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Interpretations of Gravimetric and Magnetic Anomalies on Traverses in the Canadian Shield in Northern Ontario

BY

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ABSTRACT

The Bouguer anomalies obtained on gravity traverses over the Canadian Shield in northern Ontario are separated into local and regional effects. The latter are evidently too extensive to be directly attributed to surface formations, and apparently result from conditions deep within the crust. Two characteristic strike directions are exhibited by these regional trends, east-west and northeast-southwest, allowing them to be separated into two age groups. The first (east-west striking) group of structures apparently dates from early Precambrian times, as it closely parallels folding and thrust faulting in the Timiskaming sediments, while the second (northeast-southwest striking) group is believed to result from tectonic activity of Huronian age.

Interpretation of these anomalies has been based on the assumption of a layered crust, consisting of an upper, or granitic layer, underlain by a basaltic layer. It is shown that the majority of the regional anomalies cannot be explained by structures at a depth as great as the base of the basaltic layer (36 kilometers), but could be caused by irregularities in the thickness of the granitic layer. For example, a marked gravity low, indicating a thickened granitic layer, trends east-west just south of the Kirkland Lake thrust zone. It would appear that this represents the remnant of the root of an early Precambrian mountain range, as the surface rocks along the low are dominantly granite, while Precambrian sediments and volcanics are preserved north and south of the low. A second root structure is suggested along the northwest limit of the Grenville province, where a line of thrust mountains is believed to have formed during Huronian time.

In contrast to these areas of low gravity, regions of relatively high anomaly are found to be largely covered by Precambrian sediments. The implication is that these regions were low basins in Precambrian times, so that the surface rocks were preserved from the great erosion which bared such large masses of granite elsewhere.

The conclusion is, therefore, that irregularities in the granitic layer exist as a result of Precambrian mountain-building processes, and that these irregularities produce the broad, regional gravity anomalies. A departure from isostatic equilibrium is thus indicated, since the root structures have long outlived the topographic features they once supported.

The more local gravity anomalies of the Shield are found to have a direct correlation with the known surface geology. That is, small, well defined highs are observed over belts of relatively dense Keewatin lavas, with the geological contacts quite accurately demarcated by the inflection points of the gravity profiles. By comparison of the observed curves with those calculated for type bodies, an estimate may be made of the depth to the base of the Keewatin rocks. Such estimates are of interest because of the ore deposits found within the lavas. For some of the broader lava belts, depths up to ten thousand feet are indicated.

INTRODUCTION

In the study of the history and structure of the Canadian Shield, geophysical methods, such as seismology, gravity, magnetism, and radio-activity, are coming more and more into use. The present paper is an analysis of the results of several gravimeter surveys made over the Shield area of northern Ontario and northwestern Quebec during the past few years, in an attempt to correlate the gravity anomalies with major structural trends. By combining the gravity results with recent information on the crustal layers of the region (as determined seismologically) and with tectonic studies, it is believed that a much more complete picture of this very important and interesting area is possible.

While the emphasis has been on interpreting the regional gravity variations, the use of the gravimeter in the more detailed study of Precambrian surface geology has not been forgotten. Toward the end of the paper, there are some examples which indicate what information is to be obtained from traverses over comparatively local structures.

GRAVITY MEASUREMENTS IN NORTHERN ONTARIO AND QUEBEC

The area under study extends from Ottawa to the Manitoba Boundary, and north to Moosonee. However, much of this is covered only by a few reconnaissance surveys. Detailed coverage is largely limited to the North Bay-Rouyn-Timmins triangle. Measurements of gravity in the area date from the establishment several years ago of pendulum stations by the Dominion Observatory at such points as Mattawa, Sudbury, New Liskeard and Cochrane. The earliest gravimeter traverse was that from Ottawa through North Bay and Sudbury to Sault Ste. Marie, using a Humble Oil Company instrument. During the summers of 1946 and 1947, most of the remaining stations were established with an Atlas Exploration Company gravimeter. The traverse from Cochrane to Moosonee was observed in 1947, with a North American Geophysical Company instrument.

None of the traverses can be said to be "looped" in the usual sense of the word. However, many stations along the main traverses have been repeated, so that any large drift error is guarded against. Most of the shorter traverses have been tied to one or more of these repeated bases. In the future, better ties will undoubtedly be made, and many of the present values of observed gravity may have to be adjusted. However, it is very unlikely that the magnitude of such adjustments will be sufficient to affect the interpretations which follow.

Observational routine on regional surveys of this kind is necessarily different from the methods of commercial surveys, where the work is carried on in a comparatively small area. For a regional traverse, a station spacing of four to six miles is usually satisfactory, as the structures sought are several miles broad. Stations are chosen at points which are readily identifiable on topographic map sheets, and preferably at points of known elevation. If intermediate stations are required, the elevations are obtained by aneroid barometer readings, which are usually accurate within five feet. In the case of a detailed prospecting survey, the stations may be only a few hundred feet apart. Base stations may thus be repeated every few hours, allowing the instrumental drift factor to be largely eliminated. Since very small anomalies are important in such work, the station elevations are obtained to within a fraction of a foot, by running levels during the survey.

COMPUTATION OF ANOMALIES

A gravity anomaly is the difference between the observed value of the acceleration of gravity (g) and some calculated value for the same station. Various types of anomaly are thus possible, depending on the assumptions adopted in obtaining the calculated value. Throughout the discussion, use is made entirely of the Bouguer anomaly, which allows for the decrease in gravity with altitude and also for the attraction of a layer of rock of thickness equal to the elevation of the station and extending laterally theoretically to infinity, but makes no correction for isostatic compensation.

The actual method of calculation is as follows:

First, the latitude of the station is scaled from a topographic map. (In most cases, the 8-mile sheets were used, the latitude being read to 0·1 minute. The error possible is several tenths of a minute in uncertain cases). Normal gravity at sea level is assumed to vary with latitude according to the International Formula, which is:

$$\gamma_0 = 978.049\ (1+0.0052884 \sin^2\Phi - 0.0000059 \sin^2 2\Phi)\ \text{cm/sec}^2,$$

where Φ is the latitude. Thus, having found Φ as above, γ_0 may be determined. To this theoretical gravity are applied the correct factors for the height of the station above sea level, and for the attraction of the plateau between the station and sea level. Material in this infinite sheet is assumed to have a uniform density of 2·67 grams per cubic centimetre. There is thus obtained a value of computed gravity for the given station, calculated according to the stated assumptions. The difference between this value and the observed gravity gives the Bouguer anomaly.

Just as there were differences noted between the field procedures of regional and detailed gravity surveys, so do the calculation methods differ also. When small anomalies are important, corrections must be made for topography in the vicinity of the stations. This correction is usually omitted in regional surveys, partly because of a lack of contour maps in most areas, also because the correction is negligible in considering large anomalies. Also, in making the Bouguer correction, the practice in commercial surveys is to estimate as closely as possible the actual density of rock material between the station and the datum plane, rather than assuming the average value of 2·67 grams per cubic centimetre. The aim in detailed gravimetric surveys is to obtain anomalies accurate to 0·1 milligal, since an anomaly of a few tenths of a milligal may be commercially important. The anomalies quoted below are believed correct to 1 or 2 milligals, which is sufficiently close for the study of structures whose effect is measured in tens of milligals.

The choice of Bouguer, rather than isostatic, anomalies for the study of major structures may be mentioned here. It is the purpose of the present analysis to suggest structures at certain depths within the crust, as determined seismologically, which will satisfy the gravity observations, and for this purpose the Bouguer anomalies are the proper ones to use. The relationship between these structures and isostatic compensation is suggested, but it is not the purpose here to test the classical methods of isostatic reduction.

MAGNETIC MEASUREMENTS IN NORTHERN ONTARIO AND QUEBEC

In recent years, many magnetic surveys have been made in rather limited areas in the mining districts of northern Ontario and Quebec. However, little if any use has been made, to date, of these magnetic observations in studying the major structures of the Shield. During the summer of 1947, readings were taken at gravity stations along certain of the traverses across the Shield, in an attempt to find a correlation between the larger gravity and magnetic anomalies.

Magnetic observations on such a regional scale involve difficulties not met in more local surveys. The repetition of base stations, in order to correct diurnal variations, was usually not possible. Instead, the time of each observation was carefully noted, and a correction was later obtained by measuring the records of Agincourt Magnetic Observatory at these times, thus reducing all stations to a uniform datum. In spite of this, some stations may be in error by 25 gammas (possibly more) from diurnal variations alone. More serious is the effect of magnetic material in the vicinity of the stations. All locations, of course, were chosen remote from artificial influences, and as much as possible from obviously magnetic rock material. It is believed, however, that many of the stations suffer from local effects several times greater than the regional trends sought. In this respect, the airborne magnetometer would appear useful in studying large structures, as purely local effects are minimized by it. Also, the continuous profiles obtained should clearly show any gradual trends which might not be evident from a ground survey.

INTERPRETATION OF GRAVITY ANOMALIES

After the Bouguer anomalies have been computed, they are plotted in the form of profiles for each traverse. An attempt must then be made to interpret each profile, that is, to suggest a geological structure which could produce the desired effect. It is characteristic of gravity, and incidentally other force field anomalies, that no unique interpretation is possible, due to the number of unknowns and also to the uncertainty of the observed profile. Some of the unknowns that may be mentioned are the depth and form of anomalous structure, and the density contrast between the structure and surrounding rock.

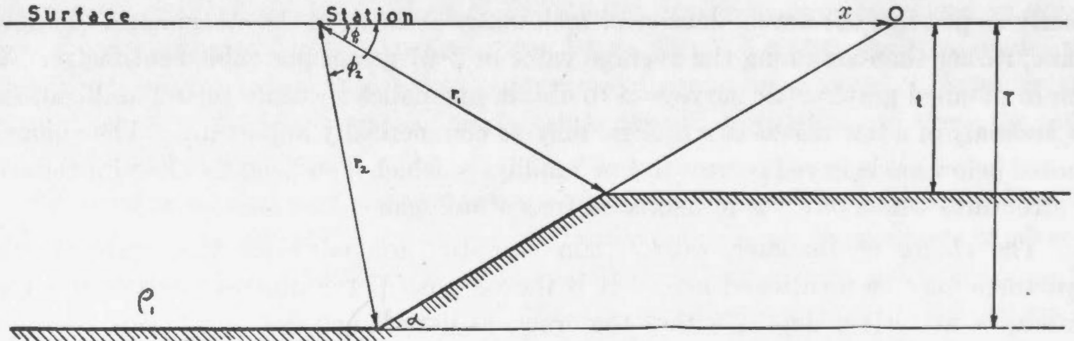


FIG. 1. Explanation of symbols used in the formula for the attraction of a step.

In order to lessen these unknown factors, certain assumptions have been made regarding the regional structures. First, the seismologists' picture of a layered crust is adopted, in which the crust proper consists of an upper or granitic layer, and an "intermediate" or basaltic layer. (The term "Intermediate" is not intended to indicate its petrographical nature). Beneath these two layers is the mantle of ultrabasic rock, extending inwards toward the core of the earth. Thicknesses of the granitic and intermediate layers have been determined in various parts of the world. Those assumed for the Canadian Shield area of Ontario are 17 kilometres for the granitic layer, and 19 kilometres for the intermediate layer, as found by Hodgson[1]. The densities of the granitic, basaltic, and ultrabasic rock types have been taken as 2·67—2·7, 2·9—3·0, and 3·2 grams per cubic centimetre respectively. The second assumption is that all of the regional gravity anomalies are produced by variations in thickness of either of the crustal layers;

[1] Hodgson, J. H.—Analysis of Travel Times from Rockbursts at Kirkland Lake, Ont., Contrib. Dom. Obs., Vol. 1, No. 1.

that is by one layer displacing the other. There is, of course, no proof of this assumption, but there are facts which make it at least reasonable. As will be shown later, there is a marked correspondence between the major anomalies and known Precambrian structural trends, suggesting that the same orogenies produced both the observed surface effects, and the hidden anomaly-producing structures. It is generally believed that the forces of such orogenies acted deep within the crust, in which case they would produce buckling and deformations of the crustal layer, hence the hypothesis that the major anomalies may be taken as expressions of irregularities along the base of either the granitic or intermediate layer. Two unknowns, depth and density contrast, are thus removed from the interpretation.

It remains to find some criterion which may be used to separate the anomalies into three classes: those which are merely the result of surface formations, those which could be produced by structures at the base of the granitic layer, and those which represent structures as deep as the base of the intermediate layer. The first type is usually recognized by its local nature, the steepness of the anomaly curve, and the immediate correlation with density distributions in the surface geology. Separation of the second and third types is more difficult, and may be ambiguous. It depends largely on the fact that a structure at a depth of 36 km. (the base of the intermediate layer) cannot produce gradients as steep as a structure at a depth of only 17 km. (the base of the granitic layer). How this can be used to separate the anomalies is indicated below. When the appropriate depth for the cause of an anomaly is determined, structures of various forms are assumed at this depth, and their effects calculated, until the best fit with the observed profile is obtained. The effect of structures of simple form may be calculated directly by formulae. One of the most useful of these is that for the attraction of a sloping step. It is:

$$\Delta g = 2G(\rho_2 - \rho_1)\ [T\Phi_2 - t\Phi_1) - x \sin\alpha \left[\sin\alpha \log_e \frac{r_2}{r_1} + \mathrm{Cos}\,\alpha\,(\Phi_2 - \Phi_1) \right]$$

where the symbols are shown in the diagram (Fig. 1). For more irregular bodies, a segment chart is employed. By placing a cross-section of the assumed body, drawn to scale, over such a chart, the anomaly for stations at any distance may be determined, and a profile drawn.

STRUCTURES AT THE BASE OF THE INTERMEDIATE LAYER

In the accompanying diagrams (Figs. 2 and 3) are shown rather highly condensed profiles, along two long traverses. One reaches from the Atlantic Coast across the Appalachians, through Ottawa to Moosonee on James Bay. The second runs westward from Winnipeg to the Rockies. There would appear to be in both these profiles very broad, gradual trends upon which the smaller (but nevertheless regional) anomalies are superimposed. In the first profile, the trend is in the form of a gradual decrease inland from the Atlantic, and also from James Bay. The second profile shows an obvious decrease west from Winnipeg. Possibly, these broad effects represent a thickening of the intermediate layer under the interior of the continent, and a further thickening under the Rocky Mountains. Certainly they appear to be of an order of magnitude broader than any of the anomalies attributed to the granitic layer, which would suggest a deeper

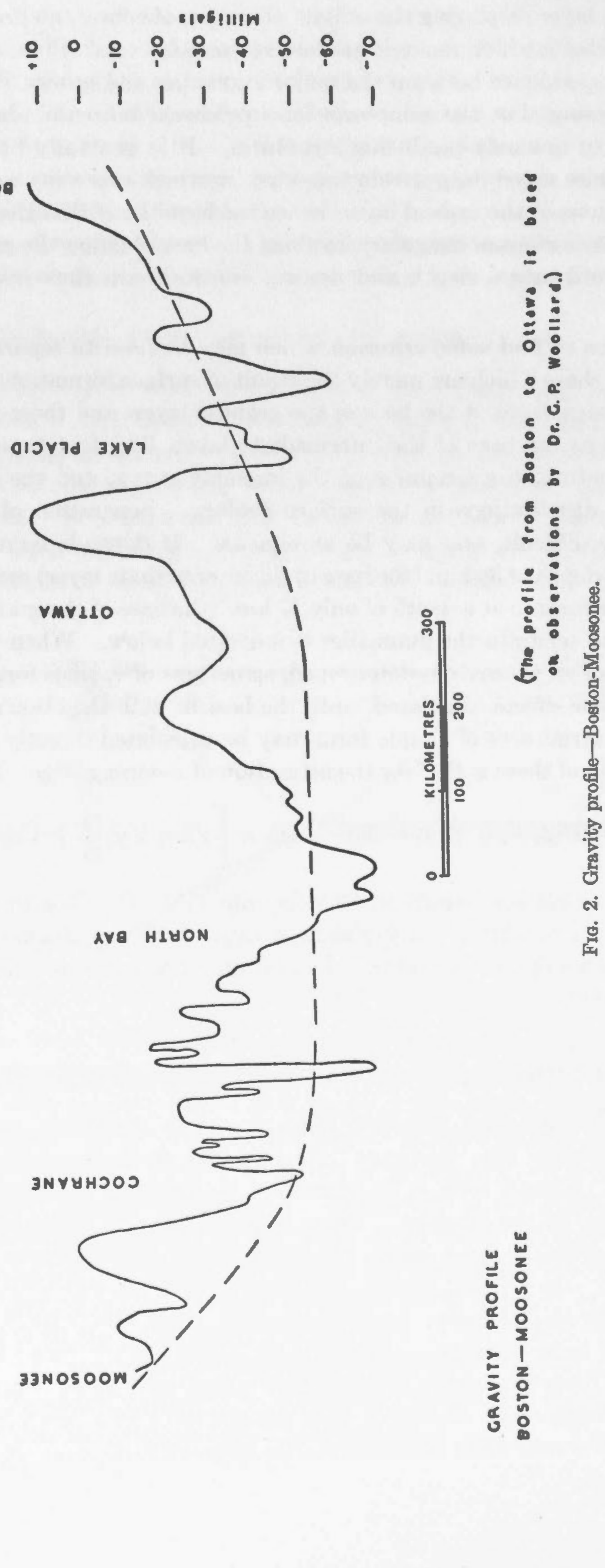


FIG. 2. Gravity profile—Boston-Moosonee.

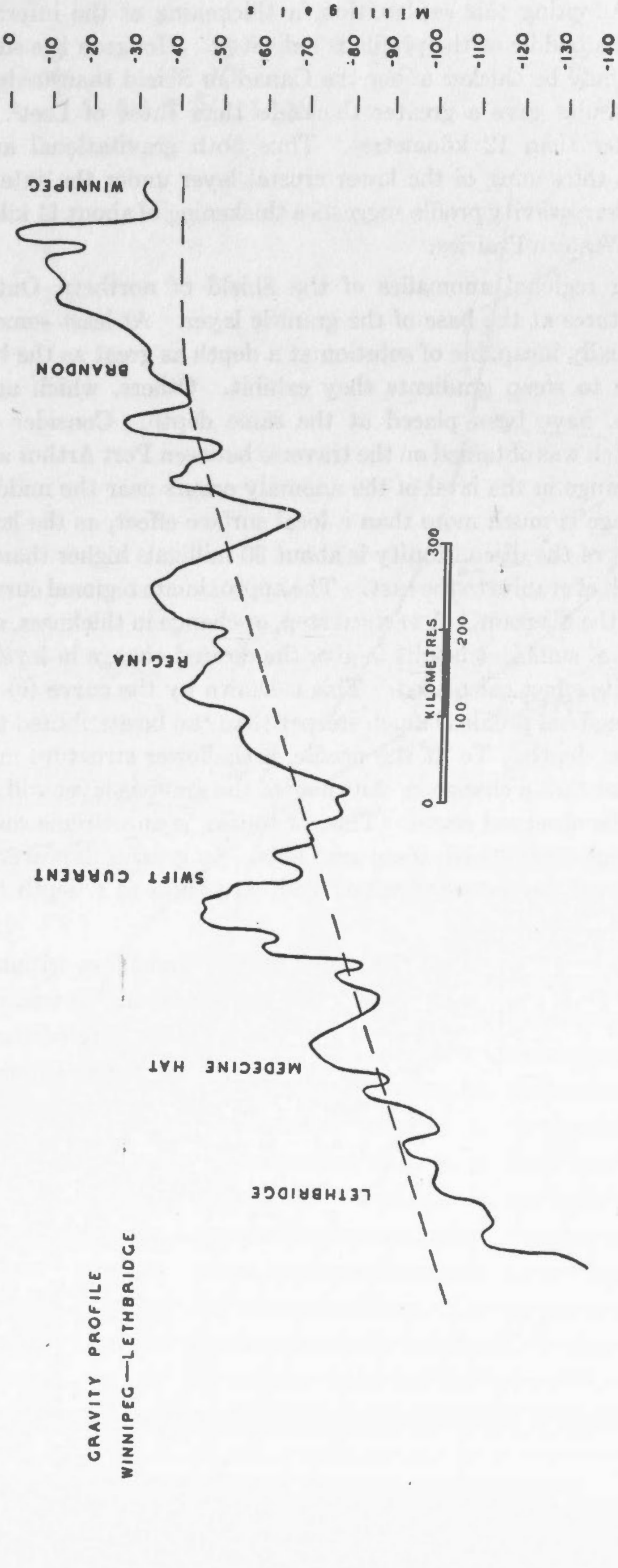


FIG. 3. Gravity profile—Winnipeg-Lethbridge.

cause for them. Adopting this explanation, a thickening of the intermediate layer of about 5 km. near the middle of the profile is indicated. Hodgson has suggested that the intermediate layer may be thicker under the Canadian Shield than under New England, as certain of his results gave a greater thickness than those of Leet[2]. The difference amounted to greater than 12 kilometres. Thus both gravitational and seismological methods indicate a thickening of the lower crustal layer under the interior of northern Ontario. The western gravity profile suggests a thickening of about 11 kilometres between Manitoba and the Western Prairies.

