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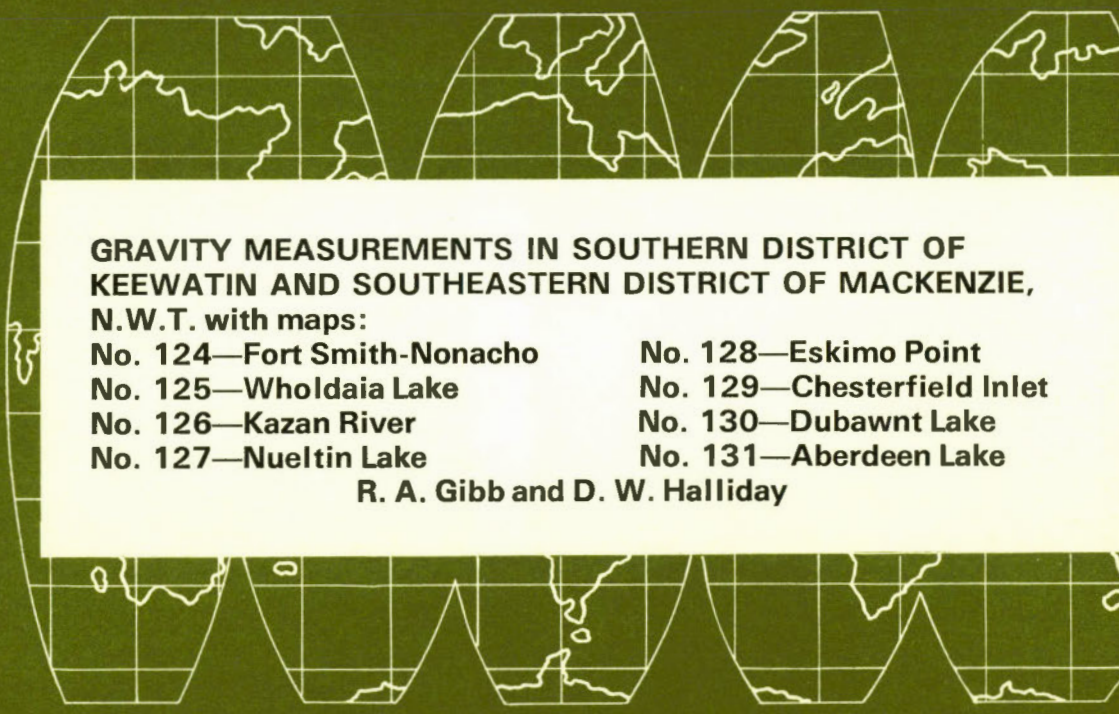

GRAVITY MEASUREMENTS IN SOUTHERN DISTRICT OF KEEWATIN AND SOUTHEASTERN DISTRICT OF MACKENZIE, N.W.T. with maps:

No. 124—Fort Smith-Nonacho
No. 125—Wholdaia Lake
No. 126—Kazan River
No. 127—Nueltin Lake
No. 128—Eskimo Point
No. 129—Chesterfield Inlet
No. 130—Dubawnt Lake
No. 131—Aberdeen Lake

R. A. Gibb and D. W. Halliday

DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA 1974

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of the

EARTH PHYSICS BRANCH

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Abstract. A total of 3,464 gravity stations was used to compile eight Bouguer anomaly maps (1:500,000) which cover part of the Western Churchill Province of the Canadian Shield in southern District of Keewatin and southeastern District of Mackenzie, Northwest Territories. Major negative anomalies in zones of high-level crust, characterized by abundant greenstones and greenschist to amphibolite facies metamorphism, are related to epizonal granitic plutons of Archean and Aphebian age. A prominent north-northwesterly trending broad regional gravity low which cuts across the dominant northeasterly trends of the Province, contains a belt of "Nueltin Lake" type post-orogenic granite of late Hudsonian age. Gravity highs are related to basic volcanic and intrusive rocks and to areas of deep-level crust, characterized by granulite or retrograded granulite facies metamorphism, roots of batholiths and an absence of greenstones.

The major feature of the gravity field, the Central Belt anomalies, crosses the area from southwest to northeast. In this belt dominant gravity, magnetic, and geological trends are northeasterly and linear in sharp contrast to marginal zones on either side in which trends appear to "wrap around" the older Slave and Superior provinces of the Shield to the northwest and southeast. These differences in trend, along with differences in crustal level, metamorphism, plutonism and tectonic style may be related to a complex origin for Western Churchill Province by ancient plate interaction during Aphebian (Lower Proterozoic) time.

Résumé. Les résultats de 3 464 stations gravimétriques ont servi à dresser huit cartes (au 1:500 000) d'une anomalie de Bouguer; ces cartes couvrent la partie ouest de la province de Churchill du Bouclier canadien, dans le sud du district de Keewatin et le sud-est du district de Mackenzie (T.N.-O.). D'importantes anomalies négatives dans des zones au niveau supérieur de la croûte, zones caractérisées par de grandes quantités de roches vertes et de chloritoschistes à des roches au faciès métamorphique à amphibolites, sont dues à des masses plutoniques granitiques, de l'Archéen et de l'Aphébien, de la zone des séricitoschistes. Une large zone proéminente de faible gravité, dont l'axe orienté nord-nord-ouest coupe les axes prédominants nord-est de la province, renferme une bande de granite post-orogénique du type «Nueltin Lake», de la fin de l'Hudsonien. Les zones de forte gravité sont dues à des roches volcaniques basiques et intrusives et à des zones profondes de la croûte, caractérisées par un faciès métamorphique à granulites ou à granulites de rétromorphisme, la présence de racines de batholites et l'absence de roches vertes.

L'élément majeur du champ de la pesanteur, les accidents de la zone centrale, traverse la région du sud-ouest au nord-est. Dans cette zone, les axes prédominants des champs de gravité, magnétique et géologique ont une orientation nord-est et rectilignes, en contraste net avec les zones marginales contigües de chaque côté, où les axes semblent «envelopper» les provinces plus anciennes des Esclaves et du Lac Supérieur, au nord-ouest et au sud-est du Bouclier. Ces différences en direction, jointes à celles des niveaux dans la croûte, du métamorphisme, de l'action plutonique et du style tectonique, peuvent résulter d'une interaction dans la tectonique des plaques, à l'origine de la formation complexe de la partie occidentale de la province de Churchill, au cours de l'Aphébien (Protérozoïque inférieur).

Introduction

The first systematic regional gravity survey of the Canadian Shield with stations at 32 km intervals was made during the period 1947 to 1950 (Innes, 1948, 1960). At that time parts of the District of Mackenzie and District of Keewatin were surveyed. The results of these surveys are shown on the Gravity Anomaly Map of Canada (1957, 1967). During the summer field season of 1970, a 13-man party from the Gravity Division, Earth Physics Branch resurveyed the southern part of the District of Keewatin and the southeastern part of the District of Mackenzie. The area covered includes sheets 55N, 55SW, 65N, 65SE, 65SW, 66S, 75SE and 75SW of the National Topographic system (Figure 1). A total of 3,464 gravity stations at intervals of about 12 km were established throughout the area. The survey was tied to the National Gravity Net (Figure 1).

The gravity stations are shown on eight Bouguer anomaly maps (scale 1:500,000) which accompany this report. The maps are contoured at 5 mgal* intervals and Bouguer anomaly contour values are given in tenths of a milligal. Gravity maps of similar scale and descriptions of the major anomalies in adjoining regions to the south and west have been presented by Gibb and McConnell (1969), Walcott (1968), Walcott and Boyd (1971) and Hornal and Boyd (1972). Underwater and sea-surface gravity measurements made in Hudson Bay to the east of the survey area, have been published separately by Goodacre, Cooper and Weber (1972) at a scale of 1:1,000,000. The results of all these surveys are shown on the recent edition of the Bouguer Anomaly Map of Canada (1974).

The survey area lies wholly in the Churchill Structural Province of the Canadian Shield. A description of the terrain and the results of reconnaissance geological mapping have been published by Wright (1967). Wright's geological compilation (scale 1:1,000,000) covers most of the area. More detailed geological maps (scale 1:250,000) and geological reports are available for much of the area, particularly in the southern part and Davidson (1972) has recently published a review of the Churchill Province and its tectonic style. Aeromagnetic maps of the Federal Government Series are available for a large part of the area. Crustal seismic results have been published by Barr (1971) in the southwestern part of the area and by Mereu and Hunter (1969) to the south of the area. The results of the Hudson Bay seismic experiment (1965) to the east of the area are summarized by Berry (1973) who has listed the original papers in an extensive bibliography.

In this report the major features of the gravity field are described and the correlation of gravity with elevation and geology is examined.

Gravity Measurements

The method of survey was similar to that used in previous land surveys of the national gravity mapping program which is designed to complete the reconnaissance gravity coverage of the Canadian landmass, continental shelves and inland waters.

Gravity Base Station Network

The survey was tied to 25 existing and nine new primary base stations including National Gravity Net stations at Churchill, Uranium City, Fort Smith, Yellowknife, Baker

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*1 mgal = 10^{-5} m/s^2

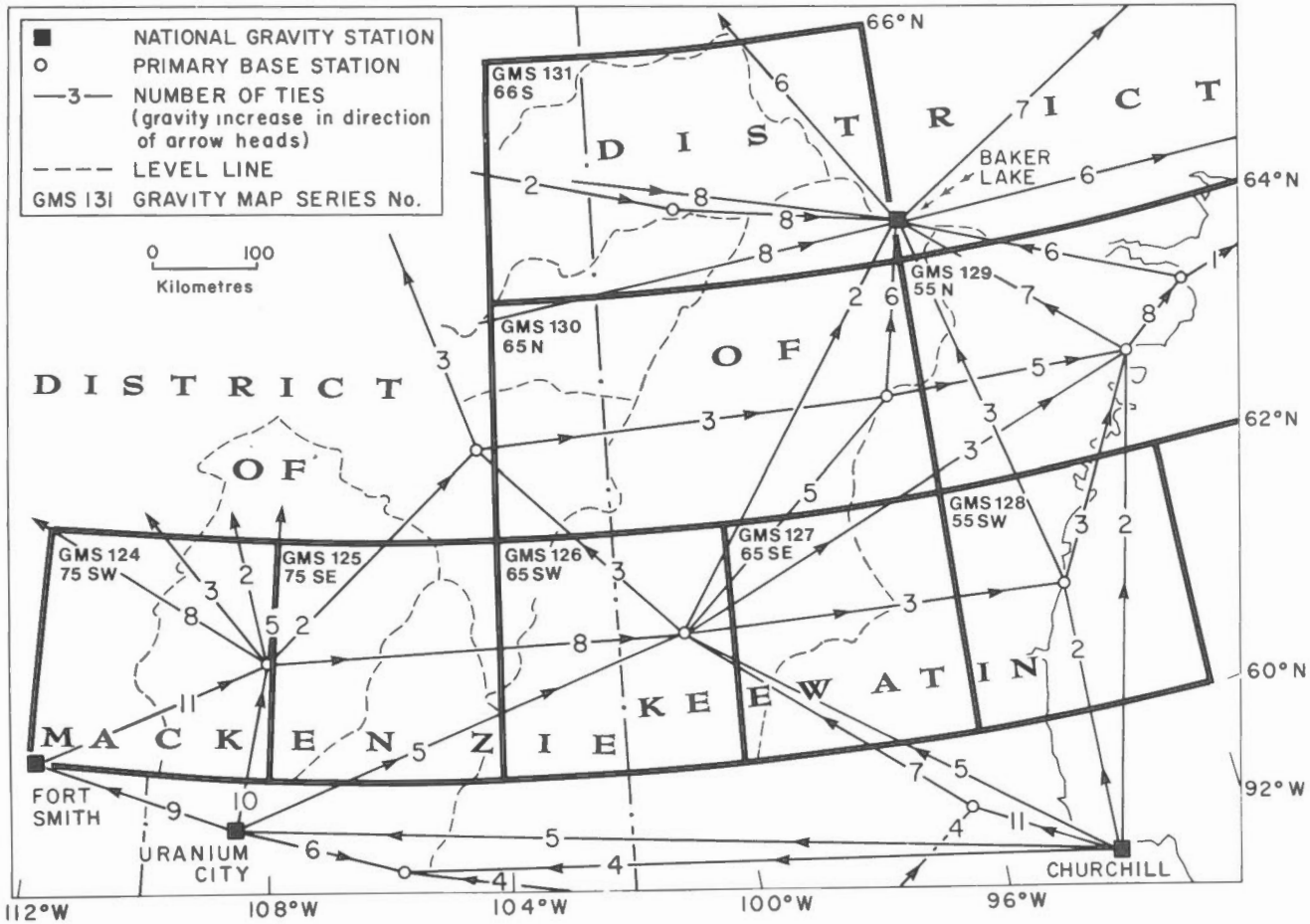

Figure 1. Index map showing gravity map sheets, gravity control stations and level lines.

