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The Establishment of Primary Gravimeter Bases in Canada

BY

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CONTENTS

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ABSTRACT

In 1952 the Dominion Observatory initiated a program to establish throughout Canada a network of well connected primary gravimeter base stations for the control and adjustment of existing and future gravimeter surveys. A total of two hundred and seventy bases occupied during the summer forms two separate networks, one in Northern Canada and the other in Southern Ontario and Quebec.

In the course of the survey gravimeter measurements were made at all available pendulum stations and the results show that the standard deviation of most pendulum determinations is about 1·2 mgals., and that the worst errors are in the measurements made before 1936 and in those throughout the unsettled regions of Northern Canada. The comparisons provided the calibration factor for the North American gravimeter to an accuracy of one part in a thousand.

The principal facts for all the gravimeter bases and the descriptions of the sites for twenty-four principal bases in Ontario and Quebec are given. The adopted values of gravity for the bases have random errors estimated to be 0·08 mgals. and 0·15 mgals. for the southern and northern networks respectively. They may also contain systematic errors (0·5 mgals. maximum) due to the unreliability of the calibration of the gravimeter.

INTRODUCTION

During the years 1944 to 1951 the Dominion Observatory carried out extensive regional gravity surveys with gravimeters in Canada. In the southern parts automobile transportation was used and about 7,500 stations were established at intervals of 8 to 10 miles along highways and passable roads. In the less accessible regions of Northern Canada, light aircraft equipped for water landings furnished the transportation for survey parties during the summers of 1947 to 1951, inclusive. An area of some 600,000 square miles, most of which lies within the Precambrian Shield and extends as far as 65 degrees north latitude, was covered. A total of some 1,500 gravimeter stations at intervals of 15 to 20 miles were observed. The extent of all gravimeter work in Canada is illustrated in Figure 1, which shows the more important highway traverses in the south and the approximate areas covered annually in Northern Canada.

Various types of gravimeters have been used to make the measurements. The first instrument was a Humble gravimeter which was used in 1944[1] and 1945. Since then most regional work in Southern Canada has been carried out with an Atlas instrument of the Mott-Smith type, and two North American gravimeters. For the northern work North American instruments have been used each season except 1950 and 1951 when the more readily portable Worden instruments were employed.

For most of this field work the gravity results and their geological and geophysical implications have been described in several recent publications by members of the staff of the Dominion Observatory (Saxov, 1953; Miller 1944, 1953; Garland, 1950, 1953; Thompson and Miller, 1953; Innes, 1953).

[1] The gravimeter became available through the courtesy of the Humble Oil and Refining Company of Houston, Texas, who own the instrument and of the American Geophysical Union, at whose disposal it had been placed by the Company.

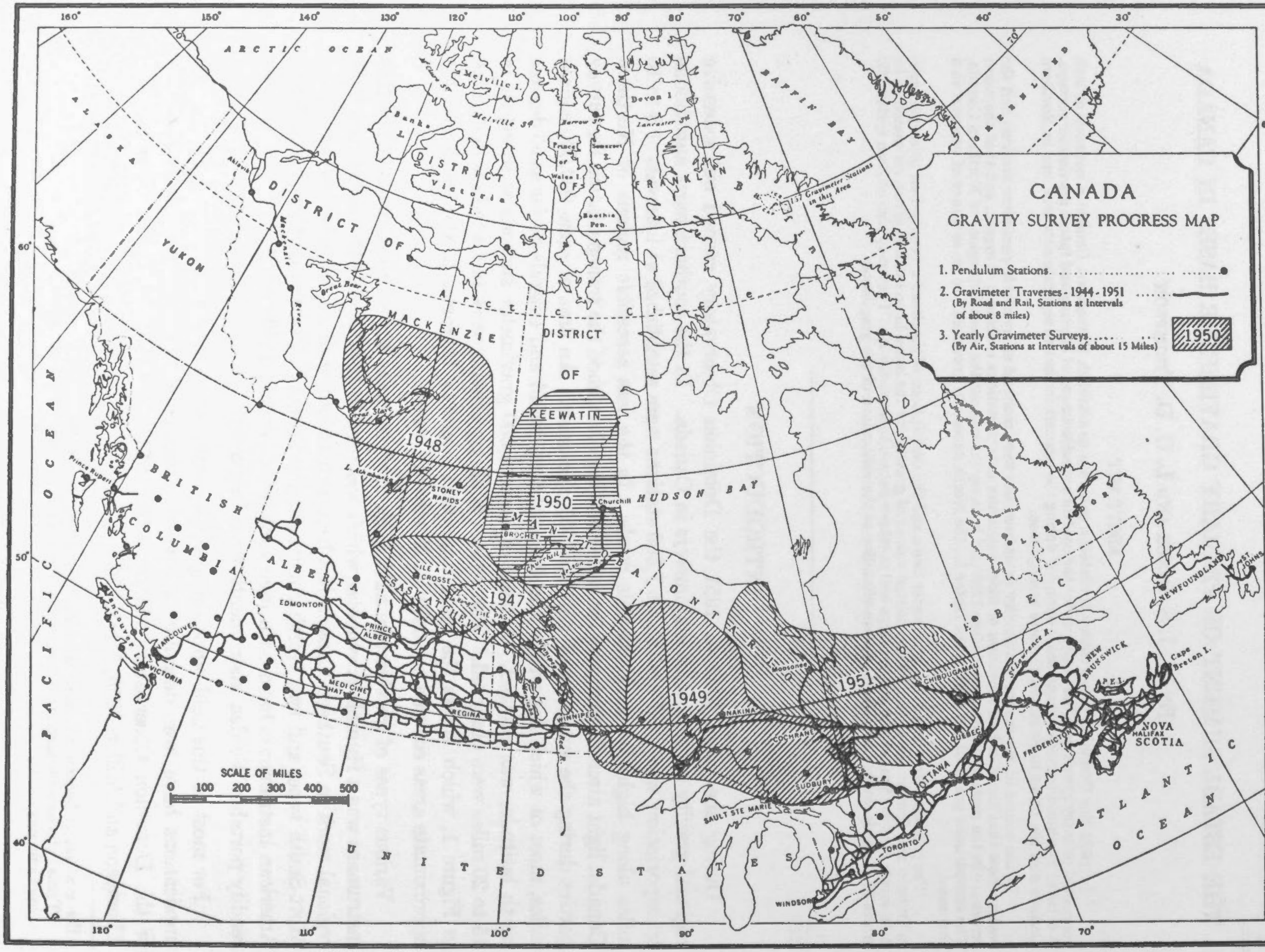

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Figure 1.—Illustrating principal highway traverses and regions in Northern Canada where gravimeter observations have been made.

The values of gravity for each of these separate surveys have been derived, for the most part, by using calibration factors supplied by the manufacturer of the instruments. The values so obtained form consistent sets for each survey, but analysis shows differences systematic with latitude, for stations common to two or more surveys where different instruments had been employed. Re-examination of the calibration factors by comparison of the gravimeter results with pendulum station values failed to resolve the differences, because the number of pendulum stations are too few and their values of gravity too uncertain to yield a precise calibration for the range of each survey.

Consequently it was decided that these difficulties could be overcome by establishing throughout the area of the several surveys a system of primary gravimeter bases that were well connected, as well as tied to all pendulum stations including the national gravity base station in Ottawa. The greater part of the 1952 field season was therefore devoted to a program of base looping. In particular the objectives were:

(i) to establish a highly reliable network of primary gravimeter bases, suitable for the control and adjustment of previous as well as future gravimeter surveys.

(ii) to occupy all pendulum stations within the network for the purpose of adjusting the gravimeter results to the fundamental datum, and to assess the uncertainty of the pendulum station values.

(iii) to calibrate the North American gravimeter No. 85 and Worden gravimeter No. 44.

A detailed account of the results of this investigation follows.

OBSERVATIONS

Most of the results of the base looping program which forms the main subject of this report are diagramatically given in Figures 2 and 3. A total of two hundred and seventy bases were established and the work required more than 20,000 miles of automobile travel in Southern Canada and nearly 15,000 miles of air travel in the northern regions. The gravimeter bases in Southern Ontario and Quebec extend from Windsor, Ontario, in the southeast to Moosonee, Ontario to the north and to Lake Chibougamau, Quebec to the northeast (see location map). One hundred and forty-five of these bases are located in southern Ontario and are interconnected to form thirteen closed circuits (Figure 2). Not shown in this diagram are the gravimeter bases along highway traverses from North Bay, Ontario to Sault Ste. Marie, Ontario and from North Bay to Cochrane, Ontario and Rouyn, Quebec and from Montreal, Quebec to Lake Chibougamau. The southern network includes gravimeter ties to twenty-three pendulum stations, having an over-all range in gravity of 840 milligals from g = 980·334 at Windsor, Ontario to g = 981·175 at Moosonee, Ontario.

The northern gravimeter bases, sixty-four in all, that were connected are shown in Figure 3. They extend from Nakina, Ontario to Stoney Rapids, Saskatchewan, which is located about 1,100 miles to the northwest on Lake Athabasca. This northern network of bases forms three closed circuits, which are connected but which have no common sides. It includes observations at twelve pendulum stations for which the value of gravity varies from g = 980·982 gals. at Sioux Lookout, Ontario to g = 981·785 gals. at Stoney Rapids, Saskatchewan, or a range of 803 milligals.

