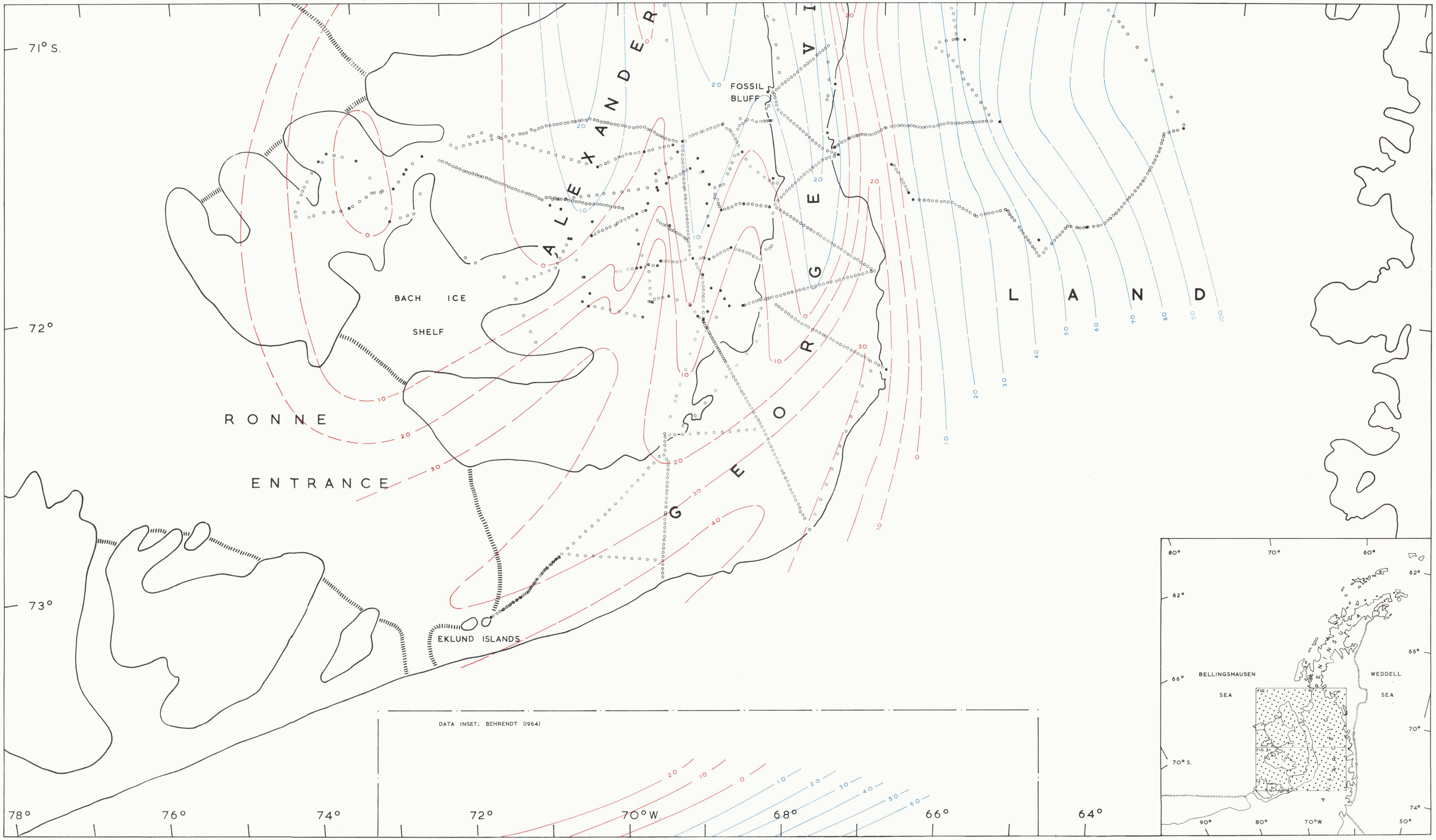

Fig. 2. Bouguer anomaly map of parts of Alexander Island and Palmer Land with contours at 10 mgal intervals.
The inset shows the location of the area surveyed in relation to the Antarctic Peninsula.

