syowa Base and Meguro (Tokyo) by using a pendulum apparatus, which occupied the unconsummated part of the gravity measurement in the second Japanese Antarctic Research Expedition, was planned and carried out. The connection between Meguro and Mowbray was carried out on the going and returning voyage again.

Results of gravity survey with a Worden gravimeter in the Ongul Islands and other districts made during the fifth and sixth Japanese Antarctic Research Expeditions are summarized in this report.

Pendulum observation

1. Instrument[1)]

The equipment used for this project is a New GSI Pendulum Apparatus which is the same that was used in the Tokyo-Melbourne tie[2)]. The instruments used in this trip are listed in Table 1. The block diagram of this apparatus is shown in Fig. 1–1.

This apparatus is the Vening Meinesz type one which consists of three minimum pendulums. Each pendulum is made of fused quartz with high-speed steel knife-edges and they are hung on flat agate planes. Two sets of pendulums A and D were used for this trip, taking into account the difficulty of seizing the other opportunity.

As mentioned below, for the set D pendulums Nos. 10, 11 and 12, good data could not be obtained in the observation at Syowa Base because of the accident in the crystal clock, but the set A pendulums Nos. 1, 2 and 3, brought good results.

The swinging case was constructed with a view to facilities for its usage and to lighten its weight for the purpose of using it in such bad conditions as Antarctica.

The weight of total equipments has been to lighten to 850 kg, compared with the

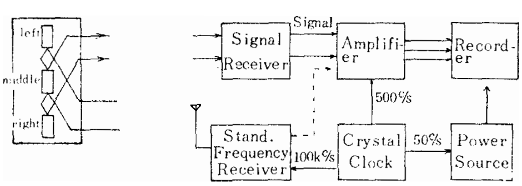

Fig. 1–1. Block diagram of the apparatus.

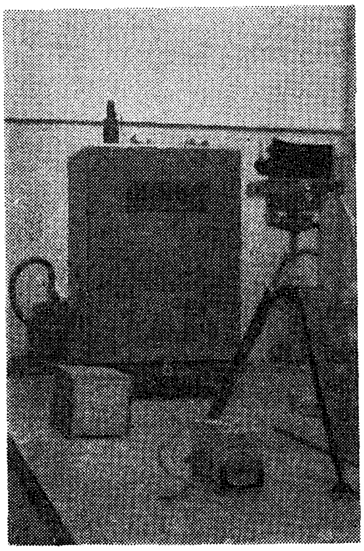

Fig. 1-2. New GSI pendulum apparatus, swinging case.

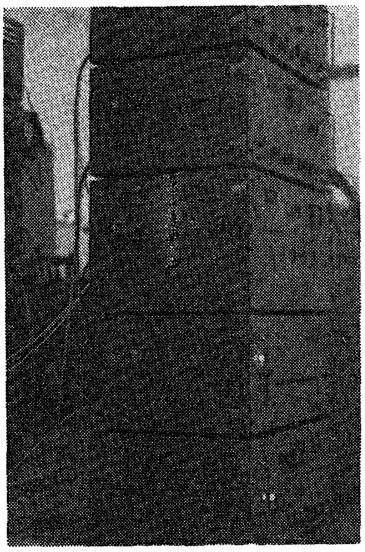

Fig. 1-3. New GSI pendulum apparatus, recorder and clock.

Table 1. List of instruments.

Instruments	Remarks
New GSI pendulum apparatus	
Swinging case	Vening Meinesz type
Base rack	
Thermostat	20−45°C, 5°C intervals
Vacuum pump	rotary type
Standard frequency receiver	for 5, 10, 15 Mc/s
Amplifier	
Crystal oscillator	GT cut, 100 kc/s
Frequency divider	
Power source	
Recorder dram	
Auxiliary instrument case I	
〃 〃 〃 II	
〃 〃 〃 III	
Pendulum set A	Nos. 1, 3, 2
〃 〃 D	Nos. 10, 11, 12
Worden gravimeter	geodetic type, No. 346

weight 1500 kg at the second expedition. It was very effective to transport by helicopter.

2. Observation

1) Station

Meguro (G.S.I., Tokyo) — On the concrete block in the gravity room, the basement of the main building, the Geographical Survey Institute. 7-1000, Kamimeguro, Meguro-ku, Tokyo, Japan (Fig. 2).

$$\varphi = 35^\circ\ 38'.6\ \mathrm{N}$$
$$\lambda = 139^\circ\ 41'.3\ \mathrm{E}$$

$$h = 28.04\,\mathrm{m}$$
$$g_{\mathrm{G.S.I.,\ Tokyo}} = 979.7770 \pm 0.0001 \text{ gals}$$
$$\text{referred to } g_{\mathrm{Kyoto}} = 979.7212 \text{ gals}$$

Mowbray — On the concrete floor of room No. 25 (former No. 14), the Trigonometrical Survey Office, Phodes Avenue, Mowbray, Cape Province, Republic of South Africa. International first order gravity station (Fig. 3).

$$\varphi = 33^\circ\ 57'.1\ \mathrm{S}$$
$$\lambda = 18^\circ\ 28'.1\ \mathrm{E}$$
$$h = 38.4\,\mathrm{m}$$

