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SAINTE-AGATHE-SAINT-JOVITE MAP-AREA, PART C

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Énergie et Ressources naturelles
Québec

PROVINCE OF QUEBEC, CANADA

Department of Mines and Fisheries

Honourable ONESIME GAGNON, Minister L.-A. RICHARD, Deputy-Minister

BUREAU OF MINES

A.-O. DUFRESNE, Director

ANNUAL REPORT

of the

QUEBEC BUREAU OF MINES

for the calendar year

1935

JOHN A. DRESSER, *Directing Geologist*

PART C

QUEBEC

PRINTED BY R. PARADIS

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SAINTE-AGATHE-SAINT-JOVITE MAP-AREA

by F. Fitz Osborne[*]

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SAINTE-AGATHE-SAINT-JOVITE MAP-AREA

by F. Fitz Osborne

INTRODUCTION

The area mapped geologically lies between latitudes 46°0′ and 46°15′ North and longitudes 74°15′ and 74°45′ West and is in the Sainte-Agathe sheet of the Topographical Survey of Canada. Transportation facilities in the area are excellent. The Montreal-Mont Laurier highway (route 11) crosses it obliquely from the southeast to the northwest corner. Other highways pass through Saint-Rémi d'Amherst, Lachute, Saint-Donat, and Saint-Adolphe, and there are many second-class and waggon roads leading to the various lakes. The Canadian Pacific railway (Mont Laurier line) enters the map-area near Sainte-Agathe and leaves it at the northwest corner. The Rouge and its tributary, Du Diable river, run from north to south in the western part of the map-sheet.

Lumbering and farming are the principal industries on which the population depend for a livelihood, but the area is popular both as a summer and winter playground. The number of summer cottages along the lakes, and of summer boarding-houses, as well as hotels open summer and winter, attest to the popularity of this section of the 'Laurentians'.

Sainte-Agathe is the largest town in the area (population, 1931 census, 2,949). Incorporated villages are Saint-Jovite (population 981), and Saint-Faustin Station (population 396).

Acknowledgments

The writer is indebted to the Topographical Survey of Canada for aeroplane photographs of the area and for the loan of a stereoscope for use in studying them. The Topographical Survey also supplied the base for the geological map accompanying this report, but the writer made some modifications based on observations during the geological work. Yvon Cousineau ably assisted the writer in the field.

Previous Work

The earliest work in this area was by W. E. (Sir William) Logan, first director of the Geological Survey of Canada. Soon after the establishment of the Geological Survey, in 1843, he began an investigation along the north side of the Ottawa river, and subsequently carried his work farther northward. Various interim reports were published in the *Reports of Progress* of the Geological Survey, and finally a coloured map was issued in the Atlas accompanying *The Geology of Canada* (1863). This map shows the distribution of formations over much of the present map-area, but, unfortunately, Logan— sharing the opinion current in his time — believed that the banded rocks or gneisses were derived by metamorphism from sedimentary rocks, and used great ingenuity to fit the irregularly disposed igneous intrusions into a sedimentary column. This detracts greatly from the value of the map In 1897, the Geological Survey of Canada issued a map (No. 590) covering about 3,550 square miles of the area north of the island of Montreal. This was based on several seasons' field-work by F. D. Adams (1), in the course of which all the area lying east of Saint-Jovite on the present map-sheet was covered. Adams recognized that certain of the rocks, such as the anorthosite and granite gneisses, are really of igneous origin, and he thus discarded part of the classification used by Logan. His map in this area, however, shows the limits of only three formations, *viz.*, limestone of the Grenville series, gneisses of all origins, and the anorthosite. The limestones were chosen for delimitation on the map because of the importance of the lime that might be derived from them to modify the soil of some of the farm-lands that were being opened-up at that time. They are not the best member of the Grenville series for use in showing the structure, because, as a result of folding, they have been thickened or thinned, or even in places entirely removed, and now appear as bands of pronouncedly lenticular habit. Furthermore, being less resistant to erosion than the adjacent formations, they commonly underlie drift-filled valleys. This map, however, was a great achievement, not only for the recognition of the true character of the gneisses, but also because of the large area covered when the country was much less easily accessible than at present.

The writer has mapped an area (2) north of the west half of the present sheet, in which the geological relationships are broadly similar, although two formations (Lacoste series and nepheline syenite) found there were not recognized in the present area. In addition, two small areas to south of the present sheet have been mapped (3).

PHYSIOGRAPHY

If the topography of the map-area be observed from the summit of one of the higher hills, such as Montagne-Tremblante, the first impression is that the numerous rounded hills rise to about the same elevation and thus indicate the level of an old erosion surface; but closer observation shows that, here and there, hills, or groups of hills, rise above the general level. Such hills are known as monadnocks, and several may be seen, at various distances from the point of observation, rising above the peneplain defined by the summits. Mount Sir Wilfrid, near Ferme Neuve, is a prominent example, and there are others close to the Ottawa

(1) ADAMS, F. D., *Report on the Geology of a Portion of the Laurentian Area lying to the North of the Island of Montreal*, Geol. Surv. Can., Ann. Rept., Vol. VIII, Part *J*, 1895.
(2) *Labelle-L'Annonciation Map-Area*, Que. Bur. Mines, Ann. Rept., Part *E*, 1934.
(3) OSBORNE, F. Fitz, *Commercial Granites of Quebec: Part II.— Rivière à Pierre, Guenette, Brownsburg, and Other Districts*, Que. Bur. Mines, Ann. Rept., Part *E*, 1932.
WILSON, M. E., *Magnesite Deposits of Grenville District, Argenteuil County, Quebec*, Geol. Surv. Can., Memoir 98, 1917.

river on the west. Such monadnocks, in general, owe their elevation to the fact that they are composed of formations resistant to erosion, or to the fact that they were situated in interstream areas unfavourable for their degradation.

The monadnock of which Montagne-Tremblante is one part is the highest of any in the western Laurentian area in Canada and is made up of many hills — Montagne-Tremblante, Black mountain, and others unnamed (see Plate III.-D). It extends southward into the Sainte-Agathe-Saint-Jovite map-area from the Labelle-L'Annonciation sheet and eastward for about 20 miles from Montagne-Tremblante lake. This block of hills covers more than 200 square miles.

Along the Rouge river and the part of Du Diable river below Saint-Jovite, another surface may be seen defined by the summits of the hills. It is 200 to 300 feet below the level of the principal peneplain and is invariably close to the river. It represents an erosion stage when the rivers were higher than at present but were entrenching themselves in the old peneplain surface. The edges of this erosion surface slope up to the old surface just as the sides of monadnocks rise above the principal peneplain surface.

There are few data on which to base any determination of the relative ages of the several features described. It is certain that the Laurentian mountains were worn down to a uniform surface, with perhaps a few upstanding monadnocks, at a time preceding the deposition of the Potsdam sandstone of Cambrian age, and it is generally assumed that the remnants of the peneplain seen at present are largely of this age. This assumption is based on the possibility that lower Palæozoic rocks once covered this part of the Laurentians and were removed in such late geological time that the surface has been only insignificantly modified by the subsequent action of ice and running water. However, there is no evidence that Palæozoic rocks ever existed in the present map-area; the nearest locality at which they are found is at Écho lake, near Shawbridge, about 14 miles from the nearest corner of the map-sheet and 36 miles from Montagne-Tremblante. Had Palæozoic rocks ever been deposited here, it might be expected that remnants would persist on the higher elevations, such as Montagne-Tremblante, but neither rock in place nor boulders that could be attributed to any Palæozoic formation were found in the map-area. Such evidence is negative, but it is possible that the erosion surface indicated by the summit levels may be of post-Potsdam rather than pre-Potsdam age. Any evidence for such an age is indirect. It has been suggested that the Monteregian hills, which are ranged across the Saint-Lawrence lowlands near Montreal, record in their summit levels an old erosion surface. The writer has shown elsewhere the strong probability that the igneous rock of the Monteregian hills may be as young as early Tertiary, so that, if such an erosion surface exists, it must be more youthful than this. It is possible that a Tertiary erosion surface extended into the Laurentian area, and the peneplain may be of late date but carved on a still older erosion surface.

The altitudes of the hill summits close to the Rouge river may be accounted for as a result of a cycle of erosion younger than the peneplanation — a cycle that did not have sufficient time to reduce the terrane to a new peneplain, but which nevertheless reduced a belt six miles wide to a level two to three hundred feet below that of the surrounding country. This erosion cycle is probably relatively young and may antedate only the last glaciation.

Glaciation

The ice sheets of the Pleistocene modified the topography very much in detail, but did not affect the larger features very greatly. In this area, no evidence for more than one glaciation, such as the presence of weathered till overlain by fresh till, has been found. The outlines of many of the hills have been rounded, and on some of the higher hills steep-walled valleys have been cut. The principal effect of the glaciation, however, has been derangement of the old drainage, and the deposition of glacial and fluvioglacial material over much of the area. On account of the height of the monadnock block near Montagne-Tremblante, the ice probably was unable to advance over a uniform front: tongues of ice, augmented by the snow precipitated on the slopes of the hills, probably first occupied the major valleys and flowed in a general southerly direction. Erratic boulders and ice scars on the summit of Montagne-Tremblante attest that, at the height of the glaciation, this peak was entirely covered by the ice-sheet, which presumably, therefore, covered the whole of the map-area, since Montagne-Tremblante marks its highest elevation. At this stage, the ice was moving S.25°E., as recorded by the striæ on hill summits and by the direction of elongation of *roche moutonnée* surfaces. In the waning or wasting stages of the glaciation, the ice-front did not melt back uniformly, but, here and there, irregular patches of ice remained stranded, and tongues of ice took the place of the ice-sheet. The direction of movement of these ice tongues was commonly in the direction of the valleys, and the striæ due to such tongues are, in some places, inclined as much as 90° to the earlier direction of ice movement. Ground, lateral, and terminal moraines that may be attributed to the ice tongues and stranded ice are found in many places, and irregularly-disposed deposits of muds, sands, and gravel were deposited against them from the water derived from the wasting of ice. Many temporary lakes dammed by ice were formed, and some with dams of morainic material have persisted to the present. Elsewhere, blocks of stagnating ice were surrounded by fluvioglacial deposits, and the basins resulting from the melting of the ice are now filled with water. It is unnecessary to mention the names of the kettle lakes in this area, but one temporary basin of deposition is of interest on account of the considerable altitude at which such fluvioglacial deposits were formed. Between Ivry and Sainte-Agathe, sand dunes are found on the tops of some of the higher hills. The dunes have resulted from the work of the wind on sand deposits formed in a temporary lake in which sand was deposited on a surface of till. With the draining of the lake, the dunes were blown up and then fixed by the growth of vegetation, although subsequently modified by running water. In some cases, the deforestation of the 'fossil' dunes has been complete in that the sand is again drifting, and, in one instance, threatens to overwhelm a farm.

The deposition of the till and fluvioglacial deposits naturally affected the course of the streams. Some were blocked and sought new channels. Others were able to cut through the unconsolidated material deposited in their valleys and to terrace it. There are many instances of streams flowing in north-south valleys which, in cutting through the deposits in their channels, have captured the drainage of east-west flowing streams. In most of such cases, the capture was relatively soon after the ice retreat, as the valleys of the streams so captured show little evidence of modification by running water.

As already mentioned, the area included by the map is a favourite summer and winter resort. Its popularity as a summer resort is largely the result of the glaciation. The many small lakes have resulted from filling of depressions gouged out by the ice or occupy valleys dammed by deposits left by the ice. The ice has also steepened the walls of some of the valleys and enhanced the ruggedness of the topography. There are several geological reasons for the choice of the area north of Montreal for skiing and other winter sports. In the final analysis, their suitability for such purposes is due principally to the great resistance the rocks of the Morin series and the red granite gneiss have offered to erosion. These formations are relatively massive and have formed the huge monadnock that occupies a large part of the area mapped. It is well known that drift deposits are likely to be thicker on the south, or lee, side of any obstruction in the path of a glacier, and the large monadnock has behaved in precisely the same way as would a smaller obstruction. On the southern slopes, the deposits of till are thicker than elsewhere and mantle the surface of the hills, giving uniform and sweeping profiles very suitable for winter sports. In addition, the monadnock served to deflect the ice from the area in its lee. Thus, in the declining stages of the glaciers, the ice was thinner there than in the unprotected places, and the deposition of fluvioglacial material contributed further to the smoothing of the topography. The massive character of the anorthosite allowed a topography of relatively coarse grain to be developed, so that the slopes to the valley are long and fairly gentle. Furthermore, the fact that the monadnock was high allowed ice to move out from it as tongues along some valleys, eroding the latter and giving them considerable relief. The character of the country is thus the result both of erosion, and of deposition from ice and running water, on relatively resistant formations.

