DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1975/59

RECONNAISSANCE GRAVITY OBSERVATIONS NEAR MAWSON AND IN THE PRINCE CHARLES MOUNTAINS, ANTARCTICA, 1969-71

by

R.J.S. COOKE

APPENDIX 1

ROCK DENSITIES IN THE PRINCE CHARLES MOUNTAINS

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APPENDIX 2

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CONTENTS

SUMMARY

Geologists of the Bureau of Mineral Resources, working with the Australian National Antarctic Research Expeditions, established thirty-four new gravity stations in Antarctica during January and February in 1970 and 1971. Four of these were near Mawson station and thirty were in the Prince Charles Mountains. Helicopter transport was used. The observed gravity values are based on the pendulum gravity station at Mawson, either directly or via a sub-base at Moore Pyramid field camp. The accuracy of Bouguer anomalies at some of these stations may be poor because of elevation uncertainties.

In the northern Prince Charles Mountains, there is an east-trending Bouguer anomaly gradient with a range of more than 160 mGal over a distance of 200 km. This is attributed to deep-seated causes near the mantle/crust interface, possibly crustal thinning beneath the Amery Ice Shelf. Alternatively it could be caused by high density rocks in the Amery Ice Shelf region.

Recent density determinations of rocks from the area are presented in Appendix 1, and notes on the use of a gravity meter in Antarctica are given in Appendix 2.

INTRODUCTION

During January and February of 1970 and 1971 geologists of the Bureau of Mineral Resources, attached to the Australian Antarctic Research Expeditions, established thirty-four new gravity stations, mostly in the Prince Charles Mountains (Pls 1 & 3). The measurements were made as time allowed during geological work by helicopter, and the methods and equipment were similar to those used in the summer of 1968-69, when useful gravity measurements were obtained from the southern Prydz Bay area (Cooke, 1970). The gravity meters used were La Coste-Romberg, No. G101 in 1970, No. G20 in 1971. The locations of all the new stations together with those of previous years are shown in Plates 2 and 3. Principal facts for all stations are given in Table 1, and descriptions of localities in Table 2; all original material relating to these measurements is filed in the Regional Gravity Group, BMR, Canberra (Survey Nos 7015 & 7105). Also included in Plate 2 are three additional stations in the Mawson area, from Langron (1966), and some BMR 1957-59 ice thickness stations (Fowler, 1971). Each of the latter is a shot location at which the depth of the rock/ice interface is known; this depth is taken into account in the Bouguer anomaly computation. The assumed Mawson base gravity value for these two surveys has been adjusted to the value for Mawson adopted for the present work, 982 481.8 mGal (Woollard & Rose, 1963).

The BMR geologists who made the gravity observations were: in 1970, J.H.C. Bain, D.J. Grainger, I.R. McLeod, & R.J. Tingey; in 1971, R.G. Dodson, R.M. Hill, J. Smart, & R.J. Tingey.

1969-70 SURVEY

Sixteen new stations were read, four in the area near Mawson and twelve in the northern Prince Charles Mountains (Pls 2 & 3). All were on rock except that at Moore Pyramid field base camp, which was in a hut on ice. Latitudes and longitudes given in Table 1 were scaled from a Division of National Mapping 1967 1:500 000-scale map. Terrain corrections have not been applied to the Bouguer anomalies. Base control for the gravity measurement was fair, and measured gravity intervals appear reliable to about 0.15 mGal or less. Stations near Mawson were tied directly to the Mawson pendulum station (which has been connected to the main world network), and those in the Prince Charles Mountains were tied to the base camp at Moore Pyramid, which was tied to the Mawson pendulum station.

Elevation control varied; stations at Rookery and Gibbney Islands were near survey stations, and heights are accurate within a few feet. The remaining station elevations were measured with the helicopter altimeters. Three-hourly synoptic pressure readings at Moore Pyramid provided the only control on diurnal variations for the work at the Prince Charles Mountains. Many loop closures were not completed. Elevation uncertainties at some stations could be of the order of 30-60 m, equivalent to Bouguer anomaly uncertainties of 6-12 mGal. For the two most easterly stations (Mount Seaton and Grainger Valley) map discrepancies suggest greater possible errors.

1970-71 SURVEY

Eighteen new gravity stations were established in the Prince Charles Mountains (Plate 3). All were on nunataks or ice-borne moraine adjacent to nunataks. Latitudes and longitudes given in Table were obtained from the

