GRAVITY MAP SERIES

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DOMINION OBSERVATORY

A Preliminary Investigation of Gravity Observations in the Somerset and Prince of Wales Islands Arctic Canada with map

No. 81—Somerset and Prince of Wales Islands

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and
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OTTAWA, CANADA

Department of Energy, Mines and Resources
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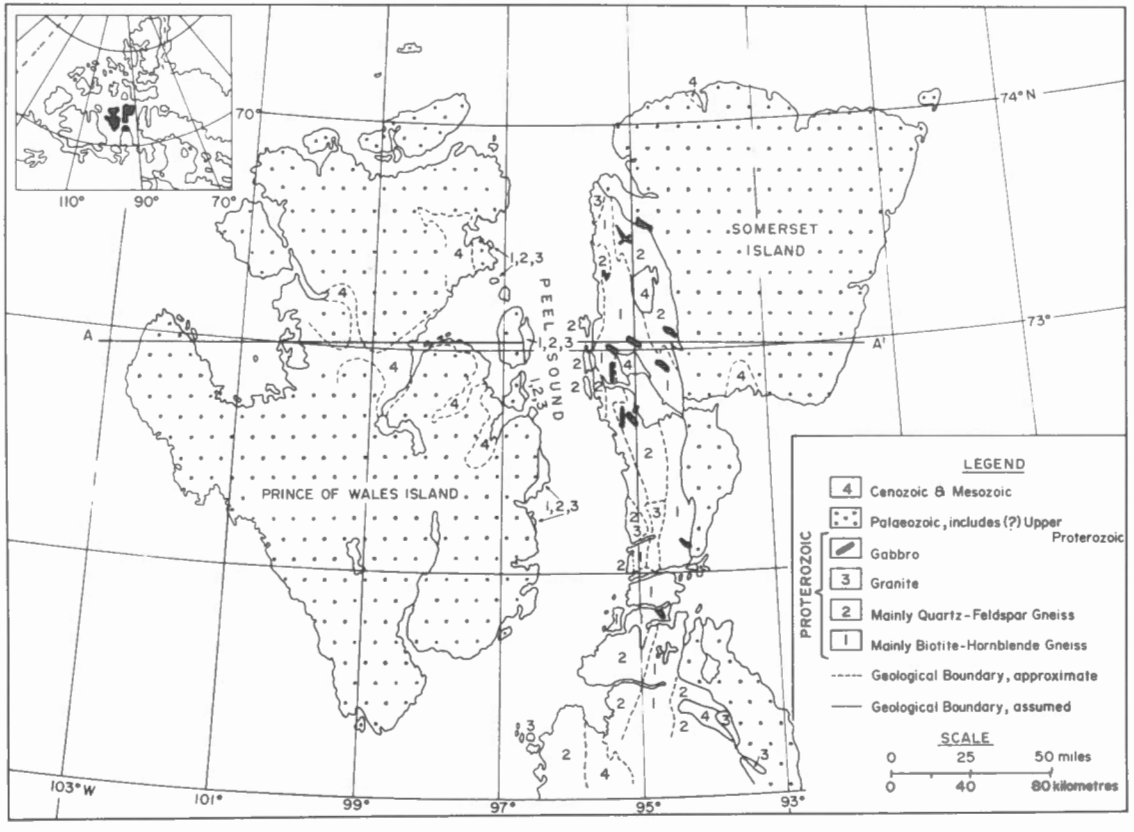

Figure 1. Geology of the Somerset-Prince of Wales Region (after Blackadar and Christie, 1963).

A PRELIMINARY INVESTIGATION OF GRAVITY OBSERVATIONS IN THE SOMERSET AND PRINCE OF WALES ISLANDS ARCTIC CANADA

A. W. J. Berkhout and L. W. Sobczak

ABSTRACT - During the spring and summer of 1965 some 750 gravity observations were made in the Prince of Wales and Somerset Islands area. The Bouguer anomaly map prepared from these data displays a series of north-trending highs and lows in the central and southern part of the area. These anomalies are attributed to density variations within the crystalline basement rocks. Two local gravity highs over western Prince of Wales Island are interpreted as indicating relatively near-surface basic intrusions.

RÉSUMÉ - Au cours du printemps et de l'été de 1965, quelque 750 observations gravimétriques ont été faites dans la région des îles Prince-de-Galles et Somerset. La carte des anomalies de Bouguer, dressée à partir de ces données, montre une série de hauts et de bas à direction nord dans le centre et le sud de la région. Ces anomalies sont attribuées à des variations de densité dans les roches de fond cristallines. Deux hauts gravimétriques locaux dans l'ouest de l'île Prince-de-Galles seraient des indices d'intrusions basiques assez près de la surface.