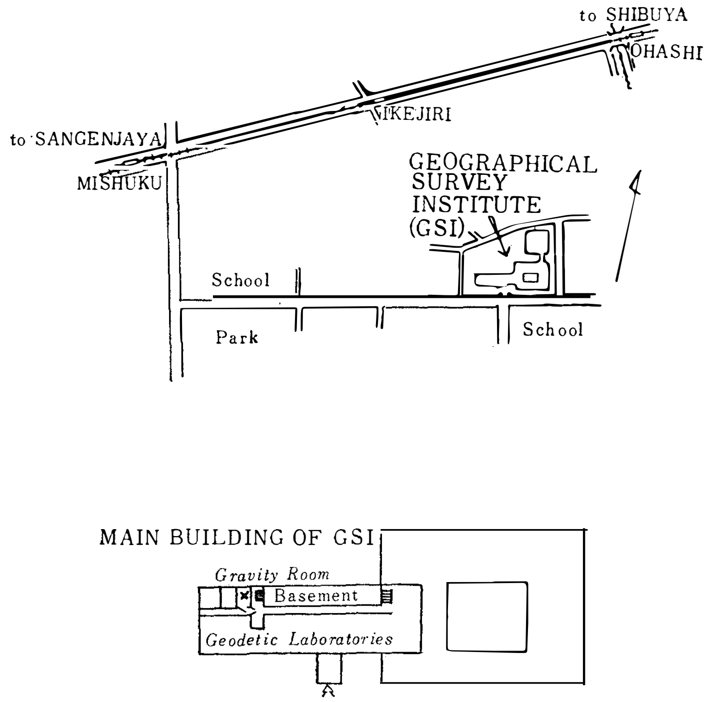

Fig. 2. Geographical Survey Office.

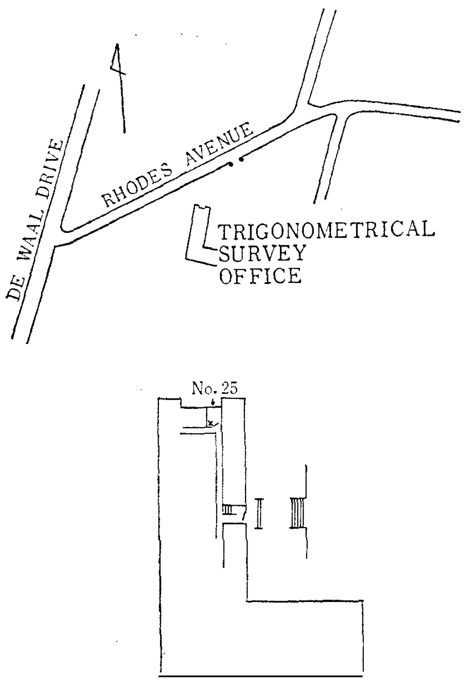

Fig. 3. Trigonometrical Survey Office.

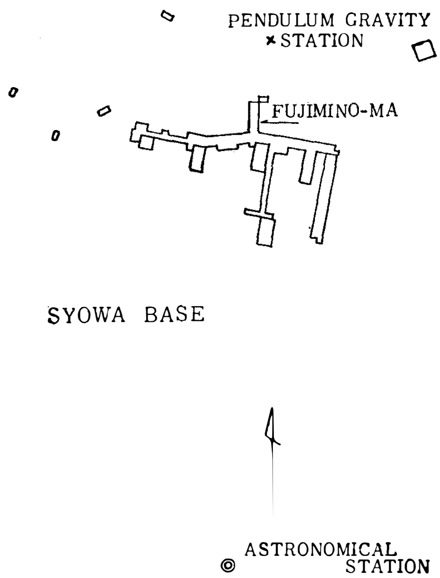

Fig. 4. Syowa Base.

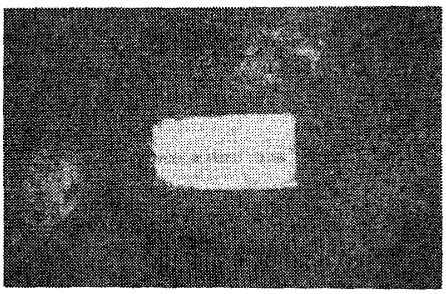

Fig. 5. Metal mark.

Syowa Base	On the exposed rock of granite-gneiss in the direction of N15°E at the distance of 20 m from the entrance of Fujimino-ma (a simple frame hut) (Fig. 4). A metal mark has been fixed here (Fig. 5). φ = 69° 00′.3 S, λ = 39° 35′.4 E, h = 14.0 m

2) Date of observations

The summary of periods of observations are as follows:

1961 October		Preparation for this trip
	9—12	measurement with the set D at Meguro
	20—23	measurement with the set A at Meguro
	30	departure of the observation ship SOYA at Tokyo
December	8	arrival of the SOYA at Cape Town
	9—10	measurement with the set A at Mowbray
	11—12	measurement with the set D at Mowbray
	14	departure of the SOYA at Cape Town
1962 January	9	arrival at Syowa Base
	14—16	measurement with the set D at Syowa Base
	19—22	measurement with the set A at Syowa Base
Februry	6	departure at Syowa Base
	26	arrival of the SOYA at Cape Town
	27—28	measurement with the set A at Mowbray
March	1— 2	measurement with the set D at Mowbray
	6	departure of the SOYA at Cape Town
April	17	return to Tokyo
May	15—22	measurement with the set A at Meguro
	23—29	measurement with the set D at Meguro

3) General method of observation

The method of observation was the same that was described in the preceding paper[2].

