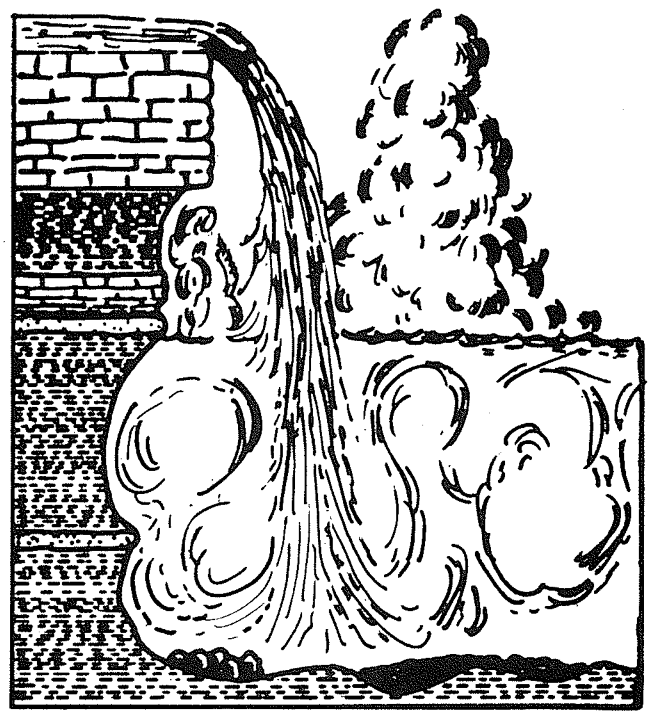
GEOLOGY OF WESTERN NEW YORK

GUIDE BOOK



NEW YORK STATE GEOLOGICAL ASSN.

38th ANNUAL MEETING

1966

DEPARTMENT OF GEOLOGICAL SCIENCES

STATE UNIVERSITY OF NEW YORK AT BUFFALO

BUFFALO, N. Y.

E. J. Buehler, Editor

NEW YORK STATE GEOLOGICAL ASSOCIATION

38th Annual Meeting

April 29 - May 1, 1966

GUIDEBOOK

Geology of Western New York
Edward J. Buehler, Editor

Department of Geological Sciences
State University of New York at Buffalo

Additional copies are available from the permanent secretary of the New York State Geological Association: Dr. Kurt E. Lowe, Department of Geology, City College of the City University of New York, 139th St. at Convent Ave., New York, N. Y.

P R E F A C E

The original plans for this guidebook were to set up a rather generalized geologic history of western New York, interspersed with pertinent articles by some of the experts in the stratigraphy of this area. When the delightful willingness of our colleagues in New York State geological research to cooperate became apparent, we decided to present the entire geologic history via articles by authorities. We here acknowledge our gratitude to the following contributing authors, not only for their ready acceptance of the assignment, but also for their care in preparation and promptness in submitting manuscript.

Paker E. Calkin - State University of New York at Buffalo

Charles V. Clemency - State University of New York at Buffalo

Donald W. Fisher - Geological Survey - New York State Museum and Science Service

Michael R. House - University of Oxford, England

William J. Kilgour - Buffalo Museum of Natural Sciences

John S. King - State University of New York at Buffalo

William A. Oliver, Jr. - U. S. Geological Survey, Washington, D. C.

Lawrence V. Rickard - Geological Survey, New York State Museum and Science Service

Irving H. Tesmer - State University College at Buffalo

Donald H. Zenger - Pomona College, Claremont, California

The host for the 38th annual meeting is the Department of Geological Sciences of the State University of New York at Buffalo. The able cooperation of the entire staff is appreciated. Dr. John S. King, department executive officer, was especially helpful in matters of finance, in facilitating the printing of the guidebook, and in innumerable details that arose in the course of making the arrangements. Dr. Charles J. Cazeau kindly took over the organization of the student paper session. Dr. Charles V. Clemency assisted in arranging details of registration and Dr. Parker E. Calkin assisted with many details of organization. We also acknowledge the help of Harvey Hambleton, curator of geology at the Buffalo Museum of Science who organized and will lead the Devonian fossil collecting trip. The graduate students of this department have been most enthusiastic in their cooperation. Finally, we thank our department secretary, Mrs. Hazel Blatt for cheerfully and efficiently handling the extra work that was given her.

We appreciate the willingness of local residents to allow access to their property for field trip stops, especially Mr. Gerald C. Saltarelli, President of the Houdaille Corporation, who also purchased an ad in the guidebook.

Finally, we thank Dr. John W. Wells of Cornell University for consenting to give the banquet lecture.

The papers in the guidebook are arranged so as to present the geologic history of the area in order. The breakdown of subject matter is based on the research specialties of the contributing authors. Some of the papers are mainly compilations from the literature, others present new material and results of original research.

The road logs are kept distinct from the text material with only enough facts to identify the features at each stop. Reference is given to the appropriate material in the text.

Edward J. Buehler
Professor of Geology
State University of New York at Buffalo
President for 1966 Meeting