Lake and Coral Harbour. In addition 76 secondary base stations were established by traversing with a LaCoste and Romberg land gravity meter (G9) between primary bases. Gravity values at these stations were subsequently adjusted by least squares to fit the values of primary stations which have standard errors less than 0.05 mgal. The primary base station network is shown in Figure 1.

Elevations

Wallace and Tiernan altimeter readings were used to compute the elevations of the gravity stations. Corrections for temperature and humidity were applied and elevation control was provided by occupying stations with predetermined elevations at least once every hour. Water surface elevations at these control points were obtained from spirit level traverses (Figure 1), from altitude profile recorder (APR) measurements and from altimeter measurements made by the Surveys and Mapping Branch of the Department of Energy, Mines and Resources. Gravity station elevations obtained in this manner have an accuracy of ±5 m (standard deviation).

Bouguer Anomaly Values

More than 90 per cent of the gravity observations were made using a Worden gravity meter (391), the remaining stations were observed using Wordens 433 and 573. Bouguer anomaly values were computed using a density of 2.67 g/cm^3 according to the method described by Tanner and Buck (1964). Terrain corrections were not computed. Such corrections are unlikely to exceed 1 mgal in most parts of the area. The simple Bouguer anomalies are accurate to within about 2 mgal with the largest part of the error contributed by the errors in elevation. The principal facts of all gravity stations and details of control stations used in the survey are available at cost of retrieval from the Gravity Division, Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa, K1A 0E4.

Geology of Western Churchill Province

The area of the gravity survey lies wholly within the Western Churchill Province of the Canadian Shield. Relief in the area is low to moderate, generally up to about 60 to 90 m (200 to 300 ft.), but local areas of much greater relief do occur. Elevations increase fairly gently from the shores of Hudson Bay to a maximum of about 600 m (about 2,000 ft.) in the southwestern part of the region. Drainage is to the north and east to the Arctic Ocean and to Hudson Bay. The terrain and its relation to glaciation and bedrock is described in more detail by Wright (1967). A map showing the regional smoothed topography was compiled from values of gravity station elevations in 1° x 1° "squares" (Figure 2).

In his recent review Davidson (1972) has aptly described Churchill Province as that part of the Canadian Shield remaining after the adjacent, better defined, younger and older structural provinces have been delineated. The following abbreviated description is based mainly on his review. The oldest rocks in the area are Archean; they occur in the Kaminak subprovince (Davidson, 1972) which trends northeasterly from Lake Athabasca to Rankin Inlet (Figure 3). The rocks are deformed volcanics and sediments intruded locally by batholiths and stocks with compositions varying from granite to gabbro. Massive and pillowed mafic lavas are overlain by locally thick piles of intermediate and

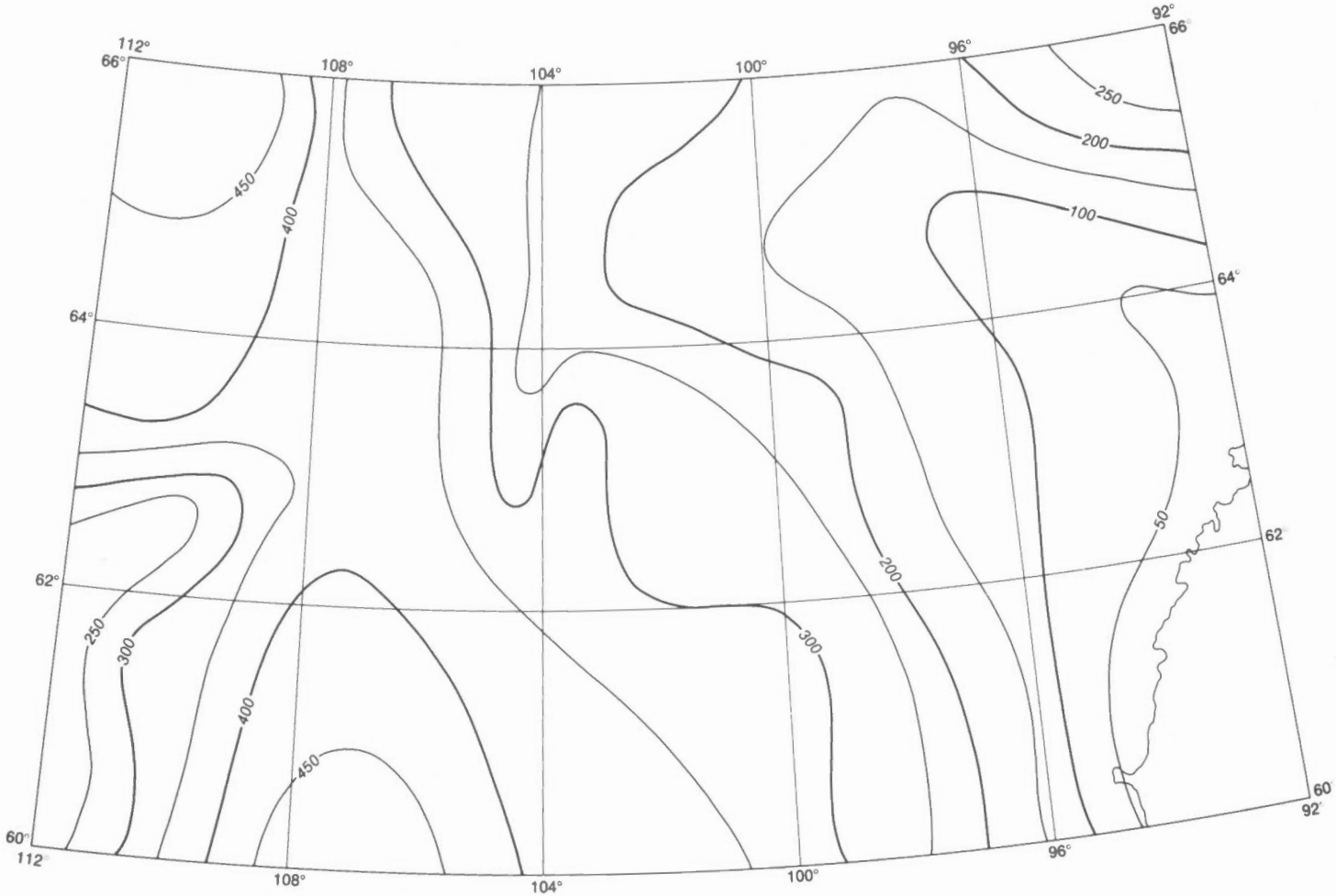

Figure 2. Contours of mean elevation in metres (1° x 1°) means derived from elevation of gravity stations.

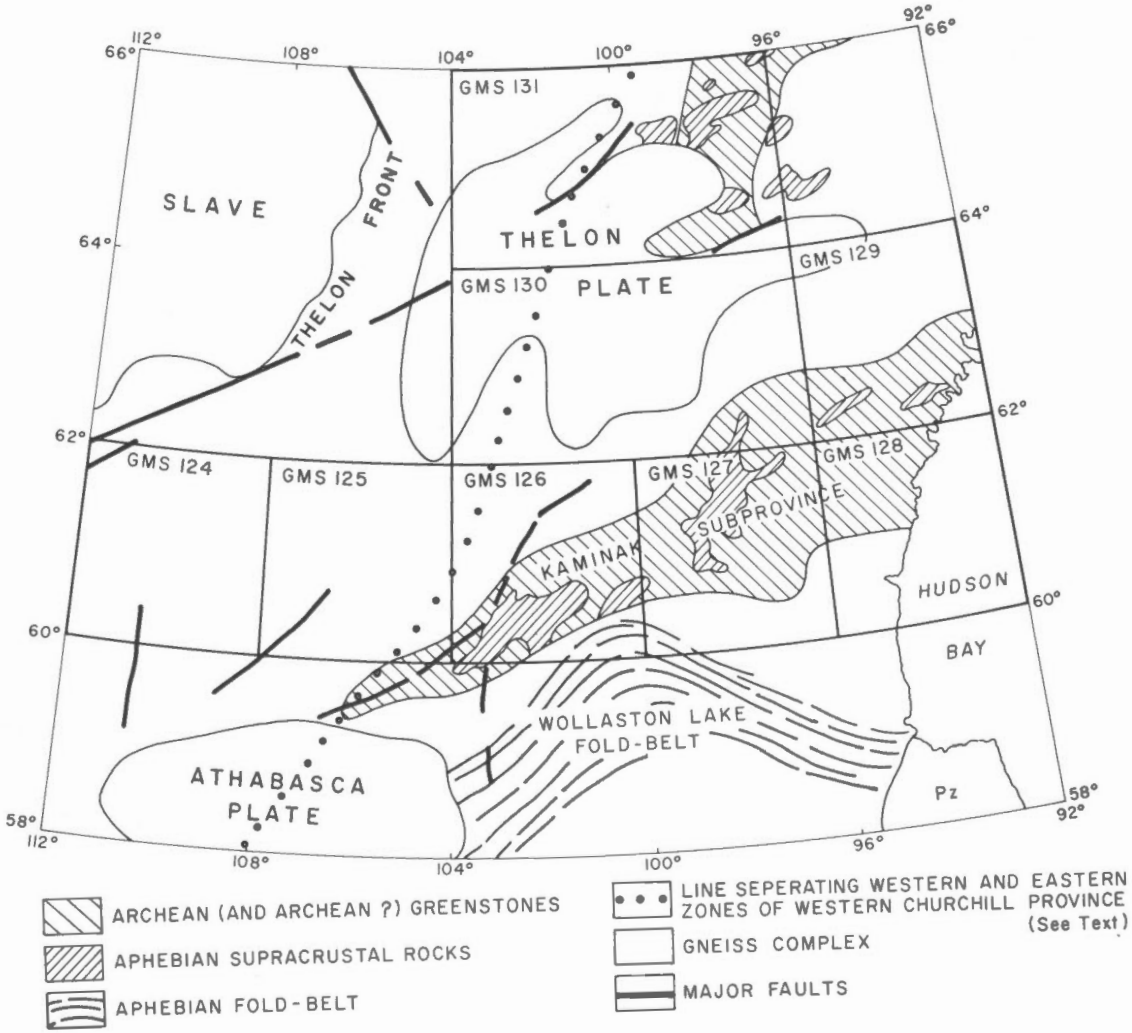

Figure 3. Major structural elements of Western Churchill Province (after Davidson, 1972) and their relation to area surveyed.

felsic volcanic rocks (Davidson, 1970a, b). Local deposits of tuff, greywacke and slate occur where the felsic piles are thin or absent. The plutonic rocks are mainly tonalite and granodiorite which disrupt the broad easterly trending Archean fold axes and which characterize the core of the subprovince. Smaller isolated greenstone belts mapped near Baker Lake may also be of Archean age.

Aphebian (Lower Proterozoic) sedimentary rocks unconformably overlie the Archean rocks of Kaminak subprovince (Davidson, 1972) and occur elsewherc as scattered remnants preserved in fault bounded synclinoria, troughs or slivers. Metavolcanic rocks north of Baker Lake may also be in part Aphebian. The Aphebian supracrustal rocks of the Western Churchill Province have not generally been studied in much detail. An exception is the assemblage overlying the Archean rocks of Kaminak subprovince (Eade, 1964, 1966; Bell, 1968, 1970a). Three distinct groups have been recognized. The earliest Montgomery Lake Group comprises locally derived conglomerate, sandstone, and grit. The Hurwitz Group unconformably overlies the Montgomery Lake Group and has itself been subdivided into three distinct parts suggesting three phases of sedimentation (Bell, 1970b) – continental to shallow marine deposition, deeper marine sedimentation (miogeosynclinal stage?) and a later exogeosynclinal stage. The third group of rocks as yet unnamed comprises arkose and conglomerate and lies unconformably on the Hurwitz Group (Eade, 1970). The scattered deposits of Aphebian strata north of the subprovince cannot usually be correlated directly with these sections and due to the distances separating these deposits correlation is probably not even justified (Davidson, 1972).

Large areas of gneiss, granite and migmatite occur between Archean belts and Aphebian fold belts and are virtually unstudied. These tracts are structurally complex and metamorphism ranges from middle amphibolite to pyroxene granulite facies (Davidson, 1972). The age and origin of these rocks is unknown – they may be reactivated Archean with updated Hudsonian radiometric ages or they may be Aphebian rocks recrystallized and metamorphosed during Hudsonian orogeny(ies). A series of plutons named the "Nueltin Lake" granites by Wright (1967) cuts both Archean and Aphebian structures. Formerly regarded as Aphebian, Eade (1971), they are now considered to be of Helikian age (Eade and Flint, 1973).

Paleohelikian (Middle Proterozoic) strata of the Thelon Plate form the oldest undeformed cover in the area (Figure 3). The rocks are red beds, volcanics and blanket sandstones of the Dubawnt Group (Donaldson, 1965, 1967). Small occurrences of fossiliferous Paleozoic sediments have been recorded at Nicholson Lake and north of Aberdeen Lake.

