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Reconnaissance Gravity Observations near Amery Ice Shelf, Antarctica, Summer 1968 / 69

by

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with an Appendix by I.R. McLeod

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SUMMARY

Eight new gravity stations in the Prydz Bay area of Antarctica were established by BMR geologists using helicopter transport during January and February 1969. A Bouguer anomaly map with contours at ten-milligal intervals is presented, based on these stations and earlier BMR stations in the same area, all of which have an estimated accuracy of 3-4 milligals or better. A strong gravity gradient is present across the coast, positive seawards.

The LaCoste & Romberg geodetic gravity meter used for this work performed satisfactorily, and its thermal control was maintained adequately under the prevailing climatic conditions. Elevation control for the gravity stations was satisfactorily provided by helicopter altimeter measurements over distances of 80 kilometres.

It is recommended that further work of this type should be carried out in the summer geological programme 1969/70.

1. INTRODUCTION

Summer 1968/69 was the first of several successive seasons in which extensive geological, surveying, and glaciological work will be done by Australian National Antarctic Research Expeditions (ANARE) in the Prince Charles Mountains area of Antarctica (see Plate 1). All field work for this programme will be carried out by helicopter. Four Bureau of Mineral Resources geologists participated in this first season. Consideration of the proposed programme showed that sufficient gravity work could be done to warrant supplying a gravity meter and other necessary equipment. No gravity programme was laid down; the geologists were to obtain readings wherever possible in the course of their other duties, in the hope that the results would provide a reconnaissance of the gravity field. A second aim was to find out how satisfactorily a thermostat-controlled gravity meter could operate and be maintained under Antarctic field conditions.

LaCoste & Romberg geodetic gravity meter G101, thermostat-controlled at approximately 50°C, was supplied for the work. Five of the standard 12-volt nickel-cadmium batteries (3½ amp-hour capacity) used with this type of meter were sent, together with equipment to allow them to be charged from a 12-volt lead-acid battery. Elevations were to be determined by helicopter altimeter in order to keep equipment to the minimum. This method was expected to be sufficiently accurate for such a preliminary reconnaissance. Gravity ties to established base stations at either or both of Mawson and Davis would relate any new observations to the world gravity net.

2. GRAVITY RESULTS

Altogether twelve stations were read: nine in the Prydz Bay area, two in the Prince Charles Mountains, and one at New Year Nunatak between the other two localities. One of the nine Prydz Bay stations was the party base camp and was intended to serve as a local base station for all other readings. However, as the camp was on floating ice, the disturbance level was too great to allow accurate gravity readings to be made. Consequently, drift control for all observations is not as good as had been hoped. Control for the other Prydz Bay stations is still fair because of repeat readings at two stations after an interval of about a fortnight, but control for the remaining three stations is poor. Similarly elevation control is adequate for the Prydz Bay stations but poor for the remainder. Consequently only the data from the Prydz Bay area are retained. Principal facts for these eight Prydz Bay stations are given in Table 1.

TABLE 1

PRINCIPAL FACTS FOR NEW STATIONS

Station No.	Informal name	Latitude S	Longitude E	Elev., metres	Observed Gravity mgal	Free-air anomaly, mgal	2.67 Bouguer anomaly, mgal
6905.0001	Sansom Island	$69^{\circ}42.4_5'$	$73^{\circ}47.2'$	58	982,607.2	28.3	21.9
6905.0002	Bosun Island	$69^{\circ}42.5_5'$	$73^{\circ}53.5'$	46	982,607.5	24.8	19.7
6905.0003	Palmer Point	$69^{\circ}43.8_5'$	$73^{\circ}55.5'$	157	982,593.9	44.4	26.8
6905.0004	Landing Bluff	$69^{\circ}44.5_5'$	$73^{\circ}43.2'$	49	982,603.8	20.1	14.7
6905.0005	"Peak 220"	$69^{\circ}51.7_5'$	$74^{\circ}28.0'$	131	982,586.2	21.0	06.3
6905.0006	"Peak 160"	$69^{\circ}52.2_5'$	$75^{\circ}08.8'$	94	982,573.3	-03.6	-14.2
6905.0007	"Polar Record Peak"	$69^{\circ}44.5_5'$	$75^{\circ}32.3'$	69	982,578.4	00.8	-06.8
6905.0008	"Island 90"	$69^{\circ}32.0_5'$	$75^{\circ}41.0$	29	982,607.0	29.4	26.2

Observed gravity values are based on a DAVIS B value of 982.5902 gal, with a check at MAWSON A, 982.4818 gal (Woollard & Rose, 1963), and maker's tables were used for calibration factor.

