CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 134

No. 115, GEOLOGICAL SERIES

# Brockville-Mallorytown Map-area, Ontario

BY
J. F. Wright

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1923

No. 1986

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 134

No. 115, GEOLOGICAL SERIES

# Brockville-Mallorytown Map-area, Ontario

BY
J. F. Wright

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1923

No. 1986.

# CONTENTS

PAGE

Introduction ..... 1

CHAPTER I

Topography ..... 4

CHAPTER II

General geology ..... 12

CHAPTER III

Structural and historical geology ..... 46

CHAPTER IV

Economic geology ..... 50

---

Index ..... 61

## Illustrations

Map 1964. Brockville-Mallorytown area, Leeds county, Ontario ..... In pocket

Plate I. A. Area underlain by stratified clay showing rough surface; typical quartzite ridge in background. One mile north of Pooles Resort 56

B. Folded Grenville limestone, with axial plane of fold dipping to the left or northwest. Island near east shore of Charleston lake ..... 56

II. A. Typical Potsdam conglomerate, Lily bay, St. Lawrence river ..... 57

B. Unconformity between Grenville quartzite and Potsdam sandstone. Near Caintown ..... 57

III. A. Metamorphic pyroxenite showing irregular shape of mineral grains and the manner in which one mineral is included within the other. Magnification about 10 diameters ..... 58

B. Grenville quartzite one foot from contact, showing penetration of feldspars in quartzite. Magnification about 12 diameters ..... 58

IV. A. Diabase showing general texture of rock and relation of lumps. Magnification 10 diameters ..... 59

B. Detail of lump in IV A, showing texture. Magnification 30 diameters. 59

Figure 1. Index map showing Brockville-Mallorytown map-area and other map-areas referred to in text ..... 1

2. A. Diagram to show classification, family numbers, and mineralogical composition of granite intrusives in Brockville-Mallorytown map-area ..... 23

B. Graphical representation of the percentages of minerals and the relative proportions of light constituents in the average types of granitic intrusives that occur in Brockville-Mallorytown map-area and Alexandria map-area ..... 23

# Brockville-Mallorytown Map-Area, Ontario

## INTRODUCTION

Up to the present no detailed map or description of the geology of the Canadian Thousand Islands region has been published. In 1910, the New York State Geological Survey published a long report describing in detail the geology of the New York side of this region, and since then a number of other areas just south of the St. Lawrence have been described in detail. The present work continues this study on the Canadian side, especially the age relations of the granitic intrusives, about which there has been considerable uncertainty. Moreover, the northwestern Adirondack region

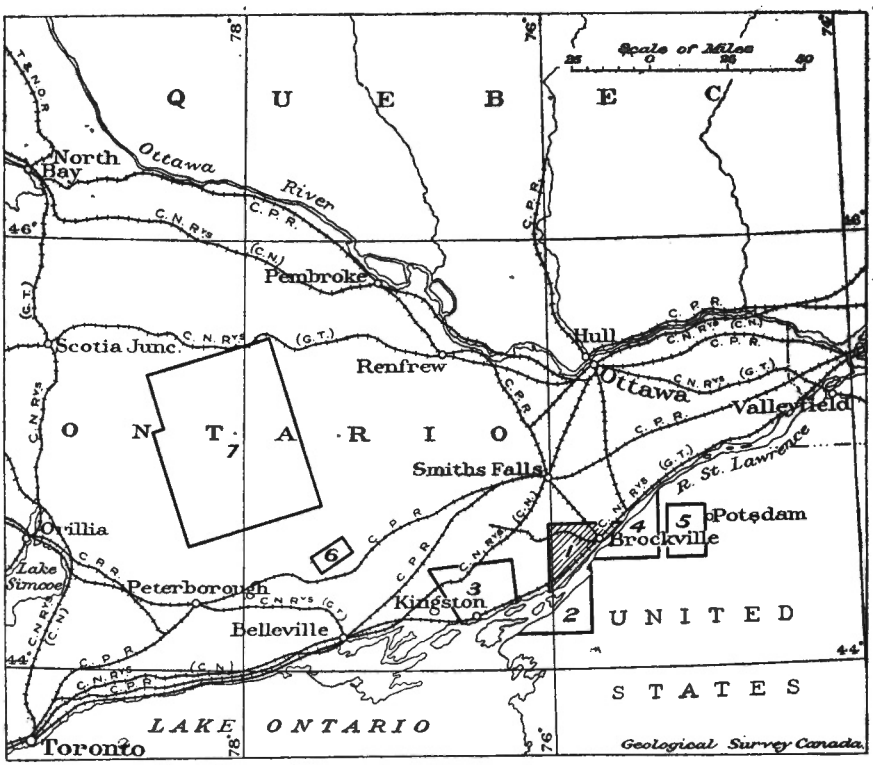



Figure 1. Index map showing Brockville-Mallorytown map-area and other map-areas referred to in text. 1, Brockville-Mallorytown; 2, Alexandria; 3, Kingston; 4, Ogdensburg; 5, Canton; 6, Madoc; 7, Haliburton-Bancroft.

and nearby Precambrian areas in southeastern Ontario appear to have a number of similar geological features, and it is desirable that some of the areas near the boundary of these two regions be studied in detail to form a basis for the correlation of the geological successions and structures.

## FIELD WORK AND ACKNOWLEDGMENTS

The field work upon which the present report and map are based was done in the summer of 1920. The Militia Department topographic maps were used as a base. The map (No. 1964) accompanying this report is adapted from the Mallorytown sheet and the southern part of the Brockville sheet. Figure 1 shows the location of the area and its position in respect to other important Precambrian areas.

Mr. A. N. MacIntosh was field assistant and helped greatly in the areal mapping. The writer acknowledges his indebtedness to Mr. M. E. Wilson for his many suggestions and help in the field work and to Professors Salisbury and Johannsen of the University of Chicago for much help in the preparation of this report.

## PREVIOUS WORK

Since the map-area is along the main water route west to the Great Lakes it was crossed by the early geologists, but the low knobs of pink granite and quartzite ridges do not appear to have much interested them. In 1851 Alexander Murray examined the country between the Rideau and the St. Lawrence and noted the characteristics of the granite, limestone, and Silurian rocks.[1] Sir William Logan in the Geology of Canada, 1863, mentions the several mineral occurrences in the area, and describes in some detail the early Palæozoic sandstones.

In 1900 R. W. Ells studied the area as part of one of a series of standard 4-mile geological sheets, but the map was never published. In the Summary Report for that year he gives notes on the rocks and general character of the Brockville area.

In 1917 M. E. Wilson mapped a small area around Brockville and his notes and specimens were used in the preparation of this memoir.

## BIBLIOGRAPHY

Alling, Harold L.—"Some Problems of the Adirondack Precambrian;' Amer. Jour. of Sc., vol. XLVIII, 1919, pp. 47-68.

Baker, M. B.—"Geology of Kingston and Vicinity;" Ont. Bureau of Mines, vol. XXV, pt. III, 1916.

Coleman, A. P.—"The Iroquois Beach in Ontario;" Ont. Bureau of Mines, pt. I, 1904, pp. 241-243.

"Sea Beaches of Eastern Ontario;" Ont. Bureau of Mines, 1901, pp. 215-227.

Cushing, H.P.—"Geology of the Thousand Islands Region;" New York State Mus. Bull., No. 145, 1910.

"Geology of the Vicinity of Ogdensburg;" New York State Mus. Bull., No. 191, 1916.

[1] Geol. Surv., Can., Repts. of Prog., 1851-52, pp. 57-91.

Cushing, H. P.—"Age of the Igneous Rocks of the Northern Adirondack Region;" Amer. Jour. of Sc., vol. XXXIX, 1915, p. 288.
"Northern Adirondack Region;" New York State Mus. Bull., No. 95, 1905.

Chadwick, G. H.—"The Palæozoic Rocks of the Canton Quadrangle;" New York State Mus. Bull. Nos. 217, 218, 1920.

Ells, R. W.—Geol. Surv., Can., Sum. Rept., 1900, pp. 134 A-138 A.

Fairchild, H. L.—"Pleistocene Marine Submergence of the Hudson, Champlain, and St. Lawrence Valleys;" New York State Mus. Bull., Nos. 209-210, 1918.

Kindle, E. M., and Burling, L. D.—"Structural Relations of the Precambrian and Palæozoic Rocks North of Ottawa and the St. Lawrence Valley;" Geol. Surv., Can., Mus. Bull. No. 18, 1915.

Logan, Sir Wm.—"Geology of Canada, 1863;" pp. 91-93, 747, 750, 816.

Martin, James C.—"Precambrian Rocks of the Canton Quadrangle;" New York State Mus. Bull., No. 185, 1916.

Miller, W. J.—"Age of Igneous Rocks of Northern Adirondack Region;" Bull. Geol. Soc. of Amer., vol. 25, pp. 243-64.

Smyth, C. H.—"Geology of the Crystalline Rocks in the Vicinity of the St. Lawrence River;" New York State Mus. Rept. for 1899, pp. 85-104.
"Diabase Dykes Around Gananoque;" Trans. New York Acad. of Sc., vol. 13, pp. 209-214.

Wilson, A. W. G.—"Trent River System and St. Lawrence Outlet;" Bull. Geol. Soc. of Amer., vol. 15, 1904, pp. 211-242.

Wilson, M. E.—"The Relationships of the Palæozoic to the Pre-Cambrian along the Southern Border of the Laurentian Highlands in Southeastern Ontario and Adjacent Portions of Quebec;" Trans. Roy. Soc. of Can., 1920, Sec. IV.

# CHAPTER I

## TOPOGRAPHY

A narrow neck from the Precambrian plateau, called the Frontenac axis, crosses the St. Lawrence west of Brockville and connects the elevated Adirondack region of New York with the great Precambrian plateau of Canada. This axis also divides the St. Lawrence lowlands into an eastern and a western part, and Brockville is near the western end of the eastern part. Thus, topographically the Brockville-Mallorytown area falls naturally into two divisions; a part of the St. Lawrence lowlands to the east and northeast and a part of Frontenac axis in the centre and west.

### ST. LAWRENCE LOWLANDS

The St. Lawrence lowlands extend from near Quebec city up both sides of St. Lawrence river to Brockville, where they are interrupted by the Frontenac axis. The Frontenac axis extends as far as Kingston where the lowlands appear again and include that part of the Ontario peninsula south of a line from Kingston to near the foot of Georgian bay. The rocks underlying this great area are nearly horizontal Palæozoic strata.

The part of the St. Lawrence lowlands in the Brockville-Mallorytown area is underlain by Potsdam sandstone and Beekmantown limestone. These rocks are nearly horizontal and are composed of alternating hard and soft beds. Their western contact with the Frontenac axis is very irregular due to the projection of Precambrian rock ridges into the lowlands. Also, a number of Precambrian inliers, east of the main Precambrian mass, form low knobs and ridges on the lowlands.

The elevation of the lowland varies from 275 feet above sea-level, which is the average elevation of the bluffs along the St. Lawrence, to 430 feet, which is the elevation of the highest flat. The surface is not flat and plain-like as it is farther east where the rocks are of nearly uniform composition, but is characterized by scarps, 10 to 40 feet high, with intervening flats. These flats and scarps are structural, hard sandstone layers forming both the tops of the scarps and the floors of the flats and benches. The scarps are in a general way parallel to the present course of the St. Lawrence; they are very straight and were first developed by stream erosion; but, undoubtedly, were straightened and worn back by glacial erosion. Throughout most of the distance from the mouth of Jones creek to Lily bay, the St. Lawrence has developed a nearly vertical scarp with an average height of 30 feet. In a few cases the brooks follow depressions cut through the hard sandstone beds to the Precambrian rocks, but generally the brook channels are shallow and narrow.

Comparatively little talus is found at the foot of these scarps. On the platforms or benches the soil is, as a rule, 6 to 18 inches thick and is composed of boulder clay and sand, and is, therefore, too dry for good farming land.

## FRONTENAC AXIS

The name Frontenac axis was given by the early geologists to the neck of Precambrian rocks connecting the great Precambrian area of Canada eastward with that of New York state. This connecting neck is a part of the Precambrian shield of Canada and its topography is similar to the topography of this great shield in nearby areas.

In the Brockville-Mallorytown area the elevation of the axis ranges from 246 to 630 feet above sea-level. Except what is locally known as Blue mountain, which is 250 feet above its surroundings, few hills rise over 100 feet above the valley floors. There are, however, many long, narrow ridges, of about this general elevation, that strike northeast and southwest, or at about 45 degrees to the general direction of the Frontenac axis and with narrow valleys between them make the surface very rough. These valleys strike parallel to the strike of the rocks, and are the result of differential erosion. A large number of the valleys have no streams flowing into them and have been reshaped by glacial scour.

A considerable part of the area, underlain by massive pink granite and syenite, is comparatively flat. This flatness is due to the fact that the granite has widespread horizontal joints, at one or another of which glacial erosion has terminated and has formed a plane. Over considerable areas a single joint plane forms the surface. This is well illustrated by the flat area along the county line road, northwest of Trevelyan.

At Mallorytown and southwest there are a number of large areas underlain by stratified drift, sand, and clay. The surface of these areas is slightly hummocky due to protruding knobs of rock, or to depressions formed by irregular deposition, or to deposition over a rough surface. The origin of these flats will be discussed later.

It has been emphasized by many writers on the physiography of the Precambrian plateau that the main features of the topography as seen today were developed in Precambrian time, not later. Convincing proof of this fact is found in the Brockville-Mallorytown area. The Potsdam sandstone, with basal conglomerate, is found in place in the lowest depressions and on top of the highest hills. South of the bluffs on the northeast shore of Charleston lake, Potsdam sandstone with basal conglomerate lies 275 feet above sea-level, and 2 miles directly east the sandstone and conglomerate are found on a hill 450 feet above sea-level. In each case the dip and strike are parallel to the surface on which the material was deposited. The Potsdam sea must have advanced over an irregular surface of Precambrian rocks, and filled the depressions with sand. Since then these Palæozoic deposits have in a few places been entirely removed, but at other places a decided thickness of Potsdam sandstone still remains. There is no evidence in this area to indicate how thick the Palæozoic rocks originally were, nor any evidence as to what was the last period of preglacial deposition. Glaciation undoubtedly helped considerably to gouge out the depressions between the hills and to carry away the Palæozoic rocks.

## EVOLUTION OF ST. LAWRENCE DRAINAGE

At present the Brockville-Mallorytown area drains southwest to the St. Lawrence. The divide between the waters flowing southwest into

the St. Lawrence and northeast into the Ottawa is a few miles north of this area. It consists of a number of sandstone and drift ridges, irregularly oriented.

From evidence furnished by the valley of Trent river, by soundings of the present Lake Ontario bottom, and the St. Lawrence River channel, together with the general southwest direction of the present drainage, there is little doubt that the Frontenac axis, in preglacial time, formed the divide between waters flowing east into the Ottawa basin and west across western New York state.[1] Black river formed the headwaters of the St. Lawrence and flowed northwest to a point about 10 miles east of Watertown, thence northeast in the valley occupied at present by Indian river, which is parallel and a few miles south of the present St. Lawrence channel.[2]

The general course of the St. Lawrence across the Brockville-Mallorytown area is northeast, approximately at right angles to the Frontenac axis. Lake Ontario is 246 feet above sea-level, and the water surface at Brockville is 245 feet, a drop of but 1 foot in about 50 miles. Soundings along this channel show that there is no definite, single channel, continuous for this distance, but that there are a number of connected river courses constituting two or more fairly navigable channels for most of the distance. The width of the river across the Brockville-Mallorytown area varies from 2½ miles at Rockport to more than 4 miles at Patterson bay and about 1 mile at Brockville.

The channel where it crosses the Frontenac axis is near the centre of a wide depression along a line that runs at right angles to the river and cuts Grenadier island. The average elevation of the Precambrian rock ridges, a mile north of the river, is 350 feet; back 3 miles the average is 425 feet, and back 7 miles it is 400 feet or more. One mile south of the river the average elevation is 300 feet, back 4 miles it is 400 feet, and back 10 miles 500 feet or more. From Blue mountain, southeast of Charleston lake, this broad depression is very noticeable.

From the distribution of the basal Potsdam conglomerate and sandstone it may be inferred that the early Palæozoic sea must have advanced from the northeast up a broad depression. Back from the river the basal Potsdam beds are thinner, and the basal sandstone horizon at Caintown—between 4 and 5 miles back from the present river channel—outcrops about 25 feet above the base of the section along the river. This progressive overlap on the south side of the depression is well shown by Chadwick's section[3] of the Canton area about 25 miles east and 10 miles south of the river.

In late Precambrian and early Palæozoic time an extensive peneplain was developed along the southern edge of the Precambrian plateau. If the tops of the Precambrian hills now partly covered by Potsdam sandstone represent the surface of this peneplain, there was a broad depression in the plain at least 150 feet in depth. This pre-Potsdam depression may have been caused by differential erosion of rocks of different hardness, by differential erosion along a wide fault or shattered zone, or by warping. The depression occupied by Charleston lake is underlain by crystalline

[1] Wilson, A. W. G., "Trent River System and the St. Lawrence Outlet," Bull. Geol. Soc. of Am., vol. 15, 1903, pp. 211-42.
[2] "Geology of the Thousand Islands Region," New York State Mus. Bull. No. 145, p. 141, 1910.
[3] New York State Mus. Bulls. Nos. 217, 218, 1920, Section in pocket.

limestone, and probably can best be explained by differential erosion in pre-Potsdam time. Nevertheless, there is little crystalline limestone, or any type of rock in the St. Lawrence depression which erodes at a rate markedly different from that of the prevalent granite. A number of marked joint planes and small fault planes strike parallel to the present St. Lawrence channel, and indicate a small amount of adjustment, but there is little evidence of extensive faulting. The most reasonable explanation is that this broad depression is the result of warping, and that it represents a continuation of the lower St. Lawrence valley. M. E. Wilson has reached the conclusion that the early Palæozoic formations, Potsdam, Beekmantown, and Chazy, were deposited in a broad depression extending over a large part of the region now included in the lower Ottawa and St. Lawrence valleys.[1]

This pre-Potsdam depression was probably completely filled with Palæozoic sediments. As mentioned above, the divide between the waters flowing east and west crossed St. Lawrence river in this area in late Tertiary time. However, in late Pleistocene time there appears to have been a marked depression in the site of the present St. Lawrence channel, because the Wisconsin ice-sheet was slightly deflected down this depression as indicated by the direction of glacial striæ on both sides of the river. Back from the river some distance on both sides the ice moved south 25 degrees west to south 30 degrees west, whereas on the Thousand islands and near the river on both sides the direction of ice movement was from south 35 degrees west to south 50 degrees west.

The Palæozoic sediments in this depression show little evidence of warping or faulting since they were deposited. However, back from the river 10 to 15 miles on both sides, the early Palæozoic sediments are slightly deformed. This deformation is well illustrated in the Canton[2] area to the east, and near Delta[3] about 6 miles northwest of the Brockville-Mallorytown area. Dr. Wilson,[4] in the paper referred to concluded that the Palæozoic sediments in the lower Ottawa and St. Lawrence valleys were down-warped along the whole southern border of the Laurentian plateau, and down-faulted in scattered localities.

A part of the late Tertiary divide formed by the Frontenac axis was destroyed in late Pleistocene time and the country to the west and northwest began to drain east down this old Precambrian or early Palæozoic depression instead of southwest. This great change in the drainage direction was probably brought about by differential uplift of the Precambrian plateau. In late Tertiary time the eastern part of the Precambrian plateau was from 800 to 2,000 feet higher than it is at present.[5] There is little evidence to indicate the amount of late Tertiary elevation of the southern and centr ıl parts of this plateau, but the deep linear valleys so characteristic of northeastern Ontario indicate that this area must have been higher when these valleys were eroded than it is at present.

