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SILURIAN FORMATIONS OF THE NIAGARA ESCARPMENT IN ONTARIO

(Preliminary Account)

By

T. E. Bolton

OTTAWA
1953

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Figure 1. Columnar sections ..... In pocket

SILURIAN FORMATIONS OF THE NIAGARA ESCARPMENT IN ONTARIO

INTRODUCTION

Silurian sedimentary formations underlie the whole of the Ontario-Michigan basin, but exposures of Lower and Middle Silurian strata are mainly confined to the Niagara escarpment. The detailed stratigraphical and palaeontological investigations undertaken by Logan (1863) [1], Parks (1909), Schuchert (1914),

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

Williams (1919), and Caley (1940, 1941, 1945) have clearly defined the Silurian of Ontario. Nevertheless, recent reviews of the Silurian System of New York (Gillette, 1947), Michigan (Ehlers, 1948), and Illinois (Lowenstam, 1948) have indicated that the earlier theories concerning the stratigraphic relationships of its various formations in Ontario should be revised.

The conclusions presented in this report are based principally on detailed examinations of the numerous escarpment sections exposed between Niagara Falls and Manitoulin Island. The term Cataract group is applied to the Lower Silurian (Alexandrian) Series, and is divided into the Whirlpool, Power Glen, Manitoulin, Cabot Head, and Grimsby formations. The Cabot Head is restricted to the Cataract shales, and the Grimsby is enlarged to include the red shales below the typical red sandstone as defined by Williams (1919). The name Power Glen is introduced for the shales overlying the Whirlpool and underlying the Grimsby in the Niagara Falls region, and is correlated with the Manitoulin and lower part of the Cabot Head formations.

The Clinton and Albemarle groups are assigned to the Middle Silurian (Niagaran) Series, the latter group name being here proposed for the late Niagaran dolomites of the Ontario Peninsula. The Clinton is divided into the Thorold, Neagha, Reynales, Irondequoit, Rochester, and DeCew formations in the Niagara Peninsula, and into the Dyer Bay, Wingfield, St. Edmund, and Fossil Hill formations in the north. The Thorold, Dyer Bay, Wingfield, and St. Edmund were formerly included in the Cataract formation, and the DeCew was formerly regarded as basal Lockport. The Fossil Hill and St. Edmund formations, formerly part of the Lockport formation, are here defined; the former is correlated with the Lower Clinton Reynales formation.

The late Niagaran Albemarle group is divided into the Lockport, Amabel, and Guelph formations. The Lockport is confined to the Niagara Peninsula; and the remainder of the

sediments formerly included in this formation throughout the Ontario Peninsula are here included in the new Amabel formation. Three members - Gasport, Goat Island, and Eramosa, are included in the Lockport formation, and four members - Lions Head, Colpoy Bay, Wiarton, and the widely developed Eramosa, are recognized in the northern Amabel formation. A prolific fauna is outlined from the Wiarton member, which contains correlatives of both the Guelph of Ontario and the Racine of Wisconsin.

ACKNOWLEDGMENTS

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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. Numerous courtesies extended in the field by the officials and men of this company were much appreciated.

STRATIGRAPHY AND PALAEONTOLOGY

General Statement

Undeformed Lower and Middle Silurian sedimentary formations dip gently southwest in Ontario. Along the Niagara escarpment proper the Lower Silurian rocks consist of sandstone, dolomite, and shale - the Cataract group - and are divisible into five formations: Whirlpool, Power Glen, Manitoulin, Cabot Head, and Grimsby. The Middle Silurian Clinton and Albemarle groups are composed essentially of dolomites, with shales confined to Niagara and Bruce Peninsulas. Two different facies are represented in the Clinton group of Ontario. In Niagara Peninsula, the southern facies is divisible into six formations - Thorold, Neagha, Reynales, Irondequoit, Rochester, and DeCew - whereas the northern facies is represented by four formations - Dyer Bay, Wingfield, St. Edmund, and Fossil Hill - which, with the exception of the Fossil Hill, are confined to Bruce Peninsula and Manitoulin Island. The Albemarle group is also composed of two facies; in the Niagara Peninsula its representatives 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 divisible into members. The stratigraphic relationships of these various strata are illustrated in

Figure 1.

The profound lithological and faunal differences between the Silurian strata of western New York-Niagara Peninsula and of Bruce Peninsula-Manitoulin Island-northern Michigan have been attributed to a structural barrier - the Cincinnati or Cataract (Cumings, 1939) axis, but results of the present investigation indicate that an axis proper probably did not exist, at least not in the escarpment region. The pronounced facies changes and associated faunal variations indicate, rather, that two sites of deposition existed, one in the Niagara Peninsula area, and the other in the Bruce Peninsula-Manitoulin Island-northern Michigan region. These two sites were separated, in the writer's opinion, by a broad shelf that extended from Hamilton to Owen Sound, and that influenced sedimentation principally during Niagaran (Middle Silurian) time.

