GRAVIMETRIC CONNECTION BETWEEN TOKYO AND McMURDO SOUND

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Abstract: A gravimetric connection from Tokyo (Japan) to McMurdo Sound (Antarctica) via Sydney (Australia) and Christchurch (New Zealand) was carried out by means of two LaCoste & Romberg gravimeters in October 1980 as part of international gravimetric connections around the Circum-Pacific zone.

The gravimetric connection between Tokyo and McMurdo Sound could not be performed so precisely because scale values of the gravimeters employed could not be accurately determined. The gravity measurements in McMurdo Sound, however, were precisely performed using the two gravimeters in spite of low ambient temperatures. It was ascertained that the International Gravity Standardization Net 1971 (IGSN 71) is a homogeneous network inclusive of the gravity stations in McMurdo Sound.

1. Introduction

In gravity measurements with spring-type gravimeters, reading values of the gravimeters are converted to the corresponding milligal values using the scale values. A precise calibration of the scale values of each gravimeter is therefore essential not only for improving the measuring accuracy in gravimetry but also for standardizing the data obtained by different gravimeters. According to examinations on scale values so far made (*e.g.*, NAKAGAWA *et al.*, 1977), it was revealed that the scale values of LaCoste & Romberg gravimeters given by the manufacturer are too small without exception and that their correction factors are estimated to be about 1.0005. For example, in a gravimetric connection between Singapore (Singapore) and McMurdo Sound (Antarctica), its gravity difference amounts to about 5 gal ($=5\times10^{-2}\,ms^{-2}$), so that an error due to uncertainty of the scale values reaches about 2.5 mgal when the scale values given by the manufacturer are used.

Mainly from this point of view, a project on precise international gravimetric con-