---

[1] Wilson, M. E., "The Relationships of the Palaeozoic to the Pre-Cambrian along the Southern Border of the Laurentian Highlands in Southeastern Ontario and Adjacent Portions of Quebec," Trans. Roy. Soc. of Can., vol. XIV, Sec. IV, p. 26, 1920.

[2] New York State Mus. Bulls. Nos. 217, 218, 1920.

[3] Geol. Surv., Can., Sum. Rept., pt. D, 1920, p. 82.

[4] Trans. Roy. Soc. of Can., vol. XIV, Sec. IV, 1920.

[5] Spencer, J. W., "Submarine Valleys of the American Coast and in the North Atlantic," Bull. Geol. Soc. of Amer., vol. 14, 1903, p. 211.

It is possible that the general slope of the surface of the late Tertiary peneplain of the Precambrian area was to the southwest.

Towards the end of Pleistocene time the eastern part of North America was submerged beneath the sea. After the ice retreated this region was again elevated to its present position and the tilted shore-lines indicate that this uplift was differential to the northwest.[1] These marked changes in elevation were undoubtedly important factors in determiring the general directions of post-glacial drainage.

In late Tertiary time the depressions occupied by the present St. Lawrence channels were undoubtedly filled with early Palæozoic sediments. The profile of the islands and the smooth and well-polished rock surfaces indicate that the tongue of ice that moved down this broad depression eroded intensely, with the result that all the sediments, except a narrow area on Hill island, were removed from the Thousand islands as far west as Gananoque. Glacial scour along this old pre-Palæozoic depression was probably an important local factor in determining the course of the present St. Lawrence river in the Thousand Islands region.

In its early stages the water of the St. Lawrence was at least 25 feet higher than now, and covered a proportionally larger area. The evidence for this is the well-developed river terraces cut in the drift along the north side of the depression, back of Rockport, now approximately 25 feet above the river. Also, the extensive sand deposits along the river and on the islands in it indicate that the water spread over an area considerably greater than now and stood at a higher level. The river bar deposits on Tar island, and a number of well-developed terraces between Butternut bay and Brockville, indicate a long interval when the water was at least 15 feet higher than it is at present. These terraces may correspond to Spencer's Mill Haven terrace.[2] From a study of wave erosion near Toronto and terrestrial tilting indicated by the great accession of water to Niagara river, Spencer puts the age of St. Lawrence river as 3,500 years or perhaps slightly less; but Coleman puts the age as 8,000 years.

## POT-HOLES

About 300 feet east of the English church at Rockport there are two well-developed pot-holes. They are in massive pink granite, and one is at least 8 feet 2 inches deep and 18 inches in diameter; the other at least 4 feet deep and 23 inches in diameter. They are about 6 feet apart on the same outcrop, on the top of a hill that rises 330 feet above sea-level or approximately 85 feet above the St. Lawrence and is one of the highest hills in the vicinity.

In neither case was the bottom of these holes reached, as the lower layers of gravel in them are well cemented and could not be penetrated with a shovel. These gravels are composed of hard white quartzose material very different from any of the glacial gravels of the region.

The smaller diameter of these two pot-holes indicates that they are river pot-holes, and not glacial pot-holes, which would have a greater

[1] Johnston, W. A., "The Trent Valley Outlet of Lake Algonquin and the Deformation of the Algonquin Water-plane in the Lake Simcoe District, Ont." Geol. Surv., Can., Mus. Bull. No. 23, 1916.

[2] "Origin and Age of the Ontario Shore-line—Birth of the Modern St. Lawrence River." Am. Jour. of Sc., vol. 43, pp. 351-362, 1917.

diameter. They may have been made by a river that once flowed over the later Precambrian and early Cambrian peneplaned surface. A number of typical glacial pot-holes were noted, also, along the St. Lawrence and on the Thousand Islands.

## GLACIAL EROSION

The abrasional work of Pleistocene glaciation is conspicuous along the north edge of the Brockville-Mallorytown area and in the valley of the St. Lawrence; but, in the intervening area, the effects are not so noticeable. The ice moved from the northeast across the flat-lying Palæozoic formations of the Ottawa valley, and struck the Frontenac axis about at right angles. Between Charleston and Graham lakes, the generally smooth character of the gradual slope of the surface is noticeable. In this area glacial striæ and troughs are well developed.

Southeast of Charleston lake, valleys near the contact between granite and quartzite have steep walls on the side of the quartzite and sloping walls on the side of granite, perhaps due to selective glacial erosion. On account of the brittleness and highly jointed character of the quartzite the ice was able to pluck it away and formed steep cliff faces, whereas the granite, with its well-developed horizontal jointing, more readily formed gently sloping valley walls. The absence of much talus at the foot of these cliffs and the presence of glacial striæ on their walls indicate that the amount of disruption by freezing and thawing since glacial time has been slight.

In the St. Lawrence valley, the direction of the glacial striæ is more nearly southwest than it is on the north side of the Frontenac axis. This indicates that a tongue of the ice moved parallel to the valley. That this tongue was an effective erosion agent is indicated by the flat and gentle profiles of a number of the islands, by the irregular character of the bottom of the channel, and by the smoothed and polished surfaces of the rocks along the river bank and on the islands. The stoss side of some of the islands composed of pink granite, for instance the group off Rockport, is the steep side, and the lee side is gently sloping, which is the reverse of the rule in glaciated areas. Between Rockport and Club island the water is 240 feet deep, but half a mile east it is only 40 feet deep. Many other deep holes are indicated on the charts. This irregular bottom may be partly the result of glacial plucking.

The effects of glacial erosion are not so noticeable across the centre of the area, although many roches moutonnées were noted, especially near Rockfield. However, glacial erosion in this part of the area was not deep enough to remove the weathered tops from the diabase dykes. Because of its mineral composition, diabase weathers deeper in a given time than most metamorphic or igneous rocks and glacial erosion was not great enough to remove the thickness of fresh quartzite or granite represented by the difference between the depth of weathering of diabase and these rocks. Along the north edge of the sheet, and along the St. Lawrence, the diabase dykes have been eroded deep enough to reach fresh rock, and in many cases a glacial trough is eroded along a diabase dyke.

## RESUME OF THE PHYSIOGRAPHIC HISTORY

The physiographic history of the Brockville-Mallorytown area is similar to that of nearby areas along the southern border of the Precambrian plateau of Canada, and along the border of the Adirondack mountains of northern New York state. Therefore, much of the evidence bearing on the development of the topography of this local area must be derived from detailed studies in these neighbouring areas.

The two great events in the physiographic history of the Brockville-Mallorytown area which find expression in the topography of the area are: (1) the long period of planation in late Precambrian time, when the essential features of the present topography of the Frontenac axis were developed; and (2) the long period of planation from late Palæozoic time to the present, when the topography of the St. Lawrence lowlands was developed.

*Late Precambrian Planation.* The late Precambrian and early Cambrian period of planation probably began after the intrusion of the granitic intrusives and continued until the Upper Cambrian sea spread over the land. This period was so long that in Upper Cambrian time these deep-seated granite intrusions were exposed. It is quite probable that these intrusives represent the igneous core of an old mountain range and, if so, this range was eroded to a peneplain during this period, because when the Potsdam sediments were deposited the area was nearly flat, the igneous core well exposed, and only patches remained of the sediments into which these rocks intruded.

Also, from a study of the contact between the Precambrian and the late Cambrian or Potsdam sandstone, and from the character of the Potsdam sediments, it is evident that the country was low and flat in Potsdam time and that a long period of erosion preceded the advance of the Upper Cambrian seas over the area. As pointed out before, the surface between the Precambrian and Potsdam rocks, in detail, is irregular and almost identical with the Precambrian surface in the area at present. The Precambrian rock beneath this contact is fresh and unweathered, just as it is in the recently glaciated surfaces beneath the boulder drift. In the depressions and on the sides of the hills this sharp and unweathered Precambrian surface is covered by a basal conglomerate from 1 foot to 10 feet thick, which in turn is followed by sandstone, sandy limestone, and limestone. No shale is present in these late Cambrian rocks. This indicates that the seas did not erode the materials for these sediments, for there would have been considerable clayey material from the decomposition of the feldspar-rich rocks of the area. Instead, the late Cambrian seas advanced over a low, slightly warped land surface, covered with a thick regolith of sand that had been worked and reworked by rivers, and all the clayey material carried away and deposited. The general flatness of this palæoplain and the well-sorted character of the materials which the advancing seas found on it indicate a long period of erosion during which the land was probably stationary.

From a detailed study of this palæoplain and the contact between it and the Potsdam sediments in the Canton area 25 miles east of the Brockville-Mallorytown area, Chadwick has summed up the history of this

interval as follows: (a) peneplanation; (b) slight uplift and further deep weathering or rotting under moist and warm climate; (c) possibly glaciation followed by arid, cold, and desert conditions; (d) slow submergence under an encroaching sea.[1]

Whether the tremendous denudation of this interval was accomplished in one or many cycles of erosion is unknown, and probably for this part of the Canadian shield will remain unknown. In the southern part of the shield north of lake Huron and 300 miles northwest, at least three widely separated periods of peneplanation preceded Silurian deposition.[2]

Whether, in the Brockville-Mallorytown area, the sediments cut by the granitic intrusives correspond to the Timiskaming series or to the Lower Huronian series, and the granite to that cutting the Timiskaming series, or to that cutting the Cobalt series, is not known. Thus, with our present knowledge of the relations of the Grenville series, a comparison with nearby areas gives little information about the physiographic history of this part of the Precambrian plateau, and little idea of the comparative length of the erosion period that preceded Cambrian deposition.

*Erosion Period Between the Palæozoic and the Present.* The second great period in the physiographic history of the Brockville-Mallorytown area followed the cessation of the deposition of Palæozoic sediments and the uplift of the area from beneath the sea. There is no definite means of dating the beginning of this uplift, but it was probably near the end of the Palæozoic, either at the end of the Devonian period or at the time of the Appalachian revolution, which closed the Palæozoic era. By the end of the Mesozoic era the country is thought to have been brought nearly to base-level, and the extensive Cretaceous peneplain probably extended northward beyond the southern border of the Canadian shield.[3] This erosion cycle was interrupted by elevation, and by the end of Tertiary time the country was again nearly base-levelled. All through late Tertiary time the divide between the waters flowing east, down the St. Lawrence, and west, down the Mississippi, crossed this area. In Pleistocene time the Labradorean ice-sheet crept down over this nearly base-levelled surface and by erosion and deposition destroyed the divide and caused many drainage changes. Since glaciation, the St. Lawrence has flowed across the lowest part of this late Tertiary divide, and occupies the valleys and depressions between the hills on the late Precambrian-early-Cambrian palæoplain, and the hills themselves form the Thousand islands.

---

[1] "The Palæozoic Rocks of the Canton Quadrangle," New York State Mus. Bulls. Nos. 217, 218, p. 44, 1919.

[2] Collins, W. H., "The Huronian Formations of the Timiskaming Region, Canada," Geol. Surv., Can., Mus. Bull. No. 8, 1914.
"An Outline of the Physiographic History of Northeastern Ontario," Jour. of Geol., vol. XXX, pp. 199-210, 1922.
Wilson, M. E., "Timiskaming County, Quebec," Geol. Surv., Can., Mem. 103, pp. 17-20, 1918.

[3] Cushing, H. P., "Geology of the Northern Adirondack Region," New York State Mus. Bull., No. 95, 1905, pp. 425-6.

# CHAPTER II

## GENERAL GEOLOGY

### GENERAL STATEMENT

The oldest rocks known in southeastern Ontario or northern New York state are sedimentary and belong to what is known as the Grenville series. This series has a patchy and irregular distribution over a wide area in eastern Ontario and the lower St. Lawrence. It consists principally of quartzite, garnet gneiss, and crystalline limestone, but includes many other varieties of metamorphic sediments. The strata being highly deformed and patchily distributed it is almost impossible to determine accurately the thickness of the series; but, originally, it was great.

The Grenville series is intruded by irregular masses of igneous rock consisting of anorthosite and pyroxene-rich basic types. These basic intrusives vary greatly in abundance and composition throughout the Grenville sub-province, especially in eastern Ontario and northern New York. Later, both the Grenville series and these basic intrusives were intruded by tremendous masses of granitic magma which worked its way up slowly through both these series and spread irregularly in various directions along planes of weakness. This great mass of granitic magma either assimilated large bodies of the Grenville sediments, or thrust them aside in such a manner that their erosion remnants now have a patchy distribution between large granitic areas.

Following the granitic intrusives are the diabase dykes of late Precambrian age. Unconformably overlying these Precambrian metamorphic and igneous rocks are the nearly horizontal, early Palæozoic sediments (Plate II B), represented by the Potsdam sandstone, Beekmantown limestone, and Chazy shale. Forming a thin mantle over the above rocks are unconsolidated Pleistocene glacial deposits and marine Champlain clays.

In the Brockville-Mallorytown area the Grenville series is represented by quartzite, garnet and biotite gneiss, crystalline limestone, and metamorphic pyroxenite developed locally. By far the most abundant member is quartzite, which outcrops as long bands, as irregular areas, or as large inclusions in the granitic intrusives. The basic intrusives, so abundant in other areas, are only sparingly represented here, if represented at all. Granitic intrusives are abundant and have intimately penetrated the Grenville series, so that in many parts of the area it is difficult to decide whether to map small areas as granite or Grenville. By some authors these granitic intrusives have been divided into two groups, the older called Laurentian granite and the younger called Picton or Algoman.[1]

[1]Cushing, H. P., "Geology of the Thousand Islands Region," New York State Mus. Bull. No. 145, 1910, p. 41. Baker, M.B., "The Geology of Kingston and Vicinity," Ont. Bureau of Mines, vol. XXV, pt. III, 1916, p. 2.

In the detailed mapping of the Brockville-Mallorytown area only one of these two granites was recognized.

Late Precambrian diabase dykes are fairly abundant in this area. Early Palæozoic sediments are scattered over the area as outliers or tongues from the main Palæozoic area of the St. Lawrence valley. The Potsdam sandstone is about 130 feet thick, and is overlain by about 20 feet of Beekmantown limestone and dolomite. Glacial deposits, marine clay, lake clay, and recent deposits form the mantle rock of the area. This succession may be tabulated as follows:

*Table of Formations*

| | | |
|---|---|---|
| Quaternary | Recent | Lake silt and peat. |
| | Pleistocene | Marine clay, lake clay, and glacial drift. |
| | *Great Unconformity* | |
| Palæozoic | Ordovician | Beekmantown limestone, sandy limestone, and dolomite. |
| | *Disconformity ?* | |
| | Cambrian | Potsdam conglomerate, sandstone, and limy sandstone. |
| | *Great Unconformity* | |
| Precambrian | Diabase intrusives | Diabase dykes |
| | *Intrusive contact* | |
| | Granitic intrusives | Granite, granodiorite, syenite, and syenodiorite |
| | *Intrusive contact* | |
| | Basic intrusives | Diorite |
| | *Intrusive contact* | |
| | Grenville series | Quartzite, garnet and biotite gneiss, crystalline limestone, and local metamorphic pyroxenite |

## GRENVILLE SERIES

### GENERAL CHARACTER AND DISTRIBUTION

The Grenville series is represented by quartzite, garnet and biotite gneiss, and crystalline limestone, with various contact metamorphic modifications of these rocks. These three main types were probably deposited as sand, mud, and calcareous material, respectively, but, since deposition, have been intensely metamorphosed, so that often it is difficult to decide whether a particular outcrop or band of gneiss is sedimentary or igneous. Undoubtedly, in many cases, a large proportion of the abundant feldspars in these meta-sedimentary rocks was added by magmatic solutions, and especially is this true of the biotite gneisses. In the Brockville-Mallorytown area quartzite forms more than three-fourths of the rocks of the series, but if an area 10 miles to the west were mapped, crystalline limestone would form three-fourths of the series. A very notable feature is the absence of conglomerate or any other evidence of the base of the series.

The Grenville sediments are distributed in three nearly continuous belts striking in a general northeast-southwest direction across the area.

In each belt quartzite is the outstanding type of rock. The gneiss and limestone are interbanded with the quartzite or outcrop on one side or the other of the main quartzite band. The belts vary greatly in width and continuity, but the southern one extends from a little more than 2 miles west of Rockport on the St. Lawrence, to about 4 miles north of Brockville; the middle belt from Watertown to Caintown; and the northwest belt forms Blue mountain and extends to Centre lake.

### QUARTZITE

The quartzite varies from white to light grey or pink, depending upon the amount of iron and other impurities present. Generally the beds are thick and massive, and it is difficult to determine the dip or strike. However, some beds show dark lines or bands that represent original impure laminæ or beds in the sandstone, not destroyed by metamorphism. The massive beds are closely jointed, with nearly vertical joints. Some of the thinner beds tend to break into polygonal blocks when struck by a hammer, or when they fall from the cliffs. This tendency is due to fracture cleavage.

Thin sections of the quartzite examined under the microscope show a variety of minerals, of which quartz is the most abundant. The following table shows the mineralogical composition of representative sections, the percentages being determined by the planimeter method.

*Table I.—Mineral Composition of Grenville Quartzite*

| Specimen numbers | 49 | 382 | 9 | 61 | 56 | 62 | 5 | 50 | 13 |
|---|---|---|---|---|---|---|---|---|---|
| Quartz | 98·2 | 92·1 | 89·5 | 75·0 | 75·0 | 71·0 | 54·4 | 52·0 | 41·9 |
| Orthoclase | ..... | ..... | 0·7 | 9·8 | 11·8 | 11·9 | ..... | ..... | ..... |
| Microcline | ..... | 2·2 | ..... | ..... | ..... | ..... | 5·7 | 27·2 | 21·0 |
| Oligoclase-albite | ..... | 1·5 | 2·9 | 12·0 | 10·0 | 9·5 | 19·7 | 12·1 | 27·0 |
| Biotite | 0·6 | 2·3 | 1·4 | 0·3 | 0·5 | 0·8 | ..... | 2·5 | 4·7 |
| Diopside | ..... | ..... | 0·8 | 1·5 | ..... | ..... | 15·0 | ..... | ..... |
| Magnetite | 0·4 | 0·9 | 2·1 | 0·6 | 0·9 | 1·1 | 0·8 | 1·0 | 1·2 |
| Tourmaline | ..... | 0·2 | 0·3 | ..... | 0·3 | ..... | 0·6 | ..... | 3·1 |
| Titanite | ..... | ..... | 0·5 | 0·6 | 1·9 | ..... | 1·2 | ..... | 0·6 |
| Calcite | ..... | ..... | ..... | ..... | ..... | 5·4 | 2·1 | 2·3 | ..... |
| Accessories | 0·8 | 0·7 | 2·4 | ..... | 0·6 | 0·3 | 0·5 | 2·9 | 0·5 |
| | 100·0 | 100·0 | 99·6 | 99·8 | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 |

49 Along road one-half mile east of Junetown.
382 One mile northeast of Brockville. Collected by M. E. Wilson.
9 South of Grand Trunk railway (Canadian National) 2 miles west of Lyn station.
61 Doctor island, Little Grenadier group.
56 Along road one-half mile north of Rockfield.
62 Lot 5, south side of Hill island.
5 Along brook one mile south and east of Lyn.
50 East of road from Mallorytown to Pooles Resort and 1 mile from Pooles Resort.
13 South of Grand Trunk (Canadian National) 4 miles west of Lyn station. Nos. 50 and 13 taken within 4 inches of granite contact.

In thin sections of typical quartzite the quartz is in the form of round to subangular grains from 0·06 to 4 millimetres in diameter, with an average size of about 1 millimetre. The outline of the small grains is regular, but the large ones are irregular. Bands or patches of granulated quartz through which small bits of white mica are scattered are abundant, especially near and around the larger grains. Much of the quartz has a cloudy appearance due to included minute dust particles. Hematite threads are abundant along the fractures of some of the quartz and rutile needles and gas inclusions are abundant in many of the quartz grains.