TABLE 1

PRINCIPAL FACTS FOR NEW GRAVITY STATIONS

STATION NUMBER	LATITUDE SOUTH (Deg Min)	LONGITUDE EAST (Deg Min)	ELEVATION m	OBSERVED GRAVITY (mGal)	FREE-AIR ANOMALY (mGal)	BOUGUER ANOMALY (mGal)	INFORMAL NAME
7015.0001	70 18.45	65 12.80	1468	982 238.7	60	-104	Moore Pyramid Camp
7015.0002	70 17.90	64 11.10	2051	982 130.6	132	-97	Carter Peak
7015.0003	70 47.10	67 37.50	1280	982 410.2	146	+3	Grainger Valley
7015.0004	70 16.30	65 48.70	1370	982 280.3	74	-80	Mount Jacklyn
7015.0005	70 08.70	65 36.50	1285	982 298.4	73	-71	Mount Stalker
7015.0006	70 12.30	65 30.70	1239	092 298.3	55	-84	Mount Edward
7015.0007	70 16.40	65 37.40	1132	982 327.5	47	-79	Mount Albion
7015.0008	69 34.50	65 05.80	1824	982 165.2	139	-65	Stinear Nunataks
7015.0009	69 53.90	64 21.60	1986	982 172.6	178	-45	Riddell Nunatak
7015.0010	70 35.80	67 10.60	776	982 486.4	78	-9	Mount Seaton
7015.0011	70 28.30	65 38.30	1297	982 344.7	104	-41	Martin Massif
7015.0012	70 53.60	65 26.60	1483	982 305.8	99	-67	Mount Bewsher
7015.0013	67 46.00	62 50.20	628	982 347.1	63	-7	Painted Peak
7015.0014	67 36.65	62 30.00	63	982 466.0	17	+10	Rookery Island
7015.0015	67 33.45	62 19.40	40	982 453.0	1	-4	Gibbney Island
7015.0016	67 47.15	62 10.80	826	982 331.0	107	+14	Woodberry Nunatak
7105.0001	70 18.45	65 12.80	1468				Moore Pyramid Camp
7105.0002	70 40.05	64 15.80	1897	982 212.8	146	-66	Mount Forecast
7105.0003	71 25.43	67 53.15	1135	982 467.5	124	-3	Blustery Cliffs
7105.0004	71 11.40	65 51.98	1350	982 367.5	103	-48	Armonini Nunatak
7105.0005	71 12.55	66 11.93	1306	982 419.3	140	-6	Mount Gleeson
7105.0006	70 40.35	67 16.10	968	982 457.7	104	-4	Murray Dome
7105.0007	70 42.80	66 23.58	1152	982 392.8	94	-35	Mount Trott
7105.0008	73 04.78	66 19.58	1725	982 369.7	121	-72	Mount Stinear
7105.0009	72 13.00	68 37.02	1225	982 488.8	130	-7	Clemence Massif
7105.0010	71 15.45	67 34.87	1176	982 479.7	158	+26	Mount Meredith
7105.0011	70 34.65	66 38.37	779	982 415.7	9	-78	Mount Abbs
7105.0012	70 42.10	66 32.51	1000	982 382.4	37	-75	Mount Bunt

7105.0013	70 46.65	66 12.90	1324	982 359.4	110	-38	Mount Afflick
7105.0014	70 59.40	67 09.14	1020	982 472.3	117	+3	Taylor Platform
7105.0015	69 45.30	69 01.00	188	982 607.1	66	+45	Trost Rocks
7105.0016	70 20.80	68 49.24	210	982 664.0	95	+71	Manning Platform
7105.0017	70 29.75	68 12.63	215	982 631.3	55	+31	Ritchie Point
7105.0018	70 31.10	67 14.66	540	982 522.5	45	-15	White Massif
7105.0019	70 23.80	67 19.45	820	982 441.4	58	-34	Mount McCarthy
7105.0020	70 18.10	65 14.00		982 255.5			Moore Pyramid

Observed gravity values are based on the value 982 481.8 mGal at Mawson A given by Woollard and Rose (1963). The manufacturer's calibration table was used to reduce the gravity meter readings. These stations are NOT on BMR scale and datum as given by Langron (1966).

