GRAVITY MAP SERIES

of the

DOMINION OBSERVATORY

The Gravity Field
of
Northern Saskatchewan
and
Northeastern Alberta
with maps

No. 16—Green Lake—Stanley
No. 17—Mudjatik—Geikie
No. 18—Black Lake
No. 19—Lake Athabasca
No. 20—McMurray

R. I. Walcott

OTTAWA, CANADA

Department of Energy, Mines and Resources
OBSERVATORIES BRANCH

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CONTENTS

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R.I. Walcott

ABSTRACT - The report area covers National Topographic System sheets 74 and 73 NE and includes most of northern Saskatchewan and part of northeastern Alberta, Canada. The principal feature of the Bouguer anomaly field is a belt of intense anomalies parallel to the northeast structural trend of the crystalline basement of the region, bounded on the northwest and southeast by regions of comparatively low gravity relief. This belt comprises the Fond du Lac low, a linear anomaly at least 500 kilometres long, about 70 kilometres broad and with an amplitude of about -30 milligals, and the smaller Lisgar Lake and Stony Rapids highs with amplitudes of about +20 milligals. The Fond du Lac low defines a belt of low-density rocks which geological mapping in one area suggests are granites. If the change in load due to the crustal density changes is compensated, as implied by studies of earth deformation due to unloading of Pleistocene Lakes, then the crust is about 6 kilometres thinner beneath the low than in adjacent areas. A three-dimensional model based on postulates of complete compensation and lateral changes in crustal density can explain the major features of the anomaly field.

RÉSUMÉ - Le présent rapport porte sur la région représentée par les coupures de cartes n^{os} 74 et 73 NE du Système de référence cartographique national, et comprend la plus grande partie du nord de la Saskatchewan ainsi qu'une partie du nord-est de l'Alberta (Canada). La principale caractéristique de l'anomalie de Bouguer est une zone de fortes anomalies parallèles à l'orientation nord-est de la structure du soubassement cristallin de la région, bordée au nord-est et au sud-est par des régions à relief gravimétrique relativement faible. Cette zone comprend l'anomalie négative de Fond du Lac, anomalie linéaire longue d'au moins 500 km, large d'environ 70 km et d'une amplitude approximative de -30 milligals, ainsi que les anomalies positives moins étendues de Lisgar Lake et de Stoney Rapids dont les amplitudes atteignent +20 milligals. L'anomalie négative de Fond du Lac représente une zone de roches de faible densité qui pourraient être des granites, comme l'indique la carte géologique d'une de ces zones. S'il a pu y avoir compensation des changements de charge qu'ont entraînés les variations de densité de la croûte terrestre, ainsi que le supposent des études sur la déformation de la croûte due au vidage des lacs du Pléistocène, il est possible de conclure que la croûte est environ 6 km plus mince au droit du point bas qu'aux alentours. Il est possible d'expliquer, à l'aide d'un modèle tridimensionnel établi en supposant une compensation complète et des variations latérales de la densité de la croûte terrestre, les principales caractéristiques des anomalies.

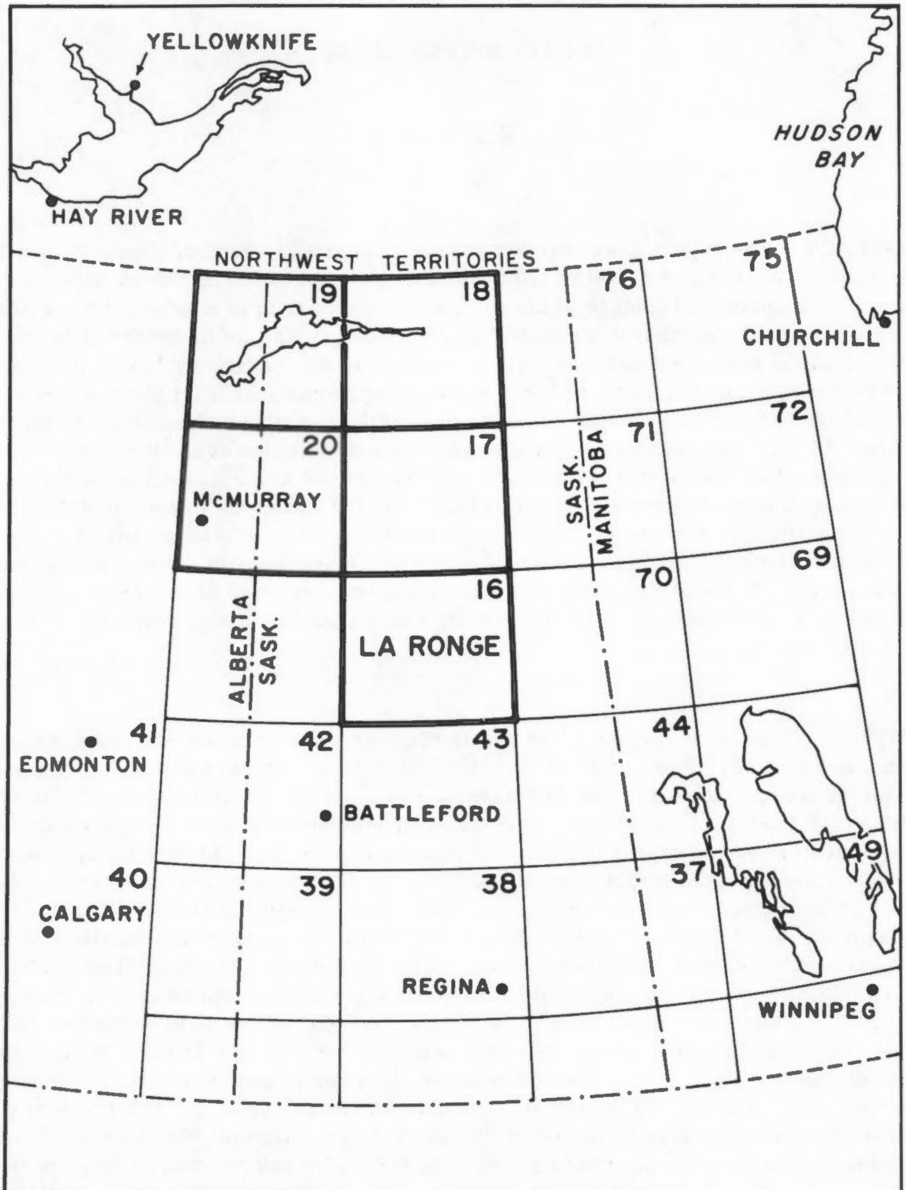

Figure 1 - Location map. The numbers are those of the published maps of the Gravity Map Series. The heavy line indicates the maps discussed in this report.

