A REGIONAL BOUGUER ANOMALY MAP OF NORTH-WESTERN PALMER LAND

By P. F. BUTLER *and* M. MCARTHUR

ABSTRACT. A regional gravity survey of north-western Palmer Land is described. The data are presented as a Bouguer anomaly map and discussed in relation to the geology of the area.

PRELIMINARY gravity investigations in north-western Palmer Land and Alexander Island were begun in 1969–70 by I. F. Smith and F. M. Burns, and continued in 1970–71 by F. M. Burns and P. F. Butler. During the field season of 1972–73, M. McArthur commenced a more detailed study along both coasts of George VI Sound and in north-western Palmer Land between lat. 70° and 71°S. In 1973–74 this survey was extended northward to the Wordie Ice Shelf and southward to the Batterbee Mountains by P. F. Butler and A. A. J. Almond.

This paper describes the gravity surveys of George VI Sound and Palmer Land completed during 1972–74. The aims were to investigate the structure of George VI Sound and possible regional, sub-ice geological disconformities in north-western Palmer Land. The results, which have been collated with previous gravity data from Alexander Island (Burns, 1974; Butler, 1975), are presented as a contoured Bouguer anomaly map (Fig. 1).

THE GRAVITY SURVEY

Worden Master gravimeters Nos. 556 and 743 were used for the gravity measurements. Several primary stations in the survey area were established by air from the base station at Stonington Island, where Kennett (1965) determined an absolute gravity value of 982·5094 cm. sec.$^{-2}$. Survey methods and techniques using dog-sledge transport have been previously discussed (Burns, 1974; Butler, 1975; Renner, 1980).

The accuracy of station elevations was greatly increased in this survey, since there already existed a network of topograhical survey control points into which all gravity stations were linked by a simple barometric loop system. The method proved to be effectively independent of atmospheric pressure variations, giving accuracies not usually obtainable in Antarctic gravity surveys. The elevations of all gravity stations in this area were considered to be accurate to within ± 5 m., resulting in a maximum error of ± 1 mgal. in the Bouguer correction. Local density variations were ignored and an average value of 2·67 g. cm.$^{-3}$ was assumed in order to correlate with previous surveys in the region. Gravity drift loops were run concurrently with those of the barometers, all closures being within an interval of a few days. The error resulting from gravimeter drift was therefore kept to a minimum and in most cases it is considered to be less than $\pm 0 \cdot 2$ mgal. In the 1973–74 season, however, gravimeter No. 743 exhibited an unusually high but mainly consistent drift rate; thus, for a few stations in the Batterbee Mountains area, the drift error may approach ± 2 mgal. Station positions were fixed on 1:200,000 planimetric compilations, reducing the positional error to a few hundred metres. Latitude corrections are thus estimated to be within $\pm 0 \cdot 2$ mgal.

In mountainous areas the available maps provide only a diagrammatic outline of the relief, and the lack of detailed vertical control therefore creates difficulties when assessing terrain corrections. In addition, there is the contribution to the total terrain effect from the unknown sub-ice topography. To calculate terrain corrections for the area, five stations were chosen to represent different grades of terrain severity. For each, a topographical contour map was prepared on the basis of available survey data and supported with detail from air and ground photography. Terrain-correction tables (Bible, 1962) were then applied. Consideration was also given to ice depths obtained from radio echo-sounding measurements (Smith, 1972) over the area, and the total terrain correction evaluated from both ice and rock effects. Finally, each gravity location was compared with one of the five representative stations and assigned an equivalent terrain-correction value. In areas of extreme topography the error in these values may be as high as ±5 mgal.

Consideration of the above errors result in an estimated error for the Bouguer anomaly value of ±5·1 mgal.

During the field season, 119 specimens suitable for density determination were collected. These were measured under laboratory conditions and the results are given in Table I.