Origin of Western Churchill Province

The Western Churchill Province is made up of four main elements: (i) volcanic-sedimentary belts of Archean age; (ii) igneous and metamorphic complexes which yield K-Ar radiometric ages characteristic of the Hudsonian orogeny; (iii) Lower Proterozoic fold-belts containing distinctive Aphebian sedimentary and volcanic rocks resting in places on an Archean basement; and (iv) Middle Proterozoic blanket sediments which occur in large supracratonic basins.

The origin of the Churchill Province has recently been considered by McGlynn (1970) who stated "before deposition of Aphebian sediments, all of what is now Churchill Province is thought to have been underlain by deformed Archean supracrustal and granitic rocks". This view is supported by several inliers of Archean rocks within the province which are unconformably overlain by Aphebian rocks and further supported by

local isotope studies (Rb-Sr, U-Pb, etc.) which usually yield dates older than those obtained from K-Ar isotope analysis which are generally representative of the Hudsonian orogeny (1735 m.y.).

McGlynn has described three major geosynclines in which Aphebian rocks may have been deposited separately on an Archean basement. The most northerly is the Coronation Geosyncline (Hoffman, Fraser and McGlynn, 1970) the remnants of which occur around the periphery of and on the Slave Province. The second geosyncline extends across the central part of Western Churchill Province and eastwards to Baffin Island. The third is the Circum-Ungava Geosyncline which is described in more detail by Dimroth, Baragar, Bergeron and Jackson (1970). Of the three, the concept of a single central geosyncline, extending from northern Saskatchewan to Baffin Island is the most speculative, although Jackson and Taylor (1972) have recently defined the northern half of this belt as the Baffin Geosyncline. From the general distribution of Aphebian rocks, McGlynn suggests that the three belts were separate intracratonic geosynclines possibly of significantly different ages. Corresponding closely in area to the three geosynclines, McGlynn has tentatively identified three orogenic zones which may be phases, possibly of significantly different ages, of the Hudsonian orogeny.

Another view of the formation of Churchill Province has been expressed by Gibb and Walcott (1971). They suggested that the Slave and Superior provinces were once separated by Aphebian seas. The rudimentary Churchill Province comprised a number of Archean microcontinents and island arcs with associated peripheral geosynclinal basins. As the Slave and Superior protocontinents converged, these embryonic Churchillian fragments coalesced to form the Churchill Province. Convergence was accomplished by consumption of Aphebian oceanic lithosphere along several subduction zones which were probably active at different times and which may account for the different phases of the Hudsonian orogeny.

Thus, Churchill Province may have been characterized by both Cordilleran type orogeny and by collision type orogeny during its formational history. A dynamic origin for Churchill Province can explain the mosaic of Archean belts, gneiss complexes and Aphebian fold belts, the different isotopic ages and different phases of orogeny perhaps more plausibly than the more stabilistic view. However it is difficult to find unequivocal evidence of plate motions during Aphebian time. The northward convergence of the Australian craton towards Southeast Asia with Churchill Province corresponding to the East Indian Archipelagos (Gibb and Walcott, 1971) is analogous to the structural complexity which may have existed in the Aphebian. To substantiate this hypothesis, criteria must be developed for recognition of cryptic sutures within the province, and paleomagnetic measurements must be made to estimate major horizontal displacements which must have occurred if a dynamic origin is correct.

In his review, Davidson (1972) emphasizes the lack of basic data to support a synthesis of the tectonic evolution of Churchill Province. Huge areas remain virtually unstudied and the detailed information that is available is widely scattered and stems mainly from studies of supracrustal rocks and regions of economic importance. While leaving synthesis for the future, Davidson does point out some important features of the Western Churchill Province:

a) orogenic development in the province had ceased by 1700 m.y. ago;

b) several orogenic phases of differing age probably constitute the "Hudsonian Orogeny";

c) a single geosyncline cannot account for the present distribution of Aphebian sedimentary facies;

d) an ill-defined line (Figure 3) extending from northwest Saskatchewan to southern Boothia Peninsula separates a deep crustal zone to the northwest in which granulite facies are common, greenschist facies and supracrustal rocks are absent or rare, and in which trends are northerly to northeasterly, from a zone to the southeast in which metamorphic grade varies, supracrustal rocks are more abundant and trends are northeasterly to easterly; and

e) there is a crude alternation of fold-belt terrain and greenstone terrain northwards from the Churchill-Superior boundary in the eastern half of Western Churchill Province.

Deep Structure

Crustal thickness information from seismic studies in the survey area is limited. Two of the eight land stations of the Hudson Bay seismic experiment of 1965 were located at Chesterfield Inlet and Eskimo Point. An unreversed line of the Project Early Rise experiment of 1966 extends from Lake Superior to a point just south of the survey area (Mereu and Hunter, 1969). A reversed profile, forming part of a larger experiment in 1966, extends southeast from Yellowknife and crosses the western part of the area (Barr, 1971).

Estimates of crustal thickness range from a minimum of 26 km at Chesterfield Inlet and 24 km at Baker Lake (Ruffman and Keen, 1967) to a maximum of about 50 km just south of the area. Several interpretations of the Hudson Bay data have been made (Hobson, Overton, Clay and Thatcher, 1967; Ruffman and Keen, 1967; Hunter and Mereu, 1967; Barr, 1967; Overton, 1968; Ruffman, 1968; Hajnal, 1968; Hall, 1968). Most interpretations agree that the crust thickens to the south from about 30 km south of Chesterfield Inlet to 35 km in the centre of the Bay along the north-south line of the seismic experiment. The average crustal thickness under the Bay is about 35 km with an average P_1 velocity of about 6.30 km/s and an average of P_n velocity of about 8.25 km/s.

In the Yellowknife profile Barr (1971) assumed a crustal velocity of 6.1 km/s and found no significant difference in crustal thickness in the Slave (33.9 km) and Churchill (34.5 km) structural provinces. However, at the East Arm of Great Slave Lake, the boundary between these provinces is marked by a local increase in thickness of 4 km (37.9 km). These are minimum thicknesses computed on the assumption that no low velocity layers occur in the crust. A possible increase in crustal velocity to about 6.5 km/s just above the M discontinuity would increase these thicknesses by about 7 per cent (Barr, 1971). Upper mantle velocity appears to be constant under the Slave and Churchill provinces (8.10 km/s). The only variation noted by Barr occurs west of the Shield boundary where the upper mantle velocity increases to 8.23 km/s.

Rock Densities

Density determinations made from rock samples collected in the survey area were combined with measurements of samples collected in surrounding regions to obtain mean values for major rock types. All rock densities available from the Gravity Division's density file for an area bounded by latitudes 60°N and 70°N and longitudes 88°W and 120°W were used to compile Table I. All densities were measured without saturation or drying. Although the saturation density is usually taken as representative of rocks in situ, significant errors will not be introduced in this area as the majority of rocks are virtually non-porous. In the case of sandstones and other porous rocks the mean values listed will be lower than the saturated equivalents by up to about 0.20 g/cm^3. The densities of 2,536 samples were used to compile Table I which lists rock densities according to rock

TABLE I

Rock Densities According to Rock Type

Rock Type	No. of Samples	Range (g/cm^3)	Mean (g/cm^3)
Acid dyke	21	2.56 – 2.69	2.60
Acid gneiss	404	2.55 – 2.75	2.64
Acid volcanic	19	2.42 – 2.75	2.60
Amphibolite	19	2.80 – 3.13	2.97
Basic volcanic	54	2.66 – 3.07	2.85
Conglomerate	15	2.40 – 2.67	2.59
Dolomite	63	2.44 – 2.87	2.76
Gabbro	150	2.75 – 3.16	2.94
Granite (undivided)	775	2.53 – 2.75	2.62
Greenschist	37	2.63 – 3.09	2.81
Greywacke	38	2.56 – 2.83	2.70
Limestone	13	2.57 – 2.84	2.72
Mafic dyke	6	2.68 – 3.00	2.82
Mafic gneiss	57	2.61 – 3.44	2.83
Mixed gneiss	266	2.52 – 3.07	2.71
Mudstone	8	2.66 – 2.75	2.70
Pelite	16	2.63 – 2.96	2.77
Quartzite	130	2.56 – 2.80	2.65
Sandstone	92	2.20 – 2.70	2.44
Schist	203	2.54 – 3.07	2.72
Shale	6	2.66 – 2.79	2.73
Siltstone	4	2.60 – 2.73	2.63
Slate	48	2.63 – 2.79	2.71
Syenite	69	2.51 – 2.81	2.64
Ultramafic rock	23	2.90 – 3.31	3.01
Nueltin Lake granite*	32	2.61 – 2.71	2.62

*Eade (1973)

type. Additional density data are given by Dence *et al.* (1968) for the Nicholson Lake area and by Eade (1973) for the "Nueltin Lake" granite. The unweighted mean density of all samples (2,536) is 2.68 g/cm^3 with a range of 2.20 to 3.44 g/cm^3.

Correlation of Gravity with Geology

A simplified map of the Bouguer anomalies is shown in Figures 4 and 5. The anomalies have a range of 110 mgal from a maximum of 20 mgal to a minimum of -90 mgal. The mean value is -55 mgal. In the following analysis the gravity anomalies are correlated with geology by gravity map sheet. In a subsequent section a synthesis is presented in which some of the major regional gravity features are interpreted and discussed in more detail.

GMS 124 Fort Smith-Nonacho (75SW)

Most of the rocks in the Fort Smith-Nonacho area have been mapped as granite and granodiorite or as mixed gneisses (Henderson, 1939a, b; Wilson, 1941; Mulligan and Taylor, 1969). The gneisses are often distinguishable from the granite only by texture but

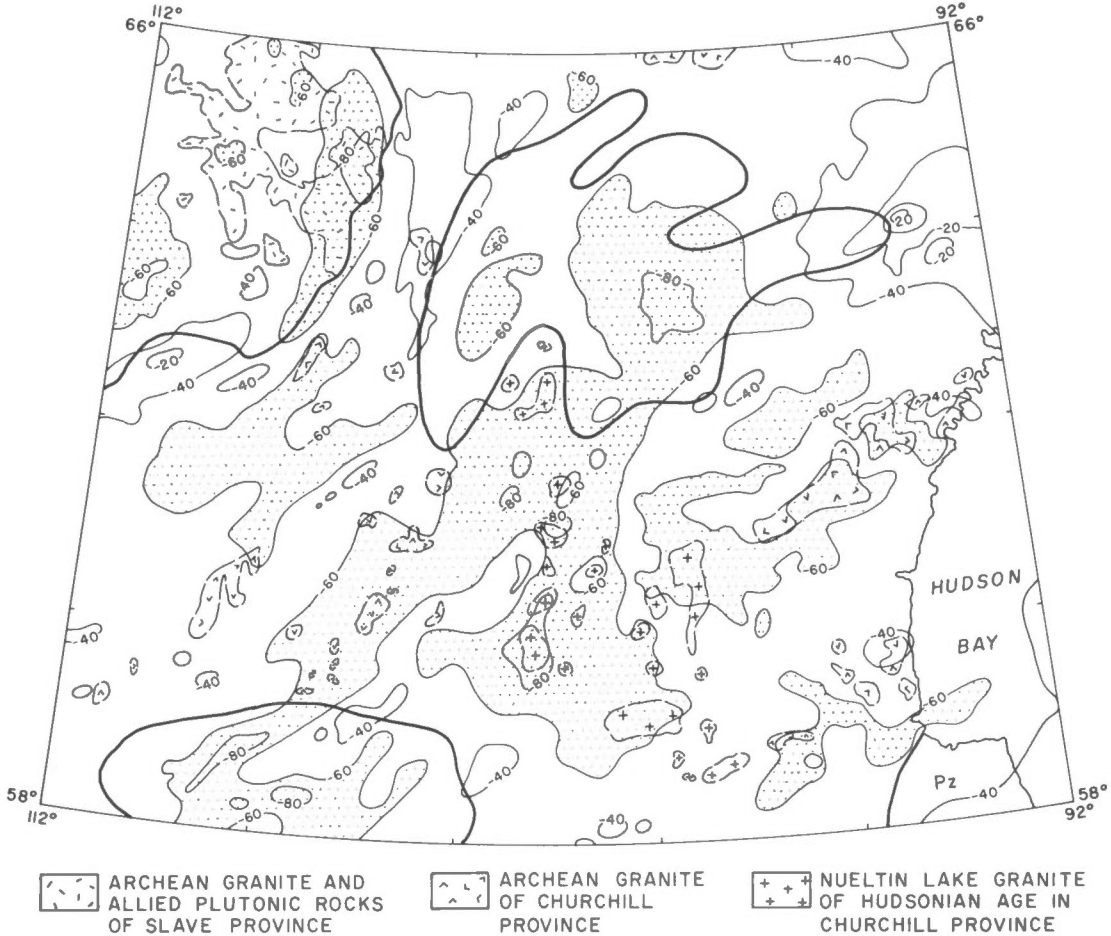

Figure 4. Correlation between gravity lows (dots) and distribution of granites of Slave and Western Churchill Provinces (from Geological Map of Canada, Geol. Surv. Can., Map 1250A).