Most of the sections examined contain one or more feldspars. The three feldspars determined definitely are orthoclase, oligoclase-albite, and microcline. In sections of typical quartzite the feldspars are scattered throughout the whole section and are granulated just as the quartz grains are. In sections from near the granite contact, however, the feldspars are in bunches and contain abundant quartz inclusions. They intimately interlock the quartz grains in such a manner as to suggest that feldspathic solutions penetrated the semi-plastic quartzite and crystallized under great pressure (Plate III B). As a general rule, the contacts between granite and quartzite are sharp, but in a few places the quartzite can be distinguished from granite only by the tendency to break into polygonal blocks. Cushing noted and described the same relations in the Alexandria area to the south. He says, "Here and there in the region rocks are found, which present a puzzling half-way stage between quartzite and granite, so that they are likely to be classed, now with one rock, and again with the other, according as the observer comes upon them from quartzite or granite." Cushing[1] concluded that these rocks represented quartzite in various stages of granitization, and a study of thin sections of this type of rock confirms this conclusion.

The two micas noted were a few small flakes and threads of a brown, highly pleochroic biotite, and a white mica with a high interference colour. Some of the biotite has weathered to a green chloritic material, but in most of the sections the biotite is fresh.

In many sections there is a colourless to light green pyroxene with the optical characters of diopside. This pyroxene is fresh, has good cleavage, and probably originated through the recrystallization of calcium, magnesium, and quartz in the original sandstone.

In two sections calcite is disseminated in small bits throughout the whole section, and in another section it forms a band across the section as if it represented an original lamina in the sandstone.

A number of well-developed wedge-shaped titanite crystals were noted, but many of the titanite crystals are rounded or corroded and are, apparently, residual. Pyrite cubes are present in a number of sections and good hexagonal tourmaline crystals are abundant. Apatite and zircon grains were noted in all sections, and some of these grains are rounded and corroded as if wave worn, but others are quite fresh.

### GARNET AND BIOTITE GNEISS

In this group are included: (1) dark grey to black gneiss which contains red garnets and whose surface weathers irregularly, giving the out-

[1] New York State Mus. Bull. No. 145, p. 32.

crop a very heterogeneous appearance; (2) dark foliated gneiss, without garnets, outcropping in narrow bands, or as inclusions in the granitic intrusives.

These rocks are distributed in small patches over the whole area and in many cases the outcrops are too small to represent on the map. However, along the St. Lawrence from a short distance west of Rockport to Patterson bay, and along a belt running northwest and just north of Mallorytown, these basic sediments are especially abundant as inclusions in the granite. Their distribution in relation to the quartzite bands suggests that the inclusions are remnants of once continuous bands of Grenville sediments. At no place is a very large area of these rocks exposed and many of the outcrops are so granitized that thin sections or chemical analyses afford little information.

The rocks as shown by the following analyses are rich in quartz and biotite.

*Table II.—Mineral Composition of Sedimentary Gneisses*

| Specimen number | 36 | 44 | 69 |
|---|---|---|---|
| Quartz | 59·5 | 50·0 | 51·0 |
| Orthoclase | 10·0 | 18·5 | 19·2 |
| Oligoclase-albite | 8·0 | 6·9 | 16·0 |
| Biotite | 21·2 | 20·6 | 31·0 |
| Hornblende | ..... | 2·0 | ..... |
| Accessories | 1·3 | 2·0 | 2·8 |
| | 100·0 | 100·0 | 100·0 |

36 Along Caintown road 2 miles north of Mallorytown.
44 Basic inclusion in granite along the St. Lawrence one mile west of Cole lighthouse.
69 North of road and one-fourth mile west of Escott.

The quartz grains that form the base of the rock show little evidence of an original clastic structure, but present the mosaic appearance characteristic of typical mica schists. The large grains are fractured and have an irregular outline, but the small grains are more rounded and fairly regular in outline. The quartz of these gneisses, like that in the quartzite described above, is dull in appearance and contains many inclusions.

The small grains of orthoclase in the thin sections can be distinguished easily because they are partly weathered to kaolin-like material. The plagioclase, which is oligoclase-albite, is fresh and is scattered throughout the whole section. Only one plagioclase was observed in any of the thin sections or separated by partial mechanical mineral analyses of samples of these rocks.

Biotite in threads or flakes with frayed ends is segregated in bands across some sections, but in others it is disseminated throughout in small flakes between the quartz grains. The biotite varies from light green to brown and is strongly pleochroic. In some sections small garnets are abundant: they are all of a dark red variety, showing dodecahedral forms with distinct parting or fracturing. Small grains of magnetite, titanite,

apatite, and zircon were noted in all sections. Most of the zircons are corroded and rounded. A few crystals of tourmaline and small masses of epidote were noted in many of the thin sections.

These gneisses have the appearance of basic igneous rocks, and the following evidence that they are sediments is, therefore, given. Outcrops of this type are abundant in the Alexandria area south of the St. Lawrence, and it is possible that inclusions in the Picton granite, described by Cushing as Laurentian gneiss, are of sedimentary origin. In the Kingston area, 12 miles to the west, Baker[1] had chemical analyses made of these dark coloured boitite gneisses, and on the basis of those analyses and his petrographic study, concluded that they were of sedimentary origin. All the black gneiss and schist areas studied in detail in the Brockville-Mallorytown area were found to be metamorphosed sediments and to belong to the Grenville series.

The best evidence in favour of a sedimentary origin for these gneisses is their field distribution in relation to the Grenville quartzite, and the presence in them of many rounded and corroded apatite and zircon grains. As already pointed out, bands and inclusions of these gneisses are distributed in long, narrow belts, parallel to the thick quartzite bands or beds. The granitic intrusives are concentrated along these belts, because the beds of gneiss were less competent than the quartzite, and the intrusives were able to penetrate them more easily. The position of the gneiss outcrops suggests that they were interbanded with the quartzite and form a part of the Grenville series.

In the biotite gneisses a great many of the zircon crystals are rounded and corroded, although some are fresh. It is possible that, locally, some of the zircons in an igneous rock might be corroded by magmatic solutions, but it is not likely that a large proportion of the zircons throughout the whole rock would be corroded. Also, some of the zircons during deposition might escape severe wear and be deposited fresh. In igneous rocks the apatite and zircon crystals are clustered with the basic ore minerals, or are inclusions in them or the biotite, whereas in these gneisses, and especially in the quartzite, the zircon and apatite grains are distributed in the small spaces between the quartz or feldspar grains—a mode of occurrence that suggests a residual origin for these rocks. Both corroded apatite and zircon grains are fairly abundant in these gneisses, and this criterion, outlined by Trueman,[2] was found very useful in determining their origin.

The mineral analyses show a high percentage of quartz and biotite with a low percentage of feldspar. As far as can be determined from apparently ungranitized specimens, the original feldspar content was very low. This high percentage of quartz and biotite suggests a sedimentary origin, because igneous rocks rich in quartz are generally poor in ferromagnesian minerals.

In no thin section or sample studied were two plagioclase feldspars found, and Carlson's criterion was not applicable to this area.[3] It may be that the clastic material was so thoroughly weathered and sorted that all

[1] Baker, M. B., "Geology of Kingston and Vicinity," Ont. Bureau of Mines, vol. XXV, pt. III, p. 4, 1916.

[2] "The Value of Certain Criteria for the Determination of the Origin of Foliated Crystalline Rocks," Jour. of Geol., vol. XX, 1912, pp. 244-258.

[3] Carlson, C. G., "A Test of the Feldspar Method for the Determination of the Origin of Metamorphic Rocks," Jour. of Geol., vol. XXVIII, pp. 632-42, 1920.

the original plagioclase was decomposed before deposition, and that the plagioclase present was introduced by magmatic solutions and would have the same composition as the plagioclase of the intruding granite, or was the result of recrystallization under metamorphism.

### CRYSTALLINE LIMESTONE

Outcrops of this rock are abundant on the islands in Charleston lake. The outcrops are white to dirty grey in colour and the surface weathers into irregular forms, because some beds are more resistant than others. These hard beds contain a large proportion of quartz, and are from 1 inch to 6 inches thick. They represent impure beds in the original limestone.

Calcite is the most abundant mineral and is in the form of large rhombohedral crystals with distinct cleavage. Small, angular grains of quartz, microcline, and oligoclase-albite are distributed among the calcite grains. Magnetite and diamond-shaped titanite grains are abundant, and there are a few fresh biotite flakes and some chloritic material that is probably weathered biotite. A few flakes of graphite are disseminated throughout the rock. Sections from the hard, impure beds show an increase in the proportion of quartz, with the addition of a light green pyroxene, similar to the pyroxene of the quartzite, and probably diopside.

### METAMORPHIC PYROXENITE

Along and north of the road running northeast on the first concession line and one mile north of Butternut bay, is a band of grey to rusty weathering, badly deformed, and crumpled rock that represents a highly metamorphosed member of the Grenville series. Throughout the whole band, either parallel to or cutting across the beds, are many aplite dykes and quartz veins. To the north of the pyroxenite is a band of garnet gneiss and this is followed by thick-bedded quartzite. To the south there is a large mass of massive pink granite. The rusty-weathering rock apparently is the result of the contact action of the granite on an impure member of the Grenville series.

An examination of thin sections shows that the minerals have completely recrystallized, have very irregular outlines, and interlock. The diopside contains many inclusions of quartz and feldspar, and a few of the large albite crystals contain inclusions of diopside (Plate III A).

The mineral composition of this rock is given in Table III. The most abundant mineral in a number of the thin sections is diopside. It is a colourless to light green non-pleochroic variety when fresh, but along fracture and cleavage planes weathers black to dark green, and in some cases yellowish to red. This coloration is, probably, due to the weathering of a small amount of iron oxide in the mineral. All the optical characters of this mineral are close to those of diopside.

Two feldspars with indices of refraction less than Canada balsam are present. One is twinned and is albite; the other, optically negative and untwinned, is orthoclase. The orthoclase is slightly cloudy, whereas the albite, in every identified case, is fresh, and this distinction was used in measuring the proportion of the two feldspars.

The proportion of quartz depends upon proximity to the quartzite band to the north, the amount increasing as the quartzite is approached.

*Table III.—Mineral Composition of Metamorphic Pyroxenite*

| Specimen number | 4 | 27 | 403 | 21 |
|---|---|---|---|---|
| Diopside | 76·2 | 52·6 | 38·5 | 22·5 |
| Albite | 15·5 | 12·5 | 16·7 | 20·2 |
| Orthoclase | 4·0 | 15·4 | 9·0 | 8·3 |
| Quartz | 2·2 | 17·5 | 33·8 | 21·8 |
| Biotite | ..... | ..... | ..... | 23·2 |
| Accessories | 2·1 | 2·0 | 2·0 | 4·0 |
| | 100·0 | 100·0 | 100·0 | 100·0 |

4 Along road running northeast and 1 mile north of Butternut bay.
27 Along brook about 1 mile northeast of No. 4.
403 Railway cut, Brockville-Westport branch, 1¾ miles northwest of Brockville. Collected by M. E. Wilson.
21 About ¾ mile southwest of No. 403.

The quartz grains are enclosed as inclusions in the diopside and many of the grains throughout the sections are round, but some of the larger grains are very irregular. Dust inclusions in the quartz are abundant, just as in the quartz of the quartzite. Biotite is irregularly scattered throughout one section and is probably secondary, because this specimen was collected from a shatter zone along which there had been considerable movement.

Accessory minerals noted were epidote, titanite, magnetite, tourmaline, apatite, and zircon. Epidote is probably the most abundant accessory mineral, and all sections contain titanite in well-developed wedge-shaped crystals or round to angular grains with corroded outlines. Small bits of calcite were noted in two sections.

The position and relation of the pyroxenite with relation to the granite indicate that it is a contact metamorphic rock. The variation in the proportion of minerals in the section, and their interlocking character, point to the same conclusion. Originally, this was probably a siliceous dolomitic bed in the Grenville series and the heat and solutions from the granite magma caused a recrystallization, with the addition of magmatic material. Most of the albite and orthoclase were added; because, where the aplite dykes are most abundant, the proportion of feldspar is greatest. The plagioclase in the nearby granite is oligoclase-albite, but these aplite dykes represent the composition of the final solutions given off by the magma, and are generally more acidic than the main magma, as illustrated by the pegmatite dykes.

## STRUCTURAL FEATURES OF THE GRENVILLE SERIES

Well-developed, nearly vertical joints are abundant in the Grenville quartzite. In most outcrops there are two sets of joints about equally well developed, approximately at right angles to each other. In a few outcrops the joints are spaced 2 to 3 inches apart; but, generally, they are

more than a foot apart, and the quartzite breaks up into large blocks. Joints striking in almost every direction were noted, but the majority fall into two groups, one striking north 50 degrees west and north 35 degrees east and the other striking north 25 degrees west and north 65 degrees east. Along some of the joints there has been a little movement, indicated by their slickensided surfaces. The joints are, probably, due to compression, and the two groups may indicate compression from two directions. In contrast with the quartzite, the biotite schist and garnet gneisses are well foliated and not jointed. Commonly, the foliation is parallel to the bedding and the biotite is distributed in narrow parallel bands.

The crystalline limestone is massive except where impure quartz beds are developed, and these are jointed or foliated. The limestone is plastic and would readily yield to deformation, but owing to the marked tendency of calcite to recrystallize under the conditions of deformation, no foliation resulted. The dips of the Grenville rocks, where determined, are 60 degrees or more. A number of drag folds are developed in the garnet gneiss and other less competent members of the series. On the islands near the east shore of Charleston lake, a small, but well-developed, overturned anticline, has its axial plane dipping to the northwest (Plate I B). Everywhere the beds and the axial planes of the drag folds dip to the northwest, and the strike is to the northeast.

The parallelism of the Grenville quartzite beds to one another and to the granitic belts might suggest that the Grenville series is highly folded. However, this area is evidently on the northwest side of a large intrusive mass that strikes in a general northeast direction, and it is possible that in making room for itself the granitic magma thrust the Grenville sediments upward, and spread in somewhat parallel belts in the zone between the thick, competent quartzite bands. It is possible that the regularity of the strike and the parallelism of the heavy quartzite beds and granitic bands could have been produced by the intrusion of the granitic magma under lateral pressure into an alternating series of competent and incompetent beds such as the Grenville series is in this area.

## ORIGIN OF THE GRENVILLE SERIES

The results of detailed work on the Grenville series in the Grenville subprovince favour a marine origin for the rocks. The quartzite, garnet gneiss, and crystalline limestone are the metamorphosed equivalents of sandstone, shale, and limestone, the three types of sediments of a normal marine sedimentary series.[1] No evidence against a marine origin for the Grenville of the Brockville-Mallorytown area was found from a detailed study of these rocks. Where these sediments are not highly feldspathized and recrystallized, the fineness and rounded character of the grains indicate that the sandstone must have been originally fine grained and free from impurities. This, with the apparent distribution of the various types of sediments in distinct, parallel bands, suggests good assortment of the materials during Grenville sedimentation.

[1] Wilson, M. E., "Geology and Mineral Deposits of a Part of Amherst Township, Quebec." Geol. Surv., Can., Mem. 113, 1919, p. 9.

## BASIC INTRUSIVES

In many parts of the Grenville subprovince, basic intrusives are abundant, but in the Brockville-Mallorytown area, rocks that possibly belong to this group were found to outcrop only in small areas. They are best seen on the west end of Tar island and on a ridge about 1¼ miles north of Butternut bay where an irregular mass intrudes the Grenville quartzite. Many outcrops of diorite or gabbro, ranging from 5 to 100 feet in length, were noted.

These rocks are black, medium to coarse grained, and massive to schistose, in some places being typical hornblende schists. In thin sections they are seen to be composed chiefly of basic andesine ($Ab_4$ $An_3$), hornblende, and augite, with some biotite. Some quartz and a small amount of orthoclase are present, most of which is probably secondary as it is more abundant in the schistose varieties. The feldspars have granulated edges, and probably all the biotite is secondary after hornblende. The augite is slightly titaniferous and in many places has weathered to magnetite and leucoxene.

The following is the average mineral composition of five sections of these rocks:

| | |
|---|---|
| Andesine | 37·5 |
| Hornblende | 32·2 |
| Augite | 12·2 |
| Biotite | 8·5 |
| Orthoclase | 3·2 |
| Quartz | 1·8 |
| Accessory | 5·2 |
| | 100·6 |

These rocks do not show the ophitic texture characteristic of the diabase dykes, and do not appear to be related in any way to the late Precambrian diabase intrusions. About 30 feet east of the diorite outcrop at the west end of Tar island there is an outcrop of pink granite, but the contact between the two rocks is everywhere drift-covered. The narrow aplite stringers were noted cutting the diorite, however, and these dykes may be from the granite, in which case the diorite is the older. The field relations and the schistose character of the outcrops also suggest that these dioritic intrusives in the Brockville-Mallorytown area are older than the granitic intrusives. They intrude the Grenville sediments. In the Canton quadrangle, 20 miles to the east, the basic intrusives are older than the granite, but, as already stated, in the Brockville-Mallorytown area, their relative age could not be established; possibly it could be in the area immediately to the northwest.

## GRANITIC INTRUSIVES

In this group is included those acid plutonic rocks varying in composition from acid granite to granodiorite and syenite that intrude the Grenville series. The granitic members are pink to salmon red, but the granodioritic members are mostly greenish grey or dark grey to nearly black with a few outcrops slightly pinkish. The pink or red colour is due to the abundance of pink potash and acid plagioclase feldspars, whereas

the darker rocks contain a greater proportion of a slightly more basic plagioclase, together with some biotite and hornblende. These rocks are mostly fresh and massive, although some—especially the larger—outcrops are slightly foliated. Nearly horizontal and vertical joints are well developed.

Outcrops of these intrusives are abundant all over the area and form about 50 per cent of the outcropping bedrock. The granitic rocks are mixed with the different members of the Grenville series so that in many cases it is difficult to map each type separately, and in places to decide whether to map the outcrop as Grenville or as granite. The granite outcrops are either low, round knobs protruding through the drift or long, smooth ridges.

The more abundant and common minerals of these intrusives are quartz, orthoclase, microcline, microperthite, plagioclase (albite to andesine), biotite, and hornblende. The following table shows the quantitative mineralogical composition of representative sections of these rocks, and on the diagram (Figure 2) are plotted the mineralogical compositions of forty-two thin sections from the area. In plotting these analyses the percentages of quartz, potash feldspar, and plagioclase feldspar are calculated to 100 per cent, and each one of the three corners of the diagram represents 100 per cent of one of these minerals.

*Table IV.—Mineral Composition of Thin-section Samples of Granitic Intrusives*

| Specimen numbers | 17 | 33 | 50 | 58 | 72 | 80 | 65 | 73 |
|---|---|---|---|---|---|---|---|---|
| Quartz | 35·4 | 24·0 | 42·0 | 24·2 | 35·0 | 21·0 | 1·2 | 1·5 |
| Potash feldspar | 26·4 | 50·0 | 37·2 | 32·4 | 15·0 | 4·0 | 34·0 | 14·0 |
| Plagioclase feldspar | 18·0 | 19·0 | 12·1 | 30·5 | 31·0 | 39·4 | ..... | 22·0 |
| Microperthite | ..... | ..... | ..... | 4·0 | 4·0 | 26·8 | 25·0 | 18·0 |
| Biotite | 18·6 | 9·0 | 4·5 | 5·7 | 10·0 | 4·0 | 15·2 | 7·0 |
| Hornblende | ..... | ..... | ..... | ..... | ..... | 2·0 | 20·5 | 33·0 |
| Accessories | 2·5 | 1·5 | 5·1 | 3·2 | 5·5 | 3·5 | 4·1 | 4·6 |
| | 100·9 | 100·0 | 100·9 | 100·0 | 100·5 | 100·7 | 100·0 | 100·1 |

17 Brockville granite. East of Jones creek and one-half mile from the St. Lawrence.
33 Brockville granite. Near cemetery east of toll-gate.
50 Mallorytown granite. Near Escott Centre.
58 Granodiorite. North of Rockport.
72 Granodiorite. Rockfield.
80 Granodiorite. East of Tilley.
65 Syenite. Tilley.
73 Syenodiorite. East of Charleston lake.