These stations are NOT on BMR scale and datum as given by Langron (1966).

Gravity intervals between stations in Prydz Bay are certainly reliable to within a few tenths of a milligal, although there is the possibility that observed gravity values may contain a small systematic error caused by a gravity meter tare since ties to both Mawson and Davis were carried out after the field work. The drift rate during the Prydz Bay work appears normal as measured over a fortnight, and the rate implied by the measurements at stations of known value at Mawson and Davis is also normal over a fortnight, so there is no evidence of tares during this period.

Elevations were determined by A-B-A ties with the helicopter altimeter and were controlled additionally by 3-hourly pressure observations at the base camp. Two stations were re-occupied several times for elevation, and the observations were within ± 20 ft and ± 3 ft of the respective means. Rough checks on some other elevations are possible from mapped spot heights of features where stations were read, since the observers noted estimated heights of summits above stations. Station elevations are believed to be reliable within 30 or 40 feet at worst. Latitudes were scaled from a Division of National Mapping 1964 map at 1:500,000 scale. Random errors from all sources are believed to amount to no more than 3 or 4 milligals in Bouguer anomaly.

The eight new stations are plotted in Plate 2, together with five earlier BMR stations in the area. All earlier BMR observations in Antarctica are reported by Langron (1966). Most were spot observations at great distances from each other, and no group was adequate to allow local trends in gravity anomaly to be estimated. The new stations together with these earlier five do, however, form such a group. The gravity values at the five earlier stations were adjusted to the datum described in Table 1, and Bouguer anomalies were calculated. Gravity intervals between earlier BMR Antarctic gravity stations are known within 2 milligals (Langron, 1966). The accuracy of Bouguer anomaly values at the earlier stations is probably slightly greater than that of the recent work since all readings were made very near sea level and do not suffer from elevation uncertainty. The contours of Bouguer anomaly for this group are drawn at 10-milligal intervals in Plate 2 and despite the inaccuracies involved, they undoubtedly demonstrate a strong positive gradient seawards. However, the station spacing and the small number of observations do not allow any inferences to be drawn other than broad correspondence between the strikes of the gravity anomaly and the coastline, which is here about 300 kilometres from the continental slope (Plate 1).

3. GRAVITY METER PERFORMANCE

A detailed log of the gravity meter's temperature behaviour during storage on standard nickel-cadmium batteries, and the charging times for each battery, was kept during the fortnight before field readings commenced. The five batteries did not perform equally well, but the best ones showed themselves capable of regulating the meter temperature for at least 8-10 hours and occasionally even longer under the prevailing conditions. During this time, the average ambient temperature for battery charging was about 0°C (the lowest recommended by the manufacturer) and for meter storage about 5°C. During the later phase of operations the gravity meter was stored using a heavy-duty lead-acid battery for thermal regulation. This was far more satisfactory and avoided the necessity for constant attention by the geologists to the meter and batteries except during traverses. Gravity meter temperature was satisfactorily maintained during all traverses but one.

4. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions are that the LaCoste & Romberg gravity meter can be used satisfactorily in field operations under Antarctic summer conditions, and that useful gravity work can be accomplished by field parties of this type. Consequently it is recommended that a gravity meter be supplied for the next planned season, summer 1969/70, when it is expected that geological parties could take gravity readings in the Prince Charles Mountains.

Greater confidence in the results will be possible if readings at either or both of Mawson and Davis are made before and after the field work. Gravity meter drift control is highly desirable on days of gravity traverses. This should be more easily obtainable in the next season, assuming that base camp will be on or adjacent to rock. Gravity ties between Australia and Mawson and Davis can be achieved by making readings in Canberra, Melbourne, or Hobart before and after the season's work.

Elevation control from helicopter altimeter observations is adequate for work of this type, although it loses accuracy rapidly as flight distances lengthen unless fixed heights are available for reference at outer ends of flights from base. It is not clear to what extent this will be so in the forthcoming season. Undoubtedly elevations of many peaks will be known from the surveying programme, but these may not be usable for control. Base control will be more reliable if continuous recording of pressure can be achieved in addition to synoptic observations. Satisfactory elevations should be obtainable at distances up to 80 kilometres from base, as has been demonstrated in the present work and in tests carried out by the author during the New Britain helicopter gravity survey in February-March 1969.