TABLE I. DENSITIES OF ROCKS FROM NORTH-WESTERN PALMER LAND

Rock type	*Number of specimens measured*	*Maximum density* (g. cm.$^{-3}$)	*Minimum density* (g. cm.$^{-3}$)	*Average density* (g. cm.$^{-3}$)
Granite	21	2·69	2·54	2·61±0·04
Granodiorite	23	2·92	2·56	2·68±0·08
Diorite	8	2·89	2·67	2·76±0·08
Gabbro	9	2·98	2·74	2·86±0·08
Mesozoic volcanic rocks	40	2·96	2·58	2·72±0·08
Metamorphic complex	18	2·94	2·58	2·71±0·09
All rocks	119	2·98	2·54	2·71±0·10

DISCUSSION

The north-western coast of Palmer Land is formed by a series of high, deeply dissected mountain massifs, dropping steeply westward from the ice-covered plateau to the relatively narrow trough of George VI Sound. The geology (Fig. 2) of north-western Palmer Land has been described by Ayling (1966), Rowe (1973), Skinner (1973) and Smith (in press). Palaeozoic metamorphic and igneous rocks are the oldest in the area and these are unconformably overlain by a thick Mesozoic volcanic sequence. The Tertiary is represented by a phase, or phases, of intense igneous activity with intrusions of basic, intermediate and acid rocks. There then followed a period of uplift and block faulting with faults parallel to the axis of the Antarctic Peninsula.

Farther west lies the high mountain chain of eastern Alexander Island, tilted gently from north to south and variously dissected by easterly flowing glaciers. On Alexander Island, the oldest known rocks (Bell, 1975) are (?) Carboniferous sediments and interstratified volcanic rocks (Fig. 2). This sequence is extensively folded and sheared, and is intruded by dioritic and granitic bodies. Volcanic rocks and fossiliferous marine sediments comprise the Upper Jurassic–Lower Cretaceous Fossil Bluff Formation, which crops out along much of the east coast of Alexander Island and is probably unconformable on the (?) Carboniferous rocks. There is a further tuffaceous sequence of (?) late Cretaceous age which is seen to overlie the (?) Carboniferous sequence in the north-west of Alexander Island. Finally, the youngest rocks described are late Tertiary dolerite and camptonite dykes, and sparse, sub-aqueously erupted basaltic lavas.

Separating north-western Palmer Land from Alexander Island is George VI Sound, the structure of which remains an enigma. King (1964) suggested that it was a rift valley, bounded by normal faults and generated by crustal uplift, whereas Horne (1967) postulated the formation of the high west coast escarpment of George VI Sound by underthrusting of the Alexander