And some rin up hill and down

dale, knapping the chunky stanes

to pieces with hammers,

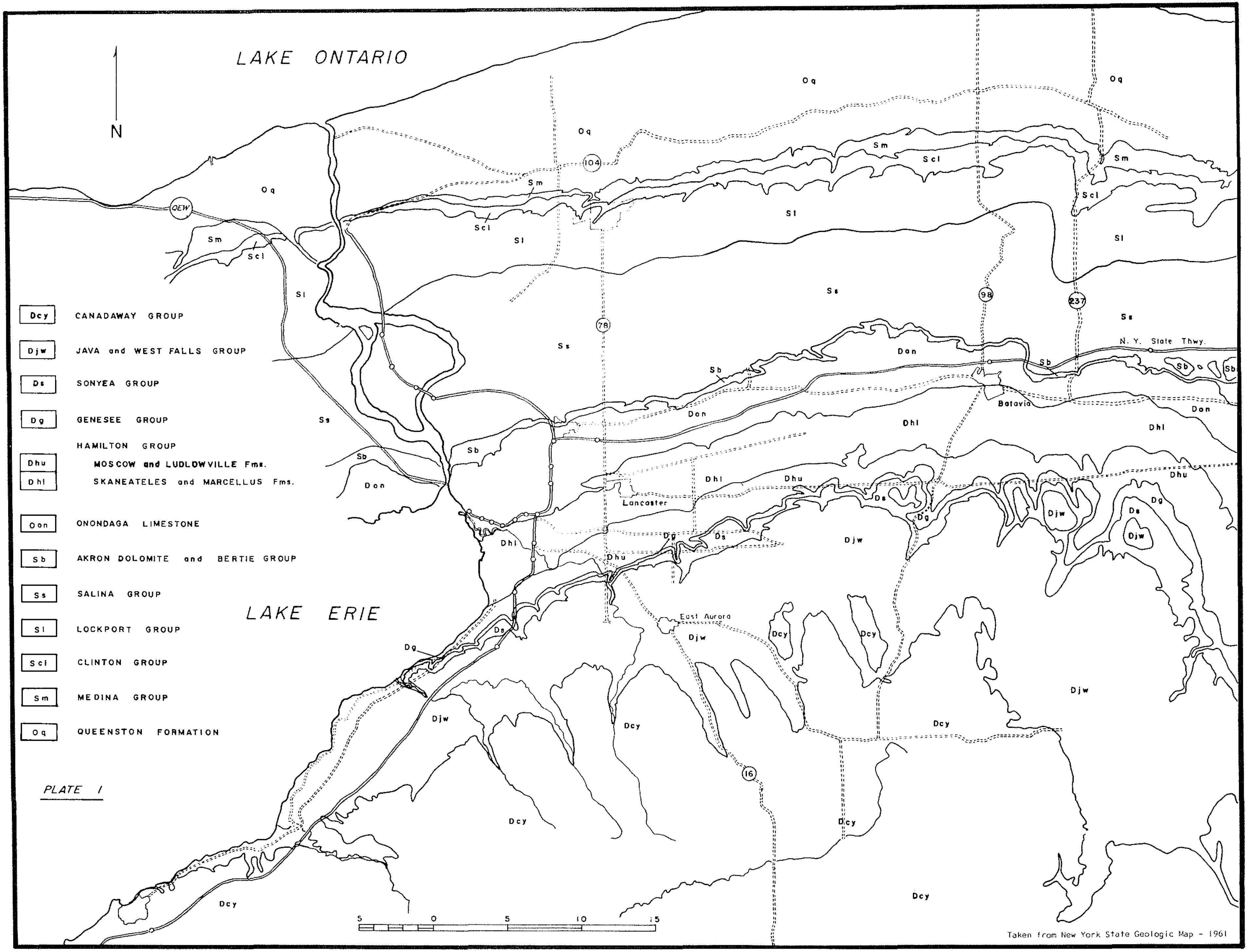
Like sae many road runners run daft

They sae it is to see how

the warld was made!

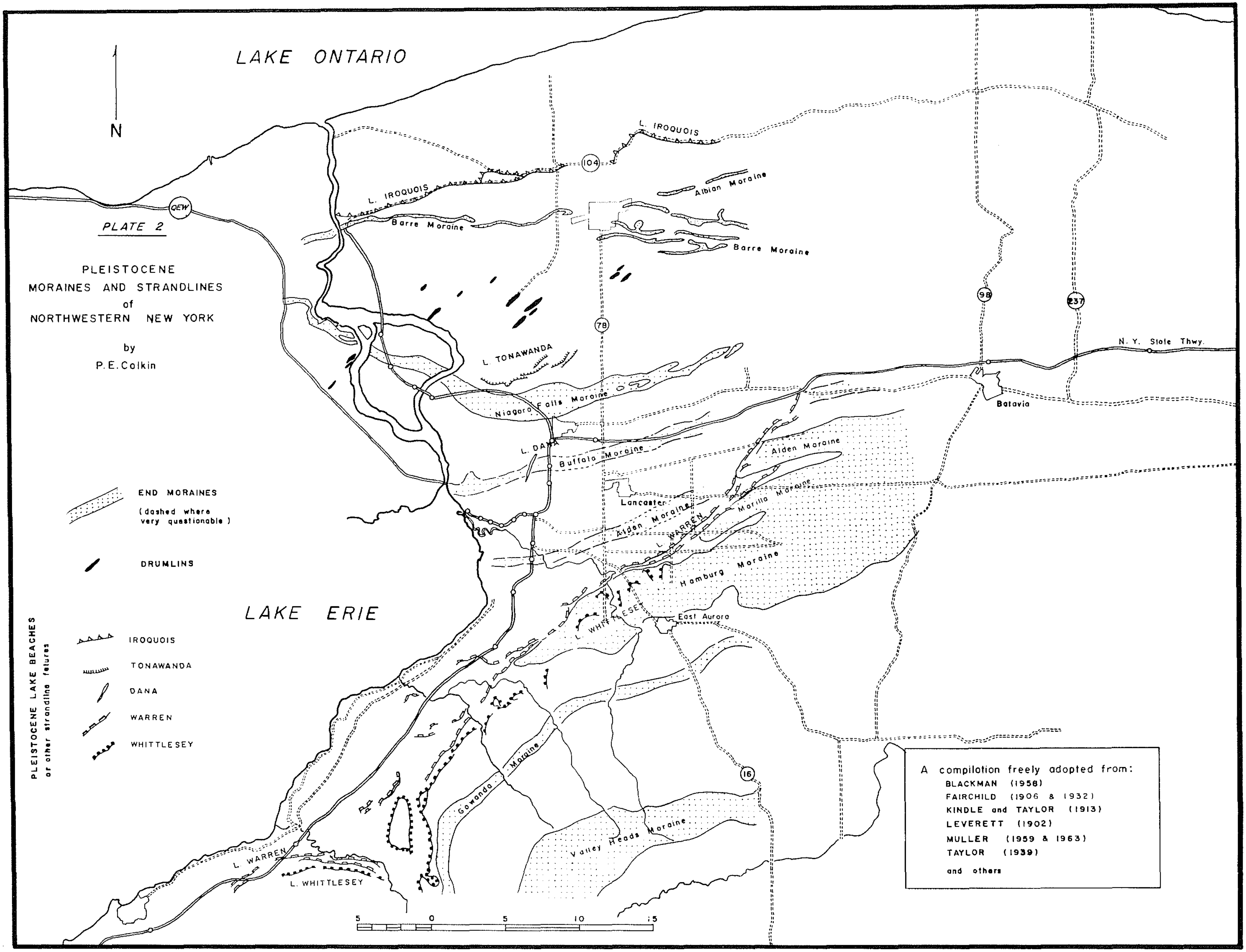
--Sir Walter Scott
St. Ronan's Well--1824