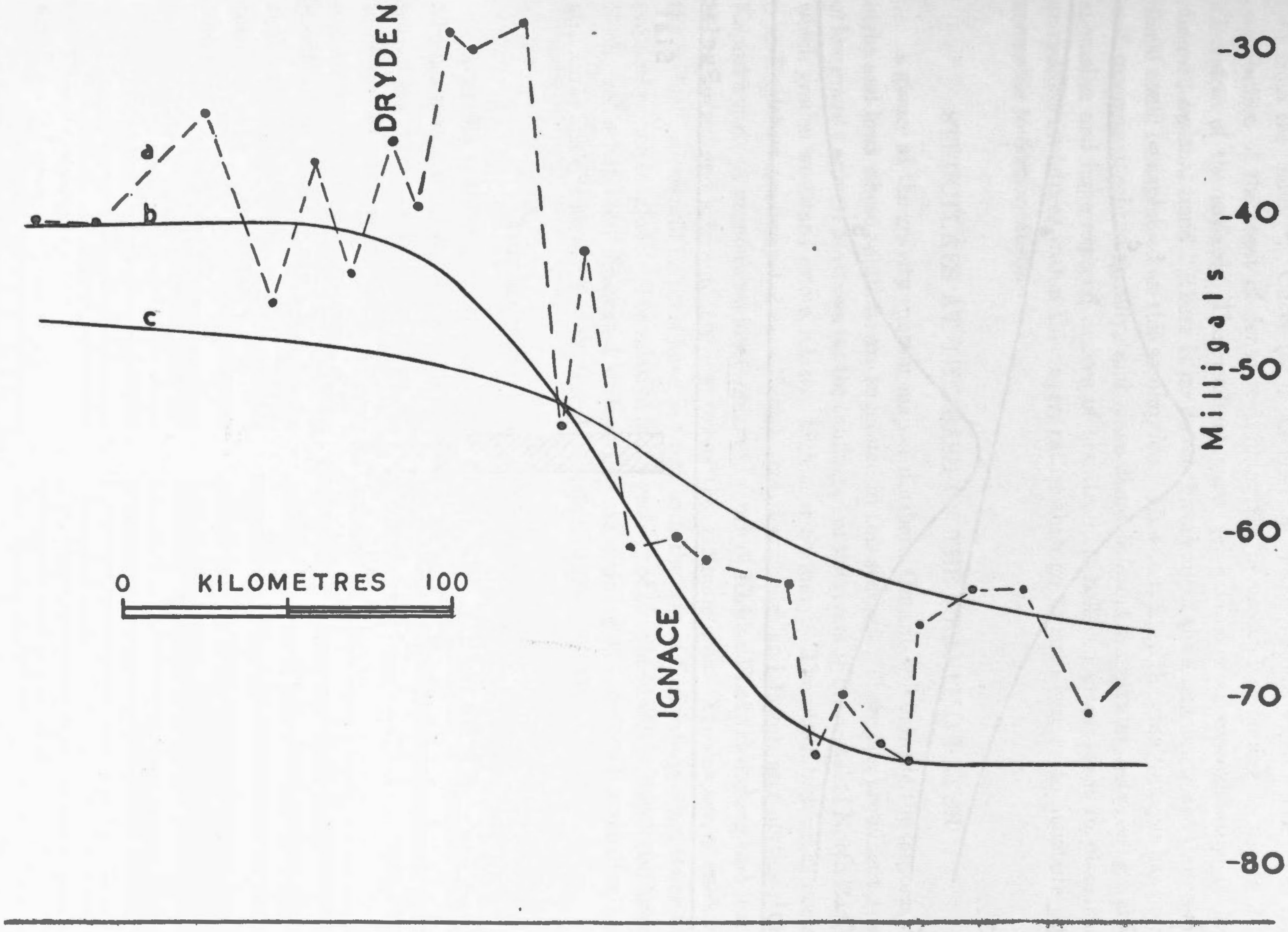
The remaining regional anomalies of the Shield of northern Ontario have been attributed to structures at the base of the granitic layer. At least some of these can be shown to be practically incapable of solution at a depth as great as the base of the intermediate layer, due to steep gradients they exhibit. Others, which appear to form a pattern with these, have been placed at the same depth. Consider first the profile shown in Fig. 4, which was obtained on the traverse between Port Arthur and Dryden, Ont. A rather abrupt change in the level of the anomaly occurs near the middle of the profile. Obviously the change is much more than a local surface effect, as the level over a broad area of granite west of the discontinuity is about 30 milligals higher than the level over a similar broad stretch of granite to the east. The approximate regional curve is indicated by the solid line (b) in the diagram. A vertical step, or change in thickness, at the base of the intermediate layer, of sufficient height to give the desired change in level of the anomaly was assumed, and its effect calculated. This is shown by the curve (c). It is apparent that the observed regional profile is much steeper than can be attributed to even a vertical step at such a great depth. To fit the profile, a shallower structure must be assumed. It will be shown later that a change in thickness of the granitic layer will give a very close approximation to the observed curve. This, of course, is an extreme case; not all of the anomalies of this type exhibit such steep gradients. In general, however, closer approximation to the observed curves are obtained with structures at a depth of 17 kilometres, rather than 36 kilometres.

The conclusion reached is that the major gravity anomalies within the area under study are best explained by structures within the granitic layer. It would appear that the effects of variation in thickness of the intermediate layer are only noticeable in traverses covering a significant portion of the continent. In the latter case, a very gentle decrease in gravity is noted as one proceeds inland from the Atlantic, or from James Bay, or toward the western mountains. A thickening of the intermediate layer under the interior of the continent is offered as an explanation of these trends.

In this connection, the work of Schwinner[3] in the Alps may well be mentioned here. Schwinner attempted to explain certain major Bouguer anomalies on the basis of variations in crustal thickness, adopting an average thickness of 50 kilometres. He met precisely the situation outlined above, in that the observed profiles had gradients which could not be approximated by any structure at such a great depth. Instead of attempting a solution at a lesser depth, he pictured the situation illustrated in Fig. 5. Immediately above the

[2] Leet, L. D.,—Trial Travel Times for Northeastern America, Bull. Seis. Soc. Am., Vol. 31, pp. 325-334, 1941.

[3] Schwinner, R.,—"Geophysikalische Zussamenhänge Zwischen Ostalpen und Bomischen Masse"—Beiträge zur Geophysik, Vol. 23, 1929.



(a) Observed Profile.
(b) Suggested Regional Curve.
(c) Effect of a vertical step of 5 km. at a depth of 40 km.

FIG. 4. Gravity profile—Ignace-Dryden.

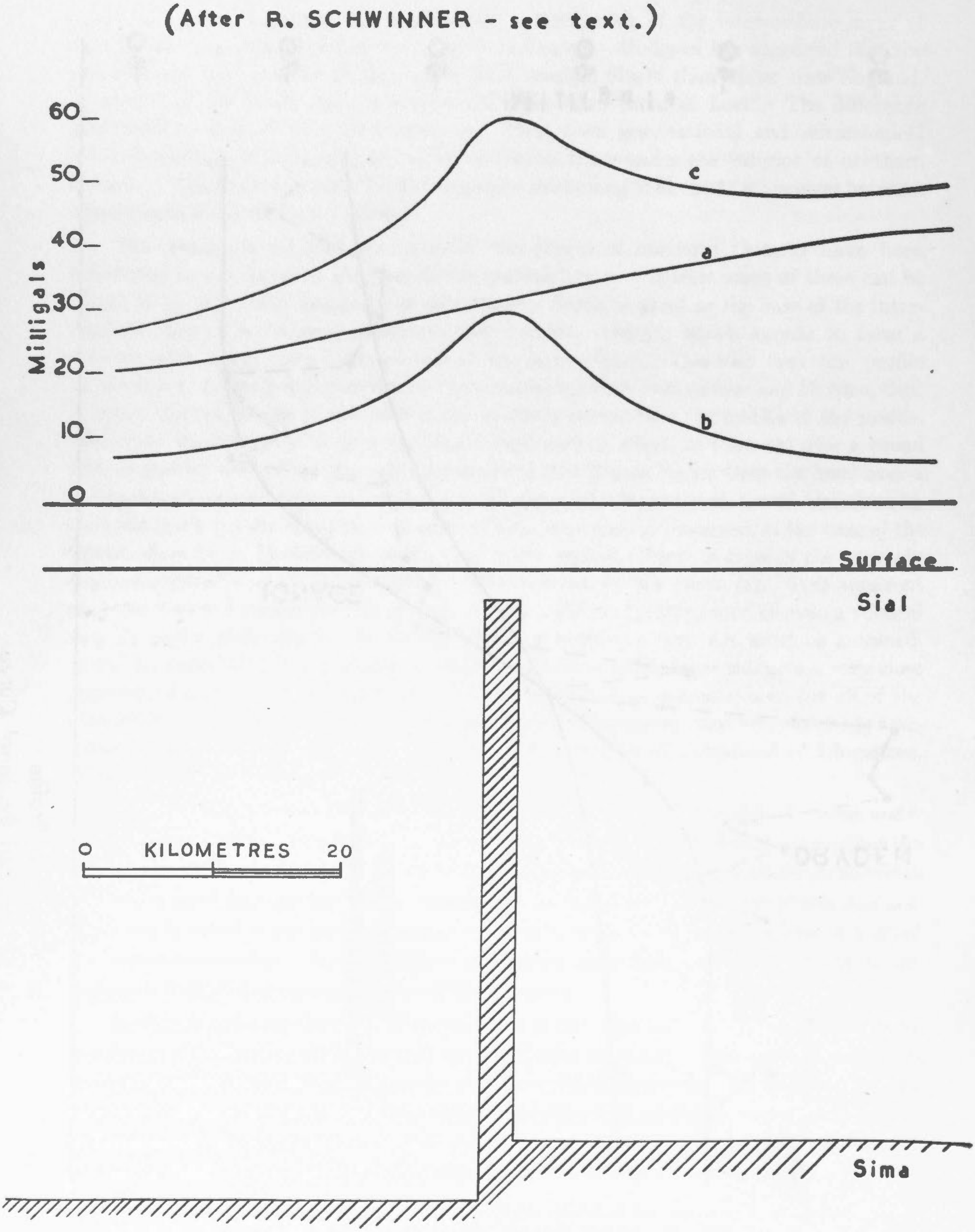


Fig. 5. Profiles related to Sial and Sima after Schwinner.

step-like thickening of the "sial"* a great fissure has formed, and become filled with basic rock from the "sima"*. Curve (*a*) is the effect of the step alone, while curve (*b*) is the contribution of the sheet of dense rock filling the fissure and extending to within 2·5 kilometres of the surface. The resultant curve (*c*) gave a good approximation to his observed regional trend. There is no doubt that many of the anomalies of the Canadian Shield could be explained on this assumption. However, since the granitic layer has been well recognized seismologically, and since there is some correlation between gravity anomalies and large exposed masses of granite, it is believed more direct to place the anomalous structures within this layer, rather than go to such lengths to attribute the anomalies to deeper causes.

STRUCTURES AT THE BASE OF THE GRANITIC LAYER

A glance at the gravity contour map of northern Ontario will indicate the important highs and lows whose solutions are suggested in this section. There is a prominent area of low gravity around Mattawa (at the confluence of the rivers 35 miles east of North Bay), which grades westward into a relative high near Sudbury. The other high areas occur near Englehart (midway between New Liskeard and Kirkland Lake), and northeast of Kapuskasing. A pronounced low is observed south of Kirkland Lake stretching east from Matachewan, and a less intense low covers the Timmins area. Profiles across each of the major features will be considered in turn, with the aim of first interpreting them on physical principles alone. The relation to the geology of the Shield will be developed later. Each profile has been illustrated with a diagram showing the observed anomalies, the structures finally adopted, and the calculated effect of the structure.

The Mattawa Low and the Sudbury High

A profile running generally east-west from near Chalk River to Thessalon (about 30 miles west of Blind River)† crosses both the low near Mattawa, the Sudbury high, and a second low west of this high, as shown in Fig. 6. The regional curve is apparently the resultant effect of a central anticlinal thinning of the granitic layer with synclinal thickening, both east and west. Thus, the Mattawa low can be explained by a thickening of about 4 km. along a strip 90 kilometres wide. As indicated by the contour map, the strike of the structure is Northeast to Southwest. The central anticline indicates that the granitic layer is about 2·5 km. thinner than normal under the Sudbury district, while west of this, in the Blind River area, there is a second thickening.

* These terms are used by Schwinner, who apparently considered the sial to include the complete crust. They have been avoided elsewhere in this paper in favor of the more modern layer terminology.

† With the exception of those between Cochrane and Moosonee all stations referred to in this publication are located on provincial highways. In cases where there may appear to be some doubt regarding the location of a station it is suggested that the reader consult the Map Indicating Main Automobile Roads Between United States and Canada published by the Canadian Government Travel Bureau of the Department of Trade and Commerce or the official road maps of the Provinces of Ontario and Quebec. The geology of the region is covered by the Lake Huron, Lake Nipigon, and Kenora sheets on a scale of eight miles to an inch and by other maps of the Geological Survey mentioned in the text. It is suggested that these may be consulted with advantage by the reader in perusal of the paper.

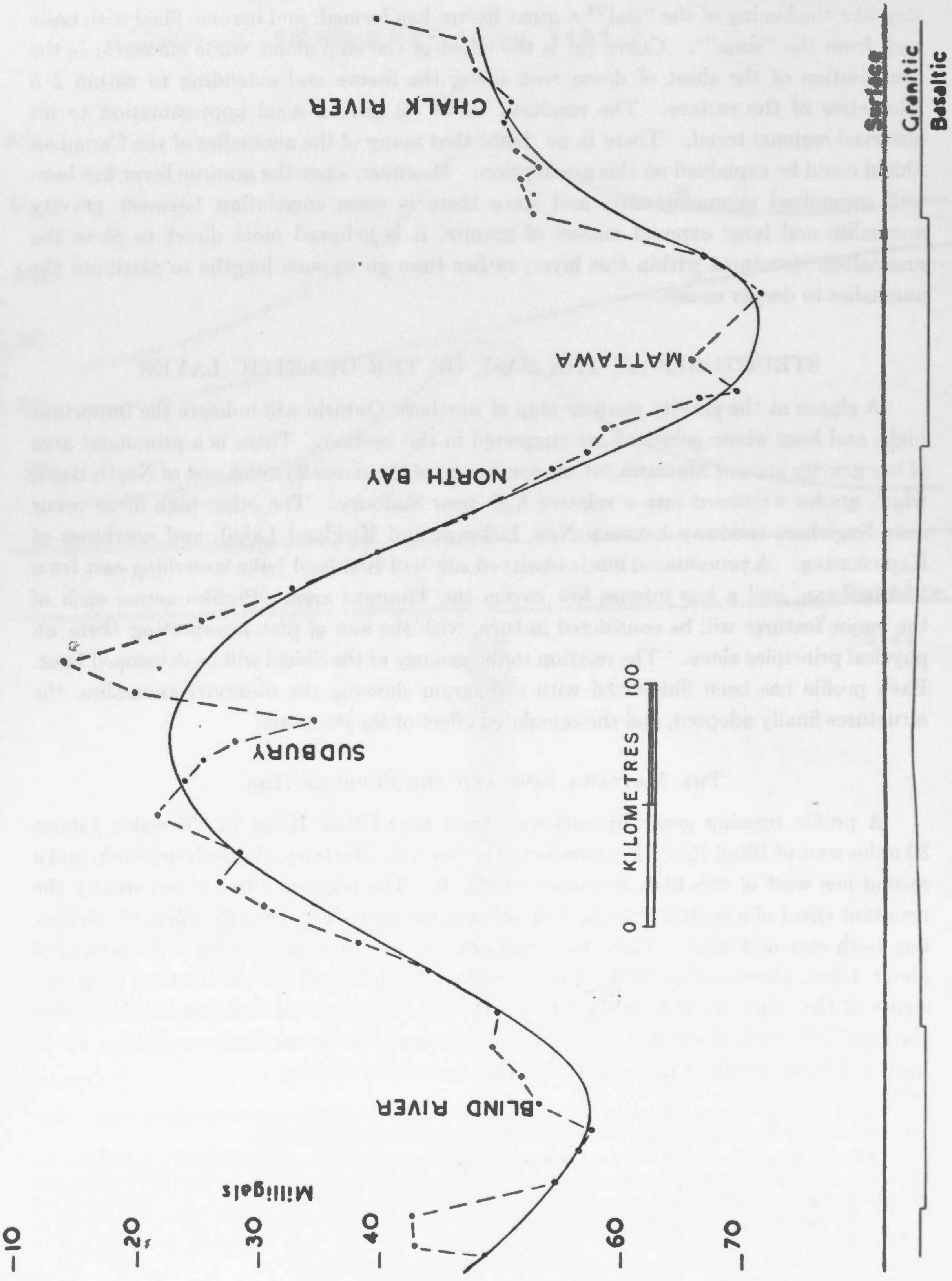


FIG. 6. Mattawa-Sudbury profile.

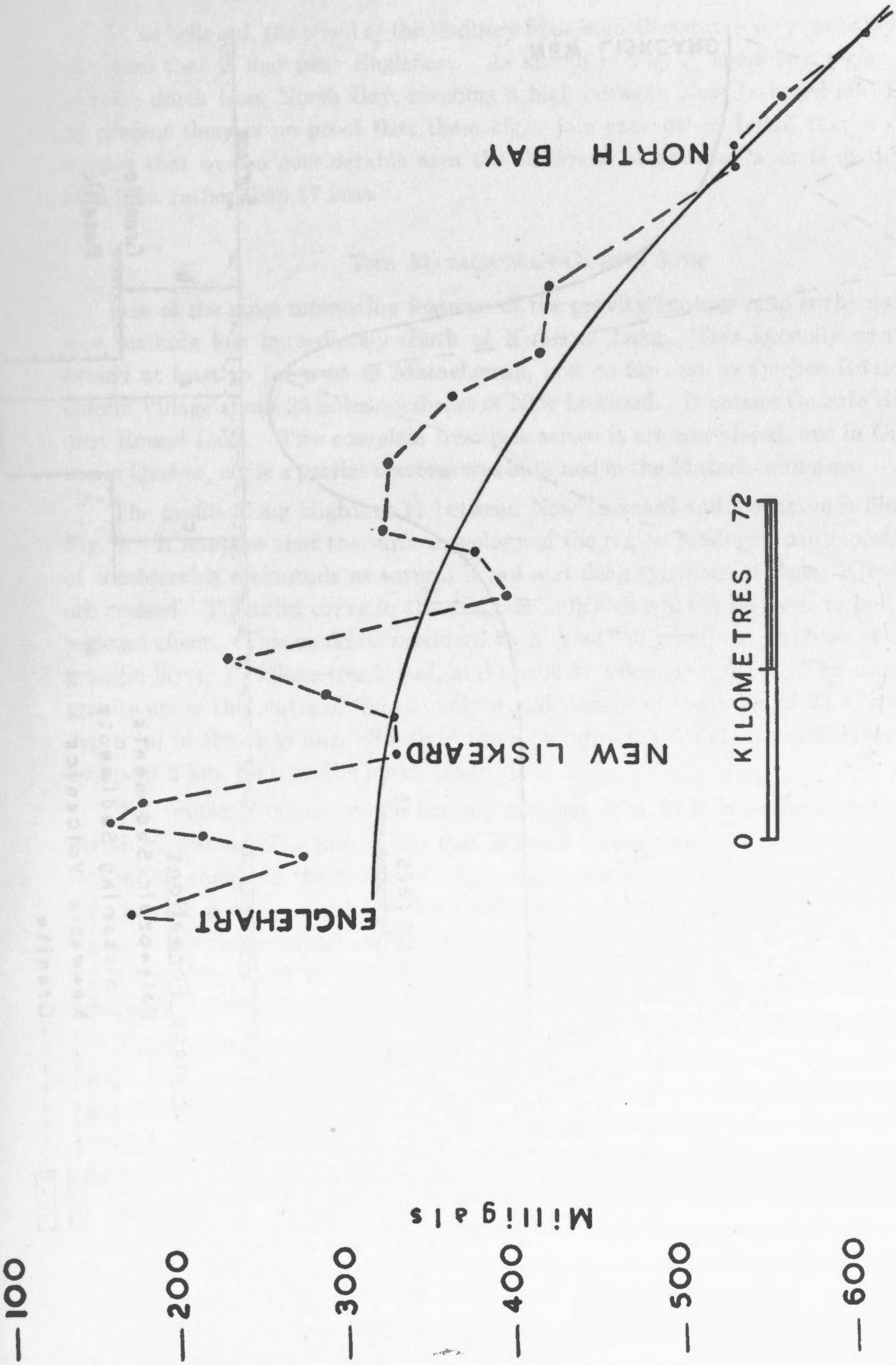


FIG. 7. North Bay-New Liskeard profile.