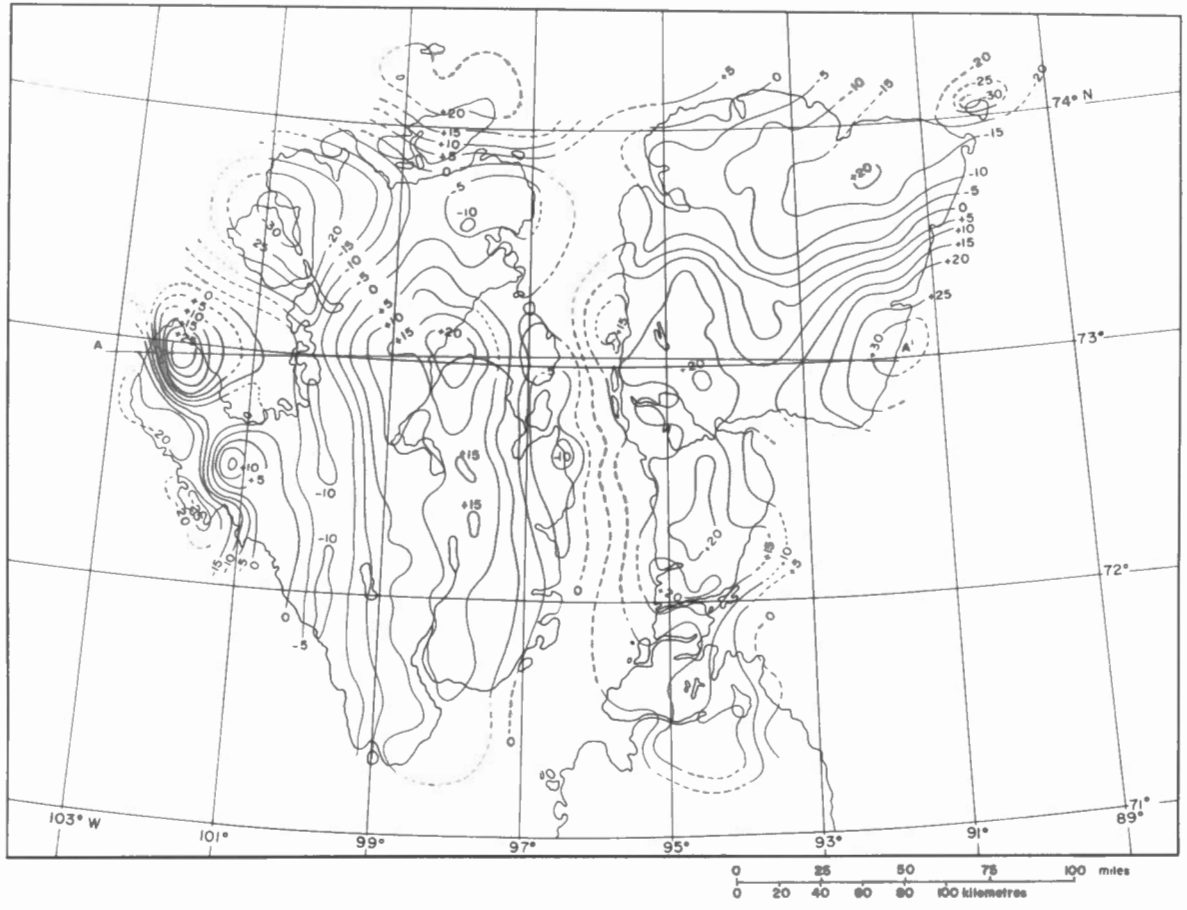

Figure 2. Bouguer anomaly map of the Somerset–Prince of Wales region (contours at intervals of 5 milligals).

INTRODUCTION

In the spring and summer of 1965 some 750 gravity observations were made in the Prince of Wales and Somerset Islands region of the Canadian Arctic Archipelago (Figure 1). The survey was carried out as part of the Polar Continental Shelf Project of the Department of Energy, Mines and Resources, Ottawa. In this report the data are presented in the form of a Bouguer anomaly map and a preliminary analysis of these data is made in response to the interest of the petroleum industry in the area. A more complete analysis is being prepared by Berkhout, as part of his graduate studies at Queen's University, Kingston.