TABLE 2

DESCRIPTION OF GRAVITY STATION LOCATIONS

7015.0002	Carter Peak. Position doubtful, presumably the highest point of Carter Peak.
7015.0004	Mount Jacklyn. Southern end of mountain, 300 m from south end of central valley.
7015.0005	Mount Stalker. Isolated rock immediately off west side.
7015.0006	Mount Edward. On moraine and windscar on western side of Mount Edward.
7015.0007	Mount Albion. On moraine at north end of mountain.
7015.0008	King Nunataks, NE of Stinear Nunataks. On summit of largest nunatak.
7015.0009	Riddell Nunatak. In saddle to west of trig station.
7015.0010	Mount Seaton. Near campsite in valley on northwest side of glacier, northwest of Mount Seaton.
7015.0011	Martin Massif. At campsite to southeast of main peak.
7015.0012	Mount Bewsher. At campsite on moraine between Mount Bewsher and Mount Macgrath.
7015.0014	Rookery Island. Less than 1 m from survey beacon on highest point.
7015.0015	Gibbney Island. Less than 1 m from survey beacon on highest point.
7015.0016	Woodberry Nunatak. On flat top of southernmost large nunatak.
7105.0002	Mount Forecast. Campsite 20 m west of rock edge on western side of Mount Forecast.
7105.0003	Blustery Cliffs, Fisher Massif. 10 m NW of Blustery Cliffs survey cairn.
7105.0004	Armonini Nunatak, centre of topmost helipad, on moraine to the south of eastern peak.
7105.0005	Mount Gleeson. At campsite on moraine tail, 6 km northeast of Mount Gleeson.
7105.0006	Murray Dome. Campsite on low saddle at northeast end of Murray Dome.
7105.0007	Mount Trott. On moraine on western side of Mount Trott.
7105.0008	Mount Stinear. At survey beacon.
7105.0009	Clemence Massif. At Parker Peak survey point.
7105.0010	Mount Meredith, 50 m from cliff edge, on western side of snowfield that is 6 km from southest end of massif and most westerly to go over the southern face of the massif.
7105.0011	Mount Abbs. On moraine near the middle of the base of the northern side, 100 m from rock outcrop.
7105.0012	Mount Bunt. On moraine 200 m off northern end of more westerly of the two northern peaks of Mount Bunt.
7105.0013	Mount Afflick. On moraine at southeast end of Mount Afflick.
7105.0014	Taylor Platform. At camp on moraine near northeast end of Taylor Platform.
7105.0015	Trost Rocks. 40 m south of survey beacon, 20 m west of edge of 60 m cliff.
7105.0016	Manning Platform. 20 m east of Else Platform survey marker at highest point.
7105.0017	Ritchie Point. Middle of flat platform between two melt lakes. 30m east of large sandstone boulder.
7105.0018	White Massif. On grey rock 20 m from edge of glacier, and 250 m off central northern part of massif.
7105.0019	Mount McCarthy. On boulder on southern side of moraine, about 150 m east of eastern edge of mountain.

latest series of 1:100 000 scale maps of the Division of National Mapping. The base station for all field measurements was in the cold porch of the mess hut at the Moore Pyramid base camp (BMR No. 7105.0001). This hut was 10 m from the radio hut used as base station in 1969-70 (BMR No. 7015.0001), and at the same elevation. The differences in gravity intervals between the above stations and the pendulum gravity station at Mawson were less than a few tenths of a milligal. Hence the same observed value of gravity was adopted for both base-camp stations. A gravity tie was made between Moore Pyramid base-camp and a permanently marked station (BMR No. 7105.0020) at the foot of Moore Pyramid (used also as regional magnetic station). Several of the other new field stations are at sites which can be reoccupied.

Repeat gravity measurements at four of the new stations suggest that the accuracy of the measurements is about two to three tenths of a milligal at most stations, and perhaps half to one milligal at a few. Errors of this magnitude are not important because of the large errors possible in elevation measurement. These are shown by repeat measurements to be as high as 50-75 m, corresponding to errors of 10-15 mGal in Bouguer anomaly. Uncertainties in latitude are believed to be negligible. Discrepancies between elevations measured during this work and previously mapped spot elevations and ice-surface contours are in places greater than the apparent uncertainty in the present measurements; some are greater than 300 m. It appears from this work that mapped spot elevations, most of which were determined barometrically, are not to be relied on. Consequently, an uncertainty of about 15 mGal in simple Bouguer anomaly is considered a reasonable claim for the worst of the present stations, with many of them having uncertainties nearer to 5 mGal. Topographic corrections, which appear necessary for some stations, have not been applied to the Bouguer anomalies.

DISCUSSION AND RECOMMENDATIONS

Gravity measurements made up to the end of the 1970-71 field season show an increase in Bouguer anomaly of about 160 mGal in a distance of 200 km from west to east of the Prince Charles Mountains, and there is no evidence that the maximum value in the east has been reached.

The origin of this anomaly pattern is considered to be near the upper mantle/crust boundary rather than within the crust near the surface. Measured rock densities do not seem to vary systematically in the area (see Appendix), and except for a small area of sediments near Beaver Lake (Mond, 1972), the rocks are all high grade metamorphics (McLeod, 1964) with an average density close to 2.67 g/cm^3, which value was used in the Bouguer anomaly reductions. Although, the list, in the Appendix, of measured densities in the area shows that some rocks such as basic gneiss, basalt, or amphibolite have high densities, such rocks make up probably no more than 5 percent of the outcrop. However, the Amery Ice Shelf may cover an area where high density rocks exist near the surface. The topography suggests that it could lie in a rift valley. Basic intrusions with high density are known in rift valleys elsewhere in the world.

The gravity pattern could also be caused by crustal thinning beneath the Amery Ice Shelf, in the same way that the Bouguer anomaly pattern seen at a continent/ocean-basin transition passes from negative values over the continent to positive values over the deep ocean basin. This possibility seems to be suggested by a Russian tectonic map of Antarctica (Begiazarov, 1969), although the data sources for this map are not known. However, the edge of the continental shelf in this region is perpendicular to the strike of the gravity gradient and about 400 km to the north.

It is recommended that the gravity program in the Prince Charles Mountains be continued, preferably by a geophysicist attached to the field party. This should allow more time to be spent on the gravity survey, with the establishment of a network of accurate sub-base Stations. Attention should be given to establishing a more uniform station network with greater emphasis on elevation measurement. The first requirement will need gravity stations on the ice plateau and ice shelf. Accurate gravity reductions need ice-thickness measurements, and these can be made ideally with a portable device such as a radar. One specific object of a future gravity survey should be the measurement of one or more gravity, sea-depth, and ice-thickness profiles east-west across the Amery Ice Shelf.

