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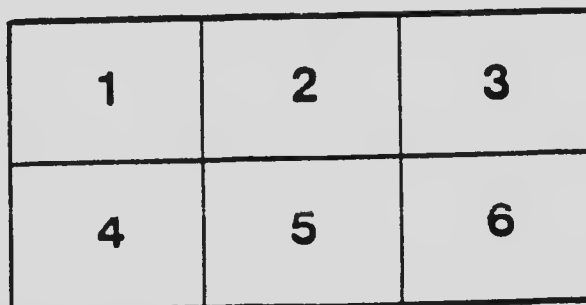
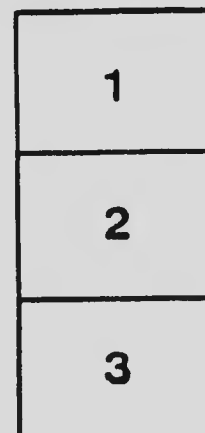
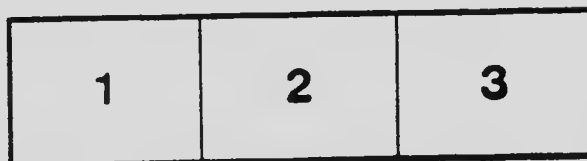
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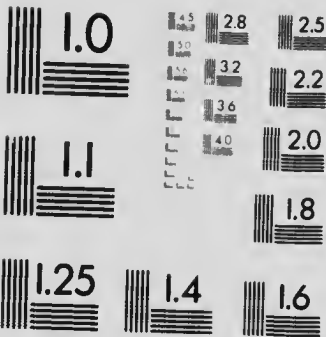
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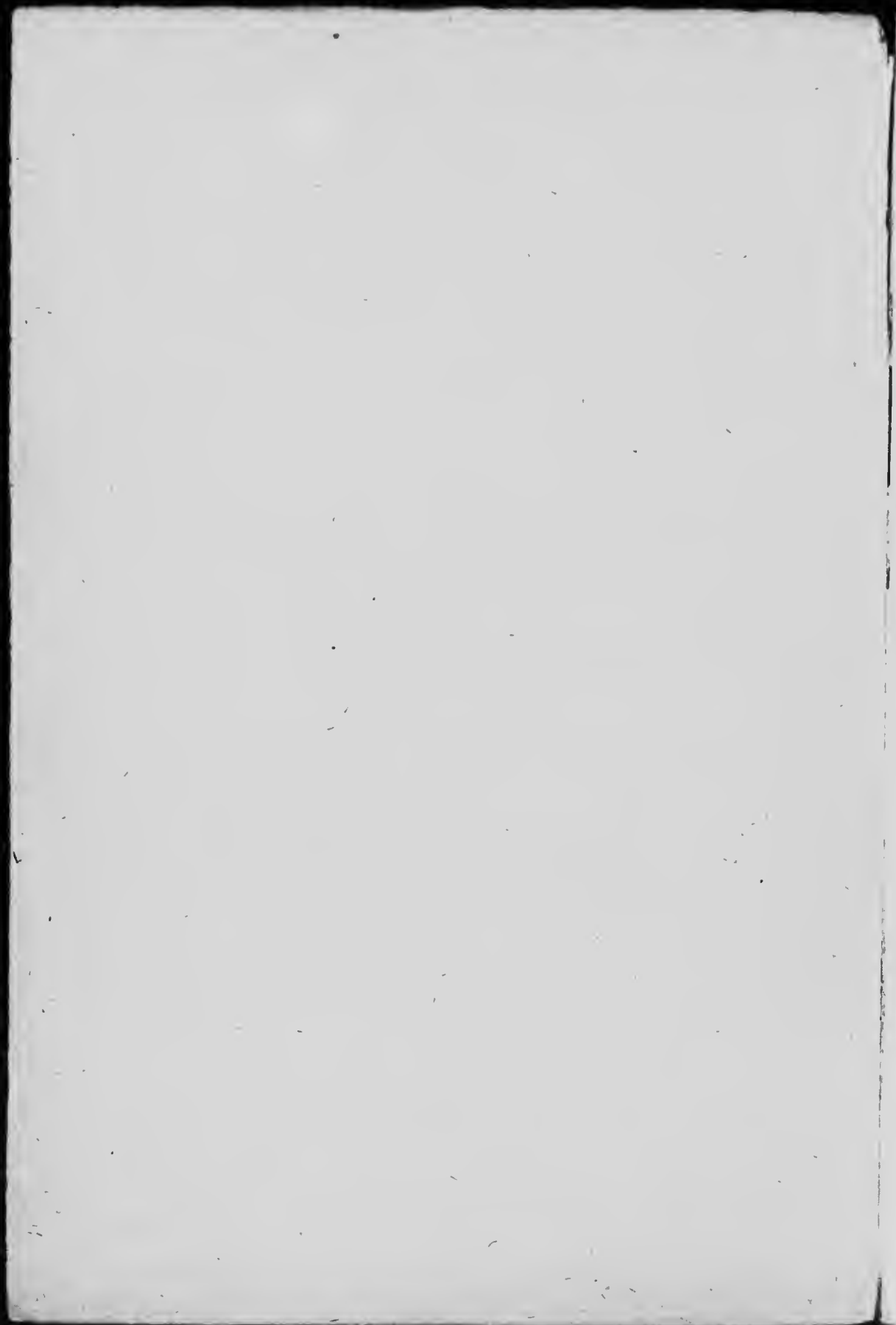
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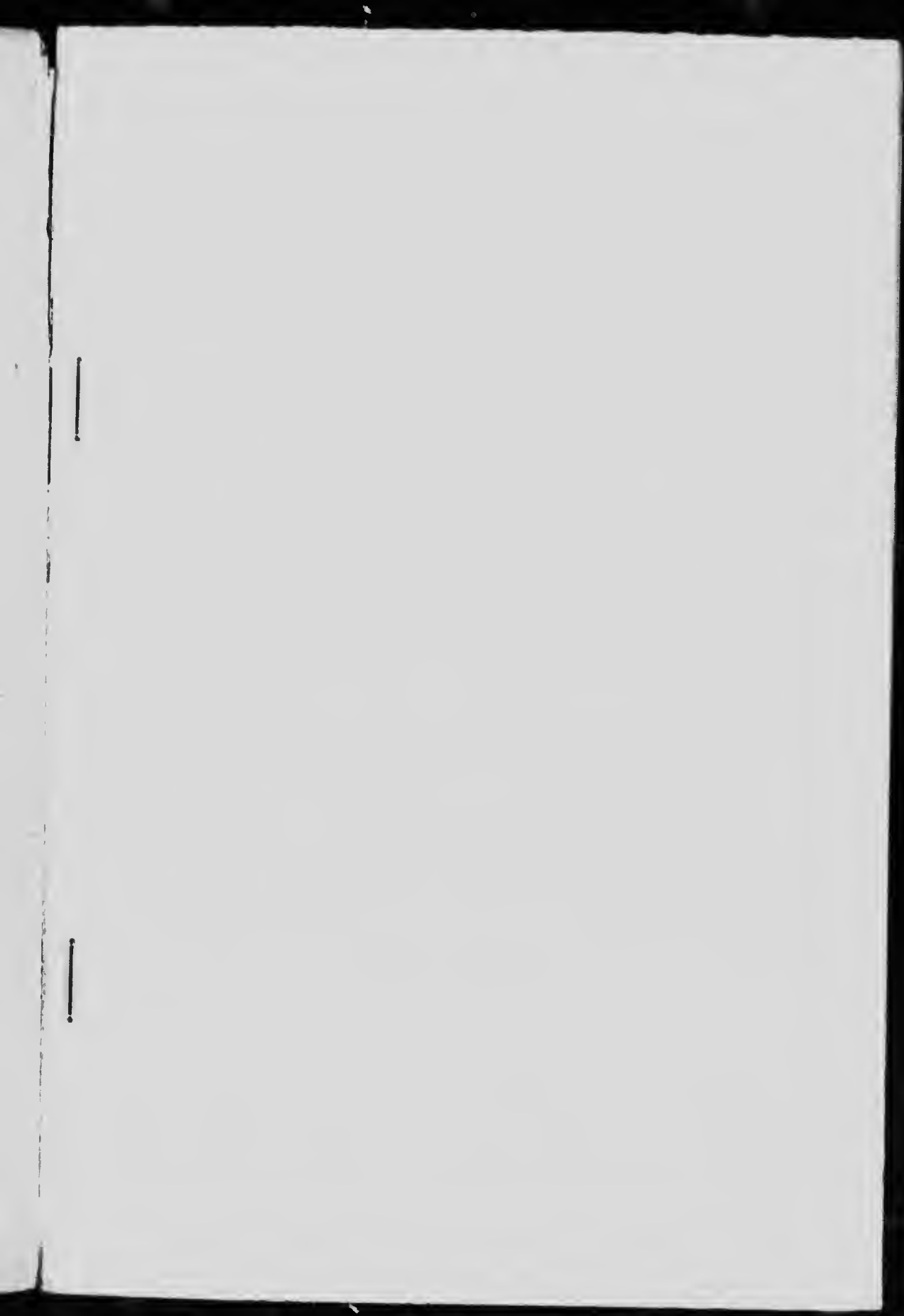
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Flower pots, Flowerpot island, Co. Kerry. The lighthouse, the pedestal, the pedestal, the pedestal. Page 62 and 74

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NO. 91 GEOLOGICAL SERIES

**The Silurian Geology and Faunas of
Ontario Peninsula, and Manitoulin
and Adjacent Islands**

BY
M. Y. Williams



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The Silurian Geology and Faunas of Ontario Peninsula, and Manitoulin and Adjacent Islands.

CHAPTER I.

INTRODUCTION.

PURPOSE AND CHARACTER OF REPORT.

The "Geology of Canada," by Sir Wm. Logan, published by the Geological Survey of Canada in 1863, includes the only comprehensive account so far published of the Silurian system of southwestern Ontario. This report has long been out of print and so is inaccessible except in the better equipped scientific libraries. Since 1863, many advances have been made in the science of geology, and it is consequently desirable that such fundamental knowledge as that relating to the Silurian rocks of the oldest settled parts of Ontario should be thoroughly revised and brought up to date. Not only is it a part of broad and enlightened education to have a clear knowledge of natural surroundings, but the proper development of our mineral resources and even our agriculture depends upon a clear understanding of geological facts. That no metal mines occur in the area described is true, but the production of non-metallic products such as lime, building stone, salt, gypsum, natural gas, etc., is and has been of the greatest importance in the development of the Ontario peninsula which is one of the most thickly settled parts of Canada.

Taken in conjunction with the recent memoir of this department on the "Devonian of southwestern Ontario", by Clinton R. Stauffer, the present memoir completes the general description and mapping of the geology of southern Ontario as far east as the areas underlain by rocks belonging to the Ordovician system.

As described in the summary reports, the field work upon which this report is based was done during the summers of 1912 to 1916 inclusive. The whole field, including the most inaccessible parts of Manitoulin and adjacent islands and Bruce peninsula, was covered by the author or his assistants; hundreds of miles of formation boundary were followed and surveyed; numerous geological sections were studied and measured; zonal and formational collections of fossils were made, including thousands of individuals, and representing the various geological units throughout their range in southwestern Ontario. Economic deposits were studied; and special trips were made to important areas in New York, Michigan, Wisconsin, and Illinois for the purpose of comparing geological occurrences in Ontario with those of the adjacent well-known regions.

ACKNOWLEDGMENTS.

Special acknowledgments are due Professor Charles Schuchert of Yale university, who spent two weeks with the author in the field during the preliminary work of 1912, and one week in 1913. His contributions to the knowledge of the Medina-Cataract problem are acknowledged elsewhere. Professor Schuchert has also kindly criticized this memoir in regard to its more important paleontological and stratigraphical conclusions.

Professor George H. Chadwick of the university of Rochester, guided the author in his studies of the Cayuga formations in western New York state and has assisted materially in solving the Cayuga problems in the Niagara peninsula. His kindness in allowing the author access to his unpublished manuscript on "The stratigraphy of the New York Clinton" has made it possible to bring the Clinton nomenclature of this memoir into harmony with the latest interpretation for New York state. His criticism of this memoir has been most helpful and constructive.

Doctors E. O. Ulrich and R. S. Bassler have kindly identified *bryozoa* and *leperditia* sent them by the author.

The assistance and kindness shown the author by managers of companies and others in the regions visited, have been acknowledged in the annual summary reports, where the names of student assistants are also mentioned. Special recognition, however, is due George S. Hume who assisted the author for two successive years and took charge of the mapping of the Niagara escarpment from Warton to Niagara Falls.

The author has been in frequent consultation with E. M. Kindle, paleontologist of the Geological Survey, Canada, during the office and laboratory work required in the preparation of this memoir, and in 1913 Dr. Kindle accompanied him on a reconnaissance trip over the most important sections along the Niagara escarpment between Clinton, New York, and Collingwood, Ontario. His criticism, advice, and assistance are gratefully acknowledged.

The fossil material studied by the author includes, besides his own and his assistants' collections, collections made by E. M. Kindle in preparation of the Niagara Folio, the collections made by J. Stansfield and H. V. Ellsworth, in 1912, and the old collections in the possession of this Survey.

PREVIOUS WORK.

Many eminent geologists have published descriptions of various phases of the geology of southwestern Ontario, the following being a brief review of the more important contributions to date. For publications not mentioned the reader is referred to the selected list given under Bibliography.

The Rogers brothers of Pennsylvania contest with Alexander Murray, assistant to Sir William Logan, the honour of publishing the first description of the Silurian formations of Ontario. In the report of 1843, the first to be issued by the newly organized Geological Survey of Canada, Murray traced the formations of western New York into western Ontario, then western Upper Canada, giving a general description and outline of their areal extent. A similar report was published the same year by

Rogers and Rogers in the "Transactions of the American Philosophical Society". It devolved upon the Canadian Survey, however, to complete the task of surveying the Ontario region. Murray, in spite of much other work, returned from time to time to his original task, describing the east side of Bruce peninsula and the Manitoulin islands in the report of 1847-48, the west side of Ontario peninsula from the north end of Bruce peninsula to Amherstburg, in 1848-49, and rounding out the field work by completing the mapping of the Niagara escarpment as described in the report of 1850-51. The geological map of western Ontario first appeared as part of a map of the region from the west end of lake Ontario to lake Michigan, in the Canadian Institute proceedings in 1854, accompanying an article by Sir William Logan "On the physical structure of the western district of upper Canada". Meanwhile the solving of geological problems went on harmoniously in Canada and New York state, the heads of the two surveys, Sir William Logan and James Hall, respectively, being on the best of terms. In 1852 Hall published the "Palaeontology of New York", vol. II, which greatly facilitated working out the palaeontology and stratigraphy of Ontario. In 1863, Logan published his "Geology of Canada", in reality as stated, a summary of the work of the Canadian Geological Survey from the beginning. With maps, illustrations of fossils, and descriptions of formations, this is still the only work that claims to be a geology of Canada and its excellence is recognized by all authorities. Between the years 1863 and 1910 many publications dealing directly or indirectly with the Silurian system of Ontario appeared in government reports of Canada and the United States and in various periodicals. T. Sterry Hunt, chemist to the Canadian Geological Survey, published many observations on the geology of Ontario, including notes on the salt and gypsum deposits; Robert Bell described the geology of the Manitoulin islands; Alexander Winchell wrote on the "Geology of petroleum in Canada west"; H. A. Nicholson wrote on the "Palaeontology of Ontario"; Hall further described the Niagara and Lower Helderberg formations of United States and Canada; Whiteaves described the Guelph fauna of Ontario; and Clarke and Ruedemann described the Guelph fauna of New York. These and other publications of like character added information but made no basic changes in the geology as laid down by Logan in 1863.

In 1910 the "Monroe formation", by Grabau and Sherzer, appeared as a report of the Geological and Biological Survey of Michigan. This vigorously attacked the accepted interpretation of the age of those formations of western Ontario which had formerly been considered the oldest Devonian formations of the region. As a result an awakened interest was centred on western Ontario, culminating for the Devonian system in the "Report on the Devonian of southwestern Ontario", by C. R. Stauffer, and for the Silurian system in papers by Charles Schuchert, Grabau, and the writer, and the present memoir. The meeting of the Twelfth International Geological Congress in Toronto in 1913 necessitated much geological housecleaning, and when Professor Charles Schuchert accompanied the writer over the Silurian rocks of the Georgian Bay region and Manitoulin island and later went with Dr. W. A. Parks over the Silurian sections of Credit Forks, Hamilton, and Crimsby, he saw clearly that new correlations for the so-called Clinton and Medina horizons must be made. Schuchert's

work has been followed up by the writer, along with a revision of the whole Silurian system in southwestern Ontario.

The economic side of the Silurian geology of Ontario has been dealt with in recent reports as follows: "Building and ornamental stones", W. A. Parks, 1912; "Gypsum in Canada", L. H. Cole, 1913; "Salt deposits of Canada", L. H. Cole, 1915; "Oil and gas in Ontario and Quebec", W. Malcolm, 1915; "Records of wells drilled for oil and gas in Ontario", Cyril W. Knight, 1915; "Petroleum and natural gas resources of Canada", F. G. Clapp, 1914-15. (See Bibliography for fuller references.)

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CHAPTER II.

GENERAL CHARACTER AND GEOLOGY OF SOUTHWESTERN ONTARIO.

INDUSTRIES.

That part of southwestern Ontario underlain by rocks of Silurian age, includes some of the richest and most thickly settled agricultural districts in Canada. With splendid transportation facilities, manufacturing industries have developed rapidly in centres such as Welland, Brantford, Guelph, Kitchener, Stratford, and a host of smaller places. The shallow soil near the edge of the Niagara escarpment is largely covered by wood lots or is used for pasture. The rocky land on Bruce peninsula and Manitoulin island, now that the best of the timber has been harvested, is utilized for farming and grazing in the more suitable areas, and elsewhere is left for the growth of hardwood. Excellent farm land occurs in parts of Bruce peninsula, particularly west of Lyon head, and much good farm land is worked on Manitoulin island, areas near Manitowaning, Little Current, and Mindemoya, at the head of South bay, Gore bay, and on Barrie island, being settled by prosperous farming communities.

Throughout the Georgian Bay and Lake Huron regions, fishing is an important industry and the abundance of game fish, combined with the natural picturesqueness and variety of scenery, are strong attractions for summer tourists.

The mineral products obtained from the Silurian rocks consist of commonplace non-metallics, such as road metal, building stone, quicklime, salt, gypsum, gas, and some oil. These products, however, are of great potential value when their proximity to the centres of population is taken into account. The splendidly ordered gypsum mine at Caledonia formerly owned by the Alabastine Company and now owned by the Ontario Gypsum Company, is a revelation to the average man, who disconcerts mining entirely with his part of Ontario. The salt wells of the Kincardine, Goderich, and Sarnia regions practically control the Canadian market for salt and immense reserves are as yet untouched. The salt production for 1917 is valued at \$1,095,866. The gas produced in Ontario in 1917 was valued at \$3,182,154 and this was mostly derived from the Silurian formations.

TOPOGRAPHY.

The topography of the Silurian areas is generally of low relief, the only feature of important dimensions being the Niagara escarpment which forms a step upward to the west and south from the lowlying Ordovician plains to the east and north. This sinuous escarpment is the outcropping edge of the resistant Niagara (Lockport) dolomite, into which the agents of erosion have eaten. On the mainland of Ontario, the eastern extension of the Silurian system is practically terminated by the Niagara escarpment, but the Manitoulin dolomite and the Whirlpool sandstone, at the base of

the Cataract formation, extend in places considerable distances to the east or north from beneath the Niagara dolomite, forming at their eroded edges one or more additional, but insignificant escarpment. On Manitoulin island the escarpment formed by the Manitoulin dolomite is comparatively conspicuous. To the west and south of the Niagara escarpment, the land surface in general tends to slope away to the southwest down the general dip of the formations. Numerous modifications occur, however, due to accumulations of glacial and outwash materials and to glacial and other erosion of the hard rock surfaces. Examples of eroded rock surfaces are common along the Niagara escarpment, on Bruce peninsula, and on Manitoulin and the adjacent islands. On Bruce peninsula and the islands to the north, the solid dolomite has been sculptured into innumerable mounds, hills, and valleys, the latter containing more or less gravel, clay, and soil. Excepting the southern half of Niagara peninsula which is mostly very level, the areas underlain by Silurian rocks are generally undulatory, the more prominent hills being due for the most part, as at Durham, to the presence of glacial moraines, and the more pronounced valleys being due to river channels, such as those of the Saugeen and the Grand. Where the drift is deep, the outcrops of rock are practically confined to the river valleys.

The maximum recorded elevation for the region described is 1,700 feet A. M. T. at Dundalk. The maximum for the Manitoulin island is 1,020 feet A. M. T. southeast of lake Manitou. The minimum elevation for any part of the country obviously depends upon the elevation of the great lake into which its streams empty.

GENERAL GEOLOGY.

Southwestern Ontario lies in the northern, central part of the Palaeozoic sedimentary area which occupies the basin of the Great Lakes, exclusive of lake Superior, extends from the Appalachian mountains on the east to Kansas and Nebraska on the west, and includes the drainage basin of the Mississippi river as far south as Oklahoma, northern Tennessee, and central Alabama. Of this vast area, the rocks of Silurian age outcrop over only a small part. The other systems of Palaeozoic rocks represented in Ontario are the Cambrian, Ordovician, and Devonian. The Carboniferous system with its coal beds is found nowhere within the province, but outcrops to the west in Michigan and to the south in Ohio. The Palaeozoic formations rest upon an uneven floor of Pre-Cambrian, igneous and metamorphic rocks, which consist of granites, diabases, gabbros, gneisses, schists, quartzites, crystalline limestones, etc. This basal complex outcrops to the north as the Canadian Pre-Cambrian shield. Corresponding to the gentle southerly dip of the Pre-Cambrian floor, the sedimentary strata in southwestern Ontario are inclined in general to the southwest with an average dip of about 20 feet a mile. East of lake St. Clair, however, a basin structure occurs and there is in consequence an easterly dip in the region south of lake St. Clair and east of Detroit river. The maximum thickness of the Palaeozoic strata, as taken from a well record in the basin just mentioned, is 3,635 feet, of which 35 feet is basal arkose or conglomerate, 1,625 feet includes the Ordovician and any lower Palaeozoic strata that may be present, 1,725 feet is the thickness of the Silurian system, and 280 feet is the thickness of the Devonian formations present.

On the east and north the Silurian rocks are bounded approximately by the Niagara escarpment, which is a well-defined and conspicuous feature of the landscape from central New York to Niagara Falls, and thence through Hamilton, to the vicinity of Collingwood, along the south and

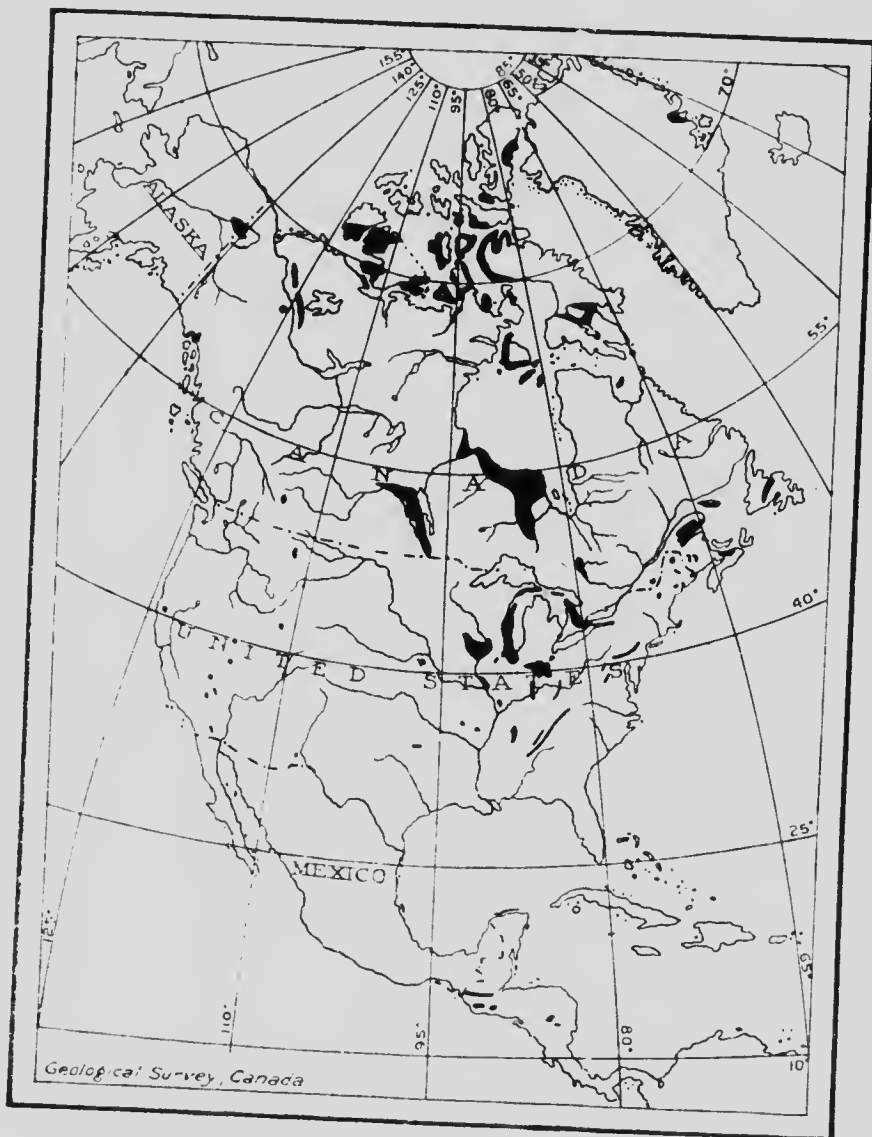


Figure 1. Diagram showing, in black, the distribution of Silurian rocks in North America.

western shores of Georgian bay, through a chain of islands to Manitoulin island, throughout the length of Manitoulin, Cockburn, and Drummond islands to the northern peninsula of Michigan. The islands separating Georgian bay and the North channel from lake Huron are so continuous and so closely connected by reefs that the break here is more apparent than real.

Although Silurian formations underlie the whole area from the Niagara escarpment to the limits of the province on the south and west, the area not overlain by Devonian strata is much more restricted, as may be seen from the map, and the actual exposures of rock occupy only a small part of this area.

The sandstones, shales, and interbedded dolomites, comprising the lower part of the Silurian system (the Medina-Cataract, the Clinton, and Rochester subdivisions) outcrop along the front of the Niagara escarpment, or in case of the harder subdivisions, occur by themselves to the east or north as more or less localized escarpments. The overlying, heavy-bedded dolomite of Niagara age (Lockport) forms the practically continuous white cliffs of the Niagara escarpment.

West and south of the Niagara escarpment, the Lockport dolomite outcrops over wide areas of country, particularly on Bruce peninsula and Manitoulin and the neighbouring islands, where large areas of barren rock are exposed. The Guelph dolomite overlies the Niagara (Lockport) dolomite and outcrops over considerable areas to the south and west of the Niagara belt, continuing as far north as Fitzwilliam island. The waterlime, shales, and gypsum beds of the Cayuga group are rarely seen at the surface, sections occurring as indicated on the map in the valleys of Grand River, Saugeen river, and in some other stream channels. The salt beds do not outcrop at all.

In many parts of Ontario peninsula, bedrock is deeply covered by surface deposits, consisting of boulder till, and outwash materials such as clay, gravel, sand, etc. The study of this surficial geology is an extensive subject in itself and has been described in part by J. W. Goldthwait and F. B. Taylor (see Bibliography).

In areas where rock exposures are scarce owing to the thickness of the surface deposits, the land is generally good and the country is thickly populated. In consequence, rock outcrops are of great potential value as a source of raw material for building stone, road metal, lime manufacture, etc., and those discovered in the preparation of this report have been indicated on the map.

ROCK STRUCTURE.

Since Pre-Cambrian time, southwestern Ontario has not suffered in any way from violent deformation, but on the other hand the movements of the earth recorded elsewhere in faults and sharp folds have resulted in gentle structural undulations, which rarely assume a magnitude of dip of 200 feet per mile, but which are nevertheless controlling factors in the accumulation of oil and gas. The oil fields of Essex, Kent, Lambton, and Middlesex counties are located for the most part on gentle domes and anticlines, and the gas fields between Niagara and Detroit rivers, where studied, have been shown to be closely associated with inverted

basin structures, although varying rock porosity in some cases is the primary controlling factor of gas as well as of oil occurrence, and in formations that do not carry water the oil and gas may be found in the basins and synclines.

A few conspicuous indications of structure have been cited in previous reports. In the "Geology of Canada", 1863, and again as restated by Malcolm the Cincinnati anticline which is a decided feature in the Ohio valley, "forms a gentle curve running from the west end of lake Ontario, through Woodstock, along the Thames, and through Chatham to the southern part of Essex county. This diffuse fold is possibly composed of subordinate folds, none of which are pronounced or have limbs dipping at more than a few feet per mile." The diffuseness of this fold is well demonstrated by a detailed study made by the author of the structure at the Bothwell oil field where low minor folds are quite complex in arrangement. There are very good grounds for locating the broad anticline as above stated, but it is well to emphasize the diffuseness of its characters and not to expect a continuous, clearly defined, structural feature. It is probably a zone of low folds rather than a single well-marked anticline.

Anticlines have been located by Bell on the map of Manitoulin island, and judging from the shape of the topographic features of the land some of these at least may be as indicated. Much more detailed work is required, however, to interpret satisfactorily the comparatively gentle structure of Manitoulin island.

Two anticlines at Rockwood were described by Logan.² The one at the top of the Niagara (Lockport) is a well-marked structure and is further described below. The reference to a cross fold from Eden through Rockwood to Orangeville, appears to be based upon re-entrants in the supposed boundary between the Guelph and Lockport formations, re-entrants which do not exist in the revised boundary. The marked anticline in the top of the upper Lockport dolomite, which extends through Rockwood village, is very clearly defined 200 yards southwest of the road bridge crossing the Eramosa river. Here, the river cuts through the crest of the anticline which for a width of about 100 yards has dip of about 5 degrees to the east and west. Farther from the crest the dip is 10 to 11 degrees on the east and somewhat less on the west. Eastward as far as the river and south of the railway track, the strata dip at the rate of 4 to 5 degrees to the east, but for three-quarters of a mile north of the railway bridge, the river bed is on the crest of a low anticline which merges into the more pronounced structure south of the railway. A small syncline intervenes between this anticline and the crest of the main anticline west of Rockwood station, and eastward from the railway bridge a similar syncline occurs, succeeded eastward by a low anticline. Thus it is clear that the main anticline is flanked to the eastward by minor folds. To the west the dip is clearly shown, although undulatory, as far as a small remnant of Guelph dolomite south of the Grand Trunk railway, about 400 yards west of Rockwood station. The Eramosa beds which form the upper part of the Lockport formation intervene between the rock at the village and the Guelph remnant to the west and allowing

¹Geol. Surv., Can., Mem. 81, p. 45.

²"Geology of Canada", 1863, pp. 330 and 343.

for their thickness (40 to 50 feet) and averaging the rock dips, it is estimated that the dip to the west is about 70 feet in 1,200 feet, or at the rate of about 300 feet per mile. As the average dip of the formation to the west is about 20 to 30 feet per mile, it is clear that the anticline is well marked. The crest of the anticline extends through the Agricultural grounds, the west side of the schoolyard, and through the middle of the rock-cut on the railway about 235 yards west of the station, and crosses the road between concessions IV and V, Eramosa township, near the north side of lot 6. The axis of the anticline extends nearly northwest from Eramosa river, but curves more and more to the north in its northern exposures. To the south of Rockwood the rock is covered with a thick mantle of surface material.

Stauffer¹ described an anticline passing through St. Marys as follows: "Running nearly north and south through the city there is a rather pronounced anticlinal or monoclinal fold . . . which brings up the Silurian² to the east and drops the Devonian to the west. The Thames river cuts into the side of this fold so that at the dam near the Queens Street bridge the dip is upstream, while a quarter of a mile below the bridge, the dip is downstream. The excellent artesian wells which supply St. Marys with such a quantity of good water may depend on this same structure."

Folds have been mentioned at other localities, but it is difficult to prove their existence.

As may be seen from the cross section passing through Elora (see Map 1715), there evidently is a monoclinal fold to the west of that town. Such a fold is strongly suggested by comparing the altitude of the top of the Guelph outcrops at Elora and the altitude of the top of the formation derived from the depth at which Guelph dolomite was struck in a well drilled on lot 6, concession V, Pilkington township, about 5 miles west of Elora.

Undulations are clearly marked along the north end of Bruce peninsula between Cabot head and Tobermory, a clearly cut escarpment being exposed all the way and the water-level being everywhere a handy reference plane. The best marked anticline extends from the outlet of Gillies lake northwesterly to the small area of Cataract exposures on the northern shore. The easterly dip of this fold as seen on the north shore is about 110 feet in a mile, the corresponding dip at Gillies lake being much less. The dips to the west are similar. A well-marked syncline parallels the anticline on the east and includes the three conspicuous bluffs west of Cabot head, whose axes are at right angles to that of the syncline. Farther west the undulations are not so easily determined because of the lack of horizon-markers, but they are quite evident to an observer coasting along the shore. Other slight undulations may be seen along the east side of Bruce peninsula.

The gentle monoclinal structure of the Niagara peninsula is clearly illustrated by the three structural sections accompanying the special map of this region. Kindle states³ that "Between the New York Central Railway bridge and the elevator shaft at the falls the beds dip to the south at

¹Geol. Surv., Can., Mem. 34, p. 113.

²Detroit River series and hence now considered Devonian.

³U. S. Geol. Surv., Niagara Folio No. 190, 1912, p. 14.

an average rate of $28\frac{1}{2}$ feet to the mile. The rate of dip along the northern two-thirds of the gorge is somewhat less.

"A group of more than twenty wells drilled for the Tonawanda Gas Company affords complete data concerning the rate of dip about Getzville. The available facts indicate that along an east-west belt of territory, the southerly dip of the rocks is about 10 or 12 feet greater to the mile than in the contiguous territory on the north".

Getzville is 5 miles east of Tonawanda and almost due east of the comparatively steep dips indicated in the section passing through Niagara falls. At Getzville, this change of dip has caused the accumulation of an important gas pool in the Medina sandstones.

To the westward the monoclinial structure merges into the broad diffuse east-west fold of the Cincinnati anticline which is generally considered as having its axis along the Dundas valley¹.

¹Geol. Surv., Can., vol. V, pt. 2, pl. V, pp. 1-94.

CHAPTER III.

SUMMARY AND CONCLUSIONS.

GENERAL GEOLOGY.

The Silurian system is bounded below, in Ontario peninsula, by the red Queenston shale and on Manitoulin island by the Richmond shales and limestones. These underlying formations belong to the Cincinnati group of the Ordovician system and are only facies of the same sedimentation. Above, the Silurian is bounded by different Devonian formations, the Oriskany sandstone and Onondaga limestone in the Niagara peninsula, and the Sylvania sandstone and Detroit River series in the Lake Huron, Lake St. Clair, and Detroit River regions. In intermediate areas the facts are less definitely known. The total thickness of Silurian strata at lake St. Clair is from 1,725 to 1,750 feet.

The Silurian system falls lithologically into three subdivisions, a lower one typically marked by an alternation of elastic and calcareous sediments, the result of changing conditions of the land in respect to the sea; a middle group of massive dolomites, suggestive of widespread seas of moderate depth; and an upper division of saline sediments containing lenses of salt and gypsum and impure, elastic dolomites. The saline deposits are probably those of shallow, interior basin, water bodies, which received great quantities of detrital material from the surrounding areas where older formations elevated above sea-level were being actively eroded. The last phase of Silurian sedimentation represented a brief return to normal marine conditions, which were terminated by the uplift preceding Devonian time.

The oldest Silurian division includes: (1) the sandstones and shales of the Niagara peninsula (Medina) and the contemporaneous dolomites, shales, and shaly dolomites (Cataract) of the Georgian Bay region; (2) the limestones of the Clinton formation which scarcely extend in outcrop beyond the Niagara peninsula; and (3) the Rochester shale which thins out a few miles north of Hamilton.

The middle division includes the widespread Niagara dolomite, suitably known as Lockport dolomite, and the Guelph dolomite which is indicative of a shallowing sea, approaching interior basin conditions.

The upper division of the Silurian includes the Cayugan group, with its Salina shales, gypsum and salt, these being the extension of the Camillus shale of New York, and the overlying Bertie waterlime and Akron dolomite, which merge laterally into the lower Monroe dolomites of the Lake Huron-Detroit River region.

The best marked unconformities or breaks in sedimentation occur: (1) at the base of the Silurian where the Whirlpool sandstone and Manitoulin dolomite overlap the Queenston shale and marine Richmond formation; (2) at the base of the Lockport dolomite which successively overlaps from the north the Cataract, the Clinton, and the Rochester formations; (3) at the base of the Salina which overlies what appears to be an erosion surface at the top of the Guelph formation; and (4) at the top of the Silurian as represented by the Bass Island series in the west and the Akron dolomite in the east. The contact between the Akron dolomite

and the overlying Oriskany sandstone and Onondaga limestone is characterized by an erosion unconformity, and the corresponding contact in the west between the Bass Island series and the Sylvania sandstone probably similar, but it is known in Ontario only from well records.

ECONOMIC GEOLOGY.

All the Silurian calcareous sediments in Ontario are highly magnesian and are classed as dolomites. This implies that where sufficiently free from impurities such as clay and silica the Silurian dolomites may be burnt for lime manufacture and are especially suitable for hydrated lime; but they are entirely unsuitable for the manufacture of Portland cement. Guelph dolomite at Guelph, Fergus, and elsewhere is extensively used for the manufacture of quicklime. The Manitoulin, Clinton, Lockport, Bertie, and Akron dolomites are generally suitable for quicklime manufacture and have been used to some extent. Natural rock cement was formerly made from the argillaceous dolomites or "waterlimes" at the base of the Lockport dolomite at Thorold, Mt. Albion, and elsewhere, and from the Bertie "waterlime" of Bertie township. This industry is now abandoned, because of the inferiority of natural rock cement to the high grade Portland cement now used in construction work.

The best known Silurian building stones are obtained from the Whirlpool sandstone, the Credit Valley "Brown stone" being especially favourably known, and from the Lockport and Guelph dolomites. The great extent of the exposures of the last two named formations makes them easily available for many cities and towns, and it is only because stone has given place to cheaper building materials that this fine natural resource has been very little developed. The Manitoulin or lower Cataract dolomite of Manitoulin island is in many cases suitable for building stone, although here as farther south it is commonly too thin-bedded and shaly.

The best Silurian rock for road metal includes the upper and harder beds of the Lockport dolomite, the denser and harder beds of the Guelph dolomite, and much of the Akron dolomite (including probably a part of the Bertie beds) outcropping near Cayuga, Dunnville, and elsewhere in the Niagara peninsula.

Large gypsum deposits occur in the Salina formation along the Grand river between Paris and Cayuga. These are at present mined at Caledonia and York.

Extensive and as yet only partly developed beds of salt occur in the Salina formation over a large area extending east from lakes Huron and St. Clair, between Kincardine and Port Lambton, as far as Brussels, London, and Dutton. Another area is situated in the vicinity of Windsor. These areas are the centre of the salt industry in Canada.

Much gas is derived from the Medina sandstone (the Whirlpool and overlying beds) in Niagara peninsula and as far west as Delhi. The Clinton limestone furnishes gas in the Onondaga, Caledonia, Cayuga, and Port Colborne fields. The Guelph dolomite is gas-bearing in eastern Essex county.

Some oil is obtained from the Whirlpool sandstone near Brantford (this is variously reported from the Whirlpool and the underlying Queenston) and the Guelph and Salina furnish the oil of the Tilbury field of Kent and Essex counties.

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CHAPTER IV.

THE SILURIAN SYSTEM.

GENERAL STATEMENT OF EXTENT.

The Silurian system includes the sediments deposited between the emergence of the land from the sea which closed the Ordovician period, and the like emergence which brought the Silurian period to a close. According to the author's interpretation for Ontario, the Silurian formations would be those lying between the sediments of Richmond age (including Queenston shale) below and the Oriskany sandstone, Onondaga limestone, or Sylvania sandstone, whichever happened to be the local overlying formation of the Devonian system, above.

As geologists are not unanimous regarding either the lower or the upper Silurian limits some explanation of the author's conclusions is necessary. Let us first consider the lower Silurian boundary.

LOWER BOUNDARY.

Until recent years, geologists have unanimously placed the Ordovician-Silurian boundary at the top of the well-recognized marine Richmond formation. This conclusion was based on a mass of paleontological evidence and was in accord with stratigraphic evidence as well. Geologists, following the terminology of New York state, also unanimously accepted the base of the "Red Medina," now known as Queenston shale, as the lower boundary of the Silurian. This decision was based on the assumption that the Queenston shale overlies and was younger than the Richmond formation, and was a continuous deposition with the overlying "Medina" used in the restricted sense. As no fossils were known in the Queenston shale, paleontological evidence was entirely lacking. In 1909¹ Grabau showed that the Queenston shale is merely a delta phase of Richmond sedimentation, and hence is of the same age as the Richmond. The majority of geologists at once accepted the top of the Queenston shale as the top of the Ordovician system in accordance with the long recognized treatment of the Richmond marine sediments. A few geologists, however, continued to interpret the Ordovician-Silurian boundary as being at the base of the Queenston and so placed it at the base of the typical Richmond formation. For this view of the case the reader is referred to the writings of E. O. Ulrich.² So far as Ontario is concerned a stratigraphic break between the top of the Queenston shale and the overlying Whirlpool sandstone is indicated not only by a decided change in sedimentation but also by mud cracks in the Queenston filled with sand from the Whirlpool beds. In the Georgian Bay region, however, where the Manitoulin dolomite overlies shale of the marine Richmond formation, there is a far more decided break in both sedimentation and fauna. Not a single species listed by

¹ *Science*, new ser., vol. XXIX, p. 356.

² "The Ordovician-Silurian boundary", Twelfth Inter. Geol. Cong., 1913, C. R., pp. 593-667.

Forsterite from the Richmond of this region is known in the Manitowishewick dolomite, and the genera that cross over are few in number and of varying characters. These facts have caused the author to adopt the more widely accepted view of stratigraphers.

UPPER BOUNDARY.

The problem of the upper contact of the Silurian system in the Detroit-Lake Huron region is even more complicated and obscure than is that of the lower contact just described. In the Niagara peninsula and vicinity the Oriskany sandstone, or in its absence the overlying Onondaga limestone (both of undoubted Devonian age) disconformably overlies the Akron dolomite of undoubted Silurian age and the boundary is definitely located. From the vicinity of Woodstock westward, however, the Monroe formation of Grabau intervenes between the easily-recognized Silurian and Devonian formations, and Grabau has placed all of this series in the Silurian system. Unfortunately for the solution of the problem, outcrops of Monroe strata are scarce, few good sections are known and much has to be inferred from samples taken from drill holes.

The accompanying table gives Grabau's interpretation of the Monroe formation. This succession was determined from the studies made by the Michigan geologists during the sinking of a salt shaft near Detroit and from natural sections and bore-holes in Ohio and Michigan. Notwithstanding the criticisms of this interpretation of the sequence of formations by the Rev. Thomas Nattress,¹ there is good reason to believe that it is substantially correct.

Monroe formation	Dundee formation		
			<i>Disconformity</i>
	C. Upper Monroe or Detroit River series	Lucas dolomite	200
		Amherstburg dolomite	20
		Anderson limestone	35-50
		Flat Rock dolomite	10-100
			<i>Disconformity</i>
	B. Sylvania sandstone and dolomite		30-300
			<i>Oolitic</i>
	A. Lower Monroe or Bass Island series	Raisin River dolomite	200
		Put-in-Bay dolomite	100
		Tymochtee shales	50
		Greenfield dolomite	100
		<i>Disconformity</i>	
Silurian formation			

The lower Monroe or Bass Island series is undoubtedly Silurian and will be described under "Cayuga group." Grabau has demonstrated that the typical Sylvania sandstone of Michigan is in part of sand dune origin and hence represents continental sedimentation transgressing the Silurian land. A further discussion of the characters and age of the Sylvania

¹Nattress, Thomas. See Bibliography.

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Boundaries and Subdivisions of the Silurian System of Southwestern Ontario.

System.	Formation.	Localities.			
		Niagara river.	Dundas.	Bruce peninsula.	Detroit river.
Devonian.	Onondaga Oriskany	Onondaga limestone. Oriskany sandstone and conglomerate in lenses			Onondaga-Dundee limestone. Oriskany? sandstone thin lenses, age uncertain
	Detroit river. Sylvania.				Detroit River limestone and dolomite, four members. Sylvania sandstone.
Silurian.	Akron.	Akron dolomite.			Raisin River dolomite.
	Bertie.	Bertie waterlime.			Put-in-Bay dolomite. Tymochtee shale.
	Salina.	Camillus shale including gypsum.	Present land surface.	Present land surface.	Greenfield dolomite. Camillus shale including salt and gypsum
	Guelph.	Guelph dolomite.	Guelph dolomite.	Guelph dolomite.	Guelph dolomite.
	Lockport.	Eramosa beds. Dolomite. Gasport dolomitic limestone Det'ew waterlime.	Eramosa beds. Dolomite. Chert beds.	Eramosa beds. Dolomite.	Lockport dolomite.
	Rochester.	Rochester shale.	Rochester shale (very thin.)		Rochester shale.
	Clinton.	Irondequoit dolomite. Williamson? shale. Reynales (Wolcott) dolomite. Furnaceville? (Sodus) shale.	Irondequoit dolomite (very thin.) Reynales (Wolcott) dolomite.		Dolomite.
	Medina-Cataract.	Thorold sandstone. Grimsby sandstone. Cabot Head shale.	Grimsby sandstone. Cabot Head shale.	Cabot St. Edmund Head shale. Dyer Bay dolomite. Shale.	Cabot Head shale.
		Manitoulin beds (shale and calcareous sandstone). Whirlpool sandstone.	Manitoulin dolomite. Whirlpool sandstone.	Manitoulin dolomite.	Manitoulin dolomite.
	Richmond and Queens- ton.	Queenston shale.	Queenston shale.	Queenston shale.	Queenston shale.

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sandstone is to be found below. The controversy, however, centres about the age of the upper Monroe or Detroit River series. The paleontologic and stratigraphic evidence apparently conflict, and it is, therefore, necessary briefly to review the evidence in order to make the author's conclusions clear.

The Devonian characters of the Detroit River series are well represented by the following fossils: *Syringopora cf. hisingeri* Billings, in the Flat Rock dolomite; *Cystiphyllum americanum* mut. *anderdonense* Grabau, *Favosites basaltica* mut. *nana* Grabau, *Conocardium monroicum* Grabau (closely related to *C. trigonale* Hall), in the Anderdon limestone; *Romingeria umbellifera* Billings, *Panenka canadensis* Whiteaves, *Conocardium monroicum* Grabau, *Proetus crassicaarginatus* Hall, in the Amherstburg dolomite; and *Romingeria umbellifera* (Billings), *Conocardium monroicum* Grabau, *Panenka canadensis* Whiteaves in the Lucas dolomite. Grabau¹ says of the fauna of the Flat Rock, Anderdon, and Amherstburg beds: "Its most characteristic feature is its Devonian element. If the fauna were considered by itself, it would probably be pronounced a Silurian or an Onondaga fauna without hesitation, though there is a considerable Silurian element." The position of this fauna beneath 200 to 250 feet of the Lucas dolomite with a Silurian fauna, forces us to consider this as Silurian." It will be seen below just how important the Silurian element in the Lucas dolomite is. Continuing, Grabau says² "To sum up, the stromatoporoids of this fauna are partly Silurian and partly of Devonian types. The corals are represented by nine Silurian species and thirteen species identified with or most nearly like mid-Devonian species. The brachiopods are, with two exceptions, of types otherwise known only from the mid-Devonian. The pelecypods are similarly mid-Devonian types, and so are the trilobites. The gastropods and cephalopods, on the other hand, are without exception upper Silurian types."

Of the Lucas fauna, Grabau says³ "This is the highest fauna of the Monroe group, and it is throughout a Silurian fauna." An analysis of his summary of this fauna, however (page 221), gives the following information:

Of corals there are two specific identifications, one species (*Cylindrohelium profundum*) being new and one species (*Cladopora dichota*, n.) persisting from the Anderdon limestone; of seven species of brachiopods, four (*Peosserella lucasi*, *P. subtransversa*, *P. uilaoellosa*, *P. planisinosi*) are found only in the upper Monroe, two (*Schuchertella intersticiata* and *Spirifer aodestus*) in the upper Silurian, and one (*Camarotoechia seniplicata*) in the upper Silurian and lower Devonian; of three pelecypods, two (*Panenka canadensis* and *Conocardium monroicum*) are found in the lower horizons of the upper Monroe and are of decided Devonian character, and one (*Pterinea bradti*) is a new species considered a derivative of a species of the lower Monroe (*P. laui*); of nineteen species of gastropods listed on page 212, three (*Hemionota subacinata*, *H. tricarinata*, and *Pleurotoma teie rinotus*) have their nearest relations in the upper Silurian of Gottlund, six (*Eotomaria aregi*, *E. galteensis*, *Lophospira bispinalis*, *Pleurotomaria cf. relacis*, and *Poleuaita cf. creaulata*) are Guelph, and three (*Solenospira aiwuta*, *S. extenuatus*, and *Holopea subconica*) are Manlius, two species (*Pleuronotus subangularis* and *Trochomena ovoides*) are closely related to

¹Michigan Geol. and Biol. Surv., Pub. No. 2, Geol. ser., p. 217.

²Ibid., p. 221.

³Ibid., p. 221.

Devonian forms; and the remaining five species (*Acanthomma holopiformis*, *A. holopiformis* nmt. *obsoleta*, *A. laxa*, and *A. Newberryi*) are confined to the Lucas and Amherstburg beds.

In all, twenty-four genera are recognized in the Lucas dolomite, these, two are known only in the upper Monroe, and the remainder are represented as follows: six, Ordovician to Carboniferous or later; two, Ordovician to Devonian; two, Ordovician to Silurian; one, Silurian Carboniferous; two, Silurian to Devonian; four, Silurian; and one, Devonian. Thus six genera of the Lucas unquestionably have Silurian affinity. These consist of one genus of coral (*Cylindrohelium* a new genus to which Gr. Van doubtfully refers a Guelph species), and five genera of gastropods represented by species "mostly exotic in character." In view of the presence of unquestioned Devonian elements in the Lucas fauna, and the decidedly middle Devonian character of the faunas of the other upper Monroe divisions which underlie the Lucas, it seems decidedly inadvisable to place this whole formation in the Silurian on the evidence of gastropods which are admittedly "exotic," and are of a class of organisms known to be poor guide fossils in the Paleozoic system. It would seem much more logical to consider the Detroit River series or upper Monroe as of Devonian age, the Silurian species present being regarded as holdovers from Silurian time. This is in accord with Grabau's alternative correlation. He says:

"If correlation were to be based on faunal evidence alone, a different interpretation of the stratigraphy of Michigan would probably be adopted. In that case, the lower Monroe would be correlated with the upper Cayugan.

Faunally the upper Monroe might be considered as the indigenous lower Devonian. . . . On this hypothesis, the Sylvania would represent the continental condition appearing at the end of the Silurian.

Grabau, and Stauffer² as well, were greatly impressed with the erosion interval at the top of the Monroe formation, an interval sufficient to allow of the removal of the Lucas and Amherstburg dolomites from the top of the Anderson limestone at Amherstburg and Sibley before the Cayugan sediments were deposited. This interval seemed to them to . . . the degree of magnitude required to separate systems. It must be remembered, however, that the formations eroded were to a considerable extent magnesian calcinites and calcarenites, or in other words dolomites formed from the erosion of other dolomites and hence the time required both for their deposition and for their erosion would be much less than that required for the deposition and erosion of ordinary dolomite. As there was little time for hardening, the erosion of these dolomites would undoubtedly be rapid.

That the time interval between the lower and upper Monroe may have been at least as long as that mentioned above is suggested by the presence, between these divisions, of the continental Sylvania sandstone. Grabau states³ that there is reason to believe that the Sylvania sandstone overlaps disconformably the different members of the lower Monroe, and even rests on the Niagara formation in Indiana. This indicates a much

¹Ibid. p. 233.

²Geol. Surv. Can., Mem. 34, p. 285.

