RLC

CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

MEMOIR 241

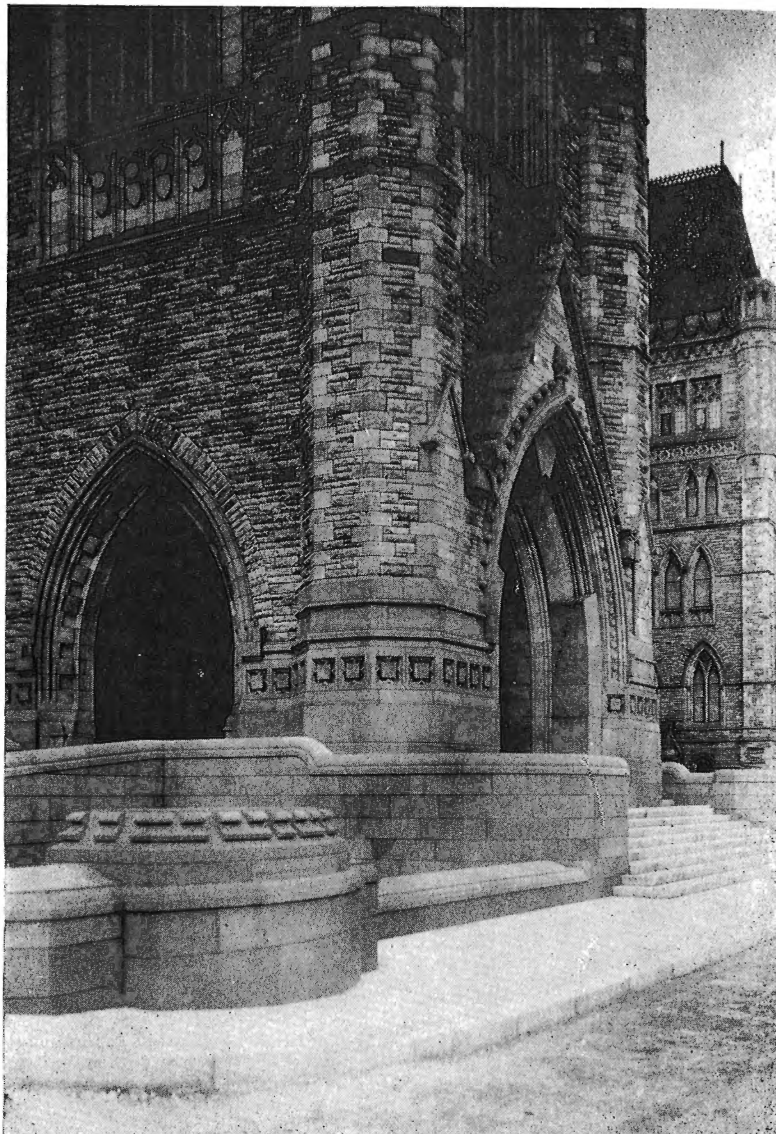
GEOLOGY OF THE OTTAWA-ST. LAWRENCE LOWLAND, ONTARIO AND QUEBEC

BY
Alice E. Wilson

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1946

$1.00
Price, ~~25 cents~~

No. 2474



Base of Peace Tower of the main building of the Parliament Buildings at Ottawa, showing the use of Nepean sandstone in the structure. The trimming stone used at the base and at intervals in the tower is another sandstone, from Nova Scotia.

*ERRATUM

GEOLOGICAL SURVEY OF CANADA MEMOIR 241

INDEX

*Please insert.

INDEX—CONTINUED

INDEX—Continued

INDEX—Concluded

CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

MEMOIR 241

GEOLOGY OF THE OTTAWA-ST. LAWRENCE LOWLAND, ONTARIO AND QUEBEC

BY
Alice E. Wilson

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1946

Price, 25 cents No. 2474

CONTENTS

CONTENTS — *Concluded*

CHAPTER VI

Illustrations

PREFACE

The Ottawa-St. Lawrence Lowland represents an area in Canada of some 5,500 square miles lying mainly between and west of the junction of St. Lawrence River and Ottawa River. It forms a characteristic part of the much larger province of the St. Lawrence Lowlands, underlain by flat-lying Palæozoic formations that, in turn, rest unconformably on an eroded basement of much older Precambrian rocks. The Ottawa-St. Lawrence Lowland includes the city of Ottawa, and for more than a century has been subject to intermittent geological study and palæontological investigations.

The present account is based largely on the author's own field work extending over a period from 1925 to 1941, inclusive. It deals, for the first time in connected form, with the Palæozoic geology and economic resources of the area, and is illustrated by a general geological map of the region and by two more detailed maps of the area about the city of Ottawa. The memoir includes a full bibliography of the many contributions concerned with the geology or palæontology of the Ottawa-St. Lawrence Lowland. This is intended to serve a dual purpose, as a guide to future investigations of early Palæozoic formations in other parts of Canada, and as a convenient reference bibliography for a series of presently planned Geological Survey Bulletins that will deal particularly with the identification and description of the prolific fauna of the Ottawa formation.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, September 25, 1945

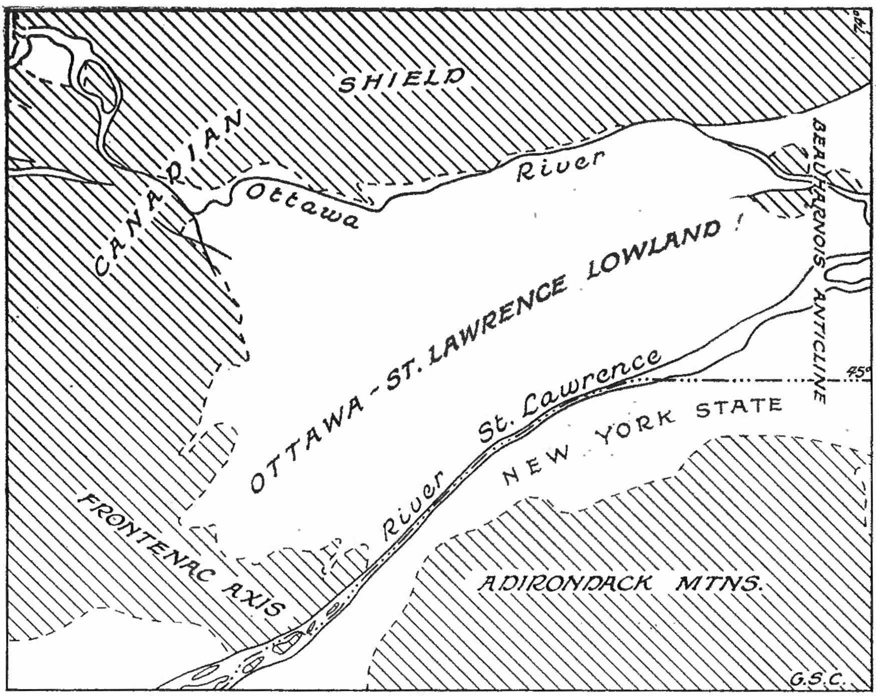


Figure 1. Figure showing the position of the Ottawa-St. Lawrence Lowland relative to adjacent areas of Precambrian rocks (in ruling).

Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The Ottawa-St. Lawrence Lowland is a well-defined basin within the greater physiographic province of the St. Lawrence Lowlands, and the greater part of it, here described, lies north of the International Boundary. The basin occupies, altogether, an area of some 7,900 square miles (*See* Figure 1) lying between the Laurentian Highlands of the Canadian Shield on the north and the Adirondack Mountains on the south. Its western margin is along the Frontenac axis, an irregular, northwesterly trending belt of Precambrian rocks, which connects the Canadian Shield with the Adirondacks and forms the Thousand Islands where it crosses St. Lawrence River. The eastern border is defined by a lesser axis named by Logan (1863) the 'Beauharnois anticline', and which extends from the Canadian Shield near St. Jerome, Quebec, south to the Adirondacks. This axis is mantled with basal Palæozoic sandstone, except near Rigaud and the Lake of Two Mountains where Precambrian rocks emerge through the sandstone to stand above the surrounding country.

The Canadian part of the Ottawa-St. Lawrence Lowland has an area of about 5,500 square miles, most of which is included within the borders of the accompanying geological map (No. 852A, in pocket). The present discussion of the Palæozoic formations, however, includes reference to the remainder of the basin extending west to the Canadian Shield and southwest to the Frontenac axis.

The map-units used in this report are defined by lithological changes and by recognizable disconformities. New names have been introduced to clear the confusion arising on the one hand from the use of the same name for a formation and for the period in which it was deposited, and, on the other hand, from the use of names of formations and members to designate what are really faunal associations. This confusion is particularly evident in the several classifications of the beds that constitute the Ottawa formation.

PREVIOUS HISTORY

In 1841 and 1842 Sir William Logan, preparatory to his directorship of the Geological Survey, made brief reconnaissance explorations in parts of the basin under present consideration. He recorded some general observations and gathered some fossils. His Preliminary Report dated December 6, 1842, gives some description of the Ottawa and St. Lawrence Valleys. The fossils collected were submitted to British geologists who "with cautious hesitation" pronounced that the containing strata belonged to Murchison's Lower Silurian system.

In his Report of Progress for 1842, Logan outlined the margin of the Palæozoic rocks west of a line that extends northeast from Lake Champlain to Quebec City. He traced the basin west beyond the present city of Ottawa, south to the Rideau Lakes and Brockville, and east again to Lake Champlain. He then described the rocks at the southwest of the region as continuing westward to the Mohawk Valley and recrossing the Canadian boundary at Kingston, from which point he outlined the boundaries of the rocks of central and western Ontario. Although he regarded all the Palæozoic rocks of eastern and western Ontario as parts of one basin, it can be seen that he recognized the existence of the Frontenac axis. In a succeeding report, for 1845-46, he gave a more detailed description of the Ottawa Valley, and though still a little vague about the Frontenac axis he recognized an eastern and a western area of Palæozoic rocks.

In 1851 Alexander Murray explored a part of the eastern area, using the New York nomenclature to describe the formations he encountered. He also recognized a number of the faults. In 1853 Murray ascended Ottawa and Bonnechère Rivers, and in 1854 he traversed the Great Lakes, and, on his return to Ottawa Valley via Georgian Bay, discovered the Palæozoic inliers bordering the valley of the upper Ottawa.

Logan's 1863 report on the Geology of Canada includes scattered descriptions of the Palæozoic formations within the Ottawa-St. Lawrence basin. In this report he first mentions the Beauharnois anticline, which marks the eastern boundary of the basin under discussion, though he describes it only in its southern part, from the International Boundary to the Lake of Two Mountains.

The first map to include the Ottawa-St. Lawrence Lowland was issued in 1864 to accompany Logan's 1863 report. Four geological maps by R. W. Ells were issued by the Geological Survey in the years 1901 to 1906. These covered the Palæozoic lowland region and much more of the adjacent Precambrian terrain. In 1906 the Geological Survey issued a more detailed map by Ells of the district immediately around the city of Ottawa. Since that date several maps have been published that include only small parts of the basin.

In 1856 Elkanah Billings was appointed Palæontologist to the Geological Survey, and was responsible for the determination of fossils and the stratigraphy of the basin as represented in the 1863 report. In 1857 he visited and described some of the Palæozoic inliers just beyond the northwest margin of the basin. From his appointment until his death in 1875 most of Billings' numerous publications contained descriptions of fossils from this region.

In 1874 and 1875 H. G. Vennor ascended Ottawa River. He was concerned mainly with the Precambrian rocks of the region, but in his reference to the Palæozoic formations he was the first to note the absence of the Potsdam and the Beekmantown from the base of the extreme end of the tongue of Ordovician rocks that extends up Ottawa Valley. Traces of the Beekmantown, but not of the Potsdam, have since been found. Vennor describes outcrops of Chazy limestone, which are now considered to be the base of the Ottawa limestone, the Pamelia beds of Black River age.

In 1895 N. J. Giroux, who had been doing geological work in Quebec, was assigned to study this basin. He was 'in the field' during 1895 and 1896, but died the following winter. His uncompleted work was incorporated in several maps and reports by R. W. Ells.

During the years 1891 and 1896 R. W. Ells was assigned to the study and mapping of the Precambrian region bordering the northern and western margins of the Palæozoic basin. His surveys necessarily included some of the Palæozoic rocks, and in 1897, after the death of N. J. Giroux, he undertook the completion of the main Palæozoic basin. As the work proceeded the results were published in the several Annual Reports of the Geological Survey.

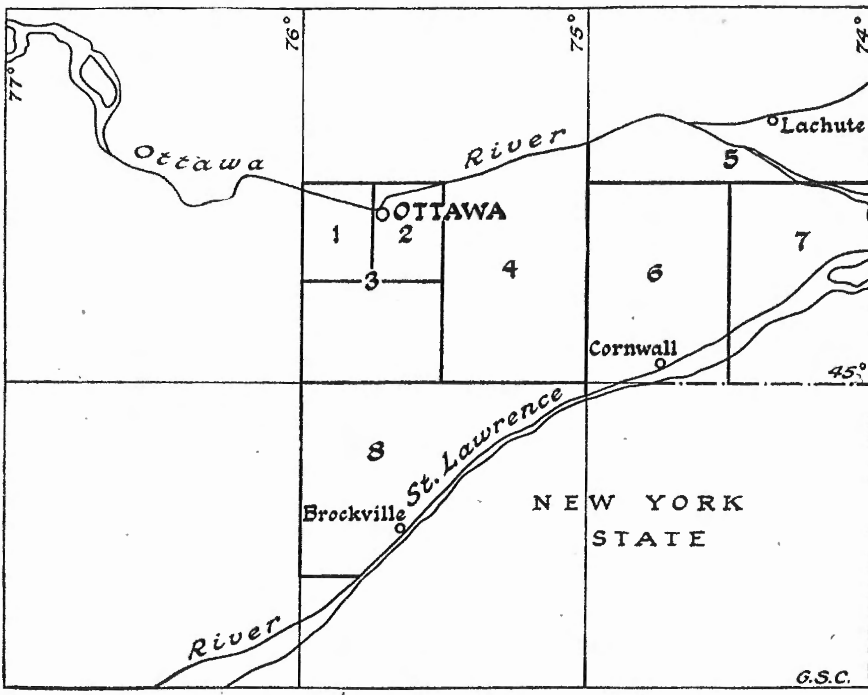


Figure 2. Index of separate geological maps covering parts of the Ottawa-St. Lawrence Lowland: (1) Map 413A, Ottawa sheet (East Half); (2) Map 414A, Ottawa sheet (West Half); (3) Map 588A, Nepean; (4) Map 587A, Casselman; (5) Map 662A, L'Orignal; (6) Map 661A, Maxville; (7) Map 660A, Valleyfield; (8) Map 710A, Prescott.

A number of later papers, included in the Bibliography, dealing with various geological aspects of parts of the region, have been published by several authors: H. M. Ami, W. A. Johnston, P. E. Raymond, M. E. Wilson, E. M. Kindle and L. D. Burling, A. E. Wilson, and others.

The Pleistocene and Recent geology of the Ottawa-St. Lawrence Lowland is treated in this report in a general way only. In most of Logan's reports prior to 1863 he made some reference to the surface deposits, but in the Geology of Canada of 1863 his treatment of Pleistocene and Recent geology and physiography is more detailed. In 1898, Ells described the sands and clays of the Ottawa basin, and in the same year W. J. Wilson published some notes on the Pleistocene geology of the district. In 1901 Ells described some ancient channels of Ottawa River, basing his conclusions on records of well borings.

The first systematic study of the Pleistocene of a limited district within the region was carried on by Joseph Keele and W. A. Johnston for the XIIth International Geological Congress excursions. In 1916 Johnston discussed the various oscillations of sea-level in the Ottawa district during the latter part of Pleistocene time, and in 1916 he published a study and map of the Pleistocene and Recent deposits of the area.

In 1922 E. J. Whittaker made a comparison of the fossil and present invertebrate fauna of Mackay Lake, Ottawa, and in 1926 E. M. Kindle similarly studied the fossil and modern diatoms of the present and late Lake Champlain stages of the same lake.

FIELD WORK AND ACKNOWLEDGMENTS

The field work for this report was carried on from 1925 to 1941, with some interruptions. Within the area mapped (*See* Map 852A, in pocket) every known outcrop of Palæozoic rocks was visited and plotted.

Much of the bedrock is covered by unconsolidated glacial and marine sediments. The interpretation of the stratigraphy, the ranges of fossil species, and the boundaries of formations as indicated on the Nepean, Prescott, Casselman, L'Orignal, Maxville, and Valleyfield maps (Figure 2), are based upon field observations, the study of thicknesses obtained from many wells, and upon the construction of more than a hundred parallel and intersecting structure sections.

The writer wishes to express indebtedness to I. Gringorten, J. A. Calder, J. Lambert, and R. Lill for their able and untiring assistance during four consecutive field seasons, 1936 to 1939. Gratitude is also expressed for information and courtesy from the managers of quarries and plants, garagemen, and many other residents of the region.

CHAPTER II

GENERAL CHARACTER OF THE AREA

The surface of the Ottawa-St. Lawrence Lowland rises gently to the west in places as a series of low steps. The minimum elevation, 70 feet above sea-level, is near the mouth of Ottawa River along the eastern margin of the basin. Immediately to the north, along the 'Beauharnois anticline', the low floor is interrupted by steep, Precambrian inliers with an elevation of 600 feet. The saddle between these inliers and the Canadian Shield to the north has a minimum elevation of 175 feet. Southward along the Beauharnois anticline towards the Adirondacks the floor rises gradually from the 70-foot minimum to an elevation of 250 feet, then abruptly to 600 feet, to a sandstone highland that extends east and south beyond the map-area. From the minimum elevation on its eastern margin the floor of the lowland gradually rises to a maximum of 500 feet at the Frontenac axis on the west.

Within the lowland region the Palæozoic bedrock is covered by unconsolidated Quaternary deposits, or outcrops in low ridges and scattered exposures. Only near its northern margin, where faulting has disturbed the originally flat-lying sediments, is any considerable thickness of bedrock exposed.

The entire lowland is a basin roughly triangular or subquadrate in outline, drained by the upper St. Lawrence and lower Ottawa Rivers and their several tributaries. The St. Lawrence flowing northeasterly crosses the western part of the basin. In part of its course it forms the International Boundary and truncates the Canadian part of the basin on the south and west. East of the point where the boundary changes to follow the 45th parallel the river continues within the lowland region under discussion. The St. Lawrence flows at a higher elevation than the Ottawa. It falls over a long series of rapids, attaining the low level of the Ottawa only a short distance west of the junction of the rivers.

The older Palæozoic formations bordering the St. Lawrence are not much disturbed by faulting. The height of land between the two rivers everywhere lies within a few miles of the St. Lawrence. Ottawa River, to the north, flows at a lower level because the region is down-faulted along a series of faults at or near the Precambrian margin. The expression of the break between the Laurentian Highland and the lowland region varies from place to place. Along the eastern quarter of the margin, a fault brings the oldest Palæozoic formation adjacent to but considerably below the level of the Precambrian rocks. On the east-centre quarter the faulting occurs within the Palæozoic rocks themselves. On a part of the western half, above Ottawa, the basin is limited abruptly on the north by the Eardley fault scarp, where the Precambrian rises in places to 1,100 feet above sea-level. In the western quarter there is no broad lowland, and, consequently, no clearly defined margin.

Ottawa River crosses this irregular terrain along fault lines or flows in and out around fault blocks. Its comparative youth is well illustrated near the city of Ottawa. For some miles above the city it flows in an erosional or slightly faulted trough between the rocky banks of a low, plateau-like area;

on the southwest side of the river the removal of the Ottawa limestone from the surface has exposed the weaker Rockcliffe shales and sandstones, and the river has widened its bed, forming Lake Deschênes. Nearer the city it is again narrowed, traversing a complicated faulted zone of Ottawa limestone over which it flows in a series of rapids culminating in Chaudière Falls. Emerging from the confining banks of Ottawa limestone it again broadens somewhat, flowing less swiftly and depositing the sediments scoured from above the city.

In March and Torbolton townships a low depression separates that part of the limestone-capped plateau on the west side of Ottawa River from the higher land to the south. The depression, evidently a former river channel, is now occupied by Constance Bay, Constance Creek, Constance Lake, Mud Lake, Shirley Creek, and Shirley Bay. A rise of less than 25 feet in the present average water-level of the Ottawa would again make an island of cons. VI, VII, and VIII, March and Torbolton tps., and at the same time would flood another depression south of Lake Deschênes, now drained by Watts, Still, and Water Creeks. Below Ottawa the river valley is outlined by terraces of clay and sand lying against Precambrian rocks on the north side, and, on the south, linking isolated bluffs of Ottawa limestone that mark the position of some of the fault blocks. The summit of the bluffs, though higher in the Ottawa limestone section, has approximately the same elevation as the plateau-like banks above the city, and the elevation of their exposed bases is approximately that of river-level above the city.

The features of the Ottawa-St. Lawrence Lowland record a sequence of Precambrian events followed by a very long period of erosion; a series of Palæozoic deposits later subjected to faulting; a second, long period of erosion; glaciation; a last invasion and withdrawal of the sea; and subsequent erosion to present time. The deposition of the Palæozoic rocks and their lithological and structural features are considered in the following chapters. There is no evidence of submergence during the later Palæozoic, Mesozoic, or Tertiary times.

The basin lies within one of the oldest settled parts of Ontario and western Quebec, and has many historic landmarks connected with the struggles and early settlement of the country. Ottawa, the capital of the Dominion, is the largest city, but there are a number of smaller, progressive cities and towns, particularly along the St. Lawrence. Agriculture, especially dairy farming, has been the main industry for many years, but recently a rapid industrial growth has followed the increasing development of comparatively cheap electric power. The development of the potential power of the rapids of the International section of the St. Lawrence should greatly increase the population and industries of the region.

CHAPTER III

STRATIGRAPHY

GENERAL STATEMENT

The Ottawa-St. Lawrence Lowland is underlain by rocks of Ordovician age, with the possible exception of the basal sandstone. Some authorities consider the latter to be of late Cambrian age, but the evidence is not conclusive. The Ordovician formations include rocks of Beekmantown, Chazy, Black River and Trenton, Utica, Lorraine, and Richmond age. The maximum thickness is about 2,200 feet, though certain formations vary somewhat from east to west. Of this thickness the Lower Ordovician and possible Cambrian is represented by 350 feet, the Middle Ordovician by 900 feet, and the Upper Ordovician by 950 feet of sediments.

The strata have no general direction of dip and strike, and, particularly in the northern half of the region, are broken by faults and down-dropped fault blocks. Over the greater part of the basin the rocks are flat-lying or gently undulating, but they are tilted at varying angles in the fault blocks or on nearing the principal fault zones.

The Lower Ordovician sediments were laid in a shallow sea transgressing from the east. It deposited the typical sequence of sand and dolomite or dolomitic limestone, and some shale in the declining stages as the waters again withdrew to the east.

Between this emergence and the next invasion there was a long erosional interval during which rocks of Lower Ordovician and early Middle Ordovician age were laid down elsewhere. Thus, some 700 feet of Beekmantown sediments were deposited in the Montreal region, followed by an emergence, followed in turn by the deposition of 890 feet of Chazy rocks in Champlain Valley, none of which is represented in the Ottawa-St. Lawrence Lowland.

The Middle Ordovician sediments are mainly of limestone and were first deposited in this region when the Chazy sea spilled over into the basin from the Montreal area, not long before it, too, retreated again to the east. During the brief subsequent erosional interval there was evidently some warping of the entire region of northeastern America, for the next invasion of Middle Ordovician time advanced around the south side of the Adirondacks and entered the lowland basin from the west across the Frontenac axis.

