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SILURIAN STRATIGRAPHY AND PALÆONTOLOGY OF THE NIAGARA ESCARPMENT IN ONTARIO

By
Thomas E. Bolton

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
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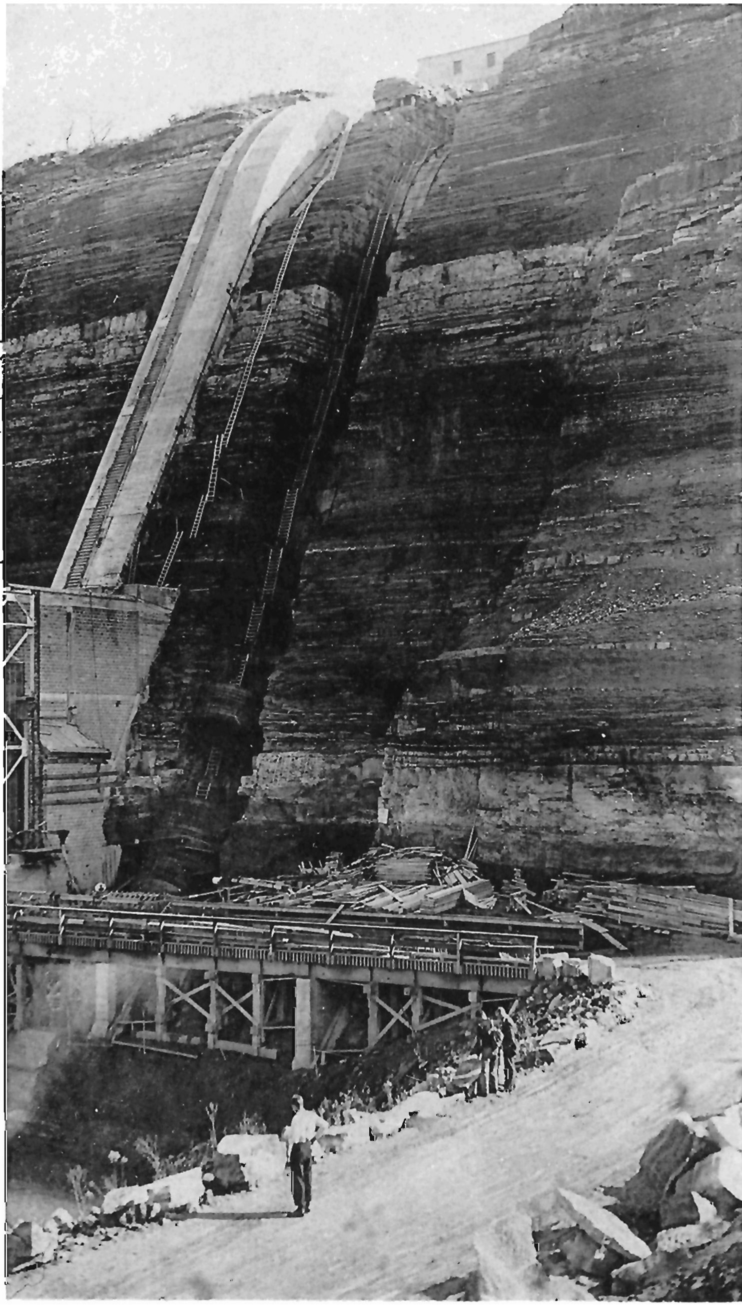

SILURIAN SECTION, DECEW FALLS, ONTARIO

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PREFACE

The Silurian rocks of southwestern Ontario have long been known as an important source of gas, oil, building stone, and other materials. They have been studied off and on for a hundred years or more, but many of the relationships are still obscure.

This report describes the result of a detailed study of sections exposed on Manitoulin Island and along the Niagara escarpment from Niagara Falls to the Bruce Peninsula. The various groups, formations, and members into which the Silurian has been divided in different parts of Ontario are described and correlations suggested on the basis of observed facies changes and palæontological evidence.

The Ontario units are further correlated with those in Michigan and those in New York.

The faunas of the various units are discussed and many new species described.

GEORGE HANSON,
Director, Geological Survey of Canada

OTTAWA, April 15, 1956

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CHAPTER I

INTRODUCTION

Statement of Problem

Silurian sedimentary formations underlie the greater part of the Ontario-Michigan basin, and extend westward into Wisconsin and Illinois. The Niagara escarpment, extending in an almost unbroken line from east-central New York State through southern Ontario and Manitoulin Island into northern Michigan, exposes rocks of both Lower and Middle Silurian age. Detailed lithological and palæontological examinations of these rocks have served to place our knowledge of the Silurian of Ontario on a relatively secure foundation. However, recent stratigraphic and ecological investigations of the Silurian sediments of New York (Gillette, 1947)[1], Michigan (Ehlers, 1948), and Illinois (Lowenstam, 1948) have indicated that the correlations formerly proposed for the various Silurian formations in Ontario need revision.

A new field of inquiry was opened in 1947 at the site of the Hydro-Electric Power project at DeCew Falls, St. Catharines (*see* Plate I). A detailed lithological and palæontological investigation was commenced on this section in the autumn of 1948 and the results obtained were incorporated in an unpublished Master of Arts thesis at the University of Toronto (Bolton MS., 1949). In an attempt to attain a clear conception of the Silurian stratigraphy of the Ontario peninsula, numerous sections exposed along the Niagara escarpment between Niagara Falls and Manitoulin Island were examined. During the 1950 and 1951 field seasons several key sections were measured between Niagara Falls and Dyer Bay (Bolton, 1953, 1953 MS.) and in order to establish recognizable horizons from one locality to another and to gain information pertaining to facies changes, as many as possible of the intervening exposures were also investigated. The geographic location of each section is shown on the accompanying map (*see* Figure 1, enclosed). The fauna collected from each formation recognized in all these sections is compiled either in special faunal tables or included with the lithological descriptions.

This research was confined principally to the vertical sections outcropping along the escarpment proper. In order to trace the distribution of a Racine (late Niagaran) fauna found in the upper part of the Lockport equivalent on the Bruce Peninsula, many outcrops behind the escarpment in that particular area were examined. The Lockport-Guelph contact was also studied in these outcrops. During the 1951 and 1953 field seasons the Silurian formations established on the mainland were further traced across Manitoulin Island into northern Michigan, as well as eastward from Niagara Falls to Utica, N.Y. The present report, however, includes only brief descriptions of these sections (Bolton, 1954).

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[1]Dates and names in parentheses are those of publications listed in the Bibliography at the end of this report.

Historical Sketch

The Silurian strata of the Great Lakes Region have been studied by many eminent American and Canadian geologists; the resulting stratigraphic terminology is summarized in Table II, and discussed in the sections dealing with the individual groups and formations. Hall (1852), Hartnagel (1907), Schuchert (1914), Chadwick (1918), Grabau (1909), Ulrich (1911, 1914), and Bassler (1906, 1909) laid the foundations for the New York Silurian stratigraphy and palæontology. Recently Alling (1947), Sanford (1935, 1936), Gillette (1947), and Fisher (1953, 1954) proposed new and interesting correlations for the Clinton strata of New York.

In southern Ontario the Silurian strata and their faunal assemblages have been outlined by Murray (1843), Logan (1863), Billings (1866), Bell (1867, 1870), Grabau (1901), Schuchert (1914), Parks (1909), and Williams (1919). The contributions of each of these men have helped greatly towards an understanding of the Silurian. Logan originally outlined the distribution of these sediments; Grabau demonstrated that the top of the Queenston shale represented the top of the Ordovician; Schuchert and Parks outlined the Cataract formation; Williams mapped in detail the Silurian of southern Ontario. More recently, a critical study of the various Silurian formations was undertaken by several graduate students of the University of Toronto. Johnson (1934 MS.) surveyed the Cataract formation; Nowlan (1935 MS.) revised the Niagaran series; Shaw (1937) completed these stratigraphic investigations by an examination of the Guelph formation. The northern extension of the Silurian was outlined on Manitoulin Island by Way (1936 MS.). Holstein (1936 MS.) and Crombie (1943 MS.) investigated the heavy minerals of the various Silurian formations in Ontario, and to complete this series of studies Laird (1935) reported upon the nature and origin of the chert pebbles in the Lockport formation. Only the conclusions reached by Laird and Shaw have been published, although many of the theories proposed by the other students were incorporated in these publications. Cumings clearly outlined the close relationship of the Ontario and Michigan strata in his 1939 paper on the Silurian system in Ontario. The most recent investigations were carried out by Caley (1940, 1941, 1945), during which the entire Silurian of the Ontario mainland was remapped. At present Armstrong (1953, 1955) of McMaster University is reviewing certain sedimentary problems in the Cataract rocks of the Niagara Peninsula. The Whirlpool phase of this project has been described by Gietz (1952 MS.), the Grimsby by Pelletier (1953 MS.), and the Thorold by Sutterlin.

Valuable information on the stratigraphy and palæontology of the Niagaran rocks exposed along the western rim of the Michigan Basin has been contributed by Ehlers (Michigan), Cumings (Wisconsin), and Lowenstam (Illinois). The stratigraphic sequence developed by Ehlers for the Niagaran series of northern Michigan has proved of great assistance in determining the relationship of the Silurian strata outcropping on Manitoulin Island and Bruce Peninsula.

Acknowledgments

The writer is deeply indebted to Professor Madeleine A. Fritz of the University of Toronto, from whom he received much valuable advice and guidance during the preparation of this material as a doctorate thesis (Bolton, 1953 MS.). The research was begun during the tenure of an Imperial Oil Graduate Research Fellowship.

The major part of the field work and palæontological research was completed under the auspices of the Geological Survey of Canada. To Dr. J. F. Caley and Dr. B. A. Liberty of the survey, and Mr. R. Day of the Hydro-Electric Power Commission the writer is indebted for criticism and helpful discussion of the many problems pertaining to Silurian stratigraphy. In the field, the writer was assisted in 1950 by B. Sivak, in 1951 by G. E. Bourns, and in 1953 by W. M. McNeely.

Permission to examine the DeCew Falls section and the diamond drill-cores from the new Niagara Falls project was kindly granted by the Hydro-Electric Power Commission of Ontario; the numerous courtesies extended by the officials and men of that company were much appreciated.

CHAPTER II

STRATIGRAPHY AND PALÆONTOLOGY

General Statement

In southwestern Ontario the various undeformed Palæozoic formations are found in concentric belts with the strata dipping southwest towards the centre of the Michigan Basin. Differential weathering of the harder and softer rocks has produced the Niagara escarpment as the eastern boundary of a cuesta. Along this escarpment the Lower Silurian or Alexandrian rocks consist of sandstone, dolomite, and shale; they constitute the Cataract group. This group, and each of the succeeding groups, are divisible on the basis of lithology into formations: Whirlpool sandstone, Power Glen shale, Manitoulin dolomite, Cabot Head shale, and Grimsby sandstone. Each of these formations is lithologically uniform, a product of continuous deposition, and may consist of one type of rock or of two or more varieties of related rocks. Several different lithological units are considered equivalent as a result of lateral gradation.

The Middle Silurian or Niagaran, represented in the Niagara escarpment by the Clinton and Albemarle groups, is composed essentially of dolomites; those shales that are present are confined to the Niagara and Bruce Peninsulas. Two different facies are represented in the Clinton group of Ontario. Six formations are contained in the southern, Niagara Peninsula facies: Thorold sandstone, Neahga shale, Reynales dolomite, Irondequoit limestone, Rochester shale, and DeCew dolomite. Throughout the remainder of the escarpment four formations are assigned to the Clinton: Dyer Bay dolomite, Wingfield shale, St. Edmund dolomite, and Fossil Hill dolomite. These formations, with the exception of the Fossil Hill, are confined to Bruce Peninsula and Manitoulin Island. The Albemarle group also is composed of two facies; the Niagara Peninsula Albemarle strata are referred to the Lockport and Guelph formations, whereas the northern strata are included in the Amabel and Guelph formations. Both the Lockport and Amabel formations are further divisible into members. The stratigraphic relationships of the various strata recognized along the Niagara escarpment are illustrated in Figure 2 (enclosed); the regional geology is shown in Figure 1 (enclosed). The classification followed in this report for the Lower and Middle Silurian sediments of Ontario is given in Table I.

The marked lithological and faunal differences in the Silurian strata of western New York-Niagara Peninsula and Manitoulin Island-northern Michigan have been attributed to a structural barrier. This barrier, defined as the northeastern branch of the Cincinnati Arch or Algonquin Arch, extended eastward from Lake St. Clair region to Cataract, Ont. (*see* Roliff, 1954, Figures 3 and 4). As representatives of the Clinton group were apparently absent north of Hamilton, and as the entire dolomite sequence forming the white weathering bluffs in the Bruce Peninsula-Manitoulin Island region was believed to be Lockport in age, Cumings

TABLE I

Classification of Lower and Middle Silurian

Series	Niagara Peninsula (Niagara Falls-Hamilton)				Hamilton-Tobermory, and Manitoulin Island		
	Group		Formation	Member	Group	Formation	Member
Niagaran Series (Middle Silurian)	Albemarle Group		Guelph		Albemarle Group	Guelph	
Niagaran Series (Middle Silurian)	Albemarle Group		Lockport	Eramosa	Albemarle Group	Amabel	Eramosa
				Goat Island			Wiarton
							Colpoy Bay
				Gasport			Lions Head
						?	?
Niagaran Series (Middle Silurian)	Clinton Group	Upper	DeCew		Clinton Group		
			Rochester				
			Irondequoit				
		Mid.					
		Lower	Reynales			Fossil Hill	
			Neahga			St. Edmund	
			Thorold			Wingfield	
						Dyer Bay	
Alexandrian Series (Lower Silurian)	Cataract Group		Grimsby		Cataract Group	Cabot Head	
			Power Glen			Manitoulin	
			Whirlpool			Whirlpool	

(1939) postulated that the maximum influence of this arch or 'Cataract axis' was during Clinton time. However, the results of the present investigation show that: (1) between Hamilton and Owen Sound a uniform thickness of Lower Silurian sediments was deposited (*see* Figure 2), (2) sediments of Clinton age, as here defined, were deposited north of Hamilton over the same area (Fossil Hill) as well as on the Bruce Peninsula and Manitoulin Island (Dyer Bay-Fossil Hill sequence), and (3) only a part of the dolomite facies assigned to the 'Lockport' in the Owen Sound-Manitoulin Island region was equivalent to the true Lockport of the western New York-Niagara Peninsula district. As a result, rather than resort to the postulate of an axis or barrier proper in the escarpment region, the writer (1953) prefers to consider the presence of two major sites of deposition, one in the western New York-Niagara Peninsula area (Appalachian basin province) and one in the Owen Sound-Bruce Peninsula-Manitoulin Island-northern Michigan region (Michigan basin province), with an intervening broad, shallow platform area that extended from north of Hamilton to Owen Sound. Between these basins, during Lower Silurian sedimentation faunal migration was mainly unrestricted, although certain forms apparently were confined to each site (*see* Tables III-V); in particular, some species are found in the Manitoulin strata of Manitoulin Island that geographically range only as far south as Owen Sound. During Clinton time the influence of this postulated platform on sedimentation is evident from the pronounced facies changes and associated faunal variations. In particular the Lower Clinton Reynales dolomite was deposited on the platform as far as Georgetown and north of this locality the same age of sediments is represented by the Fossil Hill dolomites. Furthermore the restriction of the Lower Clinton Dyer Bay-Wingfield-St. Edmund sediments to the Bruce Peninsula-Manitoulin Island site and the Upper Clinton Irondequoit-Rochester-DeCew sediments to the Niagara Peninsula may be attributed to the presence of this platform between the two major basins. A period of non-deposition marks Middle Clinton time on the Niagara Peninsula site with a distinct disconformity separating the Lower Clinton Reynales dolomite from the Upper Clinton Irondequoit limestone. No evidence has been discovered as yet to prove whether this withdrawal affected sedimentation in the Manitoulin Island-northern Michigan area. Hence the sequence of strata in that region may contain representatives of the early Niagaran Clinton time. The development of the various facies observed in the Albemarle group, which appear however to be the result of continuous deposition, could be accounted for by this theory.

Sanford and Moseley (1954) contend that a Lower and Middle Silurian transgression eastward from Michigan to New York best explains these variations in facies. Both transgressive or regressive fluctuations of the easterly migrating strand line and distance from source controlled the character of the sediments, producing an almost completely carbonate sequence in the northern site and a more clastic sequence to the south and east. It is evident from the results here presented that throughout Lower and Middle Silurian time the principal source of the sediments deposited over Ontario undoubtedly lay to the south and east, with some contribution to the northern site, particularly in early Clinton time (Dyer Bay-Wingfield-St. Edmund formations), from the north. An east-west transgression and regression is distinctly shown by the sediments comprising the Cataract group during Lower Silurian time and a second regression is indicated during early Middle Silurian time, deposition of Middle Clinton sediments in west-central New York State supporting an eastern migration at this period in the southern site. A late Middle Silurian eastward transgression is presumed by Sanford and Moseley (1954), based on the belief that coralline bioherms (Fossil Hill formation) of Clinton age in the northern site represent a facies found well up in the Lockport of New York State, but supporting evidence for such a theory has not been definitely established in supposedly connecting strata in southern Ontario.

Cataract Group

As a result of the many detailed investigations over the past hundred years the terminology applied to Silurian strata has undergone considerable alteration and modification. A comprehensive summary of the various classifications advanced up to 1936 is presented in the "Lexicon of Geologic Names of the U.S.A." (Wilmarth, 1938). A brief resumé of the terminology proposed for the Lower Silurian sediments is necessary at this point so that the classification used in the present report may be clearly understood (*see* Table II).

The name Medina was introduced by Vanuxem and Hall in 1840 to include the entire sequence of red sandstones and shales lying between the Ordovician 'Hudson River' shale and the Silurian Clinton in New York State. This subdivision prevailed until 1905 when Grabau (1908) assigned the lower red shales to the Upper Ordovician Queenston formation and the term Medina, accordingly, was restricted to the overlying sandstones. In 1913 Kindle and Taylor grouped the Lower Silurian strata exposed at Niagara Falls under the term Albion; the following year, however, Kindle reverted to Grabau's earlier definition of the Medina. Ulrich and Bassler (1923) subsequently proposed the Medinan series to include, like Hall's Medina, both the Queenston and Lower Silurian strata. Goldring (1931) and Gillette (1940) accepted the Medinan as defined by Ulrich and Bassler and assigned the Lower Silurian strata to the Albion group. Cumings (1939) further modified the series by excluding the Queenston shales. Fisher (1954) has since adopted Medinan as a group term for Lower Silurian strata, and reintroduced Vanuxem's Ontarian series (1842) to include all pre-Salina (pre-Upper Silurian) strata.

Many of the stratigraphic names proposed by these New York geologists became firmly rooted in Ontario Palæozoic literature. Schuchert, in 1913, established the idea that the term Medina was applicable only to the upper sandy beds, namely, the Grimsby and Thorold. Most of the Lower Silurian sediments of Ontario were assigned to the Cataract formation. This formation, which included the Whirlpool, Manitoulin, and Cabot Head members, was traced by him from Manitoulin Island southward to where it 'wedged out' beneath the Medina. At the same time he recognized a disconformity between the Cataract and the overlying Medina (upper part of Grabau's Medina). Later (1914, p. 294) he stated that "the typical

Medina formation shades through lateral alteration into the typical Cataract." Williams (1919) further modified Schuchert's classification by affirming that Grabau's Medina was applicable to strata exposed from Niagara Falls to Hamilton, whereas Schuchert's Cataract was traceable only from Dundas north. He confirmed, however, Schuchert's ideas of facies relationships by noting that the 'Medina-Cataract' formation varied so distinctly by lateral gradation that a hyphenated term seemed best suited for the name of the formation as a whole (p. 23). Johnson (1934 MS.), on the other hand, revived Schuchert's idea of the Cataract and retained the Medina and Cataract as individual units. In his opinion faunal evidence pointed to a distinct province for the Medina rocks; the Grimsby and Thorold were accordingly both excluded from the Cataract. Shaw (1937), in his account of the Guelph and Eramosa formation, concluded that the term Medina was not applicable to the Lower Silurian strata of Ontario in any sense. In his opinion, the original description of the Cataract formation should be altered to include the Grimsby, but the Thorold should be retained as basal Clinton. This assignment of the Thorold to basal Clinton had been advocated earlier by Chadwick (1918), Ulrich and Bassler (1923), Nowlan (1935 MS.), and recently confirmed by both Gillette (1940, 1947) and Fisher (1953). Caley (1940, 1947) revived the divisions advanced by Grabau, including in the Medina formation all the strata between the Queenston below and the Clinton (Furnaceville-Neahga) above. Caley recognized, as had both Schuchert and Williams, that "lithologically the Cataract is only a facies of the Medina that like the Queenston below changes as it is traced westward and northward from an almost purely clastic assemblage to one largely composed of limestone" (1940, p. 26). The faunal differences were the result of variations in habitat.

The term Cataract group is applied in this report, however, in preference to the terms Medinan, Medina, or Albion; the following argument is offered to justify this proposal. The Medinan (as a series connotation) embraced both the Queenston shales and overlying red sandstones; hence the Ordovician-Silurian contact was placed at the base of the Queenston in New York. In contrast, the Queenston shales of Ontario are regarded as Richmond in age, and the base of the Silurian is drawn at the top of these shales. As previously outlined, the original Medina embraced the red semicontinental facies of eastern and central New York and the term Cataract has always implied the predominantly marine Lower Silurian strata of Ontario. The relationship of the Lower Silurian strata from east to west and northwest is definitely one of facies. This red semicontinental sequence of eastern and central New York, a lithological entity in itself, is considered equivalent in time to the varied marine deposits of western New York, Ontario, and northern Michigan. The use then of the term Cataract for a completely different rock sequence appears justified. The Albion group, as defined by Gillette (1940), embraces primarily marine sediments in its type locality at Niagara Falls, and the group is here regarded as synonymous with the Cataract. The name Cataract, therefore, is retained for the marine facies of the Lower Silurian and ranked as a group (Bolton and Liberty, 1955; Liberty and Bolton, 1956). Gillette's assignment of the

Thorold sandstone entirely to the Clinton is accepted; the Grimsby sandstone thus defines the top of the Cataract group. This group is divided into the following formations:

Niagara Falls to Stoney Creek	Stoney Creek to Clappison Corners	Clappison Corners north
Grimsby	Grimsby	Cabot Head
Power Glen	Cabot Head	
	Manitoulin	Manitoulin
Whirlpool	Whirlpool	Whirlpool

WHIRLPOOL FORMATION

Niagara Falls; Sections 1, 13, 16, 30, 47, 49, 50, 56, 58-61, 65, 69, 73 (*see* Figure 1).

Definition and Distribution. The term Whirlpool was first proposed by Grabau (1909) for the 25 feet of quartzose sandstone forming the base of the Medina at Niagara Falls. Whirlpool (White Medina of subsurface terminology) sandstone may be traced in natural outcrops and in quarries from Niagara River north along the Niagara escarpment to Duntroon, 8 miles south of Collingwood. From that locality north it has never been definitely detected. The name is also applicable to the basal white coarse sandstone at least as far east as Medina, N.Y. Its westward limit, as determined from well records, appears to follow a line from Port Bruce, Lake Erie, northeast through Aylmer, Brantford, and Guelph, thence north to Duncan, southwest of Collingwood.

Lithology. It is typically a massive to thick-bedded, white to light grey, fine-grained, crossbedded, compact, unfossiliferous, quartzose sandstone or orthoquartzite. Variations from the standard include the following: narrow thin-bedded zones, confined to the upper beds; red mottled zones, as in the Niagara Falls drill-cores and at section 58; deep chocolate-red horizons, as at Terra Cotta and Credit Forks; coarser grained sandstone from Niagara Falls eastwards; grey shale partings in the Niagara Falls region and in some of the more northern sections; thin zones of rolled grey shale pebbles or mud galls, commonly in lenses, at various horizons in the Niagara Falls, DeCew Falls, and Hamilton sections. Petrological studies have been undertaken on various exposures of the Whirlpool sandstone by Alling (1936), Holstein (1936 MS.), Sanford (1939), Bolton (1949 MS.), Gietz (1952 MS.), and Fisher (1954). Alling classified the Whirlpool of the Niagara section as a feldspathic sandstone, quartz dominating, with microcline, plagioclase, garnet, leucoxene, magnetite, apatite, tourmaline, and zircon in an accessory role. Most of the above minerals were identified during the present investigation, though the role of the feldspars appears far less significant in the sandstones sectioned. Holstein obtained a similar suite of minerals, and stressed the role of the two most dominant heavy minerals zircon and collophane. Although the abundance of both minerals varied laterally and vertically, zircons apparently dominated the lower suites and collophane the upper. Holstein (1936 MS., p. 56) concluded from his studies that "the Whirlpool contained a definite, constant and characteristic suite of light and heavy minerals by which it may be distinguished from other sandstone formations of similar appearance."

Contacts and Thickness. Everywhere the Whirlpool formation rests sharply on the upper Ordovician red Queenston shales. Minor undulations extend the sandstone downwards into the green clay shale that commonly marks the top few inches of the Queenston. Its upper contact with the Manitoulin dolomite is sharp and well defined, although a thin transitional zone of grey shale is present in some sections. On the other hand, the contact with the Power Glen shales is transitional and therefore arbitrary; it is everywhere drawn at the top of the massive sandstone beds (*see* Plate I).

The thickness of the Whirlpool varies both locally and regionally; in general it appears to thin westward and northward. It is from 18 to 28 feet thick at Niagara Falls, 12 feet thick at DeCew Falls and Hamilton, about 15 feet at Belfountain and Cataract, 22 feet on Nottawasaga River tributary, 10 feet at Primrose, and about 6 feet at Duntroon. These measurements, and data from borings, indicate local thickenings throughout the region. Deposition upon an undulating erosion surface and variations in the sandstone strand line may explain these irregularities. The thicker units, along the escarpment in particular, probably represent extensions of the sandstone facies westwards with displacement in part of the Manitoulin dolomite.

Origin. Various theories have been advanced to explain the origin of this sandstone unit. A. W. G. Wilson was the first to assign a sand dune origin to the Whirlpool sandstone. Grabau (1913) also considered that wind played a major role in its deposition, though occasional shallow water conditions undoubtedly existed. Williams (1919) believed both wind and water action produced the present sedimentary structures. The well-sorted nature of the sediments could be due either to long distance transportation, wave action, gentle currents, or to wind. As only the most stable detrital minerals are present Holstein (1936 MS., p. 56) concluded that "wind and water were jointly responsible for the transportation of the constituent grains from their source to the present sites of deposition." Grabau (1913) considered the Whirlpool to be a local formation unconnected with any direct eastern source. In contrast Williams (1919) concluded that the source beds of the sediments lay to the east in the Appalachian region. Alling (1936) suggested that most of the quartz was derived from a pre-existing sandstone. Holstein (1936 MS.) decided that the heavy mineral suites were not typical of a Precambrian distributive province; rather the degree of sorting increased to the northwest suggesting source beds to the south and east. He concluded from this evidence that the sedimentary rocks composing the Appalachian highlands, as well as the rocks of the Adirondacks, were the source beds. Lockwood (1942) reverted to an aeolian origin. Gietz (1952 MS.) showed that, on the basis of lateral variation of grain size and sorting, the Whirlpool sandstone had its source to the south and east of its present location. Size distribution curves from five localities in Ontario revealed that, with increasing distance from Niagara Glen, there was a shift in the maximum frequency towards the finer grained sizes, accompanied by a limitation in the spread of the sand grain sizes. The consistent decrease in average size of grains along the Niagara escarpment from Niagara Glen westward, and from Niagara Glen north to Queenston, indicates that the direction of transportation of the detrital material of the Whirlpool sandstone was from the south and east. Recently, an aeolian origin for the lower Whirlpool and aqueous for the remainder was advanced by Fisher (1954, p. 1987).

Any theory advanced for the origin of these sediments should explain (1) the gradation of white to grey sandstone eastward into red, coarser grained sandstone, (2) the easterly increase of impurities combined with a decrease in the degree of sorting, (3) the presence of mud-galls and grey shale lenses both along the horizontal bedding planes and along the inclined foresets of the crossbedded planes, (4) the limited size of the cross-bedding, suggestive of aqueous rather than aeolian origin, (5) the presence of both well-rounded, frosted and subangular, clear quartz grains, (6) the predominance of only the most stable detrital minerals, and (7) the reasonable constancy in thickness along the Niagara escarpment with westward thinning. The belief that the Whirlpool was deposited as marginal sediments derived from the east and laid down on the undulating and mud-cracked Queenston surface by transgressing shallow seas under reducing conditions apparently satisfies these requirements. Quartzose sandstones similar to the Whirlpool have been deposited on stable shelf areas, and as such represent tectonic stability according to Krumbein (1948). Wind possibly played only a minor role in the transportation of this clastic material from the elevated Appalachian source region. To the east red 'Medina' clastics, and to the north Manitoulin dolomite, occur at the same stratigraphic position.

POWER GLEN FORMATION

Niagara Falls; Sections 1, 4, 9, 10 (*see* Figure 1).

Definition and Distribution. The name Power Glen was proposed (Bolton, 1953) for the 48 feet of shales with interbedded sandstones and limestones that separate the Whirlpool below from the Grimsby above at DeCew Falls, Ont. (*see* Plate 1). There is no basis for dividing this unit, either lithologically or faunally, into the equivalents that occur at the same stratigraphic horizon farther north as suggested by Fisher (1954). These shales represent a distinct lithological entity and as such warrant special designation (Liberty and Bolton, 1956). They are exposed in their entirety only along the Niagara gorge and at DeCew Falls.

The northern limit of this formation appears to lie between Grimsby and Stoney Creek. Outcrops of possible upper Power Glen occur at Twenty Mile Creek (4)[1], at Grimsby gorge (9), and in the road-cut just west of Grimsby (10). These grey shales are gradually replaced eastward by red beds; near Medina, N.Y., the entire sequence is one of red shales and sandstones. The westward limit has not been accurately defined as yet.

Lithology. At its type locality the Power Glen consists of dark grey to green, fissile, calcareous to arenaceous shale with interbedded thin bands of light grey, fine- to medium-grained, calcareous sandstone present at various levels. Microscopic studies show that subangular to subrounded quartz grains form 60 to 70 per cent of the sandstones, the grains being consistently finer than those of the Whirlpool sandstone. Interstitial carbonate, next in abundance, appears to replace both quartz and plagioclase grains. Accessory minerals, all detrital in origin, include microcline and albite, chlorite, leucoxene, magnetite, pyrite, zircon, sphene, tourmaline, and apatite. This suite of minerals is not unlike that of the Whirlpool, but notable is the absence of the dominant Whirlpool mineral collophane. Examples of variable sedimentation are numerous; noteworthy is the red, fossiliferous, oolitic ferruginous limestone, the lower surface of which is conformable with the bedding, whereas the upper surface undulates regularly.

Contacts and Thickness. The exact base of the Power Glen, as already noted, is arbitrary. A 1-foot thick fossiliferous, sandy transition zone, consisting of alternating thin sandstone and shale beds, lies between the massive Whirlpool sandstone and overlying shale facies. These beds have been assigned in the past to the Whirlpool, but represent the initial beds of a sedimentary phase entirely different from that which provided the pure, massive Whirlpool sandstone, and are designated as part of the Power Glen formation. The position of the upper boundary has been variously placed by the earlier workers. At DeCew Falls it is placed between the grey and overlying red shales, and this clear-cut contact appears regular and constant over the entire exposures. The associated colour alteration marks an environmental change within the site of deposition that persisted throughout the remainder of Cataract sedimentation. As in the case of the Whirlpool-Power Glen contact, no break in deposition is recognized.

The Power Glen sections along the Niagara River are marked by an increase in whitish grey, fine- to medium-grained, calcareous sandstone, particularly in the upper half of the formation. Seams of red oolitic ferruginous shale and intraformational conglomerate beds occur in the upper layers. The lower contact is again transitional into the Whirlpool sandstone. The upper contact is distinct and is variously marked by a lithological change from grey sandstone to red Grimsby sandstone, from grey sandstone to red shale, and from green siltstone to red siltstone.

The thickness of the Power Glen formation ranges between 34 and 48 feet, these variations corresponding in general with the differences in thickness of the underlying Whirlpool formation. Grey shales only are exposed northeast of DeCew Falls.

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[1]Numbers in parentheses are those assigned to the individual sections on Figure 1.

Fauna (*see* Table III). The Power Glen shales contain few fossils which where present occur mainly as moulds and casts in the shales. Fucoidal markings and worm burrows are, however, abundant at practically every horizon. Brachiopoda, Pelecypoda, and Gastropoda make up 99 per cent of the definitely recognizable fauna, with Pelecypoda, many of which appear to represent new species, dominating many horizons. As many of the species appear spasmodically, no definite zoning can be established. The only species that approaches the category of a zone marker is the bryozoan *Helopora fragilis* as it appears to be restricted in the DeCew Falls exposure to the upper 27 feet of the Power Glen, where it is generally associated with argillaceous sandstone. *Hormotoma subulata*, the most prolific gastropod, ranges throughout most of the formation. Numerous scolecodonts were collected by Eller (1940, 1944) from the Niagara gorge exposures of this formation. The following palæoecological observations might be noted: (1) *Pterinea*, *Rhynchonella*, *Rhynchotreta*, and *Stegerhynchus* occur mainly as united valves; (2) most pelecypods, as well as the brachiopods *Lingula* and *Parmorthis eugeniensis*, occur as complete single valves, convex upwards, parallel to the bedding; (3) the majority of species appear to represent mature forms; (4) specimens of *Parmorthis* and *Rhynchotreta* seem smaller in size than representatives of the same species in other formations; (5) orientation of the bryozoan *Helopora fragilis* is random in most beds; the westerly alignment in some beds is possibly a reflection of local currents; (6) the character of the material affords no evidence of transportation before burial; (7) the faunal assemblage suggests a shallow, muddy, marine environment.

Origin and Correlation. This formation represents an off-shore facies characterized by shales and a minimum of lime deposition. Gradual replacement of the grey shales by coarser red clastics to the east, and gradation into a lime facies to the north indicate that the source of these sediments lay to the south and east. The Power Glen fauna is similar to the Medina fauna of New York State. An even closer affinity exists between the Power Glen fauna and the more northern Manitoulin and Cabot Head faunas. This formation is thus equivalent to the Manitoulin and, at least, the lower part of the Cabot Head formations.

MANITOULIN FORMATION

Sections 13, 16, 47, 58-61, 65, 69, 71, 73-75, 77, 88, 120, 121, 128, 139, 190 (*see* Figure 1).

Definition and Distribution. The term Manitoulin was applied by Williams (1913) to the 50 feet of thin- to thick-bedded, blue-grey to buff weathered dolomite exposed on Manitoulin Island. Manitoulin strata are widely distributed along the Niagara escarpment, extending from Stoney Creek northward across Manitoulin Island into Northern Michigan. The writer cannot agree with the extension of the term Manitoulin to strata at Niagara Falls as advanced by Williams (1919) and Fisher (1954) as this formation neither persists nor retains its lithologic character beyond Stoney Creek. The 3 to 4 feet of calcareous strata recorded high in the Niagara Gorge shale section by Caley (1940, p. 29) and Fisher (1954, p. 1989) is probably lensitic as it is not consistent in cores from the many diamond drill-holes of the Hydro-Electric Power Commission of Ontario project (*see* Appendix B). At DeCew and Niagara Falls the 'Fish Creek'-Manitoulin-Cabot Head sequence defined by Fisher (1954, p. 1981) comprises a single lithologic entity, the Power Glen formation, which, in its entirety, is a southern shale facies of the Manitoulin dolomite and extension of the Cabot Head shale of the Hamilton region.

Lithology. At Stoney Creek (13) the Manitoulin formation is 4 feet thick and is dominantly an even bedded bluish grey to buff, crystalline, dolomitic limestone, sparingly fossiliferous. At Hamilton (16) the Manitoulin has much the same lithology, but the thinner calcareous beds are separated by numerous grey shale partings. As exposed in the Milton-Belfountain region the Manitoulin consists of thick- to thin-bedded, grey, buff weathered, dense to fine-grained, argillaceous dolomitic limestone with grey shale partings throughout, and lenses of white chert. The 26-foot Manitoulin exposure on Nottawasaga River (65) is similar lithologically. Shale, however, forms a smaller percentage of the total rock, and chert is more abundant. Some of the finest preserved fossils were collected from these chert lenses. A major change in the Manitoulin may be noted immediately north of this section. At Primrose (69) the formation becomes typically thin bedded or unevenly weathered. This lithology is best developed at Duntroon (73); at a point below Eugenia Falls; in the Owen Sound quarries (88); in the low Manitoulin scarp around Kemble (120-121); and east of North Kepple (128). The basal half of the formation is generally more massive, and argillaceous material is at a minimum. Chert is abundant, particularly near the top of the formation, with most of the fossils again concentrated in the chert. The Manitoulin strata exposed on Manitoulin Island are divisible on the basis of lithology and fauna into two units. The lower unit consists of the typical thin-bedded, brown and brownish grey, fine-grained, fine to medium crystalline, dolomitic limestone, varying in thickness across the island. Fossils are nowhere abundant, being associated also with argillaceous partings. Cup corals and the Brachiopoda *Parmorthis eugeniensis*, *Platystrophia daytonensis*, *Coelospira planoconvexa*, *Dolerorthis flabellites*, and *Strophonella* sp. predominate. The upper biohermal unit, Bidwell member of Way (1936 MS.) and Cumings (1939), is a massive grey and blue-grey, grey to brown weathered, fine-grained and finely crystalline, dolomitic limestone with green shale inclusions and thin-bedded zones at various intervals. Corals dominate: *Favosites* sp. and *Palaeophyllum williamsi* in the eastern exposures, *Paleofavosites asper* in the west. The brachiopod *Orthorhynchula bidwellensis* characterizes many of the sections, reaching its maximum development in the central part of the island in the fossiliferous exposures north of Bidwell. The actual contact between the typical Manitoulin dolomitic limestone and upper biohermal phases is difficult to establish.

Contacts and Thickness. The lower limit of the Manitoulin formation is easily established. Everywhere from Duntroon south it rests conformably upon the Whirlpool sandstone, the contact being best exposed in sections 13, 47, 65, 69, and 73. The possible unconformity at Stoney Creek (13) recorded by Lockwood (1942) could not be found. Throughout the Bruce Peninsula the Manitoulin rests directly upon Upper Ordovician Queenston red shales, the contact being seen to best advantage along the low scarp on the east shore of Owen Sound Bay. On Manitoulin Island the contact is with the marine Upper Ordovician Kagawong dolomitic limestone and is best observed in quarries west of Kagawong and south of Gore Bay. At these localities the Manitoulin rests sharply on 6 inches of thinly bedded, grey, finely crystalline, argillaceous limestone. It is overlain transitionally by the Cabot Head shales, with the contact drawn at that level where alternating grey shales and limestone predominate over the typical Manitoulin dolomite.

Various thicknesses have been assigned to the Manitoulin formation by the earlier workers in Ontario due, in all probability, to the fact that the upper contact of the formation is transitional. The thickness gradually increases from 4 feet at Stoney Creek (13), to 11 feet at Hamilton (16), 15 feet at Credit Forks (59), and 26 feet on the Nottawasaga River (65). From the latter locality northward the thickness is reasonably constant. The maximum thickness is over 50 feet in a local biohermal development southeast of Green Bay on Manitoulin Island.

Fauna (*see* Table IV). A rich and varied fauna characterizes the Manitoulin dolomite with Brachiopoda the most abundant of all the megascopic fossils, many species of which are common to all sections. *Enterolasma* sp. and *Neozaphrentis* sp., *Hallopora magnopora*, *Leptaena rhomboidalis*, *Dolerorthis flabellites*, *Platystrophia biforata*, *Parmorthis eugeniensis*, *Stegerhynchus neglectum*, and *Coelospira planoconvexa* dominate the assemblage. Vertical zoning appears impossible, although *Plectodonta transversalis* is confined to the Stoney Creek and Hamilton sections and *Helopora fragilis* is rare in the upper beds. An entirely different faunal assemblage from that outlined above for the Ontario mainland characterizes the upper massive unit of the Manitoulin on Manitoulin Island. Many of the species are apparently restricted to the Island or are closely related to Lower Silurian species of Ohio and Illinois. The coral *Paleofavosites asper* in particular is extremely abundant in many of the exposures and several Brachiopoda are associated, the most characteristic of which are *Orthorhynchula bidwellensis* and *Platystrophia daytonensis*. The former brachiopod occurs low in the section west of Gore Bay and higher in the eastern sections. A large scolecodont fauna was found by Eller (1944) in the Manitoulin beds throughout their areal extent. The largest concentration of scolecodonts, both of species and individuals, was found in the near-shore, ripple-marked deposits of the Niagara area with the greatest number of specimens being collected from impure sandstone strata assigned to the Manitoulin formation by Eller but here included in the Power Glen formation. A decrease in numbers northward coincided with an increase of calcareous and dolomitic material and the development of typical Manitoulin beds. Scolecodonts were noticeably more abundant in the impure dolomites of the Credit Forks section and along the edges of the bioherms on Manitoulin Island.

Origin. By comparison with the distribution and environment of modern polychaetes, Eller (1942) concluded that the Manitoulin sea was a shallow, warm, well-aerated body of water of relatively low salinity. The Manitoulin dolomite was deposited, during early Silurian time, in those regions that lay beyond the influence of clastic sedimentation. Data from borings indicate that it underlies most of southwestern Ontario.

At first the deposition of this dolomite apparently was confined to the more northern regions, coinciding in part with the deposition of Whirlpool sandstone to the south. As time went on, however, there was apparently a decrease in the amount of sediment supplied from the east to such an extent that clastic material was largely excluded from much of Ontario and the carbonate facies spread southward. Only in the Niagara region did clastic sediments still predominate and there formed the Power Glen formation ('Fish Creek' division of Fisher, 1954). At this time also, to the north on Manitoulin Island, a biohermal facies was developed. The abundance of fossils, the dolomitization of the limestone with the development of a saccharoidal texture, and the presence of chert nodules and concretionary beds conformable with the bedding indicate that the Manitoulin was essentially a normal marine limestone (Krumbein and Sloss, 1951, p. 137). Association of this limestone with the quartzose Whirlpool sandstone further indicates deposition under stable conditions during early Silurian time (Krumbein and Sloss, p. 139). The close of the Manitoulin was marked by a reversal of the earlier conditions, resulting in an increase in clastic sediments and the gradual extension of the Cabot Head shales over most of Ontario. This was characterized by Fisher (1954, p. 1981) as the commencement of regressive conditions.

CABOT HEAD FORMATION

Sections 13, 16, 21, 37, 46, 47, 59, 61, 62, 65, 71, 77, 105, 140, 160, 187, 190 (*see* Figure 1).

Definition and Distribution. The term Cabot Head has been variously interpreted since it was first applied to the strata exposed at the northeastern tip of Bruce Peninsula by Grabau (1913). As later defined by Williams (1919) it consisted of 'some' 130 feet of predominantly green shale and included the Dyer Bay and St. Edmund dolomite 'lentilles'. Bassler (1923), Johnson (1934 MS.), Nowlan (1935 MS.), Way (1936 MS.), and Cumings (1939) restricted the name Cabot Head to the 74 feet of green and reddish shales lying between the Manitoulin and Dyer Bay dolomites as the Dyer Bay and overlying sediments were considered sufficiently distinct to warrant separation. All of these workers were in reasonable agreement as to the lower limits of the Cabot Head but the definition of the upper limits proved a major problem. Johnson (1934 MS.) considered that the bryozoan *Helopora fragilis* was confined to the Cabot Head and stressed this occurrence in defining the limits of the formation. Actually the bryozoan is not confined to the Cabot Head but is common to the Dyer Bay formation of Ontario, and to the Lower Clinton formations of New York State (Gillette, 1947). *H. fragilis* undoubtedly reaches its maximum development in the Cabot Head shales, but should not be used as an index fossil to limit the formation. Lithological character is a more reliable limiting criterion and, on this basis, only the 74 feet of shales underlying the Dyer Bay are assigned to the Cabot Head formation at the type locality. As thus defined the Cabot Head is a lithological unit. The lower contact is everywhere gradational with the top of the Manitoulin formation and the upper contact is placed at a sharp lithological change, but the horizon at which this change takes place is different from place to place. In almost every section between the type locality on the Bruce Peninsula and Hamilton, the Cabot Head strata include near the top a thin red facies of variable lithology and thickness, predominantly composed of red calcareous sandstone and arenaceous limestone, overlain by green shales of variable thickness (*see* Appendix A, sections 37, 46, 65, and 71). Neither unit is developed to such a degree, however, as to warrant formational rank. In the Stoney Creek-Hamilton region, red shales and sandstones are of sufficient importance to be assigned to the Upper Cataract Grimsby formation and interpreted as a near-shore facies of the type Cabot Head. The Cabot Head formation in this area is thus restricted to the grey shales separating the Manitoulin and Grimsby formations. Still farther south and east the lithological unit known as the Cabot Head disappears entirely, its place being taken by part of the Power Glen formation as well as the Grimsby. Furthermore, the Grimsby is overlain in the Niagara region by the Lower Clinton Thorold sandstone. As the latter is traced north it gradually grades into interbedded sandstone and shale (21). The green shales and underlying red arenaceous limestones in the Cabot Head sections north of Hamilton region, in the writer's opinion, are northern equivalents of the Thorold (?) and Grimsby, respectively, and will be so referred to in future discussions. This variability in the composition of the Cabot Head formation combined with the basins and platform theory previously outlined would better explain why the Cabot Head is overlain successively from north to south by the Dyer Bay (77, 187), Fossil Hill (62, 65, 71, 105), Reynales (37), or Grimsby (13, 16, 21) formations rather than an unconformable relationship.