INTRODUCTION

The Gravity Map Series is a continuing program of the Gravity Division, Dominion Observatory, for the publication of Bouguer anomaly maps of Canada at a scale of 1:500,000. Maps 16 to 20 of that series cover the National Topographic System sheets 73 NE and the whole of sheet 74 in northern Saskatchewan and north-eastern Alberta. Gravity Map Series sheets 70, 71 and 76 join the area to the east (Gibb and McConnell, 1968) and sheet 43 (Buck, 1967) to the south (Figure 1). The maps were prepared from field observations made by the Observatory at a station spacing of about 8 miles (10-12 km) during 1960 and from data available from a few larger-scale local surveys also conducted by the Observatory.

The basic gravity data are Bouguer anomalies which are shown in units of tenths of milligals and contoured at 5 milligal intervals on the 1:500,000 maps accompanying this report. The report itself is divided into three parts. The first presents a description of the geology and topography as well as of the gravity of the area and is intended to provide the background necessary to interpret the maps. The second part examines the relationships between gravity and topography and gravity and geology and attempts to identify that part of the anomalous gravity field probably caused by topography and therefore unrelated to geology. The third part, titled 'Interpretation', discusses those difficulties encountered in analysis of very extensive gravity anomalies due to isostatic effects and to the physical nature of the mass anomaly and presents a simple three-dimensional model to explain the principal features of the gravity anomaly field.

Data and Accuracy of Observations

The survey was conducted in the same manner as described in previous publications of the Dominion Observatory (e.g., Tanner, 1961; Tanner and McConnell, 1964). The accuracy of the observed gravity values and those elevations determined by altimeter is therefore similarly estimated to be 0.25 milligal and 25 feet, respectively. Gravity control was provided by a network of stations tied by a LaCoste gravimeter. Elevation control was provided by roadside bench marks and the well determined elevation of Lake Athabasca. The Bouguer density used in the Bouguer reduction is everywhere 2.67 g/cm^3. The accuracy of the Bouguer anomalies is estimated to be equal to ± 2 mgal, most of the uncertainty being due to the poor elevation control. No correction was made for the terrain effect as relief is for the most part moderate. The correction is unlikely to exceed 3 milligals anywhere and is less than 1 milligal over most of the area.

The principal facts for all gravity stations and location sketches of the control stations are available on request from the Dominion Observatory, Ottawa (Winter, 1967).

DESCRIPTIVE NOTES

Topography

A broad, gently warped plateau covers most of the area (Figure 2). Its surface is one of low relief although a few topographic residuals, steep-sided flat-topped

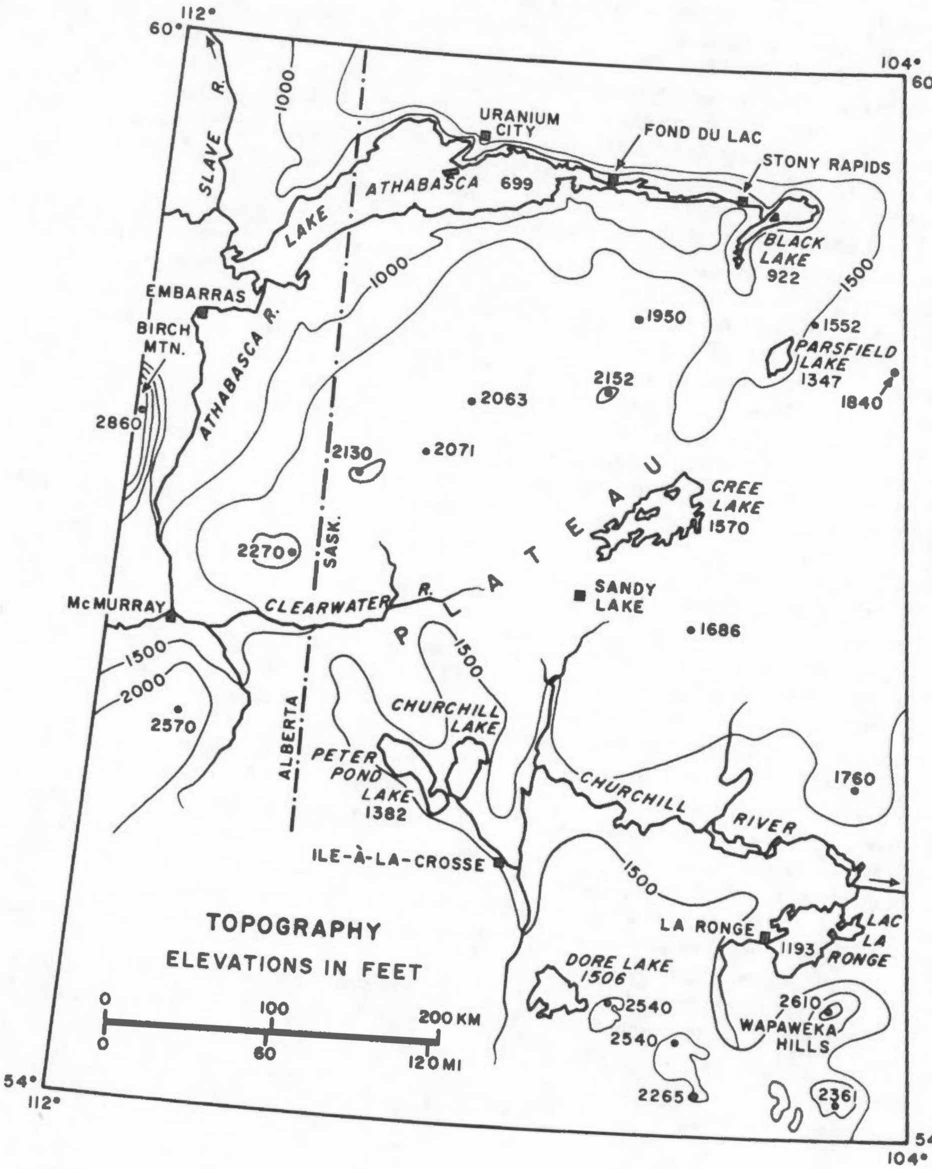

Figure 2 - Topography with contours in 500-foot intervals.

hills, rise 1,000 feet above the plateau in the south and west. South of Lake Athabasca the plateau edge is defined approximately by the 1,500-foot contour (Figure 2) and the average elevation of the plateau is 1,670 feet. North of the lake the mean elevation is about 1,550 feet. Lowlands surrounding Lake Athabasca and extending westwards and north of Slave River form a distinct break in the plateau. The elevation of the lowlands in the vicinity of Lake Athabasca is about 700 feet and decreases northward toward Great Slave Lake in the Northwest Territories to about 500 feet. The boundary between the plateau and the lowlands is in places abrupt, as on the north shore of Lake Athabasca, elsewhere elevations first increase rapidly from about the 800- to the 1,100-foot contour and thereafter rise less rapidly to the plateau edge.