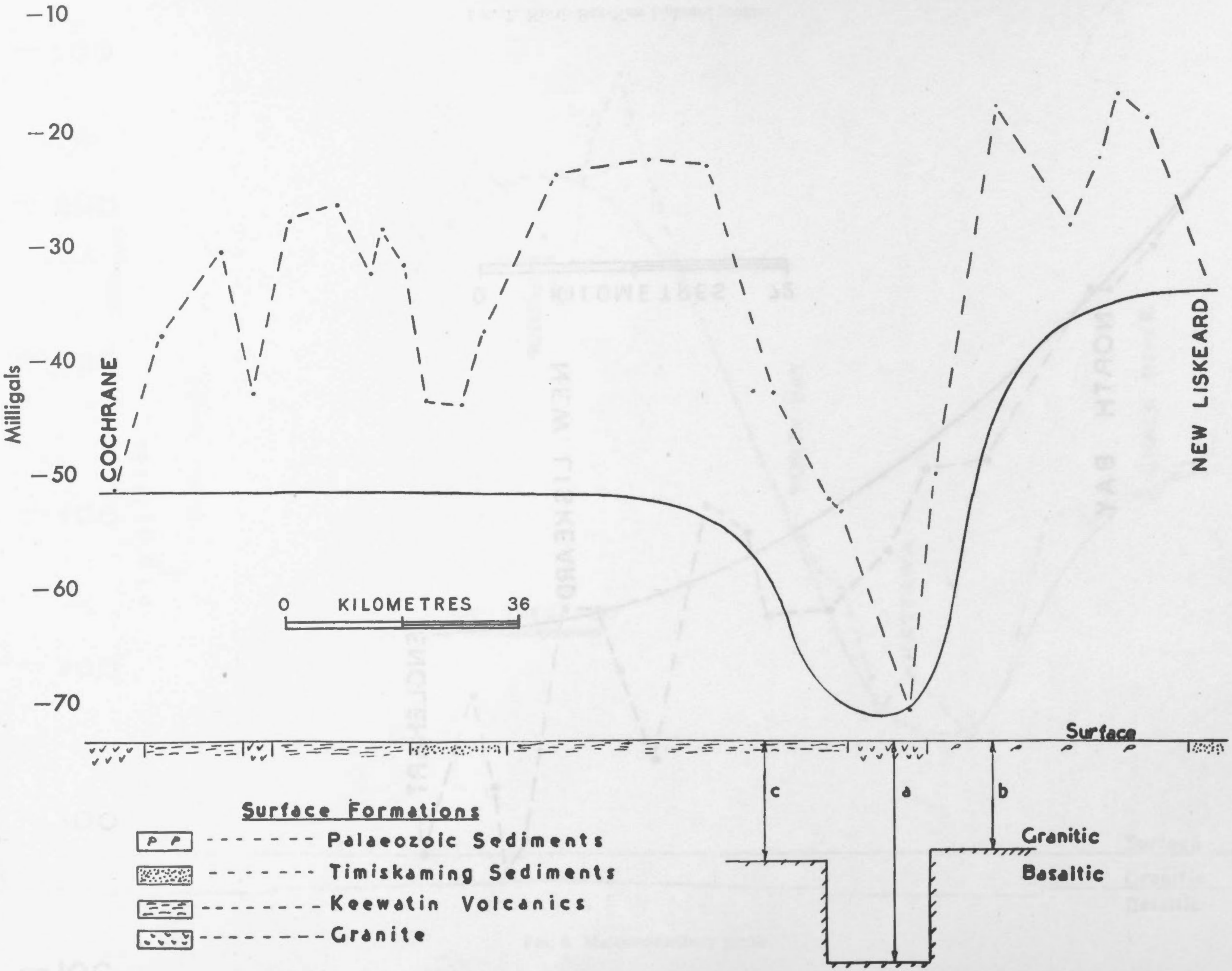


Fig. 8. New Liskeard-Cochrane profile.

If, as believed, the trend of the Sudbury high is northeast it is very probably the same structure that is met near Englehart. As shown in Fig. 7, there is a regional gravity increase north from North Bay, reaching a high between New Liskeard and Englehart. At present there is no proof that these highs join each other, but if they do, it would suggest that over a considerable area the thickness of granitic layer is of the order of 14·5 kms. rather than 17 kms.

The Matachewan-Guerin Low

One of the most interesting features of the gravity contour map is the narrow east-west striking low immediately south of Kirkland Lake. This anomaly was found to extend at least as far west as Matachewan, and as far east as Quebec Route 46, near Guerin Village about 25 miles northeast of New Liskeard. It crosses Ontario Highway 11 near Round Lake. Two complete traverses across it are considered, one in Ontario and one in Quebec, while a partial traverse was obtained in the Matachewan area.

The profile along Highway 11 between New Liskeard and Cochrane is illustrated in Fig. 8. It happens that the surface geology of the region produces many local anomalies of considerable magnitude as several broad and deep synclines of dense Keewatin lavas are crossed. The solid curve in the diagram indicates what is believed to be the normal regional effect. This could be produced by a "root" of granite at the base of the normal granitic layer, 16 kilometres broad, and about 16 kilometres deep. The total depth of granite under the centre of the anomaly would thus be of the order of 33 kilometres (the depth (a) in the diagram). South of the structure (at (b)) the granitic layer is thinner by about 2 km. than on the north (at (c)).

The profile obtained on the easterly traverse (Fig. 9) is in marked contrast to that described above. The low in this case is much broader and shallower, indicating a corresponding change in the structure. Once again, certain surface effects must be smoothed out, leaving a curve which can be attributed to a synclinal thickening of the granitic layer, 48 kilometres broad and about 8·5 kilometres deep. The depth of granite rock at (*a*) is therefore about 25·5 kilometres (as compared to 33 kilometres to the west). The granitic layer immediately south of the structure (*b*) is thinner than it is on the north (*c*).

Unfortunately a complete profile across the low was not obtained in the Matachewan area. However, the profile from Elk Lake to Matachewan (Fig. 10) would suggest a structure as deep, and as steepsided, at least on the south side, as that met on the central traverse. In fact, the greatest negative Bouguer anomaly of the entire region is that at Matachewan townsite.

The Matachewan-Guerin low is thus conceived as representing a relatively narrow, east-west striking thickening of the granitic layer. A strike length of at least seventy miles is suggested, but the structure varies in character along its length, apparently becoming deeper and narrower toward the west.

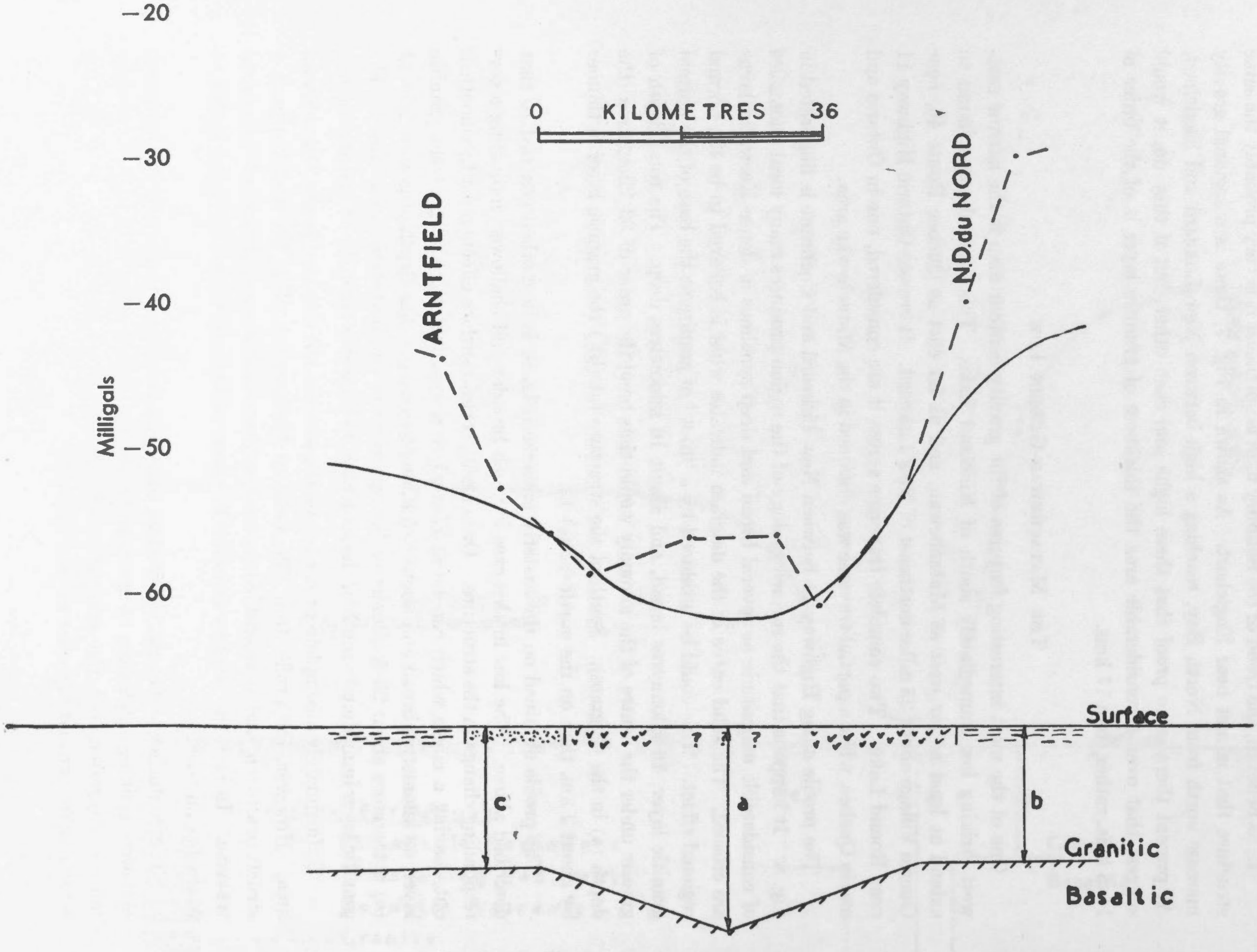


FIG. 9. Notre Dame du Nord-Arntfield profile.

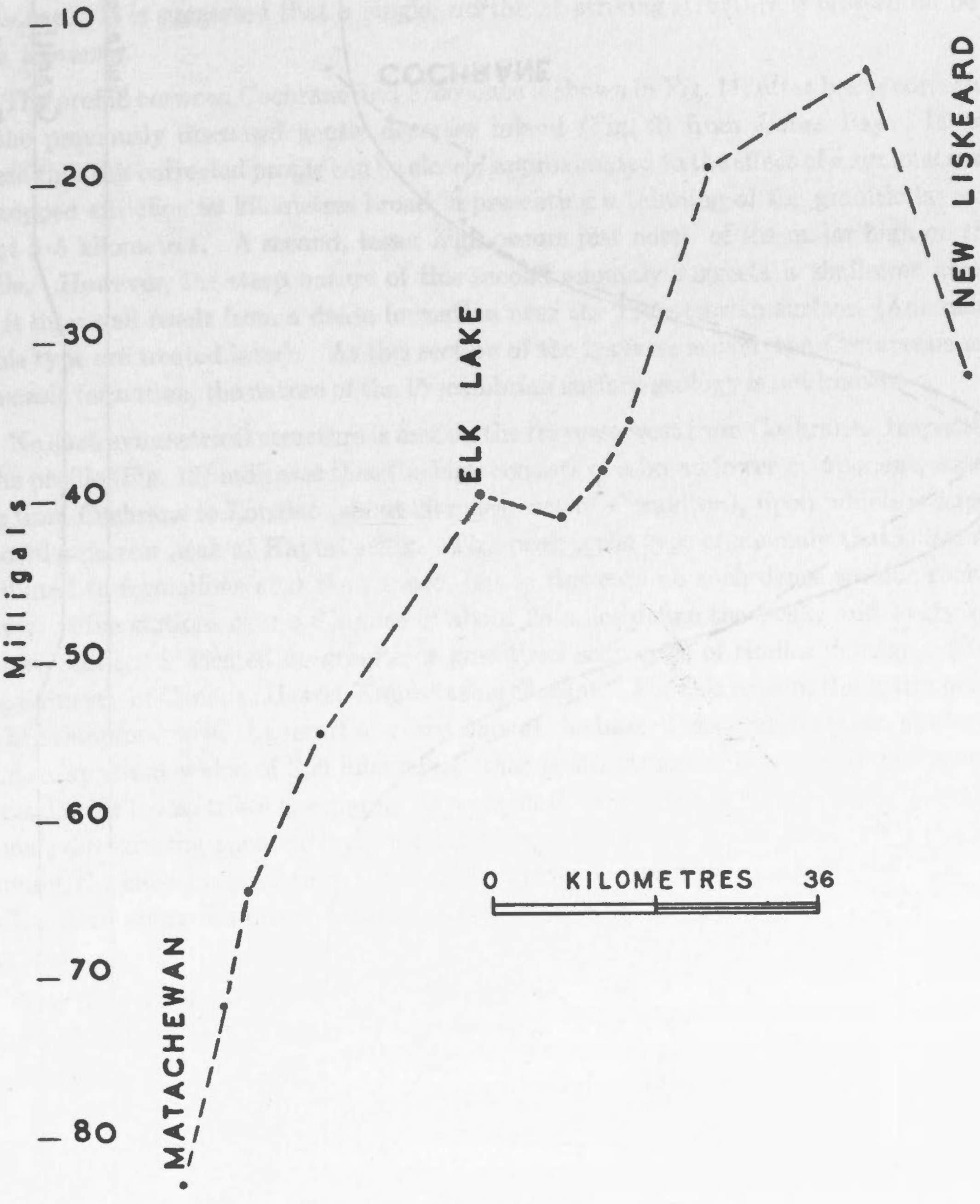


Fig. 10. New Liskeard-Matachewan profile.

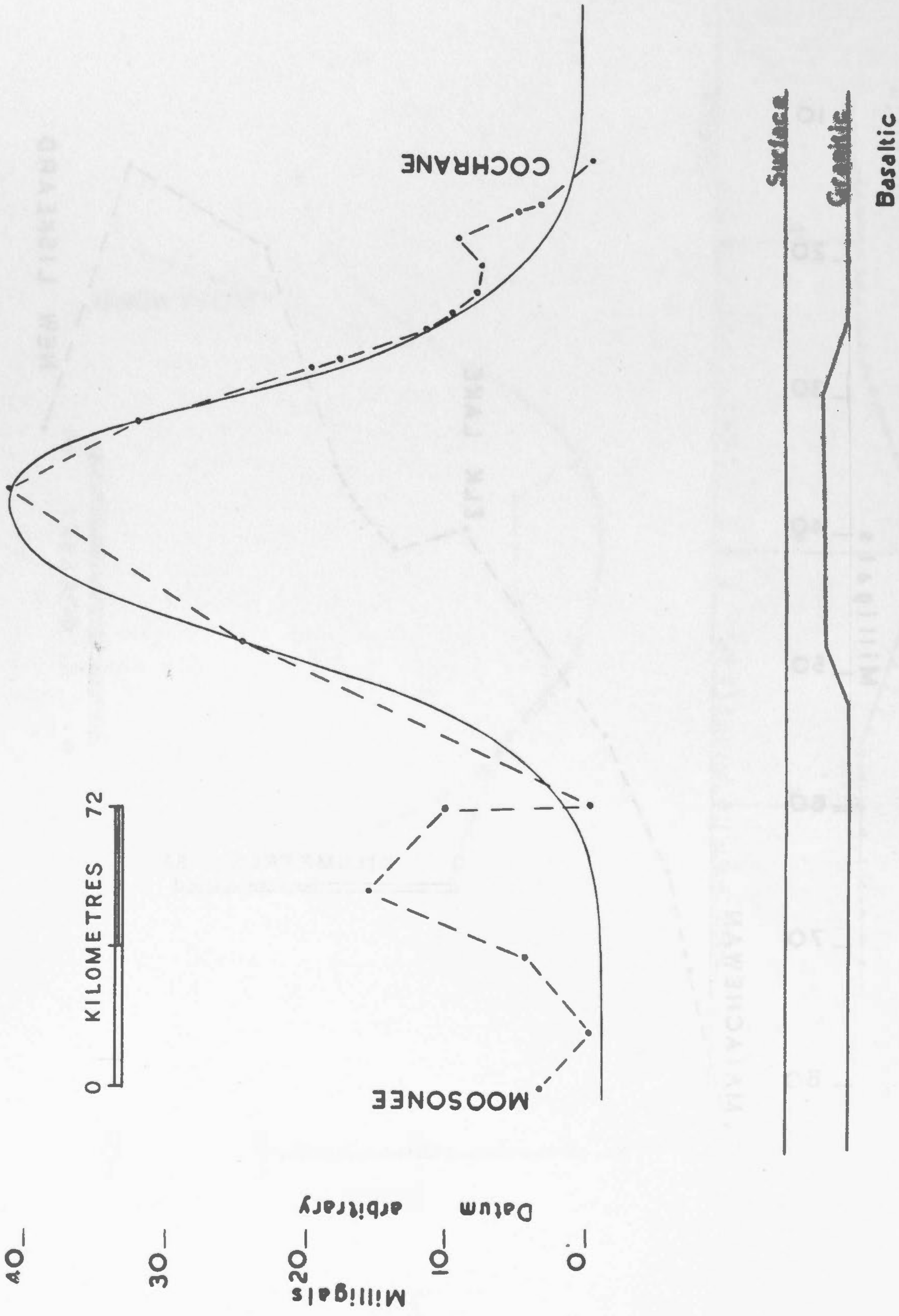


Fig. 11. Cochrane-Moosonee profile.

The Kapuskasing-Fraserdale High

The location and general trend of this feature are indicated by the anomaly map. On the profile west from Cochrane, the peak of the high was found to be near Kapuskasing. Subsequently, a similar maximum was observed at Fraserdale, between Cochrane and Moosonee. It is suggested that a single, northeast striking structure is crossed on both these traverses.

The profile between Cochrane and Moosonee is shown in Fig. 11, after being corrected for the previously discussed gentle decrease inland (Fig. 2) from James Bay. It will be seen that this corrected profile can be closely approximated to the effect of a symmetrical, flat-topped anticline 80 kilometres broad, representing a thinning of the granitic layer of about 5·5 kilometres. A second, lesser high occurs just north of the major high on this profile. However, the steep nature of this second anomaly suggests a shallower cause, and it may well result from a dense formation near the Precambrian surface. (Anomalies of this type are treated later). As this section of the traverse is over the Cretaceous and Palæozoic formation, the nature of the Precambrian surface geology is not known.

No such symmetrical structure is met on the traverse west from Cochrane. Inspection of the profile (Fig. 12) indicates that the high consists of a broad lower component, extending from Cochrane to Longlac (about 20 miles east of Geraldton), upon which is superimposed a narrow peak at Kapuskasing. This peak is the type of anomaly that is usually attributed to formations near the surface, but in this case no such dense surface rock is known. Five stations over a distance of about 25 miles define the peak, and every one of these stations is located on granite or granitized sediments of similar density. (Geological Survey of Canada: Hearst-Kapuskasing Sheets). For this reason, the entire profile has been assumed to be the result of a structure at the base of the granitic layer, as shown. Over an apparent width of 350 kilometres (that is the structure is probably not crossed perpendicular to its strike) the granitic layer is on the average 2·5 kilometres thinner than normal, the thinning apparently decreasing toward the west. In addition to this general thinning, the basic material from the basaltic layer is assumed to have risen an additional 8 kilometres along a narrow fissure near Kapuskasing, producing the gravity high in that area.

The Kapuskasing-Fraserdale high may, therefore, be taken as indicating a northeast trending band of thinned granitic layer. Like others of the major structures suggested, it must be assumed to change in character along its length.

The Port Arthur Low

What is termed the Port Arthur low is a large area, as yet not completely defined, of low Bouguer anomaly near the head of Lake Superior. Along the Trans-Canada Highway, the low is first met west of Nipigon, where the anomaly decreases rapidly. The general level remains low as far west as Ignace, until it rises again in two abrupt

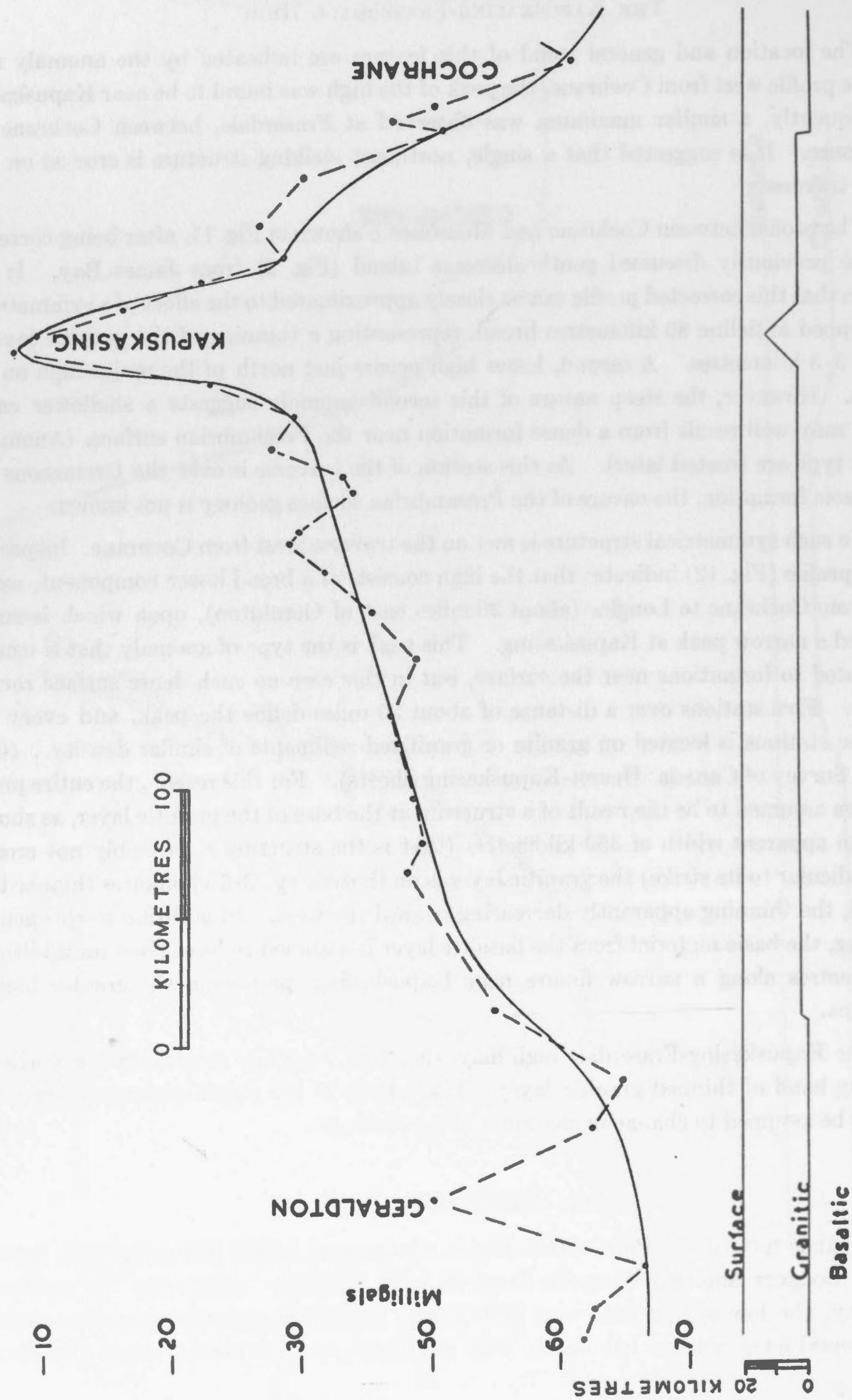


FIG. 12. Cochrane-Geraldton profile.