[face page 6]

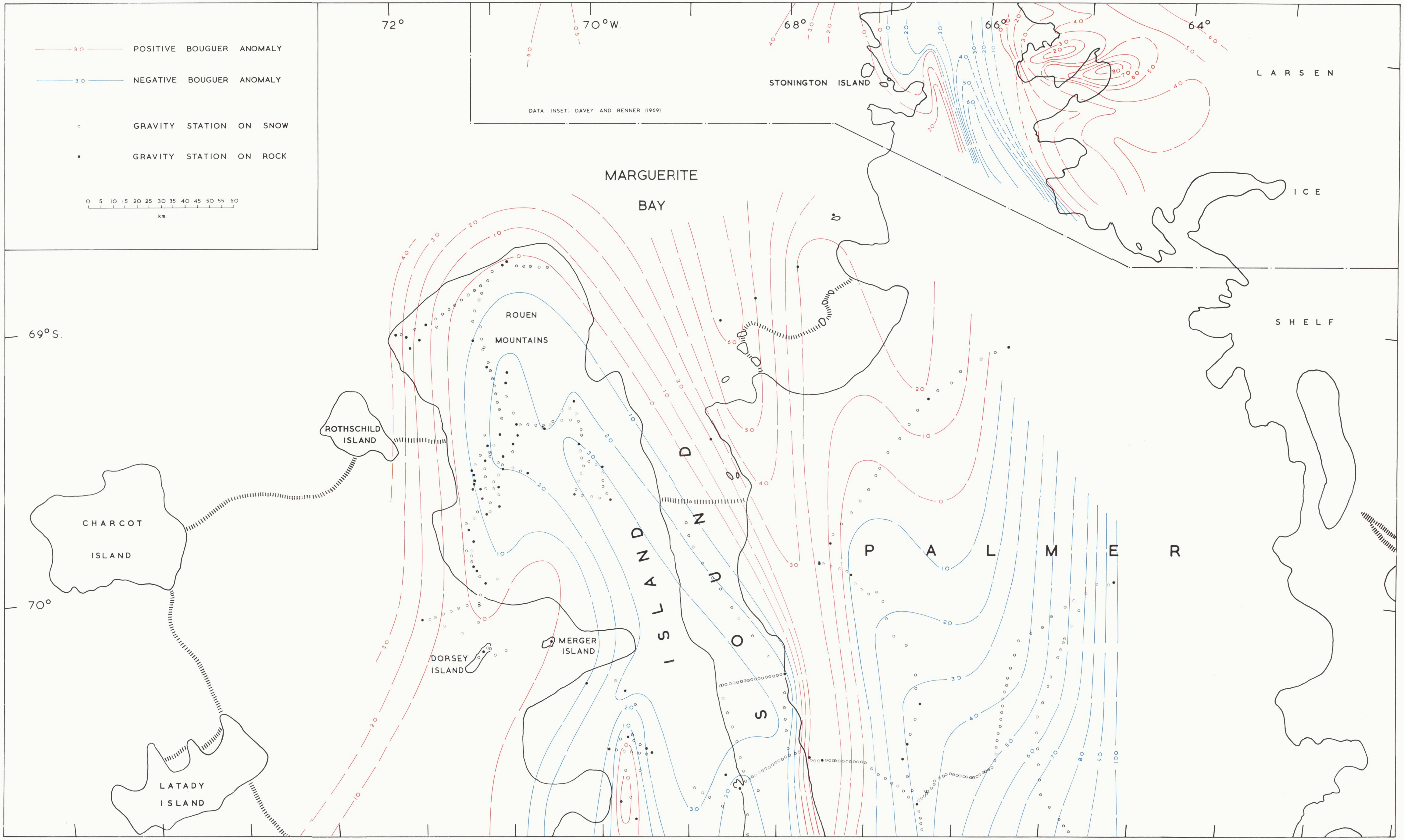

Fig. 1. Bouguer anomaly map of parts of Alexander Island and Palmer Land with contours at 10 mgal intervals.