The two major river systems in the area are the eastward-flowing Churchill River which rises in the plateau south of Lake Athabasca and discharges into Hudson Bay and the Athabasca River system which rises in the Rocky Mountains, and flows northeastwards into Lake Athabasca and then by way of Slave River, Great Slave Lake and the Mackenzie River flows northwards into the Arctic Ocean. The minor drainage pattern is a dendritic network of small streams and lakes which drain into either of the two river systems. The watershed between the two river systems is ill-defined and follows a tortuous route across the broad swell of the plateau south of Lake Athabasca.

Geology

The report area lies at the southwestern margin of the exposed portion of the Churchill Province of the Canadian Shield, and Precambrian rocks consisting of a crystalline basement complex and flat-lying Late Proterozoic sandstones are exposed, or covered by only thin drift in about two thirds of the area (Figure 3). The remaining third consists of flat-lying Palaeozoic and Mesozoic sedimentary rocks which thicken progressively towards the southwest above a gently dipping surface of low relief cut on the crystalline basement.

The crystalline basement complex consists of strongly folded metamorphic and intrusive rocks which range in composition from alkaline granite and quartzite to norite, basic granulite and peridotite. The structure is complex even over short distances but a broad structural trend in a northeast-southwest direction gives a pronounced structural grain to the region. Most of the rocks of the basement complex have assemblages indicating amphibolite or granulite facies metamorphism; the remainder are retrogressively metamorphosed rocks and are commonly associated with shear zones and faults.

Comparatively little of the basement complex has been mapped at a scale of 1 inch to a mile or larger although most of the area has been covered by 1 inch to 4 mile reconnaissance surveys. One of the most extensive areas which has been covered by large-scale mapping occurs at the east end of Lake Athabasca in the vicinity of Stony Rapids (Johnstone, 1960, 1961, 1962, 1963, 1964; Colborne, 1960, 1961, 1962; Colborne and Rosenberger, 1963) and is shown in Figure 5.

There, a conformable sequence of metasedimentary and metavolcanic rocks is composed of biotite gneiss, biotite augen-gneiss, hornblende-biotite gneiss, meta-arkose, garnet-quartz-feldspar gneiss, gneissic noritic rocks, pyroxenite and volcanic tuff interbedded with biotite gneiss. The sequence is intruded by syntectonic and post-tectonic plutons of granitic rocks mostly composed of biotite-granodiorite. This area is typical of those parts of the basement complex which have been mapped. Compara-

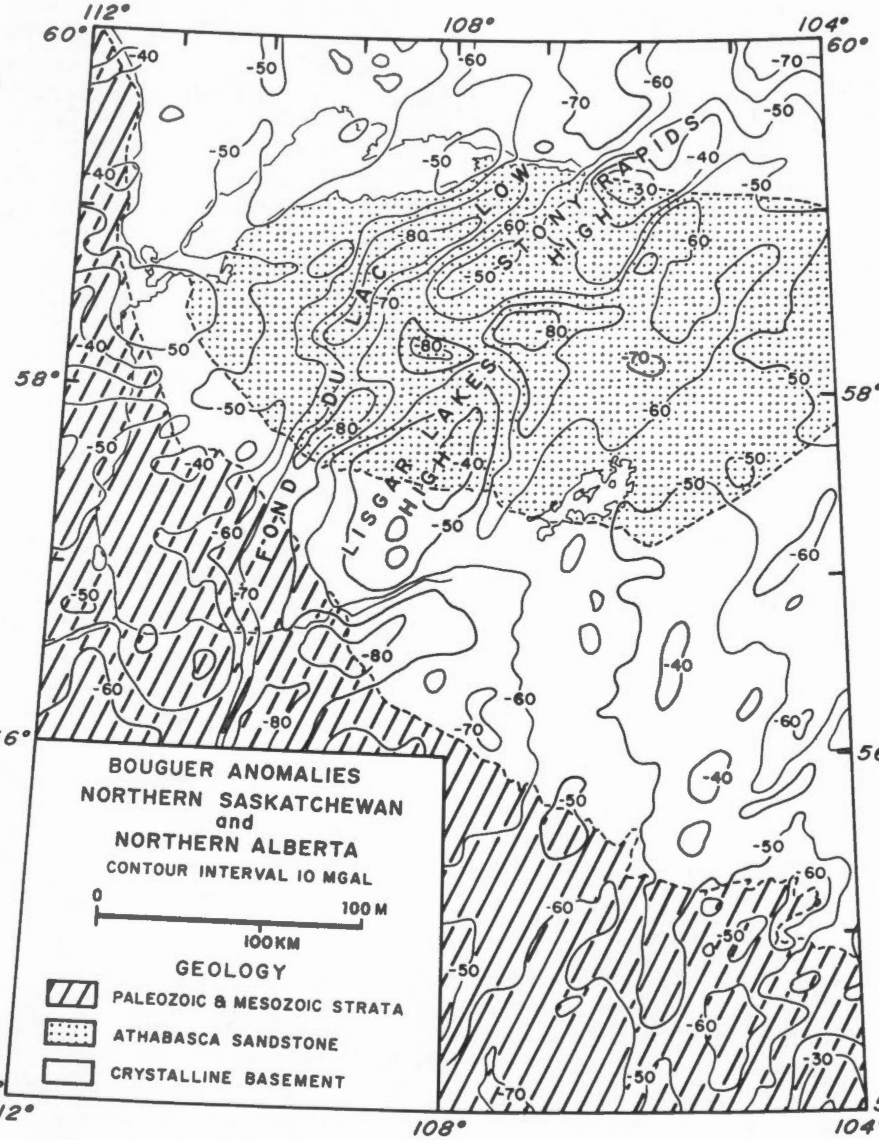

Figure 3 - Outline of Bouguer anomalies and major geological divisions.

tively little work has been done on the metamorphism of the basement rocks although Money (1965) includes a detailed description of the assemblages in the vicinity of Needle Falls, Churchill River.

The Athabasca formation (Fahrig, 1961) consists of interbedded shale, sandstone and conglomerate, by far the greatest proportion being sandstone. The formation has an approximately elliptical outline measuring 240 x 140 miles and unconformably overlies the crystalline basement immediately south of Lake Athabasca. The age of the formation is probably Proterozoic. A minimum age is given by pitchblende veins cutting the sandstone which have a Pb^{206}/U^{238} age of 400 m.y.

Rock Densities

About 255 specimens of the crystalline basement were collected during field work by the Gravity Division and their density measured in the laboratory. The unweighted average density was 2.69 g/cm^3 with a range of 2.54 to 3.14 g/cm^3. These results may be compared with the detailed analysis of Gibb (1968) who obtained an average density of 2.67 g/cm^3 for approximately 2,000 specimens from the Shield in the Nelson River area, weighted according to their abundance.

Twenty specimens of Athabasca sandstone showed a range of 2.30 to 2.50 with an unweighted mean of 2.37 g/cm^3. This, the dry density of the formation, is likely to be considerably lower than the field density because the rocks are moderately porous and will tend to be saturated. The bulk density is considered therefore to be about 2.40 - 2.50 g/cm^3.