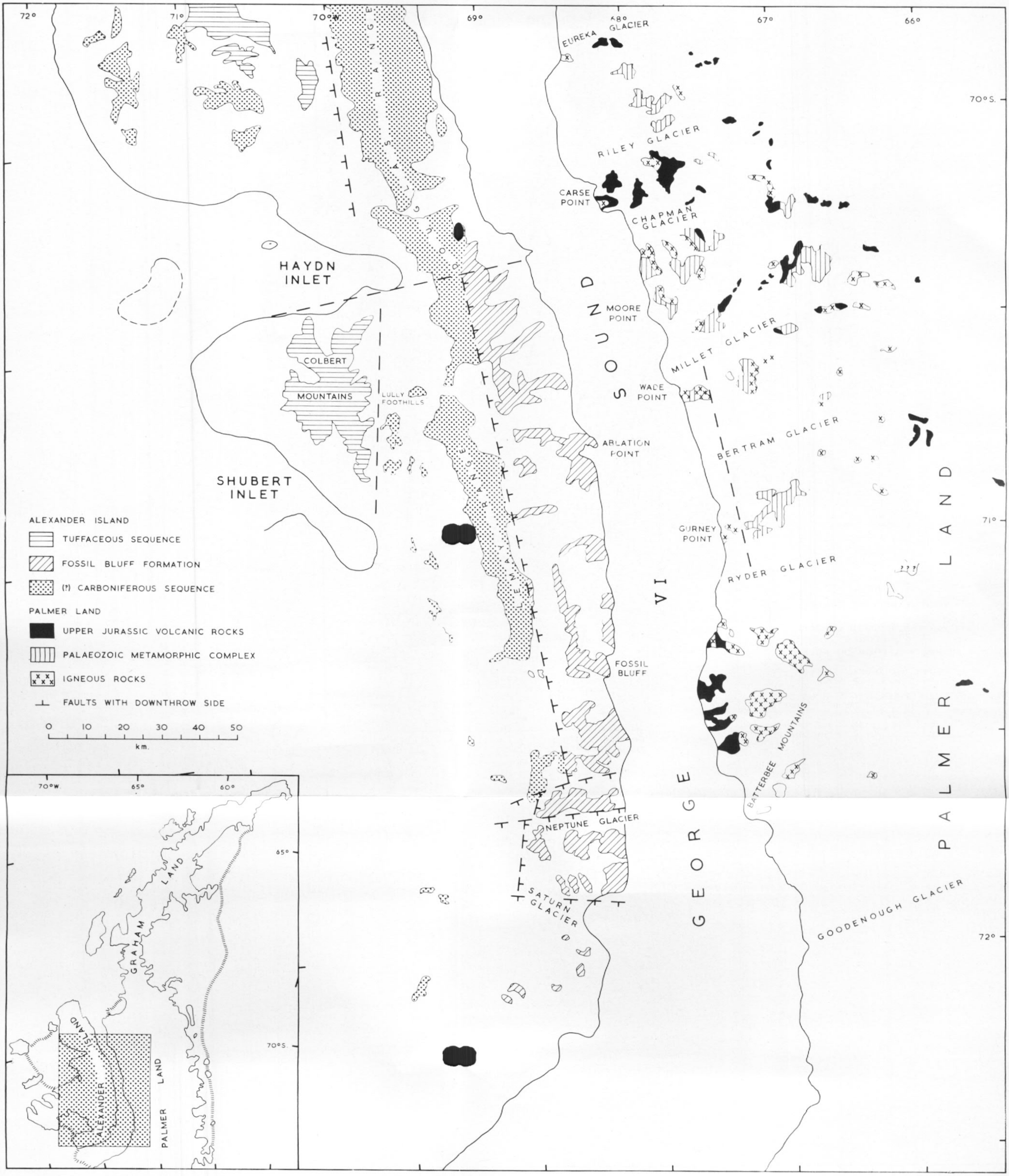
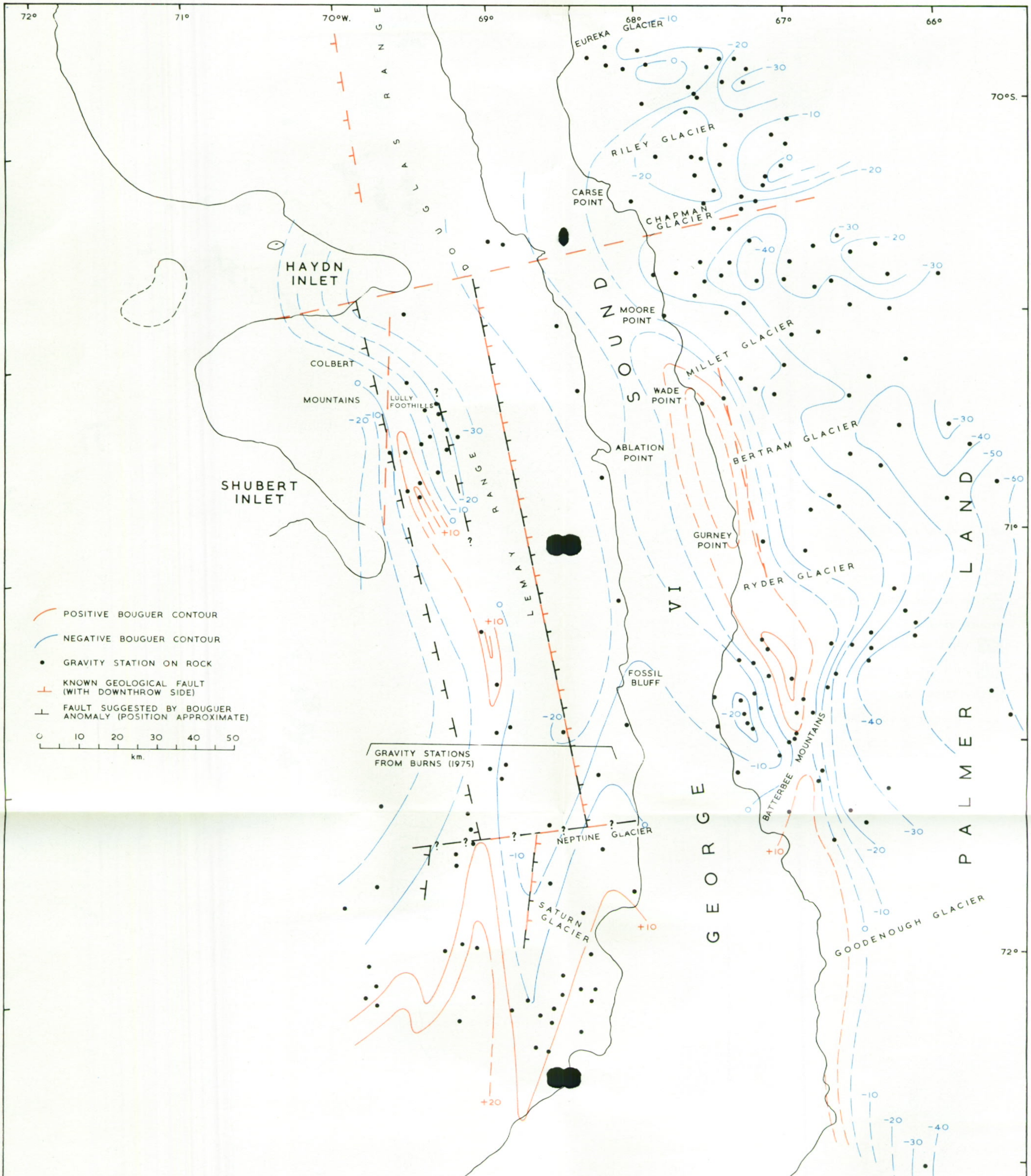