<u>NOTE</u>: In subsequent field seasons some of these recommendations were followed and wide network of gravity stations was established throughout the Prince Charles Mountains.

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APPENDIX 1

ROCK DENSITIES IN THE PRINCE CHARLES MOUNTAINS

by

R.J. Tingey

The densities of 48 rock specimens from the northern Prince Charles Mountains in Australian Antarctic Territory were determined in the Petroleum Technology Laboratory of the Bureau of Mineral Resources (BMR) using the water displacement method. Check determinations on 13 of the specimens were made by the mercury displacement method; no significant difference was observed between the results obtained by the two methods.

The rock densities, specimen localities and field descriptions of the rock specimens are listed in Table A1. The map (Pl. A1) shows the specimen localities and rock densities.

The rock specimens were collected by BMR geologists mapping the northern Prince Charles Mountains and nearby areas. In contrast with other parts of Antarctica the northern Prince Charles Mountains area has extensive rock exposures, and geological mapping to date has shown they consist mainly of metamorphosed acid rocks with minor intercalations and dykes of basic rocks. The metamorphism is,at most localities, of high grade, and hornblende-granulite and amphibolite facies rock types are predominant. A small enclave of sedimentary rocks is exposed in the Beaver Lake area (Crohn, 1959; Mond, 1972), but neither large sedimentary rock masses beneath the ice cap, nor large intrusive masses of basic or ultrabasic rocks near the present exposed surfaces are suggested by the geological evidence available.

The rock specimens chosen for density determinations reflect the generally acid nature of the rocks exposed, but the densities of some basic types also were determined. The average of the measured rock densities is 2.73 g/cm^3, which agrees closely with the value of 2.74 g/cm^3 given by Dobrin (1960) for the average density of metamorphic rocks. The densities of individual rocks types also conform to the appropriate values given by Dobrin and there is no reason to suppose that the measured densities of rock specimens from the northern Prince Charles Mountains indicate any anomalies in the densities of the rocks exposed there.

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TABLE A1

DENSITY DETERMINATION SPECIMENS - DESCRIPTION & DENSITY

BMR Registered No.	Location	Field description of rock	Density g/cm^3 (Water-displacement)	Density g/cm^3 (Mercury-displacement)
7028 0268	NE Stinear Nunataks	Augen gneiss	2.85	2.84
7028 0269	NE Stinear Nunataks	Augen gneiss	3.09	3.12
7028 0275	Riddell Nunataks	Microbanded garnet-biotite gneiss	2.86	2.84
7028 0403	Moore Pyramid	Migmatite (gneiss fraction)	2.67	
7028 0425	Vrana Peak	Pyroxene-quartz-feldspar gneiss	2.65	
7028 0430	Vrana Peak	Garnet-sillimanite gneiss	3.12	
7028 0434	Mount Turnbull	Garnetiferous granite-gneiss	2.61	
7028 0437	Carter Peak	Mafic granulite	2.90	
7028 0454	Farley Massif	Banded mafic gneiss	2.77	
7028 0455	Farley Massif	Banded felsic gneiss	2.63	
7028 0466	Mount Mercer	Banded felsic gneiss	2.62	
7028 0467	Mount Mercer	Banded mafic gneiss	2.67	
7028 0469	Mount Shennan	Mafic gneiss	2.74	
7028 0470	Mount Shennan	Garnet-quartz-feldspar gneiss	2.59	
7028 0474	Summers Peak	Mafic gneiss	2.67	2.68
7028 0479	Stinear Nunataks	Garnetiferous augen gneiss	2.71	
7028 0480	Stinear Nunataks	Quartz-feldspar gneiss	2.65	
7028 0515	Mount Dwyer	Biotite-garnet-feldspar-quartz gneiss	2.67	
7028 0520	Mount Peter	Migmatite	2.75	
7028 0525	Mount Wishart	Inclusion in marble	2.82	
R 18001	Trost Rocks	Garnet-quartz-feldspar gneiss	2.96	
7128 0105	Amery Peaks 6 km SW of Mount Seaton	Charnockite	2.60	
7128 0109	Amery Peaks W side of Mount MacKenzie	Charnockite	2.61	