The initiation of Upper Ordovician deposition is less certainly defined. The preceding erosional interval must have been short, for the top of the Middle and the base of the Upper Ordovician lacks no deposits known elsewhere. Drill records indicate an abrupt change in the nature of the limestone, but there is no well-exposed contact. In the Georgian Bay region a definite unconformity exists. The Upper Ordovician sediments of the Ottawa-St. Lawrence basin consist of shale, with the exception of a few feet of limestone interbedded with shale at the base and again at 100 feet from the top. The amount of shale indicates that at no stage was the basin very deep. Even during Richmond time, when thick beds of limestone were being deposited in the Arctic regions and to the west and southwest, only minor quantities of limestone were laid in this basin. The initial invasion into the lowland in Upper Ordovician time was from the north, but later it combined with a contemporaneous invasion from the Gulf of Mexico.

There is no evidence within the region of a later Palæozoic invasion, but younger rocks may have been laid down and subsequently worn off during the long erosional interval that followed. It is a curious fact, however, that no trace of either Silurian or Devonian boulders have been found in the till, though every other type of rock is represented from the earliest Precambrian to the latest Ordovician.

An immense interval of unrecorded time elapsed between the withdrawal of the latest Ordovician sea and the beginning of the glacial period, for at present the irregularly eroded surface of the Ordovician and Precambrian rocks is overlain directly by unconsolidated Pleistocene deposits of glacial till and varved clays, and by marine beds of clay and sand from the post-glacial Champlain Sea.

For practical mapping purposes and for use in the interpretation of well borings the formations to be described have been divided primarily upon a lithologic basis. In previous works the 'formations' within the larger time divisions have been based upon fossils that were thought to be typical of certain horizons. Further study of the fossils have shown that many forms have a longer range within the Ottawa limestone than at first supposed, their persistence or non-persistence largely depending upon local conditions. For example, it is possible to map the Black River-Trenton 'formations' as they have been defined on the bases of local lithology and of fossils considered to be diagnostic. A section, however, constructed upon thicknesses as they have been estimated on these bases in several localities, when adjusted to meet the requirements of exposures, would present unreasonable variations of thicknesses within sediments of continuous deposition.

TABLE OF FORMATIONS

Era	Period	Sub-epoch	Formation	Description
Cenozoic	Quaternary	Recent		Alluvium
		Pleistocene	Champlain	Marine clay and sand
				Till and varved clays
		Great unconformity		
Palæozoic	Ordovician	Richmond	Queenston	Red shale
			Russell	Grey shale with heavy interbedded dolomite
		Lorraine	Carlsbad	Grey shale and sandy, rusty shales with thin dolomitic layers near top
		Gloucester	Billings	Black shale with few feet of brown shale at base
		Collingwood	Eastview	Limestone with a little interbedded shale

TABLE OF FORMATION — *Concluded*

Era	Period	Sub-epoch	Formation	Description
		Disconformity		
		Trenton and Black River	Ottawa	Limestone with a little shale and some sand at the base
		Disconformity		
		Chazy	St. Martin	Impure limestone
			Rockcliffe	Shale with sandstone lenses
		Disconformity		
		Beekmantown	Oxford	Dolomite with a little shale at the top
			March	Interbedded sandstone and dolomite
	Ordovician or Cambrian		Nepean	Sandstone
Great unconformity				
Precambrian Archæan (?)			Grenville	Crystalline limestone, quartzites, and metamorphic rocks; associated granite and granite-gneiss

PRECAMBRIAN

It is not a purpose of this report to discuss Precambrian geology except in its relationship to the Palæozoic formations. In general, the Precambrian complex bordering and within the basin consists of crystalline limestones, gneisses, and quartzites, intruded, deformed, and metamorphosed by bodies of granite, syenite, and other igneous rocks. The existing reports and maps of these areas of Precambrian rocks are based mainly on reconnaissance work, only a few detailed investigations having been undertaken. References to both general and detailed studies are included in the Bibliography, Chapter VI of this report.

As previously noted the Precambrian complex forms the boundaries of the basin of Palæozoic formations to the north and west, and to some extent to the east. It also everywhere underlies the later sediments, as evidenced by well borings, and outcrops as isolated exposures within the lowland wherever the Palæozoic rocks have been eroded from above it. In some places it forms long tongues or ridges within the margins of the basin. Two such tongues extend southeasterly well into the Palæozoic basin from the Canadian Shield on the north. Both owe their position to faulting. One, adjacent to the Aylmer plain, is limited on the southwest by the Eardley fault, and on the east by a continuation of the Gloucester fault. The ridge slopes from an elevation of more than 1,100 feet to pass under unconsolidated surface deposits at about 325 feet. The other, a low ridge reaching an elevation of 425 to 450 feet, connects with the Shield in the region of Fitzroy Harbour, and extends across Torbolton and March townships to Nepean township. Its greatest elevation is along its southwest edge where it is cut off by the Hazeldean fault. On its northeast side, and at its terminus in Nepean township, it passes beneath the basal sandstone of the Palæozoic. Other ridges, which do not owe their origin to faulting, project into the Palæozoic basin from its southwest boundary west of Brockville, and from the western margin. They existed before the later marine invasions took place, and have been exposed by erosion. At the terminus of the two ridges in the Brockville region are a few scattered knobs in line with the ridges. The knobs appear to be the higher tops of ridges that persist beneath the thin Palæozoic cover. In addition, a number of isolated knobs of the Precambrian rocks are exposed well within the basin; all of these knobs are of white quartzite, except that some granitic rock as well as quartzite is uncovered in one place slightly west and about 8 miles north of Brockville.

ORDOVICIAN

Beekmantown

Nepean Formation

Definition and Contacts. The Nepean sandstone is that formation that overlies the unevenly eroded Precambrian floor of most of the Ottawa-St. Lawrence basin, and in turn is overlain by the interbedded sandy dolomite and sandstone of the March formation. The unconformity at the lower contact represents a long period of erosion. The contact is nowhere actually exposed, but in lot 3, con. II, March tp., the sandstone is separated from the Precambrian rocks by a few feet of drift. At its margin the sandstone appears to conform to the slope of the Precambrian surface and may have extended over it. The sandstone exposure is only a few inches thick, but increases to several feet and becomes more nearly horizontal within 20 to 30 yards. The upper limit of the Nepean is placed arbitrarily at the base of the first dolomitic or calcareous bed. This contact is conformable; nowhere is there a trace of a break in the sedimentation. As here defined the Nepean is a homogeneous formation easily recognizable in borings, but less readily detected in the field unless the upper limit is exposed. It includes all the sandstone in this region formerly designated as Potsdam, and, at the top, beds that Raymond (1913, p. 139) [1] considered to be "reworked Potsdam" and correlative with the Theresa of New York. The definition of the upper contact obviates the consideration of a variously placed, doubtful contact between a possible Cambrian and an Ordovician formation.

The formation is named from Nepean township, where the large quarries lie from which the stone was taken for the Parliament Building of Canada, and for many other large government and other buildings (*See* Plate I).

Description. The Nepean as a whole is a cream-coloured sandstone, weathering grey, and mottled with irregular rust spots. Towards the southwest margin, and to some extent in the eastern part of the basin, it has a decidedly red tinge.

Dates, etc., in brackets refer to publications listed in the Bibliography, Chapter VI of this report.

Throughout, it is made up of a coarse quartz sand. Harding (1931, p. 430), in an analysis of the sandstone from various localities, has found that it averages 99·31 per cent silica (SiO_2). Approximately the same percentage has been found to the east of the area near Beauharnois. The basal layers are rarely exposed. Of the few known outcrops some show beds of conglomerate with quartzite pebbles 1 inch to 3 inches in diameter; others contain quartzite pebbles of more uniform pea-size; still others are of coarse-grained sand. Over considerable areas of the exposed sandstone the grains are rounded, but masses with angular grains are not uncommon, indicating perhaps both marine and terrestrial conditions, probably representing a shore relationship of changing shore sands and ocean sand-bars. Numerous, well-defined, asymmetric ripple-marks are another evidence of near shore current conditions.

Some grains show a secondary growth of quartz, and much of the cementing material throughout is siliceous. Near the top of the formation the cement in places is of calcium carbonate, or of rust-staining iron oxide. In places the cohesion is so slight that the grains can be separated by the fingers. Again there are many occurrences of thin, streaky, disconnected lenses of pure quartzite from a fraction of an inch to 2 feet thick and with irregular lateral dimensions. One of the thicker quartzite lenses is exposed in a field north of the road about 3 miles east and south of Belle Rivière, Quebec. So far as known these lenses are disconnected, and have little or no effect in preventing the free circulation of water.

There are no adequate sections of the Nepean formation within the Ottawa-St. Lawrence basin, and deposition has been so irregular that no single section would be characteristic of the region as a whole. In places beds a few inches thick are overlain by beds that may be from 2 to 5 feet thick, in one place thinning out laterally to a few inches.

The Nepean sandstone is derived from the Precambrian rocks over which it is laid. From an examination of the Precambrian gneisses and of these sandstones over a wide area Harding (1931, p. 436) noted that all of the heavy minerals found in the sandstone were also in the gneisses. He concluded that the gneisses themselves were sedimentary in origin, and that the sandstone was derived from the gneisses rather than directly from the igneous Precambrian rocks.

Thickness. The thickness of the Nepean varies from a few inches to at least 500 feet. Over the main part of the basin the sandstone fills in valleys between the unevenly eroded Precambrian base beneath, and in addition there are evidences of some dune-like deposition of the sand itself. The maximum thickness yet found in wells at Ottawa is 280 feet, but at Silica, Quebec, about 16 miles east of Lachute and about 2 miles south of the Precambrian margin, a drill passed through 500 feet of Nepean sandstone without reaching the Precambrian. This unusual thickness may be due to the filling of a pre-Palæozoic trough or to a buried fault scarp near the Precambrian boundary, or to both combined. Comparison with thicknesses farther south and east is not possible, as no well has penetrated to the Precambrian.

Distribution. The Nepean everywhere underlies younger Palæozoic formations of the basin, except in the northwest, where the younger strata overlap it and extend up Ottawa Valley, resting directly upon Precambrian rocks. The exposures of the Nepean occur, therefore, around the margins of the main basin and about a few protruding Precambrian knobs.

Isolated outcrops show that the greatest area of the Nepean sandstone underlying the unconsolidated Pleistocene sediments is a broad band in the southern half of the greater part of the basin, along the margin of the Beauharnois axis, where the younger Palæozoic rocks have been eroded. The continuity of this wide band is broken farther north by several fault blocks near Rigaud and by the adjacent Precambrian outliers. Within this faulted area the narrowed and interrupted band occurs farther west than in the undisturbed area, and in the case of the Rigaud Mountain block it is represented by an additional isolated outcrop at the uplifted western tip, lying against Ottawa limestone. North of the faulted area the formation resumes its normal position between the Precambrian and the succeeding March formation.

A few, quite isolated outcrops are present on the northern margin of the basin in pockets or narrow strips adhering to the Precambrian rocks, but in most of this area the formation is cut off by faults.

In the southwestern and western margin of the basin the Nepean lies against the Precambrian of the Frontenac axis in pockets and bands between ridges, and is preserved in patches westward across the southern part of this axis. Within the western margin one small outcrop occurs against a Precambrian knob on the upthrow side of the fault running southwest of Pakenham. The most westerly outcrop found within the basin is several miles west of Almonte, and the most northerly a few miles north of Carp.

On the upthrow side of the Hazeldean fault the Nepean formation lies in its normal position against the northeast margin of the Precambrian tongue that extends from Fitzroy Harbour into Nepean township.

Only one exposure of the Nepean was found well within the basin, on the upthrow side of the Gloucester fault. It appears about a mile south and a little east of Leitrim, and extends as a narrow band for about 10 miles, cut off by the fault on one side and elsewhere passing under the succeeding March formation.

Fauna and Correlation. The only identifiable species found in the area is a small linguloid shell described as *Lingulella acuminata* Conrad. There are also a number of tracks, some having a width of 3 to 4 inches, made presumably by some animal. In addition, the formation contains curious concretionary structures of inorganic origin. Most of these are cylindrical, or flattened cylinders, with their maximum diameters ranging from a few inches to several feet. Others have irregular constrictions along their length; still others are nodule-like.

A discussion of the correlation of the Nepean sandstone is given later in connection with that of the March and Oxford formations, because the Nepean sandstone, as here defined, includes beds that have been correlated with formations in New York State of both late Cambrian and early Ordovician age.

March Formation

Definition and Contacts. The March formation lies above the Nepean sandstone and below the Oxford formation. In a few places its base rests unconformably upon Precambrian knobs that protrude above the Nepean sandstone; elsewhere both contacts are conformable. The lower contact is placed arbitrarily at the lowest dolomitic layer. It is easily recognized in well borings, but is more difficult to find in the field, because the lower basal dolomitic layer is rarely exposed and the interbedded resistant sandstone layers are widely exposed and resemble the Nepean. No outcrop was found showing the exact contact, but a typical succession, with few interruptions, from the Nepean sandstone into the alternating March sandstone and sandy dolomite, is to be seen on lot 34, con. VI, Nepean tp. The upper contact of the March is placed arbitrarily above the last occurrence of sand in any quantity. The formation is here considered as a lithologic unit, because its characteristics are persistent throughout the area, and it is a well-known water-bearing zone. The formation is named from March township, Carleton county, where good exposures occur.

Description. The March formation consists of alternating grey sandstone and sandy dolomite or blue-grey dolomite, all weathering dark rusty brown. The sand grains are large, generally rounded, and commonly loosely cemented. Some of the thick dolomite beds contain pockets, 1 inch to 3 inches in diameter, filled with large crystals of pink or white calcite. The formation represents a transition from the Nepean sandstone to the Oxford dolomite, the sand content being most evident at the base. The lower beds are 2 to 2½ feet thick. Higher up, where dolomite is more prevalent, the beds vary in thickness from 8 to 18 inches.

Thickness. No complete section of the March formation is exposed. At one locality, lot 18, con. III, Nepean tp., some 23 feet are exposed, but both top and bottom are covered. Well borings in and around Ottawa indicate a thickness of 25 to 30 feet in this part of the basin. There is some evidence to indicate that it becomes thicker to the east, and well records show that the formation is still thicker east of the Beauharnois axis.

Because the formation is a shallow-water deposit, its thickness would tend to vary, depending upon the sandy material available. Near the margins of the basin sand would probably form a considerable part of the sediment, whereas limestone and dolomite would be deposited in the deeper, central and eastern areas.

Distribution. The Ottawa-St. Lawrence basin is deeper at the centre than at the margins, and, consequently, where undisturbed by faults, progressively younger formations are exposed in roughly concentric bands within the outer Precambrian boundary. Next to the Precambrian within the basin lies the Nepean and within that the March. The concentric relationship of the March exposures is maintained along the southern part of the Beauharnois axis, but farther north, like the Nepean, it is interrupted by faulting about Rigaud Mountain. No outcrops are revealed in the faulted blocks, but the formation must be present on the Rigaud Mountain block between the Nepean and Oxford outcrops against Rigaud Mountain and again on the uptilted western tip of the block.

Along the northern margin of the basin the continuity of the band of March exposures is broken by faulting. Outcrops are few and isolated. The formation is brought to the surface or buried by the irregular tilting of the fault blocks.

The March is widely exposed in the southwestern and western part of the basin from the Brockville area north, where it surrounds or tops the Precambrian ridges projecting into the basin. The band of March exposures becomes narrow towards its northern limit. Outcrops are isolated around Carleton Place, and the farthest north exposure seen on this margin is in the village of Pakenham. But a few isolated, thick, arenaceous dolomite beds outcrop on the northwest extremity of Calumet Island, and indicate that an arm of the sea extended farther north and west up Ottawa Valley.

North and east of the Hazeldean fault, on the upthrow side, the March, like the Nepean, is repeated in its normal position relative to the Precambrian. The farthest north exposure in this irregular area is about 12 miles south of Dunrobin.

Two exposures occur well within the basin: one, in Mountain township, probably is exposed because it covers a Precambrian knob; the other borders the Nepean sandstone outcrop southeast of Leitrim on the upthrow side of the Gloucester fault.

Fauna and Correlation. Fossils found within the formation indicate a Lower Ordovician age. These interbedded sandstone and dolomitic layers were designated by Logan as the Transitional beds. The correlation of the Nepean, March, and succeeding Oxford formations is given after the discussion of the Lower Ordovician (Beekmantown) formations.

Oxford Formation

Definition and Contacts. The Oxford formation lies above the March and is succeeded by the Rockcliffe. Over the greater part of the Lowland the lower contact is placed arbitrarily above the last stratum of sand in the March formation. It is unconformable where it surrounds the Precambrian knobs that protrude above the March formation. Towards the northwest, the Oxford is thought to overlap the Nepean and the March, and to lie unconformably upon the Precambrian. The contact with the March can be recognized in borings, but is more difficult to define in the field. Natural sections showing the gradation of sand content are rare, and large areal exposures of resistant dolomite may or may not be succeeded by sandy dolomites in covered areas. The upper contact is unconformable, and can be recognized readily both in borings and in the outcrops.

The Oxford formation is named from Oxford township, Grenville county, Ontario, where it is widely exposed. The same formation was called 'Beauharnois' by Raymond (1913, p. 140), who used the name only once. The first of the eastern Ontario areas to be revised by the present writer was that covered by the Ottawa sheet, and a new name was chosen because it was not known at that time whether the Oxford beds were identical with those of the original type area at Beauharnois canal. As the present map indicates, the formation is much more widely spread in Oxford and the adjacent townships, and as the building of the new Beauharnois canal has covered some of the type area, the name 'Oxford' is here retained.

Description. The Oxford formation is mostly a thick-bedded, rusty weathering dolomite. In places it changes laterally to limestone. Many of the dolomitic beds contain hard spherical masses, from 6 inches to 2 feet in diameter, that weather concentrically (Plate II B). They have been considered variously as concretions or as algal growths called 'cryptozoons'. In the central and eastern part of the basin there is some shale at the top of the formation. Some of these upper, more shaly beds contain imperfectly spheroid or ellipsoid masses of more compact shale, 1 inch to 18 inches in diameter, which when weathered out leave shallow, basin-like depressions. The more shaly layers are very dark grey and weather rusty. As in the March formation, some of the lower thick dolomite beds contain pockets from 1 inch to 3 inches in diameter, filled with large pink or white calcite crystals. Where the Oxford lies against or overlaps Precambrian knobs the dolomite contains pebbles and boulders of quartz up to 10 or 12 inches long. One such exposure can be seen on the road about $1\frac{1}{2}$ miles east of Oxford Station, Oxford township, Ontario. Another area occurs in con. III, Godmanchester tp., Huntingdon co., Quebec. At the latter locality the dolomite also is honeycombed with irregular cavities 8 to 10 inches in diameter, lined with large quartz crystals or with amorphous quartz in places containing dark chert. Quartz also occurs here in thin, irregular sheets of variable thickness, or along vertical joint planes, where it resists weathering and stands out in relief.

Towards the western edge of the basin, where the Oxford formation overlaps Nepean and March beds, the dolomite is still thick bedded, but is very impure, with much mud and some sand. Some beds break into platy fragments, and all weather a brighter yellow than in the eastern part of the basin. These beds have been considered Oxford, not March, because of the small quantity of sand and the large proportion of dolomite.

Surface outcrops and low sections are numerous, especially near Merrickville, Ontario, but none of them reveals more than a small part of the formation.

Thickness. It is possible to obtain accurate measurements of the thickness of the Oxford only within the large down-faulted block in the central northern part of the mapped area. Within these limits it evidently increased in thickness towards the east. At Ottawa wells show a thickness of 240 feet and at Carlsbad the Oxford and March together are 350 feet thick. No wells east of Carlsbad penetrate the formation, but on the extreme east of the basin, where the older formations rise towards the Beauharnois axis, it again becomes thinner, being bevelled by erosion. To the west of the great central faulted block no well shows the exact thickness, but, calculated by the less accurate method of surface measurements, there is an appreciable decrease in thickness.

Distribution. The distribution of the Oxford, as of the Nepean and March formations, illustrates the basin-like character of the region, exposures occurring in a band of varying width around the basin, lying within the irregular and broken border of the older formations. On the east it forms a broad strip to the west of the March formation, averaging 12 miles in width in the southern part, but narrowing irregularly to the north. Similarly, the continuity of its exposure is interrupted by the faulting around Rigaud Mountain, resulting in its exposure a little farther west where it maintains the same position relative to the older formations. Its occurrence, also, on the northern margin is isolated and irregular, due to the tilting of the fault blocks along that edge of the basin.

As previously mentioned, the western side of the basin was probably shallow. Within the Canadian part, the Oxford formation outcrops along the St. Lawrence from Iroquois almost to Brockville, with one interruption. Farther north and west it occupies an irregular area of some hundreds of square miles, having a maximum width of at least 50 miles in the southern part of that area. In places it lies in irregular depressions and patches between the projecting or buried Precambrian ridges, and between isolated buried knobs. The field of exposure, very wide in the south, becomes narrower to the north, then patchy, then disappears entirely. In one small area near the western margin of the basin on the upthrow side of the fault southeast from Pakenham, outcrops occur just northeast of a Nepean outcrop. It, like the Nepean and March formations, maintains its relative position to the east and north of the Precambrian ridge across Torbolton and March townships to Nepean township. The western edge of the Oxford area is exposed north of Almonte and east of Galetta. The Beekmantown sea, however, penetrated farther up Ottawa Valley, as indicated by three, small, widely separated outcrops, one about 9 miles north of Arnprior, another along Bonnechère River at Douglas, and a third at Eganville. On the extreme western tip of Allumette Island, north and west of Pembroke, some loose, rusty weathering blocks of dolomite were seen that seem to have come from a near-by exposure, perhaps under the river. They may be from basal Ottawa (Pamelia) beds, but their thickness and density suggest the Oxford formation.

Fauna and Correlation. The presence of *Ophileta*, *Eccliomphalus*, *Hormotoma*, and other forms is indicative of an early Ordovician age. The correlation of this and the two preceding formations follows.

Correlation of the Beekmantown (Lower Ordovician) Formations

Although it is not impossible that some Upper Cambrian sandstone is present, it is probable that the Nepean-March-Oxford sediments represent continuous deposition in early Beekmantown time. It is even probable that in the western part of the basin the basal sandstone was laid down during deposition of some of the Oxford dolomite in the east. The invading sea, moving progressively westward over the Precambrian base, might have sufficient carbonates for deposition in its eastern part while depositing clastic material on its western shoreline. A static and a later retiring sea might result in concentration and deposition of carbonates directly upon the Precambrian rocks in the almost land-locked area of the upper Ottawa River Valley.

The lithologic characteristics of the Nepean, March, and Oxford formations suggest a normal succession produced by an encroaching shallow sea, grading from sandstone into interbedded sandstone and dolomite, and then into dolomite, capped in some districts by the more impure shaly beds that probably represent either a further shallowing or a withdrawal of the sea from the basin. There is nowhere any evidence of a break in sedimentation.

The Nepean has been called the Potsdam, and correlated with the formation of that name in New York State where it is regarded as Upper Cambrian in age. The correlation and, consequently, the age have been based upon a few fossils and upon the high silica content, which suggests an extended period of erosion and dissolution of original feldspars. As indicated previously, the fossils are limited to the tracks of some unknown creatures and to a linguloid form, *Lingulella acuminata*. Most of the tracks occur near Beauharnois, Quebec. One, near Perth, Ontario, and a very few from New York are also cited. It is felt that they are too indefinite for correlation. The genus *Lingulella* has been cited from New York, Vermont, Virginia, Wisconsin, Minnesota, and Tennessee, from both the Cambrian and the Lower Ordovician. It is rather too generalized a genus to be a basis for exact correlation. In eastern Ontario *Lingulella acuminata* has been found both in the sandstone layers and in a sandy limestone. No other fossils were found at the same locality, but elsewhere such beds yield *Ophileta compacta*, *Eccliomphalus calciferus*, and other Lower Ordovician forms. The absence of feldspars may be accounted for by Harding's conclusions as to the derivation of the sandstone from Precambrian sedimentary gneiss, not directly from the Precambrian igneous rocks. As stated elsewhere, there is no evidence of unconformity within the sandstone, though it is recognized that an unconformity between sand laid upon sand might be difficult to detect. The Nepean sandstone, then, may or may not have been deposited at the same time as the Potsdam of New York, and within the Nepean itself there is no definite evidence that it is of Upper Cambrian age. The possibility is recognized, but the probability is that the sandstone was deposited in earliest Ordovician time as the basal phase of an advancing sea.