The Cabot Head formation has the same general distribution as the underlying Manitoulin dolomite. Although it is only exposed in the Niagara escarpment from Stoney Creek north to Manitoulin Island, the formation underlies most of southwestern Ontario. Owing to the nature of the lithology, complete sections were found only at Stoney Creek (13), Hamilton (16), and on Nottawasaga River (65). Most of the exposures north of Clappison Corners (21) can be referred to the Grimsby and Thorold (?) facies, and discussion of these partial sections is deferred until the southern formations have been adequately described.

Lithology. The Cabot Head of the Stoney Creek-Hamilton area, and that part of this formation underlying the red beds to the north, is predominantly a grey shale with variable amounts of grey, dense, interbedded calcareous sandstone and limestone. Thin red sandstone and shale bands occur in the upper 12 to 13 feet of this shale unit in all sections. These red beds, as they occur high in the Cabot Head, may represent early advances of the southern Grimsby facies into these northern regions. An examination of well records indicates that in general the Cabot Head retains essentially the same lithology as that at its outcrops in its subsurface extent.

Contacts and Thickness. The contact of the Cabot Head with the Manitoulin is everywhere gradational, 4 to 6 feet of interbedded shales and dolomitic limestone separating the massive Manitoulin dolomitic limestone and the overlying shale facies. In the present study the base is drawn where alternating grey shales and limestones predominate over the massive Manitoulin dolomitic limestone. The upper limit of the formation is sharp and well defined wherever it can be seen. At Stoney Creek (13), Hamilton (16), and Clappison Corners (21) the overlying formation is the Grimsby sandstone; at Limehouse (37) the Cabot Head (including Grimsby and Thorold (?) equivalents) is found in contact with the Reynales; at Nottawasaga River (65), Hornings Mills (71), and Owen Sound (105) it is overlain by the Fossil Hill and finally, on Bruce Peninsula and Manitoulin Island the contact is with the Dyer Bay dolomite.

The total thickness of the Cabot Head formation varies due, as previously outlined, to differences in the placing of the upper contact (*see* Figure 2). The shale unit underlying the Grimsby formation is 50 feet thick at Stoney Creek and 34 feet thick at Hamilton, whereas the Cabot Head that includes Grimsby and Thorold (?) equivalents is over 48 feet thick at Credit Forks (59), 70 feet at Cataract (61), 52 feet at Nottawasaga River, the upper 13 feet including the Grimsby and Thorold (?) equivalents, about 100 feet (?) west of Meaford (77), approximately 120 feet at Owen Sound, about 130 feet at Jackson Cove (190), and 30 to 50 feet on Manitoulin Island.

Fauna (*see* Table V). The fauna of the Cabot Head grey shales is very similar to that of the underlying Manitoulin dolomite. Fossils are concentrated either in calcareous pockets in the shales or in the calcareous hard bands. The bryozoan *Helopora fragilis* is very abundant in both the shales and hard bands with a pronounced west and northwest orientation of specimens prevailing in many beds. The faunal assemblage closely resembles the southern Power Glen fauna and, as in that formation, no faunal zones can be recognized.

Origin. Grabau (1913) attributed the Manitoulin and Cabot Head formations to a wearing down of Appalachian sedimentary rocks following the Taconic orogeny. An increase in the quantity of detrital sediments washed into the sea in post-Manitoulin time brought about the change from the carbonate facies of the Manitoulin to the shale of the Cabot Head. These shales suggest a predominantly shallow, muddy, marine environment subjected to rapid changes in sedimentation.

GRIMSBY FORMATION

Niagara Falls; Sections 1, 2, 4, 9-11, 13, 15, 16, 21; Facies Sections 37, 46, 59, 62, 65, 71 (*see* Figure 1).

Definition and Distribution. The term Grimsby was proposed by Williams (1914, p. 184) for those red shales and sandstones lying between the Cabot Head shale below and the Thorold sandstone above. The 12 feet of mottled red and green sandstone overlain by 6 feet of grey shale exposed in the gorge of Fortymile Creek at Grimsby was designated the type section (Williams, 1919, p. 39). Red shales that underlie the sandstone at this locality were assigned to the Cabot Head by Williams. Caley (1940) followed Williams, believing that the true Grimsby was dominantly a sandstone and sandy shale facies with no lime, and as the underlying red shales were dominantly argillaceous with varying amounts of lime, they were regarded as Cabot Head. Furthermore, Johnson (1934 MS.)

and Caley both found the Cabot Head index fossil *Helopora fragilis* in these red shales. During the recent study similar red shales were found to underlie all exposures of the red sandstone, and it was finally concluded that, as the red shales and sandstones represented a local lithologic entity, the name Grimsby should be expanded to include all red beds (Bolton, 1953, p. 6). As such it is recognizable as a distinct unit in the Niagara escarpment as far north as Clappison road-cut (21), beyond which, as previously noted, equivalent red beds are included in the Cabot Head formation. Thus representatives of the Grimsby apparently underlie most of southwestern Ontario. Red shales and sandstones occur at equivalent stratigraphic horizons as part of a red bed sequence east of Niagara Falls. Gillette (1940) and Fisher (1954), however, applied the name Grimsby to the entire Lower Silurian sequence of red shales and sandstones underlying the Clinton in New York State. These red beds pass laterally into the complete Cataract group, Whirlpool-Power Glen-Grimsby sequence of the Niagara area, so that the writer would prefer to retain the term Grimsby for those beds forming a lithologic unit above the Power Glen or Cabot Head shale and below the Thorold sandstone (Liberty and Bolton, 1956).

Lithology. The lithology of the Grimsby in the Niagara Peninsula is essentially the same wherever it is exposed. Red shales, with varying amounts of interbedded red sandstone, constitute the basal half of the Grimsby from Niagara Falls to Fruitland (11), and massive, green- and yellow-mottled, crossbedded, fine-grained, red sandstone with thin lenses and inclusions of arenaceous red shale characterizes the remainder. Narrow intraformational conglomerate bands, consisting of tiny, subrounded to rounded red shale pellets, are present in both the shale and sandstone beds although they are far more abundant in the latter. The thickness of the lower red shales increases between Fruitland and Clappison Corners with thinner red sandstone bands lithologically similar to the sandstone units to the south present near the top of the Grimsby sections at Stoney Creek (13), Albion Falls (15), and Hamilton (16), until the formation is composed entirely of interbedded red shale and sandstone. The sandstones are composed of very fine-grained, subrounded to rounded, well-sorted, equidimensional, irregularly oriented, clear quartz grains, together with a small suite of heavy minerals composed of interstitial albite, chlorite, rounded and prismatic zircon, magnetite, and leucoxene in variable amounts. Nearly every quartz grain is thinly coated with hematite and is, on the average, smaller than those of the Whirlpool sandstone, a circumstance observed also in the Power Glen sandstones. In the Grimsby equivalents to the north of Clappison Corners red shales still dominate, but massive, red, fine-grained, arenaceous limestone to calcareous sandstone characterizes the upper beds. As in the southern exposures, red shale pellets are abundant both in the shale and sandstone.

Contacts and Thickness. The lower and upper contacts of the red Grimsby are distinct, as they are drawn on the basis of colour change. Westward, the formation gradually thins from 45 feet at Niagara Falls to 29 feet at Hamilton, and 12 feet at Clappison Corners. To the north of Clappison Corners complete exposures of Grimsby equivalents are rare. It is only 5 feet thick at Limehouse (37) and 4 feet on the Nottawasaga River (65), although there is a suggestion of thickening in the Owen Sound-Bruce Peninsula sections of earlier workers, as well as in drill records. A thin, hard, red bed occurs in the Owen Sound section some 85 to 90 feet above the base of the Manitoulin dolomite which may be correlated with the Grimsby facies.

Fauna (*see* Table VI). The faunal content of the Grimsby strata is sparse throughout most of the Niagara Peninsula. At DeCew Falls the lower Grimsby fauna is similar to that of the underlying Power Glen (*see* Table III). With the exception of the basal 5 inches, the fossils are sparingly developed throughout the lower shales and sandstones, with Brachiopoda and Pelecypoda dominating the assemblages. *Arthrophycus alleghaniensis* and the brackish-water brachiopod *Lingula clintoni* are the only forms recorded from the upper massive, green- to yellow-mottled, red sandstone. Fragments of this brachiopod are associated with red shale pellets and flecks, strongly suggesting transportation before burial. Thus the sparseness of fauna in the Grimsby sandstone probably is due in part to an unfavourable environment, and in part to removal of many fossils by wave and current action. Fossils are more abundant in the lower red shales at Albion Falls (15) with Pelecypoda and Brachiopoda again the dominant forms. The greatest number and variety of Pelecypoda, however, occur in the Hamilton section. Species of the Bryozoa *Phaenopora*, first recorded in the Albion Falls section, and *Helopora fragilis* are particularly abundant in the red beds at Clappison Corners, Limehouse, Nottawasaga River, and Hornings Mills.

Origin. Grabau (1913) believed that the source of the Queenston-Medina sediments was either the Tuscarora-Juniata red beds or the grey Bald Eagle conglomerates of the Appalachian region, both of which were exposed through uplift during the Taconic orogeny. The coarser and highly oxidized material derived from these highlands was deposited throughout Lower Silurian Alexandrian time along the oscillating strand lines of a shallow sea. These eastern red beds were essentially semi-continental beach deposits that were laid down while the marine Whirlpool-Manitoulin-Cabot Head (Power Glen) strata were forming in the Niagara area (Gillette, 1940). Grimsby sediments overlie the marine beds in the Niagara section due to the change from a marine environment by regression in late Alexandrian time. The Grimsby sandstone at DeCew Falls represents a western extension of the 'Medina' sedimentation. Introduction and domination of these coarser red clastics above the Power Glen-Cabot Head grey shales definitely reflects relatively major changes in elevation of the sea and land. Size analyses of representative Grimsby material collected between Niagara River and Clappison Corners by Pelletier (1953 MS.) strongly indicated a deltaic environment for the Grimsby formation, the source region lying southeast of the Niagara area. In his study, however, strata were combined which are here (*see* Appendix A) referred separately to the Grimsby and Thorold formations (Pelletier *in* Armstrong, 1953). Williams (1919) and Caley (1940) both regarded the Grimsby sandstone as the in-shore facies of the northern marine Cabot Head shales. The present study not only confirms this relationship, but also suggests that the Grimsby type of sedimentation was not confined to the Niagara Peninsula. Conditions responsible for these red sediments gradually extended during the late Lower Silurian over most of southwestern Ontario. Presence of marine fossils indicates that marine conditions prevailed despite the deposition of these red clastics in some areas. This westward migration and deposition of Grimsby red beds complete the Cataract in Ontario.

CORRELATION OF THE CATARACT GROUP

The Cataract fauna of the Ontario-Michigan basin is distinct. Most of the fossils, with the exception of long-ranging species, were apparently confined to this area, and, as a result, the relationship of these Lower Silurian rocks with those of other areas is difficult to determine. Previous correlations have been based on the Dyer Bay-Wingfield faunas, but these are here considered part of the Clinton group and their correlation is described in a later section.

Despite the foregoing, the fauna and stratigraphic position of the Cataract definitely establishes its equivalence with the 'Medina' strata of central New York. A close relationship is also recognized with the Edgewood-Brassfield faunas of Illinois and Missouri as outlined by Savage (1917), with *Lyellia thebesensis*, *Plectatrypa marginalis*, *Platystrophia daytonensis*, *Rhynchonella* ? *janea*, *Rhynchotreta lepida*, *Bucania* cf. *exigua*, and *Holopea minuta* common to both faunas.

As the facies and faunal assemblages outlined above for the Great Lakes Region are entirely different from those of the Silurian of Anticosti Island, comparison is difficult but not impossible. Many forms are present in, though not restricted to, the upper Becscie-lower Gun River strata that are also found in the Cataract. *Coelospira planoconvexa* and *Paleofavosites asper* in particular are common to both the Cataract and Becscie.

No hiatus was observed within the Interlake group of Manitoba and consequently those rocks were considered by Baillie (1951) to represent continuous deposition from early Alexandrian to Niagaran time. The Stonewall formation, as defined by Baillie, occupies a stratigraphic position similar to that of the Cataract in relation to the overlying *Virgiana* beds, and the two sequences therefore may be equivalent, although the faunal assemblages of each show no striking relationship. Rather, the Stonewall fauna, with its mixture of Ordovician and Silurian forms, appears more closely related to the transitional Ellis Bay formation of Anticosti Island, and thus may be a transition zone between known Ordovician and known Silurian strata. Stearn (1953, 1956) definitely assigns this formation to the Upper Ordovician and notes the complete absence of any Lower Silurian strata in southern Manitoba.

Clinton Group

Clinton strata of New York and Ontario have been studied in considerable detail since the time they were first described by Vanuxem in 1842 and Hall in 1843. The group is composed of a great variety of sedimentary rocks that change rapidly both lithologically and faunally, and numerous interpretations have been offered as a result of this complexity. A complete review of the problem is presented in Gillette's "Geology of the Clyde and Sodus Bay Quadrangles, New York" (1940, pp. 30-35).

A summarization of the various classifications proposed for the Clinton strata is given in Table II.

The term Clinton is generally applied to the highly fossiliferous strata present above the 'Medina' and below the Lockport in western and central New York State, but the exact limits of this group have been the source of great controversy. Many workers hold that the Thorold sandstone should be placed in the Lower Silurian Cataract group. Recently Gillette (1940, 1947) and Fisher (1953, 1954) have placed the lower boundary of the Clinton group on faunal evidence at the base of the Thorold in western New York and below the Oneida conglomerate in central New York, although Fisher still regards the Thorold of Ontario as slightly older (Fisher, 1954, pp. 1982 and 1993).

Over the years the upper limit of the Clinton has been drawn at the base of the Irondequoit, at the base of the Rochester, and at the top of the Rochester. Gillette (1947) held the last-mentioned opinion, including within the group the Rochester shale of western New York and its equivalent, the Herkimer sandstone, of eastern New York. A closer relationship appeared to him to exist between the Rochester and underlying Irondequoit than between the Rochester and overlying Lockport. The marked lateral and vertical variations of the Rochester were consistent with the variable Clinton rather than with the more stable marine Lockport.

On the basis of lithology the Clinton strata in New York State may be divided into at least sixteen formations, several of which are stratigraphically equivalent. Palæontologically, the strata may be further subdivided into five ostracod zones as follows:

Upper Clinton	..	*Paraechmina spinosa* zone *Mastigobolbina typus* zone
Middle Clinton	..	*Mastigobolbina lata* zone
Lower Clinton	..	*Zygobolba decora* zone *Zygobolba excavata* zone

Equivalents of only five of the sixteen New York Clinton formations extend into Ontario with outcrops of these formations confined mainly to the Niagara Peninsula district, although in subsurface they underlie much of southwestern Ontario. Representative Lower Clinton strata are the Thorold, Neahga, and Reynales formations. The Upper clinton consists of the Irondequoit, Rochester, and DeCew formations. The present investigation affords further evidence that (1) the Thorold sandstone, Neahga shale, Reynales limestone comprise one unit of the Clinton, (2) a disconformity exists at the top of the Reynales, (3) the Irondequoit and Rochester are closely related, and (4) the Irondequoit limestone, Rochester shale, DeCew dolomite constitute another unit of the Clinton, a major break in sedimentation occurring at the top of the DeCew. In this report, therefore, the classification adhered to is principally that which has been advocated by Gillette (1947) for the New York sediments, except for the inclusion of the DeCew dolomite as the upper unit (Bolton, 1953). This assignment of the DeCew to the Clinton is based upon its lithological similarity to the uppermost Rochester and the presence of a conglomerate zone at the base of the overlying Gasport dolomite in the DeCew Falls-Niagara Falls sections. The DeCew dolomite has in the past been regarded as a basal phase of the Lockport.

THOROLD FORMATION

Niagara Falls; Sections 1, 2, 4, 7, 9-11, 13-16, 21; Facies Sections 37, 46, 65, 71 (*see* Figure 1).

Definition and Distribution. The term 'Thorold quartzite' was applied by Grabau (1913) to strata separating the Grimsby sandstone from the overlying Reynales dolomite at Thorold, Ont. As the lower contact was marked by little more than a lithologic change, Williams (1919) and Caley (1940) assigned the Thorold to the Lower Silurian Medina and regarded both the Thorold and Grimsby as facies of the Cabot Head shales. Several workers, however, have questioned this grouping with the Medina. Ulrich and Bassler (1923), Nowlan (1935 MS.), and Gillette (1940, 1947) concluded that a major break in sedimentation occurred between the Grimsby and Thorold, and that the latter represented initial deposits of the transgressing Clinton sea. As the underlying Cataract sequence of Whirlpool sandstone, Power Glen shales, Grimsby red shales, Grimsby red sandstones, as previously postulated, represents a complete sedimentation cycle from transgression to regression, the Thorold in Ontario is defined as the primary sediments of the Clinton sea (Bolton and Liberty, 1955). It may be traced in Ontario along the Niagara escarpment from Niagara River to Clappison Corners and in subsurface throughout much of southwestern Ontario, but, as it is difficult to distinguish in well cuttings from this region, the sandstone is generally grouped in the 'Clinton'. East of Niagara River Gillette (1947) traced the sandstone some 125 miles, beyond which point it is replaced by the Oneida conglomerate.

Lithology. The lithology of the Thorold formation is comparatively uniform throughout most of its extent. A gradual increase in grain size and argillaceous content eastward from Niagara River is recorded by Gillette. In the Niagara Falls drill-cores (*see* Appendix B) the Thorold is a massive, white to light grey, fine-grained, dense compact quartzose sandstone exhibiting crossbedding on a small scale only. Thin green to grey shale and siltstone partings or pellets are scattered throughout the sandstone, whereas large and small red and green shale pellets were noted only at the base. Petrographic studies have been made of the Thorold by Alling (1936), Holstein (1936 MS.), and Sanford (1939). Alling showed the Thorold to consist of 70 per cent quartz, 6 per cent feldspar, and 20 per cent argillaceous material. In drill-core samples from the Niagara Falls Hydro project the sandstone is composed essentially of clear to dusty, subangular to rounded quartz grains cemented by secondary silica and minor amounts of calcite. Accessory minerals include calcite grains, biotite, chlorite, apatite, zircon, magnetite, leucoxene, pyrite, hematite, microcline, plagioclase (albite-oligoclase), and collophane (?). Sanford's insoluble residue studies indicated a calcareous content of approximately 1 per cent. Holstein showed that the mineral content of the two outstanding sandstones, namely the Whirlpool and Thorold, is similar, and that on the average the grain size is approximately equal. The upper sandstone, however, may be distinguished by the absence of the Whirlpool index mineral collophane and by the presence of coloured zircons. In outcrop, the Thorold is essentially the same from the Niagara gorge to Stoney Creek (12). A thin grey shale band separates the Thorold sandstone at DeCew Falls into two massive units. Zircon and leucoxene are the dominant accessory minerals in these sandstones, although phosphatic pellets are particularly abundant in the upper few inches of the formation. There is only a minor increase in the shale content between DeCew Falls and Stoney Creek, but from the latter locality north, grey and green shales are more abundant.

Contacts and Thickness. The contact of the Thorold with the underlying Grimsby is reasonably sharp, and is marked mainly by a colour change rather than any definite lithological variation. Thin bands of red argillaceous sandstone at the base of the formation represent partly reworked Grimsby strata. It is overlain abruptly by the Neahga shale or Reynales dolomite.

The thickness of the Thorold varies from 4·6 feet to 9·7 feet, averaging 8 feet, along the Niagara gorge section, and is 9 feet thick at DeCew Falls, 11 feet at Grimsby, 6 feet at Stoney Creek, 13 feet at Hamilton, and 13·5 feet at Clappison Corners (*see* Appendix A).

Fauna. The massive sandstone units of the Thorold are relatively unfossiliferous, except for the rare occurrence of *Arthrophycus alleghaniensis*. A few specimens of *Lingula clintoni*, fragmentary in nature when associated with calcareous shale pellets, are preserved in the lower grey shale units at Hamilton and Clappison Corners road-cut. A distinctive Pelecypoda fauna, associated with the bryozoan *Helopora fragilis*, is present in the Thorold (?) shale equivalent (uppermost Cabot Head) at Limehouse (37) and Nottawasaga River (65).

Origin. The Thorold throughout its areal extent represents the initial deposits of the Lower Clinton sea. In some parts of the area the basal beds were derived through reworking and redeposition of the underlying Grimsby sandstone. The fine-grained texture of the sandstone and shale suggests that these sediments were deposited far from any land mass or source of coarse clastics. Sandstone material was mainly confined to the Niagara Peninsula whereas finer clastic muds were distributed over the remainder of Ontario.

NEAHGA FORMATION

Niagara Falls; Sections 1, 2, 4, 7 (*see* Figure 1).

Definition and Distribution. The name Neahga, incorrectly spelled Neagha by Cumings, 1939 and Bolton, 1953, was proposed by Sanford (1933) for those shales overlying the Thorold and underlying the Reynales in the Niagara gorge that were formerly correlated by Chadwick (1918) and Williams (1919) with the Furnaceville shale of eastern New York. Sanford felt that the Neahga and Maplewood shales probably corresponded in age, although no positive correlation was possible either on palæontological or stratigraphic grounds. They apparently were deposited in separate basins or under different environments. Shales similar to the original Neahga can be traced stratigraphically from Niagara Falls to west of DeCew Falls.

Lithology. At Niagara Falls, the Neahga consists of blackish grey to green, platy shale with minor grey limestone. Tiny shale pebbles or lenticular shale fragments, cemented by pyrite or sand, are present in the calcareous, basal 0·3 foot in some sections. A ½-inch-thick basal conglomerate of thin, flat, dark grey, sandy pebbles was noted in D.D. core E-32. Greenish grey to dark grey, fissile shale occupies a similar stratigraphic position at DeCew Falls, and similar shales, possibly the equivalent of this formation, underlie the Reynales dolomite at Rockway (2), Ball's Falls (4), and Grimsby Beach (7). Its recognition as far north as Clappison Corners (Armstrong, 1953) is considered doubtful by the author.

Contacts and Thickness. Both the lower and upper boundaries of this formation are well defined. In the Niagara Falls region the lower contact undulates slightly, short tongues of argillaceous limestone extending downwards into the Thorold. In other localities a thin transition zone of calcareous sandstone was noted in the upper 0·3 foot of the Thorold. The formation is 5 to 6 feet thick in the Niagara gorge, decreasing westward to 15 inches at DeCew Falls, to 6 inches at Rockway, and to 3½ inches at Grimsby Beach.

Fauna. The Neahga shales are relatively unfossiliferous, the few fossils that do occur being poorly preserved. Gillette (1947) and Sanford (1935) record *Coelospira hemispherica* ?, *C. plicatula*, *Zygobolba excavata*, and *Z. curta* from the Niagara gorge exposures of this formation; Fisher (1953) added *Coelospira uniplicata*, *C. planoconvexa* and several other Brachiopoda and Pelecypoda as well as a unique brown algal microflora (1953a).

Origin. Two other irregular shale units, similar lithologically and faunally to the Neahga, occur at several localities east and south of Niagara Falls. Sanford (1935) suggested that the Neahga and closely related Maplewood shales were deposited in bays that formed as the Lower Clinton sea shallowed and consequently exposed the newly deposited Thorold sandstones to erosion. The remarkably uniform thickness of the Thorold throughout western New York State would seem to preclude this theory. Gillette (1947) concluded that the Neahga-Maplewood represented quiet areas into which currents and waves swept the light clay particles during the last stages of Thorold deposition. Thus the necessity for a complete withdrawal of the sea and for subaerial erosion was eliminated. Fisher (1953, p. 30) interpreted the green shales as a lithofacies deposited below wave base transgressing progressively younger time lines eastward with the Neahga slightly older than the eastern Maplewood. Following the deposition of these thin representatives of the initial transgression of the Lower Clinton sea, subsidence continued and relatively clear marine waters spread over most of western New York and the Niagara Peninsula, depositing the Reynales limestone and its northern equivalents.

REYNALES FORMATION

Niagara Falls; Sections 1, 2, 4, 7, 9-16, 18, 20, 21, 24, 25, 31, 33, 34, 37, 46 (*see* Figure 1).

Definition and Distribution. The term Reynales was introduced by Chadwick (1918) for the lower limestone series exposed at Lockport and Rochester, N.Y. that was formerly considered as equivalent to the more easterly located Wolcott limestone. Similar limestones or dolomites can be traced from Wolcott, N.Y., west to Hamilton, and north to Georgetown (46) and, in subsurface, extend at least as far west as Windsor.

Lithology. Lithologically the Reynales is a relatively homogeneous unit. It is a massive, thick- to thin-bedded, light grey, buff-weathered, dense dolomitic limestone to dolomite with grey shale partings present throughout the formation. The shale content increases from Grimsby north and the dolomite becomes more argillaceous. Thin sandy partings were noted at DeCew Falls. At most localities the basal 1 foot to 2 feet of the formation is a crystalline, fossiliferous limestone carrying pyrite and phosphatic nodules. The lower 4 inches at DeCew Falls is characterized by abundant glauconite (?) blebs and greenish grey shale inclusions, embedded in a dense to semi-crystalline, light grey limestone. A similar horizon, 1 foot thick, is present at Rockway (2) and Grimsby Beach (7) and a 3-inch transition zone of grey, dense, sandy limestone, overlain by 22 inches of grey, pyritic, coarse limestone, forms the base of the formation near Fruitland (11).

Contacts and Thickness. In the Niagara Falls-DeCew Falls-Grimsby Beach region the Reynales formation is conformably underlain by the Neahga shale, and north of Grimsby by either the Thorold sandstone or Cabot Head shale. The undulating surface of the upper contact is equally well defined. In the Niagara Peninsula the formation is overlain disconformably by the Irondequoit limestone. At DeCew Falls a 6-inch irregular sandstone band is regarded as the upper limit of the Reynales. Immediately above this band is a 12-inch bed of sandy, buff limestone, followed by lenses of porous limonite, above which typical pinkish grey crystalline Irondequoit limestone first appears. These beds may represent a closing phase of the Reynales or, as here advanced, the initial sediments of the Irondequoit, formed in part of material derived from the eroded upper surface of the Reynales. This disconformity between the Reynales and Irondequoit may be traced with certainty as far as Clappison Corners (21). Farther north, however, the overlying Irondequoit cannot be differentiated from the Gasport (Lockport), due to the absence of the intervening Rochester shales. As a result, the Reynales may be overlain disconformably by the southern equivalent of the Amabel formation between Clappison Corners and Georgetown.

The thickness of the Reynales is remarkably uniform despite evidence of erosion. An average of 12 feet prevails from Wolcott, N.Y. east to Fruitland (11) with a maximum thickness of 14·5 feet at DeCew Falls. The dolomite varies in thickness in the Hamilton region from 8·5 feet (13) to 10 feet (15), and decreases to 8 feet at Limehouse (37). As the thickness remains relatively constant it would seem that, following the withdrawal of the Clinton sea, erosion must have affected the entire area uniformly.

Fauna. The Reynales is sparsely fossiliferous. *Pentamerus oblongus* is abundant in the basal 2 feet of coarsely crystalline limestone in Ontario, but is absent in those sections that lack the crystalline limestone. One higher *Pentamerus* zone is present at Albion Falls (15), but again the brachiopod is associated with a limestone resembling the basal unit. *Pentameroides subrectus* has been described from the Stoney Creek section. *Stricklandia canadensis* is found at various levels in most exposures of the dolomite. *Coelospira hemispherica, Atrypa reticularis, Eospirifer niagarensis, Plectodonta transversalis,* and *Rhipidomella hybrida* are sparingly represented particularly in the Niagara gorge, and *Hyattidina congesta* characterizes the formation from Niagara Falls eastward, reaching its maximum development in the Reynales basin (Gillette, 1947, p. 50).

Origin. The variation in fauna mentioned above is best explained by differences in ecological conditions rather than by a change in age of the enclosing strata, a belief held by Sanford (1935) and Fisher (1953). Sanford concluded, from the regional distribution of the Reynales, that it was a complex formational unit transgressing time and space. Its lithology, fauna, and age varied from place to place, suggesting a shoreline migrating from west to east with clastic sediments supplied from the east and north during this migration. Fisher (1953, pp. 27, 32) subscribed to this view that the Reynales of the Niagara gorge (Lower Reynales) was older and, on the basis of phosphate zones, considered this unit and the Maplewood to be contemporaneous. Moreover, a progressively younger fauna appeared as the formation was traced from west to east with *Hyattidina congesta* of the lower Reynales being replaced by *Pentamerus oblongus* in the eastern upper Reynales strata. This theory, as well as the effect of ecology upon the Reynales fauna, is amply reviewed by Gillette (1940, pp. 51-53; 1947, pp. 51-53) to which the reader is referred.

In summary, the Reynales was deposited in the Lower Clinton seas as that body attained its maximum expansion. Variation in ecological conditions, as shown by the variety of sediments in central New York State, apparently controlled the development of the various faunal assemblages. Only the hardier forms were able to exist in the Ontario part of the sea. The close of the Reynales was marked by a withdrawal of the Lower Clinton sea from Ontario and western New York, followed by a period of erosion during which time Middle Clinton sediments (Sauquoit shales) were deposited in west-central New York.

IRONDEQUOIT FORMATION

Niagara Falls; Sections 1, 2, 4, 7-16, 18, 20, 21, 24 (*see* Figure 1).

Definition and Distribution. This limestone formation overlying the Reynales was named by Hartnagel (1907) for the town of Irondequoit, N.Y. It extends along the face of the Niagara escarpment from Niagara Falls to north of Waterdown (24) at which locality it is either missing or represented by the basal dolomite of the Amabel formation. Similar limestone is recognized as far east as Martville, N.Y., at which location it is replaced by the upper portion of the Willowvale shale. Its westward extension as determined from well records, is essentially similar to the older Reynales dolomite, forming the upper unit of the combined 'Clinton limestones'.

Lithology. In west-central New York, where it is underlain by the Williamson shale, the Irondequoit has been subdivided by Gillette (1947) into an upper limestone unit and a lower dark grey calcareous shale unit. Throughout western New York and Ontario the Irondequoit is lithologically uniform being typically a massive, white to light grey, crystalline, porous, crinoidal limestone, containing pyrite, gypsum, and stylolites. Tiny pebbles of Reynales dolomite embedded in a dense grey limestone were observed immediately above the Reynales-Irondequoit disconformity in the Highway 20 (14), Hamilton (16), and Clappison Corners (21) road-cuts. Similar pebbles were recorded by Sanford (1935) from various localities in New York State. Thick, lenticular reef-like bodies are present in the upper part of the formation at Niagara Falls and Rochester. At DeCew Falls greenish grey shale inclusions are abundant in the uppermost 3-inch-thick bed of buff, sandy limestone, and in other localities the upper few inches are argillaceous.

Contacts and Thickness. The disconformity between the Reynales and Irondequoit, as postulated by Sanford and Gillette, has been outlined in the previous discussion of the Reynales. Absence of Middle Clinton strata in the Niagara Peninsula, the undulating, irregular surface between the two formations, and the thin zone of Reynales pebbles immediately above this sharp break confirm the presence of this hiatus in this part of southern Ontario. Equally distinct is the upper contact with the Rochester shales, though there is no apparent disconformity associated with the abrupt change in lithology.

There is considerable variation in the thickness of this formation as represented in New York State. Differences of up to 15 feet have been noted between outcrops only a few miles apart, which are attributed by Gillette (1947) to the filling in of irregularities in the eroded Reynales surface. The thickness in Ontario, in contrast, appears to be reasonably constant. In the Niagara Falls area (*see* Appendix B) differences of 3 feet can be attributed to the presence of reef-like masses similar to those exposed along the gorge proper. The formation ranges in thickness from an average of 10 feet at Niagara to 8 feet at DeCew Falls, 6 feet at Grimsby east (8), 4 feet between Grimsby (9) and Ancaster (18), 5 feet at Dundas (20), 6·8 feet at Clappison road-cut (21), and 4 feet north of Waterdown (24). The formation thins regularly westward in the subsurface, this east to west thinning being consistent with the increased distance from the source area.

Fauna (*see* Table VII). The microfauna of the Irondequoit in New York State includes many forms diagnostic of the *Mastigobolbina typus* ostracod zone, thus assigning an Upper Clinton age to this formation (*see* p. 22). Gillette (1947) has outlined three distinct faunas in the Irondequoit formation of New York, one fauna characteristic of the lower shale part of central New York, a second found in the thin shale bands separating the crystalline limestone layers, and the third developed in the crystalline limestones. It is the latter faunal assemblage that is present in the Irondequoit limestone of Ontario. Although fossils are scattered throughout most of the formation, the upper foot of limestone is generally the most fossiliferous. Brachiopoda dominate the assemblages, with *Atrypa reticularis* and *Whitfieldella intermedia* numerically the most abundant fossils. Other common species of brachiopods include *Fardenia subplana*, *Strophonella striata*, *Leptaena rhomboidalis*, and *Parmorthis elegantula*. The cup coral *Enterolasma caliculum* and encrusting Bryozoa are associated with these Brachiopoda. None of the shells show evidence of transportation. The faunal assemblage recognized in the upper Irondequoit closely resembles the overlying younger Rochester assemblage, with most of the predominating megafauna of the Rochester commencing in the upper Irondequoit.

Origin. The Irondequoit limestone was deposited, after the deposition of the initial Upper Clinton Williamson sediments in west-central New York, in those regions of western New York and southern Ontario where argillaceous material was less prevalent. Deposition of clastic material continued in the east (Willowvale shales) with, however, the gradual shifting eastward of the limestone facies during the later stages of the Irondequoit phase.

ROCHESTER FORMATION

Niagara Falls; Sections 1-3, 9-16, 18, 20, 21, 24 (*see* Figure 1).

Definition and Distribution. The Rochester shale directly overlies the Irondequoit limestone and underlies the DeCew dolomite. This name was introduced by Hall in 1839, for the typical exposures of these shales near Rochester, N.Y., although in later years it was for a while supplanted by the term Niagara shales, and united with the overlying Niagara limestone (Lockport) in the Niagara group. The term Rochester was revived in 1899 by Clarke and Schuchert and has been the accepted name since that date. There has, however, been little agreement regarding the relationship of these shales to the Clinton and Lockport groups (*see* Table II). No worker has recognized a disconformity between the Irondequoit and Rochester. Williams (1919) believed a transition zone existed between the two units, but nevertheless he combined the Rochester with the Lockport in the Niagara group and left the Irondequoit as the upper member of the Clinton. The Rochester was included in the Clinton by Ulrich (1911) and Ulrich and Bassler (1923), partly on the basis of Ostracoda, and this assignment was later followed by Nowlan (1935 MS.) and Cumings (1939). Sanford (1936) recognized an hiatus between the Reynales and Irondequoit, and consequently assigned both the Irondequoit and Rochester to the Niagara group, thus removing them both from the Clinton, a somewhat similar combination to that proposed previously by Schuchert (1910). Caley (1940) concluded that the Rochester shales in Ontario rested directly on the Irondequoit with a sharp, even contact and raised the Rochester to a formation, thus placing it on equal footing with the Clinton and Lockport. Gillette (1940, 1947) however, reassigned the Rochester to the Clinton group, and this last classification is accepted by the writer for the reasons outlined in the introductory discussion of the Clinton group.

Shales of the Rochester formation are exposed at various places along the escarpment from Lakeport, N.Y., west to Hamilton, and north to Waterdown, at which locality the shales may grade into a limestone-dolomite facies. In subsurface the Rochester underlies most of the southern part of southwestern Ontario.

Lithology. The Rochester is essentially a black to grey, calcareous shale to siltstone, with numerous thin, undulating, grey, fossiliferous limestone layers or lenses. The upper 10 to 20 feet is more massive dolomitic or calcareous shale. Light grey, argillaceous, pyritic limestone, replete with crinoid columns and Bryozoa, is characteristic of the basal 1-foot of the formation. From Grimsby (9) west the grey, relatively barren shale is more compact and at Clappison road-cut (21) and north of Waterdown (24) the formation is reduced to a dark grey argillaceous limestone with grey shale partings.

Contacts and Thickness. The lower contact with the Irondequoit is sharp with a thin transition zone of interbedded argillaceous limestone and shale present in every section directly above this well defined lithological break. The upper contact is not as clearly defined on lithological grounds as the lower owing to the presence of compact dolomitic shales directly beneath the DeCew dolomite. This sequence is particularly well shown in exposures east of Grimsby where the argillaceous content of the DeCew is high and the upper beds of the Rochester are more calcareous. In these sections the upper dolomitic part appears transitional between the calcareous shales of the upper Rochester and the overlying DeCew dolomite. At Niagara and DeCew Falls the upper surface of the Rochester is wavy and ripple-marked, the contact at DeCew Falls being further emphasized by a 4- to 8-inch zone of porous, coarsely crystalline limestone containing numerous fossil fragments. Gillette (1947) reports an 18-inch transition zone of interbedded dolomite and shale at Lockport, N.Y., and other sections of the Rochester in New York show slight undulations at the contact with the DeCew. None was, however, interpreted as an unconformity by that author. The existence of an unconformity between the Rochester and DeCew was, however, claimed by Ulrich (1911), Schuchert (1914), and Chadwick (1918), and the westward thinning of the Rochester and its eventual disappearance north of Hamilton served to strengthen this hypothesis. It is here advocated that the apparent pinching out marks the northern limit of this clastic facies rather than a loss by erosion. The transitional nature of the upper contact of the Rochester and presence of a distinct hiatus at the top of the DeCew indicate that the major break in sedimentation that separated the Clinton from the Lockport occurred at the top of the DeCew and not at the close of the Rochester.

A maximum thickness of 150 feet is reported east of Wolcott, N.Y. with the Rochester thinning eastward and westward from this centre. To the east the shales grade into a thinner section of the Herkimer sandstone. To the west they thin to an average of 58 feet at Niagara Falls, 56 feet at DeCew, 35 feet at Grimsby (9), 14 feet at Hamilton (16), 5 feet at Dundas, and 2·4 feet in its most northern exposure at Clappison road-cut (21). A local thickening to 24 feet appears between Stoney Creek (14) and Albion Falls (15). A continued thinning to the west in subsurface is evident from well data.

Fauna (*see* Table VIII). The Rochester represented an environment suitable to an immense variety of invertebrate life and as a result it is extremely rich in fossils, yielding a far greater number of specimens and species than any other Silurian unit. The fossils are mostly concentrated in calcareous or sandy pockets, and, for that reason, the pure calcareous or dolomitic shales of the Hamilton region contain few fossil remains. A complete list of the fossils collected from each locality in Ontario is given in Table VIII, species identified by previous workers from the same localities being also included. The largest and most diversified fauna was collected from the section at DeCew Falls. At this, and all other localities, Brachiopoda are the most prolific group of organisms with *Atrypa reticularis* numerically the most abundant, and *Rhipidomella hybrida* and *Parmorthis elegantula* have the most persistent vertical range. Shells of these latter two brachiopods are cemented together in a 3-inch calcareous band at DeCew Falls. Other characteristic forms include *Fardenia subplana*, *Leptaena rhomboidalis*, *Plectatrypa nodostriata*, *Eospirifer niagarensis*, *Howellella crispa*, *Whitfieldella intermedia*, *W. nitida*, *Stegerhynchus neglectum*, and *Strophonella striata*. Bryozoa, next in abundance, abound in the rocks of this formation as far west as Grimsby. Bassler (1906) described eighty-four species from the Rochester of New York State alone. Over thirty species of Bryozoa were identified from thin biostromes in the Rochester shales at DeCew Falls. The most typical forms in these biostromes are *Hallopora elegantula* and *Chilotrypa ostiolata*. *Eridotrypa similis*, *Leioclema asperum*, *Hennigopora florida*, *Trematopora tuberculosa*, *Subretepora asperatostriata*, *Fenestrellina elegans*, *Ptiloporella nervata*, and *Semicoscinium tenuiceps* also are abundant but mainly confined to particular beds. *Rhopalonaria attenuata* occurs principally on the shells of *W. intermedia*, *F. subplana*, and *P. elegantula*. *Fistulopora laminata* is the most frequent encrusting bryozoan, and several of the Bryozoa are themselves encrusted by other Bryozoa, i.e. *E. similis* in one specimen is completely encrusted by *Leioclema multiporum* which is in turn partly encrusted by *Ceramoporella* cf. *orbiculata*. Echinodermata are present mainly as broken fragments of plates and stems. The cystid *Caryocrinites ornatus* ranges throughout the shales, whereas the crinoids show some zonation with *Stephanocrinus angulatus* confined to the lower 10 feet of the Rochester in Ontario, and apparently in New York. It ranges to 10 feet above the lower contact at Niagara Falls, 9·3 feet at DeCew Falls, 8·3 feet at Rockway (2), 7·7 feet at Stoney Creek and Highway 20, and 4 feet at Hamilton. Several crinoid species have been collected by Mr. M. J. Kopf of Buffalo from a 2-foot thick limestone layer 29 feet above the base of the Rochester at DeCew Falls. The characteristic Trilobita genera *Bumastus*, *Calymene*, *Dalmanites*, and *Trimerus* are found mainly in the calcareous shales. With the exception of *Calymene*, these genera are typically large forms. However, the Trilobita of the Rochester at DeCew Falls in particular are normally small, except for the occasional large pygidium or thorax of *Trimerus* found in the upper dolomitic shales. Pelecypoda, Gastropoda, and Conulariida are present throughout though never in large numbers. Ostracoda are well represented in the Rochester of New York State, but only a few are found in Ontario in the limestone layers with *Paraechmina spinosa* the only form of value for correlation (*see* p. 22). The entire assemblage typifies a benthonic marine environment.

Origin. A gradual westward shift of the argillaceous Rochester type of deposition marks the close of the clastic-free Irondequoit sedimentation in New York and Ontario. This change apparently was the result of uplift in a source region which, as evident in a coarsening eastward and thinning westward of these strata, lay to the east. The present distribution of fossils results from the varying conditions and environments which existed within the Rochester sea.

DeCEW FORMATION

Niagara Falls; Sections 1-3, 5, 6, 9-15, 16 (?), 18 (*see* Figure 1).

Definition and Distribution. The term DeCew was proposed by Williams (1914) for the 8·5 feet of dolomitic limestone overlying the Rochester at DeCew Falls. These beds were assigned to the basal Lockport by that author (1919), despite the lithological and faunal similarity of the DeCew and Rochester, on the concept that an unevenly eroded upper surface marked the top of the underlying Rochester, and the claim by Chadwick (1918) that an angular unconformity existed between the Rochester shale and DeCew dolomite. No time break was postulated, only changing conditions of sedimentation. Gillette (1947), in contrast, noted that in many New York localities an almost perfect gradation or transitional zone existed between the calcareous shales of the upper Rochester and the argillaceous dolomites of the DeCew. A similar relationship holds between the DeCew and the upper limy beds of the Rochester in Ontario. There the upper surface of the Rochester undulates, but in most cases a transition zone rather than a sharp break separates the two units and the major break in sedimentation occurs instead at the close of the DeCew. This close relationship led Cumings (1939) to include the DeCew as the uppermost member of the Rochester formation. Typical DeCew dolomite may be traced from Lockport, N.Y., west to Ancaster. At Hamilton and north of Ancaster its equivalent is the transition zone between the calcareous upper part of the Rochester and the Gasport limestone. Williams (1919) assigned the 6·5 feet of thin-bedded, argillaceous, dolomitic limestone underlying 'Lockport' limestone at Limehouse (37) to this formation, but the writer regards these beds as Reynales equivalent.