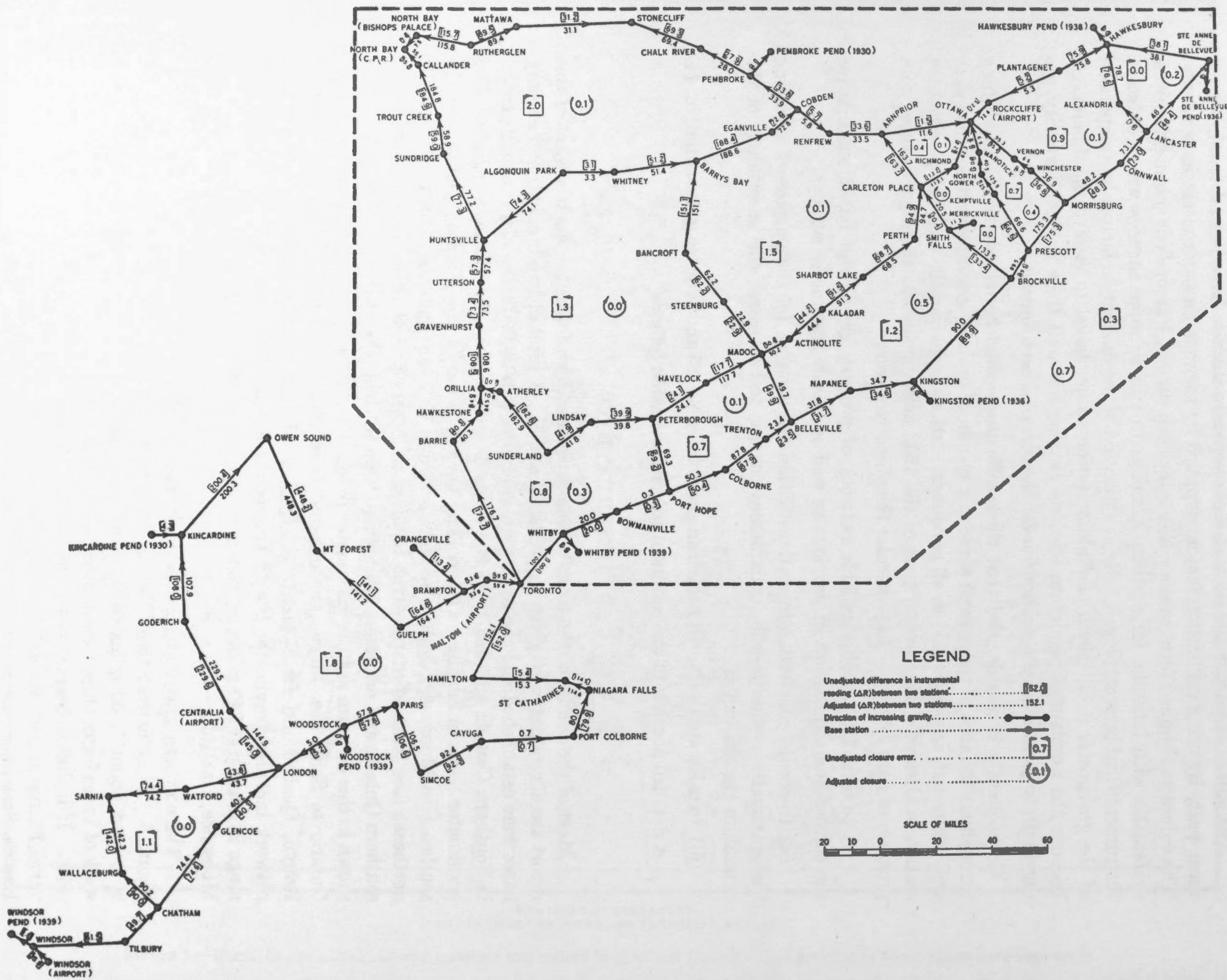

FIGURE 2.—Network of gravimeter observations in Southern Ontario.

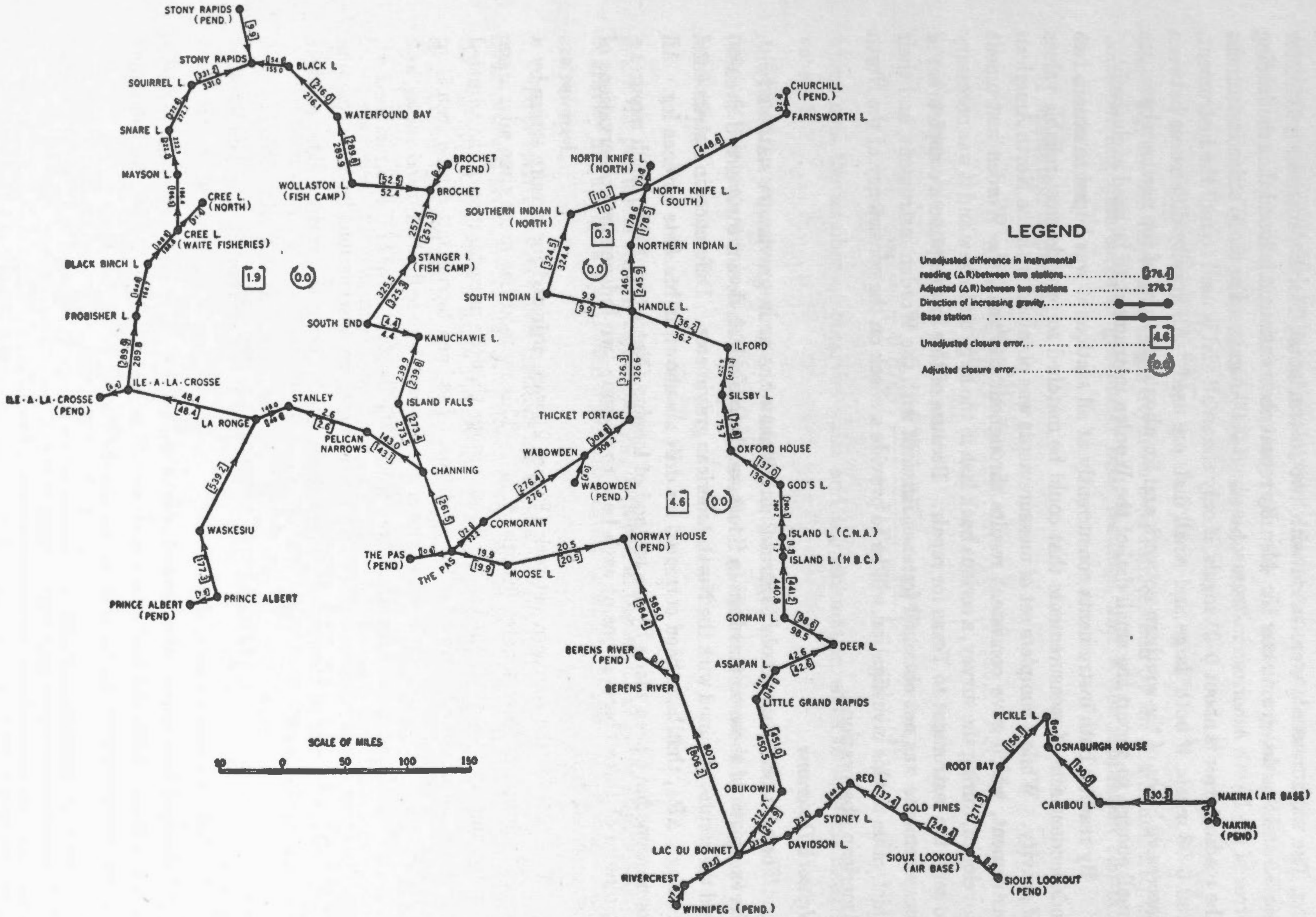

FIGURE 3.—Network of gravimeter observations in Northern Canada.

The measurements were made with two instruments[1], North American gravimeter No. 85 and Worden gravimeter No. 44. By repeat observations it is found that the reading error of the North American instrument is about 0·03 mgals. For the Worden instrument the reading error is about 0·01 mgals. if only the small dial is used to null the instrument, and 0·08 mgals. if both[2] large and small dials are used. All gravity differences between successive bases of the southern network and for about one third of the northern bases are small enough to permit the small dial of the Worden instrument to be used exclusively.

By reading both instruments concurrently at all stations it was hoped to obtain two independent sets of measurements that could be matched to provide most reliable values of gravity. While a complete set of measurements was obtained with the North American instrument, which gave consistent results throughout the year, the Worden instrument developed, during the survey, a serious back lash in the large dial screw and it was necessary to send the instrument to Texas for repair. Because of this interruption a complete set of measurements was not obtained for each network with the Worden instrument, and their chief value to this investigation will be to provide a check on the consistency of the North American observations.

Network Diagrams

The network diagrams in Figures 2 and 3 show the main gravimeter stations (with the exception of those on traverses in Southern Canada which do not form closed circuits) and the results obtained with the North American gravimeter. Differences in instrumental readings, ΔR_i, that have been corrected for drift are shown in brackets for each leg. All connections have been made by the method of looping (Nettleton, 1940) which requires a minimum of three observations at each base to provide two independent observations of instrumental drift.

The ΔR_i for the southern network (Figure 2) were adjusted for closure errors by a graphic method of least squares (Smith, 1951). This method has great time advantage over the algebraic solution, but has the disadvantage that the uncertainties of the adjusted values are not obtained. How far the adjustment has been carried out can be seen from the illustrations. The unbracketed values shown for each leg are final adjusted values, and the errors remaining in each circuit are well within the limits of error of the formal method.

The three closed circuits which comprise the northern observations have no common sides, and the errors of closure have been distributed among the various sides of their corresponding circuits.

CALIBRATION OF GRAVIMETERS

(a) North American Gravimeter No. 85

Determination of the calibration factor of the North American instrument involves the comparison of the adjusted observations with the values of gravity for the pendulum stations occupied during the process of establishing the gravimeter bases. Since the

[1] The North American gravimeter No. 85 has a range of about 250 milligals without resetting. The reset dial of the Worden instrument has been calibrated to provide world-wide measurements of gravity.

[2] It was found that the reading error using both dials was somewhat larger later in the season after the instrument had been altered.

southern network includes the national gravity base station in Ottawa to which both pendulum and gravimeter observations are referred[1], the relation between the two sets of measurements can be expressed by the linear equation,

$$\Delta g_i = K \cdot \Delta R_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where Δg_i are the differences in gravity from Ottawa measured by the pendulum, ΔR_i the corresponding differences in gravimeter scale readings, and K the calibration constant to be determined.

The solution is given by,

$$K = \frac{\Sigma \Delta g_i \cdot \Delta R_i}{\Sigma \Delta R_i^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and the probable error in K is,

$$e_K = \pm 0 \cdot 6745 \left[\frac{\Sigma (K \cdot \Delta R_i - \Delta g_i)^2}{(n-1)\, \Sigma \Delta R_i^2} \right]^{\frac{1}{2}} \ldots\ldots (3)$$

where n is the number of observed pairs and the summation signs include all integral values 1, 2, ..., n.

Since the northern gravimeter network is not connected to Ottawa nor to the southern network it is necessary to include another parameter g_0 in the observation equations which are then,

$$g_i = g_0 + K \cdot \Delta R_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

g_i are the pendulum station values and g_0, obtained in the solution[2] is the adjusted value of gravity at an arbitrarily selected pendulum station to which the gravimeter observations are referred.

To be strictly correct both methods are applicable only if the ΔR_i are totally free from observational error (Worthing & Geffner, 1948) but since the weights of the individual ΔR_i are approximately the same and about 12 times the weight of a pendulum determination, a more rigorous method is not deemed necessary.

The observational data used to make two independent solutions for the calibration factor are collected in columns (1) to (5) in Tables IV and V and the results are summarized in Table I.

All pendulum station values for the respective networks were used to obtain solutions Nos. 1 and 3. The R.M.S. value of the residuals $(g - g_P)$ is $\pm 2 \cdot 54$ mgals. for the southern network and $\pm 3 \cdot 09$ mgals. for the northern stations. By rejecting those stations having residuals greater than 2 mgals. (see solutions 2 and 4) the R.M.S. values of the residuals are reduced to $\pm 1 \cdot 05$ mgals. and $\pm 1 \cdot 14$ mgals. respectively. Solutions 2 and 4, therefore, yield the most probable values for K_n, or $0 \cdot 23150 \pm 0 \cdot 00023$ mgals. per div. for the southern network and $0 \cdot 23179 \pm 0 \cdot 00026$ mgals. per div. for the northern network.

[1] The value of gravity at Ottawa is 980·622, obtained by comparison with Potsdam (A. H. Miller, 1931).

[2] The solution is given by McCollum and Brown (1943). It is made less onerous by introducing a trial solution which approximates the linear relation sought, and then treating by least squares the differences between the observed values and the trial solution. For complete treatment, see Worthing and Geffner (1948) pp. 240–241.