Table of Formations

			Niagara Peninsula		Ontario Peninsula and Manitoulin Island
Niagaran Series (Middle Silurian)	Albemarle group		Guelph formation		Guelph formation
		Lockport fm.	Eramosa dolomite	Amabel fm.	Eramosa dolomite
			Goat Island dolomite		Wiarton dolomite
			Gasport dolomite		Colpoy Bay dolomite
					Lions Head dolomite (?)
	Clinton group	Upper	DeCew formation		
			Rochester formation		
			Irondequoit formation		
		Middle			Fossil Hill formation
		Lower	Reynales formation		St. Edmund formation
			Neagha formation		Wingfield formation
			Thorold formation		Dyer Bay formation

Alexandrian Series (Lower Silurian)	Cataract group	Grimsby formation	Cabot Head formation
		Power Glen formation	Manitoulin formation
		Whirlpool formation	Whirlpool formation

Cataract Group

The term Cataract is retained in the present report for a marine facies of Lower Silurian age, and is elevated from a formational rank to that of a group. Its separate lithological units are related through lateral gradation, and together represent a complete sedimentary cycle from transgression to regression.

Whirlpool Formation

The Whirlpool sandstone can be identified at the base of the escarpment from Niagara Falls north to Duntroon, 8 miles south of Collingwood. It is typically a massive to thick-bedded, white to light grey, fine-grained, crossbedded, compact, unfossiliferous, quartzose sandstone or orthoquartzite. Thin zones of rolled grey shale pebbles or mud galls occur at various horizons in the Niagara Peninsula exposures, and upper beds are commonly red mottled.

The Whirlpool rests sharply on the Upper Ordovician red Queenston shales. Its upper contact with the Manitoulin dolomite is sharp and well defined. On the other hand, its upper contact with the Power Glen is transitional, and is everywhere drawn at the top of the massive sandstone beds. The formation varies in thickness both locally and regionally; it appears to thin westward and northward from 28 feet at Niagara Falls to 12 feet at DeCew Falls and Hamilton, 22 feet on Nottawasaga River, and 6 feet at Duntroon.

The Whirlpool sandstone represents a marginal deposit, laid down by the encroaching shallow sea upon a stable shelf area. A constant decrease in the average size of the grains from Niagara gorge westwards indicates that the source of the detrital material lay to the south and east.

Power Glen Formation

The name Power Glen is here proposed for the 48 feet of shales, with interbedded sandstones and limestones, that separate the Whirlpool from the Grimsby at DeCew Falls, Ontario. This distinct facies can be recognized from Niagara gorge to Stoney Creek.

Eastward the shales grade into the red Medina formation and westward into Manitoulin dolomite and Cabot Head shales.

The Power Glen formation comprises a series of green to dark grey, fissile, calcareous to arenaceous shales, interbedded with thin bands of light grey, fine- to medium-grained, calcareous sandstones. The sandstone content increases south and east of the type section. Seams of red, oolitic, ferruginous limestone and intraformational conglomerate bands are present in the upper beds.

The lower contact of the Power Glen formation may be placed at the base of a sandy transition zone, 1 foot thick, consisting of alternating thin sandstone and shale beds, which lies between the massive Whirlpool sandstone and overlying shale facies, and was formerly assigned to the Whirlpool formation. These transition beds represent the initial deposits of a sedimentary phase entirely different from that which provided the pure, massive Whirlpool sandstone. Red shales or sandstones of the Grimsby formation conformably overlie the grey Power Glen shales; this change in colour is indicative of marked environmental changes within the basin of deposition without, however, any break in deposition.

The Power Glen shales are sparsely fossiliferous, with brachiopods (Parmorthis eugeniensis), pelecypods (Ctenodonta elliptica, Modiolopsis orthonota), and gastropods (Hormotoma subulata, Lophospira pulchra) forming 98 per cent of the definitely recognizable fossil types. The bryozoan Helopora fragilis is apparently restricted to the upper 27 feet of shale in the DeCew Falls section.

The Power Glen represents an offshore marine facies characterized by shales and a minimum of lime deposition. The source of the clastic material lay to the south and east.

Manitoulin Formation

Manitoulin strata are widely distributed along the Niagara escarpment, extending from Stoney Creek northward across Manitoulin Island into northern Michigan. The formation consists mainly of thin-bedded, buff-weathered, grey, dense to fine-grained, dolomitic limestone, with the basal half generally more massive. Grey shale partings are abundant at Hamilton, Credit Forks, and Nottawasaga River. Lenses of incipient white chert occur in the upper beds from Credit Forks north. The Manitoulin strata exposed on Manitoulin Island are divisible on the basis of lithology and fauna into a lower unit of typical thin-bedded, fine-grained, dolomitic limestone and an upper, biohermal unit of massive, white to grey, crystalline dolomite with green shale inclusions.