Lithology. The DeCew consists of buff weathered, argillaceous to arenaceous, fine-grained to dense, dark grey dolomitic limestone to dolomite. It appears almost as a single bed at its type locality, the characteristic conchoidal fracture or enterolithic structure obscuring the faint bedding planes. Differential weathering commonly leaves elliptical core-like structures of dense, dark grey dolomitic limestone, and vugs are numerous. From Stoney Creek (13) west, shale partings increase and the dolomite, accordingly, becomes thinner bedded. At Hamilton (16) the basal 3 feet of grey, granular dolomitic limestone assigned to the Gasport may represent the DeCew in this region; at Ancaster (18) 10 inches of grey shale separates the DeCew from the Gasport.

Contacts and Thickness. As noted in the preceding discussion of the Rochester shales, no conclusive evidence was discovered to prove the presence of a disconformity between the Rochester and DeCew formations, indeed the evidence suggests merely a change in conditions of sedimentation with a short period of shallow water environment. The upper contact of the DeCew represents a definite horizon with ripple-marks present in several localities. Thin greenish grey clay bands separate the DeCew from the overlying Gasport in the Highway 20 road-cut (14), Stoney Creek, Albion Falls (15), and Ancaster, which may be due in part to seepage along this pronounced surface.

In the various exposures along the Niagara escarpment the following thicknesses have been measured: 7·4 to 12·5 feet along the Niagara gorge, 8 feet at DeCew Falls, 5 feet on Sixteenmile Creek (3), 3 feet in the Beamsville area (6), 7 feet at Grimsby (9), 8 feet at Stoney Creek, 3·3 feet in the Highway 20 road-cut, 5·5 feet at Albion Falls, and 6 feet at Ancaster. This considerable variation in thickness could be in part the result of erosion at the close of the Clinton.

Fauna. The strata lying between the Rochester and Gasport are relatively unfossiliferous. Williams (1919, p. 59) records *Caryocrinites ornatus* in the type section and *Strophonella patenta*, *Fardenia subplana*, and *Stegerhynchus neglectum* at Thorold. Many of the graptolites described by Bassler (1909) and Ruedemann (1947) were collected from argillaceous dolomites or dolomitic shales located some 6 feet below the chert beds of the Lockport formation in the Jolly-cut section at Hamilton; i.e. *Dictyonema granti*, *D. ramosum*, *D. subretiforme*, *Callograptus ? multicaulis*, *C. ? niagarensis*, *C. strictus*, *Dendrograptus ? dawsoni*, *Thallograptus cervicornis*, *Diplospirograptus dubius*, and *Calyptograptus cyathiformis*. As these beds are considered representative of the DeCew dolomite, it follows that the graptolites are Clinton in age, and not Lockport as formerly proposed.

Origin. There was a pronounced westward migration of the Upper Clinton strand lines following deposition of the Rochester shales. This is substantiated by the development of the Herkimer sandstone at the top of the Rochester in central New York. The presence of an unconformity at the top of the Herkimer and beneath the Lockport east of Clinton, N.Y., indicates that the sea must have withdrawn from this region (Gillette, 1947, p. 113). In western New York and Ontario this withdrawal was accompanied by a reworking of the dolomitic Rochester shales and the subsequent deposition of the DeCew argillaceous dolomite. Presumably, the Upper Clinton sea was not forced entirely from this area, but at least locally the DeCew was subjected to erosion.

The northern sequence, consisting in ascending order of the Dyer Bay, Wingfield, St. Edmund, and Fossil Hill formations, will appear at first to be unrelated to the strata in the southern sequence described on the preceding pages, both in lithology and fauna. There is a complete development of this northern phase only on Manitoulin Island. Southward, the

Dyer Bay can be traced to the Owen Sound area, the Wingfield to the Wiarton area, and the St. Edmund to the northern tip of Bruce Peninsula with a possible extension to east of Wiarton. The confinement of these strata to the northern basin has been explained by the presence of a platform extending from Owen Sound to Hamilton (*see* pp. 4-7). Fossil Hill strata, in contrast, can be identified as far south as the Orangeville region and in these strata lies the key to the whole problem of correlation. The differences in lithology and faunal content and the misidentification of the few key sections outcropping in the Orangeville-Georgetown area (Cataract Axis of Cumings, 1939) through the assignment of the strata to the younger Lockport has heretofore rendered correlation uncertain. Through the recognition of the various detailed stratigraphic units outlined in the present report, it has been shown that the Fossil Hill formation grades southward into the Lower Clinton Reynales formation in this key area (*see* sections 37, 46, and 62, Appendix A). Furthermore, as the Dyer Bay and Wingfield are excluded from the underlying Cataract group on the belief that the Cataract sedimentation cycle of transgression and regression was completed with the deposition of red beds at the top of the Cabot Head shales and the presence of a Clinton fauna, the entire Dyer Bay-Fossil Hill sequence is believed early Niagaran in age and principally Lower Clinton on the mainland.

DYER BAY FORMATION

Sections 78, 114, 119, 127, 129, 135, 140, 160, 187, 219, 227-229 (*see* Figure 1).

Definition and Distribution. The name Dyer Bay was applied by Williams (1919) to an impure dolomite 'lentille' located in the upper half of the Cabot Head shales at Dyer Bay, which he considered to be the northern representative of more southern shaly Cataract deposits as "the Cataract age of the Dyer Bay beds is indicated by Bassler's determination of the ostracoda and by the identification of Alexandrian fossils in the beds on Fitzwilliam Island" (Williams, 1919, p. 36). Ulrich and Bassler (1923), however, opposed this reference of the Dyer Bay to an Alexandrian or Lower Silurian age, as the ostracod fauna contained therein corresponded in age "to the latter part of the Lower Clinton or the early part of the Middle Clinton, with the former interpretation the more likely of the two" (Ulrich and Bassler, 1923, pp. 335-336). This Clinton age for the Dyer Bay dolomite was accepted by Nowlan (1935 MS.) and Way (1936 MS.) in their studies of the Silurian on Bruce Peninsula and Manitoulin Island as they traced the Dyer Bay dolomite from its type locality on Dyer Bay across Manitoulin Island into northern Michigan, where, at its western extremity, it was replaced by the Mayville dolomite. Accordingly, the Dyer Bay was redefined as the lower member of the Mayville formation. A similar relationship has been advanced by Cumings (1939) and Swartz, *et al.* (1942), but both the Dyer Bay and Mayville are referred to the Cataract group. During the present field work an examination of the Dyer Bay dolomite was made both on Bruce Peninsula and Manitoulin Island. The Dyer Bay does extend as an important formation from north of Owen Sound on the Bruce Peninsula across Manitoulin Island into Michigan. The contained faunas tend to confirm the ideas advanced by Nowlan and Way. The belief that Cataract sedimentation closed with deposition of the Grimsby red beds or their equivalent in the Cabot Head excludes the Dyer Bay from the Lower Silurian, and the hypothesis that the late Lower Clinton Reynales grades laterally into the Fossil Hill further limits this formation. It is here considered to be the northern facies of the early Lower Clinton strata of New York and southern Ontario.

Exposures of Dyer Bay were discovered at several localities between Cabot Head and Owen Sound. At Owen Sound (Inglis Falls road-cut, section 105) the Fossil Hill rests directly upon the Cabot Head shales. A thin outcrop of Dyer Bay, however, was located 7 miles north of Inglis Falls, west of Balmy Beach (114), and a second was discovered east of this locality, northeast of Woodford (78). The southern limit of deposition of this formation, therefore, can be drawn immediately north of Owen Sound. Incomplete sections were examined east of Claverling (119), north of Kemble (127 and 129), at Oxenden (140), Colpoy Village (160), Hope Bay (187), and Dyer Bay (227-229). A complete section of Dyer Bay has been reported by Williams (1919) and Nowlan (1935 MS.) from Cabot Head. Other sections were examined on Manitoulin Island west of West Bay Village, west of Ice Lake, and south of Gore Bay (Bolton, 1954).

Lithology. The formation is everywhere a thin-bedded, brownish grey to blue-grey, finely crystalline dolomite, with numerous green to grey shale partings. Thin, coarsely crystalline dolomite lenses abound in some sections. At its base are 2 to 5 feet of thicker bedded, grey to brown, finely crystalline to dense dolomite, with thin intraformational conglomerate lenses present either within or directly above the dolomite. In general, a sharp break separates the upper and lower lithological units.

Contacts and Thickness. The lower contact is exposed in sections 140, 160, and 187 only, and at each locality there is a sharp lithological break between the dense Dyer Bay dolomite and Cabot Head shale. Exposures of the upper contact are more numerous. In sections 78, 114, 119, 127, 129, and 135 the contact between the Dyer Bay and overlying Fossil Hill is sharp and undulating with lenses of green shale separating the two formations at several localities. A 2-foot-thick bed of brown, dense dolomite directly underlying the Fossil Hill in section 127, and here included in the Dyer Bay, may be the most southern representative of the Wingfield or St. Edmund formation. From Oxenden north, however, the Dyer Bay is definitely separated from the Fossil Hill by the northward thickening Wingfield shale. The contact is distinct at Hope Bay, but some gradation is evident between the upper shaly beds of the Dyer Bay and the Wingfield shale proper, particularly on Manitoulin Island.

A thickness of from 15 to 20 feet, with the base not exposed, was measured in the type section along the shores of Dyer Bay. To the south it is 14 feet thick at Hope Bay, 13 feet at Colpoy Village, 12 feet at Oxenden, and at least 10 feet north of Kemble (127). It undoubtedly thins rapidly between this last locality and Owen Sound, but no complete section was found in this region to determine the rate of thinning. To the north, thicknesses of 12 to 25 feet have been measured on Manitoulin Island, indicating that the formation is fairly constant over most of its lateral extent.

Fauna. The fauna, locally abundant and concentrated mainly in the upper half, includes the following species:

Dyer Bay Fauna

ANTHOZOA

Aulopora sp.
Cup corals
Favosites cristatus Edwards and Haime
F. forbesi dyerensis n.var.
F. cf. *hisingeri* Edwards and Haime
F. obliquus Rominger
Halysites sp.
Syringopora retiformis Billings

ANNELIDA

Arabellites sp.
Lumbriconereites sp.
Oenonites sp.
Spirorbis sp.
Cornulites sp.

BRYOZOA

Helopora fragilis Hall
Hallopora magnopora (Foerste)
Pachydictya crassa Hall
Phaenopora ensiformis Hall
Ptilodictya cf. *expansa emarcescens* Foerste

BRACHIOPODA

Dolerorthis cf. *flabellites* (Foerste)
Platystrophia sp.
Virgiana cf. *mayvillensis* Savage
Rhynchonella ? *janea* Billings
Rhynchotreta cabotensis Williams
R. lepida Savage
Stegerhynchus neglectum (Hall)
Atrypa cf. *parksi* Williams
Coelospira planoconvexa (Hall)
Whitfieldella sp.

PELECYPODA

Pterinea undata (Hall)

GASTROPODA

Hormotoma subulata (Conrad)
Naticonema sp.
"*Pleurotomaria*" *litorea* Hall

TRILOBITA

Calymene clintoni (Vanuxem)

OSTRACODA

Chilobolbina punctata Ulrich and Bassler
Leperditia cabotensis Ulrich and Bassler
Zygobolba williamsi Ulrich and Bassler

Two faunal zones can be differentiated in this formation; a lower *Virgiana mayvillensis* zone and an upper coral zone characterized by several species of *Favosites*. The ostracod *Zygobolba williamsi* is found principally in the thin-bedded, argillaceous dolomites at the top of the formation, although it has been found at least 6 feet below the top, as well as associated with *V. mayvillensis*.

Origin. The Dyer Bay represents a northern dolomite facies which, together with the overlying Wingfield, is believed to be equivalent to the more clastic Lower Clinton formations of the New York State-Niagara Peninsula area.

WINGFIELD FORMATION

Sections 127, 140, 160 (?), 161, 187, 220 (*see* Figure 1).

Definition and Distribution. The shales and dolomites that overlie the Dyer Bay at Cabot Head were included originally by Williams (1919) in the Cabot Head shales. With the recognition of the Dyer Bay as a distinct unit, and the restriction of the term Cabot Head to those shales underlying the Dyer Bay, a special designation was required for these upper shales and Nowlan (1935 MS.) proposed for them the name Wingfield with the sequence exposed at Clay Cliffs at the northeast end of Bruce Peninsula as the type section. The St. Edmund dolomite 'lentille' directly underlying the Fossil Hill at this locality was included by Nowlan in the Wingfield. This nomenclature was accepted by Way (1936 MS.), Shaw (1937), Williams (1937), Cumings (1939), Swartz, *et al.* (1942), and Caley (1947) although the St. Edmund dolomite was separated as a distinct member comparable with the upper member of the Burnt Bluff of northern Michigan by some of these authors. In the present report the name Wingfield is applied to the shales and dolomites that overlie the Dyer Bay dolomites, and underlie the Fossil Hill or St. Edmund dolomites on Bruce Peninsula and Manitoulin Island.

This formation is a completely northern facies and although exposures are limited to a few localities it can be traced from Kemble on the Bruce Peninsula north and west onto Manitoulin Island. On the mainland it represents the thin, eastern, clastic equivalent of the thick dolomite formations that were deposited westward on Manitoulin Island and the northern peninsula of Michigan.

Lithology. Green to greenish grey shales and interbedded green to brown, dense, argillaceous dolomites characterize this formation (*see* Plate II A). A bed of massive, buff-weathering, dense dolomite present near the top of the Wingfield at Cabot Head has been called the St. Edmund by Williams (1919). Brown, white weathering, dense, hard dolomite exposed directly below the Fossil Hill in sections 127 and 140 may be the southern representative of this bed. Partial sections of Wingfield blue-green, calcareous shales at the base overlain by grey, dense argillaceous dolomites were examined on Manitoulin Island west of West Bay village and south of Gore Bay (Bolton, 1954).

Contacts and Thickness. Both the lower and upper limits of the Wingfield formation are marked by distinct lithological breaks. The lower contact of the Wingfield with the Dyer Bay dolomite is exposed at Hope Bay (section 187) and at this locality the line of demarcation is distinct. On Manitoulin Island the contact is gradational with the argillaceous Dyer Bay dolomite passing upward into green shales. The formation is overlain by either the St. Edmund or Fossil Hill dolomites, and although this contact is nowhere exposed, it is believed to be conformable from drill-core data.

The Wingfield varies in thickness as will be seen by the following: 7·5 feet at section 127, 14 feet at sections 140 and 160, 15 feet at section 187, 44 to 48 feet at Cabot Head (upper 12 feet includes 8 feet of St. Edmund dolomite overlain by 4 feet of green shales), and 20 to 37 feet on Manitoulin Island.

Fauna. A well developed Ostracoda fauna, including *Leperditia cabotensis, Chilobolbina punctata,* and *Zygobolba williamsi,* is diagnostic of the lower argillaceous dolomites and green shales. Other species identified from the Wingfield include *Pterinea undata, Lingula* sp., and Bryozoa sp. indet.

ST. EDMUND FORMATION

Definition and Distribution. The term St. Edmund was introduced by Williams (1919) for an 8-foot thick dolomite 'lentille' at the top of the Cabot Head shales as then defined, with the type section along the shore 3 miles west of Cabot Head, St. Edmund township, Bruce Peninsula. Way (1936 MS.) and Cumings (1930, 1939) report the Brachiopoda *Stegerhynchus ? winiskensis* and *Homoeospira lowi* from this unit. On Manitoulin Island the Wingfield and Fossil Hill formations are separated by up to 80 to 90 feet of dense dolomite, formerly regarded as basal Lockport (Williams, 1919, 1937), containing a similar brachiopod fauna, and the writer extended the name St. Edmund to include these dolomites. Farther west in northern Michigan (*see* Swartz, *et al.*, 1942), dolomites underlying the Manistique formation are assigned to the Burnt Bluff formation and divided into the Byron and Hendricks members by Ehlers (1921, 1930, 1948). Previous workers have traced the Burnt Bluff eastward into the St. Edmund dolomites on Manitoulin Island and divided them into two members (*see* Way, 1936 MS.) representing both the Byron and Hendricks beds. As the underlying Wingfield shales and dolomites in Ontario are also regarded as a correlative of the Burnt Bluff, the name St. Edmund is here retained for the eastern equivalent, in part, of the upper member of the Burnt Bluff formation.

Lithology. Thin-bedded, brown, fine-grained to dense dolomites that weather white typify this formation. Sublithographic, conchoidal fracturing dolomite interbedded with thin interbeds of crystalline brown dolomite characterize the upper strata, but this brown dolomite also occurs irregularly throughout the entire sequence.

Contacts and Thickness. Although no exposures of the lower contact were seen, the upper contact with the Fossil Hill was observed at several localities. It is probably the best contact available for structural studies in the entire Silurian sequence of Manitoulin Island. In every section the contact was gradational. Way (1936 MS.) drew the upper limit of his Burnt Bluff formation at the first appearance of the brachiopod *Pentamerus oblongus*. As this form was not always present in the basal Fossil Hill, the upper contact of the St. Edmund was arbitrarily drawn at the lowest development of typical brown, finely to coarsely crystalline Fossil Hill dolomite. By this definition most of Way's upper member (Assiginack) of the Burnt Bluff (Shaw, 1937, p. 320) is included in the Fossil Hill.

In the maximum thickness of 157 feet assigned by Way to the Burnt Bluff formation on Manitoulin Island at least part of the lower 130-foot thick member is equivalent to the St. Edmund as defined. During the 1953 field work the greatest thickness measured for the St. Edmund formation was 90 feet and in most localities the interval between the Dyer Bay and Fossil Hill formations, the lower 20 to 30 feet of which would represent the Wingfield formation, was considerably less than 80 feet. On the Bruce Peninsula a thickness of 8 feet is assigned to the St. Edmund at the type locality and 7½ feet farther south at Dyer Bay (Williams, 1919; Cumings, 1939).

Fauna. The dense dolomites of the St. Edmund formation are relatively barren. *Clathrodictyon ostiolatum*, cup corals, *Favosites* sp., *Homoeospira lowi*, and *Stegerhynchus* ? *winiskensis* have been identified from crystalline lenses both high and low in the sequence, and a few indeterminable Stromatoporoidea have been collected from beds just below the St. Edmund-Fossil Hill contact.

FOSSIL HILL FORMATION

Sections 46 ?, 62, 63, 65, 71, 77-81, 83-86, 105-107, 114, 115, 119, 126, 127, 129, 135, 140, 142, 150, 158-161, 168, 169, 171, 187, 190, 197, 219, 220, 222, 226 (*see* Figure 1).

Definition and Distribution. The Fossil Hill formation (Bolton, 1953, p. 12) was proposed for the thin and unevenly bedded, crystalline, fossiliferous dolomites that directly overlie the St. Edmund formation in the numerous exposures around Fossil Hill, west of Manitowaning, Manitoulin Island. It is in turn overlain by the Amabel formation. Although biostromes of the brachiopod *Pentamerus oblongus* are present in the basal part of these dolomites at several localities and coral biostromes characterize the upper beds, features which assist in distinguishing this formation from the rest of the Silurian strata, the sequence constitutes a recognizable and mappable lithological unit.

To the west in northern Michigan, lithologically and faunally similar dolomites, assigned to the Manistique formation, separate the Burnt Bluff and Engadine formations (*see* Table II). In its type section immediately south of Cordell Station the formation is divisible into two members, a lower Schoolcraft member containing two *Pentamerus* biostromes and an upper Cordell member containing numerous silicified corals (Ehlers, 1948). Extension of the term Manistique eastward from Michigan into Ontario has been advocated by Foerste (1924), Ehlers (1930), Nowlan (1935 MS.), Way (1936 MS.), and Cumings (1930, 1939). However, because (1) the limits of the Manistique appear to be drawn more on a biostratigraphic basis, (2) the formation has not yet been fully described, (3) the writer believes that in Ontario the St. Edmund and Fossil Hill formations are products of continuous deposition and as a result the limits of the two formations may be at variance with the limits of the Michigan Burnt Bluff and Manistique formations, and (4) the crystalline dolomites as so defined on Manitoulin Island form a distinct lithological unit throughout the Ontario part of the Niagara escarpment, the name Fossil Hill was proposed and is here retained. Undoubtedly the lower *Pentamerus* beds of the Fossil Hill formation are in part equivalent to the more westerly occurring Schoolcraft and the upper coral beds to the Cordell, but the exact limits of each member cannot be accurately determined on the Ontario mainland.

On the Ontario mainland, from north to south, the St. Edmund, Wingfield, Dyer Bay, and Cabot Head formations are each in turn overlain by dark brown, crystalline dolomites, reduced in thickness but lithologically similar to the type Fossil Hill. The presence of a similar fauna further confirms this relationship. The most southern outcrop that can be assigned to this formation lies southeast of Caledon (62), presumably on the Cataract axis or barrier (*see* p. 6). In this particular section, 7 feet of brown, crystalline dolomite, rich in corals, overlies the Cabot Head shale and is overlain in turn by the Lions Head and Colpoy Bay members of the Amabel formation. Approximately 10 miles southwest the Cabot Head and Amabel formations are separated by 7·7 feet of dolomite, lithologically similar to the more southern outcropping Reynales formation but containing typical Fossil Hill corals. These dolomites represent horizontally transitional strata between the Reynales and Fossil Hill.

The exact relationship of the dolomites that comprise the Fossil Hill formation with the strata of the western New York-Niagara Peninsula area has never been fully determined. Williams (1919) originally included the Fossil Hill dolomites in the Lockport. Swartz, *et al.* (1942), following Cumings and Ehlers, placed the Manistique and its Ontario equivalents between the Rochester and Lockport formations and, therefore, considered it to be Upper Clinton in age. The relationship outlined above of the most southern Fossil Hill and the most northern Reynales outcrops is reliable evidence that the southern *Pentamerus*-bearing Reynales dolomite and the northern *Pentamerus*-coral-rich Fossil Hill dolomite are traceable one into the other. Accordingly, in the Georgetown-Owen Sound area the Fossil Hill is apparently a northern facies of the Reynales, and hence Lower Clinton in age, but the possibility must be considered that the thicker

Fossil Hill sections of the northern area may be a product of continual deposition; thus they may include equivalents to the Middle and Upper Clinton strata of New York and southern Ontario.

Lithology. The Fossil Hill is a uniform, thin and unevenly bedded, brown, fine-grained to crystalline dolomite, further distinguished by the abundance of *Pentamerus oblongus* and a great variety of corals (*see* Plate II A and B). Small chert lenses and nodules are confined, for the most part, to the upper 2 feet of dense dolomite (sections 83, 126, 142, 150, 161) and the argillaceous content is high in the basal 1-foot of sections 105 and 114. As previously outlined, the section north of Georgetown (46) exposes thin-bedded, grey to buff weathered, dense, argillaceous dolomites similar to the Reynales, but with a fossil content suggesting Fossil Hill. Massive, thin-bedded, grey, finely crystalline, fossiliferous dolomites southeast of Caledon (62) are definitely related to the Fossil Hill and typical Fossil Hill dolomite prevails from section 77 north.

Contacts and Thickness. Both the lower and upper contacts are sharp and well defined. There is an abrupt change in the lithology wherever the Fossil Hill is underlain by the Cabot Head (sections 46, 62, 65, 71, 105—*see* Plate II B), Dyer Bay (sections 78, 114, 119, 127, 129, 135), or Wingfield (sections 140, 161, 187, 220). The gradational nature of the St. Edmund-Fossil Hill contact on Manitoulin Island has been discussed (p. 39) and there the lower boundary of the Fossil Hill is not readily determined. An horizon that remains relatively constant across the island was chosen to mark the contact. There is no difficulty in establishing the upper limit of the Fossil Hill in outcrops, for on the Ontario mainland it is sharply overlain by the Lions Head dolomite member of the Amabel formation. Even in those sections where the Lions Head cannot be recognized with certainty, the lithology of the overlying Colpoy Bay dolomite is sufficiently distinct to allow the position of the top of the Fossil Hill to be placed with reasonable accuracy.

The presence of dense, relatively barren dolomite beds at the top of the Fossil Hill formation in some localities could be interpreted as a transition zone between the highly organic Fossil Hill condition and that of typical Lions Head. An even closer relationship could be postulated from the sequence exposed along the shore north of Lions Head village (220) for in this section the Fossil Hill is divided into an upper and lower unit by 6 feet of thin-bedded, brown, white weathering, dense dolomite lithologically similar to the Lions Head member. It is probable that this band represents an interbed rather than transitional conditions as the Fossil Hill sequence is uninterrupted nearer the village. If the Fossil Hill is correctly correlated with the Reynales, the upper contact of the formation could represent, at least in the platform region, a disconformity of some magnitude. This disconformity would be at least equal to that postulated between the Reynales and the Irondequoit in the Niagara Peninsula-New York sections.

On Manitoulin Island the Fossil Hill is overlain by Amabel dolomites but the contact is difficult to determine because of the association of bioherms containing Fossil Hill faunas and non-fossiliferous dolomites which, on a lithological basis, could be assigned to the Amabel. This condition suggests that the contact is transitional and that either Middle and Upper Clinton sediments are also represented in the Fossil Hill formation on Manitoulin Island or the formation is younger in the northern basin than on the mainland. Investigation of the Fossil Hill fauna by the writer and detailed mapping, now underway, of the Manitoulin Island strata by B. A. Liberty may present some solution to this problem.

A gradual thickening from south to north is evident, an average thickness of 8 feet prevailing between Georgetown and Owen Sound, 12 to 16 feet in the Wiarton area, and 22 feet in the Hope Bay region. Nowlan (1935 MS.) assigned 30 feet of dolomite, composed of two biostromes, to the Manistique (essentially the same strata as the writer includes in the Fossil Hill of this region) at Lions Head and 60 feet at Dyer Bay. The Manistique formation on Manitoulin Island was reported by Way (1936 MS.) to be 42 feet thick, and by Cumings (1939) to be 55 feet thick. The detailed study of sections and barometric surveys during the 1951 and 1953 field seasons indicated that in the eastern half of the island northeast of The Slash the Fossil Hill formation was over 78 feet thick and east of Tehkummah 90 feet. At least four bioherms were noted in the latter section (Bolton, 1954).

Fauna (*see* Table IX). The Fossil Hill is the second most fossiliferous formation of the Silurian in Ontario. Banks of the brachiopod *Pentamerus oblongus* are common on the Bruce Peninsula and the base of the formation is generally rich in these Brachiopoda, but, as in the Reynales, they are not necessarily common to all sections. Corals are present in this basal zone, though few in number. A more prolific coral fauna is present in the overlying beds which, on the mainland at least, is divisible into two zones. The lower zone, with its maximum development on Manitoulin Island in the famous Fossil Hill coral beds (Williams, 1919; Bolton, 1954), consists of several species of *Favosites* (*F. favosus*, *F. hispidus*, *F. hisingeri*), *Halysites catenularia*, *Catenipora microporus*, *Arachnophyllum pentagonum*, *A. striatus*, and *Syringopora retiformis*. *Pentamerus oblongus*, *Pentameroides subrectus*, and other brachiopods are also present in this zone in certain sections. This fauna is equally well developed in the Cordell member at its type locality in northern Michigan (Ehlers, 1948). In the upper zone species of *Lyellia* and *Heliolites* occur with various representatives of the lower zone. Stromatoporoid bioherms, though present in this zone, form important zones higher in the thick Fossil Hill sequence of Manitoulin Island. A thin cephalopod concentration was found at the top of the Fossil Hill section at Cannings Falls (65), and indeed the Cephalopoda of Manitoulin Island (*Huronia*, *Stokesoceras*) have been used by Foerste (1924, 1930) to correlate the beds there with the Clinton of New York State (*see* further Cephalopoda discussion, p. 62).

CORRELATION OF THE CLINTON GROUP

The rich fossil content of the Clinton permits the recognition of several faunal zones with Ostracoda, in particular, useful for both local and regional correlation. In the Silurian rocks of Pennsylvania, Maryland, and other states of the Appalachian Valley region the following Ostracoda zones have been defined by Ulrich and Bassler (1923):

Upper Clinton
9. *Drepanellina clarki* zone
8. *Mastigobolbina typus* zone
7. *Bonnemaia rudis* zone

Middle Clinton
6. *Zygosella postica* zone
5. *Mastigobolbina lata* zone
4. *Zygobolbina emaciata* zone

Lower Clinton
3. *Zygobolba decora* zone
2. *Zygobolba anticostiensis* zone
1. *Zygobolba erecta* zone

Corresponding zones have been established in the Silurian strata of New York (*see* p. 22) and Anticosti Island.

All the Clinton formations differentiated in the Niagara Peninsula are close correlatives of equivalent formations in New York. They represent both Lower and Upper Clinton age, separated by an hiatus of considerable magnitude. Only the upper *Paraechmina spinosa* zone (Upper Clinton by Gillette, 1947), however, is present in the Rochester strata in Ontario. By means of the contained macro-fauna the group may be correlated with the Gun River and Jupiter formations of Anticosti Island. A Lower Clinton age for the Gun River is suggested by the forms *Coelospira hemispherica*, *Hyattidina congesta*, and *Pentamerus oblongus*. *Monograptus clintonensis*, *Zygobolba decora*, and *Z. anticostiensis* further determine the Lower Clinton age of the Jupiter formation. The Upper Clinton Rochester formation is further correlated, chiefly on the basis of their bryozoan fauna, with the Osgood and lower Mississinewa formations of Indiana.

The *Virgiana* fauna of the northern Dyer Bay facies is widespread in North America. It is considered equivalent to the *V. mayvillensis* zone in the upper part of the Mayville formation of Wisconsin, the *V. decussata* zones in the Port Nelson formation of the Hudson Bay region and Unit B or Fisher Branch formation (Stearn, 1956) in the Interlake group of southern Manitoba, and the *V. anticostiensis* zone in the Becscie-lower Gun River formations of Anticosti.

The *Zygobolba williamsi* fauna in the upper Dyer Bay-Wingfield strata is believed to be equivalent to the *Leperditia hisingeri-L. fabulina-Z. williamsi* zones in the Wabi formation of Lake Timiskaming, Severn River-Ekwan River (?) formations of the Hudson Bay region, and Unit C or Inwood and Moose Lake formations in the Interlake group of southern Manitoba.

The St. Edmund *Stegerhynchus* ? *winiskensis-Homoeospira lowi* fauna may be correlated with similar zones in the Hendricks dolomite of northern Michigan, and the upper part of the Wabi, Severn River and *L. hisingeri* (Units C-D or Atikameg formation) zone.

The Fossil Hill *Pentamerus oblongus* and coral zones are direct correlatives of the Schoolcraft and Cordell dolomites of northern Michigan which were considered Upper Clinton in age by Ehlers (Swartz, *et al.*, 1942). This determination was based on the presence of typical Rochester forms *Fenestrellina elegans*, *Leioclema asperum*, and *Palaeocycles rotuloides* (*Porpites michiganensis*). As previously outlined, the stratigraphic evidence suggests that at least on the Ontario mainland the Fossil Hill is Lower Clinton in age, equivalent to the Reynales formation. Equivalency of the Fossil Hill coral horizon and the coral beds of the Lake Timiskaming area have been acknowledged by Hume (1925, p. 37) and so these Niagaran strata (Thornloe limestone of Flower, 1946) are principally Lower Clinton in age as suggested previously by Flower (p. 437), and not Lockport as formerly designated. Several specimens of the ostracod *Zygobolba* were found in recent collections from this region that, by their affinities to *Z. decora*, again suggest a Lower Clinton age for at least part of these Silurian strata. Assignment of these strata to a Lower Clinton age is further strengthened by the presence of the cephalopod *Discosorus*, in association with *Armenoceras*, *Huronia*, and *Stokesoceras*, in the Fossil Hill-Manistique of Ontario-Michigan, Thornloe of Lake Timiskaming, Jupiter formation of Anticosti Island, and the Reynales of New York. Other correlatives of the Fossil Hill are the Attawapiskat 'coral reef' formation of the Hudson Bay area, and Unit D or East Arm formation of the southern Manitoba Interlake group (Foerste, 1924; Baillie, 1951; Stearn, 1956).*

The close correspondence in the fauna of these strata leaves little doubt of their equivalence. Many of the formations in North America that have been correlated on the basis of their coral fauna with the Fossil Hill strata of Manitoulin Island should now be considered products of Clinton sedimentation. Strata of Clinton age, therefore, have far greater distribution than previously assumed. The separation of the Ontario and Lake Timiskaming basins of deposition may not have been as complete as postulated by Hume (1925) and Caley (1940). The maximum Silurian inundation, during which time the Appalachian and Arctic waters united, probably occurred in early Niagaran Clinton time and not late Niagaran Lockport-Guelph time as formerly assumed.

Albemarle Group

The lower Albemarle dolomites produce the upper cliffs of the Niagara escarpment and may be traced from central New York State across Ontario and Manitoulin Island into northern Michigan. All the Bruce Peninsula and a large part of Manitoulin-Cockburn-Drummond Islands are underlain by representatives of this group. Equivalents of these rocks have also been recognized in other parts of North America.

Those dolomites overlying the Rochester shales in New York were originally assigned to the Lockport by Hall (1839, 1843), but no upper limit was given to this formation in the type area. As proposed, it apparently included stratigraphic equivalents of the Ontario Guelph formation (Lower and Upper Shelby dolomites). Ulrich (1911), Goldring (1931), Sanford (1935), Gillette (1940), and Howell and Sanford (1947)

*NOTE: For further views on correlation of these strata the reader is referred to papers by Williams, M. Y., 1956, *Trans. Roy. Soc. Can.*, vol. 49, sec. iv, pp. 117-128; Ehlers, G. M. and Kesling, R. V., 1957, *Mich. Geol. Soc., Ann. Geol. Excursion*, pp. 25-30; and Flower, R. H. and Teichert, C., 1957, *Univ. Kansas Paleo. Contr., Mollusca*, Art. 6, pp. 34-35.

applied the term accordingly, including in the Lockport formation or group all the strata between the Rochester below and the Salina above. In contrast, Clarke and Schuchert (1899), Chadwick (1918), Williams (1919, 1937), Cumings (1939), Caley (1940), and Swartz, *et al.* (1942) separated the dolomites into two formations: the Lockport below and the Guelph above. It is now general practice to restrict the Lockport in Ontario to those dolomites overlying the Clinton and underlying the Guelph. The name Lockport has been applied both in the formational sense and as a time term with the result that the entire succession of dolomites directly overlying the Cataract in the Orangeville-Bruce Peninsula-Manitoulin Island-northern Michigan region (the St. Edmund-Fossil Hill-Amabel of this report) was assigned to this division by Williams (1919, 1937) and Caley (1945). Ehlers (1930) and Cumings (1930, 1939) were among the first to recognize that the lower part of this succession could not be equivalent to the Lockport, the former author separating the dolomites of northern Michigan into the Burnt Bluff, Manistique, and Engadine formations. In the 1942 Silurian correlation chart, the Burnt Bluff was referred by Ehlers and Cumings to the Clinton and the Manistique represented an hiatus between the Rochester and Engadine. The remainder of this sequence, the Engadine dolomite, was correlated with the Lockport of New York and Racine of Wisconsin. A somewhat similar relationship was suggested by Nowlan (1935 MS.) and Way (1936 MS.) for equivalent rocks in Ontario, though their results were never published in full (Shaw, 1937). The relationship of the Burnt Bluff-Wingfield and St. Edmund, and Manistique-Fossil Hill to the Clinton of New York has been dealt with in previous discussions of the Clinton.

The Engadine of Michigan as originally defined, included both Lockport and Guelph faunas. Apparently, the Lockport fauna was confined to the lower third of the formation, whereas the upper two-thirds contained the poorly preserved Guelph fauna. These dolomites can be traced from Michigan eastward to Manitoulin Island where the lithology is a combination of Michigan Engadine and Ontario late Niagaran. Farther south on the Bruce Peninsula, late Niagaran strata can be readily subdivided into a lower dolomite formation, containing a Lockport-Racine fauna, and an upper dolomite formation, containing a Guelph fauna. This twofold subdivision persists throughout most of Ontario, but it is only in the Niagara Peninsula that lithologic equivalents of the New York Lockport formation can be recognized below the Guelph. In this report, therefore, these late Niagaran dolomites are included in the Albemarle group and are divided into a lower formation, the Amabel, and an upper formation, the Guelph, the name Lockport being reserved for the dolomite strata immediately underlying the Guelph in the Niagara Peninsula and western New York that are the southeastern equivalent of the more widely developed Amabel formation. This classification adopted for the Albemarle rocks in Ontario is outlined in Table I.

LOCKPORT FORMATION

The term Lockport, as noted above, is applied to that sequence of dolomites underlying the Guelph and overlying the DeCew dolomite-Rochester shale in the Niagara Peninsula-western New York region.

Assignment of the DeCew dolomite, formerly the basal member of the Lockport, to the Upper Clinton has been dealt with under the previous discussions of the Clinton. The Lockport strata may be subdivided into the Gasport, Goat Island, and Eramosa members, but with the exception of the Eramosa, these members cannot be recognized with any certainty north of Hamilton.

Gasport Member

Niagara Falls; Sections 1-3, 5-7, 9-16, 18, 20, 21, 24 (*see* Figure 1).

Definition and Distribution. The name Gasport was proposed by Kindle (*in* Kindle and Taylor, 1913) for the coarse, semicrystalline, crinoidal limestone overlying the DeCew beds at Gasport and Lockport, N.Y. Limestone, lithologically and stratigraphically equivalent to the type Gasport, extends from Clinton, N.Y. to north of Waterdown, Ont. Farther north the term Gasport is not applicable as crinoid columns, in the south restricted to the Gasport, occur at different horizons throughout the dolomite strata. There is no justification, therefore, for extending this name throughout Ontario to include the Engadine and Wiarton as defined by Nowlan (*in* Shaw, 1937, p. 320) for this basal Lockport unit loses its distinctive qualities in the north and merges into other members of the Amabel formation. Nor is it possible to differentiate this member from the underlying, lithologically similar Irondequoit formation north of Waterdown where the intervening Rochester shales have pinched out. It is possible that thin equivalents of both the Irondequoit and Gasport limestones are represented in the basal part of the Amabel in the area north of this locality but neither has been recognized with certainty.

Lithology. At its type locality the Gasport member is a light grey to white, coarse, semicrystalline, crinoidal limestone. In Ontario, the Gasport is typically a massive, thick- to thin-bedded, blue-grey to grey to white, coarse- to fine-grained, semicrystalline, knobby weathering, crinoidal, dolomitic limestone. Thin grey arenaceous shale lenses are present at various horizons in the Niagara Falls, DeCew Falls (1), Hamilton (16), and Clappison Corners (21) exposures. A second facies assigned to the Gasport at 16 Mile Creek (3), Fruitland (11), east Stoney Creek (12), and Stoney Creek (13) is represented by a thin-bedded, buff-grey, dense to fine-grained dolomite, less crinoidal and sparingly fossiliferous. The upper 1-foot of the Gasport is a dark to light grey, sugary dolomite. This transition zone was also observed in the Niagara Falls drill-holes, at DeCew Falls, Grimsby Beach road (7), Highway 20 (14), Albion Falls (15), Hamilton, Sydenham Road (20), and Clappison Corners.

Contacts and Thickness. The sharp lower contact of the Gasport members represents a definite horizon with ripple-marks evident at several localities. Presence of a basal conglomerate in the Gasport sections at Niagara Falls, DeCew Falls, and west of Beamsville (6) suggests that at least locally a break in sedimentation occurred at the close of the underlying DeCew. This conglomerate is 1 foot thick at Niagara Falls, 9 inches at DeCew Falls, 4 inches at section 6, and 8 inches at Hamilton and it consists of elongated, subrounded to rounded, dark grey, dense, dolomitic limestone pebbles, lithologically similar to the DeCew dolomite, embedded in coarse, light grey, porous limestone containing fossil fragments. A similar unit, but consisting of shale pebbles, was found by Schuchert (1914) at Dundas where the Gasport rests on the Rochester shale.

The member is differentiated from the overlying rocks principally by its crinoidal and crystalline character. In places where it is overlain by the chert beds forming the base of the Goat Island member the upper limit of the Gasport is readily drawn. Despite this relatively sharp change, the transition zone at the top of the Gasport and the gradual increase upwards of chert in the basal Goat Island suggest that the two members are conformable. Where the chert beds are absent, the upper limit is more indefinite, as it passes gradationally upwards into higher Lockport or Amabel members.

Thicknesses assigned to the Gasport vary considerably, with a range of from 17 to 34 feet along the Niagara gorge section alone. Westward from Niagara River crinoidal beds of the Gasport vary from 21 to 3 feet thick. Thicknesses measured at the following places are: 21·5 feet at DeCew Falls, 15 feet at 15 Mile Creek (2), 17 feet at Beamsville (5), 3 feet at Fruitland, 7 feet at Stoney Creek and Albion Falls, 13 feet at Ancaster (18), 20 feet at Sydenham Road, and 10 feet at Clappison road-cut. The most northerly exposure of possible Gasport strata is in an abandoned quarry on lot 16, con. 1, N.D.S., Nelson tp. where 3½ feet of grey, crystalline, crinoidal, dolomitic limestone overlies Irondequoit-Rochester equivalents.

Fauna. In general, the Gasport is fossiliferous, though the fossils are of a more fragmentary nature and less varied than those of the underlying Rochester. Species that are present closely resemble those of the Rochester, and this feature led many workers to group the two units, as previously noted. Although fossils occur throughout the member, they appear to be concentrated in thin accumulations, particularly in the lower beds, in which practically all the invertebrate phyla are represented, Anthozoa and Brachiopoda being the most prolific. All the species collected from the Gasport during the recent survey are listed below.

Gasport Fauna

		Localities
ANTHOZOA		
Coenites sp. indet.	—	1
Enterolasma caliculum (Hall)	—	1, 14, 15, 16, 18, 21
Favosites forbesi (Edwards and Haime)	—	1
F. niagarensis (Hall)	—	1
F. pyriformis (Hall)	—	1
Favosites sp.	—	21
Heliolites elegans Hall	—	1
H. spiniporus Hall	—	1
CYSTOIDEA		
Caryocrinites ornatus Say	—	15
CRINOIDEA		
Dimerocrinites occidentale (Hall)	—	1
Eucalyptocrinites sp.	—	1

		Localities
BRACHIOPODA		
Rhynchotreta americana (Hall)	—	1, 16
Stegerhynchus acinus (Hall)	—	1
S. neglectum (Hall)	—	16
Uncinulus obtusiplicata (Hall)	—	1
Atrypa reticularis (Linnaeus)	—	1, 2, 14, 15, 16, 18
Eospirifer niagarensis (Hall)	—	1
Howellella crispa (Hisinger)	—	1, 16
Whitfieldella cylindrica (Hall)	—	1, 16
W. intermedia (Hall)	—	1, 18
W. nitida (Hall)	—	1
W. nitida oblata (Hall)	—	1, 21
Plectodonta transversalis (Wahlenberg)	—	1, 15, 16
Strophonella patenta (Hall)	—	1, 14, 16
Strophonella sp.	—	15, 16
Protomegastrophia cf. *profunda* (Hall)	—	1
Leptaena rhomboidalis (Wilckens)	—	1, 15, 16
Fardenia subplana (Hall)	—	1, 6, 14, 15, 16, 21
Parmorthis elegantula (Dalman)	—	1, 2, 6, 16, 21
Rhipidomella hybrida (Sowerby)	—	14
Trematospira camura Hall	—	1
PELECYPODA		
Amphicoelia leidyi Hall	—	16
GASTROPODA		
Naticonema niagarense (Hall)	—	1
Gastropoda indet.	—	16, 18
CEPHALOPODA		
Dawsonoceras sp.	—	16
TRILOBITA		
Bumastus ioxus (Hall)	—	16
Dalmanites limulurus (Green)	—	1, 14, 15, 16, 21
Trimerus delphinocephalus (Green)	—	1

Among the corals, *Enterolasma caliculum* predominates in all sections of the Gasport and is more abundant numerically than in the underlying Rochester. The small coral *Favosites forbesi*, so prolific in the Rochester, appears to be supplanted by the larger corals *F. niagarensis*, *F. pyriformis*, *Heliolites elegans*, and *H. spiniporus* at DeCew Falls. Other coral biostromes are reported by Williams (1919) from the Gasport at Thorold. Brachiopoda numerically dominate the above faunal assemblage, with *Atrypa reticularis*, *Parmorthis elegantula*, *Leptaena rhomboidalis*, and *Fardenia subplana* the most prolific species, each, as a rule, larger and more typically developed than the older, Rochester forms. All the Brachiopoda appear free of encrusting bryozoans. As previously noted, broken fragments of crinoid plates and stems are characteristic of this member. Poorly preserved specimens of the cystid *Caryocrinites ornatus* and the crinoids *Eucalyptocrinites* sp. and *Dimerocrinites occidentale* were the only complete representatives of Echinodermata recognized.

Goat Island Member

Sections 1, 7, 11-16, 18, 20, 21 (*see* Figure 1).

