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DEPARTMENT OF MINES AND RESOURCES
HON. T. A. CRERAR, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES AND GEOLOGY BRANCH
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BUREAU OF GEOLOGY AND TOPOGRAPHY
F. C. C. LYNCH, CHIEF

GEOLOGICAL SURVEY

MEMOIR 216

GEOLOGY OF SAINT JOHN REGION, NEW BRUNSWICK

BY

F. J. Alcock

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Geology of Saint John Region, New Brunswick

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Perhaps no other area of similar size in Canada has presented so many geological problems as has that which includes and immediately surrounds the city of St. John, New Brunswick. For nearly 100 years geologists have been endeavouring to elucidate the history and structure of this region. On many occasions during this time, differences of opinion concerning certain groups of rocks have arisen amongst workers in the area. Some of the problems are now definitely settled; certain others, however, will probably still be the source of controversy. The information concerning the region is scattered through many reports and papers. The object of the present volume is to summarize the old information and, in addition, to present the conclusions resulting from recent field work carried out in connection with the geological mapping of the Loch Lomond and Cape Spencer map-areas immediately to the east of St. John.

PREVIOUS WORK

The first worker in the field was Abraham Gesner who was appointed provincial geologist of New Brunswick in 1838, and who published five annual reports, 1839 to 1843, describing his field investigations. Although Gesner's training was in medicine he was keenly interested in all branches of science. He was the founder of the Natural History Museum of St. John and after his retirement as provincial geologist he discovered and patented the illuminating oil, kerosene, and established at Williamsburg, New York, the first factory for its production. His second and third reports contain the first important references to the geology of the area.

In 1849 James Robb, the first professor of chemistry and natural history in King's College, Fredericton, contributed a résumé of what was known about the geology of New Brunswick to Professor Johnston, who was engaged by the provincial government during that year to report on the soils of the province. The report was accompanied by a geological map compiled from the reports of Gesner, Sir Charles Lyell's "Travels in North America," and his own personal observations and inquiries. For the most part the map represents mineralogical characters only and not geological groups, different sandstones, for example, of more than one age being shown in a single colour.

In his first edition of "Acadian Geology," 1855, Sir William Dawson makes brief reference to the geology of New Brunswick. Later editions,

1868, 1878, and 1891, deal more generously with the province. Dawson's name is chiefly associated in New Brunswick geology with the problem of the age of certain plant-bearing beds at St. John. In May 1861 he published a description of some fossil plants that had been collected by Messrs. G. F. Matthew and C. F. Hartt of that city. In the summer of that year he visited St. John and in company with these two men explored the localities and examined the large collections that had been made by them since the publication of his previous paper. In subsequent years he published numerous reports and papers dealing with the flora of these beds, and throughout maintained that their age was Devonian, correlating them with the Perry sandstones and conglomerates of Maine and the Gaspe sandstone of Quebec.

Between the years 1863 and 1904 Dr. L. W. Bailey, who succeeded Robb in the chair of chemistry and natural history at the University of New Brunswick, carried out extensive geological explorations and investigations in the province. Associated with him in much of the work was George F. Matthew, who as early as 1860 had become interested in the rocks of the St. John region, and whose name is particularly linked with the region on account of his studies of the rocks of the Cambrian group. In 1864 Bailey, assisted by Matthew and C. F. Hartt, investigated the rocks of southern New Brunswick, including those of the St. John area, for the provincial government. In 1868 Bailey and Matthew began work for the Geological Survey in the same field, and their preliminary report on three seasons' field work appeared in the Report of Progress for 1870-71. A later report by Bailey, in the Report of Progress of 1871-72, describes the rocks of the St. John and Loch Lomond area.

Bailey and Matthew were assisted in some of their investigations by R. W. Ells, who later carried out many explorations of his own. In 1877 and 1878, and later in 1906 and 1907, he studied the rocks of parts of the area under discussion. Between the years 1887 and 1891 Robert Chalmers mapped the superficial deposits of southern New Brunswick, including the St. John area.

Bailey, Matthew, and Ells all agreed with Dawson in placing the plant-bearing beds of St. John in the Devonian. Matthew, in his later work, made them still older, assigning them to the Upper Silurian. Certain authorities, to whom plant specimens and other associated fossils from these beds were submitted, regarded them, however, as Carboniferous. In order to settle this problem of age, the services of Marie C. Stopes were secured by the Geological Survey, in 1911. She made collections of her own and had access to all the available material that had previously been collected. Her conclusions that the beds are of Pennsylvanian age were published in 1914, in Memoir 41. Matthew, however, still remained unconvinced. Only a couple of years prior to his death in 1923, at the age of 86, he traversed nearly the whole of the Bay of Fundy coast from St. John westward gathering information about the disputed beds, and at the end had a paper nearly ready for publication maintaining his views of their Silurian age.

In 1912 G. A. Young mapped the rocks of St. John city and vicinity in preparation for the proposed Quebec and Maritime Provinces excursion of the Twelfth International Geological Congress, which took place the following year.

RECENT WORK

In 1913 A. O. Hayes commenced the geological mapping of an area surrounding St. John city for the Geological Survey and continued field work during the two succeeding summers. In 1914 and 1915 one of his assistants, Mr. C. L. Cummings, investigated the igneous rocks of the region, including the gneisses, granite and basic plutonic intrusives, dyke rocks, and volcanic flows, as well as certain pyroclastic sediments. This investigation was used as part of the requirements for the degree of doctor of philosophy at Princeton University. Another assistant, Mr. C. W. Robinson, in 1915 mapped the superficial deposits of the area.

In the spring of 1920 Hayes resigned from the Geological Survey. Later, in 1925 and 1926, he was employed during the summer months to complete his investigations in the St. John region. To get more information regarding certain problems, particularly the relations of the Carboniferous formations, his field was extended to include that of the Loch Lomond and Cape Spencer sheets. In connection with this work, B. F. Howell undertook the study of the Cambrian succession and faunas. Howell had begun this work independently in the summer of 1924 and completed his field studies in 1926.

In 1932 the writer was instructed to complete the geological mapping of the Loch Lomond and Cape Spencer sheets. He was assisted in the field by E. B. Gillanders and J. S. Peters. In 1936 further work in connection with certain problems was carried out.

CHAPTER II

GENERAL CHARACTER OF THE REGION

LOCATION AND AREA

The area described in the present report includes that of the Loch Lomond map-area, which lies between latitudes 45° 15′ and 45° 30′ and longitudes 65° 30′ and 66° 00′, the Cape Spencer map-area to the south, the greater part of which lies within the Bay of Fundy, and a special St. John map-area, which includes the region immediately surrounding the city of St. John and which overlaps on the two former map-areas. The area represented by the Loch Lomond sheet is about 415 square miles; the land portion of the Cape Spencer map-area occupies roughly 23 square miles; and the St. John map-area totals some 210 square miles, of which the larger part, consisting of some 140 square miles, lies beyond the limits of the other two sheets. The northwestern third of the whole area lies in Kings County and the remaining two-thirds is in St. John County.

ROCK STRUCTURE AND TOPOGRAPHY

The region is a part of the southern highlands of New Brunswick, which run in a northeasterly direction parallel to the Bay of Fundy. The structural trends of the rocks are northeast and these trends are reflected in the topography. In the area under discussion there are two principal, structural, axial belts, both composed of Precambrian rocks. Of these, the Bloomsbury in the southeast occupies the larger area and continues northeast beyond Loch Lomond map-area; the other, the Damascus ridge, lies wholly within the Loch Lomond area.

The Bloomsbury axial belt is a rolling upland country dissected by valleys, between which ridges and hills locally rise above the general level. The surface as a whole slopes to the southwest. Its greatest elevation in the area under discussion is Porcupine Mountain, about 1,150 feet high, in the extreme northeastern corner of Loch Lomond map-area. This upland country is crossed by several highways. Along the main highway from St. Martins to St. John the highest elevation is about 570 feet. On the road from Loch Lomond to West Bay the average elevation is around 300 feet, although Bloomsbury or Ennis mountain near this road rises as a prominent ridge to a height of 630 feet, and Bear mountain, a mile to the northeast, is a prominent hill over 700 feet high. This crystalline belt of rocks is bordered on the south and west by Carboniferous rocks which in the main have a lower relief; in places, however, the overlapping Carboniferous sediments lie in ridges above the level of adjacent Precambrian volcanics. To the northwest the Bloomsbury axial belt is separated from the Damascus ridge by an area underlain by Cambrian sediments and partly occupied by a group of lakes, of which Loch Lomond

is the largest. The Damascus ridge rises abruptly from the Loch Lomond depression. Ben Lomond, the highest summit, has an elevation of about 730 feet. To the northwest the Precambrian volcanics of the Damascus axial belt are overlapped by Cambrian and Carboniferous rocks.

Between Hammond and Kennebecasis Valleys there is a subordinate axial belt of Precambrian sediments, granite intrusives, and Carboniferous conglomerates, and northwest of the Kennebecasis depression, in the extreme northwestern corner of the area, rises another upland region composed of Precambrian volcanics.

The country underlain by Carboniferous rocks, which swing around the southwestern end of the Bloomsbury axial belt of Precambrian volcanic rock, has a gently rolling surface with an average elevation of about 300 feet. Seaward it slopes to coastal cliffs that range up to 150 feet high. In Mispek district there is an abrupt rise from the coast to a hilly country that has local areas over 450 feet high. Viewed from a summit the surface presents broad areas of low relief, with a few hills and ridges rising slightly above the general level. Lakes, muskeg, rocky barrens, and wooded patches alternate with one another, lending a certain amount of variety to a rather monotonous surface.

The Carboniferous rocks on either side of Hammond River form ridges trending northeast. They have rounded, gently rolling summits, though their side slopes are commonly steep.

DRAINAGE

The region except for a small area along the western and northwestern margins lies between the Bay of Fundy and Kennebecasis Valley. The latter depression has been eroded along a fault-line where Carboniferous conglomerates and sandstones have been downfaulted against Precambrian volcanics.

The most important stream in the northern part of the area is the Hammond, whose course throughout most of its length was likewise controlled by geological structure. Near Upham it parallels the strike of the Carboniferous strata, whence it swings around the Damascus ridge of ancient volcanics and intrusives, and below, from Titusville to French Village, follows a fault-line valley. At two places, one between Upham and Titusville and the other between French Village and the Kennebecasis Valley, it cuts across the trend of the formations.

The depression underlain by Cambrian rocks between the Damascus and Bloomsbury ridges contains a group of lakes which drain southward by way of Mispek Valley. The lakes owe their origin to damming by glacial gravels. Loch Lomond, the largest, has an elevation of 313 feet, and Mispek River, which has a length below it of only 10 miles, is swift and near its outlet is marked by rapids and falls. Little River, a stream draining the eastern part of the same Cambrian depression, shows a striking gorge with falls and cascades at Silver Falls.

The East Branch of Black River rises in the Bloomsbury upland and flows southwestward along it; the main stream also rises in this belt, but flows into the Cambrian basin at Garnet before turning to strike across the Precambrian rocks. Emerson Creek follows a fault-contact between Pennsylvanian sandstones and older, altered, Carboniferous rocks. The

headwaters of Gardner Creek rise in the Bloomsbury highlands; the stream follows for part of its course a contact between Pennsylvanian sandstones and underlying Precambrian volcanics before cutting across the former to reach the coast. Tynemouth, Shanklin, Mosher, and Irish Rivers rise in the upland of the Precambrian belt and flow southward, crossing the younger bordering sediments before finding their outlet in the bay. All these streams have cut deep valleys, are swift, and show numerous outcrops of bedrock. Other smaller brooks rise in the Carboniferous belt and on reaching the coast tumble over the bordering cliffs in falls or successive cascades.

St. John River, the largest stream of the province, enters the Bay of Fundy at St. John Harbour, and its lower part is shown on the St. John sheet. This lower part exhibits some interesting features, being made up of a number of reaches, some of which trend southeast whereas others run northeast. At one place, at Suspension Bridge, the river occupies a narrow, rocky gorge, and 2 miles west of the city broadens to a large lake expansion, Kennebecasis Bay, into the northeast end of which Kennebecasis River flows. The lake has a depth in places of 200 feet below sea-level. It has evidently been formed by the impounding of the waters of St. John and Kennebecasis Rivers by dams composed of glacial debris. It is possible that the original course of the river was by way of South Bay and Manawoganish Cove. For a time the overflow of the lake after damming may have reached the sea by a number of channels; but eventually the one over the low, rocky ridge at Suspension Falls became the established one.

THE COAST

Throughout most of its length the coast is bold and rocky, with long stretches of nearly vertical cliffs. At high tide there are sections, miles long, where it is quite impossible to pass, and even at low tide there are places where one cannot proceed far without a boat. Quaco Bay and the mouths of some streams, such as Emerson and Tynemouth, are marked by beaches; but other streams, such as Black River, find their way through rocky gorges which extend right to tide water. Where the coast cuts across the strike of the strata as, for example, from Cape Spencer westward, the coast-line is irregular; where it follows the structure, as northeastward from Cape Spencer past Beveridge Cove and West Beach, the outline is straight and regular. A few sea caves and sea stacks occur as evidence of the erosive power of the waves and tides. Examples of the former are to be seen at Macs Head, St. Martins, and of the latter at Beveridge Cove, Red Head, Rogers Head, Quaco, and other places.

The country along the coast is locally terraced. One of the localities where such terraces may best be seen is at Black River settlement between the mouth of Emerson Brook and Beveridge Cove. Two well-developed planes occur at elevations of about 60 feet and 150 feet above high water, and other levels up to 220 feet are represented locally. The terraces are evidently of marine origin. In places they bevel off bedrock; in others they are developed on glacial deposits. It is probable that they were developed in pre-glacial times and that later during the emergence which followed the glacial submergence there was a recutting by wave action on the glacial cover.

POPULATION AND INDUSTRIES

The region includes the largest and most important city in the province, St. John, which has a population of 47,514 (1931). Its early history began in 1635 when Charles de la Tour established a trading post that he called Fort St. Jean. It remained under French rule until 1758 when it passed to the British. In 1783 a body of United Empire Loyalists landed and established a city which 2 years later was incorporated with Carleton by royal charter as the city of St. John. The city is now one of the main winter ports of Canada. The harbour is sheltered, deep, and free from ice, and possesses a dry-dock big enough to accommodate the largest vessels. St. John river enters the harbour by a narrow gorge in which there is a reversing falls, whose direction of flow depends on whether the tide is high or low. At mid-tide small vessels can pass through into Kennebecasis Bay.

The principal industries of the surrounding region are agriculture, lumbering, and fishing. Only a small part of the area is under cultivation. The best soils are in the valleys, such as that of Hammond River, and on certain areas underlain by Carboniferous rocks. Over wide belts the soils overlie glacial gravels, and as a result are not rich. On the zones of crystalline rocks the soils are meagre. Many sections, even in the Carboniferous belt, which were once cleared and cultivated are now abandoned and are growing up again into forest, as for example, along the old Black River road past Beaver and Balls Lakes and at West Beach. In such sections the soils are much too thin for continuous agriculture.

Lumbering for timber and pulp has always been and still is an important industry. At one time ship building was a major activity. St. John, Black River, Tynemouth Creek, and St. Martins were all once noted for their wooden vessels. During the Great War there was a slight revival of the industry.

Fishing and lobster trapping are other important phases of activity in coastal districts, and limestone quarrying for road material, ballast, and fertilizer is of importance near St. John.

CHAPTER III

GENERAL GEOLOGY

The consolidated rocks of the region range in age from probable early Precambrian to Triassic. The oldest, known as the Green Head group, consist of limestone, dolomite, quartzite, argillite, and associated gneisses and schists. They are cut by numerous basic dykes and are extensively invaded by granite and other deep-seated rocks. Over these sediments lies unconformably a late Precambrian group, the Coldbrook, consisting largely of volcanic rocks, including both flows and fragmental types, ranging in composition from acid to basic. With the volcanics are associated some sediments.