The above table and Figure 2 show a considerable variation in the proportion of the minerals present in different thin sections.

From the quantitative mineralogical analyses and the graphical representation of the average of these analyses (Figure 2 B), it will be seen that the granitic intrusives of the Brockville-Mallorytown area contain between 5 and 50 per cent of ferromagnesian minerals, the plagio-

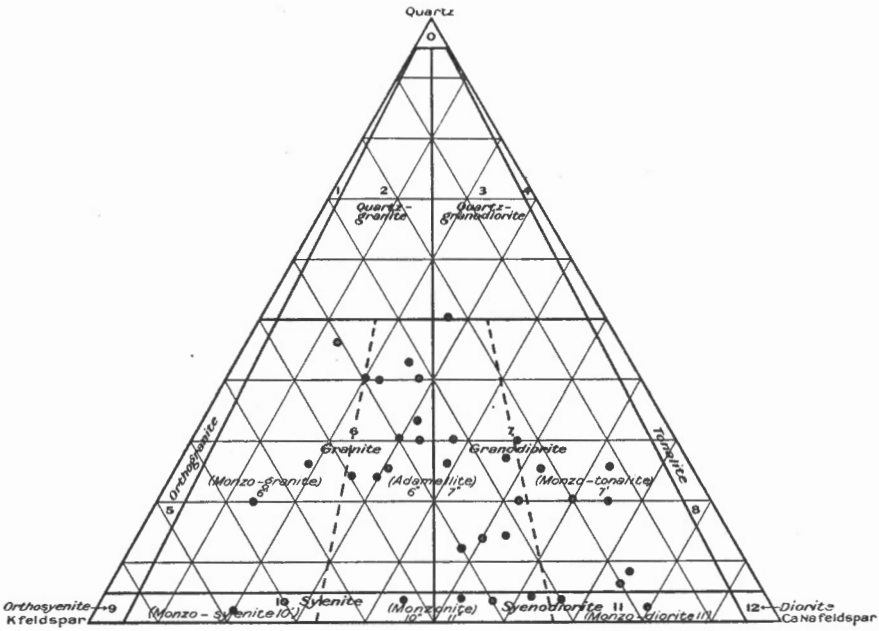



Figure 2. A. Diagram to show classification, family numbers, and mineralogical composition of granite intrusives in Brockville-Mallorytown map-area. Mineralogical analyses were made of thin sections of these rocks with a planimeter. The black dots in the figure refer to these analyses.

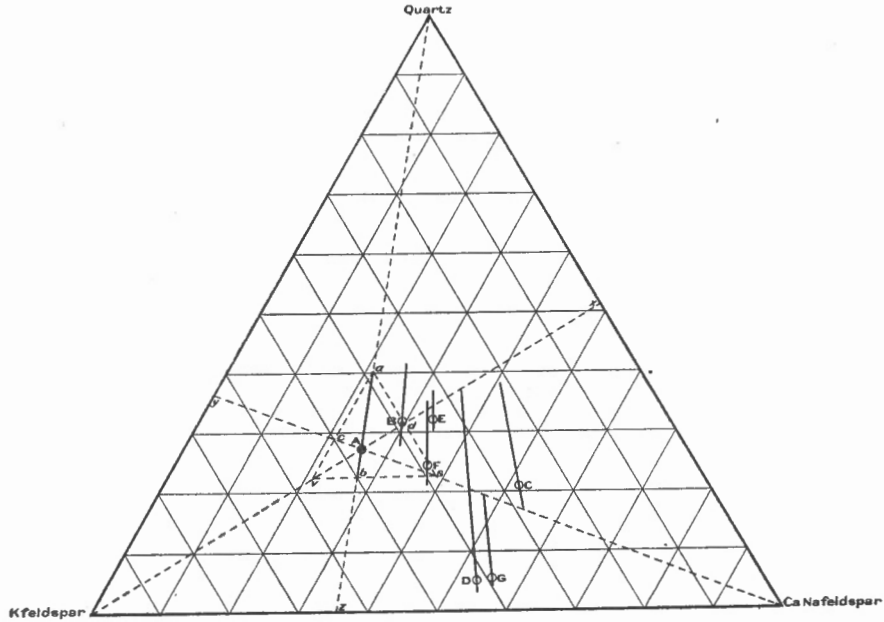



Figure 2. B. Graphical representation of the percentages of minerals and the relative proportions of light constituents in the average types of granitic intrusives that occur in Brockville-Mallorytown map-area and Alexandria map-area. (For sources of information, method of construction, and interpretation of this diagram *See* page 24.)

clase ranges from oligoclase-albite to andesine and, therefore, in the Johannsen quantitative classification, these rocks fall in Class 2, Order 2. The family depends upon the ratio of orthoclase to plagioclase and the amount of quartz. The different family numbers of these intrusives are indicated on Figure 2 A; the rock number of the Brockville granite is 226 and of the granodiorite 227.

In this report the family names granite, granodiorite, etc., are used instead of mongo-granite, adamellite, etc. The alternative families and nomenclature are indicated in the diagram. For areas of Precambrian granitic intrusives with a fairly acid plagioclase (oligoclase-albite to andesine) and without a pyroxene the classification and nomenclature adopted for the Brockville-Mallorytown area seem the best. If some of these rocks had contained a basic plagioclase (labradorite) and a pyroxene or abundant amphibole, as they do in some areas, then the family names adamellite and monzonite could be used with their original meaning.[1] Granodiorite is used as originally defined by Lindgren[2] and is applied to a rock intermediate between granite and tonalite.

Figure 2 B shows graphically the average mineralogical composition of the Brockville-Mallorytown granitic intrusives as well as those of the Alexandria area to the south. The data for rocks E, F, and G[3] are calculated from the chemical analyses. The points and lines on this diagram are located by drawing three lines, parallel to the sides of the triangle, through the points representing the percentage in the rock of each of the three corner minerals; in the case of rock A, for example, a horizontal line *vs* through 22·5 for quartz, *va* sloping northeast and southwest through 21 for plagioclase, and *as* through 39·5 for orthoclase. The intersections of these three lines form the triangle *avs*. Lay a straight edge on the apices of the original and this small triangle and connect the apex of the small triangle with its base by the line *ab*. Connect the lower corners of the large triangle with similar corners of the small one and A, the point of intersection of these three lines, and the line *ab* represents the rock, in this case the Brockville granite. The point A gives the relative proportions of light constituents, quartz (zA), orthoclase (*x*A), and plagioclase (*y*A). The actual percentages of the minerals in the rock are represented by *bz* for quartz, *xd* for orthoclase, *cy* for plagioclase, and *ab* for ferromagnesian minerals. In a similar manner either the relative proportions or the actual mineralogical composition of the other rocks plotted can be read.[4]

This diagram also shows the close correspondence between the modes of granitic rocks determined by the planimeter method and those calculated from chemical analyses for similar rocks. The increasing percentage of ferromagnesian minerals in the basic types is also emphasized by the length of the lines *ab* or *aj*. For example, in the three calculated modes from chemical analyses, the percentage of ferromagnesian minerals is less than it is in the average planimeter determination of the ferromagnesian minerals in thin sections.

It is possible that detailed work may show that a number of other Precambrian granite areas vary in composition, and that other types of

[1] Brögger, W. C., Die Eruptivgesteine des Kristianiagebeites. Kristiania, II, 1895, pp. 6 and 61.
[2] "Granodiorite and Other Intermediate Rocks," Amer. Jour. of Sc., IX (1900), pp. 269-82.
[3] New York State Mus. Bull. No. 145 (1910), pp. 176-183.
[4] Details concerning the construction and use of these diagrams are given in, Johannsen, Albert, Jour. Geol., XXX (1922), pp. 167-69.

rock, such as granodiorite, may be more abundant in the Precambrian granite batholiths than was formerly thought. In the Brockville-Mallorytown area granite is by far the most abundant type, but detailed field and laboratory work showed considerable areas of the other types.

The granodiorite and syenite types were found to grade gradually into typical granite and to represent basic phases of the granite magma. The Brockville granite was not seen in contact with the Mallorytown granite; but, because of its areal distribution and its similar character, it is undoubtedly a part of the same general magma and of the same age.

These granitic rocks are intrusive in the Grenville sedimentary series. The coarseness of the grain and the absence of chilled contacts indicate that they solidified slowly at a considerable depth below the surface. The granodiorite and syenite are differentiation phases of the magma.

These granitic intrusives are probably of middle or late Precambrian age. They are equivalent to those mapped by Cushing directly south of this area on the islands and mainland of northern New York, as Laurentian, and those mapped by Baker as Algoman in the Kingston area 15 miles to the west. On the basis of mineralogical composition and areal distribution they fall into the following five main groups:

(1) Brockville granite outcropping in Brockville and west for 6 or 8 miles along the St. Lawrence.

(2) Mallorytown granite outcropping in a long more or less broken belt from Yonge Mills through Mallorytown to Rockport and the Thousand islands. This granite is equivalent to Cushing's Laurentian of northern New York.

(3) Granodiorite outcropping north and west of Rockfield.

(4) Syenite outcropping in small areas to the north of Rockfield, Trevelyan, and east of Charleston lake.

(5) Aplite and pegmatite outcropping at various localities over whole area.

## BROCKVILLE GRANITE

The name Brockville granite is given to the granite outcropping in the town of Brockville and west on the islands of the Brock group and at intervals along the St. Lawrence to a short distance west of Jones creek. It also outcrops back from the river a mile or so and on the New York side of the river at Oak Point, though these areas were not shown by Cushing on his map of the Ogdensburg quadrangle.[1]

The Brockville granite varies from red to pink, with a few outcrops weathering greyish. It is mostly rather coarse grained, and the size of the grains and the proportion of dark minerals show little variation from place to place. However, in some cases the biotite is segregated in bunches and the outcrop has a spotted appearance. In a few outcrops a Carlsbad twinned feldspar forms well-developed phenocrysts, and the rock is slightly porphyritic, but this is not characteristic. Striated barrel-shaped tourmaline crystals are scattered abundantly through some outcrops of the granite, and along the main road near the head of Lily bay a tourmaline crystal 5 inches in diameter was noted. The granite is massive and well jointed.

In thin sections the Brockville granite is seen to be composed chiefly of quartz, microcline, orthoclase, microperthite, oligoclase-albite, and biotite, with accessory muscovite, hornblende, tourmaline, apatite, zircon,

[1] New York State Mus. Bull. No. 191, 1916.

magnetite, titanite, rutile needles, and secondary calcite, epidote, leucoxene, kaolin, and sericite. The texture is hypidiomorphic granular, and cataclastic. Some parts of the thin sections, especially narrow bands across the section, are notably granulated, but in the areas between these granulated streaks the mineral grains are irregular in outline and show little evidence of crushing. This texture may be granoblastic, as the feldspars show evidence of strain and are slightly bent. The streaks or zones of fine-grained and crushed material between the coarse-grained areas consist chiefly of fresh microcline and quartz. Biotite is also more abundant along these zones and is colourless to brownish, highly pleochroic, and has frayed ends.

The average diameter of the minerals of this granite is about 3 mm. The microcline grains are large, up to 25 mm. in length, but average about 4 mm. Some sections contain large, irregular areas of microperthite or microcline-microperthite, and only a small percentage of microcline. The oligoclase-albite crystals are smaller, and mostly have either a dull cloudy appearance or are weathered to kaolin-like material. Some of the biotite is secondary after hornblende, but the fresh-looking, nearly colourless, highly pleochroic variety is probably primary.

The following is the average of the mineral composition of nine sections of the Brockville granite.

| | |
|---|---|
| Quartz | 22·7 |
| Potash feldspar | 39·2 |
| Plagioclase feldspar | 21·1 |
| Microperthite | 0·4 |
| Biotite | 13·4 |
| Hornblende | 0·9 |
| Accessories | 2·6 |
| | 100·3 |

The Brockville granite cuts the Grenville sedimentary series, but does not cut the early Palæozoic sediments. It was not seen in contact with the other intrusives of the area. The half-mile interval between the Brockville granite and the Mallorytown granite along Jones creek is covered with drift or Palæozoic sandstone. But, because of its nearness to the other granite areas, and because of its marked similarity, the Brockville granite is undoubtedly a part of the same general magma and of the same age as the Mallorytown type.

### MALLORYTOWN GRANITE

The name Mallorytown granite is given to the granite, of which typical outcrops are abundant just east of the village of Mallorytown, and are almost continuous from about 2 miles north of Yonge Mills, to Wells island. The areas of this granite are very irregular in outline because of the manner in which it intrudes the surrounding rocks. This granite is easily recognized by its characteristic salmon red colour and is the most abundant type outcropping in the area.

The Mallorytown granite is medium to fine grained, salmon red or light pink to grey, and is both massive and slightly foliated. The colour is characteristic and is fairly constant. The greyish varieties are of

limited extent only and pass gradually into the typical salmon-coloured varieties. Foliation, also, is a local feature because, about half a mile east of Mallorytown, a well-foliated granite gneiss passes, within 600 feet along the strike, into typical massive granite. At many places a foliated granite gneiss was noticed on one side of a narrow depression and a massive granite on the other. Outcrops of the foliated granite appear to contain more mica than outcrops of the massive variety, but this is due, probably, to the parallel orientation of the mica in the gneiss, so that its flat faces cover more of the exposed surface. Mica is no more abundant in thin sections of the foliated varieties than it is in those of the massive types.

Orthoclase and oligoclase-albite are the most abundant feldspars in thin sections of this granite. Microcline, microperthite, micropegmatite, biotite, and hornblende were noted in subordinate amounts in all sections. The texture is cataclastic. All the larger grains have granulated corners or sides, the feldspar grains are bent, and the quartz shows undulatory extinction. In many cases the granulated material has recrystallized into muscovite, microcline, albite, and quartz. Accessory titanite, apatite, and tourmaline are always present, together with secondary epidote, leucoxene, chlorite, kaolin, and sericite.

The size of the grains is fairly constant. The feldspars average about 3 mm. in diameter, but some of the plagioclase grains are 7 mm. long. The proportion of the minerals throughout the whole rock is variable, as the proportion of plagioclase varies from 16 to 36 per cent, and orthoclase from 19 to 41 per cent. In many sections the plagioclase is only slightly less than the potash feldspar. A number of the sections contain more than 33 per cent of quartz.

The quartz is interstitial and invariably occurs as xenomorphic grains. Some of the grains are 6 mm. or more in length, and are made up of numerous individuals which penetrate each other and penetrate and include areas of feldspar. Most of the quartz grains are fractured and show undulatory extinction, and in some sections the quartz is badly crushed. The small particles of hematite or limonite deposited along the fractures give the quartz a dirty appearance. Small rounded grains of quartz are abundant as inclusions in the feldspars.

The potash feldspars are orthoclase and microcline. The orthoclase is in small, slightly decomposed, subhedral crystals, but in the granulated sections microcline is abundant and orthoclase is only sparingly present. The plagioclase feldspar in different sections varies from albite to oligoclase in composition, with oligoclase-albite as the most abundant variety. A few small grains of microperthite were noted in almost every section. The feldspars are slightly weathered to a kaolin-like material, but generally the twinning lamellæ are distinct. The weathered feldspars also contain small specks of hematite and this is probably the colouring matter of the salmon red feldspars. Cushing discussed, in detail, the cause of the colour of this granite, and decides that it is due to ferric oxide in the alkali feldspars, and that rocks, coloured red by ferric oxide, crystallized under temperatures not high enough to bleach the ferric oxide from the feldspar.[1] Cushing's experiments also showed that lime hastened the bleaching and

[1] "Geology of the Thousand Islands." New York State Mus. Bull., No. 145, 1910, pp. 178-180.

lowered the temperature, and this is the probable explanation of the greenish grey or dark colour of the more calcium-rich feldspars of the granodiorite.

The two important ferromagnesian minerals are biotite and hornblende. The biotite is of two varieties, a dull greenish, slightly pleochroic variety, probably secondary after hornblende, and a colourless to light brown, highly pleochroic variety which is probably primary. The hornblende is in small, elongated crystals and is a slightly pleochroic green variety. Some of the biotite and hornblende is weathered to a green, chloritic-looking material and magnetite.

Mode of Mallorytown granite from the average of twelve mineralogical analyses.

| | |
|---|---|
| Quartz | 27·8 |
| Orthoclase | 12·8 |
| Microcline | 18·5 |
| Microperthite | 3·9 |
| Micropegmatite | 0·7 |
| Plagioclase | 24·3 |
| Biotite | 6·0 |
| Hornblende | 2·6 |
| Accessory | 3·8 |
| | 100·4 |

This granite is slightly more acid than the Brockville granite.

The Mallorytown granite cuts the Grenville series and is Precambrian in age. Its relations to the Brockville granite could not be determined, because the area where the two types come together is covered with drift and early Palæozoic sandstone. It was found to grade into granodiorite west of Rockfield and into syenite north of Trevelyan. This Mallorytown medium-grained acidic type appears to occupy the central part of a large mass of igneous rock around the edge of which the coarse-grained and more basic varieties outcrop.

### GRANODIORITE

Outcrops of granodiorite are abundant north and west of Rockfield and along the western edge of the area from Tilley north to Blue mountain. Between Charleston and Graham lakes, granodiorite outcrops at various places.

The granodiorite varies from a light pink, to light green, to dark grey. It is everywhere a coarse-grained, massive rock, and many outcrops contain dull, greasy-looking quartz, bunched somewhat locally. Horizontal joints are exceptionally well developed in it.

The essential mineral constituents are quartz, orthoclase, microperthite, oligoclase, hornblende, and biotite. The texture is hypidiomorphic granular. The mineral crystals are fairly uniform in size, the feldspars averaging about 5 mm. in length. The chief feldspar is basic oligoclase ($Ab_{70}$ $An_{30}$). The twinning lamellæ are slightly bent and indicate considerable strain but show little granulation. In a number of sections the plagioclase is badly weathered to kaolin and white mica and around the edges are small aggregates of epidote and calcite. In most thin sections microperthite consisting of large plagioclase crystals with fine thread-like lamellæ of orthoclase along parallel lines in the grains is abundant.

Hornblende is the most abundant ferromagnesian mineral. When fresh, it has strong pleochroism, somewhat resembling katophorite. It is mostly altered to biotite, magnetite, and a green chlorite-like material.

The following mode is the average of the mineral composition of ten sections:

| | |
|---|---|
| Quartz | 16·4 |
| Orthoclase | 17·9 |
| Microperthite | 5·4 |
| Micropegmatite | 1·4 |
| Oligoclase | 37·4 |
| Hornblende | 9·0 |
| Biotite | 8·5 |
| Accessories | 3·5 |
| | 99·5 |

### SYENITE AND SYENODIORITE

These two types do not occupy any large area, but scattered outcrops are quite abundant between Charleston and Graham lakes, and south to Rockfield, and Trevelyan. A few specimens were collected from the outcrops, but in most cases it was impracticable to map these types separate from the granodiorite or even from the Mallorytown granite.

The syenite is similar to the granodiorite in colour and texture, and in the field was mapped as a basic phase of the granite.

Thin sections of these rocks are similar to those of the granodiorite. The feldspar crystals are slightly larger, up to 10 mm. in diameter. The edges of the grains are slightly granulated. A noticeable difference is the great abundance of microperthite in the sections poor in quartz. In a few feldspar-rich sections almost the whole rock is composed of microperthite. The typical spindle intergrowth is well developed, but in some sections the orthoclase is in lens-shaped masses more or less in parallel lines and the section of this feldspar has the appearance of an augen gneiss. Most of the quartz is graphically intergrown with orthoclase. The plagioclase is near andesine in composition.