TABLE OF CONTENTS



LAKE ONTARIO
N
LAKE ERIE
Oq
Sm
Scl
Sl
Ss
Sb
Don
Dhl
Dhu
Ds
Dg
Djw
Dcy
QEW
104
78
98
237
16
N. Y. State Thwy.
Batavia
Lancaster
East Aurora
Dcy CANADAWAY GROUP
Djw JAVA and WEST FALLS GROUP
Ds SONYEA GROUP
Dg GENESEE GROUP
HAMILTON GROUP
Dhu MOSCOW and LUDLOWVILLE Fms.
Dhl SKANEATELES and MARCELLUS Fms.
Oon ONONDAGA LIMESTONE
Sb AKRON DOLOMITE and BERTIE GROUP
Ss SALINA GROUP
Sl LOCKPORT GROUP
Scl CLINTON GROUP
Sm MEDINA GROUP
Oq QUEENSTON FORMATION
5 0 5 10 15
Taken from New York State Geologic Map - 1961

PLATE I


LAKE ONTARIO
N
PLATE 2
PLEISTOCENE
MORAINES AND STRANDLINES
of
NORTHWESTERN NEW YORK
by
P.E. Colkin
L. IROQUOIS
L. IROQUOIS
104
QEW
Albian Moraine
Barre Moraine
Barre Moraine
98
237
78
N. Y. State Thwy.
L. TONAWANDA
Niagara Falls Moraine
Batavia
L. DANA
Buffalo Moraine
Alden Moraine
Alden Moraine
Marilla Moraine
Lancaster
L. WARREN
END MORAINES
(dashed where very questionable)
DRUMLINS
Hamburg Moraine
LAKE ERIE
East Aurora
L. WHITTLESEY
PLEISTOCENE LAKE BEACHES
or other strandline features
IROQUOIS
TONAWANDA
DANA
WARREN
WHITTLESEY
Gowanda Moraine
16
A compilation freely adopted from:
BLACKMAN (1958)
FAIRCHILD (1906 & 1932)
KINDLE and TAYLOR (1913)
LEVERETT (1902)
MULLER (1959 & 1963)
TAYLOR (1939)
and others
Valley Heads Moraine
L. WARREN
L. WHITTLESEY
5 0 5 10 15

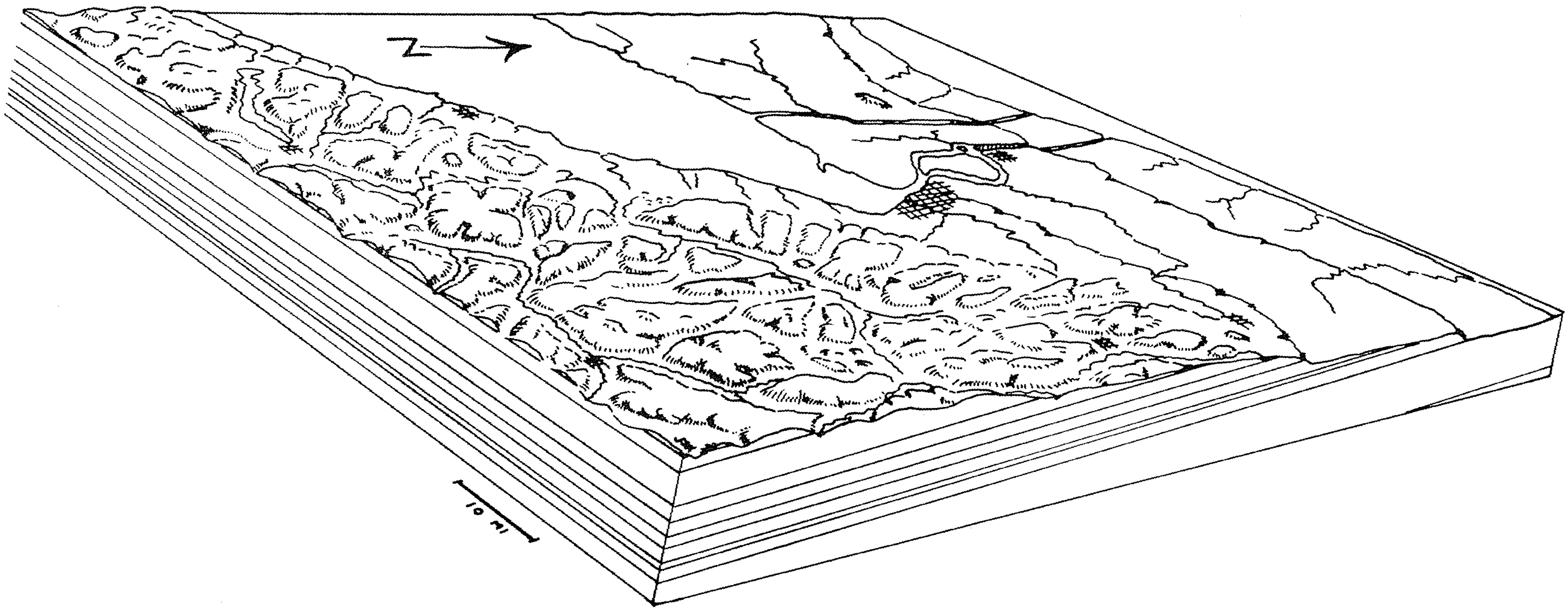


PLATE 3

PRE-CLINTON ROCKS OF THE NIAGARA FRONTIER ----- A SYNOPSIS*

Donald W. Fisher
State Paleontologist
Geological Survey, N. Y. State Museum & Science Service

Prologue

"I found the upper and middle stratum of the great cataract of Niagara to consist of fetid carbonate of lime, commonly called stink stone, or swine stone; and the inferior stratum of a compact stratified red sandstone, which strikes fire with steel, scratches glass, and which, when moistened and rubbed, emits a smell of sulphuretted hydrogen gas. It is also infusible before the blow pipe, and does not effervesce with acids."

-Hibernicus, 1820

Almost a century and a half have elapsed since DeWitt Clinton, writing under a pseudonym, expressed these amazingly perceptive observations of Niagara Gorge rocks, a description, though capable of elaboration, which still holds today. Subsequent work by Conrad (1837), Vanuxem (1837) and Hall (1843) in the mid-nineteenth century and Grabau (1901), Kindle and Taylor (1913), Schuchert (1914) and Williams (1919) in the early twentieth century greatly supplemented the articles of the pioneering geologists. During the mid-twentieth century, a resurgence of interest in Silurian rocks of the Niagara Gorge and vicinity produced detailed papers by Sanford (1935, 1939), Gillette (1947), Fisher (1953), Fisher (1954) on the Medina rocks, and Kilgour (1963) on the Clinton rocks, and Zenger (1965) on the Lockport strata; Alling (1936) and Bolton (1957) covered all of these divisions.

