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BUREAU OF ECONOMIC GEOLOGY
GEOLOGICAL SURVEY

MEMOIR 198

Geology of Woodstock Area, Carleton and York Counties, New Brunswick

BY
J. F. Caley

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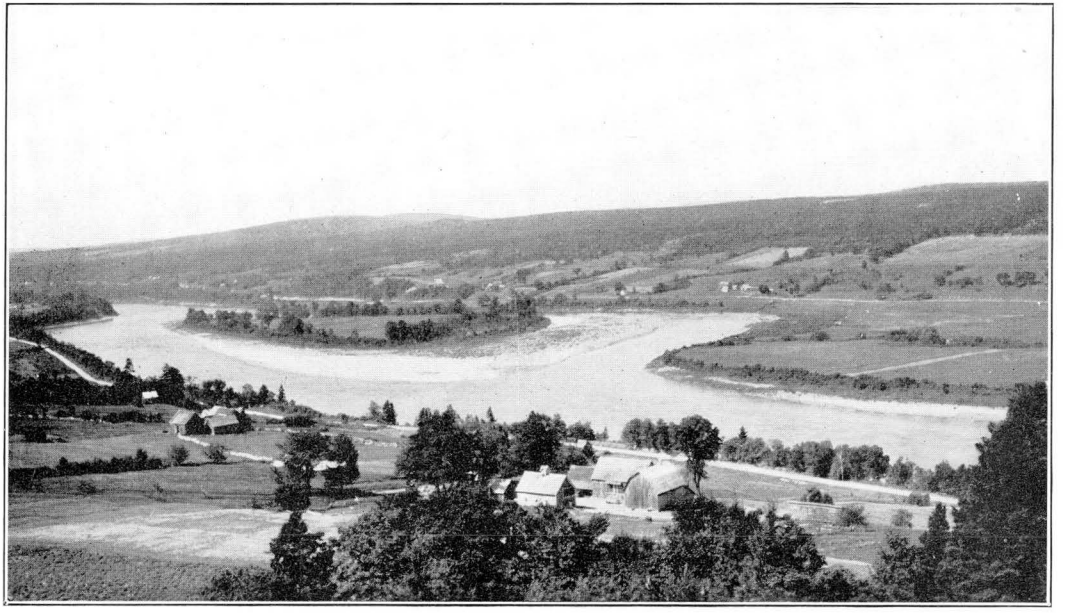

St. John River valley 4 miles below Woodstock.

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Geology of Woodstock Area, Carleton and York Counties, New Brunswick

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The writer during the season of 1935 surveyed the geographic features and mapped the geology of an area in the province of New Brunswick bounded on the north and south by latitudes 46°30′ and 46°, respectively, and extending from longitude 67°15′ west to the International Boundary. This region comprises roughly 75 per cent of the county of Carleton, and a relatively small part of south-central York, the whole embracing an area of some 880 square miles.

The principal object of the investigation was to trace, in as great detail as practicable, the bedded iron deposits known to occur in the region, and to examine these with a view to ascertaining their probable economic value. Such a project naturally included a study of the stratigraphy and structure of the associated rocks.

The area, as a whole, is readily accessible; it is roughly bisected in a north-south direction by the valley of St. John river, whose course is followed by both the Canadian Pacific railway and the trunk highway designated as Route 2 on the New Brunswick highway maps. In addition to these main arteries of transportation, and particularly in that part of the area west of St. John river, there exists a network of secondary roads which renders all parts of this section easy of access by automobile. This part of the area is given over extensively to farming and is consequently more thickly populated than the rest of the region. On the east side of St. John river the country is somewhat less accessible. The underlying rocks are, in general, such as render much of the soil unfit for agricultural purposes, resulting in few, and to some degree isolated, settlements.

The towns of Woodstock and Hartland, both situated on St. John river 12 miles apart, afforded convenient centres from which field operations were carried on.

PREVIOUS WORK

The area dealt with in the report is a small part of the region covered by map-sheets No. 2 SW. and No. 2 NW. of the series of geological maps, on a scale of 4 miles to 1 inch, published in 1886 by the Geological Survey and covering the whole of New Brunswick.

This part of New Brunswick was geologically explored during the last quarter of the past century. During that period several reports, chiefly of a reconnaissance character, were published by the Geological Survey. Since about 1907, however, little has been added to the early work. The following bibliography covers the more important works bearing directly upon the geology of the area under discussion.

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FIELD WORK

Owing to the lack of an adequate base map upon which to lay down the geology, it was found necessary to carry out a geographic survey of the area. The International Boundary line between the state of Maine and the province of New Brunswick, which is the only accurate survey in the entire region, was used as a control for the present work.

Traverses were made of all the roads and the railways in the area. The majority of these were stadia and compass traverses, though some were made with chain and compass. The rivers and smaller brooks were traversed by pace and compass, a method deemed sufficiently accurate for the present purpose since, in the case of most of the streams, numerous tie points were obtained where they crossed the various roads or railways mapped by other methods. All the above traverses were plotted on a scale of 1 mile to 1 inch, and subsequently compiled by the Topographical Division into the base used for the accompanying geological map.

The writer was assisted in the field by D. T. Nagle, C. V. Callaghan, G. F. Delong, R. G. Likely, J. R. Cameron, W. M. Benson, and E. G. Corey, all of whom carried out their various duties in an able and satisfactory manner. Dr. Bruce Rose offered helpful advice during several visits to the field.

To Dr. W. J. Wright, provincial geologist of New Brunswick, thanks are here rendered for general information regarding the area and for copies of certain maps of the New Brunswick Department of Lands and Mines.

The writer is also under obligation for courtesies extended by many people throughout the entire region.

CHAPTER II

GENERAL CHARACTER OF THE REGION

The region on the west side of St. John river is comparatively flat or gently undulating with an average elevation of from 400 to 500 feet. This plain-like effect is interrupted at various places by hills or ridges, trending in a general northeasterly direction and rising as much as 750 feet above the surrounding country.

St. John river traverses the area from north to south. It occupies a large valley, as much as 1·5 miles in width, whose slopes everywhere rise steeply to the level of the country on either side, the average elevation of which is about 300 feet above the valley bottom. The river in some places occupies almost the whole width of the valley bottom, but in others flats occur which in many places attain a width of nearly a mile. Most of the tributaries, such as the Shiktahawk, Presquile, Little Presquile, Meduxnekeag, and Becaguimec rivers, and Acker brook have cut deep valleys whose general trend is almost at right angles to that of the St. John These, in turn, have numerous smaller tributaries, the whole forming a somewhat open dendritic drainage pattern.

