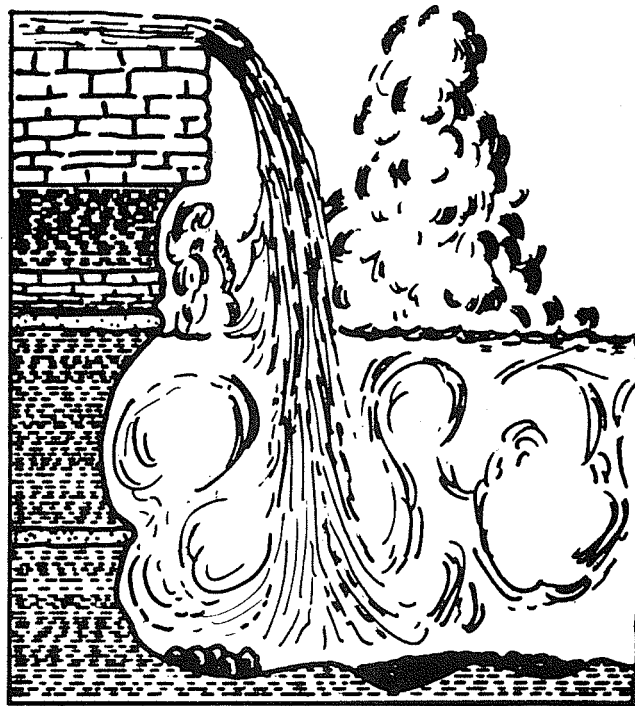


# **GEOLOGY OF WESTERN NEW YORK**

## **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

38<sup>th</sup> 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 world was made!

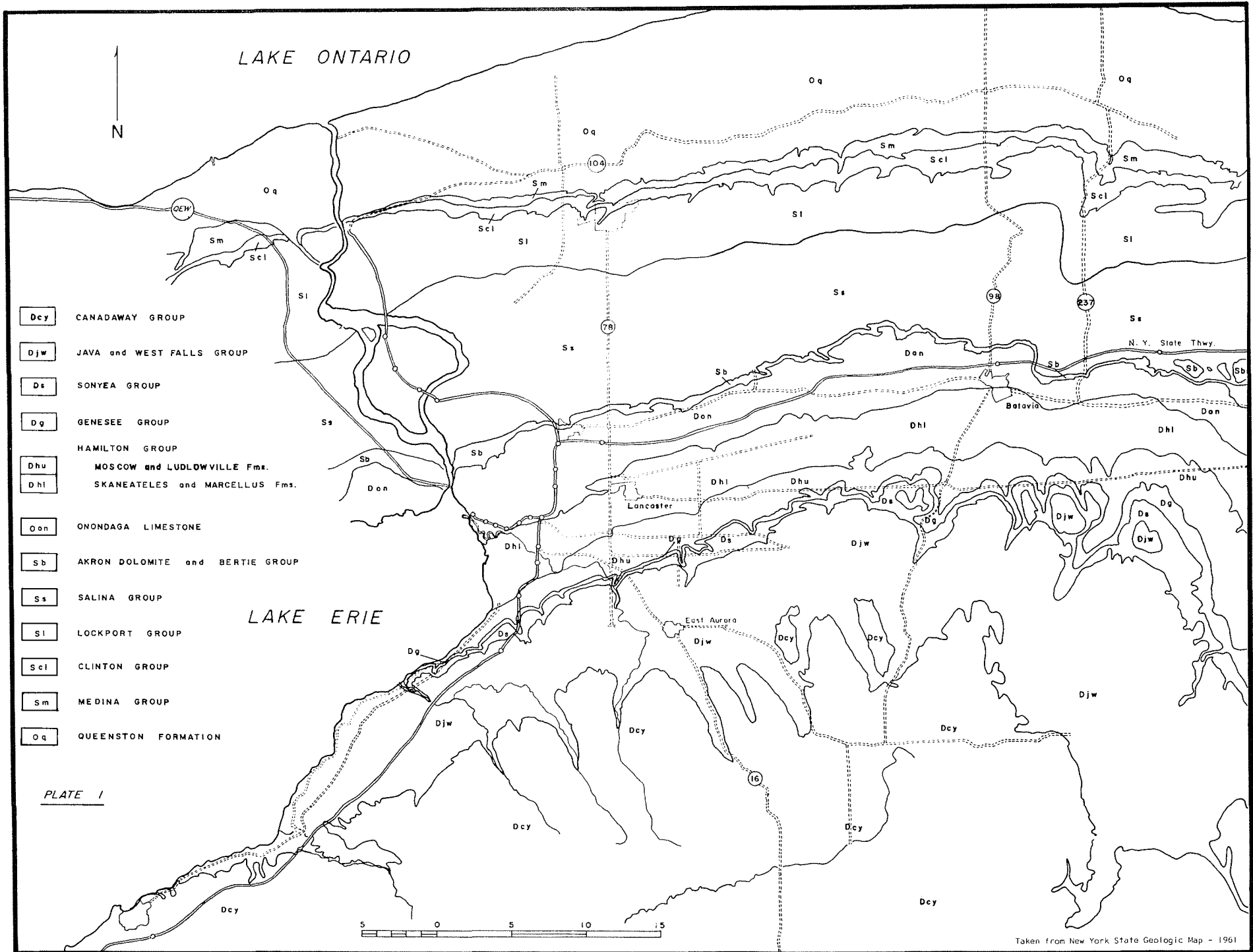
--Sir Walter Scott  
St. Ronan's Well--1824



## TABLE OF CONTENTS

	<u>Page</u>
Preface	
Plates 1, 2, 3	
Pre-C!inton rocks of the Niagara Frontier---A Synopsis..... 1 Donald W. Fisher	1
Middle Silurian Clinton Relationships of Western New York and Ontario.....10 William J. Kilgour	10
The Lockport Formation in Western New York.....19 Donald H. Zenger	19
Upper Silurian Cayuga Series, Niagara Frontier, New York....24 Lawrence V. Rickard	24
Bois Blanc and Onondaga Formations in Western New York and Adjacent Ontario.....32 William A. Oliver, Jr.	32
The Hamilton Group in Western New York.....44 Edward J. Buehler	44
Upper Devonian Stratigraphy and Paleontology of Southwestern New York State (Erie, Chautauqua and Cattaraugus Counties).....47 Irving H. Tesmer	47
Goniatite Zonation of the New York State Devonian.....53 Michael R. House	53
Late Pleistocene History of Northwestern New York.....58 Parker E. Caikin	58
The Economic Geologic Setting of Western New York.....69 John S. King	69
The Gypsum Deposits of the Salina Group of Western New York.....75 Charles V. Clemency	75
Abstracts of Technical Session.....82	82
Road Logs of Field Trips.....93	93





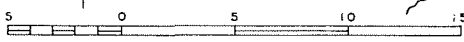
LAKE ONTARIO



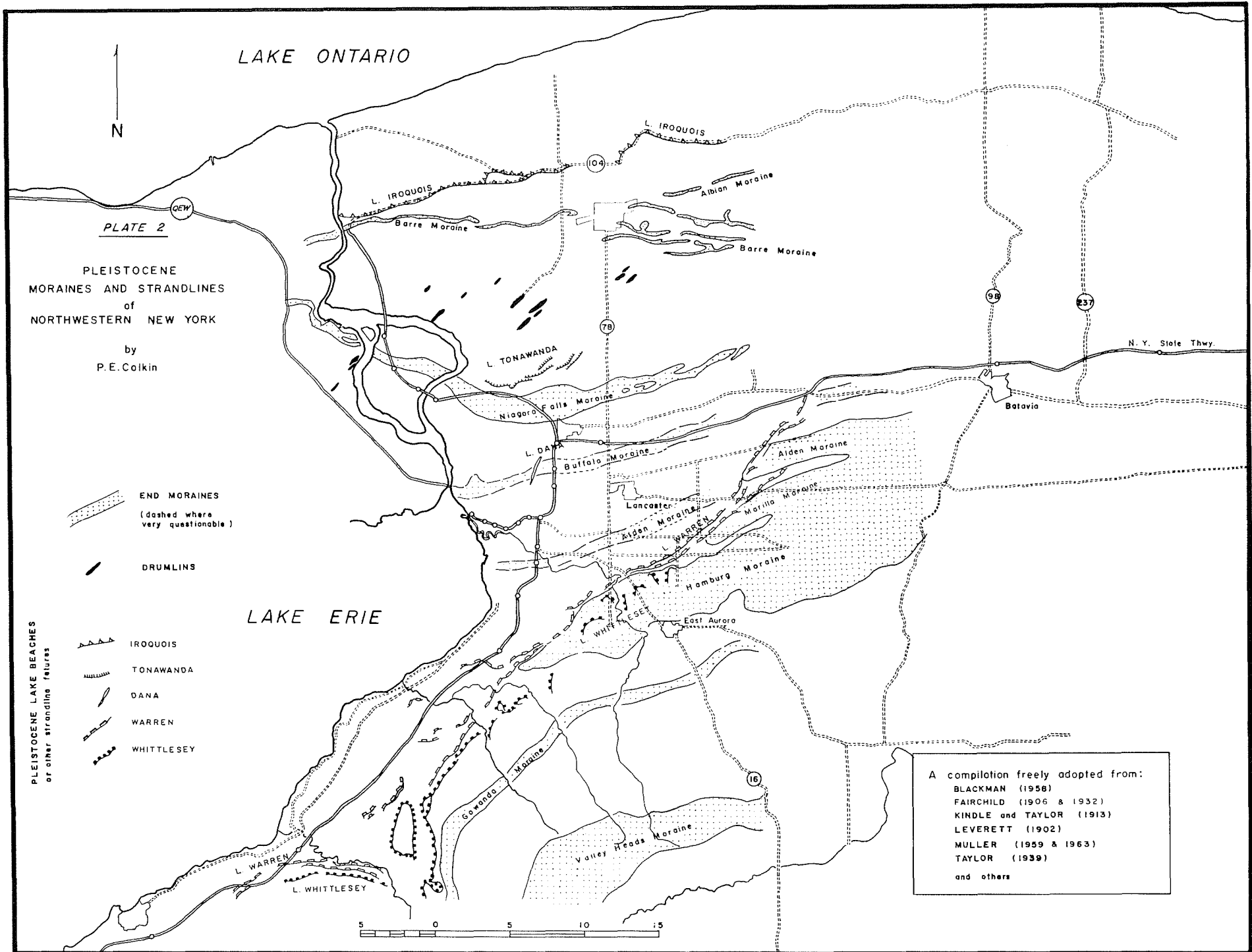
- Dcy CANADAWAY GROUP
- Djw JAVA and WEST FALLS GROUP
- Ds SONYEA GROUP
- Dg GENESEE GROUP
- HAMILTON GROUP
- Dhu MOSCOW and LUDLOWVILLE Fms.
- Dhl SKANEATELES and MARCELLUS Fms.
- Oon ONONDAGA LIMESTONE
- Sb AKRON DOLOMITE and BERTIE GROUP
- Ss SALINA GROUP
- Sl LOCKPORT GROUP
- Scl CLINTON GROUP
- Sm MEDINA GROUP
- Oq QUEENSTON FORMATION

LAKE ERIE

PLATE I











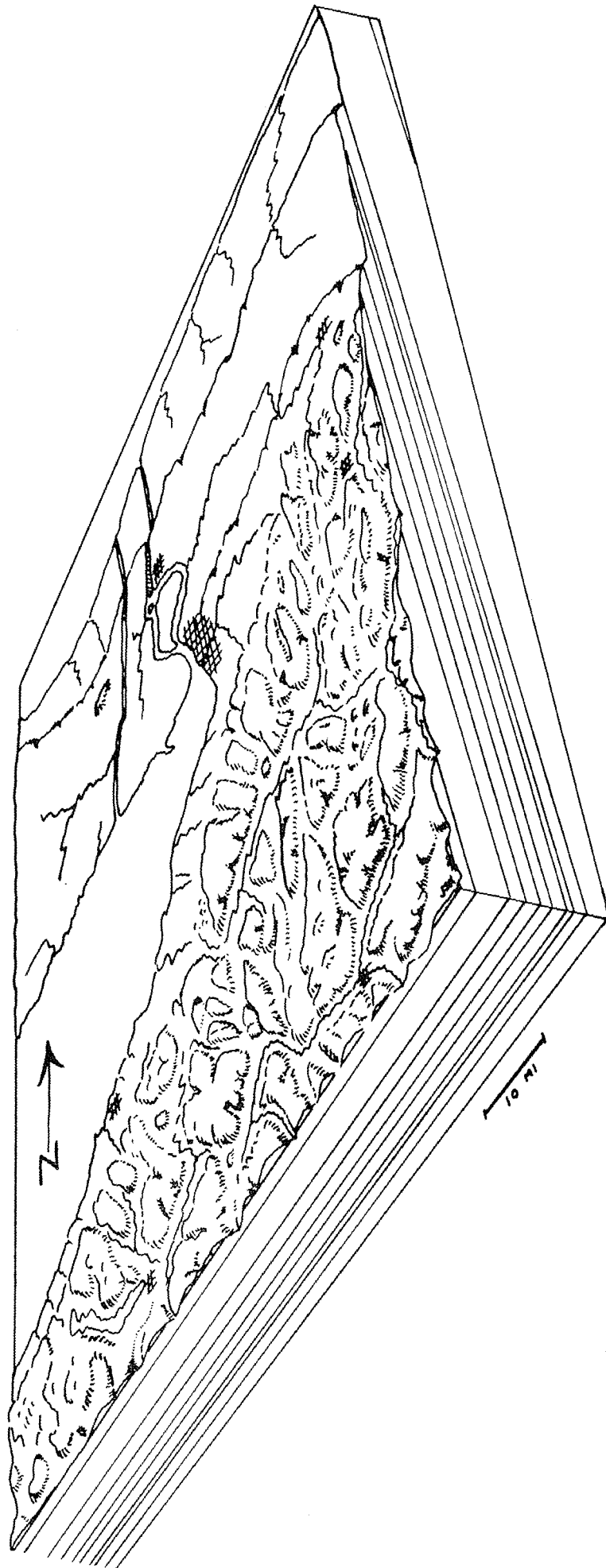


PLATE 3



# 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

---

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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

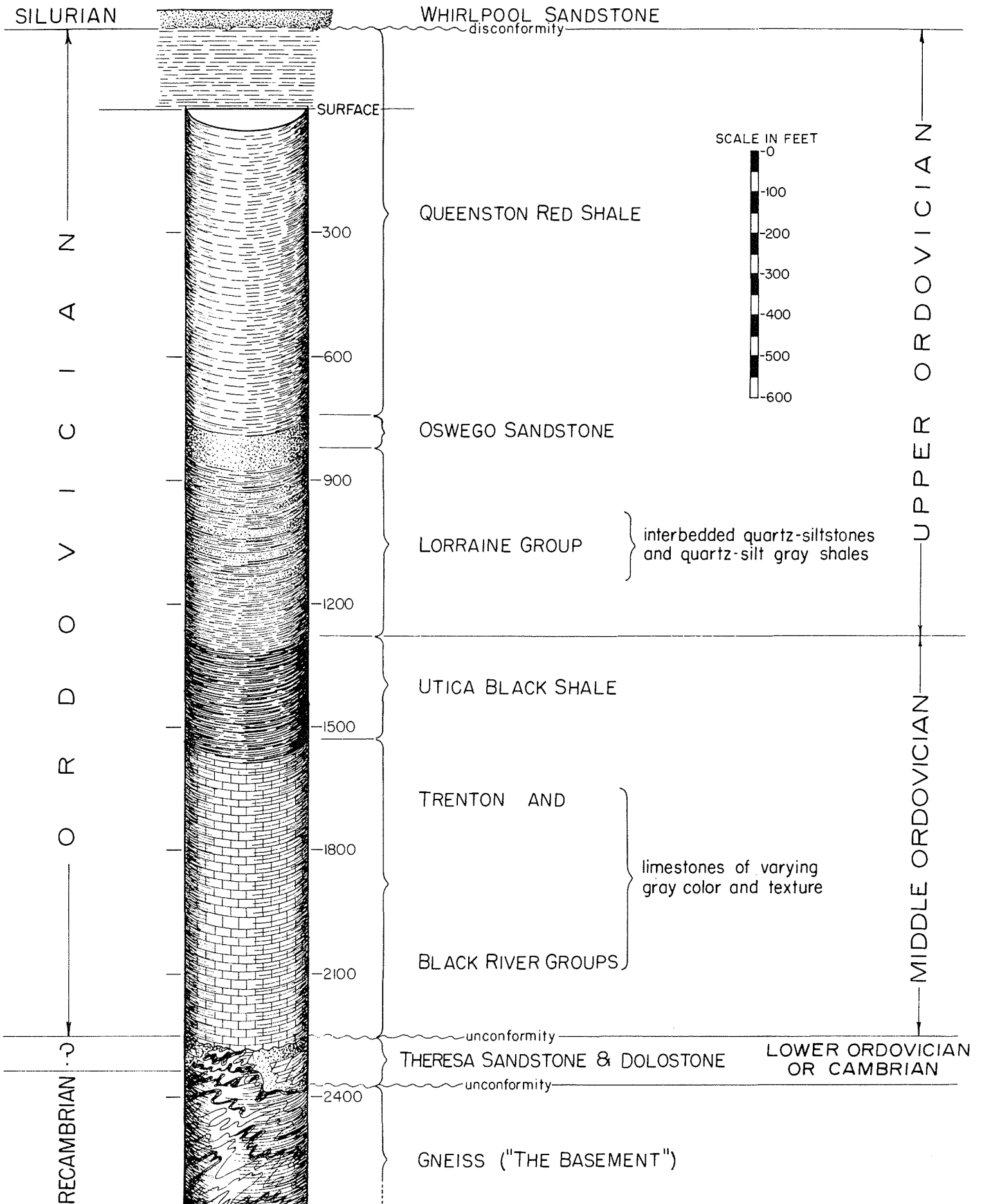
Resting upon the ancient gneisses are interbedded quartz sandstones, variably dolomitic, and quartzose dolostones, aggregating about 100'. This lithology fits the Theresa Formation, a northwestward transgressive facies which is of Late Cambrian age in eastern New York and Early Ordovician age in the 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 minerals, 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 huge 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 eugeosynclinal 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: Whirlpool 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.

