# GRAVITY MAP SERIES

of the

# DOMINION OBSERVATORY

## General Characteristics of The Gravity Field in West Central Quebec with Maps

No. 1—Eastmain
No. 2—La Grande
No. 3—Lac Bienville
No. 4—Great Whale

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## INTRODUCTION

These maps are the first in a series of Bouguer anomaly maps, at a scale of 1:500,000, which will release gravity data in a simplified form as soon as possible after completion of the field work. The reports accompanying maps will contain only generalized interpretation of the Bouguer anomalies, but will indicate correlation with geological structures wherever possible. In this report the gravity data for maps 1, 2, 3, and 4 of this series are discussed with respect to geological information obtained from Operation Fort George, carried out by the Geological Survey of Canada during the years 1957, 1958, and 1959.

## DESCRIPTIVE NOTES

The field work for the map area was carried out in 1958 by a Dominion Observatory field party* using two float-equipped Beaver aircraft for transportation. Each aircraft carried an observer who used a Worden gravimeter and two Wallace and Tiernan altimeters to make the gravity and elevation measurements respectively. The stations were sited on readily identifiable points along the shores of lakes throughout the area and, subject to the presence of suitable lakes for landing, were located at approximately 10-mile intervals. The regional field stations were established by traversing between control stations, taking single readings with both gravimeters and altimeters at each location.

The gravity control stations are part of a network extending over the whole of northern Quebec. This network, established by the well known method of looping, will be fully described in a subsequent publication. Circuit closures vary from a few hundredths to a few tenths of a milligal with the average about one-tenth of a milligal. In 1959, the network was adjusted relative to the control station of Baie Comeau airport (Bancroft, 1960).

Primary elevation control was provided by a spirit-level elevation** at Nemiscau 75 miles south of the map area, and a trigonometric water-level elevation*** at Clearwater Lake on the northern boundary of the map area. Wherever possible additional control was provided by altimeter ties to sea level

* R.K. McConnell and D.W. Lepard assisted with field observations.

** Supplied by Department of Hydraulic Resources, Quebec.

*** Supplied by Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa.

along the coasts of James and Hudson bays. A network of elevation control stations was established between Clearwater Lake and Nemiscau by the method of looping, and all elevation values for regional field stations were determined relative to these control stations.

Inaccuracies in the values of the Bouguer anomaly are caused mainly by uncertainties in station elevations. Other factors which affect the results are uncertainty of station location and errors in the gravity observations. During the course of the field work 40 stations were re-occupied using both gravimeters and altimeters and, in addition, 80 altimeter observations were made at sites where comparison could be made with elevation values supplied by other sources. Analysis of all elevation data yields a standard error of 20 feet with a maximum of 60 feet. Expressed in gravity units this means that the standard error in the anomalies due to uncertainties in elevation is 1.2 milligals with a maximum of 3.6 milligals. Repeated observations indicate a standard error of 0.2 milligal and a maximum 0.5 milligal in the observed gravity values. Co-ordinates of the stations were scaled from the best available maps, in this case 8 miles to the inch, but it is probable that the latitude values are not more accurate than 0.3 minute on the average, with the maximum error estimated to be 0.5 minute. The corresponding errors in the anomalies are 0.5 milligal and the maximum error 0.8 milligal respectively. Combining these, the average error in the Bouguer anomalies is 1.3 milligals and the maximum error is 4.0 milligals. While these may seem large it should be remembered that all errors are estimated in terms of the horizontal, vertical and gravity data currently accepted for Eastern Canada and that field techniques used were based on measuring differences. Therefore, the relative error between adjacent stations will generally be much less than the figures given above.

The conventional density of 2.67 gm/cc has been used to reduce the anomalies. The mean density for the area, based on measurements made on rock samples collected during the survey, is 2.72 gm/cc. Use of this higher density would alter the Bouguer anomalies by 0.6 milligal per thousand feet of elevation.