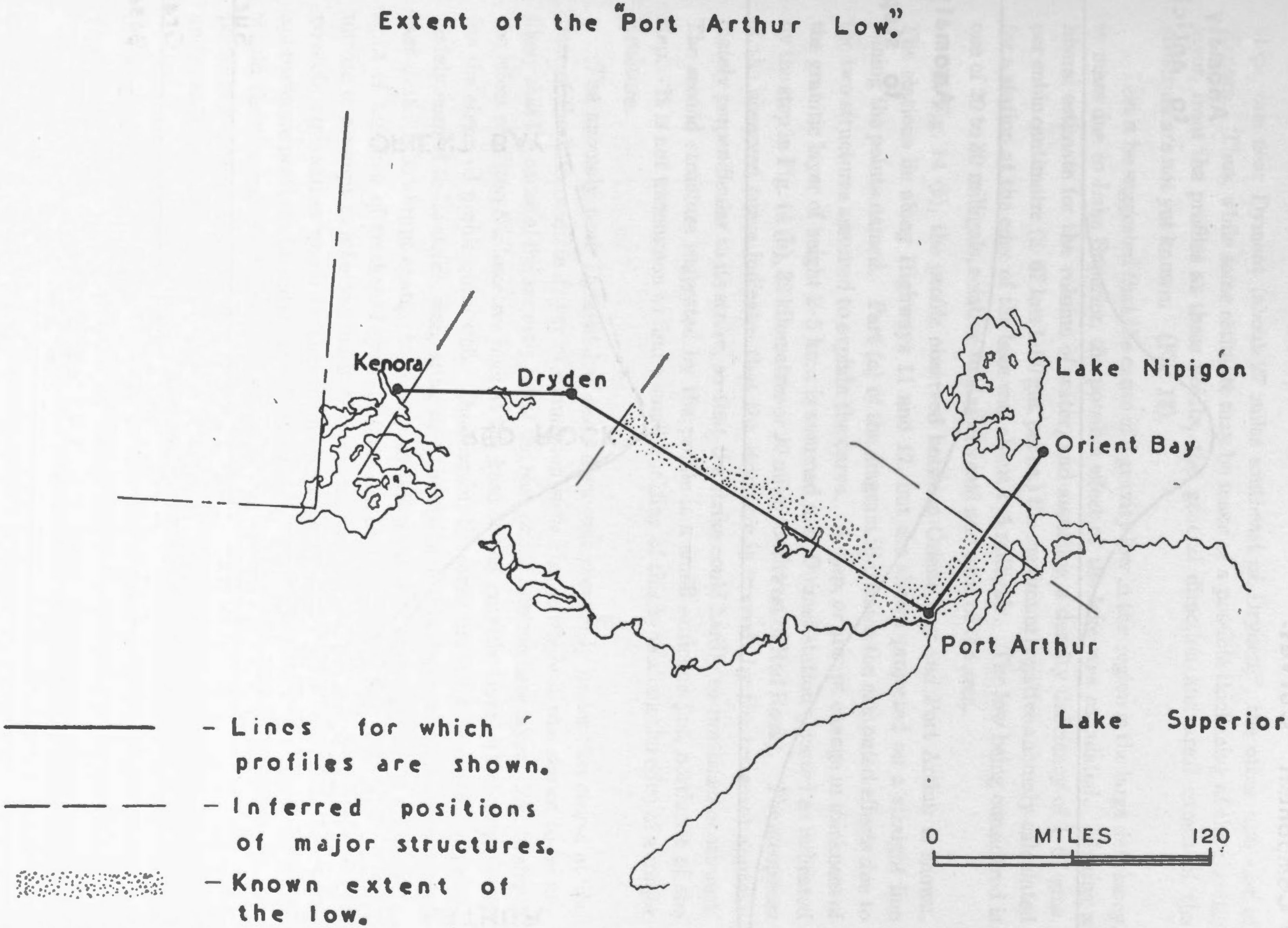


FIG. 13. Sketch showing extent of "Port Arthur low".

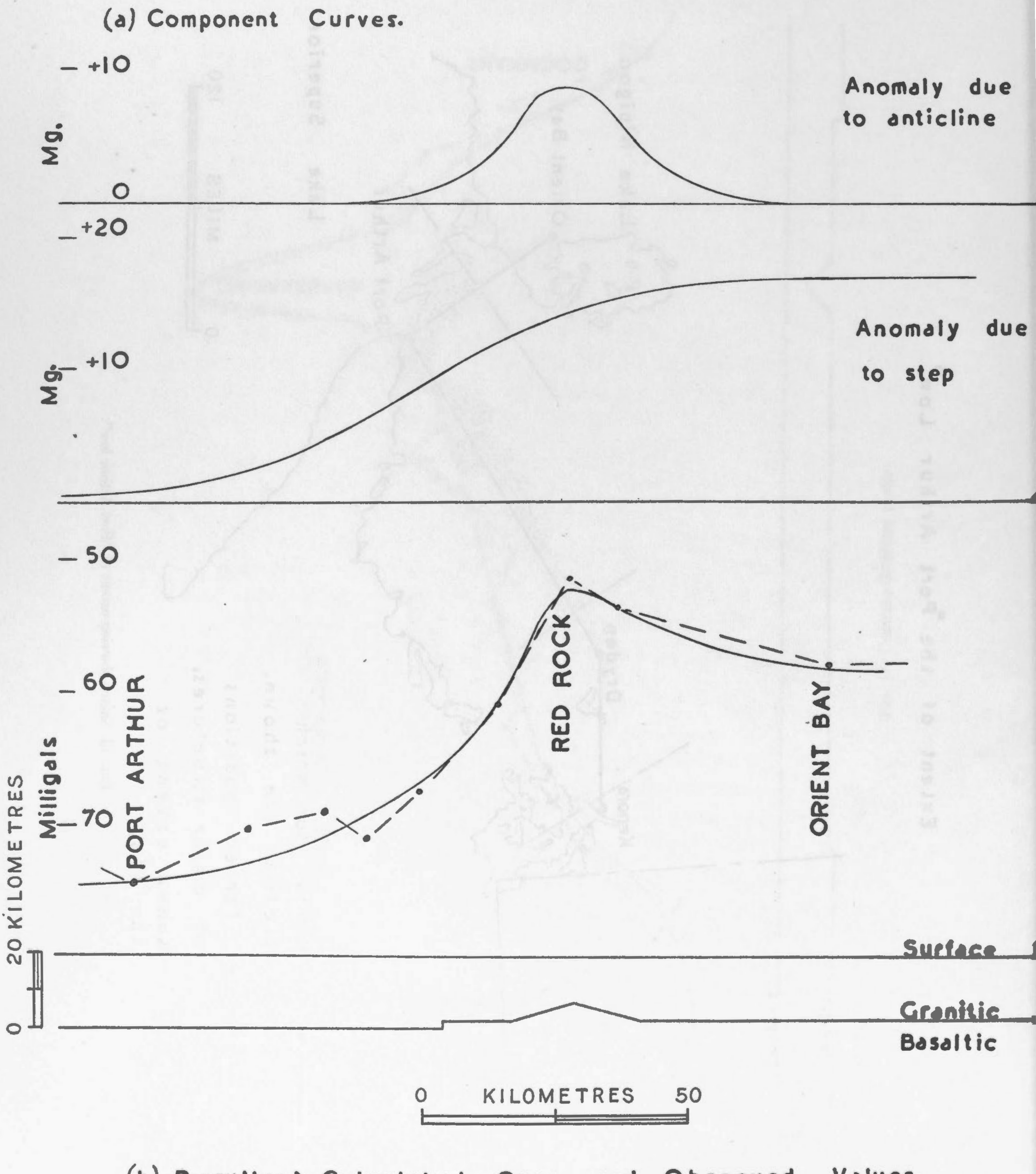


FIG. 14. Calculated and observed profiles—Orient Bay-Port Arthur.

steps, one near Dyment (about 27 miles southeast of Dryden)*, the other just east of Kenora. Thus, while some estimate may be made of a possible thickening of the granitic layer, from the profiles at these points, the general direction and areal extent of the structure are not yet known. (Fig. 13).

Lest it be suggested that the cause of a gravity low in this region is the large deficiency in mass due to Lake Superior, the possible effect of the lake was calculated. Making a liberal estimate for the volume of water, and assuming a density deficiency of 1·67 gms. per cubic centimetre (2·67 less 1·00 gm. per cc.) the maximum negative anomaly calculated for a station at the edge of the lake was about 1·5 milligals. The low being considered is one of 20 to 30 milligals, relative to stations east and west of the area.

In Fig. 14 (*b*), the profile observed between Orient Bay and Port Arthur is shown. The stations lie along Highways 11 and 17, but are shown projected on a straight line joining the points named. Part (*a*) of the diagram illustrates the computed effects due to the two structures assumed to explain the curve. A step, or abrupt change in thickness of the granitic layer of height 2·5 km., is assumed near Ouimet station (located as indicated by the step in Fig. 14 (b), 32 kilometres or 20 miles southwest of Red Rock). The steepness of the observed curve indicates that the structure is crossed (by the traverse) approximately perpendicular to its strike, so that the strike could hardly be northeast-southwest. The second structure suggested by the profile is a small anticline just northeast of the step. It is not uncommon to find a small buckling of this type along the edge of a major structure.

The anomaly near Dyment has been discussed previously under Structures at the Base of the Intermediate Layer in connection with Fig. 4, where it was shown to be unlikely that the cause of the anomaly lay at the base of the intermediate layer. Fig. 15 shows the effect of a step 5 kilometres high at the base of the granitic layer, which apparently fits the observed profile quite well. Once again, the structure must be crossed approximately normal to its strike, suggesting that the strike of this step is more northeast than east-west. The abrupt change in gravity at this point thus represents the northwesterly limit of the area of thickened granitic layer about Port Arthur. While it is probably unwise to attempt to infer the limits of this area from the results of only two traverses, a possible explanation would be that a line between Dyment and Ouimet represents the approximate northern boundary of the thickened region. The general strike of the region would then be east-west (but because of irregularities, the northern boundary may in places run northeast, as at Dyment), and the southern boundary of the region, as yet undetected, may lie somewhere south of Port Arthur.

The second change in level of the anomaly, near Kenora, represents a further thinning of the granitic layer. A step about 1·8 kilometres high gives the curve shown (Fig. 16). Presumably the granitic layer remains thinner than normal westward into Manitoba.

* The gravity observation was taken on the highway at the intersection in the little settlement about 2 miles south of Dyment railway station. On the provincial highway map, the settlement is designated by the name Borups Corners and by Dyment on the Travel Bureau maps. It probably should be Borup Corners as marked on the road signs, after Mr. Andrew Borup, the first settler, who came there in 1917.

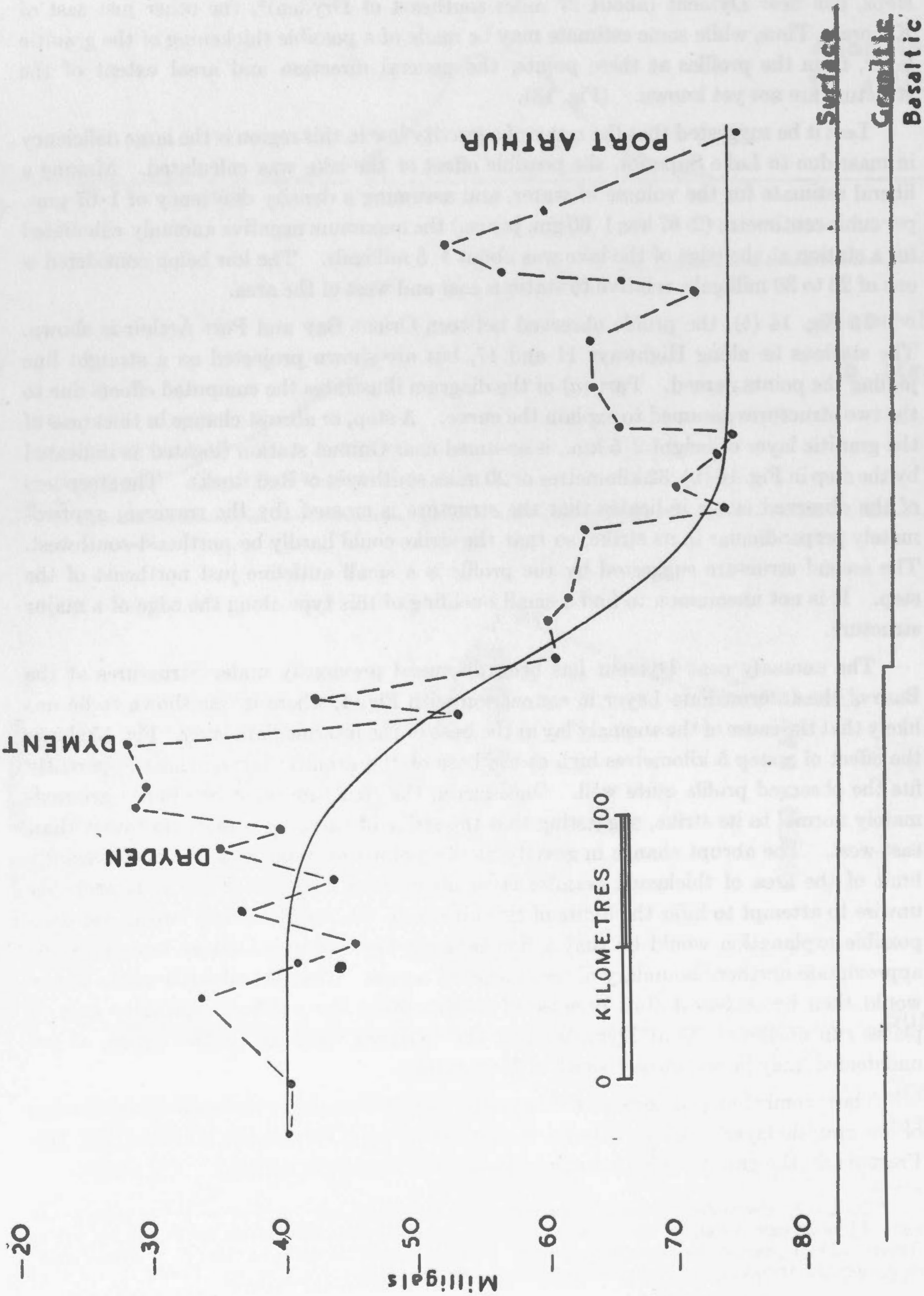


Fig. 15. Port Arthur-Dryden profile.

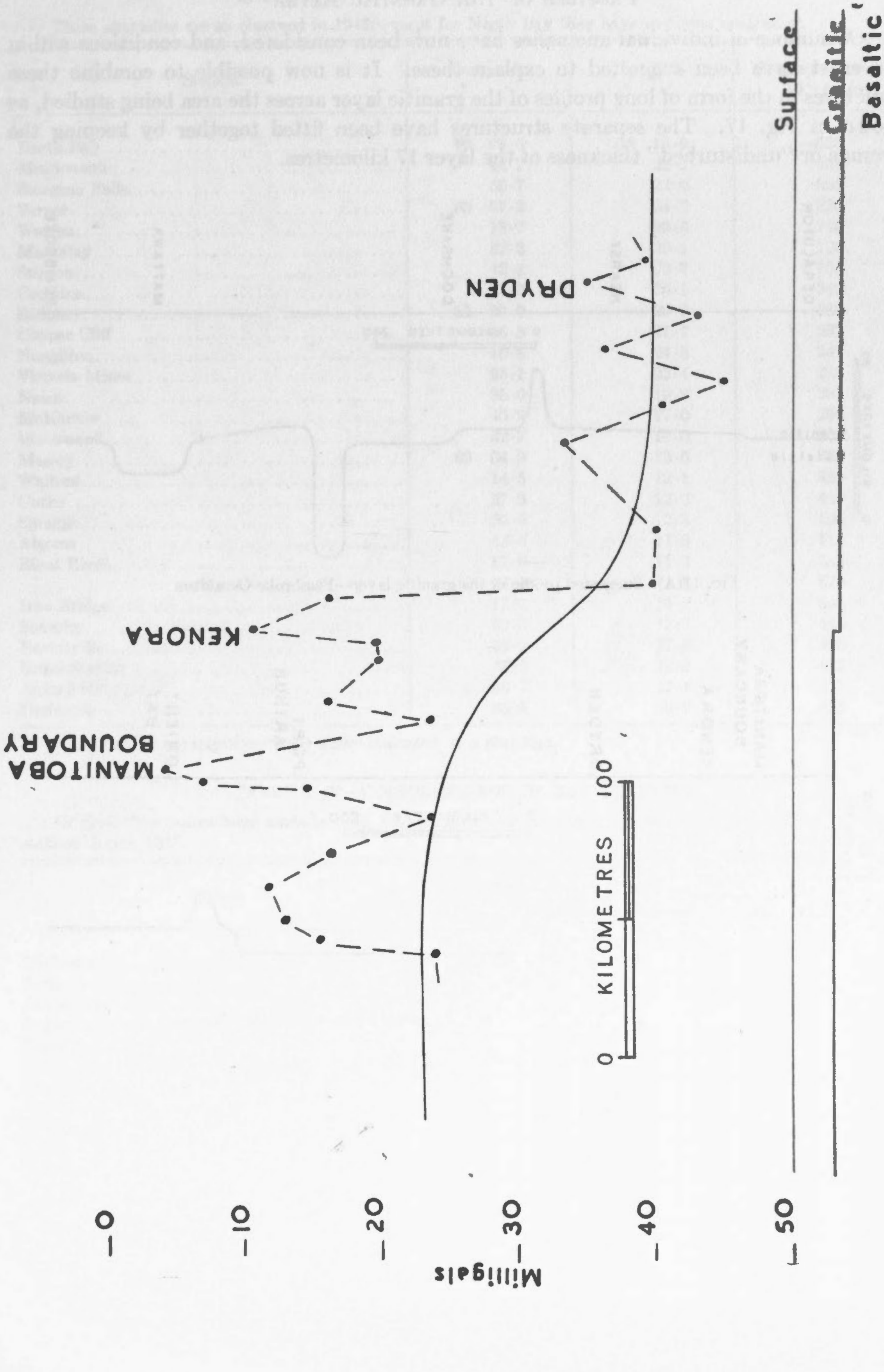


FIG. 16. Dryden-Manitoba boundary profile.

Profiles of the Granitic Layer

A number of individual anomalies have now been considered, and conditions within the crust have been suggested to explain these. It is now possible to combine these structures in the form of long profiles of the granitic layer across the area being studied, as shown in Fig. 17. The separate structures have been fitted together by keeping the average or "undisturbed" thickness of the layer 17 kilometres.

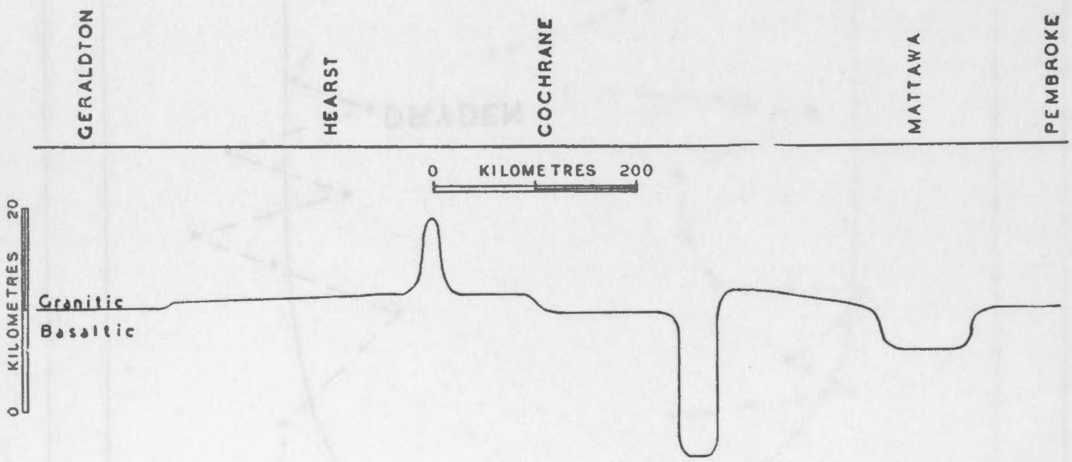


Fig. 17(A). Suggested profile of the granitic layer—Pembroke-Geraldton

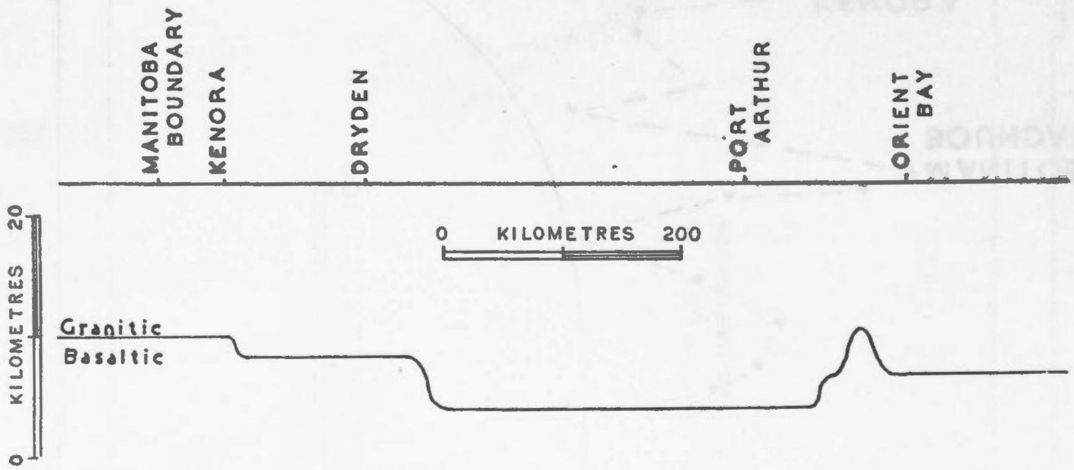


Fig. 17(B). Suggested profile of the granitic layer—Orient Bay-Kenora.