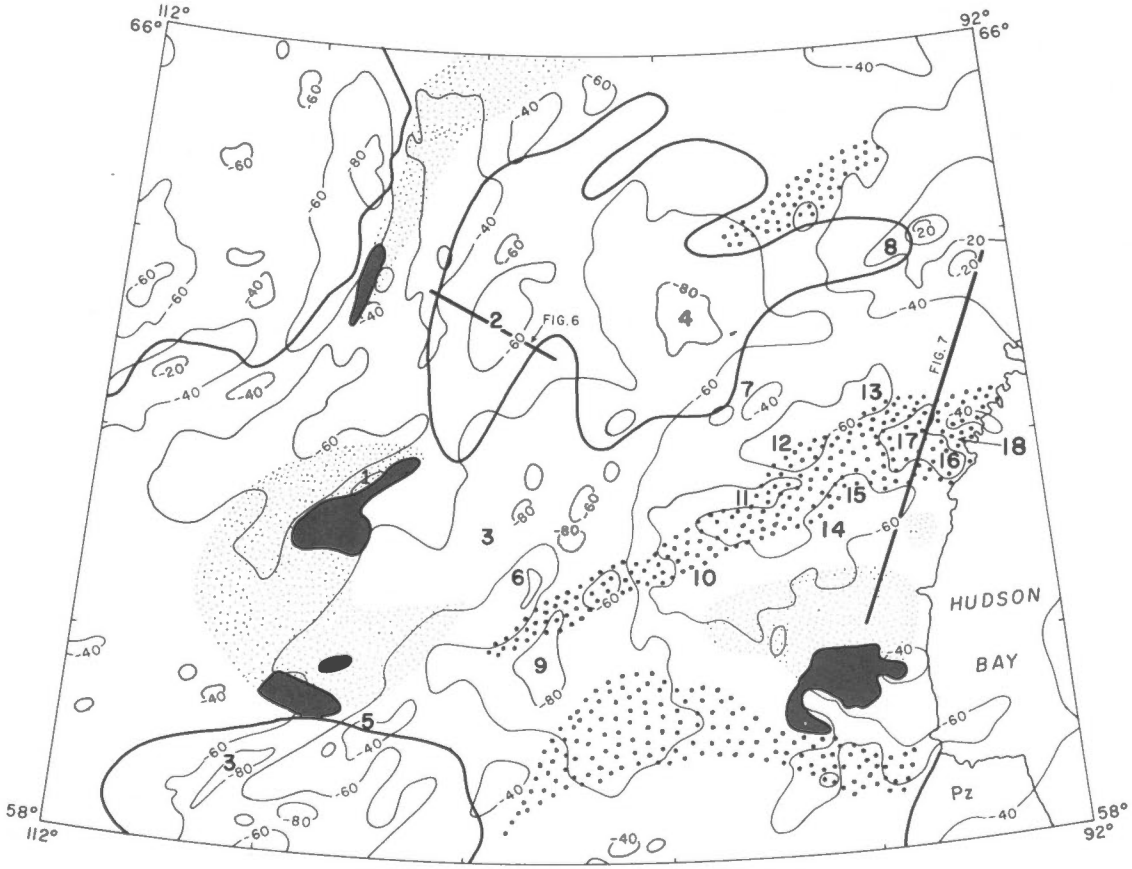

Figure 5. Simplified Bouguer anomaly map of Western Churchill Province and distribution of metamorphic facies. Major anomalies include: 1) Taltson River high; 2) Dubawnt low; 3) Fond du Lac low; 4) Kaminak River low; 5) Lisgar Lakes high; 6) Snowbird Lake high; 7) Kazan River high; 8) Baker Lake high; 9) Kasba Lake low; 10) Nueltin Lake low; 11) Bate Lake low; 12) Maguse low; 13) Savage Lake low; 14) Corbett low; 15) Turquetil Lake low; 16) Wallace River low; 17) Kaminak Lake low; 18) Tavani low. Metamorphic facies: large dots–greenschist to lower amphibolite facies; blank–middle to upper amphibolite facies; black–granulite facies (after Davidson, 1972).

in many areas remnants of sedimentary and volcanic rocks can still be recognized. The oldest supracrustal rocks in the area occur west of Nonacho Lake where metamorphosed basic volcanics, greywacke and shale grade into migmatite and paragneiss. These rocks are tentatively regarded as equivalents of rocks of the Archean (?) Tazin Group which occur north of Lake Athabasca (McGlynn, 1970, p. 92). The major feature of the geology of the area is the fault-controlled basin extending north northeasterly from the southern end of Thekulthili Lake in which sedimentary rocks of the Nonacho Group are preserved. They include conglomerate, sandstone, arkose, quartzite, siltstone and shale and rest on a basement of granite and gneiss. A recent study of the paleomagnetism and age of Nonacho Group sediments and associated dykes suggests that they were deposited sometime between 2500-1700 m.y. (McGlynn *et al.*, 1974).

A noteworthy feature of the geology is the extensive faulting in the area. A major fault system cuts the Nonacho basin from south to north and the McDonald Fault system crosses the extreme northwestern corner of the area. Smaller scale fractures and faults trending northwest and northeast are also abundant, particularly in the western part of the area to the south of the McDonald Fault. The fault zones, marked by breccias and mylonites, appear to have formed before the Nonacho and Martin sediments were deposited (McGlynn, 1970, p. 93) but later movements have also occurred along the old faults and along new faults with similar trends.

There are no large amplitude gravity anomalies in the Fort Smith-Nonacho area. Bouguer gravity values generally decrease from about -40 mgal along the western edge of the area to about -75 mgal in the northeast. Moreover, there is no obvious correlation between the gravity anomalies and the geology as described from reconnaissance mapping. By analogy with other areas, local gravity lows are probably underlain by intrusive granites and low density gneisses, and highs are probably related to denser phases of the gneissic basement, but these differences have not been distinguished during reconnaissance geological mapping. Gravity anomalies pass virtually undisturbed across the Nonacho basin confirming that the densities of the continentally-derived sedimentary fill and the basement rocks are very similar. There is also no obvious correlation between gravity anomalies and major fault zones. This lack of correlation may also be explained by the relative homogeneity of the basement rocks and sediments.

Aeromagnetic maps of this area are probably the best guide to major structures and major lithological differences within the basement. A belt of high magnetic anomaly extends northwards across the region. In the north the high magnetic anomalies are related to post-Nonacho intrusive granite at Taltson Lake and west of Lady Gray Lake. It seems likely that these "younger granites" extend southwards across the area as the form and intensity of the magnetic field does not change as the belt is followed south. This distinctive zone, although well defined on the magnetic maps, does not have a clear gravity expression.

Magnetic anomaly patterns and drainage patterns may both be used to map important fault systems and fractures, particularly in the western half of the area. Most faults trend northwesterly or northeasterly although some trend almost due north. Major north trending faults cut the "younger granites" and can be followed northwards through the Nonacho basin. To the west a series of northwesterly trending fractures with sinistral displacements of about 2 km are clearly demonstrated by the magnetic anomalies. These fractures have become the loci of drainage and they can be traced in many cases along linear lakes and rivers. The magnetic maps also show a series of linear anomalies with the same northwesterly trend suggesting that some fractures have been filled by dykes. This

fracture pattern cuts the zone of "younger granites" but does not appear to extend beyond it to the east.

In the central and eastern part of the area the magnetic pattern responds to a greywacke unit of the Nonacho Group and to local variations in the magnetic properties of the basement gneisses and granites. In this area magnetic trends are mainly northeasterly.

GMS 125 Wholdaia Lake (75SE)

Two major gravity anomalies trend northeasterly across the Wholdaia Lake area. They are the Taltson River high (15 to 20 mgal above the mean Bouguer anomaly value of -55 mgal) and the northeasterly extension of the Fond du Lac low with local minima at Wigness Lake (20 mgal below mean) and at Wholdaia Lake (25 mgal below mean).

The Taltson River high is underlain by granulites described by Taylor (1959) as garnet-quartz-feldspar gneisses and hypersthene-quartz-feldspar gneisses of distinctive colour and texture. There is a clear correspondence between the high gravity anomaly and the area mapped as granulite except at the northern extremity of the anomaly where the rocks are gneissic granite and massive granite. Elsewhere in the area granitic rocks are associated with gravity lows so that we may conclude that the granites at the northern end of the Taltson River high are probably underlain by granulites at no great depth. The magnetic field is relatively undisturbed over the granulite zone except where local concentrations of magnetite occur e.g. at Knobovitch Lake (Taylor, 1959) and at Manchester Lake where two small plutons of gabbro and anorthosite occur on the northwest flank of the zone. These plutons are too small to be detected by the regionally-spaced gravity stations. Local gravity and magnetic highs are, however, associated with another gabbroic pluton in the extreme northwest corner of the area. This pluton underlies the southwestern end of a linear gravity high which extends far to the northeast (see GMS 89, Hornal and Boyd, 1972). Both this high and the Taltson River high are linear extensions of an even more extensive gravity high which occurs on the Churchill side of the Thelon Front. This high is also underlain by granulites or retrograded granulite facies rocks (Davidson, 1972). These linear highs are separated by a zone of low gravity anomaly underlain by massive granite and granitic gneiss. This major zone extends northeasterly from Alcantara Lake (GMS 124) to south of Lynx Lake (GMS 89).

Another region of high anomaly trends southeasterly normal to the Taltson River high. It is underlain by paragneisses of mixed composition but including several types rich in biotite and hornblende. These gneisses are probably denser than the surrounding gneissic granite and granodiorite, and offer a likely explanation for the higher gravity values.

The extension of the Fond du Lac low (Walcott, 1968) crosses the southeastern part of the Wholdaia Lake area. Here the low is about 30 km wide and follows a sinuous northeasterly trend. Farther south, Walcott (1968) has suggested that granite may in part explain the low gravity values of the Fond du Lac feature although the correlation is not explicit. In this area, however, there is a one to one correspondence between gravity minima within the Fond du Lac low and rocks of granitic composition. At Wigness Lake, massive granite and granodiorite occur and at Wholdaia Lake the rocks underlying the low are gneissic granite and granodiorite (Taylor, 1959). The only difference between the rocks in the two areas is texture, according to Taylor, who used this difference to separate his mapping units. Within the Fond du Lac low the magnetic anomalies are subdued except locally where slivers of paragneiss are marked by positive anomalies.

The Fond du Lac low is flanked to the southeast by the Snowbird Lake high, a large positive anomaly which extends into the adjacent Kazan River area (GMS 126). Three small gabbroic plutons have been mapped in this area to the north of Selwyn Lake, but paragneiss and granite are more abundant. The possible cause of this anomaly is discussed in the next section.

On the western flank of the Fond du Lac low, Hoadley (1955) has mapped massive pink granitic rocks west of Dunvegan Lake. A northeasterly belt of positive magnetic anomaly extends from there to west of Abitau Lake suggesting a northerly extension of these rocks. An abrupt change in magnetic anomaly pattern and a coincident gravity gradient may mark a major fault on the western flank of the granitic belt.

Two small circular magnetic highs occur in the area; one is north of Thomas Lake where a small intrusion of nepheline syenite has been mapped and the other is east of Quinn Lake where a magnetic anomaly of about 8,000 gammas is still unexplained.

GMS 126 Kazan River (65SW)

The Fond du Lac gravity and magnetic low continues in a northeasterly direction across the northwestern corner of the Kazan River area. It is underlain mainly by glacial drift but the few isolated outcrops of granitic gneiss found in the area (Wright, 1967) suggest that granitic rocks of low density are again responsible for the strip of low gravity values. Other large gravity lows in this area are similarly underlain by granite. A large low northwest of Ennadai Lake is related to a granitic complex comprising granodiorite, granite and quartz monzonite. This low is flanked on either side by local highs. To the northwest the high corresponds to an area of high magnetic anomaly and is underlain by gneiss, schist, amphibolite and granulite (Wright, 1967). The high on the southeastern flank on the west side of Ennadai Lake is underlain by Archean metavolcanic rocks intruded by two diorite-gabbro plutons. A major fault separates these rocks from Aphebian rocks of the Hurwitz Group to the southeast (Eade, 1971). Another large low at Kasba Lake is underlain by a large batholith of "Nueltin Lake" granite. The "Nueltin Lake" granites (Wright, 1967) are late-orogenic plutons of coarse grained porphyritic granite emplaced during the final phase of the Hudsonian orogeny (Eade, 1971). At Kasba Lake the granite is massive to foliated, fine to coarse grained and porphyritic in places. Minimum gravity values (35 mgal below mean) occur over fine to medium grained foliated granite west of Gothe Island.