Principal facts for all gravity stations and location sketches of all control stations on the map are available upon request to the Dominion Observatory, Ottawa.

## GENERAL DISCUSSION OF THE BOUGUER ANOMALIES

As can be seen from the maps the gravity anomalies are all negative and their relief is rather low. The maximum observed anomaly is -26 milligals at Cape Jones near the northern end of James Bay while the lowest anomaly recorded is -77 milligals north of Lac Bienville. The mean anomaly for all stations is about -55 milligals. In a general way the anomalies tend to be more negative inland from Hudson and James bays, reflecting in part the isostatic effect of the higher elevations which is ignored in the Bouguer reduction. As the mean height of all the gravity stations is approximately 900 feet above mean sea level, and as the isostatic compensation is equal to about minus the attraction of the topography, it may be concluded that this area as a whole is overcompensated by nearly 25 milligals. Such over-compensation may be the expression of crustal depression due to glacial loading, and may be evidence that considerable uplift in this area has yet to take place before isostatic equilibrium is restored. A more complete analysis (Innes, 1960) of gravity data yields a similar result for a large area of the Precambrian Shield to the south and west of Hudson Bay.

## CORRELATION OF ANOMALIES WITH THE REGIONAL GEOLOGY

### (a) General Geology

Figure 1 provides a combined location and simplified geological map of the region. Geological information, obtained from two preliminary maps (Eade and others, 1957; Heywood and others, 1958) covers most of the region except for a small part located south of 53°N and between longitude 76°W and the coast of James Bay. The latter area is covered by an older reconnaissance map (Shaw, 1942) which does not contain the detail provided by those of Eade and Heywood.

Most of the area is underlain by Archaean gneisses, granites and related rocks which on the geological maps have been sub-divided into two main groups. One group, which underlies that portion of the map area to the south and east of Sakami Lake, consists of gneiss and schist derived primarily from sedimentary material. These rocks are interlayered with white to pink massive granite and pegmatitic granites, the largest exposure of which is in the vicinity of Low Lake.

A second group of granite-gneiss and associated granite underlies the central and northern part of the map area. The granite-gneiss consists of well-foliated rock with smaller amounts of well-banded paragneiss; in composition these gneisses vary from a granite to a granodiorite. Massive granites, granodiorites and pegmatitic granites are equally abundant and, as can be seen from Figure 1, occur in an irregularly-shaped, trunk-like mass with two arms extending from it. The main body, which varies in width from 10 to 100 miles, extends from the northeast corner of the map area and follows a slightly arcuate path southwestward to the Kanaaupscow area. The two branching arms extend from the central portion of this granite mass, one trending to the southeast near Lac Tilly, and the other northwest toward Great Whale on the Hudson Bay coast. Commonly these granites are pink to grey, massive to poorly foliated and may be porphyritic in part. They are gradational into the granite-gneiss so that the contacts between these units are arbitrary.

The only other rock types of any significance, insofar as the gravity data are concerned, is a series of Archaean volcanic and sedimentary rocks, here termed greenstones for convenience. This series occurs in two general belts (Figure 1), a central and a southern belt, both of which strike east-west. The former commences near Paint Hills Bay on the east coast of James Bay and extends eastward through the Duncan Lake area to the eastern limit of the gravity maps. Although not continuous throughout it can be considered as one belt broken by faulting and/or assimilation during granitization processes. The second greenstone belt (Shaw, 1942) lies along the Eastmain River which parallels the southern border of the map area. Lacking suitable sites for landing aircraft very few gravity stations are located in greenstone areas along the lower Eastmain River and only those outcrops within the eastern extension of this southern belt have been included in Figure 1.

As the area has been mapped in only a preliminary way, the structural features of the area are imperfectly known. Generally the trends are east-west except for the area southeast of Sakami Lake where there is a pronounced northeast-southwest trend. Near the eastern boundary of the maps there is some indication of a general change to northeast strikes. Eade (personal communication) has advised that this trend is very pronounced in the rocks found to the east of the map area.