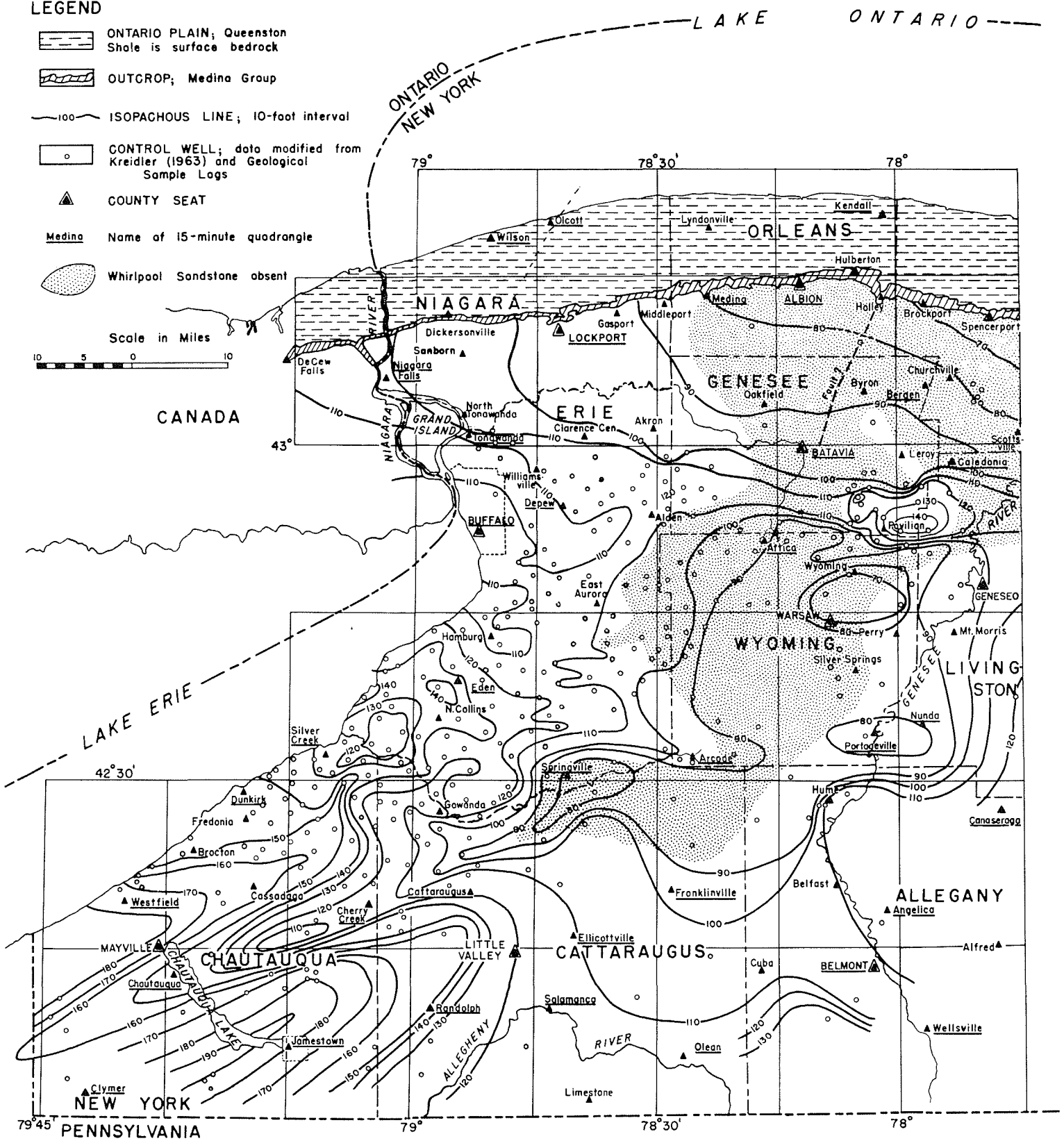
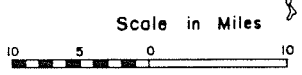
Power Glen Formation - The 48 feet of shales with interbedded siltstones separating the Whirlpool and Grimsby at the DeCew Falls section were named Power Glen by Bolton (1953, 1957). Fisher (1954, p. 1987-1991) assigned this interval to the Fish Creek (later Rumsy Ridge) - Manitoulin-Cabot Head units. 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.



**LEGEND**

-  ONTARIO PLAIN; Queenston Shale is surface bedrock
-  OUTCROP; Medina Group
-  ISOPACHOUS LINE; 10-foot interval
-  CONTROL WELL; data modified from Kreidler (1963) and Geological Sample Logs
-  COUNTY SEAT
- Medina Name of 15-minute quadrangle
-  Whirlpool Sandstone absent



ISOPACHOUS MAP - LOWER SILURIAN MEDINA GROUP  
 FIGURE 2



West

East

DeCaw Falls      Niagara Gorge      Dickersonville      Hickory Corners      Lockport      Gasport      Middleport      Medina      Knowlesville      Albion      Hulberton      Holley

R E E Y N A L E S L I M E S T O N E

THOROLD SANDSTONE

NEAUGA SHALE

G R I M S B Y S A N D S T O N E

MAPLEWOOD SHALE

KODAK SANDSTONE

crimson lake shale "c" facies  
x-bedded purple red-sandstone and siltstone "b" facies

thin-bedded mottled siltstone  
Lingula cuneata "a" facies

POWER GLEN FORMATION

siltstone

greenish-gray shale

dark gray shale with siltstone

WHIRLPOOL SANDSTONE

QUEENSTON SHALE

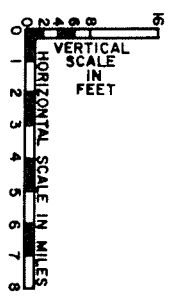
Disconformity

Disconformity

Disconformity

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, *Arthrophyucus allegheniensis*, 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. Leperditicoid 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 sandstone atop the Grimsby west of Lockport is different from that east of Lockport. The true Thorold has rare *Arthrophyucus* 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 ebbd and flowd, 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!"

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## MIDDLE SILURIAN CLINTON RELATIONSHIPS OF WESTERN NEW YORK AND ONTARIO

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The Middle Silurian rocks of Western New York and the Ontario Peninsula are assigned to the Clinton and Lockport Groups and include the Neahga, Reynales, Irondequoit, Rochester, Decew, and Lockport Formations. Only the Lower Clinton Neahga and Reynales Formations and the Upper Clinton Irondequoit Formation will be covered in this discussion. Relationship of the various units is outlined in Fig. 1.

## NEAHGA FORMATION

In the area under consideration the Neahga Shale represents the initial deposit of the lower Clinton sea as it re-invaded the area and the eastern strand line transgressed from west to east. The Neahga Shale (Sanford, 1935, p. 170-174) at the type locality in the Niagara Gorge is a soft slightly silty, calcareous gray to green shale 6' thick with the lowest 8" to 12" being harder, more arenaceous and more calcareous than the balance.

The Neahga has not been recognized east of Hickory Corners, N. Y. where it is 4' to 5' thick. To the west it is traced through outcrops at Budd Road, N. Y., Indian Hill, south of Model City, N. Y., and the Niagara Gorge to St. Catharines where it is about 2' thick.

The contact of the Neahga Shale with the underlying Grimsby Sandstone in the area north-west of Lockport, N. Y. is sharp and marked by a thin layer of large rounded pebbles of dark gray, dense dolomite, shale fragments, and an abrupt change in fauna. Where the Neahga is overlain by the Thorold, the contact is easily distinguished although the lower 8"-12" of the Neahga are usually harder and more arenaceous than the balance.

The upper contact is easily drawn whether it is with the overlying Hickory Corners Member or the Merritton Member of the Reynales Formation. Where overlain by the Hickory Corners Member the contact is sharp and abrupt, being marked by a thin 3"-6" limestone layer with abundant shale pellets and phosphate nodules in the base of the Hickory Corners. There is no evidence of disconformity where the Neahga is overlain by the Hickory Corners. In the area of Merritton and Thorold, Ontario, however, where the Neahga is overlain by the Merritton Member, large rounded and flattened pebbles of dark gray crystalline limestone have been found in the Neahga Shale which has been reworked in this area. These are considered to have been derived from the Hickory Corners Limestone which is not present here. Thus there is evidence of an hiatus of undetermined magnitude between the Neahga Shale and the Merritton Limestone in the area of Merritton and Thorold, Ontario but to the east there is no such evidence at the contact of the Neahga and Hickory Corners.

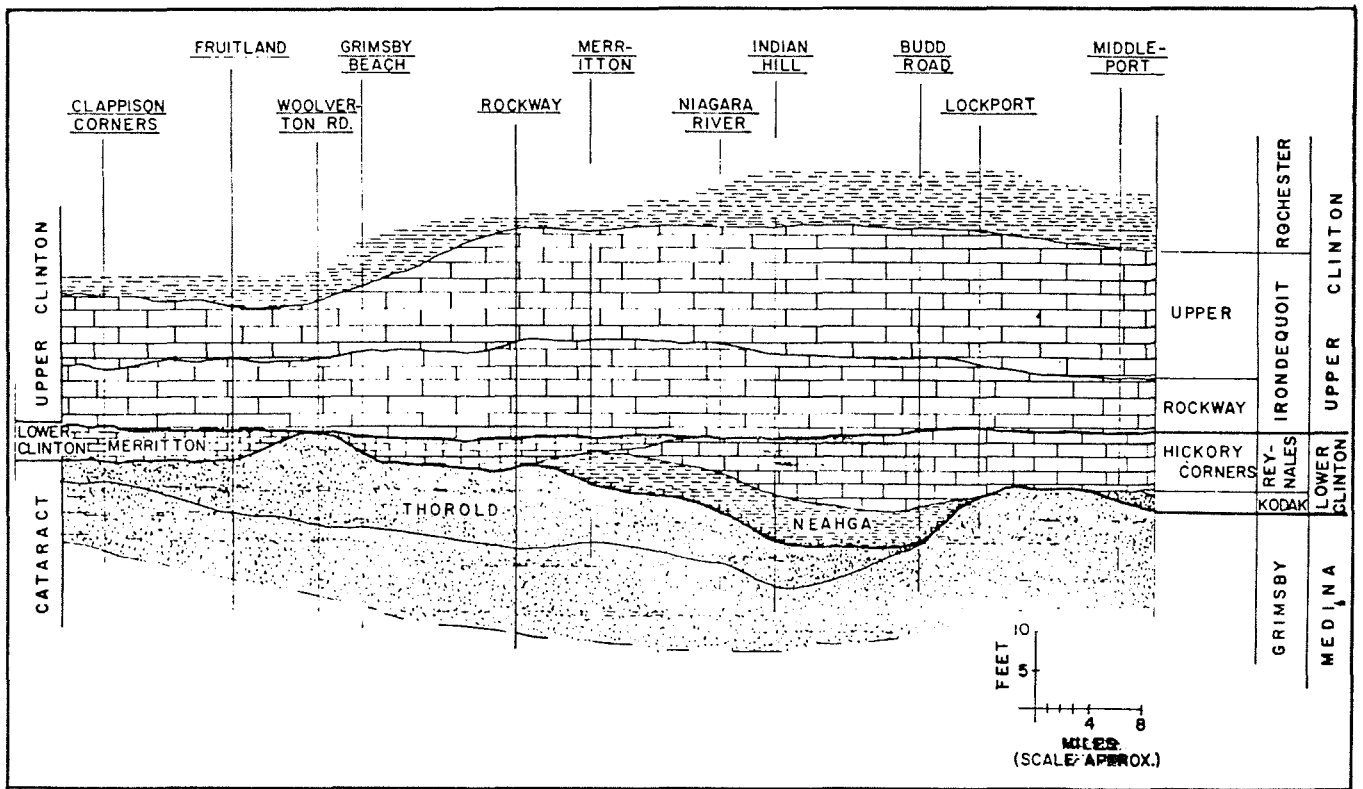


Figure 1. Restored stratigraphic cross-section of Lower Clinton units in western New York and the Niagara Peninsula of Ontario Datum is the Hickory Corners-Rockway contact.

	CALEDON-GEORGETOWN, ONT. AREA		NIAGARA PENINSULA, ONTARIO		NIAGARA COUNTY, N.Y.		GENESEE GORGE		
	FORMATION	MEMBER	FORMATION	MEMBER	FORMATION	MEMBER	FORMATION	MEMBER	
UPPER CLINTON	AMABEL (IN PART)	COLPOY BAY	IRONDEQUOIT	UPPER	IRONDEQUOIT	UPPER	IRONDEQUOIT	UPPER	UPPER CLINTON
		LIONS HEAD		ROCKWAY		ROCKWAY		LOWER	
LOWER CLINTON	FOSSIL HILL		REYNALES	MERRITTON	REYNALES	HICKORY CORNERS	WILLIAMSON	LOWER CLINTON	
				LOWER SODUS			UPPER WALLINGTON		
			NEAHGA		NEAHGA		LOWER WALLINGTON	LOWER CLINTON	
							FURNACEVILLE		BREWER DOCK
							MAPLEWOOD		
						KODAK			

Figure 2. Suggested correlation with other areas.



Fossils are not uncommon in the Neahga but are usually poorly preserved. Fisher (1953) described a unique brown algal microflora and also reported *Hyattidina congesta* in the dolomitic beds at the base of the formation at Hickory Corners, N. Y. This occurrence has been confirmed and *Hyattidina congesta* has also been found at this same horizon at Budd Road and Merritton, Ontario. Gillette (1947, p. 21) and Fisher (1953, p. 34) report the ostracode *Zygobolba curta* from this formation. Rare specimens of poorly preserved *Zygobolba sp.* have been found in the Neahga of the Niagara Gorge by the writer.

The absence of the Neahga to the east in the Lockport area is considered due to a local pinching out and non-deposition; to the west of St. Catharines its absence is due to reworking and removal. Deposition of the Neahga Shale was followed by that of the Hickory Corners Limestone with no marked break between the two.

#### REYNALES FORMATION

The Reynales Limestone was named by Chadwick (1918, p. 344-345). As restricted and re-defined in the area between Medina, New York and Clappison's Corner, Ontario by the writer (1963, p. 1133-1137) it consists of (2) lithologic and faunal units, the Hickory Corners and Merritton Limestone Members.

#### HICKORY CORNERS LIMESTONE MEMBER

This name was introduced by the writer (1963) and applied to the coarse to medium crystalline, argillaceous, highly siliceous, fossiliferous limestone which occurs at Budd Road 1.4 miles west of Hickory Corners, N. Y. between the Neahga Shale and the Iron dequoit Limestone. It is assigned to the Lower Clinton Group.

The Hickory Corners Member is a thin-bedded, dark-gray, bioclastic, argillaceous limestone with fossils throughout but more abundant and more easily obtained in the shale breaks of the lower more coarsely crystalline portion. A 2-4 inch layer containing phosphate nodules and shale inclusions occurs at the base wherever this horizon is exposed. Chert layers and siliceous streaks are abundant and are a distinctive element throughout the member.

The Hickory Corners has been recognized as far east as the Genesee gorge, but it is felt best to use names already in use in the Genesee area when referring to this part of the Reynales Formation. In this area, the lower part includes a representative of the Furnaceville Iron Ore with the part below the ore named the Brewer Dock Limestone by Sanford (1935). This name should be used only where the Brewer Dock is separated from the overlying limestone by the Furnaceville. The upper limit of the Hickory Corners equivalent in the Rochester area occurs within Fisher's (1960) Wallington and is drawn by the writer at the base of a pronounced conglomerate associated with a "crowded" *Pentamerus* layer 12-15 feet above the Furnaceville. The Hickory Corners equivalent in the Rochester area thus

consists of the Brewer Dock, the Furnaceville, and the lower part of Fisher's Wallington with the upper contact being marked by the conglomerate in the base of the overlying upper part of the Wallington.

At Middleport, New York, along Johnson Creek the unit is 8 feet thick and highly siliceous and fossiliferous. At Niagara Gorge it is 4.25 feet thick. At Thorold, Ontario, the Hickory Corners Member is absent, but large worn and rounded pebbles of chert and dark dolomitic limestone occur at the base of the Merritton Limestone Member and in the re-worked Neahga Shale. At Rockway, Ontario, 6.5 miles west of Thorold, the Hickory Corners Member and the Neahga Shale are absent owing to erosion prior to deposition of the Merritton Limestone; the Thorold Sandstone is overlain directly by dense, gray Merritton beds, with a few inches of gray to dark, hard shale occurring at the contact.

Chert pebbles occurring at the base of the Merritton Limestone as far west as Grimsby Beach Road are probably derived from the Hickory Corners Limestone which probably once extended at least that far west.

The Hickory Corners Member is underlain by the Neahga Shale except in the Lockport area where both the Neahga Shale and Thorold Sandstone are absent and the Hickory Corners Limestone is in direct contact with the Grimsby Sandstone. The contact between the Hickory Corners Limestone and the Neahga Shale is sharp but conformable and marked by a thin, coarsely crystalline, limestone layer containing black phosphate nodules and green to black shale inclusions. The Hickory Corners Limestone is absent at Thorold, Ontario, but large worn pebbles of dark limestone similar to the Hickory Corners Limestone and associated with phosphate pebbles occur here throughout the reworked basal Neahga Shale remnant. Large rounded and worn pebbles of chert probably derived from the Hickory Corners Member are also found at the base of the Merritton Limestone in this area as well as at several other localities to the west.

The upper contact of the Hickory Corners Limestone Member is easily drawn at all localities where exposed. Evidence of disconformable relations between this unit and the overlying beds is noted at most localities.