Above the volcanics in turn rests the St. John group of sediments, which range in age from Lower Cambrian to early Ordovician, inclusive. The succession commonly begins with a basal conglomerate containing fragments of the older rocks, chiefly volcanics and quartzite.

The next younger sediments are of Carboniferous age. The oldest of these is the Kennebecasis formation, which occurs in the northwestern part of the area and consists of a great thickness of sandstone and conglomerate. It locally carries plant remains of Horton or lower Mississippian age. Above it lies the Upham formation consisting of limestone and gypsum, and these beds are succeeded by another thick conglomeratic formation, known as the Hammond River, also probably of Mississippian age.

In the southeastern part of the area is a group of Carboniferous rocks that are more altered than those mentioned above, and about whose age there has, consequently, been much dispute. They have been mapped at different times as Devonian, as Silurian, and as Carboniferous, and a group of volcanic rocks that overlies them has even been called Precambrian. Plant remains definitely date the beds as Carboniferous, though whether they are Mississippian or early Pennsylvanian is not as certainly known. One specimen of *Calamites* collected near the base of the group on Black River suggests a Pennsylvanian age. The rocks consist of purplish and grey conglomerate and sandstone of the Balls Lake formation and an overlying West Beach formation consisting of sediments, volcanic flows, and tuffs, intruded by granitic rocks. The rocks are squeezed and altered and are nearly everywhere cut by quartz veins and masses, some of which reach a large size.

The youngest Carboniferous strata make up the Lancaster formation, and are definitely Pennsylvanian in age. They comprise thick deposits of clastic sediments that locally carry many plant remains. The Fern Ledges at St. John and the belt of rocks extending from Emerson Creek to St. Martins belong to this formation.

During the Triassic coarse, red, clastic sediments were deposited in several localities along the coast.

The igneous rocks of the region include the Precambrian and Carboniferous volcanics and dykes to which reference has been made, and also

plutonic intrusives. The latter are apparently of more than one age. The Green Head rocks are much more extensively invaded than any of the later strata, and it would appear as if there must have been a period of intrusion at the close of the Archæan. The late Precambrian volcanic rocks are, however, cut by granite. These intrusions may be largely Middle Devonian in age because great plutonic activity took place at that time throughout the central part of New Brunswick. The youngest granite occurs as sill-like masses in the West Beach formation, and may be Mississippian or Pennsylvanian in age.

The unconsolidated rocks of the region consist of glacial gravels deposited as ground moraine and outwash material, local patches of post-glacial clay, and river alluvium.

Table of Formations

Cenozoic	Quaternary	Recent	Alluvium Lake and marine clays
		Pleistocene	Stratified gravels Glacial drift
Mesozoic	Triassic		Quaco formation
Palæozoic	Pennsylvanian	Little River series	Lancaster formation
	Pennsylvanian and (or) Mississippian	Mispek series	West Beach formation Balls Lake formation
			Hammond River formation
	Mississippian	Windsor series	Upham formation
		Horton series	Kennebecasis formation
	Devonian		Intrusives
	Ordovician	St. John group	Suspension Bridge formation Navy Island formation Narrows formation
	Cambrian		Black Shale Brook formation Agnostus Cove formation Hastings Cove formation Porter Road formation Fossil Brook formation Handford Brook formation Glen Falls formation Ratcliffe Brook formation
Proterozoic		Coldbrook group	Volcanic rocks and sediments
			Plutonic intrusives
Archæan		Green Head group	Sediments

GREEN HEAD GROUP

GENERAL

The Green Head group[1] takes its name from Green Head, in the peninsula immediately west of St. John city, where the rocks are characteristically developed. The group is the sedimentary part of the Portland group of earlier writers, which included both sediments and intrusive rocks.

Though Gesner noted the limestones of St. John, the first definite statement of their age is given by Dawson. In his description (1862) of the rocks of the Devonian system, part of which he thought might be Upper Silurian, he cited the following as his two oldest divisions:

7. White and grey crystalline limestone, with bands of shale and beds of graphite.....600 feet or more.
8. Gneissose and other metamorphic beds, with bands of quartz-rock and slate.
   Thickness unknown.

Matthew (1863) recast Dawson's divisions and substituted local names, calling Nos. 7 and 8 the Portland series after the parish in which it is largely developed. Bailey and Matthew (1865) renamed it the Portland group, placing it in the Azoic or Precambrian.

Bailey and Matthew (1872) divided what they called their Laurentian system, by which they meant rocks of Archæan age, into two series, a lower consisting of gneisses, mica schists, syenite, diorite, etc., and an upper made up of three divisions. Of the latter, the lowest division was stated to consist of limestones and gneisses, the middle of quartzites, quartzose gneiss, and mica schist, and the upper of argillite, limestones, and graphitic shales. The suggested thicknesses for these three divisions were given, respectively, as 260, 450, and 740 feet (Matthew, 1890d).

LITHOLOGY

The strata of the Green Head group are highly folded, and are intruded by both plutonic and dyke rocks. The lack of good horizon markers, and the amount of deformation and metamorphism, render it difficult to work out the details of succession, thickness, and structure. The group is made up largely of two main types of sediments, carbonate rocks and quartzites.

A belt of limestone and dolomite extends in a northeast direction from the reversing falls through St. John city to near Coldbrook. A wider belt, consisting of carbonate rocks with other associated sediments and intrusives, runs from Green Head Peninsula northeastwardly past Ashburn Lake, Drury Cove, and Torryburn. Still farther northeast a broad belt of similar rocks cut by granite masses lies west of French Village.

The rocks are everywhere more or less metamorphosed to crystalline types. In most places the bedding planes are well marked by colour banding. Dips are steep and though there is a prevailing northeast strike there is much local irregularity. The rocks are in places veined, both parallel and normal to the bedding, by white calcite stringers. They are also cut by numerous small basic dykes.

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[1] Term introduced by Hayes. *See* Hayes and Howell, 1937, p. 13.

The limestone and dolomite have associated with them banded argillite and quartzite, and locally mica schist and gneiss. The carbonate bands vary in width from a few feet to thousands of feet. The wider bands consist of several varieties, including dolomite, dolomitic limestone, and high-calcium limestone. As a rule the high-calcium limestone occurs as lenses or bands associated with dolomitic varieties. The greatest width of high-calcium rock worked in any of the quarries is about 200 feet and that of dolomite 80 feet.

The limestone is commonly bluish or grey, though in some places it is white. Where cut by the basic dykes the bluish limestone is commonly bleached white in narrow zones along the dyke borders. The dolomite is commonly dense and in most cases breaks with a smoother surface than does the limestone, whose rougher surface is due to the presence of calcite crystals. On Green Head Peninsula much of the dolomite is white, though in places it is bluish. In other quarries the bluish variety predominates. Locally the carbonate rocks carry a little pyrite and in places some serpentine.

In places the carbonate rock shows on its weathered surface some peculiar concretionary-like markings which have been regarded as having had an organic origin. They are numerous on the northwest point of Green Head and on the east side of St. John River, east of Green Head. They have been described as *Archaeozoon acadiense,* and may possibly represent algal growths; (Matthew, 1890c); (Dawson, 1897).

Quartzite occurs associated with the carbonate rocks, and also in thick masses. One band runs along the east side of Marble Cove north of the reversing falls, and another belt crosses the Sandy Point road southwest of Mayflower Lake. The rock is grey, varying in shades from light to dark. It is commonly well bedded, in places showing pronounced colour banding. Associated with it locally are siliceous slates and argillites. In texture the rock varies from dense to coarse-grained types.

Matthew (1890d) describes what he believed to be sponge spicules from certain smooth surfaces in layers of quartzite at Drury Cove.

Dark, banded, siliceous argillites and graphitic slates are associated with the carbonate and quartzitic rocks. Mica schists and gneisses of sedimentary origin also occur, representing metamorphosed phases. Such rocks can be readily studied in a railroad cut at Brookville Station where schists and gneisses containing brown mica are interbedded with, and grade into, carbonate rocks.

Along the south side of Frying Pan Lake a band of quartzite in limestone is intruded by granite-gneiss. Near the contact the quartzite grades into a fine-grained, biotite gneiss. In thin section the gneiss is seen to consist of quartz, feldspar, and biotite; quartz is more abundant than the feldspar. The latter mineral is largely altered to sericitic products. The biotite consists of narrow shreds arranged parallel to the foliation.

On the western side of Green Head Peninsula, about half-way between Sand Point and Green Head, is a band of conglomerate, about 100 feet wide, which was considered in early reports to be part of the early Precambrian series (Bailey and Matthew, 1872, page 38). The writer believes, however, that this rock is much younger than the Green Head

group and owes its preservation to the fact that it was downfaulted into the rocks of that group.

In the conglomerate there are some layers and lenses of grey, quartzitic sandstone. The boulders of the conglomerate consist of limestone, dolomite, and quartzite, unquestionably derived from Green Head rocks, as some of the carbonate boulders contain the peculiar markings that have been called *Archaeozoon* and which are similar to those in the nearby Green Head limestones. The contacts of the conglomerate with the adjacent Green Head sediments are fault contacts. The one on the south side of the conglomerate band is particularly well shown, striking about east and west and pitching about 85 degrees to the north. The Green Head sediments strike north 65 degrees east and dip 80 degrees southeast, whereas the beds of the conglomerate strike east and west and dip 18 degrees north. It is inferred, therefore, that the conglomerate was deposited unconformably upon the Green Head sediments and was later downfaulted into them. The deposition may have taken place in either late Precambrian or in Palæozoic time.

AGE

The age of the Green Head group is regarded as Archæan because, as will be mentioned later, it rests unconformably below volcanic rocks of Proterozoic age.

COLDBROOK GROUP

GENERAL

The term Coldbrook group was introduced by Matthew (1863) to include volcanic rocks and associated sediments lying above his Portland group and below his St. John group (Cambrian and Ordovician). Bailey (1865) retained the term and classed the group as Azoic (Precambrian).

On Kingston Peninsula, between Long Reach and Kennebecasis Bay, is a group of volcanic rocks to which Matthew gave the name Kingston series (1879a). Part of this peninsula lies in the northwest corner of St. John map-area. From the fact that farther west in New Brunswick and Maine similar volcanic rocks occur interbedded with fossiliferous Silurian sediments, and also because he believed that on the northwestern side of the peninsula he had found Silurian fossils associated with volcanic rocks, Matthew regarded at least part of this series as of Silurian age. Later workers have failed to find any evidence to support this conclusion. Ells, and later Hayes and Cummings, regarded all the pre-Carboniferous volcanic rocks of the region as Precambrian. The Kingston volcanics were considered, however, to be younger than the Coldbrook. Hayes used the term St. John volcanics to include both the Coldbrook and the Kingston, and in addition certain volcanic rocks, exposed on Lepreau and New Rivers and at other places, which were believed to be still younger than the Kingston.

In the present report the term Coldbrook is used as equivalent to what Hayes refers to as the St. John volcanics. The rocks on the part of Kingston Peninsula that lies in St. John map-area resemble many of the volcanics of the Loch Lomond area, which are mapped as Coldbrook. A term is needed to include all these volcanics and since the word St. John

is applied to the group of Cambrian and Ordovician sediments it was felt that some other name would be preferable. The term Coldbrook is, therefore, extended to include all the Precambrian volcanics.

The Precambrian age of the typical Coldbrook rocks is quite evident. At a number of places such as St. John city, McCoys Corners, Handford Brook, and Ratcliffe Brook, Lower Cambrian beds overlie these volcanic rocks unconformably and the conglomerate at the base of the St. John group contains numerous waterworn pebbles of the volcanic rocks. The group is, however, much younger than the early Precambrian Green Head group. The strata of the latter are much more deformed and at one place in Rockwood Park, near the Mount Pleasant Avenue entrance, a lava belonging to the younger group can be seen resting on the eroded, upturned edges of beds of Green Head limestone.

The group covers more area than any other formation in Loch Lomond map-area. The largest belt runs northeast from Balls Lake and includes Bloomsbury ridge and the high country north of St. Martins. This zone is a southwestern part of the Caledonia ridge or massive which parallels the Bay of Fundy in St. John, Kings, and Albert Counties. The rocks of this belt consist of volcanic flows, tuffs, and breccias of both acid and basic composition, with some associated tuffaceous sediments, phyllites, and conglomerates, the whole cut by granite and quartz diorite stock-like masses and by basic dykes. Several such granite masses are shown on the Loch Lomond map, and similar bodies were found by Flaherty cutting volcanics farther east (1934, page 786). Another belt of volcanic rocks forms the Damascus ridge on the northwest side of the Loch Lomond depression. To the northeast near Barnesville it unites with the Bloomsbury belt and to the southwest it wedges out to nothing at St. John city. The belt consists chiefly of volcanic rocks, though in the neighbourhood of Marks Lake it contains a band of conglomeratic sediments. A third belt of volcanic rocks of apparently similar age forms, as already mentioned, the bulk of Kingston Peninsula, and another belt runs in a northeast direction from Rogers Head to Quaco. Hayes gives the name St. Martins to the rocks of this last belt, but correlates it with the Coldbrook.

LITHOLOGY

The Coldbrook volcanics vary from light grey through shades of greenish grey to purplish red or dark green to black. In most places the rocks are dense and massive and appear fresh in hand specimen. Locally, however, they are sheared and in places schistose. Some, particularly the darker greenstone varieties, are amygdaloidal, and in places such types show the amygdules squeezed and flattened. On surfaces polished by glaciation or water action flow structure can locally be observed. Many of the rocks are porphyritic, though the phenocrysts are small and rarely reach a length of more than a couple of millimetres.

Associated with the flow rocks are fragmental varieties of similar composition. Some of these are breccias consisting of fairly coarse, angular fragments. Others are fine-grained tuffs and ash rocks. Many of the latter have a distinctive purplish or purplish red colour, due apparently to the presence of hematite, and many are schistose.

The acid phases in thin section show phenocrysts of orthoclase, albite, and quartz in a dense matrix, the albite in some sections being more abundant than the orthoclase. Ferromagnesian minerals are commonly lacking, and a little iron oxide is usually present. Sections of the darker rocks show commonly a mass of secondary minerals, epidote, zoisite, carbonate, and secondary quartz. In some, fresh albite crystals that are apparently secondary are present. Their presence suggests a high soda content for many of the rocks.

Farther east on the Caledonia ridge a group of similar rocks was investigated in detail by Flaherty (1934). He found high-soda, rhyolitic rocks which he called quartz-keratophyres, and more basic greenstone rocks also high in soda which he grouped as spilites. The latter rocks are characterized by the presence of albite, which was probably formed from a soda-lime feldspar during the final stages in the consolidation of the lava.

THICKNESS AND SUCCESSION

The volcanic rocks form a very thick group. In Loch Lomond area no attempt was made to zone them or to work out their structure. In his work in Albert County Flaherty believed he found a conformable succession at least 18,000 feet thick. Cummings, in the area of St. John, and west, estimated the thickness of the Precambrian volcanics at 33,500 feet, a figure reached by summing the estimated thickness of sections at Coldbrook, Kingston, and other places which he regarded as representing different zones.

ASSOCIATED SEDIMENTS

In the region of Marks Lake northwest of Loch Lomond is a belt of conglomeratic sediments associated with the volcanic complex. The belt trends northeast, has a length of about 2½ miles, and a greatest width of about one-quarter mile, and wedges out to nothing at either end. The beds dip southeast at angles varying from 45 degrees to 80 degrees. They are both underlain and overlain by the dark volcanic rocks, and the uniformity of direction of dip right across the belt suggests that it is not an infolded band but an interbedded one. A further proof of this relationship is the fact that just north of the middle part of Marks Lake, thin bands of volcanic material, either sills or flows, lie between conglomerate beds. One such band, 10 inches thick, lying between layers of conglomerate is amygdaloidal. Still another interesting relationship is to be found near the northeast end of the belt, on its southern flank. Here the conglomerate is cut by a dark green diabasic rock similar to the overlying volcanic rocks. The dyke is 3½ feet wide and is locally amygdaloidal at its border. At one place it parallels the bedding of the conglomerate and at another it cuts across it.