Referring now to the gravity maps it can be seen that within the area there are no striking anomalies that persist over great distances and to some extent the contours appear to wander aimlessly. With careful inspection, however, it is found that the gravity anomalies exhibit a definite correlation with the surface geology: massive granites, granodiorites and pegmatitic granites generally are found to produce the more negative anomalies (hereafter termed negative), while the heavier granite-gneisses, paragneisses, and the Archaean volcanic-sedimentary rocks and their metamorphosed equivalents are found to produce the more positive (hereafter termed positive) gravity anomalies.

(b) <u>Areas of Negative Anomaly</u>

The most outstanding regional gravitational feature is the broad irregularly-shaped zone of lower-than-average Bouguer anomaly, that roughly coincides with the area underlain by massive granites. As the gravity data include effects of all anomalous masses whether near-surface or deep-seated, and as the granites and granite-gneisses are gradational into one another (Eade and others, 1957; Heywood and others, 1958) no particular level of the anomaly or gravity contour identifies the contact between these geological units. Relative anomaly amplitudes appear to be most significant and on the average the anomalies over the granites are 15 to 25 milligals lower than those over adjacent areas underlain by gneissic rocks. This correlation is particularly striking in the northern part of the map area.

One of the most pronounced negative anomaly areas in the southern part of the map sheet is centred about coordinates 52° 30' N and 76° 30' W in the vicinity of Low Lake. This anomaly trends east-west and on the average decreases 14 milligals across strike. The eastern portion of the anomaly correlates well with the band of granite and pegmatitic granite immediately to the east of longitude 76°W. It might be predicted, therefore, that this gravitational feature is largely controlled by these rocks, with the main granite mass centred in the Low Lake area.

Over an extensive area to the east of Sakami Lake the contours take on a northeasterly trend with gravity values decreasing to a low of less than -60 milligals. This area is underlain by gneiss and schist having moderately high densities and it seems probable that large unroofed masses of granite provide the major control of the anomalies. It is perhaps significant that the geological map shows two small bodies of massive granite near the centre of the low.

Before discussing the more positive anomalies a few remarks may be made concerning the observations in the southeast part of the map area. The Bouguer anomaly pattern here begins to show a northeast-southwest trend with the individual gravity anomalies becoming more negative southeastward. This feature marks the northwestern limit of the largest negative anomaly so far encountered in the Shield. This anomaly has been interpreted (Innes, 1957) as being probably due to a direct contrast in density between massive granites of lower density, and surrounding gneisses and schists of higher density.

(c) Areas of Positive Anomaly

Extending inland from the eastern shores of James and Hudson bays, higher gravity values are found throughout a large area which, for the most part, is underlain by granite-gneiss and paragneiss. Although generally more positive, the anomalies are quite variable and there are several individual gravity maxima within the region. Two of these, centred near Cape Jones and Fort George respectively, remain largely undefined insofar as these maps are concerned, since only the eastern extension of these anomalies is recorded.

Located northwest of Fort George, three positive anomalies with centres near Julian Lake, 54° 40'N, 76° 40'W and 54° 50'N and 75° 50'W, lie along a northeast line some 50 miles from the southeast coast of Hudson Bay. These anomalies, rising 10 to 15 milligals above background values and trending northwest, have a westward hook at their northern extremity and are separated from each other by somewhat negative anomalies. These positive anomalies cannot be completely explained on the basis of the surface geological information and as suggested subsequently may reflect a somewhat complex structural pattern.