The region has everywhere a covering of glacial till beneath the surface soil. In some places this mantle is thin, the bedrock being practically at the surface; in others, particularly along the higher slopes of St. John River valley and some of its larger tributaries, thick deposits of more or less coarse gravel may be seen. Glacial striæ were observed at only two localities, one near Payson lake just west of Jacksonville, where the course is about south 23 degrees east, the other about one-quarter of a mile west of Norton Dale on the road to Grafton, where the direction is south 30 degrees east.

About three-quarters of the area, and more particularly that part that lies west of St. John river, is underlain by more calcareous formations, and is given over largely to farming. East of the river, and in the general vicinity of the east boundary of the area, the country is rather thickly wooded and at the present time practically uninhabited. Here, a small amount of lumbering is carried on with sawmills situated at Pinder, near the junction of main Nackawic river and its northeast branch, and on the north branch of Becaguimec river some 3 miles below the east boundary of the area.

CHAPTER III

GENERAL GEOLOGY

GENERAL STATEMENT

By far the greater part of the area is underlain by highly folded and contorted sediments of pre-Silurian and Silurian age. An approximate diagonal, drawn from northeast to southwest across the area, may be said to represent the line of contact of these two series of rocks, the Silurian occupying the northwest position. The relation between the two is one of unconformity.

The pre-Silurian strata are composed chiefly of quartzites and interbedded slates, the latter in many cases quite schistose.

The Silurian rocks are dominantly red, green, and black slates, which are commonly highly calcareous. They strike in a general northeast direction and dip, for the most part, steeply to the northwest.

In the east-central part of the area the older Palæozoics are overlain unconformably by almost flat-lying Carbonifeous strata. These rocks cover an area of approximately 70 square miles; they consist chiefly of conglomerates and other coarse, clastic sediments. In addition, small outliers of Carboniferous conglomerate occur along the west side of St. John river between Upper Woodstock and Victoria corners. In general, these Carboniferous sediments appear to occupy erosional irregularities in the upturned edges of the older rocks.

Devonian rocks are believed to be present in at least one locality, viz., at the mouth of Little Pokiok brook some 2 miles below the town of Hartland. Here, coarse, grey conglomerates have interbeds of argillite carrying plant remains that have been identified as belonging to the Psilophyton flora.

In the extreme southeast corner of the area the sediments are intruded by a body of granite covering an area of about 18 square miles. A small intrusion of similar rock occurs along the course of Gibson Mill brook, and on the west side of St. John river a mass of a more syenitic type occupies a long, narrow area 8 or 10 square miles in extent. In addition to the above igneous rocks, diabase dykes cut all the sediments, with the possible exception of the Carboniferous.

The most abundant rock exposures are to be found along the beds and banks of the larger streams; even along some of these, however, there are numerous stretches, some of them miles in length, in which no outcrops occur. Along the railway lines and in roadcuts the bedrock is locally exposed, and in a few places outcrops are found on the hilltops. On the whole, however, exposures in the area are comparatively scarce.

Table of Formations

Cenozoic.....	Modern.....	Pleistocene.....	Glacial drift
Palæozoic.....	Carboniferous...	Pennsylvanian (?)	Chiefly fine and coarse, chocolate and red conglomerate with brick-red, sandy shales and sandstones.
	Devonian.....	.....	Red and grey granite, syenite, diabase dykes.
	Devonian (?)....	.....	Coarse, grey conglomerate with interbeds of dark grey argillite enclosing *Dawsonites arcuatus* Halle and *Hostimella* sp.
	Silurian.....		C: Dominantly dark grey, and bluish weathered, calcareous argillites and slates with many thin beds of limestone and occasional layers of greenish quartzose sandstone.
			B: Dark grey to black, thinly bedded and conspicuously banded, highly calcareous slates with interbedded zones of less calcareous, green and grey slate with Monograptus. Occasional zones of red, ferruginous slate with associated beds of dark-stained, manganiferous hematite.
			A: Greenish and buff weathered, thinly bedded, sandy argillites with numerous beds of sandstone. Occasional zones of light and dark grey crystalline limestone with *Zaphrentis* sp., *Favosites* sp., and crinoid stems. Grey conglomerate near the base.
	Pre-Silurian.....	.....	Grey and green quartzites with interbeds of green, thinly bedded slate. Some paraschist and micaceous sandstones. Occasional, white, crystalline limestone beds.

DESCRIPTION OF FORMATIONS

PRE-SILURIAN

Distribution. Strata referable to the pre-Silurian occur along the east bank of St. John river from just below the mouth of Little Pokiok brook to the south boundary of the area. Exposures may also be seen on the west side of the river over the same distance, but they are here interrupted by occurrences of the Carboniferous conglomerate about 1 mile below Victoria corners, and by syenitic intrusives around the mouth of Bulls creek, some 4 miles south of Woodstock. On the same side of the St. John, and south of Woodstock, similar rocks occur at various localities along both the Canadian Pacific and Canadian National Railways lines. In the southeastern part of the area, pre-Silurian rocks may be seen, particularly along Nackawic river, its Northwest branch, and Negro brook north of Temperance Vale. Several exposures occur also along the Gibson branch of the New Brunswick railway between the east boundary of the area and the County Line station. In addition to the above localities, isolated, and in general small, outcrops occur along many of the roads and smaller brooks in the parishes of Northampton and Southampton. In many places where no exposures are to be seen the presence of pre-Silurian strata beneath the overburden may be inferred from the general ruggedness and wooded character of the surface and its apparent unfitness for agricultural purposes.

Lithology. Along St. John river and on its west side south of Woodstock, the pre-Silurian rocks consist chiefly of a greenish and grey, hard

quartzite with many interbeds of green slate. Both these rock types are well bedded, the former in layers from a few inches to 2 feet in thickness, the latter in beds only a few inches thick. In the vicinity of Oak mountain, a dark green, gneissoid and rudely bedded rock occurs with feldspathic sandstone and grit. Along the railway line above the mouth of Acker brook, and below the mouth of Little Pokiok brook, are thinly bedded, somewhat sheared, greenish, chloritic para-schists and phyllites. These rocks have suffered various degrees of shearing and show much sericite along the bedding planes. Similar strata may be seen for at least 3 miles up Acker brook from its mouth. In the general vicinity of Waterville Settlement in York county, and from here northwest along the road to Grafton, as well as west of Temperance Vale and along the road from Norton Dale to Grafton, most of the exposures show thinly bedded, green and buff weathered slates and argillites, with numerous beds of quartzites. Near the contact of the granite body that occupies the extreme southeast corner of the area the rocks are somewhat different. Owing to the general scarcity of exposures, actual contacts between the granite and the pre-Silurian strata are few, but those that have been observed, as for example where the Pinder-Norton Dale road crosses the northwest branch of Nackawic river, show the rocks to be gneissic near the contact and farther away to be chiefly micaceous schists and sandstones.