Glacial and Fluvioglacial Deposits

Several classes of deposits from ice and the water flowing from it may be recognized in the area. The most widespread is till or boulder-clay. In part, this is the material left on the ground as the ice melted, and consists of finely ground material and coarse gravel with blocks of rock. Till is also the material of which some of the lateral and terminal moraines are made, but in the majority of such moraines in the area, the presence of water modified the till, so it grades in character toward the fluvioglacial type of deposit. As an example of unmodified till, the ridge forming the hog-back between the several peaks on Montagne-

Tremblante may be cited. The exact thickness of this till is unknown but is probably considerable, and blocks of rock recognizable as derived from formations found in the map-area to the north are common, although the deposits are found at elevations in excess of 2,800 feet. In places, glacial and fluvioglacial deposits have mingled: for example, on the south slope of Montagne-Tremblante, at about 2,200 feet elevation, unusual-appearing land forms, resembling to some extent irregular river terraces, are probably kame terraces. These represent deposits formed by till washed from the mountain slopes and mingled with morainic material after the summit of the mountain was free of ice.

Sands and gravels are widespread along the main valleyways and in subordinate valleys that acted for a considerable time as spillways for the water from melting ice. Along some of the streams, the deposits have been cut into terraces, but other valleys are still filled with sand and gravel to considerable depths. Some of the sand and gravel deposits have kettle lakes formed in them where entrapped ice has melted and formed depressions. A few poorly-developed eskers are seen in the area.

Varved clays are found, at elevations below 725 feet, underlying sand and gravel (Plate III.—A and B). This upper limit of the varved clays is in agreement with Wilson's determination of the upper level of the Champlain submergence in this district (1). The varved clays are restricted to the principal valleys, such as that of the Rouge. They consist of thin beds of clayey material interbedded with slightly thicker beds of material richer in sand. Such clays have been the subject of much study, and it has been concluded that they are formed in fresh-water lakes, and that the thinner clay bands represent winter conditions, and the thicker, sandy layers the deposits formed during the wasting of ice in the summer. The two beds taken together represent the deposition during one year. The beds are not horizontal, as one might expect them to be, but show dips as great as 10°, which may be the result of slumpage of the beds. Crumpling of some beds without disturbance of adjacent beds is also a common feature.

There is no evidence that marine water ever reached so far north as this in post-Pleistocene time: shells were not observed in either the clays or the sands. The upper limit of submergence by the Champlain sea, as indicated at Mount Royal and in the Arnprior-Quyon area, would suggest that, at the time of maximum submergence of the area, some water could have extended from the sea up the principal valleys into the Sainte-Agathe-Saint-Jovite area; but if so, the great volume of water from the melting ice may have been able to maintain fresh water in these temporary lakes or arms of the sea.

BEDROCK GEOLOGY

Grenville Series

The oldest and only metasedimentary series recognized in the Saint-Jovite map-area is the Grenville. The name was given by Logan on

(1) Wilson, M. E., *Arnprior-Quyon and Maniwaki Areas, Ontario and Quebec*, Geol. Surv. Can., Memoir 136, 1924, p. 14.

account of the occurrence of this series a short distance north of the town of Grenville, in the township of Grenville, which locality is 40 miles south of the present map-sheet. It is possible to trace the series from the type locality into this sheet, as was done by Logan, so there is no reasonable doubt that the rocks here called Grenville really belong in this series. The Grenville series in this and in the type area is complexly folded, so that it is difficult to get any notion of the true thickness or succession of beds. In some localities, the thickness has been estimated to be 90,000 feet or more, but in the writer's opinion this is a considerable over-estimate, for which the complexity of folding is responsible. The true thickness does not appear to be in excess of 20,000 feet. In the region from the Morin anorthosite on the west to the Saguenay on the east, the series is much more openly folded than here, and it is possible to gain some notion of the succession of beds. If the writer's interpretation is correct, massive amphibolites, probably derived from basic tuff or lava, are overlain by quartzites with associated sillimanite gneisses, which grade upward into sillimanite gneisses with little quartzite, and thence into the limestones of the upper part of the series. Depending on the folding and depth of erosion, different members of the series are found as the principal outcroppings in any district. Thus, in the township of Grenville, limestones are abundant and have given an impression of the predominance of these members; in other places, quartzites are common and much exceed the limestones in amount; or, again, sillimanite gneisses are found; or, less commonly, the lower amphibolitic beds are the principal formation exposed.

If the above succession of formations is taken as characteristic of the Grenville, it is possible to suggest some structure in the series as it occurs in the present area, from observations on the changes in the lithology in crossing the regional strike. The amphibolites, which are assumed to represent the lowest formation of the series, are not common, but they occur in some force in the thick Grenville section south of Lac Simon, on the western side of the present sheet. This part of the series may represent an anticline overturned to the east. In most places, the intrusions of igneous rock are so numerous, and have moulded the remnants of Grenville on themselves to such an extent, that it is useless to try to determine the structure of the Grenville series. It is probable, however, that in this area it is generally synclinal with a plunge to the south, with the beds belonging to the lower sedimentary part exposed.

In the area mapped, the Grenville has survived largely as remnants enclosed by the various plutonic rocks, or in the form of screens separating the members of different series. In the western part of the map-sheet, the Grenville is more abundant than on the east, and it is probable, therefore, that the series is better developed in the area immediately to the west than it is in the area here dealt with. Although the Grenville is not abundant, it deserves careful examination, as the series is likely to contain metallic and non-metallic mineral deposits.

The crystalline limestones of the Grenville series have been the subject of study since the early days of the Geological Survey of Canada. It was this member of the series that was traced by Logan on account of the desirability of finding local sources of lime for agricultural purposes.

Furthermore, the formation does not offer great resistance to erosion and, as a consequence, it underlies the valleys along which the farms were first developed, and occurs along the river channels which were the first part of the country to be explored. In the area mapped, the quartzites are nearly as abundant as the limestones, and they are equally distinctive. They, however, tend to form rounded hills which have but a thin mantle of till and vegetation and thus are unsuitable for agriculture. The outcrops are likely to be more continuous than those of limestone and many of the bands retain their integrity in the igneous rocks in which they are included.

The dark coloured members of the series are sillimanite gneisses, sillimanite-garnet gneisses, and amphibolites. They are of less distinctive appearance than the crystalline limestones and the quartzites and are commonly injected by so much igneous material that much of the original character is lost.

Montagne-Tremblante Gneiss

Adams gave the name Montagne-Tremblante Gneiss to the fine-grained gneiss forming the mass of Montagne-Tremblante. The gneiss is similar to that termed 'fine-grained rose granite gneiss' by the writer in his report on the Labelle-L'Annonciation sheet to the north of this (1).

In hand specimen, the rock is typically pink to pale rose, but in places it is of a deep-rose or brownish cast. In most exposures, the gneissic structure is inconspicuous because of the fine grain of the stone and the low content of dark minerals, but close observation shows a pronounced gneissic structure, commonly striking slightly west of north and having a steep dip. The large outcrops are typically rather homogeneous in character, but drawn-out inclusions of amphibolite and of quartzite derived from the rocks of the Grenville series interrupt their uniformity in a few places. A structure which is either the result of deformation of the gneiss, or is inherited from Grenville beds that have been almost entirely incorporated, may be seen in a few places. This takes the form of anticlines and synclines of small dimensions that may be traced on the weathered surface of some outcrops due to slight differences in the proportions of the minerals making up different bands of the gneiss. The fact that the only inclusions observed in a large part of the mass are of quartzite and a pyroxene-bearing amphibolite would perhaps be evidence that this structure is due to the practically complete incorporation of some members of the Grenville series in the magma.

The microscope shows that microcline, sodic plagioclase, and quartz together make up 90 to 96 per cent of the rock. Biotite is the only common dark mineral, although an occasional crystal of hornblende may be seen in thin sections of specimens taken near one of the inclusions of pyroxene-amphibolite. Adams has emphasized the granulated texture of the rock, but this is not characteristic of all the outcrops. In some places the texture shows a gradation toward the aplitic, similar to that

(1) *Labelle-L'Annonciation Map-Area*, Que. Bur. Mines, Ann. Rept., Part *E*, 1934.

of the granite from Guenette (1), but the Montagne-Tremblante gneiss does not contain allanite or zircon — minerals that are invariably present in the Guenette granite, both in the type locality and in the Labelle-L'Annonciation area, where fine red granite gneiss is developed along with the Guenette granite.

Adams has given the following chemical analysis, by W. C. Adams, of the gneiss. The specimen analysed was apparently a trifle richer in dark minerals than those collected by the present writer.

SiO_2	69.24
Al_2O_3	14.85
Fe_2O_3	2.62
MnO	0.45*
MgO	0.97
CaO	2.10
Na_2O	4.30
K_2O	4.33
Loss on Ign.	0.70
	99.56

Morin Series

Anorthosite:

Adams, in mapping the present area, gave the name *Morin Series* — from the township of that name — to the complex of rock, including gabbro and anorthosite, found in this area. He included in the series also certain rocks which are neither gabbro nor anorthosite, but the term *Morin* may be conveniently extended to cover all the rocks of this group. In practice, it has been so used, for examination of many areas mapped as 'Anorthosite' shows that the rocks are really the quartzose members of the Morin series described in the next section of this report. Anorthosites are of widespread development in the Canadian Shield, particularly in the Laurentian area. The massif in Morin township is the best studied of the larger masses and has particular economic significance because of the deposits of ilmenite, and of magnetite with ilmenite, found in places in it.

Most of the anorthosite is a coarse grained, or very coarse grained, rock, although in a few places it is medium grained. In either case, it consists of plagioclase feldspar almost to the exclusion of other minerals; but hypersthene, augite, biotite, ilmenite, orthoclase, apatite, and quartz are found in places, together making up from 5 to 10 per cent of the rock. By an increase in the amount of dark minerals the anorthosite grades into gabbro, and with increase in the amount of orthoclase and quartz into other members of the series, to be described later in this section.

The structure of the anorthosite is complicated, and it was found very difficult to separate the primary structural planes from those developed by shearing later than the consolidation of the anorthosite. Near the edges of the mass, the primary structures appear to dip steeply

(1) Osborne, F. F., *Commercial Granites of Quebec, loc. cit.*

* As in many of the older chemical analyses, the MnO is probably too high.

outward, but in the centre the dips are low and reversals are common. However, the whole massif is cut by nearly vertical shear planes of later development than the consolidation of the rock, parallel to which the anorthosite is granulated and along which the valleys have been etched, giving the polygonal pattern bounded by drift-filled valleys seen on the topographical map. Allanite-bearing granite-pegmatite dykes have been introduced along some of these shear planes and have themselves undergone shearing. The significance of the shear planes is uncertain, but they may have some bearing on the distribution of the titaniferous ore deposits.

The plagioclase of the anorthosite is not everywhere of the same composition, but that of most specimens falls between a medium-calcic labradorite (An60) and a medium-calcic andesine (An40). The varieties are not haphazardly arranged, but no useful purpose would be served by trying to delimit the several types. The anorthosite with the more sodic feldspar shows a greater content of dark minerals, quartz, and orthoclase than do the more calcic types.

QUARTZOSE ROCKS OF THE MORIN SERIES:

The quartzose rocks of the Morin Series include the formations numbered 4, 5 and 6 on the map of the Labelle-L'Annonciation Area (Que. Bur. Mines, Ann. Rep., Part *E*, 1934).

Microscopic examination of many of the quartz-bearing rocks of the area shows them to have characteristics that relate them to the anorthosite. This is principally shown by gradations in mineralogical composition and by the succession of the several types as seen in exposures in the field. For example, along the road from the north end of Caribou lake to the Takiteeze club, one passes from anorthosite low in dark minerals through rocks with increasing content of dark minerals to quartzose and orthoclase-bearing rocks that may be termed granite. Similarly in the microscopic examination, members connecting the anorthosites with the granites may be found.