The March formation, with a few of the upper sandstone layers of the Nepean sandstone, was correlated by Raymond (1913, p. 139) with the Theresa of New York, and considered by him to be the base of the Ordovician in eastern Ontario. The position of the New York Theresa has been redefined, and the name is now restricted to an Upper Cambrian formation having its type locality in New York. Fossils indicate that the March is of Ordovician age.

The Oxford formation is early Beekmantown in age. In the central part of the area the same species of *Ophileta* and *Eccliomphalus* range from the March into the Oxford. Farther east, in slightly higher beds, there are a few fossils not found with the *Ophileta*. In Montreal and Lake Champlain areas the Beekmantown attains a thickness of at least 1,000 feet and 1,500 to 2,000 feet respectively. The fossils found there indicate that only the lower part of this section is represented in the Ottawa-St. Lawrence Lowland.

Chazy

The name 'Aylmer' was given by Raymond (1912, p. 353) to the Chazy as represented in Ottawa Valley. Raymond recognized two divisions within the Aylmer — shale with sandstone lenses, and limestone. A later study shows that these divisions are maintained throughout the lowlands of the Ottawa and St. Lawrence. Because of their different lithology and their widespread distribution, the two components of the Aylmer are here considered as two formations. The lower shale and sandstone formation is called the Rockcliffe, from Rockcliffe Park, just east of Ottawa, where high cliffs of it border Ottawa River. The upper limestone is named the St. Martin because its best development is to be seen at Cap St. Martin, north of Montreal.

Rockcliffe Formation

Definition and Contacts. The Rockcliffe formation overlies the Oxford, and in turn is overlain by the impure limestones and shales of the St. Martin in the central and eastern part of the basin, and by equally impure limestones and dolomites of the basal Ottawa formation in the western part. The contact of the Rockcliffe with the Oxford is marked by a disconformity sharply defined by a difference in lithology. The contact of the Rockcliffe shale and Oxford dolomite may be seen in well borings, but the few exposures of the contact exhibit only sandstone lenses resting upon the Oxford, probably because the sandstone is more resistant to erosion than the shale. The exposures have been brought up by the tilting of the fault blocks near the northern margin of the basin. In an abandoned railway cutting $2\frac{1}{2}$ miles west of Cumberland the lighter grey, conglomeratic bed of the Rockcliffe is shown lying directly upon the dark, rusty weathering, rather shaly Oxford formation. Other exposures of the contact are in the quarry at the foot of the Skead road east of the Rockcliffe Aerodrome road, and about half a mile south of Rockland in the pasture east of the road. The abrupt lithological change of the disconformity represents, in this instance, a considerable lapse of time. Some of the younger Beekmantown sediments may have been eroded. The disconformity represents the time required for three events in the Montreal-Lake Champlain area; the deposition of 600 to 1,500 feet of additional Beekmantown sediments; the complete withdrawal of the sea between Beekmantown and Chazy time, and the further deposition of 300 to 890 feet of Chazy sediments before the sea transgressed into the Ottawa-St. Lawrence basin to deposit the Rockcliffe formation.

The upper contact of the Rockcliffe with the St. Martin is less definite, as one formation merges into the other.

Description. The Rockcliffe is composed of friable shales with lenses of sandstone (Plate III A). The shale for the most part is light olive-green with a few pockets of dark iridescent shale. The sandstone is fine-grained and grey in the eastern and central part of the basin, changing to a deep red where it occurs on Ottawa River above MacLaren Landing. The basal lenses of the Rockcliffe, as seen in the few exposures at the contact, contain small fragments of quartz and dolomite, and some grey-green shale, the last evidently of intraformational origin. These lenses vary from small proportions to thin, widespread sheets and to masses 20 feet or more thick and several square miles in extent. In many places, particularly on the upper surface of the sandstone lenses, there are fucoid-like structures, some of which have large bulbous swellings 2 to 3 inches across and, in some cases, constricted along the longest axis. These peculiar forms have generally been considered organic, but a section across a 4-inch specimen showed it filled with sand and without structure. Ripple-marks are present, but are usually smaller and not so common as in the Nepean.

The best exposed section of the formation is to be seen at Rockcliffe Park, where the irregular intermingling of shale and sandstone lenses is very evident. The red sandstone is well exposed along Ottawa River $2\frac{1}{2}$ miles north of Fitzroy Harbour.

Thickness. The thickness of the Rockcliffe, as of the Oxford formation, increases to the east, and there is considerable irregularity within any area, probably due to the shifting nature of the sand content. Even within the city limits of Ottawa there are variations of 20 to 30 feet. The western marginal edge thins out and finally disappears beneath the overlapping Ottawa limestone. At Ottawa, borings indicate an average thickness of about 150 to 160 feet. In a well in North Plantagenet township the formation is about 155 feet thick, and at Alexandria about 165 feet thick, making allowance for some missing sections of shale.

Distribution. The Rockcliffe appears as a narrow, almost circular, strip from 1 to 3 miles wide, much closer to the centre of the Ottawa-St. Lawrence basin than the older formations. Southeast of Russell the formation is cut off by the Gloucester fault. From there southward it is exposed as a sinuous, north-south band lying on the eastern margin of the broad expanse of the Oxford. That it curves around to the east and then swings northward on the east side of the basin is made evident by a few wells at Cornwall and by scattered outcrops of the overlying and underlying formations. It is the oldest formation to lie completely within the Canadian part of the Palæozoic basin.

On the eastern margin of the basin the continuity of the Rockcliffe band is broken by the faults near Rigaud Mountain. There the Rockcliffe is completely eroded from the central fault block, but, though not exposed, it is presumably present between the Oxford and St. Martin outcrops in the most southern of the three blocks. North of these disturbed blocks it again appears in its normal position.

Along the northern margin of the basin outcrops are isolated and irregular, depending upon the position of the several tilted fault blocks.

In the western part of the basin a few isolated outcrops extend in a southward curve from west of Richmond to Ashton. The western limit of the Rockcliffe formation in this part of the basin is marked by one outcrop on the upthrow side of the fault southeast of Pakenham. Farther north, however, an arm of the depositing sea extended up the valley of the Ottawa, for isolated outcrops continue as far as Beckett Island about 5 miles below Pembroke.

North and east of the Precambrian ridge extending south from Fitzroy Harbour the formation appears in its normal position.

Fauna and Correlation. The fauna and correlation of the Rockcliffe formation are considered after discussion of the St. Martin formation.

St. Martin Formation

Definition and Contacts. The St. Martin formation lies conformably above the Rockcliffe and unconformably beneath the Ottawa limestone. The actual transition from the Rockcliffe to the St. Martin is not exposed, but some sections with few gaps show that in a slowly deepening sea the shales and sands of the Rockcliffe were gradually overlaid by the thin limestones and shales of the St. Martin. It is probable that deposition of some of the Rockcliffe along the western margin, and of some of the St. Martin in the centre of the basin, took place at the same time, but because of the differences in lithology and distribution the two are mapped separately.

Description. The St. Martin formation is dominantly limestone, but at its western margin and at its base it is composed of shaly or dolomitic limestone intermingled with thin beds of dark shale and occasional sandstone layers. Towards the east this irregular succession gives place laterally to thick beds of impure limestone with a few intercalations of more crystalline limestone. The limestone remains grey, but dolomite beds weather rusty. Ripple-marks are present, larger in dimensions but not so numerous as in the Rockcliffe or the Nepean formations. A few of the thicker beds along the southern margin of the area contain isolated, large, round sand grains or even occasionally tiny shale pebbles. A limited section of the marginal beds can be seen on the north side of the slope about a mile east of where Green Creek crosses the Ottawa-Montreal highway, and is as follows:

Section East of Green Creek	Thickness Feet
Ottawa formation	
Brown, sandy shale and thin, dolomitic limestone	2·5
Top of St. Martin formation	
Thick, impure limestone bed with grit, no *Camarotœchia* found	1·5
Green shale	1·3
Rather pure, thin layer of rusty weathering, dolomitic limestone mixed with greenish tinted shale, *Camarotœchia* abundant	2·0
Heavy layer, homogeneous, somewhat dolomitic limestone, fine-grained, weathers rusty	1·0
Shale and impure dolomitic layers, greenish, weathering brown in spots	1·5
Heavy dense dolomite, conchoidal fracture, dark grey, weathering buff, exfoliating concentrically	2·5
Thin shale with some dolomitic content, grey, weathering buff and brown	0·3
Brownish shale	0·2
Green-grey shale, weathering buff	0·4
Brown iridescent shale	0·5
Grey shale	0·3
Light grey, sandy limestone	0·1

Dark shale	4·0
Dark shale with some sand	2·0
Dark, calcareous beds with large grains, almost pebbles, weathering grey	1·1
Total thickness	21±
Covered (base of St. Martin)	10
Rockcliffe sandstone	

No good section of the thicker limestone beds is exposed in the eastern part of the basin. It is best examined from borings. Part of the formation can be seen near Little Rideau Creek about half a mile south of the highway crossing on concession I, East Hawkesbury.

Thickness. A section of the St. Martin formation is wedge shaped, thicker to the east and thinning out near Ottawa. Its maximum thickness within the basin is not known. The section given above and a few exposures of the formation east of Ottawa show a thickness of about 20 feet. In a well at Carlsbad Springs, 11 miles southeast of Ottawa, about 40 feet of intermingled calcareous sand, sandy limestone, and shale have been assigned to this formation. The only good outcrop of the limestone in the area is on Little Rideau River in East Hawkesbury township, where some 30 feet of it is exposed. This probably overlies and is to be combined with the more sandy, shaly beds at its base, which outcrop southeast of Vankleek Hill. Still farther east, wells in North Plantagenet township and near Alexandria indicate a thickness approximating 155 feet, making some allowance for small sections lost from the cores.

Distribution. The St. Martin does not extend west of Ottawa. In the central, eastern, and northern parts of the area it follows the same pattern as the Rockcliffe, and lies between that formation and the Ottawa limestone nearer the centre of the basin.

Correlation of the Chazy Formations

The fauna and correlation of the Rockcliffe and St. Martin formations are considered together, for, although their lithology is distinct, the two formations form a regular sequence in an invading sea. As previously mentioned, it is probable that some of the Rockcliffe sandstone along the western margin was deposited at the same time as some of the limestone of the St. Martin in the centre. Such evidence as is available from borings tends to corroborate this point of view. In connection with the St. Lawrence Power and Waterways Project a shaft 12 feet in diameter and 100 feet deep was sunk on Barnhart Island, United States, near Cornwall, Ontario. The shaft passed through a thick mantle covering of unconsolidated material and penetrated 38 feet into the St. Martin limestones. Three fossil zones were revealed at 150 to 148·5 feet, 125 to 121 feet, and 112 to 111 feet, respectively, above sea-level. A core from the level of the lowest fossil zone was obtained by drilling horizontally from the bottom of the shaft out under the river for 700 feet, providing better samples from this zone than from the other two. These three zones, together with the few surface outcrops in the neighbourhood, make four fossiliferous zones of the St. Martin in this general locality. In the lowest, specimens of several species of *Hebertella* abound, with a very few specimens of *Camarotœchia orientalis*. In the second zone the proportion is more equal; in the third, *Camarotœchia orientalis* becomes much more abundant than it is below. In the fourth zone, to which belong most of the surface outcrops on the Ontario side, the limestone is replete with *Camarotœchia plena*, and *C. orientalis* was also found. The evidence then of this region is that *C. orientalis* is older than *C. plena*. This evidence is contrary to Raymond's (1911, p. 223) statement that the two forms never occur together, and that it is possible that *Camarotœchia orientalis* "arose from it (*Camarotœchia plena*) by the checking of the plications at an early stage". But the fauna as a whole corroborates his conclusion (1906, p. 562) that the Chazy formations of the Ottawa-St. Lawrence basin are of late Chazy age, for *Camarotœchia plena* in the Lake Champlain area begins at 718 feet above the base of the Chazy sediments, and *Camarotœchia orientalis* did not penetrate the Champlain basin. Raymond considers the Ottawa-St. Lawrence Chazy formations to be, in part at least, younger than the Chazy sediments in the Lake Champlain basin, for the latter began to emerge before the close of Chazy time, and the youngest Chazy in the Champlain basin is overlain by a sandstone younger than the basal beds of the Black River-Trenton invasion.

Black River and Trenton

Ottawa Formation

Definition and Contacts. The Ottawa limestone was deposited after the St. Martin formation, and was followed by the black limestone and shale of the Eastview. The lower contact is unconformable. In the centre of the basin the Ottawa formation rests upon the St. Martin, west of Ottawa upon the Rockcliffe, farther west upon the Oxford, and it probably lies directly upon Precambrian rocks in the extremity of the long arm of Palæozoic sediments and inliers extending northwest up Ottawa River. No exposure of the contact of the Ottawa with the thick limestone beds of the St. Martin was found in the eastern part of its outcrop area, but the contact with the marginal beds of the St. Martin can be seen a mile east of Green Creek, where a section of the St. Martin formation is exposed and has been described in detail. The contact there is placed at the base of the brown shale and thin dolomite layers. The contact of the Ottawa formation with the Rockcliffe is hidden by only a few feet of Pleistocene deposits in a section by the side of the road from Ottawa River to the highway at Queens Park, about 2 miles north of Aylmer, Quebec. The Ottawa-Oxford contact is covered by a few feet of unconsolidated deposits in the Ordovician inlier at Douglas, Ontario.

The upper contact of the Ottawa formation is nowhere exposed. It is known only from near contacts seen in excavations in the city of Ottawa, and from wells. It is marked by a change upward from grey limestone to a very dark, finer grained limestone, with many, isolated, large, calcite crystals, interbedded with dark shale.

The name 'Ottawa' is taken from that of Ottawa Valley, where many exposures and wells have contributed to the interpretation of the formation.

Description. The Ottawa formation is dominantly limestone, but includes some shale and small quantities of sandstone at the base. A little shale persists upward as shaly partings. In the vicinity of Ottawa there are roughly three phases: a lower phase, typical of basal deposits, consisting of shale, some sandstone, impure limestone, and dolomite; a middle phase of pure, thick-bedded, crystalline limestone; and an upper phase with small amounts of shale and thin, rather impure limestone layers near the bottom gradually giving place upward to thick beds of limestone, some pure and crystalline, some less pure with shaly partings. It is emphasized that these phases merge with one another both vertically and laterally, and that their limits in one part of the area are not necessarily those in another. For example, the thick-bedded, pure limestone phase has its greatest development at Ottawa. Farther east it is thinner, with more shale interspersed, and above it the outcrops of the upper phase show less shale near the base. West of Aylmer only the basal part of the middle phase has been recognized. Whether there is a lateral change to the west or whether the phase thins out near this margin has not been ascertained.

No complete section of the formation is exposed. Wherever seen the basal beds include a few beds of brown shales and some sandstones intermingled with thin bands of limestone or dolomite. Above them limestone becomes more prevalent. Thin or thick beds of shaly limestone interbedded with thin beds of pure, fine-grained, lithographic limestone are succeeded by a few thick layers of rusty weathering dolomite overlain, in turn, by shale and impure limestone. Mud-cracks and a few scattered sandy layers indicate shallow, near-shore conditions. These beds have their greatest development near Aylmer, Quebec, and in the down-faulted block upon which the city of Ottawa stands. That they thin out both east and west is demonstrated by Okulitch's (1935, p. 96) study of the basal beds at Montreal on the east, and on the west by the exposure in the inlier at Douglas, Ontario, where there are only a few feet of basal beds between the Beekmantown and the purer limestone phase of the Ottawa formation above. The best section seen of these basal beds is in the same locality as that exposing the St. Martin-Ottawa contact, about $1\frac{1}{4}$ miles east of Green Creek, 5 miles east of Ottawa. It is as follows:

Top of section	Thickness Feet
Thick beds of fine-grained, lithographic limestone	6·5
Thinner beds, fine-grained limestone	2·5
Thick beds of impure limestone	2·5
Thin impure limestone layers separated by shale containing *Tetradium fibratum*	3·0
Shale filled with *Tetradium cellulosum*	1·1
Thick-bedded limestone full of *Tetradium*	4·0
Shaly layer, *Tetradium cellulosum, Trochonema umbilicatum* present	1·5
Impure limestone	1·5
Limestone, light and dark grey, interbedded, with some ostracods	4·0
Shale	1·4
Impure, shaly limestone, weathering buff	1·6
Limestone	0·7
Thin-bedded limestone with shaly partings	2·5
Concealed	0·5
Thin-bedded limestone with small, dolomitic, rusty weathering blebs	1·5
Thin-bedded, impure limestone and shale	2·6
Dark grey, impure limestone containing ostracods	1·0
Concealed	3·0
Thin layer, impure, dark grey limestone with a few ostracods	0·3+
Heavy-bedded, dense, dark grey dolomite, weathering buff, containing pockets of large pink calcite crystals, 1 to 3 inches in diameter	7·5+
Dark grey shale	1·4
Fine-grained, pure limestone with large rambling *Tetradium*, interbedded with impure limestone weathering shaly and dolomitic limestone with small rusty weathering blebs	3·5
Sandy layer	0·2
Thick-bedded, grey, mottled limestone with one black limestone layer, weathering brown, containing fossil fragments of *Tetradium, Zygospira*-like brachiopods, and gasteropods	2·5
Thick-bedded, impure limestone weathering in brown streaks, with fucoids and mud-cracks	4·0
Concealed	3·0
Shaly, impure, light grey limestone with squeezed appearance	1·0
Dark grey, impure limestone, full of small, irregular knobs, and having some sand	3·5

Thin-bedded, white, impure sandstone, weathering brown and containing obscure pelecypods	1·4
Concealed	2·3
Impure, thick-bedded limestone, weathering brown, with some dark shale breaking with an iridescent surface	1·0
Concealed	2·0
Finely crystalline limestone with a few ostracods	0·7
Thick-bedded layer of more resistant limestone, with a few ostracods	1·7
Shaly, light grey, impure limestone with squeezed appearance	2·3
Limestone, ostracod and *Bathyurus* zone	0·9
Arenaceous brown shales with occasional limestone bands	2·3
Thin limestone with shaly partings; ostracod and *Bathyurus* zone	1·5
Impure, thin limestone weathering slightly rusty, filled with obscure pelecypods	0·6
Concealed (carried north to road)	
Thick beds of dark, impure limestone with some grit, full of small irregular knobs; some layers containing *Lingula* fragments	10·5
(Traced by layers to north side of road)	
Brown-weathering shale	1·5
Limestone full of grit and having *Lingula* fragments	1·0
Concealed	0·5
Thick-bedded, dark, impure limestone full of small, irregular knobs	1·0
Concealed	5·0
(Traced by layers to farm road down the hill)	
Brown sandy shale with some grit and dark knobs	2·5
Total thickness	107·0

Top of Chazy

This section bridges the transition from the basal, near-shore deposits and shallow-water sediments with a greater content of carbonates to the purer limestone beds of the middle phase. But it is by no means certain that the boundary between the lower phase and the middle phase everywhere occurs at the same height above the base of the formation.

The base of the middle phase of the Ottawa formation is shown at the top of the above section. This middle phase is dominantly thick-bedded limestone, much of which is crystalline (Plate IV). Near the bottom of it a few thick beds break with conchoidal fracture, and others weather rubbly. In a few localities chert is found in irregular nodules in its lower beds and near the top the chert is more widespread, occurring in thin sheets or nodular masses 8 inches or more in diameter. The thickness of this purer limestone phase varies considerably across the basin. The best exposures are in the neighbourhood of Ottawa, where the limestone attains a thickness of at least 150 feet. Nowhere else has this thickness of pure limestone been found. The lower part of the phase persists across the basin. Fossils with a limited range mark the phase in some exposures, but most of the fossils, particularly those occurring in the upper part of these pure limestones, are long ranging and very unsatisfactory as horizon markers. In places where chert is present, especially in the upper beds, the phase is recognizable. Intersecting cross-sections taken from exposure to exposure and checked by well borings show that the thickness of pure crystalline limestones is not maintained laterally.

A 250-foot core taken at the Canada Cement Company's plant at Hull, Quebec, passes through the two lower phases of the Ottawa formation. The greatest variation in the carbonate content of the upper part is 8 per cent, and even in the lower 60 feet, where sand and shale is more abundant, the maximum variation is only 13 per cent.

Above the purer, more crystalline beds of the middle phase, the limestone at the base of the upper phase is thinner bedded, and there appears to be considerably more shale. The only two exposures at Ottawa are near faults, one along Brewery Creek in Hull, and one north of the schoolhouse on the Montreal road east of the aerodrome road. The beds have been sheared and crushed, so that they appear more shaly than in any other outcrop seen, and perhaps in previous reports have led to an exaggeration of the amount of shale content, which is hardly sufficient to appear in an acid analysis. Other exposures, however, do indicate thin-bedded limestone with a greater shale content than is in the thick-bedded, crystalline beds beneath. The bedding gradually becomes thicker upward, and the shaly partings thinner and more widely spaced (Plate V). Wells show that this third phase constitutes the great bulk of the formation. At Ottawa it measures 450 to 475 feet in thickness. Farther east, where the pure crystalline limestones are thinner, this upper phase may be still thicker, because the same total thickness of the formation is found as far east as Montreal. The greater amount of shale at the base may be due to a shallowing of the sea, but there is no indication of emergence.

Many of the fossils persist from one phase into the next, and some forms flourish in different types of environment, such as bryozoans, which apparently preferred muddy waters for they occur in the shaly partings at all levels within the formation, or brachiopods, which thrived in clearer water for they are to be found in the purer limestones at all levels. Besides the exposures mentioned near Ottawa, a few feet of the thinner layers are to be seen in Payne River at Finch and in a quarry about a mile west of that village. The heavier beds above are best exposed at Ottawa, along the south side of Ottawa River from Rideau Hall to near Chaudière Falls where the cliff turns south and west. But these exposures represent only a fraction of the entire thickness of this phase.

The Ottawa formation has formerly been divided on the basis of certain fossils into two formations of seven members, namely, the Black River formation with the Pamelia, Lowville, and Leray members, and the Trenton with the Rockland, Hull, Sherman Fall, and Cobourg members. The palæontological limits of these members are quite indefinite. Besides the use of fossils the formations and members are defined from information obtained from surface outcrops, with some disconnected sections, and upon some minor and frequently repeated differences in lithology. A few fossil types have a limited range within the formation, but most of them range through several successive zones. Some development and change in faunal association would take place normally during the length of time required to deposit such a thickness of limestone. That the character of the two so-called formations with their seven members is homogeneous for the most part is shown by acid analyses of many well borings, which indicate 86 to 100 per cent of carbonates throughout the Ottawa formation except for small residues of sand and shale near the base.

The palæontologically defined formations and members, with one exception, do not correspond to the three, roughly defined lithological phases. The lower phase of initial deposits roughly corresponds to the Pamelia and the lower part of the Lowville; the middle, lithological phase to the top of the Lowville and the whole of the Leray, Rockland, and Hull members; and the upper phase to the Sherman Fall and Cobourg members. Curiously enough the contact between the Black River and Trenton formations, as formerly defined, was placed within the thick-bedded, pure, crystalline limestone beds. The only boundary between two of the palæontologically defined members that approximately corresponds to a lithological boundary, as it is represented in the vicinity of Ottawa, is that between the Hull and Sherman Fall members, within the Trenton, marking the change from the thick crystalline beds to the thinner limestone layers with shale at the base of the upper phase.