For additional recommendations relating to the details of field work, the Appendix should be consulted.

5. ACKNOWLEDGEMENTS

Thanks are due to ANARE for making this work possible, to the officer in charge of the operation, Mr G. McKinnon and to the four BMR geologists (I.R. McLeod, J.H.C. Bain, A. Medvecky, and D. Grainger) for agreeing to do gravity work in addition to their geological programme. They carried out the work and recorded the observations and much other important detail very satisfactorily. Other members of the field party also gave valuable assistance to the gravity programme in a number of ways.

6. REFERENCES

LANGRON, W.J. 1966 - Gravity ties to Australian Antarctica, 1953-1963. Bur. Min. Resour. Aust. Rec. 1966/24 (unpubl.).

WOOLLARD, G.P. and J.C. ROSE, 1963 - International Gravity Measurements . University of Wisconsin.

All original material relating to these measurements is filed under survey number 6905 in the Regional Gravity Group, BMR, Canberra.

APPENDIX

NOTES ON THE USE OF A GRAVITY METER IN ANTARCTICA, JANUARY-MARCH 1969

by I.R. McLeod

At the request of Geophysical Branch, the geological group of the Prince Charles Mountains party took with them LaCoste & Romberg geodetic gravity meter G101. The stated purpose was twofold: to ascertain how the meter would perform at low temperatures, and to obtain gravity readings where possible, as a broad reconnaissance for possible more detailed work. Brief instruction (time did not allow more) in the use of the instrument was given to the four geologists and one available surveyor.

Temperatures: Prevailing temperatures at the base camp ranged from about 5°C to -5°C for the first month, but in the next three weeks rarely rose above 0°C, daytime temperatures being about -10°C to -5°C. Overnight temperatures probably fell to -15°C or lower on several occasions, the lowest recorded temperature being -19.1°C.

Readings: The meter was kept at the field base at Landing Bluff; it was sent to field parties as opportunity offered, and returned to camp the same day. The instrument could have been connected to a 12-volt lead-acid accumulator had it been left with a field party, but it was not possible to proof the case against blowing or drifting snow.

The base camp was on floating ice and, despite several attempts, readings could not be obtained there because of continued oscillation of the beam. Rock was not conveniently accessible, and the readings therefore consist of isolated field readings with no tie before and after to a common base. Several readings were obtained at each of three stations: Mawson, Davis, and Sansom Island, which is a few miles from the field base. Except for the existing stations at Mawson and Davis, the altitude for all stations was obtained by the altimeter in a helicopter, because the survey stations were always some distance from the landing points.

No difficulty was encountered when reading the instrument in the field, the lowest temperature at which this was done being about -5°C. A wind speed of about 10 knots did not produce any noticeable beam movement due to vibration of the instrument. At low temperatures, the instrument when taken out of the carrying case emitted disconcerting cracking sounds for a minute or two. These had no obvious effect on the instrument and presumably were caused by sudden contraction of the outer parts.

Care was taken not to breathe on the eyepiece or bubbles, and misting was noticed only on the first two occasions that the instrument was read, when the level bubbles became partly misted, apparently behind the glass. The air temperature then was, surprisingly, above freezing.

The numerous pads used to protect the instrument in the case were inconvenient in windy weather, as they had to be put into pockets or a rucksac when taken out of the case, to prevent their blowing away. The same problem arose when the nickel-cadmium battery connected to the meter was changed in the field.

Instrument temperature: Once familiar with battery life and the charging requirements, it was possible to keep the instrument at its operating temperature of 52°C without difficulty in an unheated vehicle. The instrument was kept in its case, covered by a vinyl-covered pad, the instrument log book, and a piece of sponge rubber sheet; the whole upper surface of the case was covered by several folds of hessian, and the lid was partly closed.

As a further test, the instrument was left out of its case for several hours, but was kept in the vehicle, out of the wind. The air temperature during this period rose from -5°C to -2°C. Again, the operating temperature was maintained without the heating element having to operate continuously.

After the first two weeks, the instrument was connected to a 12-volt lead-acid accumulator in an immobile vehicle, using the plug from a nickel-cadmium battery which had consistently refused to take a charge; thereafter, no trouble was experienced in keeping the instrument at its correct temperature. The nickel-cadmium batteries were allowed to stay on charge for up to 48 hours to ensure that they were fully charged. Even so, one unexpectedly failed to keep the meter at its operating temperature for more than two hours.