Definition and Distribution. In the past, the thick sequence of dolomites that complete the Lockport in Ontario has not been subdivided, except into such local facies as the 'chert beds' present at the base of the Goat Island or the 'Barton beds'. This latter division of Spencer and Grant included the argillaceous dolomites overlying the chert beds in the vicinity of Hamilton from which the upper thin-bedded, bituminous dolomites were later separated and assigned by Williams (1915, 1919) to his new Eramosa member. This unit, according to that author, formed a consistent member of the Lockport formation throughout Ontario. The dolomites lying between the Gasport and Eramosa were referred to the 'undivided' Lockport; this included the chert beds at the base. In a more complete classification Nowlan (1935 MS.) elevated Eramosa to the rank of a formation in his Lockport group, to include the entire sequence of rocks above the Gasport and below the Guelph, recognizing two members, the Ancaster and Speedwell (*in* Shaw, 1937, p. 339). The present writer prefers to retain the name Eramosa for those bituminous dolomites directly underlying the Guelph, as evidence is lacking to support the extension advanced by Nowlan. In the most recent classification of the Lockport dolomites of Ontario Cumings (1939) and Swartz, *et al.* (1942) assigned the 'undivided' Lockport dolomites to the Suspension Bridge member However, Howell and Sanford (1947) rightly called attention to the use of this name for a Lower Ordovician formation in New Brunswick and, accordingly, proposed the name Goat Island, referring to the island at the brink of Niagara Falls. Although this member is more typically developed to the west in Wentworth county, the name Goat Island is retained for those dolomites underlain by the Gasport and overlain by the Eramosa. As the chert beds immediately above the Gasport at the base of the Goat Island member are a consistent horizon throughout the Niagara Peninsula, they will be referred to in future discussions as the Ancaster chert beds. The type section for these beds is located along the highway a short distance east of the village of Ancaster (18). The Goat Island member is recognizable as a distinct unit of the Lockport formation as far north as Clappison road-cut (21). Although the eastern extension of this member is uncertain, the name can undoubtedly be applied as far as Rochester, N.Y.

Lithology. The Goat Island member is essentially a massive, irregularly bedded, buff to white weathered, dark to light grey, dense to fine-grained dolomite with a high argillaceous content in the Hamilton area. Vugs filled with calcite, gypsum, fluorite, and sphalerite are numerous, particularly in the Niagara Falls area. Chert nodules and lenses are so plentiful at the base that a distinct stratigraphic unit, the Ancaster chert beds, may be defined along the summit of the Niagara escarpment from Clappison road-cut east to DeCew Falls. This chert is not distinct in the Niagara gorge although the occasional chert nodule was visible in cores from the Hydro-Electric diamond-drill project (*see* Appendix B). The greatest concentration of chert is to the west in the Hamilton area where lenses and nodules are crowded together; eastward from this centre lenses are scarce and the amount of chert decreases accordingly. Laird (1935) recognized an upper and a lower chert zone separated by a shale band in the various Ancaster exposures between Hamilton (Corporation quarry) and Ancaster. The lower zone lacked the lens-shaped masses of chert characteristic of the upper. Two varieties of chert are present in the member; a dense, hard, conchoidal fracturing, bluish grey to dark grey variety, and a porous, earthy, white chert derived by alteration of the former.

Contacts and Thickness. The contact of the Goat Island and Gasport is distinct despite the presence of a transition zone at the top of the Gasport. This is because the Ancaster chert beds at the base of the Goat Island member are defined above and below by a distinct change in sedimentation beyond which there is no chert. On the other hand, the upper limit of the member is arbitrarily drawn at the first occurrence of bituminous material characteristic of the Eramosa.

A thickness of from 31 to 52 feet was assigned to this member along the Niagara gorge section with the most complete exposure near Niagara Falls. At least part, if not all, of the 55-foot covered interval at Ancaster between the top of the 25-foot thick Ancaster beds and the base of the Eramosa may represent the Goat Island. On the other hand at Dundas only 25 feet of beds overlie 36 feet of Ancaster. These variations in thickness were controlled by the presence of lagoonal or inter-reef facies in the overlying Eramosa, which developed in some areas to the exclusion of the Goat Island facies. Throughout the Niagara Peninsula there has been considerable erosion, and as a result, only a few feet of Ancaster overlies the Gasport in many localities along the Niagara escarpment. The chert zone is almost twice as thick in the Ancaster region as it is at its eastern limit with the following thicknesses assigned to these beds: 13 feet at DeCew Falls, 7 feet at Grimsby Beach (7), 10 feet at Stoney Creek (13) and Highway 20 (14), 12 feet at Albion Falls (15) and Hamilton (16), 25 feet at Ancaster, 15-36 feet at Dundas (20), and 9 feet at Clappison road-cut (21). Complete thicknesses were measured only at DeCew, Albion Falls, Ancaster, and Dundas (*see* Appendix A).

Fauna (*see* Table X). The fauna of the Goat Island member is concentrated principally in the Ancaster chert, and in these beds lithistid sponges and dendroid graptolites are important. *Astylospongia praemorsa* and *Aulocopina granti* are the most common sponges; *Reticulograptus polymorphus* and several species of *Dictyonema* dominate the large graptolite fauna (Bassler, 1909; Ruedemann, 1947).

Origin. All the evidence, according to Laird (1935), is in favour of a penecontemporaneous theory for the origin of the Ancaster chert. Accordingly, the silica derived from the Precambrian crystalline rocks lying to the northeast, was primarily deposited as a chemical precipitate along with the accumulating sediments.

Eramosa Member

This thin-bedded, fine-grained, bituminous dolomite member of the Lockport formation is exposed in the face of the Niagara escarpment at Niagara Falls, Ancaster, and Dundas. In contrast to the Gasport and Goat Island it extends from Niagara Falls to Cabot Head. For that reason, discussion of the Eramosa will be deferred until the various members of the Amabel formation have been described.

AMABEL FORMATION

This name was proposed (Bolton, 1953) for the main mass of dolomites that overlie the Fossil Hill formation and underlie the Guelph formation. Reasons for the introduction of this new term and its relationship to the Lockport formation have been outlined under the discussion of the Albemarle group. In the type section at Wiarton, Amabel township, Bruce county, the 131 feet of Amabel dolomite is divisible in ascending order into four distinct lithological units: a dense, blocky dolomite at the base, the Lions Head member; a massive, sugary dolomite, the Colpoy Bay member; a blue-grey mottled, fine- to coarse-grained dolomite, the Wiarton member; and, at the top of the Amabel, a thin-bedded, bituminous dolomite, the Eramosa member. This four-fold division can be recognized throughout the Bruce Peninsula, as well as at several localities between Wiarton and Georgetown. Between this last locality and Waterdown the Amabel formation grades laterally into the Lockport formation (sections 22-29, 31-43, 46). The resultant lithology is a mixture of the two formations and differentiation into members is not possible.

Lions Head Member

Sections 62, 76, 77, 79, 80, 83-85, 87, 105-110, 114, 115, 126, 132, 135, 141, 142, 150, 151, 158, 159, 161, 166, 167, 187, 190, 196, 197, 220-222, 227 (*see* Figure 1).

Definition and Distribution. The name Lions Head was suggested by Nowlan (1935 MS.) for blocky, dense dolomites overlying the coral beds on Bruce Peninsula, which were included with the coral beds and correlated with the Manistique of northern Michigan (*see* Shaw, 1937, p. 320). Fossils are poorly preserved and are of little assistance in correlating these dolomites. The Lions Head member and Fossil Hill formation are separated by a sharp break in sedimentation at several localities; in other sections the two units appear gradational. The occurrence of dolomites similar to those of the Lions Head member near the top of the Fossil Hill formation north of Lions Head (section 220) has been dealt with in the section in which the formation was discussed. Despite the seemingly contradictory nature of the lower contact, the Lions Head member appeared to be more closely allied lithologically to the main dolomites of the Amabel formation and for that reason, was described as the basal member of the Amabel (Bolton, 1953). It forms a well-defined lithological unit from south of Orangeville north to Cabot Head. In its most southern exposures, east of Caledon, the dolomite slightly resembles the Reynales dolomite of the Niagara Peninsula. Between this locality and Walters Falls (76) the Lions Head cannot be distinguished, although thin-bedded, dense, brown dolomites directly overlying the Fossil Hill at Cannings Falls (65) and Hornings Mills (75) appear to be its equivalent. It can, however, be readily recognized throughout the Owen Sound region and on the Bruce Peninsula. On Manitoulin Island the use of the Lions Head as a separate unit for strata overlying the Fossil Hill is not, however, justified, although there is some indication that this lithology is present northeast of South Baymouth.

Lithology. The type section of the Lions Head is located along the shore of Isthmus Bay, approximately $\frac{1}{4}$ mile north of the lighthouse at Lions Head village (220, *see* Plate III A). It is everywhere a blocky, hard, conchoidal fracturing, dense, white weathered, dark brown dolomite, with chert nodules in the basal 1-foot to 4 feet of sections 77, 126, 190, and 220. This blocky, white weathered character clearly distinguishes it from the Fossil Hill formation below and the Colpoy Bay member above.

Contacts and Thickness. Its lower contact with the Fossil Hill, wherever exposed, is distinct, with a sharp break between the two units in sections 62, 85, 105 (*see* Plate II B), 107, 126, 135, 150, 158, 159, and 161. In contrast, the contact is gradational in sections 77, 79, 83, and in several localities along the Bruce Peninsula. Small chert nodules and a few coral colonies are present in the transition zone. In sections where the Lions Head is overlain by Colpoy Bay dolomites the contact is gradational, except at section 126 where there is a sharp lithological change but no unconformity between the two members.

Total thicknesses were measured at several localities along the escarpment, with the following results: section 76, 12 to 24 feet; 77, 10 feet; 80, 21·5 feet; 83, 28 feet; 87, 22 feet; 126, 20 feet; 135, 16·5 feet; 150 and 151, 6 feet; 158, 21 feet; 159 and 187, 17 feet; and 220, 24 feet. A maximum thickness of 45 feet was obtained by Nowlan (1935 MS.) from cliff exposures along Dyer Bay.

Fauna. Poorly preserved stromatoporoids and corals are the only fossils found in this member.

Colpoy Bay Member

Sections 43, 46, 48, 51-54, 57, 59, 64-69, 71, 75-77, 80, 82, 83, 87, 89, 90-92, 104, 108-111, 116-118, 122, 126, 130, 131, 135, 138, 141, 143, 150, 151, 158, 159, 162, 170, 172, 184, 186-188, 190, 194, 196, 198, 219-221, 223 (*see* Figure 1).

Definition and Distribution. The name Colpoy Bay was proposed (Bolton, 1953) for the thick series of dolomites separating the Lions Head member from the Wiarton member. The type section is exposed at the head of Colpoy Bay in the road-cut north of Wiarton, Ont. It is the most constant stratigraphic unit in the Amabel formation, and can be identified along the summit of the escarpment from Georgetown to Cabot Head (*see* Plate III B). A complete section, however, is exposed only in the Wiarton road-cut (151). Lithologically similar dolomites can be recognized in the Amabel formation of Manitoulin Island, but the term has not been extended to this region. These dolomites lithologically resemble the Engadine dolomites of northern Michigan.

Lithology. The Colpoy Bay member of the Amabel formation is typically a massive, porous, fine-grained to dense, buff weathered, white to light grey to blue-grey dolomite. Thin, grey, argillaceous partings and lenses occur in the basal 6 to 10 feet of sections 65, 89, and 109, and massive biohermal structures and thin-bedded flank deposits are present at different stratigraphic levels and in widely spaced outcrops. The dolomite of these bioherms, as developed particularly around Mono Centre as well as in equivalent beds on Manitoulin Island between South Baymouth and Providence Bay, resemble that of the overlying Wiarton facies.

Contacts and Thickness. Both the lower and upper contacts of the Colpoy Bay are gradational. The upper contact is drawn arbitrarily at that level above which the rocks are predominantly blue-grey mottled, crystalline, fossiliferous dolomites. This contact is best exposed in the Hope Bay-Cape Dundas sections (193-196), sections 186 and 188, and in the Wiarton road-cut (151). The total thickness of Colpoy Bay strata can be measured in the Wiarton road-cut only, where 58 feet of dolomite separates the Lions Head and Wiarton members. At least 47 feet of dolomite may be assigned to the Colpoy Bay south of Owen Sound and 50 feet at Eugenia Falls (75).

Fauna. The Colpoy Bay dolomite is unfossiliferous except the biohermal masses. These bioherms are composed mainly of crinoid stems and the Brachiopoda *Rhynchotreta americana* (Hall), *Stegerhynchus neglectum* (Hall), and *Leptaena rhomboidalis* (Wilckens), as well as fragments of Pelecypoda and Gastropoda.

Wiarton Member

Sections 27, 31-34, 38-40, 43, 44, 55, 72, 75, 93-97, 112, 126, 130, 133, 134, 136, 137, 151, 155, 156, 163-165, 173-183, 186, 189, 191-195, 202, 206, 211, 214-218 (*see* Figure 1).

Definition and Distribution. The crinoidal dolomites that overlie the Colpoy Bay (Engadine *of* Shaw, 1937, p. 320) were named Wiarton by Nowlan (1935 MS.), with the sequence exposed in the road-cut immediately north of Wiarton, Ont., designated as the type section. This term was adopted by the writer (1953) for that member of the Amabel formation that directly underlies the Eramosa or Guelph dolomites from Cabot Head south to Georgetown. The main outcrops along the escarpment proper are located at Wiarton (151) and Eugenia Falls (75), but undoubtedly several of the higher, inaccessible promontories along the east coast of Bruce Peninsula are capped by this member. A large area of the peninsula proper, however, is underlain by Wiarton strata and it was from these exposures that most of the lithological and fauna data were obtained. Outcrops south of Owen Sound and at Rockwood confirm the extension of the Wiarton south to the Georgetown area. No definite Wiarton equivalents could be established in the Amabel dolomite of Manitoulin Island, although a meagre fauna similar to that found in the Wiarton of the mainland was discovered at one locality north of South Baymouth.

Lithology. The Wiarton member is characteristically a massive, porous, coarse- to fine-grained, blue-grey mottled, light grey, crinoidal dolomite, weathering white to buff, with purple-mottled massive, basal beds. Bioherms are well displayed in it south of Owen Sound (95) where two mounds, 6 to 15 feet high, 80 feet wide, and 50 feet apart, are separated by 5·5 feet of dipping and truncated 'inter-reef', thin-bedded, bituminous, slightly petroliferous dolomite. Chert nodules with crinoid columnals, Brachiopoda, and *Calymene* cf. *clintoni* are abundant in these interbiohermal beds (*see* Plate IV).

Contacts and Thickness. Both the lower and upper contacts of the Wiarton member are gradational. A discussion of the upper contact will be deferred until the Eramosa member has been described. No complete Wiarton section was discovered. A thickness of 16 feet is allotted to the Wiarton in the type section, but the 31-foot covered interval that separates the top of the road-cut from the lowest known Eramosa at this locality may be occupied by Wiarton or Eramosa dolomites, or by both. At least 44 feet of dolomite separates the Colpoy Bay from the Guelph south of Owen Sound.

Fauna (*see* Table XI). The Wiarton member contains a rich and varied fauna and good collections were made at several localities, the best fauna being obtained from the top 6 feet of the road-cut immediately north of Wiarton. Species identified from this and other localities are listed in Table XI. Forms common to both the Racine formation of Wisconsin and the Guelph formation of Ontario are abundant, the molluscan assemblage best displaying this relationship. Predominantly Racine forms are the Pelecypoda *Amphicoelia leidyi*, *A. neglecta*, *Mytilarca acutirostra*, *Streptomytilus aphaea*, and *Cypricardinia arata;* Gastropoda *Poleumita ? pauper*, *Phanerotrema occidens*, *Straparollus mopsus*, *Strophostylus ? elevatus*, and *Subulites terebreviformis;* and Cephalopoda *Michelinoceras whitfieldi*, *Amphicyrtoceras laterale*, *A. orcas*, and *Cyrtorizoceras byronense.* This Racine affinity is further revealed by the cystid *Gomphocystites glans*, crinoids *Pycnosaccus* cf. *caliculus*, *Siphonocrinus pentagonus*, *Macrostylocrinus* cf. *striatus*, *Eucalyptocrinites crassus*, *E. obconicus*, and *Lecanocrinus* cf. *pisiformis*, Brachiopoda *Barrandella fornicata*, *Stegerhynchus whitii*, *Howellella crispa simplex*, and *Nucleospira pisiformis*, and Trilobita *Bumastus* cf. *armatus*, *Cheirurus* cf. *welleri*, *Scutellum acamus*, and *Sphaerexochus romingeri.* An even greater number of Gastropoda and Cephalopoda are characteristic of the Guelph dolomites of Ontario and New York. *Loxoplocus* cf. *solutus*, *Lophospira* cf. *bispiralis*, *L.* cf. *hesplerensis*, *Trochonema fatuum*, *Eotomaria durhamensis*, *E. galtensis*, *Coelocaulus esterella*, *Euomphalopterus elora*, *Holopea guelphensis*, *Poleumita durhamensis*, and *P. parvula* are principally Guelph Gastropoda and Guelph Cephalopoda include *Kionoceras* cf. *scammoni*, *K. darwini*, *Euryrizoceras orodes*, *Amphicyrtoceras williamsi*, *Phragmoceras ontarioense*, and *Lechritrochoceras desplainense.* The enclosed fauna is, therefore, a link between the typical Clinton-lower Lockport and Guelph assemblages. The association of Guelph and Racine forms in this transition fauna suggests that the typical Guelph fauna of Ontario and the typical Racine fauna of Wisconsin were products of a special environment (*see* Shaw, 1937, p. 336.)

Eramosa Member

Niagara Falls; Sections 17-19, 45, 70, 97, 98, 112, 113, 125, 144, 146-149, 152, 153, 192, 200-203, 209, 212, 215, 217, 218 (*see* Figure 1).

Definitions and Distribution. The name Eramosa was introduced by Williams (1915) for the bituminous dolomites at the top of the Lockport on the Eramosa River near Guelph, Ont., but later redefined by Nowlan (1935 MS.) and Shaw (1937) to include the entire sequence of dolomites between the Gasport and Guelph. As previously noted (p. 49), the Eramosa here includes only those thin-bedded dolomites that were deposited at or near the close of the Lockport-Amabel period of sedimentation in Ontario. By this definition it not only embraces the bituminous dolomites of Williams but also thin non-bituminous horizons which are present near or at the top of the Amabel formation. In the widely scattered outcrops of this member along the escarpment particular attention was given to the upper and lower boundaries and their relationship to the Guelph formation above and the Goat Island-Wiarton members below. Eramosa dolomite can be traced from Niagara Falls to Cabot Head, and Williams (1919), reported it on several islands north of Bruce Peninsula, but did not recognize the member on Manitoulin Island. North of South Baymouth, the writer identified poorly bituminous strata in the Amabel dolomites that, by their overall lithology, could be justifiably correlated with the Eramosa of the mainland (Bolton, 1954), but it is preferable not to extend the term to this region. This member is not as consistent as suggested by the above outline. Its thickness varies considerably and detailed examination of the Wiarton member has shown, accordingly, that the stratigraphic position of the Eramosa is not constant. At most localities it occupies a position between the Wiarton and Guelph. In some localities, however, it is overlain by Wiarton strata (i.e., south of Owen Sound); in other localities the thin-bedded Eramosa dolomite grades laterally into massive Wiarton bioherms (sections 97, 192, 202-203). Finally, in some sections the Eramosa member is absent entirely, the Guelph resting directly on Wiarton bioherms. From this relationship, it is concluded that the Eramosa, in the northern part of the Ontario peninsula at least, is a particular facies directly associated with the development of bioherms in the Wiarton member. It is most constant and thickest in the region to the south where conditions of sedimentation seem to have been less varied.

Lithology. At least two distinct lithologies can be assigned to the Eramosa. In the Owen Sound-Bruce Peninsula region it is characteristically a thin-bedded, dark brown, fine-grained to sugary, highly bituminous dolomite that emits a strong petroliferous odour when struck with the hammer. Thin coral biostromes and lenses of crystalline dolomite are present at different levels in sections examined around Hepworth (148), Sky Lake (200), and east of Guelph (45) and small nodules of white chert were found west of Wiarton (153), in the Sky Lake road-cut, and northeast of Ferndale (218). The basal beds (113, 144, 153) are generally more massive, thick-bedded, white weathered, fine-grained dolomites, with a slightly greater argillaceous content but smaller bituminous content and less noticeable petroliferous odour. They are commonly heavily laden with the brachiopod *Whitfieldella.* Thin-bedded dolomites that are associated with the Wiarton and Guelph bioherms on Bruce Peninsula (sections 192, 202-203, 209, 215) are identical with the typical Eramosa except for a lower bituminous content. In contrast, between Niagara Falls and Shelbourne, the Eramosa is a massive, thick- to thin-bedded, brown, fine-grained to dense, bituminous dolomite. Dark grey shale partings are abundant in the Niagara Falls, Dundas (19), and Guelph sections.

Contacts and Thickness. Both the upper and lower limits of the Eramosa member are difficult to define in the region south of Shelburne. The base is arbitrarily drawn at the first occurrence of bituminous material and associated petroliferous odour. A gradual change in lithology is evident at the close of Lockport sedimentation in Ontario, with the Eramosa conformably overlain by Guelph dolomite, indicating that the Lockport-Guelph sequence is a product of continuous sedimentation, the various lithologies arising from widespread, gradual changes in the basin of deposition. The stratigraphic position of the Eramosa-Guelph contact, therefore, may vary throughout Ontario, but is always drawn at the base of the massive, thick-bedded, brownish grey, porous, saccharoidal dolomite. This upper limit may be more closely defined in the Owen Sound-Bruce Peninsula area as the lithology of the Eramosa there is as a rule quite distinct from the characteristic Guelph lithology.

Structures reported in the Eramosa at several localities are primarily the result of doming over local bioherms in the underlying Wiarton dolomite, but low dips were observed also where the Eramosa grades laterally into Wiarton bioherms. Two possible interpretations can be advanced from this field evidence to explain the Eramosa-Guelph sequence. In the older hypothesis the Eramosa was deposited at a constant horizon on an undulating surface produced by reefs or bioherms in the underlying dolomites, and Guelph sediments in turn were laid down on a plane, the topography of which reflected this older surface. This explanation would account for the undulating nature of the Guelph-Eramosa contact. A relatively sharp change in sedimentation must be assumed in such a theory, but such a change is evident in only a few sections. As there is a variation in the stratigraphic position of this contact, and a gradation laterally into Wiarton bioherms of dolomites lithologically similar to the Eramosa, the Eramosa may be defined, rather, as a transition facies that originated during the change in conditions necessary for Guelph sedimentation. Towards the close of the Lockport-Amabel sedimentation, bioherms, initiated during Colpoy Bay deposition, accumulated over a wide area in Ontario between which the Eramosa dolomites were deposited as inter-reef, lagoonal (Shaw, 1937), or flank sediments. This condition persisted into Guelph time as sedimentation continued uninterrupted until the close of Niagaran time throughout Ontario, resulting in one large reefal complex. Thus, in areas favourable to the development of bioherms organic accumulation continued unbroken into the Guelph, whereas in areas not as favourable Eramosa dolomites were deposited around and/or over these bioherms in late Wiarton and early Guelph time (section 220). It is therefore facies controlled.

This hypothesis also explains the great variation in thicknesses assigned to the Eramosa dolomites. Despite the limited number of complete sections and the difficulty in defining the lower limit of this member, the following thicknesses were measured: 7 to 34 feet at Niagara gorge, 43 feet at Ancaster (18), 58 feet at Dundas (8), 30 feet at Guelph (Williams, 1919), 50 (?) feet at Wiarton (covered interval, section 151), and over 27 feet near Cooks quarry.

Fauna. Most of the Eramosa is relatively unfossiliferous, except for the argillaceous dolomites exposed in the Canada Crushed Stone quarry at Dundas (19) and the thin biostromes of the northern outcrops.

Eramosa Fauna, Dundas, Ont.

ANTHOZOA

Favosites forbesi Edwards and Haime

BRYOZOA

Hallopora sp. indet.
H. cf. *elegantula* (Hall)
Subretepora sp.
Pachydictya crassa (Hall)

BRACHIOPODA

Craniops squamiformis (Hall)
Dolerorthis flabellites (Foerste)
Stegerhynchus neglectum (Hall)
S. indianensis (Hall)
Reticularia bicostata (Vanuxem)
Whitfieldella parvus Shaw
Leptaena rhomboidalis (Wilckens)
Fardenia subplana (Hall)

PELECYPODA

Pterinea sp.

GASTROPODA

Naticonema niagarense (Hall)
Hormotoma sp.
Tentaculites minutus Hall

TRILOBITA

Bumastus ioxus (Hall)
Calymene niagarensis (Hall)
Encrinurus ornatus Hall and Whitfield

OSTRACODA

Leperditia sp.
Paraechmina spinosa (Hall)
Bonnemaia sp.
Dizygopleura cf. *symmetrica* (Hall)

In the Bruce Peninsula region, the Eramosa yielded the following species: *Rhopalonaria attenuata*, *Rhynchotreta americana*, *Stegerhynchus* ? *pisa*, *S. whitii*, *Howellella crispa*, *Whitfieldella intermedia*, *W. nitida*, *Parmorthis elegantula*, *Homoeospira evax*, and *Leperditia* sp. from east of Park Head (113); the graptolite *Thallograptus* and a few eurypterid fragments from Cooks quarry, Wiarton (153) and Sky Lake (200), among which *Eurypterus* sp. and *Eusarcus logani* were identified; *Pycnostylus guelphensis*, *Favosites* sp., *Eospirifer eudora*, *Whitfieldella* sp. from Sky Lake road-cut; *Strophonella striata* and *Calymene niagarensis* in chert nodules northeast of Ferndale (218). For a more comprehensive list of the Eramosa fauna the reader is referred to Shaw (1937) and Caley, *et al.* (MS.). As noted by Shaw (pp. 339-342), although of little correlative value, the general faunal assemblage of Anthozoa, Bryozoa, Brachiopoda, Mollusca, Ostracoda, and Eurypterida is significant in the determination of facies. Such an assemblage could readily flourish in a brackish, lagoonal or estuarine facies of the extensive, primarily reefal 'Lockport' sea.

GUELPH FORMATION

Niagara Falls; Sections 19, 100-103, 123, 124, 143, 145, 146, 151, 153, 157, 199, 200, 204, 205, 207-209, 212, 213, 217 (*see* Figure 1).

Distribution. Guelph dolomites underlie a belt of country west of the Niagara escarpment from Niagara Falls to the tip of Bruce Peninsula. Williams (1919) recognized Guelph as far north as Fitzwilliam Island, and the term possibly may be extended to include those dolomites that are exposed around and north of South Baymouth on Manitoulin Island (Bolton, 1954) although preliminary results from detailed mapping of the island by B. A. Liberty indicate that these dolomites may still be part of the Amabel formation. The Guelph will not be discussed in the same detail as the preceding formations, as reliable descriptions of the Guelph in Ontario are given in the reports of Williams (1919), Shaw (1937), Caley (1940, 1941), and Bolton and Liberty (1955). Only a brief description will be included of those exposures on Bruce Peninsula that best show the relationship between the Guelph and underlying dolomites.

Lithology. The rocks at the base of the Guelph formation are massive, buff weathered, light grey, porous, saccharoidal dolomites. In most places the basal 10 feet contain bituminous material and can be regarded as transitional between typical Eramosa and typical Guelph. Small bioherms are also a common feature of these beds at Niagara Falls, east and north of Wiarton (sections 123, 124, 157, 204, and 206), Sky Lake (200), and northwest of Ferndale (217). The 'reefal complex' nature of the Guelph, so well exhibited in the exposures on the Bruce Peninsula, is fully discussed by Bolton and Liberty (1955, pp. 30-34).

Fauna (*see* Table XII). A complete list of the Ontario Guelph fauna has been published by Shaw (1937) and Caley (1940), and the fauna collected from the basal beds examined by the writer are listed in Table XII. The presence of the cup coral *Zaphrentis* cf. *racinensis* in the thick-bedded, slightly bituminous dolomites directly overlying typical Eramosa was used by Shaw to delineate the lower contact. Other species found in these dolomites with the possible exception of the coral *Pycnostylus guelphensis*, are also represented in beds older than the Guelph, but do not include the typical Guelph brachiopod *Trimerella grandis* and pelecypod *Megalomus canadensis.*

CORRELATION OF THE ALBEMARLE GROUP

The Lockport formation of the Niagara Peninsula is directly correlated with equivalent rocks in New York and the Guelph formation is the correlative of the Oak Orchard (Lower and Upper Shelby) dolomites of that state. These correlations are based on both lithological and faunal evidence.

Along the northern and western rim of the Michigan basin the Albemarle group can be traced directly into the Engadine dolomites of northern Michigan, in which Racine and Guelph faunas are recognized. The Racine fauna described from the Wiarton member of the Amabel formation indicates that the Albemarle strata of Ontario are correlatives of the Racine-Guelph formations of Wisconsin. All these strata are products of continuous sedimentation as neither a stratigraphic nor palæontological break exists within the entire sequence of rocks. A similar relationship probably exists between the Albemarle group of Ontario and the Port Byron strata of Illinois, the Cedarville-Peebles dolomite of Ohio, and the Huntington dolomite of Indiana. The faunas of each include *Pycnostylus elegans*, *P. guelphensis*, *Conchidium occidentale*, *Trimerella grandis*, and *Megalomus canadensis.*

Guelph and Lockport-Racine correlatives have been reported from Great Slave Lake, Hudson Bay, James Bay, and Lake Timiskaming. Analysis of the faunas from these areas indicates that they are probably equivalent to the Lockport-Racine subdivision of the Albemarle rather than the Guelph as the species are more diagnostic of that time.

CHAPTER III

SYSTEMATIC PALÆONTOLOGY

General Remarks

Identification of the fossils collected from the various units described in the preceding section has constituted the major part of this study and extensive faunal lists are included. Preservation of the fossils on the whole left much to be desired so that specific determination was made for the most part on external characteristics. Several apparently new species were discovered, particularly among the pelecypods of the Cataract shales, but only a few were sufficiently abundant to warrant description. Also included are descriptions of species, proposed in unpublished manuscripts by Johnson (1934 MS.) and Way (1936 MS.), that have proved to be important in the Silurian strata of both the Ontario mainland and Manitoulin Island. Types of these species located in the collections of the Royal Ontario Museum of Palæontology were loaned to the author by Dr. Madeleine A. Fritz. This part of the report also incorporates observations made by the writer on several of the species and genera studied. The main palæoecological observations made in conjunction with the specific studies of the fauna have already been presented in the sections in which the formation or member containing them was discussed.

ANTHOZOA

Favosites species

Colonies of *Favosites* are most abundant in the Fossil Hill dolomites of the Ontario peninsula and Manitoulin Island. In individual coralla, as well as in those of apparently related species, the nature of the tabulae, the number, size, and arrangement of mural pores, and the shape of the corallites vary, each feature being dependent upon the degree of preservation. For that reason, the various species described from this formation were separated principally on the basis of the corallite's size in mature specimens. The corallite dimensions allotted to each species are tabulated below.

Species	Maximum diameter
F. hisingeri (Edwards and Haime)	1 mm.
F. niagarensis (Hall)	1·5 mm.
F. hispidus Rominger	2 mm.
F. sp.	3-5 mm.
F. favosus (Goldfuss)	5 mm. up

Forms that possess a hemispherical to spherical corallum, and corallites ranging in size from 0·5 to 2 mm., were assigned to *F. forbesi* Edwards and Haime. The variety *F. forbesi dyerensis* n. sp. includes forms with close set tabulae (Plate V, figures 1-3, Plate XI, figure 2). Several new species have been described by Way (1936 MS.) from the Fossil Hill and Manitoulin dolomites, none of which have been recognized in the mainland equivalents.

ECHINODERMATA

Megacystites (?) sp. indet.

Two small cystid specimens were collected from the upper beds of the Wiarton member north of Colpoy village and at Wiarton. Their preservation is poor and only one row of tiny basal plates, 2 rows of large central plates, and an upper row of at least 5 long plates could be outlined. The bud-shaped specimens measured 12 to 14 mm. in length and 7 to 8 mm. in depth. They are questionably referred to the genus *Megacystites;* their closest correlative is the small cystid *M. greevillensis* (Foerste) from Ohio, but they differ from this species in their smaller size.

BRACHIOPODA

Platystrophia species

Uniplicate, biplicate, and triplicate forms of *Platystrophia* are known in the Silurian strata of Ontario. Forms with three plications in the sinus have been referred to *P. biforata* (Schlotheim). Many of the forms present in the Manitoulin dolomites of the Ontario peninsula and Manitoulin Island show two plications in the sinus, and these have been referred to *P. daytonensis* Savage. Several small forms of *Platystrophia* were found in the Wiarton member which have all been referred to the species *P. daytonensis laurelensis* McEwan, although the following variations may be noted. One group apparently has only five to six plications on the side, instead of the normal eight to nine, but still corresponds in size to the *laurelensis* variety, and a second group of small specimens are uniplicate with four to five plications on the side. The latter species may be young forms of either *P. biforata* or *P. daytonensis laurelensis*, or an aberrant form of the latter species. One specimen was collected that contained two plications in the sinus which also may be an aberrant form.

Stegerhynchus indianensis (Hall)

Specimens of this species from the Eramosa dolomites exposed in the Canada Crushed Stone quarry at Dundas vary widely. A complete gradation exists from very small forms without a sinus to large and broad forms with four fine plications in the sinus and six on each side. This finer plicated fauna is developed locally in association with varieties of *Eospirifer* and *Encrinurus*. It is comparable to variants assigned to this species by Hall in the original description of Indiana material, but not to the restricted species of Shimer and Shrock (1944).

Whitfieldella parvus Shaw

Specimens of this species were collected by Shaw (1937) from the Eramosa dolomite at Guelph, Rockwood, and Dundas. Shaw noted that this form may represent an early development stage of *W. nitida* (Hall), but that a specific designation seemed warranted as all the specimens collected were characteristically of small size. During the recent investigation extensive collections of *Whitfieldella* were made at Dundas and east of Park Head in which both *W. nitida* and *W. parvus* were present in the same assemblages, with a complete gradation existing between the two species. *W. parvus*, therefore, would appear to represent a young form of *W. nitida*.

PELECYPODA

Numerically Pelecypoda are the most abundant forms in the Cabot Head and Grimsby faunas with representatives of *Modiolopsis*, *Ctenodonta*, and *Cleidophorus* widespread. Noteworthy is the abundance of *Ctenodonta glenna* n. sp. in the Cabot Head and Grimsby shales (Plate XI); these forms are consistently smaller and display the typical taxodont dentition better than the holotype collected from the Power Glen shales at DeCew Falls. The new pelecypod species *Cleidophorus albionensis*, *C. minor*, *C. major*, and *C. wentworthensis* were particularly abundant in the Grimsby red shales and sparingly developed in the upper shales of the Cabot Head on Nottawasaga River (Plate XII). Several small specimens of *Conocardium* were located in the Wiarton member. After comparison with the holotype, two of these specimens were determined as *C. elegantulum* Billings, a species common in the Jupiter and Chicotte formations of Anticosti Island (Plate XII, figures 7-9). The remainder are larger forms and apparently unrelated to any described species.

GASTROPODA

Holopea guelphensis (Billings)

This species was previously considered typical of the Guelph fauna of Ontario, but casts suggesting it were collected from almost every locality of the Wiarton member (Plate XII, figures 17-18). The majority differ from the holotype in that they are about half the size, their whorls have a greater overlap, and they have a pleural angle of 78 degrees rather than 80 degrees. Although these small forms predominated, gradations were found between them and specimens that were identical with the holotype. This variation is attributed to ecological factors, many of the associated genera being likewise reduced in size.

CEPHALOPODA

The Fossil Hill and Wiarton dolomites contain a prolific but widely scattered Cephalopoda fauna. Echinodermata, Gastropoda, and Trilobita are generally abundant in the assemblages, whereas Brachiopoda are rare. The Fossil Hill Cephalopoda commonly occur in conjunction with coral bioherms. According to Flower (1942, 1943), this assemblage, embedded in a massive, hard dolomite, characterizes a typical Cephalopoda facies. Beds carrying such a fauna are generally extremely limited both stratigraphically and geographically and, accordingly, it is possible that many of the Racine species identified from the Wiarton member may be separate species. On the basis of size and shape, however, their closest correlatives are the species designated.

Two distinct faunas can be recognized in these Silurian dolomites. One is an early fauna, found in the Fossil Hill and hence Clinton in age, which, as noted by Flower (1943), is principally an Arctic one characterized by *Discosorus* and other related orthocones. It extended south into the Manistique-Fossil Hill of northern Michigan and Ontario, the Hopkinton dolomite of Iowa, and the lower Reynales of New York. The cephalopod assemblage described from the Fossil Hill exposures on Nottawasaga River in which *Michelinoceras* and *Leurocycloceras* are the dominant genera, is a representative of this early fauna. As it is rich in species and individuals the association can be regarded as a natural ecological assemblage. The second, younger upper fauna is widely developed in the Wiarton member and is as a rule a bioherm association in which cyrtoconic and breviconic Cephalopoda are conspicuous and orthoconic genera rare. This combination is recognized throughout the Arctic region indicating in all probability that most of these genera common to the European and American Silurian entered from boreal waters (Flower, 1943, p. 88). The upper fauna, collected in Ontario from rocks definitely pre-Guelph in age, consists of both Racine and Guelph species; this combination suggests that the separate assemblages present in the two younger formations are ecological derivatives developed through differentiation and migration of the older Wiarton fauna as the Guelph and Racine environments evolved.

Closely allied to the Wiarton upper cephalopod fauna is one from the 'Niagara formation' at Grimsby, Ont., originally described by Billings (1866, pp. 82-90). As defined by Logan (1863, p. 322) the Niagara formation, series, or group in Ontario included all strata from the base of the Reynales to the top of the Guelph. In Bassler's "Bibliographic Index of American Ordovician and Silurian Fossils", 1915, the various species are assigned to the Lockport formation; later Foerste (1934, pp. 116-118) included them in the upper part of the Lockport formation. The present section at Grimsby (*see* Appendix A) is capped by at least 8 feet of Gasport limestone so that the cephalopods could have been collected either from the Gasport, and therefore are low Lockport, or from loose boulders washed down from above the falls, and therefore probably high Lockport. As modified from Foerste, the cephalopod fauna consists of the following cyrtoconic and orthoconic species: *Anaspyroceras varro*, *Geisonoceras ? oberon*, *Kionoceras cadmus*, *Michelinoceras brontes*, *M. pylades*, *M. remus*, *Amphicyrtoceras grimsbyense*, *A. pettiti*, *Ectocyrtoceras billingsi*, *E. thales*, *Grimsbyoceras clitus*, *G. corydon*, *G. teucer*, *Streptoceras heros*, *S. janus*. Of these fifteen species, *M. brontes* is listed in the present report from the Fossil Hill formation, and *M.* sp. aff. *M. brontes*, *M.* cf. *pylades*, *G. oberon*, *A. varro*, *A. pettiti* from the Wiarton member of the Amabel formation.

An undescribed 1867 Survey collection by T. C. Weston, again loosely assigned to the Niagara formation of the east Gore, Grimsby, Ont., consists principally of cyrtoconic genera similar to the Wiarton fauna. In the same collection, and embedded in rock lithologically similar to that containing the cephalopods, are brachiopods *Eospirifer radiatus*, *Leptaena rhomboidalis*, pelecypod *Mytilarca* sp., gastropod *Poleumita* cf. *crenulata*, and trilobites *Bumastus ioxus*, *Calymene niagarensis*, *Cheirurus niagarensis*, *Scutellum* sp. aff. *S. rochesterense* Howell and Sanford. Many of these species are also common in the Wiarton member.

It is unfortunate that the exact stratigraphic position of the cephalopods in these two collections is not determinable. However, they do offer further support to the correlation of the Lockport formation of the Niagara Peninsula and the Wiarton member of the Amabel formation of the Bruce Peninsula.

Anaspyroceras varro (Billings)

One orthoconic species in particular is widespread in the upper cephalopod fauna. It is a small, slender, closely annulated and gradually tapering form with a small, central, tubular siphuncle. This orthocone is identical with the holotype of *Orthoceras varro* Billings (G.S.C. No. 2727) collected from the Lockport dolomites at Grimsby, Ont. It is here assigned to the genus *Anaspyroceras* Shimizu and Obata 1935 which, as redefined by Flower, is applicable to orthochoanitic conchs with the aspect of *Spyroceras*. Variants of this form can be recognized although, in general, the closely spaced annulae are transverse. Specimens, compressed and rounded in cross-section, were found in which the closely spaced annulations and sutures sloped apicad. In other specimens the sutures were straight in one part of the conch and sloping in another part. The cancellated surface of these variants suggests the genus *Metaspyroceras*, but the centrally located, tubular siphuncle places the nautiloids as *Anaspyroceras*.

TRILOBITA

Encrinurus ornatus Hall and Whitfield

Pygidia of this species are abundant in the Eramosa dolomite exposed in the Canada Crushed Stone quarry at Dundas. They are here all referred to *E. ornatus*, although the following variations were noted. The width and length were approximately equal except in two specimens. In these forms the eighth pair of pleural segments were united to form a short spine, and the width to length ratio was more characteristic of *E. deltoideus* Shumard. At least eighteen to twenty-six axial segments could be outlined on these specimens. In general, four to six tubercules were present on the axial segments with one to two pair on the larger pleural segments.

Description of Species

Phylum, **ANTHOZOA**

Subclass, **Schizocoralla**

Genus, *Lyellia* Edwards and Haime 1851

Lyellia thebesensis Foerste *paucivesiculosa* n. var.

Plate VI, figures 1-7

Lyellia thebesensis Foerste, 1909, Bull. Sci. Lab. Denison Univ., p. 95, Pl. IV, figs. 69A and B.

Lyellia thebesensis Foerste, Savage 1917, Ill. State Geol. Surv., Bull. 23, p. 116, Pl. V, figs. 6, 7.

Lyellia paucivesiculosa Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", p. 114, Pl. VI, fig. 5; Pl. VII, figs. 1, 2.

Lyellia paucivesiculosa Way (*nomen nudum*), Fritz 1941, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part I, Contrib. Roy. Ont. Mus. Palæo., No. 5, p. 13.

Description. "Coralla forming globular masses up to 75 mm. in diameter, with an epitheca lining the under surface. Calices round, crenulated by twelve septae, very regularly 1 mm. in diameter, and separated from one another by less than half their diameter. Walls of the corallites striated lengthwise. The tabulae average eight or nine in a distance of 5 mm. and are irregularly straight or concave. The coenenchyma, when narrow, is occupied by a single row of plates which are more distinctly tabulate than vesicular; but when slightly wider is occupied by true vesicular plates which are nearly twice as abundant as the tabulae of the corallites" (Way, 1936 MS., pp. 114-115). Differs from *L. thebesensis* Foerste in extreme narrowness of coenenchyma.

Discussion. Several specimens of *Lyellia* were collected from the Manitoulin formation that internally resemble both *L. thebesensis* and *L. paucivesiculosa*, as both straight and concave tabulae are equally well developed. As a result of these intermediate forms, Way's species is recognized as only a variety of *L. thebesensis*.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7491; allotype, Roy. Ont. Mus. Palæo. Cat. No. 7490; upper biohermal beds of Manitoulin formation, lot 24, con. XI, Bidwell tp., Manitoulin Island; hypotype, G.S.C.[1] No. 11066, Manitoulin formation, Owen Sound.

Subclass, **Tabulata**

Genus, *Favosites* Lamarck 1816

Favosites forbesi dyerensis n. var.

Plate V, figures 1-3; Plate XI, figure 2

Favosites forbesi dyerensis Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", p. 113, Pl. VII, fig. 4.

Favosites forbesi dyerensis Way (*nomen nudum*), Fritz 1941, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part I, Contrib. Roy. Ont. Mus. Palæo., No. 5, p. 11.

Description. "Corallum massive, hemispheric. Calices of unequal size, varying from 0·5 to 2·5 mm. in diameter, the larger ones usually forming clusters. In some specimens the smaller corallites are developed nearly to the exclusion of the larger while in other specimens the larger corallites predominate. Walls thin, lined by twelve or more septae. Mural pores irregularly spaced in one or two rows. Tabula horizontal, very closely set, averaging two to 1 mm. and commonly four in the same distance" (Way, 1936 MS., p. 113).

Discussion. Differs from *F. forbesi* Edwards and Haime in the abundant tabulation. Species widespread in the Dyer Bay dolomites of Bruce Peninsula and Manitoulin Island.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7538; allotype, Roy. Ont. Mus. Palæo. Cat. No. 7562; Dyer Bay formation, upper West Bay cliff, Bidwell tp., Manitoulin Island.