A detailed study of the entire succession of the beds within this comparatively large region, and the examination of many wells, have shown that there was no break in deposition; that all the rocks average 86 per cent or more of carbonates, except for a few basal layers; that the thickness of the several lithologic types has shown a variability not due to the consecutive deposition of several individual members but to the variable duration of local conditions during one deposition; that, although a few fossils have a limited range, there is a dove-tailing of the range of many others, considered typical of the several members, across the boundaries of both members and formations; and that other fossils recur higher up where conditions are similar.

For these reasons, and for the practical use of geologists and drillers, the formation is here considered as one, and the seven members of the former two formations are regarded as zones of faunal associations, with very indefinite and variable boundaries, depending upon the coincidence of a few short range fossils and minor variations in the limestone. The name 'Black River-Trenton' is retained as a time term.

Thickness. Wells at Ottawa and Montreal show that the Ottawa formation originally maintained a thickness of 690 to 700 feet. In the Ottawa-St. Lawrence Lowland, however, the total thickness is preserved only in the large down-dropped block in the north-central part of the basin, and in a limited area adjacent to and south of the block, where the faulting has down-warped a small section of the upthrow side, preserving the complete thickness of the Ottawa formation with a thin covering of the Eastview and Billings shale above it. On the east and west sides of the basin the formation is bevelled by erosion.

There is some evidence that the Ottawa formation was thinner in the extreme northwest. In almost all of the inliers the limestone of the few beds exposed is less pure, and the rusty weathering, dolomitic content more evident than in the corresponding beds in the centre of the basin, suggesting slower and more marginal deposition. Where exposed on the western edge, and in the inliers within the Precambrian Shield northwest of the basin, the basal beds are known to be thinner than in the vicinity of Ottawa. Most of these exposures are topped by beds that are not more than 140 feet above the base in the complete section of the central area. Thicknesses from surface outcrops are not as reliable as from wells, but in the several sections examined these beds of the Ottawa formation in the western part of the basin appear to have attained a thickness of barely 100 feet. Again, no beds of the Hull 'member' have been seen in the western part of the area or in inliers. If present, typical, thick-bedded, crystalline limestone would have been resistant to erosion. If changed laterally to more shaly layers the change would suggest marginal deposition. In addition, east of Lake Clear, near Esmonde, Ontario, an inlier shows a mingling of fossils from several faunal associations. The top of the formation, protected by some overlying shale, occurs in one inlier only, on the south side of Lake Clear, but unfortunately there is no well here to ascertain the thickness.

Distribution. The Ottawa limestone occupies more than 400 square miles in the central part of the Ottawa-St. Lawrence basin. On the south and east its regular margin lies against the St. Martin formation; on the north the margin is interrupted by the tilting of the several fault blocks; and on the west it is partly cut off by the Gloucester fault. Between Russell and Ottawa a section of the area of exposure is covered by younger rocks.

To the northwest of this large expanse, and north of the long Precambrian projection southeast from Fitzroy, is a small area of the basal Ottawa beds.

To the west of the large central expanse and separated from it by older formations, brought up by the Gloucester and Hazeldean faults, is an isolated area of Ottawa limestone of considerable extent, which occupies the northwest corner of the Ottawa-St. Lawrence basin. The area is cut by faults into three slices, and the underlying Beekmantown is repeated by two faults radiating from near Pakenham. On each slice the Ottawa formation on its western margin overlaps the Beekmantown. Besides these larger areas there are four, small, isolated tracts of Ottawa limestone occurring in grabens from 7 to 18 miles long, and 2 to 8 miles wide, namely, northwest of Arnprior, northwest of Renfrew, on Allumette Island and the surrounding country, and in a horseshoe expanse extending from the Fourth Chûte of the Bonnechère to Lake Doré and to Eganville, and five small remnants, at Calabogie Lake, Ashdad, northwest of Esmonde, Lake Clear, and southwest of Killaloe.

Correlation. The Ottawa formation comprises those beds usually called Black River, with its three members: Pamelia, Lowville, and Leray; and Trenton, with its four members: Rockland, Hull, Sherman Fall, and Cobourg.

Originally the entire formation, exclusive of the lowest member, the Pamelia, was included under the term 'Trenton'. Later, when the fossil content was better known, the succession was discussed under the 'Trenton and Black River groups', indicating that the various authors recognized a lithological unit though palæontologically some gradation was evident, and in Ontario the terminology of New York State was applied. In recent years in New York State the term 'Mohawkian' has been substituted in place of 'Trenton and Black River groups'. The Pamelia, originally excluded from the 'Trenton-Black River group' was first studied in New York State, where diagnostic fossils were not found, and where the contact with the formation below it is concealed. It is there considered to be of Chazy age. Raymond (1912, p. 353) first introduced the name into Ontario. He correlated with the New York Pamelia similar beds at Kingston and in Ottawa Valley that lay above the topmost Chazy formation and which later he (1913, p. 141) assigned to the Black River group, from its fossil content. The Black River, including the Pamelia of Ontario, was divided into three and the Trenton into four members, really beds differentiated mainly by faunal associations. On the accompanying map (No. 852A) the approximate boundaries of these associations ('members') are shown in dotted lines in order to correlate as nearly as possible the beds upon which palæontologists have done detailed work.

The Ottawa formation, then, is correlated with the Pamelia and Mohawkian of New York, and with rocks of Black River-Trenton age in the Montreal, central, and western Ontario areas. Rocks of this age have not yet been found in the northern regions of Canada.

Collingwood and Gloucester

Eastview Formation

Definition and Contacts. The Eastview is a thin formation that overlies the Ottawa limestone and is covered by the Billings. The lower contact is not exposed, but it is thought to be disconformable, because, though the beds have the same dip as the formation beneath, there is a change in the texture and colour of the rock, and, where exposed, the topmost beds of the Ottawa limestone are somewhat weathered. It may be noted in this connection that Sproule (1936) has found the base lying unconformably upon both lower and upper beds of Black River-Trenton age on Manitoulin Island.

The upper contact is conformable, and is placed arbitrarily at the top of the uppermost limestone bed. The name 'Eastview' is chosen because the formation underlies the western edge of the village of Eastview, across Rideau River from Ottawa.

Description. The Eastview is composed of limestone interbedded with shale. The limestone is dark grey and fine-grained, with some large calcite crystals. It is thick bedded at the base with shaly partings, and gives place upward to thinner beds with more shale, the latter dark and friable. Both rock types weather rusty. No section is exposed, and even outcrops are rare. Its presence has been detected by wells and excavations within the city of Ottawa.

Thickness. The Eastview has a maximum thickness of about 20 feet at Ottawa. It apparently thins out and disappears towards the east. If it ever occurred west of the Gloucester fault it has been eroded.

Distribution. The Eastview formation is found in excavations at Ottawa and a few beds of it are exposed on the east bank of Rideau River. At Lemieux, Ontario, another outcrop is revealed in Nation River, at low water. There are several scattered exposures of the shale above it between Ottawa and lots 13 and 14, cons. III and IV, North Plantagenet tp., and it is presumed that Pleistocene deposits cover the Eastview lying between this shale and the top of the Ottawa formation, which outcrops within a short distance. The Eastview at most is not widespread.

Correlation. The correlation of the Eastview will be discussed with that of the Billings, when the ages of both formations are considered together.

Billings Formation

Definition and Contacts. The Billings is that formation that lies above the Eastview and below the grey shales of the Carlsbad. It is a lithological unit embracing the top shales of Collingwood age and all the shales of Gloucester age. The lower contact is conformable, and is placed arbitrarily above the uppermost limestone of the Eastview. It has only been seen in excavations and wells, though there are a number of exposures of the shale a few feet above the contact. The upper contact, too, appears to be conformable, but is difficult to detect because the change to grey shale is not clearly defined in the fresh cuttings of wells, and the contact is nowhere exposed. An outcrop in a stream crossing the Ottawa-Morrisburg road, south of Ellwood, is thought to be very near the contact. It shows the black Billings shale with a few intercalated bands of dolomitic rock.

The name 'Billings' is chosen from that of Billings Bridge, a suburb of Ottawa, where the formation outcrops in the cutting of a stream.

Description. The Billings is a shale formation throughout. The lower few feet weather brown and pass imperceptibly upward into thick beds of black, fissile shales. There are a number of exposures but no complete sections. The best to be seen is in Bear Creek, con. III, Cumberland tp., Ontario.

Thickness. The exact thickness of the Billings formation is not known. One well a short distance east of Billings Bridge penetrated 255 feet of the Billings black shale without reaching the Eastview formation. Another well not far from the first but on the other side of a minor fault reached the Eastview at a depth of 203 feet. The Billings formation probably has a thickness of 260 to 300 feet

Distribution. The Billings is not widespread within the basin. Its region of exposure forms a somewhat horseshoe-shaped area with its curved tip lying under part of Ottawa. One arm extending southward is cut off by the Gloucester fault; the other extends eastward, outcropping in Green Creek. An outcrop still farther east, in Bear Creek, demonstrates that the formation continues eastward though offset by one of the many faults. That it once covered a much larger area is shown by four isolated outcrops; east of Hammond, east of Clarence Creek, west of Plantagenet, and at St. Isidore de Prescott. A well at Fournier reveals that the formation underlies heavy Pleistocene deposits in that district.

Correlation of Eastview and Billings Formations

The Eastview and Billings formations of the Ottawa-St. Lawrence Lowland represent a continuous sequence of beds, but are distinctive lithologically. Together they make up the former Collingwood and Gloucester of the basin, but the division between the two is different. The Eastview and Billings are defined by lithology, the Eastview being limestone interbedded with shale, and the Billings all shale. The terms Collingwood and Gloucester are retained as time terms.

Originally the Collingwood was defined by Raymond (1911 and 1913) as limestone and shale with the trilobite *Ogygites latimarginatus* Hall (*canadensis* Chapman) as the diagnostic fossil. Later this trilobite, associated with an otherwise Trenton fauna, was found in 90 feet of thick-bedded, grey limestone in the Georgian Bay region. Parks (1928) lowered the Trenton-Collingwood contact to include these thick-bedded, grey limestones, limiting the upper boundary of the Collingwood by a *Triarthrus* that admittedly is found below the Collingwood-Gloucester contact as well as above it. On this basis the Collingwood embraces thick-bedded, grey limestone, dark, fine-grained limestone with shale, and at the top 15 feet or more of brown weathering shale, with lower and upper contacts indefinite. The thick-bedded, grey limestone Parks called Lower Collingwood, and the limestone interbedded with shale, with the upper 15 feet or more of shale, Upper Collingwood. In the Ottawa-St. Lawrence Lowland the black, fissile shales above the Collingwood remained Gloucester, as defined by Raymond. Because of the variability of the boundaries and the several types of lithology embraced by the term 'Collingwood', and the inclusion in it of the 15 feet or more of shale more closely allied to the Gloucester above, it is felt that a lithological definition of the formations is more reasonable and practical in the Ottawa-St. Lawrence Lowland. The Eastview, then, is to be correlated with the lower part of Raymond's original Collingwood and with most of the Upper Collingwood of Georgian Bay as defined by Parks. The Billings is correlated with the Gloucester plus the 15 feet or more of shale originally included in the Collingwood and lying above the uppermost limestone of the Eastview. The black shale is also found in central Ontario near Whitby; in the Eastern Arctic; on Baffin Island and on Grenfel Tickle, Labrador.

DUNDAS-LORRAINE

Carlsbad Formation

Definition and Contacts. The Carlsbad is the shale formation of the Ottawa-St. Lawrence area that lies above the Billings and is overlain by the

Russell formation. Neither lower nor upper contact is exposed, but it is thought from the dip of the outcrops that both contacts are conformable. From the nature of the Billings shale in the highest exposure mentioned above on the Ottawa-Morrisburg road, and from the basal Carlsbad beds as seen in a quarry about half a mile east of Billings Bridge, it is thought that the change is gradual. The position and nature of the upper contact is even less certain, for there are no exposures near it, and, as the formation above is also largely shale, the contact is difficult to detect in well cuttings.

A deep well at Carlsbad Springs, Ontario, has given the most complete record of the formation, and the name is chosen from that of the village.

Description. The Carlsbad formation is dominantly grey shale, with some impure limestone or dolomitic bands and a little sand. The few outcrops show local variations common to shallow or near-shore deposits. A generalized section, compiled from scattered outcrops and a limited number of well borings, consists of interbedded dark shale and rusty weathering bands of dolomite overlain by beds of clear, grey, fissile shales, which, in turn, are succeeded by more rusty weathering, thin, dolomitic bands and shale, in places having a small sand content, and overlain by more shale. Shale predominates throughout.

Exposures of some of these phases can be seen in an interrupted section in a creek that crosses the road about midway between Hurdman Bridge and Billings Bridge. North of the road, in the creek bed, is a small exposure of Billings shale. Higher up in the creek and just north of the next road is an outcrop of Carlsbad separated from the Billings exposure by a covered area. It consists of interbedded shale and thin, rusty weathering bands of dolomite. South of this second road and about 500 feet east of the creek is a quarry in the overlying grey, fissile shales. Above this again, at Leitrim, is the interbedded shale and rusty weathering dolomite with some sand. No exposure of the shale has been seen higher than this.

Thickness. The maximum thickness of the Carlsbad is estimated at about 500 to 550 feet. As stated above, the exact positions of its contacts with the Billings below and the Russell formation above are difficult to ascertain from well cuttings. The well at Carlsbad Springs shows 600 feet of combined Billings and Carlsbad, and another well farther east, near Vars, shows 800 feet.

Distribution. The Carlsbad occurs only in the southwest part of the large down-dropped block of the eastern half of the northern margin of the basin, protected by the older, more resistant rocks brought to the surface on the upthrow side west of the Gloucester fault and by the tilting of the down-dropped block. It occupies less than 160 square miles in the form of a band about 8 miles wide. From its western edge, just south of the city of Ottawa, it extends a little south of east for about 20 miles. A small area in the centre is overlain by younger rocks.

Correlation. The Carlsbad may be correlated in a general way with the Dundas of central Ontario and with the 'Lorraine' of Nicolet Valley, Quebec. Foerste has concluded that the 'Lorraine' sediments of eastern Ontario and Quebec were deposited contemporaneously with those of New York, but in a separate basin.

Fossiliferous outcrops are few, but a comparison of the fauna suggests that the lowest beds of the Dundas and the 'Lorraine' of Quebec are missing from the St. Lawrence area. The *Whitella* fauna, characteristic of the lowest

Dundas horizon, is lacking in the basal Carlsbad, and only long range fossils occur in both. Foerste (1916) has divided the Quebec 'Lorraine' into four not very clearly defined faunal zones, which, from the top to the bottom, he named the *Pholadomorpha*, *Proetus*, *Leptæna*, and *Cryptolithus* zones, respectively. No species from the Cryptolithus zone has been found in the basal Carlsbad. It seems probable, then, that the Carlsbad represents sediments deposited some time after the beginning of Lorraine time. The Billings formation was deposited in a sea that invaded the basin from the Arctic. The Carlsbad, on the other hand, is the most northern representative of a later invasion from the south. It is reasonable to suppose that some sediments were deposited to the south before that invasion reached this area.

Richmond

Russell Formation

Definition and Contacts. The Russell formation overlies the Carlsbad shales and in turn is overlain by the Queenston. Both contacts are thought to be conformable, but neither of them is anywhere exposed, nor are there wells penetrating the formation.

The Russell formation is named from the township of Russell in which it occurs.

Description. The Russell consists of grey shale and interbedded, heavy, rusty weathering, dolomitic limestone. The grey shale has been seen only in diggings from a few surface wells. The thick-bedded, dolomitic limestone outcrops in the bed of a creek, about lot 24, con. VII, Cumberland tp., Ont., and fossiliferous blocks a few feet higher in the section are strewn around shallow excavations, now overgrown, on lots 25 to 28, con. VIII, Cumberland tp.

Thickness. The thickness of the Russell formation is not known, but it must be very thin to occupy the limited space between the highest known Carlsbad and the lowest known Queenston beds.

Distribution. The Russell formation occupies a very small area north and west of Russell village, in the southwest corner of the down-faulted block on the eastern half of the northern margin of the basin. It forms a narrow, circular rim around the margins of the succeeding formation.

Correlation. The Russell formation may be correlated with the Meaford of the Georgian Bay area.

Queenston Formation

Definition and Contacts. The Queenston formation overlies the Russell. It represents the latest Ordovician sediments in Ontario, and in the Ottawa-St. Lawrence basin is overlain by Pleistocene deposits. The lower contact is not exposed, but is thought to be conformable. The upper contact, exposed in several places, is very irregular, the unconformity representing the passage of all later Palæozoic, Mesozoic, and Tertiary time.

Description. The formation is a red shale, occasionally streaked or mottled grey-green. The best outcrop is in a quarry about 4 miles north of Russell, Ontario, where from 8 to 10 feet of it are exposed. Another outcrop, easy of access, occurs in the bed of Castor River, about 2 miles west of

Russell, where the upturned edges of the shale mark the course of the Gloucester fault.

Thickness. Estimates based on a number of intersecting structure sections indicate a thickness of about 100 feet for the Russell and Queenston formations combined. Many years ago a boring put down in the quarry north of Russell, referred to above, passed through 70 feet of shale, but this may have included shale at the top of the Russell.

Distribution. The Queenston occurs only in one small area west and north of Russell, Ontario, in a small basin at the extreme southwest corner of the down-faulted block mentioned below. The southern tip of the trough is truncated by the Gloucester fault.

Correlation. The Queenston is identified with the formation of that name at the type locality in the Niagara Peninsula. It is the only deposit in Ontario of these red shales east of Credit River Valley.

QUATERNARY

The superficial deposits were not a part of the investigation of this report except in so far as they are involved in the discussion of the underlying Palæozoic rocks and the limit of their distribution is a result of the structural disturbances that took place in Palæozoic times.

Pleistocene and Recent sediments of till, late marine deposits, and lacustrine and fluvial muds and sands succeed the Ordovician rocks. They vary in thickness from nil to 200 feet where they lie in boulder hills and sand dunes and where they fill in the unevennesses of tilted blocks or erosional surfaces.

Palæozoic deposition within the basin was followed by a long period of emergence. If there were any Palæozoic rocks younger than the Queenston they were eroded during that time.

Pleistocene

Glacial Deposits

Thin, irregular deposits of till and a few eskers overlie Palæozoic sediments in the higher levels of the western and in some of the central parts of the basin. Much thicker, terminal moraines and drumlins occur on the east from Hawkesbury to Cornwall (Johnston, 1916, p. 3). Many sections of glacial material expose stratified gravels sorted by glacial streams. In some areas of the basin, particularly in the central and eastern parts, varved clays lie upon the Palæozoic rocks or Pleistocene till, and bear witness to the presence of marginal lakes and rivers during the retreat of the ice-sheet.

Champlain Deposits

In the central and eastern part of the basin, sand and clay containing marine shells and fish remains lie either directly upon the Palæozoic rocks or, in some places, bury thinly spread glacial debris, and boulder hills. Marine beaches are found at various levels, the highest being 690 feet (Johnston, 1916, p. 5) on Kings Mountain northwest of Hull. Most of the evidence of the marine invasion has been obliterated from the higher land between Ottawa and St. Lawrence Rivers in the western part of the basin.

The great weight of ice in Pleistocene time depressed the northern part of the continent, which was slow to recover its normal position after the withdrawal of the ice. During this period a gulf of the Atlantic Ocean penetrated the Greater St. Lawrence Lowland and inundated the Ottawa-St. Lawrence basin. Fresh water gave place to brackish, and brackish water to salt water. The northern boundary of the invasion was defined largely by the zone of faulting along the Palæozoic-Precambrian border. This sea, known as the Champlain Sea, never transgressed far over the Canadian Shield, stopped by a wall where the Precambrian rocks rose abruptly above the Palæozoic basin, along the Eardley fault west of Gatineau Valley, and also east of Papineauville, where, to the north of the present Ottawa River, a scarp rises above the highest beach. Between these points, where the faulting lies within the Palæozoic rocks, the Precambrian formations to the north rise with a gentle monoclinal slope, and a bay of the Champlain Sea probably penetrated farther north over the low Precambrian levels of the country now drained by Gatineau and Lièvre Rivers and to a lesser degree by Blanche and North Nation Rivers. Along the southwestern margin of the lowland the Champlain Sea penetrated beyond the boundaries of the basin over the Frontenac axis nearly to Lake Ontario. The southern boundary lay in New York State.

Recent

Recent deposits are made up of lacustrine marls replete with fossils and alluvial sediments. The exposed Palæozoic rocks and the unconsolidated glacial and marine sediments have been considerably modified by more recent erosion along Ottawa and St. Lawrence Rivers and their long, winding tributaries.

CHAPTER IV

STRUCTURE

The original uniform configuration of the Palæozoic deposits of the Ottawa-St. Lawrence Lowland has been modified greatly by two major sets of faults. Of these, the principal set of faults, or in some places fault zones, has a general east-southeast trend with a slight curve somewhat convex to the west of south. Towards the west of the basin the general direction of these faults is about south 60 degrees east. Progressively eastward they swing to more nearly true east. The general pattern resembles slightly curved radii stemming not from a centre but from an elongated east-west mass to the north of the western part of the basin (Figure 3, *in pocket*).

Most of the lesser set of faults developed as relief to the stresses caused by the primary faults. The whole pattern reflects a torsion-tension movement to the north of east.

The faulting within the Canadian part of the basin is almost entirely confined to the northern half, though a few minor faults extend southeast to the International Boundary. Roughly, the faulting forms the northern boundary of the present Palæozoic formations, separating them from the Precambrian rocks.

Due to the location of the faults the position of the Palæozoic beds relative to the Precambrian rocks has four aspects on the northern margin of the basin.

East of Papineauville the Palæozoic basin is separated from the highlands by the Grenville fault, with an abrupt rise of the Precambrian rocks on the upthrow side to the north. The exposures suggest only a small throw in this region because only the oldest Palæozoic rocks outcrop south of the fault. But the throw of the fault is probably considerably greater than is indicated by surface observations. A drill hole at Silica, Quebec, about 2 miles south of the present Precambrian scarp, revealed more than 500 feet of basal sandstone, which means either that the sand filled in an old channel or was deposited in a sinking area. The abruptness of the Precambrian wall and its relation to the downthrow side suggest an older fault, or perhaps subsequent movement along a former fault in the Precambrian.

The second section extends from Papineauville to Hull, a distance of some 35 to 40 miles. In this section the two sets of faults cross into the northern edge of the Palæozoic area, leaving a rim of the oldest Palæozoic sediments lying with a gentle monoclinic slope against the Precambrian, north of the broken region.

The third section extends roughly from Hull to a little west of Arnprior, approximately 35 miles. This section enters the narrowed area of the Palæozoic sediments extending northwest up Ottawa Valley. The trend of the primary faults here parallels the direction of the valley. The Eardley fault on the northeast abruptly defines the limit of the Palæozoic basin in that direction. On the southwest of the margin of the narrowed valley another fault of lesser throw separates the Palæozoic sediments from the Precambrian rocks on that side. Between these two faults are at least two others, perhaps more, that cut the Palæozoic sediments into long, narrow strips tilted towards the northeast so that the older beds are brought up on their southwest sides. In one place a Precambrian knob stands in the midst of the older formations of Palæozoic rocks, brought to the surface on the upthrow side of one of these long, narrow blocks.

The fourth section is the northwest limit of the Palæozoic basin, which narrows and is gradually lost in the Canadian Shield. Within this area are long, narrow grabens within which are the only Palæozoic rocks preserved. The boundary faults of the grabens all have the same general trend as the primary faults of the entire basin.