7128	0110	NE side of Mount Trott	Granite-gneiss	2.60	2.60
7128	0123	N end of Mount Abbs	Granite vein	2.57	
7128	0124	N end of Mount Abbs	Garnetiferous gneiss	2.77	2.71
7128	0125	SE end of Mount Afflick	Acid gneiss	2.61	
7128	0128	N side of Mount Abbs	Acid gneiss	2.60	
7128	0129	S of Summit of Taylor Platform	Acid gneiss	2.61	
7128	0132	2 km SE of Summit of Taylor Platform	Garnet-biotite gneiss	2.77	
7128	0201	Mount Forecast	Hornblende-quartz-feldspar gneiss	2.74	
7128	0211	Mount McMahon	Amphibolite	3.02	
7128	0217	Mount McMahon	Garnet-hornblende-quartz-feldspar gneiss	2.65	
7128	0224	Wall Peak	Garnet-quartz-feldspar gneiss	2.56	
7128	0229	Mount Willing	Fine-grained amphibolite	3.01	
7128	0231	Husky Massif	Amphibolite	2.67	
7128	0236	Chapman Nunatak	Granite-gneiss	2.52	
7128	0239	Fisher Massif	Sheared granodiorite	2.65	
7128	0240	Fisher Massif	Amphibolite (Metamorphosed amygdaloidal basalt)	2.85	
7128	0248	Depot Peak	2-pyroxene-plagioclase granulite	3.18	
7128	0249	Depot Peak	Garnet-quartz-plagioclase gneiss	2.65	
7128	0343	Mount Gleeson area	Basic gneiss		2.75
7128	0344	Mount Gleeson area	Granitic-textured gneiss	2.74	2.72
7128	0345	Mount Gleeson area	Banded gneiss	2.70	2.70
7128	0346	Mount Gleeson area	Specular banded gneiss	2.92	2.88
7128	0349	Mount Gleeson area	Banded gneiss	2.60	2.55
7128	0350	Mount Gleeson area	Granitic-gneiss	2.59	2.55
7128	0390	Mount Meredith	Granite	2.62	2.59
			MEAN	2.73	2.73