³Ibid. page 56.

greater erosion than that at the top of the Monroe. Again, in the character of the Sylvania sandstone good evidence of emergence and continental conditions exists, and the erosion at the top of the Monroe may so far as evidence goes, have been in part at least due to current action although the final conditions were those of emergence. Admitting, however, the difficulty in explaining the lack of sufficient sedimentary or other records which elsewhere might be expected to mark the long period required for the deposition of the upper Monroe and the erosion which removed a large part of it, it must be remembered that the difficulty is not removed but only shifted to Silurian time by considering the upper Monroe of Silurian age. The deciding element in the whole argument appears to the writer to be found in the fossils which are admitted by all to be Devonian in all essential characters.

Although Stauffer formerly preferred to place the upper Monroe in the Silurian system, he has in his later writings given up this opinion. He says:¹ "It may be that the unconformity (disconformity) at the base of the Oriskany in western New York, represents the one occurring at the base of the Detroit River series, and that the unconformity (disconformity) at the top of the Oriskany is the one so prominent at the base of the Onondaga in Ohio, Michigan, and extreme south-western Ontario. If this be the case, these two unconformities run together at various places in Ontario near the eastern end of lake Erie, but diverge rapidly to the westward from Springvale. There is thus represented an unknown interval during which it is probable the Detroit River series was deposited; for to maintain that such a fauna as that found in the Amherstburg dolomite is Silurian is more impossible than to find a place for it among the recognized Devonian formations."

Having settled the time classification to be adopted in this memoir for the Detroit River series, the age of the Sylvania sandstone has to be considered. Grabau concludes² that the sand, which may have been derived from the St. Peter or Potsdam sandstone to the west, was probably in part water and in part wind-borne at first, but later, as emergence continued, it was entirely wind-borne for a time, the sand dunes being reworked by the subsequent, advancing sea. This would account for the presence of Detroit River fossils in intercalated shale beds in the upper part of the Sylvania sandstone and for the intermingling of sand and dolomite as is found to be the case in the wells of western Ontario. Such a formation is typically tangential, and different parts of it may readily be assigned to different periods of time. In Ontario, however, the last phase of sedimentation seems to be predominant, and this fact, along with the content of Detroit River fossils in lenses near its top, favour placing the Sylvania at the base of the Devonian as here represented. As suggested in Stauffer's statement quoted above,³ the thin lenticular sandstone at the base of the Dundee at Detroit river may represent the Oriskany horizon. That the purely aeolian deposition may, as stated by Grabau in his alternative correlation of the Monroe formation, be classed as Silurian (better ep-Silurian) in the sense that it occurred during continental conditions at the close of the marine Silurian deposition, is possible, although improbable, as this would pre-suppose that the Sylvania sandstone bridged the gap

¹Bull. Geol. Soc. Am., vol. XXVII, 1915, p. 77.

²Ibid., page 79.

³Ibid., page 76.

occupied by the highest Silurian and the Helderbergian strata elsewhere. The classification adopted by the writer seems more satisfactory for the description of Ontario occurrences.

In adopting the above classification, the terms upper Monroe and lower Monroe are obviously no longer appropriate, since the so-called Monroe is now seen to belong to different geological systems. Grabau's alternative names "Detroit River" and "Bass Island" will hence be used.

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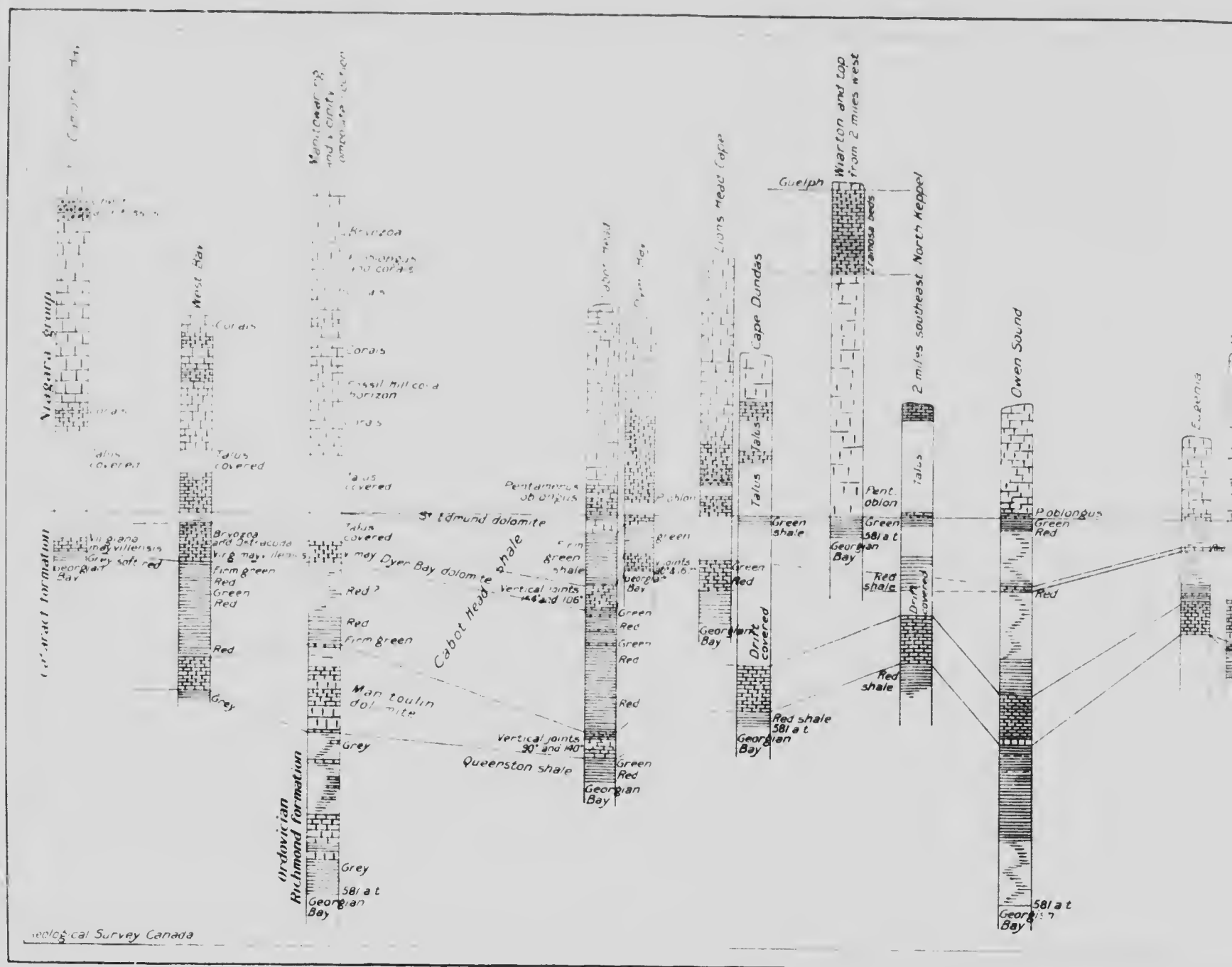


Figure 3. Diagram showing sections along the Niagara escarpment

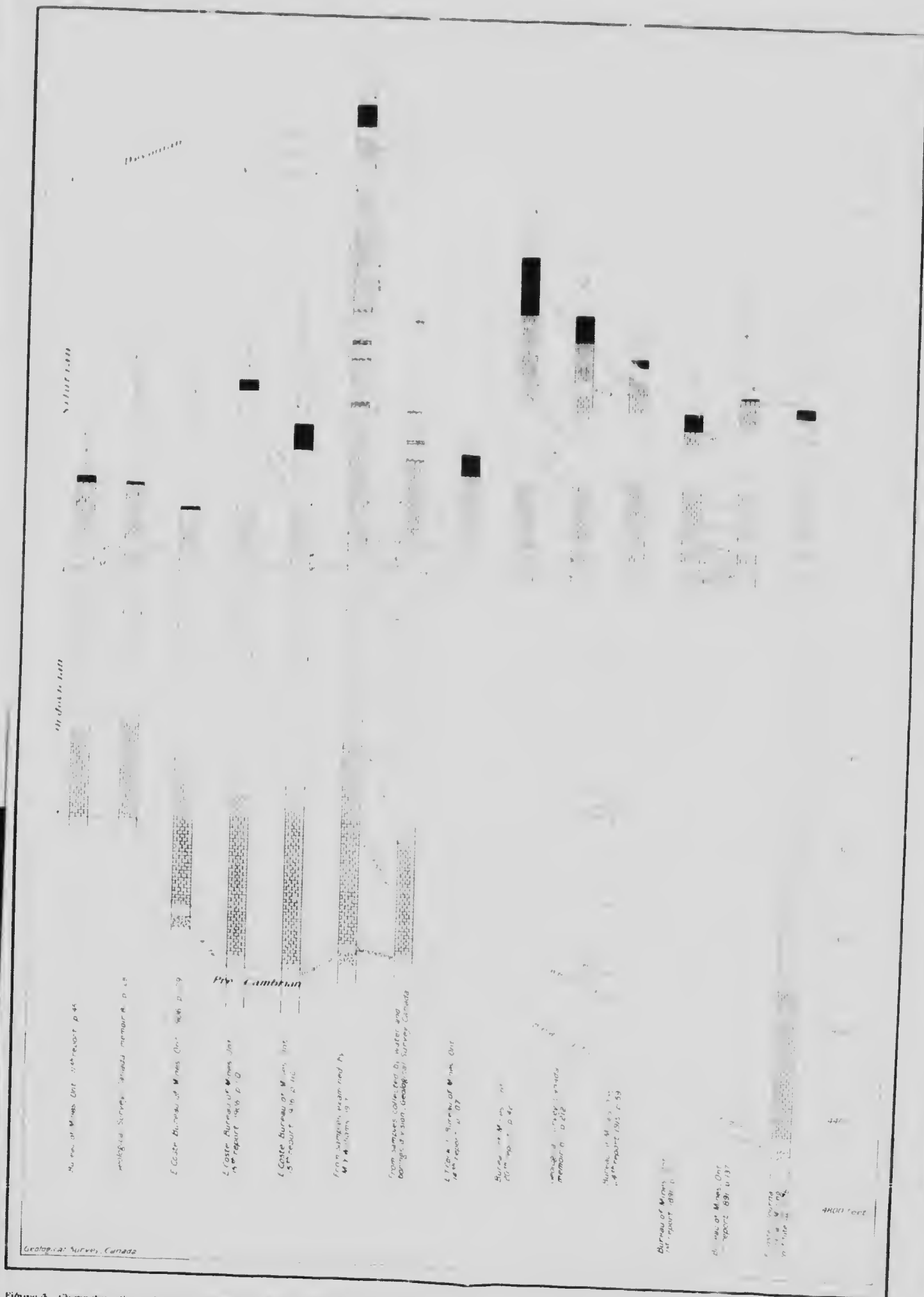


Figure 4. Characteristic geological sections in Ontario peninsula prepared from records of borings, the base of the Silurian being taken as the point of reference. To accompany Memoir by M. V. Williams.

CHAPTER V.

DESCRIPTION OF FORMATIONS.

THE MEDINA-CATARACT FORMATION.

EXPLANATION OF NAME.

The Ontario sediments of the Medina-Cataract formation vary so distinctly by lateral gradation that a hyphenated term seems best suited for the name of the formation as a whole. The term Medina, as restricted by Grabau, is applicable to the formation at Niagara Falls and may be extended to Hamilton, if minor changes are overlooked. It would thus include the sediments between the Queenston shale below and the Clinton formation above, the subdivisions in ascending order consisting of the Whirlpool sandstone, the Manitoulin beds more or less developed into dolomite (a decided dolomite at Stony Creek and Hamilton), the Cabot Head sandy shales, the Grimsby sandstone (thin at Hamilton), and the Thorold sandstone (absent at Hamilton). The term Cataract as defined by Schuchert is applicable from Dundas (and fairly applicable at Hamilton which is in the transition zone) north, and includes the Whirlpool sandstone, the Manitoulin dolomite, and the Cabot Head shale which contains in its upper half on Bruce peninsula and Manitoulin island the Dyer Bay and St. Edmund dolomites. The littoral deposition of sand forming the Whirlpool sandstone terminated southwest of Collingwood and the Grimsby and Thorold sandstones grade northward into mudstones and sandy shales of the Cabot Head shale division, probably because of the lack of sandy material due to the distance from its source. As may be seen from Figure 3, the Cataract rests successively to the north upon the Queenston and marine Richmond sediments and is overlain successively by the Clinton and the Lockport dolomites.

GENERAL DESCRIPTION.

The term "Medina," as already stated, is here used in the restricted sense defined by Grabau,¹ that is to include the "upper Medina" of the older reports or the sandstones and shales between the Queenston shale below and the Clinton formation above. Believing that the Queenston shale is separated from the "upper Medina" by a systemic boundary, Grabau found it impossible to use the term Medina to include the "upper Medina" and the Queenston shales as had formerly been done, and he concluded that the term was first referred to the section near Medina, New York, where the upper division is the prominent one. The term Cataract includes the so-called "Ontario Clinton" and the Whirlpool sandstone, or the sandstones, dolomite, and shale between the Queenston, or in the north the Richmond, below, and the Clinton, or farther north the Lockport, above. From Hamilton north "Cataract" is used exactly as defined by Schuchert, the author of the term. The present usage,

¹Science, new ser., vol. XXIX, 1909, p. 356.

not the conception of the facts, however, differs from that of : in the Niagara peninsula, where Schuchert restricts the term to the Grimsby and Thorold sandstones (described below), using Cataract for the lower members of Grabau's Medina. There is accord, however, in the belief that the Grimsby and Thorold sandstones are only facies of the top of the Cabot Head shale occurring farther north although they represent another faunal invasion. Briefly, the contention is that the term "Medina" should be used for as much of the formation formerly included as is possible, and as restricted by the term "Cataract" is applicable throughout the Niagara peninsula, and that the term "Clinton" is entirely necessary and is properly applied to the sections from Hamilton north where the phases of sedimentation exclusive of the Whirlpool stone are so different from that of the Medina that the sedimentation formerly classed as "Clinton". In referring to the whole of south Ontario, the hyphenated term, Medina-Cataract, seems most satisfactory. The names of sub-divisions, like Cabot Head shale, may, however, be used wherever the distinguishing characters are present.

As already stated the Cataract formation above the Whirlpool stone was formerly thought to be Clinton. This was because of the following considerations: the thinning out of the Clinton limestone in the overlying Rochester shale from Niagara river westward; the absence of the Manitoulin dolomite in the same region; the disappearance of the Thorold sandstone or Grey Band of New York, in the vicinity of Hamilton; and the wrong interpretation of the Whirlpool sandstone as the "Grey Band" from Hamilton north. These mistakes are more evident in the "Paleontology of New York" vol. II, 1852, and are also evident in the "Geology of Canada", 1863, and Logan, to some extent, the difficulties involved. On page 322, he says "The bluish-black shales which in the state of New York afford a well-marked division between the Clinton and Niagara formations, are available for this purpose, at a short distance in Canada. . . . We, therefore, propose to include in the Niagara series, the two bands of limestone which underlie the shales, and which, in New York, constitute the upper part of the Clinton formation." The Cataract fossils, particularly those collected at Hamilton and Dundas (e.g. *Calospira planiconvexa*, etc.) were figured by Hall as if they were Clinton fossils, and subsequently palaeontology was built back up the error in stratigraphic determination. Confusion reigned in the transition zone between Hamilton and Niagara river where both Medina and Cataract characters are fairly well-marked, but from Hamilton north the dolomite and shale of Medina age were unhesitatingly classed as "Clinton". The "Clinton" of Ohio, in part thought to correspond in age with the Cataract, formed another anomaly and it was only after a long tangle was straightened out by Schuchert for Ontario, that harmony was finally attained. Such differences as may exist in recent publications are rather matters of terminology than of interpretation of facts. The study of the northern sections by the author in 1915-16 has added additional information relating to the top of the Cataract section and has corrected interpretations of the author which were embodied in Selders account of the Cabot Head region.

¹Paleontology of New York, vol. II

Following is a description of the members of the Medina-Cataract formation, taken in ascending order.

WHIRLPOOL SANDSTONE¹ MEMBER.

Extent and Characteristics.

From Niagara river to the vicinity of Duntroon, about 8 miles south of Collingwood, the Whirlpool sandstone is the basal member of the Medina-Cataract formation, and so the oldest representative of the Silurian system. The typical sandstone consists of fine quartz grains, is light grey in colour, and is in part cross-bedded. At some localities, notably in the vicinity of Credit Forks, chocolate-brown beds occur interbedded with the grey. From a thickness of 25 feet at Niagara river and 30 feet reported from a well boring at Thorold, the Whirlpool sandstone thins to the west and north, being 4 feet thick at Glen Huron and 6 feet thick, 3 miles west of Duntroon. At Mitchell's mills, 2 miles west of Kolapore, 6.5 feet of green shale with sandy beds at the base, may represent an offshore occurrence of the Whirlpool sandstone. This is the extreme north-westerly occurrence known to the writer.

West of the Niagara escarpment, the information relating to the extent of the Whirlpool sandstone is derived from records obtained from well borings. In spite of the devious methods by which many of these records have been kept, a fair idea of the geographical distribution of the sandstone may be obtained from them. Thus we learn that no sandstone occurs at the top of the Queenston west of the city of Guelph, neither is any present at Kitchener, London, Petrolia, nor in Kent county. At Beachville, calcareous sandstone is reported, which may represent the Whirlpool sandstone, in part reworked at a later time. In Colchester township, Essex county, 62 feet of sandy limestone occurs at the Manitoulin dolomite horizon and the sand content may represent the Whirlpool deposition. In Norfolk county, the Whirlpool sandstone is reported to be 5 feet thick at Port Burwell, 23 feet at Vienna, 27 feet at St. Williams, 10 feet at Vittoria, 18 feet at Port Ryerse, 12 feet at Port Dover, and 3 to 5 feet in the vicinity of the town of Simcoe. Thicknesses are reported elsewhere as follows: in Haldimand county, between 10 and 30 feet; in Welland, 19 feet at Port Colborne and 30 feet at Thorold; and near Brantford between 10 and 20 feet. From the above evidence (omitting the uncertain evidence from Essex county) the western underground extension of the Whirlpool sandstone may be limited within our knowledge by a line drawn from a point near Duncan, 13 miles southwest of Collingwood, southeasterly past Heatherton and thence southerly between Guelph and Kitchener, and southwesterly to lake Erie near Port Stanley.

The Whirlpool sandstone everywhere rests on the red Queenston shale, which is almost universally mud-cracked at the top, the sandstone projecting down into, and filling the cracks. In general, the lower half of the sandstone is thick-bedded to massive, the upper half is thin-bedded, and, where overlain by shale, grades into the overlying beds, through a

¹ *Four. Geol.*, vol. XVII, No. 3, p. 218.

North and west, from the vicinity of Dundas, the Whirlpool sandstone was described by Sir Wm. Logan (Logan 1893, p. 313) under the name of "Grey band". The true "Grey band" of former writers, now known as the Thorold quartzite, does not occur to the west and north of Hamilton and as a consequence, Logan confused the more northern occurrences of the Whirlpool sandstone with it.

transition zone of alternating sandstone and shale. Crossbedding is observed in some part of almost every section, but is confined to a limited thickness. Shale lenses occur here and there in the crossbedding. With the overlying Manitoulin dolomite the contact is sharp, but the lower dolomite beds are arenaceous. At Glen William, ripple-marks occur in the upper bed of sandstone, and at Credit Forks oval masses of sandstone are enclosed in shale coverings, which are in many cases full of worm burrows. The upper beds of the sandstone here are undulatory, and "pillow" structure occurs locally, at the very top. One specimen of "pillow", about 2 feet long, is shaped like a sheaf of wheat with shal containing casts of worm burrows or fucoids wrapped around its side, and partly over one end. Ripple-marks occur on some of the "pillows". The base of the overlying dolomite is full of vugs of pink celestite.

Under the microscope, typical Whirlpool sandstone taken from one of the "pillows," is seen to be made up of angular to subangular quartz grains of 0.1 mm. average diameter. No secondary quartz was observed but there is recrystallization indicated by wavy extinction, along the margins of the sand grains, which are closely compressed, in interlocking arrangement.

Fossils are of rare occurrence in the Whirlpool sandstone and are found for the most part in the upper beds. The following have been obtained by the writer and his assistants. *Pleurotomaria* sp. (fragmentary), *Homotoma subulata* Hall? *Coronulites*, and casts of worm burrows or castings and fucoids (see Table and Plates II, III, and VIII).

Origin.

The origin of the Whirlpool sandstone is a subject of some interest. A. W. C. Wilson¹ has described the Whirlpool sandstone ("grey band" of Ontario) as of probable sand dune origin, and cites the mud-cracked character of the upper Queenston shales, and the crossbedding of the Whirlpool sandstone itself, in support of his contention.

Grabau² derives his "Medina red sands" and "Thorold quartzite" from the erosion of the folded Juniata beds and Bald Eagle quartzites of the Appalachian region. He says of the Whirlpool sandstone,³ "A. W. C. Wilson has interpreted this lens of sandstone as the remnant of an old dune area, reworked by the advancing sea, and this interpretation is favoured by the character of the grains composing this rock as well as by its distribution. Some of the bedding surfaces of this quartzite show wave-marks closely resembling those of modern shallow beaches, a feature repeated in a number of higher beds farther east. The Whirlpool quartzite is not known at Rochester The Whirlpool quartzite is thus seen to be a local formation apparently unconnected with any direct eastern source."

That the shales and sandstones of the Queenston and Medina beds were derived in general from the Appalachian region, there seems little reason to doubt, and it appears to the writer that though the "Whirlpool quartzite" may be "apparently unconnected with any direct eastern source" its deposition may be readily explained as the result of geological processes at work after Queenston time.

¹Can. Rev. of Sc., vol. IX, No. 2, 1903, pp. 129-132.

²Bull. Geol. Soc. Am., vol. XXIV, 1913, pp. 414-415.

³Ibid. page 411.

Grabau has hypothesized the erosion of Bald Eagle beds to supply the material of the Thorold quartzite. No good reason is apparent why these beds may not have been eroded to some extent at least, before the Thorold deposition. As might be expected, the Queenston shales are more arenaceous in the east, nearer their source, and it is more than probable that sand bars of river origin, flood-plain deposits of gravel and sand, and possibly piedmont deposits of coarse materials characterized their landward extension during their period of deposition.¹ The nearby old land might be expected to furnish such deposits. With the return of shallow water conditions indicated by mud-cracks in the Queenston shales of western New York and Ontario, rejuvenation of the erosion processes would follow, and though shale would be carried farther seaward, a littoral zone would receive the sandy deposits. Wind may have played a large part in the distribution of the sand over the mud-cracked Queenston surface or gentle currents may have been the distributing factor. Again, the cleanly sorted, even-grained nature of the Whirlpool sandstone, although due no doubt in great measure to its long transportation by stream action and to subsequent wave action in the littoral zone, may be dependent to some extent upon the effective sorting done by the wind. The fact that from Rochester eastward the Whirlpool sandstone has not been recognized, may be explained on the ground that sorting has been less effective and consequently the red sandstone of contemporaneous age with the Whirlpool cannot be distinguished from similar beds above and below. It is difficult indeed to determine the boundary between the Queenston and Medina sandstones from Rochester eastward.

Thus the origin of the material of the Whirlpool sandstone very probably dates back to the emergent period marking the interval between Ordovician and Silurian time. That the Whirlpool sandstone has received its present form during the advance of the sea at the commencement of Silurian time is shown by the following characters: (1) the formation has a comparatively uniform thickness; (2) crossbedding is limited to a part of the beds only and is more regular than is that characteristic of wind deposition; (3) the upper beds are generally thin, and are interbedded with shale or contain pillow structure; (4) the upper beds are sparingly fossiliferous, the fauna being characteristic of the marine littoral zone.

Shale occurs in the crossbedded sandstone at Credit Forks, but this may be the case even in acolian deposits as shown by Grabau.²

As will be shown later, subaerial distribution of the Whirlpool sand over the semi-emergent Queenston surfaces may readily have resulted in alternating sand and shale beds on the invasion of the Silurian sea. Easterly trade winds at this time, as suggested by Grabau,³ would appear to fulfil the required conditions. Whether such winds existed or not the emergence of the land would readily account for seaward extension of the coarser elastic deposits as described by Wilson.⁴

¹Bull. Geol. Soc. Am., vol. XXIV, No. 3, 1913, p. 464.

²Principles of stratigraphy, p. 561.

³Grabau, A. W., "Palaeozoic delta deposits," p. 140 of seq.

⁴Wilson, A. W. G., Can. Rec. Sci., vol. IX, No. 2, 1905, p. 113.

Fauna of Whirlpool Sandstone.

Gastropoda.

Pleurotomaria sp. Niagara River.

Horquatomia subdata (Conrad)? Glen William.

Vermes (bucrows and trids).

?Cornulites.

MANITOULIN¹ MEMBER.*General Description.*

At its typical occurrences, on Manitoulin island, the Manitoulin member which rests on Richmond shale and is overlain by Cabot shale is a resistant, thin to thick-bedded, grey or buff-weathering dolomite which when fresh, is hard and of light, blue-grey colour. Near the top the dolomite is thin-bedded and argillaceous; midway up beds 10 feet or more in thickness occur; and thin beds are again present near the top. At the escarpment of Manitoulin dolomite, about 1 mile east of the head of Manitowaning bay, measures 50 feet in height, so that allowing for glacial action and other erosion, the total thickness here must have been at least 60 feet.

In the vicinity of Manitowaning, local coral and bryozoan reefs occur in the upper 20 feet of the dolomite. The reefs are several feet in diameter, and cause local thickening of the dolomite and a blocky structure.

At Cabot Head lighthouse, the Manitoulin dolomite is about 10 feet thick, but beds occur to the westward which give no indication that the total thickness is 25 to 30 feet. At Owen Sound, 32 feet of this dolomite is exposed in a quarry, the rock being thin-bedded, and of grey color with blue shale partings. From 23 feet at Credit Forks, the thickness of the dolomite decreases to the southeast to 8 feet at Stoney Creek, below which the dolomite gives place to calcareous shales. At Niagara gorge a 3-foot bed of calcareous sandstone rests on 25 feet of shales. This sandstone appears to represent the southeastern extension of the upper part of the Manitoulin beds.

Well records give the Manitoulin dolomite as 15 to 20 feet thick in Brautford; 42 feet thick in Pilkington, and 29 feet in Peel town, Wellington county; and 50 to 60 feet thick between Allenford and Wilmot. At Woodstock 35 feet of calcareous sandstone is reported and in the western part of Kent county the Manitoulin dolomite is 20 to 50 feet thick. A record of a well in Coleclester South township, Essex county, 62 feet of "grey blue and white sandy limestone" is reported from the Manitoulin horizon. It is consequently fairly certain that excepting the local calcareous shales and sandstones at the Manitoulin horizon in the eastern and southern part of the Niagara peninsula, the Manitoulin dolomite underlies the whole of the Silurian area of southwestern Ontario. Where such records are not reported it is by no means certain that they are absent, as they may easily have been overlooked in keeping the well records.

¹Proposed by author, Ottawa Nat. vol. XXVII, 1903, p. 37. Formerly proposed by A. C. Lane, Geol. Mich., vol. I, 1874, as a group name to include Niagara and Guelph. This usage is not generally recognized.

In the south, the Manitoulin beds rest on the Whirlpool sandstone. Even where the basal beds are shale, the contact is well-defined, but transitional sandstone and arenaceous shale alternate above the top of the well-defined Whirlpool sandstone. Where dolomite rests on the sandstone, the contact is generally sharp, but the lower dolomite beds are sandy or arenaceous. The dolomite rests with sharp, even contact on red Queenston shale from Collingwood west and north to the end of Bruce peninsula, the Queenston last being seen at Cabot head. On Manitoulin island the contact is with green Richmond shale. This contact is sharp, but the basal Manitoulin dolomite is somewhat argillaceous. The two faunas have practically nothing in common.

Microscopic Characters.

A specimen of fresh Manitoulin dolomite from a quarry at Owen Sound, proves under the microscope to be composed of interlocking grains of dolomite of 0.12 mm. average diameter.

Two specimens of the dolomitic sandstone of Niagara river were examined microscopically. One proved to be made up of rounded quartz grains of 0.13 mm. average diameter, with about 50 to 55 per cent dolomite. The other is composed of rounded to subangular quartz grains of 0.10 mm. average diameter, and 5 to 15 per cent of dolomite. One, small, worn fragment of plagioclase was observed in each slide, the size corresponding to that of the average quartz grains.

The arrangement of the crystals of dolomite indicates that they have crystallized around and have filled in pore spaces between the quartz grains.

Under the high power, the edges of the quartz grains are found in many cases to be gently etched, indicating some solution by the highly charged dolomitic waters which surrounded them.

Fossils.

As will be seen from the table (page 30 and Plates III, V, VI, and VII) the Manitoulin dolomite is for the most part decidedly fossiliferous.

Origin.

Of the origin of the Manitoulin dolomite, Grabau says¹: "The Keppel (previously named Manitoulin by the author) dolomite is an earlier deposit before the sands and muds from the Appalachians reached this point, or during the earlier period of the erosion of the folded red beds of the Ordovician." Schuchert² says "the Cataract province spreads westward through the Saint Lawrence embayment", and concludes "that the normal marine junction of the Cataract and Brassfield seas is prevented by the Medina delta".

¹"Palaeozoic delta deposits," p. 490 of 469

²"Medina and Cataract formations of the Silurian of New York and Ontario", Bull. Geol. Soc. Am., vol. XXV, p. 294

Fauna of Mendocino Dolomite.

Genera and species.

Fungi.

Butthotrephix gracilis (Hall)*Hyalodictyon Vesiculosum* (Nicholson and Mun.)

Algae.

Streptelasma cf. *haskinsii* (Forster)*Entedasma* cf. *geometricum* (Forster)*Zaprentis bilateralis* (Hall)*Palasophyllum imbedderes* (Chadwick)*Palasophyllum* (C. *Yathophylloides*?) *williamsi* sp. nov.*Amplopus shumardi* (Edwards and Haine)*Homophyllum bollii* (Billings)*Cervularia gracilis* (Billings)*Ceratopora tenuia* (Roumiger)*Synopora retiformis* (Billings)*Pseudosiphosia asper* D. Grubisny*Lyrites catenularia micropora* Whitfield

Cyanea.

Brachycystis tecumseth (Billings)

Crinoids.

Euchirocrurus ontario Springer n. sp.

Bryozoa.

Homonotrypa cf. *colluens* (Forster)*Halopora magnipora* (Forster)*Halopora fragilis* (Hall)*Pachydictya turgida* (Forster)

Brachiopoda.

Lingula cuneata Conrad*Strophonella striata* Hall*Leptæna rhomboidalis* (Walcot)*Planorbis* cf. *transversus* (Walcot)

¹ Reported by Parks, Twelfth Inter. Cong. Citiz., Guide Book No. 7, 1913, p. 10, identified by Rasler.

Although described by the two writers from widely divergent points, one idea is back of both statements, that is, an encroaching from the northward, tending to deposit calcareous material, was involved by detrital material from the Appalachian province. The greater thickness of the Manitoulin dolomite in the north and the sandy shaly part of this member in the south, indicate quite clearly the encroaching fairly deep, marine conditions over the littoral zone occupied by Whirlpool sandstone. That the supply of detrital material became greater in post-Manitoulin time than the deposition of calcareous deposits is shown by the shaly or sandy characters of the subsequent members of the Cataract formation.

CABOT HEAD SHALE MEMBER.

General Description.

The Cabot Head shales, as already explained, were formerly included with the Manitoulin dolomite in the Clinton formation of Ontario. Schuchert, in 1912, included these shales in the Cataract formation. In 1913 the author² proposed for them the name "Kagawong member" or "Kagawong shales." This name was preoccupied by Foerste, who had applied it to an upper Richmond member. "Cabot's Head", proposed by Graham³ in 1913 for the red and grey Cataract shales, included dolomites of the midland of Ontario. In its corrected form "Cabot Head" following the recognized form of the place name on maps and charts, the author finds it applicable for the Cataract shales of southwestern Ontario and the Georgian Bay region.

Detailed Description and Sections.

The Cabot Head shales vary much in character in different parts of the same section, as well as at different localities. They include grey and red shales and fine-grained, shaly sandstones, ferruginous, sandy dolomite, and grey, shaly dolomite. At Niagara river, where some sandy dolomitic beds and grey shales below them are classed as a southern facies of the Manitoulin dolomite, only 3 or 4 feet of grey shale are classified as Cabot Head. Here, the Grimsby sandstones are thick and characteristically developed. As they become shaly to the north they add to the thickness of the Cabot Head shales of which they are a southern facies. The general colour of the shales from Niagara river to Warton is grey, but red, sandy beds occur in the upper half including a red, sandy, dolomitic bed well exposed at Kelso, Launchouse, and Cataract. The shales of Bruce peninsula and Manitoulin island contain red beds in their lower half and beds of dolomite interbedded with grey shale in their upper half.

At no place do the Cabot Head shales show more variations than at the type locality of Cabot head. The nearly flat-lying Manitoulin dolomite at Wingfield basin, upon which Cabot Head lighthouse stands, dips gently to the southwest beneath the escarpments of three prominent

¹Bull. Geol. Soc. Am., vol. XXIV, 1913, p. 107.

²Ottawa Naturalist, vol. XXVII, pp. 37-38.

³Bull. Geol. Soc. Am., vol. XXIV, no. 3, Sept., 1912, p. 160.

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bluffs, known locally as Bowlder, Middle, and West bluffs. Talus obscures much of the section, but as worked out it consists in ascending order of 70 feet of shale, red near the base and containing firm beds bearing *Holopora fenestrata*, and firm and green near the top; 4 feet of soft green shale; 15 feet of thin, even-bedded dolomite (Dyer Bay); 32 feet of firm green shale; 8 feet of rather massive, creamy weathering dolomite (St. Edmund); and 4 feet of soft, green shale. Lockport dolomite succeeds, the lowest 8 feet being thin-bedded, green in colour, and in part mud-cracked.

The above section was described by Logan¹ and copied by Grabau.² Logan's description follows: "At Cabot's Head, the very summit of the Medina formation, 'Queenston' is seen at the water's edge; and there rest upon it about twenty-six feet of a dolomite."

On the dolomite, repose 103 feet of red, partly sandstones, partially striped and spotted with green, and interstratified with beds of red and green argillaceous shale; none of which exceed six or eight inches in thickness. The green argillaceous beds appear to be quite free from calcareous matter, and the stone is carved by the Indians into tobacco pipes. These red and green strata are succeeded by about fifty-five feet of green calcareo-argillaceous shales and thin-bedded limestones, and terminated by the massive limestones of the Niagara series."

Three miles west of Cabot head, a fine exposure, locally known as the "Clay cliffs," occurs on the shore (Plate XXXI). The Manitoulin dolomite is here below the water, the section being, in ascending order from the water up, as follows: lower 22 feet obscured by talus, probably red shale; 5 feet of soft, red shale; 17 feet of soft, red shale, interbedded near the base with thin calcareous shale, and containing also firm shale beds to about one-fifth the total amount; 3 feet of green clay shale; 15 feet of massive to thin-bedded dolomite (Dyer Bay); 36 feet of thin-bedded, firm, green shales; 8 feet of buff-weathering dolomite (St. Edmund) containing *Pavonia cristatus*; 11 feet of covered interval, succeeded by 4 feet of dolomite belonging to the Lockport formation and bearing *Pentamerus oblongus*. From a comparison with the Cabot Head section it is evident that the upper 8 to 10 feet of the covered interval includes thin dolomites belonging to the base of the Lockport formation and that only the lower few feet are shale beds.

The upper dolomites ("limestones") were clearly included by Grabau in the Cabot Head shales, and so there appears no good reason for redefining the term. Ferruginous limestone is found near the top of the Cabot Head shales at Credit Forks and Limestone, and thin-bedded dolomites occur interbedded with shale in the upper part of the Cabot Head beds

¹Geology of Canada, 1883, pp. 312-320.
²Ibid., page 460.

³In seeing the section at the Clay cliffs, for the first time, the author confused the 15 feet of dolomite in it with the Manitoulin dolomite at Cabot head, and as a covered interval at the base of Centre and West bluffs suggested a structural break, he stated in the Summary Report of the Survey for 1913 (p. 183) as follows: "Cabot Head was proposed by Grabau for the shale under discussion and it is here accepted. The writer, however, wishes to draw attention to the fact that the measurements and description of the section at Cabot head, which were taken from Logan, are seriously in error, due to the failure on the part of former workers (and the writer also upon a previous occasion) to recognize a structural disturbance, which repeats much of the section." For the same reason the thickness of these shales is given in the Summary Report for 1912 (p. 279) as 50 feet. Likewise the plate published by Schubert (a) which was taken from a photograph by the author, is wrongly described in the title. In reality it is a 15-foot bed of dolomite (Dyer Bay) high up in the Cabot Head shales. The true Cataract (Manitoulin) dolomite is here submerged. The section given by Logan, though differing slightly in measurement, is substantially correct, as may be seen by a comparison with the section by the author given above.

(a) Bull. Geol. Soc. Am., vol. XXV, 1914, pl. 13, fig. 2, opposite p. 287.

on Manitoulin island. The dolomite beds at Cabot head are worth of some designation, particularly as they carry, as will be described later, characteristic fossils. It is proposed to designate the lower, the Dyer Bay dolomite lentille, and the upper, the St. Edmund dolomite lentille. The lower dolomite contains numerous characteristic fossils at Dyer Bay and St. Edmund is the township in which the clay cliffs are situated and there the upper dolomite is best exposed. These dolomites are described in detail below.

The Cabot Head shales on Fitzwilliam and Manitoulin islands are in general soft, red, clay shales in their lower beds, but contain soft, green shales, firm, green shales, and dolomites (Dyer Bay) near the top. Thin at the northeastern extremity of Fitzwilliam island, 45 feet of soft, red clay shale is overlain by 6½ feet of soft, green shale and thin, firm, green shale interbedded. West of Tannock cove, in a partial section, soft green shale is overlain by 15 feet of green-grey, fine-grained dolomite (Dyer Bay) which is succeeded by 22 feet of firm, pea-green shales. A covered interval obscures the beds above.

In the partial sections along the east side of lake Manitoulin soft, firm, green shale occurs above 10 to 15 feet of exposed, red shale, while where exposed at another place, overlies firm, green shale. On the road between West bay and Kagawong, the section from the Manitoulin dolomite up is as follows: 40 feet of soft red shale; 4½ feet of hard, green shale, calcareous at the base; 10 feet of soft, red shale; 5 feet of soft, green shale; succeeded by fine-grained Dyer Bay dolomite. Red shale was also observed one-half mile west of lake along the road to Gore Bay (27 feet of shale exposed), near the site of the former Indian village of Campbell bay; and at water level at the end of the point between Campbell and Helen bays. Red clay is also reported along the east side of lake Wolsey.

Southward from Cabot head, both the Dyer Bay and St. Edmund dolomites extend to Dyer Bay; the Dyer Bay is seen at Gun point and both are missing on Colpoy bay. From Owen Sound east and south as already stated, the lower Cabot Head shales are green or grey, the upper red, containing ferruginous limestones. Thin, calcareous beds occur throughout the section, and arenaceous (sandy) beds and thin sandstones are common in the southern sections. The Cabot Head shales are 140 feet thick at Owen Sound, 60 feet at Cataract, 42 feet at Hamilton, 66 feet at Stoney Creek, 63 feet at Jordan, and 5 feet at Niagara river. At the last-named locality, the beds consists of grey shale and thin sandstone, the grey and red sandstone above being included in the Grimsby sandstone which appears to be clearly the sandstone phase of the upper Cabot Head shales occurring to the west and north.

Depending upon the evidence obtained from well records, there is from 4 to 65 feet of Cabot Head shales at Port Burwell, 65 feet at Beauville, 30 at Glen Allen, 21 miles northwest from Campbell, 75 to 100 feet east of lake St. Clair, and 100 feet in Colchester township, Essex county. Although some well logs do not clearly show the presence of Cabot Head shale, enough has been learned to make it seem probable that the Cabot Head shales extend (underground) to the southwestern base of the Cataract.

For the fossils of the Cabot Head shales see the Plates IV, V, and VII.

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At Cabot head and the "Clay bank" 3 miles to the west, the complete core exposed. This is 15 feet thick, and consists of thin, even-bedded

(appearing massive where little weathered), greenish grey, argillaceous dolomite. Characteristic ostracoda occur at the top of the section (see table). About 10 feet of this dolomite connects Centre and West bluffs, at Cabot head, as a ledge or shelf. The bedding is 1 to 3 inches thick and the formation is cut by two sets of vertical joints, with direction 149 degrees (south 31 degrees east) and 281 degrees (west 11 degrees north).

Ten feet of thin-bedded dolomite occurs in the section at the north-eastern extremity of Fitzwilliam island, and in these beds *Virginia mayrillensis* Savage occurs plentifully, along with *Schuchertella curvistrata* Savage, etc. (see table). From Fitzwilliam north and west, *V. mayrillensis* is common in the Dyer Bay beds, but generally at one definite horizon. At Tamarack cove the dolomite is 15 feet thick, rests upon green shale, and is overlain by firm, green-weathering shale. *V. mayrillensis* and the characteristic ostracoda occur here. On the southeast side of lake Manitou, about 12 feet of Dyer Bay beds occur containing *V. mayrillensis*. The thickest known section of Dyer Bay beds is exposed along the road between West Bay Indian village and Kagawong, just north of a lakelet, on lot 17, concessions VIII and IX, Billings township, Manitoulin island. Here, at least 25 feet of dolomites with some inter-bedded shale are included in the Dyer Bay beds. A few inches of grey, semicrystalline dolomites occur near the middle, *V. mayrillensis* occurring just below and the Dyer Bay ostracoda 6 or 7 feet higher up. West of Ice Lake on the road to Gore Bay, 5 feet of calcareous shale occurs at the top of 20 feet of red shale containing some firm green beds. In the upper 5 feet of shale, the Dyer Bay ostracoda occur at the top and *V. mayrillensis* occurs near the base.

The Dyer Bay beds are well developed and extend as ledges considerable distances from the base of the Lockport dolomite between the west side of lake Manitou and the western end of Manitoulin island, and also on Cockburn island. Typical outcrops occur on the north end of the island in Mindemoya lake, on the west side of Kagawong lake, near West Bay and Ice Lake as mentioned, at the west side of Campbell bay and at Pitman point, Cockburn island. These outcrops almost invariably contain *V. mayrillensis* which was thought throughout the field work to be a small form of *P. oblongus* marking the base of the Lockport formation as the typical *P. oblongus* lifts the basal beds of the Lockport dolomite at Owen Sound, Dyer bay, etc. As a consequence the Dyer Bay dolomite was mapped with the Lockport. This error has been corrected so far as could be done in the office. The true Cataraugus 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.

Southward from Colpoys bay, the typical Dyer Bay beds are absent, but 2 or 3 feet of ferruginous limestone occurs a little above the centre of the Cabot Head shale as far south as Kelso. This has been termed the "iron band" and contains common Cataraugus fossils, among others being *Rhynchonella? janae* which also occurs in the Dyer Bay dolomite. It seems probable that this is the southern representative of the Dyer Bay dolomite of the north (for the chemical composition of the iron band at Linthouse, see table page 111).

The recognized fauna of the Dyer Bay dolomite, as shown in the accompanying table, includes one species of plants, five of corals, nine of brach-

lopods, one of pelecypods, four of ostracods, and one of trilobites. Of these, two brachiopods and three ostracods are new species found only in the Dyer Bay dolomite (see Plate VII).

Fauna of the Dyer Bay Dolomite.

Genera and species.	Barrow Bay.	Dyer Bay.	Cabot head.	Fitzwilliam island.	Tamarack cove.	South bay.	West bay.	Ice Lake.	Helen bay.	Cockburn island.
<i>Plants.</i>										
<i>Butthotrephis gracilis</i> Hall			x							
<i>Anthozoa.</i>										
<i>Enterobasania cf. geometricum</i> (Foerste)				x						
<i>Streptelasma cf. hoskinsoni</i> Foerste		x	x							
<i>Syringopora retiformis</i> Billings			x							
<i>Favosites cristatus</i> Edwards and Haine	x	x	x							
<i>Favosites obliquus</i> Rominger		x	x							
<i>Brachiopoda.</i>										
<i>Strophonella striata</i> (Hall)			x		x					
<i>Schuchertella curvistriata</i> Savage				x						
<i>Platystrophia bifurcata</i> (Schlotheim)				x						
<i>Virgiana mayvillensis</i> Savage				x	x	x	x	x	x	x
<i>Rhynchotrema thebesensis multistriata</i> Savage				x						
<i>Rhynchotrema cabotensis</i> Williams n. sp.			x							
<i>Rhynchonella? janae</i> Billings	x		x							
<i>Rhynchonella? bidens</i> Hall	x					x				
<i>Hondrospira cf. immanata</i> Savage				x						
<i>Pelecypoda.</i>										
<i>Pterinea cf. undata</i> (Hall)			x							
<i>Ostracoda.</i>										
<i>Lepeditia cabotensis</i> Ulrich and Bassler			x		x					
<i>Chidobolbina punctata</i> Ulrich and Bassler			x							
<i>Zygobolbina williamsi</i> Ulrich and Bassler.			x		x			x		
<i>Trilobata.</i>										
<i>Calymene cf. eltoni</i> (Vanuxem)	x									

St. Edmund Dolomite Lenticle.

Description. A bed of fine-grained, light buff-weathering dolomite occurs near the top of the Cabot Head shale division of the Cataract formation in the vicinity of Dyer bay and Cabot head. At the type locality along the shore 3 miles west of Cabot head, on lots 3 and 4, concession XIV, St. Edmund township, Bruce peninsula, the dolomite is 8 feet thick and tends to be massive. *Favosites cristatus*, a beautiful branching coral, is its characteristic fossil and *Atrypa parksi* occurs rarely. Four feet of soft green shale intervenes between the top of the St. Edmund and the base of the Lockport dolomite, which is thin-bedded as exposed at Cabot head. The character of the St. Edmund at Cabot head is the same as at the type locality. At Dyer bay, the St. Edmund is poorly exposed, but is represented by slabs full of *Favosites cristatus*. The thickness appears to be less at Dyer bay however, as is also the thickness of the thin beds at the base of the Lockport, judging from the covered interval. Southward

on Bruce peninsula, the horizon of the St. Edmund dolomite is generally talus covered. On Manitoulin island this dolomite has not been recognized and appears to be absent.

Microscopic Characters. Examined under the microscope, a specimen of St. Edmund dolomite from the Clay cliff near Cabot head proves to be made up of an aggregate of small, uniform, rounded grains of dolomite with an average diameter of 0.01 mm.

A specimen of ferruginous sandy dolomite from near the top of the Cabot Head shale, at Linchouse, under the microscope, proves to be composed of rounded, worn dolomite grains from 0.09 to 0.22 mm. in diameter with a little ferruginous matter. The smaller dolomite grains interlock and show no signs of wear. Numerous sections of bryozoa are present.

Fauna of St. Edmund Dolomite. This is recognized only at the exposures in the vicinity of Cabot head, where it contains *Favosites cristatus* Edwards and Haine and *Atrypa parksi* Williams, n. sp. (see Plates IV, V, and VII).

Origin of Cabot Head Member.

Of the origin of the Cabot Head shales Grabau says¹: "Westward however, the northern series of deposits (the Upper Juniata) were washed into the sea, the shore of which during Medina time did not probably extend much farther east than Rochester. In western Ontario, encroachment of the sea began earlier, for here we have the marine Keppel (Manitoulin, author) dolomite resting on a surface of Queenston. These dolomites were probably formed while erosion was beginning in the east and while the early Medina sands were spread by the streams over the Ordovician land surface. Then as the product of this erosion was carried farther westward by repeated reworking, it finally entered the sea, which had then advanced farther east. Thus the fossiliferous Medina beds of western New York and the red and green Cabots Head sands which rest on the Keppel dolomite were deposited."

The lack of sandstone in the north is doubtless due to the distance from the shore and the source of the sedimentary materials. The fact, however, that in the north the lower beds are red and in the south the upper beds are red is not easily explained on Grabau's hypothesis alone, particularly as there appears to have been continuous deposition of one kind or another throughout the region. However, highly oxidized sediments on being washed out to sea met deoxidizing agents in the form of plant and animal organisms, and it is clear that normal marine conditions extended farther eastward into New York during early Cabot Head time than during late Cabot Head and Grimsby time. Thus, in the Niagara peninsula the lower Cabot Head, and the underlying Manitoulin beds clearly represent marine conditions and the colour is grey; higher beds are sandy, representing shallower water, and red is the predominant colour. Grabau derives the sediments forming these deposits from the older, highly oxidized formations such as the Juniata-Bays. In the Georgian Bay region, however, it is hardly probable that the origin of the sediments is as simple as supposed by Grabau. The author has shown

¹Bull. Geol. Soc. of Am., vol. XXIV, No. 7, Sept., 1913, p. 469.
Geol. Surv. Can., Mus. Bull. 67, p. 6.

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that in the Lake Timiskaming region, a long period of erosion laid bare early Trenton fossils resting in an irregular basal conglomerate on the Pre-Cambrian rocks, and upon these deposits Niagara limestones were laid down. Elsewhere in the same region, as shown by G. S. Hume,¹ 70 feet of strata lie between the top of the Trenton and the base of the Niagara. Thus a considerable amount of erosion is shown to have occurred in the north during the period including the deposition of the Cabot Head shales. That some of the eroded material should be carried southward is altogether probable and the mingling of the detritus eroded from the Richmond shales with the materials coming from the Adirondicks and the nearby crystalline rocks, together with the deoxidizing influence of marine conditions, may easily account for the gray colour of the upper part of the Cabot Head shales. The red colour of the lower Cabot Head shales of the Georgian Bay region may be due to the inwashing of highly oxidized sediments from the nearby Proterozoic areas to the east and north during the predominance of littoral conditions. The probability of sediments coming from these nearby sources cannot be ignored.

The St. Edmund dolomite (a magnesian calcilutite) shows evidence of being composed of dolomite (and may with the Dyer Bay dolomite have been derived from older dolomites of the northern realm.

GRIMSBY SANDSTONE MEMBER.

Characteristics and Distribution.

The 56 feet of red and grey shale and sandstone at Niagara river, limited below by the Cabot Head shale and above by the Thorold sandstone, has been named by the author the Grimsby² member. At Grimsby, the type section consists of 12 feet of thick-bedded, mottled, red and grey sandstone, and 6 feet of grey shale which lies immediately beneath the Thorold sandstone. The underlying strata are red Cabot Head shales.

The Grimsby sandstones show considerable variation, some beds, particularly in the lower half, being decidedly shaly. Crossbedding is common in the thicker beds and lenses and pillow structure are fairly common. The pillow structure appears to the writer to be due to the rolling by current action of masses of sand over thin beds of mud, the incoming sand preserving the form. Current action was certainly present as shown by crossbedding.

The Grimsby sandstone is seen as far west as Dundas, where it is not easily differentiated from the Cabot Head shales, but is about 14 feet thick. Eastward, it increases in thickness, being as above stated, 56 feet at the American line. In Canada this member rests upon the Cabot Head shale, and is doubtless the inshore equivalent of the upper beds of the shale as seen north of Dundas. As far west as Stoney Creek the Grimsby sandstone is overlain by the Thorold quartzite. Whether the upper grey shales and sandstone at Hamilton are to be included with the Grimsby or the Thorold, it is not easy to decide, but on the evidence of pillow structure which is a well known characteristic of the Grimsby sandstone, the lower beds are referred to that member. It is prob-

¹ Geol. Surv. Can., Sum. Rept., 1913, p. 190.
² Geol. Surv. Can., Sum. Rept., 1913, p. 181.

able that the upper, thin, grey sandstones and shales are a facies of the Thorold sandstone.

On the evidence of well borings, 25 feet of sandstones at Port Burw and 45 feet at Paris are referred to the Grimsby member. About 7 feet of sandstones and shales are referred to the Grimsby at Dundas, and Kelso, Grimsby beds are lacking. A well record at Beachville indicates that the Grimsby sandstone is lacking there, and it is also lacking at London. The northwestern, underground extension of the Grimsby appears from the above evidence to be approximately limited by a line drawn from the Niagara escarpment between Dundas and Kelso, southwestward passing to the north of Paris and to the east of Beachville and terminating at the lake Erie shore perhaps in the vicinity of Port Bruce.