In the Genesee gorge the Hickory Corners equivalent is overlain by a pronounced conglomerate associated with *Pentamerus* 15-18 feet above the Maplewood Shale. The same conglomerate has been observed on Salmon Creek, Town of Ogden, where it also is associated with *Pentamerus*.

At Budd Road the member is separated from the overlying dolomite by a foot of soft, crumbly, brown shale containing a few large, weathered, dark-colored, limestone pebbles, some of which contain pyrite and *Hyattidina* and which resemble the underlying limestone. The change from the dark, crystalline, fossiliferous Hickory Corners Limestone to the soft, brown, unfossiliferous, overlying shale is abrupt. This relationship between the Hickory Corners Limestone and the overlying unit is observed in varying degree at many localities west of Salmon Creek.

The Hickory Corners Limestone Member is highly fossiliferous at most localities, with bryozoans and brachiopods generally the most common forms found. *Hyattidina congesta* is found at most localities but is uncommon west of Indian Hill (3.5 miles east of Lewiston) in New York. Poorly preserved ostracodes of the genus *Zygobolba* are the only ostracodes found, and these only rarely in this member. Rexroad and Rickard (1965, p. 1217) have reported the presence of typical *celloni* zone conodonts in the Hickory Corners Member.

Although the contact of the Hickory Corners Member and the overlying Merritton Member has not been observed, the Hickory Corners is considered older on the basis of physical evidence. In Western New York, deposition was continuous throughout Neahga and Hickory Corners time. In Ontario, however, it is concluded that the Hickory Corners was deposited but that it and part of the Neahga were removed prior to deposition of the Merritton Member.

The Hickory Corners Limestone Member was deposited over a wide area in the same eastwardly transgressive Lower Clinton sea as the Neahga Shale. As time passed, the sediments which were deposited became less argillaceous, and conditions were more conducive to the development of a marine fauna. The broken and worn nature of the fossils attest to shallow, rough-water conditions. Hickory Corners deposition was closed with continued migration of the eastern strand line to the east and with the western strand line also moving eastward into the area. This resulted in the removal of the Hickory Corners Limestone to the west of the Niagara River and the exposure of the Thorold Sandstone and Neahga Shale prior to deposition of the overlying beds. Thinning and disappearance of the Hickory Corners unit to the west is thus attributed to a relatively greater uplift than to the east. Migration of the strand lines, and the center of deposition, is presently thought due to a change in the relative location and elevation of the Cataract shelf. The Furnaceville Iron Ore was deposited as a stringer within or at the base of the Hickory Corners equivalent in the Genesee area and was closely connected with strand line movements in this area during deposition of the Hickory Corners to the west.

#### MERRITTON LIMESTONE MEMBER

The Merritton Limestone Member as named and defined by the writer (1963) is a buff to gray limestone at its type locality in the railroad cut west of lock 5 on the Welland Canal near Merritton, Ontario. It is assigned questionably to the Lower Clinton Group.

The Merritton Limestone Member is a medium crystalline, buff weathering, gray to buff argillaceous limestone. It is thin-bedded with thin shale partings being relatively common. Considerable glauconite and pyrite are included in it, although they vary at different localities. The basal 6-inch bed is for the most part very dense and fine-grained and carries black phosphatic sand grains, glauconite, and flat, worn chert pebbles at most localities.

The member is not known east of Thorold, Ontario. It can be traced westward by outcrops from Thorold to Georgetown, Ontario. At Thorold the unit is 2 feet thick. The maximum thickness of 3.5 feet is at Rockway, Ontario, and at Clappison's Corners it is 2 feet thick. It is absent at the Woolverton Road cut west of Grimsby, Ontario, where the road cuts the cuesta and is also absent in the railroad cut at Limehouse, Ontario, northwest of Hamilton, Ontario.

Although the Merritton Member is lithologically distinct, it is very thin. Chert pebbles probably derived from the older Hickory Corners member, are found at the base of the unit at several localities between Thorold and Grimsby Beach Road. This, together with its overlap on the underlying Neahga Shale, Thorold Sandstone, and Cabot Head Shale, its absence at several localities, and the introduction of a new fauna with no intermingling, indicates a considerable gap in the record.

The disconformity at the top of the Merritton Limestone is not as marked as that at the base. It is marked by large worn pebbles, abrupt change in fauna, and an abrupt change in lithology to a brown shale which grades upward into the brown to buff Rockway Dolomite. The top surface of the Merritton is exposed over a considerable area in the vicinity of Merritton and is very rough, irregular, phosphatic, and lithologically distinct from the overlying unit.

The fauna of the Merritton Member is characterized by an abundance of *Pentameroides* (*Pentamerus*, as identified by previous investigators), and it is primarily on the occurrence of this brachiopod that the Reynales of Ontario has previously been correlated with the Reynales of western New York. At several localities, particularly at Thorold, corals are also common and form an important part of the fauna.

Schuchert (in Williams, 1919, p. 49) believed that the Clinton form of *Pentamerus* is distinct from the younger "Lockport" occurrences to the north. In this connection, Dr. A. J. Boucot has identified as *Pentameroides* representative specimens of supposed *Pentamerus* collected by the writer from several Ontario localities (personal communication, 1962). It is likely that past references to the occurrence of *Pentamerus* in the Reynales of this area have been in error. In the more northerly areas and along the Bruce Peninsula, all specimens collected to date have been identified as *Pentamerus*, no specimens of *Pentameroides* having been observed although extensive collections have been made. The writer has found no ostracodes in the Merritton Member.

The Merritton Limestone was deposited on the eroded Thorold-Neahga-Hickory Corners surface in a relatively clear and shallow sea covering the entire area. Following its deposition the sea withdrew to the west and a period of reworking and erosion followed so that only a thin Merritton remnant remains today in Ontario as evidence of its former extent. East of Thorold it was removed (if ever deposited).

The Merritton probably represents some part of the Fossil Hill Formation of the more northerly areas. The Merritton Member disappears east of Thorold, and its correlation with units in the Genesee area is conjectural on the basis of present knowledge. Lithology and



stratigraphic relationships appear to favor a correlation with the "crowded" *Pentamerus* beds which in the Genesee area form the upper 4-5 feet of the Wallington Formation as defined by Fisher (1960). However, the presence of *Pentameroides* in the Merritton raises the distinct possibility that the Merritton is post-Wallington in age since in both the Central States and the Michigan basin *Pentameroides* occurs above *Pentamerus*. Until further evidence bearing on the problem becomes available it is referred questionably to the Lower Clinton.

#### IRONDEQUOIT LIMESTONE

The upper, more dolomitic, and sparingly fossiliferous part of the Reynales Formation (of previous investigators) is removed and included in the Irondequoit Limestone as a result of the present investigation. Thus, the Upper Clinton Irondequoit is made up of a lower dolomitic limestone, herein named the Rockway Dolomite Member, and an upper limestone member.

#### ROCKWAY DOLOMITE MEMBER

The name Rockway Dolomite Member of the Irondequoit Limestone (Kilgour, 1963) is applied to the 12 feet of buff to brown and gray dolomite which occurs in Fifteen Mile Creek at Rockway, Ontario, between the Merritton Limestone Member below and the upper part of the Irondequoit Limestone above. It has been considered the upper sparsely fossiliferous, more dolomitic part of the Reynales Formation by previous investigators.

The Rockway Dolomite is a dense to compact, fine-grained, buff to gray dolomite which weathers buff. The unit is for the most part massive with a few gray shale breaks throughout. Three to fifteen inches of blocky brown shale is found at the base of the unit. At most localities a 3-12 inch dolomitic limestone bed occurs at the top of the member overlying a thin, gray to brown shale. The upper contact of this bed with the more coarsely crystalline overlying upper Irondequoit marks the upper limit of the Rockway Member. Close examination is usually required to ascertain this contact, since it frequently occurs in what appears to be a physically unbroken sequence and may thus be quite indistinct. It has in fact been misplaced by Williams (1919) and Bolton (1957).

The Rockway Dolomite Member disconformably overlies the Hickory Corners Limestone, and the Cabot Head Shale.

Evidence that the contact of the Rockway Member with the underlying beds is disconformable is best noted at Budd Road, Niagara Gorge, and Merritton, and has already been discussed in connection with the upper contacts of the Hickory Corners and Merritton Members of the Reynales Formation.

Previous investigators have considered the upper contact of the Rockway Member with the overlying upper part of the Irondequoit Limestone to be disconformable and to represent the entire interval of the

Middle Clinton, although there is no physical evidence of such an important disconformity in the Niagara County and Ontario Peninsula area. In fact, there is stronger physical evidence of a disconformity at the base of the Rockway Dolomite Member, and it is for this reason that it is included in the Irondequoit Limestone as the western equivalent of the sparsely fossiliferous, more dolomitic facies of the lower part of the Irondequoit Limestone as it occurs in the Rochester area.

During Rockway time there was a reduced influence of the Cataract shelf. The Rockway Dolomite was deposited during a time of relatively steady and constant conditions as indicated by its uniformity and continuity over a wide area. It represents a facies of the lower part of the Irondequoit of the Genesee area where an increased amount of shaly interbeds indicates a greater terrestrial influence than to the west where the Rockway was being deposited.

The only fossil usually found in the Rockway Dolomite is the large brachiopod *Constistricklandia canadensis* which has not been noted in association with *Pentameroides*. Bolton (1957, p. 83) has reported *Costistricklandia* from the lower 11 inches of the Irondequoit as he originally recognized it at Decew Falls, Ontario. He has since (personal communication, 1962) removed these beds from his Irondequoit and considers them a part of the Rockway Member as it is defined in this paper.

No ostracodes have been found in the Rockway Member by the writer. Rexroad and Rickard have recently (1965, p. 1219) reported the occurrence of abundant specimens of *Pterospathodus amorphognathoides* Walliser and *Ozarkodina gaertneri* Walliser, the chief guide species for Walliser's *Amorphognathoides* - zone, in the Rockway Member of the Niagara Gorge, as well as numerous other species characteristic of this zone.

#### CORRELATION

A suggested correlation of the Clinton units between the Genesee and Caledon areas is given (Fig. 2). Since any effort to correlate the Clinton units defined in this paper is complicated by either the lack of a fauna or by the varying distribution of certain faunas, this correlation is based largely on stratigraphic and lithologic criteria with secondary reliance on faunal evidence.

Clinton ostracodes of zonal importance in the area west of the Genesee gorge occur rarely. The only ostracodes reported by others (Gillette, 1947; Fisher, 1953) or found by the writer are poorly preserved specimens of *Zygobolba* which occur only rarely in the Neahga Shale and Hickory Corners Limestone. No ostracodes have been found as yet in the Merritton or Rockway members. Because of this situation it is presently impossible to correlate on the basis of the ostracode zones established by Gillette (1947, p. 22).

## SUMMARY

The restored cross section (Fig. 1) summarizes the writer's concept of Lower Clinton relationships in the western New York - Ontario area. The Lower Clinton Group includes the units between the Thorold Sandstone below and Irondequoit Limestone above. The Lower Clinton Reynales Limestone includes two lithologic (and faunal) units--the Hickory Corners and Merritton limestone members. The Rockway Dolomite is included in the Upper Clinton Irondequoit Formation as its lower member. The Hickory Corners, Merritton, and Rockway units are separated by disconformities, the magnitude of which varies from one locality to another. As a result, the distribution of the individual units is discontinuous with one or more of them missing at most localities.

No intermingling of the faunas of the three carbonate units occurs; they are distinctive and easily recognized. The older fauna is restricted to the Neahga Shale and Hickory Corners Limestone and is characterized by abundant specimens of *Hyattidina congesta* in association with other brachiopods including *Eocoelia*. Bryozoa are exceedingly common in the Hickory Corners Member. The second and younger association is characterized by an abundance of the brachiopod reported previously as *Pentamerus* but now identified as *Pentameroides*. With corals, this association is restricted to the Merritton Limestone Member.

The youngest "association" is the occurrence of *Costistricklandia canadensis* in the Rockway Dolomite. This is the only fossil commonly found by the writer and only in the area between Thorold and Mount Albion, Ontario.

With these refinements in the nomenclature and definition of the Reynales Formation, the Lower Clinton Group between Medina, New York, and Clappison's Corners, Ontario, consists of shale and limestone units which are genetically related by deposition during a time of widespread and frequent depositional changes. These changes were caused by strand line fluctuations connected with frequent shifts in the location and elevation of the Cataract shelf to the north and west. Because of low relief in the general area, relatively minor changes had widespread affect. The change from a relatively thick sequence of sandstone and sandy shale of the Medina to the limestone and shale of the Lower Clinton marked the beginning of the controlling effect of the Cataract shelf in this area. Its effect was apparent earlier and farther south than has been previously postulated.

The striking differences between the Lower Clinton Group of western New York, and the Niagara Peninsula of Ontario are the result of frequent diastrophic changes rather than facies changes. Physical evidence, which when considered collectively offers strong support for this interpretation, includes abrupt vertical and lateral changes in lithology and fauna, absence or overlap of units, and the occurrence of thin conglomerates. The absence of the Thorold Sandstone in the Lockport area and differences in the relationship of the Neahga Shale with the overlying unit depending on whether it is the Hickory Corners or Merritton Limestone are most noticeable.

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## THE LOCKPORT FORMATION IN WESTERN NEW YORK

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On examining the Lockport sequence in western New York and in neighboring Ontario, one may understandably question the writer's seemingly unnecessary change of Lockport "Dolomite" to Lockport "Formation" (Zenger, 1962; 1965). In this region, the Lockport is practically all dolomite, exceptions being the dolomitic limestone beds in the Gasport Member. In west-central and east-central New York, however, the Lockport includes sandstone, limestone, and shale. A brief statement of the overall relationships within the Lockport will follow a more detailed description of the very interesting section in the type area in western New York.

Hall (1839) designated exposures along the old Erie Canal (now represented by outcrops along the Barge Canal) south of Lockport as the type section of the Lockport. In western New York the lower part of the formation is well exposed along the Niagara Escarpment. From 1959 to 1961 excellent exposures were made available through the excavations of the Niagara Power Project. Most of these sections are now covered, although the lower part of the formation may be observed along the access road about two miles south of Lewiston. Quarries provide continuous sections of parts of the Lockport, most, however, being in the lower part of the unit.

Generally characteristic of the carbonates are a brownish-gray color, medium to thick bedding, stylolites, carbonaceous parting, mineralized vugs, and poorly preserved fossils. The Lockport in the Niagara Falls and Tonawanda quadrangles is divisible into five vertical members which will be described from oldest to youngest (see Figure 1).

The DeCew is considered by this writer as the basal member of the Lockport. It ranges in thickness from 8 to 15 feet between Niagara Falls and Lockport. Dolomitic shales are common in the lower part whereas thicker bedded, fine-grained, silty dolomite is prevalent in the upper part. At many outcrops the more dolomitic portion of the DeCew exhibits a convolute or enterolithic structure. This irregular bedding, considered a kind of flow roll by the writer, can be seen along the road leading to the docks on the Canadian side of the gorge opposite the American Falls; along the road across the escarpment south of Lewiston; and in the vicinity of Lockport (Frontier Dolomite quarry and "The Gulf"). Caves and other solution features are common, Devil's Hole being the most notable. Fossils are neither abundant nor well preserved. *Atrypa reticularis*, *Fardenia? decewensis*, *Trimerus delphinocephalus*, and *Buthotrephis gracilis* are among the forms present.

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\* The writer is very grateful for the support of the New York State Museum and Science Service.

Except where the enterolithic structure in the more massive dolomite is in immediate contact with the underlying Rochester, this contact is gradational through a few feet of dolomitic shales. The upper contact with the Gasport Member of Niagara Falls is sharp and commonly marked by a corrosion surface which this writer interprets as a minor diastem. Farther west in Ontario, however, the contact is perhaps a more significant disconformity. Many workers are of the opinion that the DeCew should be placed in the underlying Clinton Group. The lower gradational contact with the Rochester and the sharp upper contact with the Gasport at some localities near Niagara Falls tends to support their contention. On the other hand, in the Tonawanda and Lockport quadrangles there is evidence of a gradational to interfingering relationship between the DeCew and Gasport. The writer considers the corrosion surface to be of minor significance time-wise. The lithologic nature of the main dolomitic portion of the DeCew (dolomite content, texture, bedding, and topographic expression) seems more closely related to the Lockport than to the underlying Rochester. The DeCew is truly transitional between the Clinton and the main mass of the Lockport and its stratigraphic assignment in western New York seems to be a subjective matter.

The Gasport Member (Kindle and Taylor, 1913, p. 7), which extends from Hamilton, Ontario, to the Albion quadrangle, ranges in thickness from 15 to 30 feet in this area. It is well exposed along the escarpment. It is, perhaps, the most interesting member of the Lockport. The Gasport is characterized by brownish-gray, coarse-grained, low-insoluble, fossil-fragmental, pelmatozoan-rich limestone and dolomite. Fossils, which are quite well preserved in the less dolomitized beds, are predominantly brachiopods, corals, bryozoans and stromatopoids including *Atrypa reticularis*, *Leptaena "rhomboidalis"*, *Rhynchotreta americana*, *Stegerhynchus neglectum*, *Whitfieldella nitida*, *Cladopora* spp., *Cystiphyllum niagarensis*, *Diplophyllum caespitosum*, *Enterolasma caliculum*, *Favosites* spp., *Fenestrellina elegans*, *Hallopora elegantula?*, *Clathrodictyon vesiculosum*, and *Stromatopora concentrica?*. Small bioherms of limestone and of replacement dolomite are exposed along the Niagara Gorge, along the main north-south road at the northern edge of Pekin, in the roadcut just west of the Niagara Sanatorium two miles west of Lockport, and in the Royalton quarry near Gasport. A dark, silty, finer-grained dolomite occurs between bioherms. Dendroid graptolites have been found in such beds both in the Frontier Dolomite quarry at Lockport and in the Royalton quarry. Bioherm detrital beds are present adjacent to some bioherms.