The main structural feature of the area is a large, down-dropped block bounded by fault zones on the north, west, and south. The block extends eastward from the city of Ottawa. It is oblong, with its greatest dimension east-northeast, and is so tilted that its maximum throw is at the west and south. About the centre of the block the gradual upward inclination eastward is interrupted by a slight break or further down-warping. From there eastward the upward inclination is resumed until the eastern extremity of the block almost regains its normal monoclinal position against the Precambrian rocks of the Beauharnois axis. The Gloucester fault, or fault zone, on the west and southwest margin of this block is the key fault of the central part of the area. The faulting on the north side of the block involves the 35 to 40-mile section of the basin in which the faulting along the northern margin of the lowland crosses Palæozoic sediments (Plate III B). This section of the fault system presents a peculiar tearing pattern and is part of the 'radial' fault pattern of the basin. On the north side of the longer faults of this margin of the block, secondary faults developed towards the northeast at an angle of 120 to 130 degrees to the longer faults and forming, within this marginal zone, numerous small tilted blocks, some of which are even upthrust. The long fault on the south and southeast of the block was clearly to relieve the tension along its northern margin, and the few secondary faults on the upthrow side where it borders the large down-faulted block afford relief to that more stable region.

Almost all the faults have their largest displacement about midway of their length. The throw varies from zero to a maximum of approximately 1,800 feet, along the Gloucester fault, west of Russell where the Queenston shale is brought down to the level of the Oxford dolomite.

It is to be noted that a line joining the position of the maximum throw of the series of faults on the north of the large down-faulted block is practically parallel to the east-northeast fault forming the southern boundary of the block. This peculiar alinement of the position of maximum throw of each fault may be an expression of a buried Precambrian fault along which later movement has occurred.

Along the line of the Gloucester fault the fault block to the east sinks at a nearly uniform rate. The older rocks of the upthrow side gradually rise until the Nepean sandstone is exposed about 2 miles north of South Gloucester, and then sink again, covered in turn by the March and Oxford.

The dip of the faults has not been observed, but it is known to be steep around Ottawa where none of the numerous, closely placed wells crosses a fault plane. The faults, themselves, are concealed except in a few places where their positions are indicated by down-dragged adjacent rocks. They have been usually detected by the juxtaposition of rocks of different beds or formations.

The exact age of the faulting cannot be established, nor whether it took place at one, two, or even more times. The fact that the youngest Ordovician rocks are cut by the faults shows that the latter must have developed during post-Ordovician time. The presence on St. Helens Isle, Montreal, of Lower Devonian rocks enveloped by igneous rocks and intruded by dykes suggests a period of faulting succeeding Lower Devonian deposition. In the Gaspe and Chaleur Bay region Alcock (1935) has established that folding took place at two periods, one at the close of the Ordovician and one at the close of the Lower Devonian. It is probable that the faulting of the Ottawa-St. Lawrence Lowland is related to the disturbances of one or both of these periods and that it is connected with the northern Appalachian movements.

CHAPTER V

ECONOMIC GEOLOGY

No outstanding supply of economic minerals or metals has been found within the area mapped. The Precambrian rocks to the north and west of the Palæozoic lowland have produced small, commercial quantities of mica, pyrite, galena, molybdenite, celestite, graphite, apatite, feldspar, and quartz. In recent years the discovery of brucite in limestone of the Grenville series, and the utilization of dolomite beds in the same series, have afforded an abundant source for the manufacture of basic refractory materials and metallic magnesium, and have opened up important industries. But the economic geology of the Precambrian rocks of these boundary areas is pertinent to the Ottawa-St. Lawrence Lowland only to the degree to which it affects and will affect the increasing industrial life of this lowland.

ROCK PRODUCTS

Building Stone

The region has a large supply of good building stone. Seven types are readily available to any part of the basin: Grenville dolomite or limestone, Nepean sandstone, Oxford dolomite or limestone, Rockcliffe sandstone, St. Martin limestone (to a limited degree), Ottawa limestone, and field stone.

Quarried Stone

Grenville Dolomite. Limestone and dolomite are among the oldest of the rocks in the Grenville sub-province of the Canadian Shield. Though its density makes it difficult to work, outcrops near towns on the Precambrian border of the basin have been quarried, particularly to supply material for foundations of buildings.

Nepean Sandstone. The great durability, coarse grain, massive appearance, and rust-mottled colour of the Nepean sandstone make it a beautiful and valuable stone for building purposes. It is perhaps more suitable for large, massive architecture than for smaller buildings, though it has recently been used for the lower story or even the foundations of private houses. Its full dignity, however, is revealed in the main Parliament Buildings of the Dominion, standing on Parliament Hill. It has also been used for many other large government buildings in Ottawa.

The supply for Ottawa has been taken for many years from outcropping strata about 10 miles west of the city, just north of Highway 15. The sandstone forms a north-south ridge that crosses several properties in Nepean township.

Near Mirabel, Quebec, about 8 or 9 miles east of Lachute (Plate II A), are large areas piled with loose masses of thick slabs of Nepean sandstone heaped up by glacial action. These are cut on the spot, and shipped to Montreal for building purposes.

Several outcrops of Nepean sandstone in the area have not yet been used for any purpose.

Oxford Dolomite. In the western part of the basin where the Oxford dolomite is widely exposed the formation is thin and includes many impure beds. In the eastern part of the basin the formation is thicker and composed mainly of dolomite, but it is, for the most part, deeply covered by unconsolidated deposits. There are quarries, however, both in the east and in the west but the stone is only locally used for building. On lot A, rge. 1, Lochaber Gore tp., Que., is a quarry the stone from which was used for culverts for the Canadian Pacific north shore line between Montreal and Ottawa. Near Iroquois, Ontario, are several quarries from which the rock was taken for that part of the St. Lawrence canal. Quarries in the vicinity of Valleyfield have supplied some rough building stone.

In New York State to the south this rock is used more extensively. One probable reason for the lack of development of the dolomite within the lowland is the greater accessibility of other material.

Rockcliffe Sandstone. The Rockcliffe sandstone is patchy in its occurrence, and not very important economically. Nevertheless, it is used locally for building stone and for flagstones.

St. Martin Limestone. As has been shown, previously, the St. Martin limestone does not extend over the western part of the basin, and is only a thin, impure, marginal deposit in the central part. To the east and southeast, however, near Hawkesbury and along the St. Lawrence, the thicker, purer limestone beds have been quarried for building stone.

Ottawa Limestone. The Ottawa limestone is well adapted for building purposes and in the city of Ottawa it has been used for churches, business blocks, and residences. The thick, pure limestone beds of the lower half of the Ottawa formation, comprising the Leray, Rockland, and Hull beds, are especially suitable and have been quarried extensively for building stone. In the upper half of the formation the Cobourg beds offer an almost limitless supply. The latter beds are exposed largely in cliffs, such as those along the south bank of Ottawa River from Rockcliffe to the west of Ottawa where the scarp curves inland, crossing west of the central section of the city. In the past there have been a number of quarries along the inland limb of this curved escarpment, but in recent years these old quarries have been filled in as the city has grown. To the east and southwest of Ottawa and in Hull are large quarries, the stone from which has been used in Ottawa and Hull and has been shipped to neighbouring towns.

To the south of the mapped area, the Mille Roches quarries in Leray-Rockland beds have supplied building stone locally, and have been used in canal construction.

Altogether there are scores of small quarries in the Ottawa limestone. Some have changed their product to crushed stone; some have been abandoned. Many of them are water-filled, but they are still a potential resource.

Stone for Canal Construction. Local stone was used in the construction of the canals built to overcome the rapids in Ottawa, St. Lawrence, and Rideau Rivers. Along the Ottawa, at the Grenville and Carillon canals, great blocks of Oxford and St. Martin limestone line the canal walls. In the series of

St. Lawrence canals the type of rock used has depended mainly on the bedrock through which the canals run. The canal banks are lined successively with Oxford limestone or dolomite, St. Martin limestone, and the Leray-Rockland beds of the lower Ottawa limestone, the last obtained largely from the nearby Mille Roches quarries.

One large quarry, on lot A, con. X, Russell tp., now abandoned, supplied stone for both the Ottawa and Cornwall canals.

Field Stone

Boulders of glacial origin are to be found, scattered sparsely over wide areas or thickly congregated in others. Varied assortments taken from the fields have been used in building farmhouses, mills, and barns, but are now used mostly for foundations.

Selected Precambrian boulders, particularly those that are deeply coloured, are used locally in building residences, and are more widely used for ornamental chimneys and fireplaces.

Crushed Stone

A number of large quarries produce crushed stone as a primary or secondary product: the quarry of the Canada Cement Company north of Hull; Foster's quarry, southwest of Ottawa; the quarry on the road running north from Eastview; the crushing plant of Devil's Garden at Rigaud; and the Mille Roches quarries west of Cornwall are some that more recently have produced crushed stone. Many small quarries are also producing it.

A unique occurrence of boulders that are being broken up for crushed stone is found on the north side of Rigaud Mountain, the Devil's Garden, an area of many acres of amassed glacial boulders of considerable size, sorted to some degree. One theory of the origin of the accumulation is that a sub-glacial stream rolled the boulders from the north up against the steep, northern fault-face of Rigaud Mountain. The deflected current was retarded, leaving the boulders piled against the mountain face. A Montreal company has cut and crushed the boulders for various purposes, but a considerable supply still remains.

North of the Mountain road and 2 to 2½ miles west of Hull is an outcrop of Grenville limestone that is crushed to make a sparkling white, pebbly material marketed for artificial stone, for a fine, white gravel used in walks, and a variety of other domestic products.

In addition, a number of quarries have been worked for railway ballast. Perhaps the most outstanding of these is the large quarry in Oxford dolomite along the railway line between Oxford Mills and Merrickville, opened and operated for the Canadian Pacific Railway. Another quarry in impure Grenville limestone, northeast of Lachute, was used in the construction of bridge piers for the Canadian Pacific north shore line between Montreal and Ottawa. Numerous other smaller quarries are worked intermittently to supply local needs.

The construction of provincial, county, and township highways has made a large demand for crushed stone and gravels, and at least two score quarries operated for road metal have fallen more or less into disuse as the roads were completed. The supply is there, however, and no doubt some of these quarries will again come into production as existing roads require improvement or new roads are constructed.

No place in the basin is far from a source for crushed stone when it is needed.

Stone for Cement

A large quarry north of Hull is now owned and operated by the Canada Cement Company. This quarry, or series of quarries, produces a limestone of very high calcium carbonate content. The rock is mainly from the Hull beds of the Ottawa formation.

More than 100 years ago the first hydraulic cement plant in Canada was established at Hull, though the rock came from the Ottawa side of the river. The present plant has produced for nearly 60 years, though it has changed hands a number of times and has been greatly enlarged during that period.

A few other quarries have produced small quantities of limestone for cement from time to time, but they have closed down.

Sand and Gravel

The Ottawa-St. Lawrence basin has been subjected to glacial action, and most of it is covered with glacial debris. Every size of rock fragment of glacial origin is to be found, from silt and sand to large boulders. Subsequent to the retreat of the glaciers the rivers have sorted the gravel in many places. In addition, the invasion and retreat of the Champlain Sea deposited fine sand and left irregularly placed beach gravels, often of unsorted sizes.

The sand of the basin, therefore, is in part fine Champlain Sea sand, and in part coarser, less disintegrated sand of glacial origin, mostly piled around the margins of the basin within or at the edges of the Laurentian Hills.

The gravels, too, were deposited in part by the Champlain Sea and tributary streams, but although their sorting was due to water action, their origin, in the main, was the result of glacial action. In large areas of exposed bedrock over which the glaciers moved the gravel would consist largely of material from the rock beneath, even though it might contain many other constituents. Where gravel is used for itself, as on gravel roads, this factor is of no particular importance. When, however, gravel is used for concrete exposed to frost action an economic factor is involved.

The Oxford formation is mostly dolomite, and covers a large area of the basin. Some beds of dolomite also occur in the lower 50 feet of the Ottawa limestone. Dolomite is a rock consisting of about equal proportions of calcium and magnesium carbonates. Upon exposure, the calcium carbonate dissolves more readily than the magnesium carbonate leaving an outer lattice of magnesium carbonate (magnesite) crystals. When used in concrete the lattice of magnesium carbonate takes up, in its interstices, more water than can be absorbed in the mixture. If placed near an outer surface reached by frost the expanding water cracks the concrete, forming a 'pop-out'. Such, unfortunately, can readily be seen in many concrete roads and cement buildings of the district.

This distinction between pure limestone and dolomitic limestone in gravels should be considered in preparing concrete for use in constructions exposed to frost action.

Stone for Lime

Lime is produced from the rocks of the Ottawa-St. Lawrence Lowland as lump lime, crushed quicklime, and slaked lime and is used for chemical, metallurgical, constructional, and agricultural purposes. The largest plants, however, are not within the area mapped, but farther up Ottawa Valley near the margin of the basin, at Carleton Place and within grabens at Fourth Chûte of the Bonnechère, and at Eganville. Within the map-area there are at least a dozen quarries that produce rock for lime in smaller quantites, as a secondary product. In the early days almost every farmer calcined limestone for lime, mortar, or agricultural purposes. The ruins of old limekilns dot the country side.

Abrasives Materials

At Silica, Quebec, about 16 miles east of Lachute and $2\frac{1}{2}$ miles east of St. Canute, there is a large quarry in the Nepean sandstone. The plant is operated by the Canadian Carborundum Company, and the product is used in the manufacture of carborundum and other abrasives.

Drilling at this quarry showed that the sandstone persisted to a depth of at least 500 feet.

Miscellaneous Uses

Concrete Blocks. Frazer-Duntile Company, Limited, operates a plant south of Carling Avenue and west of Ottawa. The stone is quarried from a long ridge of the lower limestone beds of the Ottawa formation. It is cut for sills and lintels, crushed for use in roofing or other construction, and processed for concrete blocks with air spaces for use in the interior of outer walls of buildings.

Ornamental Stone. The limestone of the Leray beds, Ottawa formation, forms a long, low ridge across a number of lots of con. XII, Finch tp., Stormont co. The stone is a very dark, pure, fine-grained limestone. It takes a high polish, and is sold commercially as a black marble for interior decoration. It is shipped for this purpose to New York, Montreal, Toronto, Winnipeg, Vancouver, and other places.

Stone for Acid Towers. A number of plants near the large lumber mills along Ottawa River quarry some of the purer limestone from the Ottawa formation for use in the acid towers of the sulphide pulp mills.

Ferrosilicon Alloys. At Beauharnois, Quebec, on St. Lawrence River, about 6 miles east of the eastern boundary of the map-area, St. Lawrence Alloy and Metals Company, Limited, manufactures ferrosilicon products for use in all grades of steel. Nepean sandstone with a very high percentage of silica is the raw material. The principal source is at Melocheville, Quebec, about 3 miles east of the map-area, but material is also procured from Buckingham and Perth, the latter just west of the area mapped.

Glass. Supplies of Nepean sandstone for making glass and for use in manufacturing steel have been taken from near the eastern part of the area. The principal present sources are just east of Cascade Point, at the junction of Ottawa and St. Lawrence Rivers, and at Melocheville, Quebec.

Brick. The marine clays of the Champlain Sea furnish material for making bricks, and brickyards, large and small, are to be seen in many parts of the lowland.

The red Queenston shale from north of Russell is also used for making brick. It is quarried and shipped to the plant of Ottawa Brick and Terracotta Company, Limited, just west of Billings Bridge at Ottawa.

WATER

Potable Waters

The main urban population is along Ottawa and St. Lawrence Rivers, and water supplies are taken from these rivers. A few of the smaller, more inland towns and villages make use of tributary streams and lakes, pumping the water into standpipes or large tanks. Elsewhere water is obtained from wells, and is raised by windmill, electric or gasoline engine, force pump, or hand pump.

North of the area, within the Precambrian Shield, are numerous lakes from which adequate supplies of potable water may be obtained for northern parts of the area.

No adequate survey has yet been made of the underground water resources of the entire basin, but such drilling for water as has been done has provided some informative data.

The typhoid epidemic at Ottawa more than 30 years ago stimulated drilling within the city or in its immediate environs. More than eighty wells were put down. Six of them penetrated 1,000 feet or more, thirteen were sunk to depths of at least 800 feet, and numerous others to 500 feet or more. Wells in the rural areas also have yielded some information, but not many of these penetrate to any great depth, and in many instances adequate records have not been kept.

The Ottawa limestone contains water, but the flow varies from place to place depending upon the continuity of cracks and joint planes, for the limestone is not porous. The largest and most continuous supplies of potable well water are obtained from the March formation. The covering of Oxford dolomite is relatively impervious, and the porosity of the March sandstone layers allows free movement within the formation.

It has also been shown that the Gloucester fault is sealed, as the water-table stands at different levels on either side of it. On the other hand, drilling at several localities along the Montreal road has shown a scarcity of water, due either to escape along the faults separating the irregular fault blocks, or, if the faults are sealed as along the Gloucester fault, to the small size of the catchment area of each block.

Within the large down-dropped block that has its greatest throw west of Russell, the main catchment area is the exposed, porous or jointed rocks along and for some distance south of Ottawa River. The southwest part of the block is covered by impermeable shales of the Billings and Carlsbad formations. A deep well drilled in this shale-covered area has shown that water within the strata below that has migrated for a long distance from its catchment basin becomes too highly mineralized for domestic use.

Mineral Springs

A number of mineral springs within the region have been used for medicinal purposes, and at one time provided quite an industry, but modern synthetically medicated waters have lessened the value of the natural saline springs. Health resorts grew up around some groups of springs, such as Caledonia Springs and Carlsbad Springs (formerly Eastman Springs). Water was used from Victoria sulphur spring, near Green Creek, east of Ottawa; from Alfred, lot 10, con. VI, Alfred tp.; from Borthwick spring, east of Hawthorne, Gloucester tp.; from lot 9, con. VI, W. (?), Hawkesbury tp.; from Russell Lithia spring, near Bourget; from Plantagenet springs; from Winchester springs; and from St. Benoit spring. Another, rather weakly saline spring occurs at St. Eustache. Two other springs occur west of the mapped area in the tongue of Palæozoic rocks extending northwest up the Ottawa River Valley, namely Dominion spring, 2 miles from Pakenham, and Diamond Park spring on lot 26, con. XII, Pakenham tp. The latter is radioactive, but loses its activity quickly because of the small amount of radium dissolved in the water.

Caledonia Springs, about 10 or 11 miles south of Hawkesbury, has been known since 1806. In early days it was not easily reached, but it is now on the Canadian Pacific Railway line between Montreal and Ottawa. The source of the water is the Cobourg limestone beds of the upper part of the Ottawa formation. There are four springs, three of them, Saline, Sulphur, and Gas springs close together, the fourth, Duncan spring, 2 miles distant. According to Elworthy (1917, p. 24) these springs, the best known in Canada with the exceptions of Banff Springs, Alberta, and Fairmont Springs, British Columbia, were the only ones that had been examined for radioactivity.

In addition, four artesian wells have been drilled at or near Caledonia Springs, one of which, the Artesian sulphur spring, penetrated 100 feet into the rock and yielded water with sufficient hydrogen sulphide to be used for sulphur baths. This artesian well and the four springs show some radium emanations and small quantities of radium in solution, but any radium emanation in the gas at the mouth of the springs is immediately dispersed. Analyses of the springs, made several times since they were known, have shown that the chemical content of the water varies over the years, the change supposedly due to variations in the rate of precipitation of certain of the constituent minerals. A comparative table of the latest analysis made by Elworthy (1918) of the four springs and the more important artesian well is as follows:

Comparative Analyses of Springs and Artesian Well at Caledonia Springs

Constituents	Parts per million				
	Saline spring	Sulphur spring	Gas spring	Duncan spring	Artesian sulphur spring
Sulphuric acid	2·1	3·3	2·1	3·4	98·6
Bicarbonate acid	930·	861·0	925·0	1,200·	645·0
Nitrous acid	Trace	....	0·14	....	3·2
Phosphoric acid	....	Trace	1·0	1·2	....
Metaboric acid	Trace	Trace	Trace	Trace	Trace
Chlorine	4,194·0	3,086·0	4,412·	5,137·5	1,418·5
Bromine	10·0	14·5	2·4	10·0	4·8
Iodine	1·6	2·5	0·6	1·5	Trace
Oxygen	0·18	....	3·1	0·23	4·09
Silica	15·0	17·9	17·1	10·9	21·7
Iron	1·2	Traces	0·6	1·3	1·0

Comparative Analyses of Springs and Artesian Well at Caledonia Springs
Concluded

Constituents	Parts per million				
	Saline spring	Sulphur spring	Gas spring	Duncan spring	Artésian sulphur spring
Aluminium	0·21	....	3·5	0·26	4·6
Manganese	....	....	....	0·05	0·04
Calcium	41·0	39·8	70·8	43·5	27·7
Strontium	2·9	0·8	2·1	1·8	2·1
Magnesium	143·0	108·0	137·0	145·0	38·5
Lithium	2·4	1·8	4·7	17·2	1·6
Potassium	78·4	57·2	60·9	86·0	37·5
Sodium	2,691·4	2,030·6	2,808·94	3,339·3	1,076·2
Ammonium	4·89	4·37	5·81	10·7	1·77
Carbon dioxide gas	40·5	61·0	38·5	48·7	30·4
Hydrogen sulphide gas	0·7	0·94	0·3	....	10·9
	Units				
Radium emanations	70·	73·	90·	53·	56·
Dissolved radium	5·6	5·6	8·4	5·6	1·7

Carlsbad Springs, on the line of the Canadian National Railway from Ottawa to Montreal, is about 8 miles east of Ottawa. There are seven saline springs in the neighbourhood, six of which belong to the Sanitorium and have been used for sulphur baths and medicinal drinking water. The springs differ from one another in details, but on the whole they resemble the group at Caledonia Springs. Five of them show some radium emanations and minute quantities of radium in solution.

Both Caledonia Springs and Carlsbad Springs still maintain a degree of summer accommodation.

Winchester Springs and Plantagenet Springs have become small agricultural villages, their centres probably chosen because of the springs. Borthwick, Alfred, and Hawkesbury springs have fallen into disuse for all practical purposes.

The more important springs occur within the down-dropped block in the north half of the basin where there has been structural disturbance. The springs appear to have two sources—limestones and shale or clays. Of the limestones the upper part of the Ottawa limestone, the Cobourg beds, yields most water. The Caledonia springs, as mentioned above, come from these beds. In the Alfred spring, from the same source beds, chlorides predominate, but considerable quantities of bicarbonates are present. The Plantagenet springs issue from the same Cobourg beds, and contain a predominance of chlorides with some bicarbonates. The Hawkesbury spring, from the same beds or a little lower, is of the same nature. The source of the water of the Winchester spring is much lower stratigraphically, being from the thin St. Martin beds just above the Rockcliffe formation.

Of those springs issuing from shale, the Carlsbad springs are the most noteworthy. They issue from the Carlsbad shales above the Billings shale. The Borthwick spring, east of Hawthorne, was of the type in which chlorides predominate but with some bicarbonates. It has not been of commercial value.

Two small saline springs have been noted in Two Mountains county, Quebec, at St. Benoit and St. Eustache. The source of both is the clay over the Nepean sandstone. The St. Benoit spring carries mainly sodium chloride; the St. Eustache spring is only feebly saline.