The conglomerate is characteristically dark in colour on a freshly broken surface. It is well cemented and for the most part breaks across the pebbles instead of around them. The pebbles are extremely well rounded and on a weathered surface stand out prominently. The majority of them are less than an inch in diameter, but there are many between 1 and 2 inches and rare ones are as much as 5 inches across. The commonest variety is white quartz, though quartzite pebbles, white, grey,

or reddish, are also abundant. Some grey biotite gneiss, dark argillitic types, and a few greenstone ones are also present. In a road cut where some blasting had been done, immediately north of the west end of Marks Lake, some well-rounded pebbles of massive red granite were found. This occurrence is of interest as it shows that there were granites of pre-Coldbrook age undergoing erosion at the time the volcanics and their associated sediments were laid down. The finer grained parts of the sedimentary band also locally contain numerous fragments of red feldspar, and in one thin section of the rock some fragments of microcline occur, suggesting a source from a granitic terrain. The rock is cut by quartz veins and stringers some 6 inches wide. Some of the veins cut across pebbles and matrix alike. A point of interest, however, is the fact that some of the pebbles are traversed by quartz veins that stop at the borders of the pebbles, showing they were derived from rock that had been mineralized by quartz prior to formation of the pebbles.

ST. JOHN GROUP

GENERAL

Gesner (1840, page 8) mentions the finding of brachiopods in the slates at St. John. These strata were later grouped by Dawson (1862) as members Nos. 5 and 6 of his Devonian system. Worm burrows, trails of animals, and numerous specimens of *Lingula* were recognized. Matthew (1863) gave the name St. John group to the beds. At that time he saw no evidence that they were unconformable to the formations that lie immediately below and above. In a footnote he states that subsequent to the writing of this paper he and his brother, C. R. Matthew, found on Cold Brook new fossils, including a small orthoceratite and numerous specimens of trilobites belonging to two or three species.

In 1865 more fossils were collected by Bailey, Matthew, and Professor C. F. Hartt. Hartt, reporting on them in 1865, pronounced them to be Primordial, a conclusion that was later affirmed by Billings who regarded them as representing horizons older than the Potsdam of New York. Descriptions of numerous forms prepared from notes by Hartt appeared in the second edition of Dawson's "Acadian Geology" (1868, pages 637-657). The term Acadian group was suggested by Dawson for these beds.

The group was studied by Bailey in 1877, and in his report (1879) and in another by Bailey, Matthew, and Ells (1880) the term Cambrian was used as an alternative to Primordial, Primordial Silurian, or Lower Silurian, terms that up to this time had been employed. From this time and almost until his death in 1923 the great student of these Cambrian rocks was Matthew, who published numerous papers dealing with their succession and faunas. The recent work of Professor B. F. Howell of Princeton University on these beds and on their contained faunas has furnished most of the information presented here.

DISTRIBUTION

The beds of the St. John group underlie several areas of the St. John and Loch Lomond region. The belts in the main trend northeasterly,

paralleling the general strike of the strata. The rocks as exposed today are synclinal or faulted remnants of formations that once covered wider areas and which have been partly removed by erosion and partly concealed by younger strata.

Probably the most important, though not the largest, area is one about 6 miles long and about a mile wide upon which much of the city of St. John is built. It was here that the rocks were first studied and where the best exposures occur, in the form of rock cuts along many of the streets, the railroads, and the highways near the city. At Silver Falls, Little River has cut a canyon in these strata. A few outcrops along the Loch Lomond road suggest that the belt is connected under the drift with the Loch Lomond one. At St. John the rocks form a syncline.

The Loch Lomond belt, about 14 miles long and 2 miles wide, lies to the southeast of Loch Lomond and Second and Third Lakes. To the southeast the strata rest on Precambrian volcanics and to the north they lie with a fault contact against similar rocks. Exposures throughout this belt are few, as much of the region is of low relief. The best outcrops are along the Barnesville road and Ratcliffe Brook.

A third important belt lies along Porter and Germaine Brooks and the lower part of Handford Brook. This belt is some 7 miles long and about 3 miles wide. Like the strata in the Loch Lomond belt, these beds dip off Proterozoic volcanics to the southwest and to the northwest they rest in fault-contact against a complex of igneous rocks. One of the best sections of Cambrian rocks in the entire region occurs in this belt along Handford Brook.

A small area of Cambrian sediments lies south of Hammond River and north of Marks Lake. The exposures consist of white sandstone and quartzite overlain by shales. Another small area occurs at Garnet on the Black River road from Loch Lomond. Other patches occur along Kennebecasis Bay at Sand Point, Hastings Cove, Milkish Head, on Kennebecasis Island, and a fringe on the east side of Long Island, at what are known as Marble Cove and Agnostus Cove.

SUCCESSION

Though the strata are locally well exposed and in a few places fossils are fairly abundant, there are no thick undisturbed sections where the complete succession can be studied and the strata divided into members whose thicknesses and fossil content can be worked out in detail. The succession has, therefore, to be built up from a number of separate areas and the task is rendered more difficult by the fact that beds of different ages in places resemble each other lithologically whereas those of the same age locally differ in character at different places. In addition, beds of the same age may carry fossils at one place and show none at another. A general succession has, however, been worked out, partly through a comparison of the faunas with those of the Cambrian succession in other regions.

Matthew separated the lowest beds of his St. John group under the name Etcheminian group, which he regarded as Palæozoic but older than Cambrian. He placed its thickness as 1,200 feet. The remaining part of

the original St. John group he divided into three divisions. The lowest was called Acadian, its thickness was estimated to be 200 feet, and its age was considered to be Lower Cambrian. The middle division was named Johannian, and its thickness was placed at 750 feet. The upper became the Bretonian, its assigned thickness was 700 feet, and in age it ranged from Upper Cambrian into early Ordovician.

The following table is adapted from Howell, and summarizes the divisions as worked out by him. All the formation names, and in addition the series names, with the exception of those mentioned above as having been introduced by Matthew, are Howell's.

Lower Ordovician (Arenig)		Suspension Bridge formation	*Tetragraptus* zone
Lower Ordovician or Upper Cambrian (Tremadoc)	Bretonian series	Navy Island formation	*Dictyonema flabelliforme* zone
		Narrows formation	*Peltura* zone
			Parabolina zone
Upper Cambrian	Johannian series	Black Shale Brook formation	*Olenus* zone
		Agnostus Cove formation	*Agnostus pisiformis* zone
		Hastings Cove formation	*Paradoxides matthewi* zone
Middle Cambrian	Loch Lomond series	Porter Road formation	*Paradoxides abenacus* zone
		Fossil Brook formation	*Paradoxides eteminicus* zone
	Handfordian series	Handford Brook formation	*Protolenus* and *Beyrichona* zone
Lower Cambrian		Glen Falls formation	
	Etcheminian series	Ratcliffe Brook formation	

DESCRIPTION OF FORMATIONS

Ratcliffe Brook Formation

Howell (Hayes and Howell, 1937, pages 58-63) has given the name Ratcliffe Brook formation to a series of unfossiliferous, mainly red clastic rocks that Matthew called Etcheminian. "The beds of the Ratcliffe Brook formation are mostly dark purplish red, fine-grained, micaceous sandstones . . . so fine-grained and thin bedded that they resemble heavy-bedded, hard shales. Interbedded with the reddish beds at many places are pale greyish green layers and beds of about the same texture as the reddish

ones. There are some beds of coarser, reddish sandstone which is cross-bedded; and at the base is a small basal conglomerate, whose pebbles average about the size of hickory nuts and walnuts." Howell states that the pebbles "are derived principally, if not entirely, from the Precambrian rocks immediately surrounding the Cambrian basins.

"The only thick sections of the Ratcliffe Brook formation that are known to be well exposed . . . are the ones on Handford brook, Ratcliffe brook, Lancaster Street (West St. John), and Catons Island. Thinner sections or parts of thinner sections can, however, be seen at a number of other places. . . . Various beds of the formation crop out along Porter road for some distance west of McCoys Corners, and the basal conglomerate is well exposed along the top of the highest ridge just west of the Corners. The basal conglomerate also crops out along the road northeast of Third Lake . . . and in the Hammond River valley, south of Upperton. The upper part of the formation may be seen at Glen Falls, at Seely Street and in Rockwood Park (Saint John), and just north of a small pond on a wood road that runs east from the Churchland road, southwest of Loch Lomond. . . . A small outcrop of the finer-grained beds was seen on the Old Loch Lomond road, about ¼ mile from its eastern end. Somewhat larger outcrops . . . were found on the eastern side of the valley that runs down to Courtenay Bay, west of the dry dock in East Saint John.

"The total thickness of the formation is different at each place where it can be accurately or approximately determined. The greatest known thickness is found at Handford Brook, where it is about 2,000 feet. The minimum thickness is about 20 feet, in and about Saint John.

"No undoubted fossils, except worm trails, have ever been found in this formation, as far as the writers have been able to determine from observations. . . . The only worm trails seen . . . were found" . . . in one bed of olive-grey, thin-bedded, rather soft shale on Handford Brook.

The strata are considered by Howell to be probably of non-marine origin and possibly to have been deposited under semi-arid climatic conditions. Because the Ratcliffe Brook beds appear to be conformably succeeded by the Glen Falls formation, and this by the fossiliferous Handford Brook formation of Lower Cambrian age, and because Lower Cambrian beds in eastern Massachusetts and in Newfoundland are predominantly purplish, therefore, "until more conclusive evidence is discovered, the Ratcliffe Brook formation must be correlated with some doubt with the Mesonacid-bearing strata of other parts of the North Atlantic basin."

Glen Falls Formation

The basal member of the Glen Falls formation is ordinarily a white sandstone, commonly very coarse grained and sparingly conglomeratic at its base. In places it is well cemented and becomes a white quartzite. Rarely the white rock is absent and the base of the formation is then a dark grey or blackish sandstone. The white sandstone varies markedly in thickness from place to place. On the west side of the cut on Gooderich Street it is 8 feet thick, whereas on the east side it is about 30 feet. Typical exposures of the sandstone occur on Handford Brook, Ratcliffe Brook, along Barnesville road northeast of Third Lake, at Glen Falls and nearby

points in the narrow part of Loch Lomond Valley, in Rockwood Park, on Seely Street in St. John, and at Hastings Cove in Kennebecasis Valley. The dark grey sandstone phase may be seen on Lancaster Street in West St. John.

The white sandstone grades upward into a heavy, black, siliceous rock called, by Howell, the Black sandstone, and the latter grades upward almost imperceptibly into grey sandstone that forms the base of the succeeding Handford Brook formation.

No fossils other than worm trails have been found in the Glen Falls formation. Its conformable position beneath, and gradation into, the overlying formation whose upper part at least is Lower Cambrian gives rise to the reasonable inference that it is likewise of Lower Cambrian age.

Handford Brook Formation

Thick beds of hard, compact, fine-grained, grey sandstone, designated, by Howell, the *Beyrichona* sandstone, lie at the base of this formation. It grades so imperceptibly into overlying *Protolenus*-bearing shale that it could scarcely be mapped as a separate lithological unit. In addition to the type exposures on Handford Brook, beds of this zone may be seen at St. John on Lancaster and Seely Streets, in Rockwood Park, and at Glen Falls. The sandstone which averages around 75 feet in thickness carries a scanty and peculiar fauna, which includes small bivalved crustaceans belonging to the genus *Beyrichona*.

The *Protolenus* shale, which succeeds the *Beyrichona* sandstone, consists of heavily bedded, hard, micaceous, brown-weathering beds, about 10 feet thick. The member is best exposed on Handford Brook where the *Protolenus* fauna was first discovered. It occurs also on the north side of Milkish Peninsula at Marble Cove on Long island, along Lancaster and Seely Strees and in Rockwood Park in St. John, and at Glen Falls.

On the east side of Long Island, in Kennebecasis River, the oldest Cambrian rocks exposed are peculiarly blotched and spotted, grey sandstones, interbedded with grey shales. The blotches are yellowish buff and have resulted presumably from weathering of crystals and masses of pyrite. These beds contain *Ellipsocephalus* and *Protosiphon*, which prove that they belong in the *Protolenus* zone. Similar mottled sandstones outcropping a couple of miles to the southwest of the above locality, on the northern side of Milkish Point Peninsula, underlie sheared and distorted dark grey shale. In the shale and about 10 feet above the sandstone, a lens of limestone carries fragments of a large species of *Paradoxides*. The sandstone must, therefore, lie nearly, or quite, at the top of the *Protolenus* zone.

The *Protolenus* fauna of the upper member of the Handford Brook formation is a typical marine fauna that permits reliable correlations to be made with Lower Cambrian strata present elsewhere in the North Atlantic province, particularly in southeastern Newfoundland and northwestern Europe.

Fossil Brook Formation

This formation is best exposed on Fossil Brook, a tributary of Porter Brook. Its basal member is in places a hard, siliceous, black limestone, about 5 feet thick, designated, by Howell, the Black limestone. The

remaining beds are grey shales. The only locality where the Black limestone is known to occur in place is near the southwestern end of Seely Street in St. John, but loose fragments, common where Porter road crosses Fossil Brook as well as near the headwaters of McDermott Brook, were evidently derived from beds nearby. On Milkish Point Peninsula at Glen Falls, and at Lancaster Street in West St. John, the basal limestone is apparently represented by grey shales with limy layers.

The Black limestone commonly contains many fossils, although mostly fragmentary. Some blocks are packed full of pieces of trilobite tests. Where the limestone is represented by limy shale, fossils are found in both shaly and limy layers, although more abundantly in the latter. The lithological character of the Black limestone and the abrupt entrance of *Paradoxides* suggests a possible stratigraphic hiatus or age of non-deposition between the limestone and the underlying *Protolenus* shale, although no direct evidence of a break was recognized in the poor exposures of the contact beds that are available.

The Black limestone or equivalent beds are overlain by shale, which varies in character from place to place. At Seely Street where the total thickness is about 2 feet and on Lancaster Street the shale is grey and thinly bedded, whereas at Fossil Brook, where it crosses Porter road, loose blocks of thickly bedded, soft, light grey and probably limy shale occurs. Shale of this age is also exposed on the north side of Milkish Point Peninsula about a mile west of Milkish Point. The top member of the formation is an olive-grey shale, slightly darker than the beds below and carrying a characteristic fauna. It is well exposed on Handford Brook, in the banks of Fossil Brook just north of where it crosses Porter Road, along Ratcliffe Brook, on the north end of Caton Island in St. John River, and on Cold Brook at Glen Falls. Formerly an exposure on Seely Street, St. John, furnished numerous fossils to collectors. Its thickness varies from 25 to 35 feet.

The Fossil Brook formation is marked throughout by species of *Paradoxides,* particularly *Paradoxides eteminicus. Paradoxides lamellatus* is confined to the lower shale member, and the beds containing it were differentiated by Matthew as the *Paradoxides lamellatus* zone. Although there is a gradual transition in lithology and fauna from the lower to the upper shale member the upper shales are characterized by the entrance of new species, particularly of *Harttella matthewi,* and may be designated the *Harttella matthewi* zone. It and the succeeding zone at the base of the next formation are the two best Cambrian zones in New Brunswick for gathering fossils.

Dawson's original designation "Acadian" for *Paradoxides*-bearing strata of North America has commonly been used to apply to all rocks containing *Paradoxides,* and is more or less synonymous with Middle Cambrian. The Fossil Brook formation is, therefore, an early formation of Middle Cambrian time, seemingly homotaxial with the *Paradoxides bennetti* zone of Newfoundland and the *Paradoxides groomi* zone of northwestern Europe.

Porter Road Formation

This formation comprises two shale members, each of which is characterized by its contained fauna. The basal member, which is not sharply

divided from the previous formation, consists of dark, rather hard, heavily bedded, grey, fissile shales that are abundantly fossiliferous. It outcrops on Porter road, downhill from where the road crosses Porter Brook, and on Cold Brook, downstream from Glen Falls. Shearing has destroyed the fossils at the latter outcrop. The largest and most characteristic fossil of this member is *Paradoxides abenacus*. The beds have a thickness of about 25 feet.