72°
71°
70°W.
69°
68°
67°
66°
70°S.
71°
72°
EUREKA GLACIER
RILEY GLACIER
CARSE POINT
CHAPMAN GLACIER
HAYDN INLET
MOORE POINT
MILLET GLACIER
COLBERT MOUNTAINS
LULLY FOOTHILLS
WADE POINT
BERTRAM GLACIER
ABLATION POINT
SHUBERT INLET
GURNEY POINT
RYDER GLACIER
FOSSIL BLUFF
BATTERBEE MOUNTAINS
NEPTUNE GLACIER
SATURN GLACIER
GOODENOUGH GLACIER
GEORGE VI SOUND
PALMER LAND
LASSUS RANGE
DOUGLAS RANGE
LE MAY RANGE
ALEXANDER ISLAND
TUFFACEOUS SEQUENCE
FOSSIL BLUFF FORMATION
(?) CARBONIFEROUS SEQUENCE
PALMER LAND
UPPER JURASSIC VOLCANIC ROCKS
PALAEOZOIC METAMORPHIC COMPLEX
IGNEOUS ROCKS
FAULTS WITH DOWNTHROW SIDE
0 10 20 30 40 50
km.
70°W.
65°
60°
65°
70°S.
GRAHAM LAND
ALEXANDER ISLAND
PALMER LAND

Fig. 2.



72°
71°
70°W.
69°
68°
67°
66°
70°S.
71°
72°
EUREKA GLACIER
RILEY GLACIER
CARSE POINT
CHAPMAN GLACIER
HAYDN INLET
DOUGLAS RANGE
MOORE POINT
COLBERT MOUNTAINS
LULLY FOOTHILLS
MILLET GLACIER
WADE POINT
ABLATION POINT
BERTRAM GLACIER
SHUBERT INLET
LEMAY RANGE
GURNEY POINT
RYDER GLACIER
GEORGE VI SOUND
PALMER LAND
FOSSIL BLUFF
BATTERBEE MOUNTAINS
GRAVITY STATIONS FROM BURNS (1975)
NEPTUNE GLACIER
SATURN GLACIER
GOODENOUGH GLACIER
POSITIVE BOUGUER CONTOUR
NEGATIVE BOUGUER CONTOUR
GRAVITY STATION ON ROCK
KNOWN GEOLOGICAL FAULT (WITH DOWNTHROW SIDE)
FAULT SUGGESTED BY BOUGUER ANOMALY (POSITION APPROXIMATE)
0 10 20 30 40 50
km.

