GRAVITY MAP SERIES

of the

DOMINION OBSERVATORY

The Gravity Anomaly Field in The Ungava Region of Northern Quebec with maps

No. 5—Cape Smith-Povungnituk
No. 6—Wakeham Bay

J. G. Tanner
and
R. K. McConnell

OTTAWA, CANADA

Department of Mines and Technical Surveys

DOMINION OBSERVATORIES

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Gravity Map Series No. 6 - Wakeham Bay

Geological Map - Cape Smith-Wakeham Bay

The Gravity Anomaly Field in the Ungava Region, with Maps No. 5, Cape Smith-Povungnituk; No. 6, Wakeham Bay

J.G. Tanner and R.K. McConnell

ABSTRACT - During the summer seasons of 1959 and 1960, field parties of the Dominion Observatory made 614 regional gravity measurements in the Cape Smith-Wakeham Bay area of New Quebec. The Bouguer anomalies indicate that the area as a whole is in a state of isostatic equilibrium. A linear Bouguer anomaly correlates with the basic volcanic and intrusive rocks of the Cape Smith belt. Calculations based on observed anomalies indicate that the folded basic rocks of the belt are thicker than 20,000 feet. Negative anomalies that flank the Cape Smith positive anomaly can be explained isostatically by regarding the Cape Smith belt as a load on the crust. The thickness of the root, about 10,000 feet, calculated from the load itself agrees with that computed from the negative anomalies.

A local positive anomaly in the Payne Bay area indicates the presence of a large intrusive body. The presence of a gabbroic intrusion at the surface is confirmed by rock samples. Computations based on a residual Bouguer anomaly profile across the feature suggest that the body extends to a depth of about 40,000 feet, is approximately 20 miles in diameter and has a central dome a few thousand feet wide extending upward from the main body to the surface.

RÉSUMÉ - Au cours des étés 1959 et 1960, des équipes itinérantes de l'Observatoire fédéral ont fait 614 mesures gravimétriques régionales dans la région cap Smith—baie Wakeham (Nouveau-Québec). D'après les anomalies de Bouguer, la région se trouve en équilibre isostatique. Une anomalie Bouguer linéaire se rattache aux roches basiques volcaniques et intrusives de la zone de Cape Smith. D'après des calculs tirés d'anomalies observées, l'épaisseur des roches basiques plissées de la zone dépasse 20,000 pieds. Les anomalies négatives qui bordent l'anomalie positive peuvent s'expliquer du point de vue isostatique en considérant la zone de Cape Smith comme pesant sur l'écorce terrestre. L'épaisseur de la racine d'environ 10,000 pieds, calculée d'après le poids lui-même, concorde avec celui qu'on a établi à l'aide des anomalies négatives.

Dans la région de la baie Payne, une anomalie positive locale marque l'emplacement d'un massif intrusif. Des échantillons de roche corroborent la présence d'une intrusion de gabbro en surface. Des calculs basés sur le profil transversal d'une anomalie Bouguer résiduelle font croire que le massif est épais d'environ 40,000 pieds, qu'il a un diamètre de près de 20 milles ainsi qu'un dôme central, large de quelques milliers de pieds, qui s'étend du massif principal jusqu'à la surface.

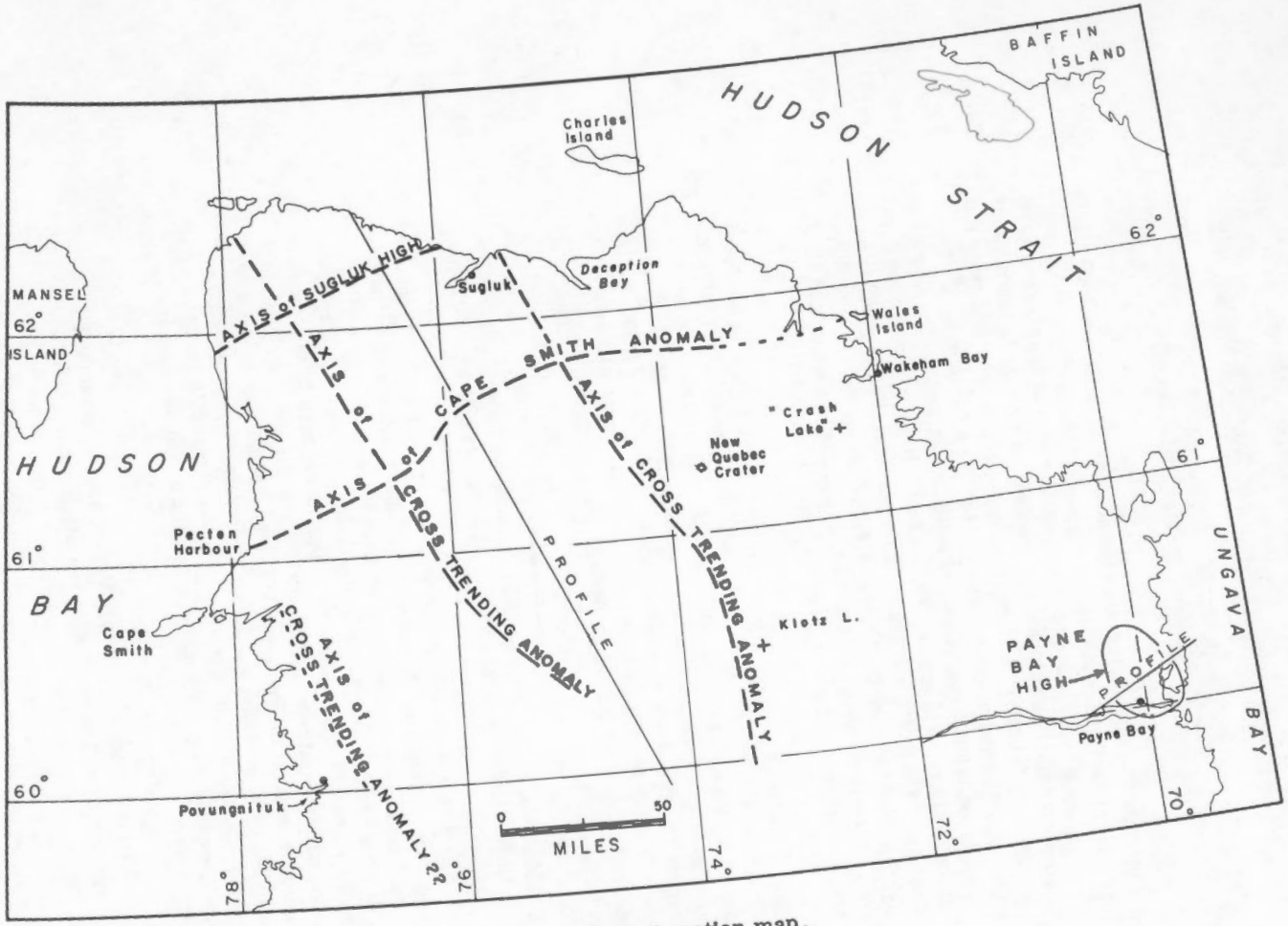

Figure 1. Location map.