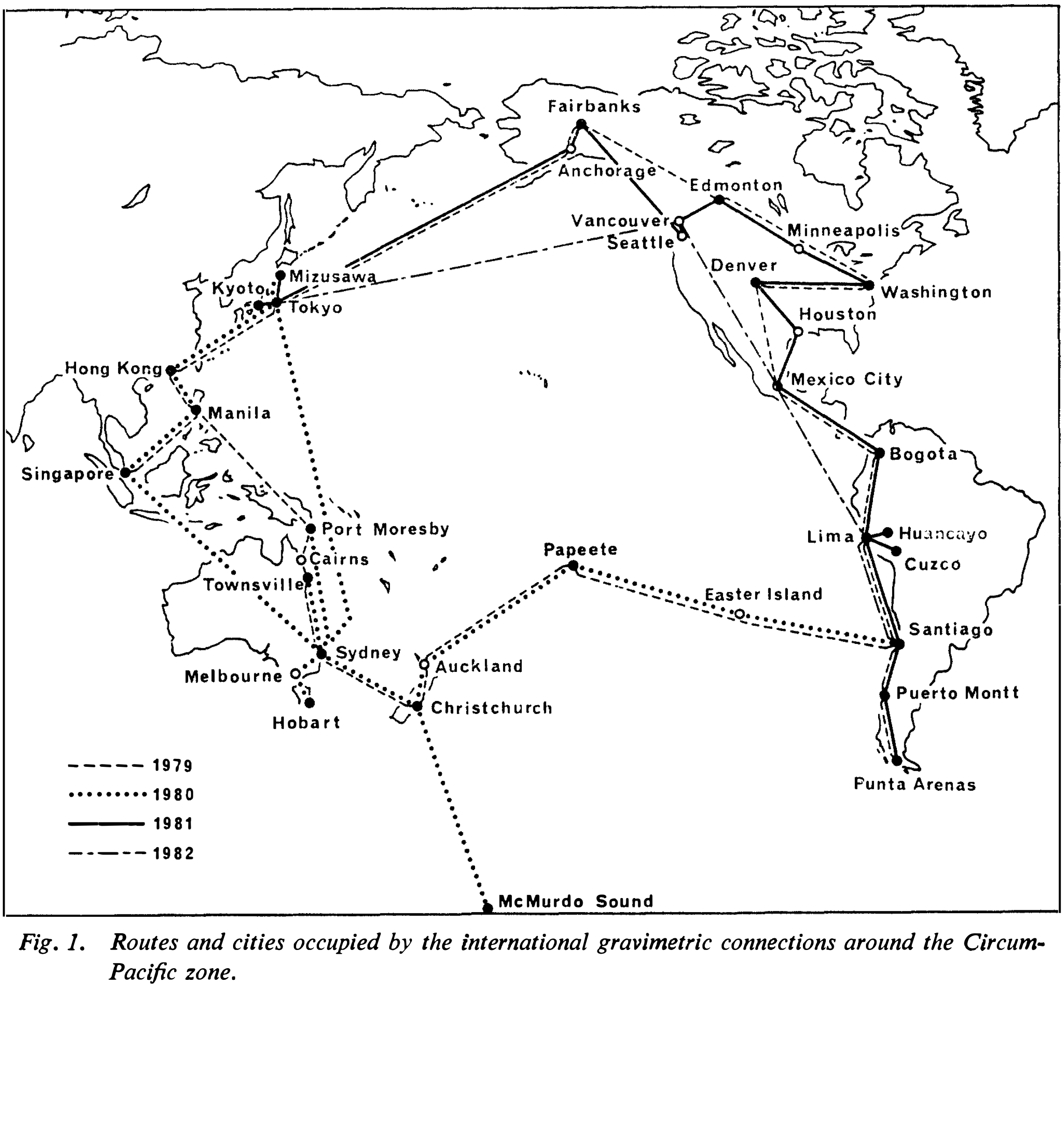

Fig. 1. Routes and cities occupied by the international gravimetric connections around the Circum-Pacific zone.

nections around the Circum-Pacific zone using several LaCoste & Romberg gravimeters (model G) was conducted for the purpose of:

(1) determining a better correction function for the scale value of each gravimeter by using absolute gravity stations,

(2) establishing an up-to-date gravity net useful for detecting possible gravity changes in the future, and

(3) offering new data valuable for the maintenance and improvement of the IGSN 71.

Four investigation trips were carried out for this project during the period from 1979 to 1982 employing two to eight gravimeters. The routes and cities where gravity measurements were made by these investigations are shown in Fig. 1. In each city, gravity measurements were made at three to nine measuring stations. An accuracy of the investigations was estimated to be better than ± 0.01 mgal for local gravity measurements within a city and ± 0.03 mgal for international gravimetric connections except some gravimetric connections carried out by means of only two gravimeters.

As part of the project, a gravimetric connection between Tokyo (Japan) and McMurdo Sound via Sydney (Australia) and Christchurch (New Zealand) was carried out employing two gravimeters in October 1980 (NAKAGAWA *et al.*, 1981). This paper is a report on the gravimetric connection between Tokyo and McMurdo Sound. The final report of the project of the international gravimetric connection including the whole results as well as their interpretation has been separately published in March 1983 (NAKAGAWA *et al.*, 1983).

2. Method of Gravity Measurements

The gravimetric connection along the route of Tokyo—Sydney—Christchurch—McMurdo Sound was carried out with two LaCoste & Romberg gravimeters G-124 and G-183 in October 1980. The gravimetric connection by means of the G-183 was

Table 1. Measuring stations in McMurdo Sound.

City (Code)	Station	BGI No.	Latitude	Longitude	Height
McMurdo Sound	C	59676C	77°51′.0 S	166°40′.4 E	43.18 m
(MMD)	D	D	77 51 .0	166 39 .9	12.09
	EJ21		77 51 .0	166 40 .0	32.00
	L	L	77 49 .5	166 48 .2	19.99
	N	N	77 49 .7	166 40 .0	33.20
	KN		77 49 .8	166 48 .1	11.00

Station	Location
C	BM, Earth Sci. Lab., McMurdo Station
D	Garage J-58, McMurdo Station
EJ21	East of J-21 Hut, McMurdo Station
L	GS, Scott Base
N	GS, near Seismic Hut, Scott Base
KN	Between K Hut and N Hut, Scott Base

BGI: Bureau Gravimétrique International.
GS : Gravity Station. BM: Bench Mark.