The upper member is a thinly bedded, gritty, finely fissile black shale. It is exposed downhill from the outcrop of the *Paradoxides abenacus* shale on Porter road, near the foot of the hill. Fossils are common, although not so abundant as in the zone below. The most characteristic member of the fauna is *Goniagnostus confluens*, Matthew's old "*Agnostus nathorsti confluens.*" These beds have a thickness of not less than 25 feet and not greater than 75 feet.

The Porter Road formation is Middle Cambrian and seems to be about the age of the older beds of the *Paradoxides hicksi* zone of Newfoundland.

Hastings Cove Formation

This formation, consisting mainly of thinly bedded, black shales with a few lenses and nodules of dark limestone, is nowhere fully exposed, so that its relations with earlier and later formations are inferred from faunal evidence. The first exposure to be noted is a small one on the southeastern side of the road that parallels the southeastern shore of Loch Lomond, about opposite the narrowest part of the lake. Only a few feet of strata are visible. The beds, however, are quite fossiliferous, the limestone lenses having particularly well preserved specimens. A second, larger exposure is in the western bank of Hammond River, near its headwaters. Here the beds are so marked, twisted, and faulted that the shales have yielded no fossils, and those in the limestone lenses are distorted. A third exposure, along the southeastern shore of Hastings Cove on the eastern side of Kennebecasis River, consists of squeezed, black shales in which are thin layers and lenses of grey limestone that carry a fauna presumably somewhat younger than that found at the other localities. The beds are dragged up against an upfaulted block of Precambrian rocks.

The fauna at the first two localities is characterized by a species of *Paradoxides*, related to *Paradoxides abenacus*, and certain other fossils, notably a new Agnostian trilolite, *Triplagnostus lomondensis*, related to *Agnostus gibbus*. The fauna of the third locality was discovered by Matthew who recognized that it was younger than that of the Porter Road formation. It includes fragments of a large *Paradoxides*, probably the same species as occurs at the other two localities, as well as other trilolites, of which *Goniagnostus nathorsti*, the *Agnostus nathorsti* of Matthew, is the most characteristic.

The continued presence of *Paradoxides* in the Hastings Cove formation indicates a Middle Cambrian age, and the formation is believed to be about the same age as the upper part of the *Paradoxides hicksi* zone of Newfoundland, though it may include beds that are equivalent to lower strata of the *Paradoxides davidis* zone.

Agnostus Cove Formation

This formation consists of black and grey shales and micaceous grey sandstones, with lenses and concretions of buff-weathering limestone. The type exposure of these beds is on the eastern side of Long Island, in the lower part of Kennebecasis River, where the thickness is not less than 200 feet. Similar beds exposed in the main city of St. John, East St. John, and in West St. John probably belong to this formation, though no reliable correlation can be made as they carry no fossils. Some of the shales and sandstone that outcrop on Caton Island, in St. John River, and those on Kennebecasis Island and at Sand Point, on the eastern shore of Kennebecasis River, may also belong to this formation.

Limestone lenses at the type locality carry large numbers of triolites similar to, or conspecific with, *Agnostus pisiformis*, together with other fossils. It is probable, therefore, that the Agnostus Cove formation is of the same Upper Cambrian age as strata that elsewhere in the North Atlantic province belong to the *Agnostus pisiformis* zone. In southeastern Newfoundland and in Scandinavia such strata are younger than those carrying *Paradoxides* and older than those carrying *Olenus*.

Black Shale Brook Formation

This formation is more properly a zone as it is based primarily upon loose pieces of black shale and thin limestone in the bed of Black Shale Brook, near Hardingville, west of Porter Brook. Outcrops of similar shale, though unfossiliferous, occur a short distance upstream and are provisionally included in the formation. The pieces of float carry fossils, amongst which are *Olenus* and a form first known as *Agnostus pisiformis obesus*. Other outcrops of similar shale, all unfossiliferous, may belong to this formation, e.g., those beneath, and immediately upstream from, the covered wooden bridge over Upper Hammond River, some of the black shale comprised in the big syncline at St. John, East St. John, and West St. John, and, finally, some of the shale exposed near the northern end of Caton Island.

The presence of *Olenus* and *Agnostus pisiformis obesus* at Black Shale Brook correlates those beds with Upper Cambrian *Olenus*-bearing strata of Newfoundland and Scandinavia that overlie the *Agnostus pisiformis* zone there.

Narrows Formation

This formation comprises black shales with limestone concretions and interbeds of thin sandstone that are exposed only in the St. John syncline. Most of the outcrops have been covered by buildings and pavements of the main city of St. John. Outcrops may be seen, however, on the eastern side of the Narrows, at the upper end of the harbour below the Reversing Falls, and black shales exposed on the eastern half of Navy Island belong to the upper part of the formation. Fossils are everywhere rare, although Matthew found enough to prove that two well-known northwestern European faunas are represented. These are the *Parabolina* and younger *Peltura* faunas, both assigned by Howell to the post-Olenian Cambrian.

Navy Island Formation

This formation consists mainly of thinly bedded, black shales. The type exposures are on the western half of Navy Island, where the shales carry *Dictyonema flabelliforme.* The formation outcrops also along the western shore of the Narrows, at the inner end of St. John Harbour.

Dictyonema flabelliforme is a Tremadoc fossil, beds which in America and Scandinavia are regarded, on their general faunal character, as Lower Ordovician. In Great Britain, however, the Tremadoc is regarded as Upper Cambrian, owing to the fact that there is an erosional break above it.

Suspension Bridge Formation

Thinly bedded, black, graptolitic shales that make up this formation outcrop on the western shore of the Narrows, at the upper end of St. John Harbour, north of Suspension Bridge. The beds, of which a thickness of some 50 feet is shown, are faulted or thrust against Precambrian rocks just west of the Narrows.

Graptolites, *tetragraptus* and *didymograptus*, present in this formation prove the beds to be of Arenigian or early Ordovician age.

PRE-CARBONIFEROUS IGNEOUS ROCKS

GNEISSIC ROCKS

Gneissic rocks occur in a zone west of St. John, and farther northeast along the same strike another belt runs in a northeast direction from near Coldbrook to Golden Grove. They are intimately associated with sediments of the Green Head group and also with massive plutonic rocks that intrude that group. Some appear to be recrystallized Green Head sediments. Many are evidently primary gneisses of intrusive origin whose banded structure is original, and due to movements during consolidation or to the streaking out of partly digested included material. Others again may be deformed granites. Finally, as for example south of Green Head, there appear to be hybrid types resulting from an intimate interjection of Green Head rocks by material from the plutonic bodies.

Much of the gneiss is a biotite variety. Most of the zone extending from Coldbrook to Golden Grove is made up of this type of rock. Its chief characteristic is its large content of black biotite, much of which has a common orientation giving the rock a foliated appearance. In places also there is an alternation of narrow, dark and light bands in which are concentrated, respectively, dark and light minerals.

One variety of biotite gneiss consists of quartz, orthoclase, plagioclase, and biotite, with accessory magnetite and zircon. Quartz is the most abundant mineral and its boundaries are very irregular. The feldspar is considerably altered to sericitic products. The biotite fragments are for the most part arranged in bands and many have a common orientation.

Other phases of the gneiss carry hornblende in addition to the biotite. The hornblende is fresh and appears to have crystallized somewhat later than the biotite. Some of it, filling in spaces between the feldspar crystals, occurs in long bands parallel to the foliation. Locally certain phases of the gneiss show an alternation of irregular, light-coloured bands rich in feldspar and with considerable hornblende.

Many of the gneissic rocks are granite-gneisses whose chief characteristics are a granitic texture and marked foliation. Such types are well exposed in a belt extending north of Rockwood Park and lying between granite to the northwest and Green Head rocks to the southeast. Another zone runs past Frying Pan Lake between the same belt of granite and a zone of Green Head rocks on the northwest side. Farther northeast, in the region immediately east of Riverside, similar granitoid gneisses lie between an area of Duck Lake gabbro and an area of Milkish Head granite to the northwest.

The granite-gneiss has ordinarily the appearance of a fine-grained granite carrying pink feldspar, quartz, and a green ferromagnesian mineral, concentrated in long, irregular bands that produce the foliation. The green mineral is chiefly chlorite, which is probably secondary after hornblende and biotite. In thin section the rock is seen to consist of feldspar, hornblende, chlorite, biotite, and quartz. The feldspars are orthoclase and plagioclase that vary from oligoclase to andesine; accessory magnetite and apatite are present, and considerable secondary chlorite, sericite, and epidote. The quartz is fresh and shows no strain shadows. It would appear that the magnetite, hornblende, and biotite crystallized first and were strung out before the crystallization of the feldspar and quartz. The feldspar is itself drawn out to a slight extent, suggesting some movement after its crystallization.

The gneiss locally contains dark bands of gabbro-like rock and also light-coloured bands of unfoliated, granitic rock. Granite dykes and pegmatite dykes in places crosscut the foliation. Near the golf links and rifle range, in the northern part of St. John city, gabbro cuts granite-gneiss and both these rocks are cut by granite. Inclusions of limestone occur in all these rocks.

MASSIVE PLUTONIC ROCKS

Massive plutonic rocks of composition varying from granite to gabbro occur in a northeasterly trending belt that begins north of Fairville and extends through Indiantown, Rockwood Park, and Brookville to Smithtown and Robertson. They are intimately associated in places with gneissic rocks of similar composition. Granite occurs also in Kennebecasis River on Kennebecasis Island, on Milkish Head, and on the mainland to the southeast. A belt of granite also borders Manawoganish Cove southwest of St. John, and several areas of granite lie in the wide belts of Precambrian volcanics of the Loch Lomond sheet.

Granite

Fairville Type. North of Fairville is a considerable area of a rather homogeneous granite characterized by coarseness of grain and red colour. It contains numerous red feldspar crystals, commonly $\frac{1}{3}$ to $\frac{1}{2}$ inch in diameter, surrounded by smaller crystals of hornblende, biotite, quartz, and feldspar. On the southeast side of the area, just north of Fairville, the rock is finer grained and of lighter colour than that throughout most of the area, and in the northwestern part at Milford the feldspars are white.

The rock is cut by a few diabase dykes. Acid granitic dykes are rare. Near Rockwood Park along the path which runs parallel to the Sandy Cove road are two exposures that show instructive relationships. In one, a dark rock full of small black hornblende crystals is in contact on one side with granite of the typical Fairville type and on the other, a few feet away, with a diabase dyke. Two pegmatite dykes cut the dark rock and they can be traced for a few inches into the granite, to where they merge into it. At the second locality a dyke, 30 feet wide, consisting of a pyroxene-bearing diabase cuts granite of the Fairville type and is cut in turn by numerous dykes and stringers of acid granite.

The Fairville granite in thin section contains feldspar, hornblende, biotite, and quartz, with a little magnetite as an accessory mineral. The feldspars consist of oligoclase, orthoclase, and a little microcline. Hornblende and biotite are present in about equal amounts.

Milkish Head Type. Along either side of Kennebecasis Bay are areas underlain by intrusives of the same general type, varying in composition from granite to granodiorite. The granodiorite phase occupies Torryburn Point and most of the area between Riverside and Rothesay. A zone at Ketepec at the western edge of the St. John sheet, along the south side of St. John River, consists of similar rock. The granitic phases lie on the northwest side of the river, forming the peninsula of Milkish Head and part of Kennebecasis Island. At Milkish Point the granite is acidic, containing red feldspar and abundant quartz. On Kennebecasis Island darker varieties occur locally, and the small patches that outcrop on Long Island are also mainly dark and dioritic in composition. Inclusions of gneiss are present in the intrusive in Ketepec area, and at one place the granodiorite itself takes on a gneissic structure. Both the granitic and granodiorite phases are cut by aplite dykes and porphyry, porphyrite, and diabase dykes.

The granodiorite is a medium-grained rock containing a larger proportion of biotite and hornblende than the granite. In thin section the rock shows hornblende, biotite, plagioclase, orthoclase, and quartz, with magnetite, ilmenite, apatite, and sphene as accessory minerals. The hornblende is fresh and is pleochroic in shades varying from grass-green to olive-green. The biotite is about equally abundant with the hornblende and shows considerable alteration to epidote along its cleavage planes. The plagioclase, which is oligoclase-andesine, is much more abundant than the orthoclase. There is considerable quartz.

The granite variety from Kennebecasis Island shows much the same mineralogy, though the ferromagnesian minerals are less abundant than in the granodiorite and the quartz is more abundant. The orthoclase is also about as common as the plagioclase, and the latter mineral here is oligoclase which is considerably altered to sericitic products.

Rockwood Park Type. A narrow belt of granitic rocks running in a northeast direction for a distance of about 3½ miles crosses Rockwood Park and Fisher Lakes. The rocks bear considerable resemblance to the Milkish Head varieties, and like them vary in composition from granite to granodiorite and locally to quartz diorite. Some phases, particularly at Indiantown, resemble the Fairville granite.

These intrusives cut gneiss, and in places contain many gneissic inclusions. At Indiantown they intrude gabbro and in the southern part of the Fairville granite north of Fairville a dyke, 200 to 300 feet wide, of apparently Rockwood Park type cuts Fairville granite.

The Rockwood park intrusives are of two main types. The first resembles the Milkish Head granodiorite. It is a medium-grained rock containing abundant black hornblende with white feldspar and quartz. In thin section it is seen to consist of hornblende, biotite, plagioclase, orthoclase, and quartz, with accessory magnetite and apatite. The plagioclase varies from oligoclase to andesine.

The other variety, almost as abundant, carries pink feldspar, and the hornblende commonly has a greenish tinge instead of being black. At Indiantown this variety becomes very pink and resembles some phases of the Fairville type.

Along the coast west of Taylor Island the granite varies considerably. It contains numerous inclusions of gneiss and other dark rocks, and is cut by numerous aplite and diabase dykes.

Germaine Brook Type. Granite occupies a considerable area in the wooded country west of Germaine Brook. It is best exposed on some of the small streams that flow eastward to Germaine Brook, and on others that flow northward to Hammond River. It is also exposed on Hammond River itself, at Upham. Similar rocks are also exposed on Curry Brook, a tributary of Irish River, and on Irish River, above the mouth of Curry Brook.

The rocks are fresh, massive, fine grained, and reddish, containing an abundance of red feldspar. Dark minerals can also be seen in hand specimen; in places the amount of quartz is so small that the rock approaches a syenite. Locally it contains miarolitic cavities, and in places small amounts of pyrite. Towards the borders of the masses the rock becomes fine grained, but never gneissic. It has apparently not metamorphosed the surrounding volcanic rocks to any great extent.

A thin section of the rock at Upham shows the most abundant mineral to be an unstriated feldspar, either orthoclase or anorthoclase, which is everywhere cloudy due to kaolinization. Albite is also present, though in much less amounts. Quartz and graphic intergrowths of quartz and feldspar are present. The ferromagnesian minerals present include a little augite with secondary chlorite and a green-yellow epidote, which is also probably secondary. A pale brown hornblende, part of which at least may be original, is present in some sections. Apatite is an abundant accessory mineral and occurs as long, slender crystals and small, irregularly shaped ones. Magnetite is also present in considerable amounts and some zircon.

The rock by its texture and contact phases suggests normal intrusive relationships with the surrounding volcanics. The early workers, however, had different ideas regarding its origin. Bailey (1879, page 8) described it as a metamorphosed phase of the felsites and breccias that surround it. Ells (1879, page 3) suggested that the rock is the basal part of volcanic flows, and that the crystalline character was produced by slow cooling. W. D. Matthew, however (1895, page 204), appears to favour a normal

intrusive origin. An analysis of a sample from Upham shows that it is a soda variety. Silica amounted to 64·86, Al_2O_3, 15·02, Na_2O, 3·92, and K_2O, 2·37 per cent.

In the Irish River area referred to above there is no doubt about the granite being intrusive into the volcanics. The contact at one place on Curry Brook is irregular and the granite sends fingers into the volcanics and also contains volcanic inclusions.