TABLE I.—CALIBRATIONS OF NORTH AMERICAN GRAVIMETER No. 85

SOUTHERN NETWORK

1. Using All Pendulum Stations:

Number of Stations	22
Range in Gravity	841 mg.
Calibration Factor (K_n)	0·2315 ± 0·0002 mg/div.
Percentage Error in K_n	± 0·09
R.M.S. Residual ($g - g_p$)	± 2·54 mg.

2. Deleting Stations Nos. 4, 12, 13, 17, because of Large Residuals and No. 23 because Established Using Air Travel:

Number of Stations	17
Range in Gravity	574 mg.
Calibration Factor (K_n)	0·2315 ± 0·0002 mg/div.
Percentage Error in K_n	± 0·09
R.M.S. Residual ($g - g_p$)	± 1·05 mg.

NORTHERN NETWORK

3. Using All Pendulum Stations:

Number of Stations	12
Range in Gravity	803 mg.
Calibration Factor (K_n)	0·2315 ± 0·0005 mg/div.
Percentage Error in K_n)	± 0·21
Error in g_0	± 1·03 mg.
R.M.S. Residual ($g - g_p$)	± 3.09 mg.

4. Deleting Stations Nos. 4, 5, 6, 7, 12, because of Large Residuals:

Number of Stations	7
Range in Gravity	788 mg.
Calibration Factor (K_n)	0·2318 ± 0·0003 mg/div.
Percentage Error in K_n)	± 0·11
Error in g_0	± 0·51 mg.
R.M.S. Residual ($g - g_p$)	± 1·14 mg.

These two values hardly differ significantly, and since there is no information[1] in the results to show which is the better calibration it might seem best to adopt the mean value for both networks. However, since the northern network consists only of three circuits, none of which have common sides to facilitate the elimination of possible cumulative error in the ΔR_i, the value obtained for the southern network (0·2315 mg. per div.) has been adopted for all observations taken with the North American gravimeter in 1952. This value is 1·3 per cent smaller than the value supplied by the manufacturer in 1948.

(b) The Calibration Factor of North American No. 85 during the Seasons of 1948 and 1949

As a considerable number of the 1952 gravimeter bases were occupied with the North American instrument during the surveys of 1948 and 1949, it is now possible to determine the calibration factor of the instrument for these years by comparison with the values of gravity based upon the 1952 calibration. Comparisons over gravity differences totalling about 350 milligals give the following calibration factors,

1948	0·2326 ± 0·0001 mgals. per div.
1949	0·2341 ± 0·0003 mgals. per div.

[1] The error of the calibration factor varies directly with the errors of the pendulum measurements, and inversely with the range in gravity and the square root of the number of stations. Both solutions 2 and 4 give about the same accuracy for K_n or ± 0·1 per cent, because the smaller number of stations used in solution 4 is offset by their larger range in gravity, while the errors in the pendulum station values are approximately the same magnitude for both networks.

These differences are unexpectedly large and differ significantly from each other and from the value obtained for the calibration factor from the 1952 measurements (0·2315 mgals. per div.). No satisfactory explanation can be given to account for the different results which suggests an increase in the calibration factor for 1949 and a decrease since that time. The instrument gave satisfactory service each year and although the time between base readings was somewhat longer than in 1952, the changes are too large to be due to poorer base control. Nor does it seem that non-linearity of the instrument can account for the apparent change in the calibration since no significant change in the constant was found over the same latitudes in 1952.

(c) Worden Gravimeter No. 44

The breakdown of the Worden instrument during the field season, which also resulted in an alteration of the calibration factor while being repaired, did not permit a sufficient number of observations to be taken for an independent calibration against pendulum station values. Consequently an alternate least square method (McCollum and Browne, 1943) based upon comparative readings with the North American gravimeter, has been followed. The relative calibrations are based upon the adopted value of K = 0·2315 mgals. per division for the North American instrument and the results are given in Table II.

TABLE II.—THE CALIBRATION OF WORDEN GRAVIMETER No. 44

	Small Dial		*Large Dial*
First Calibration	Southern Network	Northern Network	Northern Network
Transportation	Automobile	Aircraft	Aircraft
Number of Comparisons	51	30	17
Average Gravity Interval	19 mgal.	25 mgal.	55 mgal.
Matching Factor	0·4814	0·4808	3·036
Percentage Error	± 0.04	±0.07	± 0·09
R.M.S. Residuals	± 0·11 mgal.	±0·17 mgal.	± 0·30 mgal.
Calibration Factor (mgals. per division)	0·1115	0·1113	7·028

—	*Small Dial*	*Large Dial*
Second Calibration	Southern Network	Northern Ontario
Transportation	Automobile	Aircraft
Number of Comparisons	45	4
Average Gravity Interval	17 mgal.	105 mgal.
Matching Factor	0·4825	3·195
Percentage Error	± 0·05	± 0·05
R.M.S. Residuals	± 0·11 mgal.	± 0·22 mgal.
Calibration Factor (mgals. per division)	0·1117	7·396

Observations from both networks provided the data for the first calibration. The two solutions for the small dial calibration do not differ significantly and their weighted mean value, 0·1114 mgals. per scale division, has been adopted as the best value for the first part of the season. The corresponding large dial constant depends upon 17 comparisons made over a 500 milligal range in the western circuit of the northern network. Because of the failure of the instrument, the observations of the other circuits are too uncertain to be used in the reduction. The best value for the calibration of the large dial is, therefore, 7·028 mgals. per scale division. The constants supplied by the manufacturer are both 0·3 per cent greater, or 0·1117 and 7·047 mgals. per division, respectively.

The second part of the table gives the statistics of the calibration after the instrument was repaired in mid-season. Comparisons made over forty-five gravity differences in the southern network were used for the small dial calibration. The calibration of the large dial depends on four comparisons made in Northern Ontario using aircraft transportation. Although more comparisons using the large dial are desirable, the gravity intervals of each comparison are quite large and the calibrations of both dials appear to be equally reliable; both solutions show that the Worden measurements have been matched with the North American observations to one part in two thousand. The absolute error in adopted constants depends, of course, on the accuracy of the constant adopted for the North American instrument (± 0·1 per cent).

The constants adopted for this calibration of the Worden are:

Small dial	—	0·1117 mgals. per div.
Large dial	—	7·396 mgals. per div.

These factors are about 0·3 per cent smaller than those supplied by the manufacturer.

THE ACCURACY OF THE GRAVITY DIFFERENCES

The accuracy of the gravity differences between successive stations in the networks depends upon how accurately the drift has been estimated in reducing the primary observations, and how well the calibration factor of the gravimeters have been determined.

The standard deviation σ, of a difference in gravity as measured by each instrument is given in Table III. The deviations have been estimated by two methods,

(i) from the residuals of the primary observations (at least two residuals for each gravity difference)

(ii) from the closure errors of the networks using the following equation[1],

$$\sigma^2 = \frac{1}{m} \sum_{i=1}^{i=m} \frac{\epsilon_i^2}{n} \qquad (5)$$

ϵ_i is the closure error of the i^{th} circuit, n the number of gravity differences forming the circuit and m is the number of circuits in the network.

TABLE III.—STANDARD ERROR OF GRAVITY DIFFERENCES

	From Residuals	*From Closure Errors*
A. SOUTHERN CANADA (AUTOMOBILE TRANSPORTATION)		
(i) North American Gravimeter	± 0·03 mgals.	± 0·08 mgals.
(ii) Worden Gravimeter (small dial only)	± 0·02 mgals.	± 0·06 mgals.
B. NORTHERN CANADA (AIRCRAFT TRANSPORTATION)		
(i) North American Gravimeter	± 0·08 mgals.	± 0·15 mgals.
(ii) Worden Gravimeter (both dials)	± 0·08 mgals.	± 0·12 mgals.

Both methods of reduction show that the errors in the gravity differences of the northern network are nearly twice as large as those estimated for the southern observations.

[1] See McCollum and Brown (1943) also Cook (1951)

The larger deviation of the Worden measurements can be attributed to the larger reading error of the instrument when the high range dial is used, as was necessary for a large number of the observations in the northern network. The greater error in the measurements made with the North American instrument, on the other hand, can be accounted for by the variable drift rates observed for a portion of the work in Northern Canada. At first it was thought the erratic behaviour of the instrument might be related to the mode of transportation, but it has since been found due to a faulty reset mechanism which introduced small tares in the readings. It is believed that most of the error from this cause is confined to the several legs of the network where the gravity differences are larger than usual.

The standard deviations estimated from the closure errors of the networks are, for both instruments, considerably larger than those estimated from the residuals. Although the reason for this is not clearly understood, and requires further investigation, there is some confirmation from the results of the relative calibrations that the closure errors provide the more reliable estimates of the deviations. In Table II the residuals, whose root mean square values have been computed for each solution, are the differences between the values obtained by the separate instruments for the various gravity differences over which the instruments were compared. Since the measurements with each instrument are independent, the sum of the squares of the standard deviation for each should be equal to the sum of the squares of the residuals that are defined above, or,

$$(\sigma_N^2 + \sigma_w^2)^{\frac{1}{2}} = \text{Root Mean Square of the Residuals},$$

where σ_N and σ_w are the standard deviations of the North American and Worden gravimeters, respectively. Substituting the values for σ_N and σ_w for the southern network from Table III gives,

$$[(0{\cdot}08)^2 + (0{\cdot}06)^2]^{\frac{1}{2}} = \pm 0{\cdot}10 \text{ mgal.},$$

which is in good agreement with $\pm$ 0·11 mgal., the value obtained for the root mean square of the residuals for both calibrations of the small dial using observations from the southern network.

Substitution of the deviations of the two instruments for the northern network gives

$$[(0{\cdot}15)^2 + (0{\cdot}12)]^{\frac{1}{2}} = \pm 0{\cdot}19 \text{ mgals.}$$

This value is intermediate to the value of the root mean square of the residuals from the small dial calibration ($\pm$ 0·17 mgals.) and from the large dial calibration ($\pm$ 0·30 mgals). The agreement is as good as might be expected when it is considered that the standard deviation from the closure errors of the Worden measurements is based upon observations using both the high range and low range dials.

The main conclusions to be drawn from these calculations are,

(i) the closure errors of the networks provide the most reliable estimates for the standard deviation of the gravity differences.

(ii) the residuals of the comparative observations have a random distribution and sufficient comparisons have been made to provide a reliable calibration of the Worden instrument in terms of the constant adopted for the North American gravimeter.

In addition to the random errors of observations that have just been discussed, the gravity differences and, of course, the adopted values of gravity for the bases are subject to cumulative error arising from the uncertainty in the calibration of the gravimeter. This has been found to be about $\pm$ 0·1 per cent for the North American calibration and, therefore, the gravity values for the base stations may have systematic errors varying from 0 to $\pm$ 0·5 milligals, with the outlying stations of each network having the larger error.

THE ADJUSTED VALUES OF GRAVITY

(a) Pendulum Stations

The most probable values of gravity for the pendulum stations are those derived from the gravimeter observations using the adopted value for K_N ; they are listed in column (7) of Tables IV and V. The differences $(g - g_P)$ are given in column (8) and include errors of the gravimeter observations as well as those of the pendulum determinations. The standard deviation of the gravimeter observations have been estimated to be less than 0·1 milligals and it is likely, therefore, that each difference $(g - g_P)$ is dominated by the error in the corresponding pendulum measurement. The root mean square of the differences[1] therefore, may be taken as a good value for the standard deviation of the pendulum observations.