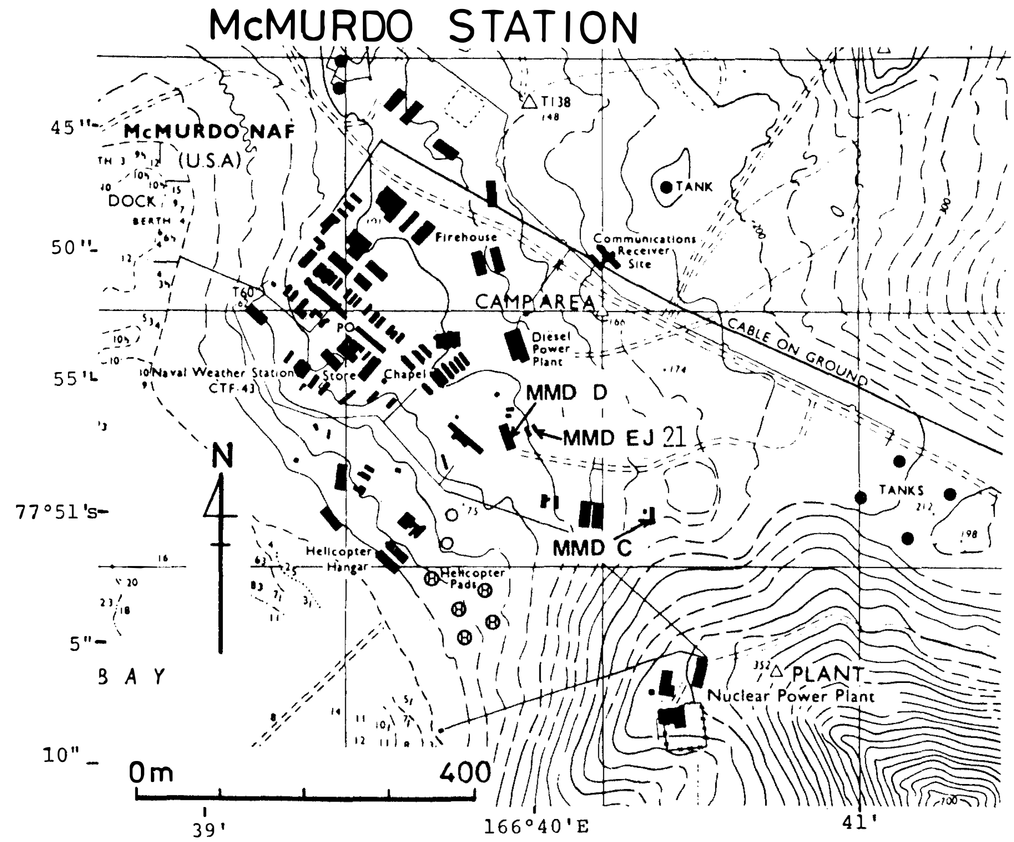

Fig. 2a. Location map of measuring stations in McMurdo Station.