This synopsis treats the pre-Clinton rocks of the Niagara Frontier (northern Erie, Niagara, and Orleans Counties in New York and the eastern half of the Ontario Peninsula). In North America, Clinton Group rocks are termed Middle Silurian though by European usage they would be called Lower Silurian as they equate with the upper Llandovery of the type Silurian of Great Britain. The Medina Group, which underlies the Clinton, is Lower Silurian by any standards since it is correlative with the lower Llandovery.

The Rocks Beneath The Surface

PRECAMBRIAN

In the Niagara Frontier, if one were to drill vertically into the crust, deeper than the lowest bedrock exposed in the Niagara Gorge, one

*Published by permission of the Assistant Commissioner, New York State Museum and Science Service.

would encounter progressively older horizontal sedimentary rocks of Ordovician and Cambrian (?) ages and ultimately a "basement" of harder rocks which have been intensively metamorphosed to gneisses (Figure 1). These Precambrian rocks are the foundation upon which the younger sediments were deposited. Gas well data reveal that, in the Niagara Frontier, the Precambrian surface slopes southeastward. In the Bradshaw #1 and #2 wells in Newfane Township, 4 miles SSW of Olcott, Niagara County, the Precambrian was reached at 2,134' and 1,980', respectively. To the east in the Emilkamp Well, Clarendon Township, 5 miles SSW of Holley, Orleans County, the Precambrian was reached at 3,019'. Deep wells in Willoughby and Bertie Townships, Ontario penetrated the Precambrian at 3,030' and 3,255', respectively.

Northward, the interval between the surface and basement diminishes so that the closest Precambrian outcroppings occur some 80 miles north of Toronto and north of Lake Simcoe, Ontario. New York's Adirondack Mountains, too, exhibit several types of Precambrian rocks: meta-anorthosite, charnockite, marble, metaquartzite, amphibolite, metagabbro and a variety of other gneisses.

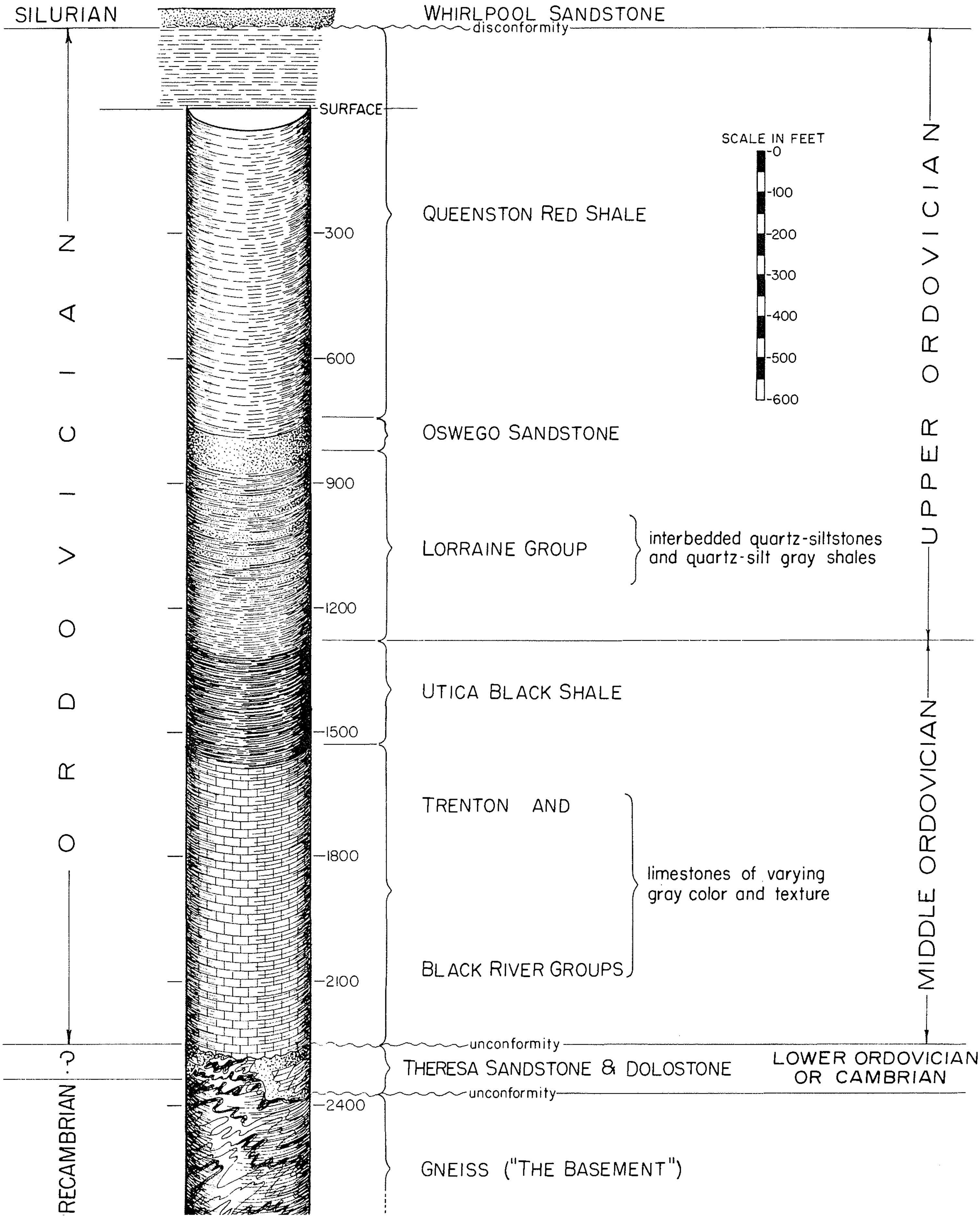
PALEOZOIC

Resting upon the ancient gneisses are interbedded quartz sandstones, variably dolomitic, and quartzose dolostones, aggregating about 100'. This lithology fits the Theresa Formation, a northwestward transgressive facies which is of Late Cambrian age in eastern New York and Early Ordovician age in the St. Lawrence Valley. As fossils have not been recovered from these "Theresa" cuttings in the Niagara Frontier, its age here is uncertain.