Bouguer Anomalies

Bouguer anomalies have a range of 69 milligals from a minimum of -87 to a maximum of -19 milligals and the mean Bouguer anomaly for the area is -55 milligals based on 1,300 approximately equally spaced observations. Those parts of the anomaly map in which the anomalies are systematically greater or less than the mean will be referred to as gravity highs and lows, respectively.

The most striking feature of the Bouguer anomaly map (Figure 3) is the central belt of unusually intense linear gravity highs and lows parallel to the structural trend in the basement rocks. On either side of this central belt anomalies show comparatively low relief except in the extreme south of the area. In this report attention is principally directed toward the anomalies of the central belt and only passing reference will be made to anomalies outside the belt.

A continuous gravity low within the central belt, given the name Fond du Lac low cuts right through the area and is bounded on the west by an area of low gravity relief and on the east by a discontinuous high. The Fond du Lac low is at least 500 km long, averages about 70 km in width, and is about -30 milligals in amplitude. The names Stony Rapids high and Lisgar Lakes high are given to the adjacent gravity highs (see Figure 3). These two highs are separated by an east-west trending gravity low which diverges from the Fond du Lac low expanding eastward to form a large area of low gravity with locally intense anomalies.

CORRELATION OF GRAVITY

Topography

A mean free-air anomaly of -9.2 milligals occurs in the area of N.T.S. sheet 74. Such an anomaly may be due to a combination of causes; incomplete attainment of equilibrium following removal of a Pleistocene ice cap (Innes and Weston, 1966), the influence of the mass deficiency of compensation for the Rockies, or may indicate other wide and perhaps deepseated mass anomalies. However, analysis of this regional anomaly can only be attempted over a larger area than that investigated here. Accordingly it is assumed that the regional anomaly is constant everywhere throughout the area and is equal to -10 milligals.

On very small-scale maps there is a clear inverse relationship between elevation and Bouguer anomaly (viz. Bouguer Anomaly Map of Canada, 1968) indicating compensation for variations in regional topographic load of the earth's crust. On larger-scale maps the relationship is not so clear, partly because of the smaller amplitude of the anomalies due to compensation and partly because of the obscuring effect of the anomalies associated with geological structures. If it is assumed that topography is compensated in some particular manner then the Bouguer anomaly due to the compensating masses can be calculated and compared to the observed Bouguer anomalies. In the present case it is assumed that compensating masses are condensed as a surface density at a depth of about 40 km. The gravity effect of these compensating masses was calculated to a radial distance of approximately 150 kilometres and to this was added the isostatic effect of the more distant topography in the Hayford zones 18 to 1 from Kärki, et al. (1961). The resulting values (Figure 4a) corresponding to the isostatic correction with reversed sign are compared to the trend of observed Bouguer anomalies obtained by fitting a third-degree polynomial surface by least mean squares (Figure 4b). In comparing the two surfaces it can be seen that though there is considerable correspondence in amplitude there is also some considerable divergence in shape. This divergence must be due at least in part to the intense northeast-trending 'geological' anomalies of the central belt which tend to obscure the east-west trend indicated in Figure 4a. Nevertheless the considerable correspondence in amplitude (both surfaces show a range of from -40 to -60 milligals) and the broad correspondence in shape (a broad low in the south rising towards the northwest) indicates that the trend is probably due to the change in compensation with change in topography. The gravity effect due to topography, however, does not vary by more than about 20 milligals throughout the entire area. The conspicuous regional anomalies must therefore be due to some other cause.

Geology

Gravity contours on both the free-air and Bouguer anomaly maps follow in a general way the structural trend of the crystalline basement and it is likely that gravity anomalies are closely related to the density variation within the basement. It is, however, very difficult to demonstrate this unequivocally, largely because of the disparity in scale between geological and gravity mapping. Large-scale geological mapping is necessary to delineate the variation in basement rock types because of the small size of rock units of uniform lithology and because of the extremely complicated structure.

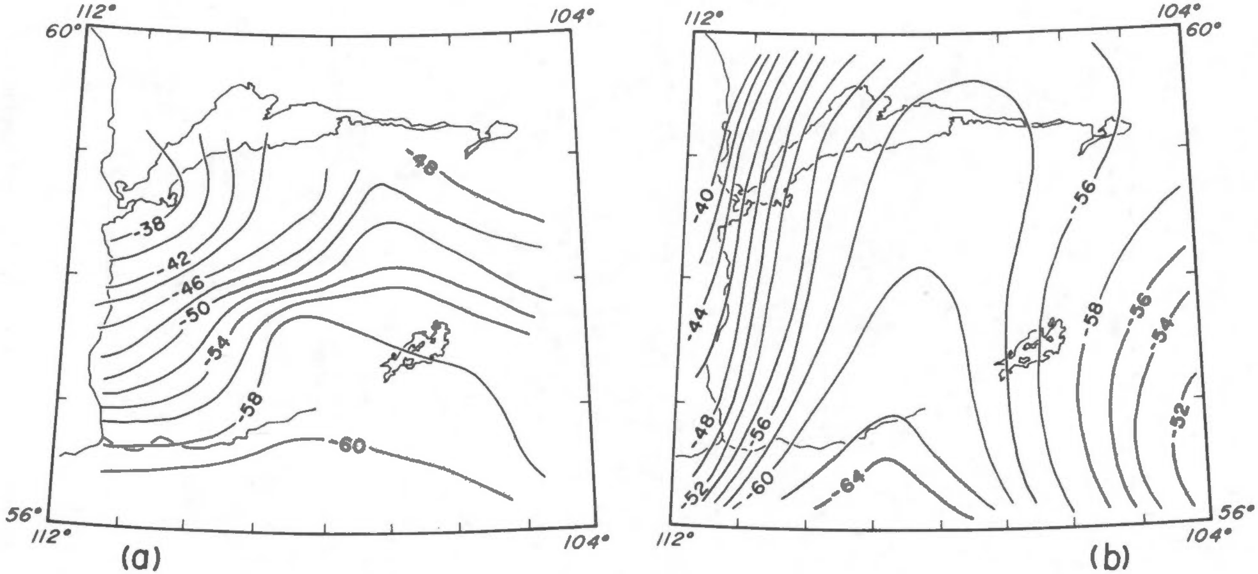

Figure 4 - (a) Calculated gravity effect due to masses compensating for topography.
(b) Third-order polynomial trend surface of observed Bouguer anomalies.