The largest gravity high in the area is the Snowbird Lake high which extends westwards to the Wholdaia Lake area (GMS 125). It corresponds to an area of rocks of higher metamorphic grade comprising mainly paragneiss and gneissic granite with minor amounts of metasediments, metavolcanics and amphibolite. Several small mafic and acidic plutons have also been mapped in this area (Taylor, 1963). Taylor has also mapped pyroxene bearing gneiss in the southwest of the area where the metamorphic grade increases. This block of metamorphic rocks is bounded to the east by a wide zone of faulting which extends northeasterly along the Striding River and the east side of Snowbird Lake. This zone is marked by mylonitization, by a belt of intense magnetic anomalies (MacLaren, 1959), and by a steep gravity gradient. Several of the mafic plutons, which vary in composition from gabbro to pyroxene gabbro with interbands of pyroxenite and anorthosite are restricted to the fault zone and its vicinity, while others coincide with local positive closures within the gravity high. Eade (1971) has suggested that a similarly trending fault which separates volcanics intruded by gabbro from Hurwitz Group rocks to the southeast may be an extension of this zone of faulting. A further

possible extension to the northeast has been mapped by Eade (1966) west of North Henik Lake in the Nueltin Lake area (GMS 127).

About 40 km northwest of Dimma Lake in the northeast corner of the map-area, a small circular gravity high corresponds to an intense magnetic high (about 7,000 gammas). Both anomalies have a diameter of about 14.5 km and their source is unknown.

GMS 127 Nueltin Lake (65SE) and GMS 128 Eskimo Point (55SW)

GMS 127 and 128 can be divided into two areas, the northeasterly trending Kaminak subprovince and a Hudsonian migmatite-gneiss complex (Davidson, 1970a) which bounds the subprovince to the southeast. To the northwest (GMS 129 and 130) the subprovince is bounded by a similar Hudsonian migmatite-gneiss complex. The gravity anomalies associated with Kaminak subprovince are distinguished by steep gravity gradients which separate small oval to elongate positive anomalies from larger oval to circular negative anomalies. This gravity pattern owes its origin to closely spaced batholithic complexes usually separated by keels of denser volcanic-sedimentary rocks (greenstones) and is very similar to that mapped in the Timmins-Senneterre area of Superior Province (Gibb *et al.*, 1969). There, the anomaly level is also about -70 mgal over batholithic complexes, but higher values over the surrounding volcanic-sedimentary rocks (about -35 mgal) suggest that thicker keels may have been preserved in Superior Province. A regional gradient gradually increases southwards over the migmatite-gneiss complex where local highs correspond to small volcanic remnants, the largest of which occurs north of Edehon Lake.

Within Kaminak subprovince two lines of negative anomalies underlain by corresponding Archean batholithic complexes flank a central belt of greenstones. In the northeast the batholiths occupy a more central position in the core of the greenstone belt. The northeasterly line comprises three major lows underlain by the Bate Lake batholith (Eade, 1966), the Maguse batholith (Bell, 1971), and the Savage Lake batholith (GMS 129; Davidson, 1971a); the southern line also comprises three gravity lows underlain by the Corbett batholith (Bell, 1971), the Turquetil Lake complex (Davidson, 1970b), and the Wallace River complex (Davidson, 1970b). The Kaminak Lake complex and the Tavani complex (Davidson, 1970b) are more centrally located at the northeastern end of the Province. The offshore gravity results in Hudson Bay suggest that the subprovince may extend some 80 km out into the Bay and that at least two more related batholithic complexes occur offshore.

The minimum anomaly over the batholiths ranges from -60 mgal at Tavani to -80 mgal at Wallace River with minimum values of -70 to -75 mgal over the majority of the batholiths. These differences are probably related to different density contrasts between batholithic and country rocks. The composition of the batholiths is extremely variable. The Tavani complex has a migmatitic core described by Davidson (1970b) as consisting of a bewildering assortment of layered and schlieren gneisses, migmatite, and hornblende tonalite laced with a variety of granitoid veins and dykes. The Wallace River complex has a core of massive, homogeneous pink, biotite adamellite with microcline megacrysts (Davidson, 1970b) surrounded by a variety of denser rocks including tonalite, gabbro and migmatite. Cores of low density adamellite similar to that at Wallace River occur in several batholiths. Some such as the Maguse and Corbett batholiths and Savage Lake batholith appear to be almost wholly composed of adamellite, while others such as the Turquetil Lake and Kaminak Lake complexes are mainly composed of varieties of tonalite. Although the gravity minima are consistently between 70 and 90 km apart throughout the subprovince, the gravity pattern suggests that the batholithic complexes

are connected either at the surface or at very shallow depths. Thus, the Corbett batholith and Turquetil Lake complex underlie two minima within a much larger anomaly. In the same way the Wallace River and Kaminak Lake complexes are interconnected and are connected to a further northeasterly extension on the northeastern side of Southern Lake (GMS 129). If the dense supracrustal rocks were absent from the region, the negative anomalies would coalesce to form one large gravity low similar to the vast anomaly north of Tulamalu Lake, which is informally named the Kaminak River low (GMS 130).

All of these batholithic complexes are considered to be Archean (Davidson, 1972) with the exception of the Bate Lake granodioritic pluton which cuts Hurwitz rocks (Eade, 1966) and is therefore late Aphebian and the possible exception of the Corbett batholith which may also possibly be Aphebian (Bell, 1971).

The Neultin Lake granite (GMS 127) is also marked by a large negative anomaly. Nueltin Lake is the type-area for the younger post-orogenic granites of late Hudsonian age described by Lord (1953), Wright (1967) and Eade (1971, 1973). The Nueltin Lake batholith varies in composition from biotite granite to quartz monzonite. The granite is red to pink and massive with phenocrysts of microcline and abundant fluorite. The age of the Nueltin Lake granite is about 1800 m.y. according to age determinations and it intrudes rocks of the Hurwitz Group (Eade, 1971). Similar rocks underlie the large negative anomaly at Kasba Lake (GMS 126).

GMS 129 Chesterfield Inlet (55N)

The Kaminak subprovince extends over the southern part of GMS 129 where major negative anomalies are associated with the previously mentioned Savage Lake, Kaminak Lake and Tavani batholithic complexes (GMS 128) and positive anomalies are related to envelopes of volcanic-sedimentary rocks. A local gravity high is underlain by a small pluton of ijolitic and syenitic rocks at the northeast side of Kaminak Lake (Davidson, 1970c). The extension of Kaminak subprovince for about 80 km beneath Hudson Bay is suggested by the gravity pattern.

North of the subprovince the main feature of the gravity field is an easterly trending regional gravity gradient. Gravity values steadily increase northwards over a migmatite-gneiss complex to maximum values of −5 mgal at both Baker Lake and to the north of Chesterfield Inlet. The monotonous field is relieved by a few local anomalies of 5 to 10 mgal magnitude. These anomalies are mainly positive and are underlain by gneisses, granulites and amphibolites derived mainly from volcanic rocks and associated plutons of diorite, gabbro and anorthosite.

The regional gradient forms the southern flank of a major gravity high lying mainly outside the present area but which extends from Baker Lake to Southampton Island with local maxima at the east end of Baker Lake and at Daly Bay (GMS 139, 140 and 141). The local high at the east end of Baker Lake, the southern tip of which occurs in GMS 129, is of particular interest as it lies along the same trend as the Lisgar Lakes high, the Snowbird Lake high and the Kazan River high (see GMS 130). That part of the anomaly in GMS 129 is underlain by Dubawnt sandstone and conglomerate in the west and by gneisses and other high grade metamorphic rocks in the east. A local maximum (peak value −5 mgal) is underlain by a hornblende diorite pluton (Wright, 1967). A similar but smaller pluton lies on the axis of the high about 12 km to the south. Several other gabbroic plutons occur to the east both north and south of Chesterfield Inlet.

GMS 130 Dubawnt Lake (65N) and GMS 131 Aberdeen Lake (66S)

Most of the area covered by these two map sheets is underlain by Helikian cover rocks of the Thelon Plate. These rocks belong to the Dubawnt Group which consists of a

lower red-bed sequence, a predominantly volcanic sequence, and an upper sandstone sequence. The lower red-beds are up to 5,600 m thick and comprise a basal conglomerate, well-sorted sandstone, siltstone and mudstone. The volcanic rocks include porphyritic andesite, latite, and trachyte intruded by syenite. The upper sandstone sequence is about 1,000 m thick and covers most of the Thelon Plate west and north of Dubawnt Lake. The Thelon Plate covers an area of about 70,000 km^2.

The Kaminak River low, a very extensive anomaly covering about 40,000 km^2 dominates the gravity field in this area. It has an amplitude of only -30 mgal and is underlain by granite, granodiorite and allied rocks, by porphyritic volcanics of the Dubawnt Group, and by local patches of the upper sandstone sequence of the Dubawnt Group (Wright, 1967). There is no obvious correlation between this anomaly and the reconnaissance geological mapping (Wright, 1967) but it seems likely that the granitic complex, now stripped of older supracrustal rocks, which underlies the anomaly is the source. The important Fond du Lac low appears to terminate at Kaminak Lake in the southwest of the area but there is some indication on the gravity map that this strong northeasterly trend may continue through the Kaminak River low as far as Schultz Lake.

In the west of the Dubawnt Lake map-area the Dubawnt low (Hornal and Boyd, 1972) has an amplitude of about -30 mgal and is underlain by upper sequences of the Dubawnt Group. Farther north to the northwest of Beverly Lake a basement arch within the Thelon Formation is marked by a belt of gravity highs. This correlation suggests that the sediments of the Dubawnt Group may have a significant gravity expression.

Other local anomalies in the northwest part of the area are related to volcanic belts and granites. In the southeast there is an important anomaly, here named the Kazan River high. This anomaly is similar in size and amplitude to the Snowbird Lake high to the southwest. At its northeastern end, Bell (1971) has mapped a migmatite terrain comprising three major units; a mafic unit derived from metavolcanic rocks and mafic plutons of the Kaminak Group, a gneiss and schist unit derived from metasedimentary rocks, and a granitic unit possibly derived from granitic plutons.

Interpretation and Synthesis

Correlation of Gravity with Granites

Many examples of the consistent correlation of granites with gravity lows have been given in the descriptions of the individual map sheets. Gravity anomalies associated with epizonal granites such as those of Kaminak subprovince are generally of greater amplitude than those underlain by mesozonal or catazonal granites of the western part of the area. Major batholiths and their relationship to the gravity field are shown in Figure 4. Three groups of granites are shown – Archean granites of the Slave Province with radiometric ages ranging from 2500 to 2800 m.y., pre-Hudsonian granites of the Churchill Province in the range 1850 to 2500 m.y. and late Hudsonian granites ("Nueltin Lake" granites) in the range 1970 to 1800 m.y. In a recent report Eade (1973) has assigned a Helikian age to the "Nueltin Lake" granites because they transect and are younger than Hudsonian structures.

The granites of the Slave Province generally occur as massive or gneissic batholiths. Most frequently they are composed of granodiorite, quartz diorite and quartz monzonite (McGlynn and Henderson, 1972). In the Churchill Province, Davidson (1972) has identified three types of granite – Archean granite little affected by later orogeny, pre-Hudsonian granite, reworked in the Hudsonian, and Hudsonian granite. They are

difficult to separate and Davidson notes that unless magmatic granitic plutons cut Aphebian supracrustal rocks it is only an assumption that they were produced during the Hudsonian orogeny. They may be remelted and remobilized older granites of an Archean basement. The only large batholiths of unequivocal Hudsonian age are the "Nueltin Lake" granites which follow a north-northwesterly trend.

Three regional gravity lows, two with predominantly northeasterly trends and one with a crosscutting north-northwesterly trend, assist in identifying these major belts of granitic intrusive activity with corresponding trends (Figure 4). The largest low crossing the whole area from southwest to northeast belongs to the Central Belt anomalies which are discussed in a later section.

To the east of the Central Belt anomalies, the main feature of the geology is Kaminak subprovince which also has a general northeasterly trend although easterly Archean structural trends are preserved within it. A gravity anomaly belt, distinguished by steep gravity gradients and intense lows, is clearly related to the rocks of the subprovince and particularly in the east has the same general northeasterly trend. Areas of relatively positive anomaly are underlain by volcanic-sedimentary sequences of the Kaminak Group and intense negative anomalies are invariably related to Archean batholithic complexes. These complexes are made up of clusters of smaller batholiths and stocks with a wide variety of compositions, structures and textures (Davidson, 1970b). The major rock types include granite, granodiorite, tonalite, gabbro and migmatite close to the boundaries with country rock. In general the granitic and granodioritic bodies were the last phase of intrusion. Model studies suggest that the granites extend to depths of at least 7.5 km although some may extend to even greater depths.