Measurement at each station were made with the pendulum No. 11, hung freely on the middle agate plane and with the pendulums No. 10 on the left plane and No. 12 on the right plane, swung in anti-phase each other as for the set D. As for the set A pendulums Nos. 1, 3 and 2 were arranged in order of left, middle and right.

One set of measurement takes within about 20 minutes and produces one pair of records of pendulums' periods which contain about 10 minutes' swings for each pendulum. Signals from pendulums, at intervals of 0.5 second indicating transits of pendulums are recorded with standard time signals of 500 c/s from the crystal clock on a spark chronograph paper winded round a drum rotating one round per second synchronizing with standard time signals. Four groups of signals from pendulums at intervals of about 5 minutes, one group of signals contains 10 times of pendulums swings, are recorded in one set of measurement.

Observation at one station has 8 to 10 sets of measurements.

4) **Correction to an observed period of a pendulum**

Corrections applied to an observed period of a pendulum were amplitude correction and temperature correction. Clock rate correction was applied to only the data obtained at Mowbray in return trip. No pressure correction was added. The pressure in the swinging case was kept between 0.2 and 0.5 mmHg during the observation at every station.

a) Amplitude correction.

The amplitude correction was applied according to the formula $\Delta T=\alpha/16$, where α is the amplitude determined from observing the movement of light images from pendulums at the Recorder head.

b) Clock rate correction

A GT cut crystal oscillator was used for these observations. Fig. 6 shows one example of the drift of the oscillating frequency of this clock. The oscillating frequency is 100 Kc/s, and it was corrected by comparing with standard frequency by means of zero beat method and was kept within accuracy of 5×10^{-8}.

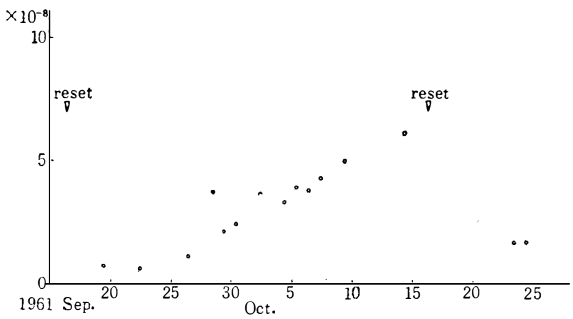

Fig. 6. Clock rate.

Standard radio waves used for this correction at each station were as follows:

Station	Standard radio wave	Frequency
Meguro	JJY	10, 15 Mc/s
Mowbray	ZUO, WWV	10 Mc/s
Syowa Base	WWV	10 Mc/s

Unfortunately, there were some accidents about this clock during the trip. One accident was the miscount of the frequency divider circuit caused by a large fall in voltage of the electric source at Syowa Base. This damaged the observation with the pendulum set D. Another accident occurred at Mowbray on return way. The accident was that the thermostat of the crystal oscillator did not work well, so that the clock rate was compared with ZUO three times in every measurement. The clock rate correction was added to each observed period.

c) Temperature correction

The temperature correction coefficient of the set A was determined to be $\alpha=$

21.4×10^{-8} sec/°C by the former experiment and this value has been used for temperature correction to the period. But the temperature coefficients of these pendulum sets could not be obtained from the experimental observation made after this trip accurately. Since the old value $\alpha=21.4\times10^{-8}$ sec/°C was used for all pendulums in this report, it should be remembered that some problems have been left in the temperature coefficient.

The temperature selector of the thermostat was set to be 30°C at Meguro and Mowbray and to be 20°C at Syowa Base, taking into account the atmospheric temperature at each station.

A thermometer installed inside the swinging case was read just before and after each swing in order to know the temperature of the pendulums. The temperature correction was not to applied each observed period, but the mean correction determined from the mean temperature was added to the mean periods at that station.

5) Observation

The station G.S.I., Tokyo is one of the most important reference stations and connected to the international first order gravity station Kyoto with sufficient accuracy, and

$$g_{\mathrm{G.S.I.,\ Tokyo}}=979.7770\pm0.0001 \text{ gals}$$
$$\text{referred to } g_{\mathrm{Kyoto}}=979.7212 \text{ gals}$$

The room is air-conditioned and the temperature of this room is kept about 24°C.

Preparation for this work was begun from the middle of September. The adjustment of the apparatus was made carefully at the laboratory of G.S.I. because the lay days of the SOYA in Cape Town was limited in minimum, so that the observations at Mowbray had to be completed as smoothly as possible in spite of using two sets of pendulums.

As for the set D, the upper planes of the knife edges which will contact closely with the lower planes of the arms of the pendulums were repolished, because the instablility in the period which had occurred before the observation at G.S.I. Tokyo was supposed to be caused by the irregularity of the flatness of these planes.