The Manitoulin rests conformably upon the Whirlpool sandstone from Duntroon south, upon the Upper Ordovician

Queenston red shales in Bruce Peninsula, and upon the Upper Ordovician Kagawong dolomite on Manitoulin Island. It is overlain transitionally by the Cabot Head shales, the contact being drawn at that level where alternating grey shales and limestone predominate over the pure Manitoulin. The thickness of the Manitoulin formation gradually increases northward from 4 feet at Stoney Creek to 11 feet at Hamilton, 26 feet on Nottawasaga River and at Owen Sound, and 50 feet in its biohermal development on Manitoulin Island.

The Manitoulin dolomite carries a rich and varied fauna, many forms of which are common to all sections. Brachiopods, the most abundant of all the megascopic fossils, are represented by Dolerorthis flabellites, Platystrophia biforata, Parmorthis eugeniensis, Coelospira planoconvexa, and Stegerhynchus neglectum. The bryozoan Helopora fragilis is present in the upper beds. On Manitoulin Island the upper unit is characterized by the coral Palaeofavosites and the brachiopods Platystrophia daytonensis, Parmorthis eugeniensis, and a new species Orthorhyncula.

The Manitoulin is a normal marine limestone deposited during early Silurian time in those regions that lay beyond the influence of clastic sedimentation. An increase in clastic sediments and the extension of the Cabot Head shales over most of Ontario mark the close of Manitoulin sedimentation.

Cabot Head Formation

The name Cabot Head is applied to those shales that directly overlie the Manitoulin dolomite, and are overlain successively, from south to north, by the Grimsby, Reynales, Fossil Hill, and Dyer Bay formations. In its northern development, the formation contains equivalents of the more southern, red, Grimsby facies and, possibly, of the Thorold. Cabot Head shales underlying the Grimsby are 50 feet thick at Stoney Creek and 34 feet at Hamilton, and the combined Cabot Head of the more northerly localities (See Figure 1) is 52 feet thick on Nottawasaga River, 120 feet at Owen Sound, and 40 to 50 feet on Manitoulin Island.

The fauna of the Cabot Head is very similar to that of the underlying Manitoulin dolomite, but it may be distinguished by an abundance of the bryozoan Helopora fragilis in both shales and hard bands. Both the faunal assemblage and lithology suggest a predominantly shallow, muddy, marine environment subjected constantly to rapid changes in sedimentation.

Grimsby Formation

The name Grimsby is expanded to include those red shales and sandstones lying between the Cabot Head or Power Glen shales below and the Thorold sandstone above. The formation is recognizable as a distinct unit in the Niagara escarpment as

far north as Clappison Corners. Farther north, red beds near the top of the Cataract are considered equivalent to the Grimsby, but are included in the combined Cabot Head formation (See Figure 1).

Red shales, with varying amounts of interbedded red sandstone, constitute the basal half of the Grimsby from Niagara Falls to Fruitland, and massive, green and yellow-mottled, crossbedded, fine-grained, red sandstone characterizes the remainder. The argillaceous content increases from Fruitland north to where, at Clappison Corners, the formation is composed entirely of interbedded red shale and sandstone. In the north the Grimsby equivalent at the top of the Cabot Head is principally fine-grained, arenaceous limestone grading to calcareous sandstone and underlain by red shale.

Both the lower and upper contacts of the 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.

A sparseness of fauna in the upper sandstone phase of the Grimsby is probably due in part to an unfavourable environment, and in part to removal of the fossil remains by wave and current action before burial. Fossils are more abundant in the lower red shales, with pelecypods and brachiopods again the dominant forms. Bryozoans, including Helopora fragilis, Phaenopora expansa, and P. ensiformis, characterize the upper red calcareous equivalent of the Grimsby in the north.

Red Grimsby sandstone spread gradually over most of southwestern Ontario in late Lower Silurian time. It represents the western extension of the Medina facies and the close of Cataract sedimentation in Ontario.

Clinton Group

The Clinton formation of previous authors is enlarged in the present report to include the Thorold sandstone at the base and the Rochester shale and DeCew dolomite at the top in Niagara Peninsula, as well as four formations in Bruce Peninsula and Manitoulin Island, and, accordingly, is elevated to the rank of group.

It is composed of a great variety of sediments, which change rapidly both lithologically and faunally. Representative strata exposed in the Niagara Peninsula may be directly related to five of the New York Clinton formations, and although the northern development of the Clinton appears quite unrelated to these sediments lithologically and faunally, it is correlated on stratigraphic evidence mainly with the Lower Clinton sequence.