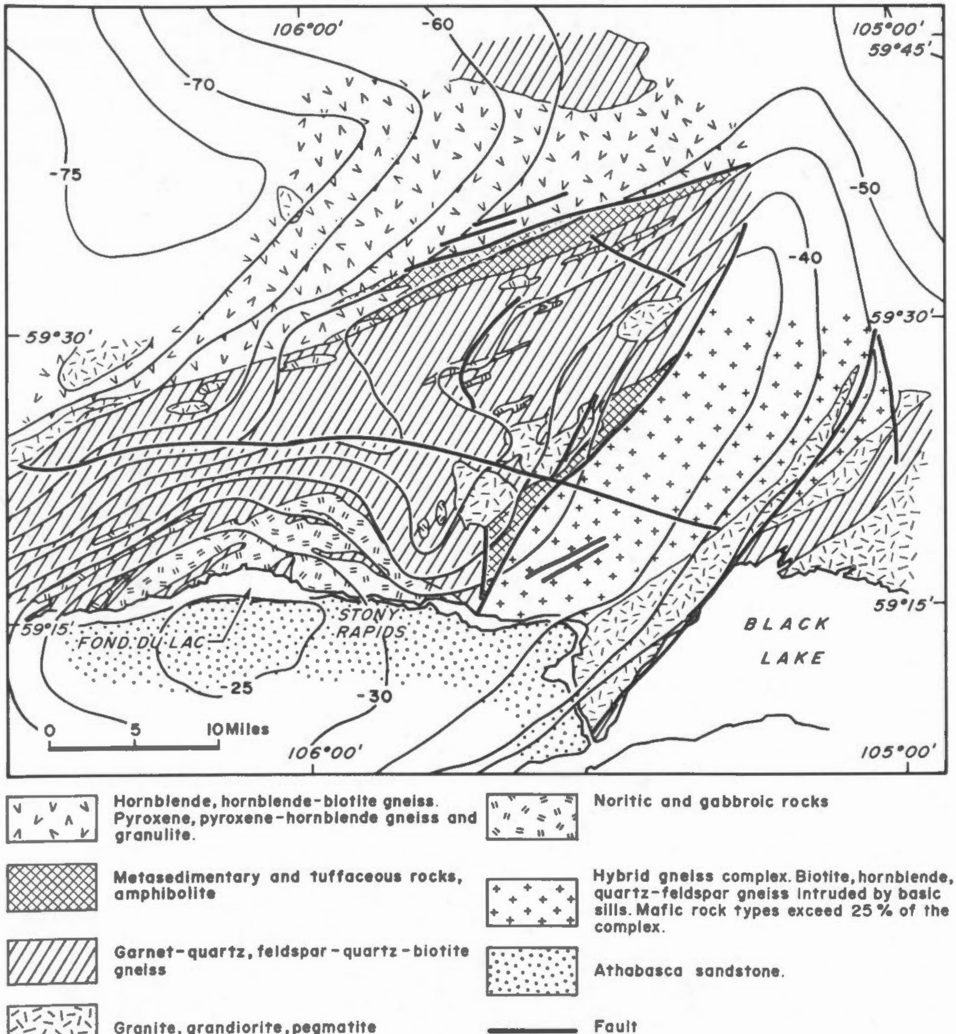

Figure 5 - Bouguer anomalies and geology in the Stony Rapids area.

This is clearly shown by the large-scale mapping, 1 inch = 800 feet, carried out in the vicinity of Milliken Lake (Bell, 1955). Apparently, in the Canadian Shield a scale of 1 inch to 1 mile is the smallest that can be conveniently used without compromising lithologic discrimination, but on this scale formations are at least two orders of magnitude smaller than the gravity highs and lows of interest. Another difficulty is that with gravity observations at 8-mile intervals it is impossible to correlate highs and lows with rock units of smaller dimensions.

These problems have been partly overcome in the vicinity of Stony Rapids on the eastern side of Lake Athabasca. There, large-scale gravity and geology mapping provides one of the few areas where a detailed study of the relationships between gravity and geology can be made. Figure 5 shows a generalized geological map of the area together with Bouguer anomaly contours. The geology has been published by the Department of Mineral Resources, Province of Saskatchewan (see References to Colborne; Colborne and Rosenberger; and Johnstone), and the gravity data is taken from Bouguer anomaly map No. 18 of the Gravity Map Series. The gravity contours follow the structure of the region closely. The gravity high in the vicinity of Stony Rapids is clearly related to the noritic rocks of higher than mean regional density and also to the hybrid gneisses, a formation containing at least 25% mafic rocks (Johnstone, 1963). At first sight the Bouguer anomaly low at the northwest side of Figure 5 is also related to high-density rock as it lies at the edge of a formation containing a high proportion of mafic rock types, hornblende gneiss and pyroxene granulite. However this is misleading as the formation is underlain at least in part by granite which intrudes the formation, generally as dyke and sills too small to be shown on the map of Figure 5. The proportion of granite increases to the north and west and at the limit of the geologically mapped area granite exceeds metamorphic rocks in volume (Johnstone, 1961). The low is manifestly related to the low-density granitic rocks.

There is a large density contrast between the Athabasca sandstone and the Palaeozoic strata on the one hand and the basement on the other, probably about 0.3 g/cm^3. Relief at the base of the superincumbent strata of around 2,000 feet will give rise to anomalies of not more than 8 milligals. Such anomalies will, if present, be superimposed on a background of anomalies due to basement geology of more than 40 milligals amplitude. Therefore it is not likely that reconnaissance mapping can provide information as to the relief at the base of the superincumbent strata. More detailed local surveys, however, may be of some value in structural interpretation of the sandstone if adequate separation of the gravity effects of the basement and sandstone can be achieved.

INTERPRETATION

In the interpretation of gravity anomalies of small area it is usually possible to ignore any isostatic gravity effects as very much less intense than the observed anomaly. Also the nature of the disturbing mass is generally simple and a single body with a uniform density contrast may be sufficient to explain the anomaly. Both of these points need a critical re-evaluation in the interpretation of larger-scale, regional anomalies. Therefore before going on to suggest a possible model for the central belt anomalies a short discussion of the isostatic effect and the nature of the disturbing mass is given.

Isostatic Effect

Northern Saskatchewan has been a tectonically stable region since the Late Proterozoic and the basement structure seen today has been preserved since that time. The gravity anomalies, too, have presumably persisted since the Late Proterozoic because of their correlation with basement structure and lithology. Therefore, we may conclude that the upper crust has been able to support stress differences sufficient to cause anomalies of about 70 milligals for hundreds of millions of years. Yet studies of crustal response to surface unloading of North America (e.g., Farrand, 1962; Broeker, 1966; Mathews, 1967) and Fennoscandian (Niskanen, 1948) ice caps and, most important, Lake Bonneville (Crittenden, 1963) indicate a change of elevation with time which follows an exponential decay curve with a relaxation time measured in only thousands or even hundreds of years. In particular, Crittenden has demonstrated that the unloading of 450 feet (145 metres) of water from Pleistocene Lake Bonneville, a change in load equivalent to a gravity anomaly of only 6 milligals, covering an area of 200 x 100 miles, caused a rise of about 210 feet (64 metres) near the centre of the load. Therefore, although it is evident that the upper crust has sufficient strength to support large stress differences for considerable lengths of time, the earth as a whole deforms easily and quickly and appears to have very low long-term strength for loads of the size of Lake Bonneville. This apparent conflict is resolved in those earth models in which a strong crust floats in hydrostatic equilibrium on a weaker and denser substratum. Loads on or within the crust in these models are supported by down-buckling of the crust-mantle boundary and, in part, by rock strength. The important feature of the Lake Bonneville example is that it gives an estimate of the magnitude of the stress difference that can be supported by rock strength alone, and, if we assume the crust-mantle boundary moves in the same way as the surface of the earth, a measure of the degree of compensation that has been attained. Crittenden reports that 75% of compensation has been achieved within the last 25,000 years with initial and present stress differences of 30 bars and 7 bars, respectively. Upward movement, however, appears to be continuing at present (Crittenden, 1963, Figure 3). The implication is that loads in excess of 7 bars are compensated at depth and loads that have existed for many millions of years are likely to be almost, if not completely, compensated. The same should be true of loads within the crust as for superincumbent ice caps or topography. Therefore any regional crustal density change giving a gravity anomaly is likely to be largely compensated and the gravity field will be made up of the gravity effects of the anomalous crustal mass together with that of a compensation mass.