INTRODUCTION

The area covered by this report (Figure 1) includes that part of the province situated west of Ungava Bay and north of latitude 60°N, known as the Ungava Peninsula. Consistent with other publications in this series, the data is presented in the form of Bouguer anomaly maps on a scale of 1:500,000. To assist with the interpretation, a compilation of the available geology has been made on a map of the same scale.

The main features of the gravitational field investigated are positive Bouguer anomalies over the Cape Smith belt and an intrusive mass located north of Payne Bay (Figure 1). Particular attention is also given to negative anomalies flanking the Cape Smith belt and to three northwest trending negative anomalies that can be traced across the map area. Because the data used are regional and have not been supplemented by detailed observations in anomalous areas, the interpretation has been restricted to a consideration of the most obvious cause of the anomalies.

DESCRIPTIVE NOTES

a) General

Field parties of the Dominion Observatory operated within the area during the summer seasons of 1959, 1960 and 1961. The 1959-1960 operations were carried out by 10-man field parties using float-equipped Beaver aircraft for transportation. Except for one or two detailed studies over circular features the entire program was devoted to regional work. In 1961 the field party was primarily involved with a study of the New Quebec Crater, but, as a Beaver aircraft was attached to the party, several apparently erroneous observations made in previous years were investigated.

The gravity stations are distributed at approximately 10-mile intervals throughout the area except for a region located 50 miles north of the New Quebec Crater where few observations were possible because of its inaccessibility by float-equipped aircraft. Subsequently, some regional data were obtained for this area from the Falconbridge Mining Company which kindly provided the principal facts for 9 gravity stations established during the course of their local surveys.

b) The Gravity Observations

All gravity observations were made with intermediate range Worden gravimeters having scale constants of approximately 0.4 mgal per division. Observational techniques were similar to those described in other publications of the Dominion Observatory (Tanner and Uffen, 1960; Innes, 1960). As the field conditions and instrumentation were comparable to those discussed in an earlier report of this series (Tanner, 1961), the observed gravity values are similarly estimated to be in error by less than 0.25 mgal.

The control network within the area was established by the method of looping (Nettleton, 1941), and is shown in Figure 2. These stations, spaced at approximately 75-mile intervals, form part of a network that covers almost all of Quebec west of longitude 68°W. Circuit elosures vary from a few hundredths to 0.45 mgal and the average is about 0.15 mgal. An adjustment was made on this network in 1960 using a least-squares method suggested by Smith (1951).

As several different instruments and observers were used during the programs, a summary of the yearly operations is given in Table I.

TABLE I

SUMMARY OF YEARLY OPERATIONS

Year	Observers	Instruments	No. of Stations
1959	R. K. McConnell D. W. Lepard	Wordens #391, #433 and #460	431
1960	B. van Oort H. Davidson	Wordens #391 and #431	169
1961	M. Ferguson	Worden #573	14
		Total Stations	614

c) The Elevation Measurements

The heights of most gravity stations were computed from altimeter readings taken concurrently with the gravity-meter observations. Two Wallace and Tiernan altimeters were carried by each observer and temperature and humidity were recorded. For the reduction of the altimeter data it was assumed that the atmospheric pressure varied linearly in the time interval, usually 2 to 4 hours, between observations at control elevations.

Elevation control within the region was provided by sea level and by elevations supplied by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa. Sea-level observations along the coast of Hudson Bay were not corrected for tidal effects as the maximum variation in water level is only about 5 ft. However, in Hudson Strait and Ungave Bay, tides as great as 40 ft necessitated corrections to the data.

Inaccuracies in the adopted elevations arise from uncertainties in the control elevations and from errors in the relative altimeter measurements made by the Dominion Observatory. As the control elevations, exclusive of sea level, were established by several different methods (transit, radar altimeter, etc.) and as the altimeter readings are subject to variations in atmospheric pressure which differ markedly from day to day and from place to place, the problem of determining the errors contained in the elevations is complicated. One method