A broad north-northwesterly gravity trend cuts the western half of Kaminak subprovince. This crosscutting trend is a regional gravity low which also cuts across the Central Belt anomalies near the centre of the map-area (Figure 4). The majority of the "Nueltin Lake" granites (Lord, 1953; Wright, 1967; Eade, 1971) lie scattered along the axis of this low. These granites are post-kinematic Aphebian (Helikian?) bodies which intrude Aphebian supracrustal rocks, as opposed to most other granitic plutons in Western Churchill Province which may represent an older reworked basement (Davidson, 1972). Eade (1971) suggests that the "Nueltin Lake" granites were emplaced under dilatant conditions and that their location was determined by the convergence of two prominent trends one northeasterly and one easterly. The Dubawnt low underlain by sediments of the Thelon Formation (Figure 4), may be an extension of the north-northwesterly trend which appears to correlate with the distribution "Nueltin Lake" granites (Figure 4). It may reflect the presence of "Nueltin Lake" type granite beneath the Thelon Plate. This possible interpretation is discussed in the next section.

The Dubawnt Low

The Thelon Plate is the name given by Stockwell (1970) to the area within Western Churchill Province underlain by Paleohelikian rocks of the Dubawnt Group (Figure 3). The Dubawnt Group comprises a lower immature red-bed sequence, a middle volcanic sequence, and an upper mature sequence of quartz arenites, conglomerates, siltstones and dolostones (Donaldson, 1967). A prominent gravity anomaly, named the Dubawnt low by Hornal and Boyd (1972) is associated with the western part of the Thelon Plate (Figure 5). The Dubawnt low has an amplitude of about -30 mgal and covers an area of about 6,000 square kilometres. There are two alternative explanations for this anomaly; it may be caused by rocks of the Dubawnt Group preserved in a fault-controlled basin or it may be caused by a subjacent granitic pluton.

Rocks of the Thelon Formation (see Table II) cover most of the western part of the Thelon Plate. In places they lie disconformably on older formations of the Dubawnt Group but mainly they appear to lie unconformably on basement. They are overlain locally by dolostone and glacial drift. Fraser *et al.* (1970) suggest that the cratonic cover was much more extensive than its present distribution would suggest and that the rocks of the western Thelon Plate are preserved by faulting. The western edge of the plate is fault-controlled and several significant faults occur within the unit. The gravity low occurs entirely within the outcrop limits of the Thelon Formation with its long axis parallel to the main direction of faulting. Faults with a similar trend could control a local depression or trough in which lower members of the Dubawnt Group or conceivably older sediments are preserved. Vertical movements associated with the McDonald Fault may have been responsible for the formation of depressions at its extremities in which sediments are preserved. To the northwest of the McDonald lineament the Thelon Formation appears to be very thin; two basement arches or windows in the Aberdeen Lake area are defined by local gravity highs. Gravity lows flank these arches on each side but are underlain by Thelon Formation suggesting a correlation between sedimentary thickness and gravity anomalies.

TABLE II

Dubawnt Group*

Dolostone	siliceous, stromatolitic
Basalt	
Thelon Formation	sandstone, conglomerate, siltstone
Disconformity	
Pitz Formation	mainly volcanics
Martell Syenite	pyroxene-biotite syenite
Christopher Island Formation	trachyte, andesite, latite
Slight angular unconformity	
Kazan Formation	sandstone, siltstone, conglomerate
South Channel Formation	conglomerate, sandstone, siltstone
Major unconformity	
Basement	

*After Donaldson (1967)

The average density of Paleohelikian sandstones collected in the area is 2.39 g/cm^3. The average density of all rocks listed in Table I is 2.68 g/cm^3. If the latter value is accepted as representative of the basement density, the density contrast between sediments and basement is 0.29 g/cm^3. To allow for uncertainty in the true in situ density contrast which may be higher due to the degree of saturation of the sediments, three models for the basin (Figure 6 a, b, c) were determined using density contrasts of 0.2, 0.25, and 0.35 g/cm^3. These yield basin thicknesses of 2.5, 3.5 and 4.4 km respectively. In all models a vertical fault is located at the western side of the basin whereas at the opposite flank a steeply dipping (about 40°) fault is required to fit the gravity data.

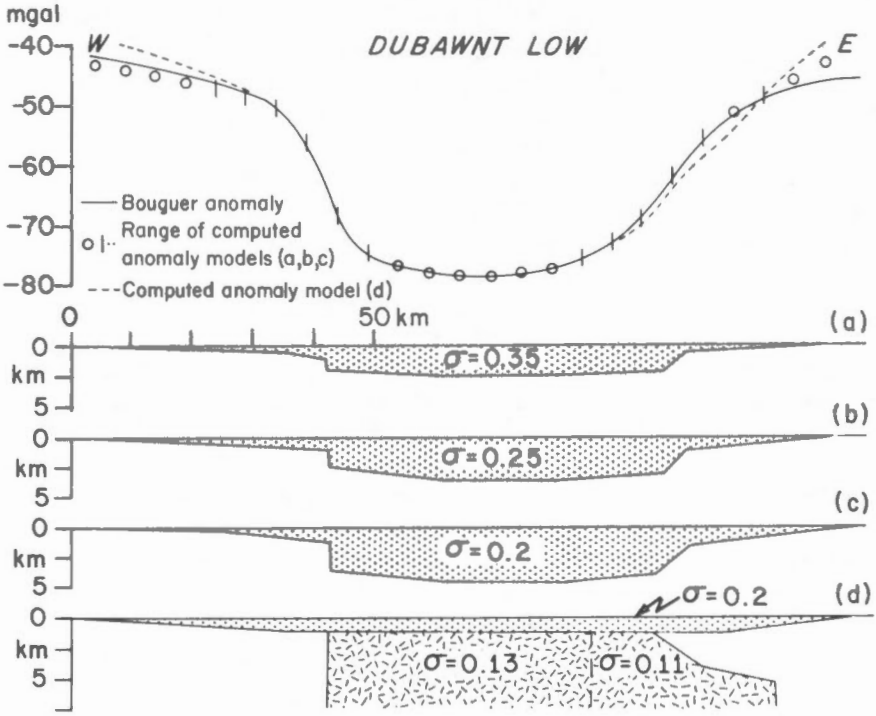

Figure 6. Bouguer anomaly profile across the Thelon Plate and alternative geological models (see text). σ is the density contrast (g/cm^3).

In the alternative model, the source of the anomaly is considered to be a subjacent granite batholith. In this model the Thelon Formation is assumed to be only 1,000 m thick. The granite extends to a depth of 7.5 km with a density contrast of 0.13 g/cm^3 (Figure 6d). A smaller density contrast, which is more likely, would extend the granite to greater depths. Such a body may be one of the "Nueltin Lake" granites. From sparse radiometric age data, Eade (1971) has suggested that the "Nueltin Lake" granites and acid volcanics of the Pitz Formation of the Dubawnt Group (Table II) may be related to the same igneous event. The Dubawnt gravity low may be an extension of the north-northwesterly trend which appears to correlate with the distribution of "Nueltin Lake" granites (Figure 4). The Dubawnt low is similar in form to the gravity low associated with the Nueltin Lake batholith but greater in magnitude by about 12 mgal. The results of seismic refraction surveys lend some further support to this interpretation. The greatest calculated thickness of sediments in the western part of the Thelon Plate was 1,920 m at a location 6.4 km south of Hornby Point (Overton, 1971) which lies to the north of the Dubawnt low.

Correlation of Gravity with Metamorphism

Davidson (1972) has divided the Western Churchill Province into broad zones of similar predominant metamorphic facies. The general relationship between these zones and the regional gravity anomalies is shown in Figure 5. Three characteristic types of metamorphic zones were recognized by Davidson, (1) greenschist to lower amphibolite

facies, (2) middle and upper amphibolite facies, and (3) granulite and retrograde granulite facies. Most of the rocks belong to the middle and upper amphibolite facies; they include the gneiss complex and granite plutons. Three fold belts contain rocks of greenschist to lower amphibolite facies. The belt northwest of Baker Lake and the Wollaston fold belt show no clear relationship with the regional gravity anomalies, however, there is a characteristic gravity response associated with the rocks of the Kaminak subprovince where large density differences occur between granitic plutons and volcanic-sedimentary rocks metamorphosed during the Kenoran orogeny.

Comparison of broad zones of predominantly similar metamorphic facies with the gravity anomalies reveals at least one other important and consistent correlation. There is a close correspondence between rocks of the granulite facies and positive anomalies. This correlation has been recognized elsewhere in the Shield (Gibb and McConnell, 1969; Tanner and McConnell, 1970). In the Fort Smith-Wholdaia Lake region granulites underlie a prominent positive anomaly some 200 km in length and 40 km wide. Other smaller areas of granulite and retrograde granulite facies rocks, underlie the highs of the central belt, the high parallel to the Thelon Front and the high southeast of Kaminak subprovince (Figure 5). A distinction between Hudsonian and Kenoran metamorphism cannot at present be made throughout the Province. In some areas Archean rocks retain the effects of Kenoran metamorphism with no Hudsonian overprinting, in other areas Hudsonian metamorphism is superimposed on Archean rocks, and in others Aphebian rocks have been affected only by Hudsonian metamorphism.

A model of the crust derived from the gravity anomalies, the surface distribution of the rocks and their densities is used to illustrate the relationships between gravity, crustal structure and metamorphism (Figure 7). The profile extends from amphibolite facies rocks near the eastern end of the Thelon Plate across Kaminak subprovince and terminates in granulite terrain to the south. The main disturbing masses in the model are the basic volcanic rocks (2.85 g/cm^3) of Kaminak subprovince and the plutons of adamellite (2.65 g/cm^3) with rims of tonalite (2.75 g/cm^3). This disturbed zone is flanked on either side by tonalite gneiss and mixed gneiss (2.73 g/cm^3) and mafic gneiss and mixed gneiss (2.80 g/cm^3). To satisfy the gravity anomalies, the major density discontinuities must extend to depths of up to 7.5 km. The densities used are representative values adopted from Table I.

Windley and Bridgewater (1971) have distinguished two main types of Archean terrain with differing rock units, metamorphic grade and structural style. These are high-level terrains with abundant greenstone belts and low-level terrains in which greenstone belts are relatively rare. According to Windley (1973) recent reliable age determinations show that the oldest rocks in most continents are in a high grade of metamorphism and most greenstone belts are comparatively younger. This is a reversal of previous thinking which generally held that the oldest rocks were in the greenstone belts.

Windley's classification can be extended to a three way classification of crustal level for Western Churchill Province as shown in Table III.

The crustal model derived from gravity data is comparable to high-level crust as defined above and as shown in Figure 8. Deep-level crust found in the western part of the area and also northeast of Baker Lake is characterized by a more positive anomaly field, by more extensive anomalies and by fewer local distrubances. The Central Belt anomalies are underlain by intermediate-level crust.

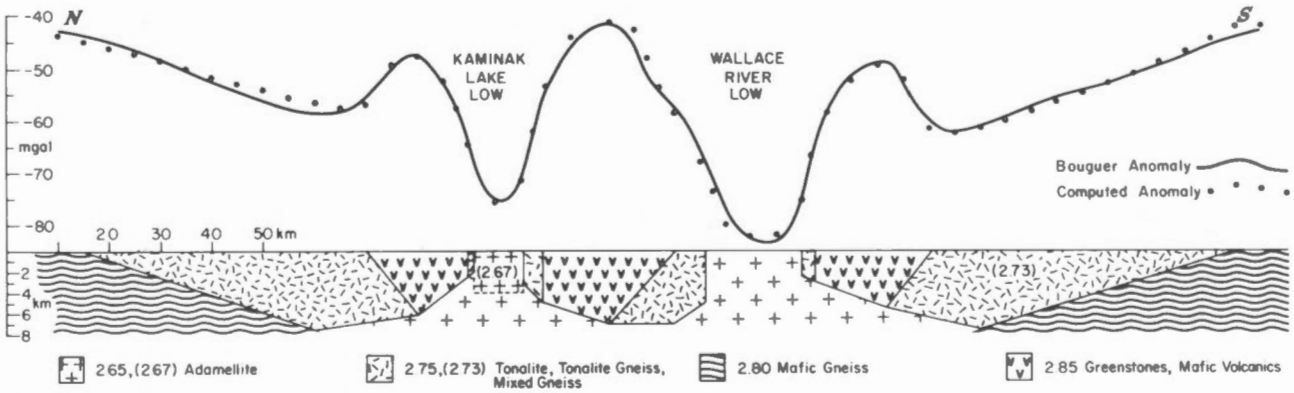

Figure 7. Crustal model derived from Bouguer anomaly profile crossing Kaminak subprovince. Densities are g/cm^3.