The medium-quartzose rocks are green on the fresh surface but weather buff. The more acidic rocks are likely to be of coarse grain and of a buff colour, weathering to light buff on the surface. The very potassic granites are mauve or pink and of coarse grain. The intergradations make the field separation of the varieties of considerable difficulty, and for the purposes of the map accompanying this report the several members are grouped. Another reason for grouping them is that there are few data that would suggest different economic significance may be attached to the different members.

The mineralogical variation in the several members of the Morin series as a whole may be shown by the accompanying schematic representation (Figure 1). Practically all the rocks of the series fall into this scheme, in which the vertical lines represent the mineral composition of the rocks. The only rocks not included in the scheme are the pyroxene syenites and the hypersthene granites, which are relatively unimportant in the present area. A number of unusual rock names might be applied

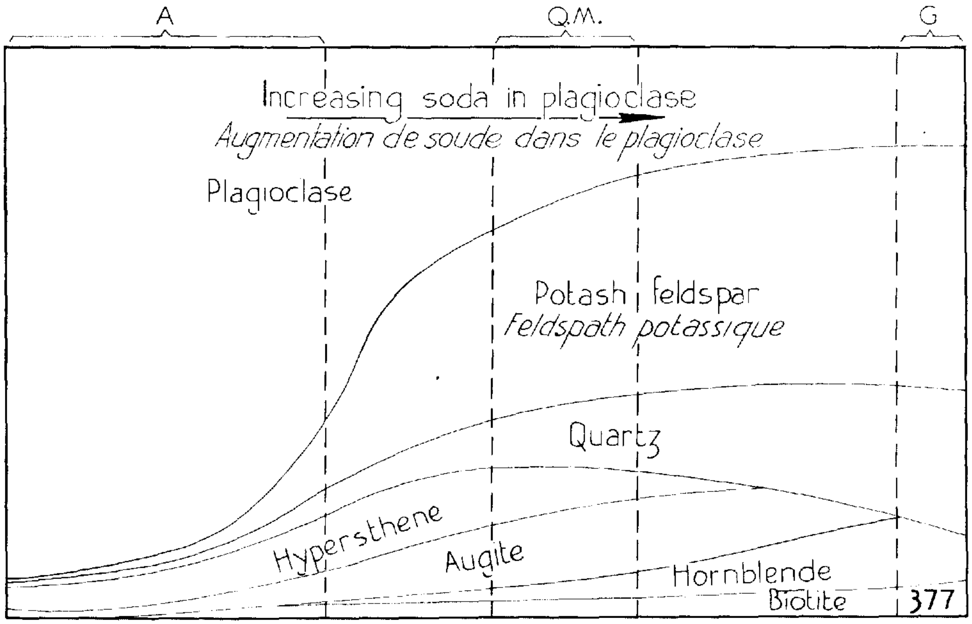


FIGURE 1.— Schematic representation of the rocks of the Morin Series.

to the several varieties, but no useful purpose would be served by giving them here.

DIABASE DYKES

At several localities in the map-area, diabase dykes were observed to cut the other formations described. None were noted in the anorthosite, but near Saint-Jérome and New Glasgow several were seen. The only rocks in the region known to be younger than the diabase — if all the diabase is of the same age — is the stock in Chatham and Grenville townships to the south of the Saint-Jovite area (1). No particular economic significance can be attached to the diabase dykes of this area, and for that reason they were not traced. In general, they strike east and west and are nearly vertical. In places, the dykes are observed to be apparently displaced to north or south of their linear projection. This may perhaps be due to faulting, but it is more probable that the dykes, although occupying the same east-west zones, are discontinuous, no evidence for a fault being observable except the apparent offset of the dyke. In some of the zones, the main dyke is observed to be split into a number of smaller dykes having the same trend as the larger. The writer did not see any dykes of this character in the area mapped by him to the north of the Saint-Jovite sheet, but, as shown by Logan,

(1) OSBORNE, F. F., *The Chatham Grenville Composite Stock, Quebec*, Trans. Royal Soc. Can., Vol. XXVIII, Sect. IV, 1934, pp. 49-64.

they are plentiful near the edge of the Laurentian area to the south of Saint-Jovite. One diabase dyke is found southeast of Lac Ouimet and is the northernmost observed.

The diabase dykes are less than 100 feet wide and therefore are too narrow to be useful as a source of black granite, or to be the parents of ore-bodies such as are found associated with diabase in some regions.

Age Relationships

The relationship in the age of the formations is a vexed question. The Grenville series is the oldest group. The red granite gneiss is intimately associated with the Grenville and may be the next younger series. At the south end of Lac Archambault and near the northeast corner of the map-sheet, a rose granite gneiss with all the quartz of opalescent character is found. A similar opalescence of quartz is found in inclusions of quartzite in the anorthosite and was observed by the writer near the south edge of the anorthosite massif at Morin Heights. The change in the colour of the quartz is assumed to be due to the anorthosite, and if the red granite gneiss is the same as the Montagne-Tremblante gneiss, then the anorthosite is younger than it.

Although, in places, the anorthosite appears to grade into the quartzose rocks of the Morin series, at a locality south of lake Supérieur the anorthosite is cut by the more acidic facies. This fact does not invalidate the conclusion that the anorthosite and the quartzose rocks belong to the same series, for it is a common phenomenon for the more acidic members of a series to cut the more basic. Across the road from Sunnybrook farm, south of Saint-Jovite on the Saint-Jovite-Lachute road, Montagne-Tremblante gneiss is observed to be cut by a granite believed to belong to the Morin series.

All the rocks described in the preceding section are cut by the diabase dykes, and no crystalline rocks younger than the diabase were observed in this area.

Ages of Igneous Sequences:

The determination of igneous sequences present in any area of Precambrian rocks in Canada is of more than academic significance: it is generally accepted that most ore deposits, particularly those containing copper, gold, lead, and zinc are related in origin to igneous rocks, and it is advisable to enquire into the possibility of the series that have given rise to ore deposits in other districts being represented in the Sainte-Agathe-Saint-Jovite map-area.

The data presented in preceding sections of this report would indicate that two principal igneous series (1) are present, *viz.*, Montagne-Tremblante gneiss and Morin series. It remains to enquire what mineral deposits might be expected near each.

(1) Buddington, from a study in the northwestern Adirondack region in New York State, believes two series are represented there also. Buddington, A. F., *Geology and Mineral Resources of the Hammond, Antwerp, and Lowville Quadrangles, New York State*, Mus. Bull. 296, 1934, pp. 94-106.

In the Sainte-Agathe-Saint-Jovite area, no mineral deposits are known to be related to the Montagne-Tremblante gneiss, but, as pointed out with respect to the same series in the report on the Labelle-L'Annonciation area, a fine-grained red gneiss in southeastern Ontario is apparently related to the mineral deposits of the southeastern Ontario gold belt. Although many stringers of fine pegmatite material are known in the Montagne-Tremblante gneiss, they were not concentrated to give the thick dykes found in association with some other series. The evidence here points to the crystallization of the gneisses without much concentration of volatile components that might have given rise to mineral deposits.

The deposits of titaniferous ore are known to be related to the anorthosite members of the Morin series. Deposits of graphite in the area, and of silica and china-clay a short distance south of the area, are enclosed by, and probably related to, more acidic members of the same series. Aside from occasional grains of chalcopyrite and pyrrhotite found in rocks of the Morin series, no deposits other than those of titanium are known to be related to the series.

Recent mapping in the mining districts of Abitibi by officers of the Quebec Bureau of Mines has shown many rocks that are classed as soda (albite) granites and related rocks in close geographical relationship to ore-bodies. The writer had the opportunity to examine some of these rocks in thin section and would consider that they represent a series different from any found in the Sainte-Agathe-Saint-Jovite sheet. The rocks of the Abitibi region appear to have been derived from a magma with a high concentration of water, thus promoting the formation of biotite at an early stage, in contrast to the relatively dry magma of the Morin series in which biotite is only abundant in the younger differentiates. It is possibly this difference in the amount of water that accounts for the presence of ore deposits in the Abitibi district and the lack of them in the Laurentian area. As discussed in the report on the Labelle-L'Annonciation area, the considerable depth of cover under which the rocks in the Laurentian area crystallized may be responsible for the scarcity of ore deposits there. Rock series that produced mineralization, and the associated ore deposits, may have been formed at a higher level and removed by erosion.

ECONOMIC GEOLOGY

BUILDING AND MONUMENT STONE

The writer has given the results of studies of some of the commercial granites on the north side of the St. Lawrence river in the Annual Reports of the Bureau for 1932 and 1933. It was concluded that the Laurentian area might supply more varieties of stone than are now quarried. Accordingly, in the Sainte-Agathe-Saint-Jovite sheet, special attention was paid to formations that might yield commercial granite. Trial blocks were taken from two formations.

A red granite forms outcrops of moderate size along the west side of Du Diable river between Saint-Jovite and Brébeuf. The stone is medium grained and red with, in some places, an arrangement of constituents (mixture) that might make it suitable for monuments. The stone takes a good polish and works fairly easily, though not so easily as finer grained stone. In most of the outcrops, the rift is approximately horizontal, and the grain approximately vertical and in the direction of the regional strike. An outcrop of the same kind of stone was seen west of the Rouge, about three miles north of Huberdeau. The poor condition of the road makes this occurrence less easily accessible than that near Brébeuf. The stone is unlike any quarried in Quebec and, given a suitable quarry site, might well compete as a monument stone with some imported red granites.

The rose granite gneiss forming the mass of Montagne-Tremblante has facies that work easily and might be used for curbing, paving sets, and building. The prevailing colour of the formation is pink, grading to brown, but southwest of Saint-Jovite the fine granite gneiss has a pleasing red colour that might make it suitable for monuments. Tests of the stone showed it to work easily. The rift is approximately horizontal and the grain nearly vertical in the direction of the regional strike of the formation.

The granite here is similar in appearance to that at Guenette, but appears to work a trifle more readily. Under the microscope it is seen that the stones from the two localities differ in texture; and allanite, zircon, and fluorite, found in the Guenette rock, were not observed in that of the Sainte-Agathe-Saint-Jovite area.

The large area of this formation found in the present map-sheet makes it probable that a careful examination would show favourable quarry sites for stone for building purposes at least, and it is possible that monument stone would also be found.

A green facies of the Morin series has been quarried for local use from an outcrop a short distance north of Saint-Jovite. The stone is in relatively thin sheets, and rather closely jointed. It is quite effective in appearance and resembles the green granite quarried at Chicoutimi. The village church at Saint-Jovite is constructed in part of this stone and the general effect is sombre. The coursing is irregular and some stained joint-surfaces have been left on the face. Its use in this church, however, shows that blocks of sufficient size for buildings can be quarried here. The general tone of the stone is so dark that it should be used in contrast with lighter-coloured material.

CHINA-CLAY AND SILICA

Although china-clay has not been found in place in the present map-area, considerable work has been done on deposits near Saint-Rémi-d'Amherst (1), a short distance south of the limits of the sheet. On

(1) Wilson, M. E., *Geology and Mineral Deposits of Part of Amherst Township, Quebec*, Geol. Surv. Can., Memoir 136, 1919.

account of the possibility of commercial deposits being found in the present area, a brief account of the geology of the Saint-Rémi occurrence will be given.

The deposits near Saint-Rémi are in a mass of Grenville quartzite, a remnant within the intrusive granitic rocks, by which it is completely surrounded. The tendency for quartzite to persist under such circumstances, whereas other members of the Grenville have been removed, was emphasized in the writer's report on the Labelle-L'Annonciation area (1), and many such remnants are found within the granite in the Sainte-Agathe-Saint-Jovite area. At Saint-Rémi, the quartzite was originally feldspathic, but the feldspar has been replaced by kaolin-like minerals and sericite. In a few places, actual pseudomorphs after feldspar in the new minerals may be seen. This process did not result in a concentration of kaolin, but the products were concentrated and re-distributed by solutions derived from the nearby granites. Not only were the kaolin minerals leached and redeposited, but also new quartz was formed. This later quartz is in irregular stringers and pockets in the quartzite. In places, it forms relatively large crystals. The small crystals and the cores of the large ones are water-clear, but a layer about 1/8 inch thick on the larger crystals is mixed with kaolin and, therefore, cloudy. This clouding of the outer part is taken as evidence that the transportation, and possibly even the formation, of the kaolin minerals was only proceeding after the deposition of the secondary clear quartz. After the kaolin started to be transported, the quartz continued to grow and included the kaolin. The quartz crystals are quite unetched on the surface, probably because circulating surface waters that might have attacked them were not present.