Conformably overlying the Gasport is a 20 to 25 foot unit of low insoluble dolomite designated the Goat Island Member by Howell and Sanford (1947, p. 34) for the exposures on Goat Island at the brink of the falls. In the Niagara Peninsula of Ontario the lower part of the equivalent interval is characterized by very abundant white chert nodules. The unit is completely exposed and accessible along the access road of the Niagara Power Project, where it is brownish-gray, medium-grained, thick-bedded, vuggy, saccharoidal dolomite. Chert nodules are found sporadically in its lower part and higher at the Eramosa contact. Between Niagara Falls and Medina the insoluble content is very low, averaging three percent. At its easternmost recognizable point at Clarendon the Goat Island is very cherty and crinoidal and the insoluble content (excluding chert nodules)

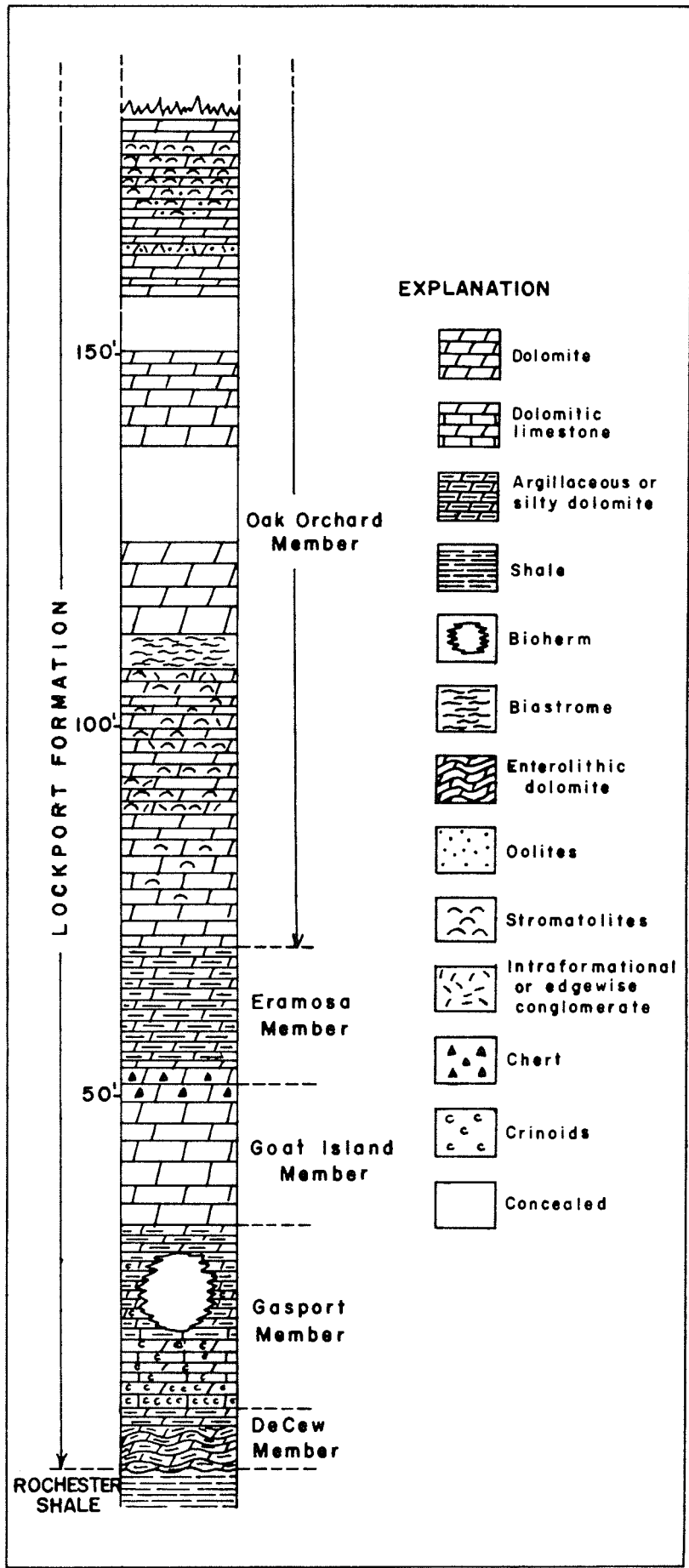


Figure 1.--Columnar section of the Lockport Formation in the Niagara Falls area





is higher. These characteristics suggest an easterly passage into the crinoidal, quartzose Penfield Member at Rochester. Poorly preserved fossils include *Leptaena "rhomboidalis"*, *Protomegastrophia profunda*, *Whitfieldella nitida*, *Enterolasma caliculum*, and stromatoporoids. The lower contact with the Gasport of Niagara Falls and Lockport is conformable. Along the access road the Goat Island-Eramosa contact is along a limonitic shaly parting. Chert nodules with well-preserved fossils are found on both sides of this contact. Along Oak Orchard Creek south of Shelby (Medina quadrangle) the Eramosa is absent and the thin- to medium-bedded Goat Island grades upward into the Oak Orchard Member. The "lower Shelby" of Clark and Ruedemann (1903, p. 9-11) would be within the Goat Island as used here although the lower Guelph faunas were not found. Other Goat Island exposures are in the Frontier Dolomite quarry at Lockport and along the Barge Canal south of that city.

Overlying the Goat Island in the Niagara Falls and Tonawanda quadrangles is 18 to 20 feet of dark-gray, light-gray weathering, thin- to medium-bedded, fine-grained, silty and bituminous dolomite which average more than 15 per cent insoluble. These beds have been assigned to the Eramosa Member (named by Williams, 1915, for exposures along the Eramosa River in Ontario). Occurring on shaly parting surfaces is a brachiopod-mollusk assemblage characterized by *Dawsonoceras americanum*, *Lechitochochras desplainense?*, *Atrypa reticularis*, and *Stegerhynchus neglectum*. The Eramosa is considered to be, at least in part, the equivalent of the Eramosa Member in Ontario; the New York section, however, is much thinner, darker, and finer-grained. The Eramosa in New York apparently pinches out somewhere in the Tonawanda or Medina quadrangle. Twenty feet of the unit crops out along the access road where it is the uppermost Lockport member exposed; the upper 12 feet, weathering distinctly lighter than the overlying Oak Orchard Member, may be observed in the lower part of the Niagara Stone Company quarry about four miles east of Niagara Falls.

The Oak Orchard Member forms the upper 120 to 140 feet of Lockport in western New York. It is a brownish-gray to dark-gray, medium- to thick-bedded, medium-grained, bituminous, stylolitic, low-insoluble dolomite (average less than 2% insoluble). Carbonaceous shaly parting are common as are mineral-filled vugs. Stromatolite zones and generally poorly preserved stromatoporoids and corals are also characteristic. A lower stromatolite zone is exposed in the Niagara Stone Company quarry beneath a biostrome containing a profusion of relatively well-preserved specimens of *Favosites niagarensis?* A higher stromatolite zone was exposed in the excavations for the intake area of the power project (on the north side of the Niagara River two miles above the falls). Loose blocks showing the hemispherical structure of the stromatolites may be seen in dump piles beside the Barge Canal in the southern part of the Lockport outcrop belt in the Lockport quadrangle. The unit has been traced more than 100 miles to the east, although exposures are very scanty east of the Tonawanda quadrangle. It is considered to be roughly the time equivalent of the Guelph Dolomite of Ontario but the characteristic buff, saccharoidal dolomite of the Guelph is not present in New York. A chert-nodule zone occurs in the Oak Orchard Member in the Medina quadrangle and eastward. Guelph fossils were reported from such chert nodules ("upper Shelby" of Clarke and Ruedemann, 1903) at the type section (Howell and Sanford, 1947) along Oak Orchard Creek south of Shelby. The writer

considers the Oak Orchard as an indivisible lithologic unit with sporadic Guelph fossils. The upper contact with the overlying Salina Group is everywhere covered, but diamond drill cores south of Albion, south of Lockport, and at the north end of Grand Island bridge suggest a conformable contact.

In the vicinity of Rochester the Lockport is divided into three vertical members, in order of decreasing age, as follows: The DeCew (silty and sandy dolomite), the Penfield (dolomitic sandstone and quartzose dolomite), and Oak Orchard with characteristics similar to those in western New York. Between Rochester and Syracuse the Lockport undergoes a facies change into limestone-dolomite complex which is considered a separate member, the Sconodoa. In the Oneida region the Sconodoa passes eastward into the shale and dolomite of the Ilion Member which in turn pinches out southeast of Utica. Faunal and lithologic evidence suggests that the Ilion is the time equivalent of the upper Lockport (i.e., Eramosa? and Oak Orchard Members) at Niagara Falls. There is other evidence to support the contention that the uppermost Clinton in east-central New York (upper Herkimer Formation) is the time equivalent of the lower Lockport in western New York. Those interested in the detailed aspects of these correlations are referred to Zenger (1965) and to Berdan and Zenger (1965).

Petrological evidence (dolomitized bioherms, fossils, oolites, etc) suggest that the dolomite originated through replacement.

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UPPER SILURIAN CAYUGAN SERIES,  
 NIAGARA FRONTIER, NEW YORK\*

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Introduction

During the Late Silurian, 410 million years ago, that portion of New York State west of the Hudson River and south of Lake Ontario and the Mohawk River was the site of a shallow sea whose connection with the ocean was restricted by reefs and adjacent lands. The presumably arid climate of that time caused rapid evaporation of the restricted sea and the precipitation of dolomite, anhydrite and halite as the salinity of the water was increased. Red and green shales, thin siltstones and occasional black shales were also deposited. These poorly fossiliferous rocks now comprise the Upper Silurian Cayugan Series of New York.

The Cayugan Series of the Niagara Frontier (Niagara, Erie, Orleans and Genesee Counties) contains five formations given in the list below. Thicknesses quoted are those determined for the vicinity of Buffalo. This series overlies the Oak Orchard Member of the Lockport Group ("Middle" Silurian) and is disconformably overlain by the Edgecliff Member of the Onondaga Limestone (Middle Devonian).

Late Silurian, Cayugan Series	
Akron Dolomite, 8 feet	
Bertie Formation, 45 feet	
Williamsville Member, 7 feet	
Scajaquada Member, 8 feet	
Falkirk Member, 30 feet	
Camillus (O-atka) Shale, 100 feet	} Salina Group, 400 feet
Syracuse Formation, 100 feet	
Vernon Shale, 200 feet	

Owing to the unconformable nature of the upper contact, the Edgecliff limestone may rest upon the Akron Dolomite or any of the members of the Bertie Formation at various exposures along the outcrop east of Buffalo.<sup>+</sup>

Although the Cayugan Series of the Niagara Frontier is 400-700 feet thick, less than 100 feet at the top are exposed in surface outcrops. Consequently, not much is known of the lithology, paleontology, and

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+ The author did not have access to the report by Oliver (this book) hence the omission of the Bois Blanc (editor's note)

stratigraphy of this series in western New York. In an effort to discover some of the more important features of the Cayugan Series in this area, the writer turned to the available subsurface information derived from sample logs and radioactivity logs of wells drilled for natural gas in western New York. This has proved to be a very productive investigation.

The results of this investigation, which has been expanded to include Cayugan rocks throughout New York, northern Pennsylvania, and northeastern Ohio, will be given in another report upon completion of the study. However, it can be stated here that the major results will include: (1) recognition and correlation in the subsurface of Cayugan rock units originally defined on poor and incomplete surface outcrops, (2) an accurate and detailed description of the distribution of evaporites - halite and anhydrite - in these rocks and (3) correlation of the Cayugan rocks of New York with those of Pennsylvania, Ohio and Michigan. At present, it appears that individual salt beds can be recognized and traced in the subsurface and that the Cayugan subdivisions "A" through "H", delineated by Landes (1945), Evans (1950), and Ellis (1962) for the Michigan basin and by Ulteig (1964) for northeastern Ohio, can be recognized in New York and Pennsylvania.

#### Salina Group

The term Salina (Dana, 1863) has had various applications in the past but in recent years has generally been applied to post-Lockport and pre-Bertie rocks. In New York it contains three formations, Vernon, Syracuse and Camillus, and is approximately 900 feet thick in Onondaga County, the type area. In the Buffalo region it is about 400 feet thick but in southcentral New York the group exceeds 2000 feet in thickness. Studies now in progress indicate that this increase is due almost entirely to the introduction of thick salt beds in the center of the Salina basin.

#### Vernon Shale

In its type area, Oneida County, the Vernon Shale (Clarke, 1903) is a massive, poorly stratified brick-red shale with some gray-green shale, shaly dolomite, sandstone and green-black shale ("Pittsford shale"). It is 400 feet thick. Fossils - brachiopods, gastropods, cephalopods, pelecypods, eurypterids, and cyathaspid fishes - occur in a calcareous shale near the middle of the formation. No specific exposure was designated as the type section but in recent years the outcrop along Downing Brook, 1.3 miles south of Sherrill, has been utilized as a standard reference section (Fisher, 1957).

Westward across New York the Vernon thickens to about 600 feet north of Cayuga Lake, then thins to about 200 feet in Erie County. In the vicinity of Buffalo, the Vernon consists of green shale and dolomite with anhydrite. A little red shale and siltstone occur near the top of the formation. No surface exposures of the Vernon are known in the Niagara Frontier. Salt beds occur in the middle of the Vernon in the Genesee River Valley.

Throughout most of the subsurface and presumably along the outcrop belt as well, the Vernon may be subdivided into three parts. Significant facies changes occur. In all three divisions these changes involve the lateral replacement of red shale in the east by mixed red and green shale, then green or gray shale and dolomites, and finally dolomites with anhydrite and halite in the west.

### Syracuse Formation

The Syracuse Formation of Clarke, 1903, has recently been redefined, described and traced along the Silurian outcrop belt by Leutze (1955, 1959). The name originally was proposed for the subsurface salt beds of the Salina Group, but it is now also applied to the associated dolomites, anhydrites and shales. Thus the formation can be recognized along the outcrop belt where the salt beds have been dissolved by ground water.

In Onondaga County, Leutze subdivided the Syracuse into five members, some of which are exposed in the standard reference section, a railroad cut near Manlius Center. These consist of gray shales and gray or brown dolomites with interbedded clay (leached salt beds) and gypsum. The formation is about 160 feet thick. Leutze discovered fossils in several horizons within the formation and assembled a collection of brachiopods, pelecypods, ostracodes, gastropods, cephalopods, and eurypterids. He was able to map the Syracuse Formation and to recognize its subdivisions eastward into southernmost Herkimer County but was unable to carry his detailed work west of Cayuga Lake where the formation is virtually unexposed.

In the vicinity of Buffalo, the Syracuse consists of dolomites and anhydrite but lacks significant beds of salt. It is about 100 feet thick and is not known to be exposed in the Niagara Frontier.

In the subsurface the Syracuse is a readily recognizable portion of the Salina Group but it cannot be subdivided into the five members distinguished by Leutze along the outcrop. The majority of the halite and anhydrite beds of the subsurface Salina Group occur in the Syracuse Formation. Thicknesses in excess of 1000 feet are attained in the center of the Salina basin.

### Camillus Shale

The upper portion of the Salina Group in Onondaga County and eastward consists of a chunky green shale, unfossiliferous, with some red beds in southernmost Herkimer County. Leutze (1959) restricted the application of the name Camillus (Clarke, 1903) to this portion of the Salina. It is about 200 feet thick in the type area, somewhat thinner both east and west of there.

In the Niagara Frontier the Camillus is 80-100 feet thick and includes the O-atka beds of Chadwick (1917), formerly assigned to the overlying Bertie Formation. The Predominate lithology is a green shale, but dolomite, anhydrite and siltstone, also occur. Eurypterids have been reported from a dolomite bed near the top of the formation in

Chadwick's O-atka beds. This uppermost portion of the Camillus is exposed at Akron Falls, Indian Falls, Morganville and Oatka Falls. Another exposure of the Camillus is a small section along Murder Creek north of Akron.

At several localities along the Silurian outcrop belt there are underground mines for gypsum formed by conversion of the subsurface anhydrite of the Salina Group to gypsum through hydration by ground water. The National Gypsum Company has a mine at Clarence Center, the Bestwall Gypsum Company at Akron and the United State Gypsum Company at Oakfield. The stratigraphic position of the gypsum beds mined by these companies has, in the past, been assigned to the Camillus. They are located about 200 feet below the base of the Onondaga Limestone. In nearby gas wells, the Camillus is anhydritic but significant beds of anhydrite occur only in the Syracuse Formation, 150 to 200 feet below the Onondaga. Further study is needed but it appears that the gypsum mines may be in the Syracuse rather than the Camillus. The thickness of the Camillus in the subsurface appears to be quite uniform but the formation has several facies. Dolomite and anhydrite comprise significant portions of the Camillus in the center of the Salina basin; red shales become predominate in the east.

#### Bertie Formation

The type section of the Bertie Formation (Chapman, 1864) is located in Bertie township, Welland County, Ontario. In an abstract Chadwick (1917) subdivided the Bertie of western New York into four members, in descending order: Buffalo cement bed, Scajaquada shale and dolomite, Falkirk dolomite and O-atka shale (here included in the underlying Camillus). Chadwick later (see Clarke, 1918, p. 42) renamed the upper member Williamsville as the term Buffalo was preoccupied. The Bertie of western New York is everywhere underlain by the Camillus Shale and overlain, where complete sections are found, by the Akron Dolomite. Owing to the relief of a pre-Onondaga unconformity, however, exposures are found where the Onondaga Limestone directly overlies the Williamsville Member of the Bertie or some lower member. Chadwick was first to point this out.

The thickness of the Bertie Formation in western New York is uncertain because few exposures continue downward into the underlying Camillus Shale. It is believed to be about 50 feet thick where all members are present. Its thickness will, of course, vary from place to place depending upon the amount removed by erosion prior to deposition of the Onondaga Limestone. The contact of the Bertie with the overlying Akron Dolomite is gradational. Its contact with the underlying Camillus is much less clearly understood because of the lack of good exposures. Some authors (Grabau, 1901, p. 115) and Alling (1928, pp. 27-28) have suggested that this contact possibly is disconformable.