Thorold Formation

The Thorold sandstone extends along the Niagara escarpment in Ontario from Niagara Falls to Clappison Corners. It is essentially a massive, white to light grey, fine-grained to dense, quartzose sandstone, but exhibits a marked increase in grey shale content from Stoney Creek north.

Both lower and upper contacts of the formation are distinct. Thin bands of red argillaceous sandstone at the base of the formation represent partly reworked Grimsby strata. The thickness of the Thorold ranges from 5 feet along the Niagara gorge to 13 feet at Hamilton.

Arthrophycus alleghaniensis is found in the massive sandstones, and fragments of the brachiopod Lingula clintoni are preserved in the interbedded shales.

The Thorold represents the initial sediments of the transgressing Lower Clinton sea rather than, as formerly considered, the closing phase of the Cataract.

Neagha Formation

Sanford (1935) proposed the name Neagha for those shales overlying the Thorold and underlying the Reynales in the Niagara gorge that were formerly referred to the Furnaceville formation. These shales are restricted to the Niagara Falls-DeCew Falls area.

The formation consists of greenish black fissile shale, with minor amounts of grey limestone. It is 6 feet thick at Niagara Falls and 1.3 feet at DeCew Falls. The basal 0.3 foot is commonly calcareous, and contains tiny shale pebbles or fragments embedded in pyrite or sand. The lower contact of the Neagha undulates slightly, whereas the upper contact is sharp.

Reynales Formation

The Lower Clinton Reynales dolomite may be traced from Niagara Falls north to Georgetown. It is a massive, thick- to thin-bedded, buff-weathered, light grey, dense dolomite or dolomitic limestone. Grey shale partings increase from Grimsby north, and the dolomite becomes more argillaceous. The basal 1 foot to 2 feet of the formation is a crystalline, fossiliferous limestone carrying pyrite and glauconite.

The Reynales formation is conformably underlain by the Neagha shale in the Niagara Falls region and by the Thorold sandstone or Cabot Head shale in the north. In Niagara Peninsula, it is overlain disconformably by the Irondequoit limestone, the

contact being marked by an undulating surface that can be traced as far north as Clappison Corners. Farther north the Irondequoit cannot be differentiated from the Gasport, due to the absence of the intervening Rochester shales. As a result, the Reynales is believed to be overlain disconformably by the southern equivalent of the Amabel formation.

The thickness of the Reynales is remarkably constant despite unquestionable evidence of erosion. It is 14.5 feet thick at DeCew Falls, 8.5 feet at Hamilton, and 8 feet at Limehouse.

The basal crystalline limestone is heavily laden with the brachiopod Pentamerus laevis, whereas the remainder of the dolomite is sparsely fossiliferous, characterized chiefly by the brachiopod Stricklandinia canadensis.

Irondequoit Formation

The Upper Clinton Irondequoit formation extends along the face of the escarpment from Niagara Falls to north of Waterdown, at which locality it is either missing or represented by the basal dolomite of the Amabel formation. It is 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 and Clappison Corners road-cuts. The upper 3 inches of the formation is highly argillaceous. In Ontario the thickness of the Irondequoit formation is fairly constant, ranging from 10 feet at Niagara Falls to 4 feet at Grimsby, 7 feet at Clappison Corners, and 4 feet north of Waterdown.

Brachiopods Atrypa reticularis, Fardenia subplana, Whitfieldella intermedia, and Parmorthis elegantula are the most abundant fossils in the Irondequoit. The faunal assemblage compiled for the upper beds in particular closely resembles the overlying younger Rochester assemblage.

Rochester Formation

The Rochester formation is exposed at various places along the Niagara escarpment between Niagara Falls and Waterdown. It is essentially a black to grey, calcareous shale to siltstone, with numerous thin, undulating, grey, fossiliferous limestone layers or lenses. The upper 10 to 12 feet of the formation is more dolomitic or calcareous.

The lower contact of the Rochester is sharp, and although shales and grey, argillaceous limestones are interbedded in the basal foot, there is no apparent disconformity associated with the abrupt lithological change from the Irondequoit limestone. The Rochester is 58 feet thick at Niagara Falls, 35 feet at Grimsby,

14 feet at Hamilton, and 2.4 feet at Clappison Corners.