The Theresa, in turn, is overlain by a relatively thick sequence (ca. 1150') of Ordovician carbonates, slightly dolomitic in the lower portion --- the Black River and Trenton Groups. Within this interval, the Pamelia and Lowville facies are recognizable. Following is a zone of black shale (Utica) which is succeeded by the Lorraine Group, a series (ca. 480') of gray shales in which the quartz content increases and coarsens stratigraphically upward, culminating in the Oswego Sandstone (Figure 1). North of the Niagara Escarpment, the subsurface section terminates within the Late Ordovician Queenston Shale, the oldest surface bedrock in the Niagara Frontier.

To the north, the Medial Ordovician (Mohawkian) overlaps first the Early Ordovician (Canadian) and then the Late Cambrian (Croixian) so that north of Lake Ontario and west of the St. Lawrence Lowlands, Mohawkian strata rest on the Precambrian Canadian Shield. To the south, the subsurface rock section increases as successively younger Silurian and Devonian strata dip beneath the surface; near the Pennsylvania border the Theresa is about 11,750' below the surface. In addition, basinward thickening of most of the Groups further depressed the Precambrian surface; an isopachous map of the Medina Group will serve as an example (Figure 2). Note the narrow, southwestward projecting isopach pattern denoting thinner Medina deposits, possibly reflecting an older structural high; this seems to be a prolongation of the Clarendon-Linden structure which passes through Holley and Batavia.

FIG. 1 SUBSURFACE SECTION IN THE NIAGARA FRONTIER



The Surface Rocks

UPPER ORDOVICIAN

Queenston Shale - Grabau (1908, p. 622) separated the older red shale portion of the "Medina" of previous literature as the Queenston Shale, from its typical exposure along the Niagara River at Queenston, Ontario. The unit is remarkable for its homogeneity. It is a purplish-red (crimson lake) argillaceous rock with indistinct shaly bedding. By volume, the Queenston consists of 95% clay minerais, 4% quartz (as silt), 1% carbonates, and a trace of accessory minerals. In the subsurface to the south and east, the Queenston becomes more quartzose, and sandstone and siltstone accounts for most of its volume; in these regions it is more properly termed the Juniata Formation. Sporadically distributed throughout the upper 100' are thin bright green seams which follow the joints or crude bedding. These green seams are thought to represent the percolating effect of ground water in changing red ferric oxide to green ferrous oxide -- the reduction being accomplished by humic acids.

Only about 200' of the Queenston's thickness is visible in the area under discussion. Well records disclose a thickness averaging 1000' so that assuming a southerly dip of 50'/mile, the red shale extends north about 16 miles beneath Lake Ontario. The Queenston Shale is the surface bedrock of the Ontario Plain, whose soil is an admixture of red, sticky, residual clay and glacially transported sediments. Where the north-flowing tributaries to Lake Ontario have excavated this soil, exposure of Queenston may be found; the largest of these are along Eighteenmile Creek, which flows north from Lockport, and along Sandy Creek near Murray, northwest of Holley, but the finest exposure is along the Niagara River.

Although the Queenston has not yielded fossils in New York, its age is conclusively demonstrated in Ontario by Richmond (latest Ordovician) fossils from the Meaford, Oakville, and Ottawa areas (Liberty, 1964, p. 47). Lack of fossils in New York coupled with a uniform argillaceous makeup, red color, and great thickness support the view that the Queenston represents the landward side of a hugh delta; the source materials were supplied by erosion from an emergent eastern land during the closing phases of the Taconian Orogeny, about 425 million years ago. This uplift had earlier produced the Taconic Mountains by emplacing, via gravity sliding, a great block (klippe) of older Ordovician and Cambrian eugeosynclinai deposits into a Middle Ordovician sea of mud. Widespread mud flats replete with shrinkage cracks marked the close of the Ordovician.

LOWER SILURIAN - Medina Group

The Medina Group is a relatively thin rock stratigraphic unit but because it is the principal reservoir for natural gas in western New York, it holds especial interest. The Group is characterized by white, gray, pink, red, and mottled sandstones and siltstones with subordinate red, green, and gray shales. Carbonates are conspicuously absent and carbonate as cement is minimal. Aside from the Salina Group, which records hypersaline environments with meager faunas, the Medina is the least fossiliferous segment of the New York Silurian. In western New York in both outcrop and subsurface, the Medina is treated either as a single rock unit or is separable into several facies from which four formations are formally designated: Whirpool Sandstone, Power Glen Shale, Grimsby Sandstone, Thorold Sandstone. By some workers, the Thorold is considered the basal member of the Clinton Group. In Ontario, the Manitoulin Dolostone and Cabot Head Shale are equivalent facies of the Power Glen and Grimsby. The geographic distribution, thickness, and stratigraphic relations of the Medina Group are depicted in Figures 2 (isopachous map) and 3 (stratigraphic profile).

