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GRAVITY MEASUREMENTS IN NORTHERN ONTARIO

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No. 29 — Pickle Crow-Armstrong
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R.A. Gibb and R.K. McConnell

DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA 1970

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CONTENTS

GRAVITY MEASUREMENTS IN NORTHERN ONTARIO

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ABSTRACT - A total of 3,241 gravity stations, observed by the Dominion Observatory in the period 1949-1965, was used to compile ten Bouguer anomaly maps (1:500,000 scale) of northern Ontario. The major negative anomalies in the area are the Patricia Low which outlines an area of multiple intrusions of granite and the Niskibi River Low whose source is also considered to be intrusive granite. Major positive anomalies are underlain by the Cape Henrietta-Maria basement arch in the Hudson Bay Lowlands and the Kapuskasing Belt - an ancient zone of probable crustal rifting.

RÉSUMÉ - Les données de 3,241 stations gravimétriques obtenues par l'Observatoire fédéral de 1949 à 1965 ont servi à compiler dix cartes au 1: 500,000 des anomalies de Bouguer dans le nord de l'Ontario. Les anomalies négatives principales de la région sont celle de Patricia, qui délimite une zone renfermant de multiples intrusions granitiques, et celle de la rivière Niskibi, également attribuée à une intrusion de granit. Les anomalies positives importantes se retrouvent au-dessus de l'arche du soubassement du cap Henriette-Marie dans les Basses-Terres de la baie d'Hudson et la zone de Kapuskasing, ancienne zone probable de fissuration corticale.

INTRODUCTION

The regional gravity survey of northern Ontario was completed in 1963 by R.K. McConnell and a party from the Dominion Observatory. The survey covers an area of about 500,000 km^2 corresponding to sheets 42NE, 42NW; 43; 52 NE; 53SE, 53NE; and 54SE of the National Topographic System (Figure 1). The last two sheets include a small part of Manitoba.

Helicopters and light aircraft were used to establish a total of 2,888 gravity stations at intervals of between 6 and 12 km in the area which is bounded by latitudes 50°N and 58°N and longitudes 80°W and 92°W (Figure 1). In addition, 102 stations observed in the period 1949-1961 and 251 stations observed in 1965 are incorporated in the ten Bouguer anomaly maps (scale 1:500,000) which accompany this report. The maps are contoured at 5 mgal intervals and Bouguer anomaly values are given in tenths of a milligal. Underwater gravity measurements recently obtained in Hudson Bay are not shown on the maps; gravity maps of the Bay will be published separately (Goodacre, Weber and Cooper, 1970).

Much of the survey area is underlain by Paleozoic and younger sediments of the Hudson Bay Lowlands which are described by Sanford, Norris and Bostock (1968). Archean rocks of the Superior structural province, described by Ayres, Bennett and Riley (1969), Duffell, MacLaren and Holman (1963) and Bennett, Brown, George and Leahy (1967), occupy the southwestern and extreme southeastern parts of the area. Some inliers of Archean and Proterozoic rocks occur within the Hudson Bay Lowlands (Sanford, et al., 1968).

The first geophysical measurements in the area were gravity observations made between 1947 and 1949 at intervals of between 8 and 32 km. These stations formed part of a larger survey of the shield which was reported by Innes (1960). Since then in addition to the new gravity data, aeromagnetic maps of the Federal-Provincial Government series have been published for the whole area and new geological maps have become available for much of the area. Seismic investigations of the Hudson Bay region have been published (Hobson, 1968) and several theories concerning the structure and evolution of the area have been proposed (e.g., Kalliokoski, 1968; Goodwin, 1968; Ayres, et al., 1969). The densities of some 6,800 rock samples collected from the area have also been determined by the Geological Survey of Canada and the Dominion Observatory as a further aid to the interpretation of the gravity anomalies.

In this report only a brief description of the major features of the gravity field is given; a more comprehensive interpretation is given elsewhere (Gibb, 1970).