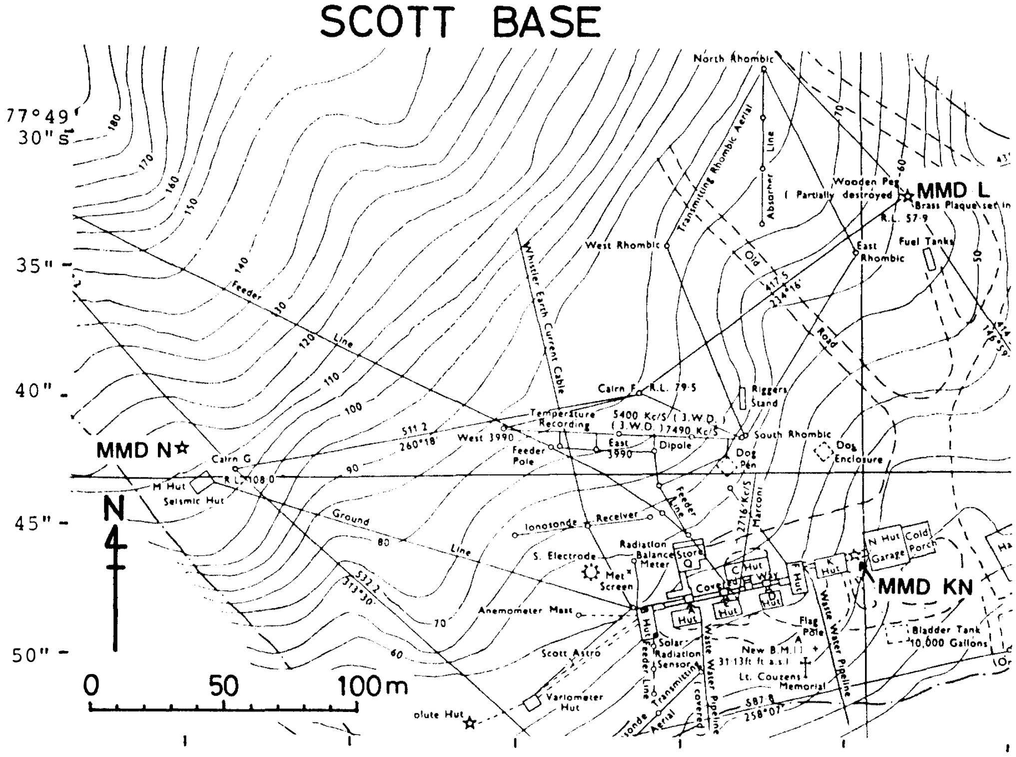

Fig. 2b. Location map of measuring stations in Scott Base.

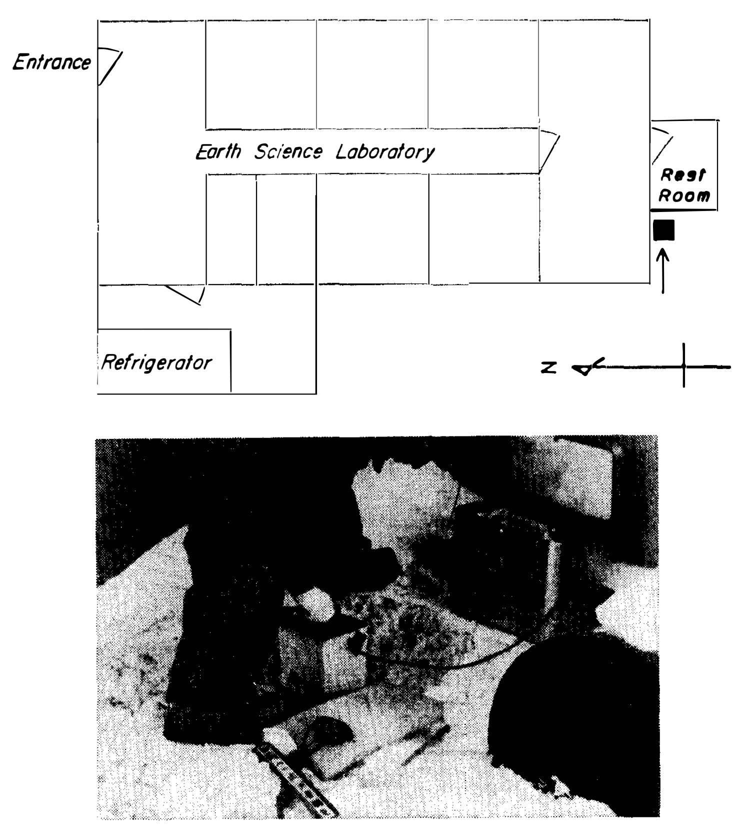

Fig. 2c. Diagram of the gravity station McMurdo Sound C (MMD C): Bench Mark near Earth Science Laboratory in McMurdo Station.

carried out by one of the authors (M. FUNAKI) directly along this route, while that by means of the G-124 by the other (H. FUJIMOTO) via several cities on the route between Tokyo and Sydney.

The gravimeters were transported by a C-141 aircraft between Christchurch and McMurdo Sound and by a jeep in McMurdo Sound. The two investigators stayed in Scott Base (New Zealand) with two gravimeters over three nights. Fortunately the weather continued to be calm.

Gravity measurements were carried out at three stations in both Scott Base and McMurdo Station (U.S.A.), respectively, as listed in Table 1. Location descriptions of the gravity stations are shown in Figs. 2a–2g.