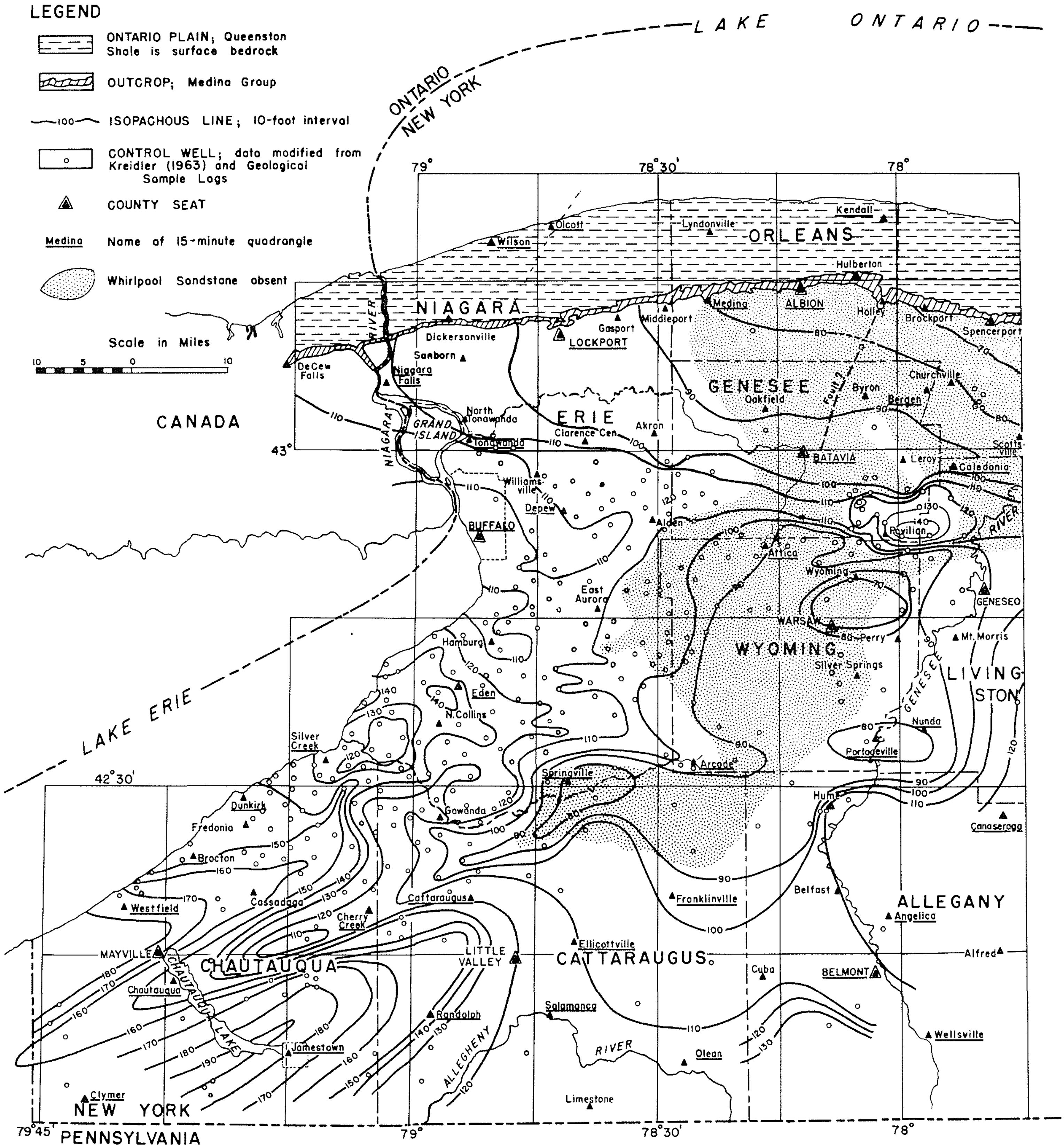
Whirlpool Sandstone - To the sandstone traditionally referred to as the White Medina, Grabau (1909, p. 238) applied the name Whirlpool from the type exposure along the Niagara Gorge at the Whirlpool and extending downstream to Lewiston. This unit is a medium- to thick-bedded, very light gray to white pure (93-97% quartz) quartzose sandstone with scarce inclusions of flat pebbles of green shale; the cement is almost entirely silica and accessory minerals constitute the remainder. It is medium to coarse grained with the middle part consistently coarser than either base or top. Well rounded, frosted quartz grains are plentiful and where these are unusually large, a "salt and pepper" effect is produced. Large scale cross-bedding occurs throughout and negative sun cracks are ubiquitous at the basal contact with the Queenston Shale. The Whirlpool is the product of an aeolian sand spread like a veneer over sun-cracked mud flats.

Good outcrops of the Whirlpool are at DeCew Falls, the old Lackawanna quarry, 0.7 mile southeast of Dickersonville (now Camp Stonehaven, Boy Scouts of America), along Niagara Rd. 1.3 miles west of the Niagara County Fairgrounds where both base and summit are visible and along the East Branch of Eighteenmile Creek one mile northeast of Gasport. To the east, the Whirlpool merges with the lower *Lingula cuneata* facies of the Grimsby; at the old Holloway quarry north of Medina about 12 feet of gray thin-bedded siltstone borders on a Whirlpool-Grimsby ("a" facies) assignment.

No fossils have been found in the Whirlpool and those attributed to it in previous literature occur in thin calcareous siltstones within the overlying Power Glen Formation.

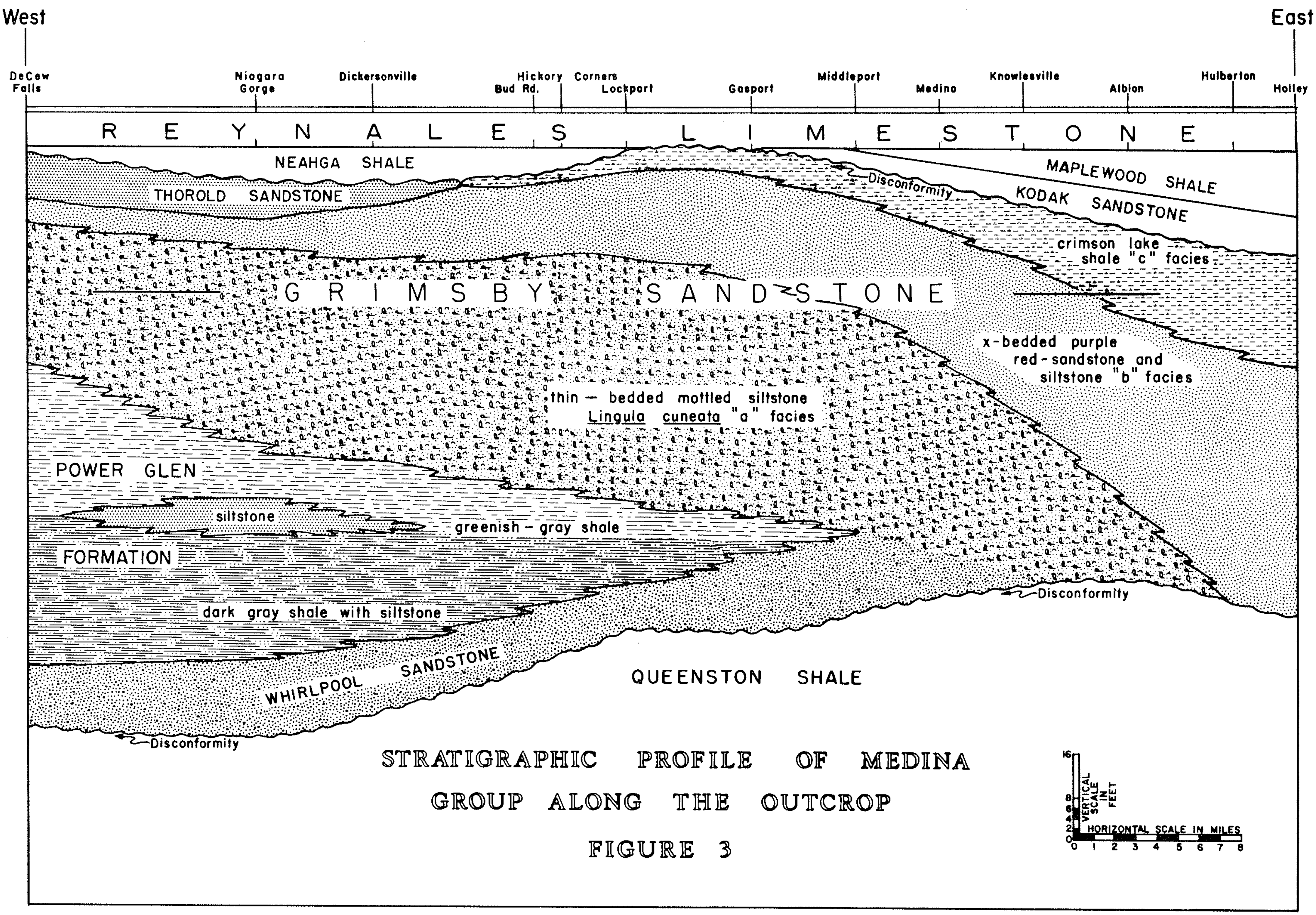
Power Glen Formation - The 48 feet of shales with interbedded siltstones separating the Whirlpool and Grimsby at the DeCew Falls section were named Power Glen by Bolton (1953, 1957). Fisher (1954, p. 1987-1991) assigned this interval to the Fish Creek (later Rumsy Ridge) - Manitoulin-Cabot Head units. However, this tripartite division seems not to be traceable beyond the Niagara Gorge; furthermore, the presence of the Manitoulin and Cabot Head here is debatable. After analyzing the subsurface relations, it seems better, in New York, to adopt Bolton's name Power Glen for the non-red argillaceous facies of the Medina Group.