The alternative to this hypothesis of a magmatic origin is that the kaolin minerals were formed from the feldspar by weathering processes. The deposits have been explored to a depth of 125 feet and the lack of comparable weathering on adjacent formations, as well as lack of etching of the faces of the quartz, are arguments against weathering. It is true that the quartz of the quartzite, but not the newly deposited quartz, is much shattered, thus making the rock relatively permeable to solutions, but such a shattering is common in quartzite included in granite.

The principal product shipped from Saint-Rémi at present is the finely-crushed quartzite and quartz, which, on account of freedom from iron, are industrially valuable. China-clay was formerly produced. It is probable that concentrations of china-clay of workable size yet remain to be exploited in this area.

Quartzite is found in the Sainte-Agathe-Saint-Jovite area in a number of places along the Rouge river. One inclusion of quartzite in granite is found on the west side of the Rouge, below the mouth of Du Diable river. Another mass is at Quartz mountain, so named by Logan, along the Rouge near the northern boundary of the sheet. These deposits might supply silica. In a few places, alteration of the feldspar of the quartzite to chalky kaolin-like minerals was noted, but the quartz stringers and crystals were not observed elsewhere than at Saint-Rémi.

(1) Que. Bur. Mines, Ann. Rept., Part *E*, 1934.

Nevertheless, the quartzites are worth attention as possible sources both of silica and china-clay.

Pegmatite dykes associated with the granites are another possible source of silica. A pit has been sunk on a pegmatite a short distance north of Cordon lake, by M. L.-E. Parent, M.P., of Sainte-Agathe. The quartz is pure white or colourless and free from intergrowths of other minerals, although tourmaline, allanite, fluorite, and microcline are found in the same deposit. Cover of drift material prevents the extension of the vein from being traced. An analysis of the quartz, made in the laboratories of the Quebec Bureau of Mines, gave: gold, none; SiO_2, 99.82 per cent; Fe_2O_3, 0.10 per cent. A part of the iron shown in the analysis may be from the hammers used in collecting the specimens, for the quartz appears exceptionally pure.

GARNET

Garnet is a constituent of some of the gneisses of the Grenville series, but in such occurrences the grains are of relatively small size and much shattered, and are mixed with biotite and other rock minerals. In some places pegmatite dykes and quartz veins have penetrated the garnetiferous parts of the Grenville and in the process of their injection part of the garnet material has been absorbed and later redeposited as a constituent of the dykes and veins. In such occurrences, the garnet crystals are larger, less shattered, and less mixed with biotite than are those in the Grenville itself. In most places where such deposits are exploited, little attempt is made to separate the garnet from the other constituents, but the whole mass, including quartz and feldspar, is crushed for use in sand-blasting. If the quartz and feldspar break into angular fragments rather than thin flakes, the material is effective for such a use, provided it is reasonably free from biotite, the flakes of which prevent effective sand-blast action.

Garnet Products, Limited

One garnet deposit was being worked in the Sainte-Agathe-Saint-Jovite area during 1935, on lot 10, range *A*, of Joly township, on the east side of the Rouge, close to the railway. The property is owned by Garnet Products, Limited, of Montreal, incorporated November, 1934. A quarry has been opened on the west face of a fifteen-foot ridge of garnetiferous Grenville with associated garnetiferous pegmatite dykes. The material is rich in biotite and hand-sorting is necessary to eliminate some of it. A small mill (Plate IV.— B), consisting of jaw crusher, rolls, and screens, makes three products of 8–, 16–, and 90–mesh, all intended for sand-blasting. During 1935, considerable trouble developed in the operation of the mill and production was relatively small.

GRAPHITE

Graphite was first mined in Canada from deposits occurring in limestones of the Grenville series in Grenville township. The mineral is a common constituent of these limestones and in some places the deposits are sufficiently large and rich in graphite as to be of economic value. The largest deposit seen in the area is that on lots 15 and 16 of range VI, Amherst township, where considerable work has been done. Many of the workings are now inaccessible for examination and little information can be given concerning the deposit other than is found in the reports by Wilson (1) and Spence (2). The following particulars are quoted from Spence's report:

" *Range VII, lots* 15 *and* 16.— This property was first actively exploited in 1909 by Graphite, Ltd., of Montreal, who put down a 90-foot shaft, besides carrying out a lot of surface work. Work was prosecuted for several years, and in 1912 a large mill was erected. After only a few months work, however, the Company went into liquidation in 1913. For six months during 1914, work was conducted under lease by Messrs. Reilly & Layfield, and again for a few weeks in 1916, under option, by the Multipar Syndicate, of London. Since the last-named ceased work, the property has been idle: it is now understood to be under purchase by Graphite Products, Limited, of 55 St. Francois Xavier Street, Montreal, who contemplate installing flotation treatment in the mill, and who also own lots 11 to 14 and 20, 21 in the same range.

" The graphite body on these lots is in the nature of a contact deposit between crystalline limestone and an intrusive rock, probably of gabbro type. The occurrence closely resembles that at the Miller mine, on lot 10 in range V of Grenville township, being characterized by an abundance of typical contact metamorphic minerals, such as wollastonite, diopside, titanite, hornblende, vesuvianite, scapolite, etc. These minerals, together with the graphite, occur as an aggregate of coarsely crystallized individuals in a silicated zone in the Grenville limestone, probably at its contact with pegmatite. The underground workings, being flooded when the property was visited, could not be examined.

" These workings consist of a shaft 125 feet deep, from which levels were run at 40, 80, and 125 feet. The extent of these levels was not ascertained but is said to be considerable. From the uppermost level, a raise has been put through to the surface, terminating in an open cut, 50×30 feet and 30 feet deep.

" While a certain amount of flake graphite occurs disseminated in the adjacent limestone and also, in greater quantity, in narrow bands in this rock, the majority of the ore consists of foliated graphite approaching plumbago in character. Most of this, however, is so intimately associated with foreign mineral substance as to require milling in order to fit it for market. A certain proportion might, perhaps, be cleaned sufficiently by hand cobbing to render it suitable for crucible work, but it would probably prove more expedient to put the whole of the ore through a milling process.

(1) Wilson, M. E., *Op. cit.*, pp. 38-41.

(2) Spence, H. S., *Graphite*, Mines Branch, Dept. of Mines, Pub. No 511, 1920, pp. 46-48.

" The irregular form of the ore-bodies, which appear to consist of pockety and discontinuous masses, enclosed in limestone, necessitates the mining of large quantities of dead rock, so that the proportion of graphite to the amount of rock mined is low.

" The workings are connected by 150 feet of tramway with the drying kiln, situated back of the mill building. The latter is a large 3-storey, wooden structure equipped with dry concentrating machinery of the usual type . . . and has a capacity of 200 tons of ore per 24 hours.

" According to Cirkel (1), the graphite-bearing zone here has a width of 200 feet and extends for a distance of over two miles. In this zone occur lenticular bodies and nests of graphite ranging up to several feet in diameter, with other irregular shoots of both plumbago and disseminated flake. From 640 tons of rock mined, 15 tons of cobbing ore and 227 tons of milling ore were obtained. By cobbing ore is meant ore that can be cleaned sufficiently by hand to be marketed without undergoing crushing and refining. The milling ore is stated to carry about 15 per cent of graphite".

The deposit is near a facies of the Morin series of intermediate composition, and dykes and irregular bodies of pegmatite are common. The presence of scapolite — a mineral containing chlorine — and of fluorite, together with some molybdenite, in association with the graphite may be taken as evidence that the graphite was produced in the Grenville due to metamorphism by the nearby bodies of igneous rock or offshoots from them.

Another occurrence of disseminated graphite was noted a short distance north of the junction of the Du Diable river with the Rouge, in the first range of Salaberry township. Bands of limestone with flake graphite occur here in Grenville rocks near dykes of granite. Some massive graphite occurs here also, and flakes of graphite are found in the granite close to the limestone. The extent of this occurrence cannot be determined on account of the drift covering, but graphite is to be seen in the limestone in two localities separated by 200 feet of drift. Considerable pyrite appears to have accompanied the formation of the graphite at this locality.

Two pits have been sunk in Grenville limestone with disseminated graphite on the east side of the Rouge a short distance north of the village of La Conception. The deposits are near an offshoot of rocks of the Morin series, but the ore is of low grade.

LIMESTONE

Crystalline limestones of the Grenville series are more abundant in this area than in the Labelle-L'Annonciation area (2). The limestones,

(1) Trans. Can. Min. Inst., Vol. XV, 1912, pp. 261-9 ; Can. Min. Jour., Vol. 33, 1912, pp. 435-7.

(2) Osborne, F. F., Que. Bur. Mines, Ann. Rept. Part *E*, 1934.

on account of their relatively slight resistance to erosion, commonly underlie valleys. They were important sources of lime for modifying soil in the early days of colonization but more recently have come into industrial use as chicken grits, stucco dash, and for the manufacture of glass. For some of these purposes impure material may be used, but for glass making relatively pure calcium, or calcium-magnesium, carbonate is essential.

A band of limestone is found along the Rouge river above and below La Conception. All the observed outcrops are impure, due to admixed silicate minerals and pyrite. A composite of the limestone, consisting of material collected in part by the writer and in part by L. H. Cole, was analysed in the laboratories of the Mines Branch at Ottawa, with the following result (1):

SiO_2	17.80
Fe_2O_3	0.85
Al_2O_3	2.95
$Ca_3(PO_4)_2$	0.04
CaO	44.34
MgO	0.60
Ign.	35.42
Total	102.00
S	0.24

Purer limestone (dolomite) is found south of Saint-Jovite on the east side of Du Diable river, on lot 20, range II, Salaberry. Some material has been quarried from the band of limestone that forms the flank of the hill, and the foundation of a lime kiln is still visible in the vicinity. The material is paper-white with much less disseminated silicate minerals than in the occurrence near La Conception. A partial analysis made in the Bureau of Mines laboratory gave: CaO, 30.75; MgO, 21.70; SiO_2, 3.20; and Fe_2O_3, 0.08 per cent. This material is a dolomite and is sufficiently low in iron and silica to make the deposit of commercial interest.

The bulk of the silica appearing in the analysis is present in the rock as combined silica, in the hydrous magnesian silicate, serpentine. A white diopside rock, with associated tremolite, is found near the deposit.

Weathered limestone from some outcrops near Saint-Jovite has been used for surfacing roads. The material has disaggregated due to weathering and is so friable it may be removed with pick and shovel. This limestone is too impure for most purposes, but is quite an effective substitute for gravel on roads which are little used.

SAND, GRAVEL, CLAY

Sand and Gravel

Deposits of sand and gravel are abundant in the outwash material along the stream channels. Much of the outwash has been cut into

(1) Goudge, M. F., *Limestones of Canada*, Mines Branch, Dept. of Mines, Pub. No. 755, 1935, p. 81.

terraces, along the faces of which the beds are easily accessible for exploitation (Plate IV.— C and D).

The gravel is used locally for building and road making. Little effort has been made to exploit the sand, although 500 tons of foundry sand for use as mould cores was shipped from near Saint-Jovite during the summers of 1934 and 1935 by D. V. McLean of Montreal. The sand was obtained from the stream terraces on the west side of the Du Diable river near Saint-Jovite.

A considerable variety of sand is available in these terraces. Some is fine and grey, perhaps suitable for brass founding; other deposits are of a buff colour and fine-grained; and still other material is coarse in grain. Screen analyses of sand from the terrace opposite Saint-Jovite are given in the accompanying table:

SCREEN ANALYSES OF SANDS

Screen Mesh	Sample I		Sample II		Sample III	
	Per cent retained on sieve	Cumulative	Per cent retained on sieve	Cumulative	Per cent retained on sieve	Cumulative
+ 10	0.62	0.62	1.03	1.03		
+ 14	0.30	0.92	1.45	2.48		
+ 20	0.50	1.42	2.84	5.32		
+ 28	2.31	3.73	9.04	14.36		
+ 35	3.15	6.88	12.98	27.34		
+ 48	4.10	10.98	21.17	48.51	0.05	0.05
+ 65	5.55	16.53	24.61	73.12	0.06	0.11
+100	15.89	32.42	20.84	93.96	0.50	0.61
+150	18.31	50.73	4.51	98.47	3.77	4.38
+200	24.89	75.62	1.26	99.73	24.27	28.65
—200	24.38	....	0.27	....	71.35	....

I.— Dark olive sand, 2 to 4½ feet from top of terrace.