Referring again to Figure 1 it is seen that the gneisses are rather highly folded in an east-west direction within the area of these three anomalies. This strong folding may well be the reason for the westward trend of the anomalies at their respective northern limits. In addition, Eade (personal communication) has indicated that the Julian Lake area is underlain by pyroxene-bearing gneisses which are probably more dense than the surrounding granite-gneiss; the presence of which would cause higher gravity values. However, these pyroxene-rich rocks only underlie, at the surface at least, the region covered by the northern portion of the Julian Lake positive, leaving the southern half of the feature unexplained and thus, perhaps, minimizing the effect of surface geology as an explanation of the anomaly. Also there is no information available to suggest that the surface geology can explain the sister anomalies to the northeast.

Under these circumstances several different suggestions could be put forward to explain this anomaly pattern, but one of the most interesting to the author relates these anomalies to structural trends associated, perhaps, with another period of deformation. Admittedly, no detailed analysis can be presented in defence of this argument at this time, but it can be pointed out that a circle of radius 50 miles, centred near 54°N, 77°W, encompasses a region in which the gravity anomalies trend in several directions (namely northwest, northeast, and east-west). Some of this variation can be directly related to structural trends observed on the surface and, on this basis, it does not seem unreasonable to suggest that the highs located northeast of Fort George may be related to trends not recognized on the basis of present geological information. Accepting a structural origin for these anomalies, then this very diversity of trend may well indicate that there was more than a single period of deformation.

Other positive regional anomalies are found associated with the Archaean volcanic-sedimentary belts with the most striking anomalies occurring within the central belt. Here the anomalies are highly variable, reflecting the large density differences between the rocks of the volcanic-sedimentary group and the granites. The most pronounced gravity high is in the vicinity of Duncan Lake and correlates well with an east-west trending exposure of volcanic sedimentary rocks some 30 miles long with a maximum width of 8 miles. The anomalies over the greenstones have a range of 14 milligals with higher values to the east, suggesting that here the rocks include denser phases of the volcanics, and/or are more persistent with depth. Horizontal gradients associated with this feature are larger than elsewhere within the map area. To the east in the vicinity of Alder Lake the gradient of the anomaly across the contact between the massive granites to the north and the greenstones to the south is almost 4 milligals per mile.

The greenstone belt trending northeast through the Sakami Lake area (Figure 1) appears to influence the gravity field only in a minor way. The anomalies here are not significantly higher than over the surrounding gneisses and, as the gravity contours trend northeast in the same direction as the folding in the gneisses, it may be concluded that the gneisses provide the major control.

Further to the northeast of Sakami Lake, in the vicinity of Lac Grande Pointe, the anomalies increase to form a pronounced northeast-trending gravity high. This anomaly, which has an over-all length of 35 to 40 miles and rises about 20 milligals above the background value, can be explained by the underlying gneisses and schists, included in which are amphibolites of high density derived from basic volcanic rocks. It is noted that the axis of this anomaly coincides with the synclinal axis of a major fold in these rocks.

## CONCLUSIONS

A preliminary analysis of gravity data in the Eastmain, La Grande, Lac Bienville and Great Whale areas has indicated the following:

1) From a consideration of the mean Bouguer anomalies and the mean elevation of the gravity stations, it is concluded that the earth's crust throughout this large area is over-compensated by about 25 milligals. Such over-compensation may be the expression of a depressed crust due to glacial loading - a crust not yet fully restored to isostatic equilibrium.

2) Major variations in the Bouguer anomaly field are caused by systematic differences in the density of the Precambrian rocks. The large granite masses in the area are characterized by negative anomalies while the more dense, surrounding gneisses tend to produce the more positive anomalies.

3) Large anomaly variations over the area underlain by gneiss may reflect both compositional and structural changes within these rocks.