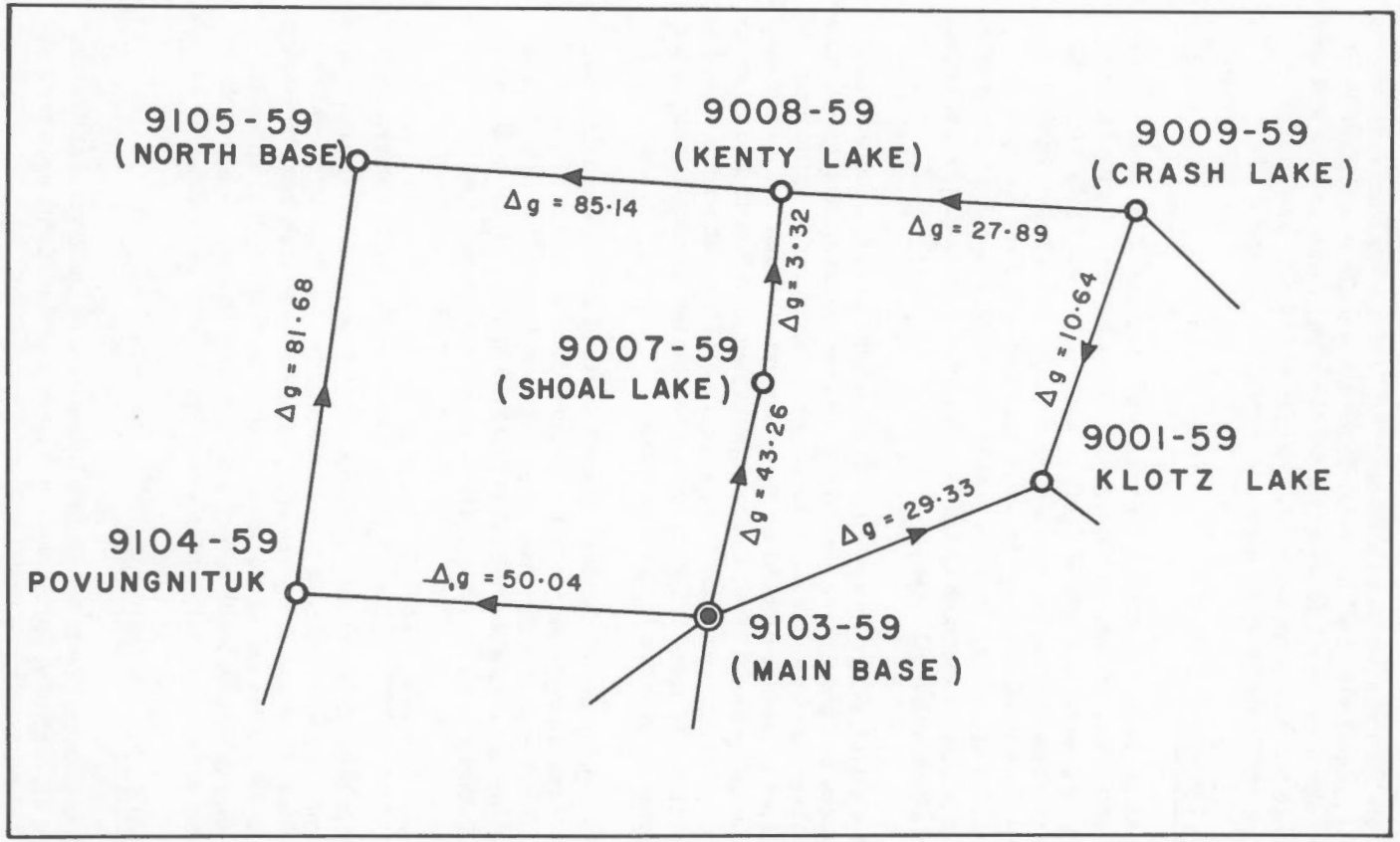

Figure 2. Control station network within the map area. The gravity differences are shown in milligals.

to obtain an estimate of the average error in the elevation data is to compute the r.m.s. deviation of all heights calculated for some reference, such as mean sea level, from a series of altimeter ties to that level from other control elevations. An analysis of all altimeter connections made to mean sea level during the Ungava surveys indicates that the elevations of the gravity stations are good to 25 ft. Assuming a mean crustal density of 2.67 gm/cc, the corresponding error in the Bouguer anomalies would be 1.5 mgal.

d) Terrain Effect

Terrain corrections have not been made as most of the area is relatively flat. There is one region, bordering Ungava Bay and Hudson Strait, where the presence of steep-walled valleys and high coastal bluffs forced the observers to choose the station locations carefully. These topographical features can be approximated by the mass distributions shown in Figures 3 and 4. Included in the diagrams are graphs of the corresponding terrain effects, which indicate that a careful choice of location for a gravity station can reduce the terrain effect to 3 mgal or less.

A study of the observers' field notes and the available topographical maps indicates that unduly large terrain effects have been avoided for all but a few of the observations in this northern region. For example, the gravity station located at latitude 61°52'N and longitude 72°44'W lies in a river valley which, in cross-sectional view, can be represented by the configuration shown in Figure 4. The instrument was set up about 50 ft from one wall in a fiord one mile wide with walls 1,000 ft high. From Figure 4 the terrain correction for this particular observation is about 10 mgal.

The application of terrain corrections would not substantially change the trends of the contours shown on the Bouguer anomaly maps. However, to avoid significant errors in the mass distribution computed from the observed Bouguer anomalies over the Cape Smith belt, the location of the profile was chosen such that a minimum topographical effect was encountered.

e) Summary of Errors

It is difficult to assign a probable error to any one station or group of stations because the different factors contributing to the total error vary so markedly from place to place. However, the authors believe that the average error in the anomalies due to elevation, gravity measurements, latitude, terrain, etc., is no greater than 2 or 3 mgal except in a few instances in the northern and eastern coastal regions where errors may be as large as 10 mgal.

f) Principal Facts

The principal facts for all gravity stations on the maps and location sketches of all control stations shown in Figure 2 are available upon request from the Gravity Division, Dominion Observatory, Ottawa.

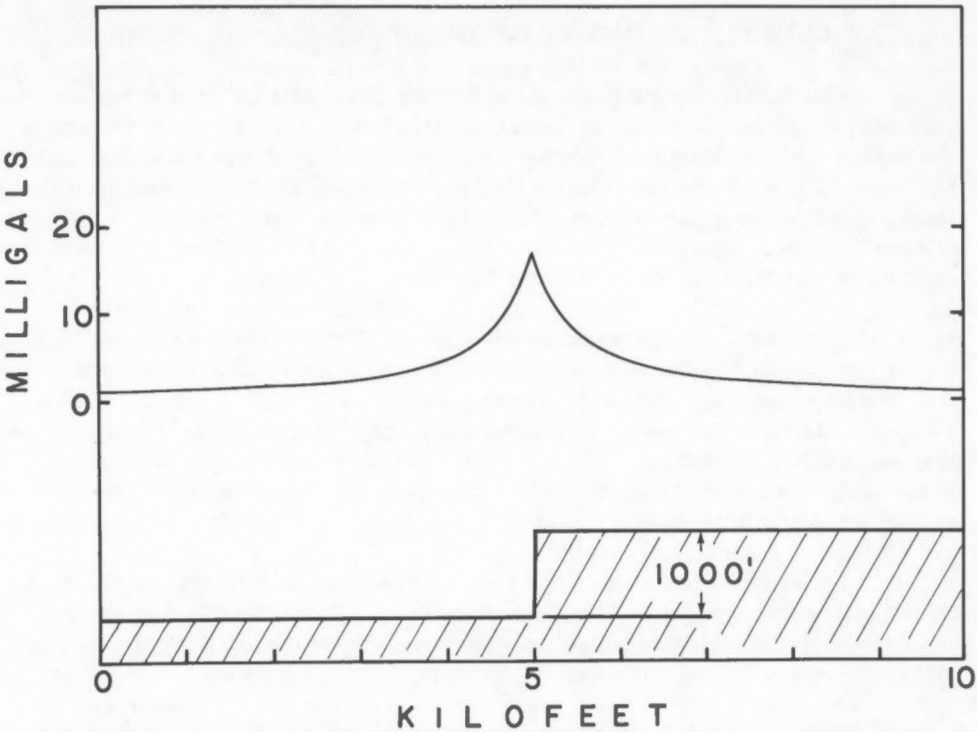

Figure 3. Terrain effect over an escarpment. The gravitational effect of the land mass has been computed using an adaption of the line integral method (Hubbert, 1948) to digital computers.