Microscopic Characters.

A specimen of green-grey sandstone, from a bed 9 feet above the base of the Grimsby member at Niagara river, proves under the microscope to consist of subangular to rounded quartz grains with an average diameter of about 0.1 mm., some chlorite and kaolin, and a very little calcite.

Origin of Grimsby Sandstone.

As already described, Grabau's hypothesis¹ derives the Medina beds from folded Juniata-Bays and Bald Eagle formations in the Appalachian region. Erosion having cut through the Juniata-Bays red beds, we next attack the grey Bald Eagle conglomerate. The Grimsby sandstone appears to be an inshore phase of the early erosion of the Bald Eagle. The finer sediments were deposited farther out to sea, forming the upper Cabot Head beds, and the coarser materials, mixed with the coarser, highly oxidized materials from the red beds, were deposited in an estuary along the littoral zone of the sea in what is now the Niagara peninsula of Ontario. (For fossils see the following table and Plate VIII.)

Fauna of Grimsby Sandstone.

Genera and species.	Niagara river.	Thorold.	Jordan.	Hamilton.	Waterdown.	Flamborough.
<i>Brachiopoda.</i>						
<i>Langula cuneata</i> Conrad	x	x	x			
<i>Langula clintoni</i> Van Dine					x	
<i>Dalmanella eugeni</i> Williams n. sp.					x	
<i>Canadoterebra</i> St. Yachus neglecta Hall.	x				x	
<i>Pelecypoda.</i>						
<i>Pterinea cf. undata</i> Hall	x				x	x
<i>Pterinea brisa</i> Hall						
<i>Modiolopsis pringenta</i> Conrad	x ²				x	
<i>Modiolopsis orthonota</i> Conrad	x ²					
<i>Modiolopsis kelseensis</i> Williams n. sp.						x
<i>Ctenodonta macfarlanei</i> Hall						x
<i>Nuculites cf. ferrugineus</i> Foerste						x
<i>Gastropoda.</i>						
<i>Bucanella trilobata</i> Conrad	x					

¹Ibid., page 409.

²Reported by Grabau.

THOROLD SANDSTONE MEMBER.

Characteristics and Distribution.

The grey sandstone at the top of the Medina in New York, and southern Ontario, formerly known as the "Grey Band", has been called by Grabau the "Thorold quartzite". The sandstone is light grey, thin to thick-bedded, and at Thorold is a true quartzite. Elsewhere, "sandstone" more fittingly describes it. The sandstone is commonly crossbedded and contains at Grimsby and elsewhere *Dadalus archimedes* Ringueberg and *Arthropycus harlani* Hall.

At Niagara gorge the Thorold sandstone is 7 feet thick; it attains a thickness of about 12 feet near DeCew falls, is 6 feet thick at Storey Creek, and at Hamilton and northward is not clearly differentiated, if present, from the Grimsby sandstone and shale. At its lower contact the Thorold sandstone is marked by little more than a lithologic change from the Grimsby sandstone below. The top bed of sandstone upon which the Clinton (Reynolds (Wolcott) dolomite rests, is thick and free from calcareous matter. At some localities, however, the Reynolds dolomite is arenaceous at the base.

Fauna of Thorold Sandstone.

Genera and species.	Niagara River.	Thorold.	Grimsby.	Dundas
<i>Worm burrows</i>				
<i>Dadalus archimedes</i> (Ringueberg).			x	x
<i>Arthropycus alleghaniensis</i> Harlan.	x	x	x	x

Microscopic Characters.

A specimen of Thorold quartzite from Thorold, Ont., examined under the microscope, proves to consist of rounded to sub-angular quartz grains of 0.10 mm. average diameter, closely interlocked. Along their contacts, recrystallization has taken place, and some secondary silica has been deposited.

Underground Extension.

As stated above, the Thorold sandstone extends along the Niagara escarpment as far west as the vicinity of Hamilton. Well records indicate that its extent southward is not great, only red sandstones being mentioned in well logs, excepting at Port Colborne, where thin-bedded, white sandstones occur interbedded with red shales, and at Welland where grey shales are recorded above the red sandstones. It appears fairly clear that the Thorold sandstone does not extend underground much beyond a line drawn from Port Colborne northwest to Hamilton.

Origin.

The origin of the Thorold sandstone has been explained by Grabau as the result of the erosion of the Bald Eagle conglomerate, after the Juniata-Bays red beds had been cut through to furnish material for the formation of earlier Medina members. The Thorold as well as the Grimsby sand may, however, have been derived from the crystalline rocks of the Appalachian after the removal of the younger strata.

The origin of the Medina sediments, which are at Niagara river, in ascending order, sandstones, shales, sandy dolomite, shales, and sandstones, must be considered from the standpoint of the relative position of the sea and land as well as from the standpoint of the source of sediments.

A. W. C. Wilson¹ has shown that when the rate of depression of the land is greater than the rate of supply of detritus "there will be a uniform shoreward overlap of the zones of deposition", that is from deep to shallow water, limestones will overlap shales, which in their turn will overlap sandstones and conglomerates. Should the rate of depression of the land, later become less than the rate of supply of detritus, the overlap would be reversed, conglomerates and sandstones overlapping shales and shales overlapping limestones to seaward. Thus with a reversed cycle, limestones would be enclosed in shales, and shales in sandstones in a direction from sea to land. It will be readily seen from the sections of the Medina members that this is exactly the same as in the case of the Medina. In the first part of the cycle of sedimentation, whirlpool sandstone was overlapped landward by shales which comprise the base of the Manitoulin beds in its southern extension, and the shales and sandstones both were overlapped by dolomite. With the reversed order Cabot Head shales overlapped Manitoulin dolomite to seaward, and Grimsby sandstones overlapped the shales in the same direction. The Thorold sandstone and the Oneida conglomerate of New York state may represent a temporary mastery of the depression of the land over the supply of detritus. That is, the shaly character of the upper Grimsby sandstone, followed by the limited deposits of Thorold sandstone, may well indicate a slight advance of the sea at the end of Medina time.

The reason for the change of balance in the factors controlling sedimentation, as applied to Medina sediments, is to be found on the one hand in the relative change in elevation of land and sea, and on the other in the varying sources of supply of sediments as erosion progressed.

CORRELATION AND AGE OF THE MEDINA-CATARACT FORMATION

As already stated the Medina is represented in eastern New York state entirely by sandstone and conglomerate. This is because of proximity of the Appalachian mountains which were the main source of the sediments. Bassler² correlates the Oneida-Shawangunk Group formation of central and eastern New York state with the Medina below the Thorold.

According to Ulrich³ the Clinch sandstone of Tennessee is probably the equivalent of the Tuscarora sandstone of Pennsylvania and in general also the equivalent of the Medina (restricted use) of New York and Ontario.

¹ Can. Rec. of Sci., vol. IX, No. 2, 1903, p. 119.
² U. S. Nat. Mus., Bull., 92, vol. I, part II, 1915, pl. 3.
³ Bull. Carol. Geol. Surv., No. 3, vol. XXII, 1911, p. 165.

Savage has recently described in detail the stratigraphy and palaeontology of the Alexandrian series in Illinois and Missouri.¹ He has divided the series in ascending order² into Girardeau limestone, Edgewood limestone, Essex limestone, and Sexton Creek (Brassfield) limestone.

In a later article,³ Savage indicates important correlations. After referring *Conchidium decussatum* Whiteaves to the genus *Virgiana* recently described by Twenhofel, Savage says in part as follows: "In the Grand Rapids region the layers containing *Virgiana decussata* are succeeded by strata which contain the fossils *Pterinea occidentalis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*. In the Hudson Bay region a zone a few feet above the horizon of *Virgiana decussata* furnished shells of *Camarotoechia? winiskensis*, *Pterinea occidentalis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*. In the northern peninsula of Michigan early Silurian strata containing *Camarotoechia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina* overlie the strata containing *Virgiana mayrillensis*, which is a near relative of *Virgiana decussata*. In eastern Wisconsin *Virgiana mayrillensis* occurs in the uppermost layers of the Mayville limestone, above which there is a stratigraphic break, the horizon of *Camarotoechia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*, present farther east in northern Michigan, having been removed by erosion. However, there is no doubt that the strata which in northern Michigan contain *Virgiana mayrillensis* correspond in age to those containing the same species in the upper part of Mayville limestone in Wisconsin, as they are clearly a northeastward continuation of the same beds"

"In Wisconsin there was found in the quarry near Pebbles a zone only a few feet below the horizon of *Virgiana mayrillensis* and apparently conformable with it, which yielded such characteristic Edgewood species of fossils as *Dalmanella edgewoodensis*, *Rhyechanella? janca*, *R? pichotreta parca*, and *Atrypa patilla*. The position of *Virgiana mayrillensis* in Wisconsin in the upper part of the Mayville limestone, which at a slightly lower level contains a characteristic Edgewood fauna, indicates that this horizon is Alexandrian (late Edgewood) in age. It is also significant that the strata containing *Virgiana mayrillensis* in Wisconsin seems to occupy about the same position in the Silurian column as do the strata which contain *Virgiana barrandei* in the Beesie River formation of Anticosti Island."

"In Michigan the strata containing *Camarotoechia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina* conformably overlie the *Virgiana mayrillensis* beds, and thus are thought to correspond in age to about that of the Sexton Creek or Kankakee limestone which overlies the Edgewood in Illinois and Missouri, but they were deposited in a different geologic province."

"The close correspondence in the fauna of the strata overlying the *Virgiana mayrillensis* zone in northern Michigan with that of the strata above the horizon of *Virgiana decussata* in the Hudson Bay and Saskatchewan regions leaves no doubt of the equivalence of the strata containing

¹ U. S. Geol. Surv., Bull. 23, 1917, pp. 67-150.

² Ibid., p. 74.

³ Correlation of the early Silurian rocks in the Hudson Bay region, *Mem. of Geol.*, vol. XXVI, 1918, pp. 336-349.

this fauna in the areas above mentioned. They also prove that the *Virgiana mayrellensis* zone in Wisconsin and Michigan, and the *Virgiana decussata* zone in the Hudson Bay and Saskatchewan localities represent the same stratigraphic horizon."

"Besides the above-mentioned localities Hume¹ has found in Silurian strata containing *Camarotoechia? winiskensis*, and numerous ostracods in the lake Timiskaming area that he correlates with the Cataract formation, which doubtless corresponds with the *Camarotoechia? winiskensis*, *Isocyclina*, and *Lepidodonta* horizon in the regions above described."

"Kindle² found Silurian strata several hundred miles north of the Grand Rapids locality, in the vicinity of The Pas from which he obtained the fossils *Camarotoechia? winiskensis*, *Pternia cf. occidentalis*, and *Lepidodonta cf. hisingeri*. This fauna also indicates a horizon about equivalent to that of the Silurian in the lake Timiskaming region and to the strata containing *Pternia occidentalis*, *Isocyclina*, and *Lepidodonta*, above the *Virgiana decussata* horizon in the Grand Rapids section, the latter horizon not being exposed in the more northern locality. From the similarity of the faunas of the *Virgiana* zone, and of the higher strata containing *Camarotoechia? winiskensis*, *Isocyclina grandis* var. *latimarginata*, and *Lepidodonta hisingeri* var. *fabulina* in the regions above described it is inferred that during the time those strata were laid down the above-mentioned regions were a part of the same province or basin of deposition, which was rather broadly connected northward with the Arctic ocean."

The presence of *Virgiana mayrellensis* in the Dyer Bay dolomite clearly establishes its equivalence with the *Virgiana* zones described by Sauer. As the Dyer Bay dolomite which is near the top of the Cataract formation is of upper Edgewood age, it seems probable that the remainder of the Cal Head shale and the Manitoulin dolomite are of lower Edgewood age, the Girardeau and the Manitoulin dolomite have little in common.

The diagnostic species common to the Manitoulin dolomite and the divisions of the Edgewood limestone indicated are:

- Rhipidomella hybrida* Channahon limestone, Ill.
- Rhipidomella? jama* Edgewood limestone, Ill.
- Bucania cf. crassa* Edgewood limestone, Ill.

The species common to the Manitoulin dolomite and Brassfield limestone are:

- Clathrodictyon vesiculosum* Sexton Creek limestone, Ill.
- Homotrypa? confluent* Brassfield limestone, Dayton, Ohio.
- Pachydictya turpida* Brassfield limestone, Dayton and Fair Haven, Ohio.
- Strophomenella striata* Brassfield limestone, Ky.
- Herbertella fausta* Brassfield limestone, Ohio.
- Rhipidomella hybrida* Brassfield limestone, Ky.

The species common to the Dyer Bay dolomite and the Edgewood limestone are:

- Schuchertella curvistriata* Channahon limestone, Ill.
- Rhynchotretra thebesensis* var. *multistriata* Edgewood limestone, Ill.
- Rhynchomella? jama* Edgewood, Ill. and Mo.

It will be seen that the fossil evidence is not definite enough to make close divisional correlations. An anomaly is present in the close relation

¹G. S. Hume, "Paleozoic rocks of lake Timiskaming area," Geol. Surv., Can., Sum. Rep., 1916, pp. 18-19. Fossils reported by Charles Schuchert in a personal letter.

²L. M. Kindle, op. cit., p. 12.

ships of the faunas of the Manitoulin dolomite and the Brassfield limestone, for the Dyer Bay dolomite, which is much higher than the Manitoulin dolomite, is more closely related by its fauna to the Edgewood limestone which underlies the Brassfield limestone.

Schuchert's summary of the relation of the Cataract formation to other formations, written before the completion of the work done by Savage and the author, is given below for comparison. After discussing the relation of the Cataract and Medina faunas, Schuchert adds:

"It should also be stated that the Medina is of the Appalachian province, while the Cataract is either of the St. Lawrence or of the Arctic realm. These waters came in over the continent from different oceanic areas and accordingly have different organic associations. Hence the similarity of the biotas cannot be close, and this, with the marked difference in sedimentation, gives additional reason why considerable weight is laid on the forms held in common, as showing that both formations are the deposits of about one time."

Under "Relation to the Brassfield," Schuchert says: "The Cataract may also be compared with the Brassfield formation of Ohio and Indiana, as the two are clearly related, and also as both are of a limestone facies. Between the two there are twenty-four forms in common, and of these the following have the most significance in correlation: *Clathrodietyon tessellatum*, *Acervularia* (?) *gracilis* (in Ohio, *A. chertensis*), *Rhinopora verrucosa*, *Phanopora ensiformis*, *Callopora bannapora*, *Homotrypa* (?) *conspicua*, and *Hebertella fausta*.

Under "Relation to the Silurian of Anticosti," Schuchert says: "The Cataract does not readily correlate with the Anticosti section because of the marked differences and generalized character of the faunas there, and more especially because of the long range of most of the species. With the Beesie River, the only guide fossil in common is *Calospira planoconvexa* (appearing about 70 feet above the base of the Beesie River); but the Anticosti individuals are only half grown compared with those of the Cataract, a condition seemingly in harmony with the conclusion that the latter are of a younger time. Then the absence in the Cataract of the Beesie River guide, *Clonada barrandei*, also seems to indicate that the former formation is of younger age. At the top of the Beesie River, however, the fauna is more like that of the Cataract, and this similarity continues in the succeeding 300 feet of the Gun River formation."

Schuchert² says: "Even though the Medina, Cataract, and Brassfield are correlates of one another, it does not follow that each one is wholly the equivalent of any other. Each formation invades eastern North America from a different direction and each one has its own peculiar faunal assemblage. They, therefore, represent three physical provinces and marine basins. The Medina is of the northern Appalachian province, is a sandstone formation, and finally invades to a slight extent the area of the Cataract. The Brassfield province lies, in the main, west of the Cincinnati axis, is of southern origin, with limestone-making seas, spreads to the southern portion of the Appalachian province, and finally invades slightly the area of the Cataract sea. On the other hand, the Cataract province spreads westward through the Saint Lawrence em-

² *Geol. Surv. Am.*, vol. XXV, 1904, p. 101.
³ *ibid.*, p. 291.

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bayment, and finally in eastern Ontario and northeastern Ohio (known from the Clinton oil wells), unites with the other two provinces; but the Medina waters form a shoal sandy area in northeastern Ohio between the other two provinces. Very few of the species of either area intermingle. Probably it would be more correct to state that the normal marine junction of the Cataract and Brassfield seas is prevented by the Medina delta. For these reasons Medina, Cataract, and Brassfield are to be retained as names for independent marine faunas and formations."

According to Twenhofel¹ the Cataract formation is probably to be correlated with the lower portion of the Gun River formation of Anticosti Island. No sediments in the Silurian section at Arisaig have been identified as being as old as the Medina-Cataract, although it is possible that the base of the Beechhill Cove formation may be of this age.

Basler correlates the Medina-Cataract with the Lower Llandovery of Wales and Shropshire and the Lower Birkhill of Scotland.

CLINTON FORMATION.

As here described the Clinton formation includes the shales and limestones between the Medina-Cataract formation below and the Rochester² formation above.

DEFINITION AND GENERAL DESCRIPTION.

As already stated, the Manitoulin dolomite of Ontario, along with the overlying shales, were by Sir William Logan misnamed the Clinton formation. This was partly due to the mistaken idea that the Whirlpool sandstone of Ontario was the "Grey band" of New York, and partly because the Manitoulin dolomite was a convenient horizon-marker. quote Logan³, "In Canada, for reasons which will be stated in describing the Niagara formation, it is found convenient to limit the Clinton to strata beneath the Pentamerus band, and to include this band in the Niagara formation. On the Niagara river the Clinton is thus limited to a few feet, but it gradually augments to the northward". And in "Niagara Formation" Logan⁴ says: "We therefore, propose to include the Niagara series, the two bands of limestone which underlie the shales and which, in New York, constitute the upper part of the Clinton formation. So far as they have been examined in Canada, these two limestone bands contain no Clinton fossils, but such as pass upwards into the Niagara; and the upper band here possesses one or two species, which in New York, are considered to belong to the latter group only. This would thus appear, at present, to be no paleontological reason why the limestones may not be considered the base of the Niagara formation."

¹Geol. Surv. Can., Mus. Bull. 3, 1914, p. 20.

²It is now the custom of the United States Geological Survey, and the New York State Survey, to include the Rochester shale in the Clinton formation, on the ground that the Rochester shales included in the Clinton section of New York. In the opinion of the Canadian Geological Survey, this contention is not proved. Another band, in western New York and in Ontario, the Rochester was clearly considered a part of the Niagara formation by Hall, Logan, and other early workers in the region. There is no denying the continuity of sedimentary development from the Irondequoit to the Rochester, and according to Chubbuck, what has been considered by the author only an apparent break, at the top of the Rochester, is due to a disconformity and loss of fossils, however, are common to the Rochester and the Lockport and for the present the latter term, Clinton is maintained by the Geological Survey, Canada.

³Geology of Canada, 1893, p. 312.

⁴Ibid., page 322.

while geographically they present a very marked feature for a considerable distance, and afford a convenient means of describing the distribution of the two formations."

Admitting the close relationship between the Clinton and Niagara formations, it is nevertheless impossible to ignore the distinct characters both palaeontologic and stratigraphic of the Clinton formation, even in its vanishing condition near Hamilton.

Only the upper part of the Clinton of New York is present in Ontario. Thus of the seven divisions recognized by Chadwick¹ at Rochester, only three occur with certainty at Niagara, and a fourth is doubtfully recognized. The divisions at Rochester are from the base up: Maplewood (Sodus) shale; Bear Creek limestone and shale; Furnaceville iron ore and limestone; Reynales (Walcott) limestone; Sodus and Williamson (Williamson) shales; and Irondequoit limestone. At Niagara river, a shale probably of the age of a part of the Furnaceville beds (formerly called the Sodus shale), the Reynales (Walcott) dolomite, and the Irondequoit dolomite are well represented and the Williamson shale is suggested by the shaly parting between the Reynales and Irondequoit. The total thickness of the Clinton at Rochester is about 80 feet, and at Niagara river 23 feet. Hall called the Clinton the Protean group because of its varied character, shale being dominant in eastern New York, and shale and calcareous beds being about equally represented in western New York. The variation between Rochester and Niagara river is indicative of the protean character of the Clinton and the changes are striking from place to place in Ontario. The Clinton outcrops at many places along the Niagara escarpment between Niagara river and Kelso.

The Furnaceville shale is not seen west of Niagara river, unless a few inches of shale at DeCew falls represents it. The Irondequoit dolomite thins out to the westward, being last seen along with the overlying Rochester shale near Waterdown. The Reynales dolomite is 6 feet thick at Kelso and contains *Pentamerus oblongus* near the base, just as at Thorold and other more eastern localities, but it has not been identified farther west or north. A similar bed at Linchouse contains *Dictyonema retiforme*, and probably represents the horizon of the DeCew water-lime rather than the Reynales dolomite. Well records indicate that Clinton dolomite extends westward beneath younger formations as far as lake St. Clair where about 5 feet of limestone occurs at the base of the Rochester shale. Samples of drillings from a well on lot 1, concession V, Bayham township, Elgin county, and from another at Beachville, Oxford county, indicate 20 feet or more of dolomite at the Clinton horizon. For the distribution of the Clinton, see Maps 1714 and 1715. For fossils see tables under description of members and Plates IX and X.

THE FURNACEVILLE (SODUS) SHALE MEMBER.

Description.

The Furnaceville (Sodus) or lowest division of the Clinton at Niagara gorge is a soft, fissile, bluish-grey shale weathering greenish. It rests

¹The nomenclature and correlation of the Clinton formation of New York state has been recently revised by Chadwick. His nomenclature is here followed. The terminology formerly recognized is placed in brackets.

velvety and sharply on the Thorold sandstone, with no indication of transition beds. The best outcrops are along the New York Central and Hudson River railway between Niagara Falls and Lewiston and about seven-eighths of a mile north of Niagara university, here the shale is 4 to 6 feet thick. A few inches of green shale occupies the position of the Furnaceville at Decoy Falls but is unknown elsewhere in Ontario. The accompanying table gives the Furnaceville fossils found on the Niagara river.

The Furnaceville-Sodus Shale Fauna of the Niagara River.

Rafinesquina quadrata Hall & G.
Rafinesquina cuneata (Hall) G.
Calospira levisphæra (Say) A. G.
Pentamerus cuneata Conrad.
Orthis elliptica Hall?
Calymene dentata Whitfield and Hovey.
Orthis 2 sp.

Of the above, *Calospira levisphæra*, according to Chadwick, found only in the Furnaceville and Sodus shales.

THE REYNOLDS-WOLCOTT DOLOMITE MEMBER.

Description.

The Reynolds division of the Clinton is a dark grey, fine-grained dolomite limestone, approaching a true dolomite in composition (see chemical analysis, page 144). It rests with sharp even contact on the Furnaceville shale at Niagara gorge, forms the basal Clinton member along the Niagara escarpment between Thorold and Watertown, and is the only representative of the Clinton from the vicinity of Watertown to Keosau, beyond which it has not been identified. West of Niagara river the Reynolds dolomite rests successively on Thorold sandstone and Cobden shale. The contact is everywhere sharp, but the basal dolomite is conglomeratic at some localities.

Good exposures of the Reynolds occur along the New York Central and Hudson River railway between Niagara Falls and Lewiston, from one-half to seven-eighths of a mile north of Niagara university; at Niagara Glen on the Ontario side; and at numerous localities along the Niagara escarpment to the west. Some of the best localities for study are at Decoy Falls, Stoney Creek, Hamilton, Dundas and Kelso. At Niagara Falls the Reynolds is 42 feet thick and weathers into thin beds. Westward it becomes thicker and is commonly thick-bedded. At Jordan, 3 feet of shale intervenes near the middle of this division.

Guide Fossils.

Haptodina conusta and *Stricklandina canadensis* are guide fossils to the Reynolds dolomite. *Pentamerus oblongus*, formerly considered a guide fossil for New York state, is shown by Chadwick to occur in

Those reported by Graham are marked G.
 * Chadwick identifies this as *Calospira nitens* Vanuxem.

in the West of North America has been recorded so far. No sign of it in the *P. acropora* is not kept in the list. As it is but on page 119, however, *P. acropora* does not have the range. The other Reynales fossils with their distribution would count by the numbers given in the following table.

Distribution of the Reynales (Western Canada and Ontario)

Geographical names							
	Th.	W.	Ontario	Quebec	Ag.	Cal.	Ind.
<i>Trilobites</i>							
<i>Trilobites gracilis</i> Hall	Ag.						
<i>Zaphrentis</i>							
<i>Zaphrentis turtamata</i> Hall							
<i>Favosites</i>							
<i>Favosites magarensis</i> Hall							
<i>Rhynchonella</i>							
<i>Rhynchonella concentrica</i> Hall	Ag.						
<i>Strophomena</i>							
<i>Strophomena protuberans</i> Hall	g.						
<i>Strophomena lateralis</i> Hall	g.						
<i>Platystrophia transiens</i> Wahlenburg		x					
<i>Schuchertella subplana</i> Hall		x					
<i>Platystrophia bifurcata</i> Schuchert	x						
<i>Strecklandina carolinensis</i> Billings				x	x		
<i>Pentamerus oblongus</i> Sowerby		x	x	x	x		x
<i>Canarotus</i> <i>Stegodynia</i> <i>neglecta</i> Hall	Ag.						
<i>Spirifer robustus</i> Sowerby		x					
<i>Hyalonema congo</i> (C. Corb.)	Ag.						
<i>Calospira plicatula</i> Hall	g.						
<i>Calospira</i>							
<i>Diphyothoma magarensis</i> Hall		x					
<i>Ammonoites</i>							
<i>Ammonoites verticillatus</i> Hall				x			
<i>Ammonoites</i>							
<i>Ammonoites</i> <i>artensis</i> Hall and Whitford							

Recorded by Grabau
and by the author

WILLIAMSON SHALE MEMBER.

Description

The Williamson shale is an important member of the Clinton formation at Rochester, having a thickness along with the underlying Schuchert of about 21 feet. At Niagara gorge, Grabau and Kindle have stated that this shale is entirely absent. There is, however, a distinct contact between the Reynales and the Trondequoy dolomites, about 10 feet of grey shaly weathering rock that suggests the attenuated edge

See report criticizes this statement, stating that he has always considered the Clinton species of the Trondequoy. The author has been unable to find distinctive characters, although the present report.

of the Williamson. At DeCew falls, 4 inches of definitely defined, dark grey shale separates the Reynales and Irondequoit dolomites. It is probable that this is the western remnant of the Williams shale. No fossils have been found in it.

IRONDEQUOIT DOLOMITE MEMBER.

Description.

The Irondequoit member of the Clinton is a light grey or buff, crystalline, dolomitic limestone, approaching a true dolomite in composition (see chemical analysis, page 111). At Niagara gorge, reef structures consisting of lenses of dense, amorphous dolomite 6 to 35 feet across and as much as 10 feet thick, are common in the upper part of the Irondequoit dolomite and in places extend upward into the overlying Rochester shale. These reefs are composed mostly of undetermined bryozoan remains and contain as well a rich brachiopod fauna which includes numerous species common in the Rochester. Free swimming animals, such as the trilobites, also frequented the openings in the reefs. Corals were practically absent, with the exception of the little cup coral, *Enterolasma caliculus*. *Lichena concentrica* is the one identified species of bryozoa present.

The lower contact of the Irondequoit, whether with the Williams shale or the Reynales dolomite, is generally sharp and clear-cut. In one quarry in Waterdown, however, the base of the Irondequoit is cemented to the top of the Reynales. The Irondequoit is well exposed along with the Reynales dolomite as far west as Waterdown. At the Niagara gorge it is 7 feet thick and consists of a 4-foot bed at the base and an upper massive 6-foot bed. At Waterdown the section consists of a basal bed of argillaceous dolomite 4 feet thick and an upper bed of crinoidal dolomite 3½ feet thick. Northward the Irondequoit has not been reported and it is known to be absent at Kelso.

Because of its thick bedding and toughness the Irondequoit is known to the quarrymen of the Hamilton area as the "Nigger Head" bed and is commonly left as a quarry floor.

The Irondequoit fauna is closely related to the fauna of the overlying Rochester shale and the reef structures represent transitional conditions. The fauna with its distribution is shown in the following table.

Distribution of Irondequoit Fauna in Ontario.

Genera and species	Niagara river		Duffins falls	
	Bedded formation	Reefs	Bedded formation	
<i>Anthozoa</i> .				
<i>Euterodasma cabellum</i> Hall	g			
<i>Cnidaria</i> .				
<i>Glyptocrinus plumosus</i> Hall	g			
<i>Eucalyptocrinus ciliatus levis</i> Grabau and Shimer		g		
<i>Bryozoa</i> .				
<i>Lichenalia concentrica</i> Hall		g		
<i>Brachiopoda</i> .				
<i>Lapidaria rhomboidalis</i> Wilckens	Ng	g	x	
<i>Strophodontia profunda</i> Hall	g		x	
<i>Strophonella? patula</i> Hall	Ng	g	x	
<i>Plectambonites transversalis</i> Wahlenberg		g		
<i>Schizophertella subplana</i> Hall	Ng	g		
<i>Orthis flabellites</i> Foerste	g			
<i>Dalmanella elegantula</i> Dalman	x	g	x	
<i>Rhipidomella hybrida</i> Sowerby			g	
<i>Acrostrophia interplicata</i> Hall		g		
<i>Pentamerus oblongus</i> Sowerby	g			
<i>Chorinda formica</i> Hall	Ng			
<i>Rhynchotreta cuneata americana</i> Hall		g		
<i>Rhynchotreta robusta</i> Hall	x			
<i>Canarotæchia (Stegorhynchus) neglecta</i> (Hall)		g		
<i>Canarotæchia acinus</i> Hall	g			
<i>Trypa reticularis</i> Linnaeus	Ng	g	x	
<i>Trypa nodostriata</i> Hall	x	g		
<i>Trypa rugosa</i> Hall		g		
<i>Spirifer radiatus</i> (Sowerby)	Ng	g	x	
<i>Spirifer niagarensis</i> (Conrad)	Ng	g	x	
<i>Spirifer crispus</i> (Hisinger)		g		
<i>Spirifer cincinnatus</i> (Gratou)	g			
<i>Spirifer (Delthyris) sulcatus</i> Hisinger		g		
<i>Whitfieldella nitida</i> Hall		g		
<i>Whitfieldella nitida oldata</i> Hall	Ng	g	x	
<i>Whitfieldella (intermedia)</i> Hall		g	x	
<i>Whitfieldella cylindrica</i> Hall	Ng		x	
<i>Pelecypoda</i> .				
<i>Pterinea trisa</i> Hall			Hamilton	
<i>Gastropoda</i> .				
<i>Diaphorostoma niagarensis</i> Hall		g		
<i>Cephalopoda</i> .				
<i>Dawsonoceras americanum</i> Foord			x	
<i>Trilobata</i> .				
<i>Bumastus toxus</i> Hall	g	g		
<i>Glyptone niagarensis</i> Hall	g			

Grabau reports one specimen from the Niagara gorge.

Of the above, *Rhynchotreta robusta* Hall, may be taken as a fairly good fossil to the Irondequoit dolomite.

Found also in the Rochester shale.

g. Reported by Grabau.

x. Found by author.

The next correlation of the Clinton formation of Ontario with the New York State is evident from the terminology and descriptions given above. According to Bassler¹, who made use of the latest reports of his workers, it is correlated as follows: (the author, however, has eliminated formations correlated with the Rochester which is mentioned in the Clinton by Bassler); with the Clinton group of Pennsylvania, Maryland, and Virginia including the Cacapon member at the base and the Keefer sandstone near the top; the Dayton limestone or "Niagara" shale of Ohio; the Crab Orchard formation of eastern Kentucky; the middle part of the St. Clair limestone of northern Arkansas; the St. Clair limestone of central Oklahoma; the upper part of the Gr. River, the Jupiter River (Williamson and Irondequoit), and a part of the Anticosti (Irondequoit-Rochester) formation of Anticosti island; the Beechhill Cove and Ross Brook formations of Anisaid; and the Upper Llanfynydd and Tarramon of Wales and Shropshire and the Upper Birkdale and Tarramon of Scotland.

N. S. G. A. A. C. B. O. U. P.

The Niagara group as defined in this report includes the Rochester, Niagara, Shale and the Lockport (Niagara) dolomite, or in other words the strata between the Clinton dolomite and where this is lacking, Cataract formation below and the Guelph formation above.

4. = N. J. M. S. Ball 2, vol. 11, 1915, pls. 6 and 11.

[illegible]

defined at Rochester and westward and northward it is of increasing thickness, being the great cliff-forming dolomite of the Niagara escarpment.

It is this Lockport dolomite and its equivalents under other names which have made the Niagara the best known of all the Silurian formations in the regions of the Great Lakes, like Timiskaming, like Winnipeg, Hudson bay, and the Arctic.

ROCHESTER SHALE FORMATION.

Description.

The Rochester shale takes its name from the type section at Rochester, where according to Kindle it is 85 feet thick. This, formerly known as the Niagara shale, consists of fissile dark grey shale, containing calcareous beds. The harder or more calcareous beds generally occur near the top, but at Niagara falls they are most common near the middle and in the lower half of the shale.

The Rochester shale, as stated above, is closely related to the Irondequoit dolomite upon which it rests and along with which it thins out to the north of Waterdown. The contact is a gradation from shaly dolomite to shale and at Niagara river amorphous reefs project upward from the Irondequoit into the Rochester. The fauna is likewise transitional, the species of the upper shaly Irondequoit beds and of the reefs, being commoner in the Rochester than in the Irondequoit below.

The fauna of the Rochester shale is rich in genera and species, and with the exception of the *Euryptera* has all the main Silurian classes of marine organisms, well represented. The greatest profusion of species, however, is to be found among the brachiopods, bryozoa, and trilobites. For the fauna and its distribution, see the accompanying table and Plates X, XII, and XIII.

U. S. Niagara Folio No. 190, p. 7

[illegible]

Distribution of Rochester Fauna in Ontario. Concluded.

Genera and species	Niagara river		Thoreld		Deerw Hill		Lambs		Habit. Water from dock
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
<i>Cephalopoda</i> :									
<i>Orthoceras unionense</i> Worthen									
<i>Kromoceras cancellatum</i> Hall									
<i>Ostracoda</i> :									
<i>Aechmina spinosa</i> Hall	Ag ²								
<i>Tridacna</i> :									
<i>Romdonotus delphinocéphalus</i> Green	g								
<i>Bumastus toxus</i> Hall	Ag								
<i>Dalmanites limularis</i> Green	Ag								
<i>Cadymentene niagarensis</i> Hall	g								
<i>Archinurus bodoni</i> (Bigsby)	g								
<i>Enchirinus ornatus</i> Hall and Whitfield									

Note. Fossils listed by Green are marked "g" those found by the author are marked "Ag" those reported by Hall are marked "h" Basler does not note the horizon at which found in the Rochester shale.
¹ Found only in the Rochester shale.
² Good kinds to the Rochester.

LOCKPORT DOLOMITE FORMATION.¹*General Description.*

The Lockport dolomite is named from the type section at Lockport, New York, where the section consists "chiefly of dark grey to chocolate coloured dolomite".² Two horizons of Guelph fossils known as the lower and upper Shelby have been found in New York with an intervening zone of Lockport fossils. This has led to considerable confusion, but Chadwick and the author have identified the Eramosa beds (at the top of the Lockport) at Niagara river and at Rochester, thus showing that the Guelph formation is well defined in New York state and includes the beds (so far as identifications have been made) from the base of the upper Shelby up. At Niagara river the crest of the American falls is at the top of the Eramosa beds which are also exposed along the Gorge route below the power-house on the New York side. They are about 12 feet thick and comprise Clarke and Ruedemann's division 4,³ which contains a "continuous bed of chert nodules near the top", thought to be the "probable horizon of the upper Shelby fauna." Although the fossil occurrences do not exactly coincide, the conditions are similar to those described below for the Eramosa beds near the city of Guelph, where some Guelph forms occur in coral reefs at the base of the Eramosa beds and the true Guelph fauna comes in just above them. The transitional nature of the Eramosa beds is clear, and so Guelph species may be found at different horizons, but the Guelph formation in Ontario is clearly defined as a stratigraphic unit and is continuous with the New York formation above the Eramosa beds which are well recognized east of Niagara river.

The propriety of extending the use of the name Lockport over Ontario is supported by the continuity of the formation, the decided gradation where changes occur, and the marked faunal elements common throughout the formation. Of the one hundred and thirty-five species listed by the author for the Niagara dolomite of Ontario, twenty-five occur in the Lockport of New York state, and forty-eight occur in the Lockport at Thorold, only 8 miles from Niagara Falls. The northern coral development exemplified by occurrences at Cabot head and Fossil hill is quite different from the fauna of the more argillaceous dolomite at Lockport, New York, but important species are in common and it is well recognized that corals develop under special conditions and with special associates. The relationship of this coral fauna to the Louisville fauna is well marked, but the fact that the Guelph formation overlies the coral horizons of Bruce peninsula strengthens the conclusion arrived at by Butts⁴ that the Louisville of Kentucky is upper Lockport in age (see also under Guelph, page 73).

The Lockport dolomite, or "Niagara limestone" as it was formerly called, forms the upper and most important member of the Niagara formation. In Ontario, this dolomite gives rise to the most conspicuous of the Paleozoic cliffs, and outcrops in almost unbroken extent from Niagara falls, where the water pours over its very top) to Cockburn island at the head of lake Huron. The longest gap in the exposures is between Halfway

¹ For illustrations of the Lockport dolomite see Plates XXVIII A, XXIX A, XXX A, XXXII B, and XXXIII B.

² Kneller, L. M., Folio 190, p. 7.

³ New York State Mus., Mem. 5, p. 10.

⁴ Ibid., p. 99.

rock at the north end of Bruce peninsula and Fitzwilliam island. The only exposures of Lockport for the intervening distance of 22 miles are a few minor ones on Bear Rump, Flowerpot, Lucas, and Yeo islands, the remainder of these islands and the other intervening islands being composed of Guelph dolomite.

The highest Lockport cliffs are these on Manitoulin island. Near Fossil hill, about 1 mile southwest of Manitowaning, and also at Campbell bay, the Lockport arises as cliffs 200 feet in height.

The Lockport is nearly a true dolomite in composition with the exception of the DeCew, Gasport, and Eramosa divisions (see chemical analyses). When fresh, the rock is generally of a grey, or a pleasing blue-grey colour, but the familiar weathered surfaces are nearly white.

The total thickness of the Lockport dolomite at Niagara river is little less than 80 feet, or about 77 feet by Grabau's measurement. At Dundas, where the complete section is exposed, the thickness is about 135 feet. At Cabot head, the section is 160 feet thick and the top has not been recognized. On Manitoulin island, near Fossil hill, and also at Campbell bay as mentioned above, 200 feet of Lockport dolomite is exposed in section without any Guelph beds having been found. The above figures indicate the increasing thickness of the Lockport dolomite to the northwest, the lowest beds being probably older than the lowest Lockport beds in New York state. This is to be expected on the theory that the Lockport sea was an invasion from the north.

In the Niagara peninsula, the Lockport rests upon the Rochester shale. At Kelso the basal contact is with the Reynales dolomite and northward it is with the Cabot Head shales of the Cataract formation as described already. In a formation of such thickness, it is natural to expect that there will be considerable variation in bedding, character of the rock, fossil content, etc. The Lockport has such variations, but the subdivisions have more than local significance. The subdivisions and more detailed characters of the Lockport formation are described below. For the fauna, see table pages 64-68, and Plates XIV to XXI.

DeCew Waterline Member.

The basal member of the Lockport dolomite in the Niagara peninsula consists of a bed of argillaceous, dolomitic limestone, 8 to 9 feet thick which was formerly extensively worked at Thorold for the manufacture of "natural rock cement" (for analyses, see page 112). The "waterline" is fine grained and of a dark grey colour. As may be seen from Figure 1 (page 22) this bed thins out at Stoney Creek and Hamilton to about 1 foot in thickness and has not been recognized to the west or north. At Kelso, the 3-foot bed immediately overlying the Reynales dolomite is typical Lockport dolomite in character and chemical properties (see page 173). At Linchouse, however, 6½ feet of thin-bedded, argillaceous, dolomitic limestone was formerly worked for "natural rock cement." In these beds *Dietyonema reticulare*, *Argona reticularis*, and *Dalmanella limularus* occur. The first and last of these species are indicative of Rochester affinities and suggest that the lower beds at Linchouse are the equivalent of the DeCew beds. Other fossils in the DeCew are: at Thorold

Strophonella patula, *Schuchertella subplana*, and *Camarolachia* (*Steger hynchus*) *neglecta*; and at DeCew falls the Rochester species, *Caryocentrus ornatus*. Not only in fauna, but in composition also, the DeCew beds are closely related to the underlying Rochester shale. The waterline is in fact a commingling of the dolomitic Lockport sediments with the argillaceous Rochester sediments. The characteristic nature of the DeCew beds may be seen in most of the exposures, and especially well in the Niagara gorge, along the New York Central and Hudson River railway north of Niagara university (see Plate XXX). Here and elsewhere the DeCew beds rest upon uneven eroded surfaces of Rochester shale, have churned structure, and present an eroded surface at the top into which the overlying dolomite fits. In general, the greater the irregularities at the top and bottom of the waterline beds, the greater are the contortions within the beds themselves. Such characters point most clearly to a disturbance which was capable of affecting what are now the 8 or 9 feet of waterline beds from top to bottom, before the solidification of the original shales, and either just before or at the time of marine calcareous sedimentation. The probable conditions existing at this time will be discussed below.

Gasport Dolomite Member.

The term Gasport has been used by Kindle¹ for a 9-foot bed of pure, crinoidal, semicrystalline limestone occurring above the DeCew beds at Gasport and Lockport, New York. According to Kindle "Westward from Lockport the limestone becomes gradually more magnesian", and "The section on the Canadian side at Niagara Falls shows 7 feet of hard, grey, subcrystalline, crinoidal limestone, sharply differentiated from the saccharoidal dolomite above and the 9 feet of argillaceous limestone below, and clearly the equivalent of the Gasport limestone member at Lockport, although it is dolomitic throughout".

"On the American side of the gorge the bed is well exposed along the footpath to the river just south of the railroad bridges, where it has its usual crinoidal character but is 20 feet or more thick and is wholly dolomitic. Both there and farther south along the Niagara Gorge railway it contains large columnar masses. They are lighter in colour than the enclosing rock and on weathering crumble to fine, buff-coloured powder. They are of irregular outline and differ considerably in size, the larger ones having a diameter of 18 to 20 feet and a height of 8 to 10 feet. It is believed that they represent reefs of bryozoans".

As will be seen from the above description crinoidal, semicrystalline characters are the distinguishing features of the Gasport dolomite on the Ontario side of Niagara river. It is to be expected that a member which is differentiated only by the presence of crinoidal characters will vary much in thickness from place to place. Thus, westward from the Niagara river crinoidal beds assigned to the Gasport are from 5 to 28 feet thick as follows: Ontario side Niagara river, 11 feet (Kindle gives 7 feet), DeCew falls, not recognized, but at St. Catharines Power Company nearly 23 feet; Grimsby, 12 to 11 feet; Stoney Creek, 7 feet. Hamilton, about 5 feet; Ancaster, 15 feet; Dundas, 13 feet; Waterdown, 8 feet. Farther north the term Gasport does not seem applicable as crinoid columns

¹ U. S. Geol. Surv., Folio 190, p. 7.

occur throughout the 70 feet of dolomite at Kelso, and elsewhere crinoid zones occur at different horizons in the Lockport.

The Gasport is 20 to 28 feet thick at Thorold and is composed largely of coral reefs which are full of fossils. The varied life of these reefs is suggested by the following numbers of genera and species which have been recognized, corals, 9 genera, 13 species; crinoids, 2 genera, 2 species; brachiopods, 14 genera, 22 species; gastropods, 1 genus, 1 species; cephalopods, 1 genus, 1 species; trilobites, 2 genera, 2 species.

Undivided Lockport Dolomite.

The great mass of Lockport dolomite has not been subdivided except into local facies and more or less local faunal zones. Leaving out the DeCew and Gasport members, already described, and the Eramosa bed described below, there is left the great central part of the Lockport dolomite of Niagara peninsula, all but the upper beds from Kelso to Fitzwilliam island, and the whole formation on Manitoulin and Cockburn islands, to be described in a general way.

The Lockport, as already stated, is dominantly a light grey, or bluish, semicrystalline, to fine-grained and compact, magnesian limestone approximating a true dolomite in chemical composition. Cavities and porespaces are general. Chert nodules are plentiful at some local horizons and argillaceous beds occur fairly commonly in the Niagara peninsula. The dolomites are generally in beds 2 to 3 feet thick, but thinner beds and also much thicker beds are common. Jointing is general, is dominantly vertical, and very irregular. Where the rock is exposed at the surface erosion and solution by surface water has enlarged these joints to cracks that are in some cases a foot or more across.

Beds Containing Chert.

Chert nodules, 2 or more inches across, occur at different horizons in the Lockport formation. A zone of chert nodules is reported by Clarke and Ruedemann as occurring at the top of the thin Eramosa beds (determined by the writer) at Niagara falls. It is this chert horizon which is supposed to represent the location of the upper Shelby fauna (Guelph). Chert beds 5 feet thick occur 10 feet lower in the section exposed near the Ontario end of the international bridge.

The chert horizon has probably been eroded away in the section along the Niagara escarpment between Niagara falls and Stoney Creek. So chert occurs at Stoney Creek in the beds immediately above the Gasport dolomite. At Mount Albion and Hamilton numerous chert nodules occur in the 60 feet of dolomite overlying the Gasport. From these nodules Colonel C. C. Grant collected many sponges. At Ancaster the chert beds are 16 feet or more thick and at Dundas they are 10 feet thick; at both places they rest upon the Gasport dolomite.

No chert beds were noted in the sections between Dundas and Cabot head. In the bluffs at Cabot head, a limited zone of chert nodules occurs about 15 feet above the base of the Lockport formation and immediately above beds full of *Pentamerus oblongus*. Scattered chert nodules

¹New York State Mus., Mem. 5, p. 14.

occur high up in the coral horizon at Cabot head and also on Manitoulin island. At Campbell bay, on Bayfield sound, 12 feet of fossiliferous chert beds occur about 180 feet above the base of the Lockport dolomite. A very remarkable chert horizon belonging near the top of the Lockport dolomite is exposed north of Old Quarry point, near the western end of Manitoulin island. Here, angular pieces of white chert 4 to 6 inches across, derived from the underlying beds, are scattered about on the surface of the rock. This chert zone is probably 15 feet thick.

Beds Containing Pentamerus Oblongus.

Pentamerus Oblongus, which is fairly common in the Clinton, Reynales beds of Niagara peninsula, appears to be nearly or quite absent for many miles to the north. At Owen Sound, however, the lower 5 feet of Lockport beds are crowded full of *Pentamerus oblongus*, the typical Lockport corals occurring just above. About 15 feet of basal dolomite at Wiarton is similarly crowded with this interesting brachiopod. Similar beds 4 or 5 feet thick occur at Lionhead and Dyer bay, and 2 feet of these beds occur at Cabot head. At Lionhead and Cabot head, however, 8 to 10 feet of thin, even-bedded dolomite occurs beneath the *Pentamerus* beds. The contact is sharp, the thin beds containing few fossils, and the *Pentamerus* beds being very fossiliferous. At Cabot head, the thin beds contain *Favosites favosus*, *Camaratracia neglecta*, and a *Calocaulis* resembling *longispira*. It seems fairly certain, therefore, that the thin beds are basal Lockport. At Dyer bay, the basal beds are mostly obscured, and to the northward they are generally obscured as far west as West bay on Manitoulin island. Here, above 6 feet of soft, green Cataraugus shale, 20 feet of fine-grained, grey dolomite occurs with shale partings near the base. No fossils were found in these beds but they are probably basal Lockport.

Fossil Hill Coral Horizon.

The more northern occurrences of the Lockport dolomite are remarkable for the variety and numbers of their corals. These fossils are limited mostly to definite zones, which record suitable environment, as might be expected from a knowledge of the restricted conditions of temperature and pressure under which corals live. The corals at Fossil hill, about 7 miles southwest of Manitowaning, occur in great profusion about 70 feet up in the Lockport dolomite and appear to represent the acme of coral environment. It might not be expected that such favourable conditions prevailed widely at the geological moment recorded at Fossil hill, and yet similar coral assemblages are met with at approximately the same horizon at Cabot head, Campbell bay, Cockburn island, and elsewhere.

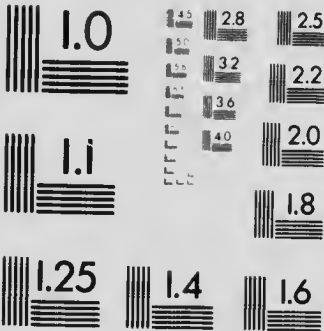
The "Barton Beds".

The 80 to 90 feet of Lockport, overlying the chert beds and underlying the Guelph dolomite in the vicinity of Hamilton, are decidedly micaceous and contain shale beds at some horizons. Spencer and Grant called these beds the "Barton beds," after the name of the township in which Hamilton is situated. The name "Barton" has never been



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recognized to any extent in geological literature as it was pre-occupied in the Tertiary of England; it has, however, considerable local significance. As will be seen later, the upper 35 feet of the "Barton beds" belong to the Eramosa dolomite. The lower part is well-defined by its argillaceous character from Mount Albion to Ancaster.

Lockport Dolomite not Differentiated.

Northward from the Niagara peninsula, the greater part of the Lockport dolomite is undifferentiated. It differs considerably in bedding and characters, but is generally thick-bedded to massive, typical dolomite, blue, grey, or less commonly buff on fresh fracture, and weathering white.

Eramosa Member.

The Eramosa beds consist characteristically of thin, even-bedded, argillaceous, arenaceous or bituminous dolomites. They are sparingly fossiliferous. These beds occur at the top of the Lockport formation throughout the western peninsula of Ontario and on the islands to the north as far as Fitzwilliam island. Good sections of the Eramosa beds, however, are few, the following being the best known (Figure 3): Niagara Falls, New York, 12 feet of thin, even-bedded dolomites with bituminous partings, their top being at the crest of the American falls; Ancaster, not well-differentiated but about 35 feet of brown-grey dolomite, with bedding planes marked by change of colour; Dundas, about 35 feet of dark blue, argillaceous dolomite, shaly at base and with bituminous partings at top; Guelph, 30 feet or more of a chocolate brown, bituminous shale and dolomite; Warton, about 50 feet of dark grey, thin-bedded dolomite, very cleavable and even-bedded in the upper 15 feet, which are quarried for flags and dimension stone; Halfway rock, 30 feet of thin-bedded dolomite. The upper part of the Eramosa beds are seen in the lower part of the "flowerpots" of Flowerpot island (see Plate I). On the western end of Fitzwilliam island, typical Eramosa beds occur at the top of the Lockport; their thickness is probably about 30 feet. On Manitoulin island the Eramosa beds have not been recognized and appear to have been eroded away.

The Eramosa beds are marked by dome structure, the dimensions of the domes varying from a few feet to 100 or 200 feet across, with a centre elevation of 15 to 20 feet. Good examples of the larger domes occur at Guelph, where one exposure south of the prison farm has the top of the dome stripped away, revealing a dome-shaped coral reef which in this case at least was the cause of the structure in the Eramosa beds.² This reef contains a fauna which is transitional from the Lockport into the Guelph.

Few fossils have been found in the Eramosa beds, excepting at Guelph. The revised list of those collected by the writer from an horizon about 25 feet below the top of the Eramosa beds is as follows: *Monomorella cf orbicularis* Billings, *Orbiculoidea subplana* (Hall), *Orthis?* near *tenuidors*

¹Geol. Surv., Can., Mus. Bull. 20, p. 1

²Ibid., p. 2

³Ibid., p. 3

Hall, *Camarotochia (Stegerhynchus) whitei* (Hall)? *Spirifer radiatus* Sowerby?
Whitfieldella nitida Hall?, *Orthoceras*, *Eusarcus logani* Williams.

The approximate chemical composition of the fossil horizon at Guelph as determined by E. Poitevin of this Survey, is as follows: insoluble matter including iron oxide, 50 per cent; bituminous matter, 25 per cent; calcium carbonate with a trace of magnesia, 25 per cent.

As already stated, the lower fossil horizon, containing *Monomorella cf. orbicularis*, is suggestive of the lower Shelby horizon of New York state, and the true Guelph above is probably represented in New York by the upper Shelby horizon which, therefore, would mark the base of the Guelph formation.

Ischnus 2.