An extremely rich and varied fauna characterizes the Rochester shales. The most abundant forms are the cystid Caryocrinites ornatus, the brachiopods Atrypa reticularis, Parmorthis elegantula, Rhipidomella hybrida, Fardenia subplana, Eospirifer niagarensis, Howellella crispa, and Stegerhynchus neglectum, and the trilobites Calymene niagarensis, Dalmanites limulurus, and Trimerus delphinocephalus. The crinoid Stephanocrinus angulatus is confined to the lower 10 feet of the Rochester in Ontario. More than thirty species of bryozoans were identified from the DeCew Falls exposure, with Fistulopora laminata, Chilotrypa ostiolata, Lioclema asperum, Hallopora elegantula, Chasmatopora asperatostriata, and Fenestrellina elegans the dominant forms. An Upper Clinton age for the Rochester is confirmed by the ostracod Paraechmina spinosa, and the entire assemblage typifies a benthonic marine environment.

DeCew Formation

The DeCew formation was assigned to the basal Lockport by Williams (1919), but the present investigation indicates that the major break in sedimentation occurred at the close of the DeCew, and that the DeCew dolomite was probably derived through the reworking of the argillaceous beds at the top of the Rochester as the Upper Clinton sea shallowed.

Buff-weathered, argillaceous to arenaceous, fine-grained to dense, dark grey, dolomitic limestone typical of the DeCew is confined to the Niagara Peninsula. Shale partings are abundant in the Hamilton area. The formation is distinguished in its type section by the characteristic conchoidal fracture or enterolithic structure.

Transitionally, the DeCew dolomite is underlain by the Rochester shales, and the position of this contact is difficult to determine in many sections owing to the dolomitic nature of these shales. The ripple-marked upper contact of the formation represents a definite break in sedimentation, and marks the top of the Clinton in Ontario. The DeCew varies in thickness from 12.5 feet at Niagara Falls, 8 feet at DeCew Falls and Stoney Creek, 3 feet in the Highway 20 road-cut, and 6 feet at Ancaster.

Only the cystid Caryocrinites ornatus was identified by Williams (1919) in the type section. Numerous graptolites, however, have been described by Bassler (1909) from the argillaceous dolomites that occur between the true Rochester and Gasport at Hamilton. As these beds are believed equivalent to the DeCew, many of these graptolites are, therefore, Clinton in age, and not Lockport as formerly proposed.

Dyer Bay Formation

The Dyer Bay extends as an important formation from no th of Owen Sound on Bruce Peninsula across Manitoulin Island into Michigan. The theory that Cataract sedimentation closed with the deposition of the Grimsby red beds or their equivalent in the Cabot Head excludes the Dyer Bay from the Lower Silurian. This formation, therefore, is considered the northern facies of the Lower Clinton, rather than a local phase of the Cabot Head as originally postulated by Williams (1919).

The formation is everywhere a thin-bedded, bluish grey, fine-grained, argillaceous dolomite, with grey to green shale partings. At its base are 2 to 5 feet of thicker bedded, grey, dense dolomite, with thin intraformational conglomerate lenses.

The Dyer Bay dolomite is sharply separated lithologically from the underlying Cabot Head shales. The upper contact is sharp wherever the formation is overlain by the Fossil Hill dolomite, but gradational where overlain by the Wingfield shale. Thicknesses of from 10 to 20 feet were measured on Bruce Peninsula, and from 15 to 25 feet on Manitoulin Island.

Important elements in the abundant Dyer Bay fauna are the coral Favosites cristatus, the brachiopod Virgiana mayvillensis, and the ostracods Leperditia cabotensis and Zygobolba williamsi.

The Dyer Bay Virgiana Zone is equivalent to the V. mayvillensis Zone in the upper part of the Mayville formation of Wisconsin, the V. decussata Zone in the Port Nelson formation of the Hudson Bay region and Unit B in the Interlake group of southern Manitoba, and the V. anticostiensis Zone in the Becscie-lower Gun River formations of Anticosti Island.

Wingfield Formation

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; exposures around the Wingfield basin at the northeast end of Bruce Peninsula are here designated as the type Wingfield. This series was formerly assigned to the Cataract formation.

The formation comprises a series of green to greenish grey shales and interbedded green to brown, dense, argillaceous dolomites. Both the lower and upper limits are marked by distinct lithological breaks. The thickness varies from 15 feet at Oxenden and Hope Bay to 40 feet at Cabot Head and 19 feet on Manitoulin Island.

A well-developed ostracod fauna, including Leperditia cabotensis, Chilobolbina punctata, and Zygobolba williamsi, is

diagnostic of the Wingfield shales and argillaceous dolomites.

The Lower Clinton Wingfield, as here defined, represents the thin, eastern, clastic equivalent of the thick dolomite formations that are developed westward on Manitoulin Island and the northern peninsula of Michigan. It may be correlated with the Leperditia fabulina - Z. williamsi Zones in the Wabi formation of Lake Timiskaming, Severn River-Ekan River(?) formations of Hudson Bay, and Unit C in the Interlake group of Manitoba.