Quartz Diorite

A belt of rock of the composition of quartz diorite runs southwest from Mayflower Lake for a distance of about a mile, crossing the Sandy Point road. Similar rock outcrops in two small masses on the east side of Green Head Peninsula between Swift and Robertson Points. On Green Head the rock is cut by aplite dykes, and both here and in the Mayflower Lake area it is cut by diabase dykes.

The rock consists of hornblende, biotite, plagioclase, and quartz. Orthoclase is present in minor amounts and magnetite, apatite, and zircon are present as accessory minerals. The hornblende and biotite are about equally abundant. The plagioclase is andesine-labradorite and is the most abundant mineral present.

Gabbro

Basic igneous rocks are known in several localities. One of the best known is Indiantown, where there are several exposures of gabbro, separated by granite. The gabbro is dark and varies from fine to medium grained. In thin section it is seen to consist of hornblende, pyroxene, and plagioclase, with some accessory magnetite. The most abundant mineral is hornblende. Some of the larger hornblende crystals are poikilitic, containing numerous laths of plagioclase with all orientations. Some contain irregular patches of pyroxene at their centres, showing that the hornblende is secondary after that mineral. The plagioclase is oligoclase-andesine and is largely saussuritized.

The Indiantown gabbro at places at the north end of the rifle range at St. John is represented by a biotite norite. The rock is fresh and consists of hornblende, biotite, monoclinic pyroxene, orthorhombic pyroxene, plagioclase, and quartz. The hornblende, which is secondary after pyroxene, is pleochroic in shades of from yellow-green to olive-green. The orthorhombic pyroxene is more abundant than the monoclinic variety and is apparently hypersthene. The plagioclase is oligoclase-andesine.

In places the gabbro appears to grade into granite, and is apparently an early differentiate of the granitic intrusives.

In the region north of Duck Lake, east of Renforth, is an area of about one square mile underlain by a gabbro that is for the most part coarser grained and contains more feldspar and less ferromagnesian minerals than the Indiantown gabbro. It varies from a fine-grained rock of the appearance and texture of a coarse diabase to a coarse-grained variety in which white feldspar crystals appear surrounded by black pyroxene. In other places it forms a coarse-grained rock in which hornblende is the principal constituent. In the northeastern part of the mass is a large inclusion of a fine-grained, greyish green pyroxene gneiss.

In thin section the rock is seen to consist of plagioclase, hornblende, and pyroxene, with magnetite as a rare accessory mineral. The most abundant mineral is the plagioclase, which is labradorite. One specimen was found to contain olivine.

Diabase dykes cut both the Indiantown gabbro and the gabbro at Duck Lake.

AGE OF THE PLUTONIC INTRUSIVES

Bailey and Matthew placed the plutonic rocks of the St. John area in the Portland group of early Precambrian age. They recognized, however, that certain granites that occur to the west and north are much younger, and in their 1870-71 report they regarded the age of these as probably Devonian. Later Bailey in his work in the northern part of the province got more direct evidence of the age of these intrusives by finding that they cut Silurian strata. We now know that they intrude Lower Devonian beds as well, and that their age is probably Middle Devonian (Alcock, 1935). In 1894 W. D. Matthew suggested the possibility that the plutonics of the St. John region might possibly also belong to the same period of intrusion as these Palæozoic granites. He was, however, much impressed by the fact that the granites as well as the sediments of the Portland group are cut by numerous dykes, whereas the Palæozoic formations are intruded by very few. He, therefore, inclined to the view that the St. John granites, granodiorites, and gabbros are probably Precambrian, and very probably early Precambrian, i.e., pre-Coldbrook. Hayes regards the plutonics as Precambrian. Cummings, however, placed not only the massive rocks but the gneissic ones as well as post-Silurian.

That some of the granitic rocks at least are younger than the Coldbrook volcanics is clear. Massive red granite intrudes the volcanics on Irish River, in the hills west of Germaine Brook, and along the Golden Grove road. In the last area greenstones believed to belong to the Coldbrook group are locally altered into hornblendic contact phases, and in places are cut by a network of small granite dykes and stringers, some of which carry greenstone inclusions. Also, where granite outcrops on the headland west of Millidgeville, in Kennebecasis Bay, the intrusive contains an inclusion of fine-grained, trachytic, volcanic rock of apparently Coldbrook age. As has already been mentioned in the description of the granites, granitic dykes locally are found cutting gneiss and gabbro. These may, of course, be later phases of a single period of intrusion or they may represent an entirely later period of igneous activity.

That some at least of the plutonics are of pre-Coldbrook age is suggested by a number of facts.

(1) The Green Head rocks are much more intimately intruded by the granitic rocks than are the Coldbrook volcanics. If all the plutonics are of Devonian age the close association of the intrusives with the early Precambrian strata appears strange, and a still stranger phenomenon is the fact that nowhere are any of the Cambrian beds known to be cut by even a single mass or dyke of granite.

(2) Granite, gneiss, and quartz pebbles occur in the conglomerate which is interbedded with Coldbrook volcanics at Marks Lake, showing

that at the time these rocks were being deposited granitic masses were undergoing erosion.

(3) Numerous basic dykes cut some of the granitic rocks, whereas the Cambrian strata are intruded by only a few.

(4) Although certain phases of the St. John granites resemble Devonian granites of the St. George-Welsford belt to the northwest, the latter belt does not show the extensive development of granitic gneisses that the St. John area does.

It would appear, therefore, that a period of plutonic intrusion accompanied deformation of the Green Head rocks in early Precambrian time. But it would also appear that the volcanism and deformation of late Precambrian time may have been accompanied by some deep-seated igneous activity. Finally, deformative movements of Middle Devonian time were accompanied by widespread intrusion of granite in the west-central part of the province, and may be responsible for some of the granitic masses and dykes of the St. John area.

DYKES

Dykes are numerous in parts of the St. John area, the commonest rock variety forming them being diabase. These dykes are clearly not all of the same age. Some, which are associated with the Mispek volcanic rocks, are Carboniferous. That the majority, however, are pre-Carboniferous is shown by the fact that although the Precambrian Green Head strata contain very many dykes, the Mississippian Kennebecasis formation of most at least of the same areas is cut by none. Most of the basic dykes are undoubtedly related to the late Precambrian volcanism that produced the Coldbrook flow and fragmental volcanic rocks. Several composed of augite porphyrite, however, cut Cambrian beds and granite at two places, Torryburn Point and on the north side of Milkish Head Peninsula. As has already been mentioned, aplite dykes are fairly abundant in the Milkish Head and Rockwood Park varieties of granite and are undoubtedly related to these intrusives.

MISSISSIPPIAN

HORTON SERIES

Kennebecasis Formation

The Kennebecasis formation, here used to include Hayes' Kennebecasis and Boar Head divisions, is characteristically developed along Kennebecasis Bay. It forms much of Kennebecasis and Long Islands, and a fringe runs along part of the northwest side of the bay; the more important areas, however, are on the southeast side. Another belt, forming a prominent ridge, lies southeast of Hammond River, between it and the Damascus ridge. The strata dip off Precambrian volcanics on the southeast and to the northwest they are brought into fault-contact with a complex of pre-Carboniferous rocks. This fault zone is now a depression occupied in part by Hammond River. East of this stream, in the northern part of the area, a narrow belt of the formation rests upon Precambrian

volcanics and Cambrian sediments and is overlain by beds of the Windsor series. Throughout parts of the region numerous large erratics, some of them weighing tons, are composed of rock of this formation.

The formation is made up of conglomerate, sandstone, and shale. The shales are commonly red and the coarser clastics are buff to reddish. The conglomerates vary from pebbly to coarse types, the latter commonly containing large boulders. The rocks of the boulders include all kinds of pre-Carboniferous rock. Large boulders of Green Head limestone and dolomite are in places numerous. Granite, gneiss, quartzite, quartz, and various types of volcanics are all common varieties. The formation in most places strikes northeast. As a rule, the beds have moderate dips, though locally they stand at steep angles and in places they are even overturned. At several places, as, for example, just north of the map-area, on the road north from Smithtown, the basal beds can be seen resting unconformably on Green Head sediments.

The beds locally contain fragments of *Lepidodendron corrugatum* and *Aneimites acadica* and also a few specimens of *Estheria,* and where these occur the strata belong to the Horton series, probably to an upper part. The formation was presumably laid down as fluvial or perhaps partly fluviolacustrine deposits.

The Kennebecasis formation was correctly mapped by Bailey and Matthew (1872) as Lower Carboniferous. Ells, however, later (1906, page 131) put it in the Devonian. Its similarity to the Upper Devonian Perry formation of Maine was one reason for this transfer. Another reason was that a collection of fossil plants found in these beds was determined by Matthew to be Devonian. As previously mentioned and to be emphasized later, Matthew's Devonian plants are now known to be Carboniferous.

WINDSOR SERIES

Upham Formation

The Upham formation is present in the northern part of the Loch Lomond area. It forms an easterly trending belt that crosses Hammond River about a mile east of Upham and again about 2 miles farther east. The area is largely covered with drift, and the amount of country actually underlain by the formation can be only approximately inferred.

The formation consists mainly of gypsum and grey, bedded limestone. Along the south side of Hammond River, southeast of Upham, are outcrops of limestone resting on pre-Carboniferous volcanics and intrusives. Farther east limestone overlies conglomerate. Between the highway and Hammond River, near where that stream enters the map-area, is a zone underlain by gypsum. The belt can be traced by a few outcrops and by sink-holes characteristic of gypsum country. A couple of outcrops form low ridges, 25 to 30 feet high, one ridge having a width of 100 feet and extending for 500 feet. The formation is overlain by shales, sandstones, and conglomerates of the Hammond River formaiton.

Although no fossils were found in the Upham formation, the presence of limestone and gypsum is considered sufficient evidence for assigning the formation to the Windsor series. There is some doubt, however, about the

age of the conglomerate that lies below the Upham beds east of Upham. It has been mapped as Kennebecasis; but it is possible that it, too, may properly belong to the Windsor series as no Kennebecasis fossils have yet been discovered within it.

MISSISSIPPIAN AND (OR) PENNSYLVANIAN

Hammond River Formation

The Hammond River, a term introduced by Hayes (Hayes and Howell, 1937, page 111), is a coarse, clastic formation resembling, lithologically, the Kennebecasis. In mapping, the chief criterion for distinguishing the one from the other is whether the beds lie below or above the limestone or gypsum of the Upham formation. Where there are no outcrops of the latter it is in places difficult to decide where certain clastic beds belong.

The only belt where the Hammond River formation is exposed in the area is in the extreme northern part of Loch Lomond map-area. It here forms a high ridge running in a northeast direction towards Hillsdale, along the northwest side of Hammond River. Outcrops continue westward and where there is none the red character of the soil helps in determining the extent of the formation. In the neighbourhood of Titus Mills, however, the lack of outcrops, and particularly of any outcrop of the Upham formation, which is believed to swing northward in this district, makes it impossible to determine just how far west the Hammond River formation extends. The next outcrops to the west consist of Kennebecasis beds.

The formation in the above belt strikes easterly to northeasterly and has low northerly dips varying from 5 to 15 degrees. The beds consist of sandstone, conglomerate, and shale. The sandstone is red to grey, the conglomerate is commonly reddish, and the shale is bright red. The boulders of the conglomerate are for the most part subangular and consist of all sorts of material, including Precambrian volcanics, granite, quartzite, quartz, and Cambrian sandstone and conglomerate. No boulders or pebbles of Windsor limestone or gypsum were observed, nor were any boulders found that could definitely be recognized as coming from the Kennebecasis formation.

In the limited area covered by the formation in the map-area it was not possible to determine with certainty whether the formation succeeds the Upham conformably or whether the contact implies a definite time-break. The abrupt change in lithology suggests that somewhere the two may have unconformable relations.

No fossils were found in the formation and it is, therefore, not known definitely whether its age is Mississippian or Pennsylvanian.

MISPEK SERIES

The term Mispek series is here used to include the rocks around Mispek, east of St. John, concerning whose age there has been so much controversy. The writer has divided the rocks into two formations, the Balls Lake and an overlying one to which he has applied the name West Beach.

Balls Lake Formation

General. The Balls Lake formation, a term introduced by Hayes (Hayes and Howell, 1937, page 113), is made up of rocks that in the early reports were included under three groups, the Bloomsbury, the Little River, and the Mispeck, divisions that were introduced by Matthew (1863, page 244). The Bloomsbury was originally described as being made up of two divisions, a lower consisting of basalt, amygdaloid, trap-ash, trap-ash slate, and some beds of conglomerate, and an upper made up of red clay slate and reddish grey conglomerate. In the former division were placed the volcanic rocks lying southeast of the Cambrian belt at St. John city and running northeast from Courtenay Bay, and also a great belt of lavas that surrounds Bloomsbury Mountain and is cut across by Black River. This last belt was later recognized by Bailey and Matthew (1872) to be Precambrian and the term Bloomsbury then became restricted to the upper sedimentary division, including the reddish sediments that rest on either side of the volcanic Bloomsbury axial belt.

The Little River group was divided by Matthew into a lower division known as the *Dadoxylon* sandstone, and an upper division, the *Cordaite* shales. These divisions included the Fern Ledge beds at St. John which contain an abundant flora, now known to be mid-Pennsylvanian in age. Matthew correlated with these beds strata to the east which the writer regards as older than the Fern Ledge beds and calls the Balls Lake formation. Matthew also mapped as *Cordaite* shales the beds that are here included in the West Beach formation.

The Mispeck group of Matthew was regarded by him as the youngest of his so-called Devonian divisions. It included both sediments and volcanics outcropping in the region west of Cranberry or Calvert Lake. The sedimentary portion is here placed largely with the Balls Lake formation, and the upper, dominantly volcanic portion is put with the West Beach formation, as it appears to occupy the same stratigraphic position above the Balls Lake formation as do the West Beach volcanics in their type area northeast of Cape Spencer.

Distribution. The Balls Lake formation laps around the Bloomsbury belt of Precambrian volcanics, which extend to the north end of Balls Lake. West and south of the Precambrian rocks the formation covers a considerable area, from near Red Head to Cape Spencer. On the north the formation disappears under a cover of Quaternary deposits. East of the Precambrian volcanics the formation is succeeded by the West Beach formation, and both these formations and the underlying Precambrian volcanic complex are overlapped unconformably by the mid-Pennsylvanian Lancaster formation. The width of the area underlain by the Balls Lake formation on this side of the Precambrian belt is much less than that on the western side. Almost continuous exposures border the coast from Red Head to Cape Spencer, and numerous outcrops occur along the road past Mispek to Cape Spencer and along the old Black River road past Beaver and Balls Lakes.

Lithology. The rocks of the formation are clastics, consisting of conglomerate, arkose, and shale. Some of the beds are grey, whereas many have a characteristic purplish shade. Some appear to be composed partly at least of tuffaceous volcanic material.

The rocks are for the most part well bedded and have a general northeast strike. West of the Bloomsbury volcanic rocks the dips are for the most part low, the beds being folded into gentle rolls. The low dips can be well seen in the cliffs from off shore. Lack of key beds makes it difficult to work out structure in detail and to determine the thickness of this zone, although the low dips make it evident that no very great thickness need be postulated.

The beds are broken and sheared, and in places the pebbles of the conglomeratic beds are squeezed into elongated forms. Quartz veins and masses of all sizes and shapes cut the beds. On Black River, below the mouth of the East Branch, is a vein 13 feet wide, and on the summit of Porcupine Hill, near the mouth of the stream, are masses one of which has a width of over 15 feet.

Locally the beds contain plant remains, but nowhere has there been found material sufficiently good for specific identification. Some large pieces of apparently drifted wood were found in the cliffs along the coast about a quarter of a mile west of Cape Spencer. A fragment of a large ribbed *Calamites* collected in some sandy beds on the East Branch of Black River near its junction with the main stream suggests an early Pennsylvanian age. Striated fragments of plants, possibly *Cordaites*, though more probably the stems of pteridosperms, also occur.