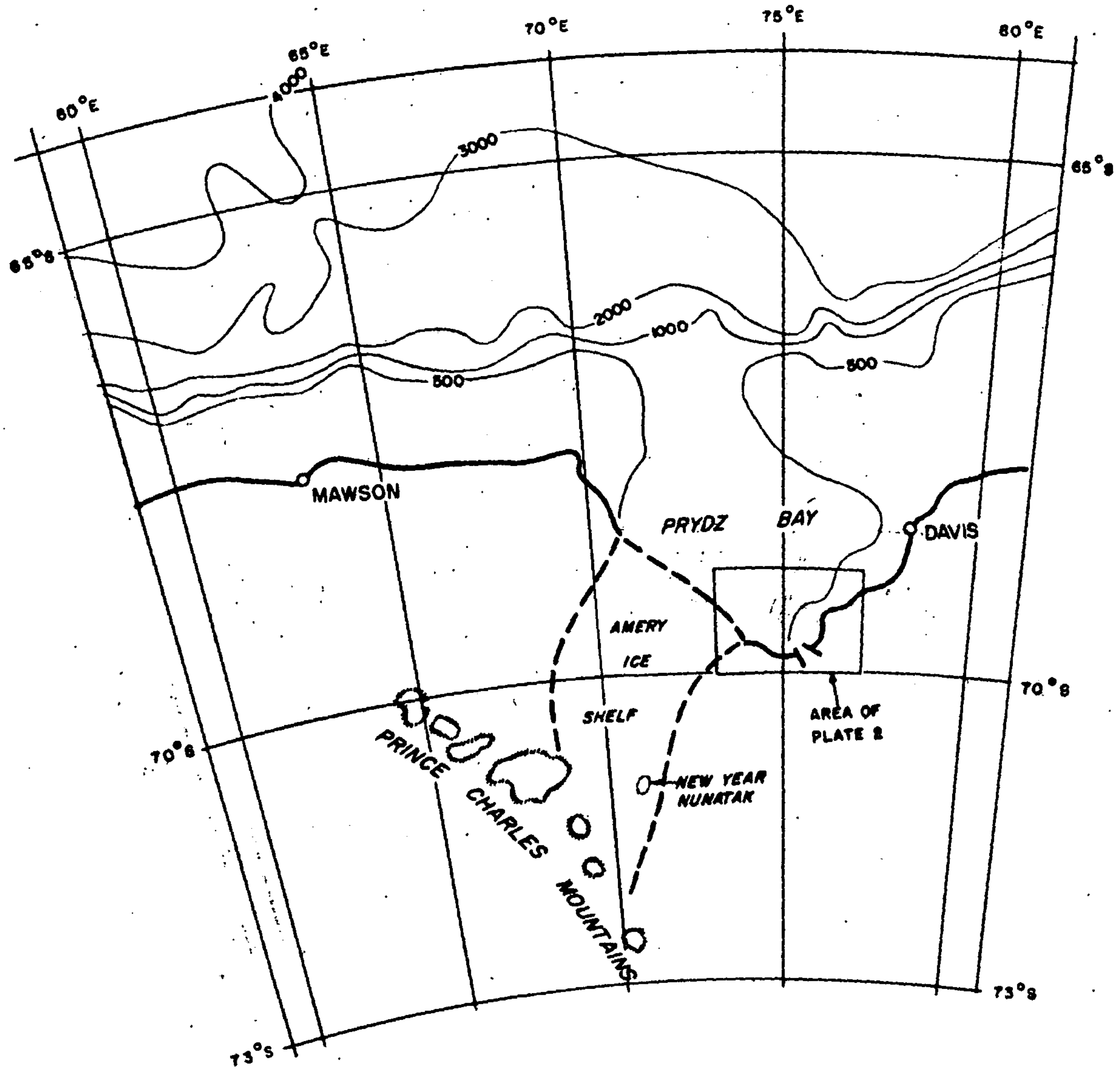
Conclusions and recommendations: The instrument was able to keep its operating temperature of 52°C in unheated storage at air temperatures down to -20°C.

A 12-volt lead-acid accumulator should be used to keep the instrument at its correct temperature while in storage at the base camp, and the nickel-cadmium batteries should be kept for field use only.