Fig. 1.

Island sediments from the east. Bell (1975) favoured block faulting of Cenozoic age to account for the north–south linearity of the mountain ranges in Alexander Island and he suggested a similar origin for George VI Sound.

The Bouguer anomaly map (Fig. 1), together with the cross-sections (Fig. 3a and b), shows several interesting features and partially reflects the complex structural history. However, the present station distribution limits interpretation to qualitative considerations only.

The regional anomaly pattern is as observed elsewhere on the Antarctic Peninsula (Behrendt, 1964; Davey and Renner, 1969), the anomalies becoming more negative towards the central north–south axis. Widespread granodiorite exposures in north-western Palmer Land may indicate more extensive underlying batholiths, which could account for the increased negative gradient in this part of the Antarctic Peninsula. North of Millet Glacier, the anomaly trend changes markedly in signature, and this coincides with a physiographic transition in the terrain, the northern sector being more mountainous. The anomalies are of a shorter wavelength and incline towards a west–east orientation. Associated with Chapman Glacier is a noticeable west–east anomaly trend roughly coincident with a west–east-trending fault as proposed by Bell. However, the fault line, which Bell (1975) continued across George VI Sound (Fig. 1) to Alexander Island, is based on geomorphological observations, and insufficient geological and geophysical evidence is available to interpret otherwise.

Superimposed upon the regional trend on Palmer Land is a narrow, almost linear anomaly trending sub-parallel to George VI Sound, and this extends south from Millet Glacier to the Batterbee Mountains. The anomaly traverses areas of contrasting lithology, for the northern end is centred over low terrain adjoining George VI Sound, whereas that to the south overlies the severe topography of the Batterbee Mountains. This anomaly has relative well-defined parameters on the mainland, but it lacks suitable control over the ice shelf of George VI Sound. Gravity readings have been taken on the latter but they cannot yet be included because here the bathymetry is unknown. In the Batterbee Mountains the anomaly reaches a maximum of +25 mgal, decreasing steeply westward to a value of −20 mgal. Reconnaissance geological observations by Ayling (1966) have indicated that the Batterbee Mountains are composed of an igneous complex of gabbro, granodiorites and granites, intruding a sequence of acid lavas and tuffs which crop out to the west. The gravity low could in part be a reflection of the less dense volcanic rocks (Fig. 3b). North of the Batterbee Mountains, the anomaly traverses areas of metamorphic and igneous rocks, though a small outcrop of volcanic rock has been observed at Gurney Point. The main axis of the anomaly lies close to a structural disconformity proposed by Smith (in press) trending parallel to George VI Sound and about 8 km. inland from the coast at Wade and Gurney Points. This separates the very low coastal headlands from the higher mountains to the east.

This linear anomaly has many physical similarities to one 70 km. to the west in Alexander Island, where Butler (1975) suggested a possible origin lay in an upthrown block of the (?) Carboniferous sequence between the younger and lighter tuffaceous sequence and the Fossil Bluff Formation. Undoubtedly, a zone of positive gravity values requires the presence of a wedge of higher-density material, but much further data are required before a faulted or other origin can be ascribed to the anomaly in north-western Palmer Land. The gravity high may continue south of the Batterbee Mountains but here occupied stations become less frequent.

It is apparent that, although the gravity data in this area have indicated general anomalous trends, the results have not yet permitted any detailed quantitative interpretation, especially concerning the structure and formation of George VI Sound. There appears to be, however, a significant, high-density structural feature underlying much of the western edge of north-western Palmer Land, though its nature, mode of emplacement and structural relationships remain uncertain. Further detailed gravity work, bathymetric control of George VI Sound and the scheduled aeromagnetic surveys could provide much additional evidence towards a greater understanding of this important structural area.