A narrow zone of clastic sediments, consisting of purplish conglomerate and sandstone resembling the typical Balls Lake beds, runs in a northeast direction through St. John city. These beds overlie Cambrian sediments and are succeeded by a zone of volcanic rocks. The latter are followed by the Fern Ledge beds of the Lancaster formation. The lower band of sediments has always been classed with the Fern Ledge strata. The latter, however, are much fresher than the lower beds, which have the Balls Lake characteristics of purplish colour, conglomeratic lithology, greater degree of cementation, and numerous quartz veins. This belt can be particularly well seen in East St. John to the rear of the Boys' Industrial Home.

West Beach Formation

General. The West Beach formation apparently succeeds the Balls Lake beds conformably. It is separated as a distinct formation because it consists dominantly of volcanic and intrusive rocks with only subordinate amounts of sediments.

The formation as exposed from Cape Spencer to Emerson Creek was first mapped by Matthew as part of his *Cordaites* shales of the Little River group. Certain granitic rocks of the belt, which will be described later, were regarded by him as altered sediments (Bailey and Matthew, 1865, page 83). As already mentioned, the volcanic rocks between Calvert Lake and Lyons Head, which are here mapped as West Beach, were included by Matthew as Mispeck.

Numerous specimens from the Cape Spencer-Black River area were submitted, after the first mapping by Bailey and Matthew had been done, to T. Sterry Hunt, and subsequently Hunt visited some of the localities where these rocks are exposed. He came to the conclusion that they so closely resembled certain Precambrian rocks of the Coldbrook group that

they must be of similar age. A fault was, therefore, postulated to account for the fact that these volcanics overlie the sediments (Devonian of Matthew) instead of underlying them as they should if the volcanics are Precambrian. However, because these volcanics were associated with conglomerates, limestone, micaceous slates, etc., different from anything in the Coldbrook, a new group was created to include them and the name Coastal given to it.

Ells was the next worker in the field to study these rocks and he came to the conclusion (1906, page 132) that the Coastal rocks should not be classed as Precambrian but as Devonian. He regarded their schistose character as being due partly to intrusions of diabase and granite and partly to folding and other causes. This was essentially a return to Matthew's original conception of their age and stratigraphic relations.

The West Beach formation includes the Cranbury Point, Partridge Island, and Courtenay Bay divisions of Hayes (Hayes and Howell, 1937).

Lithology. The formation consists of igneous rocks with which are associated some sediments. The latter include shale, limestone, and fragmental beds which in some places are partly, and in others largely, of tuffaceous origin. Shaly sediments are well exposed on the shore about half a mile east of the mouth of Black River. They are grey to yellow and are followed by other shales of a purple tint. All are finely bedded, in places showing a ribbon banding, and locally they are much contorted and dragged. They are overlain by basic volcanics.

A band of limestone occurs in the complex. It crosses what is known as the shore road in a rock cut near the foot of the hill immediately west of Black River settlement. The band is about 50 feet thick and can be followed in a northeast direction for about 1½ miles. It is a massive rock, grey on the freshly broken surface and weathering reddish brown. No fossils were found in it. The rock is locally cut by quartz and carbonate stringers, and at one place a pit was sunk in it where some small quartz veins carry a little pyrite and chalcopyrite.

In the West Beach district and along the lower part of Black River are grey and purplish banded rocks, some of which appear to be shaly sandstones and others volcanic tuffs. The rocks are locally sheared into schists. The lighter coloured have developed into sericite schists and the darker are altered into chloritic varieties.

The massive volcanic rocks of the West Beach formation include both basic and acid varieties. Three-quarters of a mile east of the mouth of Black River a headland is made up of massive greenstone flows with interbanded purplish tuffs. The rocks are cut by quartz veins and hematite seams. Similar basic volcanics border the shore from Beveridge Cove past West Beach, and again northeast of Upper West Beach.

As already mentioned, the volcanics lying above the Balls Lake sediments east of Lyons Head near Red Head are included in the West Beach formation, as are also the volcanics of the belt that runs in a northeast direction through St. John city. In the former area both acid and basic types occur. The latter belt extends for some 6 miles from southwest of Duck Cove to northeast of the drydock. It includes amygdaloidal rocks of apparently surface origin, and in addition massive, coarser grained varieties, which may be intrusive. Still farther southwest, on Taylor and

Manawoganish Islands and at Lorneville, basic volcanic rocks are interbedded with purplish clastic sediments.

The dark rocks are andesitic in composition. A thin section of a specimen from near Lyons Head shows phenocrysts of an oligoclase-andesine plagioclase in a fine-grained matrix of plagioclase needles, specks of magnetite, and secondary sericite and chlorite. Other sections are almost opaque, due to the alteration of the groundmass into sericitic and chloritic material. Sections from dark rocks at Pisarinco Cove and Partridge Island show hornblende. A dark volcanic from Lorneville contains a little quartz in addition to plagioclase and hornblende.

Lighter coloured volcanics in thin sections are acidic in composition. A section of a grey flow containing specks of hematite near Red Head shows fairly numerous crystals of orthoclase, plagioclase, and quartz in a fine-grained groundmass showing flow structure. Small specks of hornblende are present in the groundmass. Another section of a greenish rock from near Lyons Head appears to be of intermediate composition. It contains oval and lenticular phenocrysts of orthoclase, plagioclase, and quartz in a matrix consisting of interlocking rods of quartz and feldspar, and showing dark bands in which magnetite, chlorite, epidote, and apparently sericitic products are concentrated.

The belt of igneous rock extending from West St. John to Sand Cove consists of massive greenish black material, which may be partly at least of intrusive origin. Similar rock outcrops along the coast from Sand Cove to Sheldon Point. Thin sections of several specimens show a rock consisting of plagioclase, orthoclase, pyroxene, chlorite, magnetite, and ilmenite. The plagioclase is oligoclase-andesine and occurs in needles up to 5 millimetres in length, producing a diabasic texture. In places the rock shows flow structure and amygdules. Contacts, where observed, parallel the bedding of the adjacent sediments. These facts suggest an eruptive origin. On Taylor Island, however, where the diabase occurs interbedded with shales, the latter at the contact have been locally hardened and at one place on the west side of the island garnets are present in the shale, suggesting contact metamorphism. It would appear, therefore, that certain bands are sill-like bodies rather than flows. Near the headland at the southwest of Manawoganish Cove a dyke of similar rock intrudes andesitic volcanics, showing that crosscutting intrusives are also present.

CARBONIFEROUS GRANITE INTRUSIVES

Intruding the volcanic and sedimentary rocks of the West Beach formation are acidic intrusives which are probably the source of the large amount of quartz that occurs as veins and masses in that formation and the underlying Balls Lake formation. Most of the intrusive masses are in the form of sills following the bedding planes of the sediments. One such sill lies along the southeast side of Millican Lake. The prominent hill forming part of the ridge overlooking the lake is on this zone. Another belt of similar rock extends from Cape Spencer in a northeast direction, and similar rock crosses Black River below the covered bridge on the old West Beach road. In addition to these masses that follow the strike of the West Beach formation, there are other intrusive bodies of a slightly different appearance in the neighbourhood of Black River.

In the first report of Bailey (1865) these rocks were described as part of the *Cordaite* shales division of the Little River group. They are spoken of as granulite and imperfectly formed granite associated with beds of trap-ash. Later, Bailey and Matthew (1872) placed them in their Coastal group of supposed Precambrian age, and referred to them as granitoid grits, granitoid schists, imperfect gneisses, and dioritic beds.

The rocks of the Millican Lake and Cape Spencer-West Beach belts are fine- to intermediate-grained, flesh-coloured types, characterized by a lack of dark ferromagnesian minerals. They are commonly massive, are never banded, and are locally sheared. In some places they are schistose, and at one place northeast of Cape Spencer a fault breccia has been developed. They show typical granitic texture, and locally have miarolitic cavities lined with quartz crystals. In places they are traversed by pinkish, aplitic dykes of composition similar to their own. They are everywhere cut by veins of quartz, some of which carry considerable carbonate, and locally some specularite. Some small seams consist entirely, or almost entirely, of hematite.

In thin section the rock is seen to consist chiefly of quartz, orthoclase, albite, and microcline. Secondary sericite, carbonate, a little chlorite, and some iron oxide, probably hematite, are also usually present. The quartzes show undulatory extinction and are usually broken. Some of the crystals are surrounded by finely granulated material forming a mortar structure. The feldspars are also commonly bent and broken.

The age and relationships of these rocks are quite definite. A short distance to the west of Cape Spencer the sediments of the Balls Lake formation along the shore contain large fragments of plant material. The specimens are too poor to determine exactly what horizon is represented, although there can be little doubt that they are Carboniferous. At Cape Spencer the granite intrudes similar beds. The contact can be traced up the face of the cliff, and it is clearly not a fault-contact. Farther along the coast, about 1½ miles northeast of Beveridge Cove, the granite shows intrusive relations into dark volcanic rocks of the West Beach formation. The line of contact between the two rock types is here an irregular one. Tongues of granite penetrate the greenstone and contain inclusions of it. The rocks, however, do not intrude the Lancaster beds of Middle Pennsylvanian age. Their age is, therefore, Carboniferous and pre-Lancaster.

At Black River settlement a massive, coarse-grained, grey rock can be seen in a number of exposures. In a road cut at the foot of a steep hill on the shore road, immediately west of the settlement, it cuts sediments and a dark volcanic rock. It also outcrops at several places in fields, on the road near the Catholic church, and on the shore. At this last place it apparently intrudes fresh-looking Carboniferous sediments of the West Beach formation. The rock consists of quartz, orthoclase, albite, and chlorite. In two sections small amounts of epidote were observed. The scarcity of outcrops renders it difficult to determine the extent and form that these intrusions take. It is probable, however, that they are related to the other granite intrusions of Cape Spencer and Millican Lake.

PENNSYLVANIAN

LITTLE RIVER SERIES

Lancaster Formation

General. The Lancaster formation includes the famous Fern Ledge beds of the Duck Cove belt along the coast south of St. John, and a band of similar rocks bordering the shore for nearly a mile south of the mouth of Little River. These beds have yielded a flora concerning whose age there has been much dispute. As has already been mentioned, Dawson concluded that they were Devonian and Matthew in his later work made them still older by placing them in the Silurian. The work of Marie C. Stopes demonstrated that the beds are of Pennsylvanian age.

East of Emerson Creek is a northeasterly trending belt of sandstones, which were originally correctly mapped as Carboniferous. Later they were regarded by Ells (1907, page 74) as Perry formation or Upper Devonian in age, although younger than the Mispek. These beds have yielded plant remains at a number of places such as Dixon Point, McCoy Head, and the mouth of Tynemouth Creek, and W. A. Bell has identified these collections as being definitely of the same age as the Fern Ledge flora (1927, and personal communication). The stratigraphic relations of these beds to the Balls Lake and West Beach strata is known, and the age of the Fern Ledge rocks relative to those formations must necessarily be the same.

Lithology. The beds of the Fern Ledges of the Duck Cove belt consist of grey sandstones, shaly sandstones, and grey to blackish shales. In places there are thin layers of reddish sandstones. The coarser beds locally carry fragments of woody stems, but the best plant remains are in the shaly beds. The strata dip southeastward at angles of from 30 to 50 degrees off the underlying Carboniferous volcanic rocks. They are locally broken by minor faults, which have produced slickensided surfaces, and in places are cut by small quartz-carbonate stringers. The beds are much fresher than the Balls Lake sediments, are cut by no intrusives, and contain no large quartz veins.

The strata lying south of the mouth of Little River are similar lithologically to the above beds. They strike northeast and dip southeast at angles of from 30 to 60 degrees, and in places show dips as high as 80 degrees. The beds are locally crumpled and faulted and contain small, irregular quartz veins up to 6 inches in width. One zone, 15 feet wide, contains an intricate network of quartz stringers. Like the Duck Cove beds, however, there is an absence of huge quartz masses and hematite seams, so striking in the Balls Lake formation. Outcrops of similar rock, locally carrying plant remains, occur along the same strike to the northeast on the road that passes north of Buck Lake.

The belt of sediments stretching northeast from Emerson Creek to north of St. Martins is well exposed along the coast where it forms high, nearly continuous cliffs, and numerous outcrops are to be found also along many of the streams that cross the belt. The rocks consist of red, grey, and greenish grey sandstones, red shales, red and grey grits, and conglomeratic beds. In places the sandstone forms heavy beds as much as

3 feet in thickness and other zones consist of alternations of red shales and grey sandstones. The rocks are thrown into low folds and are locally broken by faults. Dips range up to 90 degrees. As already mentioned, plant remains are locally present and the flora represented is the same as the Fern Ledges. No quartz veins cut the beds.

These beds were divided on the early maps into two divisions, a lower consisting of dominantly reddish beds, which were referred to as the Lower Carboniferous, and an upper consisting mainly of grey sandstones, which were regarded as Middle Carboniferous. The basis for this grouping was partly lithology and partly some plant collections from a number of places. As has already been mentioned, however, Bell regards all these collections as of mid-Pennsylvanian age, equivalent to the Fern Ledge flora.

Two other areas of apparently the same formation occur in the same general region. The first is a basin south of Hardingville. It stretches for 5 miles west from Henry Lake and has a maximum north and south width of about a mile. The rocks are sandstones resting on Precambrian volcanics.

The other area is a narrow belt at Quaco. It rests on Precambrian volcanics and is overlaid by Triassic red beds. An interesting feature is that the basal beds consist of a grey limestone that has penetrated into the uneven surface of the underlying volcanics. The limestone has a thickness of about 20 feet. The overlying clastic beds are sandstones and conglomerates.

Flora. Over eighty species of plants have been described at different times from the Fern Ledges of St. John. Many of these species have been made from very poor material. Marie C. Stopes (1914) lists some forty forms that can be reliably determined and which she states are the only ones she could satisfactorily use in comparing the flora with those from other parts of the world, although some of the poorly preserved remains supplied a certain amount of corroborative evidence. The following is the list:

Calamites suckowi Brongniart
Annularia sphenophylloides (Zenker)
Annularia stellata (Schlotheim)
Annularia latifolia (Dawson) (=*A. stellata?*)
Stigmaria ficoides Brongniart
Adiantites obtusus (Dawson)
Rhaciopteris busseana Stur
Sphenopteris marginata Dawson (=*S. rotundifolia*)
Oligocarpia splendens (Dawson) (=*O. brongniarti*)
Sphenopteris valida (Dawson) (=*S. artemisiae-folioides* Crépin)
Pecopteris plumosa (Artis)
Diplothmema subfurcatum (Dawson)
Alethopteris lonchitica (Schlotheim)
Megalopteris dawsoni Hartt
Neuropteris heterophylla Brongniart
Neuropteris gigantea Sternberg
Sporangites acuminata Dawson
Pterispermostrobus bifurcatus Stopes
Dicranophyllum glabrum (Dawson)
Whittleseya dawsoniana D. White
Whittleseya concinna Matthew
Cordaites robbii Dawson (=*C. borassifolius?*)
Dadoxylon ouangondianum Dawson

Cordaianthus devonicus (Dawson)
Cardiocarpon obliquum Dawson
Cardiocarpon baileyi Dawson
Cardiocarpon cornutum Dawson
Cardiocarpon crampii Hartt

In addition to the above the following genera are recognized, though the species in each case is either unknown or doubtful:

Calamostachys sp.
Asterophyllites acicularis Dawson (=*A. equisetiformis*)
Asterophyllites parvulus Dawson (=*A. grandis*?)
Sphenophyllum antiquum Dawson
Sphenophyllum cuneifolium (Sternberg)
Lepidodendron sp. (foliage)
Lepidodendron sp. (in. "*Bergeria*" condition)
Sigillaria sp.
Neuropteris selwyni Dawson (=*N. schlehani*?)
Neuropteris eriana (Dawson)
Sternbergia sp. (pith casts of *Cordaites*)

The flora is of Middle Westphalian age, equivalent to that of the Joggins formation of Nova Scotia and of the Upper Pottsville of Missouri.

Structural Relations

The rocks of the belt lying east of Emerson Creek are clearly unconformable to those of the West Beach and Balls Lake formations as exposed along the southeast side of the Bloomsbury belt of Precambrian rocks. The actual contact along Emerson Creek is a fault, but the mapping brings out clearly that the Lancaster beds were deposited unconformably across both the Precambrian volcanics and the overlying Balls Lake and West Beach formations.