Orbiolidea subplana (Hall)
Schizotreta tenuimellata (Hall)
Dietyonella corallifera (Hall)
Strophodontia prolunda (Hall)
Strophonella striata (Hall)
Strophonella patenta (Hall)

Leptana rhomboidalis Wilkens
Schuchertella subplana Conrad
Schuchertella quadrata (Hall)
Schizophoria hibernica (Hall)
Platy-strophia bifurcata Schlottheim
Bilobites acutifolius (Klingenberg)
Dalmatella elegantula (Dallman)
Rhynchonella hybrida (Sowerby)
Conchidium orientale Hall
Scricklandinia mantouensis Williams n. sp.
Pentamerus oblongus Sowerby
Lorinda ventricosa (Hall)
Rhynchotrema cuneata americana (Hall)
Camarotoechia neglecta (Hall)
Camarotoechia whitei (Hall)
Camarotoechia ? acinus (Hall)
Camarotoechia ? indicensis (Hall)
Atropa reticularis (Linnaeus)
Atropa molustrata Hall
Cyrtia neta (Hall)
Spirifer niagarensis (Conrad)
Spirifer radiatus (Sowerby)
Spirifer crispus (Hisinger)
Spirifer eudora (Hall)
Homospira spiriformis Hall
Whitfieldella nitida (Hall)
Whitfieldella nitida oblata (Hall)
Whitfieldella intermedia (Hall)
Whitfieldella cylindrica (Hall)

Pelecypoda
Matheria recta (Hall)
Amplexia leidy Hall
Mytilarca acutirostra (Hall)
Streptomytilus aphaca (Hall)
Goniophora speciosa Hall

Gastropoda
Eotornaria kayseri Clarke and Ruedemann
Ceroaculus longispira (Hall)
Ceroaculus brevifatus (Hall)
Holopea gaeophilensis Billings
Diphorostoma hemisphaericum Hall
Diphorostoma niagarensis (Hall)
C. undulata

Cyphopoda
Cyphopoda
Orthoceras imbricatum (Wahlenberg)
Orthoceras bruceensis Williams n. sp.

1 Classification revised by Chadwick

CORRELATION OF THE NIAGARA GROUP.

The Rochester shale is an extension westward of the Rochester shale of New York state and is generally correlated with the Osgood limestone, and shale of west Tennessee, Ohio, and Kentucky and, according to Bassler, with the West Union limestone of southern Ohio and eastern Kentucky and the upper St. Clair limestone of northern Arkansas. Twenhofel¹ correlated his Chicotte formation of Anticosti island "on stratigraphic grounds . . . with the Irondequoit-Rochester of the New York section." The Rochester has been correlated by Schuchert and Twenhofel with the McAdam formation of Arisaig, which McLearn² correlates with "the Salopian" of Great Britain "without regard . . . to its component divisions".

The Lockport formation of Ontario and New York state is to be correlated with the Laurel dolomites, the Waldron shale, and the Louisville magnesian limestone of Kentucky³, the Glenkirk limestone of west Tennessee, the Hopkinton dolomite of Iowa and Minnesota, and a part of the Bainbridge limestone of east Missouri and Illinois⁴. Savage⁵ has recently claimed that the Mayville limestone of Wisconsin is the equivalent of some part of the Alexandrian series of Illinois and Missouri and the author correlates the Racine of Wisconsin with the lower Guelph of Ontario; thus only the Waukesha beds, including the Byron, lower and upper coral beds, remain to be correlated with the Lockport dolomite of New York and Ontario. These subdivisions may yet be traced into Ontario, the chert horizon containing fossils at Campbell bay, Manitoulin island, suggesting strongly the upper Coral beds⁶.

The long recognized Niagara strata of lake Timiskaming region have been shown by the author to contain a coral horizon closely resembling that at Fossil hill, thus indicating its relationship to the Lockport. Schuchert⁷ has correlated with the Louisville, deposits occurring along the west shore of James and Hudson bays, in the lake region of Manitoba, in southeastern Alaska, and on nearly all the islands of the Arctic archipelago north of Canada. Although much remains to be learned of these little studied regions, the fossils in many cases suggest Lockport affinities. For example, coral reefs containing "*Favosites gothlandicus* Lamarek, *Heliolites interstincta* (Linn.), and *Halysites catenulatus* (Linn.) var.,"⁸ found on the 111st meridian between Yukon and Alaska by the author, while assistant to D. D. Cairnes, suggest the Lockport coral horizon. The fossils collected by A. P. Low⁹ in 1904, on Southampton island, Hudson strait, include "*Favosites gothlandicus*, *Syringopora verticillata*, *Halysites catenularia*, and *Plasmopora foliis*," all of which are typical Lockport corals.

The Lockport is to be correlated with the Moydart¹⁰ formation of Arisaig and the upper Wenlock of Norway.

¹Ibid, p. 21.

²Am. Jour. Sci., vol. XLV, 1918, p. 135.

³Kentucky Geol. Surv., ser. IV, vol. III, pt. II, 1914-15, pp. 84, 86, 91.

⁴U. S. Nat. Mus. Bull. No. 92, vol. II, 1915, pls. 3 and 4.

⁵Bull. Geol. Soc. Am., vol. XXVII, No. 2, 1916, p. 398.

⁶Geol. of Wis., vol. II, p. 351.

⁷Bull. Geol. Soc. Am., vol. XX, 1908, pl. 67.

⁸Cairnes, D. D., Geol. Surv., Can., Mem. 67, p. 74.

⁹Cruise of the Neptune, 1906, Appendix IV, pp. 325-6.

¹⁰Geol. Surv., Can. Mem. 60, 1914, p. 60.

NIAGARA SEDIMENTATION.

From the foregoing evidence, it is clear that Niagara time commenced with seas which in places received large quantities of mud washed in from the surrounding land, the deposits forming the Rochester shale. Either the younger formations to the north were elevated above the land and were actively eroded during Rochester sedimentation or else (as believed by Chadwick) an emergence followed Rochester deposition during which not only Rochester sediments but younger sediments to the north were eroded away. With the succeeding submergence, came an overlapping of the dolomitic deposits of the Lockport sea from the north extending over higher and higher Rochester deposits (according to Chadwick) well into New York state. On the basis of this overlap, the DeCew beds must be regarded as reworked Rochester shale, their final condition being probably due to the action of currents and waves of the encroaching sea, upon loose materials derived from land erosion. The fossils contained in the DeCew beds would thus be, either dead forms contained in the Rochester shales or forms introduced under the new conditions of Lockport sedimentation. As a matter of fact their affinities are mostly with the Rochester and they do not indicate any apparent wear.

Kindle¹ has shown that beds similar to the DeCew waterline are being formed to-day in the bay of Fundy as the result of deposition and scour and although the widespread DeCew beds may not be compared directly with the modern formations of the bay of Fundy, the origin of the latter beds is instructive. The higher dolomites were deposited in wide-spreading seas, which were of such depth and temperature as to promote the growth of coral reefs even within the Arctic regions. A partial emergence of the land caused an inflow of sufficient detrital material to give the Eramosa beds their argillaceous and arenaceous character, these beds being deposited against and over coral reefs whose development they arrested. This period of diminishing seas closed Niagara time, the succeeding deposits being Guelph.

GUELPH FORMATION.²

DESCRIPTION, EXTENT, AND SECTIONS.

The Guelph is a great dolomite formation of fairly uniform character, which overlies the Lockport dolomite and is overlain by the Salina formation. The weathered rock is light grey or cream-coloured and generally has a porous, saccharoidal texture. Some beds, however, are compact fine-grained, and very hard. The beds vary from a few inches to several feet in thickness, the thicker beds being most common.

The Guelph formation underlies a belt of country in Ontario extending from Niagara river to the head of Bruce peninsula and occurs on the islands to the north as far as Fitzwilliam island. In Niagara peninsula this belt averages about 5 miles across, and from Hamilton to Chiefs point the average is about 13 miles. On Bruce peninsula the Guelph is divided into areas, isolated by denudation. Unlike the underlying Lockport, the Guelph dolomite does not occur as prominent cliffs except at the northern end of

¹Bull. Geol. Soc. Am., vol. 28, 1917, pp. 323-334.

²For illustrations of the Guelph dolomite, see Plates I, XXVIIA, XXXIIA, XXXIII, XXXIVB.

Bruce peninsula and in the islands immediately to the north. Elsewhere the rock is exposed in shelving ledges along the shore of the west side of Bruce peninsula, as glaciated exposures protruding through the surface deposits over large areas of Bruce peninsula and to a less extent in Grey and Wentworth counties, and in the valleys of streams, notably the Rocky Saugeen and Grand rivers and the upper waters of Twentymile creek (see Maps 1714 and 1715 for exposures).

Owing to the lack of complete sections, the thickness of the Guelph formation is difficult to measure. Logan estimated it on the basis of dip to be about 160 feet thick in the vicinity of Breslau.¹ He moreover, described the section at Elora as 82 feet thick and the section at Fergus as 20 feet thick "which would underlie the preceding." He placed the strata farther up the Grand river as still lower.

The writer followed the section from Fergus to Elora along the Grand river at low water and found that the river descends at a higher angle than the dip of the formation and in consequence the top beds at Fergus are about 10 feet higher than the top of the section at Elora and about the same as the top beds at Salem 1 mile northwest of Elora. The exposures above Fergus appear similar to those at Fergus and give little additional information.

The Salem-Elora section represents all the strata recognized and was found to measure about 82 feet as stated by Logan. The section consists for the most part of compact, fine-grained dolomite and is as follows in ascending order: 13 feet of thin-bedded dolomite containing *Tristylus feroxus*, *Pycnostylus guelphensis*, and *stromatopora*; 19 feet of beds 2 to 3 feet thick containing *Megalomera canadensis* in the lower 12 feet; 8 feet of beds 3 to 4 feet thick containing *M. canadensis*; 20 feet of hard, fine-grained, light buff beds about 2 feet thick; 12 feet of thinner beds at the top of the section containing *Conchidium occidentale*, *Calocaulus* sp., and *M. canadensis*. In places the thicker beds appear quite massive and no division extends very far laterally. Ten feet of higher strata occur at the top of the section at the steel bridge over a branch stream near Salem and consist of fine-grained, compact, rather thick beds containing *M. canadensis* about 8 feet below the top.

The best method now available for measuring the thickness of the Guelph is by reference to well records. Measurements cannot be derived directly, however, as it is difficult to recognize in well records the division between the Lockport and Guelph formations. The Lockport lies, however, below the Guelph in section both at Niagara river (77 feet) and Dundas 145 feet (see page 58) and in a well sunk at Guelph² the "blue slate" (Lockport) is 50 feet and the dolomite below is 100 feet thick. The Lockport is 150 feet thick. Assuming these measurements to hold approximately within a few miles radius of the locality where they were made, we are left at the following thicknesses for the Guelph: on lot 2, concessions 10, 11, Willoughby township, Welland county,³ the combined thickness of Guelph and Niagara dolomite is 220 feet; taking the Lockport as 80 feet, the Guelph is 140 feet thick. As this well is only 6 miles from Niagara, the measurement may be considered very nearly correct. A section at Kitchener⁴ gives what may be interpreted as the

¹Geology, 1870.

²Rept. Ont. Geol.

³Well record, Jour.

⁴Geol. Surv., Can.

¹1901, p. 150.

²Min. Ind., vol. III, p. 77.

³pt. II, p. 42A.

thickness of the Guelph and Niagara dolomite as 240 feet. Taking the thickness of the Lockport as 150 feet as at Guelph, the Guelph formation would be 90 feet thick. Considerable difference of thickness is thus indicated and it is probable that this is to be explained by an erosion surface at the top of the Guelph, which is clearly suggested by the varying thicknesses of the combined Guelph and Lockport dolomites seen in the cross-section from Dunnville to Grimsby (see Map 1711) and in the well records of Kent county (see Figure 1). It will be noted that 90 feet compares rather closely with the section as measured at Elora. The Elora section is certainly not complete, but may not lack as much as Logan supposed. Northward, however, reliable information is at hand as to the thickness of the Guelph formation.

The base of the Guelph dolomite is clearly exposed in the eastern part of the city of Guelph, where it rests on the Eramosa beds. The lowest bed is about 2 feet thick and is bituminous, with a smell resembling that of petroleum. Thinner, light brown, nodular beds succeed, about 12 feet being exposed along the Canadian Pacific railway near Eramosa river. *Pycnostylus guelphensis* occurs about 8 feet above the base. The base of the Guelph is also exposed at Niagara river, at Dundas, in the vicinity of Wiarton, at Stokes bay, at Halfway rock (about midway between Cabot head and Tobermory), and on Bear Rump, Flowerpot, etc., and Fitzwilliam islands.

Between the city of Guelph and Niagara river the weathered basal Guelph beds, averaging about 2 to 4 feet in thickness, are brown, have bituminous partings, and a smell resembling that of petroleum. They are also commonly full of cavities which contain at Niagara gorge "pearl spar or dolomite". In the vicinity of Wiarton and northward the basal Guelph is massive, full of cavities and pore spaces but does not have bituminous partings or an oily smell.

The Standard White Limestone quarry in the southwestern part of the city of Guelph is in strata that are probably from 40 to 60 feet above the base of the Guelph formation. The section includes about 20 feet of creamy white, porous, saccharoidal dolomite, the beds being 3 to 4 feet thick near the base and thin (probably due to weathering) near the top. *Stromatopora* and *Calocaulis* (more than one species) are common near the base, *Pycnostylus guelphensis* occurs about 8 feet up, and *Trimerella* and *Megalomus canadensis* occur near the top.

As already stated, beds high up in the Guelph formation are represented at the top of the Salem-Elora section. The sections at Galt and between Galt and Glen Morris (on the Grand river, about 6 miles below Galt) include the highest Guelph beds known to outcrop in Ontario. The highest bed of all are exposed at or near water-level in the river above Glen Morris. The dolomite is heavy, water-worn, occurs in beds about 10 inches in thickness, and is fine-grained and very hard. On fresh fracture it is buff grey. *Megalomus canadensis* was found in most of the exposures. Because of the isolated outcrops and the variations in the dip of the bedding the thickness of exposed strata could not be determined. Logan² has described the Galt section as consisting of "twenty feet of yellowish-white and greyish-white, crystalline, thick-bedded dolomite" at the base, succeeded upward by "thirteen feet of pale buff or white dolomite", and "eighteen

¹Bull. N.Y. State Mus., No. 45, 1891, p. 112.

²Geol. Surv., Can., 1863, p. 339.

et of hard, thin-bedded, bluish dolomite' at the top. He continues, 'the whole mass holds fossils, but these, in the immediate vicinity of Galt, are most abundant in the twenty feet of pale buff, thin-bedded dolomite in the middle of the section'. The strata downstream are evidently included by Logan in the upper beds and probably do not represent more than the 20 feet allowed by him, as the river runs nearly on the strike of the formation. 34 feet of section is exposed at Galt above the river bed.

At Niagara falls, all the rock above the rock of the falls is Guelph. According to the section given by Clarke and Ruedemann, 13 feet of Guelph dolomite is represented in the vicinity of the falls, the outcrop being at the car barn on the gorge route (basal), on Goat island, and on the Three Sisters islands. This section is as follows in ascending order, 8 feet of brown, thin-bedded dolomites with rough surface and black partings, 10 feet not exposed, 25 feet brown dolomites exposed at Goat island and Three Sisters islands with summit near head of rapids. Full of cavities with *Stromatopora*, *Holysites*. Weathers very scraggy. Uppermost bed (4 feet) sandy.

Besides the Fergus-Elara section, a fair section is exposed on the Rocky Saugeen river at Hayward falls just below Rocky Saugeen post-office. The gorge in the rock is 30 to 40 feet deep and in all 90 feet of rock is exposed. The surfaces are badly weathered and caves occur near the tail-race of a mill. The rock is thick-bedded to massive and contains numerous fossils, most of which were found above the middle of the section, *Leiosites hisingeri*?, *Pycnostylus guelphensis*, *Megalomus canadensis*, *Conodonta occidentalis*, and *Stromatoporoids* were recognized.

Good outcrops also occur at Durham, from which many fine specimens were obtained by Mr. J. Townsend and other early collectors.

In the vicinity of Warton, as already mentioned, the base of the Guelph is well exposed. The best exposures are about two miles northwest from Warton on the road to Oliphant where the Frasnian beds are quarried. The actual contact with the base of the Guelph is obscure, 5 or 6 feet of strata being talus-covered. About 15 feet of Guelph strata, however, are exposed in a cliff to the north and consist of porous, scraggy, rather thick-bedded dolomite containing *Pycnostylus guelphensis*, *Spirifer coloratus* and *Strophodontia* sp. At a zinc prospect about 1 mile northwest of Warton on the north half of lot 30, concession 11, Albenarle East township, Bruce peninsula, an open-cut has been made in prospecting for zinc blende. The cut starts in rock that is about 10 feet above the base of the Guelph and is 30 feet deep, thus supplementing the section just mentioned. The rock, which is light grey in colour, is very porous and scraggy and full of cavities, many of which contain zinc blende. In the dump from this excavation, many fossils have been obtained; these are quite unlike Guelph assemblages found elsewhere in Ontario and very similar to the fauna of the Racine beds of Wisconsin. The outstanding features of the fauna are the large number and variety of cephalopods present. Most of these cannot be definitely determined because of their poor preservation, those recognized being given in the following table (pages 77-79). An unidentified *Phragmoceras* is also very common. The most typical Guelph species present is *Pycnostylus guelphensis*.

Higher Guelph strata occur along the western side of Bruce peninsula, and many specimens of *Megalomus canadensis* occur in the strata along

¹Clarke and Ruedemann, p. 14

the shore between Stokes bay and cape Hurd. Beds at Stokes bay within the lowest 50 feet of the Guelph formation are crowded with very large crinoid columnals. Some of these are three-quarters of an inch in diameter. It was formerly thought that the Guelph formation in Ontario was almost free from crinoid remains, and this is mostly true for the southern and better known outcrops. In the north, however, crinoid stems are common and some of the lower beds are almost entirely made up of them.

The Fishing islands west of Oliphant and the islands north of Tobermory, have excellent Guelph exposures. The lower beds, as for example at Halfway rock, Bear Rump, Flowerpot, Middle, Lucas, Yeo, and Fitzwilliam islands, have been recognized primarily by their stratigraphic position above the Eramosa beds. These upper Lockport beds extend to the northeast, at the localities mentioned, from beneath the Guelph capping rock, with the exception that on Bear Rump island the Eramosa beds project to the southwest from beneath the higher strata. Guelph fossils were found at each of the above-named localities, however, and thus the age of the rock was verified. For higher beds, age determination depends upon location and fossil evidence. Casts of species of *Trimerella* and *Rhinobolus* are of great value in determining the age of the northern Guelph outcrops.

Reef structures occur on Middle or "Plucky island" and on Lucas and Yeo islands. In fact it is to massive reef structure that these small islands owe their preservation.

"Plucky", or middle island as it is known on the chart, is a mere islet situated about halfway between Tobermory and Flowerpot island and is not shown on the geological map. It appears as a mass of tumbled blocks of dolomite, 30 or 40 feet high, but on closer inspection it proves to have a core of solid rock from which the blocks have fallen, being undermined by wave action. The solid rock is a *stromatoporoid*-coral reef. The reef building corals were *Pycnostylus guelphensis* and *Pycnostylus elegans*. Along with the reef builders, *Favosites favosus*, *Rhinobolus guelphensis*, and *Trimerella grandis*? occur. The top of Lucas island appears to be the remains of a *stromatoporoid* reef resting on Eramosa beds. The maximum elevation is about 30 feet. Yeo island is low, probably not more than 20 feet high at any place, and is a domed-reef structure resting on more or less domed Eramosa beds which are incised by wave action on the northeast angle. The reef builders were *Stromatoporoids*, and these in some cases had their bases below the top of the Eramosa beds, the structure thus resembling the transition coral reef at Guelph described under Eramosa beds. Brachiopods and gastropods lived in association with the reef builders; *Atrypa reticularis*, *Whitfieldella nitida*?, and *Plenrotomaria*? being noted.

The most northerly occurrence of Guelph is on the southwestern extremity of Fitzwilliam island. The rock capping the ends of the numerous rock projections and the small islands just off-shore is Guelph. The typical, hummocky, Eramosa beds are exposed on the mainland at the base of the scraggy, thick-bedded Guelph and a very few typical Guelph fossils were found. Among these, *Rhinobolus gaultensis* is the most reliable guide to the Guelph. No Guelph strata have been identified on Manitoulin island. Some of the rock at South Baymouth is much like the Guelph, but although the shore was studied both east and west,

no Eramosa beds were identified and no Guelph guide fossils were found. For Guelph fossils see table page 000, and Plates XXII to XXVII.

CORRELATION.

The Guelph formation extends into New York state, including, as already stated, the upper 43 feet of the section exposed along the Niagara river and according to Chadwick probably 100 feet of higher beds. The Eramosa beds have been recognized by Chadwick and the author in the barge canal at Rochester and the dolomite above is typically Guelph. This accords with the maps of New York state. As already stated under "Lockport formation," the upper Shelby and the overlying beds may be considered the New York equivalent of the Guelph formation of Ontario. The Racine beds of Wisconsin and Illinois contain, according to Chamberlain¹, a cephalopod fauna very similar to the fauna in the lower Guelph near Warton, and also many distinctly Guelph genera and species, such as *Megalomus canadensis*, *Dinobolus Conradi*, and *Trimerella cf. grandis*. The author, while visiting the more important Wisconsin and Illinois occurrences of the Racine beds in 1914, was impressed with the decided Guelph characters of the Racine, and moreover, accompanied by Professor Stuart Weller of Chicago university, he was able to point out the great similarity of the lower beds exposed in a quarry at the locality south of Chicago known as "Stony Island," to the Eramosa beds of Ontario. The general thin-bedded character of 15 feet of these beds and the vugs of soft bitumen in some lower beds were very suggestive of the general horizon of the Eramosa beds, and the presence of a poor specimen of *Pycnostylus guelphensis* in the upper beds of the quarry was additional evidence that the contact between the Guelph and Niagara formations is exposed here. The general northward dip of the strata would readily allow for the Racine and higher beds occurring above this horizon at Chicago, and northward. More field work is necessary before the Guelph-Niagara problem is cleared up in Wisconsin and Illinois, but in the meantime the author prefers to correlate the Racine and the overlying "Guelph beds" of Chamberlain with the Guelph of Ontario.

Kindle² has reported Guelph fossils from limestone at Huntington, Indiana, which according to Foerste³ overlies the Louisville limestone. Strata of Guelph age are doubtless present. Elsewhere in the United States, few occurrences of strata of undoubted Guelph age are reported.

Pycnostylus guelphensis and *Pycnostylus elegans*, found by Dowling⁴ on Ekwan river, west of James bay, probably indicate the presence of Guelph strata in this region. Loose glacial boulders containing fossils suggesting Guelph age were found by Hume north of lake Timiskaming. These probably came from James Bay region. *Pycnostylus guelphensis* was found by Tyrrell⁵ on Davis point, lake Manitoba, suggesting uppermost Niagara or Guelph strata at this vicinity. It is altogether probable that with further detailed work, other occurrences of Guelph strata will be found in northern Canada. Tweenhofel and Schuchert⁶ have correlated the

¹Geol. of Wis., vol. II, 1873-77, pp. 374-377

²Ind. Dept., Geol. and Nat. Res., 28th Ann. Rept., 1904, p. 408

³Ind. Geol. and Nat. Res., 28th Ann. Rept., 1904, pp. 34 and 35

⁴Paleozoic fossils, vol. III, pt. IV, p. 247.

⁵Paleozoic fossils, vol. III, pt. IV, p. 284

⁶Am. Jour. Sc., vol. XXVIII, 1909, p. 118

Stonehouse formation of Arisaig, Nova Scotia, with the Guelph, and both with the Ludlow of Europe.

GUELPH SEDIMENTATION.

It is generally believed that Guelph strata were deposited in a somewhat restricted sea of increasing salinity. Thick-shelled forms such as *Trimerella* and *Megalomus* are generally taken as being indicative of high salinity and the restricted areas of known Guelph outcrops suggest narrow sea-ways. Evidence is accumulating, however, in support of Grabau's theory that the Salina was derived largely from erosion of the Guelph and Niagara formations. By a careful study of samples taken from wells east of lake St. Clair, it is seen that there is no indication of an erosion surface anywhere in the Guelph-Niagara dolomites, but that where these are unusually thick, the upper beds have distinctive characters, of colour and hardness. Although this may be due to lenticular deposition, it strongly suggests erosion in pre-Salina time. Although lamellibranchs, brachiopods, and gastropods are the most striking Guelph fossils, coral reefs are now known to be common, and great colonies of erinoids are common in some places. Cephalopods were extremely important during the early stages of the Guelph sedimentation in the region of Bruce peninsula and Wisconsin, and were fairly well represented throughout the period. The closing event of Guelph time appears to have been an emergence and erosion period during which a part of the lower Great Lakes region may have remained a partly enclosed sea.

Genera and species

[illegible]

Distribution of the Guelph Fauna—Continued.

Genera and species.	Galt. Upper beds.	Hesperet. Upper beds.	Guelph. 50 ft. up.	Rockwood. Base.	Fergus. Below middle.	Elora. About middle.	Durham. Near top.	Markdale. Below middle.	Zinc prospect. Near Wharton (basal).	Fishing Islands. Lower.	Stokes Bay. Basal beds.	Halfway rock. 100 ft. up.	Tobermory. Upper.	Cape Hurd. High up.	Cove and Echo Islands. Upper.	Middle Island. Middle.	West end Fitzwilliam Island. Lower.
<i>Brachiopoda</i> —Con.																	
<i>Whitfieldella nitida</i> (Hall)	x																
<i>Whitfieldella nitida obolata</i> (Hall)	x																
<i>Whitfieldella hyale</i> (Billings)																	
<i>Pteropoda</i> .																	
<i>Amphicælia leidy</i> Hall																	
<i>Megalomus canadensis</i> Hall																	
<i>Matheria recta</i> (Hall)																	
<i>Mytilarca neutrostra</i> (Hall)																	
<i>Pterinea brisa</i> Hall																	
<i>Pterinea occidentalis</i> Whiteaves																	
<i>Anodontopsis concinna</i> Whiteaves																	
<i>Gastropoda</i> .																	
<i>Trematodus alpheus</i> (Hall)																	
<i>Ecyclophialus circumatus</i> (Whiteaves)																	
<i>Euomphalopterus valeria</i> (Billings)																	
<i>Liospira perlata</i> (Hall)																	
<i>Eotomaria galitensis</i> (Billings)																	
<i>Cyclacaulis bivitatus</i> (Hall)																	
<i>Cyclacaulis longispira</i> (Hall)																	
<i>Cyclacaulis macrospira</i> (Hall)																	
<i>Cyclacaulis turritiformis</i> (Hall)																	
<i>Cyclacaulis constricta</i> (Whiteaves)																	
<i>Cyclacaulis daphne</i> (Billings)																	
<i>Lophospira hispidensis</i> (Whiteaves)																	
<i>Lophospira bispiralis</i> (Hall)																	
<i>Lophospira mylitta</i> (Billings)																	
<i>Euomphalus gallensis</i> Whiteaves																	

[illegible]

REVISED LIST OF SPECIES.

The following is Whiteaves' list of the fossils of the Guelph formation of Ontario, with the doubtful species omitted and the generic name corrected according to Bassler's index of Ordovician and Silurian fossil localities are from Whiteaves' earlier lists.

ANTHOZOA.

- Pycnostylus guelphensis*, Hespeler, Elora, Durham.
Pycnostylus elegans Whiteaves, Hespeler, Durham.
Favosites hisingeri, Edwards and Haine, Galt, Hespeler, Elora, Durham.
Halysites catenodaria, Linnaeus, Guelph, Elora, Hespeler, Durham.
Halysites compactus, Rominger, Galt, Elora.

HYDROMEDUSAE.

Note. Parks list is given below instead of that given by Whiteaves.

BRACHIOPODA.

- Trimerella grandis* Billings, Galt, Elora, Hespeler.
Trimerella acuminata Billings, Galt, Elora, Hespeler.
Trimerella olivensis Meek, Durham.
Trimerella billingsi Dall, Hespeler.
Trimerella dalli Davidson and King, Hespeler.
Rhinobolus galtensis (Billings), Galt, Elora, Durham.
Monomorella prisca Billings, Hespeler, Elora.
Monomorella orbicularis Billings, Hespeler.
Monomorella ovata Whiteaves, Durham.
Monomorella ovata lata, Whiteaves, Durham.
Monomorella durhamensis, Whiteaves, Durham.
Pentamerus oblongus Sowerby, Durham.
Conchidium occidentale Hall, Galt, Guelph, Hespeler, Elora, Durham.
Clorinda ventricosa (Hall), Hespeler, Elora.
Camurotarchia pisa (Hall and Whitfield), Hespeler and Elora.
Atrypa reticularis (Linnaeus), Hespeler.
Spirifer radiatus (Sowerby), Durham, Elora.
Spirifer crispus (Hisinger), Durham.
Whitfieldella hyale (Billings), Galt, Hespeler, Elora.

PELECYPODA.

- Megalomus canadensis* Hall, Galt, Guelph, Hespeler, Elora, Durham, Bellwood.
Megalomus compressus, Nicholson and Hinde, Hespeler.
Amphicelia neglecta (McChesney), Elora.
Goniophora crassa Whiteaves, Durham.
Illionia canadensis Billings, Elora and Hespeler.
Illionia ? costulata Whiteaves, Elora and Durham.
Anodontopsis concinna Whiteaves, Galt and Durham.
Prolocina galtensis Whiteaves, Galt, Durham.

GASTROPODA.

- Scenella conica* Whiteaves, Durham.
Archinacella canadensis (Whiteaves), Hespeler.
Trematodus angustatus (Hall) = *T. alpheus*? Galt, Guelph, Hespeler.
Euomphalopterus valeria (Billings), Durham, Bellwood.
Euomphalopterus halei (Hall), Durham.
Euomphalopterus elora (Billings), Galt.
Lophospira canruli (Hall), Elora.
Lophospira xanthippe (Billings), Galt.
Lophospira mylitta (Billings), Elora.
Lophospira hespelerensis (Whiteaves), Hespeler.
Lophospira guelphica Whiteaves, Durham.
Loroplocus solutus (Whiteaves), Hespeler, Elora, Durham.

¹Palaeozoic fossils, pt. IV, pp. 327-345.

GASTROPODI. Con.

- Phanerolema occidens* (Hall), Elora.
Liospira perluta (Hall), Galt.
Eotomaria gultensis (Billings), Galt.
Eotomaria durhamensis (Whiteaves), Durham.
Clothospira deiopeia (Billings), Elora.
Hormotoma whiteavesi Clarke and Ruedemann, Galt, Hespeler, Elora.
Calocaulus? vitellus (Billings), Galt.
Calocaulus? macrospira (Hall), Galt.
Calocaulus? birtatus (Hall), Galt, Hespeler, Elora.
Calocaulus? longispira (Hall), Galt, Elora, Hespeler, Guelph, Durham.
Calocaulus? turriformis (Hall), Galt, Elora, Hespeler, Durham.
Calocaulus? estella (Billings), Galt.
Turritoma boylei (Nicholson), Elora.
Turritoma constricta (Whiteaves), Durham.
Murchisonia? billingsiana Miller, Galt.
Lophospira bispiralis (Hall), Galt.
Pleuromaria cyclostoma Whiteaves, Durham.
Pleuromaria townsendii, Durham.
Euomphalus gultensis Whiteaves, Galt, Hespeler, Durham.
Euomphalus inornatus (Whiteaves), Elora, Durham.
Eccyliomphalus circinatus (Whiteaves), Galt, Hespeler, Elora, Durham.
Straparollus hippolyta Billings, Galt.
Straparollina daphne (Billings), Galt.
Poleumita sulcata (Hall), Galt, Hespeler.
Poleumita macrolincata (Whitfield), Elora, Durham.
Poleumita crenulata (Whiteaves), Durham.
Poleumita durhamensis (Whiteaves), Durham.
Poleumita parvula (Whiteaves), Durham.
Codonachilus striatus Whiteaves, Hespeler, Durham.
Pycnamphalus solarioides (Hall), Galt.
Loranema boydi Hall, Galt.
Halapea harmonia Billings, Galt.
Holopea? occidentalis Nicholson, Elora.
Subulites compactus Whiteaves, Durham.
Cyrtospira ventricosa (Hall), Galt.

CEPHALOPODA.

- Protokionoceras crebescens* (Hall), Hespeler, Elora.
Protokionoceras medullare (Hall), Elora.
Orthoceras schwyni Billings, Galt.
Kionoceras cancellatum (Hall), Elora.
Kionoceras darwini (Billings), Hespeler, Durham.
Dawsonoceras americanum (Foord), Hespeler, Elora.
Septanoceras septore (Hall), Elora.
Asaceras townsendi Whiteaves, Durham.
Marlonoceras arcticameratum (Hall), Galt.
Cyclostomiceras orodes (Billings), Hespeler.
Phragmoceras hector Billings, Hespeler.
Phragmoceras nestor canadense Whiteaves, Hespeler, Elora, Durham.
Phragmoceras parvum Hall and Whitfield, Durham.
Sphyradoceras desplainense (McChesney) "Ontario".
Disoceras graftonense Meek and Worthen, Elora, Hespeler.

CRUSTACEA.

- Leperditia bathica guelphica* (Jones), Durham, Aboyne.
Leperditia praeceolus guelphica Jones, Durham.

TRILOBITA.

- Calymene niagarensis* Hall, Galt.
Cheirurus niagarensis (Hall), "Ontario".
Ilænus aboyneensis Whiteaves, Aboyne.

LEIOPTEIIDA.

Eurypterus (Thylopterus) haydeni, Whiteaves, Elora.

Stromatoporoids of the Guelph formation in Ontario as given by Parks.¹

Actinostroma vulcani Parks, Durham.

Clathrodictyon ostiolatum Nicholson. "No locality given for Guelph occurrence."

Clathrodictyon striatellum D'Orbigny, "at all the typical localities".

Clathrodictyon fastigiatum Nicholson, Elora, Aboyne, and township of Glenelg.

Labechia durhamensis Parks, "Durham, Galt, Guelph, Elora, and throughout the Guelph of Ontario".

Labechia minor Parks, Elora, Galt, Durham, Glenora, and Glenora.

Roscnella glenelgensis Parks, Durham, Elora.

Stromatopora galtensis Dawson, Galt, Hespeler, Elora, Durham.

Stromatopora antiqua Nicholson and Murie, Durham?

Stromatoporella clora Parks, "at all of the well-known localities".

Stromatoporella clora minor Parks, Durham.

Hemastroma guelphica Parks, Elora.

CAYUGAN GROUP.

GENERAL DESCRIPTION.

"Cayugan group" is here used to include all the Silurian sediments in Ontario above the top of the Guelph dolomite. Thus in the Buffalo region, the formations included are, as recognized by Bassler², the Salina (represented by the Camillus shale), the Bertie waterlime, and the Akron dolomite, the latter correlated with the Cobleskill of eastern New York. In the Detroit River region the Salina and the Bass Island series are included in the Cayugan group. The Camillus shale division of the Salina is well marked in this western region and it is probable, as will be seen below, that the Bertie and Akron dolomites of the east are to be correlated with the Raisin River and the Put-in-Bay dolomites of the Bass Island series, and consequently, contrary to former usage, this series belongs in the Cayugan group.

The lack of outcrops and good sections is the principal difficulty met with in working out the stratigraphy and correlation of the Cayugan formations. This difficulty is illustrated by the scattered occurrence of outcrops as shown on Map 1715.

SALINA FORMATION.

Description.

The Salina, as its name implies, is the salt and gypsum-bearing formation of New York state and Ontario. The deposits of Salina age represent special conditions of sedimentation, which according to Grabau and O'Connell, are probably those of an interior basin, to which the Atlantic ocean gradually gained freer access until the commencement of the emergence of the continent as a whole, which closed the Silurian period.

¹ University of Toronto studies, Geol. ser. No. 4, 1917.

² U. S. Nat. Mus., Bull. 92, vol. 11, 1915, p. 1.

Camillus Shale Member.

Description. The Camillus shale is the lowest member of the Salina formation of Ontario; it rests unconformably on the Guelph dolomite and is overlain conformably by the Bertie waterlime in the east and the Bass Island series in the west.

Essentially a grey or green shale, this member contains also beds of argillaceous dolomite, large deposits of gypsum in the valley of Grand river between Paris and the vicinity of Cayuga, and extensive salt deposits in parts of New York state and in the area adjacent to lake Huron from Kincardine south to lake St. Clair and near Windsor.

The characters of this formation are illustrated in the following descriptions of sections, and Figure 4.

A drill core from north Buffalo as interpreted by Grabau gives a section of the Camillus, 387 feet thick, which includes, in ascending order: gypsum and shale, mottled and in streaks, 290 feet; compact shale, 3 feet; shale and limestone, 4 feet; dark limestone, 2 feet; drab shale and thin gypsum, 58 feet; shale and gypsum, 7 feet; white gypsum, 4 feet; shale, 1 foot; white gypsum, 12 feet; shale, 2 feet; pure white gypsum, 4 feet; overlain by the Bertie waterlime. The beds penetrated in the gypsum mine of the Alabastine Company at Caledonia are, in ascending order, as follows: 3 inches of gypsum; 4 feet of dark grey, impure dolomite; 3 feet of fine white gypsum; 10 feet of brown dolomite containing some gypsum; 7 feet of gypsum with thin, limy partings and limy accumulations; 4 feet of mixed dolomite and gypsum; 3 feet of impure dolomite; 6 feet of gypsum mixed with dolomite. The weathered exposures of shale along Grand river are grey-green in colour and generally soft and fissile.

The upper Camillus shales are represented by pea-green to grey, blocky shale in outcrops along Niagara river 100 yards north of the international bridge at Bridgeburg, Ont. Indications of gypsum are seen a little farther down stream. The best of the northern sections is that below the bridge over the branch of Saugeen river at Ayton. In ascending order the section is: 4 feet of hard, firm shale; 4 feet of hard, uneven dolomite, breaking with conchoidal fracture; 4 feet of hard, thin-bedded, buff dolomite with bituminous partings; 2 feet of hard, brown dolomite; 7 feet of firm, buff shales and thin dolomites; 11 feet of thin, fissile, green-weathering shale; 4 feet of light buff dolomite full of minute cavities.

Another section on the bank of a branch of the Saugeen river, on lot 19, concession VI, Normanby township, Grey county, is as follows: 3 feet shale; 10 feet hard, grey dolomite; 12 feet soft shale; 15 feet of nodular, green shale; 2 feet green shale containing red patches, probably originally all red; 2 feet of buff dolomite (calcitrite); 2 feet of green-grey, impure dolomite. This is the only locality known to the author where red shale occurs in a Camillus shale outcrop. The red shade was probably more extensive than is shown, the red beds being largely deoxidized by surface water containing humic acid derived from plants.

In the west bank of Saugeen river below Walkerton, at the crossing of the line between concessions III and IV, about 16 feet of nodular green shale is overlain by 20 feet of buff dolomite, belonging to the Bertie-Akron division.

The total thickness of the Camillus shale at Delhi, Norfolk county, is 310 feet; near London the thickness, including 170 feet of salt, is 750 feet; in Dover township, near lake St. Clair, the thickness varies between 550 and 745 feet, the least thickness being where the underlying Guelph dolomite is thickest and *vice versa*.

The varying thickness of the shale and the irregularities in the underlying formation are suggestive of warping, uplift, and erosion at the end of Guelph time, as described by Grabau.

Origin of Camillus Shale.

Grabau has made a careful study of the origin of the Camillus shale, with the contained salt and gypsum, and concludes:

"At the close of the Niagara period, there appears to have been an elevation of the continent which converted . . . the greater part of the interior Silurian sea into a vast partially or entirely enclosed basin. This elevation appears to have been accompanied by climatic desiccation which brought about a rapid evaporation of the waters and a consequent increase in salinity. Thus this great interior water body was changed from a richly peopled mediterranean, to a lifeless body of intensely saline water, a veritable Dead sea. . . . The elastic strata of the Selina series were probably derived from the destruction of the sediments which were formed during the early periods of the Silurian and during preceding periods . . . they may in fact be regarded as consolidated argillo-calcareous muds derived from older limestones and shales."

The salt deposits of New York state and the much greater deposits of the Michigan basin, whose eastern rim includes the Lake Huron-Lake St. Clair region of Ontario, were evidently the result of extreme desiccation in isolated basins. Deposition of gypsum took place as its saturation point was reached, and later the salt was deposited. These depositions alternated, responding to more or less periodic inflows of water and excess of evaporation. It has been determined that salt comprises about 77.8 per cent of the solids contained in sea water and calcium sulphate comprises 3.6 per cent. The latter, however, begins to precipitate when 80 per cent of the water is evaporated, salt not being deposited until 93 per cent of the water is evaporated. It is clear that in cases of extreme evaporation the deposits of calcium sulphate (gypsum and anhydrite), because of its small content in sea water, will form very insignificant deposits compared with that of the salt. If total desiccation took place the deposits would be in the ratio of 3.6 parts by weight of anhydrite to 77.8 parts by weight of salt. If just sufficient water were added from time to time to the evaporating basin to prevent desiccation reaching the stage necessary to deposit salt, calcium sulphate would continue to be deposited and important beds of anhydrite and gypsum would be formed, as was the case in parts of New York state and the Paris-Cayuga section of the Grand valley in Ontario.

BERTIE WATERLINE FORMATION.

Description.

The Bertie waterline formation is composed of thin-bedded dolomites, jointed waterlimes, and interbedded, dark grey shale. The lower contact

¹N. Y. State Mus. Bull. 45, pp. 127-8.

is transitional from the Canadus shale, and the upper contact with the Akron dolomite is marked by a lithologic change, which is not everywhere easily detected. As described by Grabau, the Bertie is represented in a drill core from north Buffalo, in ascending order as follows: 13 feet of shale and cement rock at the base, 5 feet of fairly pure cement rock, and 25 feet of shale and cement rock at the top.

Chadwick¹ has divided the upper part of the Canadagan group in western New York as follows (all but the Akron are divisions of the Bertie formation):

	Feet
Akron dolomite (Grabau), subcrystalline, grey to brownish, with <i>Cyathophyllum hydraulicum</i>	12 or less
Buffalo cement bed carrying enrypterids	5
Senjagada dark shales and blocky waterlimes, at base the Bridgeburg horizon with enrypterids	8
Falkirk dolomite, brownish and bituminous, below massive and often producing waterfalls; a marine fauna, but enrypterids at base.	30
Oatka beds, dark grey and shaly, with a blocky waterlime at base carrying enrypterids	20 or less.

In the criticism of this memoir the term Buffalo and used in its place.

The shales and waterlime along the bridge, probably belong to the upper part including Bridgeburg and top of Falkirk of the international bridge is probably

At a quarry north of Ridgeway, of which, Welland county, the following part of the Bertie beds occurs: 7 feet of thinly laminated, brown dolomite with bituminous partings at the base of the section (Falkirk); 4 feet of light grey, jointed dolomites (Bridgeburg); 6 feet of hard, slate-grey shale, with *Trilobites* fragments, at the top (Senjagada); 5 feet of waterlime (Akron dolomite).

About one-third of a mile due west of Ridgeway, at the road forks, heavy beds of dolomite (Falkirk) contain numerous specimens of *Whitfeldella sulcata* and *ostracoda*. These beds consist of 10 feet of thinner beds which are probably lower Bertie. Senjagada shale along the "Ridge road" south of the above-mentioned exposure the base of the Akron is about 13 feet below the Oriskany sandstone. This is the thickest Akron section known in the vicinity.

At the Municipal quarry, some east of Buffalo, on the west side of Grand river, not far from Dunnville, the exposure of the Bertie section consists in ascending order, of: 7½ feet of hard, siliceous shale with dark partings; one-half foot of hard, nodular sandstone; 1 foot of massive, hard, light grey, fine-grained dolomite (calcilitite) containing *Schuchertella hydraulicus* near the top; 2 feet of hard, grey dolomite; 7 feet of laminated and mottled, blocky dolomite (magnesian dolomite, probably Akron) overlain above a decided erosion unconformity, by lenses of Oriskany sandstone.

From Dunnville west and north few exposures of Canadagan rock occur and the Bertie and Akron beds have not been differentiated. The exposures

¹Bull. Geol. Soc. Am., No. 1, vol. 28, p. 173.

will be described under Akron dolomite. It seems probable that in Kent and Essex counties the extension of the Bertie waterline is to be correlated in age with the Pat-in-Bay dolomite and the underlying Tynochtee shales and Greenfield dolomite (see below under Bass Island series).

Fauna.

The muddy, calcareous Bertie sediments contain a rich *Euryptera* fauna, but very little else. As given by Ruedemann the fauna of the Bertie (Williamsville) is as follows:

Imenodes usquevirens (Grote and Putt).
Langda testatrix Ruedemann.
Diphyrostroma sp.
Hevegnella pat. bifurcata O'Connell.
H. pat. lucensis O'Connell.
Hormotoma gregaria Ruedemann.
Orthoceras richioides Ruedemann.
Phenymoceras acicola Ruedemann.

Clarke and Ruedemann list the following eurypterids¹ from the Bertie waterline.

Dolichopterus macrochirus Hall.
D. sibiriceps Clarke and Ruedemann.
D. ? testulincus " "
Eurypterus dekayi Hall.
E. lucensis Hall.
E. lucensis var. *pachychirus* Hall.
E. pustulosus Hall.
E. remipes Dekay.
E. scorpionus Grote and Putt.
Pterygotus buffaloensis Pohlman.
P. colbi Hall var. *juvenis* Clarke and Ruedemann.
P. grandis (Pohlman).
P. macrophthalmus Hall.

Chadwick by correspondence gives the following as occurring in the Fulkirk division of the Bertie:

Whitfieldella subata (Vanuxem).
Gomphoceras osculum Ruedemann.
Lepidites cf. scabris (Jones).

Origin of the Bertie Waterline.

According to Miss O'Connell, who has made a special study of the Bertie waterline from the standpoint of "the habitat of the Eurypterids," the deposits at Buffalo and at Herkimer, New York, both of which carry eurypterid faunas, are best explained as deltas of low-lying, meandering rivers flowing from the north. The marine organisms are supposed to have been transported upstream by tidal action. On page 117, we read: "The only available source of the lime in the Bertie is from the mud derived by the erosion of an older magnesian limestone, the Niagara

¹N. Y. State, Mem. 14, vol. I, 1912, p. 431.

²See Plate XXVII.

³See Plate XXVII.

⁴Bull. Buffalo Soc. Nat. Sc., 1903.

or in some cases, perhaps, the Trenton. Where the Bertie is eurypterid-bearing, the rock was evidently deposited above sea-level, as a river flood-plain and subae, at delta deposit. Southward and laterally the subaqueous part of the delta carries few or no eurypterid remains, but more marine organisms. That the Bertie eurypterids lived in the river is thus indicated.

An entirely different view of the case is taken by Ruedemann¹ who, after discussing O'Connell's arguments and refuting the suggestion that the eurypterid fragments had drifted into their present position, sums up as follows:

"The *Buthotrephis* has been proved in this paper to be a good sessile graptolite of the genus *Lucavolis*. It occurs in the waterline in splendidly preserved colonial stocks, which cannot have drifted any distance. The *Langulas* and *Hormotoma* occur in certain layers in such immense quantities that they are certainly in their proper surroundings where found. . . . At any rate there is not in the whole assemblage of the Bertie waterline a single genus that could be considered as indicative of a freshwater fauna, and all these marine forms are found on the same slabs with the eurypterids, so that an alternation of marine and freshwater conditions cannot be assumed either."

The above summarizes the divergent opinions as to the probable origin of the typical Bertie beds where recognized by faunal evidence. Elsewhere, they have been determined by stratigraphic and lithologic evidence and appear to be sediments derived from older rocks laid down in a shallow sea. The water was probably too salty and too muddy to favour the development of diversified life.

AKRON (DOLOMITE) FORMATION.

Description.

In the cement quarry at Buffalo about 7 feet of light grey, mottled, somewhat nodular dolomite rests on the Bertie waterline, and is terminated above by a decided erosion surface upon which lie lenses of Oriskany sandstone and beds of Onondaga limestone. This is the Akron dolomite. Small cavities are common in the Akron, which has in part wavy bedding, and contains *Cyathophyllum hydraulicum* and *Schuchertella hydraulica* (see below).

The Akron dolomite was named by Gratau² from its occurrence at Akron Falls, east of Falkirk, New York. Here, as seen by the author, the Akron, which has wavy bedding, is about 5 feet thick, light grey in colour, somewhat nodular, fine-grained, and weathers into a pitted surface. The underlying bed of Bertie waterline was formerly burnt to natural rock cement. The overlying formation is the Onondaga, but the contact is even and the disconformity is not evident.

A good section of the Akron dolomite occurs at the quarry near the schoolhouse north of Ridgeway, lot 1, concession X, Bertie township, Welland county. Here the total thickness is about 7 feet. The characters are about as at Buffalo and *Schuchertella hydraulica* and *Cyathophyllum*

¹Ibid., p. 115.

²Bull. Geol. Soc. Am., vol. 19, p. 544.

hydraulicum are found. A similar section occurs at a quarry on lot 8, concession XIII, Bertie, where Onondaga limestone overlies the Akron.

At Byng near Dunnville, in the Municipal road-metal quarry, 5 to 7 feet of Akron dolomite is terminated above by an irregular erosion surface upon which lie lenses of Oriskany sandstone. The Akron consists of thin-bedded, blocky calcilutite of mottled grey colour, and rests on hard, grey shale. At the John Weber quarry near Byng, on lot 16, concession I south, Dunn township, the Akron appears to be 15 feet or more thick, but the boundary between the Akron and the Bertie is not easily drawn.

The outcrops west of Dunnville, not easily divided into Akron and Bertie, are described below. As will be seen on Maps 1714 and 1715, a number of outcrops of the upper Cayugan dolomites occur in the vicinity of Cayuga west of Grand river. The best and most representative section is that north of the road in the river bank, on the fronts of lots 3, 4, and 5, River road, Cayuga, South, township, Haldimand county. In ascending order the section is: Camillus shale consisting of 12 feet of light grey, thin-bedded dolomite, and 8 feet of grey shale including a 1-foot bed of waterline near the top; Bertie-Akron consisting of a 3-foot massive bed of light grey dolomite, and 20 feet of light grey, blocky dolomite, overlain by cherty Onondaga dolomite.

At Springvale, an 8-foot section is exposed in a quarry, the lower 5 feet of the beds being thin and blocky and the upper 3 feet being one massive bed. The colour is light buff. This stone was burnt for lime by Mr. Winger, who says that it burnt to a strong, white lime and that it was used in the building of the convent at Niagara Falls, New York. The waterline bed is said to lie just below the exposed rock of the quarry. A short distance southwest of Springvale, the Springvale (Devonian) sandstone occurs, limiting the Cayugan above. Other small exposures similar to the above occur south of Springvale.

About 2 miles east of Hagersville, at a cut on the Michigan Central railway near where two roads cross, 8 feet of thin-bedded, jointed, cream-coloured, fine-grained dolomite is terminated upward by an erosion surface on which rests cherty Onondaga limestone.

At Innerkip, just south of the station, stone was formerly taken from a quarry and burnt to quicklime by the aid of natural gas which was struck on the quarry site. The face of rock now exposed above water is 8 feet high, consisting of light buff, fine-grained dolomite. The lowest bed, which is very fine-grained and breaks with conchoidal fracture, is 3 feet thick and is overlain by a thin bed of green, glauconitic, dolomitic, very fine-grained sandstone, $1\frac{1}{2}$ inches or less in thickness. The beds above are thinner and weather into nodules. The main sandstone bed lies on an irregular erosion surface, and streaks of sand occur 6 inches lower down and also in cracks at a slightly lower horizon. The lime burnt from the stone in this quarry was grey.