The apparatus was carried by the SOYA through the whole voyage to and from Antarctica via Cape Town and Singapore. The instruments were set in the special room designed for our instruments and the crystal clock was operated and checked during the voyage. An accident on the thermostat of the crystal clock happened just before arriving in Cape Town on the way to Antarctica, but it was mended at once.

Mowbray

The gravity station at the Trigonometrical Survey Office, Mowbray has been listed as one of the international first order gravity stations at the meeting of the International Union of Geodesy and Geophysics 1960[3]. So, Syowa Base was combined to the international gravity net as recommended at the preceding meeting of SCAR. The instruments were transported with the courtesy of the Trigonometrical Survey

Office. In placing the instruments the wooden flooring were removed and the swinging case and the signal-receiver tripod were set directly on the concrete floor. As mentioned above, the thermostat of the crystal clock did not work well in the observation at Mowbray on return trip and the clock rate correction was applied to each observed period, but the maximum value of this correction never exceeded 5×10^{-8} sec.

Syowa Base

The apparatus was transported from the SOYA stayed in the pack ice sea to Syowa Base by a Sikorsky S-58 helicopter without wooden transportation cases.

The astronomical station which had been used as a gravity station by that time could not be served as a pendulum station, because this point is located on the top of a hill where a flat area can not be found and also the point is far from the electric source in Syowa Base. A new pendulum gravity station was established on the flat exposed rock of granite-gneiss which lies about 170 metres northwards from the astronomical station, and in the direction of N15°E at the 20 metres distance from the entrance of one of simple frame huts, Fujimino-ma.

A simple frame hut which had been used as a magnetic absolute measurement room before, was moved to the pendulum site and used for this work.

The atmospheric temperature at Syowa Base during that season was within the range between -5°C and $+0$°C, and the thermostat of the swinging case was set to 20°C. Because of the large temperature difference between inside and outside the swinging case, the daily temperature change in the swinging case came to 1°C as the surrounding temperature changed. It was so hard to start the vacuum pump because of low temperature, which is operated before every swing to evacuate the swinging case, that the pump had to be heated for 2 to 3 hours every day.

Many minute mica flakes which come from weathered gneiss and float in the air, as well as low temperature make it considerably difficult to accomplish pendulum observation in such a circumstance as Syowa Base. But the microseisms at this station are so inactive that it can be expected to get good result.

3. Result

The results of the observations at G.S.I. Tokyo, Mowbray and Syowa Base are summarized in Table 2, but the observation at Syowa Base with set D were not used here. Inspecting the results, some tendency that the mean errors at each station become smaller in order of Meguro, Mowbray and Syowa Base is found. It is obvious that this tendency depends on the microseismic activity at each station. This fact can be convinced easily from the movement of the middle pendulum.

The results were reduced to Meguro (I) 31.0°C for the set D and 30.9°C for the set A. The corrected periods are listed in Table 3.

The periods of each pendulum at Meguro, the differences in periods between Mowbray and Meguro, and Syowa Base and Meguro are calculated by method of least squares. The changes in period of the pendulums during this six months' trip are

Table 2. Observed periods.

Set A

No.	Date	Station	Number of date	Mean temper-ature	Pendulum No. 1			Pendulum No. 2		
					Period	S.D.	M.E.	Period	S.D.	M.E.
	1961					$\times10^{-8}$	$\times10^{-8}$		$\times10^{-8}$	$\times10^{-8}$
I	10.20-23	Meguro (I)	14	30.94°C	1.01723279	31	8	1.01722961	31	8
II	12. 9-10	Mowbray (I)	16	31.31	1.01730091	20	5	1.01729754	20	5
	1962									
III	1.19-21	Syowa Base	18	20.58	1.01579984	18	4	1.01579603	19	4
IV	2.27-28	Mowbray (II)	16	31.18	1.01730078	27	7	1.01729699	18	5
V	5.15-22	Meguro (II)	18	30.37	1.01723311	37	9	1.01722879	35	8

Set D

No.	Date	Station	Number of date	Mean temper-ature	Pendulum No. 10			Pendulum No. 12		
					Period	S.D.	M.E.	Period	S.D.	M.E.
	1961				s	$\times10^{-8}$	$\times10^{-8}$	s	$\times10^{-8}$	$\times10^{-8}$
I	10. 9-12	Meguro (I)	20	31.01°C	0.99962240	27	6	0.99961878	33	7
II	12.11-12	Mowbray (I)	18	31.14	0.99968828	12	3	0.99968544	23	5
	1962									
III	1.14-16	Syowa Base	18	20.57	0.99821358	35	9	0.99821196	51	12
IV	3. 1- 2	Mowbray (II)	18	31.27	0.99968789	32	8	0.99968515	23	5
V	5.23-29	Meguro (II)	18	30.79	0.99962149	30	7	0.99961867	23	5

Table 3. Reduced periods.