The following mode is the average of six sections:

| | |
|---|---|
| Quartz | 3·3 |
| Orthoclase | 21·7 |
| Microperthite | 10·9 |
| Plagioclase | 30·5 |
| Hornblende | 20·0 |
| Biotite | 8·2 |
| Accessories | 5·4 |
| | 100·0 |

### APLITE AND PEGMATITE

Narrow, pink aplite dykes cut the large areas of quartzite east of Yonge Mills and north of Escott. Pegmatite dykes are scarce and only one was noted—on the hill back of Rockport. The contacts of these dykes with the quartzite are sharp, but the rock is not dense or fine-grained like the contacts of the diabase dykes. The aplites are similar, mineralogically, to the acid phases of the granite. Muscovite is the chief mica and albite the plagioclase feldspar. Potash feldspar is in all cases more abundant than plagioclase.

Pegmatite dykes are, as a rule, numerous in areas where granite is abundant, but strangely enough, are almost absent in the Brockville-Mallorytown area.

### STRUCTURAL FEATURES OF GRANITIC INTRUSIVES

A marked structural feature of these granitic intrusives is the distinct horizontal jointing in some of the rock. This horizontal jointing accounts for the flat character of some areas underlain by granite, because glacial erosion over wide areas scoured down locally to the same well-developed joint plane. The joint planes are generally about a foot apart and are parallel to the surface over wide areas.

Two sets of vertical joints about at right angles to each other are well developed in some outcrops of the granite, whereas in other outcrops joints are absent. The strike of the majority of these joints is from north 45 degrees east to north 55 degrees east and from north 30 degrees west to north 50 degrees west. These joints possibly indicate that the region has been subjected to considerable pressure from a north-south direction since the granite solidified.

The granite of some outcrops is foliated and presents a gneissoid appearance, whereas other outcrops are massive. The foliation is primary and of local origin. Often, within a few hundred feet along the strike, a well-foliated gneiss passes into massive rock; or, on one side of a narrow depression, the granite is massive and on the other side it is foliated. The strike of the foliation is always northeast-southwest, and the dip, as a rule, is to the northwest, but in some places to the southeast. The foliated rocks have the biotite in narrow zones, and thin sections across these zones show that the feldspars are much granulated. These zones are wavy and irregular in their continuation and are due to local differential flowage in a pasty or semi-solid magma. Cushing[1] concluded from a study of the foliation of the granitic intrusives of the Alexandria area, that evidence of thorough-going compression of much later date than these granitic intrusives is very clear. In the Brockville-Mallorytown area the only evidence of compression since the solidification of these granitic intrusives is the horizontal and vertical joints so characteristic of some of the outcrops. The most reasonable explanation of the origin of the irregular and local foliation of these granitic rocks is that it is due to local movements during the intrusion of the magma under lateral pressure.

As a rule, the contact between granite and sedimentary rocks is sharp, and there is no addition of foreign material recognizable in a thin section of granite taken from within a foot of a quartzite contact. Thin sections of quartzite 3 feet from the granite contact show a notable addition of feldspar in large patches enclosing, and irregularly penetrating between, the quartz grains (Plate III B). From a study of thin sections of Grenville sediments it is evident that solutions from the granite magma penetrated them for a considerable distance from the granite contacts. At the visible contacts there is no evidence that the granite assimilated sedimentary material, but solutions from the magma evidently penetrated the sediments.

The quantitative mineral analyses of these rocks show considerable variation. There is also considerable variation in the size of the grains,

[1] New York State Mus. Bull. No. 144, 1910 p. 102.

but the texture is fairly uniform. In many cases quartz-poor phases of these granitic intrusives were traced and found to grade into normal pink granite, and there can be little doubt that they are phases of the same magma and are of the same general age. The quartz-poor or syenite phases of these intrusions are probably due to the cooling of parts of the magma before differentiation had advanced to completion. When the magma reached its present position, it had the composition of granodiorite or possibly was more basic. After a time, but before crystal settling had gone far, the outer surface of the magma cooled, and this cooled part formed a blanket and retarded cooling below, allowing differentiation to go farther. In the late stages of cooling, deformation took place, producing the cataclastic texture and local primary foliation. At this time granitic material was forced along joint planes and other lines of weakness into the overlying rocks to form the few aplite dykes. Erosion has removed the quartz-poor parts from the top in the centre of this intrusive mass, and granite is exposed over a wide area.

In a few instances the sedimentary rocks are so highly granitized that it is difficult to determine the exact contact between sediments and granite, but on the whole the contacts are sharp and definite. The contacts of the granite dykes with the quartzite south of Caintown are very sharp and the granite shows no evidence of chilling along the contact. The granite dykes are, as a rule, short, discontinuous, and branching, and pinch and swell along the strike. Evidently the granite shoved the quartzite aside along poorly developed fracture and bedding planes. In the case of the biotite gneiss the granite penetrated along the cleavage planes of the foliation and bedding, and granite dykes are continuous and parallel to the foliation and bedding for long distances. These minor dykes indicate on a small scale the manner in which the granite made room for itself, and why the granite outcrops in narrow, irregular-shaped belts, or between the thick quartzite beds. Evidently, the granite in making room for itself arched the Grenville sediments upwards and spread slowly along planes of weakness between the competent thick quartzite beds. The quartzite was fractured and the magma penetrated these fracture planes, so that on both sides of a thick quartzite bed inclusions of quartzite are abundant in the granite.

## AGE OF GRANITIC INTRUSIVES

The granitic intrusives so abundant in the Brockville-Mallorytown area are post-Grenville and pre-early Palæozoic. They were intruded long before the end of Precambrian time, for they must have crystallized at a considerable depth; and before the end of the Cambrian period they were exposed by erosion. Cushing[1] has divided the granitic intrusives into the Laurentian or older group, and the Picton or younger group. Baker,[2] in the Kingston area, has divided these intrusives into the older Laurentian, and the younger Algoman groups. In the Brockville-Mallorytown area no evidence of granites of two ages was found, and the granite of the area was traced and found to be equivalent to Cushing's Laurentian

[1] New York State Mus. Bull. No. 145, 1910.
[2] Ont. Bureau of Mines, vol. 25, pt. III, 1916.

and Baker's Algoman. The following table shows the nomenclature and classification as used in these three areas.

| Alexandria<br>Cushing | Brockville-Mallorytown<br>Present report | Kingston area<br>Baker |
|---|---|---|
| Picton..... | ..... | ..... |
| Laurentian..... | Granitic intrusives..... | Algoman |
| ..... | ..... | Laurentian |

Neither Cushing nor Baker has positive evidence of two periods of granitic intrusion in this region, and both have exaggerated certain lithological and structural distinctions in their mapping. In fact, Cushing, in summing up his evidence for two periods of granitic intrusion, says that, "such a younger age for this granite then seems to us in the highest degree probable, though it falls somewhat short of actual demonstration."[1] W. J. Miller has found evidence for only one period of granitic intrusion in other areas just south of the Thousand Islands area, and has concluded that Cushing has not presented any positive evidence for two periods of granitic intrusion in the Thousand Islands region.[2] The detailed work in the Brockville-Mallorytown area favours Miller's contention.

C. H. Smyth, jun., was the first geologist to do detailed work in the Thousand Islands region and he recognized and described the two types of rock that Cushing later mapped as Laurentian and Picton granite. Smyth has the following to say concerning their age:

"But as regards the relative age of the granite and the granite-gneiss there is less certainty. As a whole, the granite is more massive, and thus a younger looking rock than the gneiss, but when the former becomes well foliated as it often does, it is practically identical with the gneiss. The most constant petrographic distinction in the field is the presence of the opaque white to blue quartz in the granite, but even this fails in the gneissic phases. Certainly the writer could find no instance of granite cutting granite-gneiss or of inclusions of the latter in the former, although inclusions of schist and quartzite are abundant."[3]

The conditions in the Brockville-Mallorytown area are similar to those described by Smyth. In no case was granite or syenite found to cut each other, and although aplite and pegmatite dykes are scarce north of the St. Lawrence, in no case was one dyke seen to cut another. Granite grades into syenite or granodiorite, and foliated gneiss grades into massive granite and the different types are so intermingled that it is impossible to map them separately.

In an area where the only sedimentary series is early Precambrian there is considerable difficulty in getting evidence for two or more periods of granitic intrusion. The contact between an older and a younger granite might be indefinite and hard to find, although it is possible that a contact breccia or a concentration of tourmaline or magnetite or certain other minerals, might suggest intrusive relations. One dyke cutting another does not necessarily prove two intrusions of great age difference, because dykes formed during the early stages of a period of intrusion may be cut

[1] New York State Mus. Bull. No. 145, p. 42.
[2] Bull. Geol. Soc. of Am., vol. 25, 1914, pp. 243-263.
[3] "Geology of the Crystalline Rocks in the Vicinity of the St. Lawrence River," New York State Mus. Rept. for 1899, p. R 92.

by later dykes from the same magma. In granitic intrusives with primary foliation irregularly developed, the occurrence of foliated granite outcrops among massive granite outcrops does not mean that the foliated granite is an inclusion in the massive granite, for in many places the two grade into one another and are of the same age. All the highly foliated inclusions in the granite of the Brockville-Mallorytown area, when studied in detail, were found to be of sedimentary origin and to belong to the Grenville series.

As no positive field evidence has yet been found for two periods of granitic intrusion in the region, and as all the structural relations of the region can be explained on the basis of only one period of extensive granitic intrusion, there seems no justification for the assumption of two periods. There may have been several periods of granitic intrusion in the area, but field evidence fails to support this contention. Extensive granitic intrusions occur in the core of mountain ranges and as mountain ranges are long and narrow it is possible that there are several roughly parallel zones or belts of granitic intrusives striking in a general northeast direction in the area between the Adirondacks and lake Superior.[1] At some place along the contact between these zones or belts the intrusive relations may be found and one zone may be proved older than another. Working out the age relations of these granites is difficult, and entails a large amount of detailed work in selected areas before definite conclusions can be drawn. The detailed work already completed in Brockville-Mallorytown area leads to the conclusion that this area is not on the contact between two of these hypothetically possible belts of granitic intrusion, and, therefore, is an unfavourable area in which to study the relations of different periods of Precambrian granitic intrusions.

## DIABASE DYKES

Diabase dykes are not so abundant nor are they so continuous as in most other Precambrian areas in southeastern Ontario. A few short, narrow dykes outcrop throughout the area, and are especially abundant southwest of Mallorytown. In general these dykes strike about northeast and dip nearly vertically. They vary in width from 2 inches to 300 feet.

In the wider dykes the diabase is medium grained, massive, grey to black in colour, and weathers rusty to brownish red. The surface forms a yellowish, rusty-coloured gossan which is so soft and decomposed that it can be easily removed with a pick and shovel. It has been extensively used for road material. On a few dykes this gossan is at least 6 feet thick, but in most places it is less than 2 feet. The surface of a large number of the dykes is, on the other hand, apparently perfectly fresh and unweathered. The dykes with weathered tops are protected on the northwest side by a ridge of quartzite or granite, as for example the dyke about 200 feet south of the main road, 2 miles west of Mallorytown. The decomposed capping is preglacial or older, for dykes that were exposed to intense glacial scour do not have such a capping, although microscopic study shows that all the dykes are badly weathered. This deep weathering may possibly be pre-early Palæozoic, because the early Palæozoic sediments have been

[1] Wilson, M. E., Geol. Surv., Can., Mem. 108, 1918, pp. 68-9.

removed from this area only recently, and little weathering has taken place since.

Of the two rocks, quartzite and diabase, diabase, because of its mineral composition, weathers faster and deeper. Furthermore, the contact of the dykes is a likely zone for fracturing that would aid the circulation of solutions in weathering. Glacial scour was not, in a few places, intense enough to remove the thickness of fresh quartzite or granite represented by the difference in depth between the weathering of the granite or quartzite and the diabase. Of course, this difference might have been considerable in exceptional cases such as where a fault plane occurred within and parallel to the dyke, but no evidence of faulting was noted in these decomposed dykes. The difference in depth of weathering of these two types of rocks was probably not great, and consequently the glacial erosion of fresh rock by the continental glaciers was not great in this part of the area.

Many of the dykes cutting quartzite divide, when traced along the strike, into two or more narrow dykes and end. The diabase dykes cut both the Grenville series and the granite intrusives, but do not cut the early Palæozoic sediments. Their contact with the country rock shows a chilled border, up to 2 feet in width.

Smyth has described in detail the diabase dykes of the Admiralty islands (about 10 miles west of the map-area) where the prevailing strike of the diabase is north and south instead of northeast and southwest as in the map-area.[1]

Table V shows the principal minerals present in the diabase. All sections are badly weathered, which makes mineral measurements difficult or nearly impossible. Under the microscope these dyke rocks are found to consist of holocrystalline aggregates of plagioclase and augite with much dense and weathered material between. The texture is ophitic, in some cases slightly porphyritic, but the material of most sections is badly weathered and the original texture destroyed.

*Table V.—Mineral Composition of Diabase*

| Specimen number | 39 | 42 | 11 | 45 | 51 |
|---|---|---|---|---|---|
| Labradorite | 60·0 | 55·0 | 46·0 | 36 | 27·0 |
| Augite | 31·0 | 30·0 | 32·5 | 56 | 67·0 |
| Magnetite | 8·0 | 11·0 | 10·5 | 6·0 | 5·0 |
| Accessories | 2·0 | 4·0 | 11·0 | 2·0 | 1·0 |
| | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 |

39 Mallorytown Landing.
42 Mallorytown-Caintown road 1 mile south of Caintown.
11 Gravel pit east of Lyn.
45 South of road 1 mile west of Mallorytown.
51 East of road running northwest from Pooles Resort and 1½ miles from the St. Lawrence.

[1] "A Group of Diabase Dykes among the Thousand Islands, St. Lawrence River." Trans. New York Acad. of Sc., vol. 13, 1893-94, p. 209.

The plagioclase in most of the dykes is basic labradorite, but in a few of the narrow dykes the plagioclase is as acidic as andesine, and biotite is one of the ferromagnesian minerals. The plagioclase has a brownish, dusty appearance, and some of the crystals are weathered so that the albite twinning lamellæ are not recognizable.

The augite fills spaces between the plagioclase crystals, and is green to brownish pink. The green varieties are non-pleochroic; the brownish varieties are slightly pleochroic. In some sections the prismatic cleavage is distinct, but generally the mineral is weathered to a slightly fibrous chloritic-looking material. The green hornblende noted in one or two sections is probably secondary after augite.

In the sections with andesine as the plagioclase, a brown, strongly pleochroic biotite is abundant. All sections contain considerable magnetite in large grains, as irregular-shaped areas, or as small threads and specks, secondary after augite or biotite. Well-developed wedge-shaped crystals of titanite and round or needle-shaped apatite crystals are abundant. A few good zircons were noted, as well as leucoxene which is either secondary after ilmenite or more probably after titaniferous magnetite.

Distributed throughout a number of the dykes are black, round lumps that in the field resemble large shot in appearance. The microphotographs, Plate IV A and B, show that these lumps are composed of very fine, dense, chloritic-looking material which in some cases has a well-developed vermicular form, whereas in others this characteristic is not so well developed. Sections of some of the lumps do not show this vermicular form, but the material is a microcrystalline mass with what appear to be small needles of feldspar through it, and the section has the appearance of poorly developed spherulites. These lumps were in the magma before it consolidated, as shown by the bending of the minerals around the lumps and the absence of fracturing of the plagioclase laths.

These lumps evidently represent centres of incipient crystallization before or during the passage of the magma to its present position. For some reason this initial crystallization stopped, and the lumps were never re-fused, but floated up with the magma to its present position where crystallization was completed, and a fine or medium-grained diabase resulted. The dense appearance of a number of these dykes indicates that they cooled at no great depth below the surface, and the wide, chilled borders indicate that the country rocks were cold. Smyth[1] notes that in the area to the west much glass is present in a number of the dykes, and that they rarely show flow structure, which indicates an approach to the vesicular structure of the rocks of volcanoes.

The discontinuous and branching character of many of the dykes along their strike, the presence of unfused centres of former crystallization, and the dense or almost glassy character of much of the material indicate that they cooled near the present surface and are, consequently, more closely related in age to the early Palæozoic erosion surface than to the granitic intrusives which must have cooled at a great depth below the surface, and were nearly unroofed by a long period of erosion preceding

[1] Ibid.

the intrusion of the diabase magma. The diabase dykes do not cut the Potsdam sandstone, but they must be very late Precambrian or possibly early Palæozoic.

## PALÆOZOIC FORMATIONS

In the Brockville-Mallorytown area the Palæozoic group is represented by non-fossiliferous sandstone and limy sandstone followed by beds of fossiliferous sandy limestone and dolomite. For the purpose of mapping and description the former series is called Potsdam, and the latter Beekmantown, but no direct evidence was found in this area to prove the advance or retreat of the sea during this time. The above division is made on the basis of the presence or absence of fossils, and on lithological character. Near Morristown, opposite Brockville, Cushing found a marked disconformity between the Cambrian and the Ordovician, but northeast of Brockville the passage from the one to the other, although not well exposed, appears to be represented by a transitional thin sandstone merging into a sandy limestone, and this into thick-bedded fossiliferous limestone.

A very irregular erosion surface marks the contact between the Palæozoic rocks, which are nearly horizontal, and the highly folded and metamorphosed Precambrian rocks. The Palæozoic formations are uniform over wide areas, showing almost no variation except the addition of considerable calcareous material at certain horizons.

### DISTRIBUTION

East of Brockville the St. Lawrence valley is underlain by early Palæozoic sediments, but to the west these rocks outcrop as tongue-like embayments between the hills of Precambrian rock, or as large and small outliers. A good example of an embayment of the Palæozoic between Precambrian ridges is the sandstone area north of the road from Caintown to Junetown; good examples of large outliers are the outcrops around Butternut bay. Small outliers are fairly abundant over the whole area, except in the rough tract southeast of Charleston lake.

### GENERAL SECTION

After many years of detailed work in the northern Adirondack region, where these early Palæozoic formations are better developed than in our area, Cushing has subdivided them into four, possibly five, formations. However, in the Brockville-Mallorytown area the whole series is not more than 150 feet thick, and its distribution is very irregular and patchy. The near-shore phases of formations, much better represented farther east, are the only outcrops here, and it is not, therefore, a very satisfactory area in which to make a detailed study; but the following section gives the thickness and general characters of the Palæozoic of the Brockville-Mallorytown area, and a possible correlation with the Ogdensburg area,[1] directly across the St. Lawrence.

[1] Cushing, H. P., "Geology of the Vicinity of Ogdensburg," New York State Mus. Bull., No. 191, 1916, p. 24.

## *Palæozoic Section*

| Brockville-Mallorytown area | | | | Ogdensburg area | | |
|---|---|---|---|---|---|---|
| System | Formation | Thickness | Lithology | Thickness | Formation | System |
| | | Ft. | | Ft. | | |
| Ordovician | Beekmantown | 30 | Fossiliferous, thick-bedded, massive, dark dolomitic limestone with thin beds of sandy limy material near the base | 120 | Ogdensburg | ..... |
| ..... | ..... | ..... | Thick to thin lens-shaped beds of grey nodular sandstone, non-fossiliferous. Grey, irregular-bedded sandstone alternating with beds of bluish grey limy material | 0–40 | Tribes Hill. | Ordovician |
| Cambrian | Potsdam.... | 120 | Lens-shaped bed of bluish grey dolomite limestone. Very hard, massive, light grey sandstone<br>Irregular-bedded, rubbly weathering, calcareous sandy material | 120 | Theresa..... | Cambrian (Ozarkian) |
| ..... | ..... | ..... | Light grey weathering, irregular-bedded, hard, nodular sandstone. Basal conglomerate | 0–60 | Potsdam.... | ..... |
| Precambrian | Grenville and igneous rocks | ? | Quartzite, granite, etc..... | ? | Grenville and igneous rocks | Precambrian |

### POTSDAM

The base of the Palæozoic section is, as a rule, conglomerate, but in some places is a thin bed of sandstone and, in one instance, is conglomerate overlying thin sandstone. The basal conglomerate lies between the hills, and varies greatly in thickness within short distances. The maximum thickness noted was 8 feet, and in this case the conglomerate abutted against a pre-Potsdam quartzite ledge near the south side of Hill island. The sandstone below the conglomerate was noted only along the St. Lawrence west of Cole lighthouse, but it is interesting because Cushing described a similar basal sandstone of which he found pebbles in the conglomerate above.[1] The sandstone, therefore, must have been indurated previous to the formation of the Potsdam conglomerate above, and it is probably an erosion remnant of a considerably older sandstone.