St. Edmund Formation

Thin- to thick-bedded, brown, white weathered, dense to fine-grained dolomites of this formation extend from Cabot Head across Manitoulin Island into northern Michigan (Burnt Bluff formation). A 2- to 4-foot transition zone at the top of the St. Edmund separates this formation from the overlying Fossil Hill dolomite. The formation is from 80 to 100 feet thick on Manitoulin Island.

Dense dolomites of the St. Edmund formation are relatively barren. On the basis of the brachiopods Stegerhynchus(?) winiskensis and Rhynchospira lowi the St. Edmund is correlated with similar zones in the Hendricks dolomite of northern Michigan, the upper part of the Wabi and Severn River formations, and Units C-D of the Interlake group.

Fossil Hill Formation

The name Fossil Hill is here adopted for the thin-bedded, fossiliferous dolomites that rest directly on the St. Edmund dolomite in the numerous exposures around Fossil Hill, west of Manitowaning, Manitoulin Island. These dolomites were formerly referred to the Lockport by Williams (1919, 1937). Similar, thin-bedded, brown, fine-grained to crystalline dolomites may be identified from northern Michigan (Manistique formation) across Manitoulin Island and Bruce Peninsula to south of Orangeville. Exposures of argillaceous, dense Fossil Hill dolomites observed south of Orangeville could be traced south into lithologically similar dolomites that were definitely correlative with the Clinton Reynales formation. It is here proposed that these dolomites of the Fossil Hill formation are of Lower Clinton age, at least in Ontario Peninsula, and represent a northern facies of the Reynales (See Figure 1).

There is a sharp lithological break between the Fossil Hill dolomite and the underlying Cabot Head shales, Dyer Bay dolomites, or Wingfield shales, but the contact with the St. Edmund dolomite is gradational. The upper contact with the Lions Head dolomite is equally as distinct, although a gradation apparently exists between the denser upper beds of the Fossil Hill and the Lions Head in the Lions Head-Dyer Bay area. The Fossil Hill formation thickens northward from 8 feet in the Georgetown-Owen

Sound area to 16 feet at Wiarton, 60 feet at Dyer Bay, and 80 to 90 feet on Manitoulin Island. These thicker sections are a result of the development of thick bioherms.

The Fossil Hill formation is extremely fossiliferous. The brachiopod Pentamerus laevis is abundant at the base of the formation, but not entirely confined to this horizon as in the Reynales; thick banks of this pentamerid outcrop on Bruce Peninsula. A prolific coral fauna, consisting of several species of Favosites, Halysites, Arachnophyllum, and Syringopora, is contained in the upper beds.

These Lower Clinton Fossil Hill dolomites are the direct correlative, lithologically and faunally, of the Manistique formation of northern Michigan. Coral beds in the upper part of the Fossil Hill may also be correlated with the Thornloe limestone coral beds of Lake Timiskaming (Lockport-Hume, 1925), Jupiter formation of Anticosti Island, Attawapiskat 'coral reef' formation of Hudson Bay, and Unit D in the southern Manitoba Interlake group.

Albemarle Group

The best exposures of late Niagaran rocks are located on Bruce Peninsula between Wiarton and Lions Head in Albemarle township. It is proposed to combine the late Niagaran Lockport, Amabel, and Guelph formations in the Albemarle group. Manitoulin Island representatives of this group are closely related to the Engadine dolomite of northern Michigan.

Lockport Formation

The term Lockport is here restricted to that succession of dolomites underlying the Guelph and overlying the DeCew dolomite in the Niagara Peninsula - western New York State region. They may be subdivided in ascending order into the Gasport, Goat Island, and Eramosa members. The basal Lockport DeCew dolomite of Williams (1919) is regarded as Upper Clinton in the present report. With the exception of the Eramosa, these members cannot be recognized north of Hamilton.

Gasport Member. This member is typically a massive, thick- to thin-bedded, bluish grey to grey, coarse- to fine-grained, semi-crystalline, crinoidal dolomitic limestone. The upper foot is generally a dark to light grey, dense to fine-grained dolomite, grading into the overlying Goat Island-Ancaster chert beds.

A basal conglomerate bed 1 foot thick marks the sharp ripple-marked lower contact at Niagara and DeCew Falls. It consists of elongated, rounded, dark grey, dense, dolomitic limestone pebbles, lithologically similar to the DeCew dolomite, embedded in a coarse, light grey, porous limestone. The member is 34 feet thick along the Niagara gorge, 21 feet at DeCew Falls, 7 feet at Albion Falls, 20 feet at Dundas, and 10 feet at Clappison

Corners.

The Gasport fauna, though more fragmentary and less varied, closely resembles the older Rochester fauna.

Goat Island Member. The name Goat Island was introduced by Howell and Sanford (1947) for the thick series of dolomites formerly referred to the 'Undivided Lockport' (Williams, 1919) or Suspension Bridge (Cumings, 1939) members.