Set A

No.	Station	Reduced period		
		No. 1	No. 2	
		s	s	
I	Meguro (I)	1.01723279	1.01722961	
II	Mowbray (I)	1.01730083	1.01729746	
III	Syowa Base	1.01580206	1.01579825	reduced to 30.94°C
IV	Mowbray (II)	1.01730073	1.01729694	
V	Meguro (II)	1.01723323	1.01722891	

	Closure $\times10^{-8}$	$\times10^{-8}$
Mowbray	−10	−52
Meguro	44	−70

Set D

No.	Station	Reduced period		
		No. 10	No. 12	
		s	s	
I	Meguro (I)	0.99962240	0.99961878	
II	Mowbray (I)	0.99968825	0.99968541	
III	Syowa Base	0.99821581	0.99821419	reduced to 31.01°C
IV	Mowbray (II)	0.99968783	0.99968509	
V	Meguro (II)	0.99962154	0.99961872	

	Closure $\times10^{-8}$	$\times10^{-8}$
Mowbray	−42	−32
Meguro	−86	− 6

listed in Table 3. As for the pendulums No. 2 and No. 10 the decreases in period which amount almost to 1×10^{-6} sec are especially noted. These decreases show that some changes occurred in the pendulums, though its cause is unknown yet. To calculate periods and differences in period, equal weight to the mean periods listed in Table 3 were assumed under these conditions.

The results are as follows:

Set D

$$T_{10\ \mathrm{Meguro}}=0.999\,621\,86\pm21\times10^{-8}\ \text{(M.E.) sec.}$$
$$T_{12\ \mathrm{Meguro}}=0.999\,618\,86\pm21\times10^{-8}\ (\ /\!/\ )\ \text{sec.}$$
$$T_{\mathrm{Mowbray}}-T_{\mathrm{Meguro}}=0.000\,066\,28\pm25\times10^{-8}\ (\ /\!/\ )\ \text{sec.}$$

from this result

$$g_{\mathrm{Mowbray}}-g_{\mathrm{G.S.I.,\ Tokyo}}=-0.129\,9\pm0.0005\ \text{gals}$$

Set A

$$T_{1\ \mathrm{Meguro}}=1.017\,232\,98\pm17\times10^{-8}\ \text{(M.E.) sec.}$$
$$T_{2\ \mathrm{Meguro}}=1.017\,229\,29\pm17\times10^{-8}\ (\ /\!/\ )\ \text{sec.}$$
$$T_{\mathrm{Mowbray}}-T_{\mathrm{Meguro}}=0.000\,067\,86\pm20\times10^{-8}\ (\ /\!/\ )\ \text{sec.}$$
$$T_{\mathrm{Syowa\ Base}}-T_{\mathrm{Meguro}}=-0.001\,430\,98\pm25\times10^{-8}\ (\ /\!/\ )\ \text{sec.}$$

from these results

$$g_{\mathrm{Mowbray}}-g_{\mathrm{G.S.I.,\ Tokyo}}=-0.130\,7\pm0.0004\ \text{gals}$$
$$g_{\mathrm{Syowa\ Base}}-g_{\mathrm{G.S.I.,\ Tokyo}}=2.762\,4\pm0.0005\ \text{gals}$$

then, the gravity value at Mowbray is

$$g_{\mathrm{Mowbray}}=979.647\,1\pm0.0005\ \text{gals (Set D)}$$
$$g_{\mathrm{Mowbray}}=979.646\,3\pm0.0004\ \text{gals (Set A)}$$

the gravity value at Syowa Base is

$$g_{\mathrm{Syowa\ Base}}=982.539\,4\pm0.0005\ \text{gals (Set A)}$$

referred to $g_{\mathrm{G.S.I.,\ Tokyo}}=979.777\,0$ gals

On the data with set D at Syowa Base

The gravity value at Syowa Base deduced also from the mean period obtained with set D without applying any correction for the accident in the clock.
The results are

$$g_{\mathrm{Syowa\ Base}}=982.5381\ \text{gals (pendulum No. 10)}$$
$$g_{\mathrm{Syowa\ Base}}=982.5358\ \text{gals (pendulum No. 12)}$$

relative to $g_{\mathrm{Mowbray}}=979.6463$ gals

These values are smaller by 1.3−3.6 mgals than the result with the set A. These results were not adopted because it was obvious that the miscount of the clock occurred actually, judging from the statistic distribution of the data.

Worden gravimeter Observation

The connection between Mowbray and Syowa Base with the Worden gravimeter could not be carried out in the 5th and 6th expeditions, because the gravimeter had been left at Syowa Base and used by the 5th wintering team during the antarctic winter 1961.

The observation in Antarctica, the observation in wide region could not be made because of the lack of time, but 8 new points were added to the list of the gravity stations near Syowa Base. The results of these observations are summarized in Table 4. Free air and Bouguer anomalies in this region are shown in Figs. 9 and 10. The correction for the drift of gravimeter were added to the observed value, but the earth tide correction is not applied, because this correction never exceeds 0.04 mgals in this region.

The gravity difference between the astronomical station, former gravity station, and the new pendulum station was observed to be

$$g_{\text{Astro. station}} - g_{\text{Pendulum station}} = -3.32 \pm 0.01 \text{ mgals}$$

from three times observations.

The mean scale value obtained from the results of calibrations which were made just before the departure of the 5th expedition and immediately after the return of the 6th expedition, was adopted for the dial constant of the gravimeter.

As for the observations in Singapore Island in the 5th expedition and the connection between Singapore and Kuala Lumpur, Federation of Malaya, in the 6th expedition

Table 4. Results of the gravity measurement with the Worden gravimeter in Nesöya and West Ongul Island.