[1]The abbreviation G.S.C. is used for the type specimens in the collections of the Geological Survey of Canada, Ottawa.

Phylum, **Bryozoa**

Order, **TREPOSTOMATA**

Genus, *Homotrypa* Ulrich 1882

Homotrypa lewisi n. sp.

Plate X, figures 4-6

Homotrypa lewisi Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", pp. 98-99, Pl. II, figs. 3, 6, 7, 8; Pl. VI, fig. 6.

Homotrypa lewisi Way (*nomen nudum*), Fritz 1942, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part II, Contrib. Roy. Ont. Mus. Palæo., No. 6, p. 21.

Description. "Zoarium large, frondescent at the base (measuring as much as 30 mm. in width and 10 mm. in thickness), dividing into as many as five compressed branches which measure 8 to 15 mm. in width and 4 to 7 mm. in thickness. Surface ornamented by slightly raised, rounded, semi-solid monticules the centres of which average 6 or 7 mm. apart and consisting of larger, rounded cells, the margins of which are raised above the solid interstitial substance. Acanthopores common but not abundant; larger and less abundant within the area of the monticules than in the surrounding zooecia.

"Tangential sections reveal that the apparently solid interstitial tissue of the monticules is in some cases non-celluliferous and in others consists of clusters of mesopores. Mesopores are rare in the intermonticular areas. Zooecial apertures rounded to sub-polygonal, six to eight in 2 mm. Cystiphragms in the zooecia of the monticules are small and often appear as small tubes against the zooecial wall while in the ordinary zooecia the cystiphragms extend up to three-quarters of the zooecial diameter.

"Vertical sections show a very short mature region in which both cystiphragms and diaphragms are developed and the walls only slightly thickened near the periphery. Cystiphragms irregular in shape and number, developed singly or in series in any portion of the mature region, often entirely wanting in several consecutive zooecia. Diaphragms well developed throughout the mature region and rarely present in the axial region. Zooecial walls crenulated deep in the axial region.

"The development of diaphragms in the axial region, the larger size of the zooecia, and the absence of semi-solid monticules readily distinguishes *H. confluens* (Foerste) from the new form" (Way, 1936 MS., pp. 98-99).

Discussion. The geographic range is extended south from Manitoulin Island to the Bruce Peninsula with the identification of this species in the Manitoulin dolomite at Owen Sound. Named by Way in honour of the late E. Lewis of Manitoulin Island.

Types. Cotypes, Roy. Ont. Mus. Palæo. Cat. No. 7513; base of upper biohermal beds of Manitoulin formation, lot 7, con. IX, Allen tp., Manitoulin Island.

Genus, *Hallopora* Bassler 1911

Hallopora caleyi n. sp.

Plate VIII, figures 1, 2; Plate IX, figures 1-3

Hallopora caleyi Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", pp. 100-101, Pl. I, figs. 1, 2.

Hallopora caleyi Way (*nomen nudum*), Fritz 1942, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part II, Contrib. Roy. Ont. Mus. Palæo., No. 6, p. 15.

Description. "Zoarium large, ramose, arising from an expanded base which may be encrusting; branches 10 to 12 mm. in diameter; surface smooth, no maculae distinguishable. Zooecia rounded, five to seven occurring in 2 mm. depending upon the number of mesopores present in the region measured.

"Vertical sections reveal that the mesopores continue well into the axial region where the tabulation of both mesopores and zooecia is essentially the same, averaging a tube diameter apart. In the mature region the straight, incomplete and curved diaphragms are crowded in the mesopores while the tabulation of the zooecia is essentially the same throughout both regions.

"Tangential sections show the zooecia to be separated by fewer angular mesopores than other Silurian representatives of the genus. The zooecia are rounded to oval, thin-walled, and often in contact" (Way, 1936 MS., p. 100).

Discussion. Distinguished from *H. elegantula* (Hall) by fewer mesopores, large size of zoarium, and absence of opercula. Specimens collected from Manitoulin exposures along the east side of Colpoy Bay extend the geographic range of this species south from Manitoulin Island to the Bruce Peninsula.

Types. Cotypes, Roy. Ont. Mus. Palæo. Cat. No. 7508; below *Orthorhynchula bidwellensis* zone, Manitoulin formation; lot 23, con. X, Bidwell tp., Manitoulin Island; hypotype, G.S.C. No. 11067, Manitoulin formation, east shore Colpoy Bay.

Hallopora obliquipora n. sp.

Plate IX, figures 4, 5

Hallopora obliquipora Johnson (*nomen nodum*), 1934, MS. Univ. Tor., "Stratigraphy and Palæontology of the Cataract Formation", p. 89, Pl. VII, figs. 1, 2.

Hallopora obliquipora Johnson (*nomen nudum*), Fritz 1942, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part II, Contrib. Roy. Ont. Mus. Palæo., No. 6, p. 16.

Description. "Zoarium irregularly ramose, consisting of subcylindrical, slightly monticulose branches, 5-7 mm. in diameter. Zooecia moderately thick-walled, oval to subpolygonal, varying in size, curving out from axis of branch and opening obliquely to the surface, 3 in 1 mm. Diaphragms numerous in immature region, few or absent in the early mature region, but occurring sparingly near the periphery. Mesopores fairly numerous and rather large, of variable size, with close-set diaphragms. Acanthopores absent" (Johnson, 1934 MS., p. 89).

Discussion. "The chief specific characters are the paucity of diaphragms in the mature region and the distinct obliquity of the apertures" (Johnson, 1934 MS., p. 89). Distinguished by smaller size of zooecia and obliquity of apertures from *H. magnopora* Foerste.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7414; upper contact Manitoulin dolomite with Cabot Head shales, Cataract, Ont.

Hallopora peculiaris n. sp.

Plate X, figures 1-3

Hallopora peculiaris Johnson (*nomen nudum*), 1934, MS. Univ. Tor., "Stratigraphy and Palæontology of the Cataract Formation", p. 90, Pl. VII, figs. 3, 4, 5.

Hallopora peculiaris Johnson (*nomen nudum*), Fritz 1942, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part II, Contrib. Roy. Ont. Mus. Palæo., No. 6, p. 18.

Description. "Zoarium composed of slender ramose cylindrical branches, measuring 5-6 mm. in diameter. Zooecia moderately thick-walled, oval to sub-cylindrical in outline, somewhat variable in size but averaging 4 in 1 mm., curving outward from the axis of the branch and opening almost at right angles to the surface. Diaphragms numerous in the immature region, few in the mature and straight, while in the peripheral zone they are crowded and characteristically curved in a sigmoidal fashion. Mesopores numerous and rather large, somewhat variable in size with close-set sigmoidally curved diaphragms" (Johnson, 1934 MS., p. 90).

Discussion. Distinguished by the small zooecial tubes and decidedly curved diaphragms. Specimens collected from the same Manitoulin beds as *H. caleyi* extend the geographic range of this species north to the Bruce Peninsula.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7413; lower limy beds, Cabot Head shales, Credit Forks, Ont.; hypotype, G.S.C. No. 11068, Manitoulin formation, east shore Colpoy Bay.

Phylum, **BRACHIOPODA**

Order, **PROTREMATA**

Suborder, **Pentameroidea**

Superfamily, **PENTAMERACEA**

Genus, *Camerella* Billings 1859

Camerella wiartonensis n. sp.

Plate XII, figures 1, 2

Description. Exterior: Subcircular in outline; hinge line short, cardinal extremities broadly rounded. Beaks small, incurved; ventral valve cardinal area narrow; dorsal interarea obsolete. Profile unequally biconvex; dorsal valve globose; ventral valve low, greatest convexity in umbonal region. High dorsal fold and broad, shallow ventral sinus, strongly defined only near anterior margin. Surface costate on the anterior half, smooth or faintly costate posteriorly; three to five costae on fold, two to three on lateral slopes. Strong growth lines, widely spaced on the lateral slopes, narrow *Stegerhynchus*-like on the costae. The length may be greater than, equal to, or less than the width. Among the cotypes, the length varies from 12 to 18 mm., width 13·5 to 17·8 mm., depth of dorsal valve 9 to 10 mm., depth of ventral valve 4 to 5 mm., and overall depth 10 to 11·4 mm. Length to width ratio 0·8 to 1·1.

Ventral interior: Dental and septal plates convergent to form a spondylium duplex. Median septum long.

Dorsal interior: Septal plates elongate and convergent, forming a cruralium duplex. Median septum short in comparison with ventral.

Discussion. The convergence of the septa of the dorsal valve is diagnostic of the genus *Camerella*, and is the distinguishing feature between it and *Parastrophinella*. This new species is represented by at least fifty internal casts with both valves present in the collection, either separately with the dorsal valve predominating, or united. In outline they are closely related to *C. greeni* (Hall), but differ from this species principally in the character of the costae. The geographic reference implied in this new species name is to the town of Wiarton.

Types. Holotype, G.S.C. No. 11592; paratypes, G.S.C. Nos. 11599-11602; Wiarton member, Amabel formation, top of road-cut, Wiarton, Ont.

Order, TELOTREMATA

Suborder, Rhynchonellacea

Family, RHYNCHONELLIDAE

Genus, *Orthorhynchula* Hall and Clarke 1893

Orthorhynchula bidwellensis n. sp.

Plate XI, figures 16-22

Orthorhynchula bidwellensis Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", pp. 85-87, Pl. III, figs. 1-19.

Orthorhynchula bidwellensis Way (*nomen nudum*), Fritz 1943, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part III, Contrib. Roy. Ont. Mus. Palæo., No. 7, p. 27.

Description. "Shape varies from trigonal in smaller to sub-elliptical and gibbose in larger specimens. Length to width as 5 to 6, ranging from 3 mm. to 36 mm. in width and 3 mm. to 30 mm. in length. Thickness ranges from 3 mm. in specimens of 8 mm. width to 22 mm. in specimens of 32 mm. width. Dorsally more convex at the lateral margins. Greatest width through the centre of the valves. Cardinal lateral angles decrease in size from 135 degrees in small to 90-100 degrees in large specimens. Surface marked by 32 to 40 coarse costae which extend to the beak and which are crossed by fine, transverse striae. Sulcus and fold are increasingly developed with growth, contain respectively 5 to 6 and 6 to 7 costae. Cardinal area small, usually one-fifth to one-quarter the length of the hinge line. Nototherium and delthyrium unmodified. Beak of the ventral valve the higher, the dorsal beak curved toward that of the ventral. Ventral interarea faintly apsacline, dorsal interarea strongly apsacline.

"Ventral valve convex on either side of mesial sinus that begins at the beak and widens to the front. Beak very small, projecting slightly above the palintrope, and but slightly incurved. Hinge teeth strong, rise from the sides of the palintrope supported by adventiceous tissue, grooved on the inner surface, and project only about 1 mm. beyond the hinge line. Musculature strong; adductor-track widens anteriorly and terminates about one-third the length of the shell presenting a squarish appearance, diductors scars not clearly defined, pallial markings monticulose.

"Dorsal valve more gibbose than the ventral, especially on each side of the fold which arises near the beak and widens to the anterior end. Beak lower than the ventral and incurved below it. The crura are long, stout, grooved on their inner surface, arise directly below the top of the beak and curving upwards attain a maximum length of 7 mm. with an attitude perpendicular to the palintrope. The cardinal process is well developed in the smallest specimens but never become large. It is thin, extends about three-quarters the height of the beak, arises from the median septum and bears a faint camera. Median septum arises directly below the beak and extends about half the length of the shell. Dental sockets shallow. Muscle-track elongate, arising anterior to the base of the crura, divided medially by the median septum, widens but slightly anteriorly, and merges into the general internal surface of the shell about half the length of the valve" (Way, 1936 MS., pp. 85-87).

Types. Cotypes, Roy. Ont. Mus. Palæo. Cat. No. 7518; upper biohermal beds of Manitoulin formation; centre lot 24, con. XI, Bidwell tp., Manitoulin Island.

Genus, *Fardenia* Lamont 1936

Fardenia plicata n. sp.

Plate XI, figures 11-15, 23

Schuchertella plicata Way (*nomen nudum*), 1936, MS. Univ. Tor., "Silurian of Manitoulin Island, Ontario", p. 88, Pl. IV, figs. 1-5.

Schuchertella plicata Way (*nomen nudum*), Fritz 1943, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part III, Contrib. Roy. Ont. Mus. Palæo., No. 7, p. 31.

Description. "Shells of this brachiopod have previously been assigned to *S. subplana* (Conrad). The present form differs from the latter in being less extended along the hinge line; in having, rounded cardinal lateral angles, ventral valve very noticeably concave below the umbo; ventral muscle scar larger; external ornamentation coarser; internal ornamentation showing only the anterior half of the shell to be sharply plicate; cardinal process bilobed within, myaphore or external appearance quadrilobed; deltidium wrinkled and crowded towards the sides of the delthyrium with growth of the cardinal process. Distinguished chiefly by the smooth posterior interior of the shells and by the larger ventral muscle scar" (Way, 1936 MS., p. 88).

Discussion. Widespread on Manitoulin Island in the Manitoulin formation. One zone was located in the Power Glen shales, DeCew Falls and another in the Manitoulin dolomites around Duntroon that contained numerous brachiopod valves comparable to this form. Preservation is different in these forms from the type species, but the high convexity of the dorsal valves, the rounded cardinal lateral angles, the strongly developed striae separated by three to five weaker striae, and the curving of the striae at the margins, particularly on the concave ventral valves, suggest this species rather than *F. subplana* (Conrad).

Types. Cotypes, Roy. Ont. Mus. Palæo. Cat. No. 7525; upper biohermal beds of Manitoulin formation; centre lot 24, con. XI, Bidwell tp., Manitoulin Island.

Superfamily, SPIRIFERACEA

Genus, *Crytina* Davidson 1858

Cyrtina extensa n. sp.

Plate XII, figures 3-6

Description. Shell small, semipyramidal, hinge line long, extending into broad wings. Ventral valve wide, flat cardinal area, unsymmetrical; wide elongate, convex pseudodeltidium. Deep ventral sinus culminating in a short, small, erect beak, extending above cardinal area. Sinus bordered by sharp, high ridges. Two narrow plications on lateral slopes. Dorsal valve gently convex with low, broad fold. Cardinal area obsolete.

Dimensions: Incomplete length, 17 mm.; width, 7·2 mm.; depth, 8·6 mm.

Discussion. This species is founded upon three small specimens collected from the Wiarton dolomite. The wing-like extensions of the cardinal area are so distinctive that the specimen warrants classification.

Types. Holotype, G.S.C. No. 11593; paratype, G.S.C. No. 11070; Wiarton member, Amabel formation, top of road-cut, Wiarton, Ont.

Phylum, MOLLUSCA

Class, PELECYPODA

Order, PRIONODESMACEA

Genus, *Ctenodonta* Salter 1851

Ctenodonta cabotensis n. sp.

Plate XI, figure 6

Ctenodonta cabotensis Johnson (*nomen nudum*), 1934, MS. Univ. Tor., "Stratigraphy and Palæontology of the Cataract Formation", p. 95, Pl. VI, fig. 7.

Ctenodonta cabotensis Johnson (*nomen nudum*), Fritz 1944, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part IV, Contrib. Roy. Ont. Mus. Palæo., No. 8, p. 4.

Description. "Valve subelliptical, moderately convex, straight in front, slanting slightly forward, rounded posteriorly. Length greater than width.

Hinge line gently arched, teeth visible in posterior part of hinge line, consisting of simple parallel ridges and sockets (Taxodont), about 4 in 1 mm. Beak high and rather sharp, situated about $\frac{1}{5}$ the distance from the anterior margin of the shell. Shell ornamentation not seen. Length 7·5 mm., height 4·0 mm." (Johnson, 1934 MS., p. 95).

Discussion. Smaller, more robust and less elongated than *C. machaeriformis* (Hall); nearest *C. minima* (Foerste) but larger and less triangular.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7416; Cabot Head shale, Forks of the Credit, Ont.

Ctenodonta glenna n. sp.

Plate XI, figures 3-5

Description. Shells convex and somewhat triangular, ranging in size from 4 mm. long and 3 mm. wide to 17 mm. long and 13 mm. wide in the holotype, thus representing young and mature forms. Umbonal region broad and fairly well marked; distinctly forward-pointing prominent beaks elevated about $\frac{3}{4}$ mm. above the poorly preserved hinge line, producing a small, somewhat concave pseudo-cardinal area; hinge length apparently less than maximum length of shell; typical taxodont dentition, beak offset approximately two-thirds distance from anterior part of hinge; pronounced concavity in front of beak; ventral and posterior margins uniformly rounded. Fine concentric growth lines preserved on unweathered surfaces.

Discussion. This species is represented by at least thirty casts of both valves, with right valve predominating, collected from the Cabot Head and Grimsby shales.

Types. Holotype and paratypes, Roy. Ont. Mus. Palæo. Cat. No. 26478; Power Glen formation, 12 and 47·6 feet above base; Power Glen, DeCew Falls, Ont.

Genus, *Cleidophorus* Hall 1847

Cleidophorus albionensis n. sp.

Plate XII, figure 12

Description. Shells small, measuring in the holotype 10 mm. long and 6·1 mm. high. Umbonal region broad; beak small, offset 3·7 mm. from anterior margin; hinge line short, bearing well developed taxodont dentition. Short umbonal ridge near hinge line. Antero-dorsal margin slopes at an angle of 30 degrees away from the beak, turning sharply at centre of shell into the rounded antero-ventral margin. Posterior sloping obliquely from end of hinge to point of maximum extension, then gently curving into arcuate ventral margin. Broad, vertical furrow extending from in front of beak half-way to ventral margin. Surface marked by fine concentric growth lines.

Discussion. This species includes all forms with an arithmetical ratio of 2·6 to 2·8 mm. (total length divided by distance beak offset from anterior margin). It is represented by at least ten casts, with both valves present in the collection, the left valve predominating. They were collected from the Cabot Head and Grimsby shale at Hamilton and Albion Falls. The new species derives its name from the latter locality.

Types. Holotype, G.S.C. No. 11594; Grimsby red shales, Cataract group, Albion Falls, Ont.

Cleidophorus minor n. sp.

Plate XII, figure 11

Description. Shells relatively small, measuring, in the holotype, 9·9 mm. long and 6 mm. high; beak offset 3 mm. from the anterior margin. This species differs from *C. albionensis* n. sp. in the greater convexity of the shell, longer and straighter hinge line, blunt anterior and posterior margins, and deeper, slightly curved furrow which extends two-thirds of the way to the ventral margin. Eight specimens with an arithmetical ratio of 3 to 3·4 mm. were collected from the Grimsby shales of Albion Falls and Hamilton.

Types. Holotype, G.S.C. No. 11595; Grimsby red shales, Cataract group, Hamilton, Ont.

Cleidophorus wentworthensis n. sp.

Plate XII, figure 13

Description. This species is closely related to *C. albionensis* n. sp. It is characterized by a more oblique slope to the dorso-posterior margin, resulting in a narrow, rounded posterior; a wide, blunt anterior; arithmetical ratio of 4 mm. Holotype length, 13 mm., height, 7·2 mm., offset of beak, 3·2 mm. Four specimens of this species were collected from the Grimsby red shales at Fruitland and Hamilton. The geographical reference is to the county of Wentworth.

Types. Holotype, G.S.C. No. 11596; Grimsby formation, Cataract group, Hamilton, Ont.

Cleidophorus major n. sp.

Plate XII, figure 10

Description. Shell largest of the four species; length, 18·2 mm., height, 12 mm., beak offset, 6·8 mm. Ovate outline; umbonal region broad, area of greatest convexity; umbonal ridge prominent, extending obliquely from beak to posterior extremity; hinge line shorter than the greatest length; taxodont dentition. Broad anterior margin uniformly rounded; posterior sloping obliquely from end of hinge to point of maximum extension, then curving into ventral margin. Shallow furrow extending half-way to anterior margin, gently curved. Surface marked by fine and commonly crowded concentric growth lines.

Discussion. This species is represented by at least twelve casts. Both valves are present, the right valve predominating in the collections from the Grimsby red shales at Albion Falls and Hamilton, and the grey shales overlying the red beds on Nottawasaga River.

Types. Holotype, G.S.C. No. 11597; Grimsby formation, Cataract group, Hamilton, Ont.

Genus, *Modiolopsis* Hall 1847

Modiolopsis creditensis n. sp.

Plate XI, figure 10

Modiolopsis creditensis Johnson (*nomen nudum*), 1934 MS. Univ. Tor., "Stratigraphy and Palæontology of the Cataract Formation", p. 92, Pl. IV, fig. 4.

Modiolopsis creditensis Johnson (*nomen nudum*), Fritz 1944, "Catalogue of types in the Royal Ontario Museum of Palæontology", Part IV, Contrib. Roy. Ont. Mus. Palæo., No. 8, p. 9.

Description. "The shell is sub-oval and convex. The beak is prominent, about one-fourth the distance from the anterior border of the valve, and slopes backwards in a sweeping, almost straight line to the central area. Hinge line is hidden but appears to be straight. Growth lines well marked in the mature part of the valve but are either absent or worn in the region of the umbone. Ventral border slightly indented. Length, 45 mm.; height, 18 to 20 mm." (Johnson, 1934 MS., p. 92).

Discussion. Differs from *M. kelsonensis* Williams in that more elongate, larger, umbone closer to anterior margin, no sinus on beak, and poorly indented ventral margin. Above description based on rubber squeezes of imperfect casts collected from the Cabot Head red beds at Niagara Falls, Hamilton, Credit Forks, Cataract, and Limehouse. Complete specimens were found during the recent study in the Power Glen shales at DeCew Falls and Grimsby shales at Hamilton.

Types. Holotype, Roy. Ont. Mus. Palæo. Cat. No. 7409; Cabot Head formation red beds (Grimsby), Hamilton, Ont.

Modiolopsis posteroaltis n. sp.

Plate XI, figures 7-9

Description. Shells relatively small measuring on the average 17 mm. long and 6 mm. wide at beak; posterior width greater measuring 8 mm., hence the specific name *posteroaltis*. Beak offset 2 mm. from anterior margin; anteroventral margin gently rounded; umbonal ridge well marked, dorsal in position, extending from beak almost to posterior margin; highest convexity about mid-length, sloping abruptly to dorsal and gently to ventral margin; posterior margin sloping obliquely from end of hinge to point of maximum extension then gently curving to straight or slightly arcuate ventral margin. No markings were observed on the weathered surfaces of the casts.

Discussion. This species is represented by at least eighteen casts with both valves present in the collection, the right valve predominating.

Types. Holotype and paratypes, Roy. Ont. Mus. Palæo, Cat. No. 26477; Power Glen formation, 3 and 9 feet above base, Power Glen, DeCew Falls, Ont.

Subphylum, **CEPHALOPODA**

Class, NAUTILOIDEA

Order, MICHELINOCERATIDA Flower

Family, MICHELINOCERATIDAE Flower

Genus, *Leurocycloceras* Foerste 1928

Leurocycloceras (?) *orangevillense* n. sp.

Plate XIII, figures 1, 2

Description. Orthoceroid, 270 mm. long, expanding from 24 mm. to 39 mm. Cross-section circular at base, depressed dorso-ventrally at top. Suture straight and transverse; chamber a depth of 7 mm. at a diameter of 29 mm.; three and a half camerae to a diameter of 23 mm., five and a half to a diameter of $37\frac{1}{2}$ mm. Broad, straight to oblique annulations, sloping apicad on sides; steeply inclined in apicad direction, flattened on adoral side. Sharp transverse striae, eight to ten occurring between crests of annulations, widely spaced on steep side of annulations, crowded on the adoral slopes. Centrally located, suborthochoanitic siphuncle, very faintly expanding within the camerae; 5·5 mm. diameter at a conch diameter of 29 mm.

Discussion. The shape, annulations, and siphuncle are diagnostic of the genus *Leurocycloceras.* Flower includes in this genus both smooth and broad, transversely striated forms. The new species, tentatively referred to *Leurocycloceras*, apparently represents an advanced stage in which both the annulations and transverse striae are equally developed. It may be related to *Dawsonoceras*, although that genus is characterized by frilled or wrinkled striae. At least fifteen specimens of this new species were collected from the cephalopod facies at the top of the Fossil Hill dolomite. The geographical reference is to the town of Orangeville, Ont.

Types. Holotype, G.S.C. No. 11598; paratype, G.S.C. No. 11069; Fossil Hill formation, Clinton group, Cannings Falls, Nottawasaga River.

CHAPTER IV

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APPENDIX A

Detailed Sections

Section 1: *DeCew Falls* (*see* Plate I)

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; light grey, dense to fine grained; nodular, unevenly bedded, buff to white weathered; lenses of crystalline, pink, crinoidal limestone.	12
	Dolomite; dark to light grey, dense; irregularly bedded, buff weathered; dense chert nodules (Ancaster chert beds); *Clathrodictyon vesiculosum minutum* (Rominger), *Stromatopora* cf. *constellata* Hall, *Favosites forbesi* Edwards and Haime, *F. niagarensis* (Hall), *Enterolasma caliculum* (Hall), *Leptaena rhomboidalis* (Wilckens).	13
Gasport	Limestone; grey to blue-grey, coarsely crystalline; knobby weathered; thin shale interbeds; uppermost 13 inches light to dark grey, dense dolomite transitional into chert beds; lowermost 9 inches a basal conglomerate of elongated to sub-rounded, dark grey limestone pebbles embedded in coarse, porous, light grey limestone matrix; crinoidal, numerous fossils concentrated in thin biostromes.	21·5
DeCew	Dolomite; dark grey, fine grained to dense; enterolithic structure, buff to tan weathered, argillaceous to arenaceous; upper contact ripple-marked, a thin shale or clay seam.	8
Rochester	Shale; green-grey to dark grey, calcareous; interbedded grey, dense to crystalline limestone; upper 12 feet dolomitic, transitional into overlying DeCew dolomite; thin siltstone and limestone interbedded transition zone at base; very fossiliferous, *Stephanocrinus angulatus* Conrad 7, 8, and 9 feet above base.	56
Irondequoit	Limestone; pink to dark grey, crystalline; massive, stylolites; uppermost 3 inches abundant greenish grey shale inclusions and highly fossiliferous; upper contact sharp, no apparent disconformity; basal foot dense buff limestone, *Atrypa reticularis* (Linnaeus), *Parmorthis elegantula* (Dalman), *Stricklandia canadensis* Billings.	8
Reynales	Limestone; dolomitic, light grey, dense, massive, buff weathered; upper beds sandy, upper contact undulating; basal 4 inches limestone, light grey, semicrystalline, phosphatic blebs and greenish grey shale inclusions; *Pentamerus oblongus* Sowerby, *Stricklandia canadensis* Billings, *Whitfieldella nitida oblata* (Hall) in basal 2 feet.	14·5

Detailed Sections—*Continued*

Section 1: *DeCew Falls*—Continued

Formation or member	Description	Thickness
		Feet
Neahga	Shale; greenish grey to dark grey, hackly; upper and lower contacts sharp.	1·25
Thorold	Sandstone; white to light grey, fine grained, massive, buff weathered; grey shale partings.	9
Grimsby	Sandstone; red, fine grained, massive, green and yellow mottled, crossbedded; varying thicknesses of red shale to siltstone; upper contact sharp; *Lingula clintoni* Vanuxem associated with green and red shale blebs.	31
	Shale; red and green; minor bands of red sandstone; *Craniops* sp., *L. clintoni* Vanuxem, *Michelinoceras* sp., *Dalmanites limulurus* Green; in basal 5 inches numerous pelecypods.	11
Power Glen	Shale; calcareous, dark grey to green, fissile; comprises nearly three-quarters of the total section, remainder arenaceous shale and thin beds of light grey, calcareous sandstone and shale; fossiliferous.	48
Whirlpool	Sandstone; quartzose, white to light grey, fine to medium grained, massive, thick bedded, buff weathered; thin zones of grey shale pebbles and small scale crossbedding; contact with Queenston red shales below sharp.	12

Section 2: *Rockway Fifteen Mile Creek*

The major falls directly under the road bridge exposes the DeCew to Irondequoit sequence; the Irondequoit to Grimsby sequence produces a second smaller falls downstream from the above.

Formation or member	Description	Thickness
		Feet
Gasport	Limestone; dolomitic, grey, crystalline; crinoidal, *Atrypa reticularis* (Linnaeus), *Parmorthis elegantula* (Dalman).	12 to 15
DeCew	Dolomite; dark grey, dense, buff weathered.	± 7 (5½, Caley, 1940)
Rochester	Shale; calcareous to dolomitic, dark grey, thin bedded; numerous grey, argillaceous limestone beds increasing in upper half; 3-inch transition zone fossiliferous, argillaceous limestone at base; fossiliferous, *Stephanocrinus angulatus* Conrad at base, and in shale 7·5 and 8 feet up from base.	44·5 (46, Caley, 1940)

Detailed Sections—*Continued*

Section 2: Rockway Fifteen Mile Creek—Continued

Formation or member	Description	Thickness
		Feet
Irondequoit	Limestone; grey, coarsely crystalline to dense at base; massive, buff weathered; crinoidal, *Enterolasma caliculum* (Hall), *Strophonella striata* (Hall), *Fardenia subplana* (Hall), *Atrypa reticularis* (Linnaeus), *Eospirifer niagarensis* (Conrad), *Howellella crispa* (Hisinger), *Whitfieldella intermedia* (Hall).	6 (7, Caley, 1940)
Reynales	Dolomite; grey to bluish grey, dense; thin (3 inch) to thick (28 inch) bedded, grey shale partings; upper contact undulating; basal 1-foot coarse, grey limestone with pyrite, green phosphatic blebs, *Pentamerus oblongus* Sowerby.	12·7 (9·3, Caley, 1940)
Neahga	Shale; soft, greenish grey to blue-grey.	0·5
Thorold	Sandstone; quartzose, greenish grey, fine grained, massive, thin to thick bedded; few green shale partings; upper contact sharp, lower contact colour change only.	10
Grimsby	Sandstone; greenish to whitish grey, fine grained, thin bedded, red mottled.	3 (exposed)

Section 7: Grimsby Beach road

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; buff, dense, thin bedded: small grey, dense and white chert pebbles, sparse in basal 3 feet (Ancaster chert beds).	7+
Gasport	Limestone; buff-grey, dense to finely crystalline, massive, crinoidal; elevation of transitional upper contact 630 feet.	4+
Covered interval	Remainder of Gasport and entire Rochester shale covered; remaining part of section exposed farther downhill.	23
Irondequoit	Limestone; grey, coarsely crystalline, massive, crinoidal; fossiliferous throughout.	6
Reynales	Dolomite; dark to light grey, dense, thin to thick bedded, buff weathered; grey shale partings and seams; upper contact sharp and undulating; basal 15 inches grey, coarsely crystalline limestone, green shale blebs, pyrite; *Pentamerus oblongus* Sowerby.	6

Detailed Sections—*Continued*

Section 7: Grimsby Beach road- Continued

Formation or member	Description	Thickness
		Feet
Neahga (?)	Shale; fissile, greenish grey.	3·6 inches
Thorold	Sandstone; quartzose, greenish grey, fine grained, massive; rare green shale parting.	6
Grimsby	Sandstone; red to reddish grey, fine grained, green mottled; interbedded red and greenish grey shale; *Lingula* cf. *clintoni* Vanuxem fragments at base of exposure.	14

Section 9: Grimsby gorge

Main falls exposes Gasport-Rochester sequence; a second smaller falls downstream exposes remainder.

Formation or member	Description	Thickness
		Feet
Gasport	Limestone; dark grey, coarsely crystalline, crinoidal, thin to thick bedded, knobby weathered, porous; lower contact sharp and undulating.	8 (11 to 14, Caley, 1940)
DeCew	Dolomite; buff-grey, dense, massive, thick bedded; conchoidal fractures.	7
Rochester	Shale; calcareous, dark grey; thin limestone beds, dark grey, dense to finely crystalline, fossiliferous.	33 to 35 (45, Caley, 1940)
Irondequoit	Limestone; pinkish grey to grey, coarsely crystalline, massive; fossiliferous.	4
Reynales	Dolomite; dark grey, dense, thin to thick bedded; grey shale partings; upper and lower contacts sharp; basal 8 inches buff-grey, coarsely crystalline limestone; *Pentamerus oblongus* Sowerby.	9
Thorold	Sandstone; whitish grey, fine grained, massive, thick bedded; greenish grey shale partings.	±7
Grimsby	Sandstone; red, fine grained, thick bedded, yellow and green mottled; sandy red shale partings and seams.	18 (exposed)

Detailed Sections—*Continued*

Section 10: *West Grimsby road-cut*

Formation or member	Description	Thickness
		Feet
Gasport	Limestone; grey, finely crystalline, massive, thick bedded, white weathered, porous.	4
DeCew	Dolomite; argillaceous, grey, dense, massive, buff weathered, conchoidal fractured.	6·5
Rochester	Shale; dolomitic, grey, hard, thin bedded; thin limestone interbeds, dense, grey, barren; upper beds gradational; fossiliferous.	30
Irondequoit	Limestone; grey, coarse to medium grained, crinoidal, massive, porous; upper contact sharp.	4
Reynales	Dolomite; grey, dense, thin to thick bedded, buff weathered; grey shale seams; upper and lower contacts sharp; basal zone dense, *Pentamerus* absent.	12
Thorold	Sandstone; whitish to greenish grey, fine grained; upper 2½ feet massive, remainder thick to thin bedded; green shale partings and 4-inch-thick bed at top.	11
Grimsby	Sandstone; red, fine grained; numerous red shale beds and partings in upper 10 feet; remainder red shale, minor red sandstone lenses.	21
Power Glen (?)	Shale; greenish grey; upper contact sharp.	1 (exposed)

Section 11: *Fruitland road-cliff*

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; buff, dense to sugary, thin bedded; abundant grey, dense to white chert nodules and lenses sparse in basal 2 feet (Ancaster chert beds); fossils in chert, *Lichenalia concentrica* Hall.	10
Gasport	Limestone; buff-grey, dense to finely crystalline, thin bedded, knobby weathered; eastward along Toronto, Hamilton, and Buffalo railway grades into more normal thin bedded, grey, porous, crystalline, crinoidal limestone.	3
DeCew	Dolomite; argillaceous, grey, thin bedded, buff weathered.	6
Rochester	Shale; calcareous, compact, dark grey; thin grey, dense limestone beds increase upward; upper beds dolomitic shale to argillaceous dolomite.	31

Detailed Sections—*Continued*

Section 11: *Fruitland road-cliff*—Continued

Formation or member	Description	Thickness
		Feet
Irondequoit	Limestone; blue-grey, coarsely crystalline, crinoidal.	3·5
Reynales	Dolomite; grey, dense; thin (3 inch) to thick (17 inch) bedded; grey shale partings; basal contact sharp, 3-inch basal transition zone of grey, dense, sandy limestone overlain by 22 inches of grey, coarsely crystalline pyritic limestone; *Pentamerus oblongus* Sowerby.	3 (12, Caley, 1940)
Thorold	Sandstone; quartzose, greenish grey, fine grained, massive, crossbedded; a few green shale beds; *Arthrophycus alleghaniensis* (Harlan).	13
Grimsby	Sandstone; red and green, fine-grained; thin bedded, argillaceous; shale, red and green interbeds; basal 10 feet red, fossiliferous shale.	24 (exposed)

Section 12: *East Stoney Creek road-cut*

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; buff, dense to sugary; dense, grey and white chert nodules and lenses (Ancaster chert beds); basal 1-foot chert free transition zone.	9
Gasport	Limestone; dark grey, sugary to finely crystalline, thin bedded, buff weathered, knobby, porous; lower contact sharp and undulating.	6
DeCew	Dolomite; buff-grey, dense, conchoidal fractured.	6·6
Rochester	Shale; dolomitic, grey to buff-grey; thin bedded, argillaceous limestone at base.	10·6
Irondequoit	Limestone; grey, crystalline; lower contact sharp; basal 3 inches denser grey limestone; crinoidal, *Atrypa reticularis* (Linnaeus).	4
Reynales	Dolomite; grey, dense, thin bedded; a few grey shale partings.	5·5 (exposed)

Detailed Sections—*Continued*

Section 13: *Stoney Creek gorge*

The entire sequence from Queenston to Ancaster chert beds is exposed in the gulch beside the railway station (revised from Caley, 1940).

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; grey, dense, thin bedded, buff weathered; chert nodules and lenses.	10
Gasport	Limestone; grey, thin bedded.	7
DeCew	Limestone; sandy, dark grey, thick bedded; grey interbedded shale.	8
Rochester	Shale; compact, dark grey; interbedded limestone.	14
Irondequoit	Limestone; grey crystalline.	4
Reynales	Dolomite; grey, thick bedded; grey shale partings.	8·5
Thorold	Sandstone; quartzose, light grey to whitish, thick bedded.	6
Grimsby	Sandstone; red, green and grey mottled; red shale interbedded in upper 9 feet; lower 27 feet red shale, siltstone, and limestone: *Helopora fragilis* Hall.	36
Cabot Head	Shale; grey with three thin red bands. Shale and sandstone; calcareous, red. Shale and calcareous sandstone; grev, fossiliferous. Dolomite; grey, thin bedded, and shale interbedded; fossiliferous.	11 1 34 4
Manitoulin	Limestone: buff to bluish grey, dense to crystalline; fossiliferous, lower contact sharp.	4
Whirlpool	Sandstone; whitish to greenish grey, fine grained: thick to thin bedded; grey shale parting near top; contact with underlying Queenston sharp.	10

Section 14: *Highway* 20

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; brown to buff, granular; abundant fossiliferous chert nodules and lenses (Ancaster chert beds).	10
Gasport	Limestone: whitish grey, semicrystalline; fossiliferous; lower contact slightly undulating; upper foot denser buff-grey, dolomitic limestone.	4
DeCew	Dolomite; buff to whitish grey, dense to granular; upper contact thin clay or shale band.	3·3

Detailed Sections—*Continued*

Section 14: *Highway* 20—Continued

Formation or member	Description	Thickness
		Feet
Rochester	Shale; dark grey; limestone, grey, argillaceous increasing upward.	24
Irondequoit	Limestone; whitish grey to dark grey, crystalline, porous, crinoidal; lower contact sharp and undulating, basal conglomerate of small Reynales fragments.	4
Reynales	Dolomite; dark to light grey, dense, buff weathered; grey shale partings; basal 2 feet grey, crystalline limestone; *Pentamerus oblongus* Sowerby.	10
Thorold	Sandstone; upper 3·5 feet light grey, fine grained; remainder grey shale and sandstone interbedded.	7·5
Grimsby	Sandstone; red and green mottled, thick bedded; red shale partings.	5·5 (exposed)

Section 15: *Albion Falls*

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; buff, dense to granular; thin to thick bedded; basal 12 feet grey chert nodules and lenses (Ancaster chert beds); lower contact gradational.	17
Gasport	Limestone; whitish grey to buff-grey, semicrystalline, porous; more massive, denser in upper 3 feet; fossiliferous.	7
DeCew	Dolomite; buff-grey, massive; upper contact sharp lithological break; grey shale partings.	5·5
Rochester	Shale; dark grey, argillaceous limestone, and grey, dense dolomite interbedded.	24
Irondequoit	Limestone; whitish grey to buff, semicrystalline; *Atrypa reticularis* (Linnaeus).	4
Reynales	Dolomite; light to dark grey, dense; grey shale partings and seams; basal 2 feet semicrystalline to dense limestone; *Pentamerus oblongus* Sowerby.	10
Thorold	Sandstone; greenish to light grey, fine grained, cross-bedded; green shale partings and seams numerous.	10
Grimsby	Sandstone; red, fine grained, and shale to siltstone, red, interbedded, shale increasing downward; fossiliferous.	14·6

Detailed Sections -*Continued*

Section 16: *Hamilton Wentworth Street Sherman Avenue*

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; light grey, dense to sugary, irregularly bedded, buff weathered; profusion of grey, dense to white, fossiliferous chert nodules and lenses (Ancaster chert beds).	12
Gasport	Limestone; whitish to buff-grey, semicrystalline to dense; porous, crinoidal; basal 3 feet dense, grey, buff weathered, argillaceous, dolomitic (?) limestone (possibly DeCew equivalent).	8
Rochester	Shale; grey, interbedded with limestone, dense, argillaceous, fossiliferous; upper 5 feet dense, dark grey, argillaceous dolomite to dolomitic limestone; many shale partings.	14
Irondequoit	Limestone; whitish to light grey, semicrystalline to sugary, massive, porous, crinoidal; upper beds argillaceous and thinner bedded; upper contact sharp lithological break; minor basal conglomerate in new Jolley Cut section.	4
Reynales	Dolomite; grey, dense; thin grey shale beds throughout; basal 19 inches grey, dense, dolomitic limestone; *Pentamerus oblongus* Sowerby, *Stricklandia canadensis* Billings.	9·5
Thorold	Sandstone; grey, fine grained, interbedded with shale, green to grey; *Lingula clintoni* Vanuxem fragments associated with shale pebbles (includes Grimsby to Neahga sequence of Armstrong, 1953).	13
Grimsby	Shale and siltstone; red, green mottled, fossiliferous; interbedded red, fine grained, calcareous sandstone.	8
	Sandstone; red, fine grained, thin bedded; red shale partings.	4
	Shale; red and green; interbedded red, calcareous sandstone; *Helopora fragilis* Hall and numerous pelecypods.	17
Cabot Head	Alternating shale and limestone or calcareous sandstone; grey; thin red sandstone bands 21 and 24 feet above base; lower contact gradational.	34
Manitoulin	Dolomite; grey, dense; dolomitic limestone, grey, fine grained, thin bedded; grey shale partings; *Plectodonta transversalis* (Wahlenberg).	11
Whirlpool	Sandstone; grey, quartzose, massive, thin bedded, buff weathered, crossbedded; shale pebbles or galls; upper contact sharp, lower contact ripple-marked, extending down into Queenston red and green shales.	12

Note: For the section exposed by the new Jolley Cut *see* Bolton and Liberty (1955, pp. 40-41) and Armstrong (1953, pp. 15-16; 1955, p. 44). Sandstones and shales assigned to the Grimsby and Neahga by Armstrong should be included in the Thorold; Grimsby is actually the red beds labelled Cabot Head.