Structure. The structure of all the rocks in the area will be discussed in detail in a later chapter. Briefly the pre-Silurian strata have suffered considerable deformation, as evidenced by the folding observed along St. John river. The general trend, broadly speaking, is northeast, but innumerable instances of local irregularity occur; the dips vary from 35 degrees to 80 degrees, the lower inclinations occurring along St. John river, whereas the higher ones seem to prevail in the east-central part of the area.

SILURIAN

Distribution. The strata here referred to the Silurian system have a very wide distribution; they underlie some 450 square miles or approximately one-half the total area covered by this report, and occupy a position on the northwest side of a rough diagonal drawn from northeast to southwest across the region.

Considering the extensive area underlain by these rocks, actual exposures are relatively scarce. The most continuous outcrops occur along both sides of the St. John from about 2 miles below Hartland bridge to the north boundary of the area. Although throughout this distance there are places where exposures are practically continuous for a mile or more, there are numerous stretches, some of them several miles in length, in which there are no outcrops. Bedrock may be seen along the Canadian National Railways line from Belleville south to near the contact with the underlying pre-Silurian, as well as throughout practically the entire course of Meduxnekeag river and along some of the roads and in adjacent fields in the extreme northwest part of the area. On the east side of St. John river, Silurian strata outcrop chiefly along Shiktahawk river, Cold stream, and the lower waters of the Becaguimec, as well as along some of the smaller streams, such as Howard brook, Hamilton brook, and others. Smaller and more isolated exposures occur along the various roads and chiefly in the general vicinity of Windsor, Esdraelon, and Knowlesville.

Lithology. The great bulk of the Silurian beds consists of slates; these are grey, black, green, or red, and vary in composition from arenaceous to highly calcareous. They are everywhere thinly bedded and in many places can be split into thin laminæ. At several localities much calcite occurs along the bedding planes and also as narrow veins. In addition to the slates, there are also argillites, clay shales, sandstones, conglomerates, and limestones.

Relationship to Other Formations. At and near the base of the Silurian in this area are conglomerates, in which many of the pebbles closely resemble the pre-Silurian rocks. Associated with the conglomerate in many places are beds of coarse-grained sandstone. South of the town of Debec, in the vicinity of O'Donnells crossing, the conglomerate rests on a quartz porphyry that appears to have supplied pebbles to the conglomerate. According to Bailey,[1] it is noticeable that going southwest from the above locality the basal beds of the Silurian successively overlap different members of the pre-Silurian and hide them from view. The above considerations would seem to argue in favour of an unconformable relationship between the pre-Silurian and Silurian groups in this area.

Probable Succession. It is very difficult to arrive at any definite conclusions relative to the stratigraphic sequence of the Silurian strata in this area. On a basis of lithology, colour, and the occasional occurrence of poorly preserved fossils, they appear, however, to be divisible into three zones, the probable succession being as follows:

C—Dominantly dark grey, in places bluish weathered, calcareous argillites and slates with many limestone beds and occasional beds of greenish sandstone.

B—Dark grey to black, thinly bedded and conspicuously banded, highly calcareous slates with intercalations of varying thicknesses of less calcareous green and grey slate, containing *Monograptus* sp. Occasional thin zones of red, ferruginous slate also occur; these show associated beds of darkly stained, manganiferous hematite.

A—Greenish and buff weathered, thinly bedded, sandy argillites with many beds of sandstone containing *Delthyris* sp. indet. at one locality. Occasional zones of light and dark grey limestone with *Favosites* sp., and *Zaphrentis* sp. indet. Grey conglomerates near the base.

Zone A

These rocks are believed to represent the base of the Silurian system in the area covered by this report. They occur chiefly in the northeast part of the region and are well exposed along Upper Howard brook, toward the head of Hamilton brook, along the road from Lower Windsor to Esdraelon, and along the small brook northeast of the last-named town.

The conglomerates are well exposed at the bridge crossing the north branch of Becaguimec river just above the mouth of Upper Howard brook. They are greenish grey and are composed of well-rounded pebbles which vary from less than ⅛ inch to 1 inch in diameter and which are embedded in a coarse, greenish, siliceous matrix. The pebbles consist chiefly of white quartzite, grey, green, and reddish chert, and black, siliceous, slaty fragments. Similar conglomerates outcrop at the following localities: (1) about ¾ mile south of Windsor on the road to Coldstream; (2) on Becaguimec river about 1 mile below the forks of the north and south

[1] Bailey, L. W.: Geol. and Nat. Hist. Surv., Canada, Rept. of Prog. 1882-83-84, pt. G, p. 9.

branches; (3) on the north branch of Hamilton brook about ¼ mile above its crossing with the Knowlesville-Highland corner road, and on the Pole Hill road about 3 miles east of the bridge over the Becaguimec. At the first and the last-named localities the conglomerate is much coarser than elsewhere, containing pebbles up to several inches in diameter. These conglomerates have everywhere a general northeast strike and their apparent repetition would point to a series of close folds.

The limestones are exposed at three principal localities: (1) near the head of Limestone brook in the parish of Brighton; (2) on the right bank of the North Becaguimec about 1 mile above Carlisle; and (3) immediately east of Henderson corners. The rock varies from light to dark grey and occurs in beds from 3 inches to 2 feet in thickness. It apparently contains a high percentage of calcium carbonate, since at each of the three above localities it has, in the past, been quarried, pulverized, and used as a reconditioner for the soil. Near Carlisle, a few very poorly preserved specimens of *Favosites* and *Zaphrentis* were obtained. The limestones occurirng at Henderson corners are associated with thinly bedded, greenish sandstone and shale; in these beds many occurrences of crinoid columns and a few fragments of Orthoceras were observed.

The great bulk of the rocks consists of greenish and buff weathered, thinly bedded, sandy argillites with green slates and numerous beds of sandstone. The best exposures occur along Upper Howard brook, near the head of Hamilton brook, and about ¾ mile south of Henderson corners on the road to Coldstream. A partial section of these rocks as seen at the falls near the head of Hamilton brook is given below.

	Approx. thickness, feet
Dark grey weathered, green, sandy argillite in beds from ½ inch to 2 inches thick..	50
Hard, green quartzite and grey sandstone with disseminated pyrite..	2
Alternating layers of green quartzite rock with green and grey, fine-grained sandstone in beds from 2 inches to 5 inches thick. Numerous intercalations of grey, sandy shale..	40

At about 30 feet from the base occur poorly preserved specimens of *Delthyris,* some crinoid columns, and much black, carbonaceous, plant-like material that resembles the stems of Psilophyton.