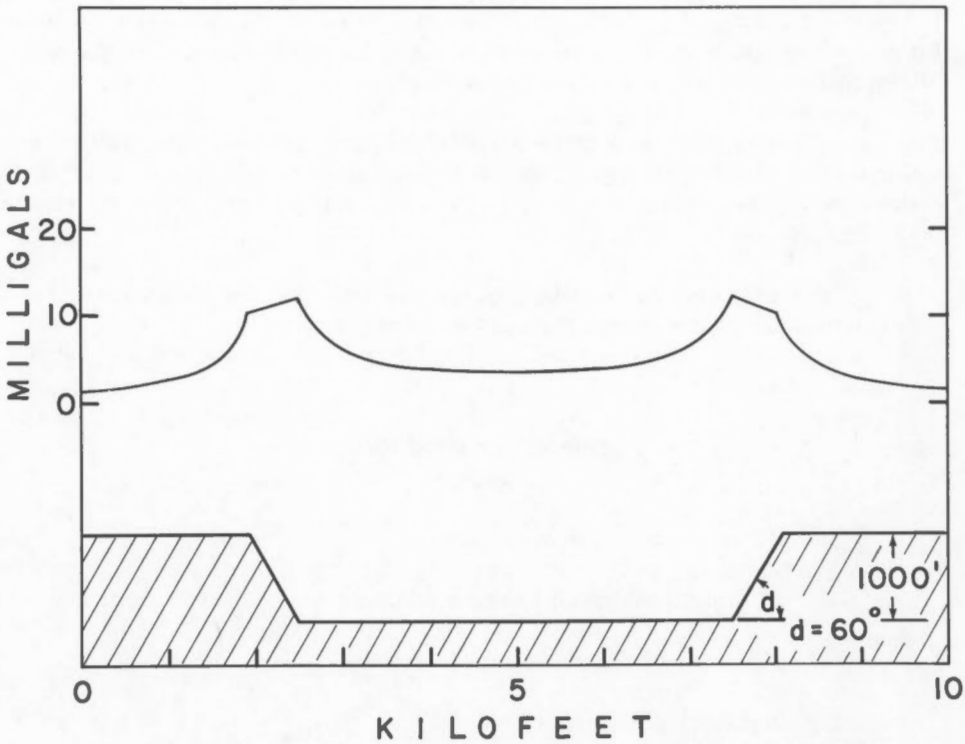

Figure 4. Terrain effect over a steep-walled valley.

GENERAL CHARACTER OF THE GRAVITATIONAL FIELD

The accompanying maps show that the gravitational field is rather variable, displaying both linear and circular trends. The dominant feature is the elongate positive anomaly located over the Cape Smith basic and ultrabasic complex. The axis of this anomaly lies roughly along the line joining Pecten Harbour and Wales Island (Figure 1). Three centres of pronounced positive anomaly, whose magnitude all exceed +10 mgal, are located over the western, central and eastern parts of the Cape Smith belt.

Flanking the Cape Smith positive to the north and south as seen on the gravity maps are two linear zones of negative anomaly 20 to 30 miles wide. The northern anomaly extends from the coast of Hudson Bay to about longitude 73°30'W. The southern anomaly spans the Ungava Peninsula and extends into Hudson Bay to the west and Hudson Strait to the east. It is also the more intense of the two, averaging about -55 mgal along its axis compared with -40 mgal for the northern anomaly.

The northwestern tip of the Ungava Peninsula is traversed by a positive anomaly (Figure 1) which is about 40 miles wide. This anomaly lies parallel to the Cape Smith anomalies and has a maximum intensity of approximately 5 mgal.

Regionally, there are three negative anomalies, trending northwest (Figure 1), which cut across the anomalies described above. The two eastern anomalies can be traced across the region while the strike length of the western one, within the map area, cannot be determined because of the lack of data over the off-shore areas of Hudson Bay. The amplitudes of the anomalies increase progressively eastward to a maximum of about 20 mgal. Similarly, the definition of the anomalies is sharper to the east.

Locally, there is a large positive anomaly located immediately north of Payne Bay in the eastern part of the map area. It is elliptical in outline, approximately 30 miles in diameter, and rises about 45 mgal above the regional anomaly level.

Table II presents a résumé of the averages and the maximum and minimum values of the anomalies and the elevations.

TABLE II

SUMMARY OF OBSERVATIONS

(i)	Total number of observations	- 614
(ii)	Maximum observed Bouguer anomaly	- +18.1 mgal
(iii)	Minimum observed Bouguer anomaly	- -61.2 mgal
(iv)	Mean station elevation	- 815 ft
(v)	Mean Bouguer anomaly	- -25 mgal

Isostatic anomalies have not been calculated because of the time required to compute them and also because of insufficient topographical information. However, a general picture of the isostatic state of the crust can be obtained by regarding the terrain as a slab whose upper surface is 815 ft above mean sea level. The effect of compensation is then equal and opposite in sign to the attraction of the terrain or 28 mgal. This would suggest that the area as a whole is in a state of isostatic equilibrium and not overcompensated as are some other areas of the Canadian Shield (Tanner, 1961; Innes, 1961).

GENERAL GEOLOGY

The surface rocks of the area (see map), all Precambrian in age, may be divided into four geological units. The oldest are the basement rocks, consisting primarily of granite and granitic gneiss, which outcrop in the southern part of the map area. These are overlain to the north by the sediments, basic volcanic and intrusive sills and the related ultrabasic rocks of the Cape Smith belt. North of this belt is an unnamed zone of paragneiss which extends to the shore of Hudson Strait. The northern end of the Labrador Trough, containing rocks similar to the Cape Smith belt, extends into the eastern part of the map area.

The interesting geological feature of the area from the point of view of the gravimetric data is the Cape Smith belt, which traverses the Ungava Peninsula in an east-west direction. It is about 250 miles long and varies in width from a maximum of 60 miles in the central part of the feature to a minimum of 10 to 15 miles at the eastern end. The belt consists primarily of sediments and a thick sequence of volcanic rocks that have been highly folded, metamorphosed and intruded by basic and ultrabasic sills that appear to have been emplaced prior to folding (Gelinas and Bergeron, 1962). In addition, there are several small granitic bodies present in the central part of the belt (Kretz, 1960; Gelinas and Bergeron, 1962).

Although detailed geological mapping has been carried out in various parts of the belt by a number of groups and institutions the main structural features have not been clearly defined because the belt has been severely folded, faulted and metamorphosed. The most complete summary has been provided by Stam (1962) who suggests a highly folded and faulted belt consisting of a thin, lower sedimentary and thick upper volcanic sequence. In the schematic cross-section given by Stam, the structures in the sedimentary layer are shown as being conformable with those of the volcanic sequence.

The contact relations of the Cape Smith belt to the northern paragneisses and southern granitic gneisses are not simple. Bergeron (1957) interprets the southern boundary of the belt as an unconformity because of the presence of a basal conglomerate at the contact in the central part of the belt. Stam (1962) suggests that, to the west, this contact may be a thrust fault and gives as evidence the absence of conglomerates and the stronger foliation, parallel to the contact, within the gneisses in the vicinity of the boundary between the geological units. The northern contact has been observed in one location by Bergeron (1959) who suggests that the paragneissic sequence may be the stratigraphic equivalent of some of the sedimentary rocks of the Povungnituk series and concludes that the contact is gradational.