Detailed Sections—*Continued*

Section 18: *Ancaster Highway road-cut*

Formation or member	Description	Thickness
		Feet
Eramosa	Dolomite; brown, dense, thin bedded, petroliferous; grey and black, bituminous shale partings; upper 20 feet more massive; top 3 feet one solid band (possible Guelph equivalent).	43
Covered interval	Eramosa and Goat Island members.	55
Goat Island	Dolomite; buff-grey, dense to sugary, massive, thick bedded; abundant grey, dense and white fossiliferous chert nodules and lenses (Ancaster chert beds); lower contact sharp and undulating.	25
Gasport	Limestone; bluish to whitish grey, crystalline, thick bedded, porous; crinoidal.	13 (16, Caley, 1940)
DeCew	Dolomite; argillaceous, grey, dense, thin bedded; grey shale partings.	6 (7, Caley, 1940)
Rochester	Shale; grey interbedded with limestone, buff-grey, dense.	9
Irondequoit	Limestone; dark grey, coarsely crystalline, massive, vuggy; lower contact undulating; crinoidal; *Arachnophyllum* cf. *striatus* (D'Orbigny).	5
Reynales	Dolomite; grey, dense, thin to thick bedded; grey shale partings.	7

Sections 19-20: *Dundas quarry–Sydenham road-cut*

Formation or member	Description	Thickness
		Feet
Guelph	Dolomite; brown to grey, dense to sugary, thick bedded.	10
Eramosa	Dolomite; argillaceous, brown to grey, dense, thick (2 feet) to thin (3 inches) bedded; gypsiferous vugs; black to grey, bituminous, fossiliferous shale partings; petroliferous.	58 (to quarry floor)
Covered interval	Probably Goat Island member.	25
Goat Island	Dolomite; grey, dense to sugary, thin bedded, buff weathered; profusion of grey, dense and white, fossiliferous chert nodules and lenses.	15 (36, Caley, 1940; 21, Nowlan and Shaw, 1937)
Gasport	Limestone; grey to buff-grey, crystalline to dense, thick bedded, knobby weathered, porous; basal contact sharp and undulating.	20 (16, Caley, 1940)

Detailed Sections—*Continued*

Sections 19-20: *Dundas quarry-Sydenham road-cut*—Continued

Formation or member	Description	Thickness
		Feet
Rochester	Shale; dolomitic, dark grey; top 1 foot argillaceous dolomite beds.	5
Irondequoit	Limestone; dark grey, crystalline, massive, crinoidal; upper and lower contacts sharp, latter undulating.	5
Reynales	Dolomite; dark grey, dense, thick to thin bedded, buff weathered, pyrite; grey shale partings.	7 (exposed)

Section 21: *Clappison Corners road-cut*

Formation or member	Description	Thickness
		Feet
Goat Island	Dolomite; buff, granular to dense; abundant grey, dense to white, fossiliferous chert nodules and lenses.	9
Gasport	Limestone; dolomitic, dark grey to whitish grey, crystalline; crinoidal, fossiliferous.	10
Rochester	Limestone; argillaceous, dark grey, dense to crystalline; dense, grey dolomite (?) pebbles (assigned to DeCew by Armstrong, 1953, p. 17); basal 1 foot sandy, calcareous shale with argillaceous limestone interbeds; upper contact undulating.	2·4
Irondequoit	Limestone; blue-grey to dark grey, crystalline; vugs with calcite and gypsum; upper 8 inches darker grey with argillaceous dolomite pebbles (assigned to base of Rochester by Armstrong); uppermost beds argillaceous transition phase as at Hamilton; minor basal conglomerate above undulating lower contact; fossiliferous.	6·8
Reynales	Limestone; dolomitic, grey, dense (in part Irondequoit by Armstrong); grey shale partings; basal 20 inches glauconitic with *Pentamerus oblongus* Sowerby.	9
Thorold	Shale; greenish grey, interbedded with sandstone, grey, fine grained; *Lingula clintoni* Vanuxem fragments (not divisible into Neahga and Grimsby as by Armstrong).	13·5
Grimsby	Sandstone; red, fine grained, interbedded with shale, red and green; *Helopora fragilis* Hall.	12
Cabot Head	Shale; green-grey, interbedded with sandstone, buff, fine grained; *H. fragilis* Hall.	17+

Detailed Sections—*Continued*

Section 23: *East Waterdown road-cut*

Formation or member	Description	Thickness
		Feet
Lockport	Dolomite; buff-grey to grey, crystalline, massive, porous; lower 6 feet of exposure dolomite, dark grey, coarsely crystalline, crinoidal; *Enterolasma caliculum* (Hall), *Fardenia subplana* (Hall), *Rhipidomella hybrida* (Sowerby), *Stegerhynchus neglectum* (Hall), *Eospirifer niagarensis* (Conrad), *Howellella crispa* (Hisinger), *Whitfieldella oblata* (Hall), *Michelinoceras* sp.; basal 2 feet thin grey shale and argillaceous dolomite partings and lenses, *E.* cf. *caliculum* (Hall), *Fenestrellina* cf. *tenuis* (Hall), *Semicoscinium tenuiceps* (Hall), *Leptaena rhomboidalis* (Wilckens), *F. subplana* (Hall), *Dolerorthis dinorthis* (Foerste), *Parmorthis elegantula* (Dalman), *Rhynchotreta americana* (Hall), *S. neglectum* (Hall), *Atrypa rugosa* Hall, *E. niagarensis* (Conrad), *Howellella crispa simplex* (Hall), *Delthyris sulcatus* (Hisinger), *W. oblata* (Hall), *Naticonema niagarense* (Hall), cf. *Bumastus ioxus* (Hall).	35

Section 24: *Road-cut and quarry*

30+ foot quarry face composed mainly of dolomite, whitish grey, sugary, thick to thin bedded, Lockport-Amabel; lower 14 feet of northeast corner of quarry consists of the following sequence, in descending order:

Formation or member	Description	Thickness
		Feet
Gasport equivalent	Limestone; buff-grey to grey, crystalline, massive, crinoidal; grey shale partings.	3·5
Rochester-Irondequoit equivalent	Limestone; grey, crystalline, massive, porous, crinoidal; top 3 inches grey shale to argillaceous dolomite; cf. *Rhipidomella hybrida* (Sowerby).	4
Reynales equivalent	Dolomite; greenish grey to grey, dense, thin bedded, buff weathered; grey shale partings; upper contact sharp.	6·5

Road-cut exposes more porous, blue-grey, crystalline, crinoidal dolomite with *Leptaena rhomboidalis* (Wilckens) and bryozoans, stratigraphically level with upper beds of quarry; similar to Wiarton facies to the north.

Detailed Sections—*Continued*

Section 31: *Milton quarry*

Upper 76 feet varies laterally and vertically; mainly dolomite, white, finely crystalline, massive, porous; lenses of brown, porous, coarse dolomite and dense, argillaceous dolomite; *Fenestrellina* sp., *Leptaena rhomboidalis* (Wilckens), *Stegerhynchus neglectum* (Hall), cephalopods—Amabel formation (reef-like Wiarton facies).

Basal 14 feet divisible into 8 feet of dolomite, grey to bluish grey, crystalline, crinoidal (possible Irondequoit equivalent); underlain by 6 feet of dolomite, grey to greenish grey, dense to fine grained, thin bedded, with green shale partings (Reynales equivalent); contacts sharp lithological breaks.

Section 37: *Limehouse railroad-cut*

Formation	Description	Thickness
		Feet
Amabel	Dolomite; bluish grey to white, finely crystalline, massive, porous, crinoidal; *Parmorthis elegantula* (Dalman), *Bumastus ioxus* (Hall) (a second exposure of similar dolomite in quarry just to north adds another 20 feet to the section).	12
Reynales	Dolomite; argillaceous, dark grey, dense, thin to thick bedded, buff weathered; grey shale seams.	8
Cabot Head	Shale; sandy, grey; dolomite, grey to buff, dense interbeds; *Helopora fragilis* Hall, *Cleidophorus* sp., *Ctenodonta elliptica* (Hall), *C. glenna* n. sp., *Modiolopsis orthonota* (Conrad), *Spirorbis* sp. (Thorold equivalent).	7·8
	Sandstone; calcareous, red, fine grained, massive, thick to thin bedded; arenaceous limestone; red shale partings; *Phaenopora constellata* Hall, *P. expansa* Hall, (Grimsby equivalent).	5+
	Shale; green to grey.	4+

Section 46

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; grey to white, crystalline, massive, thick bedded, buff weathered, porous.	10
Reynales	Dolomite; greenish to dark grey, dense, thin bedded, buff, knobby weathered; grey shale partings; disseminated pyrite; *Halysites catenularia* (Linnaeus), *Favosites* sp., *F. hispidus* Rominger, *F. niagarensis* Hall, *Protaraea* sp., *Fenestrellina* sp., *Pentamerus oblongus* Sowerby.	7·7

Detailed Sections—*Continued*

Section 46—Continued

Formation or member	Description	Thickness
		Feet
Cabot Head	Shale; bluish to grey; hard, dolomitic interbeds; *Helopora fragilis* Hall and numerous pelecypods similar to those found in the same horizon at Nottawasaga River (65).	12
	In talus at base of falls, washed out of whirlpool, blocks of shale, red, green mottled and limestone, argillaceous and arenaceous, green and red, bearing *H. fragilis* Hall, *Phaenopora expansa* Hall, cf. *Rhynchonella janea* Billings, *Stegerhynchus neglectum* (Hall), *Leperditia* sp. (Grimsby equivalent).	

Section 47

Formation	Description	Thickness
		Feet
Cabot Head	Shale; grey; dolomite, grey, dense to fine grained, buff weathered, interbedded; fossils in cherty dolomite.	10
Manitoulin	Dolomite; grey, dense to fine grained, thin to thick bedded, buff weathered, pyrite; vugs with calcite; chert with fossils; lower contact sharp, thin grey shale beds separating Manitoulin and Whirlpool.	8
Whirlpool	Sandstone; greenish grey, fine grained, thick to platy bedded; grey shale partings; elevation Whirlpool-Queenston contact 1,025 feet.	6·6

Section 62

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; whitish to grey, crystalline, massive, thick bedded, buff weathered, porous; in road-cut to west 3-foot exposure of dolomite, whitish grey, crystalline, porous.	7
Lions Head	Dolomite; white to grey, dense, thin bedded; grey shale partings; upper contact sharp and undulating; resembles Reynales of section 46 and blocky, white Lions Head of northern outcrops.	1·3 (north bank) 3 (south bank)
Fossil Hill	Dolomite; brown to brownish grey, finely crystalline; massive, thin bedded in upper and lower parts; upper contact sharp; fossils abundant.	7+ (exposed)

Detailed Sections—*Continued*

Section 62—Continued

Formation or member	Description	Thickness
		Feet
Cabot Head	Just downstream from outcrop, in creek bed, are large blocks of red, argillaceous, calcareous sandstone, similar to Grimsby equivalent of other sections; fossiliferous, *Helopora fragilis* Hall, *Phaenopora constellata* Hall, *P. expansa* Hall, *Hallopora* sp., *Rhynchonella* sp. Presence of these red beds, as well as scarcity of fossils in the lowest exposures of Fossil Hill, suggests that 7 feet is close to the true thickness of the formation. Since originally examined in 1951 the contact of the Fossil Hill with some 2 feet of green Cabot Head shale has been exposed confirming this thickness.	2+ (exposed)

Section 65: *Nottawasaga tributary* (*see* Plate III B)

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; white to light grey, fine grained, massive, porous; 6 feet of thin bedded, grey, argillaceous dolomite 10 feet above base.	49
Fossil Hill	Dolomite; grey, crystalline, massive, thin to thick bedded, buff weathered; corals and *Pentamerus oblongus* Sowerby throughout; Cephalopoda in upper 2 feet.	8
Cabot Head	Fifty-two foot composite sequence from base of Cannings Falls down river to Queenston-Whirlpool falls; three major sections:	
	Section III. Shale; grey; interbedded with sandstone, calcareous and argillaceous, grey, dense; *Helopora fragilis* Hall, Pelecypoda.	9
	Section II. Sandstone; red, fine grained, with limestone, arenaceous, red, and red shale interbeds upper 3·5 feet; remainder grey shale and argillaceous limestone, interbedded; thin red shale and sandstone beds 4 and 5 feet above base.	10
	Covered interval.	4
	Section I. Shale; grey; interbeds of sandstone, calcareous, grey, fine grained, and green limestone; fossiliferous; red shale and sandstone 15, 16, and 20-22 feet above base.	23
	Covered interval.	6

Detailed Sections—*Continued*

Section 65: *Nottawasaga tributary* (*see* Plate III B)—Continued

Formation or member	Description	Thickness
		Feet
Manitoulin	Dolomite; grey, dense, buff weathered and limestone, dolomitic, grey, crystalline; thin to thick bedded, argillaceous; white chert nodules and lenses; fossiliferous; lower contact sharp lithological break.	26
Whirlpool	Sandstone; whitish grey, fine grained, thick to thin bedded, crossbedded; rare greenish grey shale partings; lower contact sharp on Queenston red shale.	22

Section 71: *Hornings Mills*

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; whitish grey, crystalline, massive, porous.	17
Fossil Hill	Dolomite; light grey, dense, thin bedded; upper contact undulating; *Favosites* cf. *favosus* (Goldfuss).	8
Cabot Head	Shale; grey; minor thin red sandstone beds. Loose at base of falls, sandstone, argillaceous red, fine grained; fossiliferous, *Phaenopora expansa* Hall, *P. constellata* Hall; limestone, fine grained to dense, grey, fossiliferous; *P. expansa* Hall, *P. constellata* Hall, *Helopora fragilis* Hall, *Stegerhynchus neglectum* (Hall), *Rhynchotreta* sp., *Cornulites* sp.; similar to Section II at Nottawasaga River (65).	5 (exposed)
Covered interval	Mainly Cabot Head.	55
Manitoulin	Dolomite; dark grey, crystalline, brown weathered, more massive than usual, thin to thick bedded; argillaceous and thin grey shale units; white chert not as abundant; fossiliferous, confined to sandy, argillaceous dolomite; section exposed some 1,000 feet downstream from falls.	12·5

Detailed Sections—*Continued*

Section 77

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; white, dense, massive, porous.	34 (exposed)
Lions Head	Dolomite; brown to whitish brown, dense, thin bedded, blocky; basal 8 inches with rare chert nodule and *Favosites* colonies.	10
Fossil Hill	Dolomite; brown, crystalline, thin bedded; chert lenses; large and small *Pentamerus oblongus* Sowerby and *Favosites niagarensis* (Hall) in basal 3 feet; corals abundant in upper beds, *Favosites favosus* (Goldfuss), *F. niagarensis* (Hall), *Halysites catenularia* (Linnaeus) *Syringopora retiformis* Billings, *Arachnophyllum pentagonum* (Goldfuss), and Stromatoporoidea.	8·5
Dyer Bay	Dolomite; blue-grey to dark grey, crystalline to dense; grey shale lenses and partings; upper contact undulating; *Helopora fragilis* Hall, *Hallopora* sp., *Pachydictya* sp., *Rhynchonella* cf. *janea* Billings, *Dolerorthis* cf. *flabellites* (Foerste), *Leperditia* sp., *Zygobolba williamsi* Ulrich and Bassler; section actually exposed at eastern end of Fossil Hill ridge, section 78.	2
Covered interval	Dyer Bay and Cabot Head formations.	100
Manitoulin	Dolomite; dark brownish grey, crystalline, thin bedded to platy, vuggy, white chert nodules; fossiliferous; exposed in road ditch north of upper dolomite sequence; Manitoulin-Queenston contact at elevation 1,012 (Caley, 1944), with 28·6 feet of Manitoulin proper.	1 (exposed)

Section 80

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; buff to white, finely crystalline, massive.	12
Lions Head	Dolomite; brown to whitish brown, dense to sublithographic; blocky, becoming more massive in upper beds transitional into Colpoy Bay member.	21·5
Fossil Hill	Dolomite; brown, crystalline, thin bedded; upper contact sharp; lower 6 feet with *Pentamerus oblongus* Sowerby and scattered coals; remainder coral bioherm.	11 (exposed)

Detailed Sections—*Continued*

Section 88: *Owen Sound*

Formation	Description	Thickness
		Feet
Manitoulin	Composite sequence in escarpment (2) and quarry (1) sections on northeastern outskirts of the city; surveyed thickness 35 feet, reduced to 25 feet by assuming a dip of 39 feet per mile southwest.	
	(1) Most southeasterly quarry; elevation of top 713·4 feet. Dolomite, dark grey to blue-grey, granular to crystalline, thick to thin bedded, buff weathered; white, dense chert lenses and nodules concentrated in upper 4 feet; fossiliferous.	15·5
	(2) Escarpment section; elevation of Queenston red shale contact 678·3 feet. Dolomite, dark grey, dense, thin (1- to 4-inch) to thick bedded, brown weathered; fossils few, concentrated in upper 1 foot.	11

Section 105: *Inglis Falls road-cut* (*see* Plate II B)

Formation or member	Description	Thickness
		Feet
Lions Head	Dolomite; white to whitish grey, dense, massive, blocky, buff weathered; chert nodules; lower contact sharp.	9
Fossil Hill	Dolomite; brown to dark grey, dense to crystalline; basal 4 inches argillaceous; fossiliferous; lower contact sharp and undulating, elevation 790·8 feet.	7·5
Cabot Head	Shale; greenish grey, pyrite; *Lingula* fragments, *Leperditia* sp.	5+ (exposed)

Section 114

Formation or member	Description	Thickness
		Feet
Lions Head	Dolomite; whitish brown, dense, blocky.	4+
Fossil Hill	Dolomite; brown, crystalline, massive, knobby weathered; fossiliferous.	12
Dyer Bay	Dolomite; brown to dark grey, crystalline to fine grained; upper 6 inches thin bedded with grey shale lenses; contact with Fossil Hill undulating; *Helopora fragilis* Hall, *Hallopora magnopora* (Foerste), *Pachydictya crassa* Hall, *Rhynchonella janea* Billings, *Rhynchotreta lepida* Savage, *Homoeospira* cf. *lowi* (Whiteaves), *Leperditia cabotensis* Ulrich and Bassler, *Zygobolba williamsi* Ulrich and Bassler.	2 (exposed)

Detailed Sections—*Continued*

Section 126

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; white to buff, fine-grained, massive, slightly porous; basal contact sharp. Several small patches of Wiarton dolomite exposed north along road; whitish grey, blue mottled, crystalline, massive, fossiliferous.	18
Lions Head	Dolomite; brown, dense to sublithographic, blocky, white weathered; basal 4 feet very thin bedded to platy, conchoidal fractured with small white chert nodules; lower contact sharp.	20+
Fossil Hill	Dolomite; brownish to whitish grey, crystalline, thin bedded; basal 6 feet *Pentamerus oblongus* Sowerby; chert in top 2 feet.	14

Section 135

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; brown, dense, massive, porous; unfossiliferous.	12·5+
Lions Head	Dolomite; dark brown, dense, blocky, white weathered; lower contact sharp.	16·5
Fossil Hill	Dolomite; dark brown to whitish, dense to crystalline; *Pentamerus oblongus* Sowerby and corals.	15
Dyer Bay	Dolomite: brownish to dark grey, fine grained, thin bedded: upper 3 inches platy with green shale fragments and partings; *Leperditia cabotensis* Ulrich and Bassler, *Zygobolba williamsi* Ulrich and Bassler.	1 (exposed)

Section 140: *Oxenden Falls*

Formation	Description	Thickness
		Feet
Fossil Hill	Dolomite; brown, crystalline, thick to thin bedded; rich in *Pentamerus oblongus* Sowerby; elevation of base 690·4 feet.	3 (exposed)
Wingfield (?)	Dolomite: brown, dense, white weathered; poorly exposed.	14

Detailed Sections—*Continued*

Section 140: *Oxenden Falls*—Continued

Formation or member	Description	Thickness
		Feet
Dyer Bay	Dolomite; dark blue-grey, dense to finely crystalline, thin, irregularly bedded; greenish grey shale partings and flecks; intraformational conglomerate lenses; basal 2 feet thick bedded, grey, dense dolomite; fossiliferous—*Favosites forbesi dyerensis* n. var., *Coelospira planoconvexa* (Hall), *Tentaculites distans* Hall, *Spirorbis* sp., *Arabellites* sp., *Lumbriconerites* sp.	12
Cabot Head	Shale; green; exposed at base of falls.	4+

Section 151: *Wiarton road-cut*

Formation or member	Description	Thickness
		Feet
Guelph	Dolomite; brown, sugary to dense, thin bedded; more massive in basal 9 feet, buff to white weathered; rare bituminous streak and faint petroliferous odour; *Parmorthis elegantula* (Dalman), *Howellella crispa* (Hisinger); elevation of base 756 feet.	23
Covered interval	In part Eramosa dolomite; brown, crystalline to fine grained, thin bedded to platy, highly bituminous, petroliferous odour; bedding undulates and dolomite domed (Section 152).	51
Wiarton	Dolomite; white to whitish grey, blue-grey mottled, crystalline, massive, porous, fossiliferous; forms top of main road-cut, elevation of top 705 feet; lower contact transitional.	16
Colpoy Bay	Dolomite; whitish to blue-grey, purple mottled, sugary, massive, buff weathered; vugs with gypsum; lenses of overlying Wiarton facies; basal 15 feet more massive, blocky, brown, denser dolomite; lower contact transitional; crinoid columnals, cup corals, *Stegerhynchus neglectum* (Hall), *Eospirifer eudora* (Hall), cephalopods.	58
Lions Head	Dolomite; brown, dense to sublithographic, blocky, white weathered.	6
Fossil Hill	Dolomite; brown, crystalline, thin bedded; thicker bedded in upper 6 feet; top 2·5 feet massive, buff, dense, transitional dolomite with rare chert nodules; fossiliferous (Section 150).	16

Detailed Sections—*Continued*

Section 161

Formation or member	Description	Thickness
		Feet
Lions Head	Dolomite; dark to light brown, dense, blocky, white weathered; top 5 feet more massive, purple-mottled, brown, dense dolomite transitional into Colpoy Bay; lower contact sharp lithological break.	23
Fossil Hill	Dolomite; brown, crystalline, thin bedded; top 1 foot massive, brown, dense dolomite; *Pentamerus oblongus* Sowerby and Stromatoporoidea abundant, few corals.	15·6
Wingfield	Dolomite; argillaceous, dark brown to grey, fine grained, thin bedded; green shale partings and flecks; *Leperditia* sp.	2 (exposed)

Section 187: *Hope Bay*

Composite section of several exposures north along ridge from Fossil Hill road-cut to high cliff at north end of Lions Head—Wiarton (?).

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; white to light grey, sugary, massive, buff weathered, porous, unfossiliferous (possibly includes Wiarton at top).	65+
Lions Head	Dolomite; brown, dense, blocky, white weathered; thicker bands in upper 3 feet; rare chert nodule.	17+
Fossil Hill	Dolomite; coarsely crystalline, light brown, thin bedded; neither upper nor lower contacts exposed; *Pentamerus oblongus* Sowerby banks; elevation of base 657·4 feet.	20+
Wingfield	Most of 14·9-foot section covered; Caley (1947) records the following from base of Fossil Hill exposure down:	
	6. Covered interval.	2·77
	5. Dolomite; grey to brownish grey, medium grained, thin (¼ inch to 2 inches) bedded; green shale pellets and partings.	2
	4. Covered interval. Loose grey to green, argillaceous dolomite possibly from this interval.	3·34
	3. Dolomite or limestone; grey, hard, thin (½ inch to 1 inch) bedded.	2
	2. Covered interval.	4·35
	1. Shale; soft blue-grey; elevation of base 642·4 feet.	0·5

Detailed Sections—*Continued*

Section 187: *Hope Bay*—Continued

Formation or member	Description	Thickness
		Feet
Dyer Bay	Dolomite; argillaceous, grey, crystalline to dense; thin (1 inch to 6 inches), irregularly bedded; greenish grey shale partings; *Aulopora* sp., *Syringopora* sp., *Favosites* sp., *Helopora fragilis* Hall, *Phaenopora expansa* Hall, *Pachydictya* sp., *Rhynchonella janea* Billings, *Rhynchotreta lepida* Savage, *R. cabotensis* Williams, *Stegerhynchus neglectum* (Hall), *Hormotoma subulata* (Conrad), *Leperditia cabotensis* Ulrich and Bassler, *Zygobolba williamsi* Ulrich and Bassler.	9·33
	Dolomite; argillaceous, grey; intraformational conglomerate.	3
	Dolomite; grey, dense, thick bedded, buff weathered, conchoidal fractured.	2
Cabot Head	Shale; fissile, blue-green; elevation of top 628·1 feet.	2 (exposed)

Section 190: *Jackson Cove* (*after* Caley 1944)

Formation or member	Description	Thickness
		Feet
Colpoy Bay-Lions Head-Fossil Hill	Dolomite; white to light grey, medium grained, massive, buff weathered, porous (Colpoy Bay); underlain by dolomite, brown, dense, blocky, white weathered with chert nodules in basal beds (Lions Head), 12 feet exposed (elevation of top 795·7 feet); dolomite, brown, crystalline, thin bedded, fossiliferous; slump blocks in lower part (Fossil Hill), 9 feet exposed (elevation of base 764·5 feet).	55+
Wingfield	Dolomite; grey, fine to medium grained, thin (2 to 8 inch) unevenly bedded; reddish brown mottling.	8+
Covered interval	Near top loose Dyer Bay dolomite, blue-grey, fine grained; *Helopora fragilis* Hall, *Favosites forbesi dyerensis* n. var., *Rhynchotreta cabotensis* Williams, *R. lepida* Savage, *Calymene clintoni* (Vanuxem), *Leperditia cabotensis* Ulrich and Bassler, *Chilobolbina punctata* Ulrich and Bassler, *Zygobolba williamsi* Ulrich and Bassler.	49·5

Detailed Sections—*Continued*

Section 190: *Jackson Cove* (*after* Caley 1944)—Continued

Formation or member	Description	Thickness
		Feet
Cabot Head	Shales and limestone sequence; elevation of top 707·1 feet.	
	4. Shale; calcareous, greenish grey; firm, with platy, grey, argillaceous limestone bands; *Helopora fragilis* Hall.	17·4
	3. Limestone; grey, fine grained, buff weathered; *Phaenopora ensiformis* Hall, *Rhynchonella janea* Billings.	1
	2. Shale; soft, green.	1·5
	1. Shale; soft, red; thin red, calcareous sandstone to sandy limestone bands.	3·5
Covered interval	Mainly Cabot Head formation.	85·7
Manitoulin	Dolomite; grey, fine grained; thin (2 to 6 inch) bedded, buff weathered; *Dolerorthis flabellites* (Foerste).	18 (exposed)

Section 220: *North from Lions Head village* (*see* Plates II A, III A)

Formation or member	Description	Thickness
		Feet
Colpoy Bay	Dolomite; grey to white, fine grained, massive.	40+
Lions Head	Dolomite; dark brown, dense to sublithographic, blocky, unevenly (2 to 5 inch) bedded, more massive in lower 8 feet; chert nodules in basal beds.	24+
Fossil Hill	Dolomite; dark brown, finely to coarsely crystalline, massive; chert nodules, fossiliferous.	7
	Dolomite; brown, dense to sublithographic, blocky; similar to overlying Lions Head; *Pentamerus oblongus* Sowerby.	6
	Dolomite; dark brown, crystalline, thick bedded, fossiliferous; elevation of base 589·7 feet.	4·5

Detailed Sections—*Continued*

Section 220: North from Lions Head village—Continued

Formation or member	Description	Thickness
		Feet
Wingfield	Considerable variation; typical section in descending order as follows:	
	Shale; greenish grey to dark green.	2
	Dolomite; light grey, dense; green shale partings; Ostracoda.	1
	Dolomite; argillaceous, dark greenish grey, dense, compact.	3
	Shale; dark green; grading into lenses of light grey to brown, dense, knobby, argillaceous dolomite.	2
	Shale; calcareous, green to greenish grey.	2

APPENDIX B

Logs of Hydro-Electric Power Commission and Rainbow Bridge Site Diamond Drill-Holes, Niagara River, Ontario

Hole No. P-1-4

Location: 30,641·8 feet N., 306·9 feet E. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 558·3 feet
Depth of overburden: 3·2 feet
Total depth: 254·4 feet
Drilled: Jan.-Feb., 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Gasport Member
3·2-5·6	Core missing
5·6-33·9	Limestone; brownish grey to dark grey, semicrystalline to dense; crinoids restricted to lower 6 feet; poorly developed conglomerate in basal 0·5 foot; stylolite at 29·1; upper 7 feet more granular, brown dolomitic limestone
	DeCew Formation
33·9-42·4	Dolomite; dark grey to buff, dense to sugary; a few shale partings; upper contact sharp and undulating
	Rochester Formation
42·4-69·7	Shale; dark grey, in part, calcareous; hard bands at 51·1, 53·3-53·4 feet; upper contact arbitrary, drawn where argillaceous material ceases to be important but may be placed at 45·1 feet
69·7-74·9	Limestone; fossiliferous with varying thicknesses of grey shale; *Howellella crispa* (Hisinger) at 70·1 feet
74·9-88	Shale; grey; bryozoan limestone bands at 77·1-77·2, 78·6, 80·4, 87·8 feet
88 -98·1	Shale; dark grey; bryozoan limestone bands at 88, 88·3, 88·7-89, 89·1, 89·2, 89·6, 89·9, 90·3-90·6, 90·9-91·4, 91·5-91·7, 91·8-91·9, 92·1-92·4, 94·5-94·7, 95-95·6, 95·7-95·8, 96·1, 96·7, 96·9-97·1, 97·2, 97·5, 97·9 feet
98·1-100·5	Core missing
	Irondequoit Formation
100·5-111·1	Limestone; light grey to pinkish grey, crystalline; *Strophonella* cf. *striata* (Hall) at 100·8 feet, *Howellella crispa* (Hisinger) at 101·87 feet, *Parmorthis elegantula* (Dalman) at 102·3 feet, *Atrypa reticularis* (Linnaeus) at 107·6 and 109·1 feet
	Reynales Formation
111·1-124	Dolomite; dark grey, dense; shale partings and fossiliferous, crystalline limestone in basal 2·3 feet; gypsum at 113·8 feet; upper contact sharp; *Rhipidomella hybrida* (Sowerby) in shale at 124 feet

HOLE NO. P-1-4—*Continued*

Depth	Lithology
Feet	
	Neahga Formation
124 -130	Shale; black, fissile; basal 0·3 foot calcareous
	Thorold Formation
130 -138·9	Sandstone; whitish grey, fine grained; shale at 134·4, 138·2-138·6 feet (fragments)
	Grimsby Formation
138·9-142·3	Sandstone; red; minor shale partings; upper contact simple colour change in sandstone
142·3-142·6	Shale; red
142·6-143·8	Sandstone; red and grey
143·8-146·8	Shale; red, to argillaceous sandstone
146·8-147·1	Shale; red
147·1-148	Sandstone; red
148 -149·2	Shale; red; sandstone at 148·1-148·3 feet
149·2-151·3	Sandstone; red and green
151·3-151·6	Shale; red
151·6-160·4	Sandstone; red; shale at 152 (pellets), 153·5, 154·3, 155·3 (pellets), 157·9-158, 158·6-158·9, 159·2-159·3, 159·6-159·7 feet
160·4-161·4	Shale; red
161·4-162·2	Sandstone; red
162·2-165·5	Shale and sandstone interbedded; red
165·5-169·9	Shale; red; minor sandstone
169·9-172·1	Shale; red
172·1-173·3	Sandstone; red, green mottled
173·3-175·8	Shales; red; sandstone bed at 174·9-175·1 feet
175·8-180·4	Sandstone; red; shale partings in middle
180·4-182·3	Shale and sandstone; red
	Power Glen Formation
182·3-182·7	Shale and sandstone interbedded; green; upper contact transitional in appearance, red shale on sandstone
182·7-184·2	Sandstone; two thin shale bands
184·2-188·7	Shale; grey; minor limestone or calcareous sandstone at 184·7-185, 185·5-185·9 feet
188·7-201·7	Sandstone; calcareous, light grey, very fine grained; shale at 189·1-189·3, 191·6, 192·6, 197·7-198·5 (partings), 198·8, 198·9, 199·4-199·6, 200·3-200·6 feet; limestones at 188·8-189·1, 190·8-191·3 feet; thin section at 200 feet consists of finely medium- to fine-grained, clear and dusty quartz (98%) with carbonate (1%) and secondary clear quartz as cement; accessories—chlorite, zircon, microcline, albite, leucoxene, and collophane (?)
201·7-206·1	Shale; grey
206·1-207·4	Sandstone; grey
207·4-209·6	Shale; minor sandstone beds
209·6-213·1	Sandstone; calcareous, light grey
213·1-216·0	Shale; grey
216·0-222·0	Sandstone; calcareous, light to dark grey; lower contact, where shale commences, 0·1 foot thick

HOLE NO. P-1-4—*Continued*

Depth	Lithology
Feet	
	Whirlpool Formation
222·0-237·6	Sandstone; quartzose, greenish grey, fine grained; shale pellets at 232·5-233, 233·8 feet
	Queenston Formation
237·6-255·4	Shale and siltstone; red and green

HOLE NO. F-4

Location: 29,192·5 feet N., 886·8 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 565·7 feet — Depth of overburden: 0·9 foot

Total depth: 255 feet — Drilled: Feb., 1950

Core logged by T. E. Bolton, 1951.

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
0-2	Core missing
2-38·9	Dolomite; buff-grey, dense to fine, coarser bands at 36·5 and 37·6 feet; rare shale parting and calcite-filled vug; *Enterolasma* cf. *caliculum* (Hall) at 26·9 and 36 feet; lower contact transitional
	Gasport Member
38·9-48·1	Limestone; buff-grey to grey, porous, medium grained, crinoidal; green shale at 47·7-47·8 feet; lower contact undulating; basal conglomerate poorly developed; not typical Gasport facies
	DeCew Formation
48·1-57·6	Dolomite; grey to buff, dense
	Rochester Formation
57·6-111·7	Shale; calcareous, grey; upper 1·5 feet dolomitic; bryozoan limestone at 66·4, 66·8, 66·9, 67·3, 68·1-68·3, 83·4, 86·3 (shale interbedded), 87·9-88·7 (shale interbedded), 93-93·1 feet; limestone and shale interbedded at 102·1-102·4, 103·1-103·9, 104·9-106·7, 108-108·5, 108·7-110·4 feet
111·7-115·5	Limestone and shale; grey, interbedded; lower contact transitional through argillaceous limestone; *Atrypa reticularis* (Linnaeus) at 115·1 feet, *Eospirifer niagarensis* (Conrad) at 115·4 feet

HOLE NO. F-4—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
115·5-126·1	Limestone; pinkish grey, coarsely crystalline; lower contact undulating; *Atrypa reticularis* (Linnaeus) at 121·8, 122·1, 123·3, 124·2 feet
	Reynales Formation
126·1-137·4	Dolomite; dark to buff-grey, dense; grey shale partings at 130·6, 130·8-131, 131·2 feet
137·4-139·5	Limestone; argillaceous, grey, coarse grained, fossiliferous
	Neahga Formation
139·5-145·4	Shale; black, fissile; upper and lower contacts sharp
	Thorold Formation
145·4-155·1	Sandstone; quartzose, greenish grey to white, red, and green 152·8-153·2, 154·3; shale, green, 150-150·5, 150·6 feet; upper 0·8 foot abundant green shale fragments producing conglomerate
	Grimsby Formation
155·1-155·2	Sandstone; red
155·2-156·4	Shale; red
156·4-195·9	Sandstone; red, yellowish green, to green mottled, fine grained; red shale at 167·6-167·8, 169-169·7, 170-171·3, 174·5, 174·8, 175·2-175·8, 176·1-177·4, 177·9-178·8, 179·1-179·7, 180·1-180·7, 183, 185·3-188, 188·9-189·2, 189·4-190·5, 191-192, 192·6, 193·8, 194-195·9 feet; lower contact red to green shale
	Power Glen Formation
195·9-196	Shale; green
196 -196·8	Sandstone; white, fine grained
196·8-198·9	Sandstone and shale interbedded
198·9-212·2	Sandstone; quartzose, whitish grey, fine grained; grey shale at 201·7-202·1 feet
212·2-221·5	Shale; arenaceous, grey
221·5-229·8	Sandstone; argillaceous, grey, dense; gradual transition into underlying Whirlpool sandstone from 227 feet down
	Whirlpool Formation
229·8-250·2	Sandstone; white to light grey, fine grained, coarsening from 245 feet down; grey shale fragments at 249·5-250 feet; grey shale at 237·9-238·1, 238·7-238·8 feet
	Queenston Formation
250·2-256·1	Sandstone; argillaceous, red

Hole No. F-1

Location: 26,560·0 feet N., 3,349·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 568·2 feet Depth of overburden: 6·1 feet
Total depth: 274·9 feet Drilled: Jan., 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
6·1- 7	Core missing
7 -21·1	Dolomite; dark brownish grey, dense; some calcite and bituminous partings, but non-petroliferous
21·1-34·5	Limestone; highly porous (*Favosites* and Brachiopoda), granular, brown to brownish grey; basal ½ foot conglomeratic
	Gasport Member
34·5-56	Limestone; highly porous (*Favosites*), grey to brownish grey, semicrystalline
56 -67·6	Limestone; dark to light grey, crinoidal, crystalline
	DeCew Formation
67·6-80	Dolomite; argillaceous, dark grey, dense; upper 0·13 foot brownish grey
	Rochester Formation
80 -90·8	Shale; highly calcareous or dolomitic
90·8-101·5	Shale; calcareous, grey
101·5-105·1	Limestone with thin shale partings; Bryozoa
105·1-133	Shale; black with thin calcareous bands at 107·5-107·7 (Bryozoa), 109·8-110·4, 114·8-115, 115·4-116, 116·5, 123·8-124·6, 125·6-125·7, 127·8, 128·3, 128·6, 129·4, 130·8-131·1 feet
133 -134·6	Shale; highly calcareous; numerous Bryozoa and Brachiopoda
	Irondequoit Formation
134·6-145·5	Limestone; pinkish grey to grey, crystalline; upper 1 foot darker as argillaceous material increases, upper contact sharp; *Fardenia subplana* (Hall) at upper contact, *Strophonella* sp. at 134·7 feet, *Atrypa reticularis* (Linnaeus) at 134·8 and 135·4 feet, *Plectodonta transversalis* (Wahlenberg) at 137 feet
	Reynales Formation
145·5-158·8	Dolomite; dark grey, dense, rarely argillaceous; thickest shale bands in basal 2·8 feet; crinoidal dolomite brecciated in appearance
	Neahga Formation
158·8-164·7	Shale; fissile, dark black; basal 0·65 foot calcareous; tongues and lenses of argillaceous limestone, extending into or included in the Thorold

HOLE NO. F-1—*Continued*

Depth	Lithology
Feet	
	Thorold Formation
164·7-172·6	Sandstone; quartzose, whitish grey, fine grained; reddish tinged basal 4 feet; red shale at 168·6-168·9, 169·7-169·9, 170·7, 170·9 feet; green shale at 165·2, 166·9-167·5 feet; basal 0·2 foot large and small red and green shale pellets; thin section at 165·9 feet shows finely medium to fine grained, compact, clear and dusty quartz (95%); accessories, carbonate (4%), chlorite, biotite, zircon, albite-oligoclase, microcline, apatite, leucoxene, and collophane (?); thin section at 171 feet shows medium-grained, compact, clear and dusty quartz; pyrite, hematite, carbonate, chlorite, biotite, zircon, microcline, plagioclase, magnetite, and leucoxene
	Grimsby Formation
172·6-204·7	Sandstone; red, green mottled, fine grained; thin shale bands at 174-174·5, 181·1 (pellets), 183·9-184, 184·4-185·2, 186·1-186·4, 186·6-187·8, 188·6-189·1 feet
204·7-214·7	Shale; red, green mottled; sandstone bands at 205-205·5, 207·6-208·4, 210·4-210·8, 212·8-213, 213·1-213·5, 214·4, 214·7 feet
	Power Glen Formation
214·7-215·1	Shale; greenish grey
215·1-229	Sandstone; light grey, fine grained; shale bands at 215·4-215·5, 221·9-222·1, 224·2-225 feet; some fine crossbedding; grey shale pellets scattered throughout; upper contact marked by a seam of red oolitic-iron shale
229 -250	Shale to siltstone; dark grey; calcareous bands at 242·3-242·5, 243·5, 244·1-244·6, 249 feet
	Whirlpool Formation
250 -270·1	Sandstone; quartzose, whitish grey, fine grained; argillaceous material increasing upwards until upper 2 feet dark; upper contact transitional into siltstone; shale pellets at 261·7, 266-266·9 feet; some small-scale crossbedding; thin section at 256·7 feet shows fine-grained subangular, clear, compact (secondary) quartz (98%); a few small quartz aggregates; accessories, carbonate, chlorite, leucoxene, zircon, biotite, plagioclase, collophane, and apatite; thin section at 268·2 feet shows coarse-grained, dusty to clear, anhedral quartz (98%); some quartz aggregates; very compact through secondary quartz; accessories, carbonate (1%), chlorite, pyrite, zircon, biotite, and leucoxene.
	Queenston Formation
270·1-275·8	Shale and siltstone; red, green mottled; upper 0·3 foot green shale

Hole No. F-2

Location: 24,558·8 feet N., 6,175·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 552·7 feet — Depth of overburden: 34·3 feet
Total depth: 297·7 feet — Drilled: Jan.-Feb., 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
34·3-48	Dolomite; buff, sugary
48 -63·2	Dolomitic limestone; whitish grey, finely crystalline; numerous bituminous partings; a few crinoid stems and Bryozoa; upper and lower contacts gradational
	Gasport Member
63·2-80	Limestone; whitish grey, slightly porous, crystalline; stylolitic
80 -85·3	Limestone; crinoidal, grey, coarsely crystalline; numerous grey shale partings; traces of conglomerate at 85-85·2 feet
	DeCew Formation
85·3-92·2	Dolomite; buff, dense to sugary; rare shale parting
	Rochester Formation
92·2-145	Shale; calcareous, grey, fissile; Bryozoa limestone at 94-94·1, 116·5-116·9, 117·3, 119·9, 120-120·3, 120·9, 121·4, 121·6-121·9, 130·1, 138·3, 139·4-139·5, 140·2, 144·4, 144·6 feet
145 -151·8	Limestone and shale interbedded; basal 1½ feet argillaceous limestone; Bryozoa in limestone
	Irondequoit Formation
151·8-161·2	Limestone; whitish grey to pinkish grey, coarsely crystalline, finer in basal 1 foot; upper 0·4 foot highly fossiliferous, *Enterolasma caliculum* (Hall) at 152 feet, *Atrypa reticularis* (Linnaeus) at 152 and 155·4 feet
	Reynales Formation
161·2-171·3	Dolomite; buff-grey, dense; upper 1 foot transitional with numerous green shale bands; grey shale at 164·5-165, 169·4 feet
171·3-173·2	Limestone; argillaceous, grey, coarsely crystalline, fossiliferous
	Neahga Formation
173·2-179·3	Shale; grey, fissile; limestone band at 173·9-174·1 feet; basal 0·7 foot calcareous; upper contact undulating gently

HOLE NO. F-2—*Continued*

Depth	Lithology
Feet	
	Thorold Formation
179·3-182·7	Sandstone; greenish white, very fine grained; basal 1·5 feet very shaly (green); basal contact placed at a thin sandstone seam with an undulating base cutting down into green shale
	Grimsby Formation
182·7-185	Shale; red and green; interbedded sandstone
185 -187·8	Sandstone; red, fine grained; greenish tinged, white medium-grained, quartzose sandstone 185-187·8 feet with red shale 185·6-186·3 feet; basal contact with red sandstone undulating; suggestion of a conglomerate
187·8-228·2	Sandstone; red, fine grained; red shale at 190·3-190·7, 191·4-192·1, 198·7, 201·6, 202·2-202·3, 202·5, 204-204·1, 204·2, 204·5, 204·6, 207·7-209·4, 210-211, 213·4-213·8, 218-222·3, 223·2-225, 226·2-227·9 feet; white sandstone at 215-216·8 feet; lower contact in sandstone based on colour change
	Power Glen Formation
228·2-237·3	Sandstone; quartzose, whitish grey, fine grained; numerous grey shale partings; upper 5 feet commonly red tinged; many black blebs 228·7-229·8, 232·8-233·1, 233·9, 236·6-237·3 feet
237·3-239·2	Shale; arenaceous, grey
239·2-239·5	Sandstone; grey, coarse; many black blebs
239·5-244·6	Sandstone; some shale partings; Bryozoa
244·6-246·5	Shale; arenaceous, grey
246·5-247·1	Sandstone; grey, fine grained
247·1-256	Shale; grey
256 -260	Sandstone; argillaceous, dark grey, very fine grained
260 -263·2	Grey shale; sandstone 260·1-260·2, 260·6-260·9 feet
263·2-267·9	Sandstone; whitish grey, fine grained, and interbedded grey shale
	Whirlpool Formation
267·9-286·6	Sandstone; quartzose, white, fine grained; medium grained near base; grey shale at 279·9-280·8, 281·3, 281·4-281·6, 281·7, 282·1 (fragments) feet
	Queenston Formation
286·6-298·3	Sandstone and shale; red; upper 0·2 foot green shale; upper contact sharp

Hole No. K-1

Location: 24,055·2 feet N., 9,479·8 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 541·5 feet — Depth of overburden: 48·8 feet

Total depth: 304·5 feet — Drilled: June, 1950

Core logged by T. E. Bolton 1951

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
48·8-59·1	Limestone; dolomitic, buff to buff-grey, porous, finely crystalline; grey argillaceous partings; chert nodules at 54·5 feet; stylolites at 57·4 feet; small *Favosites* colony at 53·8 feet, *Enterolasma caliculum* (Hall) at 55·9 and 56·1 feet
	Gasport Member
59·1-83·6	Limestone; light grey, finely crystalline; crinoidal, rare argillaceous partings; dense grey band 63·9-64·2 feet; calcite 60-62 feet; basal contact sharp, 2-inch-thick basal conglomerate of tiny dolomite pebbles; *Favosites niagarensis* Hall 59·1-59·5 feet
	DeCew Formation
83·6-92·5	Dolomite; grey to buff-grey, dense
92·5-92·9	Core missing
	Rochester Formation
92·9-114·6	Shale; calcareous, dark grey to black, compact; bryozoan band 93·2-93·3 feet
114·6-115·7	Limestone; argillaceous, grey, finely crystalline; thin gypsum seams abundant; Bryozoa
115·7-117·6	Shale; calcareous, grey
117·6-118·3	Limestone; argillaceous; Bryozoa
118·3-146·8	Shale; calcareous, grey; bryozoan limestone bands at 119·2, 119·5-119·7, 120-120·3, 136·6-137·6, 141·2-141·3, 143·8 feet
146·8-150·6	Interbedded shale and limestone; grey; basal contact transitional from light grey to argillaceous limestone
	Irondequoit Formation
150·6-160·8	Limestone; whitish grey, porous, crystalline, crinoidal; upper 3·5 feet coarser; lower contact poorly defined as gradually finer with shale partings from 159 feet down; *Plectodonta transversalis* (Wahlenberg) at 152 feet
	Reynales Formation
160·8-169·3	Dolomite; whitish grey to light grey, dense to fine grained; a few shale partings
169·3-171·1	Limestone; grey, porous, crystalline; many grey shale partings; lower contact sharp