Two specimens of *Whitfieldella prosseri* Grabau were found just above the sandstone. These consist of moulds of the interior of the shell and the sinus in the pedicle valve is not well marked. The specimens compare closely in size and other characters with Grabau's illustrations and descriptions. Had the fossils occurred below the sandstone it might be assumed that these beds were the top of the Silurian. The sand is probably, how-

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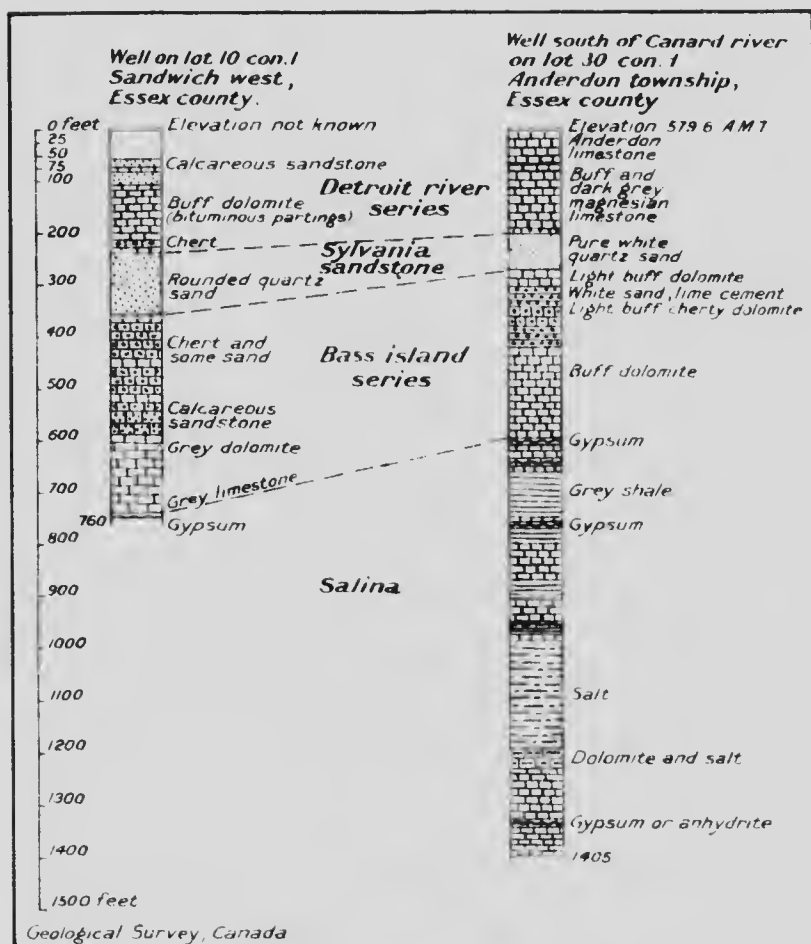
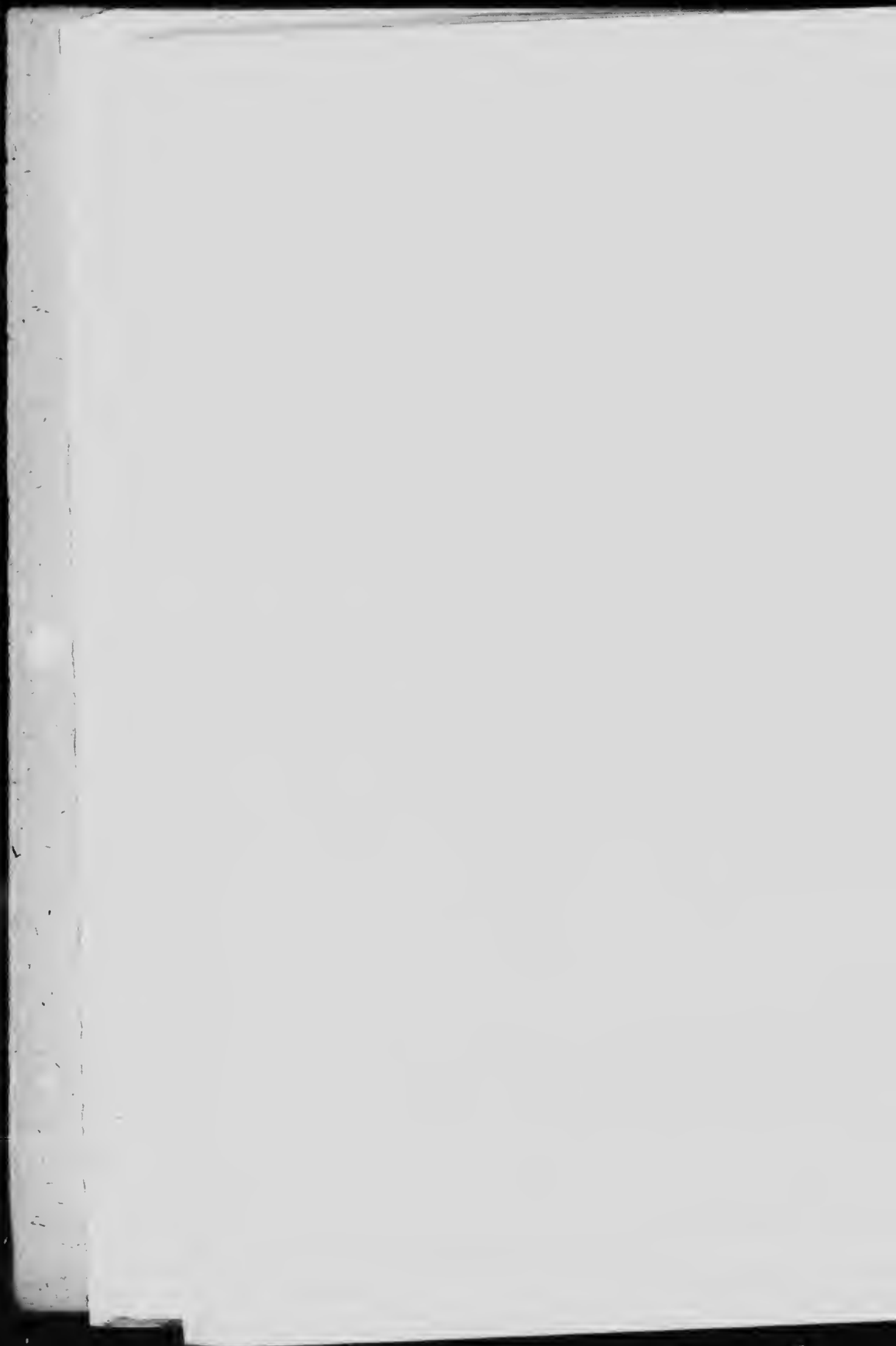


Figure 5. Diagram showing formations near Detroit river as indicated by two wells drilled by the Solvay Process Company.

To accompany Memoir by M Y Williams



ever, a forerunner of the Sylvania which has been deposited on a limestone surface scoured by shore currents during a partial retreat of the sea. The presence of *Whitfieldella prosseri* in these beds correlates them with the Raisin River dolomite of Ohio and Michigan. This outcrop forms a link between the Akron dolomite and the Raisin River dolomite, which as explained below are thought to be of the same age.

As mentioned above under "Camilius shale", about 6 feet of fine-grained, cream-coloured dolomite is exposed in the bed of a small tributary entering Saugeen river from the west just north of Walkerton. Along the Canadian Pacific railway, just south of Walkerton, buff dolomite with bituminous partings contains *Leperditias* resembling *altoides* Grabau and *Whitfieldella sulcata* (Vanuxem)? In the east bank of the Saugeen, at the crossing of the boundary between concessions III and IV, Brant county, about 20 feet of buff dolomite, fairly thick-bedded in the lower third and thinner-bedded above, overlies nodular, green shale. The dolomite is dense and fine-grained, suggesting the characters of lithographic stone.

The best northern section of the Bertie-Akron is that exposed along a small unmapped tributary entering Saugeen river from the west just south of the line between concessions VII and VIII, Brant township, and about 2½ miles north of Walkerton. The section is as follows, in ascending order from the bed of the Saugeen up: 4 feet of buff dolomite in 1 to 2-inch beds; a covered interval of about 3 feet; 5 feet of thin-bedded, buff dolomite; 10 feet of buff dolomite in 1 to 2-foot beds, 4-foot massive bed, fine-grained and hard, formerly quarried and burnt to grey lime at nearby kilns; 1 foot of soft, yellow-weathering shale; 12 feet of dolomite in beds 1 to 2 feet thick. Small exposures of rock referred to the Bertie-Akron division occur on the Teeswater river about 1 mile below Pinkerton, and on a tributary of the Teeswater one-half mile east of Bradley.

Fauna.

The fossils contained in the Akron dolomite of New York as given by Grabau¹ and corrected by Chadwick, are as follows:

PLANTS. *Nematophycus crassus* (Penhallow) horizon doubtful.

ANTHROPOA. *Cyathophyllum hydraulicum* Simpson.

BRACHIOPODA. *Schuchertella interstriata* (Hall).
Spirifer ericensis (Grabau)?

BASS ISLAND SERIES.

Definition and General Description.

Grabau has applied the name Bass Island series to the dolomites and shales of Ohio and Michigan, lying between the top of the Camilius shale as recognized in that region and the Sylvania sandstone. His subdivisions are, in ascending order: the Greenfield dolomite; Tymochtee shales; Put-in-Bay dolomite; and Raisin River dolomite. These divisions were studied at widely separated localities and the boundaries and relations are hence not very well known. As seen in Figure 5, the thickness of the

¹N. Y. Mus., Mem. 45, pp. 233-237.

Bass Island series along Detroit river is from 330 to 375 feet. The following descriptions are from Grabau and Sherzer¹.

The Greenfield dolomite is mostly thin-bedded, drab-coloured on fresh fractures, and oxidizes to a yellowish shade. Its greatest thickness at Greenfield, Ohio, is 100 feet. The principal fossils of the Greenfield dolomite are:

Schuchertella hydraulica (Whitfield).
Hindella (?) (*Greenfieldia*) *whitfieldi* Grabau.
Hindella (?) (*Greenfieldia*) *rostralis* Grabau.
Pentamerus pesoris Whitfield ?
 (horizon doubtful).
Whitfieldella subsulcata Grabau.
Whitfieldella rotundata (Whitfield).
Rhynchospira praeformosa Grabau.
Camarotoechia hydraulica (Whitfield).
Leperditia ohioensis Bassler.
Leperditia angulifera Whitfield.
Spharrococcites? *glomeratus* Grabau.

At their typical exposure, the Tymochtee shales are 24 feet thick and consist of tough, thin-bedded, bituminous shale. The contained fossils are *Leperditia alta* and a species of ?*Modiolopsis*.

The Put-in-Bay dolomite consists of more than 60 feet of massive brecciated, dolomites interbedded with thin-bedded dolomites. The colour ranges from blue to grey and cream. The commonest fossils found in the upper beds are *Goniophora dubia* (Hall) and *Spirifer ohioensis* (Grabau). The less common species are *Leperditia alta* (Conrad) and *Eurypterus micropthalmus*. The beds of this division are not known in contact with the Tymochtee shales or the Raisin River dolomite and their position and extent are hence somewhat problematical.

The Raisin River dolomite consists of grey-drab, magnesian lutites and oolites and is about 200 feet thick. The following fossils were obtained between 87 and 138 feet below the Sylvania sandstone in the Detroit salt shaft.

PLATEE.	<i>Spharrococcites</i> ? <i>glomeratus</i> Grabau.
BRACHIOPODA.	<i>Pholidops cf. orata</i> Hall. <i>Schuchertella hydraulica</i> (Whitfield). <i>Schuchertella interstriata</i> (Hall) <i>Whitfieldella plesseri</i> Grabau. <i>Camarotoechia</i> sp.
PELECYPODA.	<i>Pterinea lanti</i> Grabau. <i>Goniophora dubia</i> (Hall). <i>Tellinomya</i> sp. <i>Modiomorpha</i> sp.
GASTROPODA.	<i>Ectomaria minuta</i> (Hall). <i>Holopea</i> three sp. <i>Loromma</i> sp.
CEPHALOPODA.	<i>Cyclostoniceras oroides</i> (Billings).
OSTRACODA.	<i>Kledonia monroensis</i> Grabau.

Occurrences.

No outcrops of upper Cayugan rocks that can be directly correlated with the Bass Island series occur in Ontario, excepting the outcrop

Innerkip described above under Akron dolomite, and rocks forming the Canadian islands and reefs west of Pelee island. These islands are only a short distance from Bass islands, from whence the series name was obtained, and are described below from a brief study made of them by the author.

Hen island, which is nearest Pelee island, is a flat, park-like island of 4 or 5 acres extent, fitted out with club houses, a dock, etc. Its highest elevation is between 10 and 15 feet above the lake. Fine trees consisting of elm, maple, and hackberry furnish abundant shade. As might be expected from its exposed position, Hen island is underlain by resistant rock—a dense, fine-grained dolomite. The best exposure is on the north-west side where the following section is exposed in ascending order: 3 feet of massive, uneven weathering, fine-grained, buff dolomite containing numerous specimens of *Whitfieldella prosseri* Grabau and a few specimens of *Rhynchospira praformosa* Grabau?; 1 foot of light grey, laminated dolomite; 2 feet of massive, buff, fine-grained dolomite; 2 feet of massive, light brown dolomite containing 1 inch or more of sand mingled with the dolomite near its base. This sand, which makes up about half the material of the thin bed, weathers into relief, and shows the characters of the Sylvania sand. At the top of the section is a 2-foot bed of dense, fine-grained dolomite containing vugs of celestite (?) and weathering into a scraggy rock with numerous irregular spaces. The strike of the bedding at this locality is about east, 20 degrees south and dip south 6 degrees. Thus the strata exposed at the extreme eastern end of the island are lower in the section than those just described, about 5 feet more of the lower massive bed being exposed.

Big and Little Chicken islands are mere reefs washed by the waves except in the calmest weather.

East Sister, the largest of the group of islands, is low and flat and was formerly cultivated. Club houses are situated near the southeast end and peach trees planted some time before were struggling with weeds in September, 1914. A fringe of hackberry, maple, and wild grape surrounds the island. A gravel bar about 5 feet high is piled up along the south side, the gravel being in general under 2 inches in diameter and consisting of about 75 per cent dolomite and 25 per cent granite, etc.

At the western end of the island a small syncline occurs with direction of axis about north 40 degrees west. The dips toward the middle are about 2 to 3 degrees and the width of the syncline is only about 50 feet. Exposures to the east show buff dolomite overlying oolitic dolomite which occupies troughs 2 feet wide and 1 foot deep in the underlying rock, along an exposed length of 4 feet. This oolite corresponds closely with the description of the Raisin River oolites given by Grabau.¹ Farther west, thin-bedded, grey dolomite underlies oolitic dolomite about 2 feet in thickness. Below, to the east, dark massive rock is exposed containing numerous specimens of *Whitfieldella prosseri* Grabau and a few specimens (one observed) of *Spirifer ohioensis* Grabau. The extreme eastern end of the island consists of a dome of rock, about 50 feet wide, extending nearly east and west. Glacial striae here run about 5 degrees north of west. Probably not more than 25 feet of strata are exposed on the island, the exposures at the west end representing the top and those at the east end representing the bottom of the section.

¹ Grabau and Shetzer, p. 36.

North Harbour, the smallest of the islands, is about 300 yards long by 50 yards wide, and is covered with hackberry and maple trees. The shores are rocky except at the east end where the rock is covered with gravel. About 6 feet of beds are represented on the island, consisting of: light grey dolomite in 6-inch beds extending below the water; 2 feet of arenaceous dolomite with an irregular upper surface; and a massive 3-foot bed of dense, grey dolomite at the top. The remains of a fossil were seen in the upper bed, but no identification could be made. The beds lie nearly flat. The water on the south side is deep to the shore, that on the north side being shallower. Glacial striae on the north side run about 8 degrees north of west.

Middle Sister island is well wooded with maple, hackberry, and elm and has long been used as a fishing station. At the north end, and on the southwest, the rock is overlain by gravel. The best rock exposures are on the northwest side where a 10-foot section occurs, consisting of 6 feet of thin-bedded, buff dolomite and 4 feet of fine-grained, dense, buff grey dolomite at the top, which is irregularly bedded and contains fragments of *Whitfieldella prosseri* Grabau. Strata at the southwest end strike east 20 degrees south and dip south 6 degrees. Glacial striae at the southwest end run due west.

From the fossil evidence, there is no doubt of the Cayugan age of the dolomites of the islands described and from the presence of a sand streak in the dolomite of Hen island, it seems probable that the Sylvania sandstone itself was not much higher up. The close similarity in the lithology and fossils of all the islands suggests strongly that the same horizons are exposed on them. This supposition is further supported by the fact that the islands are probably on the strike of the same beds as a slight bending to the south of the western extension of the strike of the beds of the more easterly islands would include Middle Sister island. In other words, these islands are a remnant of the upturned edges of strata which alone in the whole formation were hard enough to resist glacial, wave, and all other erosion sufficiently to remain above the lake-level to the present time.

Of the fossils, *Spirifer ohioensis* is found in the upper part of the Put-in-Bay dolomite at Peach point, Put-in-Bay island; *Whitfieldella prosseri* is characteristic of the Raisin River dolomite, being found throughout the section of this formation in the Detroit salt shaft, and also at New Port, and Monroe, Michigan, and at Peach point, Put-in-Bay, where it is thought to mark the base of the Raisin River dolomite. *Rhynchospira praeformosa*, doubtfully determined for Hen island, is described from the Greenfield dolomite. The positive evidence thus points definitely to the Raisin River age and correlation of the strata exposed on the islands. The oölite found on East Sister island is apparently identical with the Raisin River oörites described by Grabau and is a further indication of identity with the Raisin River dolomite. The sandstone of Hen island suggests that the beds are near the base of the Sylvania sandstone and hence near the top of the Raisin River formation. *Spirifer ohioensis*, on the other hand, suggests correlation with the lower portion of the Raisin River dolomite, for this species is found in the beds at Peach point which Grabau placed at the top of the Put-in-Bay dolomite, but which may belong to the base of the Raisin River, as *Whitfieldella prosseri* is reported from the same place and the latter is exclusively a Raisin River species. If Hen island represents strata near the top of the Raisin River dolomite, there is plenty of room for the

Detroit River series, known to be thin east of lake St. Clair, to outcrop between this island and Pelee island which consists of rocks of Onondaga age. It may be noted that the distance here is less than that between Put-in-Bay island and Middle island (Onondaga), within which distance the Raisin River as well as the Detroit River series must outcrop.

Correlation of Bertie and Akron Formations with the Bass Island Series.

It has been shown above that Raisin River dolomite outcrops at Innerkip, and this locality is a connecting link between the regions occupied by well-defined Akron and Bertie dolomites and the Bass Island series. Although positive proof is lacking, there is a strong indication that the Akron and the Raisin River dolomites are to be correlated at least in part. The presence of *Schuchertella interstriata* in both formations supports this correlation and the somewhat close relationship of the *Whitfieldella* of these formations is suggestive. Again, the presence of *Laperdita alta* (Conrad) and *Eurypterus microphthalmus* Hall, in the upper beds of Put-in-Bay (which may yet have to be considered basal Raisin River), are clear evidence of Manlius affinities, since both these species occur in the Manlius of New York.

If the Akron is to be correlated with the Raisin River formation, including the upper beds in Put-in-Bay island, it would be natural to expect that the Bertie might be correlated with the Put-in-Bay dolomite if this lies just below, and the 12 feet of waterline found in the lower third of the section at Put-in-Bay is very suggestive of the Bertie beds. There is a strong probability that the Akron dolomite of New York, as stated above, is to be correlated with the Raisin River dolomite, and that the Bertie waterline may be correlated in part with the Put-in-Bay dolomite (if the latter has the relations assigned to it by Grabau) and in part with the Tymochtee shale and Greenfield dolomite. That the basin of sedimentation in Michigan and Ohio was deeper than that in New York, is shown by the thicker dolomite deposits.

Professor G. H. Chadwick disagrees with the above conclusions and offers the following alternative correlation.

Believing that the Put-in-Bay dolomite is above the Raisin River dolomite rather than below it as described by Grabau, and accepting the author's correlation of the Akron dolomite with the Raisin River dolomite, he correlates the Put-in-Bay dolomite with the lower Manlius (= Cobleskill); the Tymochtee shale with the upper Bertie (his Williamsville and Senjaquada divisions, and the Greenfield dolomite with the lower Bertie) (his Falkirk and perhaps Outka divisions).

His table is as follows:

Detroit region.	Western New York.
Put-in-Bay dolomite.	Lower Manlius = Cobleskill dolomite.
Raisin River dolomite.	"Roundout" waterline
Tymochtee shale.	Akron dolomite.
Greenfield dolomite.	Williamsville waterline and shale.
	Senjaquada limy shale.
	Falkirk dolomite.
	?Outka dolomite.
	Salina formation—shale, etc.
	Bertie.

This contention is supported by the presence of the *Maclius* species, *Leperditia alta*, and *Eurypterus microthalmus* in the upper beds on Put-in-Bay island, but on the other hand *Spirifer ohioensis* and *Whitfieldella prosseri*, as shown above, suggest the correlation of these beds with the lower part of the Raisin River dolomite.

It appears evident that no final correlation can be made until the relative position of the Raisin River and the Put-in-Bay formations is decided by additional field work, preferably in Ohio and Michigan.

GENERAL CORRELATION OF CAYUGAN GROUP.

The Cayugan members present in Ontario are much more limited in numbers than are those of central New York state, where the Pittsford shale and the Vernon shale are present below the Camillus shale and higher formations occur above the Akron dolomite. Bassler correlates the Salina shales in a general way with the High Falls shale of eastern New York, the Longwood shale of New Jersey, and the McKenzie formation of Pennsylvania, Maryland, and Virginia. He correlates the Decatur limestone of west Tennessee with the lower Salina shales and the Leclaire (lower Gower) of Iowa and Minnesota and the lower part of the Wanabakee limestone of eastern Wisconsin with the upper Salina shales (Camillus). In the upper Cayugan division Bassler includes, in ascending order: the Bloomsburg sandstone, the Wills Creek limestone, the Tonoloway limestone, and the Bossardville limestone, of Pennsylvania, Maryland, and Virginia, the Bertie and Akron being given as in part equivalent to the lower three divisions; the Sneedville limestone of Tennessee, given as in part equivalent to the Maclius of New York; the Kokomo limestone of Ohio west of Cincinnati, this being given as nearly the equivalent of the Bertie-Akron; and the Hillsboro sandstone and the Greenfield dolomite of southern Ohio and eastern Kentucky, given as representing the Bloomsburg sandstone and a part of the Maclius limestone respectively. The correlation of the Greenfield dolomite with the lower Maclius cannot stand if the writer's contention is correct, that the Greenfield dolomite is probably the equivalent of the lower part of the Bertie formation. Bassler correlates the Anamosa (upper Gower) of Iowa and Minnesota and the upper Wanabakee limestone of eastern Wisconsin with the Bloomsburg sandstone or lowest part of the upper Cayugan. He also correlates the lower Cayugan with the upper part of the Stonehouse formation of Nova Scotia, and the whole Cayugan group with the Ludlow group of England, Scotland, and Wales. Twenhofel correlates the Stonehouse with the Ludlow of Europe, but with the Guelph of America.

There is reason to believe that formations of Cayugan age will be found in northern and western Canada when more detailed stratigraphy is done.

CAYUGAN HISTORY.

The diastrophism or regional movements which terminated Guelph sedimentation, caused the sea to withdraw from the greater part of North America, but left the following water bodies: a basin which included the present Great Lakes exclusive of lake Superior, and a portion of the Appa-

lachian region as far south as southern Virginia; an arm of the sea including part of Newfoundland, Anticosti island, and Gaspé peninsula; and probably areas in Florida, Alabama, Georgia, California, and southeastern Alaska which were connected with the open seas¹. Unlike the other regions, the Great Lakes¹ Appalachian basin was practically isolated from the sea during the deposition of the Camillus shale and particularly during the extreme desiccation which caused the precipitation of the salt beds. At this period the marginal uplifted sediments were eroded and deposited in the basin, and their salt content was added to the salt contained in any ocean water that might have been entrapped during uplift and warping. A return of more pluvial climatic conditions or an inflow of the sea from the Atlantic, brought about a period of less desiccation during which gypsum was deposited. Submergence with freer access to the Atlantic continued into Bertie time, during which, according to Miss O'Connell, rivers flowing from the north over flat-lying land formed deltas in which the remains of *Eurypt-terida* were deposited along with normal marine forms. An actual shrinkage of the basin area took place during the deposition of the upper Bass island, and the Bertie-Akron sediments, but contact with the ocean continued and the faunas consequently remained generally of marine character. The sediments, however, were principally derived from the surrounding emergent formations, as is shown by their being largely magnesian calcilitities. Under these restricted conditions of sedimentation, shale deposits varied greatly in character and thickness from place to place and the dolomitic deposits varied similarly, as illustrated by the thin deposits in western New York and the thick deposits in Ohio and Michigan. Minor erosion intervals occurred marked by slight disconformities as that seen in the Raisin River dolomite on East Sister island. Sand, probably eroded from the exposed St. Peter sandstone to the west, driven by the wind over barren deserts, finally formed arenaceous streaks in the upper dolomites prophetic of the close of Silurian time.

The end of Silurian sedimentation came in the Great Lakes region by a continued emergence of the land until all was above sea-level and the whole area was dry. Subaerial deposition of sand, rock flour, etc., went on, but this sedimentation is really epi-Silurian or transitional to the Devonian and as such sediments were largely modified by the encroaching Devonian seas, they are not described here.

¹Bull. Geol. Soc., Am., vol. XX, 1910, pp. 127-693.

CHAPTER VI. ECONOMIC GEOLOGY. INTRODUCTION.

The economic products from the Silurian rocks of Ontario may be divided into two groups: the first including those products derived directly by quarrying or mining the rocks outcropping at the surface, such as building stone, road metal, gypsum, rock for flux, and cement, lime, brick, and tile manufacture; and the second those that have to be obtained by drilling such as salt, petroleum, and natural gas. One small zinc prospect, though not of economic importance, will be described under the first division.¹

Although the formations vary much from place to place, it has been found quite possible to state in general terms for what purposes the rock of a formation can or can not be used. With products such as road metal and crushed stone for concrete and building stone, location is of great importance, and it is hoped that by the use of Maps 1714 and 1715 the best outcrops may be chosen for economic development.

The raw material contained in the Silurian formations, consists of magnesian limestone and dolomite of varying degrees of purity, sandstone of different colour and character, waterlime, shale, gypsum, rock salt, petroleum, and natural gas. Sphalerite, or zinc blende, galena, celestite, and some other minerals are scattered through the dolomites in small, unimportant quantities.

For detailed descriptions of the various industries and deposits, refer to the reports mentioned in the Bibliography on: building and ornamental stone by Parks; road metal by Reinecke; gypsum and salt by Cole; natural gas and petroleum by Clapp, Malcolm, and Knight.

BUILDING STONE.

MEDINA SANDSTONE.

An excellent quality of sandstone for building purposes has been obtained for many years from the Whirlpool member of the Medina-Cataract formation. This stone varies locally in colour from white or grey, to mottled and chocolate brown, and is best known as Credit Valley sandstone, because of the extensive quarrying carried on in the valley of Credit river. The buildings of the Legislative Assembly, Toronto, are built of Credit Valley brown sandstone.

The Whirlpool sandstone outcrops along the Niagara escarpment between Niagara river and a point about 8 miles south of Collingwood. The outcrops occur along the lower boundary of the Medina-Cataract formation, of which the Whirlpool sandstone is the lowest member in this region. The following general description is taken from Parks.² "The sandstone band of the Medina formation has an average thickness of about 12 feet only . . . most of the quarries exhibit irregular bedding, with lenses of one variety cutting diagonally across others. This irregularity has proved the greatest hindrance to the profitable extraction of the stone. Most of the beds are fine-grained and present roughly three

¹This account of various raw materials used for economic purposes is supplementary to the information contained in the descriptions of the various geological formations and should be read with constant reference to the geological maps and sections.

²"Building and ornamental stones of Canada," vol. I, Dept. of Mines, Mines Branch, 1912, p. 139.

types: first, a brown to chocolate-coloured variety, quarried chiefly at the Forks of the Credit; second, a white or grey variety obtained at Orangeville and from Milton northward to the Forks of the Credit; also at Hamilton; and third, a mottled variety in which blebs and bands of white occur in the brown base. This latter kind is obtained more particularly from Merriton to Grimsby. The formation occurs along the face of the Niagara cuesta from near Merriton to Hamilton. Between Hamilton and Milton the cuesta is much broken up and the exposures are few, but from the latter place northward to Cataract, outcrops are numerous. Above Cataract, the stone is hidden very largely, but an important outcrop is known east of Orangeville and again near Shelburne. At no place is the exposure wide, as it appears only along the face of the 'mountain' and has scarcely any lateral extent. The widest and most accessible places occur where the sandstone forms the top of a shoulder, on the mountain side. Much of the quarrying has been done by removing a heavy overburden or by actually mining into the side of the hill. Unfortunately, those places where the stone is most easily obtained yield a poorer produce than where it is less accessible."

The more important areas for building stone are in the Credit Valley and to a lesser extent near Orangeville. Elsewhere, as in the Niagara and Milton areas, the stone is mostly used for rubble and rough coursing.

Dolomite and Magnesian Limestone. The Manitoulin dolomite is generally thin-bedded and argillaceous or clayey, and is consequently little used for other than rough coursing stone or rubble. In northeastern Owen Sound, about 25 feet of the Manitoulin beds are quarried for coursing stone; and a small amount of coursing stone has also been taken from small quarries (on lots 24 and 25, concession XI, Nottawasaga township, Simcoe county) about 8 miles south of Collingwood. In the vicinity of Manitowaning, Manitoulin island, the upper part of the Manitoulin dolomite is crystalline and probably could be worked locally for building stone. Much of the rock is thin-bedded, but at some localities it is very massive due to the presence of coral and bryozoan reefs; both of the extremes should be avoided in selecting a quarry site.

The Lockport (Niagara) dolomite, with its more or less local subdivisions, is generally suitable for building stone, and is accessible almost everywhere along the Niagara escarpment, and over large areas of Bruce peninsula and Manitoulin island. The DeCew waterline is highly argillaceous and is consequently weak and unsuitable for building stone. The Gasport limestone of western New York is represented on the Canadian side by dolomitic limestone, highly crystalline and crinoidal in character. The Gasport loses its identity west and north of Dundas. The colour is generally dark blue, light blue, or grey, but some local areas are brown or pink. It is principally this stone which is quarried at St. David's and Thorold where considerable amounts of dimension stone are produced.

The greater part of the Lockport formation below the Eramosa beds is grey or blue-grey on fresh fracture, weathering white, light grey or creamy. Some of the lower beds are light yellowish brown on fresh fracture. In a formation of such thickness much variation is to be expected. Rare spores are numerous and large in some horizons and particularly in those that are fossiliferous, such as the "Pentamerus" beds occurring at the base of the formation in the Owen Sound district and northward.

Iron pyrites is common in the Pentamerus beds in some places and occurs also at other horizons. Good stone, however, is present in large amount at most localities.

Extensive quarrying was formerly carried on near Beamsville in the lower part of the Lockport formation. At Owen Sound, beds about 20 feet above the base are quarried. At Shelburne, beds high up in the Lockport, just below the Eramosa division, are quarried. An example of this fine stone is to be seen in the Shelburne post-office (Plate XXXIV A).

The upper beds of the Lockport (probably a little lower than the Eramosa beds which have not been found on Manitoulin island), were quarried extensively by the Lake Superior Corporation at Quarry point about 7 miles south of Meldrum bay, Manitoulin island, for the stone work of the Sault Ste. Marie canal, on the Canadian side. The stone weathered grey, and has apparently been very satisfactory for the purpose for which it was used. Huge piles of waste at the quarry, however, show that much sorting of material was done. Many localities along the northern shore of the western end of Manitoulin island and Cockburn island afford excellent opportunity of obtaining Lockport dolomite of good quality at or near the water's edge.

The Eramosa dolomite is characteristically thin and even-bedded. At some localities these beds are almost as cleavable as slate, and toward the top the partings are commonly bituminous. The colour is generally dark grey, banding of different shades being common. Near the city of Guelph, brown shades predominate.

The Eramosa beds outcrop below the base of the Guelph formation at many localities, but they and the Guelph are not known on Manitoulin island.

At a quarry west of Wiarton (lots 7 and 8, concession XIV, Amabel township, Bruce county) the upper Eramosa beds are worked. The thin even-bedding, characteristic of this division of the Niagara, is here of great value in the production of stone of uniform thickness such as is required for monument bases and sills. The Eramosa beds are also quarried at Hamilton and Dundas, but at present the output is for road metal, concrete, etc.

The Guelph dolomite varies much in character according to locality and horizon. The lower few feet are rather thick-bedded, but partake of the bituminous nature of the underlying Eramosa beds. The colour is consequently brown and a strong oily smell is common. These beds are not used for building stone. Beds higher up are commonly fine-grained and dense, the bedding being thin and the colour light brown or grey. The beds near the top of the formation and those which appear to belong to the middle third are commonly light grey or cream-coloured, weathering sandy. Pore spaces are numerous and are of various sizes, being particularly large in the more fossiliferous beds. The bedding in the upper division is generally thick to massive.

The lower, fine-grained Guelph beds are not used for building stone although quarried at Fergus for crushed stone and lime. Beds a little higher were formerly used at Fergus, Elora, and Guelph for local construction, as were the upper fossiliferous beds at Hespeler and Galt. The stone from the higher beds is porous but cuts easily and gives a very pleasing effect in the walls and trimmings of the buildings in which it has been used. Its wearing qualities are good. Large quantities of Guelph dolomite

available in the vicinity of the towns cited above, as well as at many other places within the Guelph area, especially on Bruce peninsula. As there is a considerable demand for crushed stone in the more thickly settled parts of the country, waste material from building stone quarries can be readily disposed of.

The Cayuga formations contain no beds that are very suitable for building. The Salina formation consists of shales and thin, impure dolomites in the lower part and brittle dolomites and waterlimes in the upper or Bertie division. The overlying Akron dolomite is thin-bedded and jointed. The Bass Island (Lower Monroe) formations of the Lake Huron and Detroit River regions are similar in character to the Bertie and Akron divisions with which they are correlated in this report.

ROAD METAL AND CRUSHED STONE.

The finer-grained, harder, Silurian dolomites are well suited for the construction of macadam roads subjected to medium traffic. The more porous, crystalline beds should be carefully avoided as the rock is too soft and crumbly to be useful for road metal.

The Manitoulin dolomite (Cataract) is quarried for coursing stone and road metal at Owen Sound and this material would doubtless also be useful for crushed stone for concrete work. L. Reinecke found this stone to be inferior in toughness, and to be suitable only for roads subjected to very light traffic. On the eastern part of Manitoulin island, the Manitoulin dolomite is very similar to the Lockport in character and would doubtless give good results for crushed stone and road metal.

The Clinton limestone thins out in Ontario and generally outcrops in the face of the Niagara escarpment in such a way as to be inaccessible for quarrying. The upper beds are tough and hard to work, particularly in the vicinity of Hamilton and Ancaster where they are known as the "Nick or Head" beds. The lower Clinton beds occur at the base of the Lockport as far north as Kelso. Except for their inaccessibility, the Clinton beds would probably be useful for crushed stone and road metal.

The Lockport dolomite is extensively used for crushed stone for concrete and road metal. The largest quarry in this formation is that operated by the Canada Crushed Stone Corporation, Limited, at Dundas. The lower 32 feet of strata here are the Eramosa beds and the upper 25 are Guelph. This stone has been favourably reported on for road metal by Reinecke. According to his report it is suitable for roads subjected to light traffic and is one of the very best of the limestone-dolomite group in the country. Other quarries are operated in the Lockport at St. David's, Thorold, Hamilton, Ancaster, Waterdown, Orangeville, and elsewhere. According to Reinecke, tests made on the stone at Ancaster show it to be very similar to that at Dundas. Stone of the general characters of that already tested could be obtained at many places along the Niagara escarpment and at other localities over the extent of the Lockport outcrops.

The Eramosa beds at the top of the Lockport dolomite are cleavable, siliceous and bituminous in part, and as shown above are found suitable for road metal at Ancaster, Dundas, and elsewhere. Outcrops of these beds are to be found east of Guelph, in the quarries at Ancaster and Dundas, at the quarries for dimension stone west of Warton, at Halfway rock, on

the north shore of Bruce peninsula, and on Flowerpot and other islands in Georgian bay. These beds are generally capped by tough Guelph strata with which they could be quarried to good advantage, as is done at Ancaster and Dundas.

The Guelph dolomite varies much in character, but where fine-grained is very resistant and furnishes splendid material for crushed stone for concrete, artificial stone, and road metal. The quarries operated at Galt and Fergus furnish good stone for such purposes. Reinecke reports that the stone from the Gow quarry, Fergus, is suitable for light traffic only. It has, however, worn well on local roads. The upper 2 or 3 feet at Ancaster and the lower 2 or 3 feet of strata quarried at Dundas are Guelph. A large quarry is operated by the Canadian Pacific railway for ballast, about one mile south-west of Shaw station, and quarries are operated at Rhymal and elsewhere. Many outcrops occur for opening quarries in the Guelph rock over 100 feet of its outcrops, but where road metal is required, only the hardest and densest stone should be selected; a selection can generally be made by examining the surface exposures.

The Bertie-Akron dolomites furnish good road metal in the vicinity of Byng near Dunnville. Similar rock occurs west of Cayuga and in the bend of the Saugeen river about $2\frac{1}{2}$ miles north of Walkerton (see page 89). The outcrops of rock at Lunenburg and on the islands west of Pelee island, belonging to the Bass Island series, would be serviceable for crushed stone and road metal.

CEMENT.

Magnesian limestones carrying considerable quantities of argillaceous (clayey) matter, and known as waterlimes, were formerly burned in kilns to a natural rock cement which possessed the characters of a low grade Portland cement. With the standardizing and increased manufacture of high grade cement, the natural rock cement industry has died out.

DECEW WATERLIME BEDS.

At one time considerable amounts of the DeCew beds were mined at St. Davids, Thorold, and DeCew falls, for the manufacture of natural rock cement. Quarries were also worked in these beds at Mount Albion and probably elsewhere. Six feet of cement rock was worked at St. Davids, and 8 feet at Thorold and DeCew falls. At St. Davids and Thorold the rock was mined on the room and pillar system, the entrances being levels run from nearby quarries. The cement manufactured at Thorold was used in the building of the Welland canal and Victoria bridge. For analysis of the DeCew beds see page 112. The DeCew beds are available for mining at various places along the Niagara escarpment between Hamilton and Niagara river.

BERTIE WATERLIME.

About 6 feet of Bertie waterlime was formerly quarried at North Buffalo and burnt to natural rock cement. Beds of similar character occur at quarries north of Ridgeway (lot 1, concession X, Bertie township) and in the quarries at and near Byng across the Grand river from Dunnville. Should a demand arise for such rock, it may be obtained at the places mentioned and also in the vicinity west and south of Bridgeburg, Ontario.

PORTLAND CEMENT.

No limestones low enough in magnesia for the manufacture of Portland cement are found in the Silurian system of southwestern Ontario. Such limestones should be sought in the areas underlain by Ordovician (e.g. Trenton) and Devonian (e.g. Onondaga) formations.

DOLOMITE FOR FLUX.

Dolomite or high magnesian limestone is required in the sulphite process of paper-manufacture from pulpwood and also for flux in the basic open-hearth process of steel manufacture. Because dolomite may be obtained more cheaply for some blast furnaces, for example at Hamilton, it is used for flux instead of limestone, which is otherwise preferred. Dolomites from Rhymal and Dundas are used in the Hamilton blast furnaces. About 30 per cent of the total production, including the entire upper bed of the rock quarried at Dundas by the Canada Crushed Stone Company, is sold for flux for blast furnaces. From the analyses (pages 110 to 116), the characters of the Silurian dolomites may be studied. The distribution of the various formations is given in the chapter on stratigraphy.

MANUFACTURE OF CHEMICALS.

High grade limestone such as is required for chemical manufacture is not found in the Silurian formations. This is to be found in the Onondaga and Anderson limestones at Amherstburg and Beachville¹.

Dolomite is suitable for the manufacture of carbon dioxide, and the purer forms such as are found in the Niagara and Guelph formations are easily available for such purposes.

DOLOMITE FOR LIME MANUFACTURE.

Magnesian limestone and dolomite burn to quicklime which makes strong mortar, although it is somewhat slow in setting. For the manufacture of hydrated lime, the presence of considerable quantities of magnesium carbonate in the rock is essential.

Formerly all the Silurian dolomites were burnt to some extent for quicklime. The lime-kilns were largely operated by farmers to supply the local demand, wood being used as fuel. The remains of old kilns near rock outcrops, in nearly all parts of the country, testify to the source of the lime used in local building enterprises.

The Manitoulin dolomite was burnt for lime on many parts of Manitoulin island, and especially near Manitowaning and Gore Bay. The Lockport dolomite was formerly burnt at many localities along the Niagara escarpment, and is still burnt at Ancaster, Kelso, Linchouse, Rockwood, Owen Sound, and elsewhere.

Guelph dolomite is burnt to quicklime at Puslinch, Hespeler, Galt, Flora, Fergus, and in the vicinity of Guelph, where it is also manufactured into hydrated lime by the Standard White Lime Company.

The Bertie-Akron dolomite was formerly burnt to quicklime at Springvale, Inverkip, 2½ miles north of Walkerton along the Saugeen river, and 2 miles south of Pinkerton.

¹ *Can. Jour. Geol.*, Can. Mem. 31, 1913, pp. 271, 274, 279.

Great quantities of raw material are available for the manufacture of hydrated and ordinary lime. It is obvious that in choosing a quarry site, cherty dolomite and dolomite full of clayey impurities should be avoided. For analyses of the various rocks see pages 110 to 116.

SHALE FOR BRICK AND TILE MANUFACTURE.

The Cabot Head shale as known on the mainland of Ontario is too sandy or else contains too many calcareous beds to be useful in the manufacture of brick or tile. A considerable thickness of nearly uniform, red, plastic shale is found, however, in the Cabot Head shale of Manitoulin island. A sample of this shale collected by the author on the road allowance on lot 16, concession IX, Billings township, was submitted to J. Keele, chief of the Ceramic division, Mines Branch, Department of Mines, who reported on it as follows:

"This shale is very plastic, smooth, and stiff, when tempered with water. Owing to its stiffness it is hard to work, and would be improved in this respect by the addition of sand.

The material dries without cracking, with shrinkages within working limits, and burns to a hard, dense, red body at low temperatures.

This clay appears to be suitable for the manufacture of building brick, hollow ware blocks, and field drain tile. It may be possible to use it for roofing tile also."

The shale from which the sample was taken occurred in a 50-foot section exposed along the road for about one-eighth of a mile. It is situated about $2\frac{1}{2}$ miles from West bay, Indian village. A smaller exposure occurs on lot 28, concession IX, Allan township, about 3 miles southeast of the town of Gore Bay. The clay is exposed in the road on both sides of a small hill, which is capped with an impure dolomite. Large quantities of clay could doubtless be obtained below the surface soil on the flanks of the hill.

Other less favourably located outcrops of this shale occur on Manitoulin island, one of the best being on lot 27 on the road between concessions 4 V, Bidwell township, and $1\frac{1}{4}$ miles west of lake Manitou.

ZINC BLENDE.

Small particles of galena and sphalerite, or zinc blende, are widely scattered through the Niagara and Guelph dolomites. Particles of galena may be found in the Lockport dolomite at the top of the falls at Grimsby, at Rockwood, and east of Guelph. Zinc blende may be seen at Rockwood and elsewhere.

The only notable amount of zinc blende reported, however, was discovered by Dr. Wolverton of London, on lot 30, concession 11, Alburgh East township, Bruce peninsula, about 4 miles northwest of Winton. Under the direction of Mr. G. B. Bourne considerable prospecting has been done since 1900, an excavation having been made measuring approximately 30 feet in length, 10 feet wide, and 25 to 30 feet in greatest depth (not 100 feet by 30 feet by 30 feet, as reported in the Summary Report, 1912, page 281). The rock is massive, very scraggy and full of pore spaces and cavities, and when fresh is a light blue colour. The large amount of pore spaces and cavities is principally due to the solution of fossils which are

large and numerous, some of the cephalopods being over 1 foot long and 6 inches in diameter. The zinc blende occupies these cavities, the mineral in some cases partly replacing fossils. The action of surface waters has in some cases caused a concentration of pieces of zinc blende at the bottom of small pockets, into which the blende has fallen on being released from the rock by solution of the dolomite to which it was attached. About 110 pounds of loose blende is said to have been obtained in such a pocket, where it was mixed with soil and pieces of rock. The ore continues down to a depth of 20 feet, below which no ore has been found.

A shipment of several hundred pounds of this ore was made previous to 1912, the lot being said to assay 69.76 per cent zinc. When last visited (September 1916) about two cords of hand-picked ore was piled up alongside the prospect.

The zinc blende occurs in dolomite of lower Guelph age, closely related in fauna to the Racine beds of Wisconsin. Not far below the zinc deposits is the top of the Eramosa, arenaceous dolomite forming the upper division of the Lockport formation. These beds, because of their fine-grained, impervious nature have doubtless prevented downward movement of the surface waters, which on this account moved entirely in a lateral direction, dissolving such minerals as zinc blende under favorable conditions for solution and precipitating them where numerous pore spaces and cavities existed owing to the solution of fossils. The accumulation in local pockets is doubtless very recent, and due to surface solution.

GYPSUM.

Extensive gypsum deposits occur in the Salina¹ formation of western New York and of the adjoining Niagara peninsula of Ontario as far west as the vicinity of Paris. The gypsum occurs near the top of the Camillus shale and just below the Bertie waterline (see the description of the core drill record at Buffalo). Some gypsum occurs at the top of the shale throughout Ontario peninsula, as we may judge from evidence of well borings. In the west and north, however, gypsum occurs in small amount and salt occurs in large quantities lower down in the Salina. For further discussion of the Salina formation and the origin of the gypsum deposits, see Chapter V, page 84.

The workable deposits of gypsum, as at present known, occur along Grand river between the old gypsum mines, 4 miles southeast of Cayuga, and old workings about 1 mile northeast of Paris. Grand River practically follows the outcrop of the gypsum, which being quite soluble has been easily eroded away. Colver has mapped the workable gypsum deposits in such a way as to separate the above region into two areas, a western area included within a radius of 2 miles of Paris and not definitely determined towards Brantford; and an eastern area of oblong shape extending from a point about 4 miles east of Brantford to the bend of Grand river 4 miles west of Dunnville, the greatest width being about 6 miles in the vicinity of York. These areas contain the workable deposits at present known, the only actual mining being carried on in the vicinity of Caledonia and York. Well records, however, indicate gypsum throughout Niagara peninsula, although the exact thickness is not indicated in most logs of wells kept by

¹ Formerly known as the Onondaga formation: Onondaga is now properly used for a Devonian formation =

"Salina in Canada," Dept. of Mines, Mines Branch, 1913, p. 75.

the gas companies. In New York state, exploration is being done at more than 100 feet in depth and it is the cost of production compared with the market price which will determine the limit in depth at which the Ontario gypsum may be worked. As the average southerly dip per mile of the geological formation is about 30 feet, it will be seen that $3\frac{1}{4}$ miles south of the outcrop, a bed of gypsum will be approximately 100 feet lower than at the outcrop. Differences in the elevation of the surface of the land must, of course, be taken into account in estimating the depth of the gypsum below the surface. The gypsum is without doubt lenticular, but the horizon is extensive and there seems no reason to suppose that deposits as good as those already known may not yet be discovered in Niagara peninsula, at, however, greater depths than those now being worked. Under present conditions, the cost of working such deposits would doubtless be prohibitive.

For detailed discussion of the gypsum industry of Grand valley, see "Gypsum in Canada."¹

On January 1, 1917, the two companies formerly operating in Grand River valley, viz., the Alabastine Company, Limited, of Paris, and the Crown Gypsum Company, of Lythmore, amalgamated under the name of the Ontario Gypsum Company, Limited. The Alabastine Company manufactured wall tints, known as alabastine, and wall plaster, as well as ground gypsum for retarder in the manufacture of portland cement and for fertilizer or land plaster. The Crown Gypsum Company manufactured wall plaster. The operations of the two companies are now carried on by the Ontario Gypsum Company.

The principal mine formerly worked by the Alabastine Company is on lots 10 and 11, concession 1, west of the Hamilton road, Seneca township, Haldimand county. About 15 acres have been mined, operations being carried on in part on three different levels. The room and pillar method of mining is followed, the rooms on the second level being 20 feet square and the pillars 12 feet; the rooms on the third level are 18 feet and the pillars 14 feet. Underground haulage is done by means of horses and the gypsum is finally raised to the surface along an incline by steam power. Self-dumping cars carrying the gypsum in steel half cylinders are used. Little water is encountered, the mine being so dry and comfortable that the visiting members of the Twelfth International Geological Congress were served dinner by the Alabastine Company in August, 1913, in the main station of the mine on the second level.

The product of this mine is green gypsum which is used in the manufacture of land plaster and as a regulator for the setting of portland cement. Large reserves are held north of the present workings.²

The Carson mine "located about three miles south of Caledonia village in Oneida township" supplied the Alabastine Company with pure white gypsum for its finer products. The bed of gypsum worked³ is about 1 foot thick, and mining is carried on as at Caledonia. "Overlying the bed of white gypsum are layers of dolomitic shales and limestones, in all from 4 to 6 feet in thickness, covered by 40 to 50 feet of post-Glacial drift. The roof here is not in as safe a condition as at Caledonia, where the grey beds are from 9 to 12 feet in thickness, overlying which are 40 to 50 feet of dolomitic limestone and shales covered by the post-Glacial drift."

¹ Ibid., pages 57 to 77.

² Ont. Bureau of Mines, 1915, vol. XXIV, pt. 1, p. 153.

³ Ont. Bureau of Mines, 1915, vol. XXIV, pt. 1, p. 159.

The mine formerly operated by the Crown Gypsum Company is situated near the village of York on the south side of Grand river, on lots 58 and 59, Orinda township, Haldimand county. This is known as the Martindale mine.

The following is taken from Cole's description, page 67.

"The property on which this Company's working mine is situated is one of the first places in this district from which gypsum was mined. With the exception of about twelve years, this gypsum bed has been operated continuously since about 1866.

The beds are covered with about 70 feet of drift, shale, and limestone. The one that is being worked is reached by an incline tunnel 500 feet in length with a bearing of north 73 degrees east. This bed consists of very high grade, white gypsum suitable for the best grades of plaster of paris, and breaks clean to both floor and back so that very little waste has to be sorted out underground. Hand power is employed for drilling the waste rock in the mine. The bed has an average thickness of about 4 feet and as only the gypsum is broken, the workings are consequently very low thus making moving around underground very difficult.

The method of mining the gypsum in this mine is very similar to the room and pillar method employed in coal mines....."

For descriptions of the abandoned mines and prospects see Cole's report.

The output of gypsum for Ontario reached a maximum in 1914, the production being: gypsum mined, 89,157 tons; gypsum shipped, crushed, or ground, 43,183 tons; ground and calcined gypsum used in gypsum products, 33,705 tons; the manufactured products being valued at \$162,375 and the total production \$221,175.

The total output in 1917, crushed, ground, and calcined,² was 48,656 tons valued at \$128,828. This is a falling off of 44,744 tons since the maximum production of 1914, which was 93,400 tons of gypsum and gypsum products.

SALT.

The total Canadian production of salt is obtained from the Camillus shale of the Salina formation of the Ontario peninsula. As shown on Cole's map,³ the productive salt deposits are approximately included in the area lying between lake Huron, St. Clair river, and lake St. Clair on the west, and a line from the shore of lake Huron at Inverluron south through Brussels half-way between Seaforth and Dublin, to the east of London and to lake Erie shore half-way between Dutton and Port Stanley. The southern boundary extends from near the Elgin-Kent boundary on lake Erie shore through Thamesville, and to the shore of lake St. Clair a few miles north of the mouth of Thames river. A small area in the vicinity of Windsor is also salt-producing. The salt occurs in several beds which are more or less lenticular, as is illustrated by the occurrence of 125 feet of salt (with some shale beds) in a well bored on the south side of Thames river about 2 miles west of Prairie siding, although no salt was reported in the wells drilled all around this locality. Another similar occurrence is that of 400 feet of salt penetrated in a well

¹ Rept. Bureau of Mines, 1915, p. 42.

² Rept. Bureau of Mines, Bull. 33, 1917, p. 3.

³ Salt deposits of Canada and the salt industry," Dept. of Mines, Mines Branch, 1915, opposite p. 20

in the Wheatley oil field. The most extensive gypsum deposits do not occur in the salt area, but considerable gypsum is found in the Camillus shale overlying the salt. Some gypsum is interbedded with the salt at Goderich and gypsum occurs below the salt at Courtright. However, owing to the small amount of gypsum present and to its lower solubility than salt, little trouble is experienced in the manufacture of salt from Ontario brines.