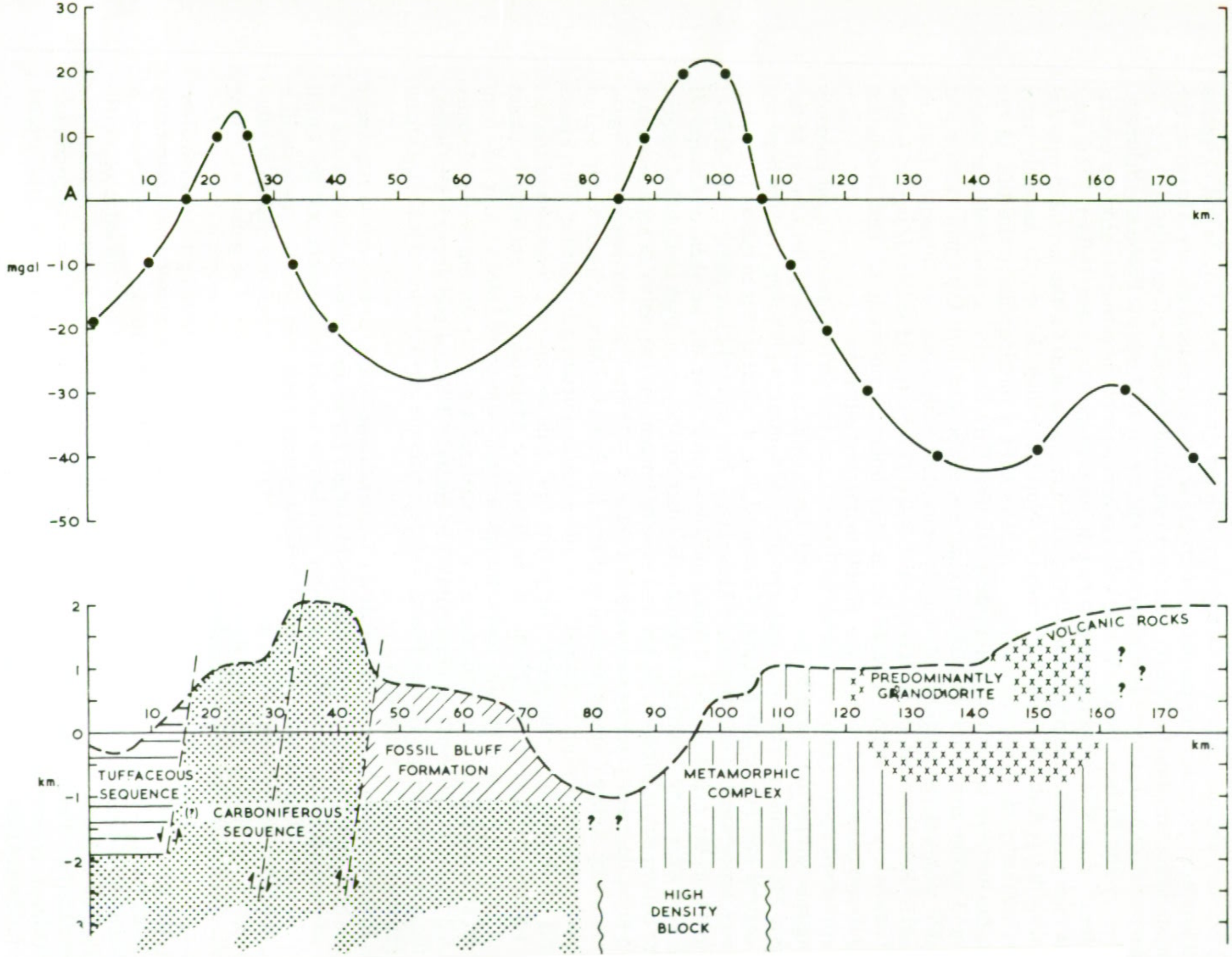


Fig. 3. Diagrammatic cross section across Alexander Island, George VI Sound and western Palmer Land, showing the general relationship between Bouguer anomalies and the geology. (Fig. 3a and b, mentioned in the text, has been replaced by this illustration.)