The member is recognizable as a distinct unit of the Lockport formation from Niagara Falls to Clappison Corners. It is essentially a thick-bedded, grey, buff-weathered, dense to fine-grained dolomite, with a high argillaceous content in the Hamilton area. Chert nodules and lenses are so plentiful at the base of the member that a distinct stratigraphic unit - the Ancaster chert beds - may be defined. The greatest concentration of chert is in the Hamilton-Ancaster area (Laird, 1935). These chert beds are defined above and below by a distinct change in sedimentation beyond which there is no chert, and readily determine the Goat Island-Gasport contact.

Thicknesses of dolomite assigned to the Goat Island vary between 31 and 52 feet along the Niagara gorge, 80 feet at Ancaster, and between 40 and 60 feet at Dundas. These variations are directly related to the inconsistent thickness of the overlying Eramosa dolomite.

The fauna of the Goat Island is concentrated principally in the Ancaster chert. Lithistid sponges (*Astylospongia praemorsa*, *Aulocopina granti*) and dendroid graptolites (*Reticulograptus polymorphus*, *Dictyonema* sp.) are important entities in these chert beds.

Eramosa Member. This member of the Lockport formation is exposed in the face of the Niagara escarpment at Niagara Falls, Ancaster, and Dundas, where it is a massive, thick- to thin-bedded, brown, fine-grained to dense, bituminous dolomite. Dark grey shale partings are abundant only in the Niagara Falls and Dundas sections. This overall lithology is characteristic of the Eramosa as far north as Shelburne; the northern facies will be discussed with the various members of the Amabel formation.

The base of the Eramosa member 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. The Eramosa is conformably overlain by Guelph dolomite, indicating that the Lockport-Guelph sequence is a product of continuous sedimentation, but the stratigraphic position of the Lockport-Guelph contact varies throughout Ontario.

The following thicknesses were assigned to the Eramosa in the Niagara Peninsula: 7 to 34 feet along the Niagara gorge; 43 feet at Ancaster; and 58 feet at Dundas.

Argillaceous dolomite exposed in the Canada Crushed Stone quarry at Dundas contained the most prolific fauna, with the brachiopods Stegerhynchus neglectum, Reticularia bicostata, Whitfieldella parvus, and the trilobite Encrinurus ornatus the most abundant forms.

Amabel Formation

The name Amabel is here proposed for the main mass of dolomites that overlie the Fossil Hill formation and underlie the Guelph formation in Ontario. In the type section at Wiarton, Amabel township, the formation is divisible in ascending order into the Lions Head, Colpoy Bay, Wiarton, and Eramosa members; these have a combined thickness of 131 feet. The Amabel grades laterally into the Lockport formation in the Waterdown - Georgetown region.

Lions Head Member. The name Lions Head is here introduced for the dense, blocky dolomites overlying the Fossil Hill dolomite at Lions Head, Ontario. The member forms a well-defined lithological unit from Cabot Head south to Orangeville. Its use as a separate unit for strata overlying the Fossil Hill on Manitoulin Island is, however, not justified, although there is some indication of this member in the Amabel dolomites northeast of South Baymouth.

The Lions Head member is consistently a blocky, hard, conchoidal fracturing, dense, white weathered, brown dolomite, with chert nodules in the basal 4 feet, characters that clearly distinguish it from the Fossil Hill formation below and the Colpoy Bay member above. Its thickness ranges from 10 to 28 feet east of Owen Sound, 6 feet at Wiarton, 17 feet at Hope Bay, 24 feet at Lions Head, and 45 feet at Dyer Bay.

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

Colpoy Bay Member. The name Colpoy Bay is here proposed for the thick series of dolomites separating the Lions Head from the Wiarton. The type section is exposed at the head of Colpoy Bay in the road-cut north of Wiarton. It is the most constant stratigraphic unit in the Amabel formation, and can be identified from Cabot Head south to Georgetown. Similar dolomites can be recognized in the Amabel formation on Manitoulin Island, but the term is not at present extended to this region. The Colpoy Bay dolomite is lithologically similar to the Engadine dolomite of northern Michigan.

This member of the Amabel formation is typically a

massive, porous, fine-grained to dense, buff-weathered, white to light grey dolomite. Thin, grey, argillaceous partings and lenses occur in the basal 6 to 10 feet, and massive biohermal structures and thin-bedded flank deposits at different stratigraphic levels and in widely spaced outcrops. The dolomite of these bioherms resembles that of the overlying Wiarton facies.

Both the lower and upper contacts of the Colpoy Bay are gradational, the upper contact being drawn arbitrarily at that level above which the rocks are predominantly blue-grey, mottled, crystalline, fossiliferous dolomites. The member is 58 feet thick at Wiarton, at least 47 feet south of Owen Sound, and 50 feet at Eugenia Falls.