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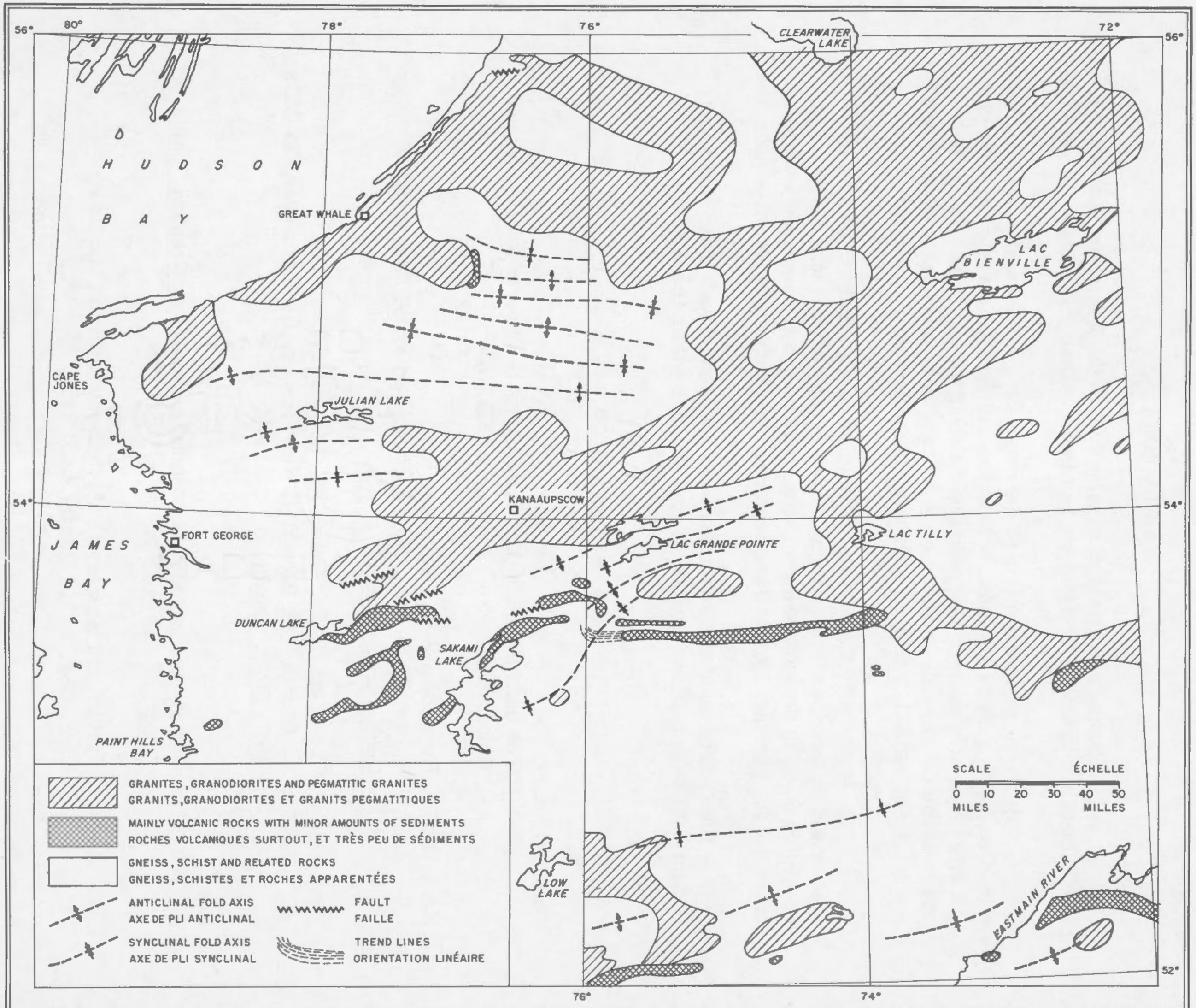


GEOLOGY AFTER EADE AND OTHERS, 1957; HEYWOOD AND OTHERS, 1958.
GÉOLOGIE ÉTABLIE D'APRÈS EADE ET AUTRES, 1957; HEYWOOD ET AUTRES, 1958.

FIGURE 1. LOCATION AND GENERAL GEOLOGY. SITUATION GÉOGRAPHIQUE ET APERÇU GÉNÉRAL DE LA GÉOLOGIE

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