The rocks everywhere show a general northeast trend and a steep dip, commonly in a northwest direction.

Zone B

The rocks referred to B have a wide distribution in the area. They occupy a strip averaging about 7 miles in width extending across the region in a northeast direction. As a whole, they consist of an interbedded series of black, greenish, and red slates. Associated with the red slates are the so-called Woodstock iron ores consisting of bedded, impure, manganiferous hematite.

The dark slates are well developed at several localities along St. John river, just below and just above the bridge at Hartland and above the mouth of Shiktahawk river. They occur also along the Cold stream and along the lower waters of Little Presquile river. They are typically dark

grey to black and highly calcareous, with much calcite along the bedding planes in various places. They can readily be recognized by their conspicuous banding, the bands being regular and commonly from 1 inch to 3 inches in thickness.

The green and grey strata, which are apparently interbedded with the black slates just described, are well developed in the southwest part of the area. They can be seen to advantage along the Canadian National Railway line between Belleville and Meduxnekeag bridge, and along Meduxnekeag river from Belleville south to the pre-Silurian boundary. They are also well exposed on the west side of St. John river below the mouth of Presquile river, and along Shiktahawk river above its confluence with the Little North branch. These strata are much less calcareous than are the black slates; in places they are really shales and soft clay slates and are everywhere thinly bedded, though in many places they appear massive on weathered surface. A few poorly preserved specimens of graptolites were obtained from the greenish grey slates at a point on the left side of Meduxnekeag river about ¼ mile below the bridge at Belleville. These have been identified as *Monograptus* cf. *M. clintonensis* (Hall) and are strongly indicative of a Silurian age.

The red, ferruginous slates are much less in volume than either the green or black strata just described. They are interbedded with the green slates and appear to occur in distinct bands. These bands are seen to outcrop at various localities along a general northeast course and also recur at somewhat widely spaced localities at right angles to this general trend. The widest zone exposing the alternation of red and green slate occurs about one mile northwest of Gordonville where the rocks are exposed over a width of 700 feet. The strike is generally northeast and the dip practically vertical.

The bedded iron "ore" is everywhere associated with either red or green slates or with alternations of both these strata; in other words, they appear to occur in zones of interbedded red and green slates similar to the one described above as occurring near Gordonville. At Jacksonville, where the Woodstock iron-bearing zone was at one time mined, both red and green slates occur, but at various other localities the "ore" occurs apparently unaccompanied by the red strata. This apparent condition may, of course, be due to a lack of exposures in the immediate vicinity of the iron outcrops. The reverse situation, however, is also true. Not everywhere that the red and green alternations have been observed has iron ore been found to occur. The probable explanation of this is that the iron formation occurs in lenticular bodies that pinch out at various places. The red slates, being sedimentary in origin, may also be lenticular in form, but even granting the association of the iron with these red slates there seems no reason why the two should not pinch out at different places, resulting in the occurrence of the one without the other.

The description of the "ores," including their distribution and probable extent, is reserved for a later chapter.

Zone C

These strata are believed to represent the highest members of the Silurian succession in the region. They have a fairly wide distribution, chiefly in the northwest part of the area, and cover about 120 square

miles. Rocks of this division show their typical development along Presquile river and along the roads and in the adjacent fields north of Centreville. Excellent exposures may also be seen at Oakville and at Jackson falls near the forks of the north and south branches of Meduxnekeag river.

The strata consist of fairly dark grey, in places bluish weathered, calcareous slates and argillites. They are thinly bedded, in layers from ½ inch to 2 inches in thickness, and many show harder, more compacted layers about 2 inches in thickness. Numerous, thin limestone beds occur, especially in the northwest part of the area, and beds of greenish, quartzitic sandstone from 4 inches to 2 feet in thickness may be seen on Meduxnekeag river a short distance above Belleville.

No trace of fossil remains has been found in these rocks. Like the rest of the Silurian, these strata have a very constant northeast strike and steep dips, commonly in a northwest direction.

Age Relations. The rocks described above under A, B, and C have all been referred to the Silurian system. It is freely admitted that within the limits of the area under investigation conclusive palæontological evidence as to age is meagre. Bailey[1] obtained a few fossil fragments from rocks here included in A; these were identified by Whiteaves and included *Pentamerus galeatus* Dalman, and *Dalmanites* sp. indet. *Atrypa reticularis* had previously been obtained from the same locality by Matthew. The above forms are all characteristic of the Silurian, the last-named occurring in the Niagaran of Ontario and elsewhere. In addition to the above, a few poorly preserved specimens were collected by the writer from the same general locality. These have been identified as *Zaphrentis* sp., *Favosites* sp. indet., *Delthyris* sp. indet., crinoid columns, and fragments of *Orthoceras*. Although none of the above is confined to rocks of Silurian age, the presence of *Favosites, Delthyris,* and crinoid columns is strongly suggestive of that system.

The only palæontological evidence relative to the age of the rocks of B is the occurrence of a few specimens of *Monograptus* cf. *M. clintonensis* (Hall); these were found on the left side of Meduxnekeag river about ¼ mile below the Belleville bridge. Although the specimens do not admit of positive specific identification, their reference to the genus Monograptus is made with reasonable assurance. They closely resemble *M. clintonensis* Hall, also *M. Priodon* (Bronn) mut. *chapmanensis* Ruedemann. The former occurs in the Clinton of New York state, the latter in beds of approximately the same age in Aroostook county, Maine. The genus Monograptus is especially characteristic of the Silurian system.

No fossils were found in the strata of C. The general lithological character and attitude of the beds of both B and C are so similar that there seems little reason to doubt that they are of the same age.

Associated Igneous Rocks. About 2¾ miles southeast of Florenceville there is a series of hills rising some 800 feet in elevation above the river. These prominences are formed of fine-grained, amygdaloidal lava of intermediate composition, probably about a latite. The rock outcrops at the top and also for about 100 feet down the west slope of the hills. It appears to strike about north 70 degrees east and to be steeply inclined. The rock is dark green to almost black in colour; thin sections show it

[1] Bailey, L. W.: Geol. and Nat. Hist. Surv., Canada, 1885, pt. G, p. 17.

to be felsitic in texture with a fine groundmass of orthoclase and albite feldspar and a small amount of quartz. Much augite is also present. The amygdules are filled chiefly with calcite, though some show a mixture of calcite and chlorite.