OIL AND GAS

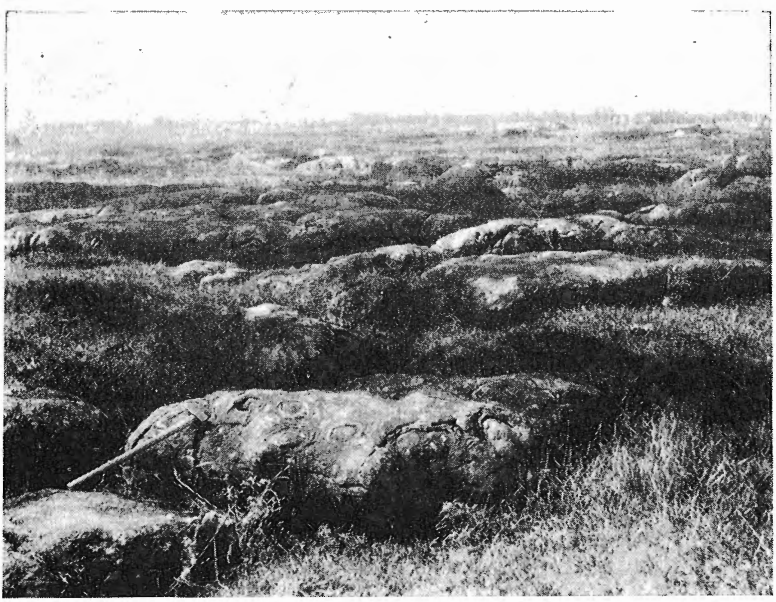
No wells drilled within the area mapped have shown more than a trace of oil, and that very rarely. A few fossils from the Eastview formation have displayed oil when split open, but oil is not an economic factor in the region.

Gas has been reported from twelve wells, of which eleven were within the main down-dropped block. The gas has formed in isolated pockets in the black, bituminous Billings shale and in the Cobourg limestone beds of the Ottawa formation. The twelfth well is east of Cornwall and penetrates rocks of Chazy age.

Both oil and gas occur only in isolated pockets, and have nowhere been found in commercial quantities. One well, just south of Ottawa in the Billings formation, produced a flow of gas for 10 days. Another well, near the centre of the fault block, produced sufficient gas for use in a private house.

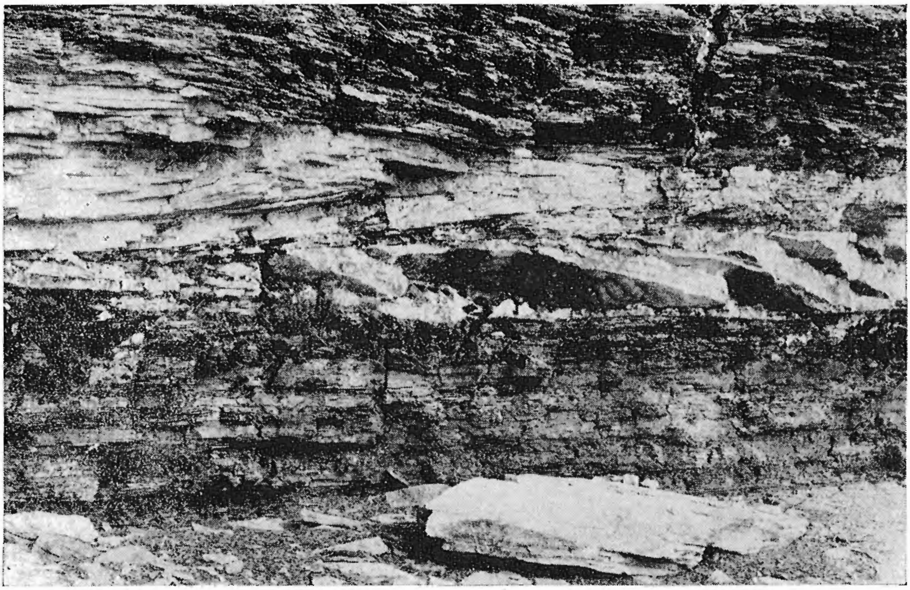
84266

A. A boulder hill of Nepean sandstone near Mirabel, Quebec. The loose rock is being cut in place and shipped to Montreal for building stone.



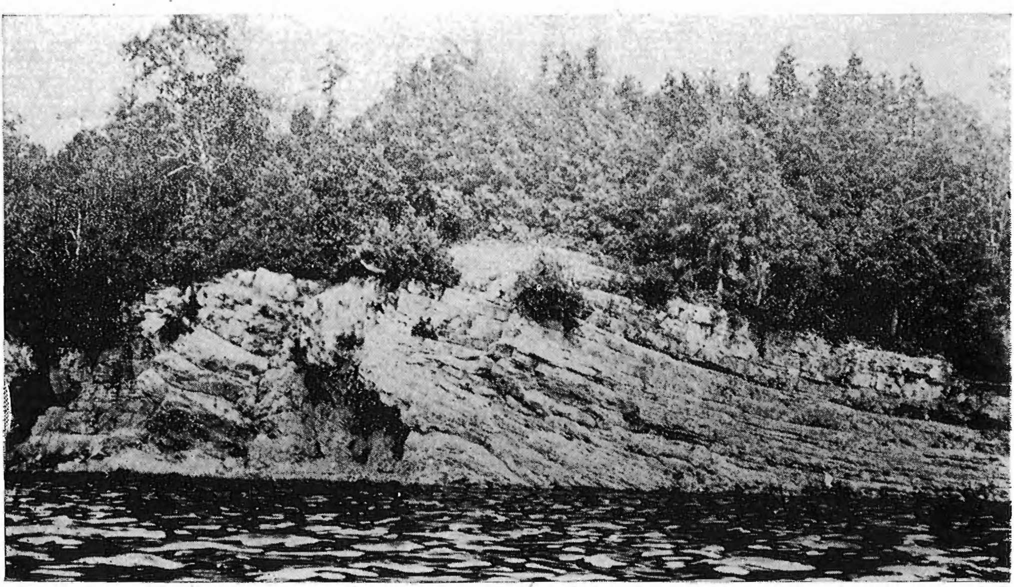
81893

B Oxford dolomite containing cryptozoons and showing the characteristic weathering along joint planes.



40250

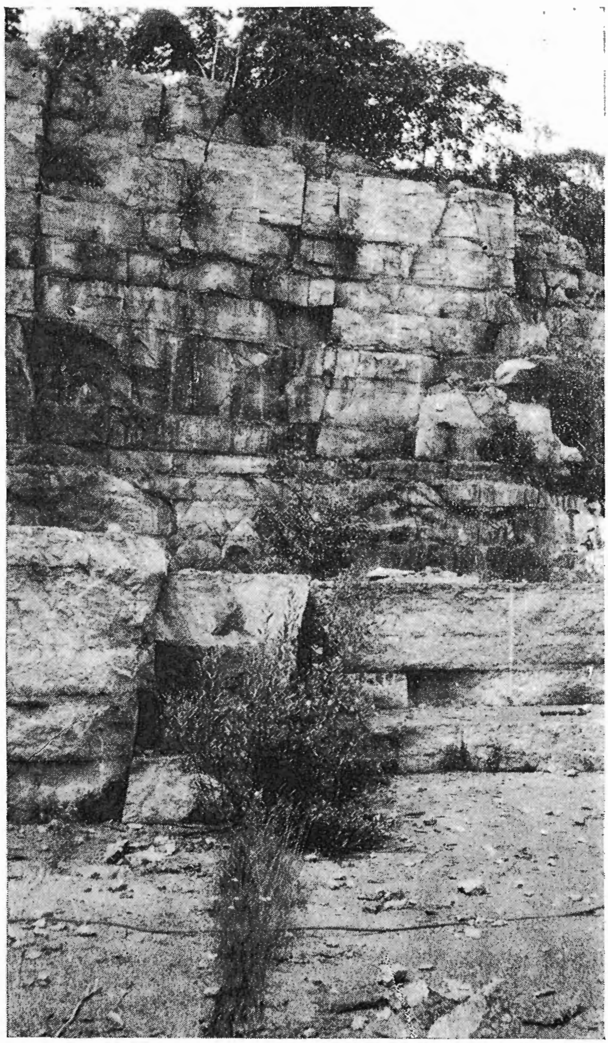
A. Sandstone lens in shale, Rockcliffe formation, concession XI, Fitzroy township.



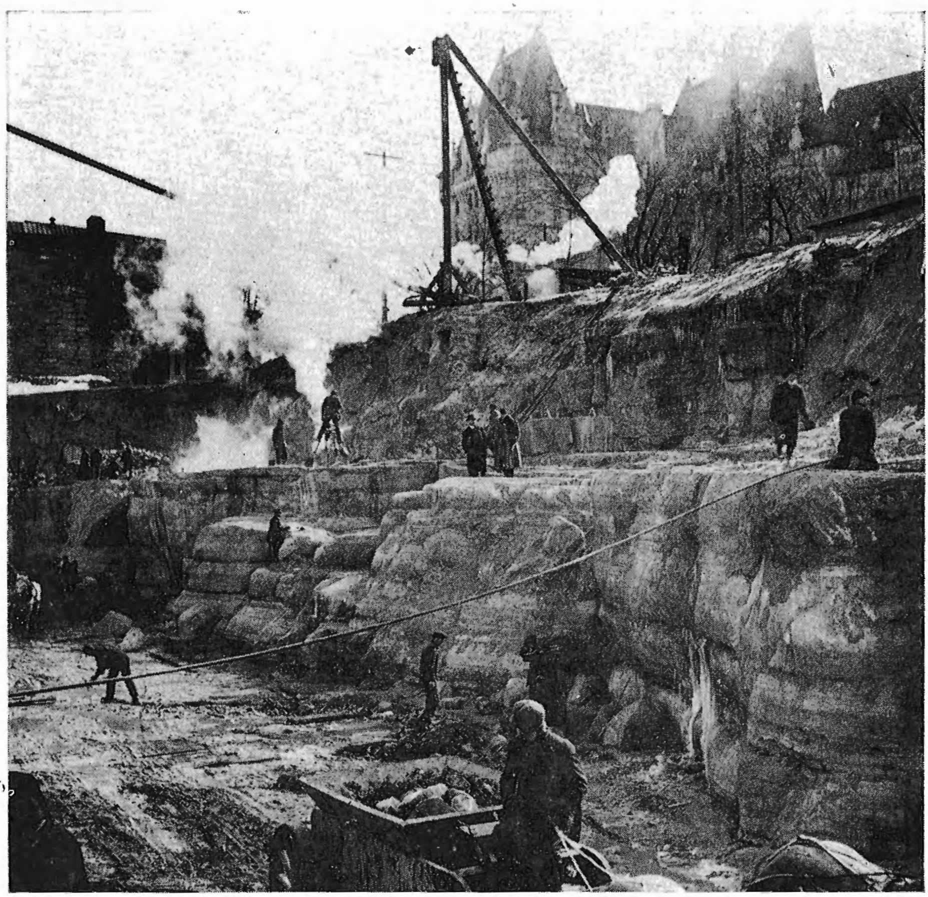
95306

B. Ottawa limestone about 250 feet above the base, showing a natural profile of the drag on the down-faulted side of a fault in the fault zone at Governor Bay, Ottawa.

PLATE IV



Thick limestone strata of the Leray-Rockland beds of the Ottawa formation. Quarry south of Rockland, Ontario.



22876

Heavy layers of the Cobourg beds at the top of the Ottawa formation, weathered by glacial action and forming the side of a buried channel underlying Sussex street, Ottawa, exposed during the excavation for the Customs Building in 1912-1913.

CHAPTER VI

BIBLIOGRAPHY

Geology

Adams, F. D.
[1] (1884): On the Laurentian System; Ottawa Field Nat. Club I, Trs. 4, pp. 21-31.

Ami, H. M.
(1882): Notes on an exposure of the Potsdam formation at Buckingham Basin, Lièvre River, Quebec; Ottawa Field Nat. Club I, Trs. 3, p. 39.
The Utica Slate; ibid., pp. 61-66.
—— Utica Slate Formation in Canada (Abst.); Can. Nat. and Geol.; N.S. 10, p. 192.
(1883): Report on Geological and Mineralogical Branch of Ottawa Field Naturalist Club; Ottawa Field Nat. Club I, Trs. 4, pp. 64-66.
(1884): Notes on Ottawa Region; Ottawa Field Nat. Club II, Trs. 5, pp. 118-121.
(1885): Additional Notes on Geology and Palæontology of Ottawa and Vicinity; Ottawa Field Nat. Club II, Trs. 6, pp. 251-259.
(1887): The Great Ice Age and Subsequent Formations at Ottawa, Ontario; Ottawa Nat. I, pp. 65-74, 81-88.
(1888): On the Occurrence of 'phosphatic nodules' in the Chazy Formation about Ottawa; Ottawa Nat. 2, pp. 45-46.
Faulting in the Vicinity of Ottawa; ibid., p. 48.
Geology of the Government Experimental Farm; ibid., pp. 71-72.
On the Sequence of the Geological Formations about Ottawa, with Reference to the Natural Gas Question; Ibid., pp. 93-96.
(1892): Additional Notes on the Geology and Palæontology of Ottawa and Its Environs; Ottawa Nat. 6, pp. 73-78.
—— The Utica Terrane in Canada; Can. Rec. Sci., 5, pp. 166-183 and 234-346.
(1893): Notes on Geology and Palæontology of the Rockland Quarries and Vicinity in the County of Russell, Ontario, Canada; Ottawa Nat. 7, pp. 138-147.
(1894): The Geology of Galetta, Ontario; Ottawa Nat. 8, p. 109.
—— *Saxicava* Sands and Gravels at Carp, Ontario; ibid., pp. 121-122.
(1895): Report of the Geological Branch, Ottawa Field Naturalist Club; Ottawa Nat. 9, pp. 167-169.
(1899): Report of the Geological Branch, Ottawa Field Naturalist Club; Ottawa Nat. 13, pp. 218-223.
[1] (1900): Geology of Some Cities in Eastern Canada (Ottawa); Roy. Soc., Canada, Proc. and Trans., 2nd ser. 6, sec. 4, pp. 129-138.
[1] (1902): Annual Report of the Geological Section of the Ottawa Field Naturalist Club; Ottawa Nat. 15, No. 11, pp. 254-262.
—— Brief Description of the Map of the Ottawa District; Ottawa Nat. 16, pp. 187-189.
(1905): On the Geology of Carp (Ontario) and Environs; Ottawa Nat. 19, pp. 92-93.

Antevs, E.
[1] (1925): Retreat of the Last Ice-sheet in Eastern Canada; Geol. Surv., Canada, Mem. 146, pp. 66-74, 95-97.

Auer, V.
[1] (1930): Peat Bogs in Southeastern Canada; Geol. Surv., Canada, Mem. 162, Index map.

Bigsby, J.
[1] (1824): A List of Minerals and Organic Remains Occurring in the Canadas; Amer. Jour. Sci. 8, pp. 77-88.

[1] Includes a part of the Ottawa-St. Lawrence Lowland.

Bigsby, J.
(1825): Notice of a Cave containing Bones in Lanark, Upper Canada; Amer. Jour. Sci. 9, pp. 354-355.

Bowman, A.
(1887): Testimony of Ottawa Clays and Gravels to the Expansion of the Gulf of St. Lawrence and Canadian Lakes within the Human Period; Ottawa Nat. 1, pp. 149-161.

Brummell, H. P. H.
[1] (1892): The Mineral Waters of Canada; Ottawa Nat. 6, pp. 160-167, 173-185.

Buchan, I. S.
(1916): The Pleistocene of Montreal and Ottawa Valley from a Railway Carriage; Can. Rec. Sci. 9, pp. 190-195.

Chamberlin, T. C.
[1] (1883): Geology of Wisconsin, Lower Silurian or Cambro-Silurian Age; Geol. Wisconsin, 1, p. 154.

Chapman, E. J.
[1] (1864): A popular Exposition of the Minerals and Geology of Canada—Part V, Palæozoic Rocks of Canada; Can. Jour., N.S. 8, pp. 185-210.

[1] (1864-1888): Exposition of the Minerals and Geology of Canada; First Edition — Third Edition.

Cole, L. H.
(1911): Investigation of Reported Discovery of Tin Ore in the Vicinity of Arnprior, Ontario; Dept. of Mines, Canada, Mines Branch, Sum. Rept. 1910, pp. 93-94.

(1923): Silica in Canada, Its Occurrence, Exploitation and Uses — Pt. I, Eastern Canada; Dept. of Mines, Canada, Mines Branch, No. 555, pp. 45-48.

(1934): Sandstone at Hawkesbury, Ontario; Dept. of Mines, Mines Branch, Investigations of Mineral Resources and Mining Industry, 1932, pp. 7-9.

Cole, L. H., and Carnochan, R. K.
(1934): Silica Deposit near Gatineau Point, Quebec; Dept. of Mines, Canada, Mines Branch, Investigations of Mineral and Mining Industry, 1932, pp. 3-6.

Coleman, A. P.
[1] (1901): Marine and Freshwater Beaches of Ontario; Geol. Soc., America, Bull. 12, pp. 129-146.

[1] (1905): Glacial Lakes and Pleistocene Changes in the St. Lawrence Valley; Inter. Geol. Cong. VIII, Rept. pp. 480-486.

[1] (1932): An Interglacial Champlain Sea; Amer. Jour. Sci. 5, ser. 24, pp. 311-315.

Craig, W.
(1889): Contributions to the Geology and Palæontology of the Townships of Russell and Cambridge, in Russell, Ontario; Physiography and General Geology; Ottawa Nat. 2, pp. 136-139.

Dawson, Sir Wm.
(1872): On the Post-pliocene of Canada, Ottawa River; Can. Nat. Geol., N.S. 6, pp. 252-253.

Dresser, J. A.
(1896): Petrographical Notes on some Archæan Rocks from Chelsea; Ottawa Nat. 10, pp. 129-133.

Ells, R. W.
(1893): The Laurentian of the Ottawa District; Geol. Soc. Amer., Bull. 4, pp. 349-360.

(1894): Report on Field Work in Ottawa, Pontiac and Carleton Counties, Quebec and Ontario; Geol. Surv., Canada, Ann. Rept. 7, pt. A, pp. 60-62.

—— Mica Deposits in the Laurentian of the Ottawa District; Geol. Soc. Amer., Bull. 5, pp. 481-488.

—— Recent Deposits in the valley of the Ottawa River; Ottawa Nat. 8, pp. 104-107.

(1895): The Potsdam and Calciferous formations of Quebec and Eastern Ontario; Roy. Soc., Canada, Proc. and Trans. 12, sec. 4, pp. 21-30.

—— Report on Field Work in Ottawa and Argenteuil Counties, Quebec; Geol. Surv., Canada, Ann. Rept. 6 (1892), pt. A, pp. 37-40.

(1896): Palæozoic Outliers in the Ottawa River Basin (followed by Ami's fossil list); Roy. Soc., Canada, Proc. and Trans., 2nd ser. 2, sec. 4, pp. 137-149.

—— The Geology of the Ottawa and Parry Sound Railway; Ottawa Field Nat. 10, pp. 165-193.

—— Summary Report on Field Work in Ottawa, Pontiac, and Carleton Counties, Quebec and Ontario; Geol. Surv., Canada, Ann. Rept. 7 (1894), pt. A, pp. 57-60.

—— [1] Report on a Portion of the Province of Quebec Comprised in South-west Sheet of "Eastern Townships"; Geol. Surv., Canada, Ann. Rept. for 1894, pt. J, Map — Montreal Sheet, Pub. No. 571.

—— The Apatite-bearing Rocks of the Ottawa District; Can. Rec. Sci. 6, pp. 213-222.

(1897): Notes on the Archæan of Eastern Canada; Roy. Soc., Canada, 2nd ser. 3, sec. 4, pp. 121-124.

—— Report (Summ.) on Fieldwork in Renfrew County, Ontario, and Pontiac County, Quebec; Geol. Surv., Canada, Ann. Rept. 8, pt. A, pp. 64-68.

—— (With remarks in paper by F. D. Adams.) Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentians; Can. Rec. Sci. 7, pp. 315-316.

(1898): Sands and Clays of the Ottawa Basin; Geol. Soc. Amer., Bull. 9, pp. 211-222.

—— Report on Field Work in Eastern Ontario (Renfrew, Addington, Frontenac, Lanark, and Carleton); Geol. Surv., Canada, Ann. Rept. 9 (1896), pt. A, pp. 53-54.

—— Formations, Faults and Folds of the Ottawa District; Ottawa Nat. 11, pp. 177-189.

—— Report on Field Work on the Perth and Ottawa City Sheets, Eastern Ontario; Geol. Surv., Canada, Ann. Rept. 10 (1897), pt. A, pp. 57-62.

(1899): Report on Field Work in Southwestern Quebec and Adjacent Parts of Ontario; Geol. Surv., Canada, Ann. Rept. 11, pt. A, pp. 116-119.

—— The Mineral Resources of the Ottawa District; Ottawa Nat. 13, pp. 14-21, 25-46.

(1900): Report on Field Work in the Ottawa Region, Quebec and Ontario; Geol. Surv., Canada, Ann. Rept. 12 (for 1899), pt. A, pp. 131-137; pt. G, pp. 10-13, 17-18.

—— The Physical Features and Geology of the Palæozoic Basin between the Lower Ottawa and St. Lawrence Rivers; Roy. Soc., Canada, Proc. and Trans., 2nd ser. 6, sec. 4, pp. 99-120.

(1901): Ancient Channels of the Ottawa River; Ottawa Nat. 15, pp. 17-30.

—— Report on the geology of Argenteuil, Ottawa, and Part of Pontiac Counties, Province of Quebec and Portions of Carleton, Russell, and Prescott Counties; Geol. Surv., Canada, Ann. Rept. 12, pt. J (1899), Map No. 121, Pub. No. 750.

(1902): Report on the Geology and Natural Resources of the Area included in the map of the City of Ottawa and Vicinity; Geol. Surv., Canada, Ann. Rept. 12, pt. G, pp. 1-51 (1899); Map, Ottawa Sheet, Pub. No. 714.

(1903): Report on Field Work in the Ottawa Region, Quebec and Ontario; Geol. Surv., Canada, Ann. Rep't. 13, pt. A (1900), pp. 129-139; Map No. 120, Pub. No. 903.

(1904): Report on the Geology of a Portion of Eastern Ontario; Geol. Surv., Canada, Ann. Rept. 14 (1901), pt. A, pp. 1-79; Map No. 119, Pub. No. 789.

(1907): Report on the Geology and Natural Resources of the Area Included in the North-west Quarter Sheet of the Ontario and Quebec Series Comprising Portions of the Counties of Pontiac, Carleton, and Renfrew; Geol. Surv., Canada, Pub. No. 977, pp. 1-71; Map No. 122, Pub. No. 660.

Ells, R. W., and Barlow, A. E.
(1895): The Physical Features and Geology of the Proposed Ottawa Canal between the St. Lawrence River and Lake Huron; Roy. Soc., Canada, Proc. and Trans., 2nd ser. 1, sec. 4, pp. 163-190.

Elworthy, R. T.
[1] (1918): Mineral Springs of Canada, Pt. II — The Chemical Character of some Canadian Mineral Springs; Dept. of Mines, Canada, Mines Branch, Bull. 20, Pub. No. 472.

Foerste, A. F.
(1913): The Richmond Formations of the Provinces of Ontario and Quebec (Abst.); Geol. Soc. Amer., Bull. 24, p. 110.

Fraser, F. J.
[1] (1931): Heavy Minerals in the Basal Ordovician Sandstones of Ontario and Quebec; Geol. Surv., Canada, Sum. Rept. 1930, pt. D, pp. 58-60.

Gauthier, H.
(1917): Road Materials in Two Mountains and Argenteuil Counties, Quebec; Geol. Surv., Canada, Sum. Rept. 1916, pp. 198-201.

Giroux, N. J.
(1896): Report of Field Work in the St. Lawrence Valley, Ontario and Quebec; Geol. Surv., Canada, Ann. Rept. 8 (1895), pt. A, pp. 68-74.

Giroux, N. J.
(1897): Report of Field Work in Eastern Ontario; Geol. Surv., Canada, Ann. Rept. 9 (1896), pt. A, pp. 59-64.