The Falkirk Member of the Bertie is composed of massive beds of dark gray dolomite, weathering yellowish brown, which are characterized by coarse conchoidal fracturing, a small marine fauna and a basal eurypterid horizon. Owing to its greater resistance the Falkirk

commonly produces a waterfall where exposed in streambeds. Its thickness varies from 18 to 25 feet. The overlying Scajaquada Member consists of dark shales or blocky waterlimes, less resistant than the Williamsville above or the Falkirk below, and presumably contains more argillaceous material than those two members. It varies from 3 to 10 feet in thickness and, in southern Ontario, eurypterids occur near its base ("Bridgeburg horizon").

The Williamsville Dolomite, because it formerly was mined for natural cement in the vicinity of Buffalo, is perhaps the best known member of the Bertie. It consists of laminated, fine-grained dolomite, up to 5 or 8 feet thick, which weathers light gray. Its pronounced conchoidal fracture, among other criteria, serves to distinguish it from the overlying Akron Dolomite which has an irregular fracture. According to Monahan (1931, p. 379) most of the fossils, especially the eurypterids, of the Bertie Formation cited by Ruedemann (1925) and others have been obtained from the Williamsville Member.

The Bertie Formation is noted for its abundance of well-preserved eurypterids, most of which apparently were obtained from the upper or Williamsville Member. In addition to these, bryozoans, brachiopods, gastropods, cephalopods, ostracodes, and graptolites also have been found.

Exposures of the Bertie Formation and the overlying Akron Dolomite are fairly common in the Niagara Frontier region. Outcrops in Buffalo are located near the Main Street entrance to Forest Lawn Cemetery, in the storm sewer on East Amherst (old Bennett quarry), and in a New York Central Railroad cut between Kensington and Morris Avenues. East of the city important localities are in Ellicott Creek at Williamsville, in the Louisville Cement quarry near Clarence, at the falls in Akron Falls Park, at Indian Falls, at Morganville and along Route 19 and in Oatka Creek at North LeRoy.

#### Akron Dolomite

The highest rock unit of the Silurian in the Niagara Frontier is the Akron Dolomite (Lane and others, 1908). The type section is an outcrop in Murder Creek, at Akron, New York, where the formation is about 8 feet thick. Other exposures are cited in the discussion of the Bertie (except Indian Falls, Morganville and North LeRoy).

The Akron consists of gray to buff, mottled and banded dolomite, fine-grained and often pitted by the solution of fossil corals. The lower contact with the Bertie is gradational and difficult to identify. The upper contact with the Onondaga Limestone is a conspicuous disconformity broadly undulating, with occasional channels or "dikes" of sandstone or arenaceous limestone extending down into the underlying Akron (or Bertie where the Akron is absent). Although not an abundantly fossiliferous rock, the Akron is the most fossiliferous portion of the entire Cayuga Series in western New York. Its fauna includes corals, brachiopods, gastropods, cephalopods, and ostracodes. Eurypterids and graptolites also have been reported but are relatively rare.



The Akron Dolomite of western New York appears to be a continuation of the Cobleskill Limestone of Eastern New York. Doubts regarding the tracing and correlation of these units, particularly the Akron, across Ontario, Monroe and Genesee Counties persist despite the efforts of several stratigraphers (Schuchert, 1903; Hartnagel, 1903; Alling, 1928; Hoffman, 1949; Rickard, 1953; Leutze, 1959). In the subsurface it frequently is not possible to separate the Akron-Cobleskill from the underlying Bertie in sample logs because the lithologic differences are slight. However, where the Cobleskill is a fossiliferous limestone, the separation is more easily made. Radioactivity logs provide an additional means of differentiating these formations in some parts of the subsurface.

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BOIS BLANC AND ONONDAGA FORMATIONS  
IN WESTERN NEW YORK AND ADJACENT ONTARIO

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### Introduction

The Devonian limestone sequence at Buffalo consists of the thin and discontinuous Bois Blanc Formation of Early Devonian age and the much thicker Onondaga Limestone of Middle Devonian age. The two formations are lithologically and faunally distinct and are separated by a disconformity; together they rest on local remnants of the Oriskany Sandstone or on rocks of Silurian age. The Bois Blanc Formation thickens rapidly to the west but thins and disappears just east of the Genesee Valley. In eastern New York its equivalent is the Schoharie Grit.

The Onondaga Limestone passes westward into the Detroit River and Columbus Formations and possibly the lower part of the Delaware Limestone in addition. Toward the east the upper part of the Onondaga (Seneca Member) grades laterally into the lower part of the overlying Marcellus Shale.

Coral faunas in the Bois Blanc and Onondaga Formations are distinct and can be used for correlating within the northeastern North American province.

### Geologic History

Little record of latest Silurian or Early Devonian history is preserved in the area between Hagersville, Ontario, 60 miles west of Buffalo and the Genesee Valley, 60 miles east. In eastern New York, this interval is occupied by the Rondout Limestone, the Helderberg Group and the Oriskany, Esopus, Carlsle Center and Schoharie Formations (fig. 1). Patches of the Oriskany Sandstone are known 50 miles west of Buffalo and sand, presumably derived from the Oriskany, is locally preserved in the base of overlying formations. Schoharie time is represented by thin and discontinuous remnants of the Bois Blanc Formation.

In contrast, the Middle and Late Devonian record is well preserved; beginning with the Onondaga Limestone a reasonably continuous picture of the area during the Devonian can be developed.

The Onondaga represents a time of widespread shelf sedimentation in New York. A fauna dominated by corals is characteristic of the early Onondaga (Edgecliff Member). Locally, patch reefs were formed and lithology and fauna both suggest relatively clear, shallow marine conditions over a broad area.

London-Woodstock Area, Ontario	Buffalo Area, Ontario-New York	Helderberg Area, Eastern New York	Series or Stage	
Delaware Ls. "Columbus" Ls. Detroit River Fm.	Hamilton Gr.	Hamilton Gr.	Cazenovia	Middle Devonian
	Onondaga Ls.	Onondaga Ls.	Onesquethaw	
Bois Blanc Fm.	Bois Blanc Fm.	Schoharie Ls.		Onesquethaw
		Carlisle Center Fm. Esopus Fm.	Deer Park	
		Oriskany Ss.		Helderberg
		Helderberg Gr.	Cayuga	
Akron-Bertie Fms.	Akron-Bertie Fms.	Rondout Fm. Cobleskill Ls.	Cayuga	Upper Silurian

Figure 1. Correlation Chart for Bois Blanc and Onondaga

Formations in Buffalo Area



Edgecliff time was closed by an influx of argillaceous material, presumably of terrigenous origin and possibly a result of uplift in borderlands to the east or north. Shaly limestone grading upward to massive limestone forms the Nedrow Member in Central and eastern New York. The argillaceous influx had less effect in what is now western New York where dark, cherty limestone prevails.

The Moorehouse Member represents a return to conditions of limestone deposition but with liberal admixture of noncarbonate mud. Less mud was deposited in western New York where lithology and fauna are more like those of the Edgecliff.

The Tioga Bentonite Bed at the base of the succeeding Seneca Member indicates volcanic activity, possibly to the southeast. In central New York, the limestone above the bentonite is darker and finer grained than the Moorehouse and contains markedly fewer fossils; the Seneca Member grades upward into the black shales of the lower part of the Hamilton Group.

The limestone-black shale contact is apparently younger to the west and older to the east, and limestone deposition persisted longer near Buffalo than in eastern New York. The top of the Onondaga (upper part of Seneca Member) near Buffalo is considered to be the approximate time equivalent of the Cherry Valley Limestone Member of the Marcellus Shale (Hamilton Group) in central and eastern New York. Near London, Ontario and in Michigan and northern Ohio, the Middle Devonian carbonate sequence is generally considered to include even younger rocks (Cooper and others, 1942).

#### Age and Correlation

A rugose coral fauna, characterized by *Aemulophyllum exiguum*, *Acrophyllum oneidense*, *Edaphophyllum sulcatum* and several other species, occurs in the thin and discontinuous Bois Blanc Formation of western New York and adjacent Ontario. The corals are accompanied by a small species of *Amphigenia* and by many other brachiopods, some of which are characteristic of Schoharie age rocks in eastern New York and other areas of eastern North America.

The characteristic rugose corals occur in the Schoharie Grit of eastern New York, the Bois Blanc Formation of Innerkip, Ontario and Michigan, the lower 4 feet of the Jeffersonville Limestone at the Falls of the Ohio (Louisville, Kentucky), and the upper few feet of the Wildcat Valley Sandstone in southwestern Virginia. In addition, some of the corals described by Cranswick and Fritz (1958) from the Upper Abitibi River Limestone in the Hudson Bay Lowlands of Ontario, belong to the same fauna.

The distinctive Schoharie-Bois Blanc rugose corals are endemic to eastern North America and give little evidence of the age of the fauna, although they are very useful for correlating within their province. Other associated corals are of apparently long-ranging species or are unstudied.

The associated brachiopods are being studied by A. J. Boucot and J. G. Johnson, California Institute of Technology. They consider the brachiopods to indicate an early Emsian (late Early Devonian) age.

Conodonts from the Bois Blanc near Buffalo and from the Schoharie Grit in eastern New York are considered late Emsian by Dr. Gilbert Klapper, Pan American Petroleum Corporation, (personal communication, October, 1965).

The Onondaga rugose coral fauna is distinctly different from the Schoharie-Bois Blanc fauna. A variety of ptenophyllid, disphyllid and cystiphylloid genera are common; most of the species, numerous genera and some families are not known to occur lower in the section. The Onondaga rugose coral fauna is constant across New York and in the Niagara Peninsula of Ontario. It is found in the lower part of the Detroit River Formation near Woodstock and Gorrie, Ontario, and in the Jeffersonville Limestone of southern Indiana and Kentucky. In all of these areas the Onondaga fauna abruptly overlies the Schoharie fauna.

The Onondaga rugose coral assemblage is composed of distinctly Middle Devonian (Eifelian) types. Some specific differences between Edgecliff and Moorehouse faunas may eventually permit recognition of two or more Onondaga faunas and have already aided in detailed correlation with other areas.

No modern study of Onondaga brachiopods is known to me. Such study is badly needed to aid both inter- and intraregional correlations.

Rare goniatities from the Nedrow Member are of Eifelian age according to House (1962, p. 253).

Recent study of the Onondaga conodont succession by Klapper, (personal communication, November, 1965) also supports an Eifelian age for the Nedrow and later Onondaga; conodont evidence from the Edgecliff is inconclusive.

The sharp separation between the Schoharie and Onondaga faunas suggests a discontinuity of rather broad extent in eastern North America. Physical evidence for this in western New York is discussed below. The best available age estimates of the two faunas indicate that the unconformity may represent late Emsian time and mark the physical boundary between Lower and Middle Devonian rocks in eastern North America.

#### Multiple Unconformity at Base of Devonian

Throughout western New York and most of the Niagara Peninsula of Ontario, rocks of Helderberg, Oriskany, and Esopus age are lacking and the Onondaga and Bois Blanc Formations rest directly on the Bertie or Akron Formations of Late Silurian age. Locally, in the Peninsula, and in central New York (east of Cayuga Lake) the Oriskany Sandstone fills part of this gap. Farther east, in the Hudson Valley, the section is much more complete and all major time units seem to be represented (fig. 1; and see Rickard, 1964).



In the Buffalo area rocks of Schoharie age are represented by the eastern featheredge of the Bois Blanc Formation. These rocks are discontinuous and the overlying Onondaga Limestone rests directly on Silurian rocks in many places.

The evidence for an unconformity between the Bois Blanc and Onondaga Formations, as well as beneath the Bois Blanc, is very strong. The physical evidence for such a break is the presence of sand in the base of the Onondaga at many localities, including some where the formation overlies the Bois Blanc. The sand may be present or absent in the base of both the Onondaga and Bois Blanc. As the Bois Blanc is discontinuous, there are six possible basal Devonian sequences (fig. 2) Figure 2 is diagrammatic but all of the sequences shown do exist within the Buffalo area. Faunal evidence for a Bois Blanc-Onondaga unconformity is considered in an earlier section.

The basal sand, whether Bois Blanc or Onondaga, is commonly considered to have been formed by reworking of the Oriskany Sandstone that presumably covered the whole area at one time. The presence of sand at the base of the Onondaga where it overlies Bois Blanc (fig. 2, situation 4 and 6) suggest that some Oriskany still existed in the area after pre-Bois Blanc erosion and Bois Blanc deposition. Pre-Onondaga erosion left patches of Bois Blanc; sand was washed onto some of these and included in the base of the Onondaga.

Stauffer (1913, p. 85) proposed the name Springvale Sandstone Member for the basal sandy beds of the "Onondaga" in Ontario, and Chadwick (1919, p. 42) extended the usage of this term to New York. The name has served to emphasize that the sands are not of Oriskany age, especially in areas where true Oriskany Sandstone does occur. However, in its type area near Hagersville, Ontario, 60 miles west of Buffalo, the Springvale is a massive sandstone, at least 8 feet thick, at the base of the Bois Blanc Formation, there 20 or more feet thick. Farther east in Ontario and in western New York where the Bois Blanc is thinner and discontinuous, the sand may be at the base of either the Onondaga or Bois Blanc or both, but is nowhere so concentrated as to form a true sandstone. Locally in central New York, a true sandstone of Onondaga age has been called Springvale (Oliver, 1954; 1963). Because of age differences and the presence of two sands the use of the term Springvale in New York and nearby Ontario is misleading, and it is recommended that such usage be discontinued. A new name may be desirable for well developed basal Onondaga sandstones to avoid confusion with the Oriskany Sandstone.

### Summary

In the Buffalo area there is evidence of at least three unconformities in the interval between the Silurian formations and the Onondaga Limestone. Two unconformities are indicated by breaks at the base of the Bois Blanc and Onondaga Formations; a third unconformity representing pre-Oriskany erosion or nondeposition can be deduced from the residues of sand in basal portions of the limestone and by the presence of

Oriskany Sandstone both east and west of the area. Whether other rock units and unconformities present farther east in New York, were ever present in the area is unknown but it seems likely that some were and the pre-Onondaga Devonian history was even more involved than here indicated.

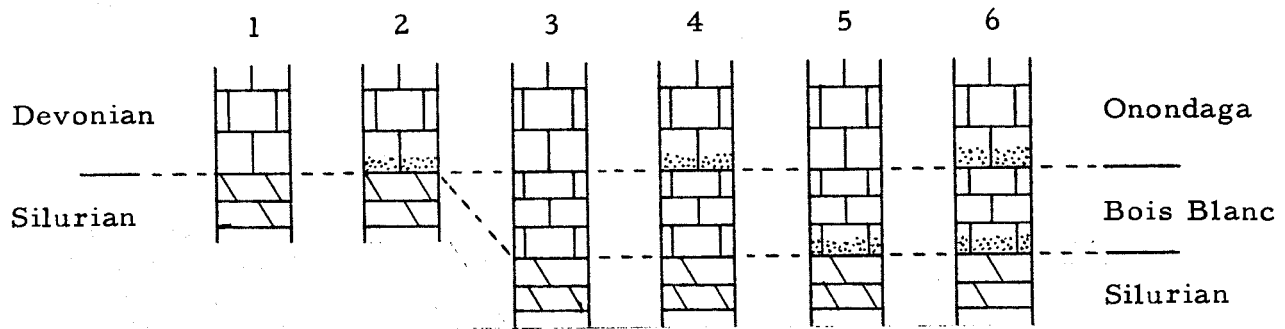


Figure 2. Basal Devonian Sequences

#### Bois Blanc Formation

The Bois Blanc Formation in the Buffalo area is a medium dark gray, fine grained limestone with a fauna numerically dominated by brachiopods. The thickness varies from a few inches to four feet, but the formation is discontinuous and is absent in many places. Where the Bois Blanc is present, its lithology is in strong contrast to the overlying coarse crinoidal-coralline limestone that forms the lowest member of the Onondaga.

The Springvale Sandstone Bed at the base of the Bois Blanc, is several feet thick at Hagersville. In New York and nearby Ontario, the sand is at most a few inches thick, but may be represented only by scattered sand grains in the lower part of the limestone or may be lacking entirely.

The Bois Blanc Formation was named by Ehlers (1945, p. 34, 80-109) for rocks in the Mackinac Straits region, and usage was extended into southwestern Ontario by Sanford and Brady (1955, p. 6). In both areas the name was used for cherty limestones underlying the Detroit River Group or Formation. The Detroit River Formation of the London-Woodstock

area, Ontario, passes eastward into the Onondaga Limestone (see age and correlation discussion), whereas the underlying Bois Blanc Formation, over 100 feet thick in the Woodstock area (Stumm and others, 1956, p. 4), thins to 24 feet at Harasville, and approximately 15 feet at Port Colborne. Near Buffalo and extending to the Genesee Valley the Bois Blanc is thin and discontinuous. Only one remnant has been recognized east of the Genesee (west of Phelps) but the Schoharie Grit in eastern New York is of the same age and deposition may have been continuous over the intervening area.

The presence of rocks of Schoharie age in the Buffalo area was recognized by Cooper, et. al. (1942, p. 1774-1775). Their *Amphigenia* zone is indicated on figure 3 as the zone of "small" *Amphigenia*.

The Buffalo area Bois Blanc is the lower brachiopod unit of Stauffer (1915, p. 6) and Zone B or the *Amphigenia* Zone of Oliver (1954, p. 626, 632; 1960).

In the Buffalo area, the Bois Blanc can be seen in the abandoned quarry in Delaware Park (Buffalo), in the creek at Morganville (40 miles east of Buffalo) and in several quarries between Fort Erie and Port Colborne, Ontario.