HOLE NO. K-1--*Continued*

Depth	Lithology
Feet	
	Neahga Formation
171·1-176·5	Shale; greenish grey
176·5-180·3	Shale; green; arenaceous shale to grey sandstone bands at 178·5-178·7, 178·9-179·2 feet; lower contact reasonably sharp, somewhat transitional
	Thorold Formation
180·3-185·9	Sandstone; white, fine grained; shale, green and red, at 181, 181·6-181·7, 183, 183·2-183·5, 183·8 feet
	Grimsby Formation
185·9-205·7	Sandstone; red, green mottled, fine grained
205·7-207	Shale; red
207 -208	Sandstone; red
208 -208·9	Shale; red
208·9-210·2	Sandstone; red
210·2-211·1	Shale; red
211·1-217·2	Sandstone; red; red shale partings at 212·6-212·9, 213·6-215, 216·5 feet
217·2-220·7	Shale and sandstone; red, interbedded
220·7-221·9	Sandstone; red, greenish mottled, very fine grained
221·9-226·8	Shale; red and green; numerous thin red sandstone bands
226·8-229·1	Sandstone; red and green; lower contact marked solely by colour change
	Power Glen Formation
229·1-234·2	Sandstone; calcareous, light grey, fine grained, fossiliferous; grey shale partings at 231·5-231·6, 232·2-232·4, 232·9-233·2 feet
234·2-236·5	Sandstone; calcareous, porous, medium grained, many black phosphatic particles and Bryozoa; conglomerate interbed
236·5-254·7	Shale; dark grey; interbedded sandstone
254·7-258·9	Sandstone; light grey, medium to fine grained; many grey shale partings imparting a conglomeratic appearance
258·9-260·2	Shale; sandy, grey
260·2-264	Sandstone; light grey, fine grained, and shale, grey, interbedded; shale increasing downwards; bryozoan limestone at 261·9 feet
	Whirlpool Formation
264 -283·3	Sandstone; pure, white, fine to medium grained; grey shale partings at 265·2, 265·6-265·8, 267·2, 275·3-275·7; crossbedding, 80 degrees to the core, at 267·2-275·3 feet
	Queenston Formation
283·3-305·5	Sandstone; red, fine grained; upper 1 foot green mottled

Hole No. C-2

Location: 20,437·1 feet N., 9,709·3 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 546·7 feet — Depth of overburden: 47·6 feet
Total depth: 290·6 feet — Drilled: Sept., 1949
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
47·6-48·8	Core missing
48·8-53·6	Dolomite; calcareous, brownish grey, non-petroliferous, granular
	Gasport Member
53·6-57·2	Limestone; dark grey, dense, crinoidal
57·2-60	Limestone; dark grey, stylolitic, porous
60 -67·6	Limestone; light grey, slightly denser, crinoidal; gypsum
67·6-75·7	Limestone; light grey, crystalline, crinoidal
	DeCew Formation
75·7-87	Dolomite; dark grey, dense; slightly argillaceous 80-81 feet
	Rochester Formation
87 -105·8	Shale; calcareous, grey
105·8-107	Limestone; grey; minor shale; Bryozoa
107 -141·3	Shale; black, fissile; thin limestones at 107·4-107·6, 109·6-109·7, 115·5-115·8, 120·1-120·3, 137·3, 138·4, 139·5, 140 feet
141·3-143·6	Limestone; grey, thin shale partings; Bryozoa
	Irondequoit Formation
143·6-149·7	Limestone; white, light grey, crystalline; grey increasing in the upper 1·7 feet; *Parmorthis elegantula* (Dalman), *Bumastus ioxus* (Hall), *Calymene niagarensis* (Hall) at 144·4 feet
149·7-151·4	Limestone; grey, denser
	Reynales Formation
151·4-161	Limestone or dolomite; light grey, dense; upper contact sharp lithological break; grey shale partings at 155·1-155·3, 158·5, 159·7, 160·6 feet
161 -163·3	Dolomite; argillaceous; Bryozoa
	Neahga Formation
163·3-168·2	Shale; fissile, greenish black
	Thorold Formation
168·2-172·8	Sandstone; light grey to white, very fine; rare shale bands, widest at 171·9-172 feet; thin section at 172·6 feet shows finely medium-grained, dusty to clear (secondary) quartz; accessories, zircon, biotite, magnetite, carbonate, apatite, microcline, albite (?), and collophane

Hole No. C-2—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation
172·8-173	Sandstone; argillaceous, green
173 -173·4	Shale; red
173·4-176	Sandstone; white to light grey, very fine grained
176 -176·4	Shale; red and green
176·4-176·7	Sandstone; greenish grey
176·7-176·9	Shale; red
176·9-177·1	Sandstone; red
177·1-177·4	Shale; red
177·4-177·5	Sandstone; red
177·5-177·9	Shale; red
177·9-180·5	Sandstone; red and greenish grey
180·5-183·4	Shale and sandstone; red
183·4-185·6	Sandstone; red
185·6-187·7	Sandstone; red; green shale fragments at 185·7 and 185·8 feet
187·7-188·1	Shale; red
188·1-191·2	Sandstone; red
191·2-191·4	Shale; red
191·4-192·7	Sandstone; red
192·7-193	Shale; red
193 -194	Sandstone; red; red shale fragments
194 -194·2	Shale; red
194·2-196	Sandstone to siltstone; red; shale partings
196 -196·3	Shale; red
196·3-199·5	Sandstone; red and green; shale pellets at 197·9 feet
199·5-199·8	Shale; red
199·8-200·1	Sandstone; red and green
200·1-200·8	Shale; red
200·8-203·1	Sandstone; red and greenish grey
203·1-204·5	Shale; red
204·5-205·1	Sandstone; red
205·1-206	Shale; red, green mottled
206 -208·2	Sandstone; red and green
208·2-209·2	Shale; red
209·2-209·6	Sandstone; red
209·6-211·6	Shale; red
211·6-213·7	Shale and sandstone; red
213·7-214·6	Shale; red
214·6-215·2	Sandstone; red, fine grained
215·2-218·5	Shale and sandstone; red and green
218·5-219·4	Interbedded sandstone and shale; red and green; a few shale pellets
	Power Glen Formation
219·4-220	Sandstone; minor shale; black shale fragments and iron stains near upper contact
220 -221·4	Sandstone; white, hard, intact
221·4-226·8	Shale and thin sandstone bands
226·8-230·1	Sandstone; calcareous; shale partings and fragments
230·1-230·6	Shale; grey
230·6-230·7	Sandstone; calcareous
230·7-232·4	Shale; grey
232·4-246	Shale; minor sandstone
246 -248·6	Sandstone; whitish grey, calcareous; many thin shale partings
248·6-251·9	Shale; minor sandstone

Hole No. C-2—*Continued*

Depth	Lithology
Feet	
	Power Glen Formation—Continued
251·9-252·3	Sandstone; whitish grey, fine grained, calcareous
252·3-252·7	Shale; sandy, calcareous
252·7-254·2	Sandstone; calcareous, whitish grey, fine grained
254·2-255·7	Shale; fissile, grey; minor sandstone
	Whirlpool Formation
255·7-284·1	Sandstone; whitish grey, fine grained; red sandstone at 277-278·1 feet and at various horizons down to 281 feet; grey shale pellets at 261·5, 270·6 273, 273·9-274·6, 279·5, 282·8 feet

Hole No. D-1

Location: 19,748·8 feet N., 10,109·9 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 554·5 feet — Depth of overburden: 37·8 feet

Total depth: 291·4 feet — Drilled: Sept., 1949

Core logged by T. E. Bolton, 1950.

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
37·8-51·8	Dolomite; reddish grey to grey, granular; gypsum and calcite-filled vugs; lower contact arbitrary, Gasport may extend up to 41·5 feet
	Gasport Member
51·8-73·8	Limestone; light grey, crystalline, crinoidal; denser and dolomitic in upper 3 feet
	DeCew Formation
73·8-82·9	Dolomite; dark grey to chocolate, dense; upper contact sharp lithological break
	Rochester Formation
82·9-137	Shale; dark grey; minor limestone beds; Bryozoa beds at 87·4, 89·1, 103·2-104·8, 105·2, 106·8-106·9 feet; slightly more calcareous in upper 22 feet
137 -141	Shale and limestone interbedded; shale increasing upward; limestone beds up to 0·4 foot thick, filled with Bryozoa

HOLE NO. D-1—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
141 -149·6	Limestone; pinkish grey, finely crystalline, argillaceous in upper ½ foot; thin shale parting at 141·4 feet; *Atrypa reticularis* (Linnaeus), and *Whitfieldella intermedia* (Hall) at 141·2 feet
	Reynales Formation
149·6-161·6	Dolomite; dark grey, dense; three shale partings; Crinoidea and Bryozoa produce mottled appearance in basal 2 feet
	Neahga Formation
161·6-166·8	Shale; dark grey, fissile; basal 0·2 foot small lenticular shale fragments cemented by pyrite and sand; lower contact undulating, possible unconformity; upper contact sharp lithological break
	Thorold Formation
166·8-172·9	Sandstone; whitish grey, very fine grained; grey shale partings at 169·8, 171·3-171·5 feet
	Grimsby Formation
172·9-195·3	Sandstone; red, green mottled, fine grained; eight 0·1-foot-thick red shale partings; upper contact in sandstone marked by simple colour change, and green shale pellets
195·3-196	Shale and siltstone; red
196 -197·1	Sandstone; red and greenish grey
197·1-197·7	Siltstone; red, green mottled
197·7-201	Sandstone; red and green, finely crossbedded
201 -202·4	Shale and sandstone; red
202·4-203·5	Sandstone; reddish grey
203·5-204·4	Shale; red
204·4-205·6	Sandstone; greenish red
205·6-207·2	Sandstone and shale; red
207·2-207·5	Sandstone; finely bedded, light red, fine grained
207·5-212·1	Shale; red, green mottled; minor sandstone
212·1-212·9	Sandstone; red
212·9-213·6	Core missing
213·6-214·4	Shale; red
214·4-215	Sandstone; red
215 -217·8	Shale; red; black shale pellets
	Power Glen Formation
217·8-218·4	Sandstone; light grey; grey shale pellets concentrated in upper 0·2 foot; *Strophonella* sp. cf. *S. striata* (Hall) at 218·4 feet
218·4-219	Sandstone; dark red; red shale pellets
219 -219·5	Sandstone; light grey
219·5-220	Shale; grey
220 -220·7	Sandstone; buff, finely crossbedded

HOLE NO. D-1—*Continued*

Depth	Lithology
Feet	*Power Glen Formation*—Continued
220·7-225·3	Shale; grey; thin calcareous sandstone beds
225·3-230·6	Sandstone; whitish grey, fine grained, impure; many shale partings
230·6-244·4	Shale and sandstone; dark grey, latter increasing in upper 2½ feet; small-scale crossbedding at 231·3-231·4 feet
244·4-250·6	Shale; grey; minor calcareous sandstone beds
250·6-253	Sandstone; dark grey, very fine grained; possibly Whirlpool formation
253 -254·1	Shale and sandstone; grey
	Whirlpool Formation
254·1-282·6	Sandstone; quartzose, white to whitish grey, fine to medium grained; coarser at base; finely banded by heavy minerals; grey shale partings at 258·2-258·3, 268·6-268·7 feet; reddish tinged from 273·3-280 feet; thin section at 254·8 feet shows coarsely medium-grained, angular to subangular, compact (secondary) quartz (99%); accessories, carbonate, zircon, leucoxene, and microcline; thin section at 282·2 feet shows coarse-grained, very compact, subrounded to subangular quartz, some corroded by interstitial carbonate; accessories, pyrite, chlorite, collophane, and zircon
	Queenston Formation
282·6-292·6	Shale and siltstone; red, green mottled

HOLE NO. D-3

Location: 17,883·7 feet N., 10,886·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 551·6 feet — Depth of overburden: 53·5 feet
Total depth: 304·3 feet — Drilled: October, 1949
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	*Lockport Formation*
	Goat Island Member
53·5-70·3	Dolomite; dark grey to brownish grey, dense to granular; rare bituminous partings in upper part; rare crinoids in basal 9 feet; chert band at 56·2 feet
	Gasport Member
70·3-94·4	Limestone; light grey to pinkish grey, crinoidal; numerous stylolites; upper contact gradual lithological change

HOLE NO. D-3—*Continued*

Depth	Lithology
Feet	
	DeCew Formation
94·4-102·6	Dolomite; dark grey to chocolate, dense; rare shale partings; upper contact sharp lithological break
	Rochester Formation
102·6-121·1	Shale and siltstone; black; rare calcareous beds in upper 2 feet; upper contact placed where shale ends
121·1-123·2	Limestone; dark grey, with Bryozoa; thin shale partings
123·2-153·6	Shale; blackish grey with minor silty to sandy partings
153·6-160·1	Shale; grey; numerous Bryozoa and Crinoidea in thin (0·2-foot) limestone beds
	Irondequoit Formation
160·1-168·5	Limestone; whitish grey, crystalline; upper 6 inches argillaceous; *Atrypa reticularis* (Linnaeus), cf. *Fardenia subplana* (Conrad) at 161·5 feet; *Favosites* sp. at 166·4-167·5 feet (reef)
	Reynales Formation
168·5-181·4	Dolomite; dark (basal 2·5 feet) to light grey, dense; some thin shale partings, particularly in basal dark, fossiliferous dolomitic limestone band; upper contact simple lithological change; thin section at 171·8 feet shows very fine-grained, euhedral to semi-euhedral, compact carbonate; rare larger euhedral carbonate surrounded by fine anhedral carbonate and associated with clumps of interstitial pyrite
	Neahga Formation
181·4-186·8	Shale; fissile, black
	Thorold Formation
186·8-197·5	Sandstone; quartzose, light grey, fine grained; basal 0·8 foot mottled by black shale; greenish grey shale partings at 190·5, 191·3-191·4, 192·2-193·1 feet; upper 0·3 foot transitional
	Grimsby Formation
197·5-198·5	Shale; red, green in upper 0·1 foot
198·5-226·5	Sandstone; massive, red, green mottled; minor silty bands at 202·2, 203·6-203·8, 206·1-206·3 feet
226·5-228·2	Shale; red; minor red sandstone
228·2-228·5	Sandstone; red to greenish grey
228·5-235·6	Shale; red; minor green mottled interbedded sandstone
235·6-236·1	Sandstone; red
236·1-238·6	Shale; red; minor sandstone
238·6-239·3	Sandstone; dark grey to red
239·3-240·3	Shale; red
240·3-243·2	Sandstone; red and grey
243·2-243·9	Siltstone; red; lower contact sharp colour change only

HOLE NO. D-3—*Continued*

Depth	Lithology
Feet	
	Power Glen Formation
243·9-244·1	Siltstone; green
244·1-246·4	Shale; grey; minor sandstone bands
246·4-252·7	Sandstone and shale interbedded; reddish mottled
252·7-253·3	Shale; grey
253·3-254·7	Sandstone and shale interbedded
254·7-256	Sandstone; white, light grey, fine grained
256 -267	Shale and siltstone
267 -270·5	Siltstone with interbedded grey, calcareous sandstone; thin section at 270·5 feet shows very fine-grained, angular to subangular quartz (90%) with varying thicknesses of interstitial carbonate (8%); accessories, chlorite (1%), pyrite, zircon, plagioclase, and leucoxene
270·5-273	Shale; grey; two limestone bands
273 -274·1	Sandstone; whitish grey, very fine grained
274·1-274·5	Siltstone; grey
274·5-275·3	Sandstone; white, very fine grained, calcareous; thin section at 275·3 feet shows fine-grained, subangular to subrounded, clear and dusty quartz (80%) with interstitial carbonate (19%) grains and patches; accessories, pyrite (in carbonate), chlorite, biotite, (rounded grains), zircon (rounded grains), andesine, rutile (rounded), magnetite, and leucoxene
275·3-276·1	Shale to siltstone; grey
276·1-279·4	Sandstone; white, fine grained
279·4-279·9	Shale; grey
	Whirlpool Formation
279·9-297·7	Sandstone; quartzose, whitish grey, fine grained; coarser at the base; shale pellet bands at 285·6-286, 289·4-289·7, 290-290·2, 291·2-291·5 feet; some thin shale partings in upper beds; upper contact where grey shale first predominates; thin section at 280·5 feet shows finely medium-grained, dusty and clear, compact (secondary) quartz (98%); rare quartz aggregates; accessories, microcline, andesine, carbonate (1%), collophane, chlorite, magnetite, leucoxene, zircon, biotite, and rutile; thin section at 287·2 feet shows finely medium-grained, subangular to subrounded, clear and dusty quartz (98%); a few quartz aggregates; accessories, zircon, albite, andesine, carbonate, chlorite, augite, apatite, collophane, magnetite, and leucoxene
	Queenston Formation
297·7-305·1	Shale; red and green; upper 0·1 foot green

Hole No. E-18

Location: 15,998·7 feet N., 10,819·1 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 567·3 feet — Depth of overburden: 70·9 feet

Total depth: 311·2 feet — Drilled: March, 1950

Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
70·9-74·3	Core missing
74·3-83	Dolomite; buff-grey, porous, sugary
83 -92·5	Dolomite; light buff-grey, finely crystalline
92·5-95·4	Dolomite; buff, sugary
95·4-106·2	Dolomite; buff-grey to light grey, finely crystalline; grey shale partings in basal 1 foot; rare crinoid stems
	Gasport Member
106·2-123·9	Limestone; grey, porous, crystalline; crinoidal, stylolitic; upper contact transitional; lower contact sharp with 0·1-inch-thick basal conglomerate
	DeCew Formation
123·9-133·3	Dolomite; buff to dark grey, dense; lower contact arbitrary
	Rochester Formation
133·3-188·6	Shale; calcareous, dark grey, massive in upper 6 feet; bryozoan limestone at 151·4-152, 152·2, 152·6-152·7, 153·8-154, 154·5, 155·6, 185·7, 186, 186·4-186·7, 187·9-188, 188·1-188·2 feet
188·6-191·4	Limestone with minor shale interbedded; lower contact transitional from argillaceous limestone to pure limestone; Bryozoa
	Irondequoit Formation
191·4-200·3	Limestone; whitish grey, porous, crystalline; basal 1 foot fine grained; *Parmorthis elegantula* (Dalman) at 192·6 feet, *Plectatrypa nodostriata* Hall at 192·8 feet
	Reynales Formation
200·3-210	Dolomite; dark grey to buff-grey, dense; greenish grey shale at 200·3, 201·5, 203·6, 206·2, 207·4, 208·1 feet
210 -212·3	Limestone; grey, coarsely crystalline, fossiliferous; basal 1·5 inches phosphatic; greenish grey shale at 210·7, 210·9, 211·1, 211·5, 211·7, 211·9-212 feet
	Neahga Formation
212·3-217·9	Shale; black, fissile; basal ½ foot calcareous dense limestone; lower contact sharp, slightly undulating

HOLE NO. E-18—*Continued*

Depth	Lithology
Feet	*Thorold Formation*
217·9-225	Sandstone; white to greenish, fine grained; top ½ foot and bottom 1½ feet dark green argillaceous sandstone
	Grimsby Formation
225 -272·6	Sandstone; red, green to yellowish green, fine grained; red shale at 233·2-233·4, 235·5-235·9, 237-237·3, 237·5, 241·1-241·4, 241·9-242·1, 243·2, 243·3-243·4, 244-244·1, 249·1-249·3, 249·8-250, 258·2-258·3, 259·3, 259·7-260, 262·1-262·9, 264·1-264·4, 265·7-266·2, 271·8-272·5 feet
	Power Glen Formation
272·6-273	Sandstone; grey, and shale, green, interbedded
273 -278·9	Shale; grey, with sandstone at 275-275·2 feet
278·9-283·4	Sandstone; whitish grey, very fine grained; numerous grey shale partings
283·4-297·4	Limestone; grey, coarse; phosphatic blebs; *Helopora fragilis* Hall and *Lingula* cf. *cuneata* Conrad at 295·8 feet
297·4-303·7	Shale; calcareous, dark grey
303·7-306·8	Shale; grey, and sandstone interbedded
	Whirlpool Formation
306·8-317·4	Sandstone; light grey, fine grained; grey shale blebs and partings in upper 1 foot

HOLE NO. E-2

Location: 11,846·2 feet N., 10,970·3 feet W. of "Monument Chippawa" (43° 03′ 44″484 Lat., 79° 02′ 47″798 Long.) Stamford tp., Welland co.

Elevation bedrock: 546·2 feet — Depth of overburden: 63·8 feet

Total depth: 339·8 feet — Drilled: Nov., 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	*Lockport Formation*
	Eramosa Member
63·8-65	Core missing
65 -71·5	Dolomite; chocolate-brown; bituminous partings; strong petroliferous odour
	Goat Island Member
71·5-87·8	Dolomite; dark grey to chocolate-grey, dense to granular; chert at 72·6, 72·8-72·9 feet; few crinoids; some gypsum bands up to 0·1 foot thick; rare bituminous partings in upper part

HOLE NO. E-2—*Continued*

Depth	Lithology
Feet	
	Lockport Formation—Continued
	Gasport Member
87·8-130·7	Limestone; basal 5·4 feet, light grey, crystalline, crinoidal; remainder light grey, semicrystalline to dense; crinoids less abundant; calcite and gypsum; typical basal conglomerate in lower 3 feet, concentrated in basal 1 foot
	DeCew Formation
130·7-140	Dolomite; dark grey, dense; occasionally chocolate coloured; lower contact transitional; upper contact wavy
	Rochester Formation
140 -156·6	Shale; calcareous, grey
156·6-157·9	Interbedded limestone, light pinkish grey, and shale, grey
157·9-194·3	Shale and siltstone; dark grey
194·3-195·6	Interbedded limestone, light grey, fossiliferous, dense, and shale, dark grey
	Irondequoit Formation
195·6-205·6	Limestone; white to light grey, crystalline; upper contact transitional; *Eospirifer niagarensis* (Conrad) at 198 feet; *Plectodonta transversalis* (Wahlenberg) at 198·7 feet; *Atrypa reticularis* (Linnaeus) at 198, 199·9 (large), 200·3, 201·8 feet
	Reynales Formation
205·6-218·8	Dolomite; light to dark grey, dense to semicrystalline; grey shale at 206·6, 209·7-209·9 feet; upper contact slightly wavy; coarse fossiliferous limestone with three thin shale partings in basal 2½ feet
	Neahga Formation
218·8-224	Shale; fissile, dark grey
	Thorold Formation
224 -233·6	Sandstone; quartzose, white; shale bands at 225·5-226·3 (silty), 227·3-228·3 (silty), 228·6-228·8, 231·4, 231·9-232·1 feet
	Grimsby Formation
233·6-234·6	Sandstone; dark red; green shale pellets at 234·2 feet
234·6-234·9	Shale; red
234·9-242·3	Sandstone; red to greenish grey; shale partings
242·3-242·7	Shale; red
242·7-242·9	Sandstone; red
242·9-243·4	Shale; red
243·4-243·9	Sandstone; red

HOLE NO. E-2—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation—Continued
243·9-244·2	Shale; red
244·2-244·6	Sandstone; red
244·6-245·1	Shale; red
245·1-245·8	Sandstone; red
245·8-246·3	Shale and sandstone interbedded; red
246·3-255·7	Sandstone; whitish grey to red; thin section at 246·7 feet shows fine-grained, anhedral, clear and dusty quartz (99%); secondary quartz forms compact sandstone; accessories, albite-oligoclase, microcline, chlorite, biotite-muscovite, zircon, and leucoxene
255·7-256·1	Shale; red
256·1-262·7	Sandstone; red; shale partings
262·7-263·1	Shale; red
263·1-265	Sandstone; red, rare shale partings
265 -266·4	Shale; red
266·4-267·3	Sandstone; red
267·3-268·5	Shale; red, 0·1 foot sandstone bed at 267·5 feet
268·5-269·4	Sandstone; red, fine grained
269·4-270·5	Shale; red
270·5-271·7	Shale and sandstone interbedded; red
271·7-272·9	Shale; red
272·9-275·5	Sandstone; argillaceous, red; lower contact simple colour change
	Power Glen Formation
275·5-284·1	Sandstone; quartzose, whitish grey, medium grained; thin grey shale partings
284·1-285·8	Shale and thin sandstones interbedded; grey
285·8-295	Sandstone; quartzose, white, fine grained; grey shale partings; upper 2½ feet coarser
295 -312·7	Shale; dark grey; a few sandstone beds with fine crossbedding; core missing 297·2-300·6 feet
312·7-316·2	Sandstone; argillaceous, calcareous, dark grey; lower contact placed where argillaceous material first appears; thin section at 315·1 feet shows medium-grained, angular to subangular, clear and dusty, quartz (95%) well separated by interstitial carbonate (4½%); accessories, chlorite, pyrite, zircon, apatite, microcline, and albite-oligoclase
	Whirlpool Formation
316·2-337·2	Sandstone; quartzose, white, fine grained, finely bedded; rare shaly partings; coarser grained in basal 5 feet; thin section at 320·9 feet shows mediumly fine- to fine-grained, subangular, dusty to clear (secondary) quartz (99%); a few small quartz aggregates; accessories, carbonate, chlorite, collophane, zircon, plagioclase, biotite, apatite, leucoxene, and tourmaline (?)
	Queenston Formation
337·2-338	Shale; red, green in upper 0·25 foot

Hole No. 1, Rainbow Bridge Site

Location: Western end of Rainbow Bridge, Niagara Falls, Ont.
Elevation bedrock: ? Depth of overburden: 5 feet
Total depth: 200 feet Drilled: ?
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Eramosa Member (?)
5 -10	Dolomite; brown, fine grained; stylolites at 6 and 10 feet; chert nodules at 9 feet; lower contact indistinct
	Goat Island Member
10 -26	Dolomite; grey; stylolites at 18-19 feet; calcite-filled vugs at 23 feet
	Gasport Member
26 -54	Dolomite to dolomitic limestone; light grey, crystalline; denser in upper beds; porous, calcite-filled vugs at 27, 30, 34, 50-52, 54 feet; poorly developed basal conglomerate
	DeCew Formation
54 -68	Dolomite; argillaceous, darker grey, denser than above; gypsum
	Rochester Formation
68 -124·5	Shale; grey; dolomitic upper beds; gypsum at 74, 100, 107, 121 feet; Bryozoa at 118-125 feet
	Irondequoit Formation
124·5-136	Limestone; dolomitic, buff-grey, crystalline, porous, calcite crystals; Brachiopoda
	Reynales Formation
136 -146	Dolomite; grey to buff, dense
	Neahga Formation
146 -150·5	Shale; blue-grey; pyrite at 148 feet; sandy at base
	Thorold Formation
150·5-160	Sandstone; light grey, fine grained; mottled green and grey brecciated zone 156-157 feet
	Grimsby Formation
160 -200	Sandstone; red and grey, fine grained; interbedded green and red shale at 160, 163-177, 190-196, 198-199 feet; Brachiopoda at 199 feet

Hole No. E-32

Location: 9,181·1 feet N., 10,934·9 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 566.3 feet — Depth of overburden: 70 feet

Total depth: 322·8 feet — Drilled: March-April, 1951

Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
70 -73·3	Dolomite; argillaceous, brownish grey, sugary; distinct lithological break at base
73·3-88·2	Dolomite; buff-grey, sugary; numerous bituminous partings
	Lockport Formation
	Eramosa Member
88·2-103·1	Dolomite; petroliferous, buff to dark grey, sugary; base placed arbitrarily at last petroliferous indication as underlying dolomites lithologically similar, except for disappearance of bituminous partings
	Goat Island Member
103·1-124·1	Dolomite; buff, sugary, rare bituminous partings; chert at 109·5, 113·2, 113·4, 116·8-116·9, 117·6-117·9, 118·4-118·7, 120·2 feet; *Clathrodictyon vesiculosum* Nicholson and Murie at 115·5, 115·8-116·1, 116·2-116·5 feet; rare *Favosites* in basal 2·5 feet
124·1-155	Dolomite; buff to buff-grey, sugary; basal 6·5 feet coarser, porous, transitional phase into underlying Gasport; *Clathrodictyon vesiculosum* Nicholson and Murie at 131·9, 132·4, 138 feet
	Gasport Member
155 -172·3	Limestone; light whitish grey, crystalline, crinoidal; upper 5 feet somewhat finer with rare stylolites; basal contact sharp; ¼-inch thick basal conglomerate
	DeCew Formation
172·3-185·5	Dolomite; dark grey, dense; upper foot lighter grey, sugary, with rare calcite-filled vugs
	Rochester Formation
185·5-197·9	Shale; dolomitic, dark grey
197·9-199·2	Shale; grey, and bryozoan limestone, interbedded
199·2-238·9	Shale; calcareous, dark grey, compact; rare thin grey limestone beds
238·9-242	Shale and limestone interbedded; latter increasing towards base; basal contact transitional

HOLE NO. E-32—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
242 -250·9	Limestone; light grey to white, coarsely crystalline, crinoidal; upper foot dark due to argillaceous content, and packed with crinoids and brachiopods; lower contact sharp; *Enterolasma caliculum* (Hall) at 242·6 feet, *Eospirifer niagarensis* (Conrad) at 242·8 and 243 feet, *Atrypa reticularis* (Linnaeus) at 242·2, 242·4, 243·4, 245·9, 247 feet
	Reynales Formation
250·9-261·3	Dolomite; light grey to buff-grey, dense; upper 2 feet greenish tinged; grey shale at 254·8-255, 255·3, 258·2, 260 feet; thin conglomeratic zone at 261·1 feet
261·3-263·8	Limestone; dark grey, crystalline, fossiliferous (Crinoidea and Bryozoa); grey shale at 263-263·2, 263·6-263·7 feet
	Neahga Formation
263·8-269·4	Shale; dark grey, fissile; upper contact transitional with calcareous content increase; basal 3 inches calcareous, with a ½-inch basal conglomerate of thin flat dark grey sandy pebbles
	Thorold Formation
269·4-279·2	Sandstone; light whitish grey, fine grained; many green shale fragments scattered throughout; green shale at 270·3, 271·3-272·1, 272·3, 272·9, 277·4-277·5, 278·4-278·5 feet; lower contact sharp on red shale
	Grimsby Formation
279·2-285·1	Shale; chocolate-red; sandstone, greenish grey, fine grained at 279·5-280, 280·8, 281-281·4, 283·5-283·7 feet
285·1-309·3	Sandstone; red to greenish grey, fine grained; green shale fragments and partings at 285·5, 285·9-286, 286·5-286·6, 287·2, 287·3, 289·7-290·1, 292, 303·1-303·5, 303·6, 303·9, 304·9-305, 305·4-305·5 feet
309·3-320·5	Shale; red and green; red sandstone at 310·6-311·3 (with red shale fragments), 311·4-311·6, 312·9, 313·6-314, 314·6-314·8, 315-316·8 feet
	Power Glen Formation
320·5-323·4	Sandstone; calcareous, light grey, fine grained; numerous grey shale partings; many tiny grey shale fragments in upper 1 foot; red hematite seam at 320·6 feet

Hole No. E-29

Location: 6,823·7 feet N., 10,898·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 573·9 feet — Depth of overburden: 68·7 feet

Total depth: 395·3 feet — Drilled: Jan.-Feb., 1951

Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
68·7-120·8	Dolomite; buff-grey to dark grey, porous, sugary; crowded with large and small colonies of *Favosites niagarensis* Hall; basal 5 feet denser and fewer corals; lower contact sharp lithological break
	Lockport Formation
	Eramosa Member
120·8-129·5	Dolomite; buff to dark grey, sugary, a few bituminous partings; strong petroliferous odour in upper 5 feet
	Goat Island Member
129·5-139·8	Dolomite; buff-grey, porous, crystalline; abundant calcite-filled vugs
139·8-179·6	Dolomite; buff-grey, dense to sugary; bituminous partings, scattered calcite seams; chert nodules at 140·8, 142·1, 142·2, 144-144·2, 146·7 feet; indeterminable Stromatoporoidea at 153·6 and 153·9 feet
	Gasport Member
179·6-186·7	Limestone; light grey, medium grained
186·7-188	Dolomite; greenish grey, very fine grained
188 -191·6	Dolomite; buff-grey, sugary; Eramosa-like
191·6-197·5	Limestone; light grey, finely crystalline; rare bituminous partings; lower contact sharp; no conglomerate noted; not typical Gasport facies
	DeCew Formation
197·5-207	Dolomite; dark buff-grey, sugary
	Rochester Formation
207 -243·9	Shale; calcareous, dark grey; limestone bands, dark grey, fine grained at 221·1-222, 223, 224·2-224·8, 226-226·5 feet
243·9-262·9	Limestone and shale; grey, interbedded; Bryozoa at 243·9 and 259·2 feet
262·9-265·1	Limestone; argillaceous, dark grey, fossiliferous; basal 6 inches transitional into underlying Irondequoit limestone; *Atrypa reticularis* (Linnaeus) at 264·6, 265, and 265·1 feet, *Stegerhynchus neglectum* (Hall) and *Fenestrellina elegans* (Hall) at 265 feet, *Hallopora* cf. *elegantula* (Hall) at base

HOLE NO. E-29—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
265·1-274·6	Limestone; light to dark grey, coarsely crystalline, finer towards base; *Strophonella patenta* (Hall) at 265·2, 265·5, 266·9 feet, *Plectodonta transversalis* (Wahlenberg) at 266·6 and 267·4 feet; *Fardenia subplana* (Hall) at 266·1 feet, *Atrypa reticularis* (Linnaeus) at 266·4, 266·6, 268·6, 269·5, 271·2 and 271·8 feet
	Reynales Formation
274·6-284·4	Dolomite; whitish grey, dense; grey shale at 275, 276·4, 278·1-278·2, 281·4, and 281·9 feet; upper contact sharp
284·4-287·1	Limestone; grey, fine grained, fossiliferous; many grey shale partings with limestone fragments; lower contact sharp, marked with phosphatic blebs; *Plectodonta transversalis* (Wahlenberg) at 285·4 feet
	Neahga Formation
287·1-292·1	Shale; dark grey, fissile; basal contact sharp with upper 0·1 inch of the underlying Thorold irregularly argillaceous
	Thorold Formation
292·1-301·5	Sandstone; whitish grey, commonly green mottled, fine to very fine grained; green shale at 292·7, 293·3-293·5, 293·6, 299·4-299·5, 299·6-300·1, 301·1-301·2 feet; many green shale fragments 300·5-300·8 feet; lower contact sharp
	Grimsby formation
301·5-301·6	Shale; green
301·6-302·2	Sandstone; red, green mottled, fine grained, argillaceous; basal ½ inch grey with green shale fragments
302·2-303·2	Siltstone; dark red
303·2-303·6	Shale; red
303·6-312·4	Sandstone; red, very fine grained; interbedded shale; sandstone contacts undulating gently
312·4-316	Shale; red; sandstone at 313·3-313·8 feet
316 -329·6	Sandstone; red, green mottled, very fine grained; interbedded shale
329·6-330·4	Shale; red
330·4-332·5	Sandstone; red and green, fine grained
332·5-333·5	Shale; red
333·5-334	Sandstone; green and red
334 -336·2	Shale; red, and sandstone, yellowish green to red, interbedded
336·2-337·6	Shale; red; green at top
337·6-339·3	Sandstone; red; red shale fragments
339·3-341·4	Shale; red
341·4-342·5	Sandstone; red, fine grained
342·5-344·3	Shale; red; sandy at base; lower contact sharp from green to red shale

HOLE NO. E-29- *Continued*

Depth	Lithology
Feet	*Power Glen Formation*
344·3-346·7	Shale; grey; impure calcareous sandstone at 345·4-345·8 feet
346·7-363·5	Sandstone; grey, very fine grained; twenty-three grey shale partings
363·5-377·8	Shale; dark grey; numerous thin sandstone bands
	Whirlpool Formation
377·8-380·5	Sandstone; argillaceous, dark grey, very fine grained
380·5-395·8	Sandstone; quartzose, whitish grey, very fine grained; rare grey shale partings

HOLE NO. H-1

Location: 6,225·5 feet N., 8,718·4 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 513·1 feet
Depth of overburden: 7·2 feet
Total depth: 201 feet
Drilled: March, 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	*Guelph Formation*
7·2-28·3	Dolomite; dark brown to brownish grey, slightly porous, sugary
	Lockport Formation
	Eramosa Member
28·3-33·8	Dolomite; buff-grey, granular; petroliferous odour
	Goat Island Member
33·8-53·3	Dolomite; dark grey to brownish grey, sugary to dense; crinoid bed at 51-51·3 feet; chert at 33·8-34·1, 34·6, 35·4, 35·9-36, 43·7, 43·9, 44·2 feet
	Gasport Member
53·3-55	Dolomite; white, semicrystalline
55 -67·7	Dolomite; dark grey to brownish grey, granular; crinoid stems scattered throughout
67·7-87·6	Limestone or dolomitic limestone; light to dark grey, crystalline, crinoidal; upper 3 feet finer grained; stylolite bands at 67·7, 70·9, 72·9, 73·4, 78·9, 82·6, 85·6, 87 feet
	DeCew Formation
87·6-95	Dolomite; dark grey, sugary to dense

HOLE NO. H-1—*Continued*

Depth	Lithology
Feet	
	Rochester Formation
95 -120	Shale; calcareous, grey; fossils at 110 feet
120 -151·1	Shale; grey; minor calcareous beds; gypsum at 126-126·2; bryozoan bands at 133·7, 141·2, 142·7, 142·8, 144·4, 145·3, 148·9-149·1, 149·5-149·6 feet
151·1-154·9	Limestone; fossiliferous; minor shale
	Irondequoit Formation
154·9-164·2	Limestone: light to dark grey, coarsely crystalline, crinoidal; upper 0·7 foot argillaceous; *Atrypa reticularis* (Linnaeus) at 161·7 feet
	Reynales Formation
164·2-178	Dolomite; light brownish grey, dense; shale partings in basal 3 feet; upper contact transitional; many Brachiopoda, parallel to bedding, convex and concave upwards
	Neahga Formation
178 -183·3	Shale; black, fissile
	Thorold Formation
183·3-189·2	Sandstone; quartzose, greenish grey, fine grained; green shale at 183·5-183·8, 184·2-184·5, 184·7-185 feet
	Grimsby Formation
189·2-190	Shale; green with grey sandstone bands at 189·3, 189·7, 189·9-190 feet
190 -190·4	Shale; red
190·4-191·3	Sandstone; red and grey
191·3-191·6	Shale; red
191·6-202·5	Sandstone; red and green, massive

HOLE NO. E-19

Location: 3,457·5 feet N., 8,491·8 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 501·4 feet — Depth of overburden: 36·0 feet
Total depth: 162·6 feet — Drilled: March, 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
36 -57·3	Dolomite; chocolate-grey, sugary with bituminous partings in lower part; some gypsum; crinoids at 53·4 feet; upper 5 feet dark chocolate-brown, very sugary, true Guelph dolomite
57·3-65·8	Dolomite; porous, chocolate to light brown, fossiliferous; selenite at 64·6 feet

HOLE NO. E-19—*Continued*

Depth	Lithology
Feet	
	Lockport Formation
	Eramosa Member
65·8-72·8	Dolomite; light brown, granular; bituminous, petroliferous odour
	Goat Island Member
72·8-97·9	Dolomite; light brown to brownish grey, granular; rare chert in lower part
97·9-106·9	Dolomite; brownish grey, sugary; some gypsum
	Gasport Member
106·9-110	Dolomite; light brown, granular; much gypsum
110 -116·2	Dolomite; dark grey to buff-grey, granular; gypsum at 110·4-110·8, 111·3, 111·6, 111·9-112, 113·5 feet; this and the above unit may belong to the Goat Island member
116·2-128·6	Limestone; dolomitic, whitish grey, crystalline; crinoidal
	DeCew Formation
128·6-136	Dolomite; dark grey to brownish grey, granular
	Rochester Formation
136 -149·9	Shale; calcareous; bryozoan beds at 149·4-149·5, 149·8-149·9 feet
149·9-190	Shale with minor thin calcareous bands
190 -194·4	Shale; grey with fossiliferous limestone beds
	Irondequoit Formation
194·4-204·7	Limestone; pinkish grey, crystalline; dolomitic pebbles at 204·4 feet; upper contact sharp; *Atrypa reticularis* (Linnaeus) at 194·7, 195·6, 199·7 feet
	Reynales Formation
204·7-218·5	Limestone; basal 3½ feet with Brachiopoda and shale partings; remainder light grey, dense dolomite; shale band at 209·5-209·6 feet; upper contact undulating
	Neahga Formation
218·5-223·2	Shale; black, fissile; shale pebbles in basal 0·2 foot
	Thorold Formation
223·2-232·5	Sandstone; light grey, very fine grained; grey shale at 224·6-224·9 feet; upper 0·5 foot calcareous sandstone, may be basal Neahga

HOLE NO. E-19—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation
232·5-233·1	Shale; red; upper 0·2 foot green siltstone
233·1-239·1	Sandstone; red and green, fine grained; a few shale partings
239·1-239·8	Shale; red
239·8-241·1	Sandstone; red, fine grained
241·1-241·5	Shale; red
241·5-241·7	Sandstone; green
241·7-243·4	Shale; red
243·4-255·4	Sandstone; red, green mottled
255·4-256	Shale; red
256 -258·1	Sandstone; red and green, two shale partings
258·1-258·3	Shale; red
258·3-261·2	Sandstone; red and green
261·2-264	Shale and siltstone; red

HOLE NO. E-8

Location: 2,604·3 feet N., 6,922·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 541·6 feet — Depth of overburden: 6·9 feet

Total depth: 162·4 feet — Drilled: Nov., 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
6·9-8	Core missing
8 -34·5	Dolomite; chocolate-brown, granular; *Favosites* sp. abundant in top porous 5 feet
34·5-67·1	Dolomite; chocolate-brown, granular to semicrystalline; bryozoans and *Favosites* sp. dotted throughout, *Favosites niagarensis* Hall at 46·2-46·8, 46·9 and 47·1 feet
	Lockport Formation
	Eramosa Member
67·1-93	Dolomite; chocolate-brown to brownish grey, fine grained, porous; bituminous, petroliferous odour
	Goat Island Member
93 -118·9	Dolomite; chocolate-brown, granular to dense; basal ½ foot calcite blebs
118·9-125·6	Limestone; light whitish grey, crystalline; vertical jointing

HOLE NO. E-8—*Continued*

Depth	Lithology
Feet	
	Gasport Member
125·6-129·3	Dolomite; brownish grey to dark grey, dense; transitional phase
129·3-143·3	Limestone; light whitish grey to grey, crystalline; rare argillaceous material and stylolites; lower contact sharp lithological break; fine conglomerate in basal 0·2 foot
	DeCew Formation
143·3-151·7	Dolomite; light grey to brown, dense
	Rochester Formation
151·7-213·3	Shale; dark grey to black and fossiliferous limestone in basal 5 feet; central part calcareous shale with numerous thin fossiliferous limestone bands or lenses; upper 10 to 20 feet sandy dolomitic shale; *Atrypa reticularis* (Linnaeus) and *Whitfieldella intermedia* (Hall) at 212·7 feet
	Irondequoit Formation
213·3-221·3	Limestone; light grey to white, crystalline; argillaceous upper 0·7 feet; lower and upper contacts sharp lithological breaks; *Eospirifer niagarensis* (Conrad) at 213·6 feet, *Plectodonta transversalis* (Wahlenberg) and *Plectatrypa nodostriata* Hall at 214·2 feet, *A. reticularis* (Linnaeus) at 213·6, 215·4, 216·1, 220·1, 220·3 feet
	Reynales Formation
221·3-231·4	Dolomite; light to dark grey, somewhat argillaceous, dense
231·4-234·3	Dolomite; dark grey, fine grained with thin shale bands of varying thickness; some pyrite; crinoid stems, *Enterolasma* sp. at 232 feet; pyritized *Fenestrellina* sp. at 233·6 feet, *Eospirifer niagarensis* (Conrad) at 234 feet
	Neahga Formation
234·3-239·3	Shale; dark blackish grey, fissile
	Thorold Formation
239·3-248·3	Sandstone; quartzose, white to light grey, fine grained; green shale bands at 240·6-240·9, 241·2, 241·8-241·9, 242-242·2, 242·8-243 feet; lower contact sharp; upper contact transitional from 239·1-239·3 feet
	Grimsby Formation
248·3-248·6	Shale; green
248·6-249·6	Sandstone; green, fine grained
249·6-263·5	Shale; red with a few 0·2-foot thick, green, very fine-grained sandstone bands