Two gravity stations (MMD L and N) in Scott Base were located on windy hills, giving rise to some problems in making gravity measurements because of strong wind (over 10 ms^{-1}) and low temperature (-24°C); there might have been an unnegligible thermal effect on the gravimeters inside of which are kept at 50°C. When the gravimeter G-124 was taken out of its carrying case on the first day in McMurdo Sound, the inside of both level meters and an eyepiece for visual reading became frosted in a few minutes. However, it did not become so frosted when taken out on the third day, presumably because it was less humid inside of the gravimeter. Furthermore, the knurled arrestment knob for clamping the spring system became very hard to turn,

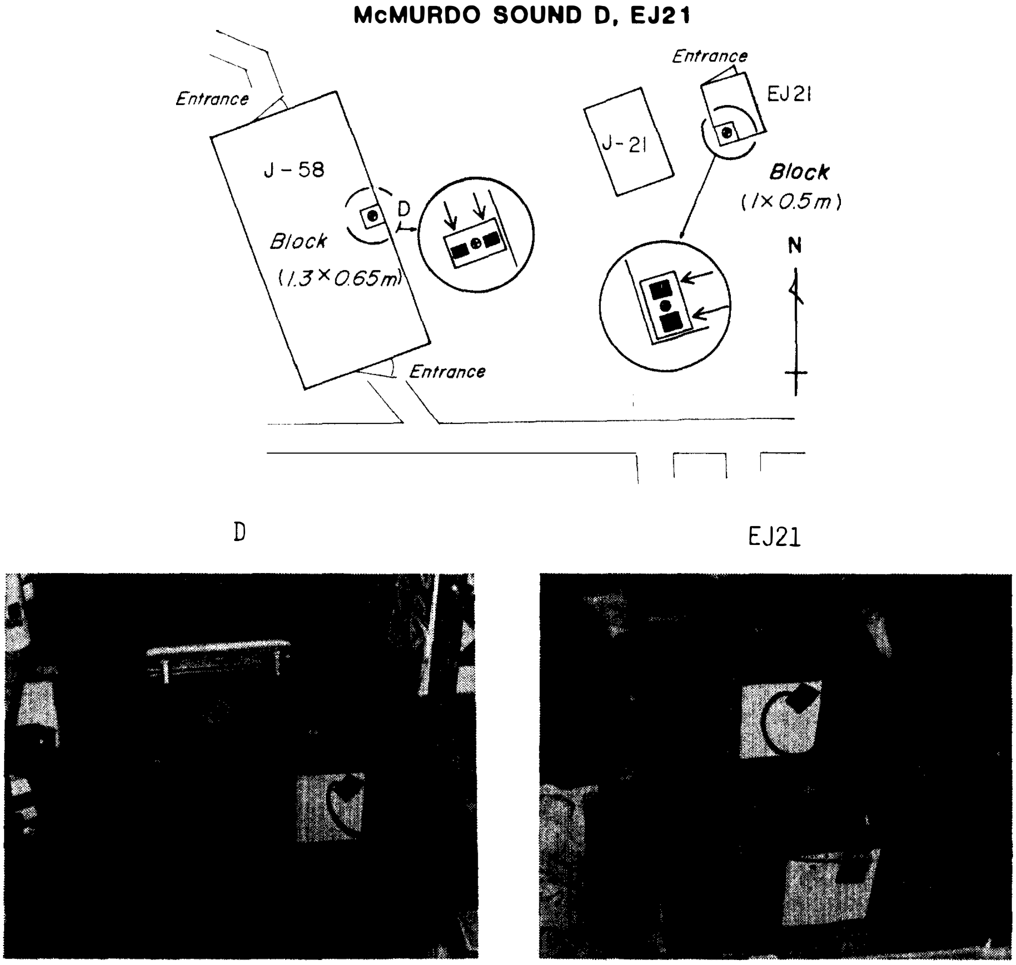

Fig. 2d. Diagram of the gravity stations McMurdo Sound D (MMD D) and McMurdo Sound EJ21 (MMD EJ21);
D : Garage J-58 in McMurdo Station.
EJ21: East of J-21 Hut in McMurdo Station.

and a spare battery for the gravimeter G-124 became inactive. On the contrary, there was not so serious trouble with the gravimeter G-183.