TABLE 1 (*a*)—NORTH BAY-SUDBURY TRAVERSE

These anomalies are as observed in 1945; except for North Bay they have not been readjusted.

Station	Longitude ° ′	Latitude ° ′	Bouguer Anomaly 10^{-4} cm/sec²
North Bay	79 28·0	46 18·9	−523
Meadowside	44·7	22·2	464
Sturgeon Falls	55·7	22·0	395
Verner	80 07·2	24·7	326
Warren	18·7	26·6	245
Markstay	32·2	29·1	136
Stinson	42·1	30·7	194
Coniston	51·0	29·1	340
Sudbury	81 00·0	29·8	280
Copper Cliff	04·5	27·7	252
Naughton	10·8	24·3	241
Victoria Mines	23·1	23·4	213
Nairn	35·0	19·8	283
McKerrow	45·3	17·0	262
Webbwood	52·7	16·0	301
Massey	82 04·9	12·5	368
Walford	14·5	12·1	439
Cutler	27·6	12·0	489
Spragge	39·6	12·3	490
Algoma	48·6	11·0	516
Blind River	57·0	11·0	533
	83 06·0	12·9	576
Iron Bridge	13·3	16·7	565
Sowerby	23·3	17·7	544
Nestorville	36·2	17·3	425
Bruce Station	45·9	19·0	452
Jacks Point	46·7	17·7	437
Desbarats	55·4	20·7	422

All anomalies are negative except where indicated by a plus sign.

TABLE 1 (*b*)—COCHRANE-NORTH BAY TRAVERSE

Original observations were made in 1946, but the anomalies have been corrected after the repetition of certain stations during 1947.

Station	Longitude ° ′	Latitude ° ′	Bouguer Anomaly 10^{-4} cm/sec²
Cochrane	81 00·5	49 03·9	−513
Holland	80 51·4	48 52·0	427
Devonshire	49·3	49·0	276
Nellie Lake	48·0	45·6	262
Porquis	46·8	42·4	324
Kelso	44·7	40·7	280
Monteith	40·6	38·6	310
Val Gagne	38·2	36·9	428
Matheson	28·0	32·0	365
Ramore	19·3	26·3	228
Bourkes	13·6	17·4	217
	15·4	13·8	216
	11·5	06·0	315
Swastika	06·0	06·4	409
	00·2	02·0	501
	00·7	00·6	509
	00·8	47 56·4	683

TABLE 1 (*b*)—COCHRANE-NORTH BAY TRAVERSE—*Concluded*

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Englehart	79	52·1	47	49·5	−150
Earlton		49·0		42·6	252
Thornloe		45·9			190
New Liskeard		40·3		30·6	300
Haileybury		38·4		26·8	300
Cobalt		41·0		23·6	259
Latchford		48·5		19·7	202
		43·6		12·0	366
Goward		47·2		06·5	348
Timagami		47·0		03·9	292
		45·4	46	55·0	297
		48·5		48·1	336
Jct. Routes 11 and 64		50·0		43·0	388
		38·2		35·0	400
		28·0		20·9	520
North Bay		28·0		18·9	523

TABLE 1 (*c*)—GRAVITY STATIONS BETWEEN COCHRANE, ONT., AND THE MANITOBA BOUNDARY

The Anomalies are those obtained in 1946. Certain stations were repeated during 1947 but the adjustments have not yet been made.

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Cochrane	81	00·5	49	03·9	−513
Hunta		16·4		06·4	407
		20·0		07·6	374
Driftwood		23·0		08·6	413
Smooth Rock Falls		38·0		16·8	304
Strickland		51·4		17·0	268
Gregoire's Mill		57·2		17·2	283
Fauquier	82	02·0		18·5	290
Moonbeam		09·4		20·4	224
Kitigan Sta		18·0		23·0	163
Kapuskasing		25·2		24·7	096
Valrita		32·7		26·6	077
Harty Sta		41·3		28·6	232
Opasatika		52·0		31·5	299
Lowther	83	02·0		33·5	280
Parthia		10·5		35·4	334
Mattice		16·1		36·7	341
Fryatt		20·4		37·5	326
		27·7		39·5	302
Hallebourg	83	31·0	49	40·2	292
Hearst		40·0		41·6	319
		53·1		43·6	356
	84	06·3		44·2	391
		24·5		45·1	369
		32·3		46·5	377
		50·0		46·0	386

TABLE 1 (*c*)—GRAVITY STATIONS BETWEEN COCHRANE, ONT., AND THE MANITOBA BOUNDARY—*Concluded*

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Hearst—*Concluded*	85	03·9	49	45·0	−395
		13·5		46·0	384
		55·7		47·1	449
	86	19·1		47·7	563
Longlac		33·0		47·2	525
Geraldton		56·8		43·6	403
	87	16·2		41·6	566
Jellicoe		31·0		41·8	525
Nezah		39·1		40·4	518
Beardmore		57·1		36·0	399
Orient Bay	88	08·0		22·2	578
Nipigon		15·0		00·5	536
(Red Rock)		20·1	48	56·7	516
Hurkett		28·6		51·2	610
Pearl		39·5		40·1	711
Ouimet		35·0		45·2	674
Loon		45·8		38·0	688
Port Arthur	89	13·0		26·3	745
Kaministikwia		35·5		32·3	591
		46·2		34·0	518
		54·3		35·9	559
		55·6		49·4	650
Argon		59·7		52·8	704
Savanne	90	14·8		57·4	626
Upsala		28·0	49	03·2	628
		40·8		03·8	649
		42·5		05·0	734
		48·3		09·4	717
		58·3		14·0	692
	91	04·3		14·8	729
		16·5		16·7	623
		31·6		21·1	611
Ignace		40·0		25·0	615
	92	02·5		30·0	418
		09·0		32·5	528
		19·1		34·9	279
Dinorwic		30·2		41·4	293
Wabigoon		36·2		43·1	285
Barclay		42·5		46·6	395
Dryden		49·9		47·6	350
Oxdrift		58·4		48·6	433
	93	08·0		48·7	365
Gunne		17·3		49·0	451
Vermilion Bay		23·1		51·0	408
		35·0		49·7	335
Hawk Lake		59·8		48·0	403
	94	15·0		43·7	389
		20·0		43·4	162
Kenora		28·4		46·5	137
Keewatin		33·0		45·9	198
		37·7		45·0	199
		48·5		42·7	164
		54·6		43·1	239
Manitoba Boundary	95	09·0		44·4	044

TABLE 1 (*d*)—GRAVITY STATIONS ESTABLISHED DURING 1947 IN THE AREA BETWEEN NORTH BAY AND COCHRANE

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
North Bay, Ont	79	28·0	46	18·9	−523
(North Bay)		27·0		16·5	576
Trout Mills		24·8		19·7	575
Feronia		19·4		21·7	597
Balsam Crrek		12·1		25.0	642
Little Jocko River		09·7		32·9	610
Jocko River		09·6		36·1	537
Timiskaming, Que. (C.P.R. Sta.)		06·0		43·0	513
Timiskaming (Pend. Sta.)		06·0		43·0	517
Dozois		08·6		50·3	467
Laniel		16·2	47	02·6	480
Fabre		22·0		12·0	356
Baie d'Africain		23·7		14·4	350
Ville Marie		26·5		19·8	352
"		26·1		19·8	344
"		26·7		19·9	356
(Fabre)		21·9		06·6	478
"		22·1		07·1	474
"		22·5		08·4	467
"		22·6		09·1	475
Lavallée River		22·2		10·8	425
(Baie d'Africain)		24·2		15·6	377
(Miron)		25·2		17·6	363
Lorrainville		20·1		21·2	255
(Ville Marie)		26·2		22·1	317
(Guigues)		26·9		24·5	402
(Guigues)		26·2		26·1	386
Guigues		26·2		27·8	275
(Guigues)		26·0		31·9	294
(Notre Dame du Nord)		26·3		35·2	453
Notre Dame du Nord, Que		29·2		35·4	396
Sutton Bay, Ont		35·3		34·0	254
New Liskeard		40·3		30·6	303
(New Liskeard)		49·3		32·2	118
Kenabeek	80	00·0		38·5	185
Mountain Chutes		08·8		39·5	341
Leeville		10·0		39·6	373
(Wabun)		14·6		40·3	404
Elk Lake		20·1		43·5	392
(Elk Lake)		29·8		50·0	542
Matachewan		39·2		56·7	826
(Matachewan)		35·7		57·5	712
"		33·0		55·0	640
(Elk Lake)		13·8		45·2	449
"		16·9		45·1	445
"		10·0		45·4	390
Robillard Lake	80	05·5	47	46·8	323
Charlton		00·6		48·9	305
Englehart	79	52·1		49·5	147
Wawbewawa		53·7		53·0	471
(Wawbewawa)	80	00·8		53·9	686
(Round Lake)		00·8		58·2	683
Swastika		06·0	48	06·4	408
Boston Creek Rd. Jct		00·8		00·8	500

TABLE 1 (*d*)—GRAVITY STATIONS ESTABLISHED DURING 1947 IN THE AREA BETWEEN NORTH BAY AND COCHRANE—*Continued*

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Heaslip	79	48·6	47	47·8	−243
Maybrook		45·0		37·5	140
Uno Park		44·9		34·8	159
Haileybury, Ont		37·9		26·9	190
Guerin, Que		15·8		39·9	533
(Guerin)		15·8		45·7	609
(Guerin)		15·7		48·6	559
Riviére Solitaire		14·3		54·8	561
		14·9	48	01·9	586
		15·7		04·7	558
		16·0		08·0	526
Arntfield		15·3		12·1	436
Rouyn		01.9		14.4	345
Noranda		01.3		14.9	341
Noranda		01·3		14·9	342
(Evain)		07·2		14·5	462
Lake Fortune		18·0		11·4	441
Kag Lake, Que		28·5		09·2	506
Cheminis, Ont		31·6		09·8	416
Bear Lake		38·7		07·0	390
Larder Lake Sta		42·5		07·1	421
(Larder Lake)		43·3		05·3	399
(Larder Lake)		42·3		03·4	364
Larder Lake		43·0		05·9	398
Dobie		48·8		07·7	462
King Kirkland		57·3		09·1	466
Kirkland Lake	80	01·9		09·0	427
Dane		00·9		04·1	403
Boston Creek	79	56·4		00·4	473
(Boston Creek)		50·8		00·4	421
(Kirkland Lake)	80	00·6		12·2	308
(Kirkland Lake)		01·5		10·9	323
		14·0		08·5	226
		16·0		11·7	256
Yorkston		14·2		22.0	258
		25·2		27·2	289
Shillington		40·8		32·5	336
		51·4		32·9	530
Timmins	81	20·0		28·6	501
Schumacher		17·7		28·6	477
South Porcupine		11·8		28·4	517
Porcupine		09·5		30·0	518
Pamour		07·2		31·6	504
Hoyle		03·4		33·1	527
Drinkwater		00·5		35·2	552
Connaught	80	55·6		37·0	506
McIntosh Springs		52·0		38·8	401
Alexo		49·0		40·3	366
Iroquois Falls		40·7		45.9	198
Porquis		46·8		42·4	324
		58·6		55·1	308
	81	00·5	49	00·2	378
Cochrane		00·6		03·6	513

TABLE 1 (*d*)—GRAVITY STATIONS ESTABLISHED DURING 1947 IN THE AREA BETWEEN NORTH BAY AND COCHRANE—*Concluded*

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Watabeag	80	33·0	48	34·1	−443
Ramore		19·3		26·3	228
Timagami	79	47·0	47	03·9	292
Jct. Routes 11 and 64		49·9	46	43·1	394
Holdridge Creek		54·1		40·8	433
Field	80	01·6		31·5	325
Sturgeon Falls	79	55·7		22·0	374

TABLE 1 (*e*)—COCHRANE-MOOSONEE TRAVERSE

This traverse was observed in 1947. Most stations were repeated on the return trip to Cochrane.

Station	Longitude °	′	Latitude °	′	Bouguer Anomaly 10^{-4} cm/sec²
Cochrane	81	00·7	49	03·7	−517
Genier		01·4		10·5	467
Clute		00·4		11·5	451
Blount		01·8		15·9	379
Gardiner		02·0		18·7	403
Workman		03·7		22·9	393
Wurtele		05·8		25·9	364
Maher		10·9		28·0	343
McInnis		19·0		32·2	266
Island Falls		21·3		32·7	246
Island Falls North		21·4		32·8	236
Brownrigg		31·8		41.7	097
Fraserdale		37·2		51·0	+015
Fraserdale		37·2		51·1	+015
Coral Rapids		40·2	50	12·7	−089
Coral Rapids North		40·3		12·8	083
Onakawana		25·7		36·0	253
Onakawana North		25·5		36·4	148
Moose River		17·8		48·5	067
Moose River North		17·8		48·8	069
Renison		08·0		57·7	151
Galeton	80	55·0	51	07·9	170
Moosonee		39·0		16·5	115

GEOLOGICAL SIGNIFICANCE OF THE MAJOR STRUCTURES DEVELOPED

The procedure so far has been merely to find structures of such size and shape as to produce anomalies approximating the observed ones, without reference to the geology of the Shield. It is evident, however, that there is a relationship between these structures and the geological history of the region. In order to follow the correspondence between the gravity anomalies and the regional geology of northeastern Ontario, reference may conveniently be made to the accompanying anomaly map and to the Lake Huron Sheet (map 155A) of the Geological Survey of Canada.

The major geological features of the area under consideration follow two distinct lines of orientation. On the one hand, certain structures, such as the great fault zone which extends from south of Kirkland Lake into Quebec, strike generally east-west, while other large structures strike northeast-southwest. This would suggest that two separate periods of tectonic activity were responsible for the major structures of the region. The exact age relationship between the two periods remains a major problem of Canadian geology, but one possibility has been clearly outlined by Gill[4] who states:

"In the Grenville sub-province, although the local structures are quite complex, there appears to be, from the limited data available, a prevailing northeasterly trend. As has already been pointed out, this trend cuts directly across the east-west trend of Keewatin and Timiskaming type rocks along a line extending from the north shore of Lake Huron to Lake Mistassini. These relations strongly suggest that the Grenville sub-province marks a late Precambrian mountain built belt with a trend later followed to the southeast by the Palæozoic mountain systems."

Similar relationships were observed by Norman[5] in the Chibougamau district of Quebec. A complete treatment of this hypothesis, that the northeasterly trending structures truncate older, east-west striking, Keewatin features, has been given by Wilson[6]. Wilson has also quoted age determinations to support this thesis. These are probably not completely reliable, but do suggest an age of 2200 million years for a Keewatin rock of southeastern Manitoba (unfortunately no good determinations of the Keewatin in Ontario are yet available) and an age between 800 and 1100 million years for Grenville rocks of Ontario.[7]

It seems reasonable to suppose, therefore, that the Keewatin and Timiskaming rocks of northeastern Ontario were deformed during early Precambrian times by forces which acted along a north-south axis. Judging from the magnitude of the thrusts involved, for example, the Larder Lake-Cadillac break, it is quite possible that mountains of considerable size were developed along east-west lines at this time. Later in Precambrian times, if the hypothesis outlined above be true, the axis of the dominant crustal forces must have changed in direction, for reasons not clearly understood. The new direction of the thrust

[4] Gill, J. E.,—The Canadian Precambrian Shield,—Structural Geology of Canadian Ore Deposits, Jubilee Volume, Can. Inst. Min. and Met., pp. 20-48, 1948.

[5] Norman, G. W. H.,—The Northeast Trend of Late Precambrian Tectonic Features in the Chibougamau District, Quebec,—Trans. Roy. Soc. Can., 3rd Series, Vol. 30, Sec. 4, pp. 119-128, 1936.

[6] Wilson, J. T.,—Some Aspects of Geophysics in Canada with Special Reference to Structural Research in the Canadian Shield. Part 2. An Approach to the Structure of the Canadian Shield,—Trans. Am. Geophys. Union, Vol. 29, No. 5, pp. 691-726, 1948.

[7] Wilson, J. T.,—Some Major Structures of the Canadian Shield,—Trans. Can. Inst. Min. and Met., Vol. 52, pp. 231-242, 1949. Appears in The Can. Min. and Met. Bull., Vol. 42, No. 450, pp. 543-554, 1949.

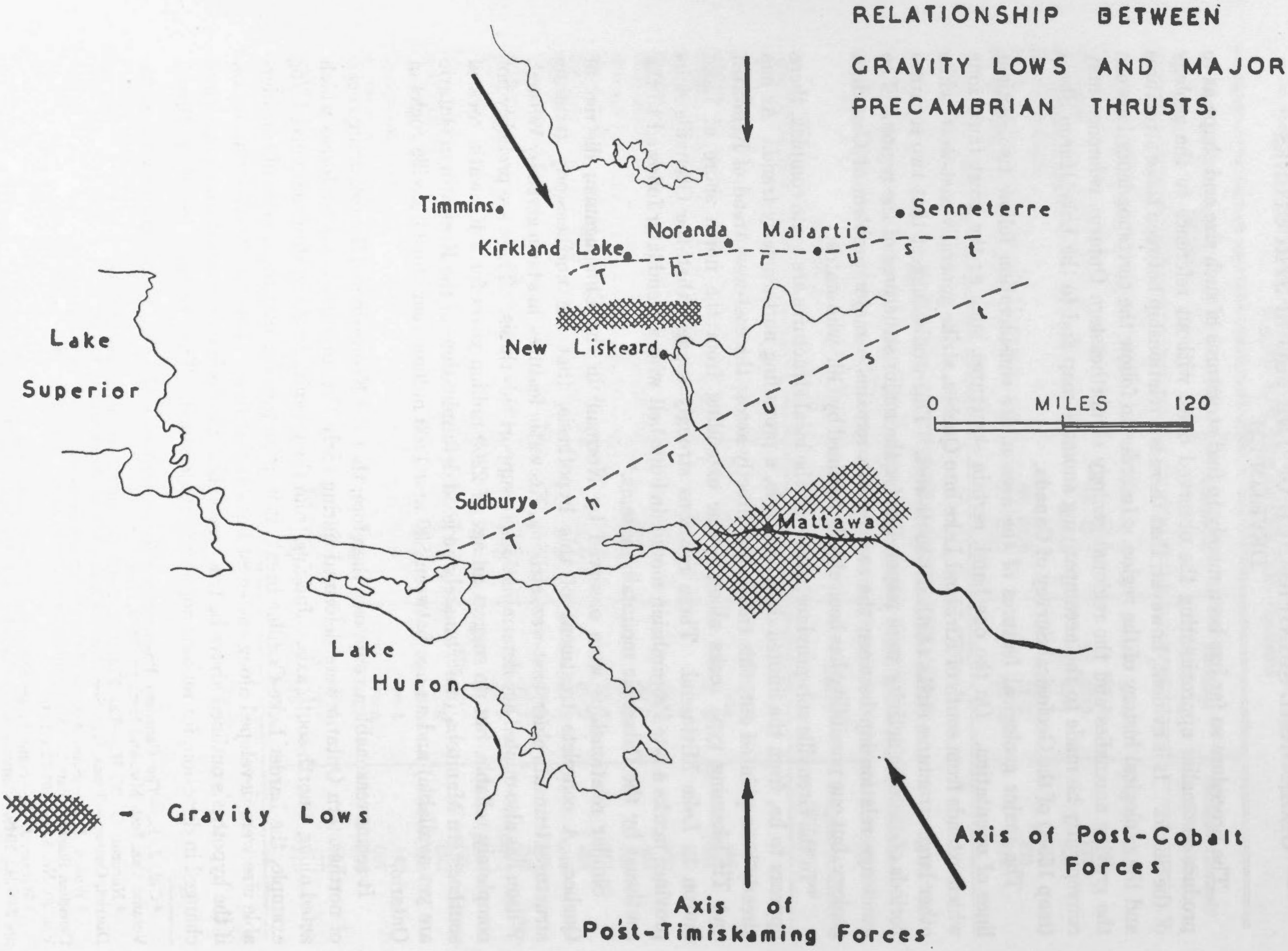


FIG. 18. Sketch showing relationship between gravity lows and major Precambrian thrusts.

forces was approximately northwest, and these forces are believed to have produced the northeasterly trending range of mountains along the border of the Grenville sub-province, as described by Gill. The foreland to the northwest of this range apparently remained a low basin, and in this basin were deposited (partly through the agent of glaciation) the products of erosion from the mountains, in the form of the Cobalt sediments. Further action of the forces after Cobalt time may well have produced the deformation in the Cobalt sediments, which has been clearly shown by Collins[8]. Later work suggests the presence of a great thrust fault bounding the Cobalt province on the southeast. This fault was recognized in the Sudbury district by Cooke[9] and has been shown as extending a long distance into Quebec in a recent publication of the Geological Survey[10]. Norman[11] has recently suggested that the northeasterly trending faults of the Chibougamau and Mistassini districts of Quebec may form part of a major late Precambrian structure which separates the Timiskaming and Grenville sub-provinces. The straight (apparently transcurrent) fault which cuts the Palæozoic rocks north of Lake Timiskaming would indicate that thrusting along an approximately northwest axis had occurred even after the Silurian period.