Hole No. N-14

Location: 1,638·1 feet N., 5,962·6 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 532·6 feet | Depth of overburden: 67 feet
Total depth: 403·4 feet | Drilled: Dec.-Jan., 1950-51
Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
67 -95·7	Dolomite; bituminous, buff, sugary; small colonies of *Favosites niagarensis* Hall scattered throughout, producing porosity
95·7-102·7	Dolomite; lighter coloured and denser; numerous small *Favosites* colonies and Bryozoa
	Lockport Formation
	Eramosa Member
102·7-110	Dolomite; bituminous, dark buff, sugary; strong petroliferous odour
110 -118	Dolomite; buff-grey, slightly more porous; few small corals and many Bryozoa scattered throughout. (Redrilling commenced at 110 feet; this zone closely resembles the dolomite at 100 feet)
118 -136·8	Dolomite; buff, sugary; faint petroliferous odour
	Goat Island Member
136·8-155	Dolomite; buff, porous, dense to sugary; numerous calcite-filled vugs; chert nodule with *Hallopora* sp. indet. at 150·8 feet
155 -175·8	Dolomite; light grey, fine to sugary; some calcite-filled vugs and gypsum seams; numerous cherty, earthy nodules down to 160·5 feet
175·8-182·4	Dolomite; buff, fine; many large calcite-filled vugs
	Gasport Member
182·4-191·3	Dolomite; light grey, porous, finely crystalline; much calcite in basal 3 feet; this part more of a transitional zone as referable to either Gasport or Goat Island
191·3-208·3	Limestone; light grey, crystalline, finer near the top, stylolitic; few crinoid stems; lower contact sharp; minor basal conglomerate in lower 0·25 inch; other zones at 0·6 foot and 1·4 feet above the base
	DeCew Formation
208·3-217	Dolomite; buff-grey, dense, massive; calcite-filled vugs at 211·8 and 212 feet
	Rochester Formation
217 -274·1	Shale; calcareous, dark grey; bryozoan limestone at 230·2-230·5, 230·8, 235-235·4, 267, 272·2-272·9, 273·2, 273·6, 273·7, 273·8-273·9 feet
274·1-278·2	Limestone and shale interbedded; basal 1½ feet mainly argillaceous limestone, transitional into the underlying Irondequoit; *Conularia* cf. *niagarensis* Hall at 276 feet, *Strophonella* cf. *striata* (Hall) at 277·5 feet

HOLE NO. N-14—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
278·2-287	Limestone; light grey to pinkish, coarsely crystalline; lower contact sharp, undulating slightly; *Fardenia subplana* (Hall) at 279·6 feet, *Atrypa reticularis* (Linnaeus) at 279·1 and 285 feet, *Eospirifer niagarensis* (Conrad) at 279·1 feet
	Reynales Formation
287 -297·1	Dolomite; dark to buff-grey, dense; green shale partings from 287·7-288·1 feet, grey shale at 290·7, 290·8-291, 294·1, 296·2 feet
297·1-299·6	Limestone; grey, coarsely crystalline; many grey shale partings; basal 0·5 inch phosphatic; Bryozoa
	Neahga Formation
299·6-304·4	Shale; black, fissile; basal ½ foot calcareous; lower contact gently undulating
	Thorold Formation
304·4-313·3	Sandstone; greenish white, very fine grained; green shale at 306·1, 306·2, 306·6, 306·7-306·8, 308·7, 309·4-309·5, 310·4-310·6 feet; lower contact sharp
	Grimsby Formation
313·3-359·7	Sandstone; red, green mottled, fine grained; red shale at top, 315, 320-320·4, 321·1, 323·2-324·8, 326-326·5, 327·8, 329·5, 331·6, 332·1-332·3, 333·8, 334·2, 337·5, 338·3, 339·2-340, 354, 356·6-356·7, 358 feet
359·7-360·5	Sandstone and shale; red, interbedded; lower contact between red sandstone and green shale
	Power Glen Formation
360·5-361·3	Shale; grey, arenaceous
361·3-371·8	Shale and sandstone; grey, fossiliferous, interbedded; red seams at top, 362·1, 363 and 364·5 feet
371·8-372·4	Sandstone; whitish grey, fine grained
372·4-372·8	Shale; grey
372·8-373·1	Limestone; grey, coarse; fossiliferous with black blebs
373·1-379·4	Shale and sandstone interbedded
379·4-386·4	Shale; grey; minor sandstone beds
386·4-390	Shale; grey
390 -394·2	Sandstone; argillaceous; numerous grey shale partings in basal 1 foot
394·2-396·6	Core missing
	Whirlpool Formation
396·6-403·4	Sandstone; quartzose, white, fine grained; rare grey shale partings

Hole No. O-1

Location: 2,013·2 feet N., 2,759·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 546·9 feet — Depth of overburden: 25·1 feet

Total depth: 270·8 feet — Drilled: Nov.-Dec., 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
25·1-26·6	Core missing
26·6-60	Dolomite; chocolate-brown to brownish grey, granular; rare bituminous partings; gypsum at 37·5 feet; *Enterolasma* sp. at 39 feet, scattered *Favosites* sp.
60 -66·5	Dolomite; light brown, highly porous, granular; *Favosites* cf. *niagarensis* Hall at 60·7 feet
66·5-70	Dolomite; dark brown to chocolate, granular; a few small *Favosites* sp.
70 -99·5	Dolomite; brownish grey, dense; some shaly matter particularly in the lower 5 feet producing mottled appearance; much gypsum; upper 7 feet highly porous; *Favosites* sp. scattered throughout
99·5-101·2	Dolomite; light brownish grey, granular
101·2-113·5	Dolomite; buff, dense to granular; *Favosites* sp. concentrated in 105-109 feet
113·5-118	Dolomite; light grey, granular; *Favosites* sp. abundant
	Lockport Formation
	Eramosa Member
118 -131·4	Dolomite; dark brownish grey, bituminous, dense; abundant shale partings; gypsum at 118·8 and 122·1 feet; slightly coarser with scattered *Favosites* sp. in the upper 4 feet; petroliferous odour; upper contact ill-defined
	Goat Island Member
131·4-150·3	Limestone or dolomitic limestone; light grey, highly porous, semicrystalline to crystalline; rare stylolites; *Favosites* cf. *forbesi* (Edwards and Haime) prolific
150·3-156·3	Dolomite; dark grey, dense; shale partings; upper and lower contacts transitional
156·3-164·3	Limestone; whitish grey, crystalline; *Favosites* sp. (tiny corallites) reef; lower contact sharp
	Gasport Member
164·3-175	Dolomite; dark steel-grey, dense; numerous shale partings; gradual downward transition into typical Gasport; two small gypsum masses at 167·2 feet
175 -186·6	Limestone; whitish grey, crystalline, crinoidal; nine stylolite bands; small *Favosites* sp. concentrated at 181·4-185 feet; pebble conglomerate (pebbles of dark grey, dense dolomite, maximum length 0·1 foot) in basal 0·85 foot; sharp contact with underlying DeCew

(Note: above divisions somewhat arbitrary; no typical Goat Island present; entire sequence coral-reef nature even up into stratigraphic Guelph equivalent; normal buff dolomite phases of Lockport possibly inter-reef phase for the Niagara region; Eramosa-Guelph contact far from definite)

HOLE NO. O-1—*Continued*

Depth	Lithology
Feet	
	DeCew Formation
186·6-195	Dolomite; argillaceous, dark grey, dense; base transitional; calcite stringers at 194 feet; *Eospirifer* sp. at 197·7 feet
	Rochester Formation
195 -200	Shale; highly calcareous to dolomitic
200 -248·1	Shale; black to grey, calcareous; limestone at 209-209·1, 209·2-209·5, 210, 210·7-211, 213-215·6 (streaks), 235·1-235·5 (streaks), 239·5-241 (streaks) feet
248·1-256·2	Shale; grey; bryozoan limestone beds increasing; pyrite blebs and thin calcite seams associated in basal 1 foot transitional into Irondequoit
	Irondequoit Formation
256·2-260	Limestone; light grey, crystalline, fossiliferous, crinoidal, shale partings at 256·6, 256·7, 256·9, 257·6, 258·3, 258·6, 259·5 feet; stylolitic; *Whitfieldella* sp. at 257·2 feet, *Atrypa reticularis* (Linnaeus) at 256·5, 257·9, 260 feet, *Parmorthis elegantula* (Dalman), *Plectodonta transversalis* (Wahlenberg) at 257·9 feet
260 -265·5	Limestone; whitish grey, less fossiliferous, crystalline; rare shale partings; gypsum at 264·1 and 264·9 feet; *Plectodonta transversalis* (Wahlenberg) at 261·8 feet, *Parmorthis elegantula* (Dalman) at 262·4 feet, *Atrypa reticularis* (Linnaeus) at 261·5 and 265 feet
	Reynales Formation
265·5-272·1	Limestone; argillaceous, dark grey, dense

INDEX OF FOSSILS

Numbers in **bold-face** *type indicate pages where species are described.*

PLATES II — XIII

G.S.C. Memoir 289

SILURIAN STRATIGRAPHY AND PALÆONTOLOGY OF THE NIAGARA ESCARPMENT IN ONTARIO

By

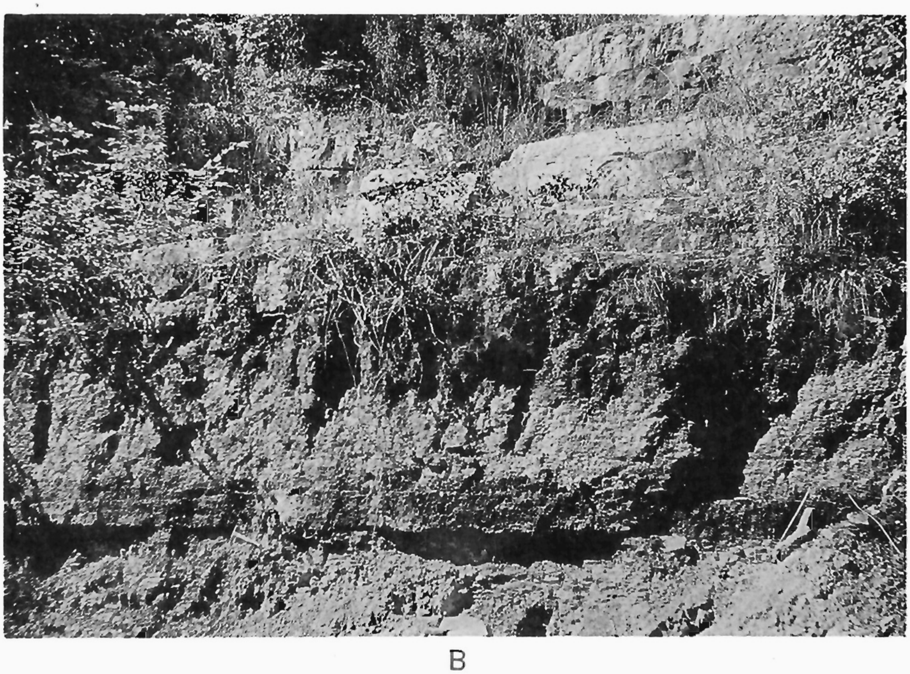
Thomas E. Bolton

PLATE II

A. Wingfield and Fossil Hill formations; north of Lions Head, Ont., section 220. (Page 37)

B. Cabot Head, Fossil Hill, and Lions Head; Inglis Falls road-cut, Owen Sound, Ont., section 105. (Page 41)

A



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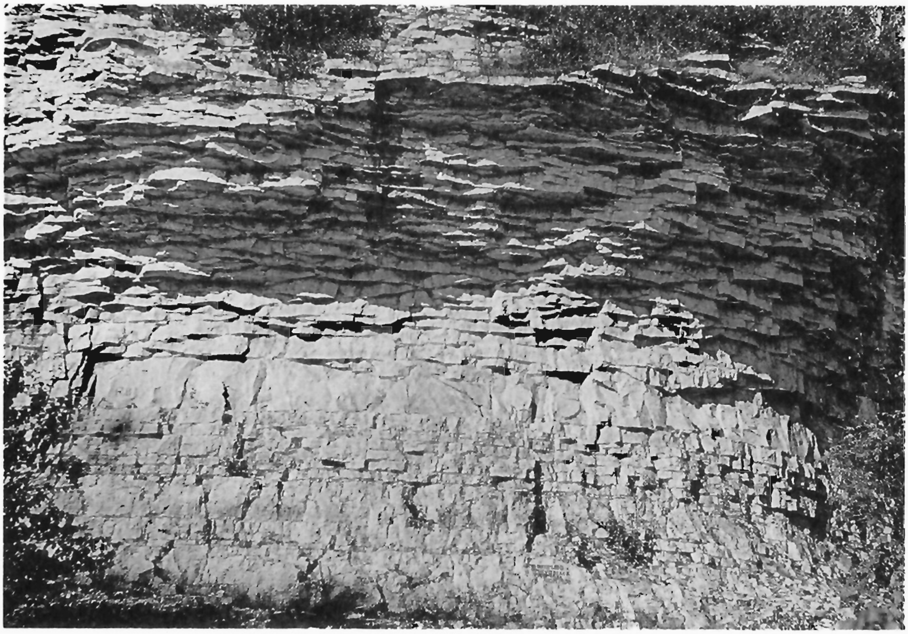

A

B

PLATE III

A. Lions Head member, Amabel formation; north of Lions Head, Ont., section 220. (Page 52)

B. Colpoy Bay member, Amabel formation; north tributary, Nottawasaga River, section 65. (Page 52)

PLATE IV

A. Bioherms in Wiarton member, Amabel formation; road-cut south of Owen Sound, section 95. (Page 54)

B. Close up of south flank of bioherm, Wiarton member, Amabel formation, section 95. (Page 54)

A

B

Plate V

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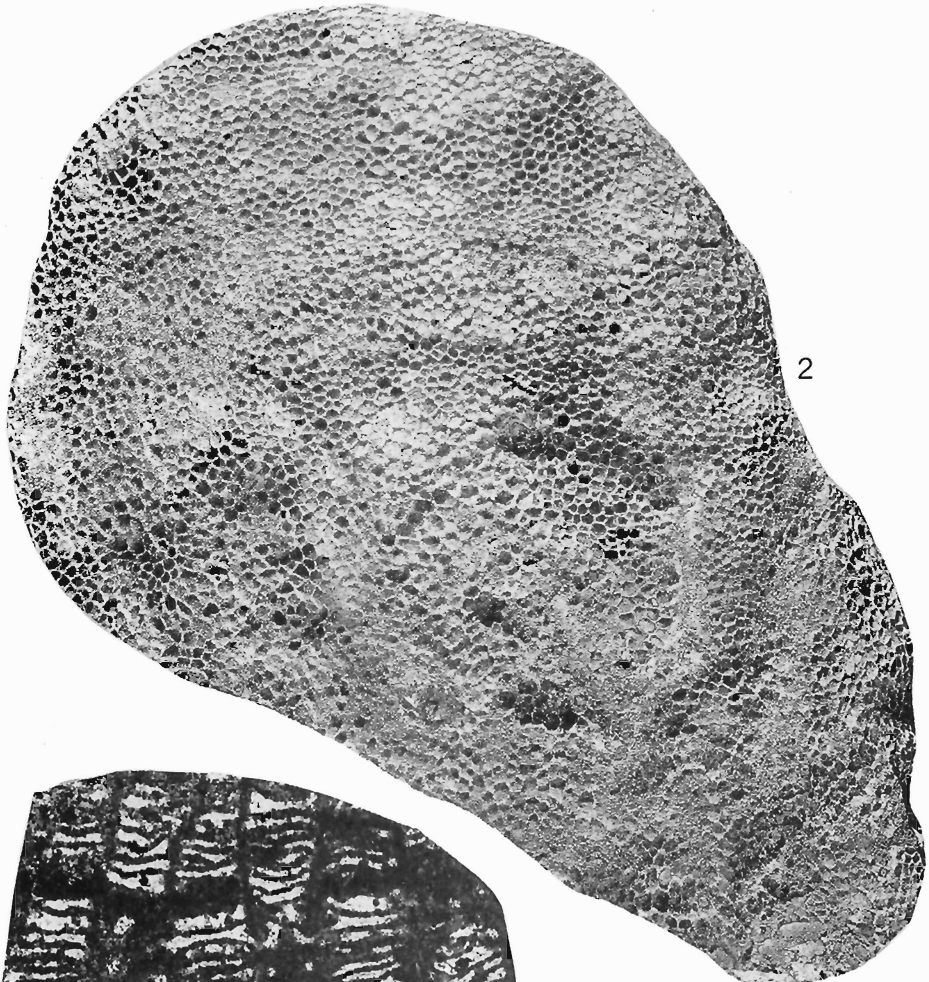

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PLATE V

Figure 1. *Favosites forbesi dyerensis* n. var. (x 1). Side view of corallum; Dyer Bay formation, Clinton group; upper West Bay cliff, Billings tp., Manitoulin Island; holotype, R.O.M.P. No. 7538. (Page 65)

Figure 2. *Favosites forbesi dyerensis* n. var. (x 1). Top view of holotype corallum. (Page 65)

Figure 3. *Favosites forbesi dyerensis* n. var. (x 10). Enlargement of part of vertical section showing closely spaced tabulae; allotype, R.O.M.P. No. 1761. (Page 65)

PLATE VI

Figure 1. *Lyellia thebesensis paucivesiculosa* n. var. (x 1). Manitoulin formation, Cataract group; southeast quarry, Owen Sound; hypotype, G.S.C. No. 11066. (Page 64)

Figure 2. *Lyellia thebesensis paucivesiculosa* n. var. (x 1). Vertical section; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; holotype, R.O.M.P. No. 1720B. (Page 64)

Figures 3, 6. *Lyellia thebesensis paucivesiculosa* n. var. (x 10). Vertical and transverse sections of a portion of a corallum; upper beds of Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; holotype, R.O.M.P. No. 1720E. (Page 64)

Figure 4. *Lyellia thebesensis paucivesiculosa* n. var. (x 1). Upper surface of corallum; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; allotype, R.O.M.P. No. 7490. (Page 64)

Figures 5, 7. *Lyellia thebesensis paucivesiculosa* n. var. (x 1). Upper and side views of corallum; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; holotype, R.O.M.P. No. 7491. (Page 64)

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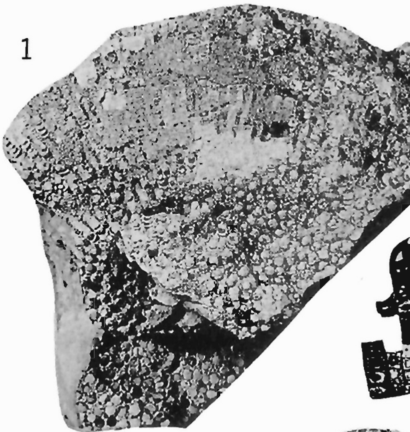

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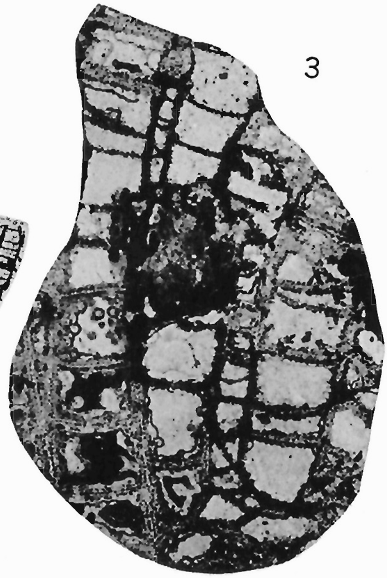

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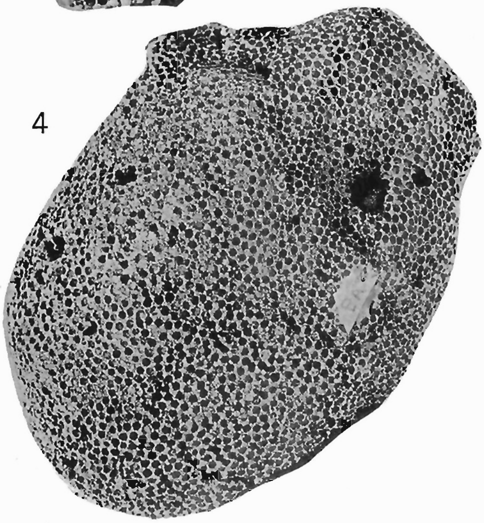

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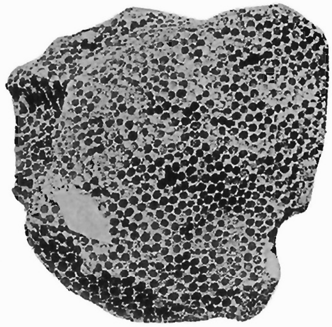

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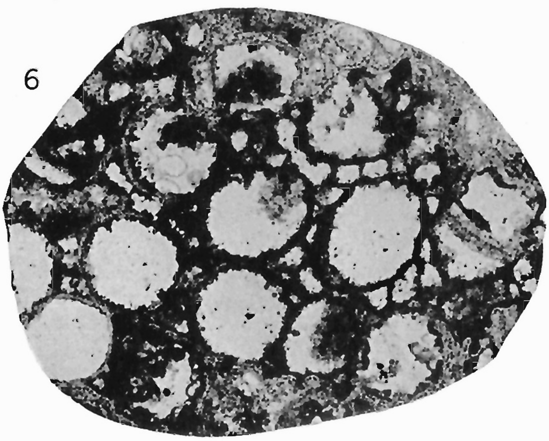

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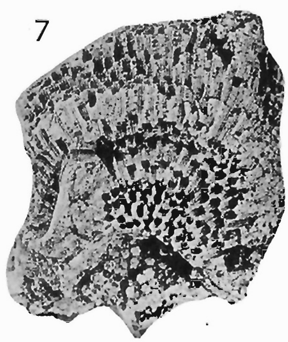

PLATE VII

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PLATE VII

Figure 1. *Siphonocrinus pentagonus* W. and S. (x 1). Wiarton member, Amabel formation; Colpoy village-Adamsville road, section 176; hypotype, G.S.C. No. 11063. (Page 54)

Figure 2. *Siphonocrinus pentagonus* W. and S. (x 5). Enlargement of upper plates on fig. 1.

Figure 3. *Siphonocrinus pentagonus* W. and S. (x 1). Wiarton member, Amabel formation; south of Lions Head village, section 182; hypotype, G.S.C. No. 11064.

Figure 4. *Siphonocrinus pentagonus* W. and S. (x 4). Plate arrangement on fig. 3.

PLATE VIII

Figure 1. *Hallopora caleyi* n. sp. (x 10). Tangential section of a portion of a zoarium; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 1707B. (Page 67)

Figure 2. *Hallopora caleyi* n. sp. (x 10). Vertical section; cotype, R.O.M.P. No. 1706B. (Page 67)

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Plate IX

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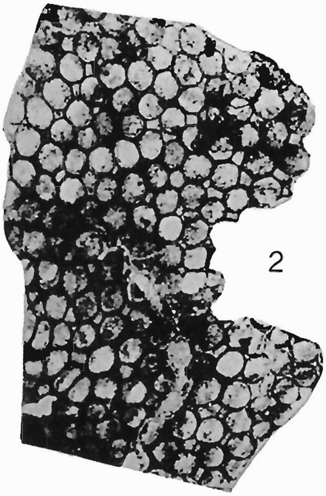

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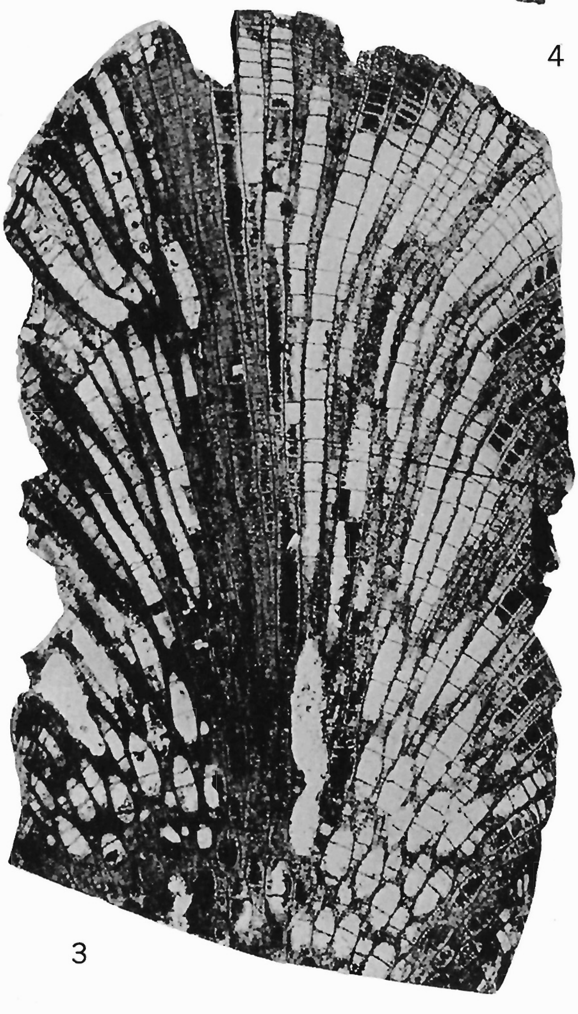

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PLATE IX

Figure 1. *Hallopora caleyi* n. sp. (x 1). Zoarium; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 7508. (Page 67)

Figure 2. *Hallopora caleyi* n. sp. (x 10). Tangential section; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 1707A. (Page 67)

Figure 3. *Hallopora caleyi* n. sp. (x 10). Vertical section; Manitoulin formation, Cataract group; east shore of Colpoy Bay, northeast of Oxenden; hypotype, G.S.C. No. 11067. (Page 67)

Figure 4. *Hallopora obliquipora* n. sp. (x 1). Zoarium; Manitoulin dolomite, Cataract group; Cataract, Ont.; holotype, R.O.M.P. No. 7414. (Page 67)

Figure 5. *Hallopora obliquipora* n. sp. (x 10). Vertical section; Manitoulin formation, Cataract group; Cataract, Ont.; holotype slide, R.O.M.P. No. 1510. (Page 67)

PLATE X

Figure 1. *Hallopora peculiaris* n. sp. (x 10). Vertical section; Cabot Head formation, Cataract group; Credit Forks, Ont.; holotype slide, R.O.M.P. No. 1509A. (Page 68)

Figure 2. *Hallopora peculiaris* n. sp. (x 1). Zoarium; Cabot Head formation, Cataract group; Credit Forks, Ont.; holotype, R.O.M.P. No. 7413. (Page 68)

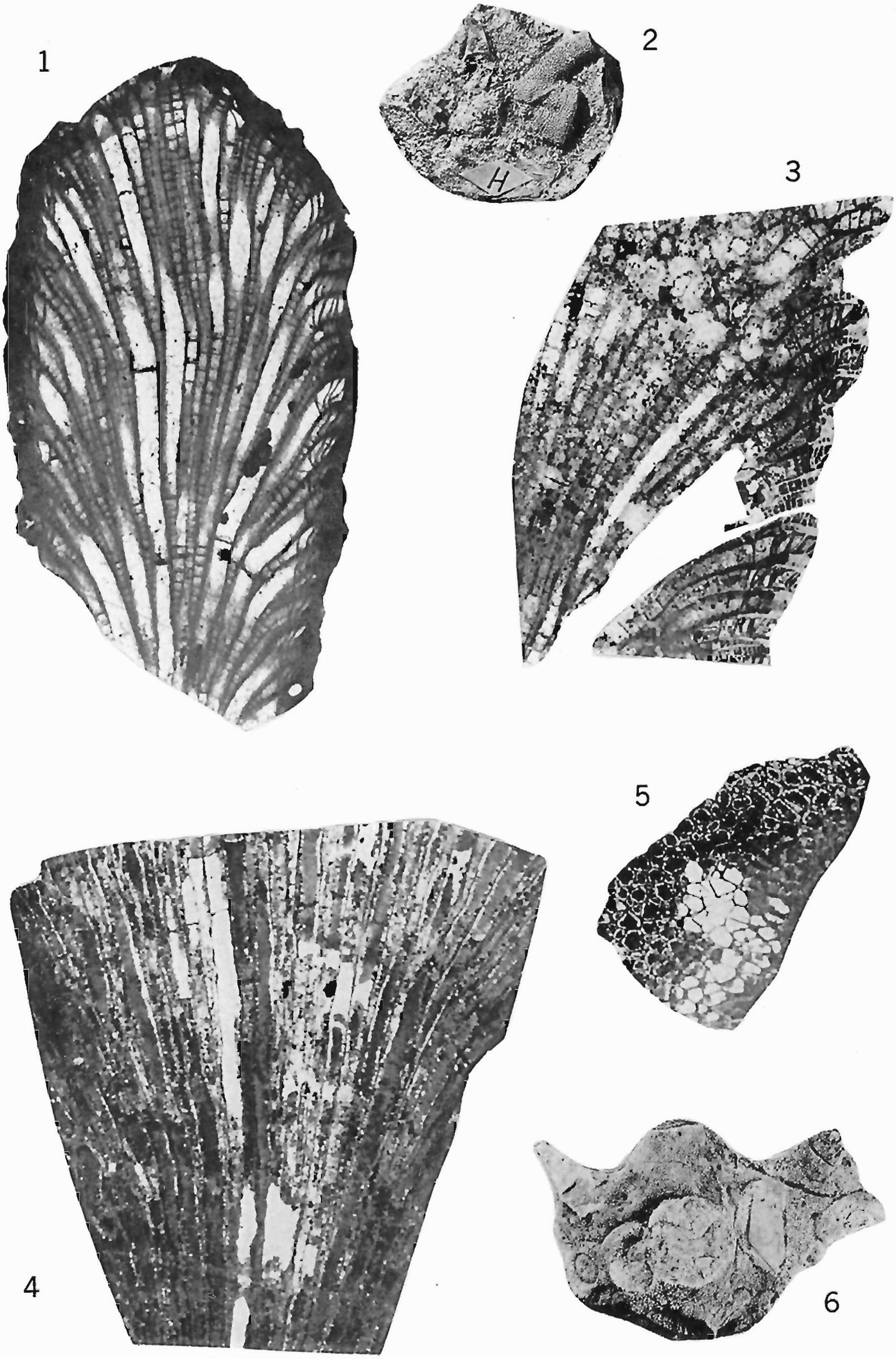
Figure 3. *Hallopora peculiaris* n. sp. (x 10). Vertical section; Manitoulin formation, Cataract group; east shore of Colpoy Bay, northeast of Oxenden; hypotype, G.S.C. No. 11068. (Page 68)

Figure 4. *Homotrypa lewisi* n. sp. (x 10). Vertical section; Manitoulin formation, Cataract group; Manitoulin Island; cotype, R.O.M.P. No. 1713. (Page 66)

Figure 5. *Homotrypa lewisi* n. sp. (x 10). Tangential section of a portion of a zoarium; cotype, R.O.M.P. No. 1713. (Page 66)

Figure 6. *Homotrypa lewisi* n. sp. (x 1). Zoarium; Manitoulin formation, Cataract group; Allen tp., Manitoulin Island; cotype, R.O.M.P. No. 7513. (Page 66)

PLATE X



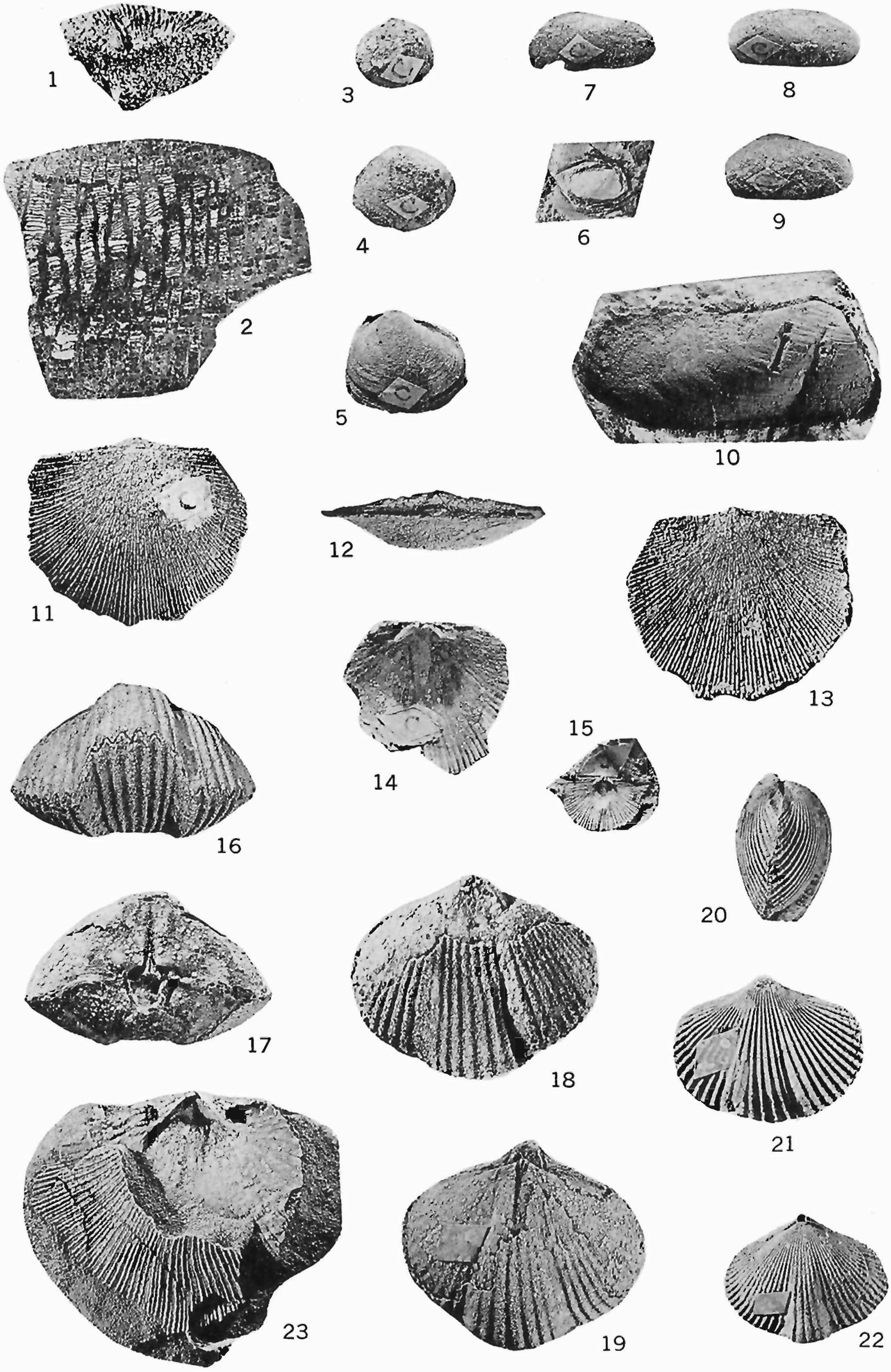

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Plate XI

Figure 1. *Goniophyllum pyramidale* (Hisinger). (x 1). Fossil Hill formation; Manitowaning-South Baymouth highway, lot 4, con. II, Manitoulin Island; hypotype, G.S.C. No. 11065.

Figure 2. *Favosites forbesi dyerensis* n. var. (x 2). Vertical section; Dyer Bay formation, Clinton group; Billings tp., Manitoulin Island; allotype, R.O.M.P. No. 1761. (Page 65)

Figures 3-4. *Ctenodonta glenna* n. sp. (x 1). Left and right valves; Power Glen formation, Cataract group; DeCew Falls, Ont.; paratypes, R.O.M.P. No. 26478a-b. (Page 72)

Figure 5. *Ctenodonta glenna* n. sp. (x 1). Right valve; holotype, R.O.M.P. No. 26478. (Page 72)

Figure 6. *Ctenodonta cabotensis* n. sp. (x 1). Right valve; Cabot Head formation, Cataract group; Forks of the Credit, Ont.; holotype, R.O.M.P. No. 7416. (Page 71)

Figure 7. *Modiolopsis posteroaltis* n. sp. (x 1). Right valve; Power Glen formation, Cataract group; DeCew Falls, Ont.; holotype, R.O.M.P. No. 26477. (Page 74)

Figures 8-9. *Modiolopsis posteroaltis* n. sp. (x 1). Left and right valves; paratypes, R.O.M.P. No. 26477 a-b. (Page 74)

Figure 10. *Modiolopsis creditensis* n. sp. (x 1). Right valve; Cabot Head red beds (Grimsby), Cataract group; Hamilton, Ont.; plastocast of holotype, R.O.M.P. No. 7409. (Page 74)

Figures 11-13. *Fardenia plicata* n. sp. (x 1). Dorsal, posterior, and ventral views; upper beds of Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 7525. (Page 70)

Figures 14-15. *Fardenia plicata* n. sp. (x 1). Ventral interiors; cotypes, R.O.M.P. No. 7525. (Page 70)

Figures 16-19. *Orthorhynchula bidwellensis* n. sp. (x 1). Anterior, posterior, ventral, and dorsal views; upper beds of Manitoulin dolomite, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 7518. (Page 69)

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Figure 22. *Orthorhynchula bidwellensis* n. sp. (x 1). Dorsal view; cotype, R.O.M.P. No. 7518. (Page 69)

Figure 23. *Fardenia plicata* n. sp. (x 1). Dorsal interior; Manitoulin formation, Cataract group; Bidwell tp., Manitoulin Island; cotype, R.O.M.P. No. 7525. (Page 70)

Plate XII

Figure 1. *Camerella wiartonensis* n. sp. (x 1). Ventral valve; Wiarton member, Amabel formation; upper 3 feet Wiarton road-cut, section 151; holotype, G.S.C. No. 11592. (Page 68)

Figure 2. *Camerella wiartonensis* n. sp. (x 1). Dorsal valve; Wiarton member, Amabel formation; south of Lions Head village, section 182; paratype, G.S.C. No. 11599. (Page 68)

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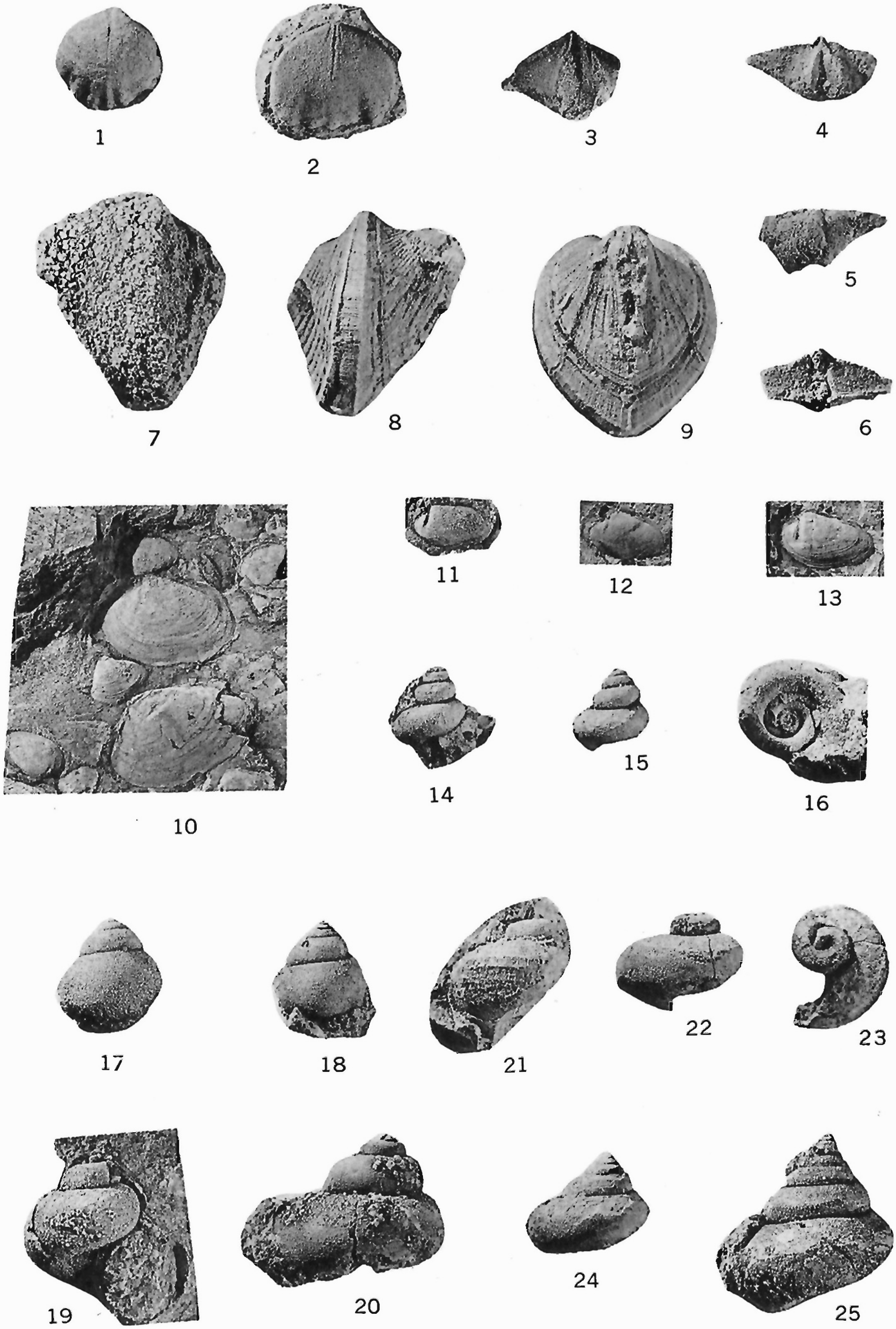
PLATE XII



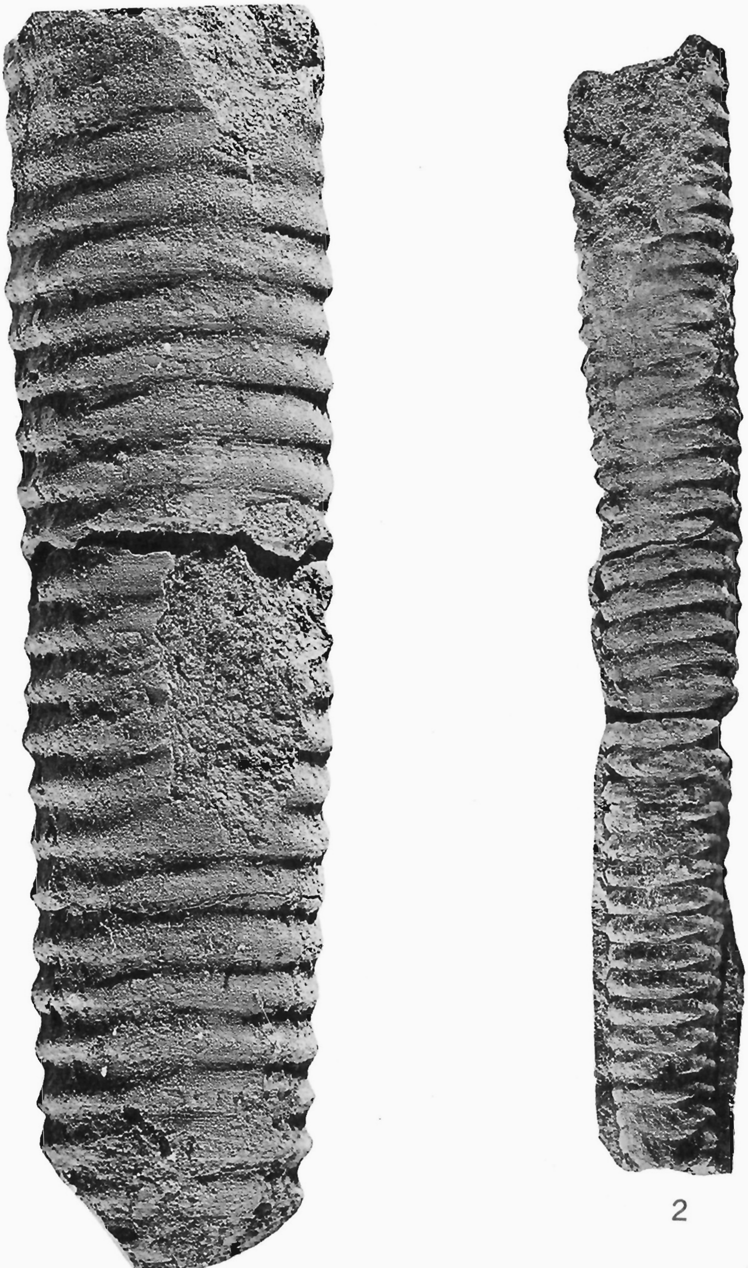


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PLATE XIII

Figure 1. *Leurocycloceras* (?) *orangevillense* n. sp. (x 1). Fossil Hill formation, 22 inches down; Nottawasaga River, section 65; paratype, G.S.C. No. 11069. (Page 75)

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