Station	Lat.	Long.	Height	g	g_0	g_0''	r_0	Δg_0	$\Delta g_0''$	Date
				gal 982.	gal 982.	gal 982.	gal 982.	mgal	mgal	
Syowa Base										
Pendulum Station	69°00′.3S	39°35′.4E	14.0m	53941	54373	54216	5548	−11.1	−12.6	
〃 〃										
Astro. Station	69 00.4	39 35.4	29.2	53609	54510	54183	5549	− 9.8	−13.1	1962 1.15
Nesöya										
Tide gage St.	68 59.7	39 34.6		53735			5542			
Point A	68 59.8	39 34.6	37.5	53501	54658	54239	5543	− 7.7	−11.9	1.29
Geod. Pt. No. 12	69 00.0	39 34.7	35.7	53431	54533	54133	5545	− 9.2	−13.2	〃
East Ongul										
Geod. Pt. No. 1	69 00.6	39 35.2	43.4	53297	54636	54151	5551	− 8.7	−13.6	1.30*
West Ongul										
Geod. Pt. No. 7	69 01.0	39 32.6	37.9	53598	54768	54343	5555	− 7.8	−12.1	1.30
Point A	69 01.1	39 31.1	16.9	54260	54782	54592	5556	− 7.8	− 9.7	〃
Geod. Pt. No. 10	69 01.1	39 29.9	36.6	53914	55043	54634	5556	− 5.2	− 9.3	〃
Geod. Pt. No. 8	69 01.7	39 31.6	47.7	53611	55083	54549	5562	− 5.4	−10.7	〃
Geod. Pt. No. 9	69 02.3	39 32.2	43.2	53607	54940	54457	5568	− 7.4	−12.2	〃
Point B	69 02.0	39 33.1	37.7	53618	54781	54360	5565	− 8.7	−12.9	〃
Point C	69 01.5	39 33.3	28.6	53794	54677	54357	5560	− 9.2	−12.4	〃

note: The dial constant of the gravimeter adopted is 0.10452 mgals/div.
The density of the earth's crust was assumed to be 2.67.
* means that this station had been occupied in the 3rd expedition.
No topographic correction was applied.

Table 5. Results of the gravity measurement with the Worden gravimeter in Singapore and Malaya.

Station	Lat.	Long.	Height	g	g_0	g''_0	r_0	Δg_0	$\Delta g''_0$	
	N	E	m	978.	978.	978.	978.	mgal	mgal	
University of Singapore	1°19′.1	103°49′.1	19.20	08050	08643	08447	0517	+34.7	+32.8	
Raffles Museum	1 17.8	103 51	8.21	07988	08241	08155	0516	+30.8	+30.0	
Nanyang University	1 20.7	103 41.4	28.87	07564	08455	08133	0518	+32.8	+29.5	5th*
Singapore air port	1 20.9	103 54.2	12.89	07942	08340	08194	0519	+31.5	+30.0	6th*
Woodlands BM 33	1 26.8	103 46.3	7.78	07759	07998	07916	0523	+27.7	+26.9	6th*
Changi SBM 4	1 21.4	103 58.3	27.52	06860	07709	07402	0519	+25.2	+22.1	5th*
Punggol	1 25.2	103 54.8	5.56	08190	08362	08305	0522	+31.4	+30.8	5th*
Paya Lebar BM 49	1 21.2	103 52.7	19.03	07788	08375	08166	0519	+31.8	+29.8	5th
Woodbridge Hospital BM 47	1 22.8	103 52.8	4.89	07593	07744	07693	0520	+29.4	+24.9	5th
Cable & Wireless Punggol Station	1 23.0	103 53.7	16.56	07810	08321	08206	0520	+31.2	+30.1	5th
Tampines Road BM 53	1 22.2	103 56.2	6.76	08153	08362	08287	0520	+31.6	+30.9	5th
Bedok BM 58	1 20.0	103 56.9	5.72	07139	07316	07254	0518	+21.4	+20.7	5th
Bukit Timah BM 17	1 20.4	103 46.7	14.32	08015	08457	08306	0518	+32.8	+31.3	5th
Jurong BM 22	1 21.4	103 43.2	9.00	07887	08164	08069	0519	+29.7	+28.8	5th
Choa Chu Kang BM 25	1 22.3	103 42.2	18.45	07689	08258	08057	0520	+30.6	+28.6	5th
Sembawang Rd. BM 38	1 26.7	103 49.5	4.50	08239	08378	08329	0523	+31.5	+31.0	5th
Jalan Kayu School	1 24.1	103 52.3	16.74	07295	07812	07630	0521	+26.0	+24.2	5th
Malaya Blick Works	1 21.8	103 40.7	2.85	08126	08214	08182	0519	+30.2	+29.9	5th
Tanjong Gedong	1 25.5	103 40.6	15.08	07275	07740	07561	0522	+25.2	+23.4	5th
Neo Tiew Road Chinese School	1 25.5	103 43.2	9.57	07766	08061	07960	0522	+28.4	+27.4	5th
Sungai Tengah Rd. Chinese Temple	1 23.2	103 43.8	8.37	08162	08420	08327	0520	+32.2	+31.3	5th
Kranji War Cemetery	1 25.1	103 45.4	26.07	07612	08417	08129	0522	+32.0	+29.6	5th
MALAYA										
Johore Bahru				07499						6th
Kulai				07666						6th
Ayer Hitam				07851						6th
Labis				06036						6th
Segamat BM 720			28. 8	07538	08427	08104				6th
Gemas Rest House	2 34.9	102 36.6		07635			0594			6th
Tampin Boundary Pillar	2 27.9	102 14.0	40. 0	05292	06526	06079	0585	+ 6.8	+ 2.3	6th
Seremban BM	2 43.0	101 56.7	54. 8	04254	05945	05332	0606	− 1.2	− 7.3	6th