Several beds of salt may be penetrated by a well; for example six occur at Goderich, the total thickness of salt being 126 feet. At Windsor, four beds are reported with a total thickness of 427 feet.

Salt is obtained by evaporating the brine pumped up from the wells. The water forming this brine is allowed to flow into the wells, usually from a water-bearing stratum high above the salt. Evaporation is accomplished by steam heat or by a vacuum process.

Besides the general production of table, dairy, and coarse salt for meat packing, etc., caustic soda and bleaching powder are manufactured by the Canadian Salt Company at Sandwich.

Salt was first discovered by Mr. Platt at Goderich in 1866, while drilling for oil. At present, salt is manufactured at Goderich, Kincardine, Wingham, Clinton, Exeter, Parkhill, Elarton, Sarnia, Courtright, Windsor, and Sandwich. The total production¹ for 1917 was 138,528 tons, valued at \$1,095,866. This is the maximum production to date. In 1916, 305,900 pounds, valued at \$2,223, were exported and 151,208 tons, valued at \$694,835, were imported, including 109,493 tons, valued at \$523,725, imported from Great Britain for the use of coast fisheries.²

Analyses of Brine from Rock Salt, Southwestern Ontario³.
Hypothetical combination: 1,000 parts by weight contain:

	I	II	III	IV	V	VI	VII	VIII
NaCl	244.860	253.105	266.415	258.770	263.921	260.812	245.111	256.891
CaCl ₂	1.265	1.066	1.895	1.484	0.477	0.111	4.964	1.007
MgCl ₂	0.966	0.534	1.884	1.017	2.010	0.297	0.503	0.467
CaSO ₄	0.728	4.037	2.757	3.730	3.939	4.476	2.405	3.971

- I. Western Canada Flour Mill's well, Goderich, Ont.
- II. American Chemical Co.'s well, Goderich, Ont.
- III. Stapleton Salt Works, Clinton, Ont.
- IV. Ontario Peoples Salt and Soda Co., Kincardine, Ont.
- V. Sparling Co., Wingham, Ont.
- VI. Western Salt Co., Mooretown, Ont.
- VII. Dominion Salt Co., Sarnia, old well.
- VIII. Dominion Salt Co., Sarnia, new well.

Analyses of Brine from the Platt Well at Goderich⁴.

	Parts per 1,000.	In 100 parts of solid residue.
NaCl.....	259.000	99.018
CaCl ₂	0.432	0.165
MgCl ₂	0.254	0.097
CaSO ₄	1.882	0.720
	261.568	100.000

¹Ont. Bureau of Mines, Bull. 33, 1917, p. 3.

²Mines Branch, Dept. of Mines, Sum. Rept., 1916, p. 174.

³"Salt deposits of Canada," table III, p. 48.

⁴Geol. Surv., Can., 1866, p. 269.

As no analyses of the brines from the Windsor wells are at hand the following analysis is given to represent this region.

A typical Brine Direct from the Well of the Delray Salt Company, Delray, Michigan, near Detroit¹.

KCl	trace
NaCl	290.6
CaCl ₂	trace
MgCl ₂	3.6
CaSO ₄	3.1
MgBr ₂	trace

Analyses of Brines from New York State, for Comparison².

	I	II
MgCl ₂	0.155	0.049
CaCl ₂	0.129	0.131
CaSO ₄	0.599	0.319
NaCl	16.921	23.295

- I. From the Onondaga natural brine.
- II. From artificial brine from the solution of the rock salt.

Analyses of Rock Salt from Attrill Well, Goderich³.

	I	II
NaCl	99.687	91.24
CaCl ₂	0.032	0.57
MgCl ₂	0.035	0.05
CaSO ₄	0.090	2.81
Insoluble	0.017	5.33
Moisture	0.079	
	100.000	100.000

- I. From the white translucent portion of the second bed in the Attrill well core.
- II. From the less pure salt from the same bed.

The following comparison is by Hunt.⁴

	Impurities.
	Per cent.
Cheshire salt	2.67
Cordova, Spain, salt	1.45
Furks Island salt	2.34
Saginaw salt	2.00
Syracuse solar salt	1.15
Syracuse boiled salt	1.50
Goderich coarse salt (analysis made in 1871) ..	1.09
Goderich medium salt	1.28
Goderich fine salt	1.62

¹Cook, C. W., Mich. Geol. and Biol. Surv., Pub. No. 15, geol. ser. 12, p. 89.

²Howlands, D. H., N. Y. State Mus., Bull. 174, p. 68.

³Geol. Surv., Can., 1885, p. 269.

⁴Geol. Surv., Can., vol. V, pt. II, p. 164 s.

For further comparison, the following analyses of rock salt are added.

Analyses of Rock Salt from New York State.

	I	II
Moisture	Trace.	Trace
Insoluble	0.7430	0.0584
CaSO ₄	0.4838	0.0793
CaCl ₂	0.0180	0.0358
MgCl ₂	0.0546	0.0888
NaCl.	98.7006	99.7410

- I. An average sample of salt mined in New York state.
 II. "Perfectly white salt."

The superior quality of the Ontario salt is clearly illustrated by comparing the above analyses.

PETROLEUM.

Of the petroleum obtained from southwestern Ontario, only a small part comes from Silurian formations, the most of it being found in the Onondaga (Corniferous) limestone of the Devonian system. Some oil, however, is obtained from the Whirlpool sandstone in Onondaga township, Brant county, and from the top of the Guelph and the lower Salina of the Tilbury field and the Guelph of the Wheatley field.

The oil production from the Whirlpool sandstone is obtained¹ from Onondaga township, Brant county, about 7 miles east of Brantford along Fairchild creek, and from an area approximately $1\frac{1}{2}$ miles long by 1 mile wide. The Whirlpool sandstone is here 20 feet thick and lies 500 feet below the surface. This field was opened in 1910, reached its maximum production of 13,501 barrels in 1914, and produced 1,617 barrels in 1916.

As interpreted from drill records, the upper Guelph and lowest Salina strata yield oil in the Tilbury field, which is situated in the eastern part of East Tilbury and the western part of Raleigh townships, Kent county. Including the gas field which extends to lake Erie and includes the eastern point of Romney township, the field is 9 miles in length from north to south and 8 miles in greatest width which is along the shore of lake Erie. In the vicinity of Stewart, East Tilbury, gas is reported from a depth of 1,363 feet and oil from 1,393, 1,418, and 1,430 feet.

Oil is also obtained from the Guelph formation in the Wheatley field at a depth of 1,290 and 1,300 feet. This field includes a small area east of Wheatley in the southwestern part of Romney township.

The production of oil for Tilbury and Romney, which was 106,992 barrels in 1906, reached a maximum of 411,588 barrels in 1907 and then rapidly fell off, being 16,297 barrels for 1916 (as reported for Tilbury, presumably including the Wheatley field)² which was a gain of 3,552 barrels over 1915, the lowest output since the opening of the field.

Oil in Ontario is generally found to occur at the top of domes and anticlines, where it is driven by the greater specific gravity of salt water. In the case of formations that contain no water this rule does not hold.

¹Merrill, Frederick G. H., Bull. N. Y. State Mus., No. 11, 1893, p. 47.

²Geol. Surv., Can., Mem. 81, 1915, p. 61.

³Ont. Bureau of Mines, vol. XXVI, 1917, p. 32.

but the Silurian formations containing oil generally contain salt water also. The present tendency is to explore the Guelph and Salina formations, where not already tested, below the domes and anticlines discovered in the development of the shallower oil fields (Onondaga or "Corniferous") (see structure, pages 11 to 14).

GAS.

Most of the gas found in Ontario is from formations of Silurian age. The Medina-Cataract sandstones and shales, the Clinton limestone, the Guelph dolomite, and the Salina shale all bear locally important quantities of gas.

The Medina sandstones are generally gas-bearing. Quoting Malcolm¹ "The greater proportion of the gas of the Selkirk, Port Dover, and Delhi fields is derived from the red Medina sandstone (Grimsby member), although small quantities are found also in the white Medina sandstone (Whirlpool member), and in the Clinton formation. The White Medina sandstone is the productive horizon for the gas of the Bertie-Humberstone, Wamfleet, Ottercliffe, Bayham, Onondaga, and Brantford fields. . . . Some of these fields derive a portion of their gas also from the red Medina sandstone and the Clinton formation." For the depths at which the top of the Medina is reached in the various fields, see Malcolm, page 29, and cross-sections and logs in this report.

The Clinton formation, according to Malcolm, supplies gas "in the Onondaga, Caledonia, and Cayuga fields, and is the most productive horizon at Port Colborne, west of the canal." For depths, see Malcolm, page 31, and logs given in this report.

Malcolm states "the Guelph is the gas-bearing formation of Gosfield, Mersea, and Wheatley. . . . At Gosfield, the top of the formation is about 1,000 feet below the surface and at Mersea about 1,100 feet. For further information as to depths, see Malcolm, page 31.

"The Salina (Onondaga) is the gas-bearing formation of the Kent gas field. . . ." (Malcolm, page 36, see page 37 for depths of top of formation.)

For the chemical composition of the natural gases of Ontario, see 23rd Annual Report of the Ontario Bureau of Mines, 1914, pp. 247-259.

It is now well recognized that the occurrence of natural gas and oil in the Silurian formations of Ontario is principally dependent upon rock porosity and structure such as anticlines, domes, monoclines, etc., and consequently developing companies are paying more and more attention to lenses of porous strata and to structure as worked out from well logs. The keeping of careful logs of the formations penetrated in drilling, and the depth at which water is struck, etc., is of great importance for the future development of oil and gas in Ontario (for structure see page 11).

According to the Bureau of Mines² the total gas production for Ontario in 1916 was 17,953,000,000 cubic feet, valued at \$2,104,499, as compared with 15,211,500,000 cubic feet in 1915. Of this amount, Welland-Haldimand produced 3,769,500,000, Kent 13,752,500,000, Elgin 351,900,000, and Lambton 55,200,000 cubic feet. The amount for 1917³ was 20,025,700,000 cubic feet, valued at \$3,182,151.

¹ Bull. page 28.

² Ont. Bureau of Mines, vol XXVI, 1917, p. 46.

³ Ont. Bureau of Mines, Bull. 33, p. 3.

ROCK ANALYSES.

MEDINA-CATARACT FORMATION.

Manitoulin dolomite, from Mitchell's Mills, lot 8, concession No. 1, Collingwood township, Grey county. Analyses by Mines Branch, Dept. of Mines, Ottawa.

CaCO_3	66.00
MgCO_3	20.54
FeCO_3	1.05
Fe_2O_3	0.06
Al_2O_3	0.74
Insoluble	10.70
Total	99.08

Analyses of Manitoulin Dolomite on Manitoulin Island.

	I	II	III	IV	V
Insoluble matter			3.86		
Silica	4.64	5.68		7.64	7.74
Ferrie oxide	1.12	0.81	0.72	0.94	0.62
Alumina	1.80	2.85	0.32	2.14	0.63
Lime	28.61	28.08	29.00	26.59	26.63
Magnesia	19.60	19.10	20.48	18.82	20.49
Carbon dioxide	43.79	43.00	45.27	41.57	43.92
Loss		0.16	0.22	0.25	
Sulphur trioxide		0.30		0.51	0.06
Alkalis			0.60		
Total	99.47	99.98	100.05	98.56	99.64

- I. Gore Bay, sample of 12 feet of uppermost part of face of cliff, northwest of Fair grounds.
- II. Top of cliff across bay, east of Gore Bay.
- III. Gore Bay, one-quarter mile west of northwest corner of Fair grounds, cliff 6 feet.
- IV. Porter's quarry, just east of Fair grounds, Gore bay.
- V. Landing at lake Manitou.

Calcareous sandstone bed thought to represent the southern extension of the Manitoulin dolomite, as taken by the author in the Niagara gorge above Lewiston. Analysis by Mines Branch, Dept. of Mines, Ottawa.

CaCO_3	38.39
MgCO_3	23.95
FeCO_3	3.14
Fe_2O_3	0.07
Al_2O_3	3.42
Insoluble matter	32.38
Total	101.35

¹Ont. Bureau of Mines, 1904, pt. II, p. 75. The formation is identified by the writer from his knowledge of the localities described.

A sample taken from a 6-foot bed of ferruginous limestone in the upper part of the Cabot Head shale at Linchouse. Analysis by Mines Branch, Dept. of Mines, Ottawa.

CaCO_3	28.84
MgCO_3	21.59
FeCO_3	2.05
Fe_2O_3	20.72
Al_2O_3	2.48
Insoluble	22.18
Total	97.86

CLINTON FORMATION.

Clinton, basal, sandy, glauconitic layer about 2 or 3 inches thick, at Dundas. Analysis by Mines Branch, Dept. of Mines, Ottawa.

SiO_2	22.42
Al_2O_3	3.46
FeO	2.72
Fe_2O_3	2.97
CaO	19.80
MgO	13.92
H_2O	3.50
CO_2	not determined.
Total	68.79

Reynales (Wolcott) dolomite at Hamilton. Analysis by Mines Branch, Dept. of Mines, Ottawa.

CaCO_3	50.85
MgCO_3	35.28
FeCO_3	2.11
Fe_2O_3	0.07
Al_2O_3	0.50
Insoluble	10.90
Total	99.71

Irondequoit dolomite, at Hamilton. Analysis by Mines Branch, Dept. of Mines, Ottawa.

CaCO_3	53.69
MgCO_3	39.19
FeCO_3	2.38
Fe_2O_3	trace
Al_2O_3	0.39
Insoluble	4.21
Total	99.86

NIAGARA GROUP.

Analyses of Rochester Shales.

	I	II
SiO_2	22.00	22.52
Al_2O_3	12.65	8.12
FeO	1.77	1.13
Fe_2O_3	0.46	1.01
CaO	20.81	21.83
MgO	7.77	10.14
H_2O	7.20	4.00
Total	72.66	68.75

I. Rochester shale, 3 feet above base at Hamilton.

II. Rochester shale, upper 4 feet, at Hamilton.

Analyses by Mines Branch, Dept. of Mines, Ottawa.

Analyses of DeCew Waterlime Beds, Lockport Dolomite.¹

	I	II
SiO ₂	21.70	14.48
Al ₂ O ₃	5.88	5.10
FeO	0.90	0.67
Fe ₂ O ₃	1.28	1.26
CaO	23.62	20.24
MgO	12.98	15.96
H ₂ O	1.00	5.60
CO ₂	not determined.	
Total	67.36	63.36

I. About middle of beds at St. Davids.

II. Redhill creek, west of Mount Albion.

Analyses of DeCew Waterlime, from Thorold Quarries Used in Piers of Victoria Bridge.²

	I	II
Calcium carbonate	56.28	47.0
Magnesium carbonate	20.07	30.32
Alumina and ferric oxide	2.20	2.71
Insoluble argillaceous residue	20.90	19.61
Water and loss by ignition	0.31	0.29
Total	99.76	99.94

I. John Brown's quarry.

II. Alex. Manning's quarry.

Rock at base of Lockport formation at Limehouse formerly burnt for hydraulic lime; probably DeCew waterlime³.

Carbonate of lime	48.07	
" " magnesium	39.63	
" " iron	0.69	
Sulphate of lime	0.10	
Alumina	0.21	
Silica, soluble	0.37	
Insoluble matter, consisting of:		
Silica	7.60	11.60
Alumina	2.07	
Ferric oxide	0.40	
Lime	0.05	11.02
Magnesia	0.19	
Potassa	0.53	
Soda	0.18	
Total		100.09

¹Analyses by Mines Branch, Dept. of Mines, Ottawa.²Ont. Bureau of Mines, 1904, pt. 11, p. 15.³Geol. Surv. Can., vol. 5414, 1885, pt. 13, p. 17.

*Analysis of Lockport Dolomite.*¹

	I	II	III
14.48			
5.10			
0.67			
1.26			
20.29			
15.96			
5.60			
Insoluble			
Total			

	I	II	III
CaCO_3	55.30	54.28	53.48
MgCO_3	42.28	39.00	42.55
FeCO_3	0.82	1.66	0.21
Fe_2O_3	0.14	0.57	0.07
Al_2O_3	0.15	0.29	0.12
Insoluble	1.21	3.00	3.50
Total	99.94	98.80	99.96

I. 3-foot bed above 6-foot bed of Reynales (Wolcott) dolomite, at Kelso.

II. Beds about 23 feet above DeCew beds, at St. Davids.

III. Government quarry at Providence Bay, Manitoulin island.

*Analysis of Lockport Dolomite from Manitoulin Island.*²

	I	II
Insoluble		
Silica		
Iron oxide	1.43	1.42
Alumina	0.71	0.99
Lime	0.59	
Magnesia	30.05	30.06
Carbon dioxide	21.19	20.46
Total	46.00	47.00
	99.97	99.93

I. Top of hill at Meldrum Bay village.

II. Fossil hill, near Manitowaning.

*Analysis of Lockport dolomite from Ryan and Haney's Quarry, near Meldrum Bay, Manitoulin Island.*³

	I	II
Silica		
Iron oxide	0.46	0.56
Alumina	0.50	0.41
Lime	trace	0.20
Magnesia	30.84	30.50
Carbon dioxide	21.11	21.55
Loss	47.10	47.40
Silicic acid	0.18	
Alkali	0.09	0.23
	0.15	0.65
Total	100.67	100.90

Analyses by Mines Branch, Dept. of Mines, Ottawa.

¹ See Bureau of Mines, 3254, p. II, p. 75.

³ Given as 11.39 which is evidently incorrect. The figures were corrected from the total as printed.

Lockport dolomite from Cockburn island formerly used for manufacturing sulphite pulp at Sault Ste. Marie¹.

Insoluble.....	4.5
Iron and alumina.....	0.5
Calcium carbonate.....	52.0
Magnesium carbonate.....	41.0
Undetermined.....	2.0
	100.0

Brownish grey, crystalline, Lockport dolomite, Grimsby.²

Carbonate of lime.....	68.92
Carbonate of magnesia.....	29.48
Carbonate of iron.....	1.10
Insoluble.....	0.50
	100.00

Lockport dolomite used in the manufacture of lime at Christie's siding near Kelso, west half of lot 3, concession VI, Nassagaweya township, Halton county.³

Carbonate of lime.....	54.12
" magnesium.....	45.45
" iron.....	0.58
Sulphate of lime.....	0.17
Alumina.....	trace
Insoluble matter.....	0.30
	100.62

Analysis of rock from Ancaster quarries, presumably from the Eramosa beds⁴.

Moisture.....	0.23
Insoluble matter.....	1.60
Carbonate of lime.....	53.30
Carbonate of magnesia.....	43.13

Average of eight samples of rock from lower quarry of Canada Crushed Stone Company at Dundas, representing about 15 feet of upper Eramosa beds. Analysed by Crowell and Murray, mining engineers, Cleveland, Ohio. Analysis furnished by Mr Doolittle, manager of Canada Crushed Stone Company.

Silica.....	1.66
Iron oxide.....	0.54
Alumina.....	0.37
CaCO ₃	54.42
MgCO ₃	43.02
Sulphur.....	0.034
Phosphorus.....	0.015
	100.059

GUELPH DOLOMITE.

Analysis of average of eight samples of upper 16 to 18 feet of quarry at Dundas, being the lower part of the Guelph formation. Analyses by

¹Ont. Bureau of Mines, 1904, pt. II, p. 13.

²Geol. Surv., Can., 1876-77, pp. 486-7.

³Geol. Surv., Can., vol. VIII, 1895, pt. B, p. 17.

⁴Ont. Bureau of Mines, 1903, p. 142.

Crowell and Murray, mining engineers, Cleveland, Ohio, and supplied by Mr. Doolittle, manager of Canada Crushed Stone Company.

Silica	0.41
Iron oxide	0.43
Alumina	0.59
CaCO ₃	55.20
MgCO ₃	43.60
Sulphur	0.016
Phosphorus	0.005
	100.251

Analyses of Guelph Dolomite, Wellington County.

	I	II
Carbonate of lime	54.25	53.97
" magnesia	45.17	45.37
" iron	0.22	0.16
Sulphate of lime	0.34	0.68
Alumina	trace	trace
Insoluble matter	0.08	0.03
Total	100.06	100.21
(Hygroscopic water after drying at 100° C.)	0.05	0.02

I. Light grey, fine crystalline, massive dolomite from Wellington quarry, south half of lot 29, gore of Puslinch township, Wellington county.

II. Light, cream-yellow, yellowish-brown weathering, very fine crystalline, compact, dolomite, from the priest's quarry on Speed river, Guelph township, Wellington county.

SALINA FORMATION.

Camillus Shale.

Lowest beds exposed in Caledonia gypsum mine. Analysis by Mines Branch, Dept. of Mines, Ottawa.

SiO ₂	12.34
Al ₂ O ₃	3.93
FeO	1.94
Fe ₂ O ₃	0.41
CaO	24.20
MgO	16.17
H ₂ O	3.00
	61.99

CO₂ not determined.

Shale accompanying gypsum at Paris.²

Water	0.75
Silica	52.02
Alumina	8.03
Ferric oxide	3.80
Calcium carbonate	9.90
Magnesium carbonate	2.34
Sulphur	1.00

¹Geol. Surv., Can., vol. VIII, pt. R, 1895, p. 17.

²Ont. Bureau of Mines, 1904, pt. II, p. 34.

Thin limestones, which are interbedded with shale below gypsum horizon at Paris.

Water	0.33
Insoluble	3.32
Calcium oxide	27.77
Magnesium oxide	15.15
Carbonic acid	33.42
Sulphur	0.60

BERTIE-AKRON FORMATION.

Bertie Waterlime.¹

Rock cut by Welland canal on north end of lot 28, concession II, Humberstone township, Welland county².

First Analysis.

Ca	44.68
Mg	36.27
Silica, Fe ₂ O ₃ and insoluble silicates	16.14
Fe ₂ O ₃ and Al ₂ O ₃	2.46
	99.55

Second Analysis.

SiO ₂	12.32
Fe ₂ O ₃ , Al ₂ O ₃	4.94
CaO	25.02
MgO	16.80
CO ₂	39.13
Moisture	0.06
	98.27

Waterlime at Springvale³.

Lime	31.58
Magnesia	17.79
Alumina	3.29
Ferric oxide	1.89
Silica	3.69
Water	0.15
Carbonic acid (ignition loss)	44.73

Waterlime, probably Bertie. Bluish, lower rock in quarry on lot 40, concession IV, North Cayuga township, Haldimand county⁴.

Water	0.55
Silica	4.14
Alumina	26.60
Ferric oxide	1.56
Calcium oxide	20.09
Magnesium oxide	14.51

Dolomite, probably Akron, occurring below Oriskany sandstone at Michigan Central cut 2 miles east of Hagersville⁵.

Water	0.35
Silica	3.44
Alumina	2.34
Ferric oxide	1.86
Calcium oxide	26.61
Magnesium oxide	17.47
Ignition loss	44.96

¹Some Akron dolomite may be included.

²Ont. Bureau of Mines, 1902, p. 31.

³Ont. Bureau of Mines, 1904, pt. II, p. 118.

⁴Ont. Bureau of Mines, 1903, p. 146.

⁵Ont. Bureau of Mines, 1903, p. 141.

CHAPTE I.

PALÆONTOLOGY: DESCRIPTION OF NEW SPECIES AND
PALÆONTOLOGICAL NOTES.

MEDINA-CATARACT FORMATION.

Lingula cuneata Hall.

The original description¹ is as follows: "Shell cuneiform, very acute at the beaks; margins nearly rectilinear, and converging uniformly from near the base to the beak; base slightly curved; the valves convex on the upper half but flattened or compressed towards the base; surface longitudinally striated.

This species is readily distinguished from any of the other species by its acutely cuneata form. but the shell is more or less exfoliated and the striæ partially or wholly destroyed. The shell is translucent and usually of a light colour, particularly in the light grey sandstone."

From an examination of a quantity of material from the Whitmore quarries, Lockport, N.Y., it is found necessary to modify the above description as follows: on practically every slab examined there are valves of two distinct shapes, the acute form as described above and another form with more obtuse beak. The latter form evidently represents the dorsal valve. A few ventral valves have subparallel sides, the beaks being acute and the general shape cuneiform. A very shallow median septum is present in the ventral valves. This extends from about 2 mm. from the beak to about 5 mm. from the front where it ends in "central scars". The septum is bounded by "concrete laterals" 1 mm. or less apart. The septum and accompanying parts are well illustrated in "Palæontology of New York"². This figure also illustrates the less cuneate ventral valves already mentioned. The shell on such parts as are well preserved shows fine radiating striæ, about four to five being spaced in 1 mm. The exfoliated surfaces show fibrous structure, resembling striæ.

The typical shells at Lockport occurring in red sandstone, average: ventral valve 18 to 19 mm. long, 9 to 12 mm. wide at front; dorsal 15 to 18 mm. long, with width as in ventral. In grey sandstone lenses, the length is generally less and the shape less cuneate. At a slightly higher horizon, occurring in highly ferruginous sandstone along with bryozoa and ostracoda, lingulas are very numerous but are only 7 to 10 mm. long. In other characters they are indistinguishable from the well-developed specimens found not 100 yards away.

At Niagara river, in a 3-foot bed of arenaceous limestone 23 feet above the Whirlpool sandstone, fragmentary lingulas occur; these are typical *L. cuneata*. Twenty-two feet higher up in red sandstone this species of lingula is again abundant, but averages only about 12 mm. in length. The lingulas of the latter horizon are abundant also near Thorold. At Grimsby and Hamilton, lingulas occur in grey sandstone near the top of the Medina section, the beds being older than the true grey band or Thorold quartzite. The lingulas of these localities are of about the same size as those of the upper horizon at Niagara river, but are generally less cunei-

¹Palæontology of New York, vol. II, 1852, p. 8.
²Vol. VIII, pt. I, pl. I, fig. II.

form. In all other respects they are similar to the typical *L. cuneata* and there are among them some decidedly cuneate forms. However, Schuchert identifies these as *Lingula clintoni* Vanuxem, formerly known as *L. oblonga*.

Dalmanella eugeniensis new species.

(Plate VII, figures 1 to 6.)

Shell wider than long, sub-oval more or less, planoconvex, hinge-line shorter than greatest width of shell. Striae fine, angular, recurved from umbo to lateral margin, increasing by intercalation on dorsal valve and dominantly by bifurcation on ventral valve. One or two well-marked growth lines present near anterior margin of shell. Length of adult specimens from 12 to 18 mm.; width 14 to 22 mm.; thickness 4-6 mm.

Ventral valve moderately convex, flattened toward anterior margin and concave between beak and cardinal-lateral angle; umbo merging into general curvature of shell; beak small, acute, scarcely incurved; cardinal area moderately high, tapering rapidly to cardinal-lateral angles; deltidial plates narrow; pedicle opening wide; hinge teeth large and strong; muscular area short, divided medially by low, rounded elevation.

Dorsal valve nearly flat, with narrow median depression which becomes shallow and ill-defined at front. Beak acute, very short; cardinal area very narrow, cardinal process small trilobed; muscular area about one-third length of shell.

This species closely resembles *Dalmanella elegantula* (Dalman), from which it may be distinguished by being wider than long, having a low broad umbo, cardinal-lateral angles of very little more than 90 degrees, smaller cardinal process, shorter crura, and being generally of larger size.

Occurrence. Cataract formation at Eugenia, Ont., in lower 10 feet of Cabot Head grey shale; at Lavender falls near Dunedin, Ont., in shale partings at top of Manitoulin dolomite; at Hamilton, Ont., in red shaly beds of Grimsby sandstone; near Owen Sound, Ont., along Pottowattomi river in Cabot Head shale just above Manitoulin dolomite.

Dalmanella eugeniensis var. *palæoelegantula* Williams n. var.

(Plate VII, figures 7 and 8.)

Small, semi-circular, plano-convex; ventral valve moderately deep, umbo moderately high and narrow, more rounded in younger specimens; cardinal-lateral angles rounded and hinge-line about one-half the width of the shell; dorsal valve nearly flat or gently convex near the beak; a narrow, median groove from beak to front, anteriorly at the bottom of a shallow sinus; length of type specimen 1 cm., width 1 cm., thickness at umbo 3-5 mm.

This variety differs from *D. eugeniensis* in being nearly as long as broad, in having a higher, narrower umbo, and, in the type specimen, in having a narrow, median groove on the dorsal valve. Younger specimens have more convex dorsal valves and lack the median groove.

This variety approaches the characters of *D. elegantula* (Dalman), and hence its variety name: it differs from the later Silurian species, how-

ever, in being proportionately wider, in having a lower umbo, and in having a smaller cardinal process and shorter crura.

Occurrence. In Cabot Head shale at Eugenia (collected by J. Stansfield and H. V. Ellsworth 1911), and in Manitoulin dolomite at Glen William.

MEASUREMENTS OF VIRGIANA MAYVILLENSIS AND PENTAMERUS OBLONGUS.

Virgiana mayvillensis Savage, *Cataract Formation.*

	Fitzwilliam island.	Tamarack cove.	South bay.	West bay.	Kagawong lake.	Helen bay.	Cockburn island.
Specimens examined	4	1	4	2	3	6	5
Smallest	2.1		2.5	1.9	1.9	2.2	2.7 em. long.
Largest	3.0		3.9	3.0	2.2	3.5	3.5 "
Average	2.5	2.1	3.1	2.4	2.2	2.6	3.1 "
Average ventral septum	0.5	1.7	0.9	0.9	1.1	1.1	0.9 "
Average ratio	2.8, 2.5	3.5, 4.0	2.4, 2.2	4.8, 4.4	3.7, 2.0	3.2, 2.1	3.1, 2.8

The average ratio is an expression of the quotients obtained by dividing the average lengths and widths of the ventral valves of the specimens successively by the average depth.

Pentamerus Oblongus in *Reynales* (Clinton) *Dolomite.*

	Rochester.	Thorold.	DeCew falls.	Jordan.	Grimsby.	Kelso.
Specimens examined	5	4	1	2	3	2
Smallest	3.1	2.0		2.0	1.7	5.0 em. long.
Largest	5.7	6.0		4.0	5.8	6.2 "
Average	4.5	4.2	3.0	3.0	3.7	5.6 "
Average ventral septum	1.9	2.5		0.2	1.9	2.5 "
Average ratio	3, 2.3	com-pressed.	1.9, 1.7	1.6, 5.2	5.3, 4.7	2.8, 2.8

Pentamerus oblongus occurs from 1.5 to 2 feet above the base of the *Reynales* dolomite.

Pentamerus Oblongus in *Lockport Dolomite.*

	Inglis mills.	Owen Sound.	Warton.	Barrow bay.	Cabot head, 25 feet up.	Cabot head, near base.	Fossil hill.	Lake Manitou.	Cockburn island.
Specimen examined	4	3	4	8	1	3	2	7	3
Smallest	2.5	5.0	3.7	2.6		5.7	3.4	2.2	3.3 em. long.
Largest	5.5	6.0	5.2	6.0		6.4	5.4	3.7	8.0 "
Average	4.3	5.5	4.8	4.5	3.5	5.8	4.2	2.9	5.6 "
Average ventral septum	2.2	3.6	2.6	3.1	2.5	1.8	2.8	1.9	3.0 "
Average ratio	3.9	4.6	2.8	3	4	2.9	6.0	2.6	4.3
	3.6	4.3	2.2	2.5	3	2	5	2.3	3.3

Rhynchotreta cabotensis, new species.

(Plate VII, figures 11 a, b, c.)

Shell small, compressed, sub-triangular, not broader than long, valves sub-equally convex. Plications 12 to 14, prominent, rounded, extending from beak to front; separated by interspaces which, at the front, are equal to or greater than the width of the plications. Growth lines prominent near the front only. Length and breadth between 6 and 9 mm., depth 2 to 5 mm., angle between cardinal slopes 70 degrees to 100 degrees or more in some cases.

Pedicle valve moderately convex; beak small, acute, gently incurved; foramen slit extending from the foramen to the contract with the beak of the brachial valve; umbo moderately well defined; median sinus containing two plications confined to the front half of the shell.

Brachial valve slightly more convex than pedicle; beak small; a shallow sinus from the beak to the middle of the shell containing three plications which rise as a low fold at the front of the shell.

The two small figured specimens measure respectively 7 mm. long, 6.5 mm. wide, 2.5 mm. deep; and 6 mm. long, 7 mm. wide, and 2.5 mm. deep. The brachial valve of the larger figured specimen, which is of about average size, is 8.5 mm. long, 9 mm. wide, and 2 mm. deep.

R. cabotensis differs from *R. intermedia* Savage in being smaller and less transverse. From *R. lepida* Savage, with which it most closely compares, it differs in the presence of a fold and sinus, and in greater proportional breadth.

Occurrence. In Dyer Bay dolomite and the overlying Cabot Head shale at the "Clay bank" along the shore about 2 miles west of Cabot head.

Atrypa parksi new species.

(Plate VII, figures 19 a, b, c.)

Length and breadth sub-equal. Beak of pedicle valve closely incurved and covering the beak of the brachial valve. Both valves convex, the pedicle with a well-marked sinus in front, not appearing in the umbonal region, and the brachial with a fold, well-marked in front, where the margin of the shell is turned up in some specimens, and only faintly indicated of forming a shallow sinus near the beak. Shell widest posteriorly; cardinal slope varying and extremities rounded. Surface marked by fine rounded plications (5 to 2 mm.) which increase generally by bifurcation and less commonly by implantation and by growth lines which are obscure except near the front of the shell. The specimen chosen as the type measures 24 mm. wide, 18 mm. high, and 10 mm. deep at the umbo. Other specimens are from 13 to 25 mm. in width. Well preserved, small specimen at Credit Forks approach the form of *A. marginalis*, having decided cardinal lateral angles, small, prominent, pedicle beaks, and straight frontal margin at the fold.

This species is most closely related to *Atrypa marginalis* Dalmat from which it differs in having considerably finer plications, rounded cardinal extremities, less clearly defined fold and sinus, and in being of larger average size.

The species is named after Professor W. A. Parks, of Toronto University, who recognized it as a new species, but left it for the author to describe in this memoir.

Occurrence. In the Manitoulin dolomite at Stoney Creek, Hamilton, Dundas, Credit Forks, Owen Sound, Cabot head, and Church hill, Manitowaning, and West bay, Manitoulin island.

Whitfieldella cataractensis new species.

(Plate VII, figures 16 to 18.)

Elongate oval, moderately convex, rounded, cardinal-lateral angles forming decided "shoulders"; narrow, shallow sinuses on anterior three-fourths of both valves; greatest convexity in posterior third; pedicel valve more convex than brachial; average length 1.7 cm., width 1.3 cm., depth 1.0 cm. A large fairly well preserved specimen measures: length 2.3 cm., width 1.7 cm., and thickness, allowing for crushing, about 1.2 cm. Another specimen doubtfully referred to this species, has no sinus in the brachial valve, which measures: length 2 cm., width 1.6 cm., depth (one valve) 0.5 cm. Surfaces of the shells are marked by growth lines only.

The number of specimens found is over forty, but many of these are mere fragments, and all are crushed or worn. It is probable that the sinuses have been accentuated by crushing. Among the fragments are remains of some small specimens and also of some large ones that have widths of from 2 to 2.6 cm.

W. cataractensis is most nearly allied to *W. quadrangularis* Foerste, from the Brassfield of Adams county, Ohio. From this species it differs in being smaller on the average, less rotund, and in having more clearly defined and narrower sinuses.

Occurrence. Manitoulin dolomite at Hamilton, Glen William, and Lavender falls; in the arenaceous Manitoulin beds at Niagara river; in limestone lenses in the Cabot Head shales at Stoney Creek, near Owen Sound, and at Credit Forks.

Nuculites (Cleidophorus) cf. ferrugineum Foerste.

(Plate VIII, figure 4 (small shells).)

Small, elliptical, beak about one-third the distance from the anterior end; a notch and short, narrow sinus in front of the beak. The larger of the two figured specimens is 1.3 cm. long and 7 mm. deep; this is an average specimen. The smaller specimen is 1 cm. long and 0.6 cm. deep.

The above specimens are larger and more elongate than the single specimen figured by Foerste; in other respects there appears to be no difference.

Occurrence. Grimsby sandstone at Kelso, and at "Sydenham road", West Flamborough township, Wentworth county, where it was collected by R. Bell.

Pterinea brisa Hall?

Species represented by left valve. Hinge line about 1.6 cm. in length. Greatest radial distance from beaks 1.5 cm.

Valve compressed, oblique. Anterior wing unknown; posterior wing distinctly separated from body and terminated in an angle of more than 90 degrees. The most distinctive character of this species is the presence of five, close set (1 mm. apart), wavy lines of growth on the body of the shell. The undulations are about 1 mm. in amplitude. On the posterior wing the lines of growth are curved, with convex side forward.

Another specimen, probably belonging to this species, is decidedly convex, measures 1 cm. on the hinge line, and 1 cm. in length. It has fine, radiating striae about three in 1 mm. and has three decided growth lines, 1.5 mm. apart, on the anterior half of the shell.

In outline this species resembles *P. elegans*, Savage.

Locality, Grimsby sandstone, at Kelso, Ont.

Pterinea cf. undata (Hall).

(Plate VIII, figure 2.)

Left valve observed: oblique, moderately convex, length of hinge line about 2.5 cm.; greatest radial length from beak 3 cm. Anterior wing rounded, separated from body of shell by a shallow sinus situated about one-third the distance from the anterior to the posterior extremity. Posterior wing not distinctly separated from the body of the shell, and not extending beyond length of shell. Hinge line making obtuse angles with outline of shell at both extremities. Umbo extending slightly beyond hinge line. Surface marked by growth lines and striations, two to three in 1 mm., the striations being seen only near the centre of the shell in this specimen.

Two small specimens measure, respectively: hinge line 1.4 cm., length 1.4 cm.; and hinge line 1.2 cm., length 1.4 cm. The broader shows faint traces of radiating striae, and both show growth lines, the broader approaching *P. undata* in characters.

This species resembles *P. undata* Hall closely in outline, but differs from it in surface markings which may, however, be exfoliation characters only. It corresponds closely with the fragment figured by Hall, "Paleontology of New York", volume II, 1852, Plate 4, bis, figure II d and e. These figures have been removed from *Modiolopsis primigenus* where Hall placed them, by Bassler¹ who has not identified them. Figure IIe (Hall) compares with this species in outline, but is a left valve, and being convex is probably not a *Pterinea*. Hall's specimens were from the Medina sandstone at Medina.

Occurrence, Grimsby sandstone, Niagara gorge south of Lewistown, N.Y.

¹U. S. Nat. Mus. Bull. 92, vol. II, p. 819

Modiolopsis Kelsoensis new species.

(Plate VIII, figure 3.)

Shells oval, and moderately convex; beak about one-third the distance from the front of the shell; a shallow but well-marked sinus from the centre of the beak downward and somewhat backward to the base of the shell; marked growth lines over the entire surface; hinge area not seen; length of type 3.5 cm., depth 1.5 cm., thickness, including both valves, about 1.1 cm.

Occurrence. In red Grimsby sandstone at Kelso, and on lot 11, concession 1, West Flamborough, Wentworth county. The latter locality is represented by a specimen collected by R. Bell and formerly labelled *Grammysia Canadensis* Billings (see figures).

Lophospira pulchra new species.

(Plate VII, figures 22a, b.)

Shell conic, slightly wider than high. Height 17 mm., width 15 to 16 mm., apical angle about 85 degrees, volutions 4, slit band prominent; a well-marked keel present on all volutions above slit band, about half-way between slit band and suture. Suture impressed, younger volutions overlapping on older about half-way to slit band, which is centrally located.

Surfaces between slit band, keel, and suture, and slit band and suture, concave. Lower surface of last volution subventricose. Fine striations, directed somewhat backward, cross the surfaces from the suture downwards to slit band, being undisturbed by the keel. From the slit band to the suture below they are directed forwards. Aperture unknown.

Occurrence. At Cataraugus, in flint nodules in lower 6 feet of Manitoulin dolomite. Collector, J. Stansfield, 1912. Only one specimen is known to the writer.¹

Observation. This species is very similar to *L. hispiralis* (Hall), of the Guelph formation, from which it differs, however, in being somewhat lower and consequently having a larger apical angle and in having the keel above the slit band persistent on all the volutions including the outer one.

Pleurotomaria species.

One specimen was found by the writers' assistant, H. V. Ellsworth, at the top of the Whirlpool sandstone, in a small gully near the cement tunnel over the New York Central tracks, south from Lewiston, New York. This specimen is fragmentary and about two-thirds the size of Hall's figured specimens of *P. littorea*. It is also proportionately lower. In other respects it corresponds with this species.

A number of casts of small gastropods occur in the upper beds of Whirlpool sandstone at Glen William, Ont. They appear to be all of one species and correspond closely to *H. subulata* as described and illustrated. They, however, show faint, but distinct "peripheral angulation and band" and so differ from *H. subulata* as so far known (Plate VIII, figure 1).

¹A small undetermined species of *Lophospira*, about 1 mm. in height and greatest diameter, occurs in the same chert nodule.

ROCHESTER FORMATION.

Strophonella decemensis new species.

(Plate XIII, figure 1.)

Brachial valve, semi-oval, longer than broad, moderately convex, broadest and most convex near the centre; lateral areas in front of the hinge-line concave, area in front of beak flattened and containing a short narrow sinus; striae line, rounded, and curved backward near the hinge line, number about 100, increasing by implantation; hinge-line less than width of shell; cardinal-lateral angles rounded. Length 3.4 cm., width 3.2 cm. Pedicle valve not seen.

This species differs from *S. patula* in having greater length than width and rounded, cardinal-lateral angles.

Occurrence. Rochester shale, 8 to 12 feet below the top at DeClerk falls near Power Glen, Lincoln county, Ont.

LOCKPORT FORMATION.

Stricklandinia manitouensis new species.

(Plate XX, figures 2, 3.)

Longer than wide, very convex; valves nearly equal; greatest convexity in posterior portion of shell; a faint sinus in the pedicle valve and a faint fold on the brachial valve; simple, rounded, radiating striae, about five in 5 mm. at the front of the shell; median septum about 3 to 4 mm. in length. The beaks are worn in all three specimens in hand, but the beaks of both valves are evidently short, the pedicle closely incurved over the brachial. The following measurements are only approximate owing to the worn condition of the specimens: No. 1, length 2.5 cm., width 2.1 cm., thickness 1.8 cm.; No. 2, length restored about 3 cm., width 3.2 cm., thickness 1.5 cm.; No. 3, length 3 cm., width 2.6 cm., thickness 1.9 cm.

This species is thicker and narrower than *S. deformis* Meek and Worthen and lacks the growth lines of that species. It compares most closely with *S. norwoodi* Foerste, from the figures of which it differs in having the fold and sinus less marked, and in having more clearly marked striations, and a tendency to greater rotundity.

Formation and Locality. Lockport dolomite, Fossil Hill horizon, plateau east of Sandfield, Manitoulin island.

GUELPH FORMATION.

Orthoceras bruceensis, new species.

(Plate XXVI, figures 1 a, b.)

Straight, gently tapering, about $2\frac{1}{2}$ mm. in the space of one diameter; surface marked by oblique annulations, about four in the width of a segment; cross-section circular, siphuncle about half-way between centre

and circumference; diameter 1.2 to 2.7 cm. Camarae deep, in the shape of short cones terminated by hemispheres, thickness unusual, 1.5 to 1.7 mm. The centres of the camarae weather out so as to leave only the walls preserved, the result suggesting double camarae.

This species is very similar to *O. unionense* Worthen, but differs in having deep, thick camarae.

Occurrence. Guelph dolomite on Bruce peninsula at Hay bay, 3 miles west of Tobermory, at Dorcas bay and Baptist harbour near Cape Hurd, and in Lockport dolomite about 15 feet above the base at Linchouse, Ontario.

APPENDIX I.

NEW SPECIES OF BRACHIOPOD.

(By A. F. Foerste.)

Rhynchotreta Williamsi new species.

(Plate VII, figures 15 a, b.)

This species is closely related to *Rhynchotreta thebesensis* Foers. from which it differs chiefly in the absence of any tendency toward the elevation of the two median plications of the brachial valve, and a corresponding depression for the median plication of the pedicle valve. Apparently, the plications are much less distinct and the beak of the pedicle valve is more strongly incurved, but it is not certain whether these differences are not due in part to the state of preservation of the single specimen here described as *Rhynchotreta williamsi*. In this specimen, the plications are distinct only near the anterior margin and are nearly obsolete posteriorly. The specimen was obtained, however, in a dolomitic rock and may be one of those casts partaking more of the interior characters of the species than of its exterior surface features. Eleven or twelve plications may be distinctly recognized along the anterior margin of the shell, in addition to which two or three plications are faintly indicated on each of the flattened sides.

Rhynchotreta williamsi was found in the Manitoulin dolomite, about 2 miles southeast of Manitowaning, on Manitoulin island, where the dolomite forms a conspicuous hill, south of the road to South bay. The species is named in honour of M. Y. Williams, with whom the writer had the pleasure of visiting the locality in question.

Rhynchotreta thebesensis was found in the Edgewood limestone division of the Medina, at Thebes, Illinois.

APPENDIX II.

NEW SPECIES OF CTINOID.

(By Frank Springer.)

Eucheroocrinus Ontario, new species.

An imperfect specimen, the only one found in rocks of this formation, the geological position being older than that of *E. chrysalis* (Hall), and *E. radialis* (Ringueberg), both from the Rochester shales. Enough is preserved, however, to show the essential characters on which the species is based, which are:

The left anterior ray ("dorsal arm") bifurcates on the third plate above the radial, and on every third brachial above that, by equal branches; thus it has three primibrachs. The left posterior ray has only two primibrachs, bifurcating inequally on the second, and on every second plate above that. The two segments of the left anterior radial are in contact, the inferior segment being a wide plate for its entire length, with parallel sides. These characters are shown in Figure 6.

The species differs from *E. chrysalis* and *E. radialis*, from Lockport, in the much smaller number of primibrachs in the dorsal arm—those species having seven to nine or more; and in the greater width and more rectangular form of the inferior segment of the radial. In the former respect it resembles a species from the Wenlock formation at Dudley, England, which has only one primibrach (perhaps "*Cheroocrinus*" *scutalis* Salter, catalogue name). In the latter it is somewhat comparable to *E. barrandeii* Walcott, from the Trenton of New York, and recalls the very wide corresponding plate in *Cremnoerinus*.

Occurrence. Manitoulin bed, Cataract formation, Stoney Creek, Ontario.

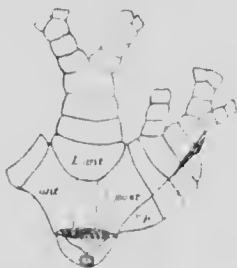


FIGURE 6. *Eucheroocrinus Ontario*, sp.
Diagrammatic view. Manitoulin
bed, Ontario. U.S.C.
Mus. No. 4330.

APPENDIX III.

NEW SPECIES OF CORAL.

(By George H. Chadwick.)

Family *Columnariidae*.Genus *Palæophyllum* Billings.*Palæophyllum* (*Cyathophylloides*?) *williamsi* sp. nov.

(Plate V, figure 2.)

Corallum composite, sub-fasciculate; corallites cylindrical; the new corallites interspersed among the older, from $1\frac{1}{2}$ mm. up to rarely 6 mm. in diameter; the mature corallites averaging about 4 mm. Gemmation appears to be lateral and fairly prolific. Outer wall strong; exterior surface slightly undulate and with septal striae; a strongly wrinkled epitheca like that of *Cyathaxonia cynodon* is preserved at a few points on the holotype. Septa usually about eighteen to twenty-four in adult corallites, not reaching the centre, rather strong and regularly arranged but occasionally very slightly twisting or curving; in addition, short, interstitial septa alternate with the long ones but are in many cases rudimentary. The central area is well-like and has a diameter varying from nearly equal to the length of the long septa to less than half that amount. The tabulae vary from strongly convex to flat or even concave in the centre with the periphery curved down, and are spaced from 1 to 2 mm. apart; they do not interrupt the longer septa. No dissepiments nor fossulae. Type specimen collected by M. Y. Williams from the Manitoulin dolomite east of Manitowaning bay, Manitoulin island.

Observations. This appears to be the species most likely to be identified as "*Diphyphyllum multicaule*" in the Cataract formation. The habit of growth is exactly that of *Synaptophyllum* except for the absence of the connecting processes, but the internal structure is wholly different, being that of *Columnaria*. The composite rather than compound mode of growth would appear, however, to be of generic value.

This species differs from *Palæophyllum stokesi* (Edwards and Haime) of the Richmond, by its smaller corallites and more widely spaced tabulae also in the entire absence of the connecting processes mentioned by Edwards and Haime and figured by Whiteaves. In its mode of growth and arrangement of tabulae it is still less like the Richmond genotype, *P. rugosum* Billings (as figured by Lamb), which is clearly distinct specifically from *P. stokesi*. Much more closely allied is *Palæophyllum thomi* (Hall) of Texas. This last is referred by Walcott to *Cyathophylloides* Dybowski whose typical species supposedly include *C. rhenanus* Frech and *C. djunctus* (Whiteaves) of the Devonian. Should this reference prove appropriate, perhaps in a subgeneric sense as used by Whiteaves, it will carry with it the other two thick-walled species which do not under-

polygonal compression, *P. williamsi* and *P. stokesi*. The corallites in *P. williamsi* are more variable in size than shown for *P. thom* and have not the peculiar structure in transverse section represented in Hall's figures, but comparison with actual specimens may leave few real distinctions.

Palaeophyllum umbelliferaceus sp. nov.

Corallum subupward, usually small, substraciform. Corallites closely set, subparallel or radiating, tapering cylindrical or becoming polygonal toward the base by mutual compression, varying from $\frac{1}{4}$ to 3 mm. in diameter, the mature polyps being seldom under $2\frac{1}{2}$ mm. Epitheca well marked, obscuring the septal grooves where not weathered away. Tabulae convex, numerous and complete, spaced $\frac{1}{2}$ to $\frac{2}{3}$ mm. apart, not interrupting the septa. Septa short, the alternate ones reaching about half-way to the centre, in some cases a little more; the longer septa, about twelve in number in mature corallites, regularly arranged, with as many intermediate ones.

When a corallite reaches maturity (3 mm.) the inner ends of the longer septa become united in a continuous ring, like an inner wall, thus producing a whorl of marginal chambers each with a single septum (the short intermediate one). These calices immediately assume a circular form, remaining in contact laterally, and new septa rapidly appear as the growing corallite enlarges upward. By crowding the circular arrangement is soon lost, but the umbels spring again with considerable regularity, simultaneously from each corallite, after from 15 to 20 mm. of upward growth.

The type specimens (six in number) were collected by M. Y. Williams from "The Rock", and a seventh specimen was obtained by M. Y. Williams from the "Devil's Needle", both localities being near Manitowaning, Manitoulin island. Formation, Manitoulin dolomite.

Observations. The more closely aggregated corallites, closer tabulae and thin wall, ally this species with the genotype, *P. rugosum* Billings of the Richmond, from which and from *P. calcinum* (Nicholson) its small size and fewer, shorter septa at once distinguish it. The peculiar multiplication by septal gemmation in marginal whorls as in *Romingeria* has not previously been remarked in *Columnaria* or *Palaeophyllum*, and may prove of subgeneric value.

PLATE II.

Medina-Cataract Fossils.

Fucoid (natural size.)

Green grey, argillaceous sandstone at top of Whirlpool sandstone, Glen William, Ont. G.S.C., Mus.
No. 4386. (Page 26.)



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PLATE III.

Midway-Cataquet Fossils.

(Figures natural size.)

FIGURE 1. Facoids in grey, impure dolomite at base of Manitoulin dolomite, Glen William, Ont. G.S.C., Mus. No. 4504. (Page 29.)

FIGURE 2. Worm burrows. Greenish white sandstone, top of Whirlpool sandstone. Glen William, Ont. G.S.C., Mus. No. 4505. (Page 26.)



PLATE IV.

Medina-Cataract Fossils.

(Figures natural size.)

FIGURE 1. *Farosites cristatus* Edwards and Haine, St. Edmund dolomite at Cabot head. (G.S.C., Mus. No. 4506. (Page 38.)

FIGURE 2. *Helopora fragilis* Hall. Grey dolomite lens in Cabot Head shale, Stoney Creek, Ont. (G.S.C., Mus. No. 4507. (Page 35.)