The paragneisses located north of the Cape Smith belt are of sedimentary origin and are mainly quartzo-feldspathic in composition (Gelinas and Bergeron, 1962). Locally there are interstratified layers of quartzite and impure dolomites and occasional lenses of amphibolite. As these rocks have not been mapped in detail there is no information concerning the structure. On the geological map compiled by Kretz (1960) lineaments, approximately parallel to the Cape Smith belt, are shown in the vicinity of Sugluk.

There are two remnants of the Labrador Trough within the area. The larger occurs in a synclinal sequence along an axis trending NNW from Payne Bay for about 35 miles. The second also occurs in a synclinal sequence and outcrops in the vicinity of Almond Lake, about 55 miles NNW of Payne Bay. Both exposures consist mainly of volcanics and sediments, and at or near the base of each sequence there is a horizon of iron-formation. Recent work has indicated the presence of an intrusive body immediately north of Payne Bay and more detailed information of this area is included in the interpretation section.

DENSITY MEASUREMENTS

As only 140 rock specimens were taken within the area covered by the two gravity maps, the rock sampling is far from complete. Density measurements on these rocks yielded the mean values given in Table III.

TABLE III

TABLE OF DENSITIES

Geologic Unit	No. of Samples	Mean Density gms./cc.	r.m.s. Deviation from Mean Density gms./cc.	Range of Density gms./cc.
Paragneissic sequence	30	2.75	0.15	2.56 - 3.08
Cape Smith Belt sedimentary and volcanic sequences	40	2.96	0.14	2.62 - 3.15
Basement Rocks mainly granites and granitic gneisses	70	2.70	0.13	2.44 - 3.24

Since some rock types may have been sampled out of proportion to their surface distribution, it is not certain that the computed mean densities are truly representative of the various rock types. However, on the basis of this minor density sampling a value of 3.0 gm/cc was chosen for rocks of the Cape Smith belt and a value of 2.7 gm/cc was used for all other surface rocks.

CORRELATION OF BOUGUER ANOMALIES AND GEOLOGY

a) General

It was not possible to make detailed traverses across the Cape Smith belt or any other anomalous region owing to the scarcity of lakes suitable for float-equipped aircraft. Consequently all profiles have been prepared using the Bouguer anomaly values of regional stations located along the plan of the profile and from the iso-anomaly lines. The gravitational attraction of the mass distributions suggested has been computed by means of a segment chart, constructed on the assumption that the disturbing body has an infinite strike length, or by means of a computer program developed at the Dominion Observatory for use with three-dimensional masses.

b) The Cape Smith Anomalies

(i) Introduction

The profile across the Cape Smith belt (Figure 5) extends southward from Hudson Strait to the 60th parallel (see Figure 1). Figure 5 (top section) shows the large positive anomaly over the belt, the negative anomalies flanking the positive anomaly and a small-amplitude positive anomaly located near the northern limit of the profile. The gradients of the profile suggest a separation into two main components; a residual positive anomaly related to the basic rocks of the Cape Smith belt, and a regional negative anomaly centred over the belt, but extending considerably beyond the outcrop limits. These anomalies (Figure 5, centre section) are respectively termed the Cape Smith high and the Cape Smith low. A third component, which has not been shown in Figure 5, is a residual positive anomaly, located to the north of the Cape Smith anomalies, designated the Sugluk high.

(ii) The Cape Smith High

This positive anomaly, located over the Cape Smith belt, is about 50 miles wide and has an amplitude of approximately 75 mgal. A correlation of the anomaly values with the surface distribution of the belt along the profile shows that the anomaly is nearly zero at the southern contact, rises abruptly northward to a broad plateau over the central region, and falls off steeply in the vicinity of the northern boundary, over which the anomaly is about half its maximum value. The anomaly values over the contacts suggest that the southern contact dips northward at a shallow angle, probably about 10 degrees, while the northern boundary is vertical. Assuming a density contrast of 0.30 gm/cc between the Cape Smith belt and the basement rocks, the thickness of Cape Smith rocks required to explain a total anomaly change of 75 mgal is approximately 22,000 ft. These observations have been used as a basis for the simplified geological section shown in the lower part of Figure 5. The thrust fault shown is that mapped by Bergeron (1957, 1959).

The average dip of the Cape Smith rocks, adjacent to both contacts, taken from maps published by Bergeron (1959) and Gelinas (1961) differs from the dip of the contacts determined from the gravity data. According to the former sources, the northern contact dips about 50° south while the southern