[face page 61]

REGIONAL BOUGUER ANOMALY MAP OF ALEXANDER ISLAND AND PALMER LAND

By F. M. BURNS

ABSTRACT. During the course of a reconnaissance gravity survey of Alexander Island, George VI Sound and Palmer Land, every opportunity was taken to obtain gravity readings at rock sites to avoid the gravity effect of an unknown thickness of ice. Bouguer anomaly values have been calculated for these rock stations and are presented as a contoured map.

THE reconnaissance gravity survey of the Antarctic Peninsula and offshore islands began in 1959. The regional gravity data so far obtained have been published as a Bouguer anomaly map of Graham Land (Davey and Renner, 1969). Apart from the establishment of a gravity base station at Fossil Bluff by Griffiths and others (1964), no other geophysical work was carried out in the southern part of the Antarctic Peninsula until 1969–70 when the author and I. F. Smith commenced a reconnaissance gravity and magnetic survey of Alexander Island, George VI Sound and Palmer Land. This work was continued in 1970–71 by the author and P. F. Butler. The object of these surveys was to investigate the nature of George VI Sound and its structural relationship to Alexander Island and Palmer Land.

Throughout these two periods the geophysical survey was carried out using dog-sledge transport from the British Antarctic Survey stations at Stonington Island and Fossil Bluff. The absolute value of gravity at these two stations has been established by Kennett (1965*a*) as 982·5094 and 982·6641 cm. sec.$^{-2}$, respectively.

This paper is concerned with the instrumentation and survey methods used and the subsequent data reduction. The associated errors in the computation of the Bouguer anomalies are also discussed. Figs. 1 and 2 show the area surveyed and the gravity station positions. The contouring is based on the Bouguer anomaly values for rock stations only.

Because of the absence of ice-thickness data, the Bouguer anomaly values have not been shown for the snow stations. However, the values obtained by assuming an all-rock column in the Bouguer correction for snow stations have been borne in mind in preparing the contoured map. The values at these stations will in general be an underestimate, but they do reveal regional trends and gradients between the rock stations in addition to those produced solely by changes in ice thickness.

THE GRAVITY SURVEY

Gravity measurements were made with Worden Master gravimeters Nos. 556 and 743. Both gravimeters were calibrated prior to being used in the Antarctic and also on their return to England. The calibration factors for each instrument are given in Table I.

TABLE I. INSTRUMENT CALIBRATION

Gravimeter number	*Calibration date and mean temperature*	*Calibration factor* (mgal/scale division)	*Mean value for calibration factor* (mgal/scale division)
556	July 1968 at 78° F	0·2297(6)	0·2286(0) at 78° F
	May 1971 at 76° F	0·2274(0)	
743	July 1968 at 84° F	0·2038(9)	0·2041(2) at 84° F
	May 1972 at 63° F	0·2038(2)	

Gravimeter No. 556 was dropped during the survey and on return to the manufacturers the vacuum flask was found to be broken. This presumably gave rise to the slightly erratic drift behaviour which only became apparent during the data reduction. As a result of this, the July 1968 value for the calibration factor was preferred.

The method of transportation and the isolated nature of the survey led to difficulties in re-charging the batteries operating the thermostatically controlled heater in the gravimeters. The calibration factors at temperatures other than those at which the instruments were calibrated were based on the manufacturer's stated "one per cent change in scale constant for a change of 140° F".

Absolute heights were obtained whenever possible by visiting topographically surveyed features or areas at sea-level. In the absence of topographical data, station elevations were obtained by a barometric method similar to that used by Kennett (1965*b*) in which pressure changes were related to elevations of the observation points. The author used Wheeler aneroid barometers and Baromec precision aneroid barometers to measure the pressure changes.