The observations were made using a Bell 47G2A helicopter supported by an Otter aircraft. The gravity readings were made with a temperature-controlled Worden gravimeter with a scale constant of about 0.4 mgal/div. The control station network was established by the base looping method and the regional observations were taken by traversing in the helicopter. At each regional station the gravimeter, two altimeters and the wet and dry bulb thermometer were read. Wherever possible, rock samples were collected for density measurements.

The Bouguer anomalies were calculated using the system described by Tanner and Buck (1964) and are believed accurate to within one or two milligals (Sobczak, 1963).

GENERAL DESCRIPTION OF THE BOUGUER ANOMALY FIELD

The Bouguer anomaly maps (in pocket , and Figure 2) reveal a variable Bouguer anomaly field that is dominated by two differently trending systems . In the central and southern regions of the map area the main trend is northerly, but in the north this trend is replaced by one which is easterly to north easterly. Since the gravitational field has not been mapped completely in the northern part of the map area, the anomalies which trend easterly to north easterly are not discussed in this report.

TABLE I

AVERAGES AND RANGES OF BOUGUER ANOMALIES,

FREE AIR ANOMALIES AND ELEVATIONS

Values	Bouguer Anomaly (mgal)	Free Air Anomaly (mgal)	Elevation (ft)
Average	2.00	11.8	288
Maximum	32.6	66.3	1396
Minimum	-32.2	-32.2	0

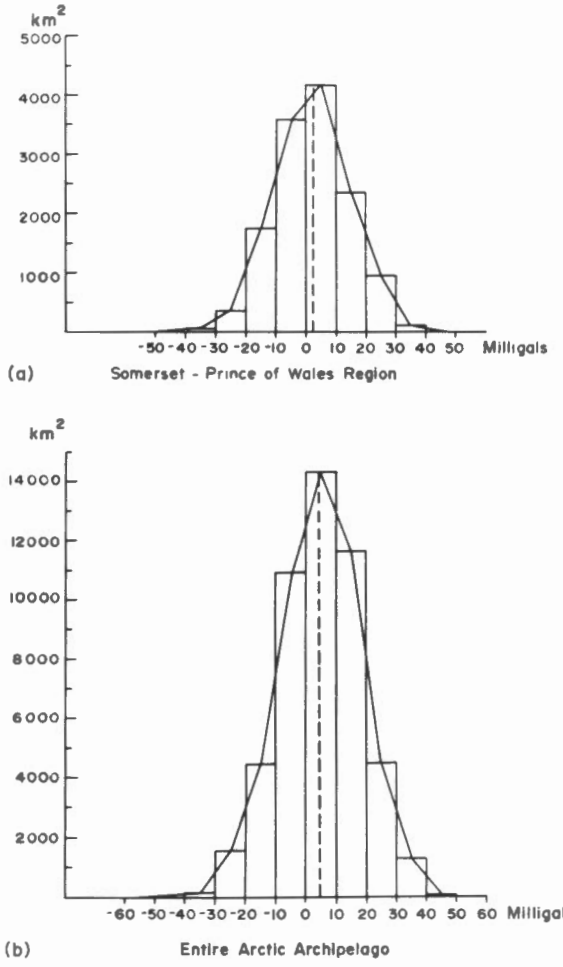

Figure 3. Surface distribution of Bouguer anomalies at intervals of 10 milligals for (a) Somerset–Prince of Wales region; (b) entire Arctic Archipelago.

The mean value of the Bouguer anomaly given in Table I takes no account of the distribution of stations. As a test of its validity a histogram (Figure 3a) was prepared in which the areas occupied by the anomalies at class intervals of 10 mgal were measured and plotted as a frequency distribution. The diagram shows this distribution to be approximately normal with a mode of 5 mgal, a mean of 2.4 mgal and a standard deviation of ±12.4 mgal. A second histogram (Figure 3b) prepared from this and other gravity data in the Arctic (Sobczak, et al., 1963), gave similar results; the mode 5 mgal, the mean 4.8 mgal, and the standard deviation ±13.5 mgal. These additional calculations confirm that the regional level of the Bouguer anomaly in this and the other regions of the Arctic studied to date is between 0 and 5 mgal, a level which differs considerably from the -40 mgal value over the Canadian Shield (Innes, 1960). There are several possible explanations for this difference. These include variations of crustal thickness and variations of the density of the crust or upper mantle or a combination of these factors.