## Onondaga Limestone

### INTRODUCTION

Overlying the Silurian rocks or the Bois Blanc Formation in the Niagara Peninsula and western New York is a complex of massive, cherty and argillaceous limestone, approximately 140 feet thick. In the early reports of the New York Geological Survey, the lower part of this complex (Edgecliff Member) was termed Onondaga, but the name was not commonly applied to the whole complex until late in the nineteenth century.

In the type area near Syracuse, the Onondaga Limestone has been subdivided into a sequence of four members and nine faunal zones. Traced laterally, lithic and faunal changes permit recognition of several facies in each member (Oliver, 1954, pl. i). In western New York, some of the changes are sufficient to warrant nomenclatorial recognition. Figure 3 shows generalized columns at the meridians of Buffalo and Leroy, New York.

### EDGECLIFF LIMESTONE MEMBER

Near Syracuse, the lowest member of the Onondaga is typically a light gray, coarse, crinoidal and coralline limestone, 8 to 20 feet thick. Towards the west this unit thins to 5 feet or less, becomes medium light gray and medium grained, and contains fewer fossils although corals are common. The lateral changes are gradual and the member can be easily recognized wherever exposed. Light gray chert is irregularly present in the upper half of the member in both the type area and near Buffalo.

The lower contact of the Edgecliff has been discussed. Sand grains, presumably derived from the Oriskany Sandstone, are present in the lower few inches of the member at some localities. The pre-Edgecliff unconformity may have several inches relief with basal sands attaining thicknesses of several inches in the bottom of "channels" and being thin or absent a few feet away on the "ridges". In the Buffalo area this is best seen in the abandoned quarry just east of the Bennett High School.

The upper contact is a sharp lithologic break in central New York. A one to two-foot gradation zone in the Buffalo area is included in the Edgecliff because of the contained corals.

Near Buffalo, the typical Edgecliff is accessible in Delaware Park (Buffalo), at the Casino in Williamsville, in the quarry northeast of Clarence and at Akron Falls. Innumerable other exposures occur along the Onondaga (actually Edgecliff) escarpment that can be traced on the topographic maps from Buffalo to the Genesee Valley.

#### EDGECLIFF REEF FACIES

Included in the Edgecliff Member but deserving special notice and separate discussion, are several small patch reefs or bioherms. These are largely composed of colonial and solitary rugose corals and tabulate corals in a matrix of coarse crinoidal debris that is both coarser grained and lighter colored than the typical Edgecliff. In a few exposures a "core" of fine grained darker limestone (apparently deposited as a lime mud) is seen. "Core" fossils are delicate branching tabulates and a few other corals. Most reef exposures consist of the coarse crinoidal-coralline facies. Bedding is lacking or visible only at contacts between superimposed colonies. This facies seems to surround the core facies and is termed "reef flank" on figure 4. Away from the reefs, bedding becomes better defined, the rock is finer grained and the member thins; normal and reef flank beds interfinger for several hundred feet away from the reef.

Figure 4 is diagrammatic and composite. Facies relationships are shown but no scale is used. In eastern New York, post-Edgecliff members are draped over the thicker reefs, the lower units pinching out and upper units thinning over the top of the reefs. Reef thicknesses up to 75 feet have been measured in areas where normal Edgecliff does not exceed 20 or 30 feet.

In the Buffalo area no complete reef thicknesses have been measured because all known reefs are deeply eroded. Exposed reefs measure 20 to 30 feet in thickness and estimates based on attitude of surrounding strata and areal extent of reef-rock suggest that thicknesses were at least 50 feet and probably much greater. This compares with off-reef thicknesses of 5 feet, although it is possible that the lower part of the overlying member in this area is actually Edgecliff in age. Reefs are round or elliptical in plane view, diameters in other parts of the state varying from 100 to 1,300 feet.

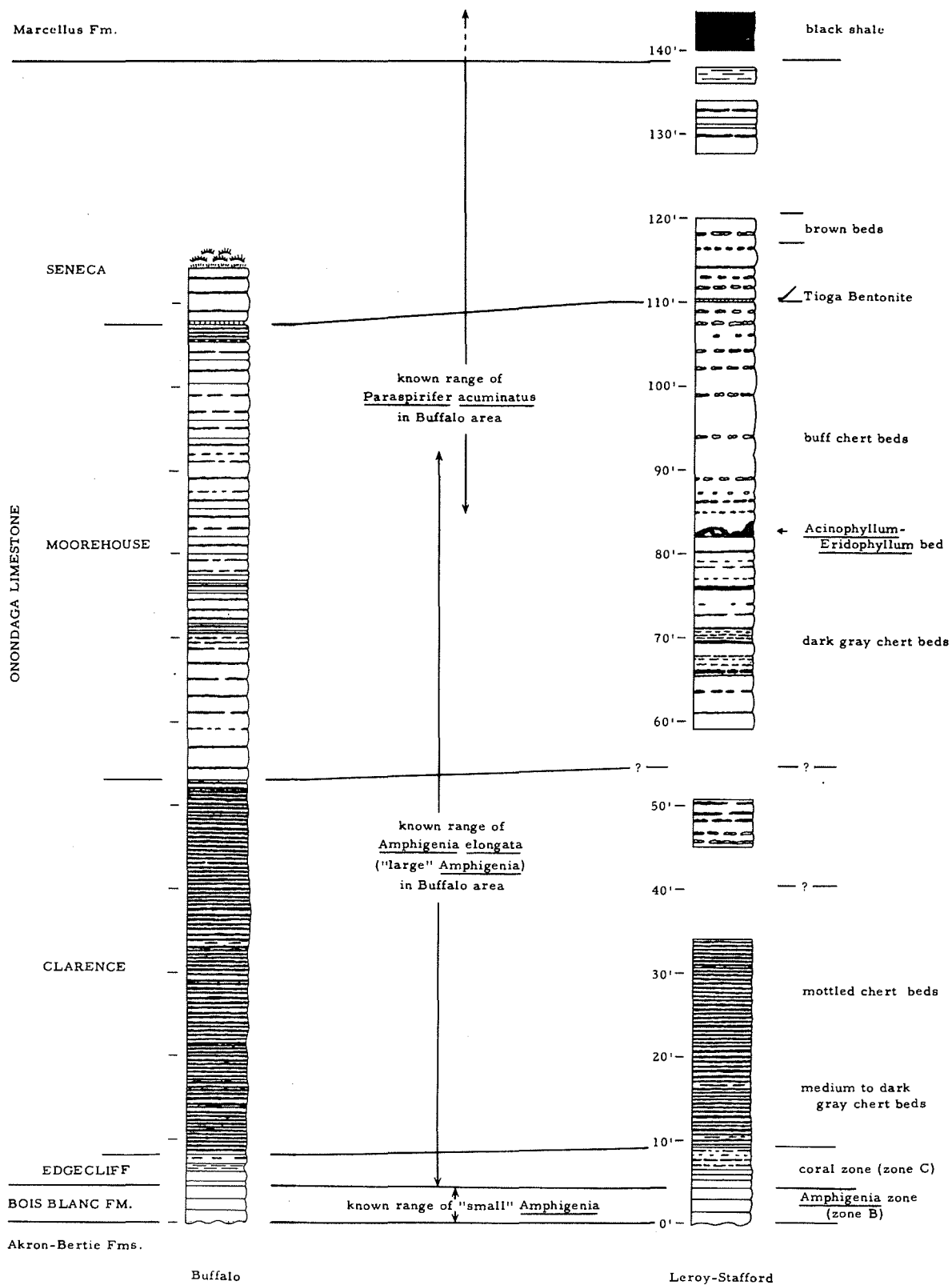


Figure 3. Composite Columnar Sections in Western New York



Although several reefs are now known in the Buffalo area, the best exposed is located northwest of Leroy, on the Byron quadrangle. The famous Fogelsanger Quarry at Williamsville provided reef specimens for collections all over the country, but has now been destroyed by Thruway construction. Other reefs are well exposed in the vicinity of Ridgeway, Ontario.

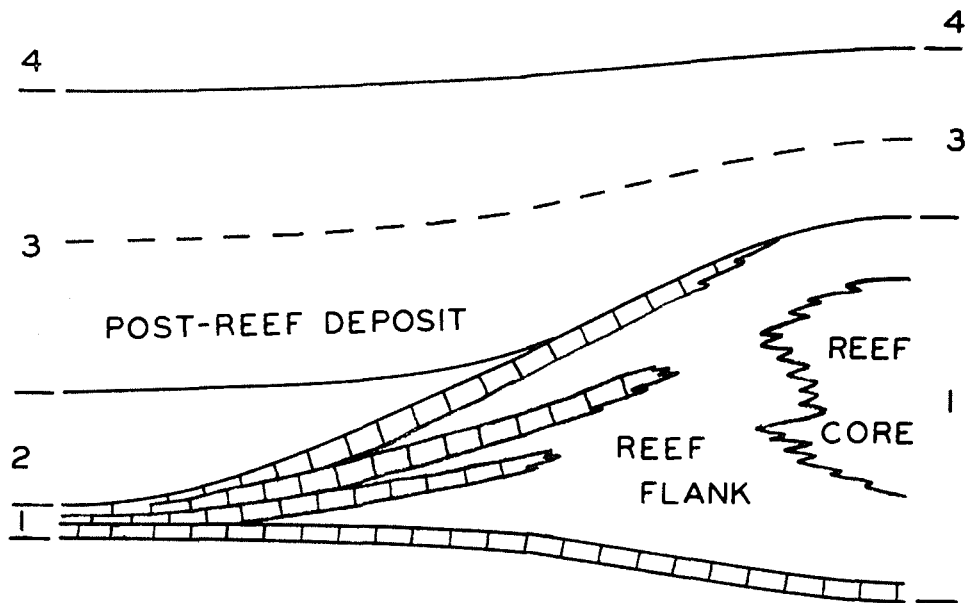


Figure 4. Composite and Idealized Reef Cross Section

- |              |               |
|--------------|---------------|
| 1. Edgecliff | 3. Moorehouse |
| 2. Clarence  | 4. Seneca     |

#### CLARENCE MEMBER

Overlying the Edgecliff Member in the Buffalo area is 40 to 45 feet of fine grained limestone and dark chert, named the Clarence member of Ozol (1964; and unpublished Ph.D. thesis, Rennselaer Polytechnic Institute, (1963).

In central New York, the Edgecliff Member is overlain by the Nedrow Member, 12 to 15 feet thick, consisting of a thin-bedded argillaceous unit with platyceratid gastropods, that grades upward to fine grained massive limestone. In western New York, the Nedrow is

replaced by the much thicker Clarence Member that is distinctly different from the Nedrow, although in the same stratigraphic position.

The type section of the Clarence Member is in and near the village of Clarence (15 miles east of Buffalo) where the member is well exposed, especially along Route 5 just east of the village center. Dunn and Ozol (1962, p. 19) report a chert content of 45 to 70 per cent for the Clarence. This compares with 5 to 20 per cent figures for under- and overlying members and for the central New York Nedrow Member (Dunn and Ozol, 1962, p. 19). The high chert content defines the Clarence Member and makes it easily recognizable in surface exposures and many drilling logs.

The Clarence Member is only sparsely fossiliferous. As a result of this and incomplete knowledge of sequences in intervening areas, exact correlation of the Clarence with the central New York Onondaga is uncertain. The Clarence is roughly equivalent to the Nedrow Member, but may include some of the lower Moorehouse and uppermost Edgecliff as well.

The Clarence Member can be conveniently seen in Clarence and at most of the mentioned Edgecliff localities. Between Buffalo and the mouth of the Grand River in Ontario the lower part of the member has been noted in only a few places, as most of the Clarence and all higher units are beneath Lake Erie. West of Dunnville, Clarence-Nedrow equivalents must be present but exposures are small and post-Edgecliff units are as yet undifferentiated.

#### MOOREHOUSE MEMBER

The Clarence is overlain by 55 feet of medium grained, light medium gray, massive limestone with a fauna composed of corals, brachiopods and a variety of other invertebrates. This is the western coral facies of the Moorehouse Member (Oliver, 1954; pl. 1). To the east, the Moorehouse thins to 20 to 25 feet at Syracuse, where it is a fine grained, medium gray massive limestone with an abundance and variety of brachiopods. Throughout New York, the Moorehouse contains varying amounts of light to dark gray chert. This is the rock presently being quarried at Bellevue and Harris Hill (both within the Lancaster quadrangle, just east of Buffalo) and at Stafford (6 miles east of Batavia).

The corals in the western Moorehouse are partly recurrent Edgecliff types but with some distinctive new forms that aid in the recognition of Moorehouse equivalents in the area south of Hagarville, Ontario. The lithology and fauna indicate a return to Edgecliff-like conditions but without the development of so rich a coral fauna as to form reefs or biostromes.

#### TIOGA BENTONITE BED

Overlying the Moorehouse Member and forming the base of the Seneca Member of the Onondaga, is a four to ten inch clay bed that has long been recognized as volcanic in origin and utilized for local correlations (see Oliver, 1954, p. 629-630 for review of previous work on this bed). The bentonite bed has been recognized and used



for correlations in the central Appalachians (Dennison, 1961) and as far west as Illinois (Meents and Swann, 1965). The bed is invaluable for local correlations and where supported by faunal data, for regional correlations as well.

#### SENECA MEMBER

Near Buffalo, the fourth and highest member of the Onondaga can be recognized only by its position above the Tioga Bentonite. Lower Seneca beds are exposed in several places and are lithologically and paleontologically like the underlying Moorehouse. Higher beds are rarely exposed but where seen are distinctly finer grained and darker.

The Seneca is 40 or more feet thick at Buffalo. Eastward the member thins to 30 feet at Leroy (fig. 3), 21 feet at the Livonia salt shaft and 19 feet at Syracuse. The eastward thinning is accompanied by lithologic change to a darker and finer grained limestone with a limited fauna. The Seneca Member is lithologically distinct in central New York. The continued usage of the name in western New York is justified by the importance of the Tioga Bentonite Bed at the base of the member.

Only a few exposures of the Seneca are known in the Buffalo area. The Tioga Bed and the lower 5 to 10 feet of the member are exposed at the Bellevue and Stafford quarries. Higher parts of the Seneca beds are exposed in Oatka Creek, north of Route 5, in Leroy. The actual contact with the overlying Hamilton Group is not known to be exposed although it is nearly so at Leroy.

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## THE HAMILTON GROUP IN WESTERN NEW YORK

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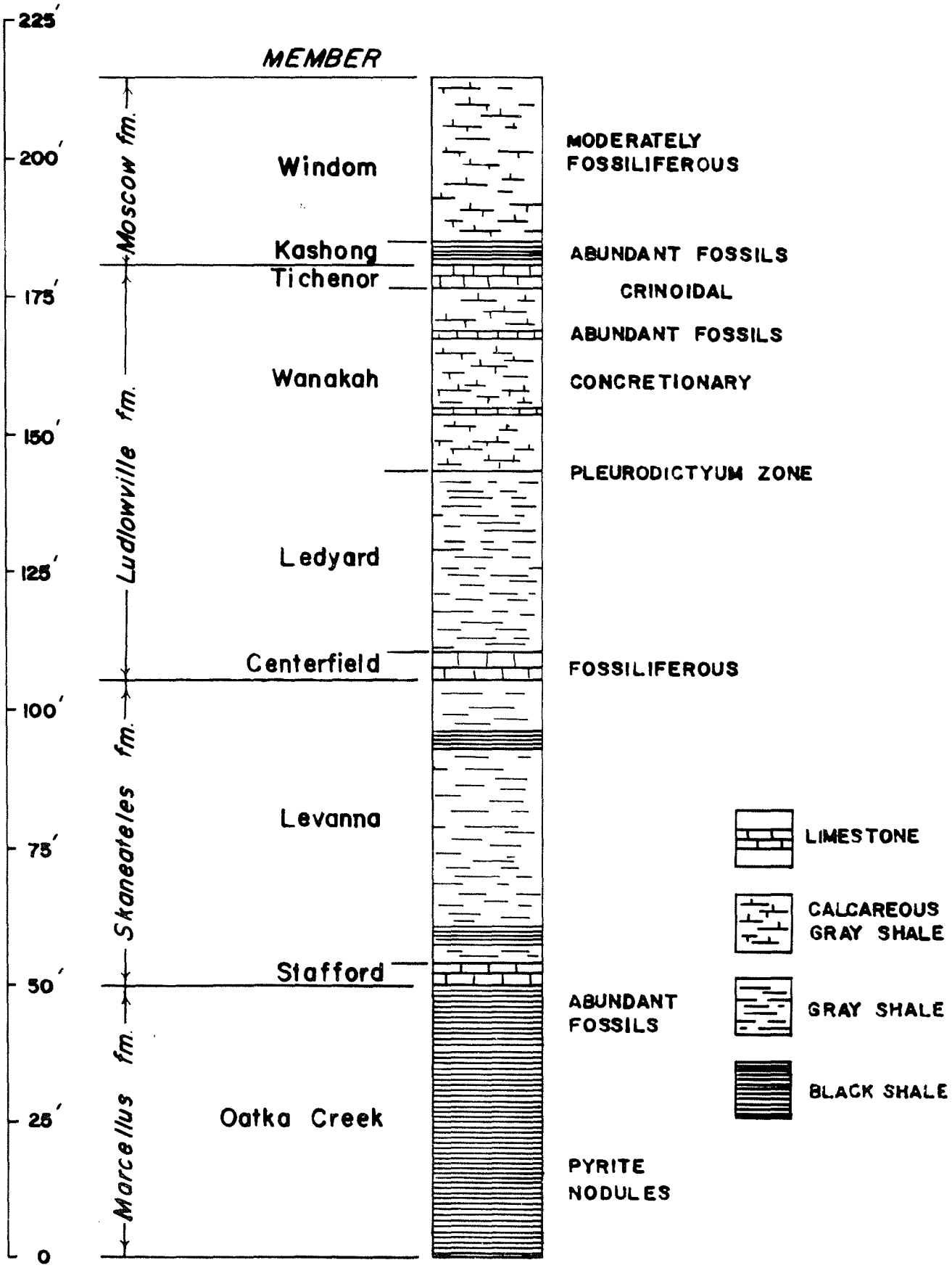
Circumstances which developed at the last minute left us without a paper on the Hamilton Group of Western New York. There was, of course, no intent to slight this most interesting and richly fossiliferous section of rock. Therefore, a column (fig. 1) a few notes and references are inserted here.