Adjustments for regional pressure gradients were applied using meteorological data from the observatory at Adelaide Island and from the Fossil Bluff station. In addition, accuracy was further increased by using a closed-loop system of traverses whenever possible. After due allowances for pressure gradients, any closure errors within loops or between two known heights were distributed evenly between the intervening stations. Finally, where loops had common stations, any differences in the heights of these stations were removed by relaxation of the network using the method of least squares. In places where radio echo-sounding of floating ice shelves had been carried out, the empirical relationship between surface elevation and overall thickness (Renner, 1969) was used to estimate the absolute surface elevation.

The quality of the heighting data was far from consistent. At best, the standard error of the mean was ± 7·6 m., obtained from the misclosures in looped data, and at worst the standard error of the mean was ± 30·5 m. as obtained from one-way determinations for the elevation of a base station.

Station positioning was achieved by a combination of plane-table mapping and compass and sledge-wheel traverses. Geographical coordinates were assigned to the maps produced by referring to common previously surveyed features. The standard of station location was very varied, being governed by the accuracy of the existing Directorate of Overseas Surveys topographical maps. However, recent topographical surveys in some areas of Palmer Land and George VI Sound have allowed re-positioning and compilation of existing plane-table maps (Christie, 1972).

In Alexander Island, much of the inland area west of George VI Sound has only been mapped by air photographic techniques (Searle, 1961). Subsequent ground traverses by members of the Survey have revealed location errors of mountain groups of up to 32 km. Three astronomical fixes were therefore obtained by the author during the geophysical survey in order to locate more accurately the plane-table maps produced.

As with surface elevation, the accuracy of station positioning varied over the area surveyed. In Palmer Land, where prolonged periods of poor visibility were encountered, stations are thought to have an accuracy of ± 3·6 km., but in Alexander Island and George VI Sound positions are thought to be within ± 0·8 km. of their true geographical location.

Data Reduction and Results

Gravimeter drift corrections were made by subtracting the static overnight and non-travel period drift changes and then removing any misclosures by assuming a linear travelling drift rate between re-occupation of stations. For unclosed loops, a travelling drift rate of 0·0486 ± 0·01 mgal/hr. was used, being the mean value obtained from 30 closed loops.

Errors arising from assuming a constant calibration factor and a linear travelling drift rate were estimated by re-occupying 11 stations. The mean standard error for the values at these stations was determined as ± 0·2 mgal. However, for some stations, notably those in northern Alexander Island where stations could not be re-occupied, the assumption of a mean value of 0·0485 ± 0·01 mgal/hr. for the travelling drift rate could give rise to a maximum error of ± 2 mgal.

Latitude corrections were made by evaluating the International Gravity Formula at each gravity station. Due to inaccuracies in the station positions, the error in this correction may be as much as ± 4 mgal in Palmer Land and ± 1 mgal in Alexander Island and George VI Sound.

Throughout this work a crustal density of 2·67 g. cm.$^{-3}$ has been used in making the Bouguer correction. Little is known of the density of the rock types and their sub-surface distribution. Kennett (1966) obtained density values for the more common rock types which are within ± 0·10 g. cm.$^{-3}$ of the above value. Since the Bouguer correction is also a function of elevation, representative heights have been assigned to particular areas so that likely errors may be evaluated. These are tabulated in Table II.

TABLE II. ERRORS IN THE BOUGUER ANOMALY

Source of error	*Expected error* (mgal)			
	Alexander Island		*George VI Sound*	*Palmer Land*
	Northern	*Central*		
Standard error of the absolute values of the base stations	±1·4	±1·4	±1·4	±1·4
Instrumental drift and calibration factor	±2·0	±0·2	±0·2	±2·0
Latitude correction	±1·0	±1·0	±1·0	±4·0
Free-air correction	±2·0	±2·0	±2·0	±6·0
Bouguer correction, assuming a density error of ±0·10 g. cm.$^{-3}$ and a mean station elevation of:	±4·0 914 m.	±2·5 610 m.	±0·1 30·5 m.	±6·5 1,524 m.
Terrain correction	0 to −6·0	0 to −5·0	0 to −3·0	0 to −5·0
Overall standard error for the Bouguer anomaly	+5·0 to −11·0	+3·0 to −8·0	+3·0 to −6·0	+10·0 to −15·0

Due to inaccuracies in the surface elevation, there will be corresponding errors in the free-air correction. In areas where the survey was more extended and the elevations were both high and fluctuating, errors may be as much as ± 6 mgal.