APPENDIX 2

NOTES ON THE USE OF A GRAVITY METER IN ANTARCTICA DURING THE 1969-70 PRINCE CHARLES MOUNTAINS SURVEY

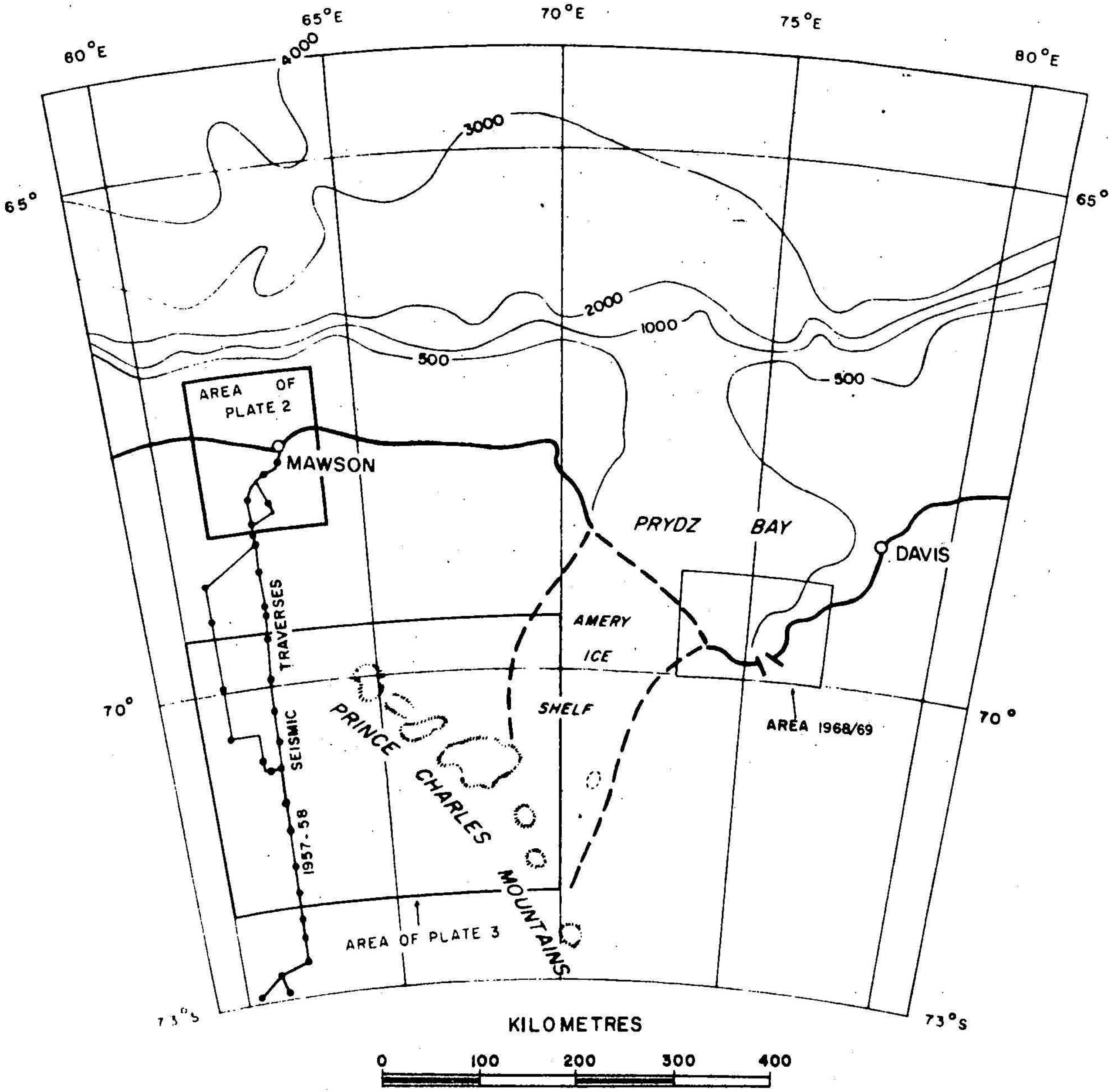
by

I.R. McLEOD

La Coste-Romberg geodetic gravity meter No. G101 was taken to Antarctica during the 1969-70 field season by the geological group of the Prince Charles Mountains party. The meter was kept at Moore Pyramid base camp, in the cold porch of the radio hut. It was taken on helicopter traverses from there by geologists, who read it before leaving and after returning to base. The helicopter altimeter was also read before leaving and after returning to base. At Moore Pyramid the gravity meter was read on the floor of the radio hut cold porch and, despite traffic through the porch while readings were being taken, this place was generally satisfactory. In the open, the meter could not be read in wind stronger than 15 knots. At Mawson the gravity station was enclosed, but even so 20 knots was the maximum acceptable wind speed.

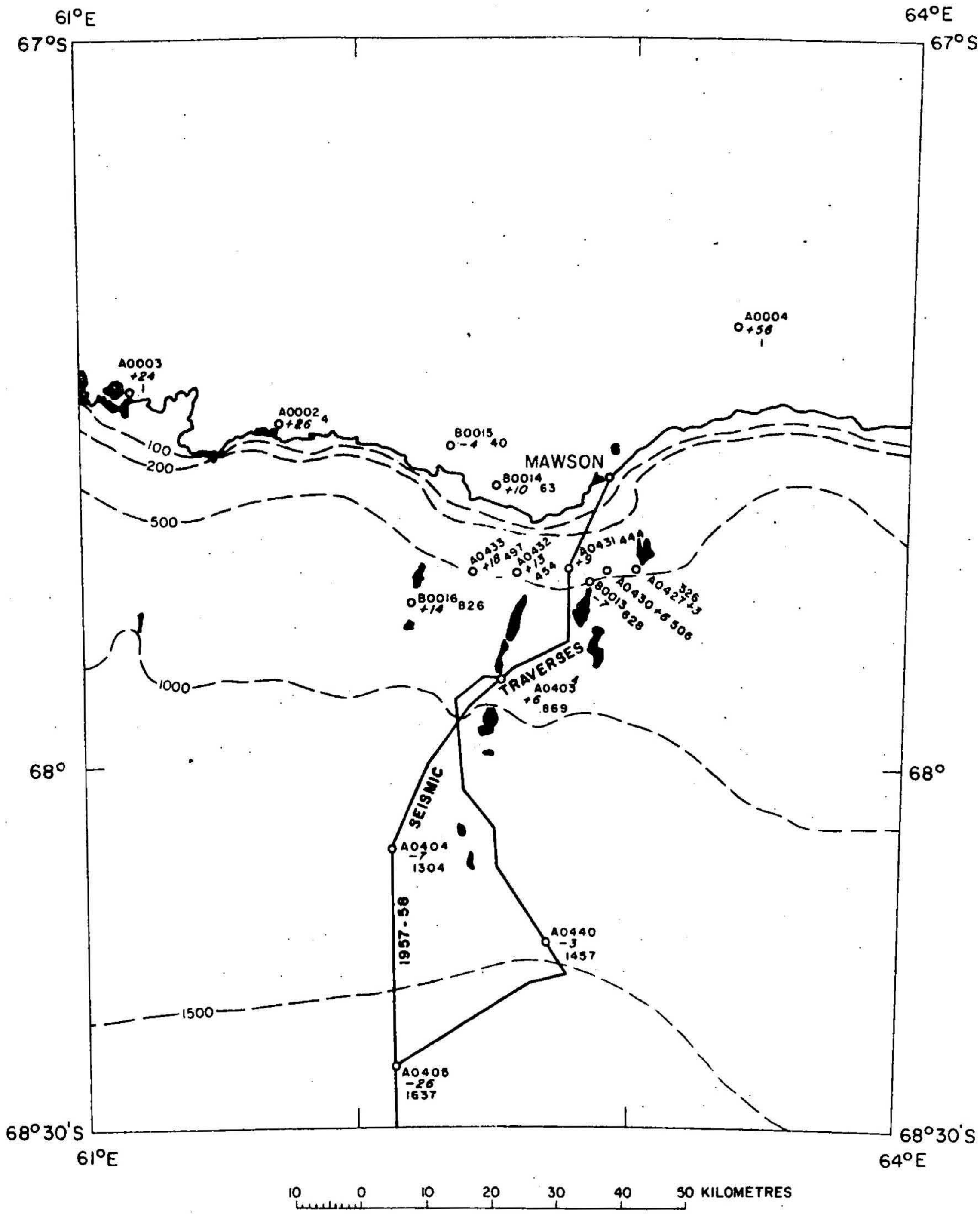
Day temperatures during most of the survey ranged from about -20 to -10°C. At the base camp the meter was stored connected to a lead-acid battery, and maintained its required temperature, 10°C, at all times. During traverses, nickel-cadmium batteries were used, and only once, when the temperature fell 1°C after the meter was connected for six hours, did the batteries fail to keep the meter at its required temperature. The nickel-cadmium batteries were rarely connected for more than four hours and there was ample time to recharge them with lead-acid batteries. The base camp radio operators helped the survey by providing and charging lead-acid batteries. However, for a systematic survey it would be wise for the operator to be independent of such an arrangement.