The lithology and structure of the Lancaster beds present evidence of an important structural break between them and the older Carboniferous beds. Though folded and faulted, the Lancaster beds are very fresh as compared with the West Beach and Balls Lake strata and they do not contain volcanics, intrusives, and quartz veins so characteristic of those beds. Accordingly, these beds have always been mapped as Carboniferous, whereas the West Beach has been placed as Devonian, Silurian, and even as Precambrian. If the Balls Lake and West Beach formations are Pennsylvanian which, as already stated, is probable, there must have been in early Pennsylvanian time a period of considerable deformation accompanied by intrusion and followed by erosion.

The relations of the Lancaster beds of the Duck Cove-Little River belt to the Balls Lake strata to the east must necessarily be explained as the result of faulting. The fault is inferred to follow a northeast direction through Buck Lake and south of Latimore Lake. This is a region of few outcrops, and as a result the exact location of the fault is not known. Its approximate position, however, can be inferred by comparing closely the lithology of what exposures there are in this general zone. Some of the outcrops along the Hickey road, even where there are no plant remains, can be correlated on lithology alone with the Lancaster beds that outcrop on the coast. Other exposures farther southeast on Beaver Lake and along Mispek River are just as definitely of the Balls Lake variety, and the fault line as drawn marks the dividing line between the two types.

Since both formations consist largely of sandstones, they locally resemble one another. This fact and the fact also that both formations strike northeast whereas north of Beaver Lake the Balls Lake beds swing to the west as if the two formations together form a broad syncline pitching southwest, explain why these rocks were formerly mapped together, the Little River beds being regarded as the basal division. Structure was apparently deemed to have more weight than fossil evidence in determining the age of the beds.

TRIASSIC

Quaco Formation

Rocks of Triassic age occur on either side of the Bay of Fundy. Their greatest development is along the coast of Nova Scotia where a continuous belt stretches from Brier Island to Cape Blomidon, a distance of 120 miles; other areas occur on either side of Minas Basin to the east. The rocks in these areas in Nova Scotia consist of several thousand feet of red sandstones and shales overlain by about 1,000 feet of amygdaloidal basalt flows. In the main area the beds dip at low angles to the northeast, though on the north side of Minas Basin the rocks are locally faulted, with resulting higher dips.

On the New Brunswick side of the bay isolated patches, referred to by Hayes as the Quaco formation (Hayes and Howell, 1937, page 120), occur at St. Martins, along the coast southwest of Quaco Head, and at Red Head or Split Rock east of Gardner Creek. At Lyons Head and Red Head, two exposures, immediately south and east, respectively, of the mouth of Little River, are regarded by the writer as of similar age. These various areas are evidently mere remnants of what was originally a much wider development. In fact the presence of similar beds on either side of the bay suggest that in Triassic times the whole region now occupied by the Bay of Fundy was a depression in which similar strata accumulated. The New Brunswick beds in each of the above areas have no volcanic members, consisting entirely of red clastic sediments. The beds for the most part dip at low angles, but they present evidence of a considerable amount of faulting.

St. Martins. The largest area underlain by Triassic sediments on the New Brunswick coast is at St. Martins, where a triangular belt has a length of 5 miles and a greatest width of 2 miles. The rocks form cliffs at Macs Head and to the northeast, and good exposures are also to be seen along the lower parts of Mosher and Irish Rivers and of Macomber Brook. The beds consist of conglomerates, sandstones, and shales of bright red shades. They strike in an easterly to northeasterly direction and dip at angles of 20 to 35 degrees to the north. On Irish River a thickness of some 1,800 feet of sediments is exposed. To the northwest of the belt the bedrock consists of Pennsylvanian sandstones against which the Triassic rocks rest in fault-contact. The southern boundary of this belt lies about half a mile north of Quaco Head, where the beds rest in fault-contact against Precambrian volcanics. The fault plane strikes northeast and dips southwest

at an angle of 40 degrees. The strata consist of red, flaggy sandstone underlain by coarse, gritty sandstone containing large boulders of sandstone and many fragments of volcanic rocks.

Quaco Head. Quaco Head itself consists of Pennsylvanian sediments, but less than half a mile to the west a belt of Triassic beds begins and continues along the coast for a distance of some 2 miles. These beds consist of red sandstones and conglomerates striking easterly and dipping northward at angles around 35 degrees. At the southern end of the belt they rest unconformably on an irregular surface of Precambrian volcanics, and to the northeast they lie in faulted contact with Pennsylvanian sandstones.

Red Head or Split Rock. Along the coast about midway between the mouths of Gardner and Tynemouth Creeks is an area of Triassic outcrops, which extends for a distance of over 1½ miles. The exposures are continuous, with the exception of a stretch a quarter of a mile wide where the lagoon of a small stream and gravel bars conceal the bedrock. Immediately west of the lagoon broad exposures can be observed at low tide, and farther west low rock cliffs border the shore. East of the lagoon the cliffs are higher, and at Split Rock itself they attain a height of over 100 feet. It is possible to pass around this section of the coast on foot only at periods of low tide.

The beds consist of sandstone, conglomerate, and shale, all of a brilliant red colour, which readily distinguishes them from the reddish brown Pennsylvanian sandstones that border the coast both to the east and to the west. The Triassic rocks are well bedded and locally are crossbedded. They contain numerous fragments derived from adjacent Pennsylvanian sandstone beds. Their strike is about east and west and they dip northward at angles varying up to 60 degrees. They rest in fault-contact with the adjacent rocks. At the western end of their exposure the actual contact cannot be observed; but the difference in altitude of the Carboniferous strata on one side and the Triassic beds on the other is evidence of a fault. The eastern contact immediately north of Split Rock is a well-marked fault dipping at a low angle to the southwest. Northeast of this fault the Pennsylvanian beds carry plant fossils. In addition to the fault at the contact, several other east-west faults with low southerly dips cut the Triassic beds in the vicinity of Split Rock. In each case the movement has been a downward one of the south block in reference to the block on the north side of the fault. The displacement on two of these breaks is, respectively, about 15 and 20 feet.

Lyons Head and Red Head. Immediately south of the mouth of Little River and northeast of Red Head there outcrops along the shore and the coast highway, for a distance of a quarter of a mile, some red, clastic beds, which were classified by Bailey and Matthew as of Carboniferous age and were correlated by them with the Kennebecasis beds to the northwest. Ells later put them in the Devonian, correlating them and the Kennebecasis beds with the Perry formation. Lyons Head, the prominent hill northeast of Red Head, is made up of similar beds. The shore outcrop consists of coarse conglomerate and red sandstone striking northeast and dipping at angles of about 35 degrees to the northwest. The conglomerate

contains large boulders, some 1½ feet in diameter, a few subangular, but the majority fairly well rounded. The largest consist of granite; white and bluish limestone boulders, most of which at least are evidently derived from the Green Head formation, are also common, as are likewise boulders of various types of volcanic rocks. The beds are very fresh looking and are cut by no quartz nor calcite veins.

Lyons Head is a hill rising to an elevation of some 300 feet above the sea. It has abrupt cliffs on three sides, and outcrops extend northward for a distance of half a mile. The beds consist of conglomerate and sandstone marked by a red colour, less brilliant than the beds of the Triassic areas to the east but brighter than the sandstones and conglomerates of the Carboniferous formations. Their general trend is northeast and the dips are to the northwest at angles up to 35 degrees. No actual contact with rocks of other formations was observed. To the east are several outcrops of basic volcanic rocks believed to be of Pennsylvanian age, and the sandstone beds apparently dip off these at a low angle.

As in the shore section, the material is fresh, friable, and only partly cemented, and the beds are not cut by quartz or carbonate veins or stringers. The boulders in the conglomerate beds are rounded, subangular, and angular, the largest observed having a diameter of about one foot. Limestone boulders of white, grey, bluish, and pink shades are abundant, and granite and granite-gneiss ones are about equally so. Greenstone pebbles are also common, and for the most part are well rounded. To the northeast of the highest peak certain beds contain pebbles and boulders of sandstone. Most of these are flat and angular, and a few have a greatest diameter of about a foot. Many have a purplish colour and contain mica, and are similar in character to certain beds of the Balls Lake formation. There can be no doubt that the beds containing these pebbles are not only younger than the Balls Lake and West Beach rocks, but that they were formed after these had been deformed into the condition in which we now see them.

No fossils have been found in the beds. It is possible that they may be of Lancaster age, but their general appearance, freshness, and structure suggest that it is more probable that they are Triassic.

This interpretation of age removes the difficulty that earlier workers in the field experienced in settling the age of the Mispek rocks. It was assumed that the Lyons Head beds, on account of their general lithological character, must necessarily be correlated with the Mississippian Kennebecasis strata. The adjacent Mispek rocks, which are much more altered, must be older, and hence were called Devonian or Silurian or Precambrian. With the recognition of the Triassic age of the Lyons Head beds, the succession everywhere falls into normal order.

PLEISTOCENE

Deposits of Pleistocene age comprise till or boulder clay, stratified gravels, and marine clays and sands. The till is evidently morainic material left after retreat of Pleistocene ice-sheets. Abundant testimony to the presence of one or more ice-sheets is afforded by polished and striated rock surfaces. Hard rocks, such as volcanics, show the best smoothing

and polishing. In places, as for example the summit of Porcupine Hill near the mouth of Black River, there are broad grooves as well as fine striæ; and lee and stoss slopes are also well shown. Erratics, too, are seen nearly everywhere, some fields in parts of the settled area being full of them. Most of the boulders are of local origin or have been transported only short distances.

The general direction of ice advance throughout the region, as shown by striæ, was southerly, but there was considerable local variation in direction of movement. Many striæ trend south to south 20 degrees east, whereas a few run southwest. Along the coast at a number of places there are striæ that trend south 65 degrees east.

The thickest deposits of boulder clay appear to be along the coast. West of the mouth of St. John River a bank of till borders the shore as far east as Sand Cove. It is for the most part an irregular mass of boulders, clay, gravel, and sand. At the Fern Ledges, however, a bed of stratified clay, 9 feet thick, occurs within the deposit about 10 feet above the foot of the bank. Above this bed is about 40 feet of coarse, gravelly boulder clay. At Negrotown Point a bank of boulder clay rises about 40 or 50 feet above the beach.

Stratified gravels and sands are widespread over the area, and at numerous places good sections are exposed where material has been excavated for road construction. They commonly show coarse crossbedding. Many of the deposits are hummocky ridges or kames along river valleys, and others are in the form of terraces. Examples of such terraces occur along Ratcliffe Brook and on Germaine Brook below Hardingville. Terraces and kames also occur along the valley from Loch Lomond to Barnesville and towards Hammond River at Upham. Terraces on the east side of Second and Third Lakes above Loch Lomond indicate that a body of water at one time stood at levels of 50 to 75 feet higher than the present level of the lakes, and that it occupied a much larger area.

Local deposits of clay and sand carry a marine fauna of sub-arctic species that is correlated with that of the Champlain stage of late Pleistocene time. These deposits are generally classified as *Leda* clay and *Saxicava* sand. A terrace of *Leda* clay occurs at Sand cove, Lancaster, and the present elevation of these terraces records a greater submergence of the land below sea-level in Pleistocene time than at present.

CHAPTER IV

STRUCTURAL GEOLOGY

The consolidated surficial rocks of the St. John area fall into six main structural groups, based on the amount of deformation that they have undergone. The first or oldest is an early Precambrian sedimentary complex which is extensively altered and intruded by plutonic rocks and dykes. The second is a late Precambrian volcanic complex of great thickness. The third is made up of Cambrian and early Ordovician sediments. The fourth and fifth groups are of Carboniferous age. Of these the earlier is locally extensively deformed and intruded by igneous rocks, whereas the later is much less deformed. The sixth, or last, group consists of fresh Triassic beds, which are locally faulted but otherwise little disturbed. An interesting feature about the general structure is that although each of the groups is separated from the one preceding it by an unconformity the beds of all have for the most part the same general trend, showing that at successive periods the deforming forces acted along the same general lines.

EARLY PRECAMBRIAN COMPLEX

The early Precambrian rocks are all highly altered and extensively intruded. The carbonate rocks are all more or less metamorphosed and some are marble. The siliceous rocks are chiefly recrystallized quartzites. Some varieties have gone over into schists and gneisses. In some zones it is difficult to differentiate gneissic material of sedimentary origin from gneisses of igneous or partly igneous origin. Dips are characteristically high and repetition of zones suggest isoclinal folding. The rocks were evidently deformed and are believed to have been intruded by plutonic masses prior to the formation of the succeeding late Precambrian volcanic group.

LATE PRECAMBRIAN COMPLEX

The late Precambrian complex consists dominantly of volcanic rocks, flows, breccias, and tuffs of both acid and basic composition. Associated with them are sediments of which some conglomerate phases contain well-worn boulders of quartz, quartzite, gneiss, and granite, derived evidently from a terrain of early Precambrian rocks. The rocks on the whole are much less altered than the early Precambrian group. Many in hand specimen are fresh looking and massive; others, however, particularly the tuffs, are in places schistose. On the whole they appear to lie in more gentle folds than the older rocks, and at one place they show an unconformable relation to beds of limestone belonging to that group. The younger series is cut by basic dykes, probably related to the volcanics, and it is likely that many of the dark dykes that cut the older sediments and their plutonic intrusives date also from this period of volcanism.

The volcanic complex is intruded by granite. In the Golden Grove road region west of Kelly Lake, along the contact zone between the volcanics to the southeast and granites and granite-gneiss to the northwest, the greenstones are in places converted into hornblendic contact phases and in places are shot through by a network of small granitic dykes. Masses of red granite also occur in other places cutting the volcanics. Whether these are of late Precambrian age or belong to the Devonian period of intrusion that is known to have affected the region immediately to the west is not known.

CAMBRIAN-ORDOVICIAN ROCKS

The Cambrian rocks are sediments that have been metamorphosed to about the same extent as the late Precambrian volcanics. They commonly have steep dips and are in many places cleaved and sheared into phyllitic types. One zone is a quartzite. In many places deformation distorted fossils present in the strata and in others probably destroyed them.

The rocks are clearly separated by a break from the preceding volcanic complex. By the time Cambrian deposition began volcanism had ceased. The volcanics were undergoing erosion at the beginning of this period of deposition for the basal Cambrian conglomerates contain numerous water-worn pebbles derived from the complex.

The Cambrian rocks have nowhere been found to be cut by granite masses or by granite dykes, but a few small augite porphyrite dykes are known to intrude them. The rocks were almost certainly deformed in Devonian time by mountain-building forces which affected much of New Brunswick. Where Cambrian beds are found near exposures of Mississippian rocks, such as east of French Village and southwest of Upham, they are much more altered and deformed than the adjacent Kennebecasis, Upham, or Hammond River strata.

CARBONIFEROUS ROCKS

Although the Lower Carboniferous rocks of the Kennebecasis and Hammond River regions are tilted and faulted they are otherwise little altered. They are strikingly fresh as compared with any of the preceding formations. They are the first beds in which granite boulders and pebbles are abundant.

An interesting feature, however, is that east of St. John city there is a belt of rocks which, although younger than the comparatively little disturbed Mississippian rocks of the Kennebecasis and Hammond River valleys, show evidence of much deformation. These disturbed Mispek beds, from their plant remains, are apparently of early Pennsylvanian age. They consist of sediments and volcanics and are intruded by dykes and sills of diabase and granite. The beds are also sheared and squeezed and are cut by numerous large quartz veins. They are overlain unconformably by later Pennsylvanian beds carrying a large number and variety of plant remains. These later beds are fresh, are not cut by intrusives, and do not contain large quartz veins. Evidently in early Pennsylvanian time there was a period of deformation accompanied by volcanism and intrusion. The movements and intrusion were restricted, however, to a limited zone

and did not affect the Kennebecasis and Hammond River region, as the Mississippian rocks of that belt resemble structurally the younger Pennsylvanian rocks of the eastern belt much more than they do the older Pennsylvanian ones. Movements again took place at the close of the Palæozoic, as is evidenced by the fact that the later Pennsylvanian strata are more deformed locally than are any of the Triassic beds.