II.— Grit and sand, cross-bedded, buff, 4½ to 10 feet from top of terrace.

III.— Silt, grey, from bottom of terrace. Overlying the sand is 8 inches of soil grading downward through oxidized sand and clay for an additional 16 inches.

CLAY

No demand for clay has yet arisen in the area, but material suitable for brick, terra cotta, and Portland cement could be obtained from the varved clays along the principal river channels at elevations of less than 725 feet. The fact that varved clays, such as those occurring in the present area, are commercially useful is shown by the fact that much of our information concerning clays has been obtained in the exploitation of deposits of this type in various parts of the world.

GROUND-WATER

In a well-settled area such as this, the question of water supply is an important one. There is a possibility that streams and lakes may be contaminated, and the ground-water is thus an important source of supply for drinking water. Fortunately, the thick deposits of sand and gravel provide excellent natural filter beds and reservoirs for ground-water. In some places it is necessary to sink common wells to reach the water, but in many localities the permeable sands and gravels overlie impermeable clays, or bedrock. In this area, the contact of permeable and impermeable beds is commonly to be found on a hillside and is marked by springs and seeps. Some of the springs deliver a considerable volume of water in their present state, and with a little judiciously applied development work could be made to yield a still greater supply. Also, with little expense, many of the seeps could be made to furnish sufficient water to supply one dwelling. The Provincial Government fish-rearing station near Morisson is an excellent example of what may be accomplished by development of springs and seeps. Here, a terrace of sand overlies till and bedrock, and the water emerges at the contact. The development work along part of the contact resulted in a yield of about 150 gallons of pure water per minute.

TITANIUM

Although titanium is widely distributed as a constituent of the earth's crust, deposits of the principal titanium mineral — ilmenite — are practically confined to anorthosite and gabbro. Titanium is used to modify the composition of steel, and in the manufacture of electrodes for the carbon arc, but its principal use is in pigments, either as pure titanium dioxide or a titanium-barium or titanium-calcium pigment. These white titanium pigments are in many respects superior to either white lead or zinc white. The great bulk of the titanium dioxide used for the manufacture of these pigments in Canada and the United States is prepared from imported orès, but an advance in price of the raw material in the early part of 1935 has caused manufacturers to again turn their attention to sources of supply in Canada.

Two occurrences of titanium-bearing ore are known in the Sainte-Agathe-Saint-Jovite map-area, and the writer is convinced that other deposits exist in the anorthosite elsewhere. In fact, small outcrops of the ilmenite-hematite type of ore were found on the road from Sainte-Agathe to Saint-Donat in range IX, Doncaster, just east of the limits of the map-area. Although in these small outcrops the material is of too low grade to constitute an economic ore, the area might profitably be examined to ascertain if a larger and higher grade body is not present in the vicinity.

The magnetometer appears to offer the most convenient and the cheapest means of prospecting for these bodies of ilmenite. In order to test the usefulness of the method, an investigation was carried out by Professor D. A. Keys, of the Department of Physics, McGill University, at the Ivry mine during the season, and it was found that this type of deposit is quite amenable to delimitation by the magnetometer.

Ivry Mine

The Ivry mine is on lots 37W and 38, range V, of Beresford township, near the village of Ivry. This deposit of titaniferous ore is economically important because of its size and proximity to the railway. More work has been done on it than on any other titaniferous deposit in Quebec, if some of the occurrences near St-Urbain be excepted. The principal development work has been confined to a quarry, but a number of strippings and open cuttings indicate something of the extent of the deposit. According to Robinson (1), about 16,000 tons of ore were shipped prior to 1922. Since 1927, some 500 tons have been sent out for experimental purposes in connection with the preparation of titanium pigments.

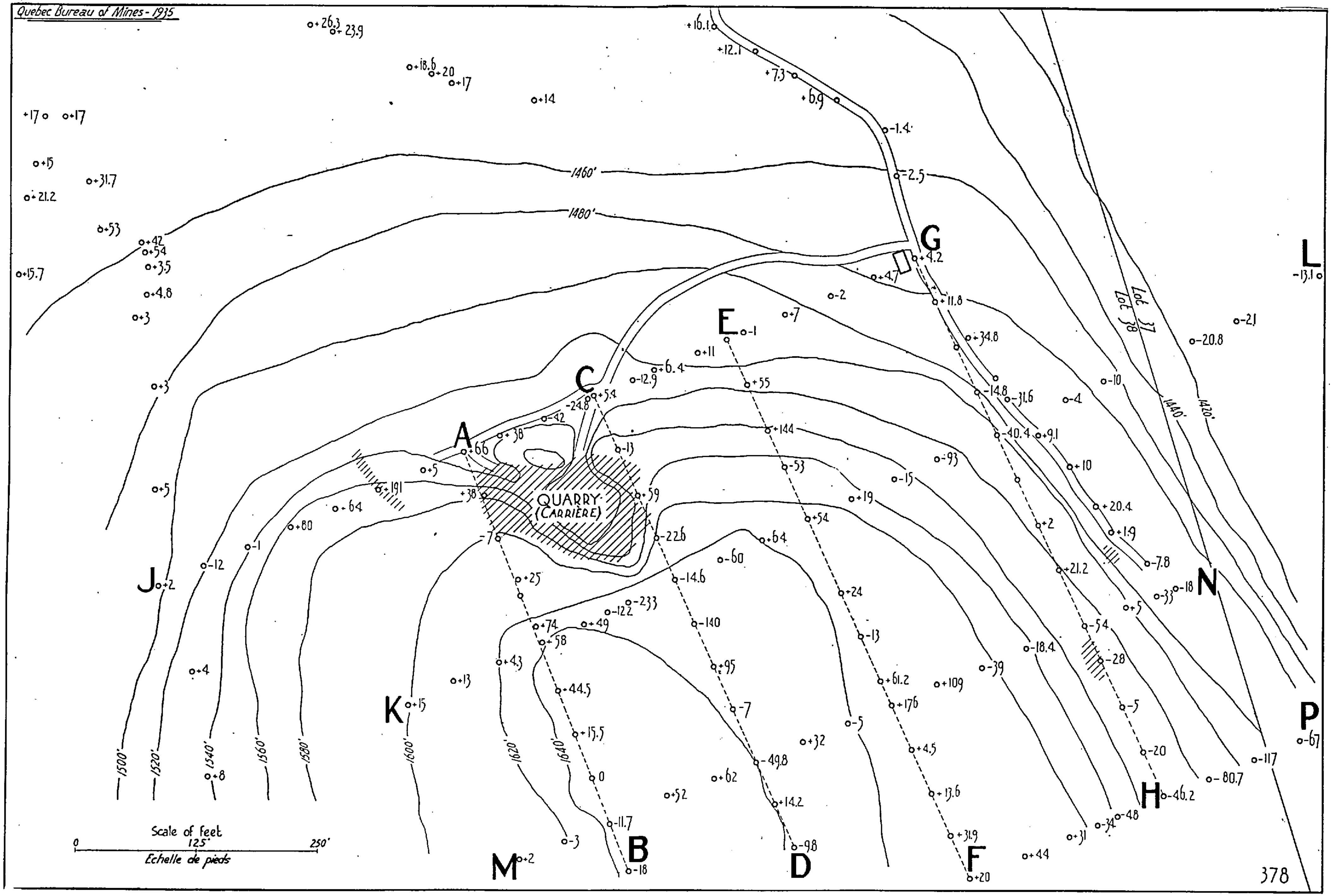
The deposit is on the northeast slope of a ridge which rises above the surrounding drift-covered terrane. Although ilmenite is exposed in several places, and three separate ore-bodies are indicated by the magnetometric survey made by Keys, most of the ore shipped has come from the quarry already referred to. This quarry is rudely elliptical in plan and the highest wall, which is on the southwest side, is about 30 feet high. The quarry is reached by an open-cut approach on the northeast side. Pits and strippings in other places have shown ore in small amount. Unfortunately, the old trenches are so filled with débris that it is impossible at present to determine the distribution of the ore. The locations of the principal outcrops are, however, shown on the accompanying magnetometric map (Map No. 378).

The Ore:

The ore of this deposit consists of an intimate intergrowth of hematite and ilmenite. The ilmenite appears to act as host for numerous, thin tabular anhedra of hematite, which lie in the ilmenite as plaques parallel to the base (0001) of the ilmenite crystals. If, therefore, a crystal of ilmenite is cut parallel to the base, the plates of hematite show their two greatest dimensions, but in sections cut in a vertical zone the hematite shows as elongated spindles. The photomicrograph (Plate V.— A) shows the general appearance of the ore in polished specimen and also the very intimate association of ilmenite and hematite, which would make any process designed to separate them costly because of the fineness of the grinding necessary.

The principal gangue mineral is feldspar, which is similar to that of the surrounding anorthosite. Quartz is present, but not in larger amount than in the anorthosite, from which it is apparently derived. Occasional grains of scapolite may also be seen. Associated with the ilmenite are pyrrhotite, chalcopyrite, pyrite, and marcasite. These are in scattered grains and in small amount only in the main part of the ore-body, but near the margins are collected into veins. The sulphides are evidently later than the anorthosite and ilmenite. The marcasite has apparently resulted from alteration of pyrrhotite, in which it forms

(1) Robinson, A. H. A., *Titanium*, Mines Branch, Dept. of Mines, Pub. No. 579, 1922, p. 56.



Map No. 378.— Sketch-map of Ivry mine, showing magnetometer readings.

small anhedra along fractures (Plate V.— B). It may be related in space to some slickensided surfaces that cut the ore and along which carbonate has been introduced.

The following analyses, quoted by Robinson, show the quality of the ore:

	I	II	III	IV
Ti	18.18	19.00	19.92	19.84
Fe	48.05	47.86	42.75	42.98
SiO_2	....	....	7.54	....
P	....	....	0.036	0.076
S	....	....	1.01	0.144
V_2O_3	....	....	....	0.04
Cr_2O_3	....	....	....	0.08
NiO	....	....	....	*Nil*

GENESIS OF THE ORE:

The problem of the genesis of the titaniferous iron ores has been reviewed elsewhere by the writer (1). As a result of a study of a number of deposits, including that at Ivry, the writer established that ilmenite (and hematite) were developed later than the silicate minerals of the anorthosite, *i.e.*, that the concentrations of these minerals could not have originated by accumulation of early-formed crystals in the magma, as would be implied by the term 'magmatic segregation' commonly applied to these deposits. This conclusion has an important bearing on the positions at which the ore may be found in the anorthosite masses. Under the older hypothesis, the deposits would be most abundant near the margins of, or at certain well defined horizons within, the anorthosite, but if the silicates are earlier than the ore minerals, no such restriction may be placed on the occurrence of the ore concentrations. From observations on numerous deposits in the present area and elsewhere, the writer would suggest that the titaniferous ores occur in the country rock along zones some distance from the outside limits of the anorthosite and, in general, not in the cores.

The actual form in which the titanium minerals were emplaced is uncertain. The writer has suggested that they were injected as a magma into the anorthosite. Gillson (2), as a result of a study of the Saint-Urbain deposits, has presented an alternative hypothesis that the deposits are of pneumatolytic origin. He points to the alteration of the anorthosite near the deposit formerly exploited by the General Electric Company at Saint-Urbain as evidence in support of this view. The writer, in his studies of that and other deposits, recognized that the alteration there was an exceptional rather than the usual feature of the titaniferous deposits.

(1) *Certain Magmatic Titaniferous Iron Ores and Their Origin*, Econ. Geol., Vol. 22, 1928, pp. 724-761 and 895-922.

(2) GILLSON, J. H. L., *Genesis of the Ilmenite Deposit of St. Urbain, County Charlevoix, Quebec*, Econ. Geol. Vol. 27, 1932, pp. 554-577.

Gillson further concluded, from observations with a Hotchkiss superdip instrument, that the deposits occur along fairly definite structural planes, and he attacked the writer's statement that the deposits are very irregular. The writer had suggested that the distribution of the titaniferous ores in part of the Adirondack region was controlled by structural features, but that, nevertheless, the individual parts of the deposits were irregular in the extreme. The presence of the three irregular and closely spaced ore-bodies at Ivry may be taken as evidence supporting this view, as is also the distribution of magnetite at Desgrosbois.