NOTE: In subsequent years lead-acid batteries were used exclusively, thus eliminating the frequent changing and recharging of nickel-cadmium cells.



RECONNAISSANCE GRAVITY OBSERVATIONS NEAR MAWSON AND IN THE PRINCE CHARLES MOUNTAINS, ANTARCTICA

LOCALITY MAP



KEY TO GRAVITY STATION NUMBERING
A = 5615 B = 7015

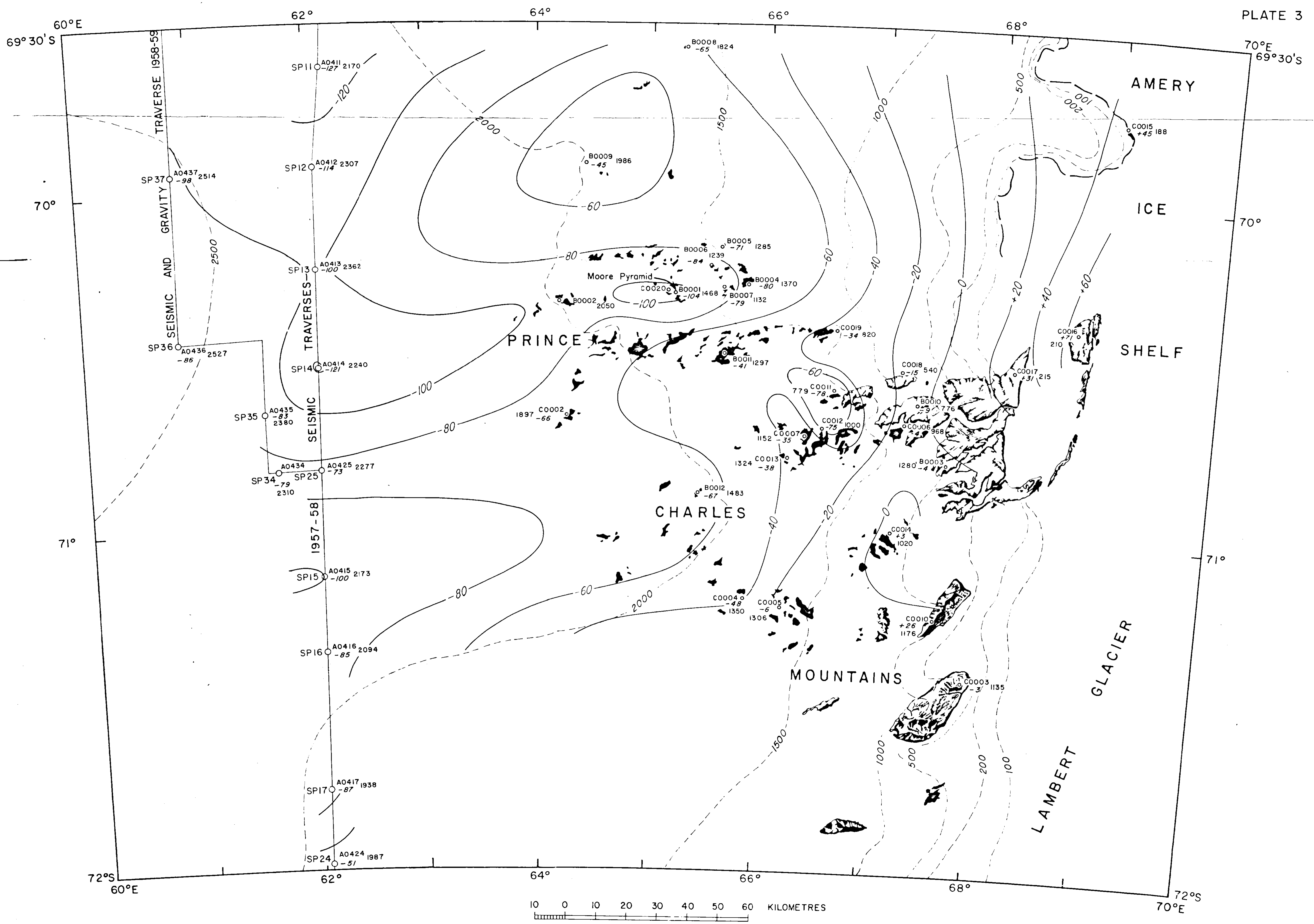
ASSUMED DENSITY;
Rock = 2·67g/cc, Ice = 0·90g/cc