The two post-Hall classical works on the Hamilton are Grabau's (1898) *Geology and Paleontology of Eighteen Mile Creek*, and Cooper's (1930) *Stratigraphy of the Hamilton Group of New York*. deWitt (1956) describes the upper Hamilton of the Eden quadrangle. Buehler and Tesmer (1963) summarize the data on the paleontology and stratigraphy of the Hamilton group in Erie County. The chart "Correlation of the Devonian in New York State" by Rickard (1964) gives correlation across the state and the depositional phases as well as other stratigraphic information.

The Hamilton sediment of western New York was deposited at the western, seaward extremity of the Catskill Delta. This facies situation is described, with varying degrees of accuracy, in every textbook on stratigraphy and historical geology and should be familiar to all. The Marcellus and Skaneateles Formations are black and bluish-gray shale with thin limestone beds. They are separated by the Stafford Limestone, regarded as the base of the Skaneateles. Large pyrite nodules are common near the base of the Oatka Creek Shale and the brachiopod *Leiorhynchus limitare* is abundant near the top. Portions of these units, especially near the top of the Oatka Creek, are fossiliferous; other are not.

The Ludlowville and Moscow Formations consist of calcareous gray shale which may weather to a clayey consistency. Concretionary layers and thin limestone beds are common. Two of these limestones, the Centerfield and Tichenor are used as key beds in correlation and subdivision of the Hamilton Group. The upper Hamilton, especially the upper part of the Ludlowville, is richly fossiliferous. The fauna is predominantly one of corals, bryozoans, and brachiopods. Some of the particularly abundant species are *Stereolasma rectum*, *Athyris spiriferoides*, *Mucrospirifer mucronatus*, and *Favosites hamiltoniae*. The tabulate *Pleurodictyum americanum* is common at the base of the Wanakah shale and the brachiopod *Ambocoelia umbonata* is abundant at the base of the Moscow shale. Some beds contain common specimens of the trilobite *Phacops rana*. The Tichenor is a crinoidal limestone. Molluscs, ostracodes and tentaculitids are also common in the upper Hamilton and there is a modest amount of plant material. Many of the fossils are extremely delicate and show little or no evidence of transportation. The fossiliferous pyrite (?) concretions occur in the Ledyard member. The Middle Devonian is separated from the Upper Devonian by the lensatic Leicester Pyrite.

# Hamilton Group of Western New York



Buehler Figure 1



Recent taxonomic studies of Hamilton fauna include Ross (1953) on tabulates, Boardman (1960) on trepostomatous Bryozoa. Hamilton ostracodes have been described in papers by Swartz and Oriel (1948), Stover (1956), Smith (1956), and Peterson (1964; 1966). Unpublished University of Buffalo M. A. theses include studies on athyrid and chonetid brachiopods by Janowsky (1965) and Geitzenaur (1965) respectively and a faunal zonation by Boehme (1964). Paleocological studies of the Hamilton of western New York are being conducted by Buehler and James R. Beerbower of McMaster University.

Some of the more fossiliferous outcrops of Hamilton rock are Como Lake Park in Lancaster, Eighteen Mile Creek in the town of North Evans, Cazenovia Creek at Springbrook, New York, Buffalo Creek at Bullis Road and South branch of Smoke Creek near Windom. The entire South Shore of Lake Erie from Buffalo to several miles beyond Eighteen Mile Creek provides excellent outcrops.

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UPPER DEVONIAN STRATIGRAPHY AND PALEONTOLOGY OF SOUTHWESTERN  
NEW YORK STATE (ERIE, CHAUTAUQUA AND CATTARAUGUS COUNTIES)

by Dr. Irving H. Tesmer

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Upper Devonian rocks in southwestern New York State consist of about 2500 feet of largely detrital material associated with the Catskill Clastic Wedge. During Late Devonian time, clastic sediment gradually spread westward and northwestward across New York State and Pennsylvania, eventually filling the epeiric seas that occupied the Appalachian Trough and adjacent areas.

There is some disagreement as to the exact boundaries that mark the base and top of the Upper Devonian in southwestern New York State but the present writer includes all strata from the base of the Genesee Member of Genesee Formation to the top of the Cattaraugus Formation (Cooper et al., 1942; Rickard, 1964). The overlying Knapp Conglomerate is considered to be Lower Mississippian (Holland, 1959).

Some authors have subdivided Upper Devonian strata into two series, an earlier Senecan and a later Chautauquan. Although there may be some paleontological evidence (especially cephalopods) to suggest this, the present writer does not see strong justification for such a division in southwestern New York State and therefore assigns all Upper Devonian units to a single series, the Chautauquan.

Within the Chautauquan Series, three groups are recognized (Tesmer, 1955), in ascending order the Seneca (600 feet), Arkwright (1250 feet) and Conewango (650 feet). The boundaries between these groups are based upon lithologic changes and facies differences that are persistent throughout the three counties of southwestern New York, namely Erie (Buehler and Tesmer, 1963), Chautauqua (Tesmer, 1963) and Cattaraugus. The Seneca Group extends from the base of the Genesee Member of the Genesee Formation to the top of the Hanover Member of the Java Formation. The Arkwright Group includes strata from the base of the Dunkirk Member of the Canadaway Formation to the top of the Ellicott Member of the Chadakoin Formation. Locally assigned to the Conewango Group is the Cattaraugus Formation. It includes redbeds, conglomerates and coarse buff sandstones interbedded with marine siltstones and shales.

The Seneca Group includes in ascending order the Genesee, Sonyea, West Falls, and Java Formations. These units are largely gray and black shales although a few limestone and siltstone beds also occur. Although the Genesee Formation varies only from about 10 to 20 feet in thickness, various members have been recognized including the Genesee Shale (2 inches to 2 feet of black shale), Penn Yan Shale (9 inches of dark gray shale) [deWitt and Colton, 1959], Genundewa Limestone (2 inches to 2 feet of light to dark gray limestone) and West River Shale (8 to 14) feet of gray shale. The Genundewa and West River Members include numerous species of conodonts and fish but the faunal content of the thin Genesee and Penn Yan Members is less well known in Erie County.

The Sonyea Formation (Colton and deWitt, 1958) is divided into an older Middlesex Shale and younger Cashaqua Shale Member. The 6 to 8 feet of black Middlesex shales contain some conodonts and the 35 to 75 feet of gray Cashaqua shales have a modest molluscan fauna including several species of the cephalopod *Manticoceras*.

The next youngest unit is the West Falls Formation (Colton, 1956; de Witt, 1956; Pepper, de Witt and Colton, 1956) consisting of an older Rhinestreet Shale (150 to 195 feet of black shale), Angola Shale (220 to 340 feet of mostly light gray shale with some interbedded dark gray shale, thin limestones and calcareous siltstones) and younger Nunda Siltstone (0 to 25 feet of light gray siltstone) Member. The Rhinestreet has a very rich conodont (Youngquist, Hibbard and Reimann, 1948) and fish (Carter, 1945) fauna, including several species of *Dinichthys* while the gray Angola shales have an entirely different faunal assemblage, almost all mollusks (Clarke, 1904). The faunal content of the Nunda Siltstone Member, limited to eastern Erie County, is as yet unknown locally.

The Java Formation (Pepper and deWitt, 1950; deWitt and Colton, 1953; deWitt, 1960) is divided into an older Pipe Creek and a younger Hanover Member. The Pipe Creek contains from one to two feet of black shale with some carbonized plant remains and conodonts. In the 85 to 95 feet of Hanover, some conodonts and mollusks have been collected. The Hanover is largely composed of gray shales but also includes some interbedded dark gray shales and thin limestones, as well as several zones of calcareous nodules. It is similar in appearance to the older Angola Shale Member of the West Falls Formation.

The Arkwright Group (Tesmer, 1955) includes an older Canadaway and younger Chadakoin Formations. These units consist of black and gray shales interbedded with an increasing percentage of gray siltstone toward the top of the group. Seven members are recognized in the Canadaway Formation of Chautauqua County, the Dunkirk (oldest), South Wales (Pepper and deWitt, 1951), Gowanda, Laona, Westfield, Shumla and Northeast (youngest). The Dunkirk Shale is composed of about 40 feet of black shale containing a few carbonized plants and conodonts. The overlying South Wales Member includes from 60 to 80 feet of interbedded gray and black shales with a limited faunal and floral content similar to the underlying Dunkirk Shale Member. Above the South Wales are found from 120 to 230 feet of mostly gray shales and siltstones with some black shale beds, assigned to the Gowanda Member. Although Gowanda fossils are not numerous nor widely distributed stratigraphically, a considerable number of species have been collected, largely mollusks and conodonts. The faunal assemblage and accompanying lithologies are quite like the older Angola Member of the West Falls Formation and the Hanover Member of the Java Formation. This marks the last appearance of the "Naples Fauna" of Clarke (1904).

The Laona Siltstone Member of the Canadaway Formation contains many species introduced for the first time in southwestern New York State. These include the brachiopods *Ambocoelia gregaria*, *Athyris angelica*, *Camarotoechia contracta* and *Tylothyris mesacostalis* as well

as the pelecypod *Mytilarca chemungensis*. The Laona attains a maximum thickness of about 25 feet of mostly gray siltstone and is essentially confined to Chautauqua County.

Above the Laona Siltstone one finds the Westfield Shale Member of the Canadaway Formation, comprised of 100 to 220 feet of gray shales with a few interbedded gray siltstones. These strata are largely barren of megafossils but a few brachiopods, plant stems and conodonts have been collected. The next youngest Shumla Siltstone Member has a nearly identical appearance to the older Laona Siltstone but is almost always barren except for scattered conodonts (Hass, 1958). The Shumla lenses as did the Laona, reaching a maximum thickness of about 35 feet. It is also essentially limited to Chautauqua County.

The thickest member of the Canadaway Formation is the uppermost Northeast Shale Member, varying from about 400 to 600 feet, and containing gray shales with considerable percentages of interbedded gray siltstones, particularly toward the top of the unit and in an eastward direction. In Cattaraugus County, where the Laona and Shumla Siltstone Members are not present, the nearly identical Gowanda, Westfield and Northeast Shale Members merge to form a very thick, undifferentiated sequence of gray shale beds with a fair percentage of interbedded gray siltstones. The Northeast Shale Member is often quite barren near the base of the unit, but the upper part of the member contains numerous specimens of *Ambocoelia gregaria*, *Camarotoechia contracta*, *Chonetes* spp., *Cyrtospirifer* spp., bryozoans and crinoid columnals.

In Chautauqua County, the Chadakoin Formation (Caster, 1934) contains an older Dexterville and a younger Ellicott Member. Both members are interbedded gray shales and siltstones, often nearly identical in appearance. The Dexterville Member, however, can be recognized by the presence of an index fossil, the brachiopod *Pugnoides duplicatus*, which is confined to this unit. In Cattaraugus County where *Pugnoides duplicatus* is nearly completely absent, the Chadakoin Formation is not differentiated into members. The Chadakoin Formation is about 250 feet thick, the Dexterville including the lower 100 feet, where recognized. Fossils are quite abundant in the Chadakoin (Caster, 1934) and various groups are represented, particularly bryozoans, brachiopods, pelecypods and conodonts. Many of the species were first introduced to the area during Laona times when a similar environment must have prevailed.

Much work remains to be done on the Conewango Group, which is locally the Cattaraugus Formation. This formation exhibits great variations in lithology, ranging from typical marine gray shales and siltstones through near-shore coarse buff sandstones and conglomerates to non-marine red shales, siltstones and sandstones. Total thickness is about 650 feet, within which there are many sandstone-conglomerate lenses. These lenses cannot be distinguished from one another in the field and must be separated by careful plotting as to geographic location and elevation. It is hoped that eventually the Cattaraugus Formation may be divided into an appropriate number of formal members (Tesmer, 1958) but presently the Cattaraugus is largely undifferentiated,

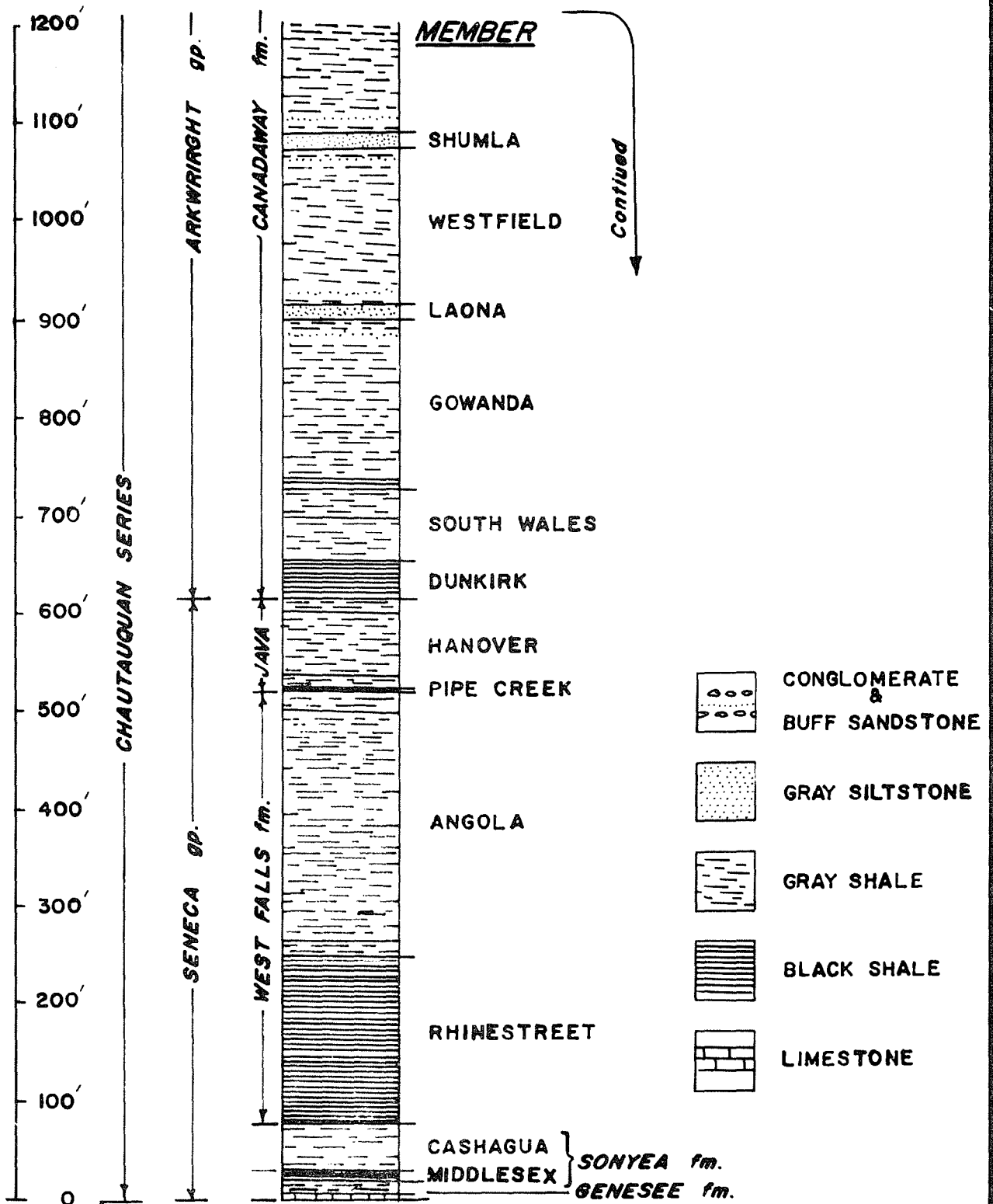
particularly in Cattaraugus County, its type locality. Faunal content is somewhat similar to the underlying Chadakoin Formation but several new genera are introduced, notably the pelecypod *Ptychopteria* (Butts, 1903; Chadwick, 1935). Some of the conglomerate lenses likely to be retained as members include the Panama, Pope Hollow, Salamanca and Wolf Creek.