The Colpoy Bay dolomite, with the exception of the biohermal masses, is unfossiliferous. The bioherms are composed mainly of crinoid stems and the brachiopods Rhynchotreta americana and Stegerhynchus neglectum.

Wiarton Member. The name Wiarton is here proposed for the crystalline, fossiliferous dolomites that directly underlie the Eramosa or Guelph dolomites from Cabot Head south to Georgetown, and are exposed to the best advantage in a road-cut north of Wiarton.

The member is characteristically a massive, coarse- to fine-grained, blue-grey mottled, light grey, crinoidal dolomite, purple-mottled in the massive, basal beds. It is in general overlain by the Eramosa dolomite, but in places has been observed to be overlain directly by the Guelph dolomite, the missing Eramosa dolomite being attributed to the development of biohermal structures in the Wiarton. A thickness of 16 feet is allotted the Wiarton in the type section and 44 feet south of Owen Sound.

The Wiarton contains a rich and varied fauna. Forms common to both the Racine formation of Wisconsin and the Guelph formation of Ontario are abundant, the molluscan assemblage best displaying this relationship. This fauna is a link between the typical Clinton-lower Lockport and Guelph assemblages. It includes the cystid Gomphocystites glans; the crinoids Siphonocrinus pentagonus, Eucalyptocrinites crassus, and Lecanocrinus cf. pisiformis; the brachiopods Platystrophia daytonensis laurelensis, Barrandella fornicata, Rhynchotreta americana, Stegerhynchus whitii, S. (?) winiskensis, Eospirifer eudora, E. radiatus, and Nucleospira pisiformis; the pelecypods Amphicoelia leidyi, Goniophora speciosa, and Cypricardinia arata; the gastropods Platyostoma cornutum, Phanerotrema occidens, Eotomaria durhamensis, Holopea guelphensis, and Subulites terebreviformis; the cephalopods Amphicyrtoceras laterale, A. williamsi, Cyrtorizoceras byronense, and Lechritrochoceras desplainense; and the trilobites Bumastus cf. armatus, B. ioxus, Scutellum acamus, and Sphaerexochus romingeri.

Eramosa Member. In its northern facies, as exposed between Shelburne and Manitoulin Island, the Eramosa is characteristically a thin-bedded, dark brown, fine-grained to sugary, highly bituminous dolomite. Thin-bedded, non-bituminous horizons associated with the Wiarton and Guelph bioherms are also included in the Eramosa. Lenses of crystalline dolomite, chert nodules, and thin coral biostromes occur in sections east of Guelph, around Hepworth, and at Sky Lake. The basal beds are generally more massive, thick-bedded, white-weathered, fine-grained dolomites, commonly heavily laden with the brachiopod Whitfieldella.

The lower and upper contacts of the Eramosa are transitional, the upper one being drawn at the base of the massive, brownish grey, porous, saccharoidal dolomite typical of the Guelph formation. The Eramosa varies considerably in thickness, ranging between 50 and 27 feet in the Wiarton area alone, the thinnest sections being associated with the Wiarton bioherms.

Small colonies of the coral Favosites and eurypterid (Eusarcus logani) fragments are the dominant fossils in this northern facies of the Eramosa.

Structures reported in the Eramosa at Shelburne and Wiarton are primarily the result of doming over local bioherms in the underlying Wiarton dolomite. The Eramosa is a transitional facies that originated during the change in conditions necessary for Guelph sedimentation. Towards the close of the Lockport-Amabel sedimentation the Eramosa dolomites were deposited between the bioherms as inter-reef, lagoonal, or flank sediments. In the non-biohermal areas south of Shelburne the thickest and most varied series of Eramosa dolomite were deposited. Immediately prior to the deposition of the Guelph some areas were dominated by Eramosa sediments, whereas in other areas organic accumulation continued unbroken into the Guelph. Guelph sedimentation eventually spread over all of Ontario and continued unbroken to the close of Niagaran (Middle Silurian) time.

Guelph Formation

The Guelph formation underlies a narrow belt of country west of the Niagara escarpment from Niagara Falls to the tip of Bruce Peninsula. Guelph and underlying Eramosa dolomites were recognized during the present investigation around and north of South Baymouth on Manitoulin Island.

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 contains bituminous material and can be regarded as transitional between typical Eramosa and typical Guelph. Small bioherms are also a common feature of this

horizon at Niagara Falls, east and north of Wiarton, Sky Lake, and northwest of Ferndale.

The fauna of these basal bioherms with the possible exception of the coral Pycnostylus guelphensis, is also represented in beds older than the Guelph, but does not include the typical Guelph brachiopod Trimerella grandis and pelecypod Megalomus canadensis.

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