The pebbles of the conglomerate vary from a quarter of an inch up to small boulders (Plate II A), with an average of about 3 inches. Small pebbles are much the more abundant, but the proportion of large and small varies greatly within short distances. In places they are angular, not having travelled far, but in other places they are subangular or considerably

[1] "Geology of the Thousand Islands Region," New York State Mus. Bull. No. 145, p. 62.

rounded. Quartzite pebbles only were found in the conglomerate of this area and in the areas to the south both Smyth and Cushing have noted the general absence of granite and gneiss pebbles in the corresponding conglomerate. Silica is the cementing material of the conglomerate, which is hard and well indurated. The sandstone beds are very uniform in appearance over wide areas. They are grey to light grey, with a few narrow and local red or rusty-coloured patches, and are fine to medium grained. Small brown spots or nodules are abundant throughout. In these nodules are limonite and rusty-coloured quartz, and Cushing describes them as "Spots of calcareous cement which weather out, leaving round brown spots."[1]

Thin sections taken from different sandstone horizons show that the rock consists of 90 to 95 per cent quartz. One thin section taken about 10 feet from the base contained about 33 per cent orthoclase. The grains vary from 0·05 to 0·5 mm. in diameter with an average size of about 0·2 mm. Some of the grains are exceptionally well rounded, but others have an irregular outline. No secondary enlargement of the quartz grains was noted. Orthoclase generally forms from 2 to 4 per cent of the rock and is slightly weathered. Other minerals present are microcline, oligoclase-albite, biotite, titanite, magnetite, apatite, zircon, red iron oxide, calcite, and rutile needles in the quartz.

The following is a chemical analysis of one of the purest beds of this sandstone:[2]

| | |
|---|---|
| $SiO_2$ | 95·35 |
| $Fe_2O_3$ | 0·27 |
| $Al_2O_3$ | 1·11 |
| $CaCo_3$ | 2·86 |
| $MgCo_3$ | 0·39 |
| $H_2O$ (105°) | 0·24 |
| | 100·22 |

About 30 feet from the base of the Potsdam, and at the base of the Beekmantown, the sandstone is very calcareous. These horizons are dark grey and are thin and irregularly bedded.

Thin sections from these calcareous beds show round grains of quartz, averaging about 0·4 mm. in diameter, embedded in a matrix of calcite. The proportion of calcite varies from 20 per cent in the sandy beds, to 85 per cent in the limy beds. A few elongated grains of orthoclase, microcline, magnetite, and pyrite were noted. Along the river road northwest of Lily bay there is a lens-shaped bed of bluish limestone, having a maximum thickness of about 12 feet. Throughout this lens, quartz is present as fine, angular to slightly rounded grains. This limy sandstone breaks into small fragments rather than into large blocks and is, therefore, awkward to blast, but it has been much used for roads.

### BEEKMANTOWN FORMATION

This formation consists of fossiliferous sandy limestone, limestone, and dolomite. It outcrops only north and east of Brockville and was not studied in detail. The basal beds of the formation are sandy and nearly

[1] "Geology of the Vicinity of Ogdensburg," New York State Mus. Bull., No. 191 ,1916, p. 31.
[2] Cole, L. H., Mines Branch, Ottawa, Sum. Rept., 1918, p. 58, Analysis No. 1727.

half of the rock consists of rounded quartz grains. The cement is calcareous and these beds are probably reworked Potsdam sand. Above these basal beds are alternating fossiliferous limy beds and thick grey to dark blue magnesian limestone and dolomite beds. The following analyses are representative of the chemical composition of these beds.[1]

| Sample number | Insoluble mineral matter | Ferric oxide | Alumina | Calcium carbonate | Magnesium carbonate | Equivalent to lime | Equivalent to magnesia |
|---|---|---|---|---|---|---|---|
| 45 | 8·00 | 1·12 | 1·48 | 54·60 | 34·84 | 30·59 | 16·65 |
| 46 | 14·85 | 1·26 | 0·14 | 50·31 | 31·53 | 28·19 | 15·06 |

Sample 45 is an average of the 10-foot face in an abandoned quarry on the south side of the Prescott road, about one mile east of Brockville town limits. The stone is very tough, hard, and fine grained, and is grey when fresh, weathering brown. Some beds are 18 inches in thickness.

Sample 46 is representative of the stone exposed in a number of small openings on the farm of George Sherwood, half a mile east of Brockville, on the north side of the Prescott road.

### STRUCTURAL FEATURES OF EARLY PALÆOZOIC SEDIMENTS

The beds are from 2 inches to 2 feet thick and for the most part are continuous and well marked throughout the series. The bedding is shown either by continuous and well-defined planes that seem to indicate halts in deposition, or by the alternation of zones of rock of slightly different composition. Some of the beds extend over large areas and are similar in composition throughout, whereas others are discontinuous and vary in composition markedly from place to place.

A few of the sandstone beds are crossbedded over wide areas. The crossbedded layers are as a rule only about 6 inches thick, and are bounded both above and below by beds that show no crossbedding. The direction of the slope of the fore-set beds is very irregular, and no conclusions could be drawn concerning the direction from which the material came.

Sun-cracks and rain-prints are developed only in the basal beds of the series, and are local.

The sandstone beds at times show ripple-marks, but these marks are most characteristic of the basal beds. In every case noted, the ripple-marks were symmetrical and of the oscillation type, which suggests that the beds were deposited where currents were absent.[2]

The Palæozoic rocks show little evidence of folding or other deformation. There are a few small local synclines and anticlines, such as the one west of Cole lighthouse. The general dip of the beds is about 3 degrees to the northeast, but is as great as 8 degrees locally. In a great many places the beds are nearly horizontal.

Many outcrops of sandstone are conspicuously jointed, and the dip of the joint-planes is nearly vertical, but the strike is variable. Some

[1] Frechette, Howells, "Limestones of Ontario" Mines Branch, Sum. Rept. 1917, pp. 30-31.
[2] Kindle, E. M., "Recent and Fossil Ripple-mark," Geol. Surv., Can., Mus. Bull. No. 25, pp. 48-49.

outcrops show one set of joints with a general strike of north 55 degrees west, and a second set, not so well developed, forming an angle of about 90 degrees with the first. Many of these are, probably, tension joints.

### ORIGIN

The early Palæozoic sea advanced over a rough surface and failed to wear it smooth, either because the quartzite resisted erosion, or because the advance was too rapid. The absence of granite or gneiss boulders in the basal conglomerate suggests a slow advance of the sea, but, perhaps, in the late Precambrian erosion interval, all detached pieces of crystalline rocks were disintegrated, and only quartzite blocks were left among the residual material.

The sea at first was shallow and a coarse basal conglomerate was deposited along the cliffs and between the hills. The finer residue was carried away and deposited outside the map-area. The tops of the hills stood as islands in this shallow sea—just as the tops of the hills now form the Thousand islands in the St. Lawrence—and at low tide a series of shallow lakes would result. In these lakes, or partly drained areas, the basal portion of the Potsdam sandstone was deposited as indicated by the sun-cracks, rain-prints, and symmetrical ripple-marks.

The undecomposed grains of feldspar show that mechanical erosion went on faster than chemical decomposition, which might suggest slight aridity, especially in an area, such as this, so near base-level when invaded by the sea. The small size and nearly perfect rounding of the quartz grains in many of the sandstone beds indicate that the sand had been wind-blown before deposition.

Cushing, discussing the area directly across the river, has placed the Potsdam and Theresa formations in the Cambrian (Ozarkian) and the Tribes Hill and Ogdensburg formations in the Ordovician (Beekmantown). Bassler[1] places the Potsdam sandstone and the Theresa limestone in the Lower Ozarkian and the Tribes Hill in the Middle Cambrian.

In the Brockville-Mallorytown area, as in other parts of the Thousand Islands region, only the upper limestones are fossiliferous. The non-fossiliferous beds are called Potsdam, and are probably Upper Cambrian in age, or are transition beds formed in the interval between Upper Cambrian and Beekmantown time. The fossils are similar to those in Cushing's Ogdensburg formation and are Beekmantown in age.

## PLEISTOCENE DEPOSITS

The superficial deposits of the Brockville-Mallorytown area are largely Pleistocene and include glacial deposits and deposits formed in bodies of standing water. They partly fill the depressions between the rock ridges, and cover most of the area underlain by the Palæozoic sandstone.

The glacial deposits consist of boulder clay and fluvioglacial drift in the form of eskers, kames, and outwash sheets of sand and gravel. The deposits formed in bodies of standing water consist of very finely laminated clay and sand, possibly deposited in lakes in front of the retreating ice or in

[1] Bassler, R. S., "North American Ordovician-Silurian Fossils." *See* correlation tables at end of report.

the Champlain sea, although no marine fossils have been found west of Brockville.

In the Brockville-Mallorytown area no evidence of more than one period of glaciation was found. Apparently, all evidence of former glacial invasion or interglacial epochs was destroyed by the last glacial invasion.

### GLACIAL TILL OR GROUND MORAINE

Boulder clay is widespread, but nowhere very thick. It forms a mantle, from 2 inches to 25 feet deep, over the Potsdam areas, and is nearly always found between the Precambrian ridges. The underlying rocks are sandstone, quartzite, and granite and the till is, therefore, sandy and stony. It is incoherent, without stratification, and greyish to brownish red in colour. In many places surface boulders are numerous, and consist of sandstone and quartzite, and a few granite blocks.

The uppermost 25 feet of the section exposed in a gravel pit along the Brockville-Westport branch of the Canadian National railway, half a mile east of Lyn station, is a reddish to greyish sandy till with many large, angular to roundish, glacially striated boulders, and is underlain by irregularly stratified fluvioglacial gravels.

In a gravel pit north of the road at Escott Centre, heterogeneous non-sorted gravel lies next to the rock ridges, but away from the ridges the gravel is stratified and well assorted. The non-stratified material consists of well-rounded pebbles and boulders of granite and quartzite ranging from ¼ inch up to 4 inches in diameter. The stratified sand and gravel are composed of quartz and feldspar grains and pebbles from $\frac{1}{10}$ inch up to 1 inch in diameter. This fine material is fairly well assorted, but the bedding is irregular.

The same kind of deposit, and the same relations, were found along the southeast slopes of the larger ridges wherever gravel pits were opened in the drift. The non-stratified material at the bottom of the pit was, probably, deposited as morainic material when the ice-front stood along the edge of the hills, and the stratified material represents outwash material from the ice-front, after it had retreated some distance.

*Fluvioglacial Sand and Gravel.* The stratified sand and gravel of fluvioglacial origin in this area are in long, fairly well-defined ridges, approximately parallel to the direction of ice movement. In general, these deposits are more sand than gravel, but in places they consist of typical fluvioglacial drift.

Sections exposing fluvioglacial sand and gravel occur in an old gravel pit about half a mile east of Lyn station on the Brockville-Westport branch of the Canadian National railway. This pit was visited by Coleman, in search of marine fossils, and was described by him as follows:

"The rock floor on which the gravel rests is exposed as ice rounded surfaces of Archæan having striations running 20 degrees east of north. The bottom of the pit is 300 feet (aneroid) above sea-level, and at one point stratified sand and gravel rise to 337 feet, while above this one finds boulder clay. At another point the stratified material is thicker, rising up to 387 feet and followed by 5 feet of boulder clay on top. In general the lower part of the section shows coarse sand and gravel, with many subangular or rounded boulders making about half the height, and above this there is stratified sand covered by a varying

thickness of very stony till. It is evident that the sand and gravel are interglacial in age, and it is not surprising that no marine or other shells were found. One of the former employees in the pit says that no shells have ever been found here, and that the pit has not been used for the last eight years."[1]

Recent cuttings in this gravel deposit show many sections similar to these described by Coleman. The coarse to fine gravel is irregularly interbedded with sandy layers, and the strike and dip of these beds are very irregular. The material as a whole is fairly well rounded and water-worn.

The fact that this gravel is overlain by boulder clay does not seem sufficient proof that it is of interglacial age. It is in a depression along the southeast edge of a Potsdam escarpment, to the north of which for a number of miles is a nearly level plain, and a slight advance of the ice-front during the final stages of its melting would carry boulder clay over these earlier formed stratified deposits at the foot of the escarpment, and, by its position, this stratified drift was protected from removal by the readvancing ice.

Near the northeast end of Grenadier island, close to the south shore, an esker-like ridge of sandy, slightly stratified glacial drift, 100 to 200 feet wide and 20 to 40 feet high, is followed by the road for more than a mile. It is the best developed esker in the area.

On the north side of Grenadier island from west of Senecal bay to within half a mile of the west end of the island, is a series of nearly conical drift hills that are joined by a fairly continuous ridge. The average height of these kame-like hills is about 40 feet above their surrounding surface, but the largest of the group rises 80 feet above the general elevation of the island. This ridge and series of hills is composed of sand and gravel very poorly stratified, but well water worn.

Hills of glacial drift similar in structure and outline to the above group occur on the northeast end of Grindstone island, and at other localities in the Thousand Islands region. Fairchild describes these deposits under the heading "Boulder Kames and Eskers,"[2] and concludes that they were built, at least in larger part, by superficial torrential streams pouring down over the steep ice-front into the standing waters of lake Iroquois.

According to this idea of the origin of these deposits they should show a delta form and structure, but Fairchild did not describe any delta characteristics nor were any noted in the deposits on the Canadian side. By the time the ice-front had reached beyond the St. Lawrence, lake Iroquois was, probably, drained, and there was no large body of water in front of the ice. Surficial glacial streams do not as a rule carry large amounts of material, because there is very little glacial debris near the top of an ice-sheet.

The shape and general direction of these hills, together with the stratified and water-worn character of the materials, indicate that the deposits were formed in the channels of sub-glacial streams and are esker-like deposits with abnormal deposition in certain places along the stream channel, due to local conditions.[3]

---

[1] Coleman, A. P., "Sea Benches of Eastern Ontario," Ont. Bureau of Mines, 1901, p. 221.
[2] "Geology of the Thousand Islands Region," New York State Mus. Bull., No. 145, 1910, pp. 153-56.
[3] Stone, G. H., "Glacial Gravels of Maine," Mon. 34, U.S.G.S., pp. 426-31.

## STRATIFIED CLAY

Stratified clay containing a few marine fossils outcrops northeast of Brockville, but no clay containing marine fossils was noted west of the brick-yards, about one-half mile north of Brockville. The marine clay north of Brockville is greenish grey, shows very little evidence of stratification, and contains very little sand. The clay at the Brockville brick-yards is similar in every respect to the Champlain marine clays of the Ottawa valley and is about 300 feet above sea-level.

West of Brockville, stratified clay is abundant and partly fills the valleys and depressions between the rock ridges. Of these clay areas the one at Mallorytown is largest. The surface of the clay is gently undulatory, and not level as is the surface of the known marine clay areas east of Brockville. Around the edges of the larger clay areas are shore features that suggest a shallow-water or lake origin for these deposits (Plate I A).

In many places the clays are sandy and in some places sand and clay layers alternate. The deposits are finely laminated and range from light grey to dark grey, depending upon the amount of sand present. When sand is abundant the lamination is well developed as compared with the nearly pure clay beds that are almost massive and indistinctly laminated. The surface of clay cuts soon weathers rough and irregular, hence the many fresh cuts made during the construction of the Provincial highway west of Mallorytown offered exceptional opportunities to study the material. Sections exposing the surface on which the clays were deposited show that in some places they were laid down on glaciated rock surfaces, and at others on boulder clay. The beds are mostly about horizontal, but near the edges of the areas the dip is parallel to the surface on which the material was deposited.

On the whole the clays are relatively free from boulders. In making a clay cut along the road about a mile east of Escott Centre, boulders were dug out of the clay. Only one boulder was seen in place and its relation to the stratification of the clay proved that it had been dropped in a body of water and later covered by mud. The workmen said that a number of such subangular boulders were found in making the cut. No fossils were found in any of the many cuts examined.

Keele, who studied the marine and lake clays of eastern Ontario in considerable detail, concluded that the clays west of Brockville "are different in some respects from the marine clay and are probably sediments deposited in former lake basins which were partly bordered by the glacial ice."[1]

According to Fairchild's determinations the marine waters were at least 250 feet deep in this area, and the sea must have been 40 miles wide.[2] If this were the case, there appears to be no good reason for the absence of marine fossils west of Brockville. According to Goldthwait's determination this area would be submerged less than 25 feet, and the sea would be narrow.

Recent detailed examination of the deltas built by tributary streams of Chaudière river, Quebec, are in accord with Goldthwait's determinations and indicate that the maximum marine submergence in this area was

[1] Keele, J., Mines Branch, Can., Sum. Rept., 1918, p. 163.
[2] Fairchild, H. L., "Pleistocene Marine Submergence of the Hudson, Champlain, and St. Lawrence Valleys," New York State Mus. Bull., Nos. 209, 210, 1918, pp. 57-63.

approximately 600 feet and not between 800 and 900 feet as determined by Fairchild.[1] In the Beauceville area, as in many other areas in the Champlain and St. Lawrence basins, it is very probable that the higher wave features and deltas are the result of glacial lake waters and of streams flowing into these lakes, and were not formed by the Champlain marine waters as surmised by Fairchild.[2]

A recently published map of the western limits of the Champlain sea shows the relative salinity of different parts, based on fossil evidence. The west end of the marine submergence is placed at Brockville, the whole of the Brockville-Mallorytown area is covered by brackish waters[3] and the Lake Ontario basin by fresh water.

Also, the recent work of Mather in the Kingston area shows that marine submergence in that area could not have followed immediately after the draining of lake Iroquois.[4]

All this evidence seems to indicate that the Champlain marine submergence was not as great as outlined by Fairchild.

Before the ice-front reached the north side of the St. Lawrence valley, lake Iroquois was drained, and the ice-front, as shown by Mather, may have been 50 miles or more north of Brockville before the advance of the Champlain marine waters into the Lake Ontario basin—if they ever reached that basin. No evidence has been found to prove that marine waters extended west of Brockville.

Little definite, direct evidence concerning the maximum marine submergence was obtained from the study of this area, but the irregular surfaces of the clay areas, the sandy character of the clay, the few subangular boulders found in it, and the absence of marine fossils suggest that the submergence was shallow and of very short duration. As suggested by Keele, the evidence from a detailed study of the stratified sandy clays of this local area indicates that they were deposited in lake basins that were closely associated with the retreating ice-front.

## RECENT DEPOSITS

The Recent deposits as compared with those deposits formed directly by the glacier or in association with the retreating ice are unimportant in extent and thickness, but are nevertheless of considerable interest, because the lake bottom silts after the lakes have been drained make the best agricultural land in the area.

### RIVER SANDS

Extensive deposits of sand occupy the depression back of Rockport and along the river road east of Rockport as far as Pooles Resort. They were deposited when St. Lawrence river stood slightly higher than at present, and the depression back of Rockport represents a back channel of the river that was filled with sand, in which river terraces were subsequently cut. The sand, probably, came from lake Ontario, for at present

[1] MacKay, B. R., "Beauceville Map-area, Quebec," Geol. Surv., Can., Mem. 127, 1921, pp. 56-58.
[2] Barker, E. E., "Ancient Water Levels of the Crown Point Embayment," New York State Mus. Bull. No. 187, 1915, pp. 165-190.
[3] Goldring, Winifred, "The Champlain Sea, Evidence of Its Decreasing Salinity Southward as Shown by the Character of the Fauna," New York State Mus. Bull., Nos. 239-40, 1920-21, pp. 153-187.
[4] Mather, Kirtley F., "The Champlain Sea in the Lake Ontario Basin," Jour. of Geol., vol. 25, 1917, pp. 542-54.

the St. Lawrence is depositing sand between the mainland and Tar island The rock ridge at Rockport and a number of other, smaller rock ridges farther east were formerly islands, but have been joined to the mainland by river deposition.