Dark gray shales with a few thin calcareous siltstones comprise the lower part whereas the upper shale portion has a noticeable greenish cast.



ISOPACHOUS MAP - LOWER SILURIAN MEDINA GROUP

FIGURE 2



STRATIGRAPHIC PROFILE OF MEDINA GROUP ALONG THE OUTCROP

FIGURE 3

Transitional from the Whirlpool below but with an abrupt contact with the Grimsby red silty shale above, the Power Glen, an eastern lateral facies of the Manitoulin Dolostone, loses its identity between Lockport and Medina and passes laterally into the *Lingula cuneata* - facies of the Grimsby (see figure 3). The Power Glen is fully exposed at DeCew Falls, in the Niagara Gorge and along Niagara Rd., 1.3 miles west of the Niagara County Fairgrounds. In the old Lackawanna quarry, the lower few feet illustrates the transition with the Whirlpool.

In the subsurface, the Power Glen is discernible, sandwiched between the "White Medina" and "Red Medina" of the drillers. It averages 110' in the Clymer quadrangle, 82' in the Jamestown quadrangle, 105' in the Randolph quadrangle, 40' in the Dunkirk quadrangle, and 45' in the Silver Creek quadrangle. In old, and in many new, records the Power Glen is not separately distinguished.

The Power Glen's meager, somewhat stunted, fauna allies it with the Manitoulin. The pelecypod *Pterinea,* and the brachiopods, *Lingula, Rhynchotreta,* and *Stegerhynchus,* and leperditicopid ostracodes are most prevalent. The bryozoan, *Helopora fragilis,* seems to be confined to the upper part of the unit. From the Niagara Gorge and the old Lackawanna quarry, Eller (1940, 1944) reported many scolecodonts from the "Manitoulin Shale of the Albion beds." Fisher (1954) and Bolton (1957) list additional, though rarer, forms.

Grimsby Sandstone - Williams (1914, p. 184) proposed the name Grimsby for the red shales and red sandstones between the Cabot Head Shale below and the Thorold Sandstone above; the type section in the gorge of Fortymile Creek at Grimsby, Ontario, exhibits 12' of mottled red and green sandstone overlain by 6' of gray shale. Eastward, the Grimsby thickens as the Cabot Head thins. From 4' on the Nottawasaga River, western Ontario, the Grimsby expands (in the outcrop) to about 75' in the Medina-Albion area, thins to 55'-60' in the Genessee Gorge at Rochester, and is traceable eastward to Fulton on the Oswego River where a few feet of red crossbedded Grimsby disconformably underlies the Oneida Conglomerate.

In Niagara and Orleans Counties, the Grimsby is divisible into three facies, here informally termed "a", "b" and "c". The lower "a" facies is predominantly a pink, white, and pale green mottled siltstone or sandstone with included pale green shale pebbles. Red shale and red sandstone interbeds are subordinate. The "a" facies is replete with lingulid brachiopods and leperditicopid ostracodes; occasional gastropods and pelecypods may be found (see Fisher, 1954, p. 1992 for a complete faunal list). Intrabed cross-lamination and wave and current ripple marks are common; particularly exquisite ripple marks occur in the northeastern portion of the old Whitmore quarries, north of Lockport. Two semi-active quarries, the Pilon quarry and Monacelli's Albion Harbor Stone Co. quarry, between Knowlesville and Albion, display this facies. Marine facies "a" disappears in the vicinity of Hulberton. The middle "b" facies consists of medium- to thick bedded dusky red and pink, hematitic sandstones with large scale crossbedding like that of the older Whirlpool. Except for the worm burrow, *Arthrophycus alleghenienis,* fossils are lacking in this facies. This is the rock formerly quarried so extensively for building and curbing stone. At present, only one quarry (old Moore quarry) is active, at Hulberton, owned by the Williams Paving Co. of Buffalo. The upper "c" facies, well exposed at Bullard Park in Albion, is a dusky red (crimson lake) crumbly shale with a few greenish-gray shale beds with a low (1-2%) calcareous content. Leperditicopid ostracodes have been found in both the red and greenish-gray shales.

Aside from the complete section in the Niagara Gorge, the Grimsby is well exhibited at DeCew Falls, in the Hickory Corners vicinity ("c" facies), in the old Whitmore suite of quarries north of Lockport ("a" facies), along Eighteenmile Creek at Lockport ("b" facies), and in the belt of abandoned water-filled quarries extending from Median "a" facies), through Albion, Hulberton to the semi-active DiLaura quarry southeast of Holley ("b" facies). At Medina, the *Lingula cuneata* facies outcrops along Oak Orchard Creek under the Route 31 bridge.

Paleoecologically, the Grimsby is a beach deposit. The *Lingula cuneata* facies records a marine, intertidal zone as evidenced by the fossils and profuse intertidal sedimentary structures. The "b" facies is considered supratidal having the effect of an emerged barrier beach. More difficult to explain is the setting of the crimson lake ("c") facies; it may have resulted from clay deposition by streams entering lagoons which were largely landlocked by the "b" facies. The Grimsby sand may have been derived from erosion of exposed older Oswego and Potsdam Sandstones with admixed red clay from broadly exposed Queenston tidal flats.