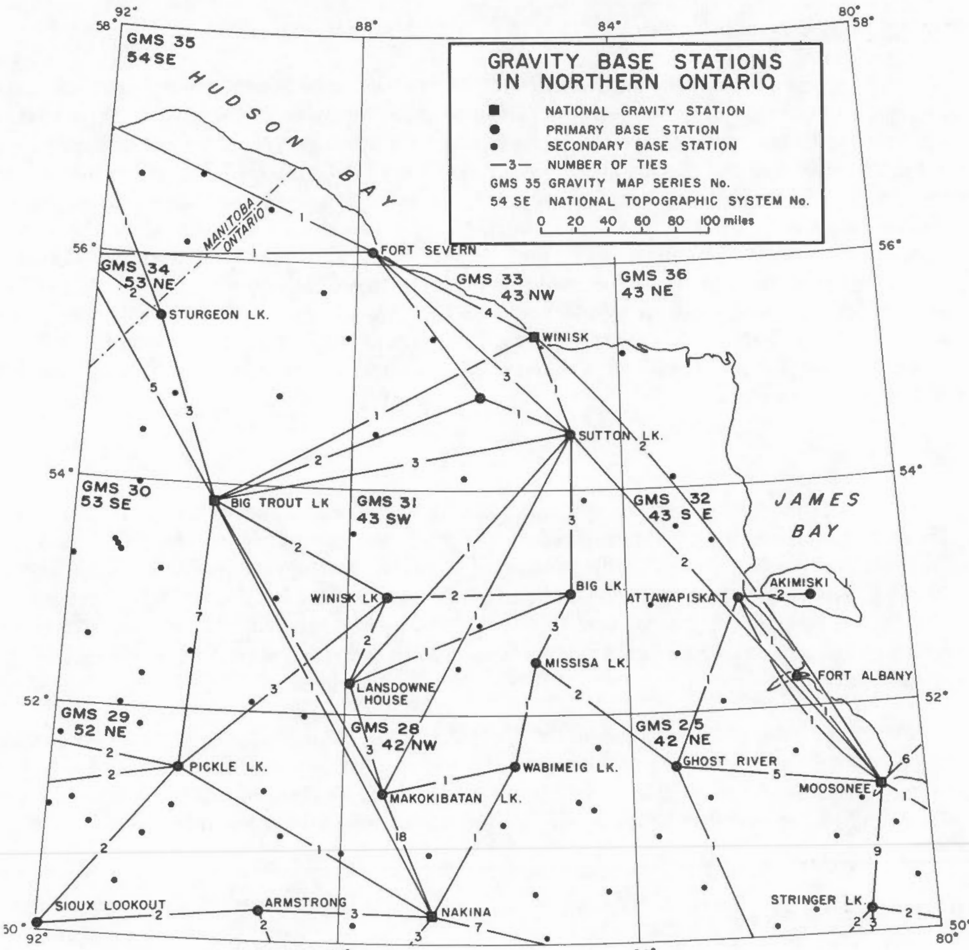

Figure 1. Location map showing gravity base network, northern Ontario.

GRAVITY MEASUREMENTS

Field methods evolved over several years by parties from the Dominion Observatory using helicopters for transportation were used in the survey and the results* were reduced using the method described by Tanner and Buck (1964).

*The principal facts of all gravity stations and location sketches of control stations used in the survey are available at cost from the Gravity Division, Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa.

Control Station Network

Figure 1 shows the distribution of 91 primary and secondary control stations in northern Ontario. The adjustment of the primary net was performed in three parts by a standard least-squares procedure, based on a value of 980.6220 gal at the National Reference Pier in Ottawa. In general the standard errors of the adjusted primary g values are less than 0.05 mgal. Secondary control stations were established by traversing with a LaCoste and Romberg land gravity meter between primary bases and were adjusted to fit the primary net. Since the time of these adjustments (1964), some additional control ties have been made in the area including direct ties between National Gravity Net stations (McConnell, 1970). Local warps of up to 0.2 mgal in the 1964 adjustment exist and a complete readjustment of the network based on the 1970 National Gravity Net stations is planned. This adjustment will include all new control work in northern Ontario.

Elevations

Altimeter readings were used to compute the elevations of the gravity stations. Appropriate corrections for temperature and humidity variations were applied and elevation control was provided by occupying stations, having predetermined elevations, wherever possible. Elevations obtained in this way usually have errors in the range 10 to 30 feet. However, no alternative method is presently available to improve the accuracy and also meet the survey requirements of fast operation and reasonable expenditure.