TABLE III

High-level crust	*Intermediate-level crust*	*Deep-level crust*
abundant greenstones	roots of greenstones	no greenstones
roofs of batholiths	centres of batholiths	batholith roots and residues
migmatites	basement gneisses	basement gneisses, anorthosites and mafic intrusions
greenschist to lower amphibolite facies	middle to upper amphibolite facies	granulite and retrograde granulite facies

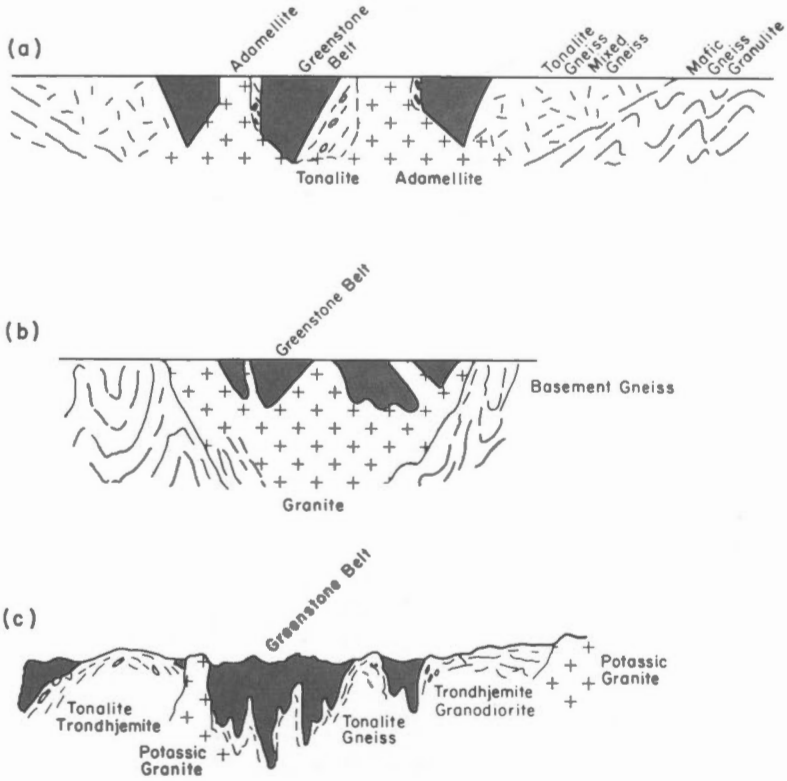

Figure 8. a) Geological model of Kaminak subprovince derived from Bouguer anomalies (see Figure 7).
b) Model of Archean crust from Windley, 1973.
c) Model of Precambrian crust from Anhaeusser, 1973.

Central Belt Anomalies

Walcott (1968) has described an important belt of intense, linear gravity lows and highs which parallels the structural trend of basement rocks in northern Saskatchewan for a distance of at least 500 km. This so called Central Belt comprises a continuous linear gravity low, named the Fond du Lac low bounded to the east by a discontinuous gravity high. The Fond du Lac low has an amplitude of about -30 mgal and a width of about 70 km. The names Lisgar Lakes high (Walcott, 1968) and Stony Rapids high (Agarwal and Kanasewich, 1968) have been given to prominent closed anomalies on the bordering discontinuous high. Alternative explanations for the Fond du Lac low have been proposed by Walcott (1968) and Wallis (1970). Walcott explained the gravity low and bordering highs using a model of compensated crustal blocks of different density. According to this model the gravity low is related to a regional change in the lithology of the crust due at least in part to granite with a corresponding thinner crust beneath the low. Wallis (1970), however, attributes the low anomaly to an intracontinental fault-bounded trough of Aphebian sediments within a higher grade Archean metamorphic terrain. This interpretation is based on the analogous relationship between the Virgin River low and the Virgin River belt of metasedimentary rocks which lies on the eastern side of the Lisgar Lakes high. In his model, Walcott correlates the Lisgar Lakes high and the Stony Rapids high with compensated crustal blocks 40 and 43 km thick respectively with average densities of 2.86 g/cm^3 and 2.90 g/cm^3. The Fond du Lac block is modelled as 34 km thick with an average density of 2.76 g/cm^3. The average density of the mantle is assumed to be 3.4 g/cm^3. According to Agarwal and Kanasewich (1968), the Stony Rapids high is related to a body of norite of density 2.92 g/cm^3. It is partially exposed but dips to the south under a layer of Athabasca sandstone about 1 km thick. Gravity interpretation suggests that the norite extends to a depth of 7 km (Agarwal and Kanasewich, 1968).

The Central Belt extends northwards into southern Keewatin retaining many of its characteristics. The Fond du Lac low continues to the northeast as a long narrow sinuous feature for at least 300 km with a maximum amplitude of about -35 mgal. At its northern extremity it broadens into a large low of similar amplitude centred about 90 km east of Dubawnt Lake (Figure 5). The name Kaminak River low has been given to this feature. The extension of the Fond du Lac low is underlain in places by rocks of granitic composition in the Wholdaia Lake area (GMS 125) and in the southwestern part of the Dubawnt Lake area (GMS 130) but much of the area underlying the low corresponds to a region of no outcrop. However the coincidence of low gravity values and subdued magnetic pattern in this narrow belt probably reflects the occurrence of granitic rocks not only in those parts of the low where they have been mapped but along its entire length.

The flanking discontinuous high comprising the Lisgar Lakes high and Stony Rapids high can also be traced northward into southern Keewatin where three major gravity highs, the Snowbird Lake high, the Kazan River high and the Baker Lake high are aligned along the same trend. The trend is thus marked by five discrete gravity highs which form a remarkably linear feature of the gravity field extending for some 900 km from Lisgar Lakes to Baker Lake in Western Churchill Province. It is clearly shown on the Bouguer Anomaly Map of Canada (1974). The tectonic significance of this trend is not clear but it does not exactly coincide with Davidson's line separating deep crustal rocks to the west from the eastern area containing abundant supracrustal rocks (Figure 3). The apparent alignment of these isolated gravity highs may be fortuitous or it may mark an important tectonic lineament. Each of the five gravity highs is underlain by high grade metamorphic rocks and associated small plutons of various compositions including diorite, gabbro,

norite and anorthosite; some also have associated alkaline intrusions e.g. the Snowbird Lake and Kazan River highs. The lineament corresponds, at least in part, to a major fault zone; major faults have been mapped between the Stony Rapids and Kazan River highs.

There are several possible explanations for the Central Belt anomalies. Two explanations for the Fond du Lac low suggested by Walcott (1968) and Wallis (1970) have already been mentioned. Walcott and Boyd (1971) have also noted a southwesterly continuation of this feature toward the edge of the craton and have suggested that it may mark a suture zone between collided continents. This interpretation is tenuously based on Wallis's correlation of part of the low with a belt of Aphebian sedimentary rocks of different metamorphic facies and, perhaps, sedimentary facies to the surrounding higher grade Archean (?) terrain.

Other explanations for the Central Belt anomalies are worthy of consideration. The Central Belt anomalies cross the Western Churchill Province from the southwest to northeast almost midway between the older bounding Superior and Slave Provinces. The Central Belt anomalies are not uniquely linear in this central part of Western Churchill Province; they form but one part of a broader swath of anomalies in which dominant trends are also northeasterly. Almost without exception anomalies in this swath are elongated with long axes parallel to the regional trend. They appear to have been squeezed or stretched. A possible explanation is that this central portion of the Province has suffered strong lateral compression from the southeast or from both the southeast and the northwest. In contrast, on both sides of the Central Belt, regional gravity trends within the Province tend to follow the boundaries of the older provinces (Figure 5). Anomalies in these marginal zones are also elongated but appear to "wrap around" the Superior and Slave Provinces respectively.

Magnetic anomalies and geological trends exhibit similar "wrap around" patterns in both marginal zones of Western Churchill Province. These regional features along with other fundamental differences in tectonic style, structure and metamorphism can perhaps be explained in terms of plate interaction as a result of a northward convergence of the Superior protocontinent (unilateral model, Figure 9 a) or by the dual convergence of both Superior and Slave protocontinents on the Churchill (bilateral model, Figure 9 b) or by some variation of this model (Figure 9 c, d, e). The unilateral model was first proposed by Gibb and Walcott (1971) who suggested that the Nelson Front forms part of the circum-Superior suture. Later Burke and Dewey (1973) noted the analogy between reactivated Hudsonian crystalline rocks of the southern marginal zone of Western Churchill Province and the Tibetan plateau environment – a modern example of reactivated crust produced by the continued convergence of India and Asia after collision. The "wrap around" gravity anomalies trace the limits of reactivated crust i.e. the area deformed above the subducted oceanic lithosphere of the former Superior Plate. The northwesterly limits of this overprinting are also reflected in magnetic and structural trends and in plutonism and metamorphism which give this area a distinctive tectonic style.

The northern marginal zone of Western Churchill Province (≡ deep crustal zone identified by Davidson (1972)) is interpreted as a more deeply exhumed equivalent of the southern marginal zone. In this instance, the polarity of subduction is less certain. The site of the ancient trench and of the present-day cryptic suture may be the Thelon Front (bilateral model, Figure 9 b) or in the Central Belt (Figure 9 c). Future work may show that these alternatives and the even more speculative models of Figure 9 d and e are gross oversimplifications of how the Province developed.

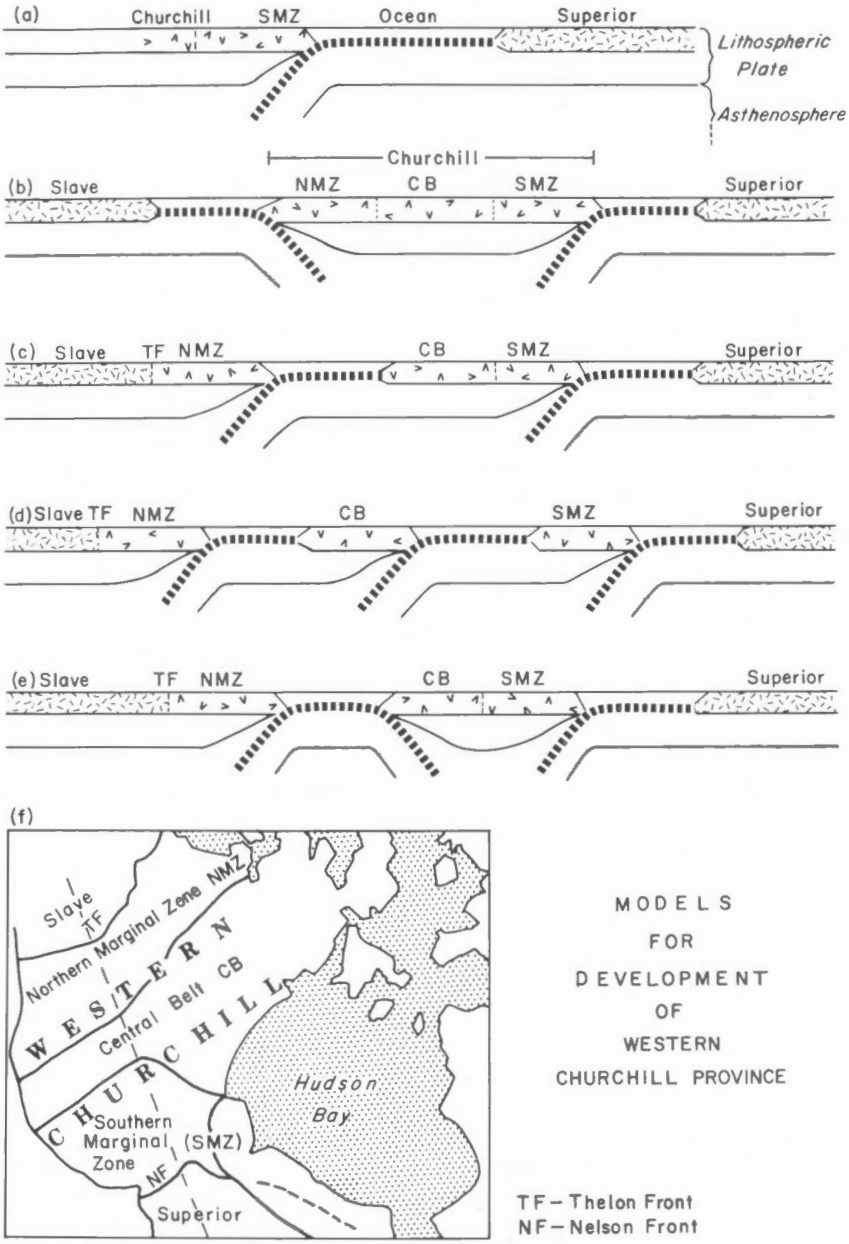

Figure 9. a) Unilateral model for convergence of Superior and Churchill protocontinents proposed by Gibb and Walcott (1971).

b) Bilateral model for convergence of both Superior and Slave on Churchill protocontinent.

c, d, e) Alternative models in which northern marginal zone is regarded as a deformed part of the Slave protocontinent and in which Churchill is regarded as fragmented.

f) Map showing line of sections. Boundaries between provinces and between zones are cryptic sutures or define the limits of overprinting and reactivation above subducted lithosphere.