### DUNE SANDS

Deposits of wind-blown sand occur north and northwest of Brockville. The sand is piled up in low, dune-shaped hills, and in places there are swampy areas between. The sand is now being moved southeasterly by the prevailing winds. At Tollgate and farther east the sands were derived from fluvioglacial material. Probably after glaciation and before vegetation covered the flat-lying area to the north, northerly winds swept all the loose sands available into dune-shaped hills in front of the rock ridge that runs northeasterly across this area, and in the region farther east.

### LAKE SILTS AND BLACK MUDS

The remnants of many once larger lakes in this area have been drained by the farmers who have put the land under intense cultivation. Vanston pond is a good example, and three other lake beds are indicated on the map. These deposits consist of layers of sand and clay mixed with carbonaceous material. In many places large tree trunks are found in this material. In places the material is black and mucky. The areas have to be well ditched, but when once brought under cultivation yield large crops.

# CHAPTER III

# STRUCTURAL AND HISTORICAL GEOLOGY

## STRUCTURAL GEOLOGY

The main structural features of the various rocks have already been discussed individually. A more general treatment of the structural features of the area as a whole follows. Large masses of granitic rocks intrusive in the Grenville sediments have thrust these sediments aside and given them a patchy distribution, and this, with their highly metamorphic character, makes structural work difficult.

As already noted, the general strike of the Grenville sediments is to the northeast; the dip is to the northwest and is everywhere steep. The incompetent beds between massive quartzite beds show many drag folds, and give the impression that the strata are tightly and complexly folded. It was impossible to determine from a study of this local area whether the three parallel quartzite belts striking northeast across the area are all parts of one bed that has been isoclinally folded, or are different beds. However, the map of the Alexandria area to the south offers considerable evidence that they represent different horizons, and that the major structure is a broad anticline striking in a northeast direction across the Thousand Islands region. Crystalline limestone outcrops in the trough of a syncline, near the southwest edge of the Alexandria area and also along the northwest edge of the Brockville-Mallorytown area. Between these two bands all the sedimentary rocks are quartzite and biotite gneiss. Unless the folding was so tight that the limestone beds were thinned and pinched out, they should be repeated, if there were a number of small isoclinal folds crossing the area. Also, the Grenville series being a normal marine series, it is natural to suppose that the quartzite and various gneisses occur near the base of the series, and would be exposed along the crest of a large anticline. The dip of the axial planes of the many drag folds in the incompetent beds between massive quartzite is, in every case, to the northwest. This broad, anticlinal structure was probably caused by the intrusion of large quantities of granitic magma under considerable lateral pressure.

Whether or not the Grenville series was folded prior to the granite intrusion it is difficult to prove. It is evident that the degree of deformation of the Grenville varies considerably in different areas in the northeastern Adirondacks and southeastern Ontario. In the Thousand Islands region the sediments are in long, parallel bands with igneous rocks between; but, in many areas, the strike of the sedimentary strata is irregular, and there is no tendency towards a linear arrangement. This variation in intensity and irregularity of folding suggests either that the Grenville strata behaved differently in different areas under regional deformation or that the cause of the deformation was almost local and not regional. Where igneous material was injected along the bedding planes of the

crystalline limestone the granitic bands are in some cases folded without fracturing, but in other cases they are broken into blocks, around which the limestone has "flowed." These facts indicate that the Grenville limestone was folded during or after the intrusion of the granitic material.

The Grenville series must have been thrust upwards during the intrusion of the granite, and it is possible that at that time the broad anticlinal structure of the region was formed. W. J. Miller[1] says, "the Grenville strata were much broken up and tilted in masses great and small, and in other cases actually domed, by the irregular upwelling of great bodies of magma (especially syenite-granite) under very moderate lateral pressure." The evidence in the Thousand Islands region favours this conclusion except that the lateral pressure in this particular area was probably very strong. The major structural features are closely associated with the intrusion of granitic magma into a series of competent and incompetent sediments under considerable lateral pressure.

No evidence of large-scale faulting was found. Among the Thousand islands, especially near Rockport, fault breccia, considerable displacement, and bending of the beds were noted, and in one place quartzite was faulted against granite. The strike of the fault planes is to the northeast, and the dip 80 degrees to the southeast. In every determined case the faults are normal and the southeast side has moved down with respect to the northwest side.

At many other places the brittle Grenville quartzite is badly fractured, but there is little evidence of much movement along these shatter zones and the faulting is apparently local and the displacement small.

Joints striking in almost every direction are found in this area, but the main directions are northeast and northwest. Apparently the northeast faults, which are parallel to the strike of the sediments, are the major set because some movement has taken place along them. Also, the diabase dykes strike in a northeast direction and probably occupy deep fissures parallel to the direction of major jointing.

## ORIGIN OF THE FRONTENAC AXIS

Along the north side of the Frontenac axis and in the depression of the St. Lawrence, Potsdam sandstone beds overlap each other and extend into the embayments along the axis just as basal beds would do if the sea advanced up the St. Lawrence valley at present. The Potsdam sandstone extended up the St. Lawrence depression as far as Kingston, but 20 miles north of this depression apparently did not extend more than a few miles back from the present Precambrian and Palæozoic contact. The pre-Potsdam valleys, until recently filled with early Palæozoic sediments, strike northeast and southwest, and indicate that pre-Potsdam drainage was in these directions. These facts indicate that the Frontenac axis was in existence in pre-Potsdam time, although it may not have been so prominent as it is at present.

The axis cannot be due to folding, for the general direction of folding is northeast-southwest, and the general strike of the axis is 45 degrees from this, or east and west. No evidence of either pre-Potsdam or post-

[1] Jour. of Geol. vol. 24, 1916, pp. 588-600.

Potsdam faulting has been noted along either the north or south side of the axis. It is possible that in this particular area the large masses of granitic magma domed the sediments more than in surrounding areas and erosion before the deposition of early Palæozoic sediments did not entirely destroy this original irregularity. The abundant quartzite exposed in the Thousand Islands region suggests the same idea, for the quartzite was apparently formed near the base of the sedimentary series, and the base of the series would be exposed first along broad, up-folded belts. Post-Potsdam faulting and warping at a considerable distance from each side of this axis have preserved the Palæozoic rocks on the Ottawa valley and on the Lake Ontario side of the axis from erosion. This local faulting and warping, combined with differential erosion, made the Frontenac axis the divide between the waters flowing east down the St. Lawrence and southwest across western New York, through Tertiary time, as well as the prominent physiographic feature it is to-day.

## HISTORICAL GEOLOGY

The first geological event recorded in the rocks of the Brockville-Mallorytown area is the deposition of thick deposits of sand, mud, and calcareous material, which later were consolidated and metamorphosed into what is now known as the Grenville series. It is impossible to determine the exact thickness of this series, because neither the top nor the bottom of the series has been found. It was probably a thick marine series, and its deposition represented a long period of time.

After the deposition of the Grenville sediments, basic igneous magma penetrated them. In the Thousand Islands region the basic intrusives are only sparingly present, but are abundant a short distance to the east and west.

The most important igneous event was the intrusion of large quantities of granitic magma into the Grenville sediments. The coarse-grained character of these rocks indicates that they cooled slowly, at some distance below the surface. The intimate penetration of this magma into the sediments in approximately parallel zones across the area indicates that the magma thrust the sediments aside and upwards under considerable pressure.

This period of intrusion was followed by a long period of erosion during which the Grenville sediments were removed and the granitic rocks were exposed. Towards the end of this period of erosion, diabase magma penetrated along fracture planes nearly to or actually to the erosion surface.

In late Cambrian time the area was low and nearly flat, and the sea again invaded it from the northeast. Of the deposits formed in this sea only the basal Potsdam sandstone and a thin Beekmantown limestone formation remain. Northeast of Brockville there is little evidence of a time break between the Potsdam and Beekmantown, for the limy sandstone apparently grades upward into fossiliferous Beekmantown limestone.

There is, too, little evidence as to how long deposition continued in this particular area, but the well-cemented character of the early Palæozoic sediments suggests deep burial. At Montreal, which is about 125 miles

east of Brockville, deep wells have penetrated the Palæozoic to a depth of 2,400 feet without reaching the base of the series. Middle and late Ordovician formations outcrop in the Ottawa valley. The extent and thickness of the Silurian in this area are not known, but inclusions of Devonian are found in the igneous rocks of mount Royal, Montreal, and it is possible that the whole Palæozoic section from the Potsdam to near the end of the Devonian was present over a considerable part of the Ottawa and St. Lawrence valleys.[1]

There is no geological record in this particular area from the end of the Devonian to the Pleistocene glaciation. The interval was probably a time of erosion to a low, nearly flat land surface. To the southeast, Chadwick[2] has found remnants of Cretaceous and Tertiary peneplains.

The last events in the geological record of this area are the advance and retreat of the last Pleistocene ice-sheet, and the deposition of unconsolidated glacial and marine clay deposits. This ice advance destroyed all deposits formed by former ice-sheets or during interglacial periods. The last retreat of the ice north of the St. Lawrence valley was followed by an advance of ocean waters up the valley as far as Brockville. West of Brockville the clays have the characteristics of clays formed in bodies of standing water closely associated with the retreating ice front. Elevation of at least 245 feet followed this submergence. Since this elevation St. Lawrence river has not yet cut a definite channel across the Thousand Islands region, but flows along a broad and irregular depression probably formed in pre-Potsdam time.

---

[1] Kindle, E. M. and Burling, L. D., "Structural Relations of the Precambrian and Palæozoic," Geol. Surv., Can., Mus. Bull. No. 28, 1915, pp. 3-4.

[2] Chadwick, G. H., "Palæozoic Rocks of the Canton Quadrangle," New York State Mus. Bull., Nos. 217, 218, 1919, p. 7.

# CHAPTER IV

## ECONOMIC GEOLOGY

The Brockville-Mallorytown area lies along the main water-route west to the Great Lakes and was settled in the early days of the history of Canada. Although the mineral resources received early attention, no large deposit was discovered and no metalliferous deposits have been worked since about 1880. However, deposits of pyrite and copper have been described in various reports from the "Geology of Canada, 1863" down to the present time; and from these the following facts have been culled, together with what little additional information the writer was able to obtain.

### PYRITE

#### BILLINGS PROPERTY

This deposit of iron pyrite, containing cobalt, about 2 miles northwest of Brockville, was opened up prior to 1863 and active mining was carried on from 1868 until 1879, when work had to be abandoned on account of water and unsafe shafts. In 1869 the Brockville Chemical Company built a sulphuric acid plant near the property, which was operated until 1884. Two of the local farmers, Mr. J. P. Smith and Mr. N. Sloan, worked in the mines and gave a few details about the workings.

An open pit was sunk along the northwest side of a swampy depression about 200 feet wide, which runs northeast. To the south side of the depression Grenville quartzite is intruded by pink granite. The quartzite strikes north 55 degrees east, and dips 80 degrees to the northwest. About 200 feet to the southeast of the quartzite ridge there is a band of crystalline limestone, and to the west of the pit an outcrop of quartzite. The Grenville sediments and pink granite are intruded by a diabase dyke.

From the bottom of an open pit, about 50 feet deep, a shaft inclined about 80 degrees to the southwest was sunk approximately 200 feet. The foot-wall was said to be black dyke rock, and the hanging-wall a feldspar-rich rock, probably pegmatite, and dark coloured vitreous quartzite with abundant calcite in places. From the shaft levels were run to the southwest, south, and east. The level to the southwest, known as the Big drift, was over 400 feet long and in one place 300 feet wide. In the drift to the south or the Gardener drift the ore-body was lost and work was abandoned. Along the drift to the east calcite was abundant, but work had to be abandoned on account of water and unsafe walls, for no timber was used. Mr. Sloan says that when this drift was abandoned there was plenty of ore in the bottom and along the walls of the workings.

Logan[1] thought this deposit probably formed a great interstratified mass in the rocks of the Laurentian system. Wilson[2] later described this deposit as follows: "The pyrite occurred in a series of lenses conformable to the lamination of a highly foliated pink granite gneiss. A series of irregular cavities, probably caused by folding, had occurred; in these were

[1] Logan, Sir W., "Geology of Canada, 1863," p. 747.
[2] Wilson, Alfred W. G., Mines Branch, Pub. No. 167, 1912, p. 60.

deposited calcite and iron pyrites in parallel bands, and mining took the form of gouging out the richer shoots of ore irrespective of any other consideration."

The deposit evidently strikes in a general northeast-southwest direction and dips about 80 degrees to the southeast. It lies along the contact between a basic dyke to the northwest and quartzite and granite to the southwest, and is irregular in shape with a maximum width of 300 feet, but with an average width of about 20 feet. Considerable calcite, quartz, and a dark greyish mineral were irregularly mixed with the pyrite, but in some places the pyrite and calcite were interbanded.

The most important ore mineral was pyrite and it is described by Logan as follows:

"The pyrite, which is very pure and free from earthy admixture, is of two varieties, the one being somewhat porous and dull, with a greenish hue, and the other compact, massive, with a brilliant lustre, and somewhat conchoidal fracture. Both varieties contain a small proportion of cobalt, which in the latter is equal to five or six-thousandths of the oxide of cobalt, besides traces of copper."[1]

The pyrite examined by reflected light in thin section is greenish yellow in colour, and all through some of the grains are small specks and irregular areas of calcite and a green isotropic mineral, which are the two most important gangue minerals. The pyrite replaces or partly replaces both of them.

B. J. Harrington[2] lists the minerals occurring in the deposit as pyrite, pyrrhotite, magnetite, quartz, talc, labradorite, phlogopite, a black hydrated silicate of iron, alumina, and magnesia, somewhat resembling hisingerite in appearance, calcite, siderite, apatite, and cacoxenite. Of this list pyrite, magnetite, quartz, calcite, and apatite, were recognized in thin sections of the ore, and ankerite, hematite, and limonite were also noted. A thin section of a dark brownish black specimen found on the dump was chiefly an olive green isotropic mineral which in reflected light is light green. This mineral replaces calcite, and a spherical concretion about ¼ inch in diameter consists of this mineral and thread-like bands of calcite and limonite alternating. Both this green mineral and the pyrite first penetrate and irregularly replace the calcite along the cleavage planes, but when the replacement is carried nearly to completion the evidence of cleavage and the shape of the calcite crystals are destroyed. The green isotropic mineral may be the hydrated silicate of iron, alumina, and magnesia referred to as resembling hisingerite. No mineral resembling cacoxenite was found, but these two rare and little known minerals may very well occur in some of the material in the remnants of the old dumps.

Harrington comments on the varied composition of the minerals, for there are hydrous and anhydrous silicates and phosphates, sulphides, oxides, and carbonates. The pyrrhotite and magnetite indicate that the deposit was formed under conditions of high temperature and pressure, and ankerite is found only in contact metamorphic and deposits of deep vein type.[3] A large part of the calcite is a white variety like the calcite of the crystalline limestone, and since there is a band of crystalline limestone south of the deposit and crystalline limestone and quartzite are inter-

[1] "Geology of Canada, 1863," p. 748.
[2] Geol. Surv., Can., Rept. of Prog., 1874-75, p. 304.
[3] Emmons, W. H., "A Genetic Classification of Minerals," Econ. Geol., vol. III, 1908, p. 618.

banded in other parts of the area, it is probable that crystalline limestone underlies the swampy depression at the pit.

The presence of pyrrhotite, magnetite, and ankerite, the irregular shape of the deposit, and the close association with the black dyke and the pink granite suggest that this deposit is a contact metamorphic deposit replacing the crystalline limestone and connected either with the intrusion of the basic dyke or with the pink granite.

### SLOAN PROSPECT

This pyrite property is about 1,000 feet east of the Billings property, on lot 18, concession II, Elizabeth township. In 1902, Mr. Sloan opened a pit and sunk a shaft about 20 feet and shipped about 80 tons of pyrite ore averaging about 40 per cent sulphur. He then sold the property to a Buffalo company and they opened another pit to the east in a swamp, but found little ore.

The country rock is Grenville quartzite and crystalline limestone cut by a diabase dyke. The first shaft was sunk in crystalline limestone and pyrite in alternating bands, each forming about one-half of the material removed. It is probable that the ore is similar in origin to that on the Billings property.

### SHIPMAN PROSPECT

This prospect, about 6 miles southwest of Brockville, is near the south end of lot 37, concession II, Elizabeth township. The property was worked about 1870, and the ore was hauled to St. Lawrence river about a mile distant and shipped on scows. It is claimed that the reason for closing the property was the high percentage of pyrrhotite mixed with the ore.

The workings which are on the north slope of a ridge about 60 feet high are irregular in shape, and cover an area of about 150 feet square. A tunnel, started near the foot of the hill, was run south about 10 feet where a raise was cut to meet the bottom of an open pit near the top of the hill.

The country rock is dark grey and massive. A hand specimen contains considerable quartz, and thin sections show quartz, and abundant orthoclase, oligoclase, microcline, augite, pyrrhotite, pyrite, and titanite. The rock probably is an impure quartzose member of the Grenville series that has been thoroughly recrystallized. Interbanded with this quartzose gneiss are narrow bands of impure crystalline limestone. East and along the ridge about 600 feet from the workings diorite outcrops. On the side of the hill the workings exposed a small lens of early Palæozoic conglomerate in a slight depression.

The rocks at the workings are broken and some movement has evidently taken place, for some of the fractured surfaces are slickensided. The general strike of the fracture zone is north 70 degrees east and the dip about 50 degrees north. No ore was seen in place; but, from the shape of the workings, the ore-body was probably a number of narrow veins or lenses of pyrite along a fracture zone in the quartzite gneiss.

## COPPER

An old pit on lot 7, concession II, Escott township, is said to have been worked for copper about 1870. The country rock is a dark biotite gneiss of the Grenville series. Logan[1] states that the copper ore-body was traced 12 feet and had a maximum thickness of 10 inches. The ore consisted of copper pyrites with thin veins and grains of calcite with some pyrite. About ten tons of rich copper ore was obtained, and when work was abandoned the ore-body appeared to be exhausted. At present the workings have caved in and no rock or ore was seen around the pit.

Near the east side of lot 15, concession II, Escott township, are some pits, which, between 1855 and 1865, were worked for copper. The rocks exposed at these workings are biotite gneiss of the Grenville series, intruded by pink granite. A shaft was sunk about 50 feet and at 20 feet a level was run northeast 50 feet to a large open pit. About 100 feet to the northeast, an open-cut was made across the biotite gneiss band, but no ore-body was crossed. The ore, according to Logan[2], occurs in veins traversing a micaceous schist, and the mineralized zone is 4 or 5 feet wide and includes 15 inches of solid copper pyrites.

The ore consists of chalcopyrite, pyrite, quartz, orthoclase, mica, and tourmaline, and is probably related to the intrusive pink granite in origin. Little ore could be found on the dumps and it is so long since these deposits were worked that scarcely any information concerning them was obtainable.

## MOULDING SAND

On lots 21, 22, and 23, concession I, Elizabeth township, 2½ miles west of Brockville, there is a considerable deposit of moulding sand. This deposit has been studied in some detail by L. H. Cole[3]. It is known to cover a fairly large area and is from 1 foot 6 inches to 3 feet 10 inches thick. Many tests of this sand show that it will answer all the requirements for brass foundry work, and is suitable for stove plate and similar light work; but, on account of its fineness, is not so well adapted as coarser sands for heavy moulding.

Other sand deposits such as the one under the clay near the Mallorytown Consolidated school might prove of value for moulding sand.