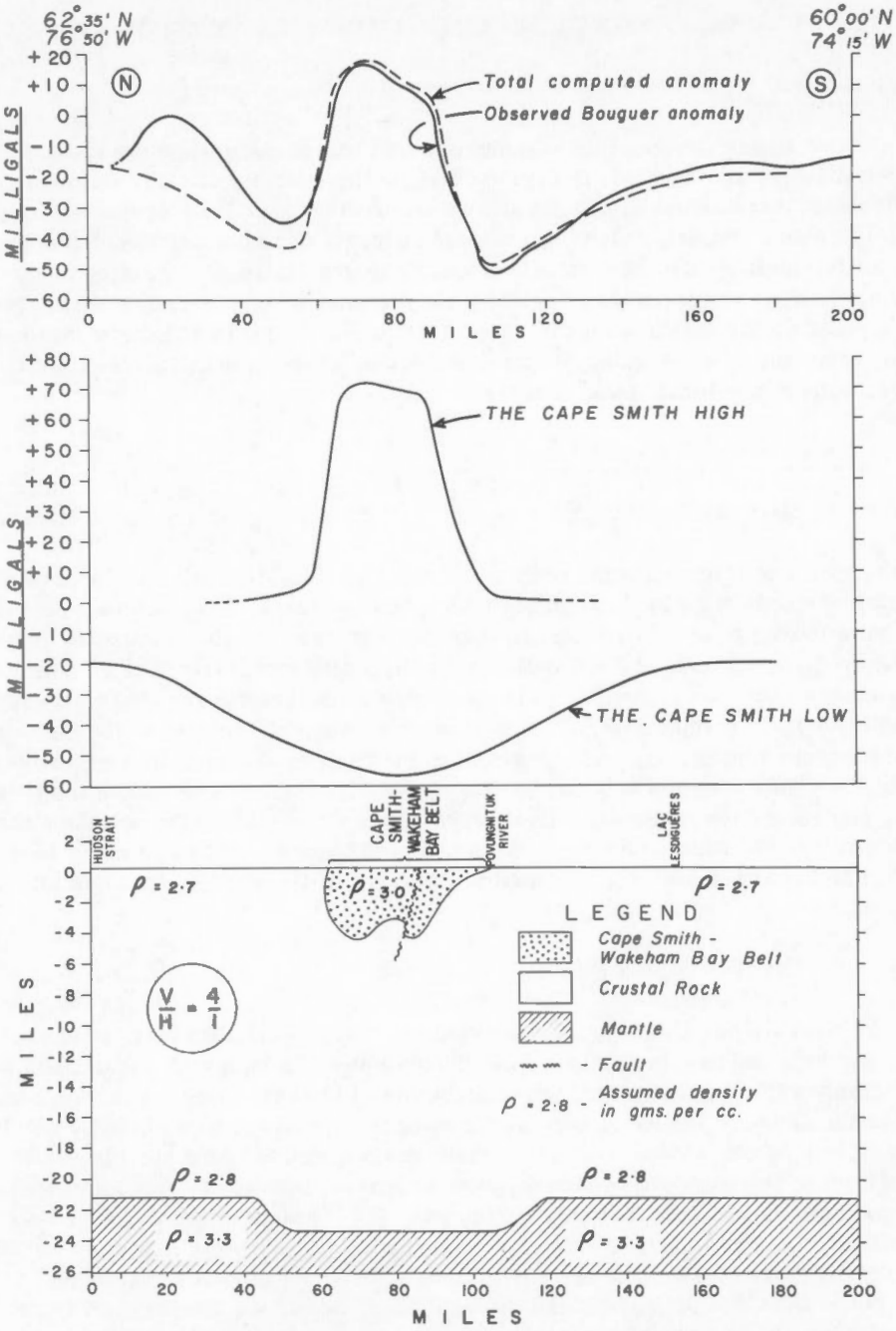

Figure 5. Bouguer anomaly profile across the Cape Smith belt. The central and lower sections respectively show the main components of the observed Bouguer anomaly profile and the mass distributions proposed to explain them.

contact dips about 30° north. An explanation of the disagreement could be the existence of near-surface structures that are not indicated by the gravitational field. The latter has been defined by regional data alone which would probably not be adequate to resolve local structures. Also, the gravimetric data reflect the presence of the high-density basic rocks and not the presence of the average-density sediments of the Cape Smith belt. Thus, a large accumulation of sediments could result in a considerable difference between the geological and geophysical contacts. However, as already mentioned, Stam (1962) suggests that the sedimentary layer is relatively thin and, in his schematic cross-section, he shows it as being conformable with the volcanic layer. Therefore, it is suggested that except for local structures, the gravity data do generally outline the structural relations of the Cape Smith belt to adjacent geological units. With regard to structures within the belt, the interpretation put forth by Stam (1962) could, with a few modifications, explain the residual Bouguer anomaly.

The dip of the southern contact determined from the gravity data appears to be consistent with geological observations whereas that suggested for the northern contact does not. Undoubtedly, the southern contact could be interpreted as an unconformity or a low-angle thrust fault. The intense deformation of the belt might favor the latter hypothesis. It is also possible that the contact may be an unconformity that subsequently served as a locus of thrusting; a structure that has been observed in the Appalachian system (King, 1951). The northern contact is interpreted to have a vertical or near-vertical dip to a depth of about 10,000 ft. A contact of this nature would not bring to mind a gradational contact as suggested by Bergeron (1957), but rather a fault. The solution of the problem requires additional gravimetric and geological observations. In particular, several detailed geophysical traverses over the contact might establish that the vertical dip is persistent throughout the length of the belt, which would strengthen the argument for a fault.

Reference has not been made to the structure that permitted the lavas and intruding magmas to rise from the deeper levels of the crust. Presumably this has not been possible because the gravitational effect of the exposed basic rocks of the Cape Smith belt masks any anomaly resulting from such a structure. A second explanation may be that tectonic forces subsequent to the period of intrusion and extrusion may have distorted the structure sufficiently to prevent recognition by means of gravimetric data. No unequivocal choice between the two alternatives is possible although in the next section reference is made to possible deep-seated structures that may have been a prime factor in the disappearance of this source structure.

(iii) The Cape Smith Low

The regional negative anomaly (Figure 5, centre section) is about 100 miles wide and has an amplitude of nearly 40 mgal. The horizontal gradients and the absence of large areas of low-density surface rocks capable of producing a negative anomaly suggest that the disturbing body is deep-seated. A variety of explanations are possible but an interesting approach is to regard the Cape Smith belt as a positive load on the crust as indicated by the Bouguer anomalies. According to the Airy theory of isostasy this load should be compensated by a root located at the base of the crust. The crustal thickening required to support the load is given by:

$$\Delta T = H = \frac{\rho_a}{\rho_{m-c}}$$

where H is the thickness of the anomalous mass, ρ_a is the anomalous density contrast and ρ_{m-c} is the density contrast between the crust and the mantle. Approximating the Cape Smith belt to a rectangular block 15,000 ft thick and letting ρ_a = 0.30 gm/cc and ρ_{m-c} = 0.50 gm/cc, then ΔT = 9,000 ft. This value agrees with the thickness of ten to twelve thousand feet computed from the Bouguer anomaly itself (Figure 5).

The root could be due to downwarping caused by the load on the crust, possibly assisted by the tectonic forces that folded the Cape Smith belt. The root might also result from faulting that could occur if the surface load were built up too rapidly, exceeding the average shear strength of the crust. As the crust was probably weakened by a major zone of fracture that served as an exit for the volcanic and intrusive rocks, a large mass excess at the surface could rupture the entire crustal column, forming a huge graben or rift structure, thereby effecting a form of compensation.

Gass and Masson-Smith (1963), on the basis of mean isostatic anomalies in the vicinity of Cyprus, have suggested that the Troodos Massif may be compensated by crustal downwarping. They do point out, however, that adjacent sedimentary troughs, if present, might also explain the negative isostatic anomalies. There is a similar problem in the Cape Smith area in that the possibility of granitic intrusions cannot be overlooked. Regional negative anomalies have been adequately explained on the basis of granitic masses (Innes, 1954; van Boeckel, 1963) and the existence of small granitic intrusions has been reported within the region (Kretz, 1960). Detailed gravity observations over these intrusions accompanied by extensive surface sampling may clarify the relationship of the granites to the regional anomaly.