[1] Should the gravimeter values of gravity contain systematic errors resulting from the unreliability of the calibration factor, the R.M.S. of the true differences would be correspondingly larger.

TABLE IV.—ADJUSTMENT OF PENDULUM STATION VALUES OF GRAVITY

(Eastern Network

	(1)	(2) Year Established	(3) g_p	(4) Δg_i(mg.)	(5) ΔR_i	(6) $K\cdot\Delta R_i$(mg.)	(7) g	(8) $g - g_p$(mg.)
1	Windsor, Ont.	1939	980·334	−288	−1239·4	−286·92	980·33508	+1·08
2	Woodstock, Ont.	1939	.357	−265	−1141·5	−264·26	·35774	+0·74
3	Whitby, Ont.	1939	.469	−153	− 665·0	−153·95	·46805	−0·95
4	Kincardine, Ont.	1930	.476	−146	− 660·1	−152·81	·46919	−6·81
5	Kingston, Ont.	1936	·524	− 98	− 419·3	− 97·07	·52493	+0·93
6	Ottawa, Ont.		·622	0	0	0	·62200	0·00
7	Pembroke, Ont.	1930	·634	+ 12	+ 54·1	+ 12·52	·63452	+0·52
8	Ste. Anne de Bellevue, Que.	1936	·645	+ 23	+ 105·1	+ 24·33	·64633	+1·33
9	Montreal, Que.	1936	·650	+ 28	+ 125·1	+ 28·96	·65096	+0·96
10	Hawkesbury, Que.	1938	·657	+ 35	+ 142·9	+ 33·08	·65508	−1·92
11	St. Jerome, Que.	1939	·661	+ 39	+ 170·9	+ 39·56	·66156	+0·56
12	Sault Ste. Marie, Ont.	1939	·682	+ 60	+ 271·0	+ 62·74	·68474	+2·74
13	Sudbury, Ont.	1936	·683	+ 61	+ 276·3	+ 63·96	·68596	+2·96
14	Quebec, Que.	1937	·728	+106	+ 462·4	+107·05	·72905	+1·05
15	Stoneham, Que.	1938	·752	+130	+ 565·5	+130·91	·75291	+0·91
16	Portneuf, Que.	1939	·754	+132	+ 567·6	+131·40	·75340	−0·60
17	La Tuque, Que.	1930	·783	+161	+ 661·9	+153·23	·77523	−7·77
18	New Liskeard, Ont.	1936	·785	+163	+ 712·6	+164·97	·78697	+1·97
19	Roberval, Que.	1939	·858	+236	+1024·3	+237·13	·85913	+1·13
20	Chicoutimi, Que.	1938	·866	+244	+1051·4	+243·40	·86540	−0·60
21	Tadoussac, Que.	1938	·880	+258	+1112·0	+257·43	·87943	−0·57
22	Cochrane, Ont.	1946	·888	+266	+1147·1	+265·55	·88755	−0·45
23	Moosonee, Ont.	1946	981·175	+553	+2394·5	+554·33	981·17633	+1·33

TABLE V.—ADJUSTMENT OF PENDULUM STATION VALUES OF GRAVITY

(Northern Network)

	(1) Pendulum Station	(2) Year Established	(3) g_p	(4) Δg(mg.)	(5) ΔR_i	(6) $K \cdot \Delta R_i$(mg.)	(7) g	(8) $g - g_p$(mg.)
1	Nakina, Ont.	1927	980·987	0	0	0	980·98885	+1·85
2	Sioux Lookout, Ont.	1927	·982	− 5	− 32·4	− 7·50	·98135	−0·65
3	Winnipeg, Man.	1946	·994	+ 7	+ 26·3	+ 6·09	·99494	+0·94
4	Berens River, Man.	1927	981·203	+216	+ 954·9	+221·06	981·20991	+6·91
5	Prince Albert, Sask.	1924	·236	+249	+1048·9	+242·82	·23167	−4·33
6	The Pas, Man.	1946	·341	+354	+1510·2	+349·61	·33846	−2·54
7	Norway House, Man.	1927	·349	+362	+1539·8	+356·46	·34531	−3·69
8	Ile a la Crosse, Sask.	1946	·409	+422	+1812·3	+419·55	·40840	−0·60
9	Wabowden, Man.	1946	·416	+429	+1844·3	+426·96	·41581	−0·19
10	Brochet, Man.	1946	·651	+664	+2852·4	+660·33	·64918	−1·82
11	Churchill, Man.	1946	·770	+783	+3379·9	+782·45	·77130	+1·30
12	Stoney Rapids, Sask.	1946	·785	+798	+3451·5	+799·02	·78787	+2·87

Generally the errors are about what we have been led to expect from repeated pendulum measurements. The worst errors are found in the earlier observations and in those obtained in the unsettled regions of Northern Canada[1]. The R.M.S. difference for all thirty-four pendulum stations is ± 2·70 mgals. For the twelve stations that are in Northern Canada the R.M.S. difference is ± 2·91 milligals, while for the twenty stations established in Southern Canada since 1936, it is ± 1·15 mgal.

It might also be pointed out that the signs of the differences ($g - g_P$) are, to some extent, systematic with the years of observation. All differences for the five 1936 stations are positive, the differences for three of the four 1938 stations are negative, while five of the seven stations established during 1939 have positive differences.

The density of the pendulum stations throughout the areas of the two gravimeter networks is probably greater than it is in other areas of Canada of comparable size. Although it has been shown that the better of these determinations are sufficient to prevent serious error in the gravimeter results, there is still much to be desired and new and more precise pendulum measurements are needed before the calibration of the gravimeters can be improved and better values of gravity derived. The greatest need is, of course, for new stations to be established throughout the large areas of Northern Canada, where so far only a few scattered measurements have been made.

(b) Gravimeter Bases

The principal facts for all gravimeter bases established during 1952 have been collected in Table VI. The data for the bases in the southern network have been tabulated in separate groups for each of the provinces of Ontario and Quebec. They are listed, for the most part, in order of increasing latitude and according to the number of the provincial highway on which they are located. The bases of the northern network have been divided into several north-south lines and tabulated generally in the order of increasing gravity.

[1] Earlier measurements have larger errors due to inconstancy of pendulum periods (see A. H. Miller, 1936). In Northern Canada the larger errors can be attributed to more poorly temperature controlled sites for the observations.

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES

A. SOUTHERN NETWORK

(1) Ontario

Station Name	Longitude	Latitude	Elevation (Feet)	Observed Gravity
	° ′	° ′		
Bases along Highway No. 2				
Windsor	83 02·4	42 19·1	588	980·3347
Windsor Airport	82 58·1	42 16·2	623	·3264
Tilbury	82 25·9	42 15·6	587	·3205
Chatham	82 10·9	42 24·4	594	·3320
Glencoe (Hwy. 80)	81 42·7	42 44·9	728	·3492
London	81 15·1	42 59·0	814	·3585
Woodstock	80 45·5	43 07·8	990	·3574
Paris	80 23·2	43 11·9	829	·3708
Hamilton	79 52·2	43 15·5	316	·4092
Toronto	79 23·5	43 40·0	370	·4444
Whitby	78 56·6	43 52·7	310	·4676
Bowmanville	78 41·4	43 54·9	365	·4722
Port Hope	78 17·2	43 57·0	298	·4721
Colborne	77 58·6	44 00·8	361	·4838
Trenton	77 34·8	44 06·5	257	·5041
Belleville	77 22·8	44 09·7	260	·5095
Napanee	76 57·3	44 15·2	315	·5169
Kingston	76 28·9	44 13·7	254	·5249
Brockville	75 41·3	44 35·4	310	·5457
Prescott	75 31·5	44 42·8	311	·5665
Morrisburg	75 11·3	44 53·9	270	·6070
Cornwall	74 44·0	45 01·9	193	·6181
Lancaster	74 30·2	45 08·4	164	·6350
Bases along Highway No. 3				
Simcoe	80 18·7	42 50·3	714	980·3461
Cayuga	79 51·8	42 56·9	600	·3675
Port Colborne	79 15·1	42 53·3	583	·3677
Bases along Highway No. 4				
Centralia Airport	81 30·2	43 17·5	813	980·3920
Bases along Highway No. 6				
Mt. Forest	80 44·8	43 58·6	1353	980·4127
Owen Sound	80 56·7	44 34·0	600	·5165
Bases along Highway No. 7				
Guelph	80 14·7	43 32·8	1042	980·3801
Brampton	79 45·9	43 41·2	715	·4182
Malton Airport	79 38·1	43 41·6	565	·4306
Sunderland	79 03·7	44 16·0	859	·4694
Lindsay	78 44·5	44 21·2	847	·4791
Peterborough	78 19·3	44 18·5	673	·4883
Havelock	77 52·9	44 26·0	700	·4939
Madoc	77 29·1	44 30·4	575	·5211
Actinolite	77 19·2	44 33·2	555	·5328
Kaladar	77 07·0	44 38·7	705	·5225
Sharbot Lake	76 41·3	44 46·4	650	·5436
Perth	76 15·0	44 53·9	439	·5595
Bases along Highway No. 8				
Niagara Falls	79 04·8	43 05·6	606	980·3862
St. Catharines	79 14·5	43 09·7	369	·4127

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES—*Continued*

A. SOUTHERN NETWORK—*Continued*

(1) ONTARIO—*Continued*

Station Name	Longitude	Latitude	Elevation (Feet)	Observed Gravity
	° ′	° ′		
Bases along Highway No. 10				
Orangeville	80 05·4	43 54·8	1397	980·3919
Bases along Highway No. 11				
Barrie	79 41·3	44 23·3	727	980·4854
Hawkestone	79 28·5	44 30·0	780	·4947
Orillia	79 24·7	44 36·5	723	·5143
Atherley (Hwy. No. 12)	79 21·8	44 36·2	738	·5118
Gravenhurst	79 22·3	44 55·2	832	980·5394
Utterson	79 19·7	45 12·7	1036	·5564
Huntsville	79 12·9	45 19·3	959	·5697
Sundridge	79 23·9	45 46·0	1100	·5876
Trout Creek	79 21·5	45 59·2	1027	·6012
Callander	79 22·0	46 13·3	670	·6440
North Bay (C.P.R.)	79 27·9	46 18·6	622	·6568
North Bay (Bishop's Palace)	79 28·0	46 18·9	677	·6550
Junc. Hwys. 11 and 64	79 49·9	46 43·1	965	·6849
Timagami	79 47·0	47 03·9	986	·7250
New Liskeard	79 40·3	47 30·6	620	·7863
Englehart	79 52·1	47 49·5	679	·8268
Rock Outcrop (Rd. to Round L.)	80 00·8	48 00·8	979	·7907
Swastika	80 06·0	48 06·4	1006	·8065
Ramore	80 19·3	48 26·3	944	·8586
Matheson	80 28·2	48 32·2	860	·8588
Porquis	80 46·8	48 42·4	944	·8729
Porquis Airport	80 47·1	48 44·4	1002	·8732
Cochrane	81 00·6	49 03·6	917	·8874
Bases along Highway No. 15				
Merrickville	75 50·5	44 55·3	357	980·5793
Smith Falls	76 01·0	44 54·2	428	·5767
Carleton Place	76 08·4	45 08·2	453	·5814
Richmond	75 49·5	45 11·0	310	·6076
Bases along Highway No. 16				
Kemptville	75 38·6	45 00·8	319	980·5819
North Gower	75 43·1	45 07·9	300	·6110
Manotick	75 41·1	45 13·6	275	·6204
Bases along Highway No. 17				
Hawkesbury	74 36·3	45 36·6	147	980·6551
Plantagenet	74 59·0	45 31·0	168	·6375
Rockcliffe Airport	75 38·3	45 27·4	178	·6388
Ottawa	75 42·9	45 23·6	274·3	·6220
Arnprior	76 21·4	45 25·9	299	·6193
Renfrew	76 41·5	45 28·1	422	·6271
Cobden	76 53·1	45 37·6	476	·6257
Pembroke	77 07·3	45 49·4	410	·6336
Chalk River	77 27·1	46 01·1	522	·6401
Stonecliff	77 53·7	46 12·8	562	·6561
Mattawa	78 42·3	46 18·7	563	·6489
Rutherglen	79 02·3	46 16·2	789	·6282
Sturgeon Falls	79 55·7	46 22·0	688	·6742