The writer is inclined to retain his formerly expressed view that the titaniferous deposits are dyke-like injections of a magma with only a moderate content of mineralizers. The hydrothermal alteration is very unimportant, and is in no way comparable in extent to that found around deposits definitely of pneumatolytic origin. The very small amount of scapolite and the sulphides probably represent the extent of the pneumatolytic action. In any case, the ore minerals were deposited before the magmatic period of the anorthosite was complete, for dykes of an anorthosite-aplite type (andesine beebachite) cut the ore at the Ivry mine. These dykes have the same mineral composition as the anorthosite but are richer in ferromagnesium constituents than the normal type. It is immaterial whether the view of Gillson or of the writer be accepted as a guide in the search for bodies of the ore. The important factor is that the deposits are not likely to be found along the marginal parts of the anorthosite mass, as would be demanded by the magmatic-segregation hypothesis.

SHEAR-ZONES AND THEIR SIGNIFICANCE:

Reference has already been made to the many, almost vertical, shear-zones cutting the anorthosite. It may be that such shear-zones are responsible for the localization of the ore at the Ivry mine, for a prominent topographic break may be traced in a northwesterly direction along the depression parallel to the general strike of the deposit. No such shear-zone was observed to cut the ore, but it is possible that there is an offset of the ore along the shear underlying the small depression west of the deposit. It may be that the ore-body extends farther westward than is indicated on the accompanying magnetometric map, and that its further continuation in that direction does not affect the magnetometer because it is in a heavily drift-filled depression. That some of these shear-zones are zones of real movement is shown by the granulation of pegmatite dykes. The pegmatite dykes, however, are probably younger than the anorthosite aplites which, in turn, are younger than the ore, so it is not unlikely that the ore-bodies might be displaced along these shears. It is probable, also, that the shears are not all of the same age.

SHAPE AND SIZE OF THE DEPOSIT:

It is very difficult to establish the size and shape of the ilmenite deposit from geological observation. When the writer examined the deposit in 1927, the contact of anorthosite with the ore exposed on the southwest wall of the quarry was apparently vertical, but in 1935 further work at the property had shown that the inclusions of anorthosite in the ore are of tabular habit, with the greater dimensions approximately horizontal, thus indicating a horizontal habit for the ore-body. The irregularity of the other exposures afforded no help in solving this problem. Professor D. A. Keys, of the Department of Physics at McGill University, undertook a magnetometric examination of the deposit, with the assistance of the writer. This investigation had a twofold object: firstly, to provide data on the size and shape of the ore-bodies; and secondly, to determine if ilmenite bodies without magnetite were amenable to magnetometric methods of delimitation. An account of the results of this survey follows.

Geophysical Survey of Ivry Deposit*

Introduction:

The geophysical survey of the Ivry deposit was undertaken to determine whether the magnetic variometer could be used on ores consisting of ilmenite without magnetite, and to attempt to obtain information concerning the size and shape of the ore-bodies.

The Askania variometer was selected as the most suitable instrument for the work on account of the low intensity of the magnetism induced in ilmenite by the earth's field. An ordinary compass or miners' dip-needle is apparently unaffected close to ilmenite, but relatively large deflections may be got with the Askania variometer. In addition to magnetism induced by the earth's field, some specimens of ilmenite ore without magnetite, and of anorthosite — the country rock of the deposit — show a weak permanent polarity. The fact that the anorthosite shows polarity is of practical interest, since it suggests a means of determining the depth to bedrock in areas underlain by anorthosite. Some of the apparently anomalous results of the survey may be attributed to the fact that the covering of sand and till is not uniform. Deflections of the needle were larger where bedrock is close to the surface than where the drift is thick. The relationship between the distance of the magnetometer needle from the pole of the magnetic body (*i.e.*, depth of cover) and the magnetic force is given approximately by the expression $1/d^2$, where d is the distance or depth.

The Askania vertical variometer consists of two steel magnets suspended on bearings of quartz. A small mirror is attached to the magnets. The deflection of the magnets may be read by observing the distance the image of a scale is displaced by the movement of the mirror attached. Two methods of adjusting the readings so they come on the scale are available: one is by means of a non-magnetic screw which may be advanced or retracted in the bar supporting the magnets; in the other method, which is the adjustment actually used in the field, the intensity of the magnetic field is modified by mounting auxiliary magnets

* By Professor D. A. Keys, Department of Physics, McGill University.

of known magnetic moment on a rod, adjustable for distance, below the centre of oscillation of the variometer magnets. If the screw adjustment is left unchanged during the observations, all the readings may be reduced to a common basis by adding or subtracting appropriate amounts. Inasmuch as few geologists are familiar with the method of calibrating the instrument for different positions of the magnet, it is given in detail here.

REDUCTION OF READINGS:

The large variations in the vertical magnetic force due to the underlying ore-bodies made it necessary to alter the position of the auxiliary bar-magnet in order to keep the magnetometer readings on the visible scale. This may be done by (1) raising or lowering the magnet, (2) changing the magnet, or (3) reversing the direction of the magnet, so that the north pole points upwards instead of downwards. In order to interpret the results of the magnetic survey, all the readings must be reduced to what they would be if the auxiliary magnet were kept in one position.

It may be readily proved (1) that the magnetic field at a distance d cm. from the centre of a short magnet of magnetic moment M is given by $2M/d^3$, for points lying on a straight line passing through the magnetic axis of the magnet. When the auxiliary magnet is held vertically in the holder below the variometer needle, the field due to this magnet will vary inversely as the cube of the distance from the centre of the needle to the centre of the magnet. This distance is read directly on the scale which holds the magnet. Since a quite small deflection of the needle causes the scale to pass beyond the field of view, the deflection, θ, caused by the field of the magnet should vary as $1/d^3$. If $1/d^3$ be plotted as ordinates and θ as abscissæ, we should obtain a straight line from which the reading θ corresponding to any value of d may be found. Such reduction lines were obtained experimentally for the two magnets, designated 'small' and 'medium', used in making most of the readings. Thus, for the small magnet with its south pole up, the readings of the deflections, θ, for various distances, d, of the centre of the magnet from the needle, were as shown in the first two columns of the accompanying table. The corresponding values in $1/d^3$ are given in the last column. The plotted results of such measurements for the small magnet, A, and the medium magnet, B, used in this investigation, are shown in Figure 2. An example will illustrate how the reduction is made.

θ (divisions)	d (mm)	$d^3 \times 10^{-6}$	$1/d^3 \times 10^9$
—14.2	300	27.00	37.04
— 9.0	290	24.39	40.98
— 2.2	280	21.95	45.55
+ 5.0	270	19.68	51.22
+14.2	260	17.58	57.39
+29.4	245	14.71	68.03

(1) See any textbook on magnetism or general physics, for example, Mendenhall, Eve and Keys, *College Physics*, D. C. Heath and Co., p. 298.

Suppose the normal reading is +5.0 when the magnet is at 270 mm. and we find that at the next station, in order to bring the needle into such a position that the scale may be read, the magnet must be moved to 300 mm. From the table we see that, should the magnet be moved from 300 mm. to 270 mm., the deflection would be increased by 5.0 — (— 14.2) = 19. 2divisions. Let the reading be +58.6. Then, if the magnet had remained at 270 mm., the reading would have been 58.6+(5.0 —(—14.2) =58.6+19.2 =77.8. This reading, however, would have been off the scale. Thus a factor of 19.2 divisions must be added to all readings taken when the magnet is at 300 mm. to reduce the readings to the standard condition when the magnet is at 270 mm. From this table and similar ones for each magnet, the readings taken when any one magnet is used may be reduced to the value they would have for a standard position of that magnet.

It is now necessary to show how readings, taken when using different magnets, may be correlated. Let the normal position be with the small magnet having its south pole up at a distance 270 mm. below the needle. Suppose, at a station, it is not possible to obtain the scale in view with the small magnet. On substituting the medium magnet, south pole up,

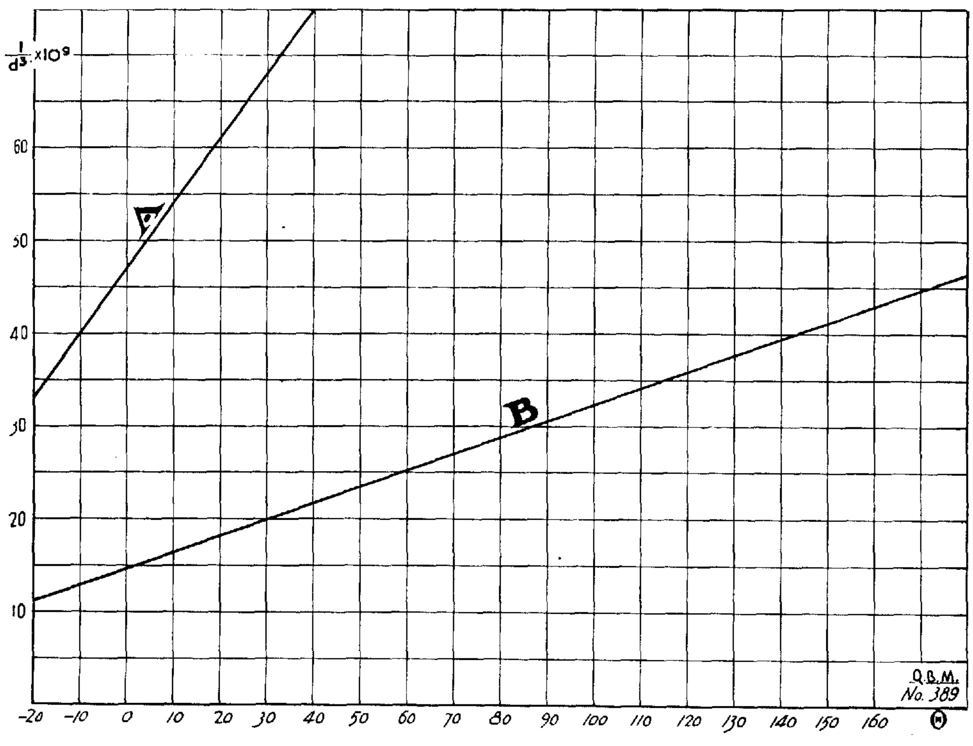


FIGURE 2.— Correlation of magnets.
(*A*, small magnet; *B*, medium magnet)

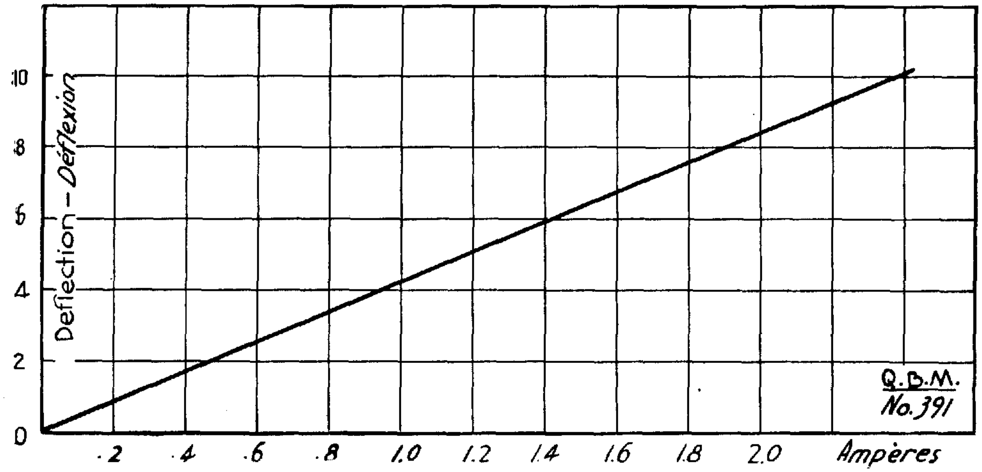


FIGURE 3.— Calibration of magnets.

at 300 mm., the reading was 24.0. The value of $1/d^3$ at this position is 37.0×10^{-9}. Looking at the graphs, we observe along a horizontal line through the ordinate 37.0 and find where it cuts the two lines of the small and medium magnets. Thus we see that, when the small magnet is at 300, the reading would be —14.5, and if the medium magnet were at 300, the reading would have been —126.5. Hence, to change from readings using the medium magnet to what they would have been had we the small magnet at the same distance, we must subtract —141. This reading is then reduced to the standard position (270 mm.) by adding 19.2, giving a total correction of —121.8. In this way, all the readings taken in the field were reduced to one standard position of the auxiliary magnet. Thus the relative values of the vertical components of the terrestrial magnetic field at each station are obtained.