Regional Anomalies

A large negative free air anomaly of up to 50 mgal amplitude, centred near Eskimo point and covering much of Hudson Bay and the surrounding region has been interpreted by Innes (1960) and more recently by Walcott (1970) as an effect of incomplete isostatic adjustment. The low is congruent with the area formerly covered by the Laurentide ice-sheet during the Pleistocene and suggests that the lithosphere which was depressed has not yet recovered from the effect of the now removed load. The northern part of this regional low is shown on a free air anomaly map derived from mean free air values on a 1° x 1° grid (Figure 10).

Isostatic Reduction

Isostatic anomalies were computed for all stations according to the method of Vening Meinesz (Heiskanen and Vening Meinesz, 1958). These values were then used to prepare an isostatic anomaly map (Figure 11) which is quite similar to the free air map of Figure 10. This type of isostatic correction is a modification of the Airy floating crust hypothesis with the major difference that compensation is assumed to be regionally distributed rather than completely local. Thus topography is regarded as a load on an unbroken crust which behaves like an elastic plate floating on a plastic sublayer. Compensation is assumed to be proportional to the bending of the crust and is spread horizontally outwards from the centre of the area according to a theoretically computed curve. The usual six values of R, the radius of regionality, were considered in the computations.

Mean elevation data for 5′ latitude x 10′ longitude 'squares' were prepared from topographic maps (scale 1:250,000) and hydrographic charts of the region. These data were used to compute the effect of compensation at points on a grid of 15′ latitude by 30′ longitude for Hayford zones A to L combined, M, N, O_1 and O_2 and for values of normal crustal thickness T = 20, 30 and 40 km. The combined effect of topography and compensation for zones 18 to 1 beyond O_2 was interpolated at the same points from a chart prepared for a value of T = 30 km, and published by Kärki, Kivioja and Heiskanen (1961). The corrections for the numbered zones were added to those for the lettered zones to obtain the isostatic corrections at the grid points. A total of 18 sets of corrections was computed for the grid points.

The smallest standard deviation about the mean value of the isostatic anomalies occurs when T = 40 km and when R = 232.4 km. This criterion was used to select the preferred set of corrections. The value to T = 40 km for the normal thickness of the crust is in agreement with results from seismic experiments which indicate a range in crustal thickness of 30 to 50 km in and around the area. Errors introduced by computing the contribution of zones 18 to 1 for T = 30 km rather than for T = 40 km are negligible in this area as the maximum contribution from these zones was only 5.3 mgal.

Regional Anomalies

The influence of geological structure persists in the maps of mean anomaly (Figures 10 and 11). Major geological elements including the Slave Province, Thelon Front, north marginal zone and central belt of Western Churchill Province can readily be identified which suggests that a part of the negative anomaly attributed to loading by the Laurentide ice may merely reflect a change in gross crustal structure and lithology. The area in question underlies the Kaminak River low (Figure 4) which terminates the

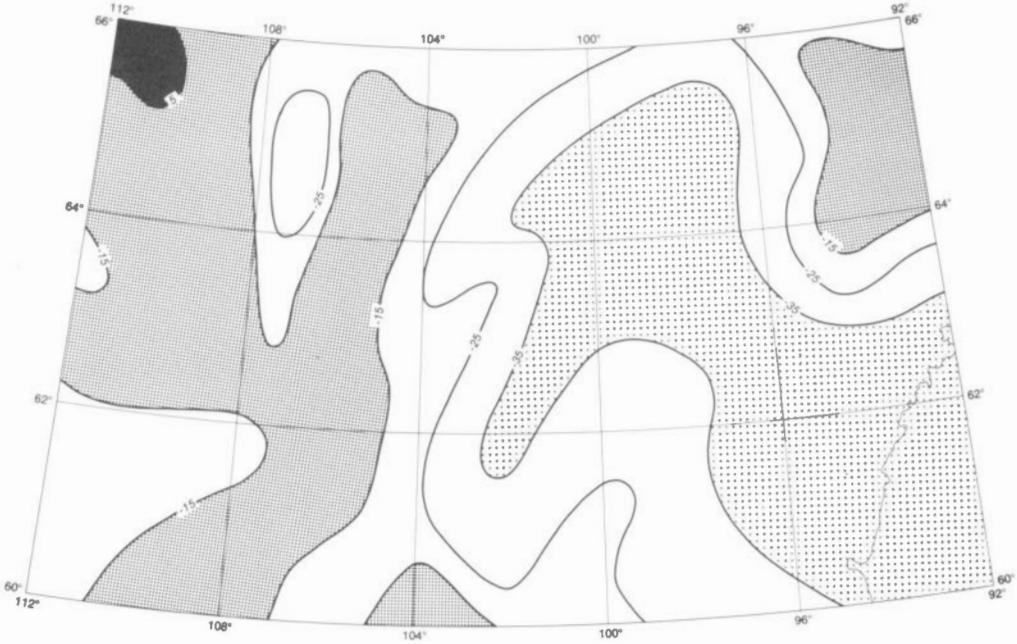

Figure 10. Map of mean free air anomalies (1° x 1° grid). Relative highs–fine stipple and black, relative lows–coarse stipple.

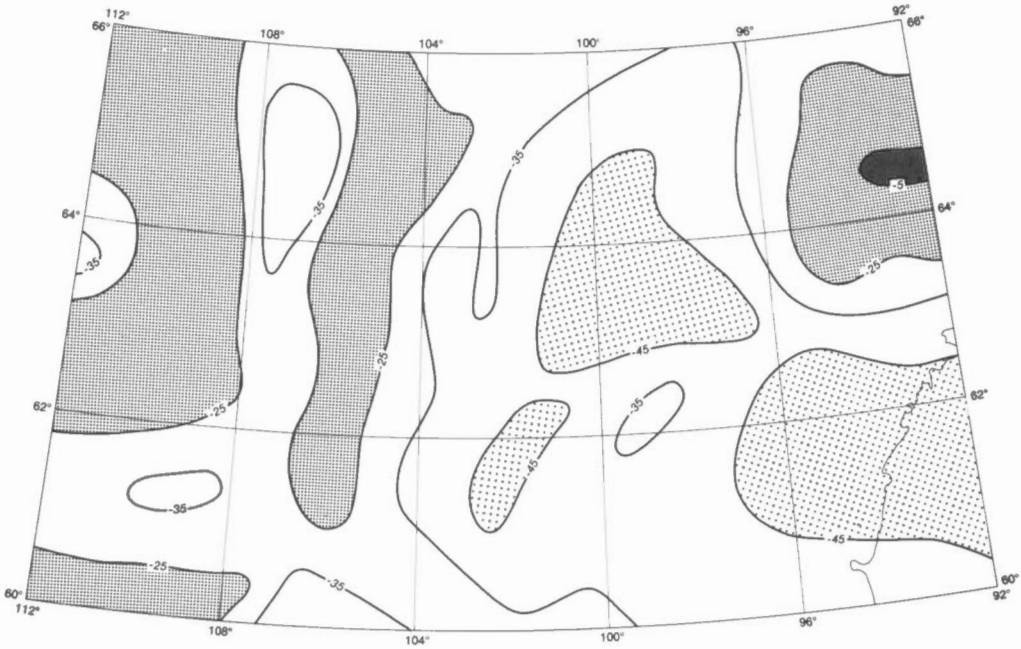

Figure 11. Map of mean isostatic anomalies (1° x 1° grid). Relative highs–fine stipple and black, relative lows–coarse stipple.

northeasterly trending Fond du Lac low. This northeasterly trend is clearly indicated in Figures 5 and 6 but only a hint of it remains on Walcott's free air map which was produced by smoothing on a somewhat larger $1^\circ \times 2^\circ$ grid (Figure 12).

Comparison of Isostatic and Bouguer Anomalies

The isostatic correction due to topography and compensation in this area varies between about 0 mgal at the coastline to about 30 mgal inland and averages about 20 mgal for a crust of normal thickness $T = 40$ km (Figure 13). The difference between Bouguer anomaly profiles and isostatic anomaly profiles drawn across two-dimensional geological structures is virtually a datum shift in this area because the dominant northeasterly geological trends are almost normal to the regional contours of topography. Thus the relative amplitude of individual anomalies selected for model studies is virtually unchanged if Bouguer anomalies are used instead of isostatic anomalies.

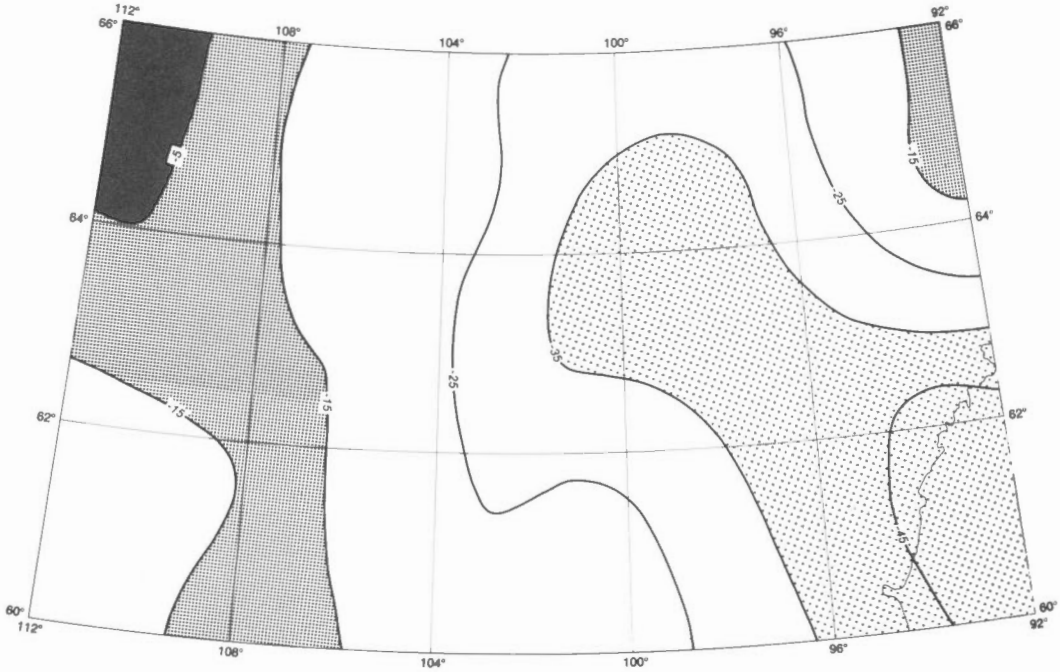

Figure 12. Map of smoothed free air anomalies (1° x 2° grid). Relative highs–fine stipple, relative lows–coarse stipple (after Walcott, 1970).

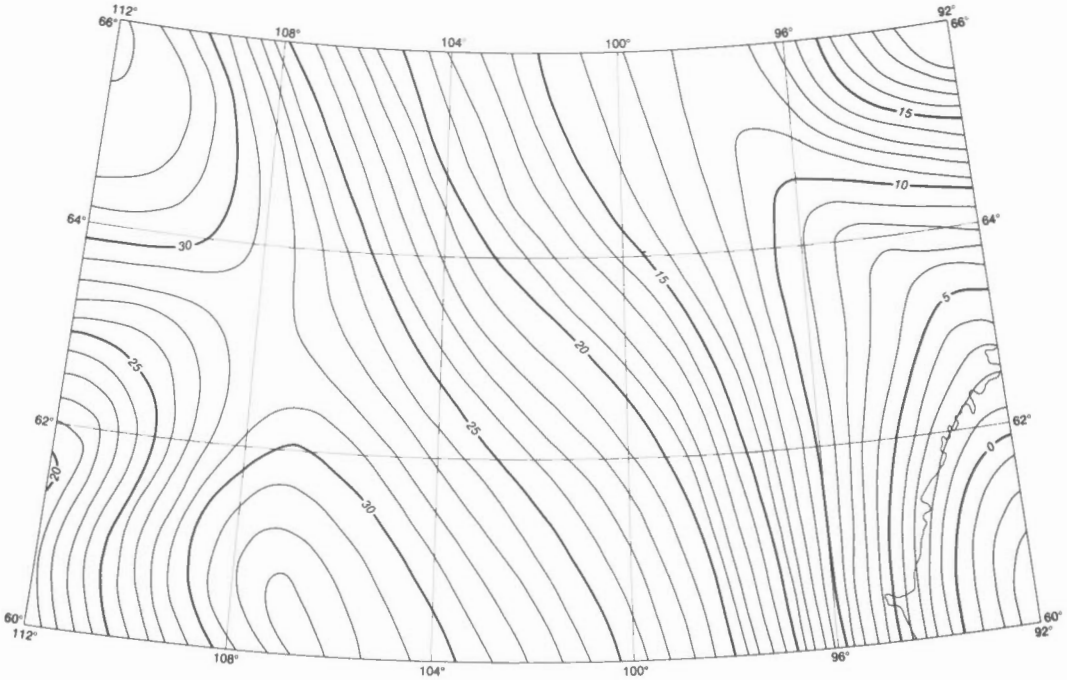

Figure 13. Isostatic correction map (contour interval 1 mgal) based on Vening Meinesz's method of reduction.

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