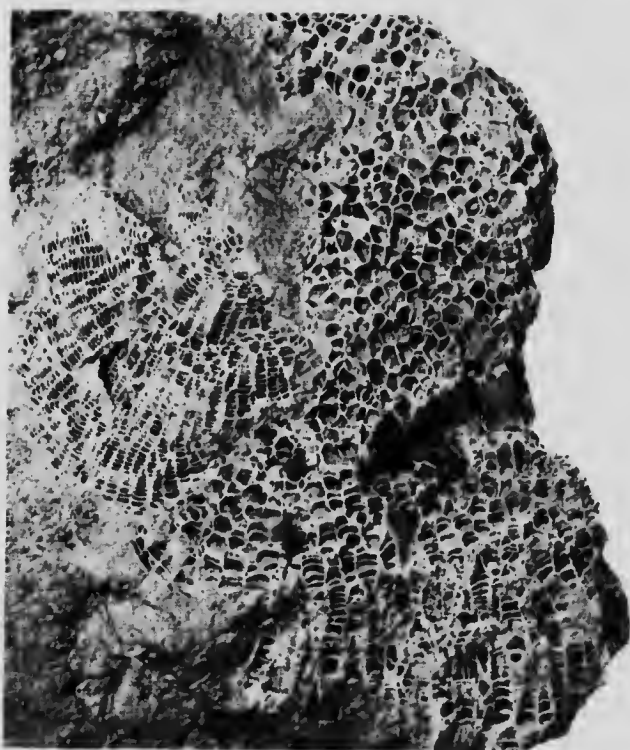


PLATE V.

Medina-Cataract Fossils.

(Figures natural size.)

FIGURE 1. *Receptaculites canadensis* Billings' type. Fine-grained lens of dolomite in Cabot Head shale, Lincolnton, Ont., Collector, R. Bell. G.S.C., Mus. No. 2590. (Page 35.)

FIGURE 2. *Synaptophyllum williamsi* Cladwick n. sp. Manitoulin dolomite east of Manitowaning bay, Manitoulin island. G.S.C., Mus. No. 4508. (Page 128.)

FIGURE 3. *Acerrularia gracilis* (Billings). Manitoulin dolomite, Manitowaning bay, Manitoulin island. G.S.C., Mus. No. 4503. (Pages 30 and 31.)

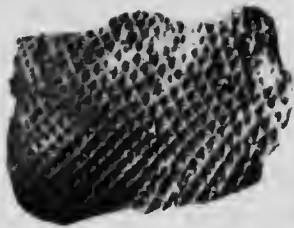
FIGURE 4a. *Enterolasma cf. geometricum* (Foerste). Manitoulin dolomite, near Ice lake, Manitoulin island. G.S.C., Mus. No. 4511. (Pages 30 and 31.)

FIGURE 4b. Calyx of 4a.

FIGURE 5. *Streptelasma cf. haskinsoni* Foerste. Manitoulin dolomite, near Ice lake, Manitoulin island. G.S.C., Mus. No. 4512. (Pages 30 and 31.)

FIGURE 6a, b; 7a, b. *Brockocystis tecumseth* (Billings). Manitoulin dolomite, near Ice lake, Manitoulin island. G.S.C., Mus. No. 4516, 4516a. (Pages 30 and 31.)

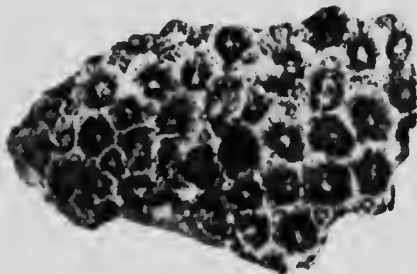
FIGURE 8. *Farosites cristatus* Edwards and Haima. St. Edmund dolomite, Centre bluff, Cabot Head. G.S.C., Mus. No. 4513. (Page 28.)



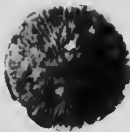
1



2



3



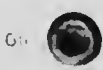
4a



4b



5



6a



7a



6b



7b



8

PLATE VI.

Medina-Cataract Fossils.

Characteristic fossils of Manitoulin dolomite.

(Figures natural size excepting 1b.)

FIGURE 1a. *Palaofavosites asper* D'Orbigny. Manitoulin dolomite, near Ice lake, Manitoulin island. G.S.C., Mus. No. 4514. (Pages 30 and 31.)

FIGURE 1b. A natural section of Figure 1a, enlarged X 2. (Pages 30 and 31.)

FIGURE 2. *Strophonella striata* (Hall). Manitoulin dolomite, Lavender falls, Ont. G.S.C., Mus. No. 4629. (Pages 31 and 31.)

FIGURE 3. *Orthis flabellites* Foerste. Manitoulin dolomite, Lavender falls, Ont. (Pages 30 and 31.)

FIGURE 4a. *Platystrophia beforata* (Seldotheim), brachial valve. Cribot Heel shale, just above Manitoulin dolomite, Eugenia falls, Ont. G.S.C., Mus. No. 4517. (Pages 30 and 31.)

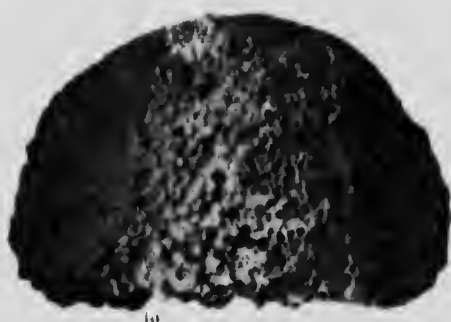
FIGURE 4b. Frontal view of Figure 4a. (Pages 30 and 31.)

FIGURE 5a. *Calospira planoconvexa* (Hall), brachial valves. Manitoulin dolomite, near lake Manitou. G.S.C., Mus. No. 4518. (Pages 30 and 31.)

FIGURE 5b. *Calospira planoconvexa* Hall, frontal view. Locality same as Figure 5a. (Pages 30 and 31.)

FIGURE 5c. Pedicle valve of Figure 5b. (Pages 30 and 31.)

FIGURE 6. Pedicle valve of *Lepæna rhomboidalis* (Willekens). Manitoulin dolomite from Blue mountain 5 miles west of Collingwood. G.S.C., Mus. No. 4520. (Pages 30 and 31.)



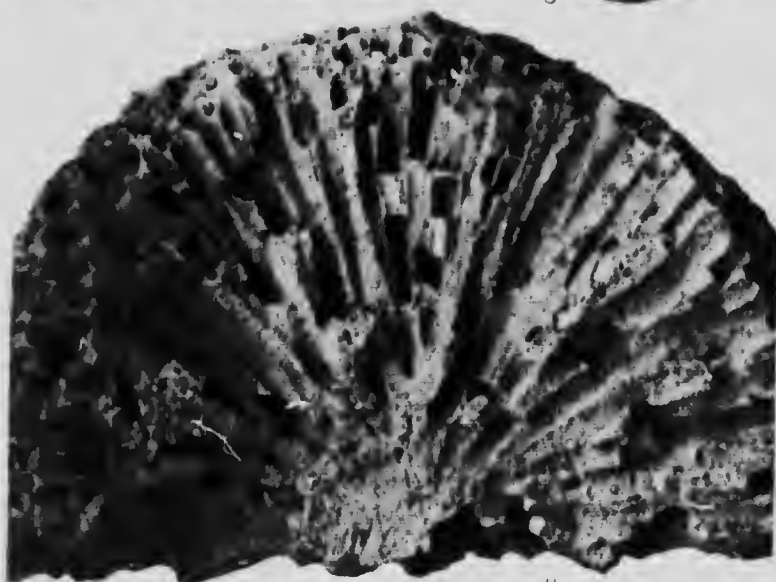
1a



2



3



1b



4a



4b



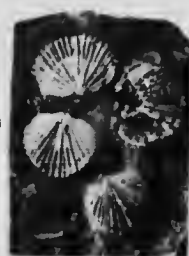
5c



5b



6



5a

PLATE VII

Medusa-shaped Fossils

(Figures natural size.)

- FIGURE 1. *Dalmanella eupennensis* n. sp., pedicle valve. Manitoulin dolomite, Lavender fall, Ont. G.S.C., Mus. No. 4521. (Page 118.)
- FIGURE 2a, b. *D. eupennensis*, pedicle and frontal views of small specimen. Locality same as last. G.S.C., Mus. No. 4521a. (Page 118.)
- FIGURE 3a, b, c, d. *D. eupennensis*, pedicle, frontal, brachial, and lateral views of small specimen. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4522. (Page 118.)
- FIGURE 4. *D. eupennensis*, interior of pedicle and brachial valves, which are attached by rock. Manitoulin dolomite, Lavender falls. G.S.C., Mus. No. 4521b. (Page 118.)
- FIGURE 5. *D. eupennensis*, interior brachial valve. Cabot Head shale, 10 feet above Manitoulin dolomite, Eugenia. G.S.C., Mus. No. 4521c. (Page 118.)
- FIGURE 6. *D. eupennensis*, interior pedicle valve. Locality same as Figure 5. G.S.C., Mus. No. 4522a. (Page 118.)
- FIGURE 7a, b. *D. anella eupennensis* var. *petiolus petiolatus* n. var., pedicle and brachial valves. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4609. (Page 118.)
- FIGURE 8a, b. *D. eupennensis* var. *petiolus petiolatus*, brachial and cardinal views. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4609. (Page 118.)
- FIGURE 9a. *Rhyndomella hydra* Savoy, brachial and lateral views. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4617. (Page 35.)
- FIGURE 9 b. Pedicle valve of 9a. (Page 37.)
- FIGURE 10a, b. *Camerozouchea spectabilis* Hall, pedicle and frontal views. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4621. (Page 35.)
- FIGURE 11a, b. *Rhynchotretra cabotensis* n. sp., brachial and lateral views. Cabot Head shale at top of Dyer Bay dolomite, Clay cliff near Cabot head. G.S.C., Mus. No. 4622. (Page 129.)
- FIGURE 12. *Rhynchotretra cf. lepida* Savoy, brachial view. Cabot Head shale just above Dyer Bay dolomite, Clay cliff, near Cabot head. G.S.C., Mus. No. 4623. (Page 35.)
- FIGURE 13a, b. *R. cf. lepida*, pedicle and brachial views, small specimen. Locality same as Figure 12. G.S.C., Mus. No. 4626b. (Page 35.)
- FIGURE 14. *R. cf. lepida*, a narrow specimen. Locality same as Figure 13. G.S.C., Mus. No. 4626a. (Page 35.)
- FIGURE 15a, b. *Rhynchotretra williamsi* Foerste, n. sp., pedicle and lateral views. Manitoulin dolomite, Manitowaning lay, Manitoulin island. G.S.C., Mus. No. 4631. (Page 126.)
- FIGURE 16a, b. *Whitfieldella cataractensis* n. sp., brachial and lateral views. Cabot Head shale near Owen Sound. G.S.C., Mus. No. 4627. (Page 121.)
- FIGURE 17. a, b, c. *W. cataractensis*, brachial, pedicle, and lateral views. Cabot Head shale, Stony Creek. G.S.C., Mus. No. 4628. (Page 121.)
- FIGURE 18. *W. cataractensis*, pedicle view of another from Stony Creek. G.S.C., Mus. No. 4629. (Page 121.)
- FIGURE 19a, b, c. *Atrypa parksi* n. sp., brachial, pedicle, and frontal views. Cabot Head shale, Credit Forks. G.S.C., Mus. No. 4673. (Page 120.)
- FIGURE 20. *Virgiana mayellensis* Savoy, pedicle valve. Dyer Bay dolomite, South lay, Manitoulin island. G.S.C., Mus. No. 4674. (Page 37.)
- FIGURE 21. *Virgiana mayellensis* Savoy, pedicle valve. Dyer Bay dolomite, Tamarack cove, Manitoulin island. G.S.C., Mus. No. 4675. (Page 37.)
- FIGURE 22a, b. *Lophospira pulchra* n. sp. Manitoulin dolomite, Cataract, Ont. G.S.C., Mus. No. 4678. (Page 123.)
- FIGURE 23. *Sirophostyles cf. cyclostoma* Hall. Manitoulin beds, Jordan, Ont. G.S.C., Mus. No. 4679. (Page 28.)



PLATE VIII.

Molina-Caturact Fossils.

(Figures natural size.)

- FIGURE 1. *Hormotoma subulata* (Conrad)?? Top of Whirlpool sandstone, Glen William, Ont. G.S.C., Mus. No. 4680. (Page 28.)
- FIGURE 2. *Pterinea cf. undata* (Hall). Grimsby, red argillaceous sandstone, Flamboro, Wentworth county. G.S.C., Mus. No. 2703. (Pages 40 and 122.)
- FIGURE 3. *Modiolopsis kelsoensis* n. sp. "Iron band" horizon of Grimsby sandstone near Kelso, Ont. G.S.C., Mus. No. 1684. (Pages 40 and 123.)
- FIGURE 4. *Ctenodonta machaziformis* (Hall) and *Nuculites* (*Cleidophorus*) *cf. ferrugineum* Foerste. Red Grimsby sandstone, Flamboro West. G.S.C., Mus. No. 2708. (Page 40.)
- FIGURE 5. *Modiolopsis kelsoensis*. Grimsby sandstone, lot 11, concession I, Flamboro West. G.S.C., Mus. No. 2709. (Pages 40 and 123.)

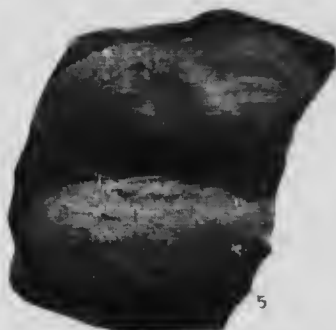
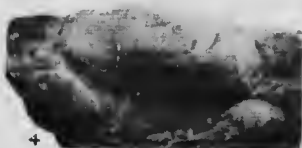
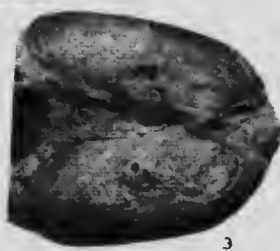
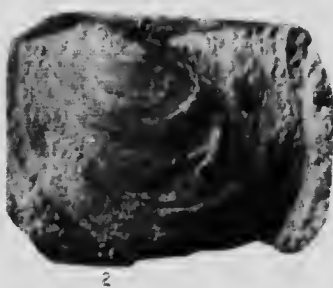
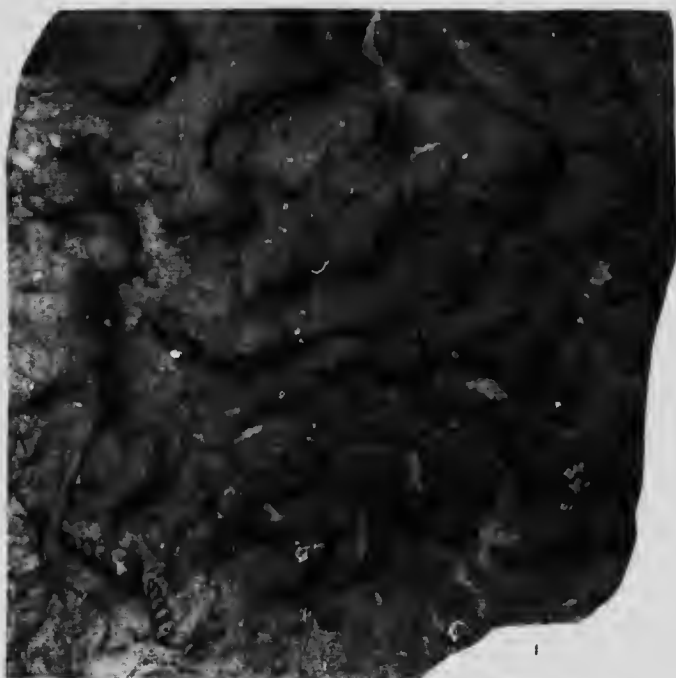


PLATE IX.

Onton Fossils.

Figures natural size.

FIGURE 1, *Stricklandonia canadensis* Billings, pedicle valve, Reynales (Wolcott) dolomite, Thorold. After Paleozoic fossils, vol. II, pt. 1, pl. 6, fig. 3. (Page 49.)

FIGURE 2, *Stricklandonia canadensis* Billings, cardinal view, Top of Reynales (Wolcott) dolomite, Grimsby, Ont. G.S.C., Mus. No. 4684. (Page 49.)

FIGURE 3, *Stricklandonia canadensis* Billings, brachial valve, Reynales (Wolcott) dolomite. After Paleozoic fossils, vol. II, pt. 1, pl. 6, fig. 2. (Page 49.)

FIGURE 4, *Ruthotrophia gracilis* var. *crassa* (Hall), Reynales (Wolcott) dolomite. After Paleontology of New York, vol. II, pl. 5, fig. 3a. (Page 49.)

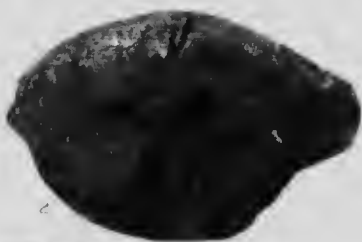


PLATE X.

Clinton Fossils.

(Figures natural size except 7b.)

FIGURE 1. *Spirifer radiatus* (Sowerby). Reynales (Wolcott) and Irondequoit dolomites. After Palaeontology of New York, vol. II, pl. 22, fig. 2f. (Page 49.)

FIGURE 2. *Hyalidina congesta* (Conrad). 2a, brachial, 2b, frontal, views. Reynales (Wolcott) dolomite. After Palaeontology of New York, vol. II, pl. 23, figs. 2c and 2d. (Page 49.)

FIGURE 3. *Calospira hemispherica* (Sowerby). 3a, pedicle, and 3b, brachial, valves. Sodus shale. After Palaeontology of New York, vol. VIII, pt. II, pl. 82, figs. 2 and 3. (Page 48.)

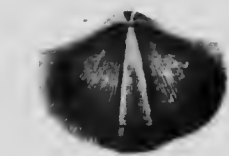
FIGURE 4. *Whitfieldella cylindrica* (Hall). 4a, brachial, 4b, lateral, views. Irondequoit dolomite. After Palaeontology of New York, vol. II, pl. 24, figs. 2a, 2c. (Page 51.)

FIGURE 5. *Whitfieldella intermedia* (Hall). 5a, brachial, 5b, lateral, views. Reynales (Wolcott) and Irondequoit dolomites. After Palaeontology of New York, vol. II, pl. 24, figs. 3a, 3b. (Page 49.)

FIGURE 6. *Rhynchotreta robusta* (Hall), pedicle valve. Irondequoit dolomite. After Palaeontology of New York, vol. II, pl. 23, fig. 7a. (Page 51.)

FIGURE 7. *Tentaculites minutus* Hall. 7a, specimens natural size; 7b, magnified about four times. Reported from "lower Clinton" of Clinton, N.Y., by Hall. After Palaeontology of New York, vol. II, pl. 41a, figs. 8b, c. (Page 55.)

PLATE X.



1



2a



2b



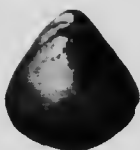
3a



3b



4a



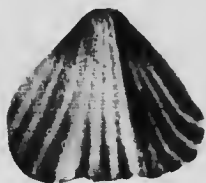
5a



5b



4b



6



7a

7b

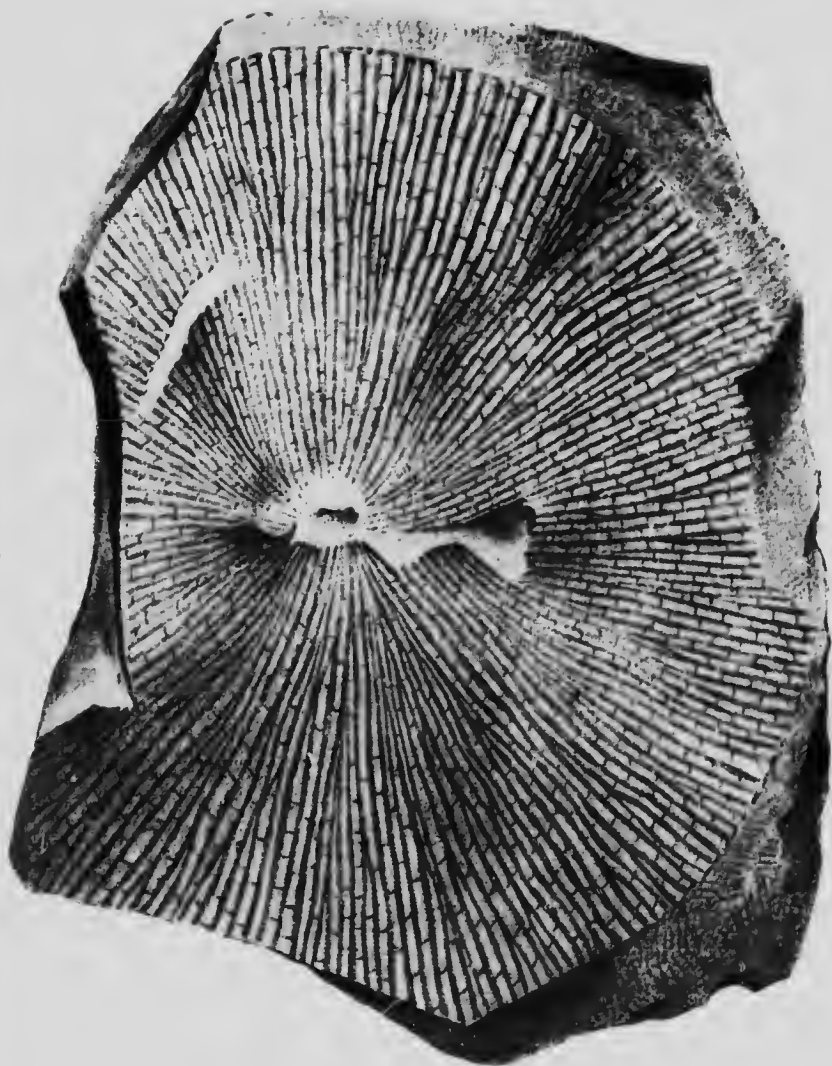
PLATE XI.

Rochester Fossils.

(Natural size.)

FIGURE 1. *Dactyonomis rectiformis* (Hall). Rochester shale. After Palaeontology of New York, vol. II, pl. 40 F, fig. 1a. (Page 54.)

PLATE XI



57237-124

PLATE XII.

Rochester Fossils.

(Figures natural size except 10b.)

- FIGURE 1. *Caryoceras ornatus* Say. After Palaeontology of New York, vol. II, pl. 49, fig. 1d. (Pages 54-56.)
- FIGURE 2. *Stephanocrinus angulatus* Conrad. After Palaeontology of New York, vol. II, pl. 48, fig. 1a. (Pages 54-56.)
- FIGURE 3. *Spirifer cuspis* (Hisinger). 3a, 3b: two specimens from brachial side. After Palaeontology of New York, vol. II, pl. 54, figs. 3c, 3d. (Pages 54-56.)
- FIGURE 4. *Atrypa reticularis* (Linnaeus). 4a, pedicle valve, 4b, frontal view. After Palaeontology of New York, vol. II, pl. 55, figs. 5n, 5o. (Pages 54-56.)
- FIGURE 5. *Atrypa nodulata* Hall. 5a, brachial, 5b, lateral, views. After Palaeontology of New York, vol. II, pl. 5b, figs. 2m, 2n. (Pages 54-56.)
- FIGURE 6. *Camarotoechia obtusiplicata* (Hall). 6a, brachial, 6b, pedicle, views. After Palaeontology of New York, vol. II, pl. 58, figs. 2a, 2b. (Pages 54-56.)
- FIGURE 7. *Rhipidomella hybrida* (Sowerby). 7a, pedicle, 7b, lateral views. After Palaeontology of New York, vol. II, pl. 52, figs. 4l, 4g. (Pages 54-56.)
- FIGURE 8. *Dalmanella elegantula* (Dalman). 8a, pedicle, 8b, frontal, views. After Palaeontology of New York, vol. II, pl. 52, figs. 3c, 3b. (Pages 54-56.)
- FIGURE 9. *Whitfieldella nitida oblata* (Hall). 9a, lateral, 9b, brachial, view. After Palaeontology of New York, vol. II, pl. 55, figs. 2c, 2a. (Pages 54-56.)
- FIGURE 10. *Bilobites acutilobus* (Ringueberg). 10a, pedicle valve, 10b, the same enlarged. After Proc. Acad. Nat. Sc., Phila., 1858, pl. VII, figs. 5 and 5a. (Pages 54-56.)
- FIGURE 11. *Whitfieldella nitida* (Hall). 11a, lateral, 11b, brachial, views. After Palaeontology of New York, vol. II, pl. 55, figs. 1n and 1o. (Pages 54-56.)
- FIGURE 12. *Spirifer niagarensis* (Conrad). pedicle valve. After Palaeontology of New York, vol. II, pl. 54, fig. 5k. (Pages 54-56.)
- FIGURE 13. *Spirifer niagarensis* (Conrad). 13a, brachial valve, 13b, interior pedicle valve, showing crura (c). After Palaeontology of New York, vol. VIII, pt. II, pl. 21, figs. 1 and 2. (Pages 54-56.)

PLATE XII

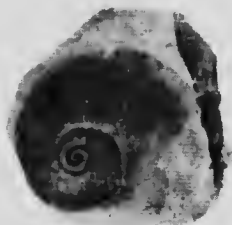
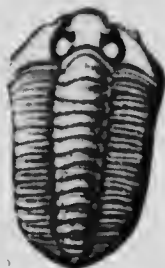
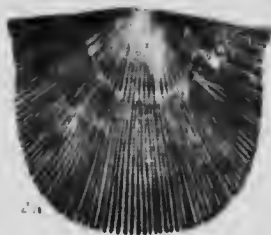


PLATE XIII.

Rochester Fossils.

(Figures natural size.)

- FIGURE 1. *Straphonella? decussata* n.sp. brachial valve. DeCew falls, Ont. (G.S.C., Mus. No. 4687. (Page 124.)
- FIGURE 2 a, b. *Schuchertella subplana* (Conrad), pedicle and ear-lid views. (From Palaeontology of New York, vol. II, pl. 53, figs. 10a, 10b. (Pages 54-56.)
- FIGURE 3. *Platyceras angulatum* (Hall). (After Palaeontology of New York, vol. II, pl. 60, fig. 4. (Pages 54-56.)
- FIGURE 4. *Homalonus delphinocephalus* (Green). (After Palaeontology of New York, vol. II, pl. 68, fig. 4. (Pages 54-56.)
- FIGURE 5. *Corymbus megarhynchus* Hall. (After Chicago Academy of Sciences, Bull. IV, pl. 23, fig. 10. (Pages 54-56.)
- FIGURE 6. *Daphnostoma megarhynchus* (Hall). (After Palaeontology of New York, vol. II, pl. 60, fig. 1. (Pages 54-56.)
- FIGURE 7. *Daphnostoma hemisphaerium* (Hall). (After Palaeontology of New York, vol. II, pl. 60, fig. 2a. (Pages 54-56.)





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PLATE XIV.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Zaphrentis stokesi* Edwards and Haime. Above Fossil Hill horizon, New England. Manitoulin island. G.S.C., Mus. No. 4688. (Page 65.)

FIGURE 2. *Zaphrentis stokesi* Edwards and Haime. Boulder bluff, Cabot head, lake Huron. G.S.C., Mus. No. 4694. (Page 65.)

FIGURE 3. *Alveolites labichei* Edwards and Haime. Skunk island, south side Manitoulin island. G.S.C., Mus. No. 2642a. (Page 65.)

FIGURE 4. *Ptychophyllum stokesi* Edwards and Haime. Fossil hill, Manitoulin island. G.S.C., Mus. No. 4696. (Page 65.)

PLATE XIV.



1



2



3



4

PLATE XV

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Cyathophyllum solitarium* Billings' type. Portage bay, Lake Manitou, Manitoulin island. G.S.C., Mus. No. 2637. (Page 65.)

FIGURE 2. *Strombodes pentaporus* Goldfuss. Fossil hill. G.S.C., Mus. No. 5073. (Page 65.)

FIGURE 3. *Ptychophyllum stokesi* Edwards and Haine. Fossil hill, Manitoulin island. G.S.C. Mus. No. 4696a. (Page 65.)

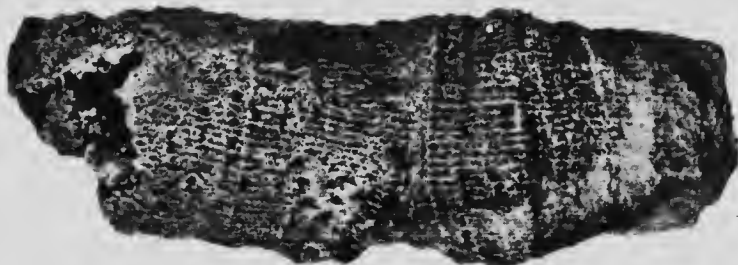
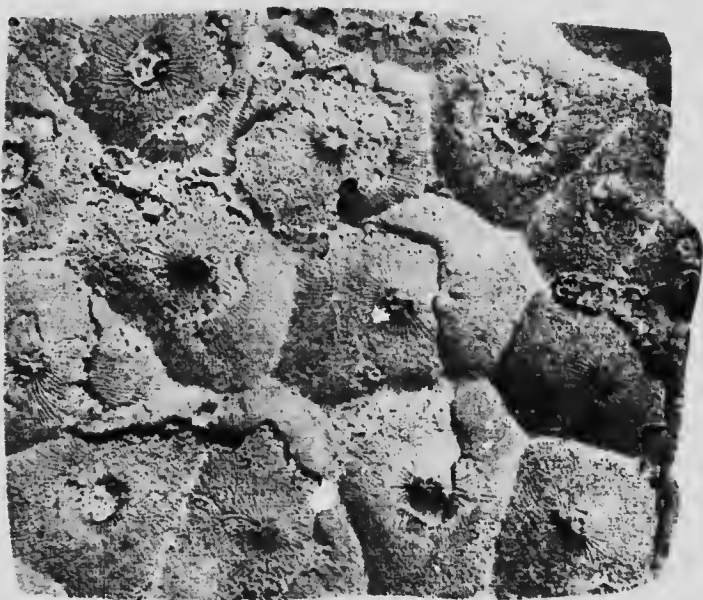


PLATE XVI.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Synaptophyllum multicaule* Hall. Fossil hill. G.S.C., Mus. No. 5074. (Page 65.)

FIGURE 2. *Strombodes pentagonus* Goldfuss. Fossil hill. G.S.C., Mus. No. 5073a. (Page 65.)

FIGURE 3. *Syringopora dolmani* Billings' type. Lake Timiskaming, collected by W. E. Logan. G.S.C., Mus. No. 2618. (Page 65.)



PLATE XVII.

Lakeport Fossils.

(Figures natural size.)

FIGURE 1. *Syringopora retiformis* Billings' type. Owen Sound, collector R. Bell. G.S.C., Mus. No. 2617. (Page 65.)

FIGURE 2. *Favosites hisingeri* Edwards and Haine. Fossil hill, Manitoulin island. G.S.C., Mus. No. 5075. (Page 65.)

FIGURE 3. *Polyfysosites asper* D'Orbigny. Fossil hill, Manitoulin island. G.S.C., Mus. No. 5138. (Page 65.)

FIGURE 4. *Syringopora fibrata* Rominger. Long bay, Manitoulin island, G.S.C., Mus. No. 5076. (Page 65.)

FIGURE 5. *Vermetopora magarensis* Rominger? Fossil hill, G.S.C., Mus. No. 5117. (Page 65.)

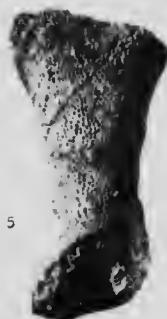
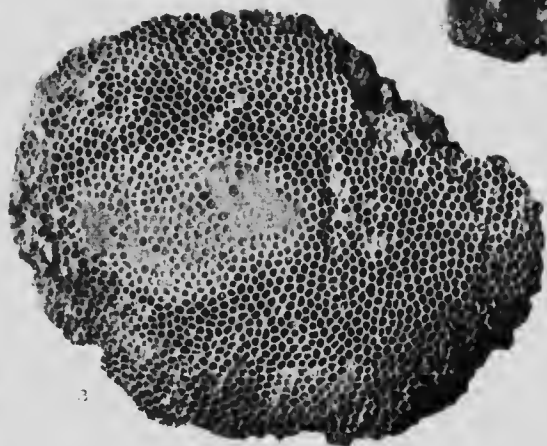
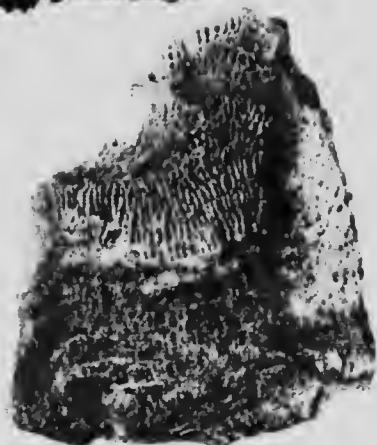
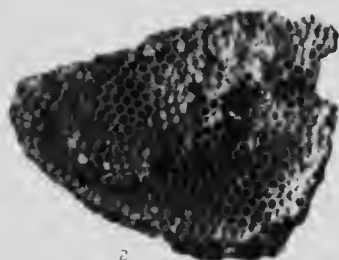


PLATE XVIII.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Favosites facinus* (Goldfuss). Fossil hill, Manitoulin island, G.S.C., Mus. No. 5118. (Page 65.)

FIGURE 2. *Favosites hispidus* Rominger. Talus at Boulder bluff, Cabot head, lake Huron. G.S.C., Mus., No. 5119. (Page 65.)

FIGURE 3. *Cladopora reticulata* Hall. Plateau east of Sandfield, Manitoulin island. G.S.C., Mus. No. 5120. (Page 65.)

FIGURE 4. *Lygella americana* Edwards and Haine. Talus, Centre bluff, Cabot head, lake Huron. G.S.C., Mus. No. 5121. (Page 65.)

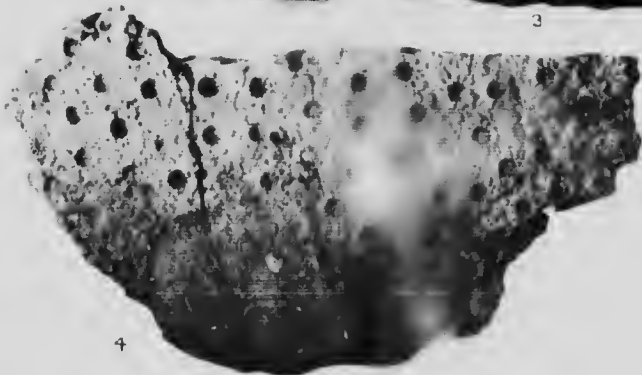
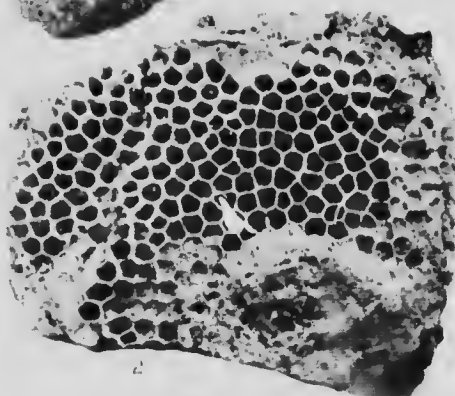


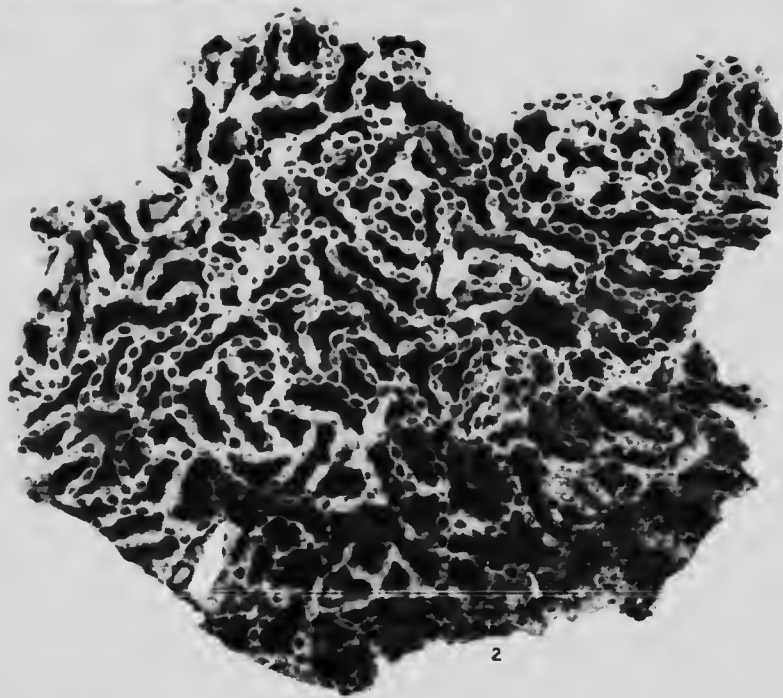
PLATE XIX.

Lockport Fossils.

Figures natural size.

FIGURE 1, *Cantex crassus* (Rominger). Fossil hill, Manitoulin island. G.S.C., Mps. No. 5124. Page 65.

FIGURE 2, *Halysites catenularia* (Linnaeus). Fossil hill, Manitoulin island. G.S.C., Mps. No. 5124. Page 65.



2

PLATE XX.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Halysites catenularia microporus* (Whitfield). Fossil hill, Manitoulin island. G.S.C., Mus. No. 5125. (Page 65.)

FIGURE 2. *Stricklandinia manitouensis* n. sp. 2a, brachial, 2b, lateral, 2c, cardinal, views. Plateau east of Sandfield, Manitoulin island. G.S.C., Mus. No. 5125. (Page 124.)

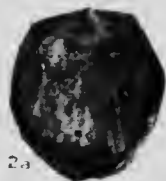
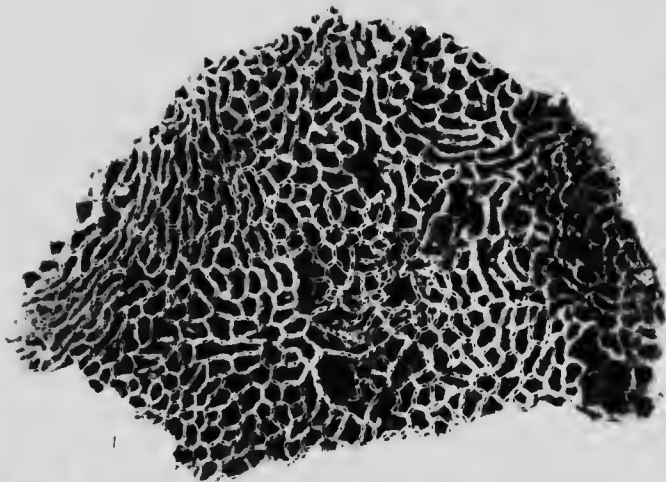
FIGURE 3. *Stricklandinia manitouensis* n. sp. Cardinal view of a comparatively thin specimen. G.S.C., Mus. No. 5126a. (Page 124.)

FIGURE 4. *Homospira opriniformis* Hall. 4a, pedicle, 4b, frontal, views. Plateau east of Sandfield, Manitoulin island. G.S.C., Mus. No. 5127. (Page 67.)

FIGURE 5. *Spirifer eudora* (Hall). 5a, lateral view of a specimen from the Niagara group of Racine, Wisconsin; 5b, pedicle view of a specimen from the Niagara group of Waldron, Indiana. After Paleontology of New York, vol. VIII, pt. II, pl. 21, figs. 20, 21. (Page 67.)

FIGURE 6. *Pentamerus oblongus* Sowerby. Eight feet above base of Lockport dolomite at Warton. G.S.C., Mus. No. 5128. (Page 67.)

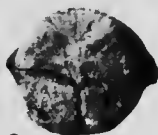
FIGURE 7. *Clorinda ventricosa* (Hall). 7a, brachial, 7b, lateral, views, of specimen from Niagara group of Waukesha, Wisconsin. After 20th Rept. New York Cabinet Natural History, pl. 13, figs. 18 and 19. (Page 67.)



2a



2b



2c



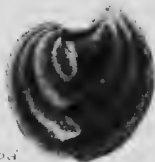
3



4a



4b



5a



5b



6



7a



7b

PLATE XXI.

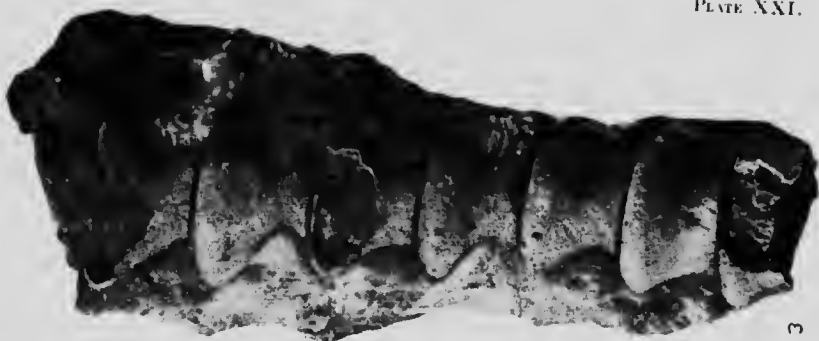
Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Dawsonocras annulatum* (Sowerby). After Palaeontology of New York, vol. II, pl. 64, fig. 1c. (Page 68.)

FIGURE 2. *Dalmanites limulacus* Green. West Flamboro, Ont. Collector, Foord, 1881. G.S.C., Mus. No. 2751. (Page 68.)

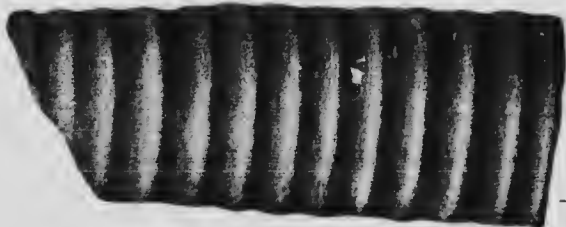
FIGURE 3. *Huronina vertebralis* Stokes. Huronia point, Cockburn island. Collector, R. Bell, 1866. G.S.C., Mus. No. 2733. (Page 68.)



3



2



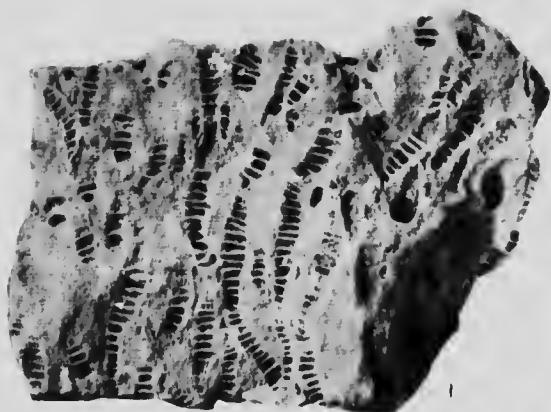
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PLATE XXII.

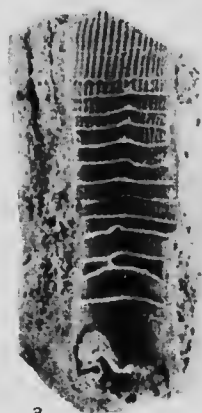
Guelpf Fossils.

(Figures natural size.)

- FIGURE 1. *Pycnostylus guelpensis* Whiteaves. Collected at Hespeler by E. Billings, 1857. G.S.C., Mus. No. 2789. (Page 77.)
- FIGURE 2. *Pycnostylus elegans* Whitenaves type. Collected at Hespeler by T. C. Weston, 1867. G.S.C., Mus. No. 2790c. (Page 77.)
- FIGURE 3. *Pycnostylus elegans* Whiteaves type. Interior view, showing tabule and marginal septa. Collected at Hespeler by T. C. Weston, 1867. G.S.C., Mus. No. 2790. (Page 77.)
- FIGURE 4. *Trimerella grandis* Billings type. 4a, brachial, 4b, pedicle, views of an internal cast from Hespeler, Ont. G.S.C., Mus. No. 2803. (Page 77.)
- FIGURE 5. *Whitfieldella hyale* (Billings). 5a, frontal, 5b, brachial, views. Hespeler, Ont. G.S.C., Mus. No. 2806. (Page 78.)
- FIGURE 6. *Amphicalia leidy* Hall. From zinc prospect near Winton. G.S.C., Mus. No. 5129. (Page 78.)



2



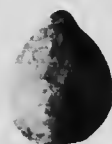
3



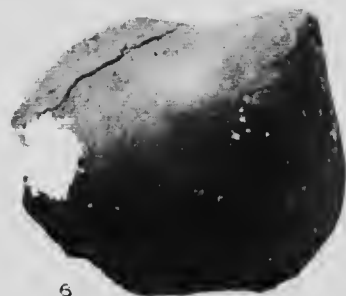
4a



5a



5b



6



4b

PLATE XXIII.

Guelph Fossils.

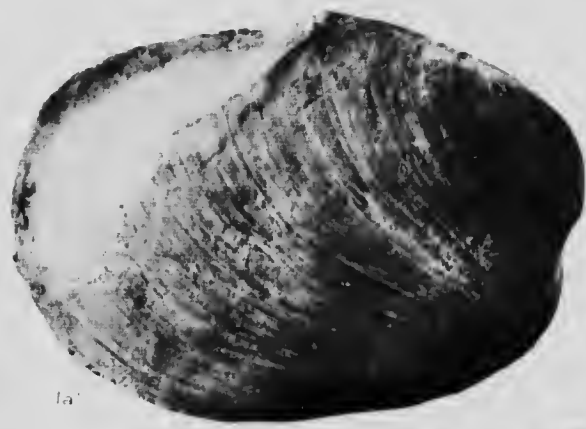
(Figures natural size.)

FIGURE 1. *Megalomus canadensis* Hall. 1a, right valve; 1b, dorsal view. Collected at Elora by D. Boyle, 1880. (G.S.C. Mus. No. 2827. (Page 78.)

FIGURE 2. *Megalomus canadensis* Hall. Right side of internal cast. From Galt, Ont. (G.S.C. Mus. No. 5130. (Page 78.)

FIGURE 3. *Conchidium occidentale* (Hall). 3a, cardinal area of cast of interior; 3b, brachial valve. After Geology of Canada, 1863, p. 337, fig. 341, a and c. (Page 77.)

FIGURE 4. *Mytilarca acutirostra* (Hall). Cast of interior. After 20th Rept. Cabinet of Natural History, New York State, pl. 14, fig. 2. (Page 78.)



1a



3a



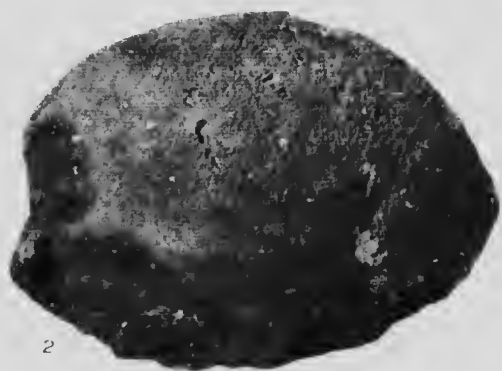
1b



3b



4



2

PLATE XXIV.

Guelph Fossils.

(Figures natural size.)

FIGURE 1. *Liospira perlata* (Hall). 1a, top, and 1b, basal, views. From Galt, Ont. G.S.C. Mus. No. 2871. (Page 78.)

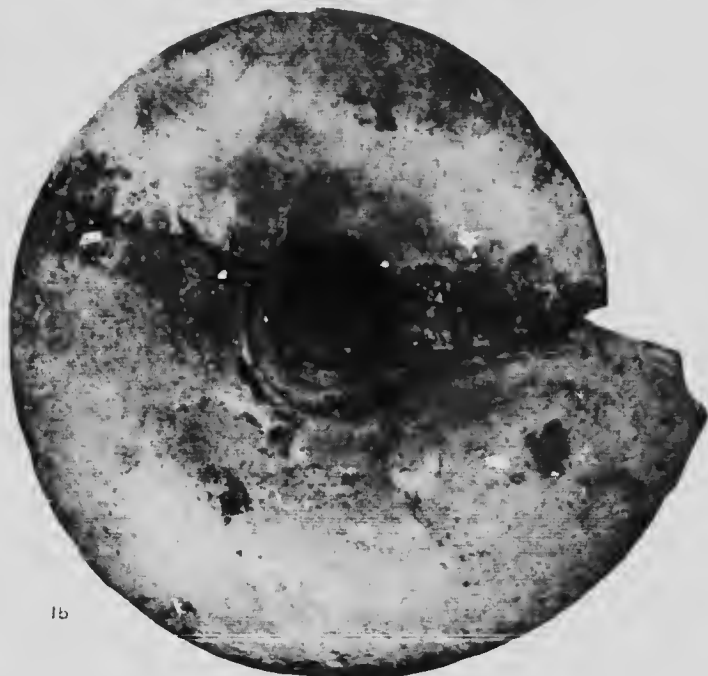


PLATE XXV.

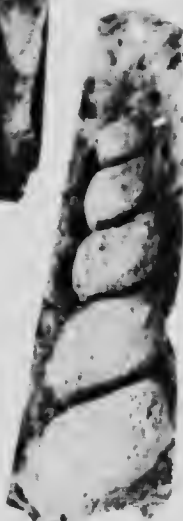
Geolph Fossils.

(Figures natural size.)

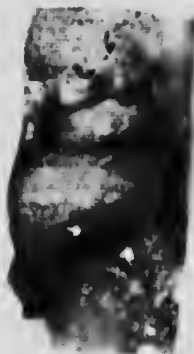
- FIGURE 1. *Calocaulus longispira* (Hall). Natural section showing interior. From Baptist harbour, Bruce peninsula. G.S.C., Mus. No. 5131. (Page 78.)
- FIGURE 2. *Calocaulus longispira* (Hall). Small specimen collected at Dealham by J. Townsend, 1874-82. G.S.C., Mus. No. 2895a. (Page 78.)
- FIGURE 3. *Hormotoma* cf. *whitecrossi* Clarke and Ruedemann. This specimen is more slender than those described by Clarke and Ruedemann. Collected at Elora or Hespeler by T. C. Weston, 1867. G.S.C., Mus. No. 2859b. (Page 81.)
- FIGURE 4. *Calocaulus vitellus* (Billings). Collected at Galt by E. Billings, 1857. G.S.C., Mus. No. 2882. (Page 81.)
- FIGURE 5. *Straperollina daphne* (Billings), umbilical view. Collected at Elora by D. Boyle, 1880. G.S.C., Mus. No. 2856. (Page 81.)
- FIGURE 6. *Holopea geolphensis* Billings. Collected at Durham by A. Murray, 1857. G.S.C., Mus. No. 2848. (Page 79.)
- FIGURE 7. *Euomphalus gallensis* Whiteaves. Collected at Durham by J. Townsend. G.S.C., Mus. No. 2853. (Page 78.)
- FIGURE 8. *Murchisonia biltingsana* Miller. Collected at Galt by T. C. Weston, 1857. G.S.C., Mus. No. 2875. (Page 81.)
- FIGURE 9. *Calocaulus vitellus* (Billings). Collected at Durham by J. Townsend, 1882. G.S.C., Mus. No. 2881. (Page 81.)
- FIGURE 10. *Trematodus angustatus* (Hall). Collected at Hespeler by E. Billings and A. Murray, 1867. G.S.C., Mus. No. 2911a. (Page 89.)



2



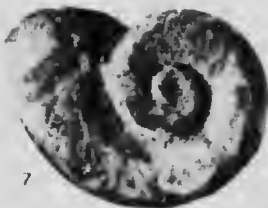
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5



6



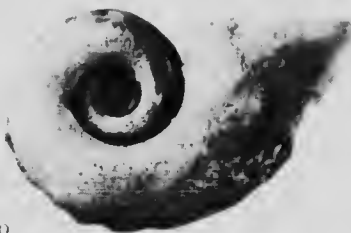
7



8



9



10

PLATE XXVI.

Guelph Fossils,

(Figures natural size.)

FIGURE 1a. *Orthoceras bruceensis* n. sp. Partly natural and partly artificial longitudinal section. From Hay bay, Bruce peninsula, Ont. (G.S.C., Mus. No. 5332. (Page 124.)

FIGURE 1b. Smallest camera showing position of siphuncle. (Page 124.)