About one mile northwest of Gordonsville and situated on a thickly wooden hill-side is an exposure of volcanic breccia. This rock has been quarried and used in the construction of two highway bridges across the Cold stream, one in the village of Esdraelon and the other about ½ mile south of that place. The rock is dark greenish grey in colour. The hand specimen shows angular fragments of quartz and black and green slate with some more or less rounded chert pebbles. The texture is fairly coarse, the fragments averaging from $\frac{1}{16}$ to $\frac{3}{16}$ inch in diameter; some green slate fragments attain a diameter of ½ inch. Thin sections reveal much carbonate along boundaries and cracks and show the rock to be composed chiefly of the following constituents: a large proportion of angular quartz fragments, much leucoxene, small amount of red ferruginous material, small amount of feldspar (indeterminable), and a large percentage of rock fragments made up chiefly of slate, dense chert or felsite, highly siliceous material, and spherulitic masses of chlorite. The rock has apparently been shattered and blown out by volcanic explosion and has settled in the same basin of deposition as the associated green slates of the Silurian system. The strike is about north 55 degrees east and the dip is practically vertical, in conformity with the general attitude of the associated slates.

DEVONIAN (?)

At the mouth of Little Pokiok brook about 2 miles south of Hartland, and extending some 1,000 feet along the railway track below the brook, are exposures whose stratigraphic position and age are not definitely known. These rocks consist chiefly of coarse, grey conglomerates composed of well-rounded pebbles ranging from less than 1 inch to 8 inches in diameter. The larger of these are composed of greenish quartzite, quartzose sandstone, and more rarely of igneous rocks; the smaller ones consist of white quartzite and green and black chert. Interbedded with the conglomerate along the railway line are beds of coarse, greenish sandstone. In the gorge at the mouth of the brook is an 8-foot zone of thinly bedded, dark grey to greenish, sandy shale and argillite which contains numerous plant remains.

The stratigraphic relation of these beds is in doubt; neither the top nor the bottom has been observed, but the beds appear to show an attitude conformable with that of the Silurian strata already described, that is, they trend northeast and are steeply inclined. According to Bailey[1] the plant remains were identified by Sir Wm. Dawson in 1871 as being those of *Psilophyton princeps*. Undoubted specimens of this genus were not obtained during the past season, but material identified by W. A. Bell as *Dawsonites arcuatus* Halle, and *Hostimella* sp. was collected. Both these are members of the Psilophyton flora. This flora occurs in the Middle Devonian of Gaspe and according to Alcock[2] has not been found below that horizon there. It is generally conceded that the earliest vascular or land plants

[1] Bailey, L. W.: Geol. and Nat. Hist. Surv., Canada, 1885, pt. G, p. 11.
[2] Alcock, F. J.: Personal communication.

known with certainty occur in rocks of Devonian age; these plants include members of the Psilophyton flora. It seems worthy of note that Cookson[1] has recently described remains of vascular plants from Victoria, Australia. Associated with these are graptolites, identified as *Monograptus* by Dr. Elles of Cambridge, and dated Lower Ludlow (Silurian) in age. The plants include members of the Psilophyton flora and "as compared with what is known from the Northern Hemisphere this flora could be regarded as Lower Devonian."[2] From the above consideration, it would appear that the Psilophyton flora is known to occur in Silurian rocks of Australia. It is equally true, however, that so far as known the flora does not occur in North America below the Devonian. In seeking to date the conglomerates here under discussion on a basis of their contained flora it is felt that their proximity to the Gaspe region is of paramount importance; consequently, they are here referred to the Devonian system.

DEVONIAN

Diabase dykes occur practically throughout all of the Silurian belt and may be observed to good advantage at the following localities: (1) along both sides of St. John river about 1¼ miles above Hartland, on the west side about ¾ mile below Florenceville, and on the east side about 1 mile above the mouth of Shiktahawk river; (2) on Shiktahawk river just below the Gordonville road crossing; (3) along Stickney brook; (4) at the top of Flannigan's hill; and (5) about ½ mile east of Charleston schoolhouse. The dykes vary from 2 feet to about 20 feet in width; they are everywhere either vertical or steeply inclined and are locally amygdaloidal. The rock is mostly dark green to almost black, medium to finely textured, and with the ophitic character often visible even to the unaided eye. Microscopic sections show that in most cases much alteration has taken place; the feldspars are extremely cloudy and, in general, the ferromagnesian minerals are altered to chlorite. In most sections, however, the ophitic, lath-like texture is well developed.

In the southeast corner of the area the metamorphosed sediments are intruded by a granitic body which covers about 20 square miles. The granite is well exposed at several localities along Nackawic river from its mouth to about ½ mile above its confluence with the Northwest branch; it may be seen to good advantage below the highway bridge at Pinder.

The granite is medium to coarse textured, the quartz, feldspar, and ferromagnesian minerals being present in roughly equal proportions. In some places large phenocrysts of feldspar give a porphyritic appearance to the rock. The colour is commonly grey to whitish, but is occasionally pink and even deep red.

Owing to the presence of glacial drift and to the general wooded character of the country underlain by the granite it is difficult to draw a boundary with any degree of accuracy. However, the contact of the granite with the pre-Silurian metamorphic rocks has been observed at one locality and its approximate position can be inferred at several others.

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[1] Cookson, Isabel C.: Phil. Trans. Roy. Soc. London, No. 251, vol. 225, pp. 127-148 (July 1935).
[2] Cookson, Isabel C.: Op. cit.

On the Pinder-Norton Dale road, where it crosses the Northwest branch of Nackawic river, the grey granite is seen in contact with the intruded rocks. Near the contact the latter are dark grey and gneissic; passing away from the granite they grade to a mica schist and finally to a coarse, micaceous sandstone. The zone of country rock altered by the granitic intrusion appears to be relatively narrow.

About 3 miles west of Temperance Vale, grey granite and mica schist again appear, indicating proximity to the contact. At a few places, as about ½ mile northeast of Clarkes corners, large inclusions of schist occur within the granite mass.

The granite body here described is part of the great batholith of central New Brunswick and is assumed to be Devonian in age.

Small outliers of the same type of rock, though more syenitic in composition, occur along the course of Gibson Mill brook and on the west side of St. John river as a narrow belt stretching from near the mouth of Bulls creek to the south boundary of the area.

CARBONIEFROUS

Distribution. The strata referred to the Carboniferous have a relatively small distribution in the area; their areal extent is probably in the neighbourhood of 70 square miles. Their chief development is on the east side of St. John river where they underlie a roughly triangular area, two of the sides of which are nearly coincident with the two branches of Becaguimec river, and the apex probably lies somewhere within a mile of the mouth of Little Pokiok brook. On the west side of the St. John the rocks are seen to outcrop about 1½ miles below Victoria corners; from here, they continue as a long, narrow strip to a point about ½ mile above Upper Woodstock. Exposures are very scarce on this side of the river, but the presence of the rock is indicated by the red colour it imparts to the surface soil.