It may be argued that the example of Lake Bonneville, situated as it is in the Basin and Range Province of the Western United States cannot be regarded as typical and that the situation under the Shield areas may be completely different. The extremely short relaxation times of uplift following deglaciation in the Canadian Arctic of about 700 to 2,000 years (Mathews, 1967) suggests, however, that the rheological properties of the mantle are similar in the two areas and that the deductions from Lake Bonneville are probably just as relevant there as in the Basin and Range Province. Therefore we have one important constraint imposed on any model to explain large gravity anomalies such as those of the central belt; a compensation mass should be included as an integral part of the model.

The Anomalous Mass

Because of the coincidence of the gravity contours with structural trends seen in the surface geology and the relationship between rock densities and Bouguer anomalies, variations in crustal density appear to be an adequate explanation of the anomalies - it is unnecessary with present knowledge to postulate that the anomalies are due to any other cause, e.g., tectonic forces or deeper seated anomalous masses. It is therefore presumed in the following discussion that anomalies such as the Fond du Lac low are caused primarily by variation in crustal density and indicate large-scale changes in lithology.

However the representation of the mass anomaly in such a case is a very difficult problem and differs in this aspect from studies of anomalies of smaller dimensions. For, whereas the smaller mass anomalies are around the same size as the uniform lithological units and can therefore be reasonably represented by a single body of uniform density contrast, the larger mass anomalies are undoubtedly composite and structurally complex in detail. This is demonstrated by the change in lithology associated with the Fond du Lac low in the vicinity of Stony Rapids. There, as previously mentioned, the proportion of granite intruding metavolcanic rocks increases towards the axis of the low over a distance of several tens of miles. Thus the shape of the larger gravity anomalies may be principally controlled by lateral density variations whereas the shape of the smaller gravity anomalies may be related to the shape of the mass anomaly itself. In other words, in smaller gravity anomalies we generally have sufficient information to deduce the shape of the mass anomaly because we can represent the mass anomaly by a simple structure of uniform density contrast; with the larger anomalies this can be only exceptionally true and we have to recognize that gradational density changes are often an important feature of the mass anomaly.

Any analysis of regional gravity anomalies without detailed information on the density distribution and structure, as in the case of the Fond du Lac low, can therefore be only approximate.

A Model for the Central Belt Anomalies

A three-dimensional model for the central belt is shown in Figure 6. This model is based on the assumptions of simple crustal block structure in which each block has uniform density and is compensated for the differential loading due to the crustal density changes. The gravity field was computed by the method of Nagy (1966) and is shown in Figure 7 compared with the actual isostatic anomaly field. The latter is derived from the Bouguer anomaly field by subtracting the field of Figure 4a. The two patterns show first-order coincidence of wavelength and amplitude of the anomalies, the most obvious difference being the very much steeper gradients in the gravity field of the model. The absolute values of density and thickness used in the model are to some extent arbitrary - the all important parameters are the density and thickness contrasts. Outside the central belt a mean crustal density of 2.86 g/cm^3 and a thickness of 40 km was chosen conforming to the standard crustal sections in Smith, Steinhart and Aldrich (1966, p. 1163) and the deep crustal structure of the plains given in Kanasewich (1966). It would make little difference to the computed gravity field if a density of 2.75 g/cm^3 and thickness 35 km had been alternatively used as long as the density and corresponding thickness contrasts were maintained.

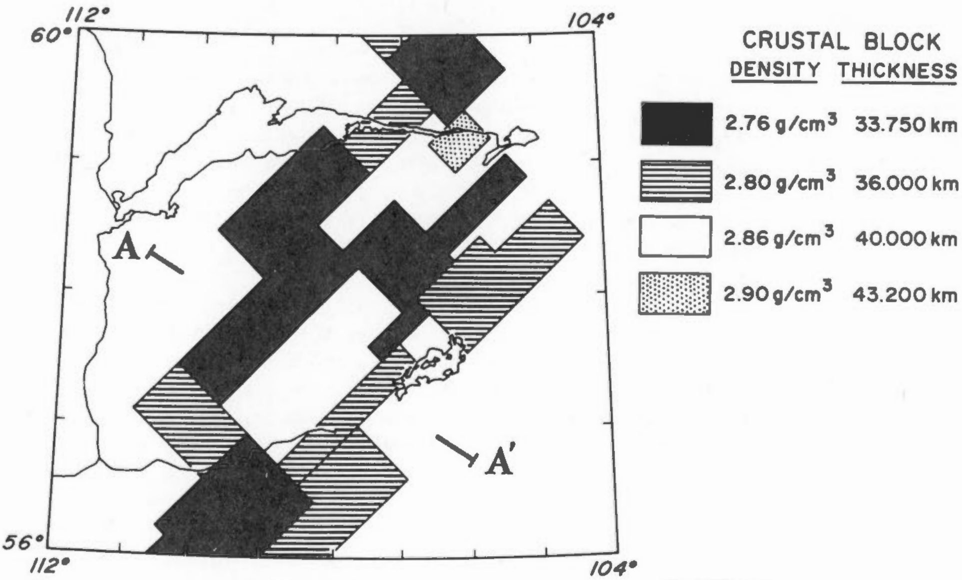

Figure 6 - An isostatically compensated model for the central belt anomalies. A-A' is the line of section for Figure 9. Density and thickness of each block is indicated. Density of mantle assumed at 3.4 g/cm^3.

Although convenient for computation the model is obviously a considerable simplification of likely geological structure. We can expect that density changes in many cases are gradational rather than abrupt and it is possible that most of the gravity difference between adjacent blocks is contributed by density contrasts in the upper 10 km of the crust. It is therefore necessary to examine the effect of such changes on the gravity anomaly patterns. In particular it is necessary to determine whether gradational boundaries so alter the gravity anomaly as to invalidate the simple three-dimensional block model as a useful interpretative tool.