TRIASSIC BEDS

The Triassic beds have as a rule gentle dips, though in places they are tilted at angles as high as 35 degrees. A number of their contacts with other formations are fault-contacts. This faulting may possibly date from the Jurassic.

LATER STRUCTURAL HISTORY

Later events in the history of the area must be inferred from the physiography, and from what is known about adjacent regions. In the Cretaceous the region was peneplained, and following subsequent uplift in the Tertiary a second peneplain was developed on the softer strata. It is probable, too, that in the Tertiary, rock terraces were cut along the Fundy coast. During the Pliocene there was renewed uplift, raising the region considerably above its level. During this period St. John River cut its channel below the present sea-level. Depressions as much as 200 feet below Bay of Fundy high tide level are known in both the lower part of the St. John Valley and in Kennebecasis Bay. During the glacial period there was a subsidence of the land, and although in Recent times there has been uplift it has not been sufficient to bring the region back to its pre-glacial level. From the evidence of a peat or forest bed beneath the Tantramar marsh at the head of the Bay of Fundy and from drowned peat beds elsewhere along the coast Chalmers (1890, page 10) inferred that the upward movement continued until the land was some 80 feet above the present high tide level. Since then, according to him, slow subsidence has been in progress until recently, and now the region is stationary or nearly so.

Post-glacial earthquake movements have produced a certain amount of Recent deformation. Matthew (1894a) found at St. John a considerable number of glacial striæ that are offset by fractures. Some of these small faults have throws of several inches. The largest throw observed was 5 inches.

CHAPTER V

ECONOMIC GEOLOGY

Although a few localities in the region show signs of mineralization no metallic deposit of economic importance has as yet been located. Reference will be made, however, to a few showings. Of the non-metallic materials the most important are limestone and dolomite.

COPPER

Chalcocite occurs on an island in Kennebecasis Bay about a mile north of Millidgeville. The area was staked in 1916 and some development work was done (Alcock, 1930). The rocks on the island consist of limestone of the Green Head group cut by masses of gabbro. The limestone has irregular strikes and dips and in places is altered to a lime-silicate rock consisting of pink garnet and green epidote. Chalcocite occurs as small masses and grains in these altered parts. There appears to be no definite trend or regularity to the deposit and the amount of chalcocite is small. The deposit had evidently a contact metamorphic origin and the probable source of the copper was the granite that intrudes the Green Head rocks on the mainland.

ZINC-LEAD

A small showing of zinc and lead minerals on which a little development work has been carried out occurs at Quispamsis on the railway line from St. John to Sussex. The occurrence is right beside the railway track, one-quarter mile northeast of Quispamsis station. Massive red granite has been uncovered for a distance of one-quarter mile, and at the mineral deposit contains an inclusion of limestone of the Green Head group. The limestone mass has a width of about 15 feet and contains a little pyrite, some dark sphalerite, and a little galena. The deposit is apparently of contact metamorphic origin. It does not seem to be economically important.

QUARTZ

Quartz veins are numerous in the Mispek group of rocks in the shore zone from St. John east to Black River, and a few are of considerable size. One outcrops on the north side of Black River about 200 feet below the mouth of the East Branch. The vein has a width of 13 feet and is exposed for a length of 40 feet in the bank and bed of the river. It strikes northeast and has clean cut vertical walls composed of Carboniferous conglomerate. The vein material is white quartz with no signs of sulphides or other minerals. A sample on assay yielded only a trace of gold.

On the summit of Porcupine Hill near the Black River road are several prominent veins and masses of white quartz which show up distinctly against the dark red conglomeratic rock that they cut. One vein has a

width at one place of over 15 feet and can be followed continuously on the surface for 200 feet. Like the vein mentioned above, these occurrences consist solely of white quartz.

A large mass of quartz outcrops on the shore about one-quarter mile southwest of Upper West Beach. The outcrop is 100 feet wide and in front of it on the shore are huge blocks of similar material 20 to 30 feet across. The mass cuts purplish bedded rocks. No sulphides were observed in it.

IRON

In the belt of rocks extending along the coast from Cape Spencer past West Beach to Black River there are small veins of bluish specular hematite or quartz with hematite cutting both the sedimentary and volcanic rocks. At places in this zone some of the sediments are stained reddish with iron. Most of the veins are less than an inch in thickness, and at no place so far as known are there indications of any deposit with economic possibilities.

MANGANESE

A deposit of manganese that at one time attracted attention occurs at Quaco Head about 2 miles south of St. Martins. The occurrence is on the shore at the foot of a cliff in a small bay immediately south of a band of white limestone which forms a prominent feature of the shore about one-quarter mile north of the lighthouse. The deposit was known prior to 1870 and was worked in a small way at intervals until 1889. It is said that several hundred tons of ore were mined. In 1889 the property was taken over by the Brunswick Manganese Company. A certain amount of development was undertaken although there are no records of how much ore was produced, and it is possible that no ore was shipped.

The rocks of the vicinity consist of Precambrian volcanics, Carboniferous limestone, sandstone, and conglomerate, and Triassic sandstone, shale, and conglomerate. The volcanics are dark purple to dark green. On the weathered surface they are seen to be made up of angular fragments, and the rock is clearly a volcanic breccia. A prominent sea-stack or flower-pot north of the deposit is made up of these rocks.

The volcanics are overlain unconformably by a limestone that is for the most part white, though locally reddish. The limestone has penetrated the volcanic fragments, and in places completely surrounds some of them. In places the carbonate seams go down as much as 2 feet into the older rock. Early descriptions refer to the volcanic as a younger rock intrusive into the limestone. The limestone has a thickness of about 20 feet. The band dips gently seaward, and is broken in places by small faults.

The limestone is overlain by conglomerate which is hard and well-cemented and shows a great variety of boulders, many of which are composed of granite. At low tide exposures of this conglomerate can be seen above the limestone. Similar rocks form high cliffs extending south towards Quaco Head. At the cove where the manganese deposit occurs there is a fault bringing the limestone against these conglomerates.

Capping all these rocks are Triassic red beds which consist of pebbly conglomerate, sandstones, and sandy shales, dipping at angles of about 35 degrees to the northwest.

The manganese occurs as small irregular veins and nodular masses in the faulted zone referred to above. The rock here is so crushed that it is a crumpled mass of rhombohedral fragments. Ore minerals also occur in the conglomerate zone on one side and as small veins in the limestone on the other. The minerals in the ore are psilomelane, pyrolusite, manganite, barite, and calcite. Some of the material is porous and honeycombed. Nodular masses up to 2 feet in diameter have been found. Owing to the slide of loose material from the cliff above, little evidence of mineralization can be seen at the present time, and it is probable that previous descriptions are correct in stating that the amount of commercial ore present here is small (Penrose, 1890).

LIMESTONE AND DOLOMITE

Limestone and dolomite are quarried at several places near St. John city. The rocks belong to the Precambrian Green Head group, and the principal quarries are on Green Head Peninsula, at Indiantown, and at Brookville. Some of the high calcium limestone is used in the pulp industry; dolomitic limestone is used for the manufacture of limestone fertilizer and a considerable amount of rock is quarried for ballast and road material. A detailed description of the various quarries of the region is given in Mines Branch Publication No. 742 (Goudge, 1934).

ROAD METAL

The area is well supplied with road metal. Gravel pits are numerous and conveniently situated adjacent to the main roads, and limestone and volcanic rocks are available for crushing at strategic places.

GYPSUM

Gypsum occurs as part of the Upham formation along Hammond River in the parish of Upham, in the northern part of the area. The belt runs in a general east and west direction and crosses both Hammond River and the railroad that runs to St. Martins. The gypsum-bearing zone can be traced partly by outcrops and partly by the presence of ponds and typical gypsum sink-holes. One outcrop occurs on the river about 1 mile below the railroad bridge. Other more prominent ones occur at points 1½ and 2½ miles eastward from the railway. Some of these outcrops stand up as ridges 30 feet high with very little overburden. Jennison (1910) estimates that the gypsum-bearing belt covers some 250 acres.

The rock on the weathered surface is white and fractured, but several feet down it is massive and compact. At a number of places anhydrite was noticed. The following analyses show the composition of average samples taken by Jennison. No. I is of snow-white material collected from the Hammond River outcrop. No. II is white material collected 2½ miles to the east.

—	I	II
	Per cent	Per cent
Lime	32·40	32·61
Magnesia	tr.	tr.
Ferric oxide and alumina	0·10	0·34
Sulphuric anhydride	46·12	46·72
Carbonic anhydride	0·75	
Water, loss on ignition	20·40	20·55
Insoluble mineral matter	0·06	0·12
	99·93	100·34

In 1907 a certain amount of material was quarried and shipped to St. John, after which operations were discontinued. It is possible that future work may reveal deposits of economic importance, and transportation facilities are good.

CLAY

A deposit of clay near Brookville (Alcock, 1930) may some day be of importance. As there is an abundance of limestone nearby it may be utilized for the manufacture of cement. The deposit lies in a marshy area drained by the northwest branch of Marsh Creek, and was evidently formed as a lake deposit. Borings are said to show thicknesses of 30 to 40 feet of clay, and one boring went to a depth of 180 feet without encountering bedrock.

GRAPHITE

Graphite occurs in at least two places in the area, one at St. John city near the Suspension bridge over the Reversing Falls, and the other west of the Golden Grove road about one-half mile northwest of Shaw Lake. In both places the mineral is associated with limestone of the Green Head group.

The former locality is near the water's edge on the east side of St. John River near its mouth. The first work was carried out there around 1872 and some graphite was shipped to the United States. Later, work was undertaken about 600 yards from the river and a few hundred tons were taken out, which were also sold in the United States. Still later, a shaft was put down 200 feet northeast of this latter working and 4 feet from the face of the limestone cliff. The deposit was reached at a depth of 15 feet. It widened rapidly until at a depth of 30 feet it was 8 to 10 feet wide. A drift was run at this level to the northeast and a continuous mass of material was found between layers of limestone and a dark igneous rock as far as the work was carried out. Some $1,200 worth of graphite was sold; but trouble with water and in marketing the material caused the work to be discontinued. The property was later worked for a short time by the Canada Paint Company (Bailey, 1898a, pages 72-74).

The deposit northwest of Shaw Lake lies in an inclusion or roof pendant of limestone in granite. The bedding of the limestone is about vertical and the graphite lies along the bedding planes. A maximum thickness of about 2 feet is exposed. It is unlikely that any large tonnage is present.

CHAPTER VI

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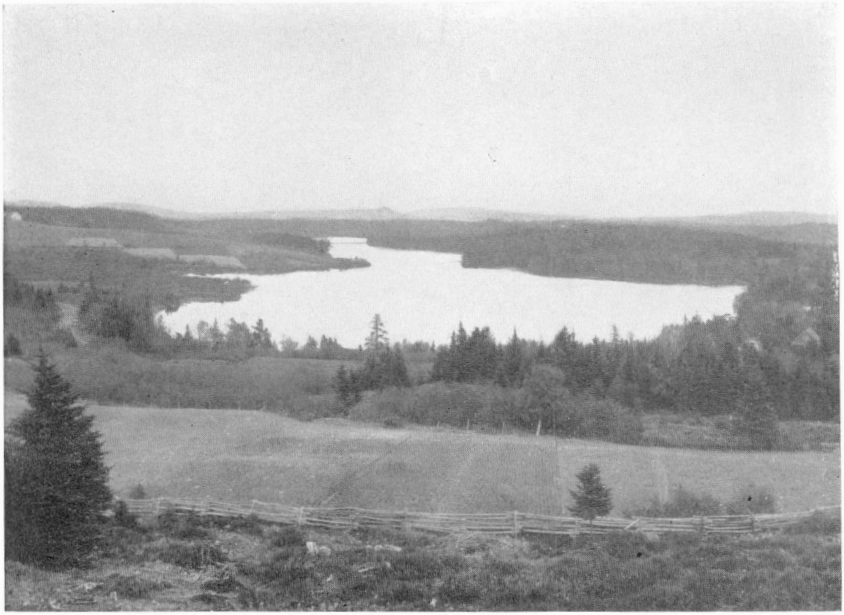


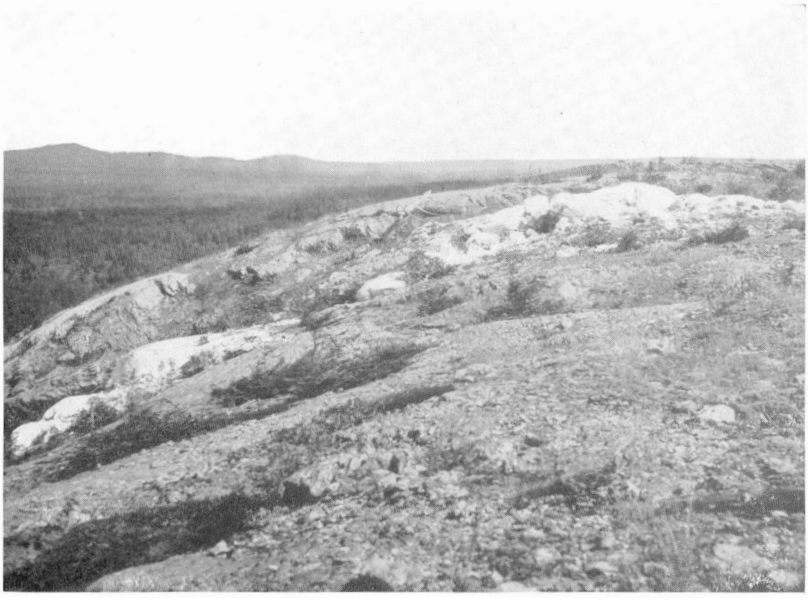
A. Looking northeast up Marks Lake, Damascus ridge region. (Page 4.)

B. The glacial dam between Loch Lomond (right) and Second Lake (left), Bloomsbury ridge in the background. (Page 5.)

A. Looking southwest from Beveridge Cove, showing the abrupt character of the coast. (Page 6.)

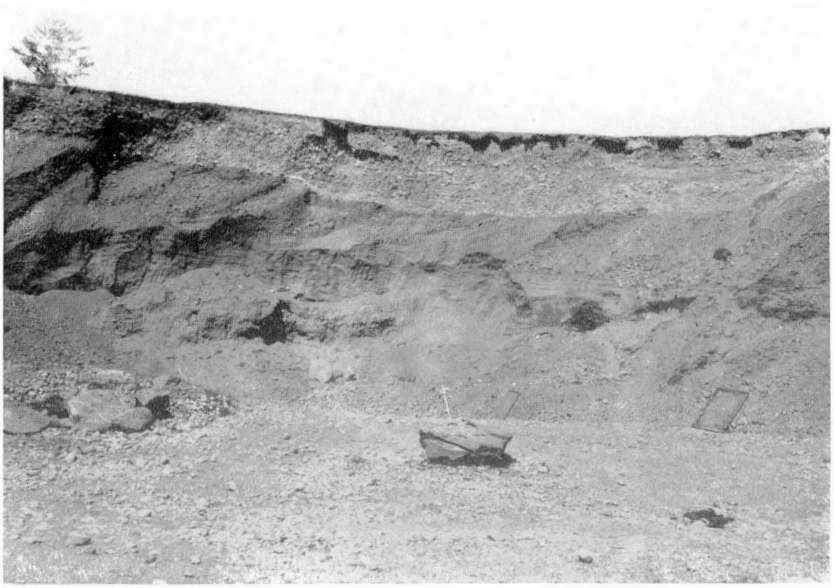
B. Carboniferous basic volcanics of West Beach formation at Beveridge Cove. (Page 34.)

A. Carboniferous hills at Mispek. (Page 35.)



B. Large quartz masses cutting sediments of Balls Lake formation, Porcupine Hill, near Black River. (Page 33.)

A. Tilted Triassic red beds with sea caves at St. Martins. (Page 40.)



B. Crossbedded Pleistocene gravels used for road material, near Silver Falls. (Page 43.)

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