REGIONAL GEOLOGY

The area lies within the Arctic Lowlands structural province which is situated between the Canadian Shield to the south and the Franklinian Miogeosyncline to the north (Thorsteinsson and Tozer, 1960). The province is underlain by generally flat-lying sediments disrupted by three salients of Precambrian rocks extending north from the main Shield area. One of these salients, the Boothia uplift (Fortier, et al., 1963; Kerr and Christie, 1965) is the main structure of the area considered here. It is flanked by the Victoria Strait Basin to the west and the Jones-Lancaster Basin to the east (Figure 4).

Lower Proterozoic rocks, mainly gneisses, form the central part of the Boothia uplift and are flanked on either side by upturned Palæozoic rocks. Late Cretaceous or Tertiary sediments are preserved as small outliers on the gneisses (Dineley, 1965 and 1966). The flanking basins contain sandstone, limestone, dolostone and conglomerate of late Precambrian or Cambrian to Devonian age (Blackadar and Christie, 1963; Tuke, et al., 1966).

Away from the Boothia uplift the sedimentary strata are predominantly flat-lying but near the axis of the uplift, folds and faults are developed. The eastern border zone, 25 to 35 km wide, has a step-like structure with linear belts of steeply dipping rocks separated by broad belts of gently undulating beds. Reverse faulting in the basement is postulated (Kerr and Christie, 1965). The western flank in which the sediments are overturned averages one kilometre in width. Numerous normal faults cut both the uplift and the flanking regions. Kerr and Christie (1965) cite stratigraphic evidence for uplift periods during Precambrian, Cambrian, Early, Middle and Late Devonian, and Pennsylvanian or Permian time, with prominent normal faulting in Tertiary time. Precambrian sills and dykes of gabbro intrude the Precambrian basement and basal sediments on Somerset Island (Blackadar and Christie, 1963).

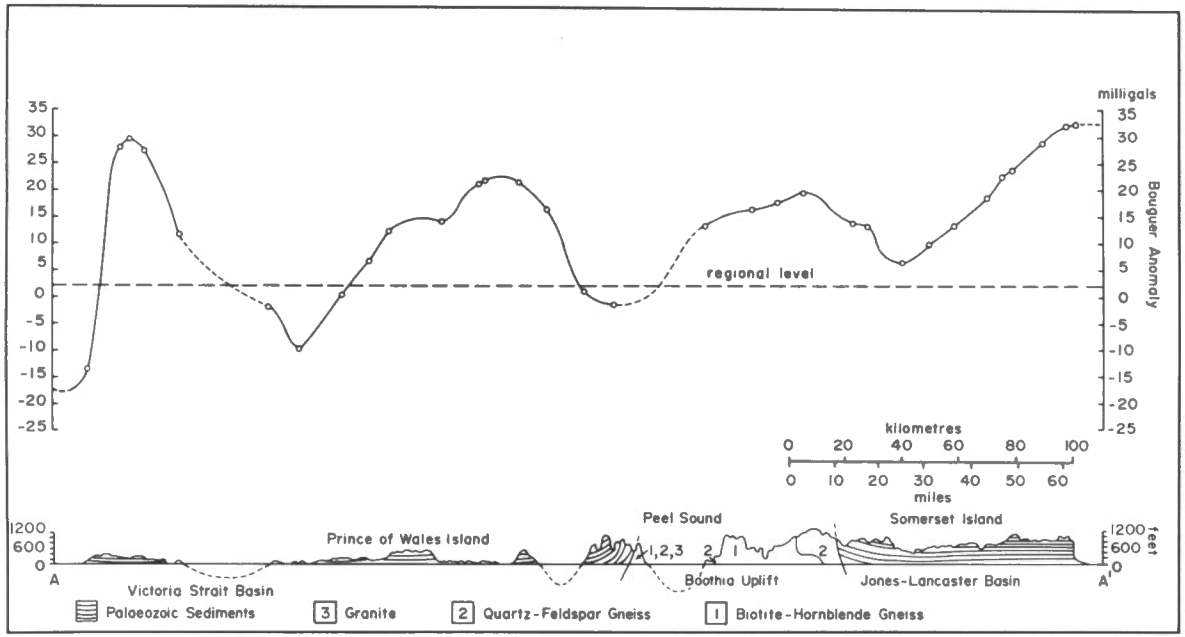

Figure 4. Bouguer anomalies along profile A - A[1].