Terrain corrections were not applied to the results. The regional topography of the area is fairly smooth; elevations increase gradually from sea level around Hudson Bay southwestwards to a maximum of about 1,300 feet in the southwest corner of the area. Terrain corrections are unlikely to exceed 1 or 2 mgal anywhere in the region.

Bouguer Anomaly Values

Bouguer anomaly values were computed in the usual manner using a density of 2.67 g/cm^3 in the Bouguer reduction. Errors in elevation contribute by far the largest part of the error in the Bouguer anomaly. Errors in the observed gravity measurements, and latitude measurements are in the range 0.15 to 0.25 mgal compared with errors in the range 0.6 to 1.8 mgal caused by elevation errors in the range 10 to 30 feet. The simple Bouguer anomalies are accurate to within about 2 mgal.

THE BOUGUER ANOMALY MAP

A large-scale free air anomaly trend which decreases towards Hudson Bay has been interpreted by Innes (1960), Innes and Argun Weston (1966) and most recently by Walcott (1970) as the effect of incomplete isostatic adjustment. The depressed field is a relict of crustal loading by the Laurentide ice sheet which covered much of Hudson Bay and the surrounding region during the Pleistocene. Apart from this regional trend most of the anomalies in northern Ontario can be reasonably explained by density variations in the Precambrian crustal rocks.

A simplified version of the Bouguer anomaly map is shown in Figure 2. The anomalies range from a maximum of 8.3 mgal in the Moosonee (GMS 25) map area to a minimum of -75.6 mgal in the Cape Tatnam (GMS 35) map area. The mean Bouguer anomaly for the whole region is -33.7 mgal so that values above and below this mean may be regarded as relative highs and lows.

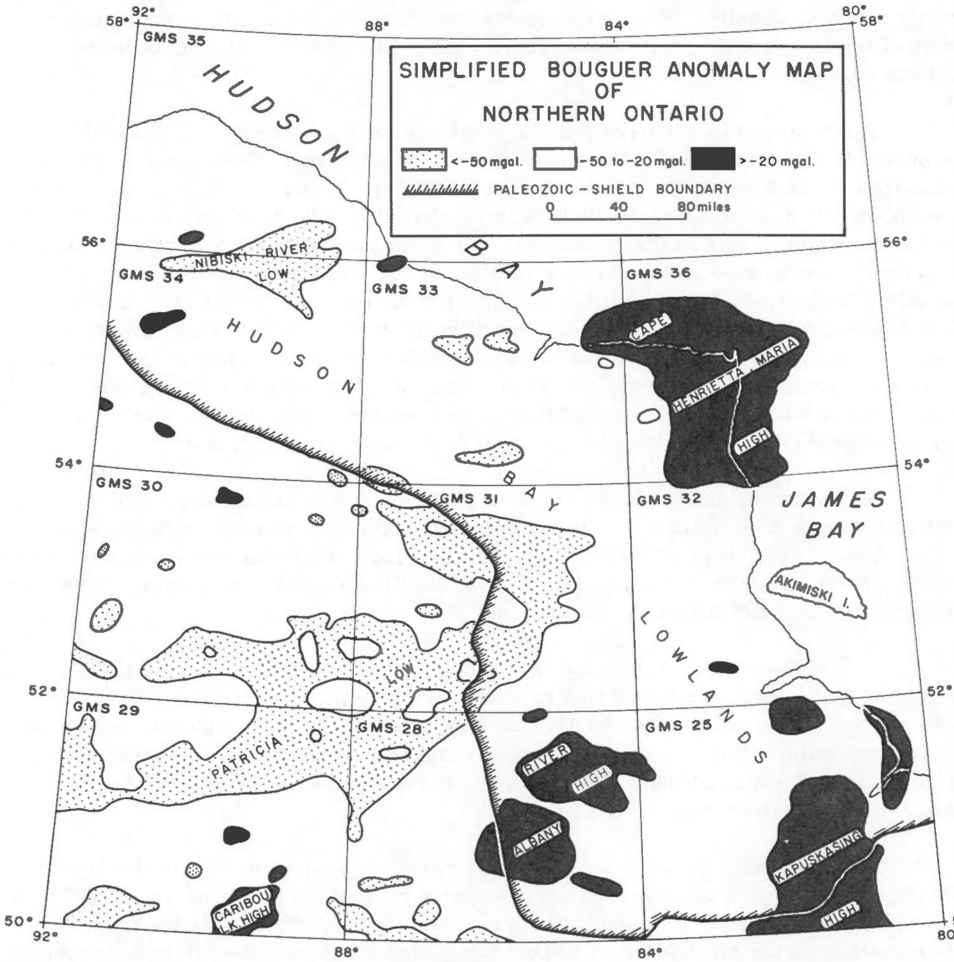

Figure 2. Simplified Bouguer anomaly map, northern Ontario.