Station	Lat.	Long.	Height	g	g_0	g''_0	r_0	Δg_0	$\Delta g''_0$	
	N	E	m	978.	978.	978.	978.	mgal	mgal	
Kajang 15¼MS	2°59!2	101°47!4	33.3	04642	05670	05297	0630	− 6.3	−10.0	6th
Kuala Lumpur Federal Hotel	3 08.7	101 42.6	45.2	04092	05487	04981	0645	− 9.6	−14.6	6th
〃 〃 Air Port	3 06.6	101 42.0	33.6	04700	05737	05361	0642	− 6.8	−10.6	6th
〃 〃 Univ. of Malaya	3 07.2	101 39.4	39.9	04814	06045	05599	0642	− 3.8	− 8.2	6th
〃 〃 Survey H.Q.	3 10.2	101 43.1	37.9	04222	05392	04967	0673	−13.4	−17.6	6th

note: The dial constant of the gravimeter adopted is 0.10452 mgals/div.
The density of the earth's crust at each station were given by the Survey Dept. about the stations in Singapore and assumed to be 2.67 about the stations in Malaya.
"5th" and "6th" mean that these stations were occupied in the 5th and 6th J.A.R.E. respectively.
* means that these stations had been occupied before the 5th J.A.R.E. also.
No topographic correction was applied.

were carried out. The results of these observations are summarized in Table 5 and Fig. 7. The earth tide correction and the correction to the drift were added to these results.

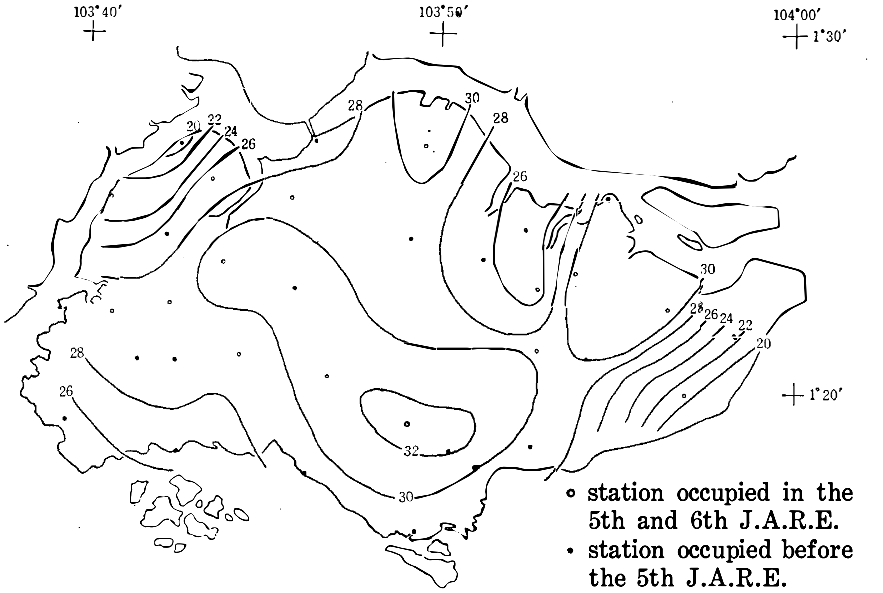

Fig. 7. Distribution of Bouguer anomalies in Singapore Island.

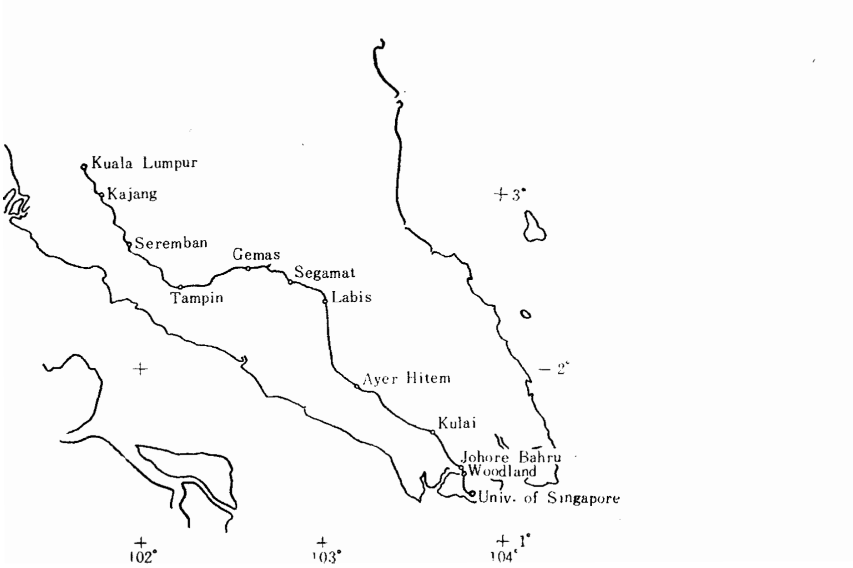

Fig. 8. Route from Singapore to Kuala Lumpur.