To show that a relationship may be expected between the structures developed within the granitic layer and the tectonic processes outlined above, reference may be made to papers by Vening Meinesz [12] and Hess [13]. These papers suggest the relatively new concept of a tectogene, which is primarily a great downbuckle of the earth's crust, (Fig. 19) constituting one stage in the formation of a range of thrust mountains. The complete process may be said to begin with the accumulation of sediments in a geosyncline followed by the application of great tangential, compressive forces, which probably act within the granitic layer. Eventually, this layer must buckle, forming a downfold as the underlying basaltic material is pushed aside. If the forces continue to act with sufficient magnitude, the fold will become isoclinal (as shown), and may extend downwards "40 to 60 km." (Hess), that is, to the base of the basaltic layer, or beyond. The overlying sediments, during this stage, become very highly folded, and if caught in the centre of the granitic fold, may be thrust upwards. Examples of tectogenes in this stage are believed to exist in the world today, among the island arcs of the West Indies and the Asiatic margin of the Pacific. Characteristics of these regions include ocean deeps (evidence of the downfolding), folded sediments, volcanics and marked negative Bouguer anomalies. For example, over the West Indies narrow strips with negative anomalies of about 150 milligals are observed, representing almost as great a negative anomaly as found in the Canadian Rockies. Following the development of the tectogene, buoyant forces acting on the granitic root cause the entire mass to rise, so that eventually the deformed sediments above the fold become mountains of considerable size. Erosion then takes place, and the

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[8] Collins, W. H.,—North Shore of Lake Huron,—Geological Survey of Canada, Memoir 143, 1925. Especially pp. 98-107, and figures 7 and 8.

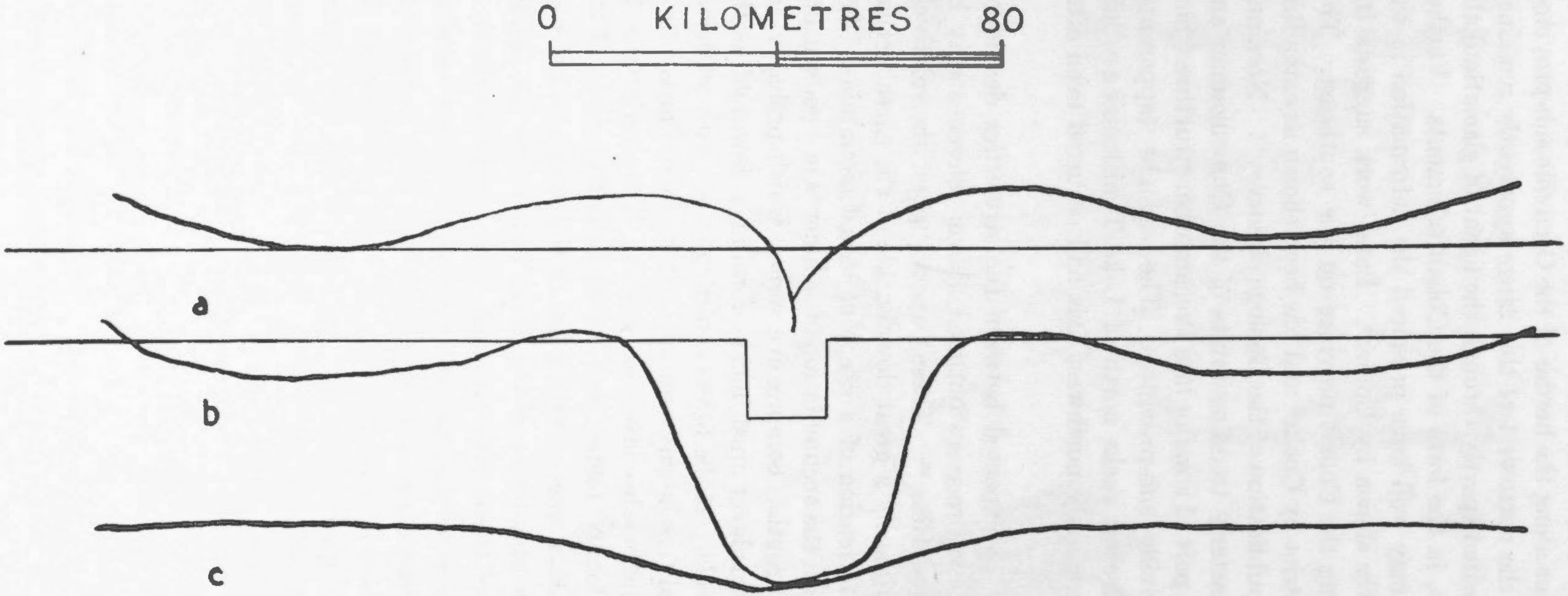
[9] Cooke, H. C.,—Problems of Sudbury Geology,—Geological Survey of Canada, Bulletin No. 3, 1946.

[10] Geology and Economic Minerals of Canada,—Third Edition, 1947.

[11] Norman, G. W. H.,—Major Faults, Abitibi Region,—Structural Geology of Canadian Ore Deposits, Jubilee Volume, Can. Inst. Min. and Met., pp. 822-839, 1948.

[12] Vening Meinesz, J. H. F. Umgrove, and Ph.H, Kuenen,—Gravity Expeditions at Sea 1923-32., Vol. II, Publications of the Netherlands Geodetic Commission, Chapter V.

[13] Hess, H. H.,—Gravity Anomalies and Island Arc Structure with Particular Reference to the West Indies. Proc. Am. Phil. Soc., Vol. 79, No. 1, 1938.



THE TECTOGENE

(as suggested by H. H. HESS for the West Indies.)

(a) Granitic Layer

(b) "Intermediate" (Basaltic) Layer

(c) Ultrabasic Layer

In light lines are shown the average thickness for the Granitic layer of Ontario and the remnantal root suggested for the Matachewan — Guerin Low.

FIG. 19. The tectogene as suggested by Hess for the West Indies.

mountains are reduced. But does the granitic root gradually disappear as the topography is levelled? The anomalies observed in the Canadian Shield would indicate that the roots outlive the mountains.

The major anomalies considered in the previous section exhibited two outstanding strike directions, east-west and northeast-southwest. It appears reasonable to consider the former structures (east-west striking) as dating from early Precambrian (post-Timiskaming) time, and the latter from Huronian time. The most prominent anomaly of the first type is the Matachewan-Guerin low, which extends for at least seventy miles across the country immediately south of the Kirkland Lake-Malartic belt of highly folded and faulted Timiskaming sediments. These sediments may reasonably be identified as the remnants of deeply eroded mountains, formed by the north-south thrust. It is now suggested that the thickened granitic layer, as developed to explain the gravity low, represents the remnant of the root formed during the tectogene stage of the mountain building. In the diagram of the West Indies tectogene (Fig. 19), the Matachewan-Guerin structure has been added, in light lines, for comparison. The latter structure, as expected, could be merely a relatively small core of the original root, since, of course, the root decreases through the very act of rising under buoyant forces. Further outflow of granite is to be expected during the long history of the mountains, but the conclusion to be emphasized here is that at least a remnant of the original root may have persisted since early Precambrian times.

The surface rocks along the axis of the low are dominantly granite and granite gneiss, while areas of Keewatin lavas appear both south and (to a greater extent) north of the low. The Timiskaming sediments are also located to the north of the trough, and their trend appears to be related to minor sinuosities in the gravity contours. For example, Fig. 20 shows the gravity results along the sedimentary belt from Swastika to Rouyn, with the anomaly contour at −40 milligals plotted. This contour may be taken as indicating the northern limit of the low, and it will be observed that the prominent southward extension of the Timiskaming rock, in the vicinity of Larder Lake, corresponds with a similar southward trend in the contour. Now, if the low does represent the effect of a remnantal root, it seems logical that the highest mountain elevations lay along what is now the axis of the low. During the great erosion, which reduced the mountains to the surrounding level, the folded sediments and volcanics which constituted the mountains were removed, exposing areas of granite. The latter rock may be assumed to have been intruded, as batholiths, during the mountain building process. Thus, the prominent rock along the course of the gravity low today is granite, while the Timiskaming sediments which best escaped erosion were those occupying some favoured position along the northern limit of the range.

Unfortunately, other east-west trending regional anomalies, while definitely suggested, are not yet as well defined as the Matachewan-Guerin low. There is recognized a second belt of Timiskaming rocks, reaching from Destor, Que., (latitude 48° 30′ longitude 79° cf. Lake Huron Sheet G.S. Map 155A) to the Porcupine area of Ontario, which is similarly characterized by thrusting assigned to forces acting along a north-south axis. As shown on the contour map, there is an area of low gravity centring about Porcupine about 8 miles east of Timmins, and at least a suggestion of its eastward continuation across the

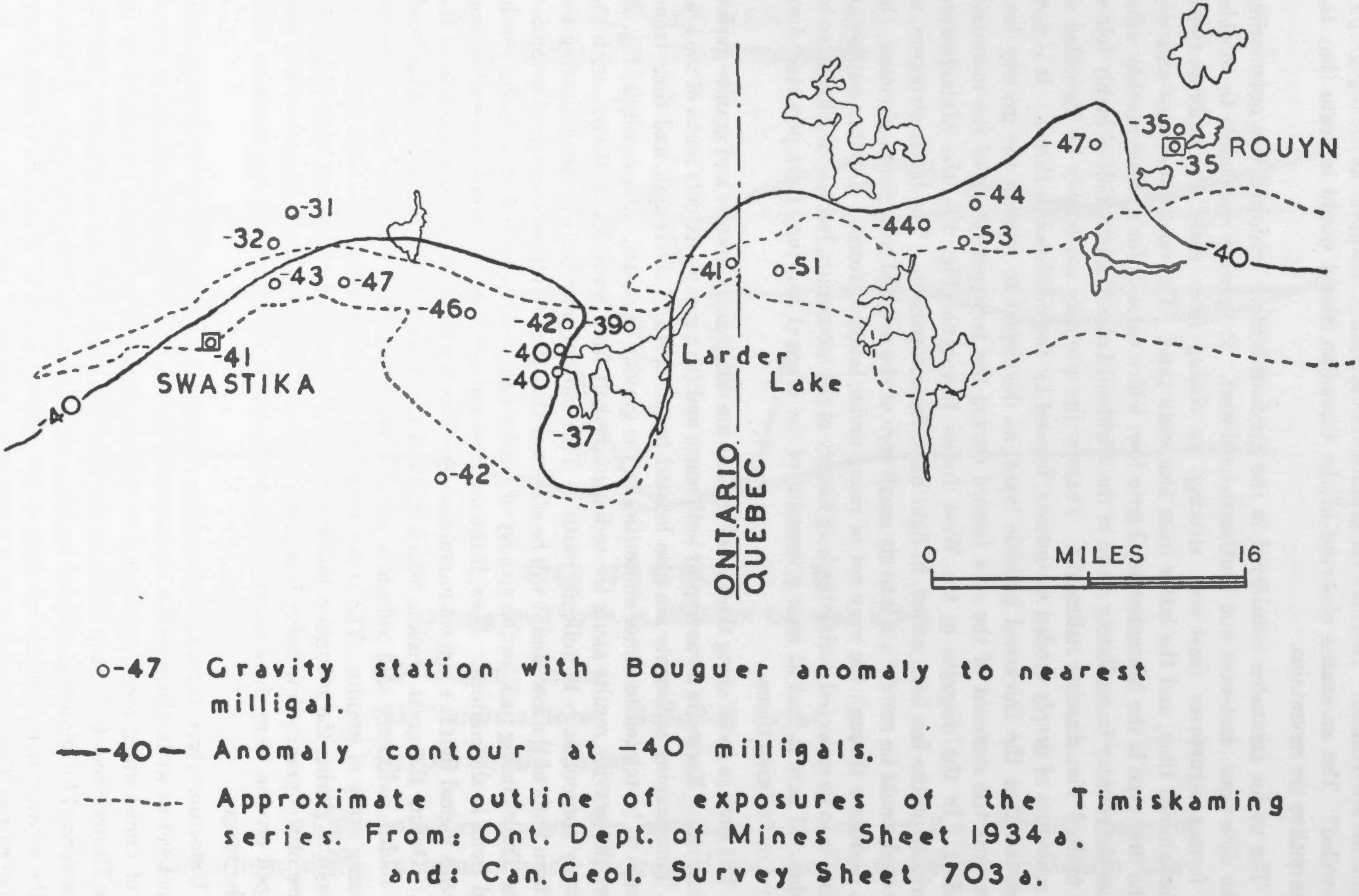


FIG. 20. Showing relation between gravity anomalies and Timiskaming series—Rouyn to Swastika.

traverse on Highway 11. However, the latter low has the characteristics of a surface, rather than a crustal anomaly, and as such is treated later. (It will be suggested that a ridge of granite extending into the otherwise deep Keewatin lavas is the anomalous structure). Further traverses are necessary to show the outlines and trend of the Porcupine low proper, but it may well represent a root structure under the granitic layer which could be related to the thrusting of the region. The second suggested anomaly of this type is the Port Arthur low. As explained previously, this could be an east-west trending feature with its northern limit extending from Ouimet Station to Dyment, and its southern limit as yet undefined. If this can be shown to be true, the root structure suggested by the low could be related to the early Precambrian folding in the volcanic and sedimentary rocks of the Rainy Lake area, as this folding has a dominant east-west trend. This orientation would also place the structure very nearly in line with the Matachewan-Guerin root, possibly indicating that it was the westward extension of the same early Precambrian tectogene.

The second group of the structures, those striking northeast, may now be considered. These, of course, are considered to have resulted from thrusts acting from the southeast during the later Precambrian periods. It was shown that a granitic layer thickening of about 4·5 kilometres could explain the gravity low in the Mattawa area. The location of this low corresponds with the assumed position of the mountains thrust up along the northern limit of the Grenville, and the thickening may, therefore, be the remnant of the roots of these mountains. During the thrusting, as granitic material flowed downward into the root being formed, a thinning of the granitic layer northwest of the root may have occurred. Hence, while the mountains were rising, the area to the northwest may have remained low, or even sank, to form a natural basin in which the Cobalt sediments were deposited. Evidence consistent with such an explanation was shown in the traverse through Sudbury (Fig.6), and also in the Englehart region. Further traverses over the Cobalt basin may well show that the gravity high exists over most of the area covered by the sediments, as would be expected if the basin was formed as suggested. Once again, the dominance of granite, and granite gneiss, along the course of the low may be noted, indicating that the axis of the gravity low represented the line of highest elevation, and hence of greatest erosion. Southeast of the low, gravity increases, suggesting a return to normal thickness of the granitic layer. Thus, along the traverse between North Bay and Ottawa, the southeasterly boundary of the thickened granitic layer appears to be near Chalk River. The latter point also marks approximately the northerly limit of large areas of Grenville sediments, beyond which granite is the dominant rock.

It has been suggested that the region of high gravity observed near Englehart is part of a much larger area under which the granitic layer is thinner than normal (the Cobalt basin). The contour map would suggest an interaction between this high and the Matachewan-Guerin low to the north. That is, the higher contours tend to distort the east-west trending low, causing it to be most narrow just north of Englehart. At the time the Cobalt basin and the mountains to the southwest were forming, the Matachewan-Guerin root was, in all probability, already an ancient structure. Possibly it suffered a certain deformation under the late Precambrian forces.

The gravity observations over the Palæozoic outlier of Lake Timiskaming are interesting. This outlier lies within the area of relatively high gravity, that is, over a supposedly thinner than normal granitic layer. Theories to explain this outlier vary in detail, but there is suggestion of a downwarping of the crust, which aided in the preservation of the Palæozoic rocks. The following paragraph is quoted from Hume.[14]

"The evidence seems to show that the Palæozoic rocks of the Timiskaming area owe their existence chiefly to a depression formed by warping of the Canadian Shield subsequent to their deposition. Afterwards these strata were further depressed and sheltered from erosive agents by a great fault which extends northwestward along the straight western shore of Lake Timiskaming and perhaps also by a small fault extending through Cobalt northeastwards towards Rivière des Quinze."

It is reasonable to suggest that the downwarping of the Shield occurred partly as a result of the thinned granitic layer, which would make the crust less competent to support the extra load of the sediments.

Still another northeast trending structure is the Kapuskasing-Fraserdale high, also attributed to a thinning of the granitic layer. As this trend is believed to be characteristic of the later Precambrian structures, the high may have been the result of the same northwesterly thrusts. The buckling of the granitic layer under the action of these thrusts seems to have taken the form of a thickening under the "Mattawa Mountains", a thinning under the Cobalt basin, a lesser thickening northwest of this, (the contour map shows a moderate low near Cochrane), and the thinning suggested by the Kapuskasing-Fraserdale high. Certain rock types may be noted along the course of this high. A large area of Timiskaming sediments is preserved west and south of Kapuskasing in the vicinity of Michipicoten, within the general limits of the high. Further north the small patches of Cretaceous sediments lie along the same high. Of course, the thinning of the granitic layer, dating from Huronian time, cannot directly explain the presence of the Timiskaming sediments, but it suggests that the region remained one of low elevation during late Precambrian orogenies. This would assist in the preservation of the earlier rocks. The Cretaceous rocks may be found to be downwarped or downfaulted; in either case the thinner than normal granitic layer beneath them could have been an assisting factor.

ISOSTATIC CONSIDERATIONS

One of the objections most likely to be raised to the above interpretations is that the granitic layer is assumed still to reflect the compensation of Precambrian topography, whereas the principle of isostasy would appear to demand the disappearance of roots as the topography is levelled. However, on the basis of recent knowledge of the strength of the crust, this is not necessarily so. It is now believed, for example, that many major topographic features of today are supported by the strength of the crust, rather than by local compensation. Indeed, the criterion of whether a feature is to be compensated or not is no longer its size alone, but rather its mode of formation. Thus, a considerable mountain chain may be formed by the outpouring of lava, and the mountains will be carried by the strength of the crust alone. The Hawaiian islands are believed to be an

[14] Hume, G. S.,—Geological Survey of Canada, Memoir 145, p.51.

example of such a feature, being supported by the intermediate layer without local compensation.[15] On the other hand, mountains formed by compressive forces, even if no larger in extent than the volcanic ones mentioned, are found to have roots, largely because the roots were formed first, by the action of the forces. Now, if the intermediate layer can be assumed to carry the entire weight of the Hawaiian islands, it is not too much to assume that the granitic layer of the Canadian Shield can withstand the unbalanced upward forces caused by the remnantal roots suggested. For example, the deepest rock assumed was that developed for the Matachewan-Guerin low. The extra 16 kilometres of granite assumed here (Fig. 8) would exert a buoyant force on the granitic layer above, equivalent to the downward load of a granitic plateau 4,000 feet high, or a basaltic plateau of about 3,600 feet. Elsewhere, the roots assumed are smaller, and the unbalanced buoyant forces correspondingly less. Assuming that the granitic layer proper can withstand these forces, there is really no reason for the roots to disappear completely. During an orogeny, granite may be assumed to flow easily, as it probably becomes plastic under the conditions of increased temperature accompanying the compression. However, during the quiet period of erosion of the mountains, the granitic material in the roots probably becomes sufficiently solidified to assume that at least a core of the original root remains intact for a very long period.

It would appear, therefore, that while the isostatic compensation of the continental mass as a whole is accomplished at some depth much below the granitic layer (possibly partly at the base of the intermediate layer and partly at some still greater depth), the compensation of certain rather major topographic features (especially those produced by great compressive forces) depends on a thickening of the granitic layer formed by these same forces. The normally solid, crystalline nature of the granitic layer would allow these granitic roots to outlive the topographic features they once supported. If this suggestion be true, it would offer a ready explanation for the apparent departures from isostasy observed at various pendulum stations in the area, such as Mattawa and Timiskaming[16].

THE USE OF THE MAGNETOMETER IN OUTLINING THE MAJOR STRUCTURES

Measurements of vertical magnetic intensity were made at gravity stations along certain traverses, for example, between Cochrane and the Manitoba boundary. These observations, reduced to the latitude of Cochrane, are shown in Fig. 22. Quite obviously, there is no close agreement between gravity and magnetic profiles, at least as regards the major gravity anomalies. It would be reasonable to expect some magnetic effect from structures at the base of the granitic layer, if the underlying basalt is more magnetic than the granite (as is usually found in surface types). However, the magnetic anomalies produced by such structures can be shown to be very small, if not undetectable. As an example, the anomaly curve is shown (Fig. 21) for the assumed step-like thickening of the granitic layer near Dyment, Ont., assuming that the susceptibility of the basaltic material is 1000×10^{-6} CGS units, that the susceptibility of the granitic rock is 100×10^{-6} CGS

[15] Vening Meinesz, F. A.,—Gravity over the Hawaiian Archipelago and over the Madeira Area; Conclusions about the Earth's Crust,—Proc. Nederl. Aka. wan Wet., Vol. 44, No. 8.

[16] Publications of the Dominion Observatory, Vol. XI, Nos. 3 and 4.