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES—*Continued*

A. SOUTHERN NETWORK—*Continued*

(1) Ontario—*Concluded*

Station Name	Longitude	Latitude	Elevation (Feet)	Observed Gravity
	° ′	° ′		
Bases along Highway No. 17—Concluded				
Hagar	80 25·0	46 27·3	691	·7026
Sudbury	81 00·0	46 29·8	881	·6860
Worthington	81 27·1	46 22·9	775	·6861
Espanola	81 46·0	46 16·1	672	·6742
Webbwood	81 52·7	46 16·0	661	·6761
Spanish	82 21·0	46 11·6	610	·6575
Blind River	82 57·4	46 10·8	602	·6493
Iron Bridge	83 13·3	46 16·7	619	·6542
Bruce Station	83 45·7	46 19·0	680	·6652
Sault Ste. Marie	84 19·6	46 30·5	600	·6841
Bases along Highway No. 21				
Goderich	81 42·7	43 44·6	718	980·4452
Kincardine	81 38·2	44 10·5	649	·4702
Bases along Highway No. 22				
Watford	81 52·5	42 57·1	796	980·3686
Bases along Highway No. 31				
Winchester	75 20·8	45 04·9	250	980·5984
Vernon	75 27·9	45 09·9	289	·5999
Bases along Highway No. 34				
Alexandria	74 38·3	45 19·0	257	980·6369
Bases along Highway No. 40				
Wallaceburg	82 22·5	42 35·2	584	980·3529
Sarnia	82 24·4	42 58·1	599	·3858
Bases along Highway No. 60				
Algonquin Park	78 35·7	45 33·1	1419	980·5526
Whitney	78 14·0	45 29·8	1266	·5533
Barry's Bay	77 40·5	45 29·5	984	·5652
Eganville	77 06·1	45 32·4	551	·6089
Bases along Highway No. 62				
Steenburg	77 39·2	44 50·5	No elevation	980·5158
Bancroft	77 51·6	45 03·5	1085	·5302
Bases along Highway No. 66				
Kirkland Lake	80 01·9	48 09·2	1048	980·8060
Larder Lake	79 42·8	48 05·8	948	·8104
Bases along Highway No. 67				
South Porcupine	81 12·4	48 28·7	920	980·8342

(2) Quebec

Bases along Highway No. 2				
Ste.-Anne-de-Bellevue	73 56·6	45 24·5	110	980·6463
Dorval Airport	73 45·5	45 27·3	97	·6454
Montreal	73 34·0	45 30·0	151	·6499
Pointe-aux Trembles	73 29·5	45 38·4	42	·6581

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES—*Continued*

A. SOUTHERN NETWORK—*Concluded*

(2) QUEBEC—*Concluded*

Station Name	Longitude		Latitude		Elevation (Feet)	Observed Gravity
	°	′	°	′		
Bases along Highway No. 2—Concluded						
St. Sulpice	73	21·2	45	49·6	35	·6786
Berthierville	73	10·7	46	05·0	29	·6880
Trois Rivieres	72	32·3	46	20·6	49	·7111
Cap-de-la-Madeleine	72	30·0	46	22·4	55	·7145
St.-Anne-de-la-Perade	72	12·2	46	34·6	38	·7428
Portneuf	71	53·0	46	41·7	19	·7530
Quebec	71	13·2	46	48·2	340	·7289
Levis	71	11·0	46	48·8	17	·7486
Montmagny	70	33·1	46	58·8	51	·7487
Ste.-Anne-de-la-Pocatiere	70	01·4	47	22·1	154	·7818
Notre-Dame-du-Portage	69	37·1	47	45·8	34	·8318
Riviere-du-Loup	69	31·7	47	49·6	290	·8232
Bases along Highway No. 15						
St. Simeon	69	53·0	47	50·7	25	980·8584
Tadoussac	69	42·7	48	08·2	10	·8816
Bases along Highway No. 16						
Petit Saquenay	70	04·2	48	12·9	58	980·8804
Grande Baie	70	51·0	48	19·1	18	·8713
Chicoutimi	71	03·8	48	25·7	75	·8648
Bases along Highway No. 19						
Grand-Mere	72	41·2	46	36·9	426	980·7191
Ste. Tite	72	33·9	46	43·4	457	·7316
St.-Roche-de-Mekinac	72	46·3	46	48·9	478(altimeter)	·7257
Riviere-aux-Rats	72	53·6	47	12·6	393(altimeter)	·7585
Lac-a-Beauce	72	46·0	47	19·3	689(altimeter)	·7650
La Tuque	72	47·0	47	26·3	545	·7750
Bases along Highway No. 41						
Lachute	74	20·0	45	39·4	226	980·6470
St. Jerome	74	00·2	45	46·8	310	·6609
St. Jacques	73	34·3	45	56·9	196	·6797
Joliette	73	26·2	46	01·3	186	·6906
Base along Highway No. 54						
Stoneham	71	23·5	46	57·6	511	980·7518
Bases along Highway No. 55						
St.-Joseph-d'Alma	71	39·4	48	33·0	302	980·8650
Roberval	72	12·6	48	30·7	346	·8587
St. Felicien	72	26·4	48	39·0	367	·8658
Bases along Highway No. 59						
Arntfield	79	15·3	48	12·1	935	980·8166
Rouyn	79	01·9	48	14·4	962	·8267
Cache Lake	74	25·6	49	49·6	1245(altimeter)	980·9440

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES—*Continued*

B. NORTHERN NETWORK

Station Name	Longitude		Latitude		Elevation (Feet)	Observed Gravity
	°	′	°	′		
Nakina (air)	86	42·5	50	13·1	973 B	980·9950
Caribou Lake	89	09·3	50	22·7	1172 B	981·0251
Osnaburgh House	90	15·8	51	08·4	1239 C	·0552
Pickle Lake	90	11·9	51	32·7	1183 C	·0802
Root Bay	91	22·6	50	55·7	1238 C	·0440
Sioux Lookout (air)	91	55·4	50	05·7	1176 B	980·9811
Gold Pines	93	10·6	50	38·4	1184 B	981·0388
Red Lake	93	49·2	51	01·6	1165 C	·0706
Sydney Lake	94	27·6	50	39·9	1166 C	·0363
Davidson Lake	95	09·4	50	26·8	1108 B	·0309
Lac du Bonnet	96	03·5	50	15·6	824 B	·0231
Rivercrest	97	02·5	50	00·0		·0130
Obukowin Lake	95	11·9	51	04·3	1067 B	·0723
Little Grand Rapids	95	27·6	52	02·6	983 B	·1766
Assapan Lake	95	10·1	52	26·1	1030 B	·2092
Deer Lake	94	01·3	52	36·9	1010 C	·2191
Gorman Lake	94	53·9	53	04·7	963 B	·2419
Island Lake (HBC)	94	40·3	53	52·2	747 B	·3440
Island Lake (CNR)	94	40·7	53	52·2	751 B	·3436
God's Lake	94	27·9	54	33·3	618 C	·4084
Oxford House	95	16·0	54	57·0	639 C	·4401
Silsby Lake	95	42·1	55	28·1	639 C	·4576
Ilford (air)	95	41·6	56	03·6	610 B	·5555
Handle Lake	97	26·4	56	40·0	816 B	·5639
South Indian Lake	98	56·8	56	47·0	839 B	·5616
Northern Indian Lake	97	15·0	57	22·7	809 C	·6209
Southern Indian L. (north)	98	17·9	57	38·0	836 B	·6367
North Knife Lake (south)	97	06·1	57	57·2	904 C	·6622
North Knife Lake (north)	96	58·8	58	16·3	904 C	·6791
Farnsworth Lake	94	03·0	58	42·5	54 C	·7661
Berens River (air)	97	01·1	52	21·3	717 B	981·2099
Norway House	97	50·1	53	58·8	720 B	·3453
Moose Lake	100	18·1	53	42·4	839 B	·3406
The Pas (air)	101	11·9	53	49·1	858 C	·3360
Cormorant	100	36·0	54	13·8	843 B	·3527
Wabowden (air)	94	34·6	54	54·8	745 B	·4167
Thicket Portage (air)	97	41·8	55	19·3	597 B	·4883
Channing	101	49·9	54	44·7	963 B	981·3965
Pelican Narrows	102	56·0	55	10·1	1067 C	·4296
Island Falls	102	21·2	55	31·8	1001 B	·4598
Kamuchawie Lake	102	00·1	56	15·6	1160 B	·5154
South End	103	14·7	56	20·2	1148 C	·5143
Stanger Island	102	11·7	57	10·7	1153 C	·5897
Brochet (air)	101	40·0	57	52·7	1159 C	·6493
Wollaston Lake	103	26·9	58	05·8	1340 C	·6372
Waterfound Bay	104	01·1	58	48·7	1261 C	·7043

TABLE VI.—PRINCIPAL FACTS FOR GRAVIMETER BASES—*Concluded*

B. NORTHERN NETWORK—*Concluded*

Station Name	Longitude		Latitude		Elevation (Feet)	Observed Gravity
	°	′	°	′		
Black Lake	104	58·7	59	14·7	920 C	·7543
Stony Rapids (air)	105	51·1	59	15·9	696 B	·7902
Prince Albert (air)	105	41·0	53	12·7	1390 C	981·2299
Waskesiu	106	05·9	53	55·6	1750 C	·2709
La Ronge	105	17·8	55	05·9	1253 B	·3957
Stanley	104	33·2	54	25·0	1167 C	·4302
Ile-a-la-Crosse (air)	107	53·6	55	26·1	1385 B	·4069
Frobisher Lake	107	57·5	56	19·3	1384 B	·4740
Black Birch Lake	107	44·9	56	53·5	1582 C	·5121
Cree Lake (Waite)	106	50·8	57	20·3	1594 C	·5558
Mayson Lake	107	08·0	57	58·3	1414 C	·5990
Snare Lake	107	38·6	58	28·3	1442 C	·6504
Squirrel Lake	107	19·1	58	54·8	1210 C	·7135

The positions of the stations have been scaled from the largest scale maps of the National Topographic Series that are available for the area concerned. All bases of the southern network are located near bench marks, railway stations and the heights of these bases are known within one foot of elevation. The heights of stations in the northern network have accuracies designated in the table as A, B, or C, depending upon whether their uncertainties are within one foot, five feet or fifteen feet, respectively. Those classified as B heights have been determined by reference to tertiary levels along base lines and meridians, while the C heights have been determined barometrically.