Since the strong wind and low temperature were suspected of causing unnegligible effect on gravity measurement, a temporary measuring point was established indoors in the case of Scott Base in order to estimate a quantity of the thermal effect on gravity measurement. But unnegligible effect of low temperature was not observed, presumably because gravity measurement at each station was carried out within several minutes after a gravimeter was taken out of its carrying case.

Gravity stations in McMurdo Station were located indoors or under the eaves, and it was neither so windy nor so cold (−17°C) even outdoors. There was, accordingly, no problem in making gravity measurements in McMurdo Station. Taking our experience into account, we would like to propose that gravity stations in Antarctica should be built indoors.

Amplitude of microseisms was very small in McMurdo Sound. No effect of static electricity on gravity measurements was observed.

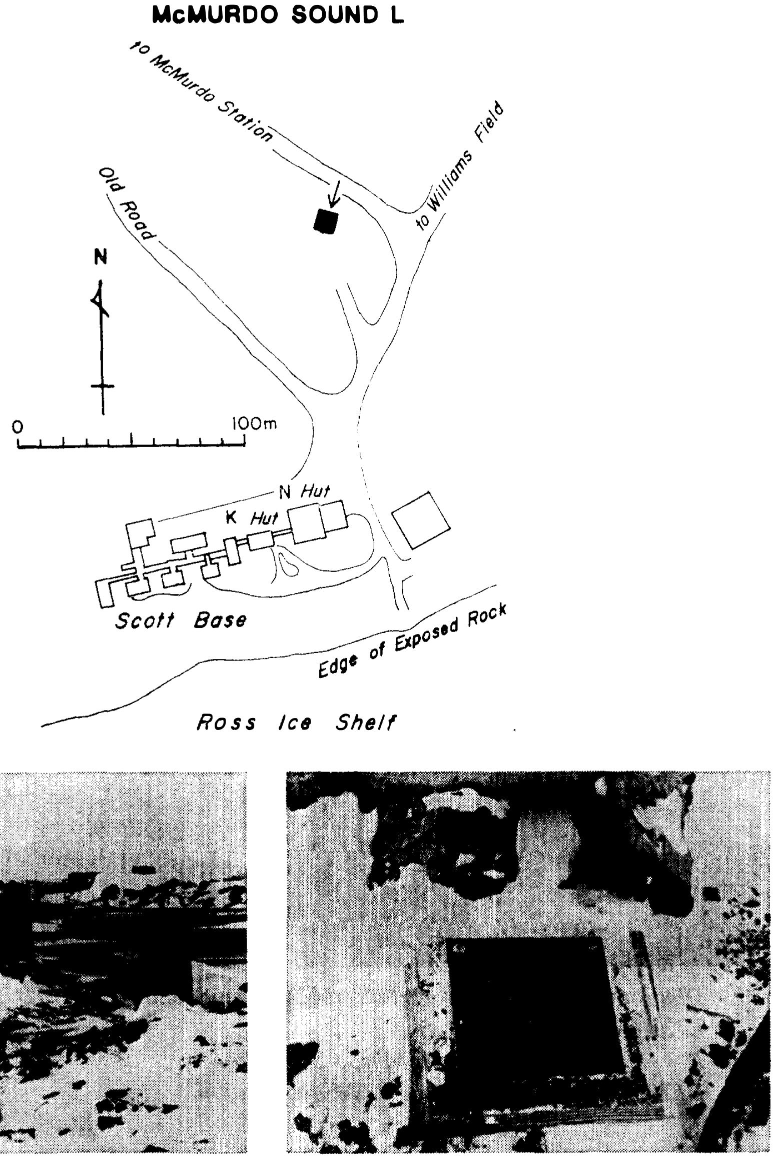

Fig. 2e. Diagram of the gravity station McMurdo Sound L (MMD L) in Scott Base.

3. Results Obtained

After the reading values of each gravimeter were converted to the corresponding milligal values using the scale values given by the manufacturer, corrections for instrumental height and earth tides were made by assuming the free-air gradient of gravity, 0.3086 mgal/m, and the gravimetric tidal factor of 1.16 with the phase lag of 0° (INTERNATIONAL ASSOCIATION OF GEODESY, 1980), respectively.