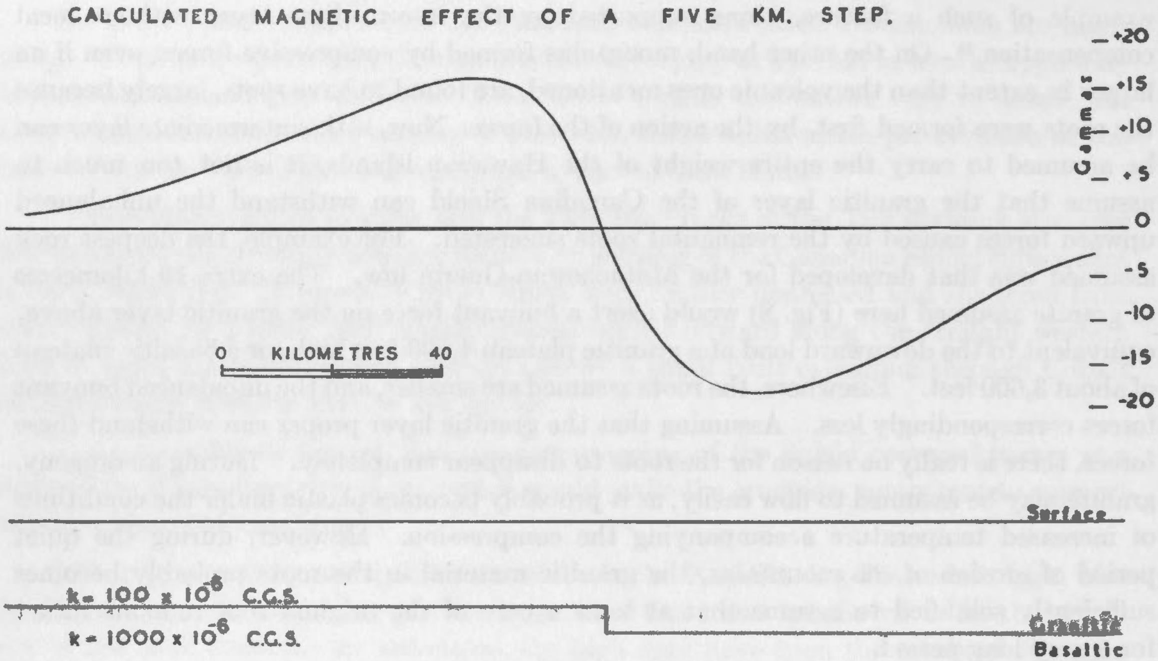


FIG. 21. Calculated magnetic effect of a five kilometre step.

units, and that both layers are uniformly magnetized. This is certainly a liberal estimate for the susceptibility of the lower layer, yet the maximum high over the step is but 16 gammas, and the maximum low off the edge of the step is only 20 gammas. This curve is shown to scale in Fig. 22, and the conclusion is that it is practically negligible in comparison with the other anomalies observed. The observed curve in the same illustration shows that readings between adjacent stations may differ by hundreds of gammas. Apparently, therefore, magnetic rocks near the surface, in the vicinity of the stations, produce effects which completely mask any smaller anomalies that might be caused by structures deep within the crust. The use of combined magnetic and gravity profiles in interpretation would thus appear to be limited to cases where the anomalous structures are not at such great depth, and where the surface formations are relatively non-magnetic. (For example, the Carboniferous Basin of New Brunswick, and the covered Shield area of southwestern Ontario, and Western Canada, have been explored in this manner. But in these cases, the structures sought were at the top of the granitic layer under only a few thousand feet of sediments.) As was suggested before, the airborne magnetometer suggests itself as the most probable means of detecting small regional trends that could be attributed to really major structures in the Shield.

SURFACE EFFECTS

The term "local, or surface effects" as used here refers to any anomaly which can apparently be correlated to known surface formations, on the basis of measured densities. While these anomalies are in general narrower and smaller than the regional effects, they are still of an order of magnitude greater than the anomalies sought in gravimetric prospecting. It should be borne in mind that no anomaly of the latter type is treated in the present discussion.

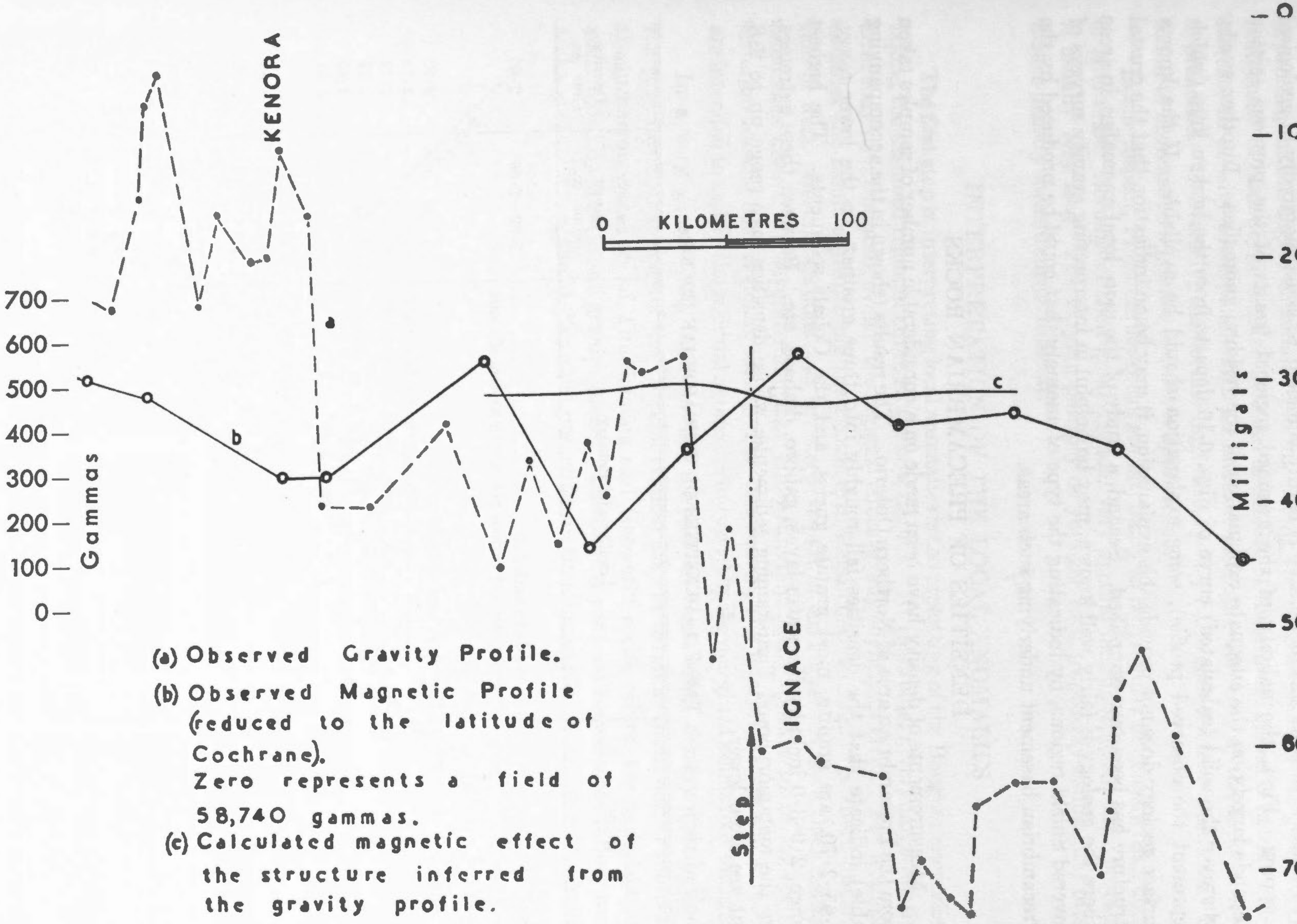


FIG. 22. Gravity and magnetic profiles—Cochrane-Kenora.

The consideration of these surface effects is important for two reasons, in spite of the fact that the present station density is hardly sufficient to assist materially in geological mapping. First, the validity of the assumed regional trends of the previous section depends largely on the adequate explanation of the residual anomalies. In other words, wherever the solid (calculated) curve of Figs. 6-16 departs from the broken lines (which represent the observed profile), some explanation should be available. If the known surface geology does not provide this explanation, it may be an indication that the crustal structure has been over-simplified. Second, a study of the more local anomalies, in areas where the geology is fairly well known, may be helpful in interpreting gravity surveys of covered Shield regions, by indicating the type of anomaly that could be produced by the Precambrian basement underlying such areas.

DENSITIES OF PRECAMBRIAN ROCKS

Measurements of density have been made on a considerable number of samples taken from the Precambrian area of Northern Ontario. The results (shown in the accompanying table) indicate that the densities fall roughly into three groups. In the lower range, 2·65–2·70, are granite, most granite gneiss, and the Cobalt sediments. The highest range, 2·9–3·0 includes Keewatin lavas, gabbro, diabase, etc. Between these extremes, are the metamorphosed Timiskaming sediments, whose densities may range up to 2·8, but are often lower.

TABLE 2—DENSITIES OF PRECAMBRIAN ROCKS

Rock	Locality and Remarks	Density Range Gms. cc.	Mean Density Gms. cc.
Granite	Round Lake batholith	2·62—2·66	2·65
	Samples taken at various points over an area of about 50 sq. miles.		
Granite-Gneiss	Markstay, Ont.	....	2·70
	Samples taken between Markstay and the fault zone.		2·72
	A visible increase in biotite content of the specimens		2·74
			2·77
			2·84
	Wanapitei—very large proportion of biotite	....	3·04
Mississagi Quartzite	Crerar, Ont.	2·65—2·67	2·66
	Coniston, Ont.	2·68—2·70	2·69
Cobalt Conglomerate	Near Sesekinika Lake, Ont.	2·77—2·80	2·79
Timiskaming Greywacke	Cadillac Area, Quebec	2·79—2·84	2·82
	Timmins Area, Ont.	2·84—2·88	2·87
Keewatin "Greenstone"	Englehart District	3·00—3·08	3·03

Rocks of Precambrian age of a given type may vary in density from place to place, depending on the degree of metamorphism. Along the southern side of the great thrust fault south of Sudbury, a marked increase in density of the granite gneiss is noted. This increase in density corresponds with an increase in biotite content, as the fault zone is approached. Conversely, the normal high density of a basic rock such as basalt may be found to decrease as a granite contact is approached.

In one respect, Precambrian rocks are less likely to be irregular in density than those of later eras. Because of their great age and very general metamorphism, their porosity is usually very low. The varying porosity of younger rock (especially sediments) often makes density measurement difficult.

INTERPRETATION OF THE LOCAL ANOMALIES

The first step in interpreting local anomalies is the replotting of the Bouguer anomalies, taking the assumed regional curve as the new datum. At this stage, a very large relative error may be introduced, even if the regional effect is only slightly in error. For example, consider the result of displacing the assumed regional curve in Fig. 15 a short distance east or west. Certain stations near the steepest part of the curve will have their residual anomalies altered by several milligals. Unfortunately there appears to be no certain criterion for the best regional curve. For this reason, the interpretations which follow are intended to satisfy the residual anomalies only within the margin of about four milligals.

In a very general way (and for the purpose of considering density distributions) the pre-Huronian geology of the Canadian Shield may be taken as consisting of comparatively narrow synclines of Timiskaming and Keewatin rocks, which are underlain and surrounded by granite and granite gneiss. The density contrast between the former rocks and the granite is about 0·25 grams per cubic centimetre, so that a considerable gravity

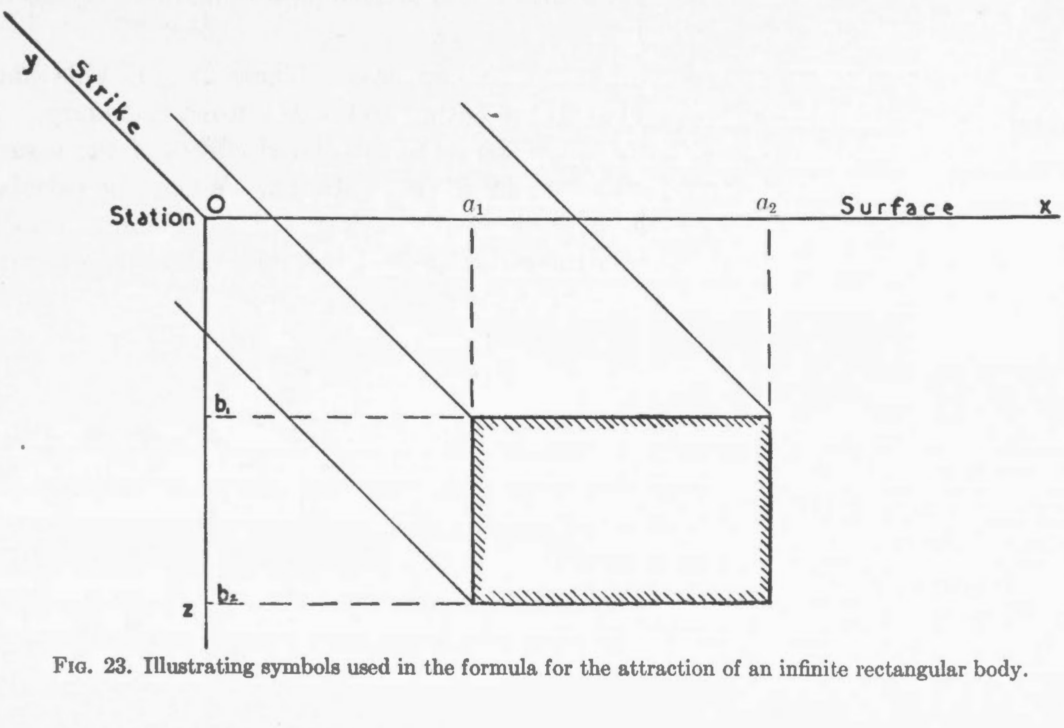


FIG. 23. Illustrating symbols used in the formula for the attraction of an infinite rectangular body.

anomaly may be expected over these synclines. Also, since the synclines lie at the surface, or at the most under a relatively thin layer of drift or sediments, a steep-sided anomaly curve may be predicted, with the edges of the denser rocks fairly accurately demarcated by the inflection points of the curve. It will be shown that along most of the traverses over the Canadian Shield of Ontario just this form of profile is met. In the case of a surface belt of Keewatin rocks (greenstone) of which the edges have been located by mapping, there is really only one unknown: the depth to the base of the Keewatin. Hence, if a good gravity profile is obtained over the belt, it should be possible to make a fair estimate of this depth. This has been attempted in the interpretations which follow. Presumably, such estimates may have some commercial application by giving an indication of the lower limit of ore zones in the greenstone. The other use that has been made of the profiles is the tracing of granite-greenstone contacts under drift, under the Cobalt sediments (near Ville Marie) and under the Palæozoic outlier of Lake Timiskaming (near Englehart).

With a fairly close spacing of stations an estimate may be made of the dip of contacts, and thus of the cross-sectional form of greenstone belts traversed. At present, however, the stations are barely numerous enough to allow such close interpretation, and the belts are treated as rectangles with vertical edges. The fact that curves calculated on this assumption satisfy the observed anomalies as closely as they do suggests that most of the Keewatin areas have steeply dipping edges.

The formula used for the attraction of a two-dimensional (i.e. infinitely long) rectangular body is a useful one. It is:

$$\Delta g = 2G\rho\left\{b_2\left(\tan^{-1}\frac{a_2}{b_2} - \tan^{-1}\frac{a_1}{b_2}\right) - b_1\left(\tan^{-1}\frac{a_2}{b_1} - \tan^{-1}\frac{a_1}{b_1}\right) + \frac{a_2}{2}\log_e\left(\frac{a_2^2+b_2^2}{a_2^2+b_1^2}\right) - \frac{a_1}{2}\log_e\left(\frac{a_1^2+b_2^2}{a_1^2+b_1^2}\right)\right\}$$

where the symbols are explained in the accompanying diagram (Fig. 23). Obviously, the formula can be much simplified for bodies at the surface ($b_1=0$), and for stations over the mid-point or edge-points of a body.

Local anomalies are considered along three traverses. These are (*a*) Ville Marie, (*b*) New Liskeard-Cochrane, and (*c*) from Port Arthur to the Manitoba Boundary. The results are illustrated in Figs. 24-27, which show the calculated effects of the assumed structures, together with the residual anomalies for each station. Where the calculated effects of bodies overlap, the resultant is shown by a dotted line. Known geological contacts are shown by solid arrows on the structure sections, while those inferred from gravity data alone are indicated by broken arrows.

(*a*) Ville Marie Traverse

In Fig. 24 are shown both the gravity and magnetic profiles running north from Timiskaming, P.Q., along route 46. The southern section of the traverse is over exposed granite but north of Fabre the surface rocks are largely Cobalt sediments (mostly Lorraine quartzite), often drift covered.

The gravity profile indicates two bands of denser rocks (presumably Keewatin lavas) underlying the Huronian. These are separated by a ridge of granite, evidently the westward extension of a granite batholith which is clearly exposed further east (G.S.C. Map

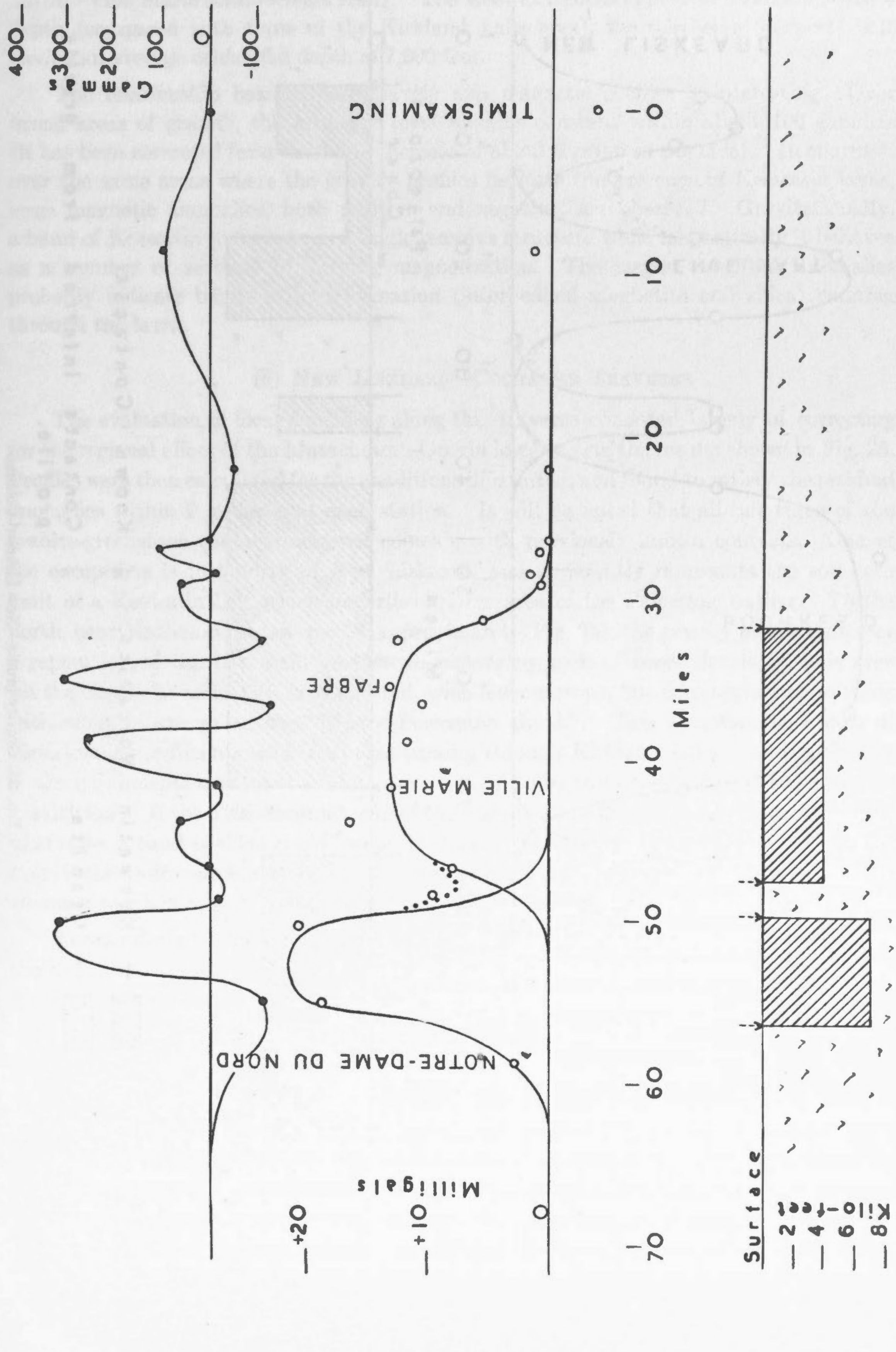


FIG. 24. Gravity profile—Timiskaming-Ville Marie-Notre Dame du Nord.

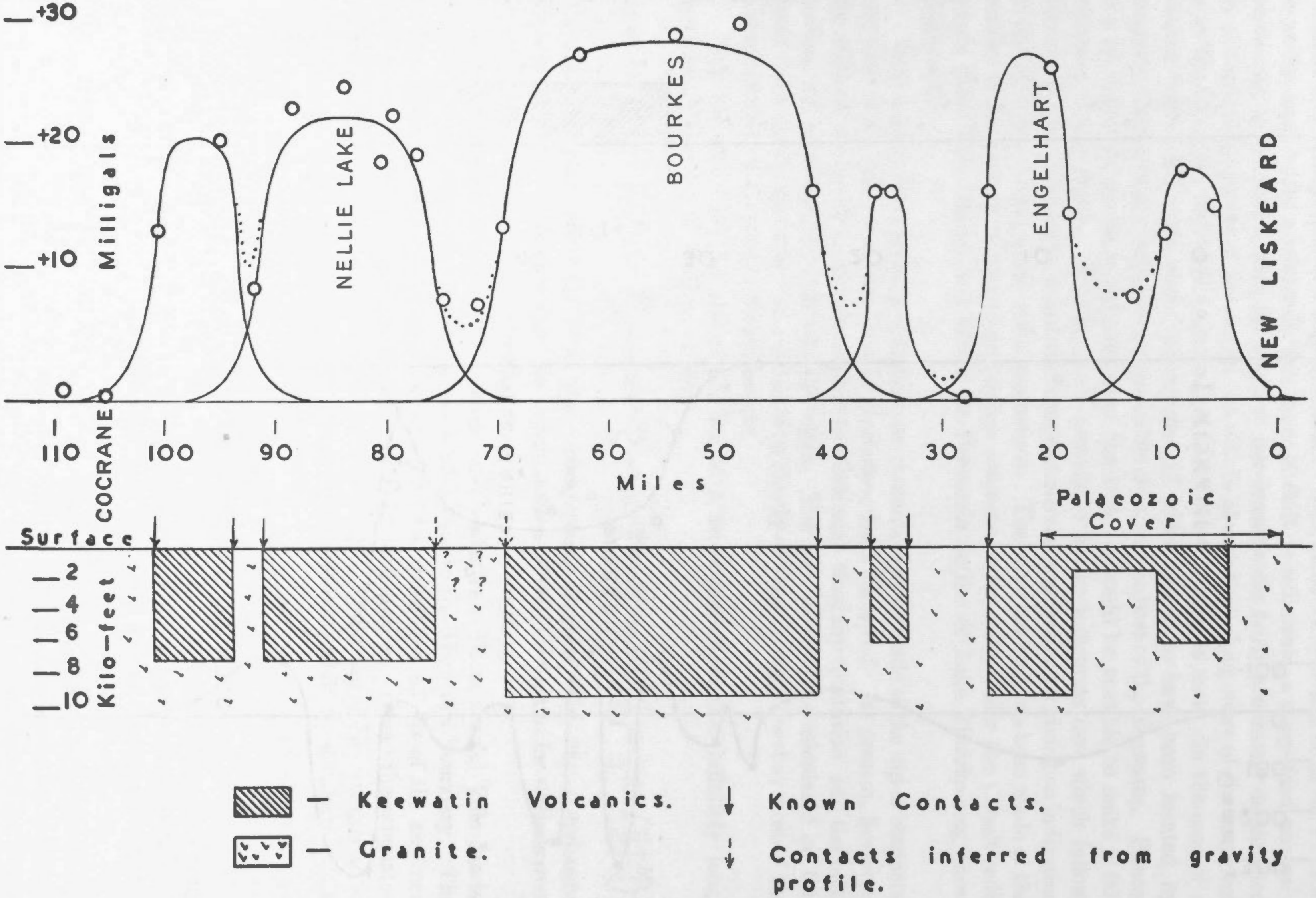


FIG. 25. Gravity profile—New Liskeard-Cochrane.