Because of the lack of suitable topographical maps, no attempt has been made to calculate terrain corrections. Griffiths and others (1964) considered that this correction would not exceed 3 mgal at most stations and at a few it would perhaps reach 5 or 6 mgal. Kennett (1966), who computed approximate terrain corrections using a Hammer chart and the available topographical maps, obtained values varying from 0·6 to 5·6 mgal in areas with topography similar to those in the area discussed in this paper. Terrain correction errors have been estimated and they are shown in Table II together with the errors previously discussed. Because the area surveyed covers three distinct topographical provinces, the treatment of the errors has been subdivided accordingly.

A standard error for the Bouguer anomaly has been computed from the individual errors and this can be seen to lie well within the ± 20 mgal which Bentley (1964) attributed to the majority of Antarctic gravity surveys. As is usual with such surveys, the relative error between adjacent stations is considered to be lower than those finally obtained (Table II); it is therefore considered that the contour interval of 10 mgal used in Figs. 1 and 2 is justified.

DISCUSSION

The regional Bouguer anomaly map (Figs. 1 and 2) shows close agreement with those of Davey and Renner (1969) and Behrendt (1964), who worked to the north and south, respectively. No quantitative interpretation of the Bouguer anomalies has yet been attempted, since it is hoped that the results of recent airborne radio echo-sounding will provide ice thicknesses over much of the area of the gravity survey. This will undoubtedly modify the isogals in areas where the Bouguer anomaly map has been contoured on relatively few rock stations.

Certain anomaly features lend themselves to a qualitative discussion. The general trend of the contours is parallel to the western coastline of Palmer Land. Positive Bouguer anomaly values occur along the west coast of Palmer Land, reaching +60 mgal in southern Marguerite Bay and +40 mgal on the western extremities of Alexander Island. In Palmer Land itself, the values decrease progressively from 0 mgal on the west coast to −100 mgal over the mid-line of Palmer Land. This trend has been noted throughout the length of the Antarctic Peninsula, and on two gravity traverses across the peninsula (Figs. 1 and 2) obtained by Davey and Renner (1969) the Bouguer anomaly value reaches a minimum of −60 mgal over the peninsula and then increases to +40 mgal on the Larsen Ice Shelf. More recent work by N. C. McNaughton (personal communication) has shown that east of long. 63°30′W., and at lat. 71°15′S., the Bouguer anomaly values increase again. This form and the horizontal gradient of approximately 1 mgal/km. across Palmer Land are general features throughout the peninsula and are most probably caused by a crustal deepening beneath the high backbone of Palmer Land, thus maintaining isostatic equilibrium. There are insufficient stations on rock to merit an analysis of the free-air anomalies and thus infer the degree of regional compensation over Palmer Land.

In Alexander Island the most notable feature is the gravity low centred over the northern half of the island, where there are minimum values of −30 mgal. The gentle horizontal gradients of this anomaly suggest that crustal deepening has again occurred or that the granitic batholith of the Rouen Mountains is only a small part of a more extensive intrusion. This mountain range, which is the highest in Alexander Island, reaches heights over 2,400 m. and has about 1,500 km.^{2} of exposed rock consisting almost entirely of xenolithic granite and granodiorite intruding the older sedimentary rocks.

No definite conclusions have been reached regarding the structure of George VI Sound. It is tentatively suggested, from the north–south trending ridge of positive Bouguer anomaly values which lie along the west coast of Palmer Land, that faulting has occurred parallel to the eastern margin of the sound at least between lat. 70°30′ and 71°30′S. The anomaly width of 25–35 km. is indicative of some deep-seated source within the Earth's crust. The isogals on the western margin of George VI Sound show only an extension of the broad gravity low centred on northern Alexander Island. However, it is in this area that there are fewest stations on rock and hence the contouring is most conjectural.

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