Goldthwait, J. W.
[1] (1913): The Upper Marine Limit at Montreal, Covey Hill and Ottawa; Geol. Surv., Canada, Inter. Geol. Congr. XII, Guide Bk. No. 3, pp. 119-126.
[1] (1914): Marine Submergence at Montreal, Covey Hill and Rigaud Mountain; Geol. Surv., Canada, Sum. Rept. 1913, p. 211.
(1926): Late Glacial Oscillations of Level in the St. Lawrence-Ottawa Valley (Abst.); Geol. Soc., Amer., Bull. 37, No. 1, pp. 173-174; Pan Amer. Geol. 45, No. 2, p. 168.

Goranson, R. W.
(1926): Calumet Island, Pontiac County, Quebec; Geol. Surv., Canada, Sum. Rept. 1925, pt. C, pp. 107 and 115.

Goudge, M. F.
[1] (1933): Canadian Limestones for Building Purposes; Dept. of Mines, Canada, Mines Branch, No. 733, pp. 35-36, 72-74.
[1] (1935): Limestones of Canada, Pt. III, Quebec; Dept. of Mines, Canada, Mines Branch, No. 755, pp. 13-19, 40-46, 58-68, 163-164.
[1] (1938): Limestones of Canada, Pt. IV, Ontario; Dept. of Mines, Canada, Mines Branch, No. 781, pp. 12-16, 44-58, 77-82, 152-156, 180-183, 190-196.

Grant, Sir J.
(1864): The Geology of the Ottawa Valley; Can. Nat. Geol., N.S. 1, pp. 419-426.

Harding, E.S.
(1907): The Treatment of Rheumatism at Caledonia Springs; Montreal Medical Journal, April.

Harding, W. D.
(1931): The Relations of the Grenville Sediments and the Potsdam Sandstone in Eastern Ontario; Amer. Miner. 16, p. 430.

Harrington, B. J.
(1879): Report on the Minerals of Some of the Apatite-bearing Veins of Ottawa County, Quebec; Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. G.
[1] (1896): The Composition of Limestones and Dolomites from a Number of Geological Horizons in Canada; Can. Rec. Sci. 6, pp. 27-32.

Hunt, T. S.
[1] (1847): Mineral Springs; Geol. Surv., Canada, Rept. of Prog. 1845-46, pp. 119, 120.
(1865): On the Mineralogy of *Eozoon canadense;* Can. Nat. Geol., N.S. 2, pp. 120-128.
[1] (1865): Contribution to the Chemistry of Natural Waters, No. 43, No. 47, and No. 65; Can. Nat. Geol., N.S. 2, pp. 172, 177, and 287.

Ingall, E. D.
[1] (1926): Deep Borings in Ontario, Quebec, and Maritime Provinces; Geol. Surv., Canada, Sum. Rept. 1924, pt. C, p. 241.

Johnston, W. A.
(1916): Late Pleistocene Oscillations of Sea-level in the Ottawa Valley; Geol. Surv., Canada, Mus. Bull. 24.
—— [1] Sutton, Barrie, and Ottawa Areas, Ontario; Geol. Surv., Canada, Sum. Rept. 1915, p. 138.
(1917): Pleistocene and Recent Deposits in the Vicinity of Ottawa, with a Description of the Soils; Geol. Surv., Canada, Mem. 101; Map, Ottawa, Carleton, and Ottawa counties, Pub. No. 1662.
[1] (1931): Deep Borings in Ontario, Quebec, and the Maritime Provinces; Geol. Surv., Canada, Sum. Rept. 1930, pt. D, pp. 67-84.
[1] (1932): Borings in Ontario, Quebec, and the Maritime Provinces; Geol. Surv., Canada, Sum. Rept. 1931, pt. D, pp. 42-52.
[1] (1934): Borings in Eastern Canada; Geol. Surv., Canada, Sum. Rept. 1932, pt. D, pp. 69-71 (1933); Geol. Surv., Canada, Sum. Rept. 1933, pt. D, pp. 155-156.

Kay, G. M.
(1939): Ottawa-Bonnechère Graben (Abst.); Geol. Soc., Amer., Bull. 50, p. 1915.
(1942): Ottawa-Bonnechère Graben and Lake Ontario Homocline; Geol. Soc. Amer., Bull. 53, pp. 585-646.

Keele, J.
[1] (1924): Preliminary Report on Clay and Shale Deposits of Ontario — Clays of Eastern Ontario; Geol. Surv., Canada, Mem. 142, Chapter VII, pp. 50-70.

Keele, J., and Cole, L. H.
[1] (1922): Structural Materials along the St. Lawrence River, between Prescott, Ontario, and Lachine, Quebec; Dept. of Mines, Canada, Mines Branch, No. 549.

Keele, J., and Johnston, W. A.
(1913): The Superficial Deposits near Ottawa; Geol. Surv., Canada, Inter. Geol. Congr. XII, Guide Bk. 3, pp. 126-135.

Kindle, E. M.
(1914): A Comparison of the Cambrian and Ordovician Ripple-marks found at Ottawa; Jour. Geol. 22, pp. 703-713.
(1918): An Ottawa Beach of the Champlain Sea; Ottawa Nat. 32, pp. 83-86.
[1] (1919): The Climatic Interpretation of Two Early Ordovician Mudcrack Horizons; Can. Field Nat. 33, No. 5, p. 96.

Kindle, E. M., and Burling, L. D.
(1915): Structural Relations of the Precambrian and Palæozoic Rocks North of the Ottawa and St. Lawrence Valleys; Geol. Surv., Canada, Mus. Bull. 18.

Logan, Sir Wm. E.
[1] (1843): Preliminary Report, Geol. Surv., Canada, Rept. of Prog. 1842.
[1] (1845): Geol. Surv., Canada, Rept. of Prog. 1845, pp. 28-33.
[1] (1847): Geol. Surv., Canada, Rept. of Prog. 1845-46, pp. 6-9, 47-67, 119-122.
[1] (1852): Geol. Surv., Canada, Rept. of Prog. 1851-52, pp. 6-20.
[1] (1857): Geol. Surv., Canada, Rept. of Prog. 1853-56, pp. 5-52.
[1] (1863): Geology of Canada; Geol. Surv., Canada, Rept. of Prog. from its commencement to 1863.
[1] (1864): Atlas accompanying Geology of Canada, Maps 1 and 2; Plate 3.

Maddox, D. C.
[1] (1930): Deep Borings in Ontario, Quebec, and Maritime Provinces; Geol. Surv., Canada, Sum. Rept. 1928, pt. C, pp. 102-104. Ibid., Sum. Rept. 1929, pt. C, pp. 41-42.
[1] (1931): Thickness of Ordovician Deposits in Ontario and Quebec; Geol. Surv., Canada, Sum. Rept. 1930, pt. D, pp. 49-57.

McGerrigle, H. W.
(1936): Lachute Map-area, Pt. II, The Lowland Area; Que. Bur. of Mines, Ann. Rept., pt. C, pp. 41-62; Maps 408, East Half and West Half.

Miller, A. H., French, C. A., Wilson, M. E.
(1931): Geophysical Survey of the Hull-Gloucester and Hazeldean Faults; Geol. Surv., Canada, Mem. 165, pp. 190-225.

Murray, A.
(1852): Report on the Geology of the Region between the Ottawa, St. Lawrence, and Rideau Rivers; Geol. Surv., Canada, Rept. of Prog. 1851-52, pp. 57-91.
[1] (1857): On the Geology and Topography of the Muskoka, Petawawa, Bonnechère, and Madawaska Rivers; Geol. Surv., Canada, Rept. of Prog. 1853-56, pp. 94-98.

Parks, W. A.
[1] (1910): Preliminary Report on the Building and Ornamental Stones of Ontario South of the Ottawa and French Rivers; Dept. of Mines, Canada, Mines Branch, Sum. Rept. 1910, pp. 110-114.
[1] (1912): Report on the Building and Ornamental Stones of Canada — Quebec; Dept. of Mines, Canada, Mines Branch, No. 203, vol. 1, pp. 121, 126-138.
[1] (1914): As above, No. 279, vol. 3, pp. 121.

Picher, R. H.
(1917): Road Materials in Soulanges and Vaudreuil Counties, Quebec; Geol. Surv., Canada, Sum. Rept. 1916, pp. 201-206.
(1918): Road Materials in a Portion of Vaudreuil County, Quebec, and along the St. Lawrence River from the Quebec Boundary to Cardinal, Ontario; Geol. Surv., Canada, Mem. 106.

Raymond
(1911): Clay Nodules; Ottawa Nat. 24, pp. 147-148.

Reinecke, L.
[1] (1915): Road Materials in Ontario; Geol. Surv., Canada, Sum. Rept. 1914, pp. 88-90.
[1] (1916): Road Materials in Ontario and Quebec; Geol. Surv., Canada, Sum. Rept. 1915, pp. 147-155.
[1] (1917): Road Material Surveys in 1915; Geol. Surv., Canada, Mem. 99; Map, Pub. No. 1665, and Map 168A, Pub. No. 1653.

Retty, J. A.
[1] (1933): Reconnaissance along the Coulonge and Black Rivers, Pontiac County, Quebec; Que. Bur. Mines, 1932, pt. D, pp. 99-103.

Satterly, J., and Elworthy, R. T.
[1] (1917): Mineral Springs of Canada, Pt. I — The Radioactivity of some Canadian Mineral Springs; Dept. of Mines, Canada, Mines Branch, Bull. 16, Pub. No. 435.

Selwyn, A. R. C.
(1882): On the Geology of the Ottawa Palæozoic Basin; Ottawa Field Nat. Club I, Trs. No. 3, pp. 34-39.

Stewart, John
(1887): The Development of the Mines of the Ottawa Region; Ottawa Field Nat. Club III, pp. 33-39.
[1] (1888): Notes on Geological work of the Summer 1887; Ottawa Nat. I, pp. 170-171.

Vennor, H. G.
[1] (1875): Notes on Some of the Galena or Sulphuret of Lead Deposits Connected with the Laurentian Rocks of Ontario; Can. Nat., N.S. 7, pp. 455-462.
[1] (1876): Explorations and Surveys in the Rear Portions of Frontenac and Lanark Counties, together with Notes on Some of the Economic Minerals of Ontario; Geol. Surv., Canada, Rept. of Prog. 1874-75, pp. 105-165.
[1] (1877): Archæan of Canada; Amer. Jour. Sci. (3) 14, pp. 313-316.
[1] (1878): Geol. Surv., Canada, Rept. of Prog. 1876-77, pp. 244-264, 277.

Whittaker, E. J.
(1922): Bottom Deposits of McKay Lake, Ottawa; Roy. Soc., Canada, Proc. and Trans., 3rd. ser. 16, sec. 4, pp. 141-156.

Wilson, A. E.
(1932): Notes on the Pamelia Member of the Black River Formation of the Ottawa Valley; Amer. Jour. Sci. 24, pp. 135-146.
(1937): Erosional Intervals Indicated by Contacts in the Vicinity of Ottawa, Ontario; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 31, sec. 4, pp. 45-60.

Wilson, A. E., Stewart, J. S., and Caley, J. F.
[1] (1941): Sedimentary Basins of Ontario, possible Sources of Oil and Gas; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 35, sec. 4, pp. 167-185.

Wilson, M. E.
(1914): Southeastern Portion of Buckingham Map-area, Quebec; Geol. Surv., Canada, Sum. Rept. 1913, pp. 196-207.
(1915): Northern Portion of the Buckingham Map-area, Quebec; Geol. Surv., Canada, Sum. Rept. 1914, p. 94.
(1916): Southwestern Portion of the Buckingham Map-area, Quebec; Geol. Surv., Canada, Sum. Rept. 1915, pp. 156-162.
(1917): Grenville District, Argenteuil County, Part of Amherst Township, Labelle County, Quebec; Geol. Surv., Canada, Sum. Rept. 1916, pp. 208-219.
(1918): The Arnprior-Quyon District, Ontario and Quebec; Geol. Surv., Canada, Sum. Rept. 1917, pt. E, pp. 42-43.
(1920): Buckingham Map-area, Map, Pub. No. 1691.
—— Mineral Deposits in the Ottawa Valley; Geol. Surv., Canada, Sum. Rept. 1919, pt. E, pp. 19-44.
—— Molybdenite in the Lower Ottawa Valley; Can. Inst. Min. and Met., Monthly Bull. 102, pp. 749-754.
(1921): Ibid., Can. Min. Inst., Trs. 23, pp. 419-425.
—— The Relationships of the Palæozoic to the Precambrian along the Southern Border of the Laurentian Highlands in Southeastern Ontario and the adjacent Portions of Quebec; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 14, sec. 4, pp. 15-24.

(1924): Arnprior-Quyon and Maniwaki Areas, Ontario and Quebec; Geol. Surv., Canada, Mem. 136; Map, Pub. No. 1739.

—— [1] Ontario's Lead Mine; Can. Min. Jour. 45, Nos. 20 and 21, pp. 477-478 and 501-502.

[1] (1925): The Grenville Precambrian Subprovince; Jour. Geol. 33, No. 4, pp. 389-407.

(1931): Ripple-marks in the Lower Palæozoics of Ottawa Valley; Can. Min. Jour. 52, No. 14, pp. 347-348.

—— Ripple-marks near Perth, Lanark County, Ontario; Can. Field Nat. 45, No. 2, pp. 25-27.

(1932): 'Samson's Boulder Stone' an Erratic near Perth, Lanark County, Ontario; Ottawa Nat. 46, pp. 177-178.

—— The Mammillary Mounds of the Bonnechère Valley; Ottawa Nat. 46, pp. 32-33.

Wilson, W. J.

(1898): Notes on the Pleistocene Geology of a Few Places in the Ottawa Valley; Ottawa Nat. 11, pp. 209-220.

Wright, J. F.

(1923): Brockville and Mallorytown Map-area; Geol. Surv., Canada, Mem. 134; Map, Pub. No. 1964.

PALÆONTOLOGY

Ami, H. M.

(1883): Notes on *Triarthrus spinosus* Billings; Ottawa Field Nat. Club I, Trs. 4, pp. 88-89.

(1884): List of Fossils from Ottawa and Vicinity; Ottawa Field Nat. Club II, Trs. 5, pp. 54-62.

(1887): Notes on the Precise Geological Horizon of *Siphonotreta scotia* Davidson (Utica); Ottawa Nat. I, pp. 121-126.

—— On the Occurrence of *Scolithus* in Rocks of Chazy Formation about Ottawa, Ontario; Can. Rec. Sci. 2, pp. 304-306.

(1888): On Utica Fossils from Rideau, Ottawa; Ottawa Nat. I, pp. 165-169.

(1889): Contributions to the Geology and Palæontology of the Townships of Russell and Cambridge, in Russell, Ontario; Palæontology; Ottawa Nat. 2, pp. 139-140.

(1895): Fossil Insects from the Leda Clays of Ottawa and Vicinity; Ottawa Nat. 9, pp. 190-191.

[1] (1896): Notes on Canadian Fossil Bryozoa; Can. Rec. Sci. 6, pp. 222-229.

—— (With Ells, R. W.) Fossil Organic Remains comprised in the Various Geological Formations and Outliers of the Ottawa Palæozoic Basin; Roy. Soc., Canada, Proc. and Trans., 2nd. ser. 2, sec. 4, pp. 151-158.

(1897): Contribution to the Palæontology of the Post-Pliocene Deposits of the Ottawa Valley; Ottawa Nat. 11, pp. 20-26.

(1899): On Some Trenton (Ordovician) Fossils from the Light Grey Limestones of Cumberland County of Russell, Ontario; Ottawa Nat. 13, pp. 238-240.

(1901): Preliminary Lists of Organic Remains Occurring in Various Geological Horizons Comprised in the Map of Ottawa District, Including Formations in the Provinces of Quebec and Ontario, along the Ottawa River; Geol. Surv., Canada, Ann. Rept. 12, pp. 49-77.

—— Lists of Fossils Obtained from the Several Formations along the Ottawa River Pertaining to the Report of Sheet No. 121 (Grenville), Quebec and Ontario; Geol. Surv., Canada, Ann. Rept. 12, pt. J, pp. 139-143.

(1904): Preliminary Lists of Fossil Organic Remains from the Potsdam-Utica and Pleistocene Formations Comprised within the Perth sheet (No. 119) in eastern Ontario; Geol. Surv., Canada, Ann. Rept. 14, pt. J, pp. 80-89.

Bassler, R. S.

[1] (1935): Classification of Edrioasteroidea; Smith. Inst. 93, No. 8, p. 4.

Bather, F. A.

[1] (1900): Treatise on Zool., Pt. 3, Echinoderms, pp. 200, 209, 210.

[1] (1908): Studies in Edrioaster, III; Geol. Mag., dec. 5, vol. 5, pp. 543-550.

[1] (1913): Caradocian Cystidea from Girvan; Edinburgh, Trans. Roy. Soc. 49, pt. 2, pp. 397, 452-467.

The Trenton Crinoid, *Ottawacrinus*, W. R. Billings, and Note on *Merocrinus* (Walcott); Geol. Surv., Canada, Mus. Bull. 1, No. 1, pp. 1-10.

[1] Includes some forms from the Ottawa-St. Lawrence Lowland.

Bathér, F. A.
[1] (1928): *Dendrocystis* in North America; Geol. Surv., Canada, Bull. 49, pp. 5-8.

Billings, E.
(1854): On Some New Genera and Species of Cystidea from the Trenton Limestone; Can. Jour. 2, pp. 215-218, 250-253, 268-274.

(1857): Fossils of the Potsdam Sandstone and Footprints on the Rock at Beauharnois; Can. Nat. Geol. 1, pp. 32-39.

On Some Characteristic Fossils of the Lower Silurian Rocks of Canada; Ibid., pp. 39-47.

On the Crinoidea or Stone Lilies of the Trenton Limestone, with the Description of a New Species; ibid., pp. 48-57.

On the Fossil Corals of the Lower Silurian Rocks of Canada; Ibid., pp. 115-128.

On Some of the Lower Silurian Fossils of Canada; ibid., pp. 203-208.

Description of Fossils Occurring in the Silurian Rocks of Canada; ibid., pp. 312-320.

On the Tertiary (Quaternary) Rocks of Canada, with Some Account of Their Fossils; ibid., pp. 321-346.

—— New Species of Fossils from the Silurian Rocks of Canada; Geol. Surv., Canada, Rept. of Prog. 1853-56, pp. 256-345.

—— On the Genera of Fossil Cephalopods Occurring in Canada; Can. Nat. Geol. 2, pp. 135-138.

(1858): Geol. Surv., Canada, Rept. of Prog. 1857, pp. 147-162, 179-192.

—— On the Cystidea of the Lower Silurian Rocks of Canada; Geol. Surv., Canada, Can. Org. Rem. dec. 3, pp. 9-74.

—— On the Asteriadae of the Lower Silurian Rocks of Canada; ibid., pp. 75-85.

—— New Genera and Species of Fossils from the Silurian and Devonian Formations of Canada; Can. Nat. Geol. 3, pp. 432-444.

(1859): On the Crinoideae of the Lower Silurian Rocks of Canada; Geol. Surv., Canada, Can. Org. Rem. dec. 4, pp. 1-72.

—— Description of a New Genus of Brachiopod and on the Genus Cyrtodonta; Can. Nat. Geol. 4, pp. 301-303.

[1] Fossils of the Calciferous Sandrock (includes those of deposit of white limestone at Mingan supposed to belong to the formation); ibid., pp. 345-367.

Description of Some New Species of Trilobites from the Lower and Middle Silurian Rocks of Canada; ibid., pp. 367-383.

Fossils of the Chazy Limestone with Description of New Species; ibid., pp. 426-470.

—— *Atrypa hemiplicata;* Can. Jour., N.S. 4, p. 316.

(1860): Additional Note on the Potsdam Fossils; Amer. Jour. Sci. (2) 30, pp. 242-243, 337-338.

—— Description of Some New Species of Fossils from Lower and Middle Silurian Rocks of Canada; Can. Nat. Geol. 5, pp. 49-69, 161-177.

(1861): On the Track of an Animal Lately Found in the Potsdam Formation; Amer. Jour. Sci., 2nd ser. 31, pp. 17-23.

—— *Astylospongia parvula* Billings; Rept. on Geology of Vermont 2, p. 956.

(1863): Description of a New Species of *Harpes* from the Trenton Limestone, Ottawa; Can. Nat. Geol. 8, pp. 36-38.

—— [1] Geology of Canada; Geol. Surv., Canada.

[1] (1865): Palæozoic Fossils, vol. 1 (Adv. sheets 1862); Geol. Surv., Canada.

—— Notice of Some New Genera and Species of Palæozoic Fossils; Can. Nat. Geol., N.S. 2, pp. 325-432.

—— Notes on Some of the More Remarkable Genera of Silurian and Devonian Fossils; Can. Nat. Geol., N.S. 2, pp. 184-198.

(1869): On the Structure of the Crinoidea, Cystidea, and Blastoidea; Can. Nat. 4, pp. 277-293, 426-433; Amer. Jour. Sci. 2, ser. 48, pp. 69-82.

(1870): Ibid. (Continued); Can. Nat. Geol. 5, pp. 180-198; Amer. Jour. Sci. 49, pp. 51-58.

—— Notes on Some Specimens of Lower Silurian Trilobites; London Quart. Jour. Geol. Soc. 26, pp. 479-486; Notice; Can. Nat. Geol., N.S. 5, pp. 90-92.

(1872): On the Genus *Obolellina;* Can. Nat., N.S. 6, pp. 326-333.

(1876): On openings in Arms of *Actinocrinus*; Amer. Jour. Sci. (3) 11, pp. 176-178.

Billings, W. R.
(1881): Notes on Two Species and One Genus of Fossils from the Trenton Limestone, Ottawa; Ottawa Field Nat. Club I, Trs. 2, pp. 34-35.

(1883): Notes on and Description of Some Fossils from the Trenton Limestone; Ottawa Field Nat. Club I, Trs. 4, pp. 49-52.

(1885): Two New Species of Crinoids (Trenton, Ottawa); Ottawa Field Nat. Club II, Trs. 6, pp. 248-250.

—— Additional Notes on the Geology and Palæontology of Ottawa and Vicinity; Ottawa Field Nat. Club II, Trs. 6, pp. 251-259.

—— Report of the Palæontological Branch of the Ottawa Field Nat. Club (Lists); Ottawa Field Nat. Club II, Trs. 6, pp. 259-262.

(1887): A New Genus and Three New Species of Crinoids from Trenton Formation, with Notes on a Large Specimen of *Dendrocrinus proboscidiatus;* Ottawa Nat. 1, pp. 49-54.

Carpenter, W. D.

[1] (1865): Notes on the Structure and Affinities of *Eozoon canadense;* Can. Nat. Geol., N.S. 2, pp. 111-120.

Chapman, E. J.

(1860): On a New Species of *Agelacrinites* and on the Structural Relations of That Genus; Can. Jour., N.S. 5, pp. 358-365.

[1] (1861-1863): A popular Exposition of the Minerals and Geology of Canada, Pt. IV — Some Remarks on Organic Remains, with Special Reference to Canadian Forms; Can. Jour., N.S. 6, pp. 500-518; vol. 7, pp. 108-129; vol. 8, pp. 17-33.

(1877): On the Probable Nature of the Supposed Fossil Tracks known as *Protichnites* and *Climactichnites;* Can. Jour., N.S. 15, pp. 486-490.

Clarke, J. M.

[1] (1892): Brachiopoda; Geol. Surv., State New York, Palæontology VIII, pts. I and II.

[1] (1901): New *Agelacrinites;* New York State Mus. Bull. 49, p. 191.

Cox, I.

(1936): Revision of the Genus *Calopœcia* Billings; Dept. of Mines, Canada, Mus. Bull. 80, pp. 7-11.

Dana, J. D.

(1871): On the Supposed Legs of the Trilobite *Asaphus platycephalus;* Ann. Mag. Nat. Hist. 4, ser. 7, pp. 366-368.