When the magnets required reversing, that is, with their north end up, in order to bring the needle of the variometer into the field of view, the fields produced by the magnet were calculated from their known magnetic moments.

RESULTS OF SURVEY:

The magnetometer readings are ordinarily given in gammas (γ's) and it is necessary to change the magnetometer readings to gammas. To do this, a wire loop of known radius is laid on the ground with the magnetometer at the centre. Various currents are passed through the loop and the corresponding scale deflections observed. From the dimensions of the loop and the strength of the current, the strength of the magnetic field may be calculated. Figure 3 shows, graphically, the results obtained when currents from 0 to 2 amperes were passed through the loop.

The vertical components of the magnetic field over the area were made in the manner described above. Lines were cleared in the woods and readings taken at each station as indicated in the map, No. 378. (The result given at each station is the average of three separate readings). These readings are given in arbitrary units, a change of one unit being equivalent to a change in vertical intensity of 36.6 gammas. The normal value over sand above bedrock in the region was about —21.0 divisions. The difference between the actual reading and —21.0 gives the anomaly due to the presence of the ore. The large variations from positive to negative values are due to the fact that the deposit is not a continuous vein or mass, but apparently consists of separate bodies. It is now necessary to interpret these readings in terms of the probable position and structure of the deposit.

INTERPRETATION OF THE RESULTS:

There are several methods of plotting the results of such a magnetic survey with a view to interpreting the shape, strike, and dip of the ore-body causing the anomalies. One method in common use is to join points of equal vertical anomalies, forming curves called 'isogams', and, from the location of the positive and negative centres of these, to deduce the position of the magnetic body. Such a procedure was used by Haanel and is still common practice. Another way of interpreting the readings is to plot the values of the readings along any line and thus obtain a profile of the variations. This profile enables an interpretation to be made of the position and approximate dip of the various veins or bodies. By plotting the readings along several parallel lines, the strike of the bodies or veins may also be deduced. Numerous experiments on observing the magnetic vertical anomalies along lines crossing various known shapes, sizes, and inclinations of artificially magnetized bodies have been made (1), and the results of such model experiments have been applied to the interpretation of field observations.

The profiles of the magnetic anomalies along two sets of lines are given in Figure 4. It will be seen that the survey indicates three separate masses of ore, one being nearly vertical, the other two flat or dipping slightly to the north. From the positions of these ore-bodies on the four traverses, and from a consideration of the readings found to the east, the strike of the ore and its limits may be deduced fairly well. In the plan of the region, Map No. 380, the probable location of the ore is indicated by hatching.

DEPTH OF ORE:

The question of the depth to which the deposit extends is one of economic importance. The northern ore-body appears to be rather flat and more in the shape of a lens than a vein. This opinion is based upon the magnetic survey. In the case of such a deposit, the approximate

(1) See *Geophysical Prospecting*, edited by Broughton-Edge and Laby, C. I. P., pp. 177-193. Also Memoir 170, Geol. Surv. Can., 1932, pp. 30-61.

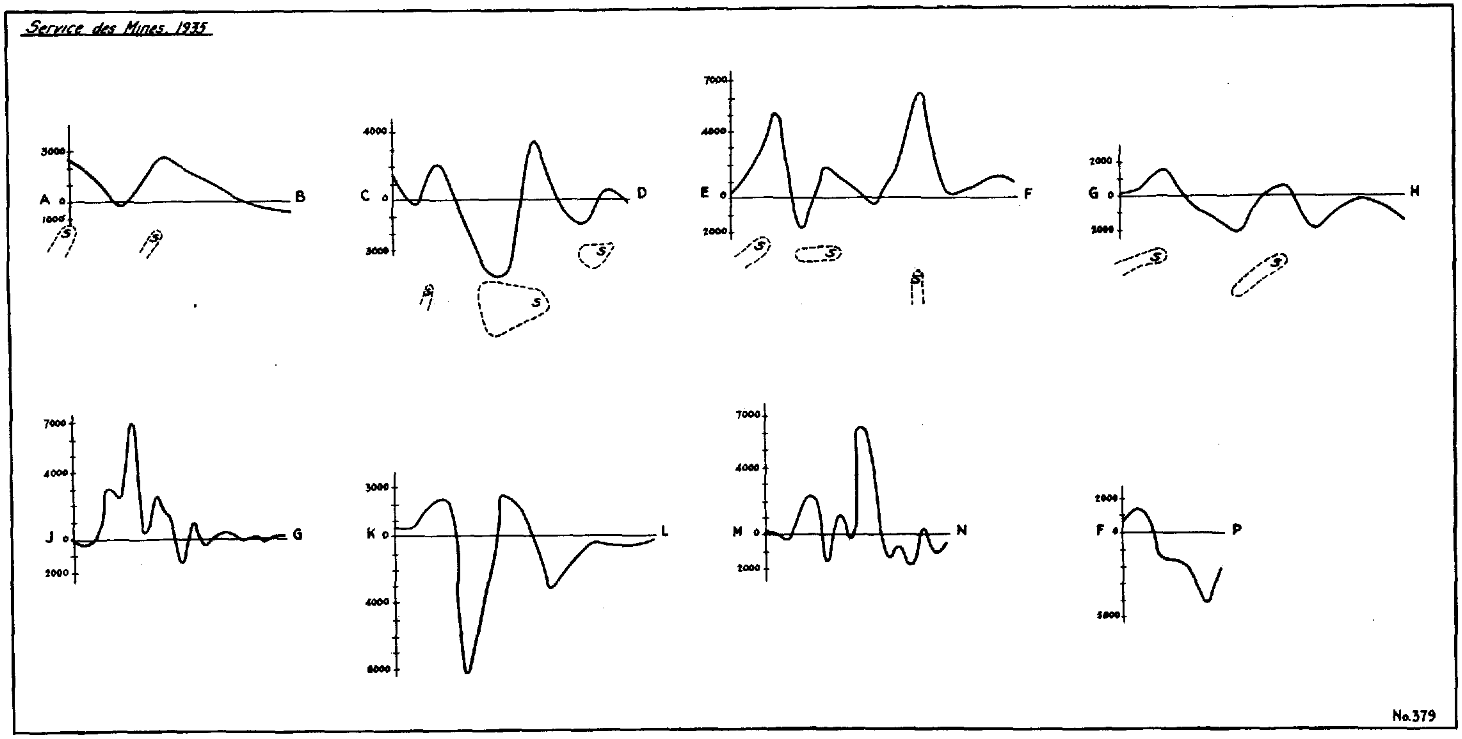
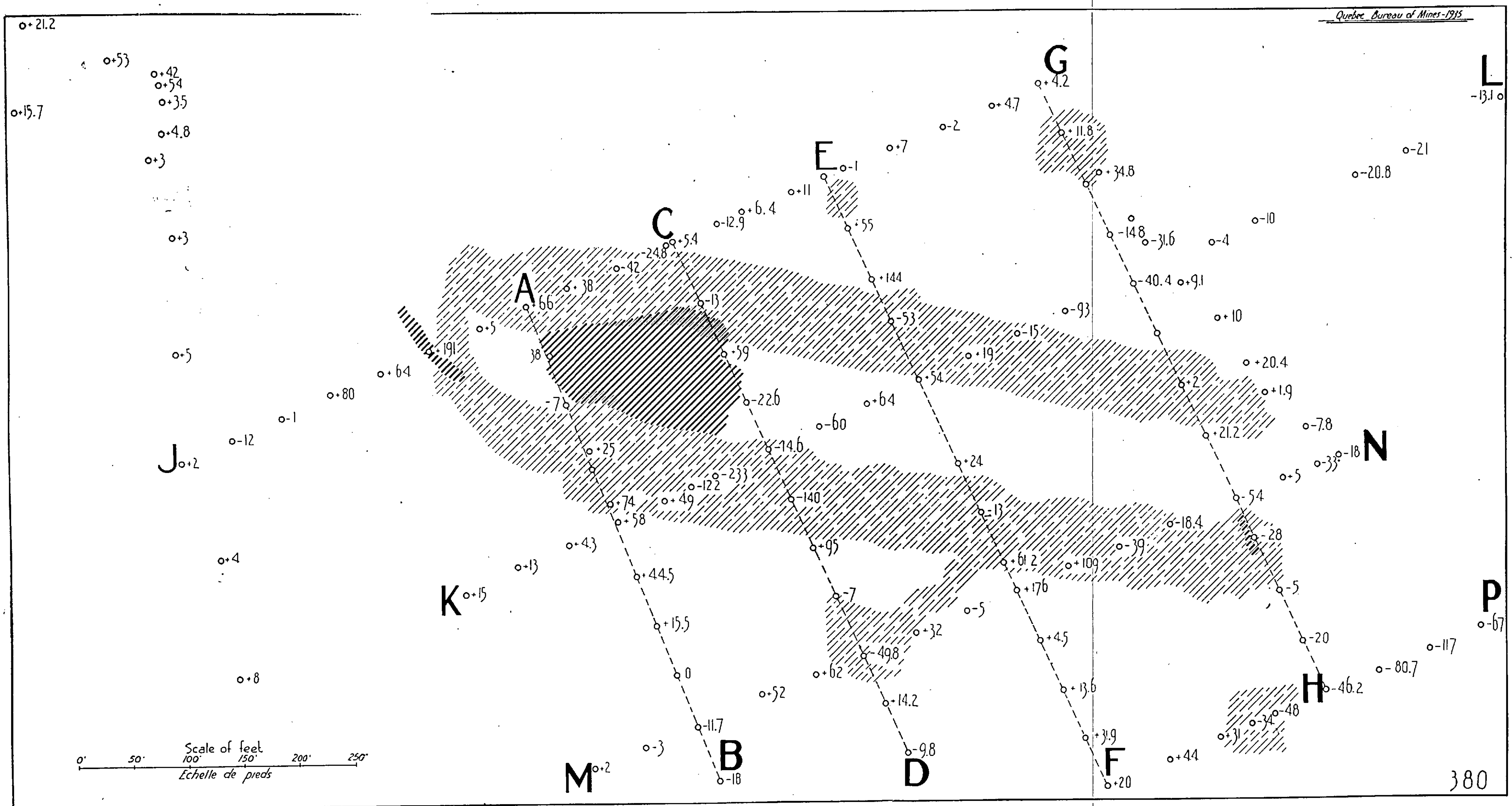


FIGURE 4.— Profiles of vertical magnetic intensity at Ivry mine. (See sketch-map Nos. 378 and 380)



Map No. 380.— Outline of ore-bodies, at Ivry mine, as suggested by magnetometer survey.

depth or thickness may be estimated, if we make certain assumptions. In a flat body in the earth's magnetic field, the south pole of the body will be near the south end and the north pole towards the north. If we consider that the north pole is some distance away, at the point where the pit was cut in the ore, an estimate of the thickness of the deposit may be made as follows: A reading of the magnetometer was taken in the pit (R_o) and a second reading 14.4 feet above the pit level (R_1). When the normal reading is subtracted from these readings, we obtain the readings V_o and V_1, respectively, due to the ore-body. Assuming an inverse-square law of force from the single pole, a depth to the magnetic pole of the ore-body of 93 feet was obtained:

$$\frac{V_o}{V_1} = \frac{(x+h)^2}{x^2}$$

where x is the depth to the pole and h the difference in level between the two stations, in the same vertical line. In this case, $V_o/V_1 = 1.32$, $h =$ 14.4 feet, giving $x = 93$ feet. Other assumptions will lead to different values for the thickness. More accurate knowledge of dip and strike could be obtained with the horizontal magnetometer. The value of the vertical component of the terrestrial field is 0.5471 œrsted, corresponding to the standard reading of 20.0 with the small auxiliary magnet, north pole down, at 329 mm. This result was obtained in the laboratory by measuring the actual field which produced this deflection of the magnetometer.

The results of this survey indicate the applicability of the vertical magnetometer variometer for locating ilmenite ore-bodies. The survey was carried out by two trained men and an assistant and was completed in three days.

Desgrosbois Magnetite Deposit

Magnetite with associated ilmenite is found near the hamlet of Desgrosbois, on lots 39, 40, and 41 of range VI, Beresford township. A few exposures of the material may be seen on a small hillock rising above the stream deposits. Not much work has been done on the deposit, but Robinson, on the map accompanying his report (1), has outlined the several areas which affect the magnetic needle and which presumably are underlain by the ore.