## GLASS SILICA

The Grenville quartzite and the Potsdam sandstone of this area have been examined as a possible source of glass silica[4]. Up to the present no thick and continuous bed has been found sufficiently free from impurities to be of commercial value.

---

[1] "Geology of Canada, 1863," p. 693.
[2] "Geology of Canada, 1863," p. 693.
[3] Cole, L. H., "Occurrences and Testing of Foundry Moulding Sands," Mines Branch, Bull., No. 21, 1917.
[4] Cole, L. H., Mines Branch, Sum. Rept. 1918, p. 56.

## ROAD MATERIALS

The construction of the Montreal-Toronto permanent highway across this area created demand for road materials. Pink granite and early Palæozoic sandstone, together with all the field boulders available, were quarried and crushed for the foundation of the road. The only local material suitable for finishing the road is diabase, of which several dykes outcrop southwest of Mallorytown and quite close to the highway. The Mines Branch has sampled and tested the important road material deposits of the area.[1]

## BUILDING STONE AND PAVING BLOCKS

Many of the farmers in the area have built houses of Potsdam sandstone gathered from the fields or from small quarries on their farms, but up to the present this is only a local industry. Along the Kingston-Montreal highway the Potsdam sandstone was extensively used for foundation material.

The massive pink granite west of Brockville has been quarried for building stone and tombstones. It varies in colour from red to light pink, and is medium to coarse-grained. In a great many specimens of the granite, mica and magnetite occur in round bunches and spoil the appearance of the polished surface. A local tombstone manufacturer says that the granite is as easily worked and polished as imported stone; but that there is no demand for it. The physical properties of this granite are given by Parks.[2]

The granite just north of the post road on lot 15, concession II, Escott township, has been extensively quarried for paving blocks. It is a medium- to fine-grained, dark rock cut by narrow dykes of pink feldspar and hornblende. Horizontal joints, as well as vertical joints, striking north 45 degrees west and south 20 degrees west are well developed. The first series of vertical joints are from 15 to 25 feet apart, and the second series are at intervals of from 2 to 6 feet apart. The stone breaks with a smooth fracture. If it were not for the pink feldspar and hornblende dykes little rock would be wasted in trimming the blocks. There is not sufficient demand in the district for paving blocks to warrant continuous work at the quarry.

## CLAY

Brick kilns have been built a short distance north of Brockville to burn the marine clay, but were not operating during the summer of 1920 owing to depression in the building trade. These marine and lake clays have been described by Keele.[3]

## CONSTRUCTION MATERIALS

Cheap transportation makes the gravel and sand in Patterson bay and on the south side of Grenadier island in good demand. During the summer of 1920 a great quantity of gravel in Patterson bay was loaded in barges

[1] Picher, R. H., "Road Materials Available along the St. Lawrence River between Kingston and Prescott." Mines Branch, Sum. Rept., 1919, pp. 153-155.
[2] "Building and Ornamental Stones of Canada," Mines Branch, vol. I, p. 303.
[3] Mines Branch, Dept. of Mines, Sum. Rept., 1918, pp. 162-67.

and taken both up and down the St. Lawrence for construction work. Wave action, in undercutting the gravel and sandbanks, has sorted the material and fine or coarse gravel may be dredged at different distances from the shore.

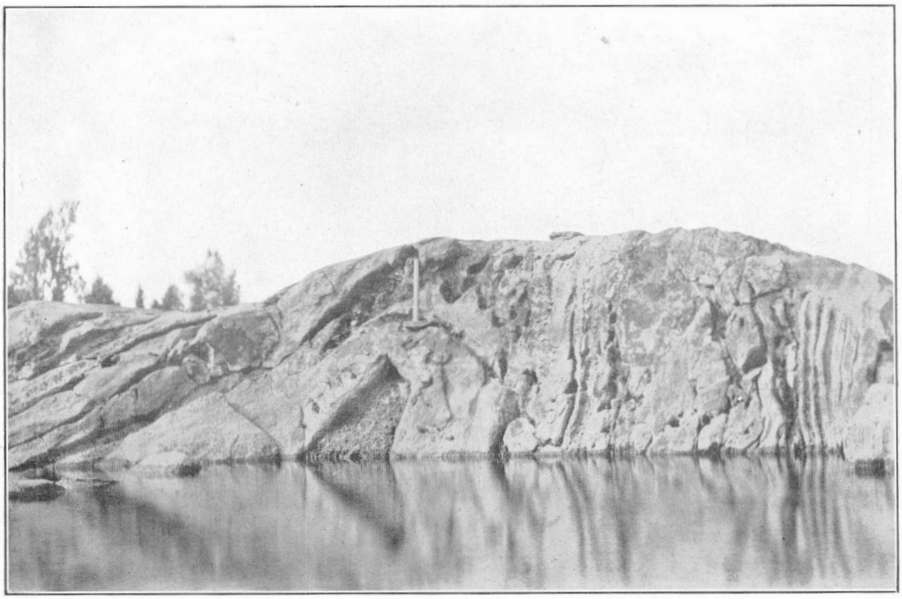
## PEAT

About 3 miles north of Brockville, a peat bog covering approximately 1,400 acres is crossed by the Canadian Pacific railway (Brockville-Ottawa line). The bog covers most of lots 4 to 5, concession III, and lots 3 to 10, concession IV, Elizabeth township. The following information is taken from Mr. Anrep's report.[1] The average depth of the peat in different areas varies from 2½ feet to 16 feet respectively, and the total volume of workable peat is approximately 14,314,000 cubic yards. One cubic yard of peat will furnish approximately 200 pounds of "dry" peat, giving about 1,909,000 tons[2] of peat fuel, with 25 per cent moisture, in this bog. The peat varies considerably in different parts of the bog, due to differences in composition and degree of decomposition. The content of ash is somewhat high, but the calorific value is satisfactory. Considerable peat has been taken from the bog, but in 1920 the plant was idle.

[1] Anrep, A., "Investigation of the Peat Bogs, and Peat Industry of Canada, 1909-10," Bull. No. 4 (second edition), Mines Branch, 1910, p. 11.

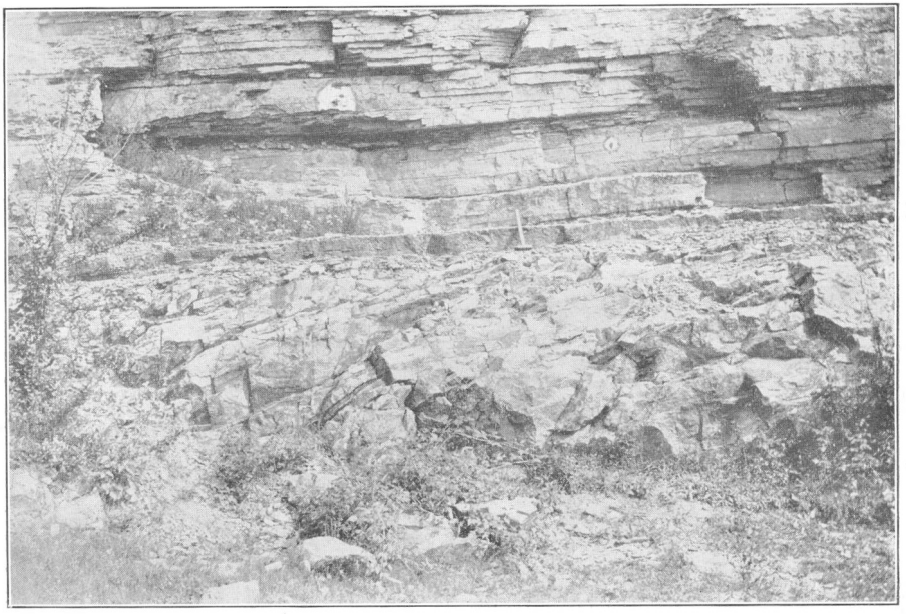
[2] Owing to a misprint the corresponding figures in Mr. Anrep's report read 1,525,750 tons.

A. Area underlain by stratified clay showing rough surface; typical quartzite ridge in background. One mile north of Pooles Resort. (Page 43.)



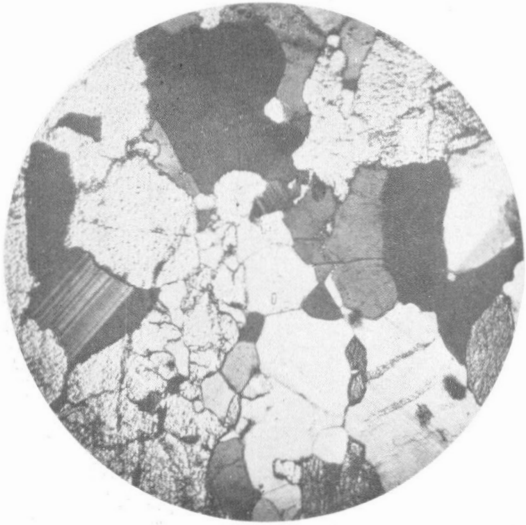
B. Folded Grenville limestone, with axial plane of fold dipping to the left or northwest. Island near east shore of Charleston lake. (Page 20.)

A. Typical Potsdam conglomerate, Lily bay, St. Lawrence river. (Page 37.)



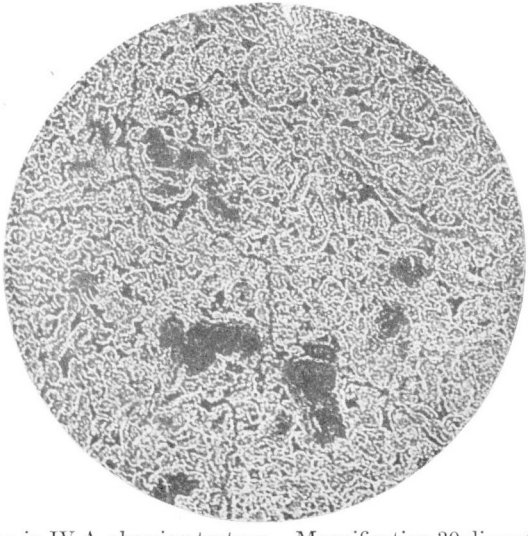
B. Unconformity between Grenville quartzite and Potsdam sandstone. Near Caintown. (Page 12.)

A. Metamorphic pyroxenite showing irregular shape of mineral grains and the manner in which one mineral is included within the other. Magnification about 10 diameters. (Page 18.)



B. Grenville quartzite one foot from contact, showing penetration of feldspars in quartzite. Magnification about 12 diameters. (Page 30.)

A. Diabase, showing general texture of rock and relation of lumps. Magnification 10 diameters. (Page 35.)



B. Detail of lump in IV A, showing texture. Magnification 30 diameters. (Page 35.)

# INDEX


PAGE

Acknowledgments..... 2
Adamellite..... 24
Alexandria area—
  Index map showing..... 1
  Rocks.....15, 17, 23, 32, 46
Alling, H. L..... 2
Analyses—
  Basic intrusives..... 21
  Diabase..... 34
  Gneisses..... 16
  Granitic intrusives..... 22, 26–29
  Grenville quartzite..... 14
  Limestone..... 39
  Pyroxenite..... 19
Ankerite..... 52
Anrep, A..... 55
Anticline.....20, 46
Aplite..... 29
Baker, M. B.....2, 17, 25, 31,32
Barker, E. E..... 44
Basic intrusives. *See* Diorite.
Bassler, R. S..... 40
Beekmantown formation—
  Lithology and anal..... 37–39
  St. Lawrence lowlands..... 4
Bibliography..... 2
Biotite gneiss.....15, 17
Black river..... 6
Blue mt.....14, 28
Boulder clay.....4, 5, 41, 42
Brick-clay—
  Brockville..... 43
Brock islds..... 25
Brockville, Ont.—
  Altitude of St. Lawrence r. at..... 6
  Beaches near..... 8
  Brick-clay and kiln.....43, 54
  Granite. *See* Brockville granite.
  Iron pyrite near..... 50–52
  Limestone, anal..... 39
  Peat bog near..... 55
  Pyroxenite near, anal..... 19
  Quartzite near, anal..... 14
Brockville granite.....24, 25
Brockville Chemical Co..... 50
Brögger, W. C..... 24
Building stone..... 54
Burling, L. D..... 49
Butternut bay.....8, 18, 19, 21
  Rocks near.....18, 19, 21
  Terraces near..... 8
Caintown—
  Contact, granite and quartzite, near.... 31
  Diabase dykes, anal..... 34
  Potsdam formation..... 6
  Rocks, Grenville series..... 14
  Rocks near, unconformity, photo..... 57
Cambrian. *See* Potsdam.
Cambrian sea..... 10
Canton area, N.Y.—
  Index map showing..... 1
  Palæoplain ..... 10
  Rocks..... 6

PAGE

Carlson, C. G.....17, 18
Chadwick, G. H.....3,10, 49
Chalcopyrite..... 53
Charleston l.—
  Anticline..... 20
    photo..... 56
  Glaciation near..... 9
  Limestone, crystalline.....7, 18
  Potsdam formation..... 5
Clay—
  Distribution and notes.....43, 44
  Stratified, N. of Pooles Resort, photo. 56
Club isld..... 9
Cole, L. H.....38, 53
Cole lighthouse.....37, 39
Coleman, A. P.....2, 41, 42
Collins, W. H..... 11
Conglomerate. *See* Potsdam conglomerate.
Construction materials..... 54
Copper..... 53
Cushing, H. P.....2, 11, 17, 25, 27, 30–32, 36–38, 40
Delta, Ont..... 7
Diabase..... 9
  Microphoto..... 59
Diabase dykes..... 33
Diorite..... 21
Doctor isld..... 14
Drainage—
  Evolution of St. Lawrence..... 5–7
Dune sands..... 45
Economic geology..... 50–55
Elizabeth tp.....52, 53, 55
Ells, R. W..... 2, 3
Emmons, W. H..... 51
Escott, Ont.....16, 29
Escott tp.....53, 54
Escott Centre.....22, 41
Fairchild, H. L.....3, 43, 44
Field work..... 2
Formations, table of..... 13
Frontenac axis.....4, 5, 47
Gabbro..... 21
Garnet gneiss..... 15
Geology, economic..... 50–55
  General..... 12–45
  Structural..... 46–49
Glaciation..... 5, 40
Glass silica..... 53
Gneiss, sedimentary, anal..... 16
Goldring, W..... 44
Goldthwait, J. W..... 43
Graham lakes.....28, 29
Granitic intrusives—
  Analyses, diagram, notes..... 21–33
  For building..... 54
Granodiorite. *See* Granitic intrusives.
Gravel pit..... 41
Grenadier isld.....42, 54
Grenville series—
  Caintown, near, photo..... 57
  Charleston l., photo ..... 56
  Composition; character; distribution... 12–30

PAGE

Grenville series—*Con.*
Quartzite, microphoto..... 58
Structural notes.....46, 47
Thickness..... 37
Grindstone isld..... 42
Haliburton-Bancroft area—
Index map showing..... 1
Harrington, B. J..... 51
Hill isld.....8, 14, 37
Historical geology.....48, 49
Indian r..... 6
Iron pyrites..... 50–52
Johannsen Prof..... 2
Johnston, W. A..... 8
Jones ck.....22, 25
Junetown, Ont..... 14
Keele, J.....43, 44, 54
Kindle, E. M..... 3, 49
Kingston area—
Index map showing..... 1
Marine submergence..... 44
Rocks.....17, 25, 31, 32
Labradorean ice-sheet..... 11
Lily bay—
Potsdam conglomerate, photo..... 57
Limestone, crystalline..... 18
*See* also Beekmantown formation.
Little Grenadier islds..... 14
Logan, Sir. W.....2, 3, 50, 51, 53
Lyn, Ont.....14, 34, 41
MacIntosh, A. N..... 2
MacKay, B. R..... 44
Madoc area—
Index map showing..... 1
Mallorytown, Ont.—
Diabase dykes near..... 33
Granite..... 26
Stratified deposit..... 5
Mallorytown granite..... 26
Mallorytown Landing..... 34
Map—
Brockville-Mallorytown area.....*In pocket*
Index..... 1
Martin, James C..... 3
Mather, K. F..... 44
Miller, W. J.....3, 32, 47
Montreal, Que..... 48
Monzo-granite..... 24
Morristown, N.Y..... 36
Moulding sand..... 53
Murray, Alexander..... 2
New York state—
Precambrian..... 5
Grenville series..... 12
Oak Point, N.Y..... 25
Ogdensburg, area, N.Y.—
Index map showing..... 1
Rocks, section..... 37
Ogdensburg formation..... 40
Ontario, lake..... 6
Ordovician. *See* Beekmantown.
Ottawa valley—
Palæozoic..... 7, 49
Palæozoic—
*See* also formation
Chazy formation
Potsdam formation
Beekmantown
Lithology..... 36–40
Montreal, thickness..... 49
Parks, W. A..... 54

PAGE

Patterson bay..... 54
Paving blocks..... 54
Peat..... 55
Pegmatite..... 29
Pegmatite dykes.....30, 32
Peneplain..... 6, 8
Photomicrographs—
Various.....58, 59
Physiographic history..... 10
Picher, R. H..... 54
Planation..... 10
Pleistocene.....7–9, 40
Pooles Resort, Ont.....14, 44
Pot-holes..... 8
Potsdam formation—
Caintown, near, photo..... 57
Distribution..... 5
For building-stone..... 54
Lily bay, photo..... 57
Lithology and analysis.....37, 38
St. Lawrence lowlands..... 4
Potsdam sea..... 5
Precambrian—
*See* also Grenville series—
Altitude of ridges..... 6
Planation..... 10
St. Lawrence lowlands..... 4
Pyrite..... 50–52
Pyroxenite—
Metamorphic, notes and anal.....18, 19
Microphoto..... 58
Pyrrhotite..... 52
Quartzite—
*See* also Grenville series—
Analyses..... 14
Pooles Resort, N. of, photo..... 56
Recent deposits..... 44
Ripple-marks.....39, 40
Road material..... 54
Rockfield, Ont.....14, 22, 25, 29
Rockport, Ont.—
Faulting..... 47
Pot-holes..... 8
Rocks.....9, 22, 25, 29
Sand.....44, 45
St. Lawrence r.—
Age..... 8
Drainage, evolution of..... 5
Glaciation..... 8, 9
Rocks in valley..... 7, 36
Salisbury, Prof..... 2
Sand..... 4, 5, 41
Moulding..... 53
Sandstone. *See* Potsdam sandstone.
Senecal bay..... 42
Sherwood, Geo..... 39
Shipman pyrite prospect..... 52
Silts..... 45
Sloan, N..... 50
Sloan pyrite prospect..... 52
Smith, J. P..... 50
Smyth, C. H.....3, 32, 38
Soil..... 4, 45
Spencer, J. W..... 7
Stone, G. H..... 42
Structural geology..... 46–49
Syenite. *See* Granitic intrusives.
Syenodiorite.....13, 22, 29
Table of formation..... 13
Tar isld..... 8, 21
Terraces..... 8

PAGE

Theresa limestone..... 40
Thousand Islands region—
  Faulting..... 47
  Former hill-tops..... 40
  Glaciation..... 8, 42
  Pot-holes..... 9
  Rocks.....25, 32, 48
Sediments..... 46
Till. *See* Boulder clay.
Tilley, Ont.....22, 28
Tilting, terrestrial..... 8
Timiskaming series..... 11
Tollgate, Ont..... 45
Topography..... 4
Tourmaline..... 53
Trent r..... 6
Trevelyan, Ont.....25, 28, 29
Tribes Hill formation..... 40
Unconformity—
  Grenville quartzite and Potsdam sandstone, photo..... 57
Vanston pond..... 45
Watertown, N.Y..... 14
Wells isld..... 26
Wilson, A. W. G..... 3, 50
Wilson, M. E.....2, 3, 7, 11, 19, 20
Wisconsin ice-sheet..... 7
Yonge Mills, Ont.....25, 26, 29