The major anomalous areas are named in Figure 2. The most striking feature of the gravity field is the Patricia Low (Innes, 1960) where the anomalies are less than -50 mgal, apart from a few local highs within the belt. The southern and eastern limits of the belt are marked by a persistent horizontal gravity gradient amounting to 5 mgal/mile in places. The negative anomalies of the Patricia Low correlate with an area of multiple intrusions of granite. This relationship is verified by comparing large-scale maps of geology (e.g., Map 2-1963 in Duffell, et al., 1963), gravity and rock density. Thus the gradients which define the southern and eastern limits of the low probably reflect this gross change in lithology and density in the Archean rocks.

Apart from two anomalies on the southern border of the survey area which are parts of larger features to the south, the only other major low of large amplitude in the area is the Niskibi River Low located in the Cape Tatnam (GMS 35) and Severn River (GMS 34) map areas of the Hudson Bay Lowlands. The minimum value of -75.6 mgal in the whole area was observed here. An elongate nose trends westwards from the anomaly and may be interpreted as an eastern continuation of a belt of negative anomalies in the Gods Lake (GMS 68) and Cross Lake (GMS 69) areas of Manitoba (Gibb and McConnell, 1969). There the negative anomalies, which reach minimum values of -60 mgal, appear to be related to the degree of granitization of the original sedimentary-volcanic sequences. In places the granite appears to be intrusive (Bell, 1962). The Niskibi River Low probably defines a region of low-density intrusive granite within the basement beneath the blanket of Paleozoic sediments.

Three major gravity highs occur in the Hudson Bay Lowlands - the Cape Henrietta-Maria High (GMS 36), the northern end of the Kapuskasing High (GMS 25) and the Albany River High (GMS 28). The Caribou Lake High, another prominent feature occurs to the south of the Patricia Low in the Pickle Crow - Armstrong (GMS 29) map area and is underlain by Archean rocks.

Innes, Goodacre, Weber and McConnell, (1967) suggested that the Cape Henrietta-Maria High may be related to Proterozoic basic flows and (or) intrusive rocks. Proterozoic sediments and diabase sills occur along the northeastern flank of the Archean inlier which extends southeast from Sutton Lake (Sanford, et al., 1968). These basic rocks may extend to the northeast below the Paleozoic sediments and could account for the high gravity values.

The maximum Bouguer anomaly of the area (8.3 mgal) occurs in the Moosonee (GMS 25) area and is underlain by a narrow wedge of Archean granulite rocks which is fault-bounded to the east and west. This peak value is regarded as a local closure superimposed on the much broader Kapuskasing High which extends far to the south beyond the survey area. In the Moosonee (GMS 25) area much of the broad anomaly is underlain by Paleozoic rocks which obscure the relations between gravity and basement geology. The Kapuskasing anomaly has been interpreted by Innes, et al. (1967) as a zone of crustal rifting.

The Albany River High and the Caribou Lake High which occur to the east and south of the Patricia Low are not readily correlatable with the surface geology. The