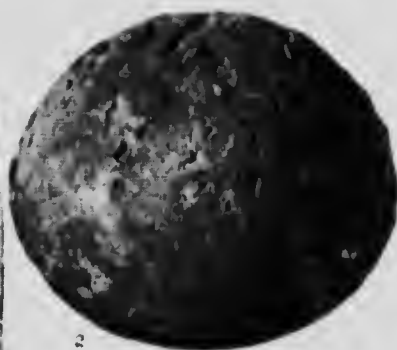
FIGURE 2. *Poterioceras* n. sp., septum next to living chamber showing location of siphuncle. From lower Guelph at zinc prospect near Warton. (G.S.C., Mus. No. 5133. (Page 79.)

FIGURE 3. *Poterioceras* n. sp., segment near distal end. (G.S.C., Mus. No. 5133a. (Page 79.)

FIGURE 4. *Poterioceras* n. sp., much of living chamber and the greater part of the body. Locality same as Figures 2 and 3. (G.S.C., Mus. No. 5134. (Page 79.)



1a



2



1b



3



4

PLATE XXVII.

Guelph and Cayugan Fossils.

(Figures natural size except 4 and 5.)

Guelph.

FIGURE 1. *Orthoceras bruceensis* n. sp., showing external characters of shell. From Pine Tree harbour, Bruce peninsula, Ont. G.S.C., Mus. No. 5135. (Page 121.)

FIGURE 2. *Marlonoceras arcticameratum* (Hall). From cape Hurd, Bruce peninsula, Ont. G.S.C., Mus. No. 5136. (Page 79.)

Cayugan.

FIGURE 3. *Eurypterus remipes* DeKay. From top of Bertie waterlous. After New York State Mus. Mem. 14, pt. 2, pl. 5, fig. 5. (Page 83.)

FIGURE 4. *Whitfieldella sulcata* (Vanuxem) magnified 2 diameters: pedicle valve. Akron dolomite one-quarter mile west of Ridgemount, Welland county. G.S.C., Mus. No. 5137. (Page 86.)

FIGURE 5. *Whitfieldella sulcata* (Vanuxem) magnified 2 diameters: frontal view showing sinus on both valves, the upper being the pedicle. G.S.C., Mus. No. 5137a. (Page 85.)

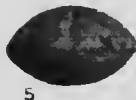


PLATE XXVIII.



A. Lockport and Guelph dolomite. Thin beds 12 feet thick near centre are Eramosa beds. Below car barn, Gorge route, Niagara falls, New York. (Pages 62 and 73.)



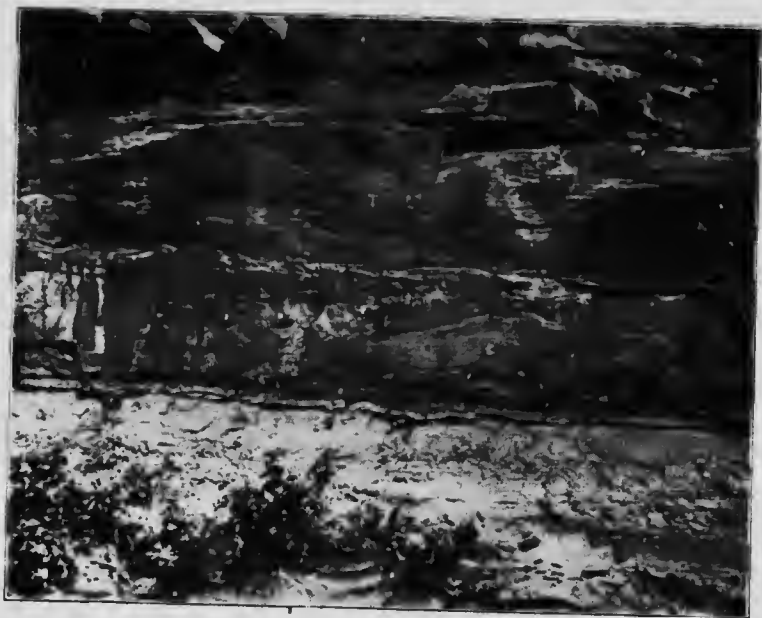
B. Medina sandstone and shale, from Manitoulin beds at bottom to Clinton dolomite at top of hill. Thorold sandstone is conspicuous bed near top. New York Central and Hudson River railway above Lewiston, New York. (Page 24.)



A. Section of Clinton dolomite, Rochester shale, and lower part of Lockport dolomite, at Grimsby. (Pages 46 and 52.)



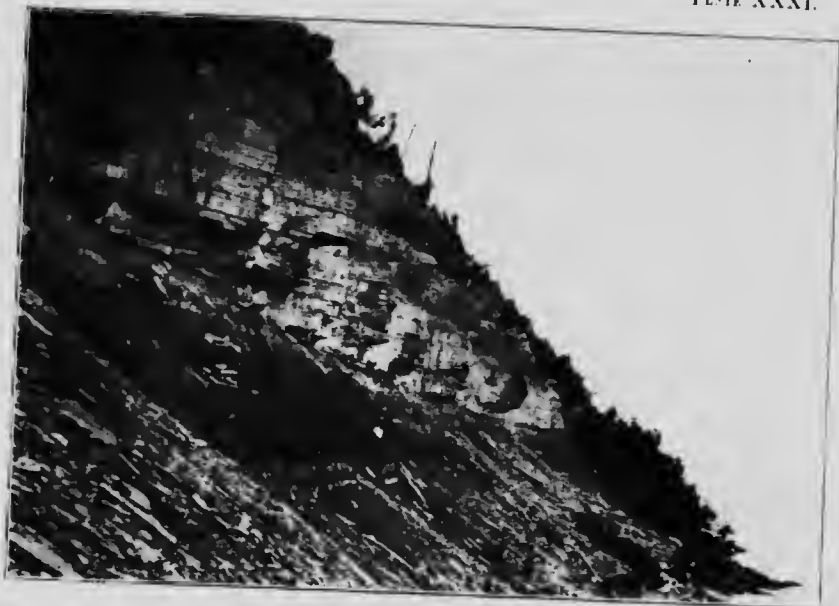
B. Section of Cabot Head shale, Grimsby sandstone and Reynolds dolomite (at very top), at falls on Twenty-mile creek, south of Jordan. (Pages 32 and 39.)



A. Section of DeCew waterline (a little more than the lower half of the picture) and the Gasport and overlying Lockport dolomite. Niagara gorge, New York (Page 58.)



B. Section of upper Cabot Head shale showing a current channel. Niagara gorge, New York. (Page 34.)



A. . . Bay dolomite and underlying red Cabot Head shale, at a locality 3 miles west of Cabot head. (Page 33.)

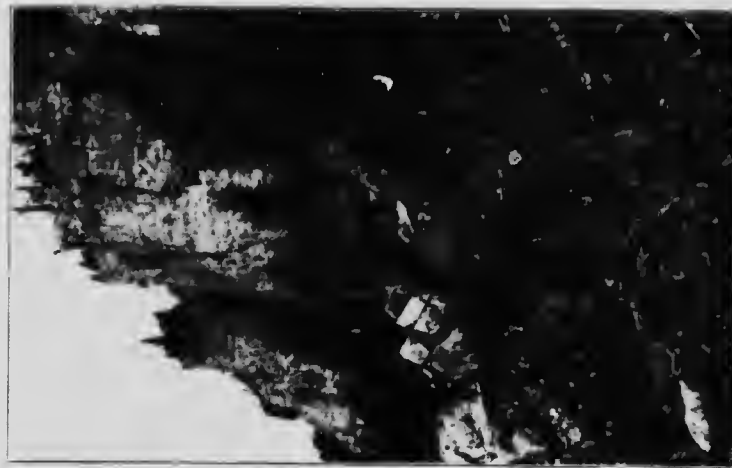


B. Quarry in Manitoulin dolomite, Owen Sound. (Page 28.)

PLATE XXXII.



A. Gorge of Grand river, in Guelph dolomite near Elora
(Page 72.)



B. Niagara escarpment. Cliffs of Lockport dolomite
near Kolapore, Grey county. (Page 57.)

PLATE XXXIII.



A. Eramosa beds and base of Guelph dolomite, near Guelph. (Page 62.)



B. Upper Lockport and lower Guelph dolomite (caves below contact), Half-way rock, north end Bruce peninsula. (Page 62.)

PLATE XXXIV.



A. Shelburne post-office, made from local Lockport dolomite. (Page 97.)



B. Larger Flower pot, composed of Eramosa dolomite, capped with Guelph dolomite. Flowerpot Island, Georgian bay. (Page 62.)

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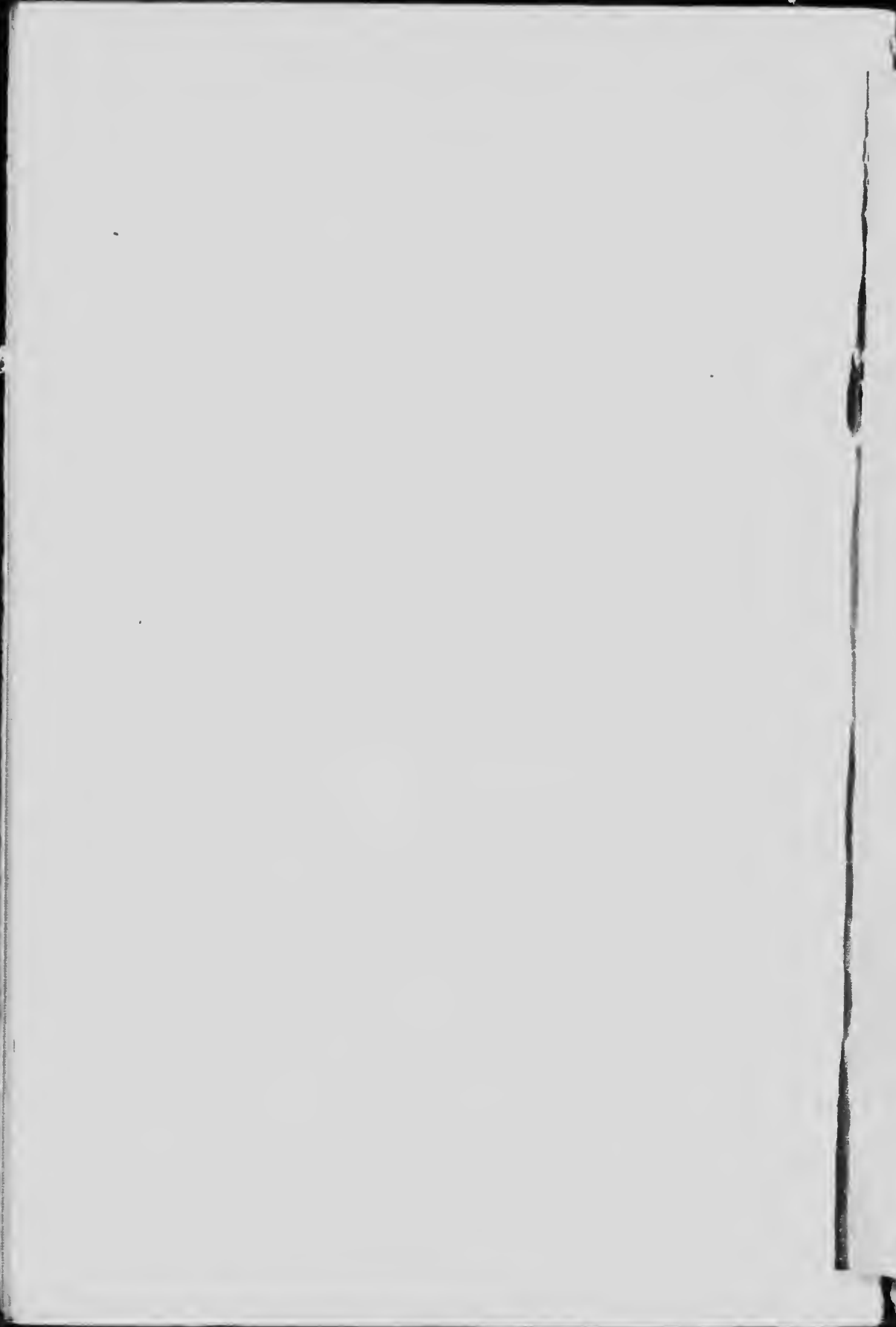
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Point Dover
Bancroft Pt

River

into

POINT BAR

Point

E

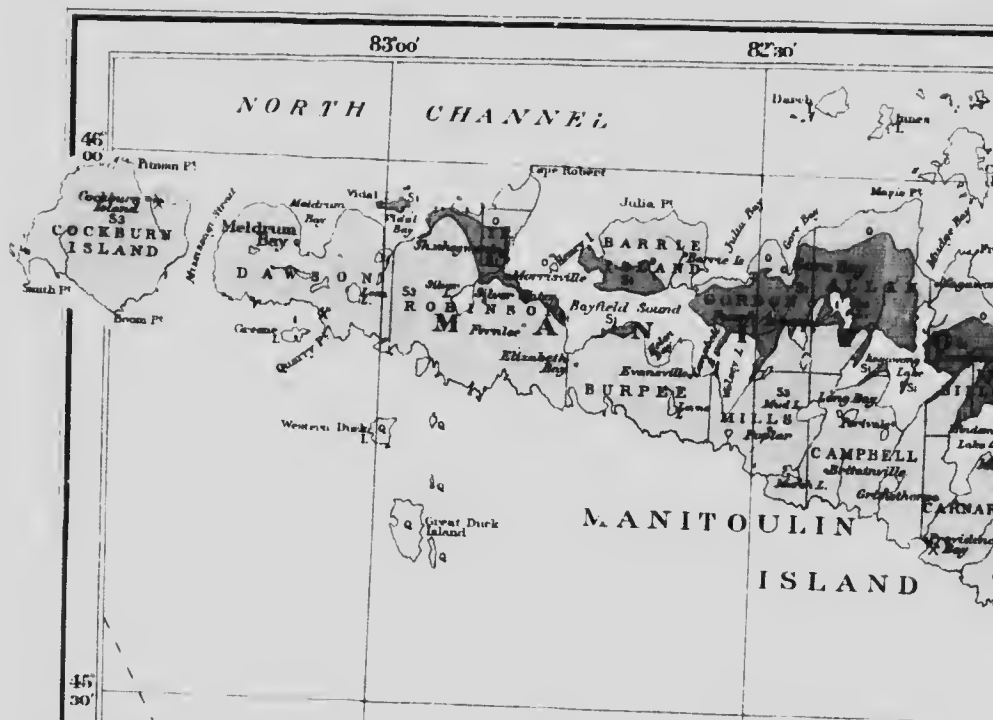
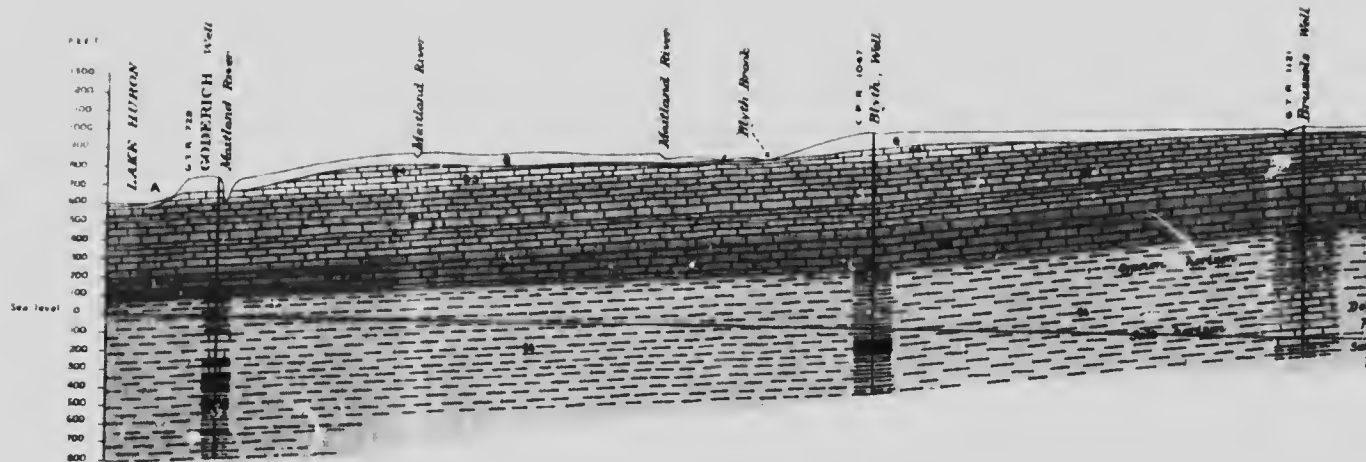
ERIE

C N I I
S T A

8000'

7930'

Devonian
Revised
Silurian



LEGEND

Q

Surface deposits
(soils, clay, gravel, etc.)

D8

Port Lambton formation
(black and greenish shale
with some thin arenaceous/sandy layers)

D7

Huron shale
(black shale, with large spheroidal
concretions near the base)

PLEISTOCENE
AND RECENT

CHEMUNG
AND PORTAGE ?

GENESSEE ?

Canada Department of Mines

J. V. MARIN, SURRELL MINISTER R.G.M. J. NELSON, DEPUTY MINISTER

GEOLOGICAL SURVEY

L. M. NELSON, CHIEF GEOLOGIST

Issued 1918

(Surface elevations estimated only excepting where marked)

Don Allen, N.W.
approximate elevation

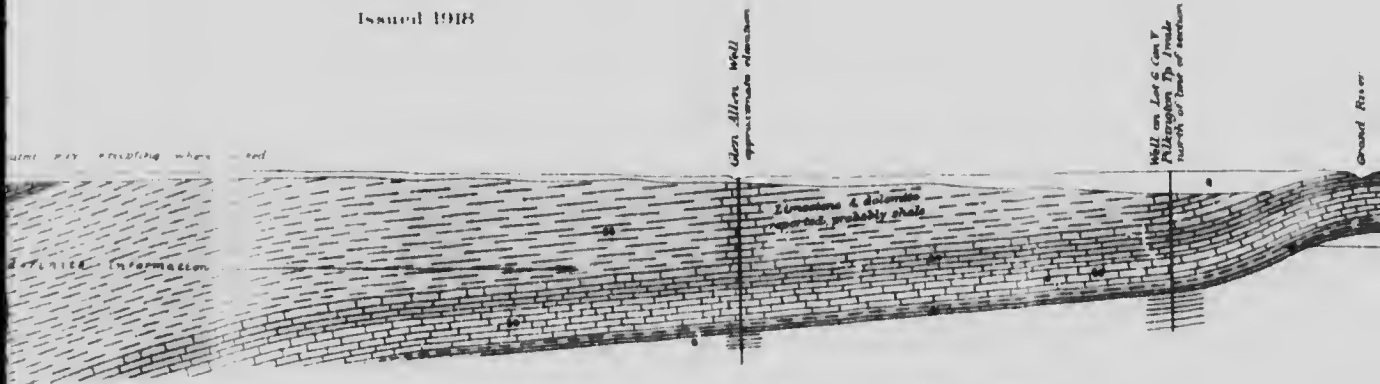
Well on line of line
approximate elevation
approximate elevation

Structural section along line A-B.

Scale of Miles



Issued 19183



Scale of Miles



D E V O N I A N

HAMILTON

Upperwash limestone
Petroia shale
Widdow beds
Olenitangy shale
(gray limestones, and soft bluish shales)

Alpena limestone
(massive gray limestone)

MARCELLUS

D4

Delaware limestone
(blue and brownish limestone, containing some thin interbeds of brown shale)

ONONDAGA

D3

Onondaga limestone
(gray to bluish limestone, portions of it very cherty)

ORISKANY

D2

Oriskany sandstone
(coarse white to yellowish sandstone)

DETROIT RIVER SERIES

Lucas dolomite
Amherstburg dolomite
Anderdon limestone
Flat Rock dolomite
(buff and brown dolomites, and gray limestone)

CAYUGAN GROUP

Akron dolomite
Bertie waterlime
(including 'Lower Monroe' of Detroit River region)
(gray dolomite) (dark gray waterlime)

SALINA

S6

Camillus shale
(gray, green and red shales, containing gray dolomite, salt and gypsum interbedded)

GUELPH

S4

Guelph dolomite
(light gray, buff and brown dolomites)

NIAGARA

S3

Lockport dolomite
(light gray and white dolomites, and arenaceous (sandy) bituminous dolomite at the top)

CLINTON

Rochester shale
Clinton dolomite and shale
(gray shale) (gray dolomite and shale)

MEDINA-
CATARACT

Thorold sandstone
Grimsby sandstone
Cabot Head shale
Manitoulin dolomite
Whirlpool sandstone
(gray and red sandstones, and shales and gray or buff dolomite arenaceous sands in Niagara Peninsula)

QUEENSTON
RICHMOND ETC.

O

Queenston shale and Richmond formation
(red arenaceous (sandy) shale gray shale and limestone)

Symbols

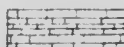


Rock outcrops

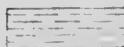
(On the Manitoulin Island, Bruce Peninsula and along the Niagara escarpment outcrops of rock are very common, but have not been specifically mapped. Elsewhere the recorded outcrops are shown.)



Quarries



Limestone or dolomite



Shale

S I L U R I A N

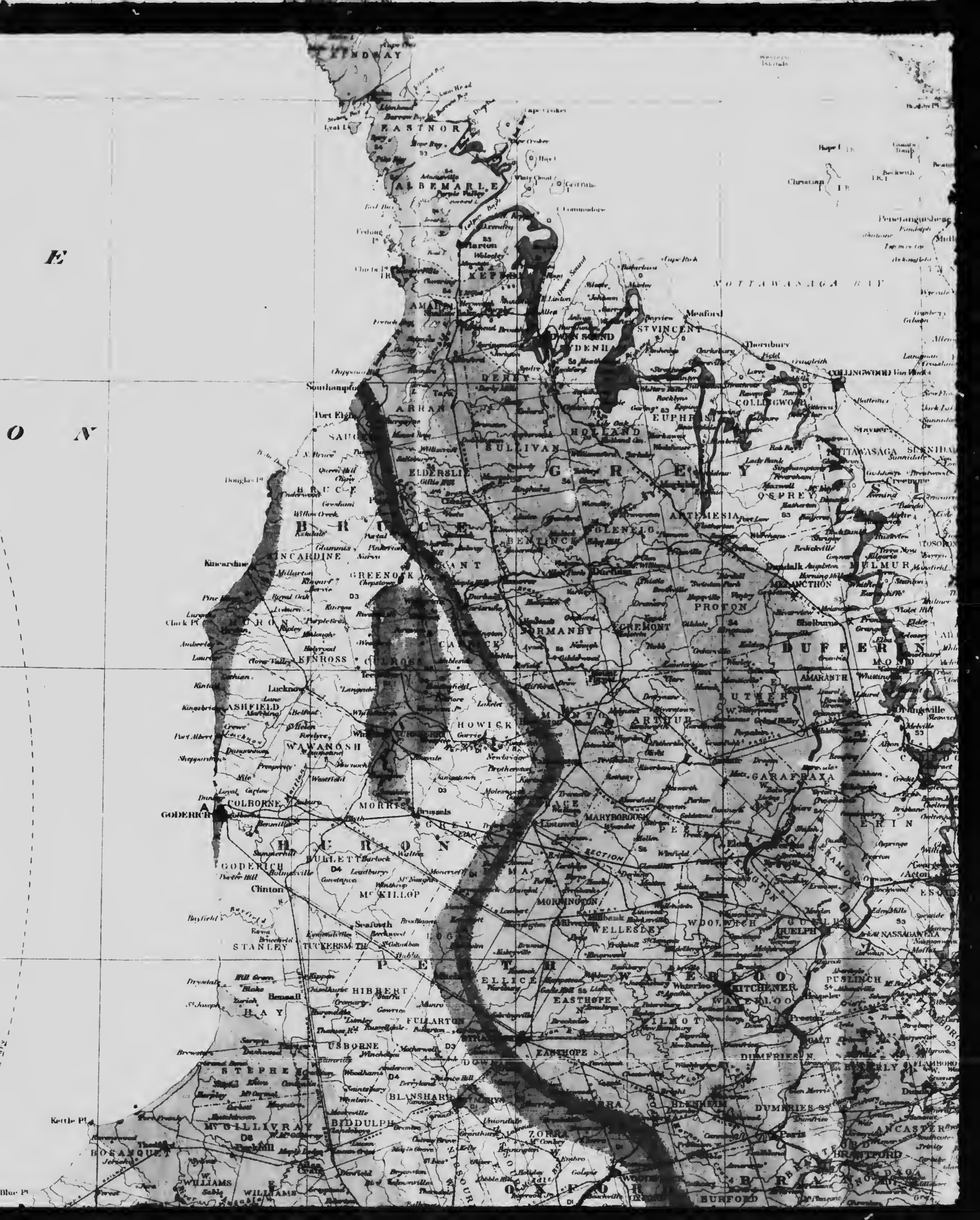
O R D O V I C I A N

L A K E

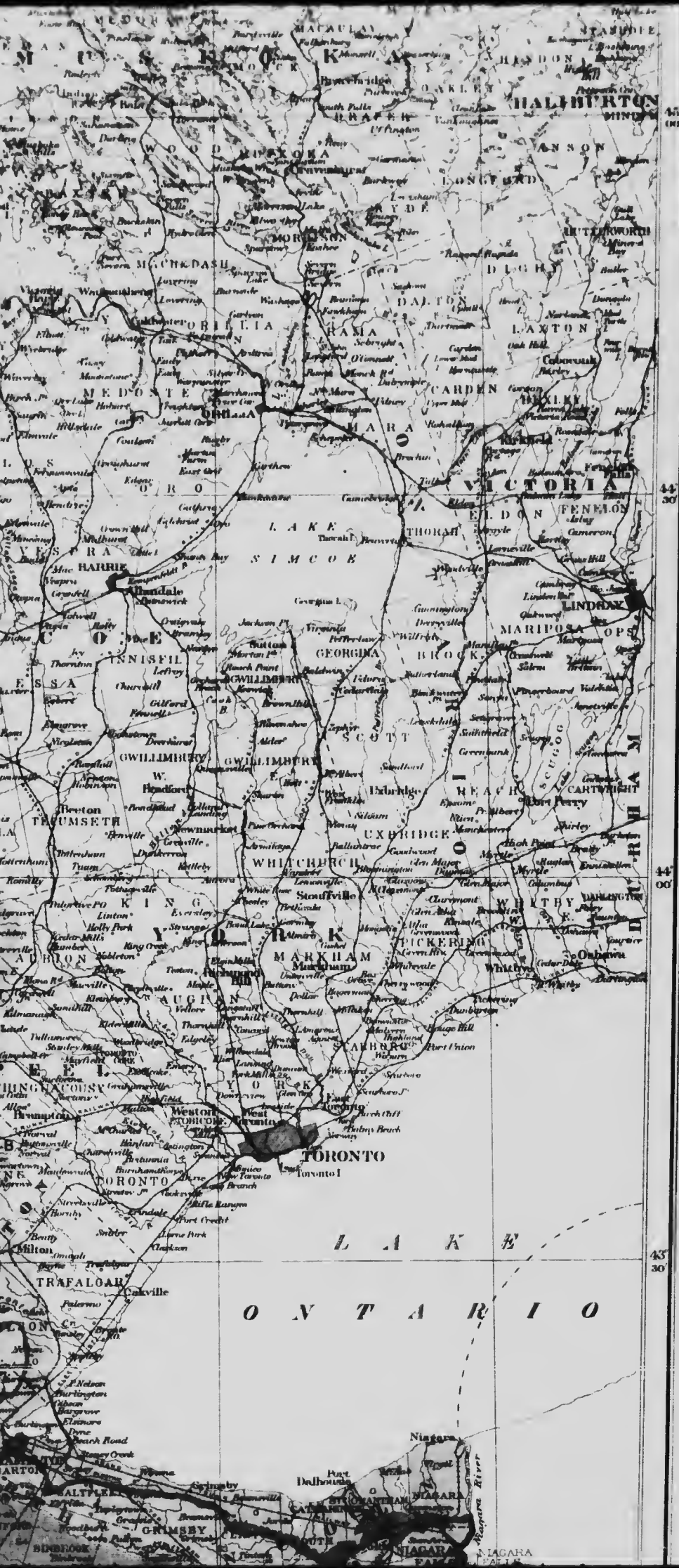
H U R O

J N I T E D

S T A F S







45
00

44
30

44
00

43
30

Geological boundary
(inferred)



83°00'
Middle Sister

N Harbour I
58° E. Longitude

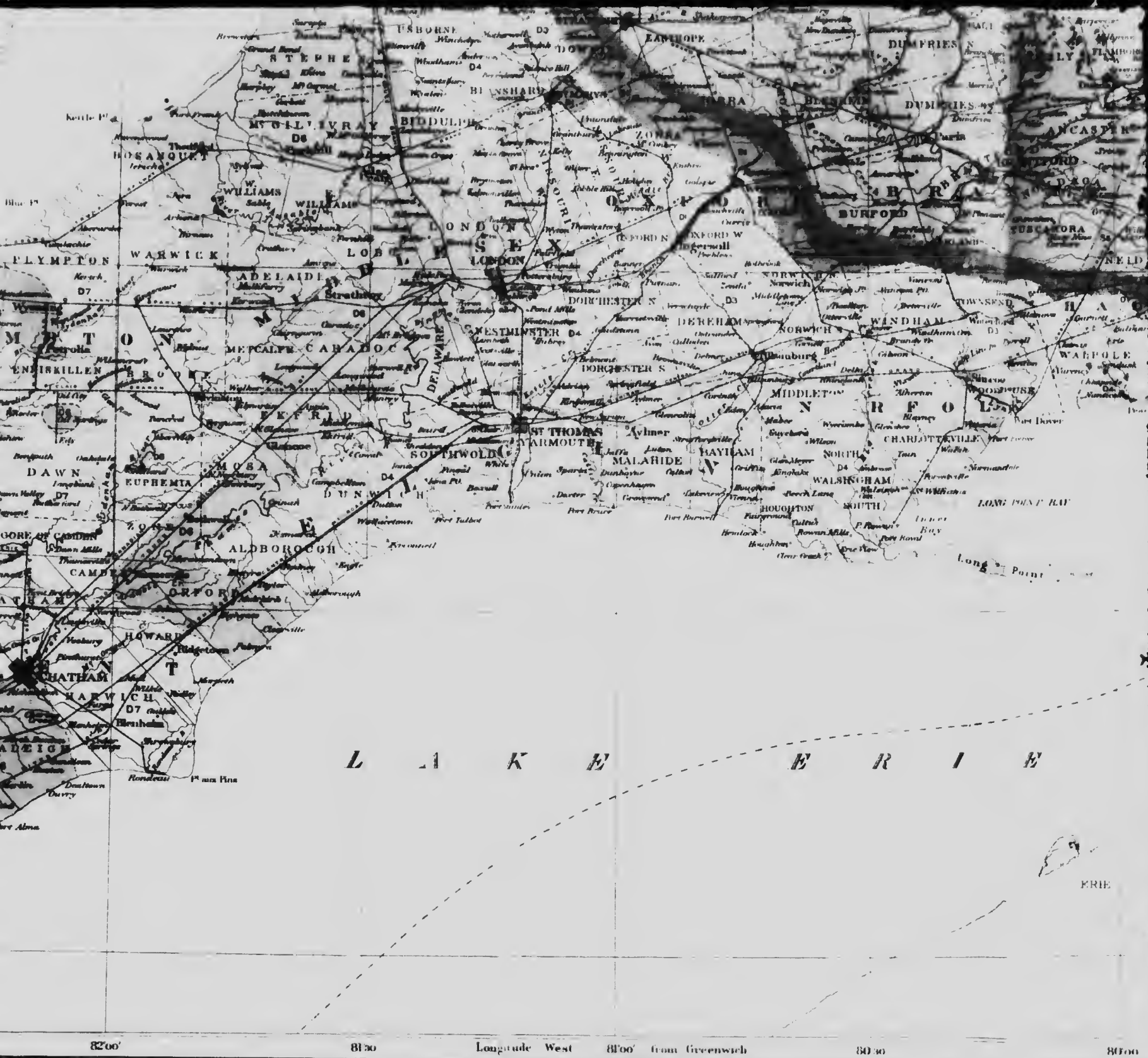
58

Chicken is

Police Passage 82

D3 Middle I

To accompany Memoir by M Y Williams



THE ONTARIO PENINSULA

Scale of Miles



L A K E E R I E

ERIE

81°30'

Longitude West

81°00'

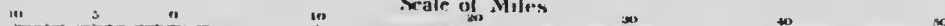
from Greenwich

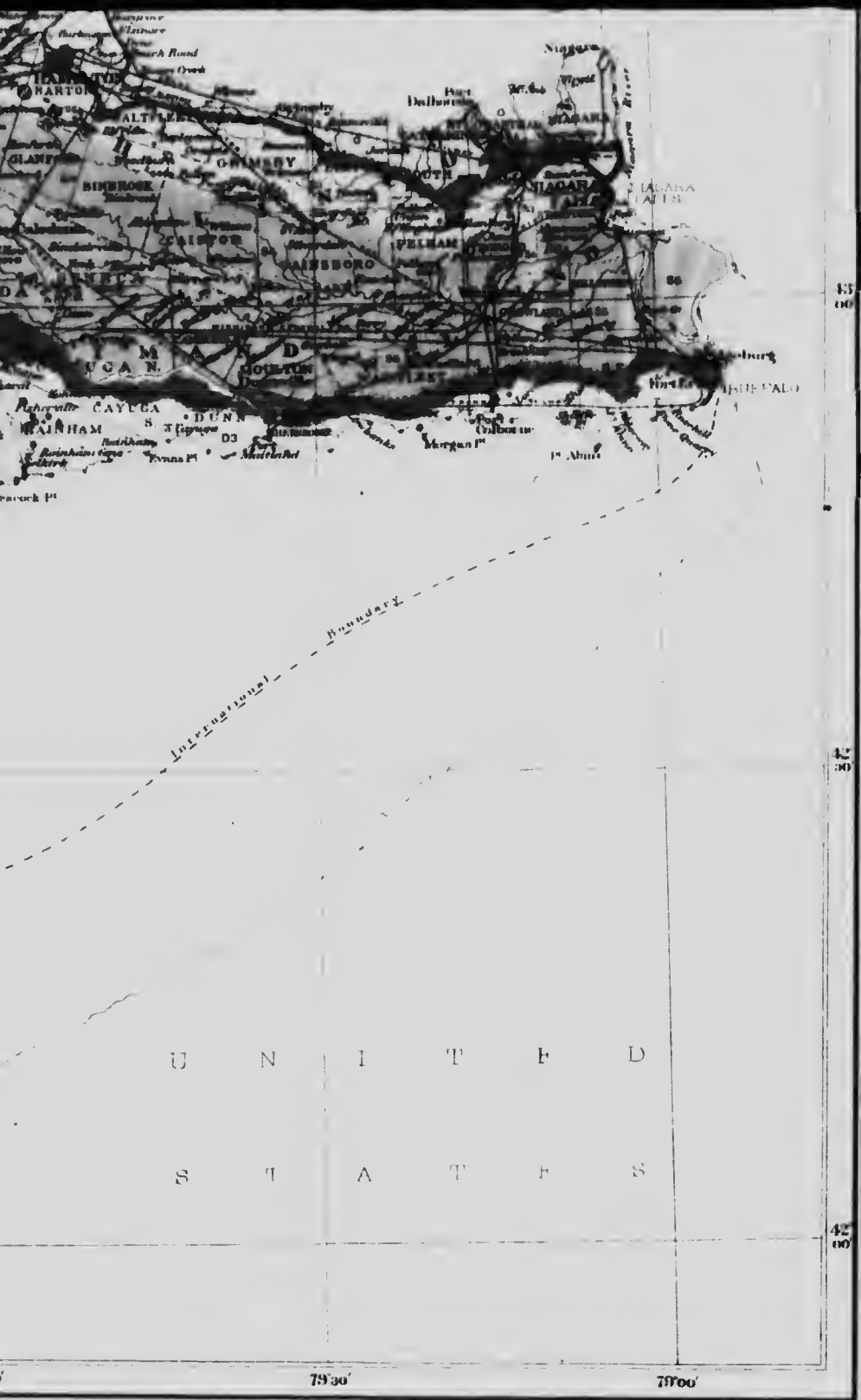
80°30'

80°00'

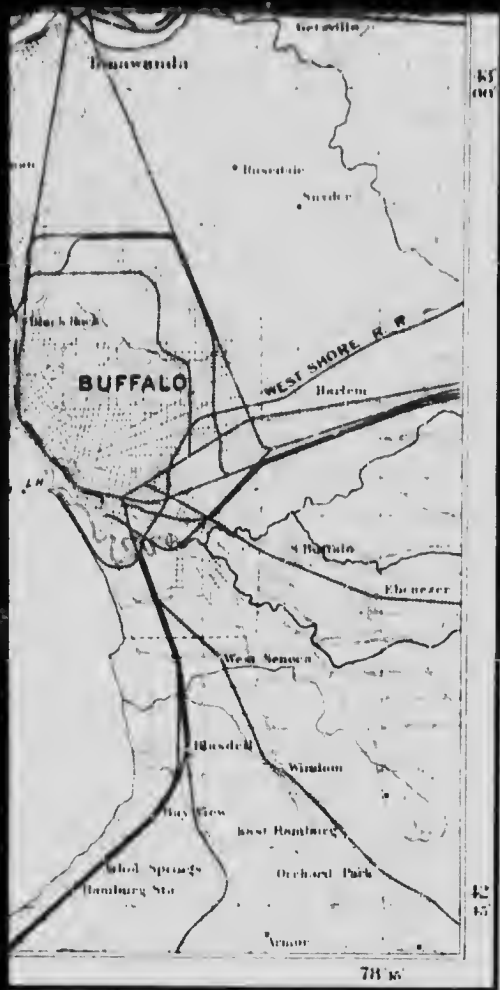
THE ONTARIO PENINSULA

Scale of Miles





*Devonian geology by C.R. Stauffer, 1910-1912.
 Revised by M.Y. Williams, 1918.
 Silurian geology by M.Y. Williams, 1912-1916.*



Publication No. 1714

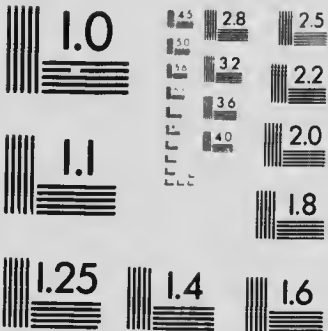
*Base map from engraved plates
of the Department of the Interior*

Devonian geology by C.R. Stauffer 1910-1912
Silurian geology by M.Y. Williams 1912-1916



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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(716) 482-3300 - Phone
(716) 288-5989 - Fax

PLEISTOCENE
AND RECENT

DEVONIAN

SILURIAN

LEGEND

Q
Surface deposits
(soils, clay, gravel, etc.)

D4
Delaware limestone
*blue and brownish limestone, containing
some thin interbeds of brown shale*

D3
Onondaga limestone
*gray to bluish limestone,
portions of it very cherty*

D2
Oriskany sandstone
coarse, white to yellowish sandstone

S6
Akron dolomite
Berne interlime
gray dolomite, dark gray waterlime

S5
Camillus shale
*gray and green shales, containing
gray dolomite, and gypsum
interbedded*

S4
Guelph dolomite
*light gray, buff and
brown dolomites*

S3
Lockport dolomite
*light gray and white dolomites
and arenaceous (sandy) bituminous
dolomite at the top*

MARCELLUS

ONONDAGA

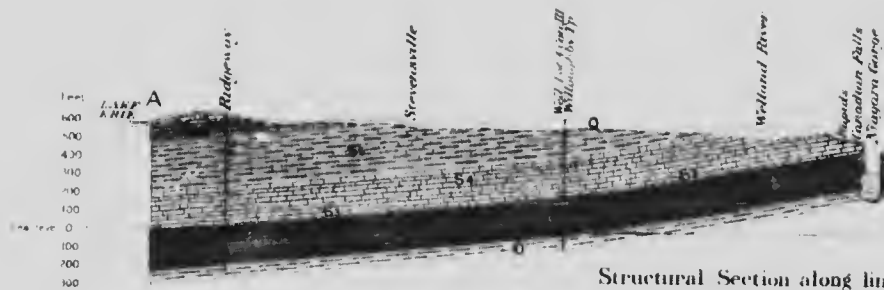
ORISKANY

CAYUGAN
GROUP

SALINA

GUELPH

NIAGARA



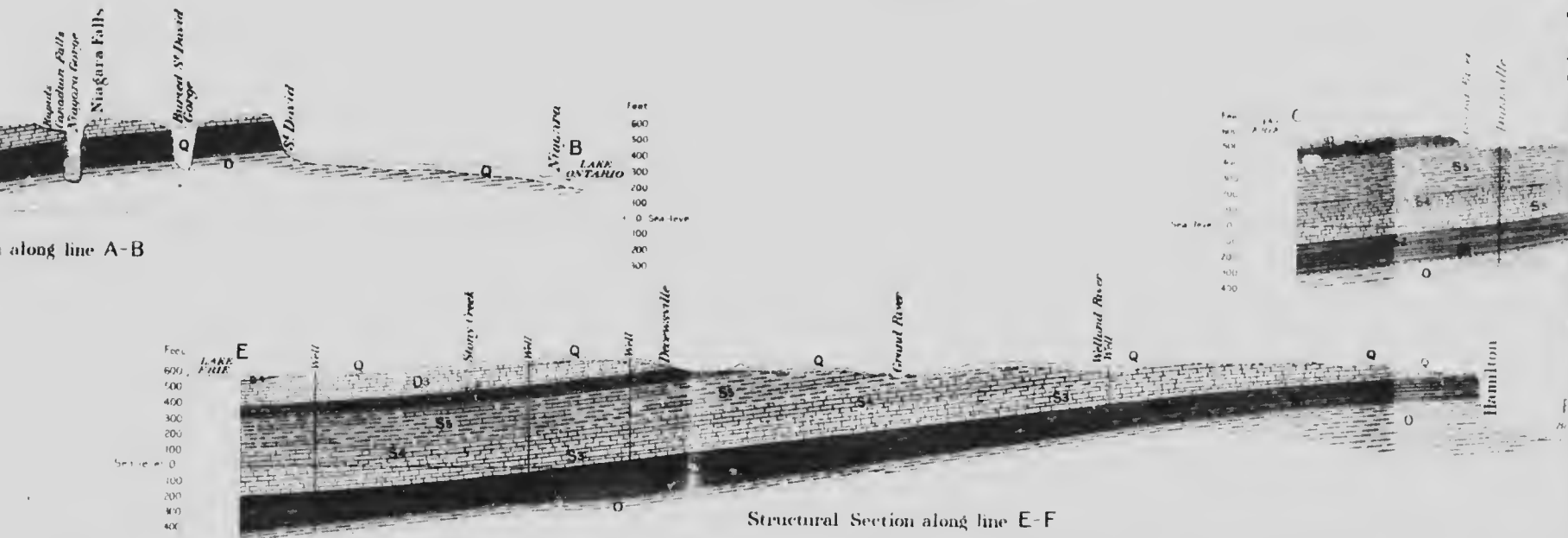
Structural Section along line A-B



Canada Department of Mines

GEOLOGICAL SURVEY

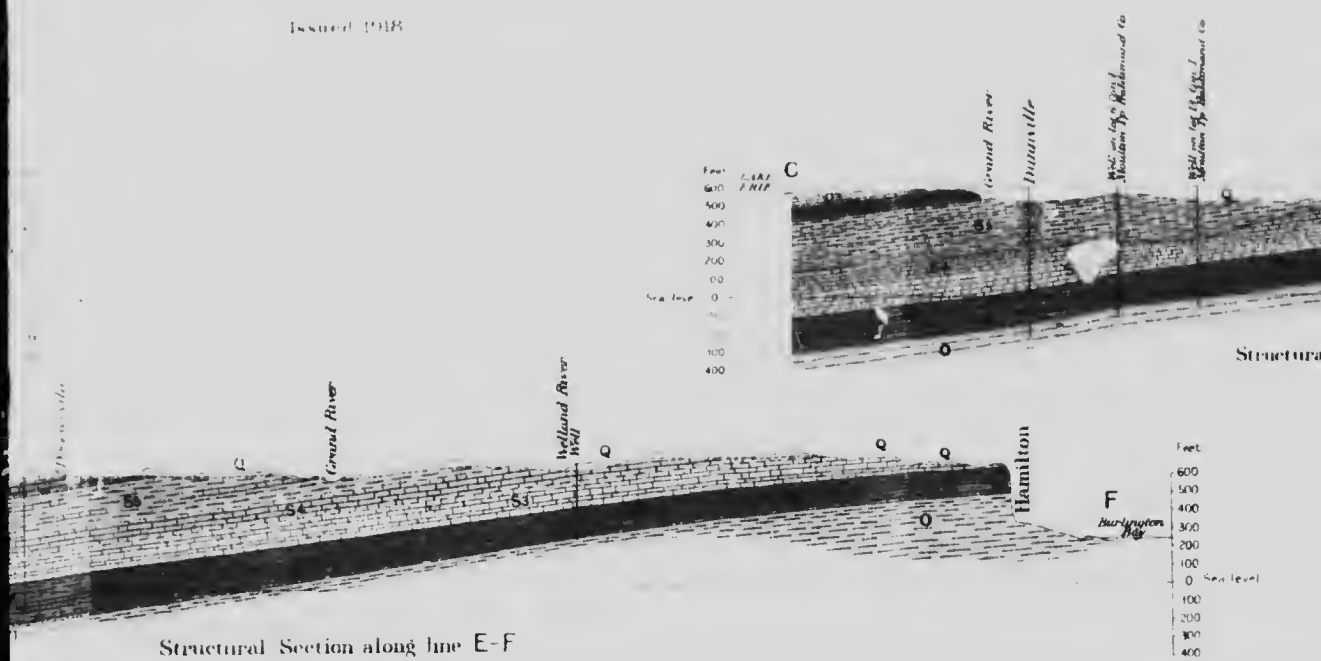
Issued 1918



Canada Department of Mines

GEOLOGICAL SURVEY

Issued 1918



Structural Section along line E-F

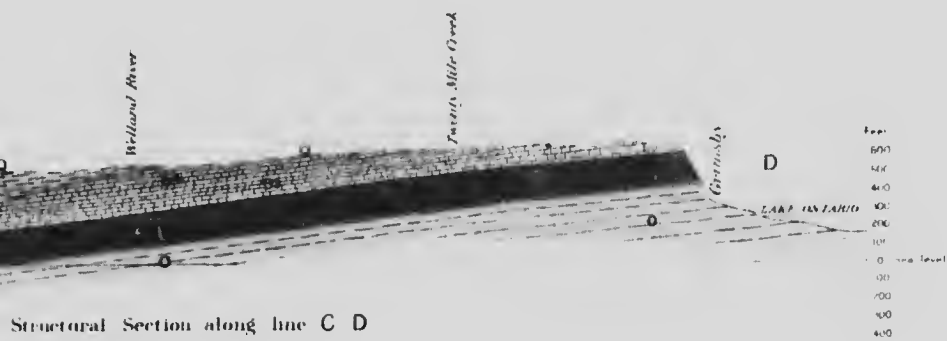
79°30'

79°15'

L A K E O N



Port Dalhousie



SILURIAN

NIAGARA

CLINTON

MEDINA-
CATARACT

ORDOVICIAN

QUEENSTON

S3

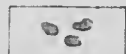
Lockport dolomite
light gray and white dolomites
and arenaceous sands, interminable
dolomite at the top

Rochester shale
Clinton dolomite and shale
(gray shale) (gray dolomite and shale)

Thorold sandstone
Gipsby sandstone
Cobol Head shale
Mantoulin dolomite
Whirlpool sandstone
gray and red varietal and shales
and arenaceous (sandy) dolomite

Queenston shale
red arenaceous (sandy) shale

Symbols



Rock outcrops
along the Niagara escarpment,
outcrops of rock are very common,
but have not been specifically
mapped. Elsewhere the recorded
outcrops are shown.



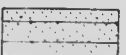
Quarries



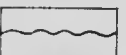
Limestone or dolomite



Shale



Sandstone



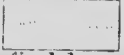
Gypsum



Geological boundary
(determined)



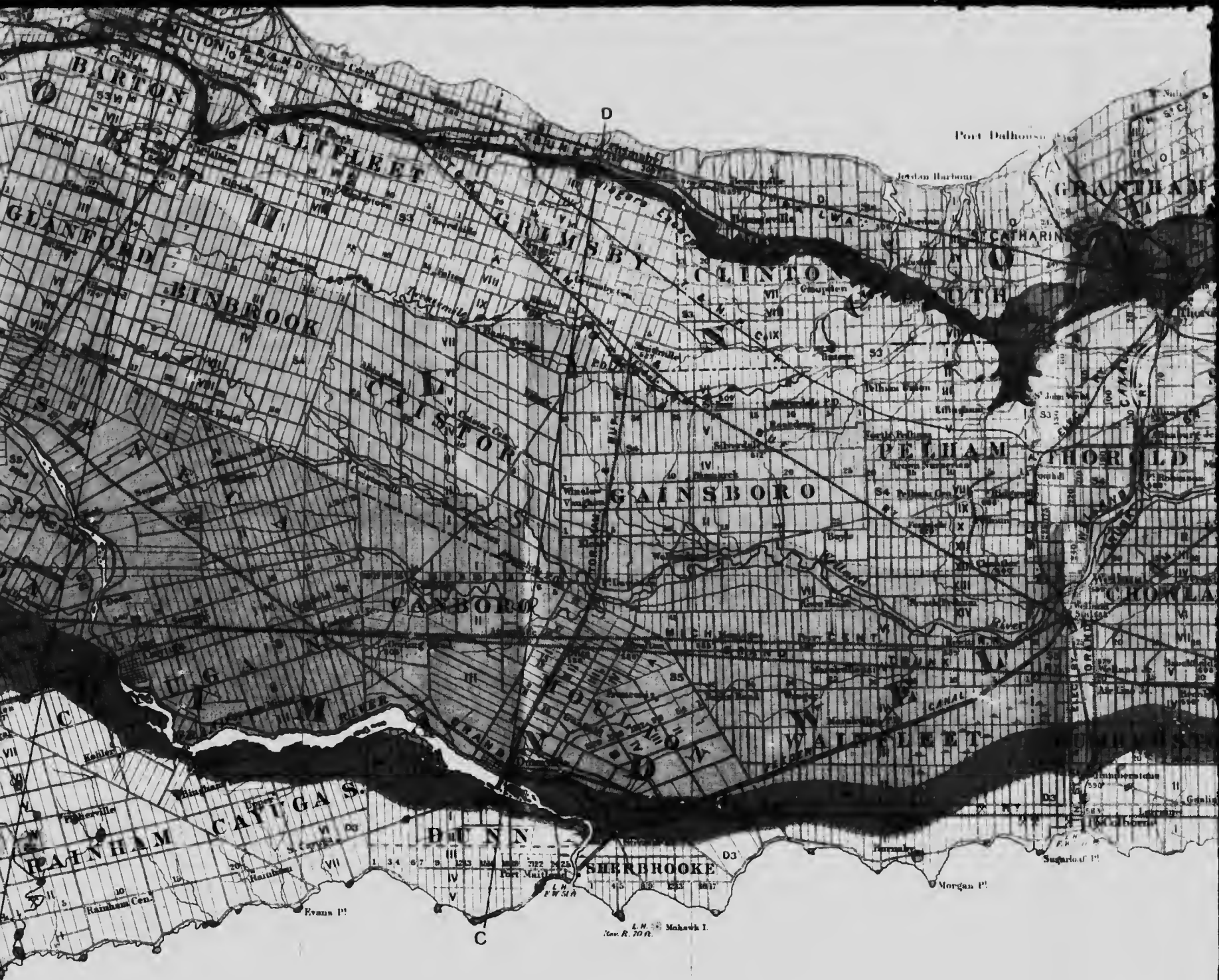
Geological boundary
(approximate)



Geological boundary
(inferred)



C.O. Senécal, Geographer and Chief Draughtsman.
A. Joanes, Draughtsman.



L A K E E R

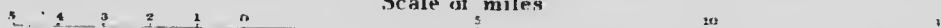
79°45'

Longitude West 79°30' from Greenwich

79°15'

THE NIAGARA PENINSULA, ONTARIO

Scale of miles





A K E E R I

Longitude West 79°30' from Greenwich

79°15'

NIAGARA PENINSULA, ONTARIO

Scale of miles

3 2 1 0 5 10 15



Publication No. 1714
Base map from engraved plates
of the Department of the Interior

Devonian geology by C.R. Stauffer 1910-1912
Silurian geology by M.Y. Williams 1912-1916