Lithology. As exposed in this area, the Carboniferous rocks consist of chocolate and red conglomerates with intercalations of brick-red sandstone and sandy shale. The conglomerates constitute the greater volume of the strata; they are composed of well-rounded pebbles from ½ to 12 inches in diameter, the larger ones consisting of greenish quartzite with some of igneous origin, whereas the smaller are chiefly red and green chert and quartz. The bedding is not well defined in these strata. In many instances the rocks form cliffs as much as 40 feet in height. Some of the best exposures may be seen along Brummagem brook extending for a distance of 2½ miles from its mouth, and also forming a prominent elevation on the north side of Becaguimec river about 1¼ miles below the mouth of the last-named brook. Less extensive exposures occur intermittently along the North branch of the Becaguimec for a distance of about 10 miles from its confluence with the South branch.

The sandstone and sandy shales typically present a brick-red colour, though in some places they are more pinkish. They show fairly well-defined bedding. In various places both the shales and sandstones show small, circular areas of light green colour. The best exposures of these rocks occur: (1) along the East Brighton road near where it crosses Little

Pokiok brook; (2) at Carlisle bridge across Becaguimec river; and (3) at various localities along Brummagem brook.

In a cut-bank on the right side of the North Becaguimec about $\frac{2}{5}$ mile below the Cloverdale road crossing there is a badly slumped exposure, rising about 25 feet above the water and extending some 50 feet laterally. It consists of buff weathered, thinly bedded, black shale containing specimens of a large Estheraea. Interbedded with the shale are occasional 2-inch beds of greenish argillite containing plant remains resembling those that occur at the mouth of Little Pokiok brook, but too poorly preserved to be identified. The relation of this exposure to the red conglomerates that occur in the stream bed both above and below could not be ascertained, but it is believed to be interbedded with the conglomerate series, though no definite proof of this was found.

Thickness. The complete lack of horizon markers that might be used to compare sections at different localities renders any precise estimate of the thickness of the Carboniferous strata impossible. An approximate figure can, however, be given. North of Becaguimec river, about $1\frac{1}{4}$ miles below the mouth of Brummagem brook, the red conglomerate is exposed in the stream bed; on the north side a hill rises some 300 feet above the water; this prominence is formed by the almost flat-lying, red conglomerate that may be seen to outcrop on the south side of the hill near its top. This would indicate that at least 280 feet of these strata occur at this locality. At no other place was more than 60 feet exposed in one section.

Structure. The prevailing dip of the Carboniferous rocks is low, probably about 20 degrees, and the general trend is a few degrees east of north. Locally, as seen on the East Brighton road near where it crosses Little Pokiok brook, the dip is as high as 45 degrees.

Relationship to Other Formations. As far as observed the Carboniferous conglomerates represent the youngest bedrock in the area. The upper limit, however, has nowhere been observed. It is possible that in the higher regions, south and west of the upper waters of the North Becaguimec, the conglomerates are overlain by still younger strata. This region is heavily wooded and difficult of access, and as far as examined contains no exposures. The lower limit of the Carboniferous was seen at only one locality. At a point about $\frac{1}{2}$ mile below the mouth of Lower Howard brook the North Becaguimec has cut down through the red shale of the Carboniferous and exposed the underlying Silurian strata. On the right side of the river and rising some 50 feet above the water, green and reddish weathered, sandy argillite and impure limestone are exposed. The bedding is not very distinct and in places the rock appears massive, but the inclination is steep. Many poorly preserved fragments of crinoid columns occur here. Resting on the up-turned edges of the above rock, and forming a steep bank about 30 feet high, is the red, sandy shale. This rock is somewhat slumped so that its attitude can not be observed, but it appears to have a much lower dip than the underlying Silurian. The above condition would indicate an unconformable relationship between the Carboniferous and underlying formation, a conclusion also borne out by the fact that all the rocks older than the Carboniferous show prevailingly steep dips, whereas the latter are practically everywhere nearly horizontal.

Age and Probable Correlation. Due to the lack of fossil evidence the Carboniferous age of the red conglomerates and shales here described is assumed chiefly on a basis of their similarity to formations of that age in other areas. Both the colour and lithology of these rocks are practically identical with those of the Bonaventure formation of Chaleur Bay region. Like that formation, also, the attitude is almost everywhere approximately horizontal, with commonly low dips and only local instances of inclinations up to 45 degrees, and in both areas the red strata rest unconformably upon the underlying formations. According to Alcock,[1] the Cannes de Roche formation is in all probability the same age as the Bonaventure formation. On a basis of fossil plants W. A. Bell concluded " a late Mississippian or early Pennsylvanian age, more probably Pennsylvanian,[2] for the former."

The occurrence of Estheraea is of interest and probable significance. As previously stated these forms occur in black shale believed to be interbedded with the red conglomerates and shales just described. The fossils are characterized by their very large size as compared with that of other Palæozoic species. The only Estheraea at all comparable in size have been observed in rocks of Pennsylvanian age in Stellarton district and near New Glasgow, N.S.

MODERN

The Modern deposits in the area consist chiefly of glacial material in the form of ground moraine, gravel hills, and kames. In general, the area is covered with a mantle of drift varying in thickness up to about 100 feet. In some places it is absent, the bedrock appearing at the surface. Gravel hummocks and ridges, some of which are kames, occur chiefly along St. John River valley, particularly along the east side of the river at intervals from the mouth of Little Pokiok brook to the south boundary of the area. Gravel from these kames is used as road metal in Carleton county.

Glacial striæ were observed at only two localities: one near Payson lake, the other west of Norton Dale on the road to Grafton; the direction of these was measured as south 23 degrees east and south 30 degrees east, respectively.

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[1] Alcock, F. J.: Geol. Surv., Canada, Mem. 183, p. 94 (1935).
[2] Geol. Surv., Canada, Mem. 183, p. 94 (1935).

CHAPTER IV

STRUCTURAL GEOLOGY

The working out of structure in the area is rendered difficult by the scarcity of exposures, the lack of key horizons, and the lithologic sameness that characterizes the strata over wide stretches. Though exposures are fairly continuous for relatively long distances along many of the streams the interstream areas are extensive and practically devoid of outcrops, so that much structural complexity may occur that can not be observed. The bedded hematite deposits proved to be of little aid, owing to their exposures being sporadic and widely spaced and to the fact that their attitude was everywhere found to be either vertical or nearly so.