Thorold Sandstone - The resistant quartzite or sandstone previously known as the "Grey Band of Eaton" was named Thorold by Grabau (1913, p. 460) from exposures at Thorold, Ontario. It is a very light gray quartzose sandstone to siltstone, somewhat finer grained and thinner bedded than the Whirlpool; locally, it may be stained yellow. The individual quartz grains are principally angular to semiangular; the cement is chiefly silica. More argillaceous than the older Medina sandstones, the Thorold is composed of 70% quartz, 20% argillaceous material, 6% feldspar, and 4% accessory minerals (Alling, 1936, p. 196).

The Thorold (*sensu stricto*) is absent east of Dickersonville (see Figure 3). Gillette (1947) regarded the white sandstone resting on the Grimsby as continuous and merging eastward with the Oneida Conglomerate. But the sanstone atop the Grimsby west of Lockport is different from that east of Lockport. The true Thorold has rare *Arthrophycus* and ligulid fragments have been seen in Ontario. Petrographically, the Thorold is a reworked western phase of the Grimsby "b" facies (see Figure 3) with the red hematite cement winnowed out. In my opinion, the lack of any transition with the overlying unquestionable Clinton Neahga Shale favors an alliance of the Thorold with the Medina group with which it is grouped by subsurface investigators. East of Lockport, the sandstone atop the Grimsby is shalier with a pronounced greenish cast, and with the ostracode *Zygobolba curta* - confined to the basal ostracode zone of the Clinton. Thus it is a basal transgressive Clinton sand -- the Kodak Sandstone (see discussion of Clinton Group by W. J. Kilgour, this Guidebook).

Epilogue

No more appropriate paleo-environmental summary of the Medina Group can be offered than that of James Hall (1843, p. 59) who concluded his detailed analysis of these rocks as follows:

> "..... one can almost fancy himself upon the shore of some quiet bay or arm of the sea, where the waves of the receding tide have left these little ridges of sand, which on their return will be obliterated and mingled with the mass around......But his foot is upon the firm rock......Everything is firm and fixed, and he is forced to recollect that millions of ages have rolled on, since the sea washed this shore, and the shells lay upon the glistening sand as he may have seen them in the haunts of his childhood.....Here was an ocean supplied with all the materials for forming rocky strata; in its deeper parts were going on the finer depositions, and on its shores were produced the sandy beaches, and the pebbly banks.....the tide ebbed and flowed, its waters ruffled by the gentle breeze, and nature wrought in all her various forms as at the present time, though man was not there to say, how beautiful!"

SELECTED BIBLIOGRAPHY

(All articles cited are not listed; those that are have extensive bibliographies).

Alling, H. L., 1936, Petrology of the Niagara Gorge Sediments: Proc. Roch. Acad. Sci., v. 7, p. 189-203, 4 figs.

Bolton, T. E., 1953, Silurian formations of the Niagara Escarpment in Ontario (Preliminary Account): Geol. Surv. Canada Paper 53-23.

____________, 1957, Silurian stratigraphy and palaeontology of the Niagara Escarpment in Ontario: Geol. Surv. Canada Memoir 289, 145p., 13 pls.

____________, 1964, Pre-Guelph, Silurian Formations of the Niagara Peninsula, Ontario: Guidebook, Geology of Central Ontario, Amer. Assoc. Pet. Geol., Meeting, p. 55-80, 2 figs., Pls. 7, 8.

Eller, E. R., 1940, New Silurian scolecodonts from Albion beds of Niagara Gorge: Ann. Carnegie Mus., v. 28, p. 9-46, 7 pls.

____________, 1944, Scolecodonts of the Silurian Manitoulin Dolomite of New York and Ontario: Amer. Mid. Natur., v. 32, n. 3, p. 732-755 pl. 4/

Fisher, D. W., 1954, Stratigraphy of Medinan Group, New York and Ontario: Bull. Amer. Assoc. Pet. Geol., v. 38, n. 9, p. 1979-1996, 3 figs.

____________, and others, 1962, Geologic Map of New York, 1961, (specifically The Niagara Sheet), N. Y. State Mus. & Sci. Ser. Map and Chart Ser. No. 5.

Gietz, O., 1952, The Whirlpool Sandstone: Unpublished M.Sc. thesis, McMaster Univ., Hamilton, Ont.

Gillette, T., 1947, The Clinton of Western and Central New York: N.Y. State Mus. Bull. 341, 191p., 20 figs.

Grabau, A. W., 1901, Guide to the geology and paleontology of Niagara Falls and vicinity: N. Y. State Mus. Bull. 45, 284p, colored map, 190 figs.

Hall, J., 1843, Geology of New York, comprising the survey of the Fourth Geological District, Part 4, 683 p., colored map, 19 pls., Medina Group (p. 34-57).

Johnson, H., 1934, The stratigraphy and paleontology of the Cataract Formation in Ontario: Unpublished Ph.D. thesis, Univ. of Toronto.

Kindle, E.M. and Taylor, F.B., 1913, Niagara Folio, U. S. Geol. Surv. Folio 190, 25p, 25 pls.

Kreidler, W. L., 1963, Selected deep wells and areas of gas production in western New York: N. Y. State Mus. and Sci. Serv. Bull. 390, 404p. map.

Liberty, B. A., 1964, Upper Ordovician stratigraphy of the Toronto area: Guidebook, Geology of central Ontario, Amer. Assoc. Pet. Geol. Meeting, p. 43-49, 1 tab, pls. 5,6.

Lockwood, W. N., 1936, The stratigraphy and paleontology of the White Medina sandstone: Unpublished M.A. thesis, Univ. of Buffalo.

Lumsden, D., 1960, The Grimsby Sandstone in New York State: Unpublished M.A. thesis, Univ of Buffalo.

Pelletier, B. R., 1953, The Grimsby Sandstone in the Niagara Peninsula: Unpublished M.Sc. thesis, McMaster Univ.

Schuchert, C., 1914, Medina and Cataract Formations of the Siluric of New York and Ontario: Geol. Soc. Amer. Bull. v. 25, p. 277-320.

Williams, M.Y. 1919, The Sulurian geology and faunas of Ontario Peninsula, and Manitoulin and adjacent islands: Geol. Surv. Canada, Memoir III.

Zenger, D.H., 1965, Stratigraphy of the Lockport Formation (Middle Silurian) in New York State: N. Y. State Mus. and Sci. Serv. Bull. 404, 210p, 29 figs., 8 tables, 1 pl.