A special carrying case should be constructed, in which the padding (and insulation) is fixed to the case and the batteries are in a separate compartment. The lid of the case should be completely closable when the battery is connected to an external power supply. As there is no guarantee that the case can always be kept under cover, it should be completely sealed against drifting snow, even when connected to an external battery, The case should have provision for carrying the instrument base plate, which is easily overlooked when an aircraft is being loaded or unloaded.

I.R. McLeod
2/4/69

PLATE I



LOCALITY MAP

KILOMETRES

0 100 200 300 400

Bathymetric contours in metres

To accompany Record No. 1970/31

G 265-102

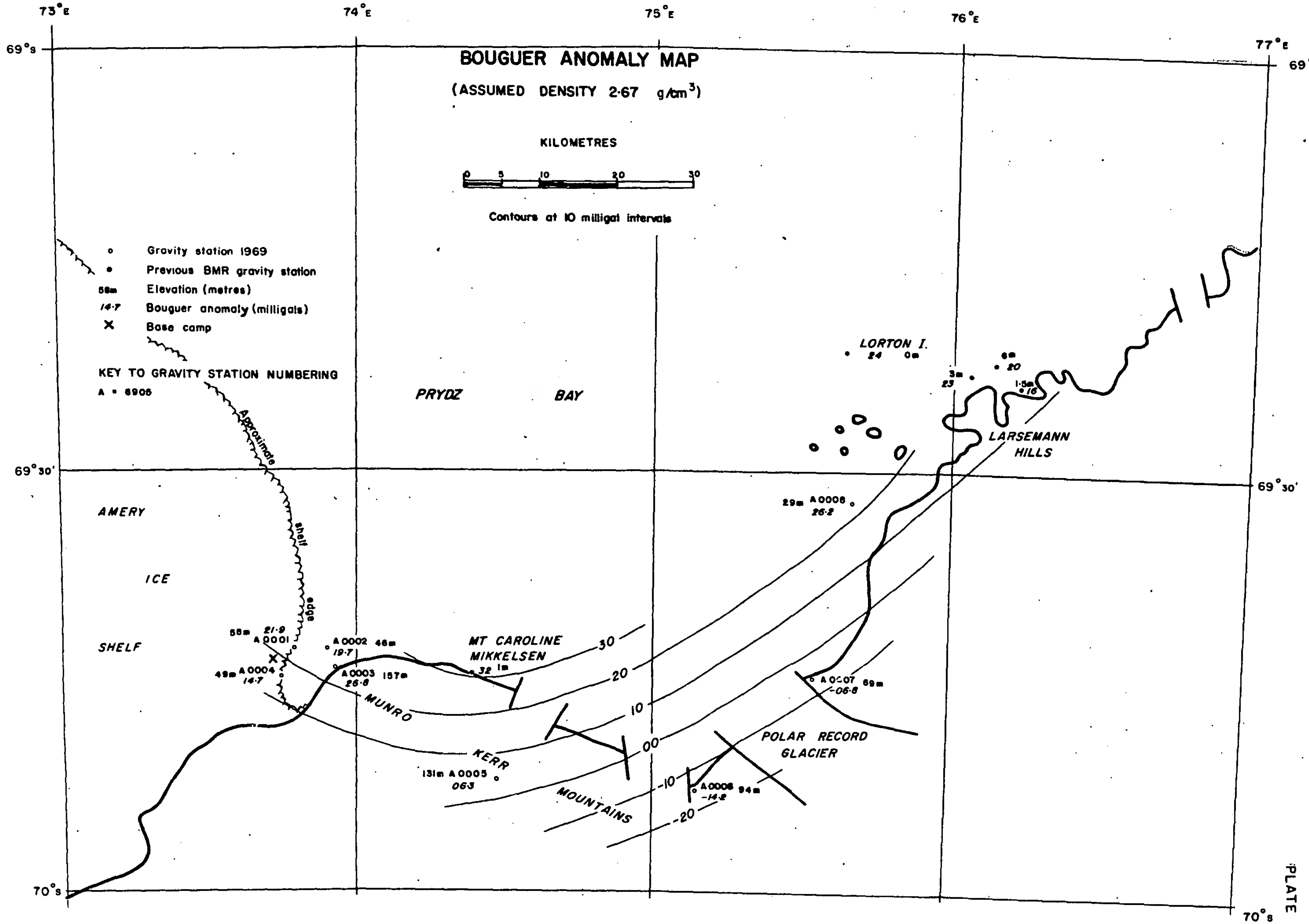


PLATE 2

To accompany Record No. 1970/31 G 265-103