As previously stated the greater part of the area is underlain by pre-Silurian and Silurian rocks. These are highly folded and contorted. They strike in a general northeasterly direction and show dips varying from 45 degrees to 90 degrees, the majority of which, in the case of the Silurian strata at least, are to the northwest.

Although the general course of the pre-Silurian rocks appears to be to the northeast, an examination of strikes and dips shows a great deal of local irregularity. Along St. John river from about 2 miles below Hartland to the southern boundary of the area innumerable folds occur. Most of these are fairly gentle flexures with dips rarely exceeding 50 degrees, although folds of a more compressed type occur in places. In the southeastern part of the area the dips are commonly steeper than along St. John river, many attaining an angle of 80 degrees and few falling below 60 degrees. This phenomenon may be due to the fact that in the former locality the lithology is commonly quartzitic, whereas in the latter, slates and argillites are the prevailing rock types; these would yield more readily to deforming forces.

No detailed structures were worked out for the Silurian rocks. Throughout the region these strata consist chiefly of slates, some of which are highly calcareous, and there is little doubt but that their thickness is considerable. In contrast with the pre-Silurian rocks the Silurian beds show a remarkable consistency of strike over wide areas; the majority of the dips are very steep and commonly in the same direction. Fracture cleavage was observed at many places and was always found to be at an acute angle to the bedding. In some few places tightly compressed folds were observed. From the prevailing number of steep dips with comparatively few instances of reversal in direction, and from the above evidence that flexures are present, it would seem a reasonable inference that the major structure of the Silurian as a whole consists of a series of compressed, isoclinal folds trending in a northeasterly direction.

Although direct evidence of faulting in the Silurian rocks is not common, it has been observed in various places. In some of the pits from which the Woodstock iron ores were mined much slickensiding is in evidence, indicating that faulting has taken place. On the east side of the road from Lower Windsor to Henderson corners, and about one-half mile south of the latter place, there is evidence of minor dislocation.

The main period of orogenic movements affecting the region under discussion seems to be post-Silurian and since the Carboniferous conglomerates and shales have nearly everywhere an approximately horizontal attitude, pre-Pennsylvania. It is, therefore, probably Devonian.

The greater structural variation in the pre-Silurian rocks as compared with those of the Silurian would seem to indicate a separate period of deformation for each group. As previously stated, the relation of the two groups is one of unconformity; the pre-Silurian rocks were, therefore, folded and elevated prior to deposition of the overlying Silurian. At the time of folding of the Silurian strata the pre-Silurian rocks were buried beneath those of the Silurian, and it is conceivable that at this time the Silurian incompetent rocks could be thrown into the compressed folds that they now exhibit without materially affecting the deeply buried and more competent quartzite strata of the pre-Silurian.

Little need be said regarding the structure of the Carboniferous rocks of the area. They appear to occupy depressions in the underlying Silurian and are seen to rest upon the up-turned edges of members of that system. The strata are characterized by an almost horizontal attitude and, as far as they have been observed, by a complete absence of any evidence of faulting. Conglomerates constitute the chief members of the Carboniferous rocks; these rarely show distinct bedding, but their attitude can readily be ascertained from the many intercalations of shale and sandstone. Except for local irregularities, the rocks have a general northeast strike; the prevailing dip is approximately 20 degrees and commonly in a northwest direction, although on the East Brighton road, near Little Pokiok brook, the inclination is 45 degrees.

CHAPTER V

ECONOMIC GEOLOGY

IRON

General Statement. Occurrences of iron ore near Jacksonville in Carleton county have been known for many years; mining was carried on intermittently from 1848 to 1884, during which time the amount of ore smelted is reported as about 70,000 tons.[1] The iron works were situated at the mouth of Lanes creek immediately above the village of Upper Woodstock. About 1863, the Woodstock ore was used in the manufacture of mail-plating employed in the construction of gun boats by the English navy.[2] In 1874, the deposits were examined and reported upon by R. W. Ells.[3] Due to the low iron content and relatively small extent the deposits have long since been abandoned, no mining having been done for the past fifty years or more. In 1931, a plane-table survey of the principal old workings was made, on a scale of 1 inch to 200 feet, by W. J. Wright, Provincial Geologist of New Brunswick, and S. C. Perry of the University of New Brunswick. This survey shows the location of the various pits from which the ore was mined and outlines the zone of red, ferruginous slate with which the iron appears to be associated.

Distribution. The distribution of the iron ore as indicated by exposures may be divided into two groups; the first includes those occurrences near Jacksonville, Carleton county, that were worked some seventy years ago, and the second includes occurrences where the iron formation is exposed but where it has not been exploited.

The first group is a series of pits located on hills that trend in a northeast direction. The pits extend from a point near Campbell corners through Moody Hill, Iron Ore Hill, and Maple Hill to Jacksontown. The occurrences belonging to the second group are situated at the following localities: (1) at Ashland, (2) at Glassville, (3) on the Glassville-Bristol road where it is crossed by the west branch of Black brook, and (4) on Shiktahawk river about ½ mile below the bridge on the West Glassville road.

Mode of Occurrence. The ore is everywhere associated with Silurian strata previously described under division B of that system. It outcrops at widely spaced localities along one or more relatively narrow zones composed of an intercalation of green, grey, and red slates; these beds have a northeast trend and extend from Campbell corners to Glassville, a distance of about 24 miles. In some places where the iron-bearing beds outcrop the red slate is not in evidence, and conversely, the red and green strata may be observed with no ore visible. The number of the iron-bearing zones is not known; the position of the exposures indicates either several zones, or, what seems more probable, a repetition of one general zone due

[1] Lindeman, E., and Bolton, L. L.: Mines Branch, Dept. of Mines, Canada, No. 217, vol. II (1917).
[2] Hitchcock, C. H.: Second Ann. Rept. Nat. Hist. and Geol. of the State of Maine, 1863, p. 418.
[3] Ells, R. W.: Geol. Surv., Canada, Rept. of Prog. 1874-75, pp. 97-104.

to close folding. The ore is in beds or lens-like bodies that conform to the structure of the enclosing slates. As seen in some of the old workings it may occur in pitching anticlines or on the steeply dipping limbs of folds, depending upon the local structure.

Lack of exposures renders it difficult to ascertain the width or thickness of the general ferruginous zone, but the following observations in this connexion may be pertinent. Near Jacksonville, an examination of the old workings and adjacent exposures of red slate indicate a width of about 200 feet. About one mile northwest of Gordonville, alternations of red and green slate are exposed over a width of about 700 feet; no iron-bearing material is visible here. About 1¼ miles west of Glassville on the Glassville-Bristol road, a similar zone of red and green slate is exposed over a width of about 300 feet. At this locality a 2-foot bed of ore occurs. In the village of Glassville, behind the pavilion, is a 4-foot zone which extends about 80 feet along the strike.