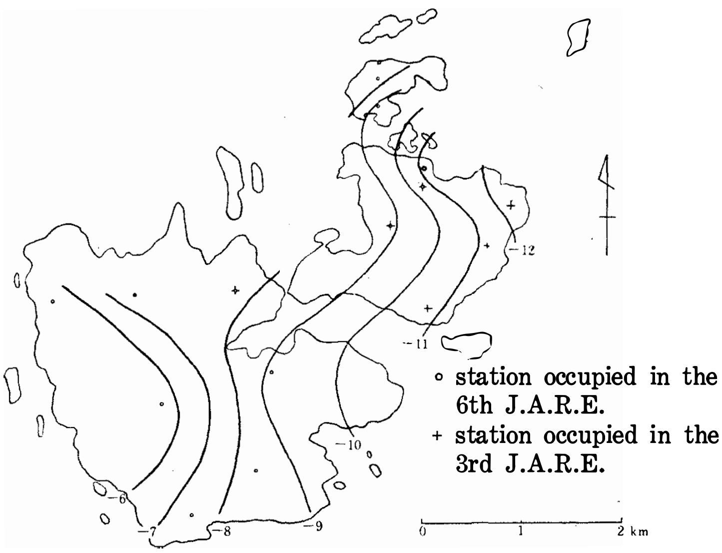

Fig. 9. Distribution of free air anomalies in the Ongul Islands.

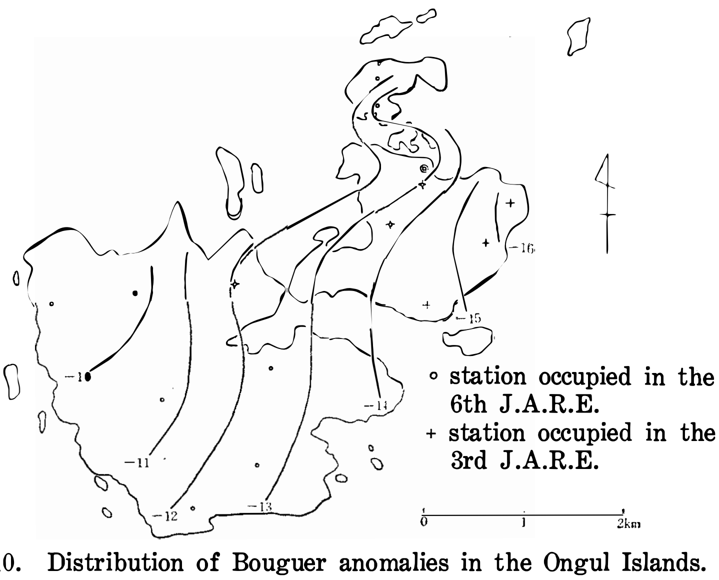

Fig. 10. Distribution of Bouguer anomalies in the Ongul Islands.

Conclusion

Mowbray

The Second Japanese Antarctic Research Expedition obtained the gravity value at Mowbray,

$g_{\mathrm{Mowbray}}=979.6470$ gals

and the 6th expedition obtained,

$g_{\mathrm{Mowbray}}=979.6471$ gals (with Set D)

$g_{\mathrm{Mowbray}}=979.6463$ gals (with Set A).

These values show good agreement with each other.

The gravity value at Mowbray determined from the international connection with pendulum apparatuses was summarized by WOLLARD in the followong table[7].

Year	Apparatus	g	Reference station
1948–9	Cambridge	979.6473 gals	$g_{\mathrm{Teddington}}=981.1962$ gals
55M	Gulf	6475	
56	Cambridge	6470	
57–8	GSI	6470	

Syowa Base

In the 3rd and 4th expeditions, the gravity values at the astronomical station in Syowa Base were determined with the Worden gravimeter. These two gravity values were reduced to the pendulum station using the gravity difference between these two stations and we get

$g_{\mathrm{Pendulum\ station}}=982.5427$ gals (3rd expedition)[5]

$g_{\mathrm{Pendulum\ station}}=982.5453$ gals (4th expedition)[6]

relative to $g_{\mathrm{Mowbray}}=979.6463$ gals

On the other hand, the result with pendulum observation is

$g_{\mathrm{Pendulum\ station}}=982.5394$ gals

The former results are larger by 3.3 and 5.9 mgals than the present result.

As the gravity difference between Mowbray and Syowa Base is about 3000 mgals, these discrepancies might be perhaps caused by the uncertainty in the dial constant of the gravimeter. The necessity of a calibration line which covers a wide gravity range is recognized again from this experience.

The Syowa Base Pendulum Gravity Station will serve as a fundamental gravity station in that region and to contribute to the completion of the world-wide gravity network and also to the research of the Antarctic Continent. It is desired that this pendulum station will be reoccupied with pendulum apparatuses in order to obtain more accurate gravity value.

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