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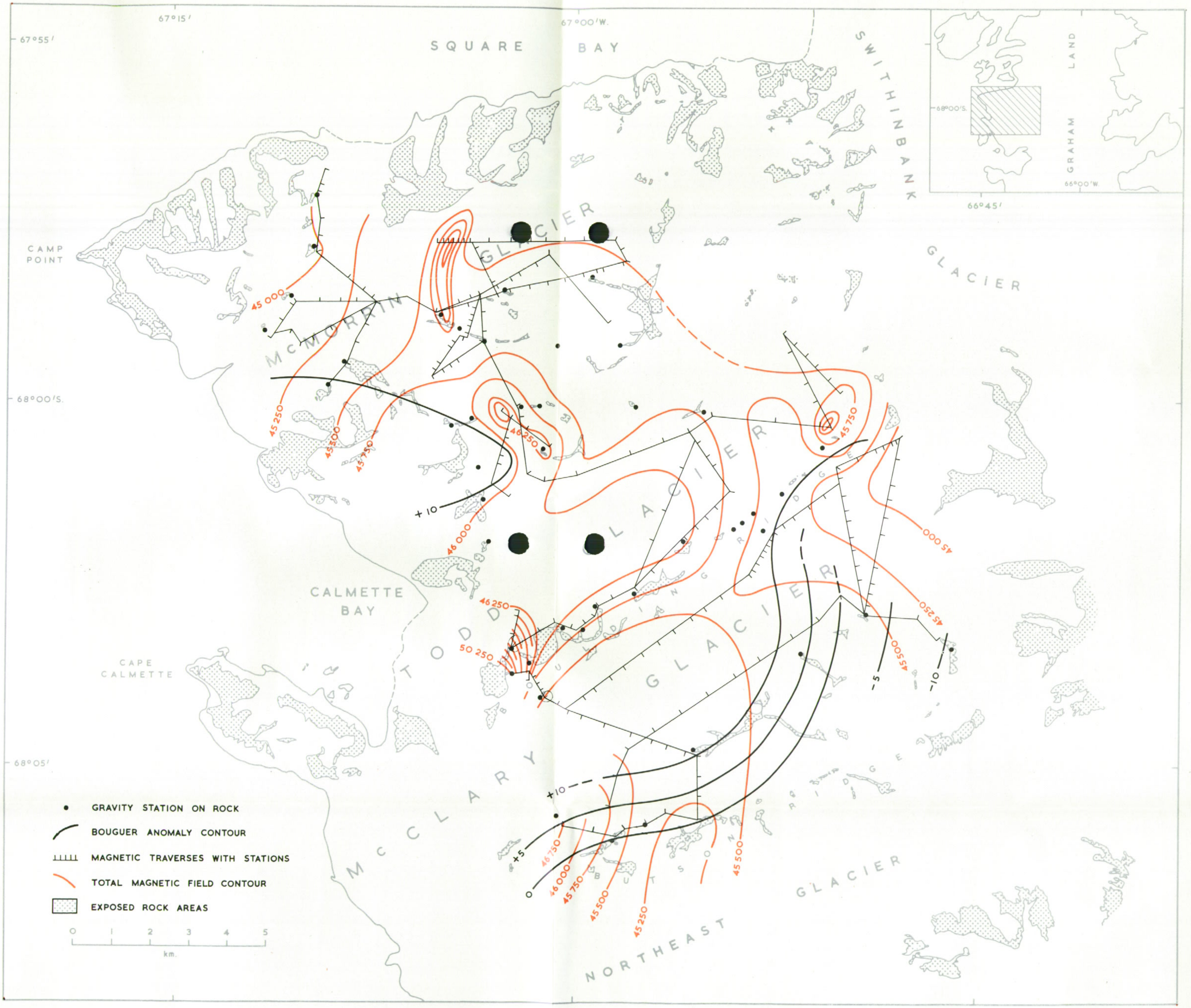
SQUARE BAY
SWITHINBANK GLACIER
GRAHAM LAND
CAMP POINT
McMORRIN GLACIER
CALMETTE BAY
CAPE CALMETTE
TODD GLACIER
McCLARY GLACIER
NORTHEAST GLACIER
67°15′
67°00′W.
67°55′
68°00′S.
68°05′
66°45′
66°00′W.
GRAVITY STATION ON ROCK
BOUGUER ANOMALY CONTOUR
MAGNETIC TRAVERSES WITH STATIONS
TOTAL MAGNETIC FIELD CONTOUR
EXPOSED ROCK AREAS
0 1 2 3 4 5
km.

Fig. 1.