Character of the "Ore." The so-called ore is a manganiferous hematite; it is compact, dark reddish to almost black, and disposed in beds from 1 inch to about 10 feet in thickness. The following are partial analyses of six specimens of the ore prepared by the Division of Chemistry, Mines Branch, Department of Mines.

Sample No.	Insol.	Fe	Mn	S	P
	%	%	%	%	%
29–6–35	25·79	20·08	15·0	0·047	0·83
24A–6–35	6·99	34·04	14·35	0·038	1·13
29–8–35	21·57	23·09	14·40	0·027	0·82
27–6–35	13·77	30·07	13·0	0·038	1·37
28A–6–35	10·65	29·43	14·2	0·038	1·37
28A–8–35	47·04	5·55	10·48	0·41	0·093

An inspection of the above table shows a remarkably high percentage of manganese. On a basis of both the manganese and iron content the Woodstock ore resembles and compares closely with the manganiferous iron ores of the Cuyuna district of Minnesota.

Thin sections show the most abundant mineral to be very finely divided hematite which probably occurs in a micro-crystalline form. It is opaque and can be viewed in its natural brownish red colour in reflected light. Unfortunately the sections at hand apparently represent portions of the ore containing the maximum of iron-bearing mineral, since little else but hematite seems to occur. In a few cases, however, small quantities of carbonate are present, and varying quantities of fine, detrital quartz may also be observed.

Origin. The combined results of field observations and microscopic study have led to the conclusion that the material is a bedded sedimentary deposit, the result of chemical precipitation accompanying volcanic extrusion. The deposit is an integral part of a sedimentary series of Silurian slates. Volcanic rocks are not exposed in actual association with the ferruginous zone, but do occur in boulders in the drift adjacent to the deposit and in the same general series now regarded as of Silurian age in other parts of the area within a radius of 10 miles.

Economic Possibilities. Historical records indicate that a deposit of iron ore near Woodstock yielded about 70,000 tons between the years 1848 and 1884 and so far as known the material was suitable for industrial use.

In the exposures now visible there is no material of commercial quality; there is, however, a highly ferruginous rock, iron formation, that is lithologically similar to iron formations that, in Minnesota and elsewhere, contain concentrations of iron ore.

It is possible that material of commercial quality exists beneath and in continuity with the old excavations near Woodstock, but if so the volume is probably insufficient to be of commercial value, since in modern practice large tonnages of uniform quality are required.

It is possible that the iron formation continues as a stratigraphic unit in the drift-covered area between the most widely separated localities where the iron has been observed, viz., 24 miles. The beds are folded; at places they undoubtedly come close to the surface and elsewhere dip beneath younger concealing rocks. Whether in the inferred extensions of this iron formation the beds thicken and contain concentrations of iron ore quality is a matter for conjecture.

The lack of magnetite in the material as found discourages an attempt to explore the concealed iron formation by magnetic surveys and no other geophysical method is known to be suitable for iron ore exploration in this district. A systematic exploration by diamond drilling would undoubtedly reveal the conditions, but the considerable cost and possibility of failure to find ore have probably been responsible for the fact that no such exploration has been made.

LIMESTONE

General Statement. During the course of this report, reference has been made to at least two horizons of calcareous beds that are sufficiently high in calcium to render the rock suitable for agricultural and pulp mill purposes. One of these horizons is associated with the pre-Silurian argillites and slates and is exposed near Waterville settlement, York county; the other is connected with the Silurian strata in the vicinity of Carlisle and Windsor in Becaguimec region.

Waterville Settlement. About 1½ miles north of Waterville settlement on the road to Temperance Vale a limestone quarry is being operated by Mr. C. W. McQuarrie of Hartland. The rock is crystalline, light grey to bluish, and disposed in beds about 2 feet thick. The following is an analysis of this rock prepared by the Canadian Pacific Railway Development Branch.[1]

	Per cent
Silica	0·68
Alumina	0·27
Iron oxide	0·25
Calcium carbonate	98·27
Magnesium oxide	0·15
Magnesium carbonate	....
Sulphur dioxide	Trace

Since August 1934 about 400 tons have been pulverized; the majority of this has been absorbed by York and Carleton counties, but at least one carload has been shipped to Houlton, Maine.

[1] 73d Ann. Rept., Dept. of Lands and Mines of the Province of New Brunswick, 1933, p. 49.

Becaguimec Region. In this region calcareous beds occur at the following localities: (1) near Henderson corners; (2) near the head of Limestone brook; (3) on the right side of the North Becaguimec about one mile above the bridge at Carlisle.

At locality (1) above, lime was first burned in 1880 and from that time until 1885 the annual production averaged 1,000 bushels.[1] The quarry at this locality has long since been abandoned.

There is an opening at locality (3) above mentioned. This is situated some 1,200 feet from the river, and at an elevation of about 100 feet above the water-level. The opening is at present about 20 feet by 10 feet by 8 feet deep. The rock is an evenly bedded, dark bluish black limestone in beds from 2 inches to 1 foot or more in thickness; these beds strike about north 80 degrees east and dip 60 degrees north. In 1934 this quarry was worked by Mr. C. McQuarrie of Hartland. When visited by the writer the working was abandoned, but it is understood that reopening of operations is contemplated.

At locality (2) above, a quarry is at present being opened. This is located on (C. Connell) lot 30, parish of Brighton, Carleton county. The locality was staked by Mr. R. S. Welsh of Woodstock in 1935. The rock is a finely crystalline, dark grey to almost black limestone. The attitude is somewhat irregular, but the general strike and dip are about north 40 degrees east and 65 degrees northwest, respectively. No rock has been taken out to date, but actual operations are contemplated for early in 1936.

Economic Possibilities. Little of a positive nature can be said relative to the economic possibilities of limestone in the region investigated. The chief use of the limestone is as a re-conditioner for the soil. It would appear that a too constant application of phosphatic fertilizer tends to sour the soil, whereas the application of from 1½ to 2 tons of pulverized lime an acre has a very beneficial effect. So far as can be learned, Carleton and York counties constitute the chief market, although the state of Maine uses considerable of the product. Just how much can be absorbed locally is not known, but a geological examination would seem to indicate that the amount that can be supplied is far greater than any probable immediate demand.

[1] Bailey, L. W.: Geol. and Nat. Hist. Surv., Canada, 1885, pt. G, p. 30.