DENSITIES

Samples of the different rock types in the area were taken by the survey party for density measurements. Density measurements of samples provided by R. G. Blackadar, R. L. Christie and R. C. Taylor were also made. A summary of these measurements is given in Table II, together with weighting factors for the rock types. The igneous and metamorphic rocks were weighted according to their areal distribution, the smallest unit being given unit weight. The sedimentary rocks were weighted according to their estimated thickness (R. L. Christie, personal communication) because weighting on the basis of surface exposure would give an anomalously high weight to the limestone which in most places occupies the upper part of the sedimentary column. On these bases the mean density of the metamorphic and igneous rocks is 2.76 g/cm^3 and that of the sediments is 2.73 g/cm^3.

TABLE II

SUMMARY OF DENSITY MEASUREMENTS

Rock Type	Number of Samples	Mean Density (g/cm^3)	Range of Density (g/cm^3)	Standard Deviation (g/cm^3)	Weighting Factor	
Biotite-hornblende (mafic) gneiss	52	2.85	2.61-3.48	±0.05	45	(1)
Quartz-feldspar (felsic) gneiss	51	2.67	2.52-2.87	±0.07	43	"
Granite	13	2.68	2.61-2.85	±0.07	6	"
Gabbro	19	2.91	2.69-3.01	±0.09	1	"
Dolostone	17	2.77	2.64-2.85	±0.06	5	(2)
Limestone	59	2.71	2.55-2.81	±0.05	5	"
Sandstone and conglomerate	22	2.63	2.34-2.85	±0.10	1	"

(1) According to areal distribution.

(2) According to approximate mean thickness.

CORRELATION OF BOUGUER ANOMALIES AND SURFACE GEOLOGY

The north-trending anomalies shown in Figure 2 are presented in an east-west profile through the central part of the map area in Figure 4. The Bouguer anomaly profile is roughly periodic with an average wavelength of 120 km and amplitude of about 10 to 15 mgal. Three sources may contribute to the anomaly field:

(i) the sedimentary basins,

(ii) variations in the near-surface basement rocks,

(iii) variations in rocks deep in the crust.

The carbonate sediments are considered to make only a minor contribution to the Bouguer anomalies. The observed anomaly over the Boothia uplift varies from -10 mgal in the west to +20 mgal in the east. Similar variations occur over the basins to east and west where the sediments are estimated to be about 3 km thick (Gregory, Bower and Morley, 1961). If a density contrast of 0.03 g/cm^3 between sedimentary and metamorphic rocks is used (Table II), the contribution of the carbonate sediments to the anomaly would be only about -4 mgal. Unless there are large thicknesses of very low density strata, such as evaporites, within the unexposed section of the sedimentary column the sediments cannot be considered important to the gravitational field.

There is no evidence for or against the possibility of deep-seated variations in crustal rocks, such as undulations of a discontinuity in density, but the surface geology of the Boothia uplift suggests that a correlation may exist between variations in near-surface lithology and the observed Bouguer anomaly. In the eastern part of the Boothia uplift mafic gneiss predominates over felsic gneiss and granite while in the west, the three rock types appear to be present in roughly equal proportions (Figure 1). If the density contrast of 0.18 g/cm^3 given in Table I between the mafic and felsic gneiss is adopted, the observed change of anomaly can be accounted for if the lithologic contrast extends to a depth of at least 4 km. Similar contrasts can explain the periodic character of the anomaly over the remainder of the profile, although the positive anomaly at the western end of the profile is in part probably due to near-surface basic intrusions as suggested in the next paragraph. This would require the existence of bands of predominantly mafic gneiss, extending to depths of 4 km or more below the sediments, at intervals of approximately 120 km.

The two well-defined, positive anomalies in western Prince of Wales Island may be caused by basic intrusions relatively near to the surface. The maximum depth to the top of the disturbing mass, estimated from the ratio of the observed change and the maximum horizontal gradient of the anomaly (Bott and Smith, 1958) is about 7 km. The more northerly of the anomalies coincides with the Rawlinson Hills which could be doming in the sediments as a result of the postulated intrusive activity.

CONCLUSIONS

The mean Bouguer gravity anomaly for the area is between 0 and 5 mgal, indicating a considerably different crust and/or upper mantle to that of the Canadian Shield. The principal feature of the Bouguer anomaly field is the zone of alternating positive and negative anomalies located in the central and southern parts of the area. It is postulated that the main source of these anomalies is a systematic variation of lithology within the basement complex; the gravity highs occur in areas where mafic gneiss predominates. Although sedimentary basins are present in the area, the available evidence suggests that they are not a major source of the anomalies.

The two local gravity highs on western Prince of Wales Island are believed to be caused by basic intrusions similar in composition to the dykes occurring within the Boothia uplift.

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