Ice surface contours in metres
o Gravity station
826 Elevation (metres)
+14 Bouguer anomaly

FRAMNES MOUNTAINS – MAWSON AREA, ANTARCTICA

SIMPLE BOUGUER ANOMALIES

PLATE 3



NORTHERN PRINCE CHARLES MOUNTAINS
ANTARCTICA

SIMPLE BOUGUER ANOMALIES

KEY TO GRAVITY STATION NUMBERING

A=5615 B=7015 C=7105

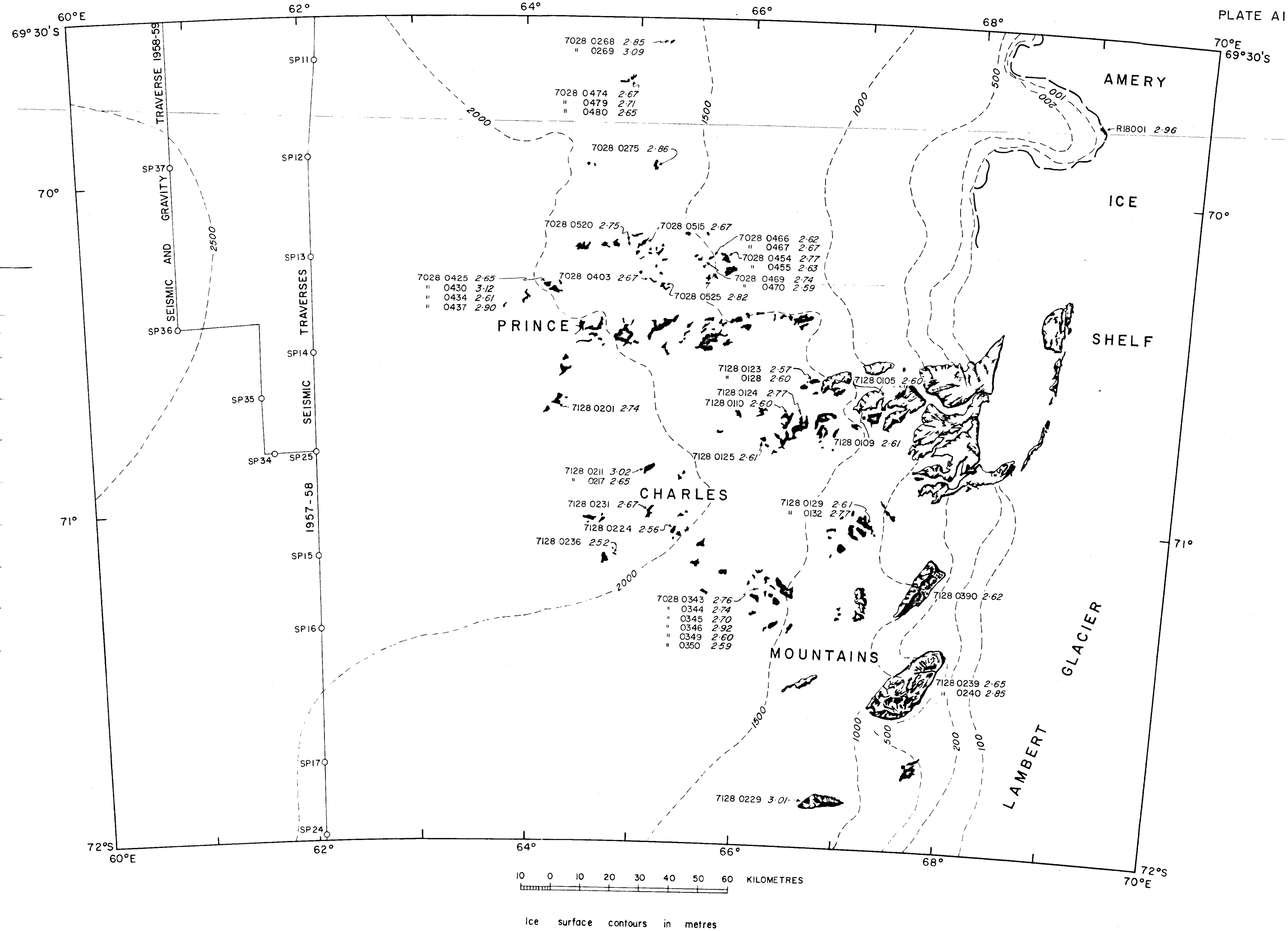
For the calculation of Bouguer anomalies, 2·67 g/cm³ has been adopted as average rock density.

o	Gravity station
-48	Bouguer anomaly (milligals)
1350	Elevation (metres)
2000	Ice surface contour (metres)
-60	Isogal (interval 20milligals)

Record No. 1975/59

ANT/B2-8

PLATE A1



NORTHERN PRINCE CHARLES MOUNTAINS, ANTARCTICA

SPECIMEN LOCALITIES AND ROCK DENSITIES