To gain some insight into the possible effects such changes have on the computed gravity, a number of simple, theoretical crustal models involving compensation are given in Figure 8. The compensated step (Figure 8a) is basic to all models described here. If the boundary between two compensated blocks is vertical then the anomaly pattern shows mirror symmetry with the anomalies positive over the thicker and denser block. The maximum anomaly is attained at a distance of about 0.6 $(t_1 \cdot t_2)^{1/2}$ from the boundary of the blocks (Walcott, 1967) but the field is still quite intense at a distance of several times the thickness of the block. This form of anomaly pattern is characteristic of the structure and may be called an edge effect of two compensated blocks. The introduction of gradational density changes into the boundary has a comparatively small effect on the amplitude of the edge effect (Figure 8b) but the gradient across the boundary between the blocks is very much reduced. We can deduce that by introducing lateral density gradations into a model we will produce less steep,

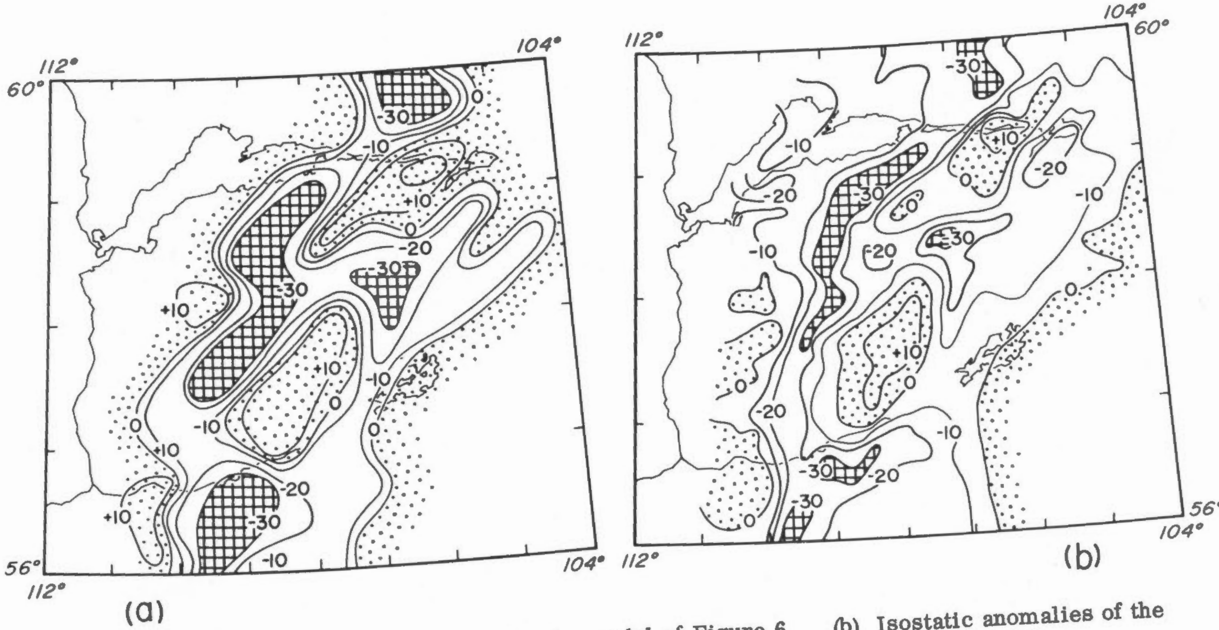

Figure 7 - (a) Calculated anomalies for the model of Figure 6. (b) Isostatic anomalies of the central belt.

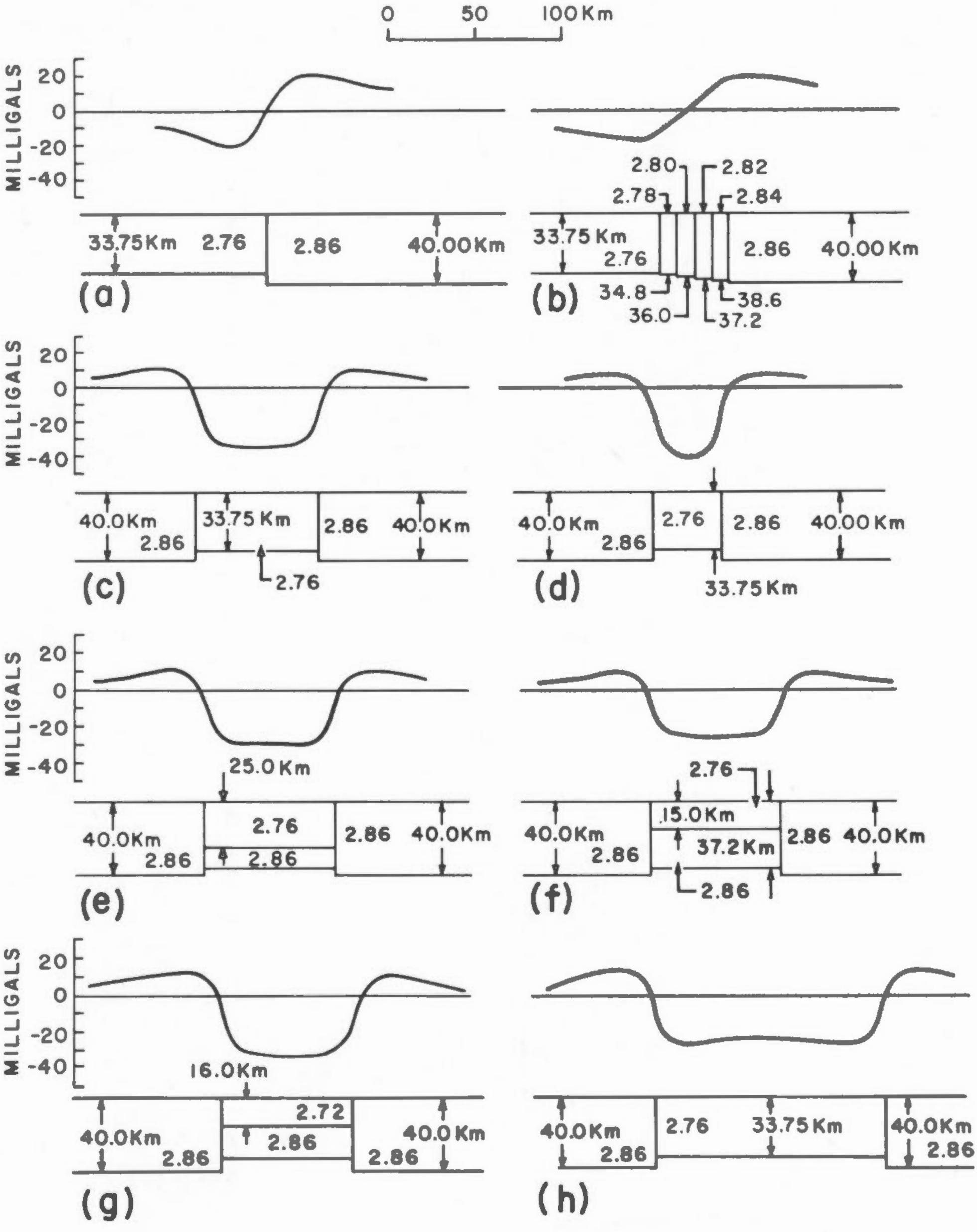

Figure 8 - Theoretical two-dimensional compensated models and the calculated anomalies.