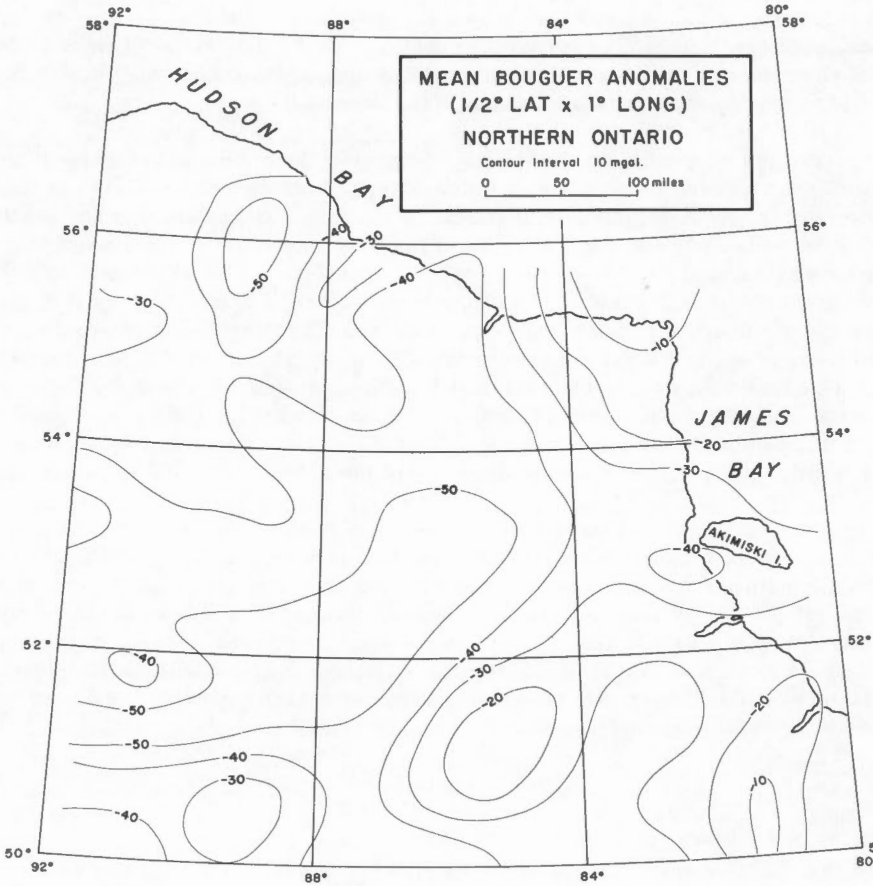

Figure 3. Mean Bouguer anomaly map, northern Ontario.

rocks underlying the Caribou Lake High include sedimentary gneiss, migmatite and metavolcanics and perhaps most significantly diabase of the Lake Nipigon region. The larger part of the Albany River High is underlain by Paleozoic sediments and in the west where shield rocks are exposed they are mapped as foliated granitic rocks with a significant amount of basic metavolcanic rock. The presence of basic rock in both these regions may explain the relatively high anomalies but additional evidence is needed to substantiate this relationship. Deeper sources may account for the positive anomalies in both these areas.

The usual correlations of gravity with geology are found in the exposed portion of the Shield in northern Ontario. Local highs are associated with the volcanic-sedimentary belts and basic intrusions and gravity lows are found over massive granites.

Local exceptions occur, particularly within the Patricia Low where two gravity highs are paradoxically underlain by porphyritic granite. In the Hudson Bay Lowlands there is no obvious correlation between gravity and sedimentary thickness and local Bouguer anomalies probably stem from structures in the basement.

Two major trends are revealed by the gravity anomalies in northern Ontario. Both differ from the east-west trends which usually characterize structures in the Superior Province. A remarkable alignment of the major anomalies in a northeasterly direction is conspicuous on the map of mean Bouguer anomalies (Figure 3). This alignment is terminated to the northeast by a southeasterly trend which parallels the Paleozoic-Shield boundary and the coastline of Hudson Bay. The latter trend is also apparent in the Bouguer anomaly contours which are characterized by alternating narrow belts of low and high, almost continuous, linear anomalies. This trend is also apparent in the geology of the exposed Shield north of latitude 54°N (see Geological Map of Canada) where not only the volcanic belts but also the granites are elongated in a similar southeasterly direction. A similar structural trend was identified by Ayres, et al. (1969) in the aeromagnetic maps of the area.

The significance of these major trends is not entirely clear. However, Innes (1960) has suggested that large-scale block faulting may explain the apparent shift in the gravity pattern from the easterly trends characteristic of the Superior Province to northeast. Other evidence of faulting involving large crustal blocks has recently been presented by Hall and Hajnal (1969) on the basis of seismic surveys in and around the English River gneissic belt of northwestern Ontario and by Ayres, et al. (1969) in the basement of the Hudson Bay Lowlands region. The major gravity trends are discussed more fully by Gibb (1970).

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