The values of gravity have been derived solely from observations taken with the North American instrument, using the adopted scale constant value of 0·2315 milligals per scale division. It has been shown that the probable error of the gravity differences between bases is slightly less than 0·1 mgal. for the southern network and somewhat greater than this amount for the northern network. For the sake of uniformity the values of gravity for all stations have been rounded off to one-tenth of a milligal.

DESCRIPTION OF GRAVIMETER BASES

Diagrams illustrating the sites of twenty-four principal gravimeter bases in Ontario and twelve in the province of Quebec are given in the Appendix. Each diagram is oriented so that the approximate north direction is to the top of the drawing. The distances to the gravimeter bases from points of references, usually portions of buildings such as post offices, railroad depots, are shown in the diagrams. While these distances are exact, it should be mentioned that neither the configuration of the buildings nor their scale are necessarily precise.

Descriptions of the gravimeter bases of the northern network are not included in this report, but must await the installation of permanent bronze markers and the erection of monuments by which it is intended to mark the sites.

SUMMARY

A total of two hundred and seventy gravimeter bases were established during the 1952 field season as part of a general program to provide a framework for the control of existing and future gravity surveys. The observations form two separate networks, one in southern Ontario and Quebec and the other in Northern Canada.

The southern bases have been well connected and the standard deviation of the gravity differences estimated to be $\pm 0 \cdot 08$ mgals. The errors in the northern network, on the other hand, are about twice as large and may be related to the poorer performance of the instruments at that time. It is considered that the reliability of these results could be greatly improved by a few additional measurements to provide more closed loops within the existing networks.

The measurements made with the North American instrument, co-ordinated with the available pendulum station values, gave the calibration factor of the gravimeter to an accuracy of one part in a thousand. A comparison of the 1952 adopted values of gravity for identical bases observed with the same instrument on previous surveys suggests that the calibration factor of the North American gravimeter varies as much as 0·7 per cent per year.

The largest errors remaining in the adopted values of gravity for the base stations arise from the uncertainty of the calibration of the instruments and no improvement in the results can be expected until more precise pendulum determinations are obtainable. The gravimeter observations show that the majority of pendulum measurements have a standard deviation of about 1·2 milligals and that some of the observations made before 1936, and some in the unsettled regions of northern Canada have much larger errors.

Emphasis is now being given by the Dominion Observatory to the development of a modern pendulum apparatus, which it is hoped, will provide more consistent values of gravity and facilitate the extension of this gravimeter program to the now unsurveyed regions of Northern Canada.

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REFERENCES

COOK, A. H.

1951 "An Investigation of the Errors of Some Recent Gravimeter Observations", *M.N.R.A.S., Geographical Supplement*, Vol. 6, No. 4.

GARLAND, G. D.

1950 "Interpretations of Gravimetric and Magnetic Anomalies on Traverses in the Canadian Shield in Northern Ontario", *Publications of the Dominion Observatory*, Vol. XVI, No. 1.

1953 "Gravity Measurements in the Maritime Provinces", *Publications of the Dominion Observatory* (in press).

INNES, M. J. S.

1953 "Gravity Measurements in Northern Ontario and Manitoba", *Publications of the Dominion Observatory* (in press).

MCCOLLUM, E. V. and BROWN, A.

1943 "Use of the Gravity Meter in Establishment of Gravity Bench Marks", *Geophysics*, Vol. 8, No. 4.

MILLER, A. H.

1931 "A Determination of the Relative Values of Gravity at Potsdam, Greenwich, Ottawa and Washington", *Publications of the Dominion Observatory*, Vol. XI, No. 2.

1936 "Gravity and Isostasy in Canada", *Publications of the Dominion Observatory*, Vol. XI, No. 3.

1944 "Gravimetric Surveys of 1944 in New Brunswick", *Geological Survey Bulletin*, No. 6.

1953 "Gravity Anomalies Over the Sudbury Basin", *Publications of the Dominion Observatory* (in press).

NETTLETON, L. L.

1940 "Geophysical Prospecting for Oil", McGraw-Hill Book Co., p. 38.

SAXOV, S.

1953 "Gravimeter Measurements in the Vicinity of Ottawa", *Publications of the Dominion Observatory* (in press).

SMITH, A. E.

1951 "Graphic Adjustment by Least Squares", *Geophysics*, Vol. XVI, pp. 222–227.

THOMPSON, L. G. D. and MILLER, A. H.

1953 "Gravity in Southern Ontario", (in press).

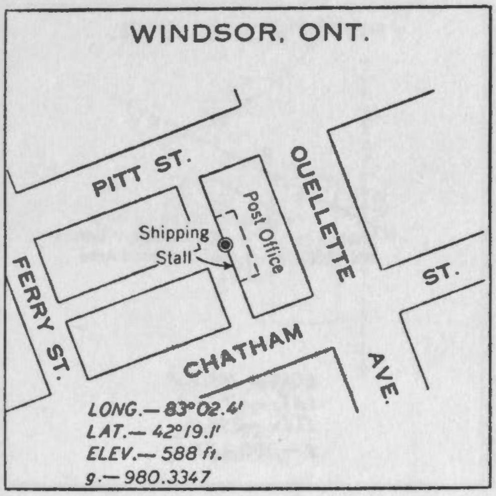
WORTHING, A. G. and GEFFNER, J.

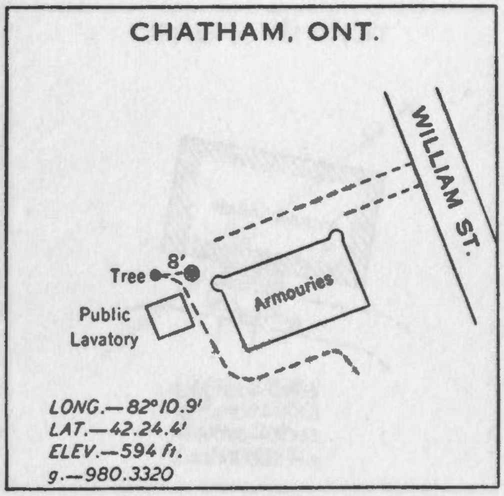
1948 "Treatment of Experimental Data", John Wiley & Sons, New York.

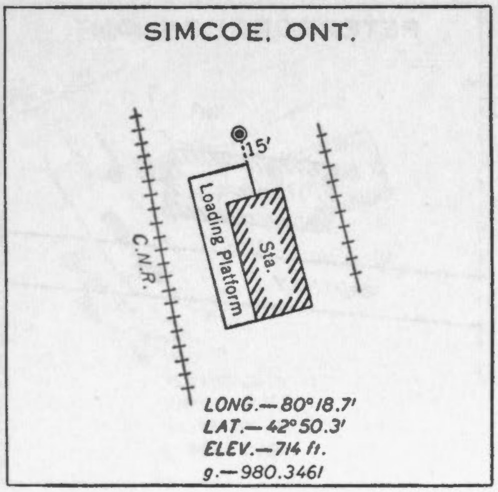
APPENDIX

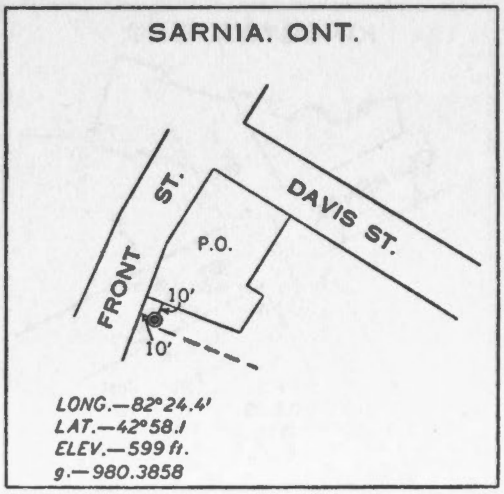
Descriptions of Sites of Gravimeter Bases

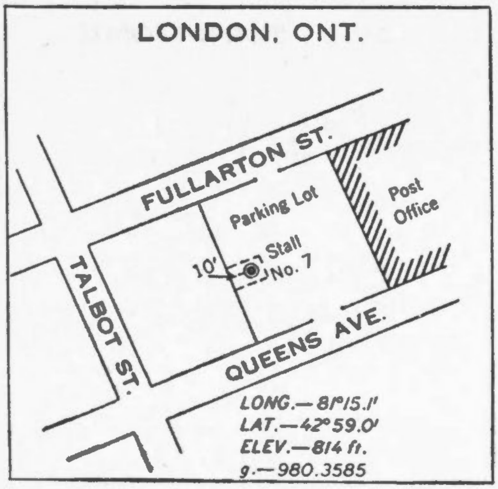
BASES IN ONTARIO

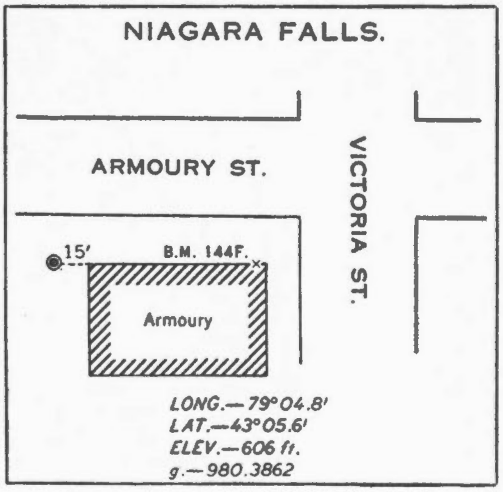












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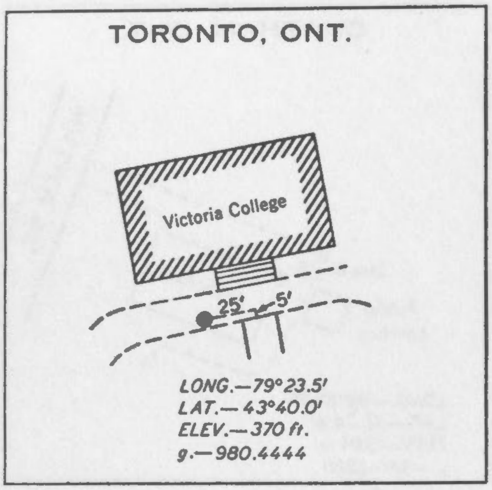