387 A—Ville Marie Sheet—West Half). The Keewatin rocks appear to reach a moderate depth (compared with those of the Kirkland Lake area), the northerly (deepest) belt having an average calculated depth of 7,000 feet.

The relationship between the gravity and magnetic profiles is interesting. Over broad areas of granite, the magnetic level remains constant within about 100 gammas (it has been corrected for a northerly increase of about 6 gammas per mile). In contrast, over the same areas where the gravity profiles indicate the presence of Keewatin lavas, large magnetic anomalies, both positive and negative, are observed. Gravitationally, a band of Keewatin rocks acts as a single massive structure while magnetically it behaves as a number of sections of varying magnetization. The largest magnetic anomalies probably indicate bands of iron formation (interbedded magnetite and silica) running through the lavas.

(*b*) New Liskeard—Cochrane Traverse

The evaluation of local anomalies along this traverse consisted largely of correcting for the regional effect of the Matachewan-Guerin low, leaving the results shown in Fig. 25. Profiles were then calculated for the conditions illustrated, and found to satisfy the residual anomalies within 2 milligals at each station. It will be noted that all but three of the granite-greenstone contacts adopted coincide with previously known contacts. One of the exceptions is just north of New Liskeard, and apparently represents the southern limit of a Keewatin belt which underlies a large area of the Palæozoic outlier. To the north, near Matheson (at mileage 73, approximately, Fig. 25), the gravity profile indicates a separation of the two main greenstone masses by rock of lesser density. This area (in the clay belt) is heavily drift covered, with few outcrops, but does appear to coincide with what is known as the "Destor-Porcupine Break". This structure is a belt of Timiskaming sediments similar to that passing through Kirkland Lake. As the density of these sediments is rather variable, there appear to be two explanations for the narrow gravity low. If the Timiskaming rocks of the region have a density little greater than that of granite, a band of them could extend to depth, and still give the profile shown. However, if the sediments have a higher density (as is often found) a ridge of granite must be assumed to reach upward toward the Precambrian surface along the course of the break.

The depths indicated for the Keewatin rocks along this traverse (about 9,500 feet for the broadest belt) are interesting, because of the associated gold deposits. This depth is the greatest for any such structure encountered on any of the traverses.

(*c*) Port Arthur—Manitoba Boundary Traverse

In Figs. 26 and 27 are shown the local anomalies and derived geological structure for a traverse from Port Arthur to the Manitoba Boundary (along Highway 17). A number of relatively narrow bands of volcanics, separated by wide areas of granitic rocks, are crossed. Even over the broad stretches of granite variations up to 5 milligals are noticed, as in the Vermilion Bay district. Some of these variations may be due to topography, but the most important factor is probably the varying density of what is

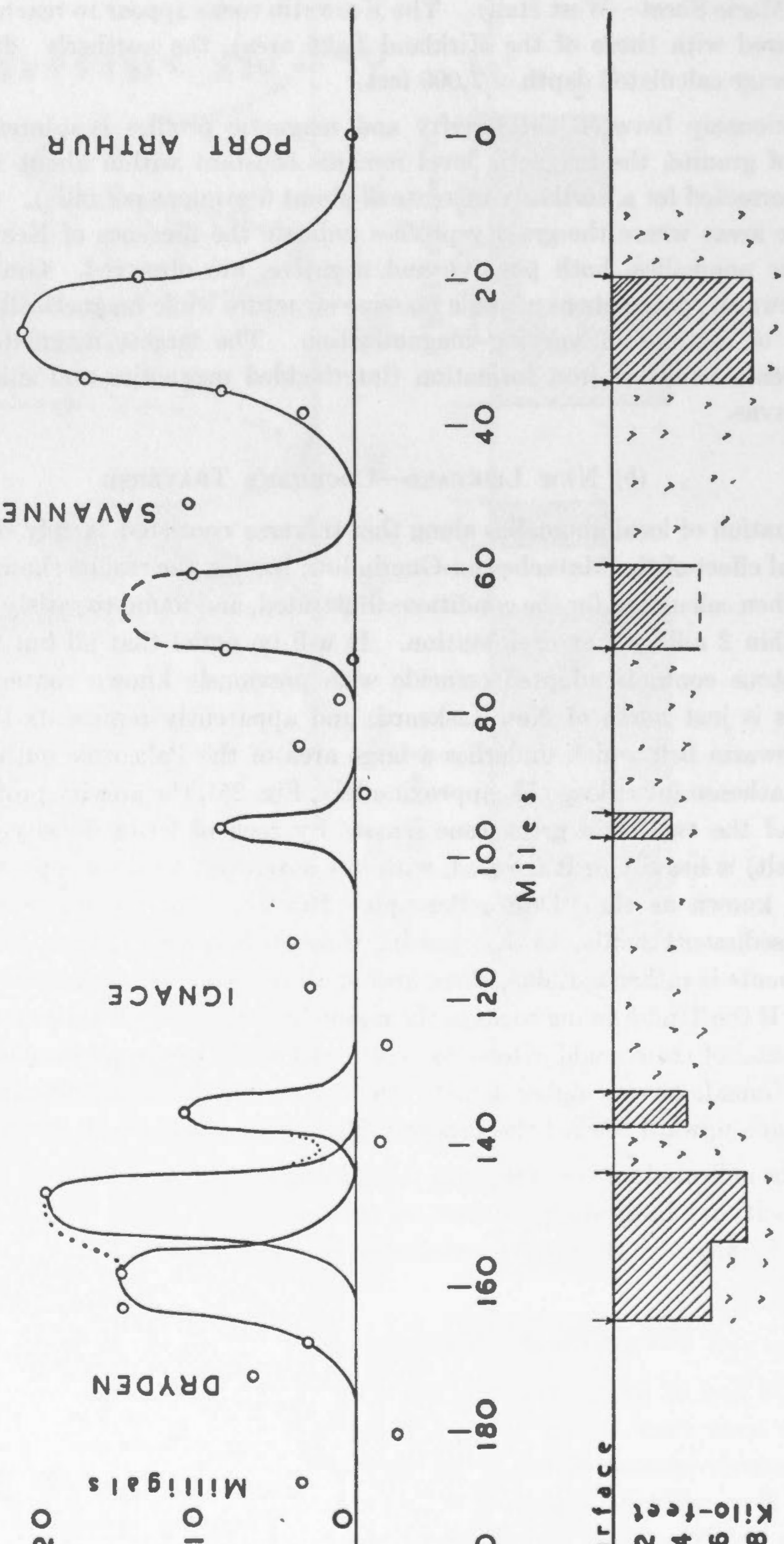


FIG. 26. Local gravity anomalies and derived geological structure—Port Arthur-Dryden.

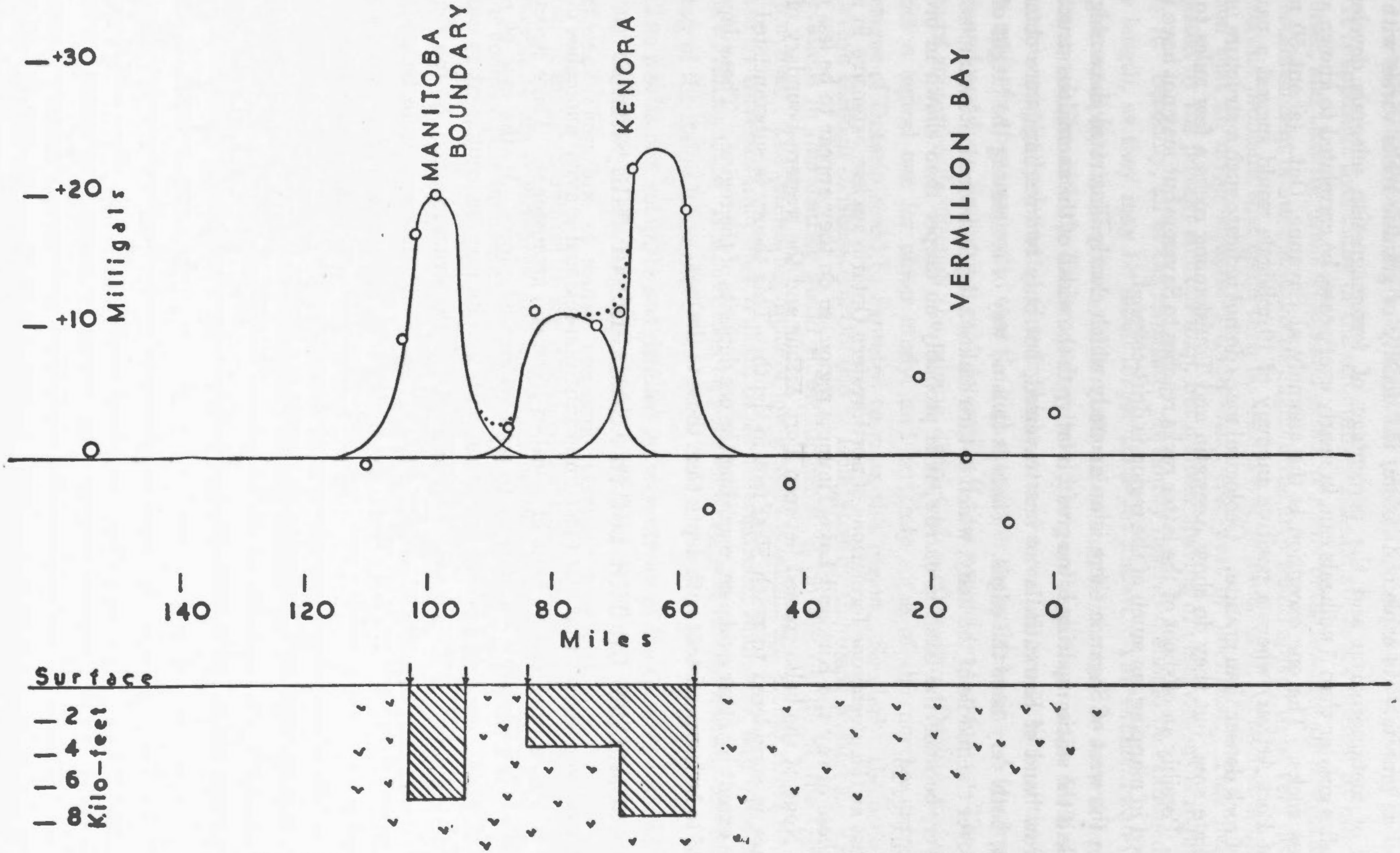


FIG. 27. Local gravity anomalies and derived geological structure—Vermilion Bay-Manitoba boundary.

mapped as granite. As explained before, the density of granitic rocks varies with the degree of metamorphism and the percentage of ferromagnesian minerals developed. Anomalies greater than 5 milligals can, in nearly every case, be correlated to known areas of dense rocks. The one exception is the anomaly at Savanne, Ont., (about 50 miles west of Port Arthur) where a positive anomaly of 10 milligals would suggest a narrow band of rock denser than granite. Geological maps do not indicate such a structure in the immediate area, but they do show Keewatin and Timiskaming rocks a few miles to the south. Possibly an offshoot of the latter rocks reaches to Savanne but may not have been observed in mapping, as much of the region is drift-covered.

To the west of Savanne there is an anomaly which clearly illustrates the ambiguity possible if the station spacing is too great, relative to the width of the anomalous structure. A narrow band of Keewatin lavas was traversed, but only two readings were obtained over it, both very near the edges. There is thus no way of estimating the height of the curve over the middle of the body, which in turn makes a depth determination impossible. However, because the band is narrow, it is probably no deeper than shown in broken lines in Fig. 26.

Just as the greenstone formations of northwestern Ontario are less extensive in area, than those of say the Kirkland Lake-Timmins region, so do they appear to be less deep also. None of the belts crossed between Port Arthur and the western boundary of the province is considered to reach 8000 feet in depth. This theory is substantiated to a certain extent by other evidence, regarding the ore deposits of the region. These deposits are said to be less persistent with depth than those to the east.

SUMMARY OF THE LOCAL ANOMALIES OF THE SHIELD

It has been shown that the most important non-regional gravity anomalies of the Shield are those produced by belts of so-called Keewatin greenstones. These structures have the necessary depth and density to produce marked effects. In the case of other rock types of the Shield the density contrast with granite may be insufficient to cause a measurable anomaly (e.g. the Huronian sediments) or the structures may be too shallow to be located (e.g. diabase sills). Gravity surveys would thus appear to be useful in tracing the limits of these greenstone areas under drift or later formations, with a good degree of reliability. From the profiles, an estimate may be made of the depth to the base of the greenstone.

Since the Precambrian basement underlying the covered Shield areas of southern Ontario and the Prairie Provinces consists of similar rock types to those in the exposed Shield, this same type of anomaly is to be expected in these areas. Across the Prairies, in particular, a number of anomalies of the order of 20 milligals, a few tens of miles broad, were obtained. It is probable that at least some of these represent bands of denser lavas in a generally granitic basement. Of course, since the Precambrian surface lies some thousands of feet beneath the surface of the Prairies, the anomalies do not exhibit the extreme steepness over the edges of the bodies, so characteristic of profiles over the exposed Shield.

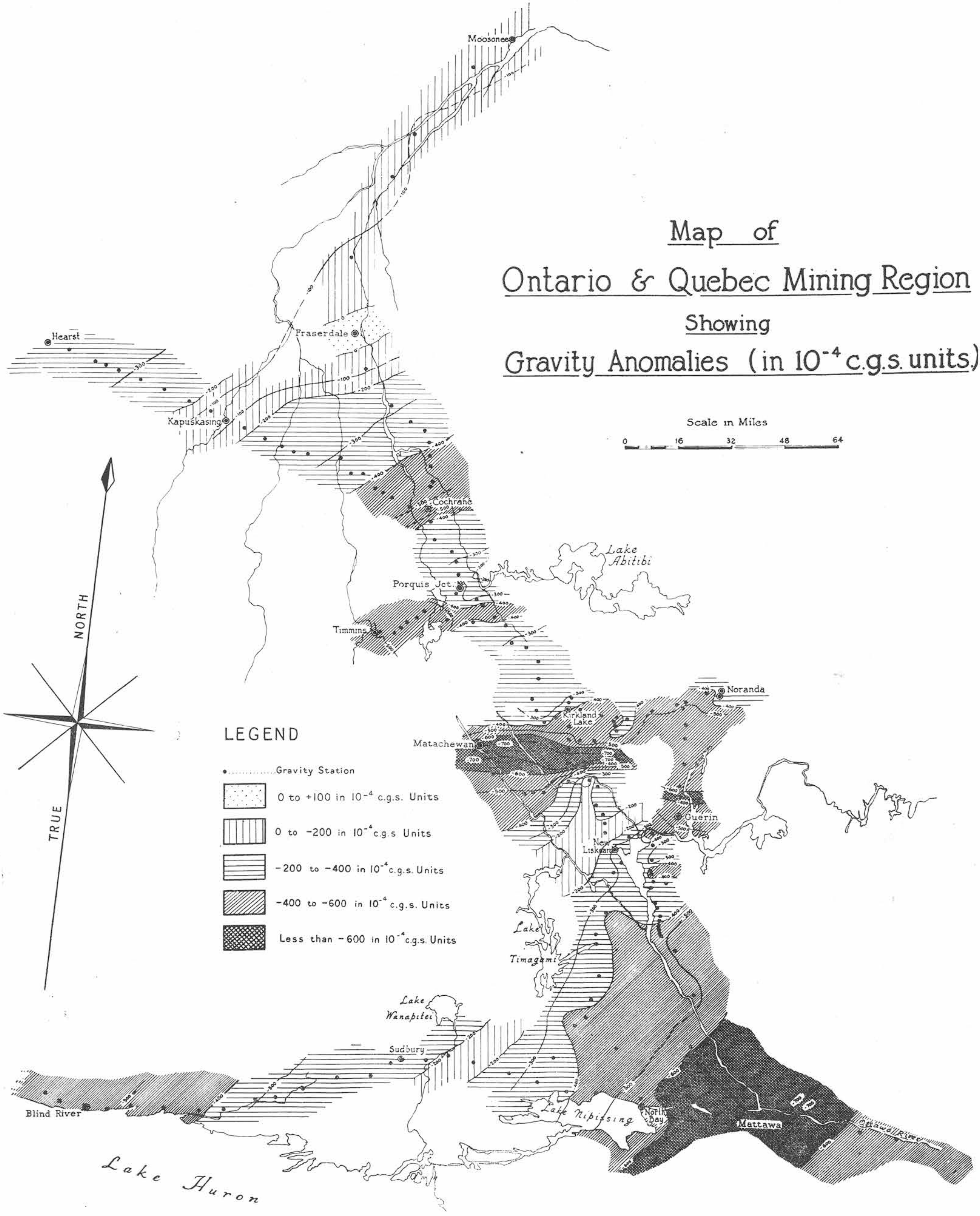
SUGGESTIONS FOR FURTHER GRAVITY MEASUREMENTS

It is apparent that many of the structures discussed above are defined by only a few traverses, and that the exact trends and extent of many of the features are not yet known. The establishment of more stations throughout the area would appear to be very desirable and certain problems that could then be settled will be mentioned. The first is the verification that all major structures trend either east-west or northeast. This has been suggested by the present contour map, but a closer spacing of observations is required to verify it. Secondly, all of the structures previously described should be examined along their length, as they may be much longer than yet known. The Matachewan-Guerin low, for example, is known to be at least 80 miles long, but it may be several hundred. Better correlation with the known geology would be possible if these major features were thus more completely defined. Gravity highs were observed in two sections of the Cobalt basin, and it has been suggested that the high may cover the entire basin. A few traverses north and east from Sudbury should determine if this suggestion is correct. The abundance of motor roads through the mining district of northwestern Quebec makes this district a logical one for closer study, and certainly some of the northeast trending structures of Ontario could be expected to cross this region. Similarly, the completion of surveys through southeastern Ontario is facilitated by the roads available. Gravity observations in this district would throw further light on the nature of the Grenville sub-province. The interesting areas of low gravity around Port Arthur could be better defined by traverses from Fort William to the International Boundary, and from Kenora to Fort Francis, Ont. It would then be possible to suggest further correlations with the geology of the Rainy River area.

The results of a complete and detailed gravity survey of the Canadian Shield would be very important in showing the crustal conditions associated with the great Shield structures. There are, of course, economic advantages to such a survey also. The tracing of major structures in the Shield automatically leads to the outlining of areas favourable to ore occurrences, and any fundamental research on these major structures is thus commercially important. In a more direct way, a complete picture of the regional gravity anomalies of the Shield would be invaluable to the geophysicist exploring for ore bodies with a gravimeter. It has been shown that certain of these regional trends exhibit surprisingly steep gradients, so that a gravimetric survey of even a small area might be confused by them if their regional nature was not realized. With a knowledge of these regional anomalies, the gravity interpreter could apply corrections to his observations, and thereby obtain a more accurate estimation of the smaller, commercially important anomalies.

ACKNOWLEDGMENT

The gravity anomalies discussed in this paper were observed, and largely calculated, by Mr. A. H. Miller and Mr. M. J. S. Innes of the Dominion Observatory, Ottawa. Their kindness in supplying these results made the preceding discussions possible. The author, however, accepts all responsibility for the geological interpretation of the data, and in this respect he wishes to thank Dr. J. Tuzo Wilson, Professor of Geophysics at the University of Toronto, for a great deal of assistance and encouragement in studying the geology of the Canadian Shield.


Map of
Ontario & Quebec Mining Region
Showing
Gravity Anomalies (in 10^{-4} c.g.s. units)
Scale in Miles
0 16 32 48 64
LEGEND
Gravity Station
0 to +100 in 10^{-4} c.g.s. Units
0 to −200 in 10^{-4} c.g.s Units
−200 to −400 in 10^{-4} c.g.s. Units
−400 to −600 in 10^{-4} c.g.s. Units
Less than −600 in 10^{-4} c.g.s. Units
TRUE NORTH
Moosonee
Hearst
Fraserdale
Kapuskasing
Cochrane
Lake Abitibi
Porquis Jct.
Timmins
Noranda
Kirkland Lake
Matachewan
Guerin
New Liskeard
Lake Timagami
Lake Wanapitei
Sudbury
Blind River
Lake Nipissing
North Bay
Mattawa
Ottawa River
Lake Huron