All of the data obtained from the whole investigations were inclusively analyzed, and both the revision of the scale values for each gravimeter given by the manufacturer and the determination of gravity values at all the measuring stations were simultaneously made by applying the least squares method (NAKAGAWA *et al.*, 1983).

Gravity values at the gravity stations in McMurdo Sound that have been determined from this investigation are shown in Table 2 together with the corresponding

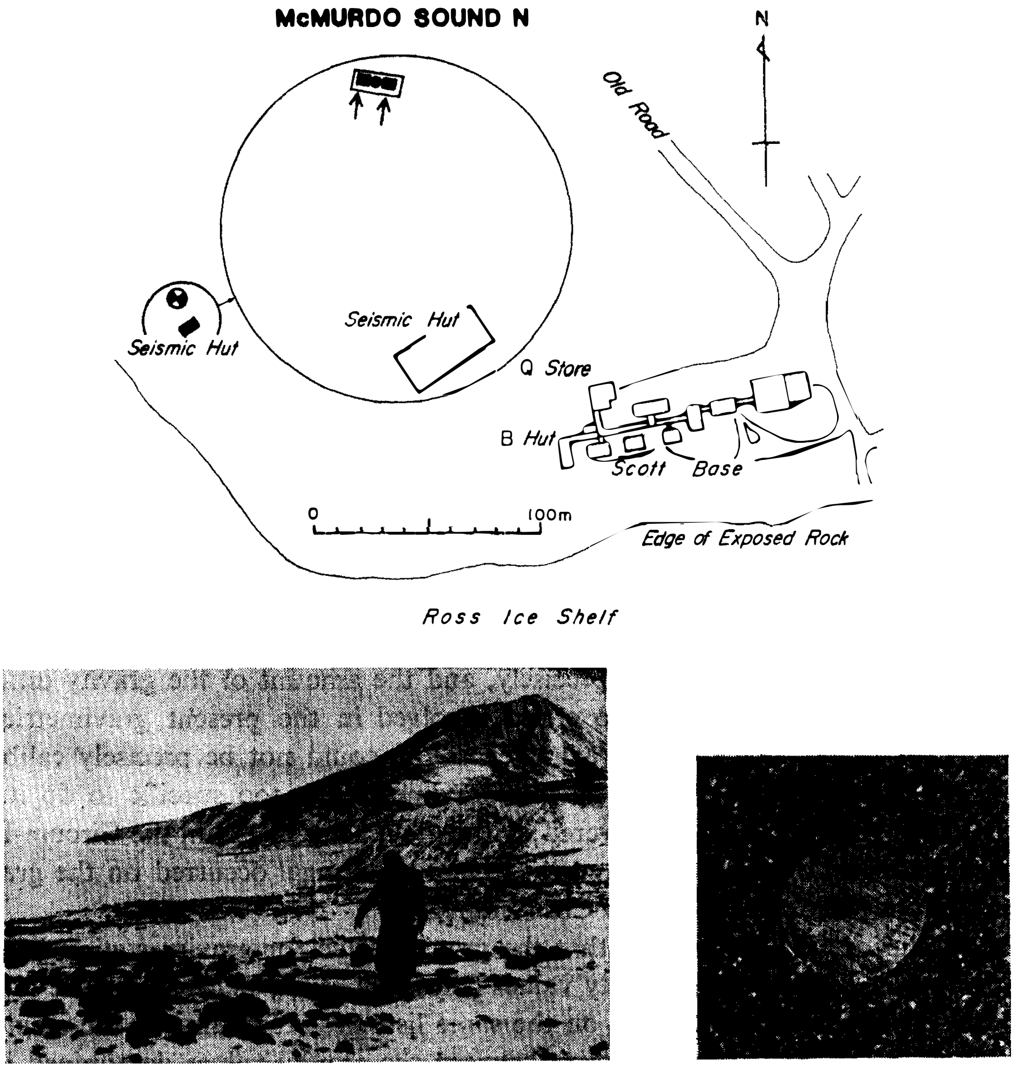

Fig. 2f. Diagram of the gravity station McMurdo Sound N (MMD N) in Scott Base.