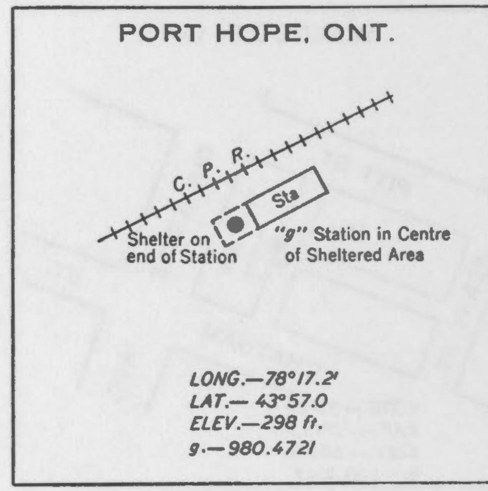

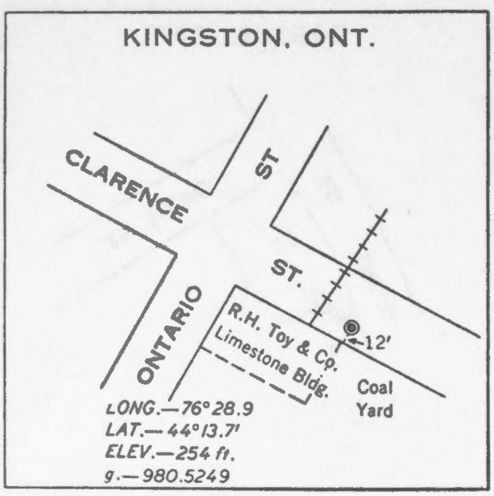

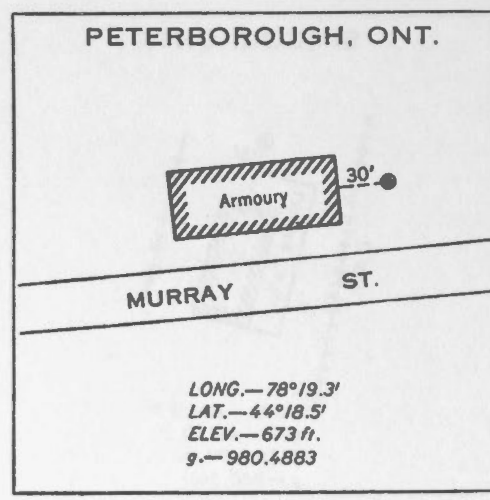

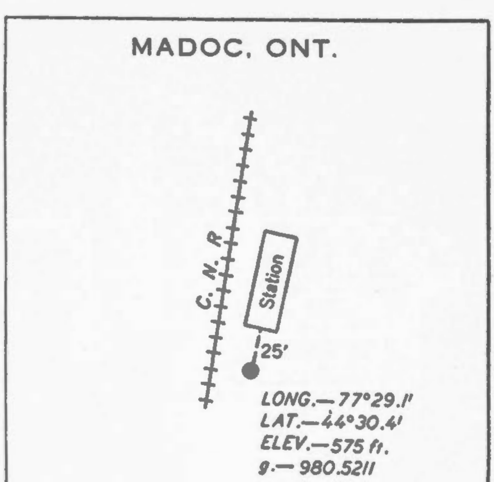

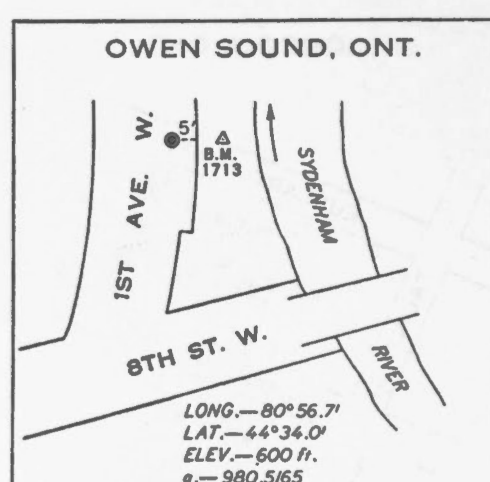

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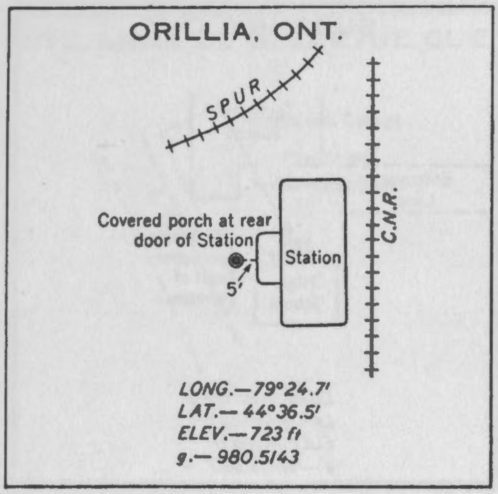

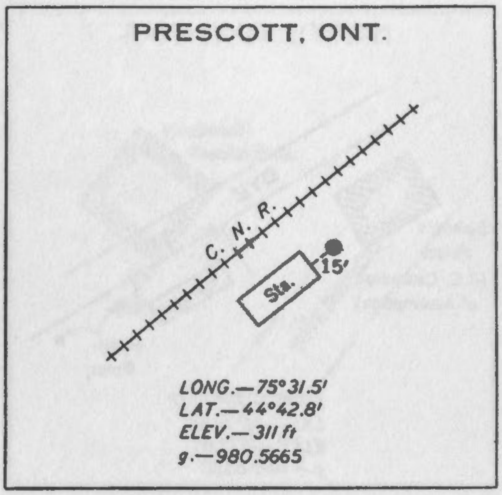

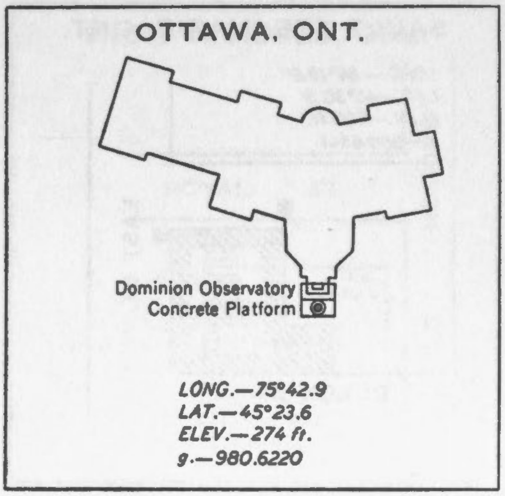

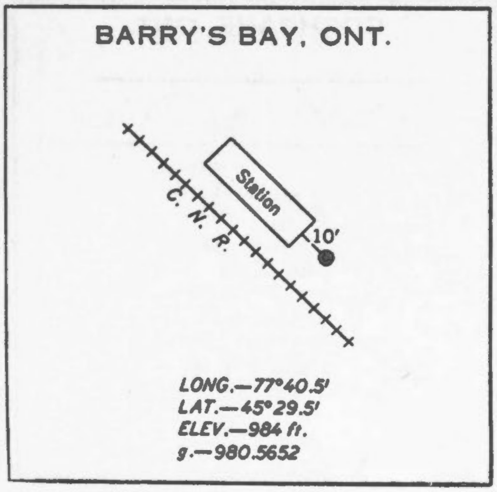

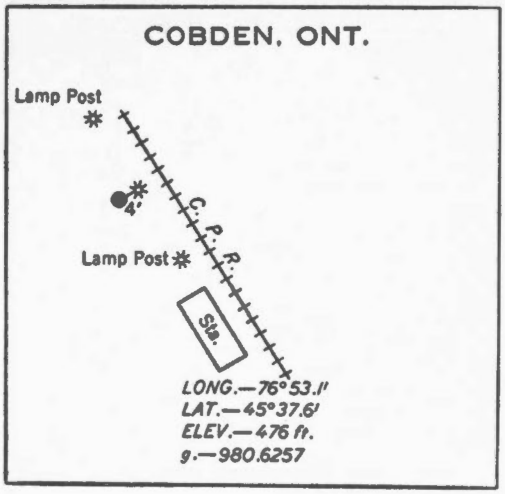

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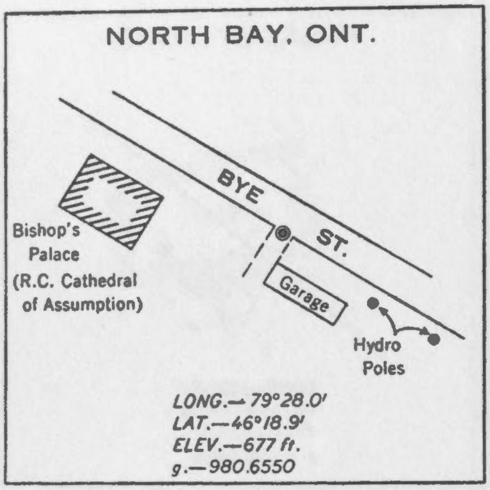