and in the present case, more realistic gradients without significant alteration of the amplitude of the anomalies. The amplitude of the anomaly across a two-dimensional compensated block (Figure 8c) is sensitive to a change in the density contrast and comparatively insensitive to variation in width of the block (cf. Figures 8h and 8d) or to the thickness of the anomalous mass (cf. Figures 8c, 8e, 8f). Thus a large change in the thickness of the anomalous mass can be readily offset by a small change in density contrast (cf. Figures 8c, 8g). For example a decrease in the thickness of the anomalous mass from 34 km in Figure 8g, to 17 km is offset by an increase in the density contrast from 0.10 to 0.14 g/cm^3.

We can deduce from the examples that all models based on the postulates of lateral density variation and complete local compensation will contain mass anomalies of about the same width, but different thickness and density contrasts are possible. Nevertheless it may be inferred from what is known of the densities of surface rocks that the average density contrast is most unlikely to exceed 0.25 g/cm^3 anywhere and it will be less than 0.15 g/cm^3 for the very large volumes of rocks necessary to explain regional anomalies. This places a very great restriction on the minimum thickness of possible structures and in most regional anomalies, where amplitudes exceed 25 milligals, the mass anomaly must extend to a depth of at least 10 km. Thus the essential features of likely structures are contained within the simple model. Unless there is geological information to provide further structural restrictions on the model it is unlikely, considering the uncertainties involved, that a more complicated model is of any advantage.

A cross section of the three-dimensional model and the observed and calculated gravity anomalies is shown in Figure 9, and illustrates the inferred crustal structure across the central belt anomalies. The block of density 2.76 represents a belt of anomalously low mass and if the geology in the vicinity of Stony Rapids can be generalized, a belt of granite. Whether the Fond du Lac low marks a granite belt or not, the gravity map does indicate a continuation of the structure southwestwards from Stony Rapids beneath the Athabasca sandstone and the Palaeozoic sediments.

SUMMARY AND CONCLUSIONS

The principle feature of the Bouguer anomaly field of northern Saskatchewan and northeastern Alberta is a belt of unusually intense anomalies that trend northeastwards across the region parallel to the structure of the basement complex. Where geological mapping at a large scale is available the anomaly contours correspond in detail with the structure of the underlying rocks. Gravity highs are located over denser, and gravity lows over lighter than usual rocks. These intense 'geological' anomalies are superimposed on a regional trend in Bouguer anomaly values related to a change in average elevation in the map area. The magnitude of this change, however, is only about 20 milligals from an average Bouguer anomaly of about -60 milligals over the highlands south of Lake Athabasca to -40 milligals over the lowlands to the northwest of the lake.

Interpretation of regional anomalies, such as those of the central belt, is complicated by an isostatic effect and the lack of information on the nature of the disturbing mass. By isostatic effect is meant that a regional gravity anomaly is likely to be made up of the gravity effect due to density changes within the crust and, also, the gravity effect of deepseated masses compensating for the difference in load arising

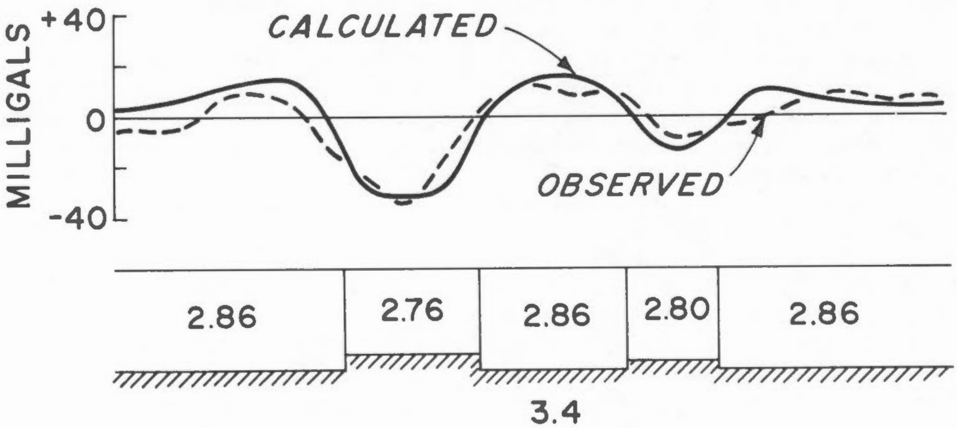

Figure 9 - Cross section of the model of Figure 6 with observed isostatic and calculated anomalies.

from those density changes. As the gravity effect of the compensating masses is of opposite sign to that due to crustal density changes the observed anomaly will always be less than the gravity effect due to the density change alone. Evidence from studies of deformation caused by unloading of Pleistocene lakes and ice caps indicates that compensation is virtually complete. Therefore the isostatic effect can be allowed for by including a compensation mass in any model of a regional gravity anomaly of equal and opposite sign to the crustal mass anomaly.

A simple model based on compensation by the Airy mechanism and lateral density variations of the crust gives anomalies of the same wavelength and amplitude as the observed anomalies and if allowance is made for gradational rather than abrupt density changes a very close fit of observed and calculated anomalies should be able to be achieved. Therefore it can be concluded that the central belt anomalies are consistent with complete compensation and there is no justification for deducing that the anomalies of the Canadian Shield indicate departures from isostatic equilibrium. It is doubtful whether it is of any value to produce a more complicated model than that shown considering the lack of information in the area. The essential features following the postulates of compensation and lateral density variation are contained within the simple block model and will not be substantially altered in a more complicated model.

These features are:

1. The dominant crustal feature in the area is the mass anomaly related to the Fond du Lac low. From the small area in the vicinity of Stony Rapids it is deduced that the low is related to the regional change in lithology and is due at least in part to granite. It is of considerable interest to determine whether this change in lithology is an inherited feature from the premetamorphic terrain and thus indicates a regional change in the original sedimentary facies or is due to granite intrusion and perhaps vertical differentiation during the long period of tectonism and metamorphism.

2. There is a decrease in crustal thickness below the Fond du Lac low of about 6 km compared to the areas immediately adjacent to the low if the assumed mechanism of compensation and the deductions from studies of crustal loading are correct.

3. The trend of gravity contours can be used to extrapolate the structure of the basement complex from the exposed area north of Lake Athabasca below the Athabasca sandstone.

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