(1872): Ibid.; Can. Nat. Geol., N.S. 6, pp. 348-350.

Davidson, T., and King, W.

[1] (1874): On the Trimerellidae, A Palæozoic Family of Palliobranchs or Brachiopoda; London Quart. Jour. Geol. Soc. 30, pp. 162 and 165.

Dawson, Sir Wm.

[1] (1864): On the Fossils of the Genus *Rusophycus;* Can. Nat. Geol., N.S. 1, pp. 363-367.

[1] (1865): On Certain Organic Remains in the Laurentian Limestones of Canada; Can. Nat. Geol., N.S. 2, pp. 99-111, 127.

[1] (1868): The Evidence of Fossil Plants as to the Climate of the Post-pliocene Period in Canada; Can. Nat. Geol., N.S. 3, pp. 69-76.

(1877): Notes on a Fossil Seal from the Leda Clay of the Ottawa Valley; Can. Nat. 8, No. 6, pp. 340-341.

(1888): Geological History of Plants, pp. 227-233.

(1889): Note on *Balanus Hameri* in the Pleistocene at Rivière Beaudette; Can. Rec. Sci. 3, pp. 287-289.

—— Note on an Echinoderm Collected by Dr. Ami at Besserers, Ottawa River, in the Pleistocene (Leda Clay); Ottawa Nat. 13, pp. 201-202.

[1] (1890): On Burrows and Tracks of Invertebrate Animals in Palæozoic Rocks and Other Markings; London Quart. Jour. Geol. Soc. 46, pp. 595-618.

(1891): Notice of above; Can. Rec. Sci. 4, pp. 234-235.

Delo, D. M.

[1] (1940): Phacopid Trilobites of North America; Geol. Soc. Amer., Spec. Pap. 29, pp. 110-111 and 132.

Donald, J.

[1] (1899): Remarks on the Genera *Ectomaria* Koken and *Hormotoma* Salter, with Descriptions of British Species; London Quart. Jour. Geol. 55, pp. 253-255, 262, 263.

Foerste, A. F.
[1] (1914): Notes on the Lorraine Faunas of New York and the Province of Quebec; Denison Univ., Bull. 17, pp. 247-339.
Notes on the Agelacrinidae and Lepidocystinae, with Description of *Thresherodiscus* and *Brockocystites;* ibid., pp. 399-474.
(1916): *Comarocystites* and *Caryocrinus;* Ottawa Nat. 30, pp. 69-79, 85-93, 101-111.
—— [1] Notes on Cincinnatian Fossils (Cystid); Denison Univ. Sci. Lab., Bull. 18, pp. 340-341.
—— [1] Upper Ordovician Faunas of Ontario and Quebec; Geol. Surv., Canada, Mem. 83.
(1919): Notes on *Isotelus, Acrolichas, Calymene,* and *Encrinurus;* Denison Univ. Bull. 19, pp. 65-82.
[1] (1920): Kimmswick and Plattin Limestones of Northeastern Missouri; Denison Univ. Sci. Lab. 19, Pl. 22, fig. 23.
—— [1] The Generic Relations of the American Ordovician Lichadilae; Amer. Jour. Sci. 4, ser. 49, pp. 26-50.
(1922): Distribution of the Ottawa Trenton Echinoderm Faunas; Can. Nat. 36, No. 5, pp. 84-86.
[1] (1924): Upper Ordovician Faunas of Ontario and Quebec; Geol. Surv., Canada, Mem. 138.
—— [1] Notes on American Palæozoic Cephalopods; Denison Univ. Sci. Lab., Bull. 20, pp. 232-234.
[1] (1930): The Actinoceroids of East Central North America; Denison Univ. Sci. Lab., Bull. 25, pp. 248-249, 292-293.
[1] (1932): Black River and other Cephalopods from Minnesota, Wisconsin, Michigan, and Ontario, Pt. 1; Denison Univ. Sci. Lab. 27.
[1] (1933): Ibid., Pt. II; Denison Univ. Sci. Lab. 28.

Foord, A. H.
[1] (1883): On the Monticuliporidae of the Chazy, Black River, and Trenton Formations, with Descriptions of Ten New Species; Geol. Surv., Canada, Con. Micro-Pal., pp. 1-26.

Grant, Sir J.
(1880): Cystidean Life; Ottawa Field Nat. Club I, Trs. 1, pp. 26-31.
(1881): Description of a New Species of *Porocrinus;* Ottawa Field Nat. Club I, Trs. 2, pp. 42-44.

Haekel, E.
(1896): Die Amphorideen und Cystoideen, pp. 41-42, 44-45, 69-70, 105-107, 118, 150, Pl. 1, figs. 4-4c; Pl. 2, figs. 15 and 16; Pl. 3, figs. 29, 35, and 36.

Hall, J., and Clarke, J. M.
[1] (1894): Introduction to the Study of the Genera of Brachiopoda (Canadian species); Pal. New York, 8.

Hinde, G. J.
(1889): On a New Genus of Siliceous Sponges from the Trenton Formation at Ottawa; Can. Rec. Sci. 3, pp. 396-399.

Hudson, G. H.
[1] (1907): On some Pelmatozoa from the Chazy Limestone of New York; New York State Mus. Bull. 107, pp. 97-131.
[1] (1911): Studies of Some Early Silurian Pelmatozoa; New York State Mus. Bull. 149, pp. 195-272.
(1912): A Fossil Starfish with Umbulacral Covering Plates; Ottawa Nat. 26, pp. 21-27, 45-52.
(1913): Does the Type of *Protopalæaster narrawayi* Present an Oral or an Aboral Aspect; Ottawa Nat. 27, pp. 77-84.
[1] (1913): The Use of the Stereogram in Paleobiology; New York State Mus. Bull. 164, pp. 103-114.
(1915): The Genus *Urasterella,* with Description of a New Species; New York State Mus., 69th Ann. Rept., pp. 117-139.
—— Notes on *Urasterella pulchella* Billings; Ottawa Nat. 28, p. 130.
—— [1] Some Fundamental Types of Hydrospires, with Notes on *Porocrinus smithi* Grant; New York State Mus. Bull. 177, pp. 163-166.
[1] (1925): Improved Technique in Illustration; Jour. Geol. 33, pp. 642-657.
(1927): The Surface Characteristics of *Astrocystites* (*Steganoblastus*) *ottawaensis;* Vermont, Geol. Surv., Rept. 15, pp. 97-110.

Jaekel, O.
[1] (1899): Stamm. Pelmatozoa, Pt. I, Thecoidea and Cystoidea, pp. 46, 50, 234, and 277.

Jones, T. R.
[1] (1858): Notes on Palæozoic Bivalved Entomostraca; Ann. Nat. Hist. 3, ser. 1, pp. 244-248.
—— [1] On the Palæozoic Bivalve Entomostraca of Canada; Geol. Surv., Canada, Can. Org. Rem. dec. 3, pp. 91-102.
[1] (1891): On some Ostracoda from the Cambro-Silurian, Silurian, and Devonian Rocks — A, From the Cambro-Silurian Rocks; Geol. Nat. Hist. Surv., Canada, Contr. Can. Micro-Pal., pt. III, pp. 62-71.

Kindle, E. M.
(1917): Recent and Fossil Ripple-mark; Geol. Surv., Canada, Bull. 25, pp. 13, 34, 35, 37, and 44, and Pls. 4, 21-23, and 27.
(1926): A comparison of Recent and Lake Champlain Stages of McKay Lake as Diatom Habitats; Can. Field Nat. 40, pp. 83-84.
(1928): A Crustacean New to the Pleistocene Fauna of Canada; Can. Field Nat. 42, No. 9, pp. 211-212.

Knight, J. Brookes
[1] (1941): Palæozoic Gastropod Types; Geol. Soc. Amer., Spec. Pap. 32.

Lambe, L. M.
(1897): Description of a New Genus of Polyzoa from the Trenton Limestone at Ottawa; Can. Rec. Sci. 7, pp. 1-3.
[1] (1899): A Revision of the Genera and Species of Canadian Palæozoic Corals — The Madreporaria, Perforata and Alcyonaria; Geol. Surv., Canada, Con. Can. Pal. IV, pt. 1.
[1] (1900): Ibid.— The Madreporaria Aporosa and the Madreporaria Rugosa; ibid., pt. 2.

Logan, Sir Wm. E.
(1852): On the Footprints Occurring in the Potsdam Sandstone of Canada; London Quart. Jour. Geol. 8, pp. 199-213.
(1861): On the Track of an Animal Lately Found in the Potsdam Formation; Can. Nat. 5, pp. 279-285; Amer. Jour. Sci. (2) 3, pp. 17-23.
(1889): Ibid., republished; New York State Mus., 42nd Rept., pp. 30-34.

Miller, A. K.
[1] (1943): Ozarkian and Canadian Cephalopods — Pt. II, Brevicones; Geol. Soc. Amer., Spec. Pap. 49, p. 51.
[1] (1944): Ibid., pt. III, pp. 47, 79-80, 82, 95, 109, 116.

Nicholson, H. A.
[1] (1875): Palæontology of Ontario, pp. 7, 8, 10, 12-14, 16-19.

Okulitch, J. V.
[1] (1935): Fauna of the Black River Group in the Vicinity of Montreal; Can. Field Nat. 49, No. 6, pp. 96-107.
[1] (1937): Notes on *Fletcheria incerta* (Billings) and *Fletcheria sinclairi* n.sp.; Roy. Can. Inst., Trans. 21, pt. 2, No. 46, pp. 313-316.
[1] (1938): Some Black River Corals; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 32, sec. 4, pp. 87-111.
[1] (1942): New Pterygometopinæ from the Ordovician of Ontario and Quebec; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 36, sec. 4, pp. 99-106.

Owen, R.
(1852): Descriptions of the Impressions and Footprints of the *Protichnites* from the Potsdam of Canada; London Quart. Jour. Geol. 8, pp. 214-225.

Parks, W. A.
(1928): Faunas and Stratigraphy of the Ordovician Black Shales and Related Rocks, in Southern Ontario; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 22, sec. 4, pp. 39-92.

Penhallow, D. P.
(1896): Contributions to the Pleistocene Flora of Canada — Nodules from Besserer's Wharf; Roy. Soc., Canada, Proc. and Trans., 2nd ser. 2, sec. 4, pp. 64-66.

Raymond, P. E.
[1] (1905): The Trilobites of the Chazy limestone; Carnegie Mus. Ann. 3, pp. 328-386.
—— [1] The fauna of the Chazy Limestone; Amer. Jour. Sci. 20, pp. 353-382.

Raymond, P. E.
[1] (1906): The Chazy Formation and Its Fauna; Carnegie Mus. Ann. 3, pp. 498-598.
[1] (1908): The Gastropoda of the Chazy Formation; Carnegie Mus. Ann. 4, pts. 3 and 4, pp. 171, 178, 186, 191, 193, 204.
[1] (1910): Notes on Ordovician Trilobites — II, Asaphidæ from the Beekmantown; Carnegie Mus. Ann. 7, pp. 35-45.
[1] Notes on Ordovician Trilobites — IV, New and Old Species from the Chazy; Ibid., pp. 60-80.
(1910): On Two New Trilobites (*Bathyurus superbus* and *Isotelus arenicola*) from the Chazy near Ottawa, Ontario; Ottawa Nat. 24, pp. 129-134.
Preliminary Notes on the 'Chazy' Formation in the Vicinity of Ottawa, Ontario; Ibid., pp. 189-197.
(1911): Chazy Formation in the Ottawa Valley (Abst.); Geol. Soc. Amer., Bull. 22, pp. 719-720.
—— [1] The Brachiopoda and Ostracoda of the Chazy; Carnegie Mus. Ann. 7, pp. 215-259.
(1912): Ordovician of Ottawa Valley; Geol. Surv., Canada, Sum. Rept. 1911, pp. 351-356.
—— On Two New Palæozoic Starfish (one of them found near Ottawa) and a New Crinoid; Ottawa Nat. 26, pp. 77-81.
—— On the Nature of the So Called 'covering plates' in *Protopalœaster narrawayi;* Ottawa Nat. 26, pp. 105-108.
—— [1] Notes on Parallelism among the Asaphidæ; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 5, pp. 111-120.
(1913): Ordovician of Montreal and Ottawa; Geol. Surv., Canada, Inter. Geol. Congr. XII, Guide Bk. 3, pp. 137-162.
—— Some Changes in the Names of Genera of trilobites; Ottawa Nat. 26, pp. 137-142.
—— A Further Note on *Cryptolithus* versus *Trinucleus;* Ottawa Nat. 27, pp. 26-30.
—— Notes on *Cyclocystoides;* Geol. Surv., Canada, Mus. Bull. 1, No. 4, pp. 23-32.
Notes on Some New and Old Trilobites in Victoria Memorial Museum; Ibid., No. 5, pp. 33-39.
Description of Some New Asaphidæ; ibid., No. 6, pp. 41-48.
Two New Species of *Tetradium;* Ibid., No. 7, pp. 49-50.
A Revision of the Species which have been Referred to the Genus *Bathyurus;* Ibid., No. 8, pp. 51-69.
—— Correlation of the Middle Ordovician Formations of Ontario and Quebec (Abst.); Geol. Soc. Amer., Bull. 24, p. 111.
[1] (1914): Table Middle Ordovician; Geol. Surv., Canada, Sum. Rept. 1912, p. 348.
—— [1] A *Beatricea*-like Organism from the Middle Ordovician; Geol. Surv., Canada, Mus. Bull. 5.
(1915): Revision of the Canadian Species of "Agelacrinites"; Ottawa Nat. 29, pp. 53-62.
[1] (1916): The Pelecypods of the Chazy Formation; Carnegie Mus. Ann. 10, pp. 325-343.
—— [1] A New *Ceraurus* from the Chazy; New York State Mus. Bull. 189, pp. 121-126.
—— The Genera of the Odontopleuridæ; Ottawa Nat. 29, pp. 135-139.
[1] (1917): Beecher's Classification of Trilobites after Twenty Years; Amer. Jour. Sci. (4) 43, pp. 196-218.
[1] (1920): The Appendages, Anatomy and Relationships of Trilobites; Connecticut Acad. Arts, Sci., Mem. 7, pp. 34-39.
[1] (1921): A Contribution to the Description of the Fauna of the Trenton Group; Geol. Surv., Canada, Mus. Bull. 31, 1921.

Raymond, P. E., and Barton, D. C.
[1] (1913): A Revision of the American Species of *Ceraurus;* Mus. Comp. Zool., Bull. 54, pp. 525-543.

Raymond, P. E., and Narraway, J. E.
(1906): A New American *Cybele;* Carnegie Mus. Ann. 3, pp. 599-604.
(1908): Notes on Ordovician Trilobites — Illænidæ from the Black River Limestone near Ottawa, Canada; Carnegie Mus. Ann. 4, pp. 242-255.
(1910): Notes on Ordovician Trilobites — III, Asaphidæ from the Lowville and Black River; Carnegie Mus. Ann. 7, pp. 46-59.

Reed, F. R. Cowper
[1] (1928): Notes on the Family Encrinuridae; Geol. Mag. 65, pp. 51-77.

Ringueberg, E. N.
[1] (1889): The Calceocrinidæ, a Revision of Family, with Description of Some New Species; New York Acad. Sci. 4, pp. 393, 395.

Roemer, F.
[1] (1876): Lethæa geognostica, Pt. 1, Lethæa palæozoica; Atlas, Pl. 11, fig. 6.

Salter, J. W.
[1] (1853): Fossils from the Ottawa River; Can. Jour. 1, pp. 221-222.
(1858): On *Cyclocystoides*, a New Genus of Echinodermata from the Lower and Middle Silurian Rocks; Geol. Surv., Canada, Can. Org. Rem. dec. 3, p. 89.
(1859): Canadian Organic Remains; Geol. Surv., Canada, dec. 1.

Schubert, R. J., Waagen, L.
(1904): Die untersilurischen Phyllopodengattungen; Jahr. geol. Reichsanst., pp. 42-44, Pl. 1, figs. 1, 2, and 4.

Schuchert, C.
[1] (1915): Revision of Palæozoic Stelleroidea, with Special References to North America Asteroidea; U. S. Nat. Mus., Bull. 88, pp. 165, 178, 219, 220.

Schuchert, C., and Cooper, G. A.
[1] (1932): Brachiopod Genera of the Suborders Orthoidea and Pentameroidea; Peabody Mus. Nat. Hist., Mem. IV, pt. 1.

Scudder, S. H.
(1896): A Caddis-Fly from the Leda Clays of the Vicinity of Ottawa, Canada; Can. Rec. Sci. 6, pp. 276-277.

Sinclair, G. W.
[1] (1940): A Discussion of the Genus *Metaconularia*, with Descriptions of New Species; Roy. Soc., Canada, Proc. and Trans., 3rd ser. 34, sec. 4, pp. 107-108.
[1] (1942): The Chazy Conularida and their Cogeners; Ann. Carnegie Mus. 29, pp. 224-225.
[1] (1944): Some Ordovician Trilobites from Ontario; Roy. Can. Inst., Trans. 25, pt. 1, No. 53, pp. 15-20.
[1] (1945): Notes on the Genera *Archæoconularia* and *Eoconularia;* Roy. Soc., Canada, Proc. and Trans., 3rd ser. 38, sec. 4, p. 92.
—— [1] Some Ordovician Lingulid Brachiopods; Roy. Soc., Canada, 3rd ser. 39, sec. 4, pp. 55-82.

Sowerby, G. B.
(1826): Notice of a Fossil Belonging to the Class Radiara, found by Dr. Bigsby in Canada; Zool. Jour. 2, pp. 318-320.

Sowter, T. W. E.
(1887): Report of the Geological Branch of the Ottawa Field Naturalist Club; Ottawa Field Nat. Club II, Trs. 7, pp. 342-349.
(1888): Preliminary Notes on the Chazy Formation at Aylmer, P.Q.; Ottawa Nat. 2, pp. 11-15.

Springer, F.
[1] (1905): *Cleiocrinus;* Mus. Comp. Zool., Mem. 25, pt. 2.
[1] (1911): On a Trenton Echinoderm Fauna; Geol. Surv., Canada, Mem. 15-P, pp. 10, 11, 25, and 37.
[1] (1920): The Crinoidea *Flexibilia;* Smith. Inst., pp. 345-348, Pl. 45.
See also Wachsmuth and Springer.

Sproule, J. C.
[1] (1936): A Study of the Cobourg Formation; Geol. Surv., Canada, Mem. 202, pp. 93-118.

Stewart, J.
(1887): Notes on Geological Work During the Summer of 1887; Ottawa Nat. 1, pp. 170-171.

Teichert, C.
[1] (1933): Des Bau der Actinoceroiden Cephalopoden; Palæontographica 78, Abt. A, p. 133.

Ulrich, E. O.
[1] (1889): On *Lingulasma*, a new Genus, and eight new species of *Lingula* and *Trematis;* Amer. Geol. III, pp. 377-390.

Wachsmuth, C., and Springer, F.
[1] (1883): Remarks on *Glyptocrinus* and *Reteocrinus*, Two Genera of (Lower) Silurian Crinoids; Amer. Jour. Sci. (3) 25, pp. 262-265.
[1] (1897): North American Crinoidea; Mus. Comp. Zool., Mem. 20.

Weller, S.
[1] (1900): Morphology of Crinoidea; Chicago Acad. Sci. Nat. Hist. Surv. 4, p. 28.

Whiteaves, J. F.
(1883): Note on the Occurrence of *Siphonotreta scotica* Davidson in the Utica Formation, near Ottawa; Can. Nat. Geol., N.S. 10, pp. 396-397.
(1897): Description of a New Genus and Species of Cystideans from the Trenton Limestone at Ottawa; Can. Rec. Sci. 7, pp. 287-292, 395.
[1] (1898): On Some Fossil Cephalopoda in the Museum of the Geological Survey of Canada; Ottawa Nat. 12, No. 6, p. 116.
(1903): Description of a New Species of *Matheria* from the Trenton Limestone at Ottawa; Ottawa Nat. 17, No. 2, pp. 32-34.
Notes on some Canadian Specimens of *Lituites undatus;* Ibid., pp. 117-122, 161-163.
(1904): The Canadian Species of *Trocholites;* Ottawa Nat. 18, pp. 13-14.
(1906): The Canadian Species of *Plectoceras* and *Barrandeoceras;* Geol. Surv., Canada, Pal. Foss. III, pp. 311, 312, 316.
[1] From the Trenton Limestone of Ontario and Quebec; Ibid., pp. 316-323.
(1908): Notes on the Pelecypoda or Bivalve Mollusca of the Chazy Formation in Canada, with Descriptions of one New Genus and four New Species from the Chazy Sandstone at Hog's Back near Ottawa; Ottawa Nat. 22, pp. 105-115.

Whittaker, E. J.
(1918): The Relationship of the Fossil Marl Fauna of MacKay Lake, Ottawa, to the Present Molluscan Fauna of the Lake; Ottawa Nat. 32, pp. 14-18.
(1922): The Fossil Mollusca Faunas of the Marl Deposits of the Ottawa District; Geol. Surv., Canada, Bull. 33, pp. 59-78.

Whittingdon, H. B.
(1941): The Trinucleidae — with special reference to North American genera and species; Jour. Pal. 15, No. 1, pp. 21-41.

Wilson, A. E.
(1913): A New Brachiopod from the Base of the Utica; Geol. Surv., Canada, Mus. Bull. 1, pp. 81-86.
[1] (1914): A Preliminary Study of the Variations of the Plications of *Parastrophia hemiplicata* Hall; Geol. Surv., Canada, Mus. Bull. 2, pp. 131-139.
(1915): A New Ordovician Pelecypod from the Ottawa District; Ottawa Nat. 29, pp. 85-86.
(1921): The Range of Certain Lower Ordovician Faunas of the Ottawa Valley, with Descriptions of Some New Species; Geol. Surv., Canada, Bull. 33, pp. 19-57.
[1] (1926): An Upper Ordovician Fauna from the Rocky Mountains, British Columbia; Geol. Surv., Canada, Bull, 44, p. 34, Pl. 3, fig. 6, Pl. 4, fig. 5.
(1932): Palæontological Notes; Can. Nat. 46, pp. 133-140.
—— Ordovician Fossils from the Region of Cornwall; Roy. Soc., Canada, Trans. 3rd ser., sec. 4, vol. 26, pp. 373-404, 6 pls.
(1944): *Rafinesquina* and its Homomorphs *Öpikina* and *Öpikinella* from the Ottawa Limestone of the Ottawa-St. Lawrence Lowland; Roy. Soc., Canada, 3rd ser. 38, sec, 4, pp. 145-203.
(1945): *Strophomena* and its Homomorphs *Trigrammaria* and *Microtrypa* from the Ottawa Limestone of the Ottawa-St. Lawrence Lowland; Roy. Soc., Canada, 3rd ser. 39, sec. 4, pp. 121-150.
(1946): Echinodermata of the Ottawa Formation of the Ottawa-St. Lawrence Lowland; Geol. Surv., Canada, Bull. No. 4.

Woodward, H.
[1] (1871): On the Structure of Trilobites; Geol. Mag. 8, pp. 289-294.
[1] (1880): Notes on the Anomalocystidae; A Remarkable Family of Cystoidea Found in the Silurian Rocks of North America and Britain; Geol. Mag., N.S. dec. 2, vol. 7, pp. 193-201.
[1] (1889): On the Discovery of *Turrilepas* in the Utica Formation (Ordovician) of Ottawa, Canada; Geol. Mag. dec. 3, vol. 6, pp. 271-275.

Woodward, H., Duncan, P. M., Etheridge, R.
(1872): On the Canadian Trilobite with Legs; Can. Nat. Geol., N.S. 6, pp. 227-231.

INDEX

INDEX—CONTINUED

INDEX—CONCLUDED