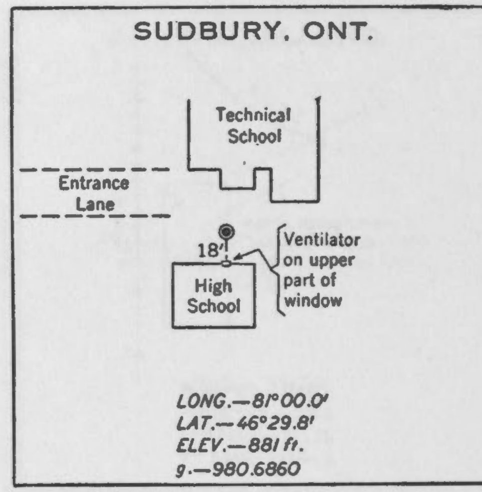

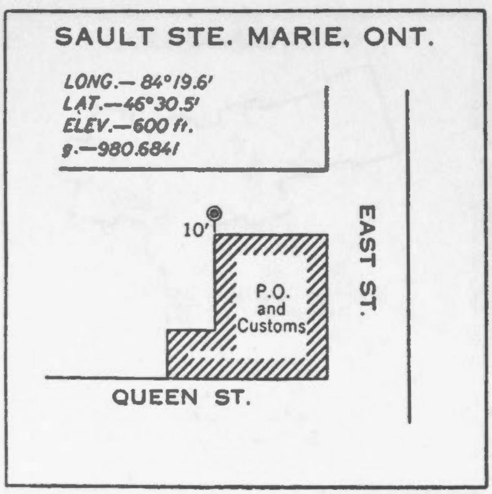

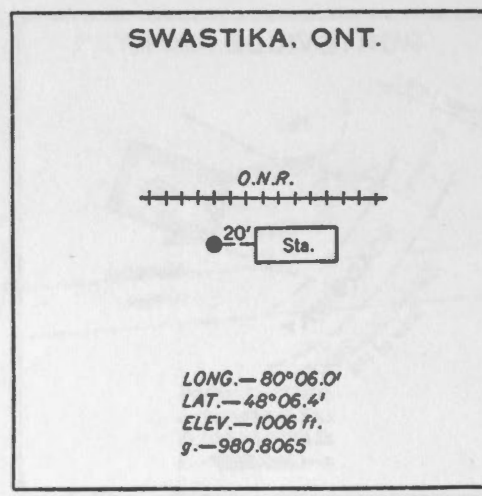

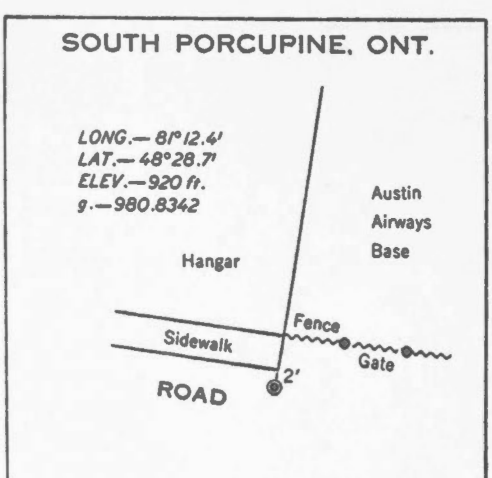

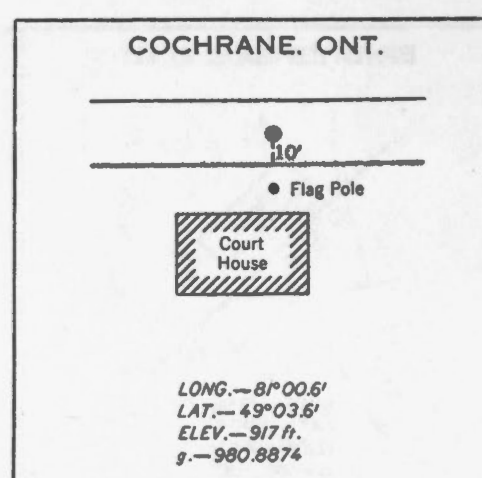

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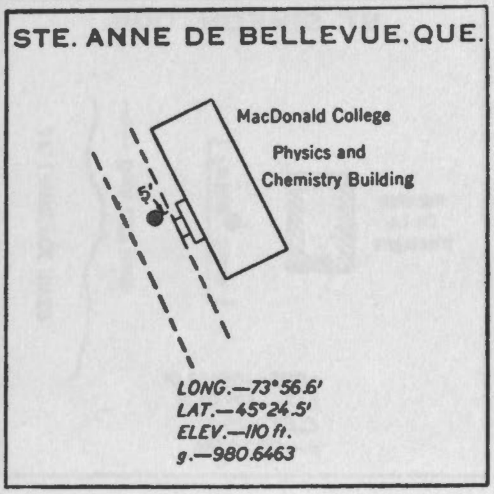

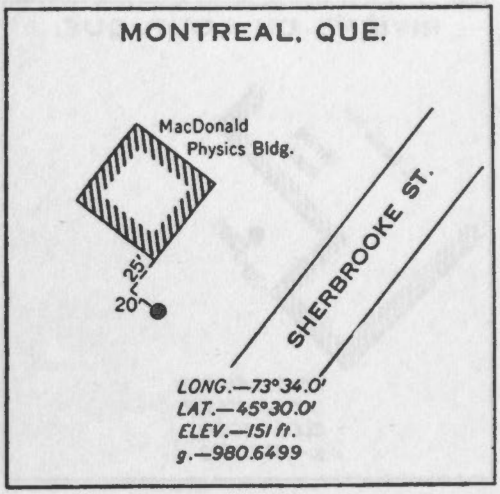

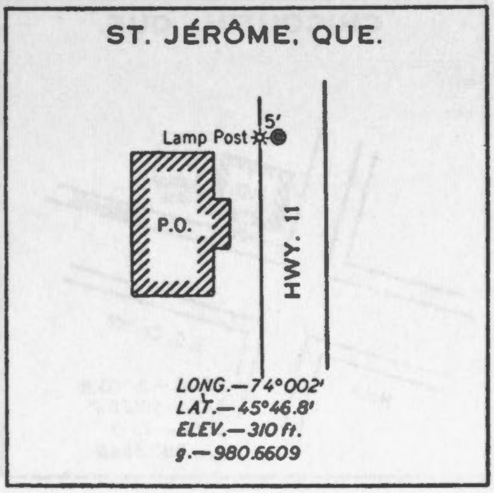

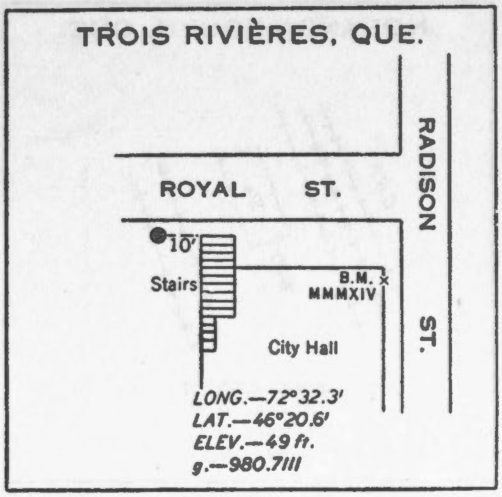

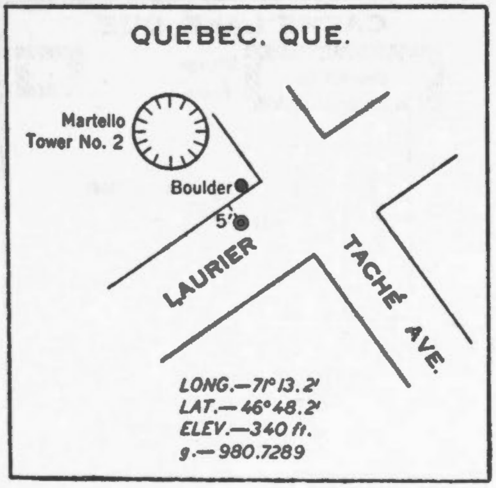

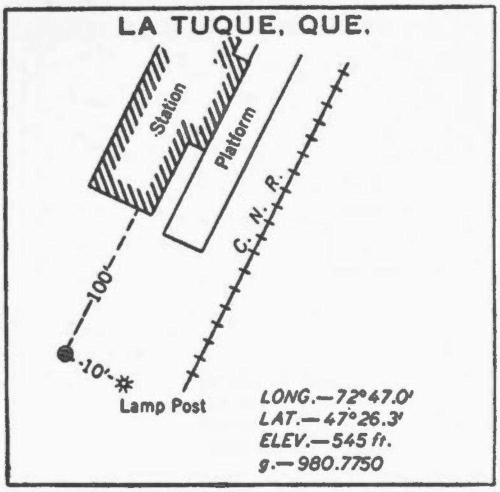

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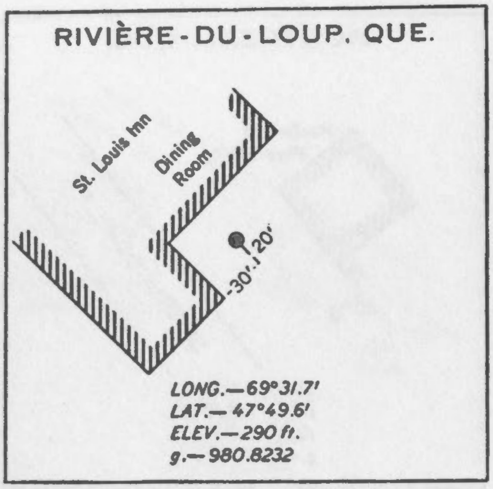

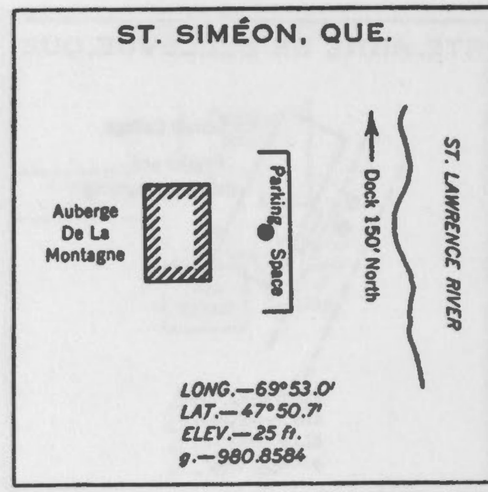

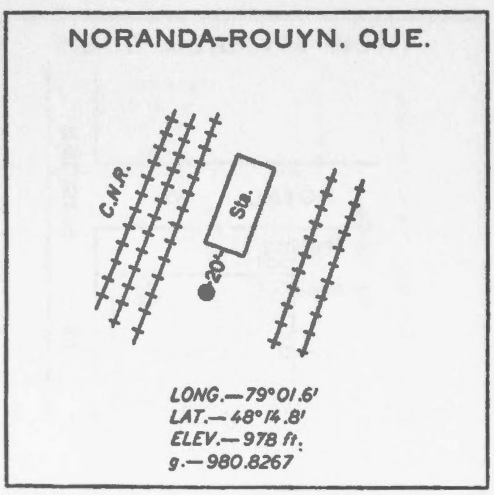

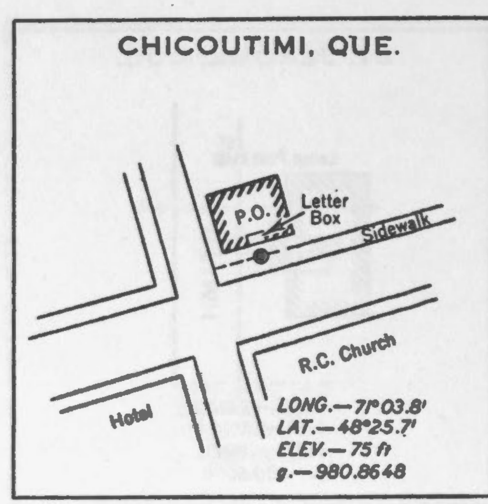

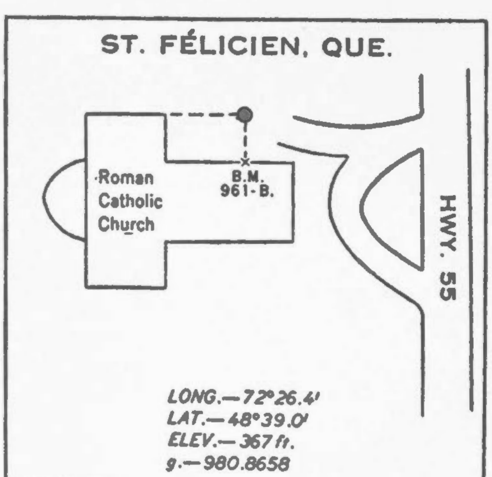

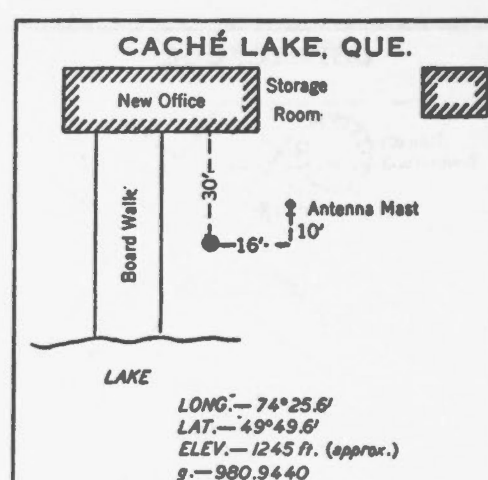

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