The ore is very different from that found at the Ivry mine and consists of ilmenite mixed with magnetite containing intergrown ilmenite. The ore minerals are further intimately associated with the silicate minerals of the country rock. Robinson gives the following analyses of the ore: (2)

(1) *Op. cit.*
(2) *Op. cit.*, p. 68.

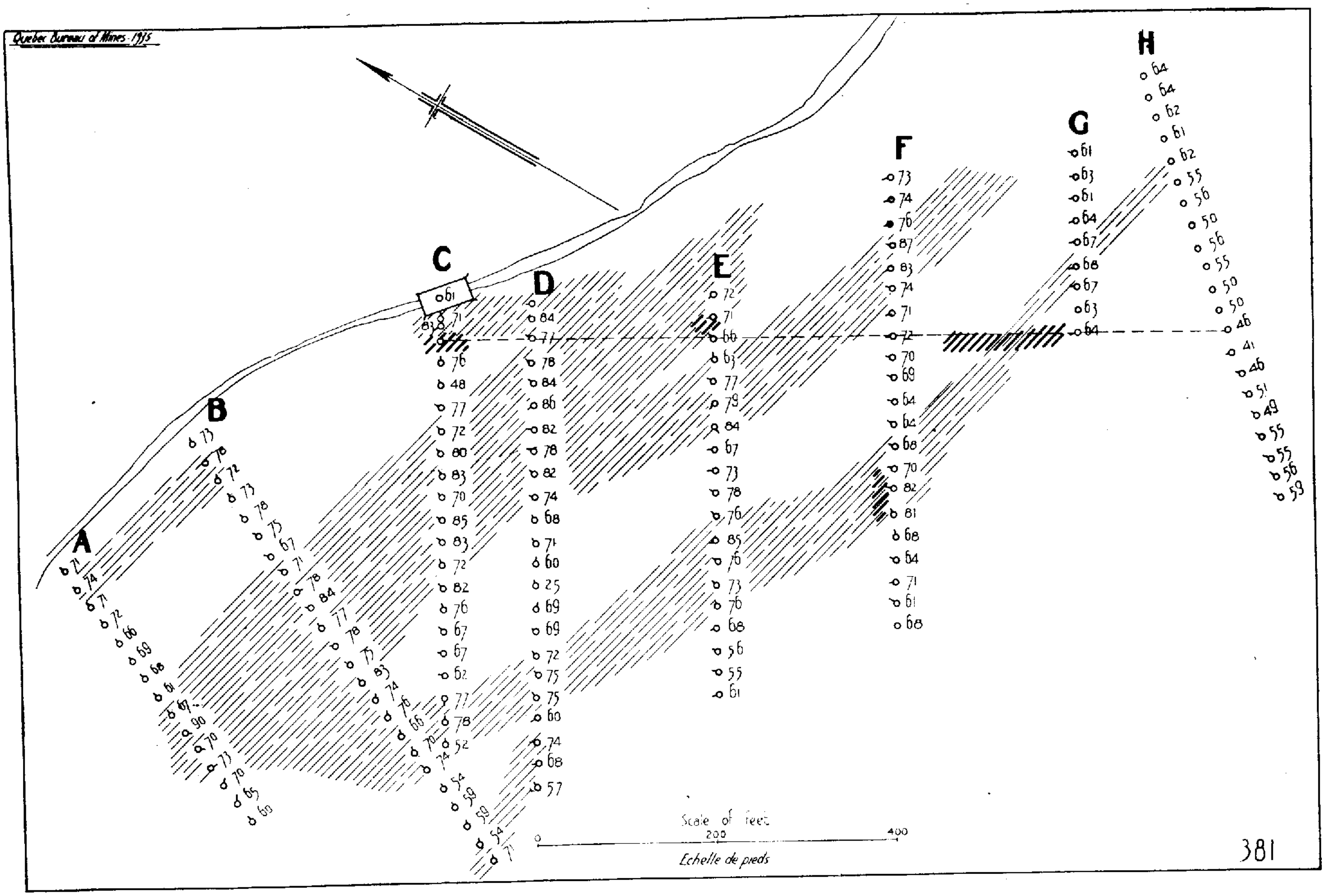


FIGURE 5.— Magnetic map of part of Desgrosbois ore-body.

	Lot 39		Lot 40
	I	II	
Iron	40.76	44.04	46.59
Titanium	4.49	5.09	18.09

The textural relationships confirm the possibility that the ilmenite might be separated from the magnetite, including that which is intergrown with it. The titanium tenor of the ore is, however, rather low for profitable mining.

Inclusions of the country rocks within the ore are horizontally arranged and suggest that the bodies are of stratiform habit, *i.e.*, they

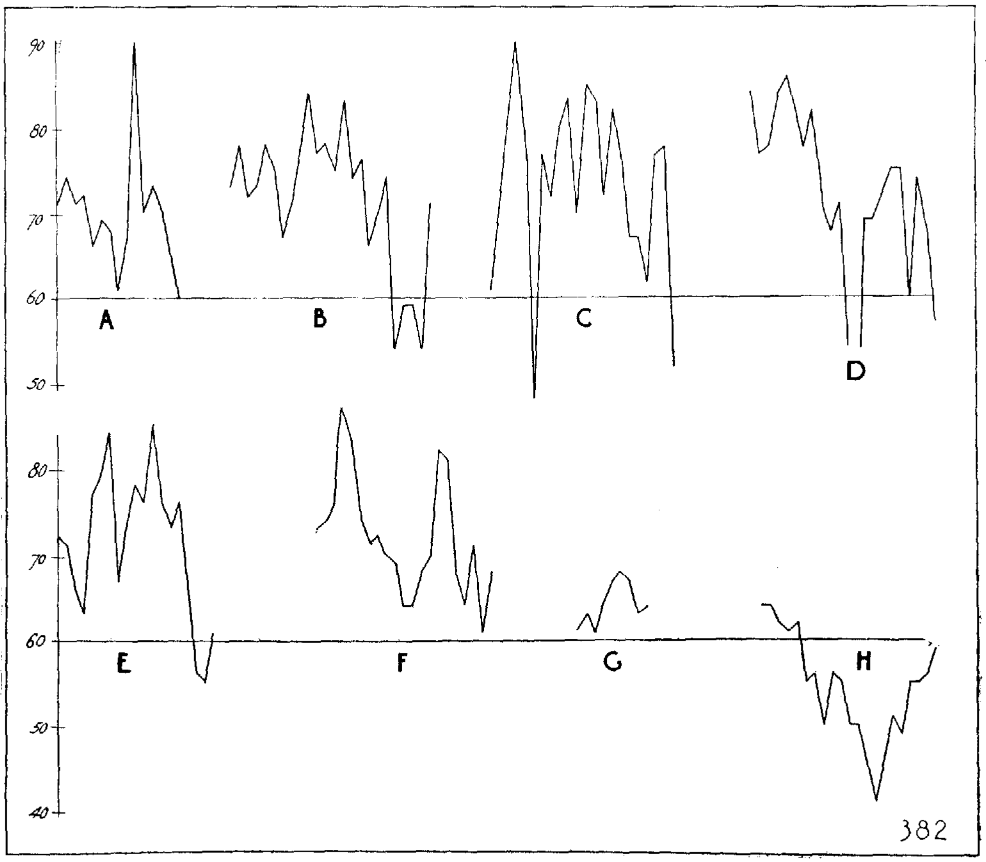


FIGURE 6.— Profiles at Desgrosbois ore-body.

do not extend to a great depth but lie close to the surface. Unfortunately, the ore is so highly magnetic that it was not possible to use the sensitive Askania variometer to determine the shapes of the ore-bodies beneath the surface, and the dip-needle that was used only outlines the position of ore-bodies and gives no information on their thickness. Keys' description of his dip-needle observations on one part of the deposit follows.

Dip-Needle Survey of Deposit (1):

A dip-needle survey of the Desgrosbois deposit was undertaken with the object of finding the strike and extent of the magnetite bodies. The ore outcrops in several places and is strongly magnetic. Boulders containing magnetite are scattered through the drift and cause local variations in the magnetic field, so that its intensity changes rapidly in a short distance. Owing to these variations in vertical magnetic intensity, a sensitive type of magnetic balance, such as the Askania variometer, could not well be used in this survey. However, the ore-body deflects the ordinary miners' dip-needle, whereas the small scattered boulders have little effect on it. The survey was, accordingly, made with an ordinary 3-inch dip-needle.

Lines were chained out across one part of the deposit and readings of the dip taken every fifty feet or so along the lines. The readings were taken twice at each station, the instrument being turned through 180° between readings, and the average value recorded. The readings and approximate direction of the magnetic meridian at each point are shown in Figure 5.

The interpretation of these readings was made as follows: The values of the dip at each station along the lines A, B, ... G were plotted separately (see Figure 6). The normal value of the dip, as determined by the dip-needle in this locality when no magnetite was present, was found to be 56°. The presence of the magnetite increases the dip, and since there is not much overburden, the increase is quite easily determined. From these profiles for each line, the approximate positions of the ore-bodies on each line may be found. When these positions are transferred to the plan, the strike and extent of the ore-body becomes apparent. It appears that the deposit consists of two main parts, approximately as shown by the hatched parts of the plan. The ore-body clearly does not extend beyond the eastern line but may continue a short distance into a swamp on the western side.

This survey was completed in six hours by two observers who measured off the lines and stations and took the readings. The survey must be considered only approximate, but such information, obtainable quickly with cheap equipment, may be of sufficient value for many purposes. A detailed survey with apparatus of higher precision would give more information but would require longer time and be more costly.

* By Professor D. A. Keys.

(Photo by Rsya Canadian Air Force)

General view of Sainte-Agathe, showing the extensive sand plain near Lac des Sables, and the drift-mantled lower slopes of the hills.

(*Photo by Royal Canadian Air Force*)

A.— Structural basin containing Xavier lake and other lakes. Montagne Tremblante gneiss on right of photograph.

(*Photo by Royal Canadian Air Force*

B.— Oblique aeroplane photograph looking northeast across junction of du Diable and Rouge rivers.

A.— Varved clays along Rouge river above La Conception.

B.— Crumpled varved clays along du Diable river, below Saint-Jovite.

C.— Drift covered valley of Rouge river with hills of quartzite and Morin series in background. Grenville limestone in left foreground.

D.— Montagne Tremblante from northeast of Morisson. Small kettle lake in drift in left foreground.

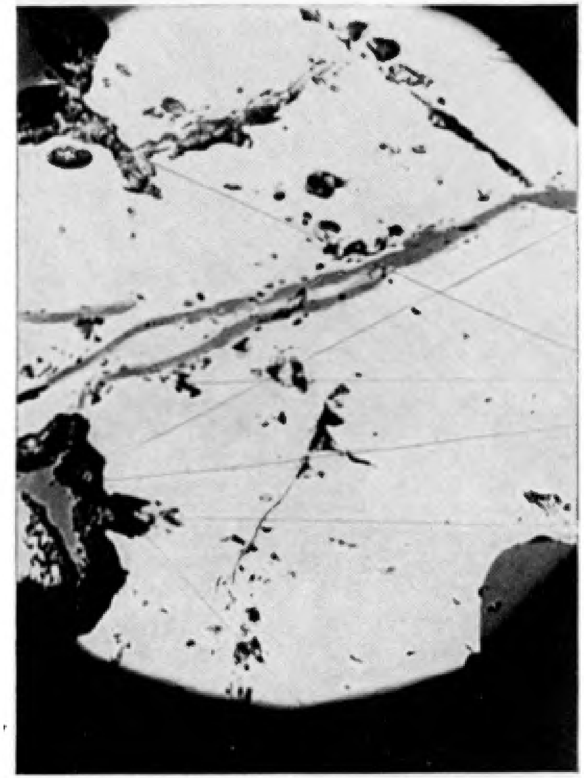
A.— Grenville limestone with fragments of gneiss that have been formed during flowage of the limestone.

B.— Mill of Garnet Products, Limited, Joly township.

C.— Edge of terrae opposite Saint-Jovite, from whic 500 tons of sandc have been shipped.

D.— View of beds in sand deposit showing their lenticularity and cross bedding.

A.— Ore from Ivry mine, showing hematite (light) in ilmenite. The section is nearly parallel to the basal plane of ilmenite crystals and shows the greatest dimensions of the included hematite. × 100.



B.— Pyrrhorite in Ivry ore, showing the development of marcasite close to veinlet of iron oxide. × 100.

ALPHABETICAL INDEX