(iv) The Sugluk High

Little can be said regarding this positive anomaly located north of the Cape Smith belt because of the lack of adequate geological observations and scanty specific gravity data. Kretz (1960) indicates the presence of some lineaments that coincide with the approximate axis of the anomaly and that may suggest a fold belt. Based on a residual anomaly of 25 mgal and a density contrast of 0.05 gm/cc between the paragneisses and the basement rocks (Table III), a folded belt 35,000 ft thick is indicated.

c) <u>The Northwest Trending Negative Anomalies</u>

These anomalies, two of which are well defined (Figure 1) and a third or westerly one, is poorly defined, are roughly parallel to the trend of the Labrador Trough. In general, they distort the Cape Smith positive anomaly more than the negative anomalies that flank it. Since the latter are attributable to a deep-seated source, the mass distributions causing the northwest trending anomalies are probably located near the surface. This is apparently confirmed by the presence of doubly plunging canoe and basin folds in the Cape Smith belt

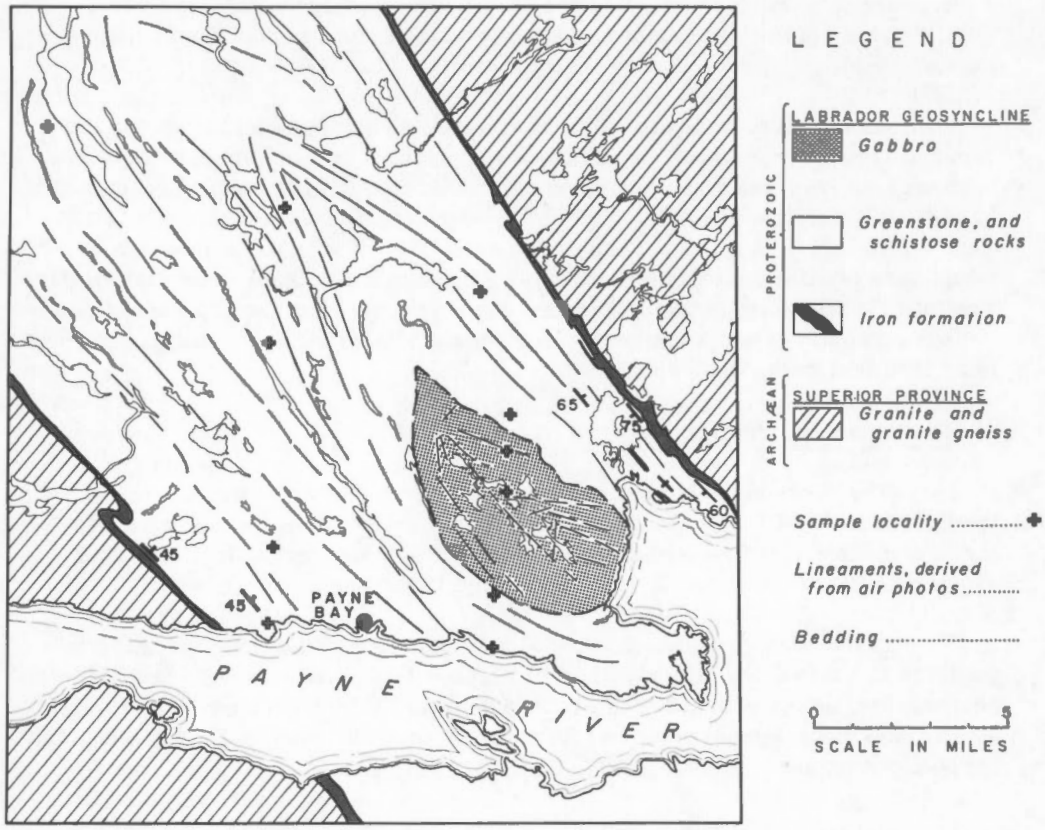

Figure 6. Geological sketch map in the Payne Bay area. The surface distribution of the gabbro has been obtained from airphotos.

(Kretz, 1960; Beall, 1959) that are indicative of east-west crustal shortening. Therefore, the best explanation of the anomalies is that they are caused by folding and/or faulting in the surface or near-surface rocks. But the lack of sufficiently detailed gravimetric and specific gravity data in the areas underlying these anomalies prohibits an estimate of the dimensions of the structures causing them.

As the structures producing the anomalies are parallel to and apparently become more intense toward the Labrador Trough, it is possible that they have been derived from the same period of crustal stress that folded the Trough rocks. In addition, the most easterly of the three negative anomalies intersects the Cape Smith belt in the Cross Lake area where Beall (1959) has mapped cross folding and faulting which is presumably younger than the main east-west folding. The latter would suggest that, assuming the northwest trending and the Labrador Trough structures have a common origin, the period of folding in the Trough was later than that in the Cape Smith belt.

d) The Payne Bay Positive Anomaly

The rocks underlying this anomaly are part of the northern extension of the Labrador Trough and are Proterozoic in age. The most abundant surface rocks are schists and altered greenstones. These rocks occur in a synclinal sequence which to the west dips 45° east, and to the east dips 60° west.

In the central region (Figure 6) along the axis of the syncline there is a gabbroic intrusion, the lateral extent of which has been determined from airphotos. Two samples of the body, provided by Dr. I. Stevenson of the Geological Survey of Canada, show considerable variation in grain size, texture and content, but both are probably gabbros.

Immediately north of the inferred main mass of the gabbro there is a zone of light-weathering rock that gives rise, from the photographs, to a terrain different from that of the schistose country rock and may represent another phase of the intrusion. This has not been shown on the map (Figure 6) because of the lack of confirming ground observations. The northern limit of this rock is located along the southern crescent of the lake situated two to three miles north of the main intrusive mass.

In addition to the samples of the basic intrusion Dr. Stevenson also provided several specimens from the surrounding area (Figure 6). One of these, taken from the region west of the gabbro, is also a basic rock resembling that collected from the centre of the intrusion with the exception that it is more coarsely crystalline. This may indicate still another zone of gabbro and, if so, would suggest that the gabbroic intrusion has considerable lateral extent.

Table IV is a list of densities of the specimens obtained from Dr. Stevenson and includes a brief description of the rock based on a hand-specimen study.

TABLE IV

DENSITY MEASUREMENTS IN THE PAYNE BAY AREA

Sample Number#	Description	Density gm/cc
SG- 181B-63	Coarse-grained gabbro	2.89
SG- 182 -63	Medium-colored gabbro	2.99
SG- 170B-63	Medium-colored gabbro	3.02
SG- 180-63	Chlorite sericite schist	2.99
SG- 171 -63	Siliceous greenstone	2.84
SG- 184 -63	Greenstone	2.92
MW- 197 -63	Greenstone	2.84
SG- 169 -63	Biotite chlorite schist with quartz veins	2.70

#Refers to number used by the Geological Survey of Canada

From the data contained in Table IV mean densities of 2.95 and 2.85 gm/cc have been adopted for the gabbroic and the schistose rocks respectively. The Archaean granitic gneisses out-cropping in the area have not been sampled and the average density given in Table III, 2.70 gm/cc, has been assumed.

Figure 7 is a residual Bouguer anomaly profile taken across the feature in an approximate east-west direction. The anomaly is centred over the outcrop area of the intrusive body and reaches a maximum of 45 mgal at this point. In either direction from the apex, the anomaly decreases at a rate of 3 to 5 mgal/mile and terminates at a distance of 15 miles from the centre of the profile.