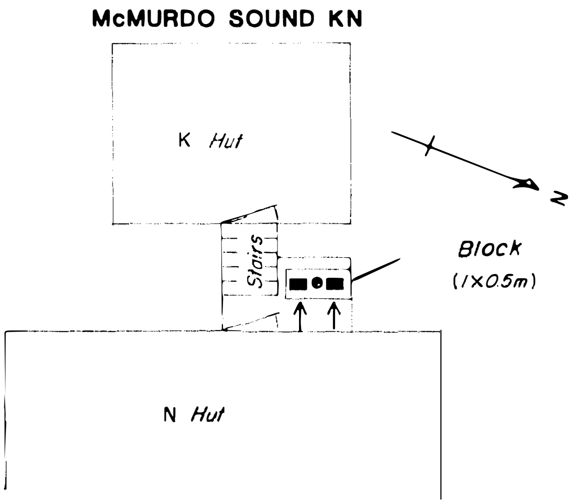

Fig. 2g. Diagram of the measuring station McMurdo Sound KN (MMD KN) between K Hut and N Hut in Scott Base. No photograph is available.

Table 2. Gravity values at the measuring stations (unit in mgal).

Station	Determined	IGSN 71	Difference
MMD C	982 969.852	982 969.771	0.081
MMD D	982 973.458	982 973.381	0.077
MMD EJ21	982 972.714		
MMD L	982 976.614	982 976.551	0.063
MMD N	982 973.204	982 973.111	0.093
MMD KN	982 977.867		
Average difference			0.079

values given on the IGSN 71. As seen in Table 2, differences between the gravity values newly determined and those given on the IGSN 71 were within the range of 0.079 ± 0.016 mgal. The amount of this deviation, ± 0.016 mgal, is comparable to that of local gravity measurements in other cities concerned. It was concluded that the gravity measurements in McMurdo Sound were precisely performed by means of only two gravimeters in spite of the severe environment.

On the other hand, the gravimetric connection between Christchurch and McMurdo Sound could not be performed so precisely, and the amount of the gravity difference itself, 0.079 mgal, is comparable to errors involved in the present gravimetric connection. The scale value of the gravimeter G-183 could not be precisely calibrated, because the gravity range covered by this gravimeter was too specific to do it. Although a wide gravity range was covered by the gravimeter G-124 in the Circum-Pacific gravimetric connection, a jump amounting to about 0.1 mgal occurred on the gravimeter G-124 from McMurdo Sound to Christchurch.

In conclusion, it was clarified that the gravity value for gravity station MMD L on the listing of the IGSN 71 gravity values (MORELLI *et al.*, 1974) should be replaced by that at gravity station MMD N on the same listing. According to the results obtained from this project, the differences between the gravity values determined in this study and those given on the IGSN 71 in McMurdo Sound are comparable to those in the other cities, which are distributed between ± 0.1 mgal. It was ascertained that the IGSN 71 is a homogeneous network inclusive of the gravity stations in McMurdo Sound.

4. Summary

The gravimetric connection between Tokyo and McMurdo Sound was carried out as part of the international gravimetric connections around the Circum-Pacific zone. Gravity measurements in McMurdo Sound were performed with an accuracy comparable to those in the other cities in spite of low temperature. However, the gravimetric connection between Tokyo and McMurdo Sound itself is not so precise as those achieved by the international gravimetric connections carried out in the greater part of the Circum-Pacific zone. Nevertheless, the gravimetric connection to Antarctica brought not only a further large gravity difference into the project of international gravimetric connection but also the possibility of making a precise gravimetric connection between Tokyo and Syowa Station (Antarctica) via McMurdo Sound.

An absolute gravity apparatus should be employed to perform a precise gravimetric connection to Antarctica, or else the scale values of gravimeters must be determined as precisely as possible and then the route of gravimetric connection should be so arranged that gravity measurements might be carried out at some cities in high latitudes other than Antarctica. Simultaneous gravity measurements with, at least, several gravimeters are necessary to reduce errors originating from inaccurate scale values of the gravimeters, because the gravimeters are apt to suffer from troubles caused by low temperature and/or strong winds. Key gravity stations in Antarctica should be indoors. It is otherwise recommended that gravity connections are planned in the middle of summer in Antarctica in order to prevent winds from disturbing gravity measurements.

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Numerical calculations were carried out using a computer system at the International Latitude Observatory of Mizusawa.

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