Although the density data indicates that the greenstones and the schists are a potential source of positive anomaly, it would appear for several reasons that the gabbro is the principal cause. First, the anomaly is centred directly over the region where the gabbro outcrops. Second, there is no positive anomaly in the Roberts Lake area, 30 miles NNW of Payne Bay, although it is underlain by the schistose rocks. Other indirect evidence is derived from recently compiled, unpublished gravity maps to the south that do not show large positive anomalies over the Labrador Trough, even in the vicinity of the Leaf Basin where basic volcanic and intrusive rocks are exposed over a considerable area (Gross, 1960). One argument favoring the schistose rocks as a major cause of the anomaly is the persistent 45° to 60° inward dips on either side of the axis of the syncline. If these dips continued downward for some distance the result would

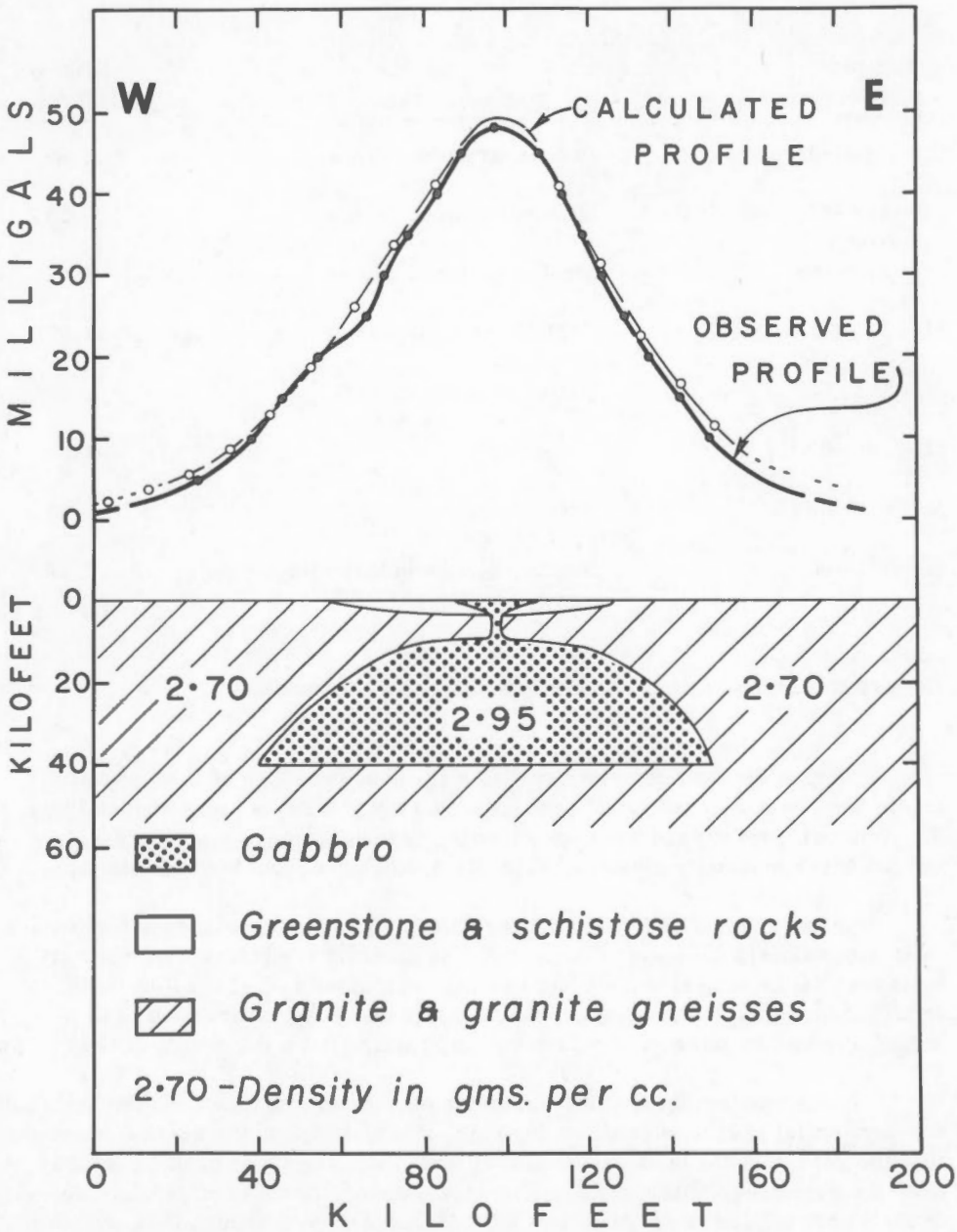

Figure 7. Bouguer anomaly profile across the Payne Bay feature. A dome-shaped mass distribution has been proposed for the gabbroic intrusion.

be a considerable thickness of the greenstones and schists. The data at hand do not permit any final solution of the problem but the available evidence suggests that the gabbroic intrusion is the main cause of the anomaly.

A model frequently proposed for anomalies such as this is a vertical pipe extending downward into the deeper layers of the crust. However, anomalies caused by such distribution result in profiles that are concave and not one that slopes off more or less linearly from the maximum value as in Figure 7. The alternative suggestion is a model that is essentially tabular such as the dome-shaped body shown in Figure 7*. Undoubtedly this is an oversimplification of the mass distribution, but it does point out that a large intrusion is needed to explain the observed anomaly. The configuration of the feeder is hypothetical and the mushrooming effect shown at the surface is based on the concept that the intruding magma spread out from the axis after penetrating the base of the syncline.

CONCLUSIONS

The main results of the preliminary interpretation of the regional data obtained during 1959 and 1960 are summarized below.

1. The area as a whole is in a state of isostatic equilibrium.

2. The positive Bouguer anomalies over the Cape Smith belt are caused by the high-density basic volcanic and intrusive rocks that comprise the belt.

3. Negative anomalies flanking the Cape Smith positive anomaly are interpreted to be part of a regional negative anomaly that can be explained by the existence of a root at the base of the crust. The thickness of the root obtained from this regional anomaly is in agreement with that required by the theory of isostasy to compensate for the crustal load caused by the high-density basic rocks of the Cape Smith belt. This approach to the interpretation of these gravimetric data should be applied to other regions, where there are similar associations of positive and negative anomalies, to investigate the possibility of isostatic compensation occurring at higher levels within the crust. Also, it should be possible to study the role, if any, of structural deformation as a means of compensation.

4. The local positive anomaly in the Payne Bay area is attributed to a large, tabular gabbroic mass that has intruded a synclinal sequence of Proterozoic rocks. The relatively high-density greenstone and schistose rocks present in the syncline may also contribute to this positive anomaly.

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*The computations for this model were made using a method developed by Drs. D. Nagy and J. van Boeckel of the Dominion Observatory. A paper on this subject entitled A new method for three-dimensional model studies of regional gravity anomalies using a digital computer is in preparation.

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