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# Generalized Stratigraphic Column for the Upper Devonian of SW New York State

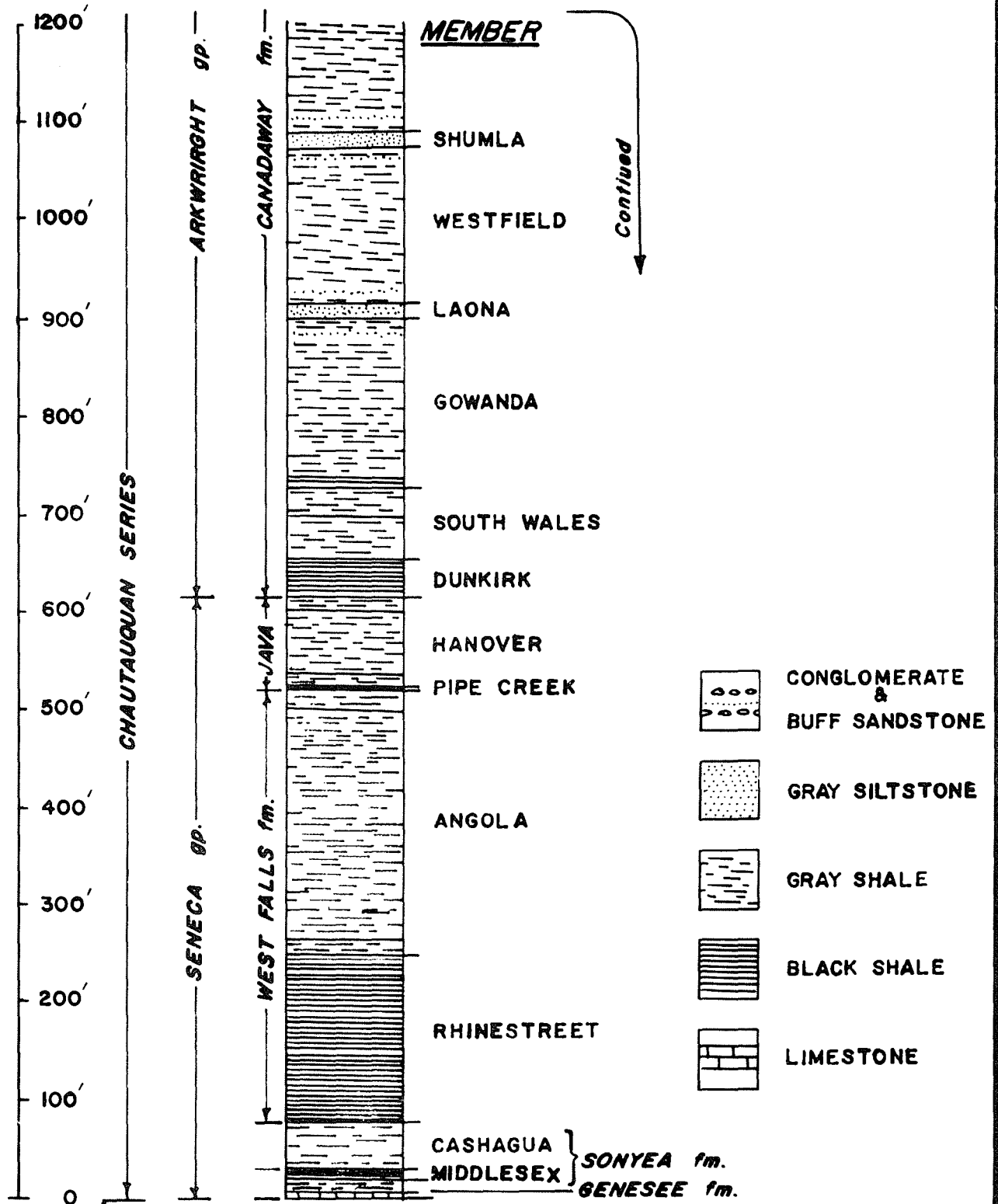


Tesmer Figure 1





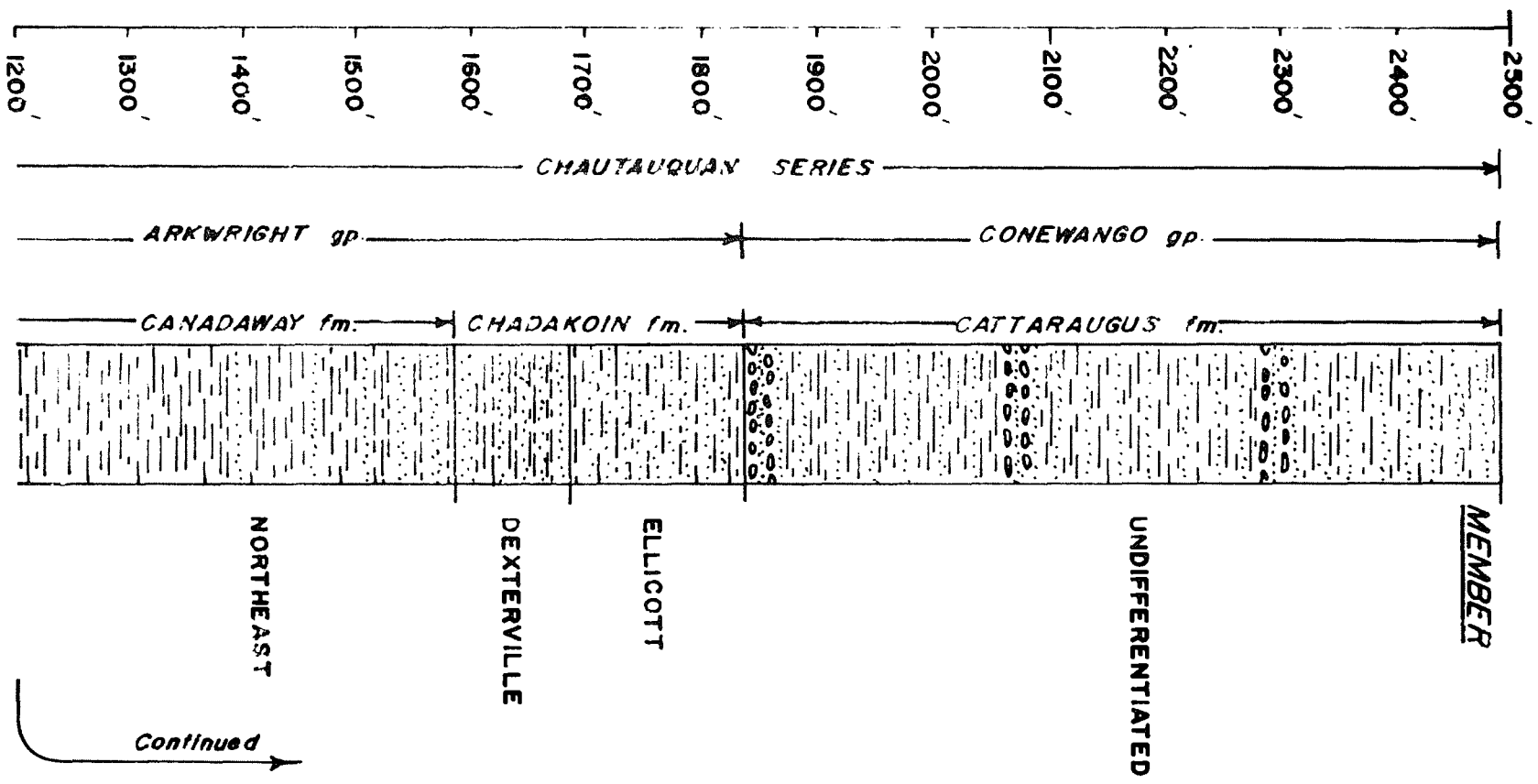
# Generalized Stratigraphic Column for the Upper Devonian of SW New York State



Tesmer Figure 1



Tesmer Figure 1 (cont'd)





## GONIATITE ZONATION OF THE NEW YORK STATE DEVONIAN

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Goniatites are not uncommon in calcareous shales concretions, shales and siltstones in western New York and typically horizons bearing them tongue eastwards towards the more littoral deposits of the Catskills. Earlier goniatite horizons, in general, tongue farther east than the later horizons. Thus the Cherry Valley agoniatic fauna is known almost to the Helderbergs, whilst the latest Famennian faunas, of the Gowanda and Ellicott Shales, have not been traced farther east than Chautauqua County. Faunas lack generic diversity when compared with corresponding European faunas, but they have a value far exceeding this apparent poverty since the horizons may be placed within successions which are known with greater stratigraphic precision than those of Europe. Their importance in establishing a zonal standard and for evolutionary studies generally cannot be over emphasized.

The most striking absentees from the New York goniatite faunas are, from the Middle Devonian, *Maenioceras*, *Sobolewia* (both known in Virginia), *Wedekindella* (known with *Maenioceras* in Canada), *Anarcestes* and *Pinacites*. The Senecan shows greater European affinity, but the probable absence of *Koenenites* (known in Michigan) and *Timanites* (known in Canada) and the rarity of *Beloceras* is striking. Only three genera of Famennian goniatites are known and clymenids are apparently absent. Future collecting may nevertheless yield more records. Elsewhere the author has related the unusual features of the goniatite faunas to a possible migration route from Europe and European Russia via the Arctic, around the northern borders of the Old Red Sandstone continent (House 1964).

## ONONDAGA FORMATION

The earliest certain goniatite occurrence in the state is *Foordites* cf. *Buttsi* (Miller) from the Nedrow member (Oliver 1956). This genus is not known before the Eifelian in Europe. No indubitably Lower Devonian goniatites are known.

## HAMILTON GROUP

The first probable Givetian indicator is *Cabrieroceras plebeiforme* (Hall) from the *Werneroceras* Bed (Rickard 1952) just below the Cherry Valley Limestone: it occurs with *Parodiceras* sp. and *Subanarcestes* cf. *micromphalus* (Roemer). Shales immediately above the *Werneroceras* Bed contain *Agoniatites nodiferus* (Hall) (*vide* Rickard).

The Cherry Valley Limestone has yielded the types of *Agoniatites vanuxemi* (Hall), *A. intermedius* Flower, and *A. floweri* Miller, but it has been suggested (House 1962, p. 254) that these may be synonyms. In view of the importance of its descendants, *Parodiceras discoideum* (Hall) may be used as the zonal index. The succession given here for the higher Hamilton is substantially more detailed than an earlier generalized statement by the author in 1962. This results from study of the Tornoceratidae (House 1965). Skaneateles tornoceratids, *T. (T.) arkonense* etc., (better known from the Ontario contemporaries) are characterized by a shallower lateral lobe than those of the Ludlowville [*T. (T.) uniangulare widderi*], and this trend, essentially towards an increasingly steep ventrad face to the laterumbilical saddle continues in the Moscow with the genotype from the Leicester Pyrite, *T. (T.) uniangulare uniangulare* (Conrad). A distinct ribbed form first noted by Professor J. W. Wells, from the King Ferry Shale on Cayuga Lake has been named *T. (T.) amuletum*. It is probable, but not certain, that this species is younger than *T. (T.) uniangulare aldenense* from the Alden Marcasite. Agoniatitids are also not uncommon in the Hamilton, but these have not, as yet, been studied in detail. The highest agoniatitid known is *Sellagoniatites unilobatus* (Hall) from Norton's Landing, Cayuga Lake. This genus occurs in the Canadian N. W. T. and in Europe is restricted to the upper Givetian (House and Pedder 1963, p. 512).

#### GENESEEE GROUP

The earliest occurrence of Frasnian goniatites is in the Tully where *Pharciceras amplexum* occurs. Tornoceratids are common including forms comparable to *T. (T.) arcuatum* (House) from the Koenenites-bearing Squaw Bay Limestone of Michigan.

Typical lowest Frasnian ponticeratids occur in the Genesee Shale, especially *P. perlatum* (Hall), and others, also *Epitornoceras peracutum* (Hall), the latter a rare genus also known in the European low Frasnian. From the Genundewa Limestone come the types of *Probeloceras genundewa*, *Manticoceras apprimatum*, *M. contractum*, *M. fasciculatum* and *M. styliophyllum*. At Bethany Center *T. (T.) uniangulare compressum* is abundant. The record of a *Koenenites* from the West River Shale may be based on a *Manticoceras*.

#### SONYEA GROUP

From The Middlesex shale there are several records of noded goniatites probably referable to *Sandbergeroceras*. Goniatites are rare at this level and all so far found are crushed.

The fauna of the Cashaqua Shale is rich and varied. This is the source of *Probeloceras lutheri*, *P. (?) accelerans*, *Manticoceras sinuosum*, *M. tardum*, *M. neapolitanum* (formerly thought to be a ciymenid), *Neomanticoceras naplesense*, *Eobeloceras* and probably also *Sandbergeroceras*. The fauna is at present being studied by Mr. W.T. Kirchgasser of Cornell. Particularly famous is the horizon of concretions with barytic replacements which lies some six feet below

the top of the formation in the gullies between Conesus and Honeoye Lake and especially in Shurtleff's Gully, 2.75 miles S. E. of Livonia.

#### WEST FALLS GROUP

There are singularly few records from the Rhinestreet Shale. At the top of the Unit *Manticoceras* and *Tornoceras* occur in concretionary horizons just below the 'Scraggy Bed' on Big Sister Creek and thereabouts. Large manticoceratids occur in giant concretions around the northern promontory of Grandview Bay. From the Angola Shale, however, many fine specimens are known. Recent work by the author has shown that Clarke's Big Sister Creek localities lie in the lower part of the Angola Shale where cyclothemic units of black shale, worm burrowed shale, grey shale and shale with concretions are repeated many times. A succession of the lowest six of these has been traced bed-for-bed as far east as the Warsaw Valley. The Gibson's Glen goniatite horizon is higher than these. The concretionary horizons almost invariably yield goniatites, but these become rarer to the east. Manticoceratids are chiefly of the *M. rhynchostoma* group and oxyaonic groups: *Aulatormoceras* and *Tornoceras* are also common. Scattered records are known from the Gardeau, and farther east the records of *Beloceras* by Wells (1956) and of *Shindewolfoceras* are of interest in that they have not yet been found in supposed equivalent rock in the west.

#### JAVA GROUP

Goniatites are extremely rare in the Pipe Creek Shale, but from the Hanover Shale, especially from nodules in the lower fifteen feet, they are not uncommon. This is probably the source of the types of *M. cataphractum* and *Aulatormoceras rhysum*.

#### CANADAWAY GROUP

No goniatites are yet known from the Dunkirk Shale or South Wales Shale. From the Gowanda Shale at Corell's Point on Lake Erie shore 250 yards S.W. of the outlet of Walker Creek, 2.85 miles west of Brocton, Chatauqua Co. (House 1962) the *Cheiloceras* fauna is known. The same horizon, with *Cheiloceras amblylobum*, *Tornoceras* (*T.*) *concentricum* and *Aulatormoceras bicostatum* has now been located, in an identical concretionary layer, in Little Canadaway Creek below Lamberton, 2,200 feet N.W. of the junction of Lake Road and Rt. 20 at an altitude of about 630 feet, and again in Walnut Creek, below Forestville, about 200 yards upstream of the railroad culvert and at an altitude of about 847 feet. It is now clear that the horizon which yielded the types of *Aulatormoceras clarkei* is lower than this and occurs three feet above a 2 inch siltstone in the creek floor below the Sheridan Road bridge over Walnut Creek at Forestville. Both horizons are in the upper part of the Gowanda Shale.

## CONNEAUT GROUP

The only record from this group is still the *Sporadoceras cf. pompecki* recorded by the author from the Ellicott Shale in Porter's Creek, Summerdale (House 1962). Higher horizons have not yet yielded goniatites in New York, but in Pennsylvania from near the horizon of the Panama Conglomerate comes *Sporadoceras milleri*. The occurrence of probable *Chonopectus* in the Corry Sandstone is of interest in that the same genus occurs with Famennian clymenids in the English River Formation of Iowa and forms allied to *Chonopectus (Whidbornella etc)* occur in the late Famennian in England. Syringothyrids are not critical in this respect.

## CORRELATIONS WITH EUROPE

The writer has little to add to his views expressed in 1962. Regarding the position of Tully, it is still the case (as in 1962) that critical conodont zonation of the type Frasnian and Givetian has not been made. Until this is done any views are rather speculative. Farther the correlation between the conodont and ammonoid zonations in Europe is still, in the author's opinion, unsatisfactory. Clearly more critical work on the faunal successions both in Europe and New York is required before any dogmatic opinion can be given.

## ACKNOWLEDGEMENTS

Recent work by the author in New York has been aided by the N. Y. Geological Survey and the D. S. I. R. (now S. R. C.) to whom he is very much indebted. Also appreciated is the encouragement from Professor J. W. Wells and the field assistance of Mr. W. T. Kirchgasser.



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## LATE PLEISTOCENE HISTORY OF NORTHWESTERN NEW YORK

by Parker E. Calkin

## Introduction

A number of excellent surficial geological studies have been made over northwestern New York. The most comprehensive were done by Leverett (1902), and by Kindle and Taylor (1913). These authors and others, including: J. W. W. Spencer (1881-1915), G. K. Gilbert (1887-1908), A. W. Grabau (1901-1920), H. L. Fairchild (1902-1932), F. G. Taylor (1895-1939) have roughly delineated moraines, glaciolacustrine features (plate 2), and have discussed chronologies of glacial retreat, lake formation, and the Niagara Gorge formation. However, with the exception of two recent areal studies (Blackmon, 1956 and D'Agostino, 1957), and local studies by E. Muller, these works were based largely on topographic features. Insufficient detail has been uncovered to clearly define the end moraines and drift sheets in most of the northwestern New York area. Furthermore, there was never any agreement among authors as to the number or importance in the glaciolacustrine chronology of moraines that were delineated.

Although in recent months, the writer and others have begun an attempt to reevaluate and add to the knowledge of this area, this paper is largely a compilation of the published literature. Emphasis is placed on features observed in following the road guide accompanying this report.

Evidence from striae and drumlins of the latest ice advance and interpretation of heavy mineral provenance (Dreimanis, 1961; Connally, 1964) suggests that Western New York was strongly affected by the Erie Glacial Lobe which was fed by an ice flow northeast or north-northeast of Lake Ontario. During its general southwesterly advances, ice also spilled out southeasterly from the Erie Basin into western New York.

## Pre-Valley Heads (Port Huron?) Time

Preliminary studies suggest that most of the morphologic glacial features of northwestern New York may be attributed to the Port Huron Stade (Late Cary) and the following interstade; however, evidence of prior glaciation is found in adjacent area (see fig. 1).

In southwestern New York, the existence of pre-Illinoian glaciation may be inferred in the Salamanca re-entrant (Allegheny Park area) from relationships of subsequent deposits (Muller, 1965). In the same area, terrace remnants containing possible morainal material above the Allegheny River may be Illinoian in age (MacClintock and Apfel, 1944). Isolated erratics and spotty occurrence of till mapped by Muller (1963) southeast of the Wisconsin terminal moraine in Chautaugua County may belong to the outer-phase Illinoian of Shepps et. al. (1959).

At the well-studied Don and Scarborough beds locality near Toronto, the clayey York Till resting on Ordovician bedrock is considered by most to be of Illinoian age. Here also, much of the Sangamon interglacial episode is represented by the overlying Don beds which contain more than 70 species of trees and herbs, 20 diatoms, and 6 mammals. These fossils suggest that the maximum mean annual temperature was at least 6°F warmer than at present (Terasmae, 1960; Goldthwait et. al., 1965).

Correlations of many fossil organic sites in Quebec (Terasmae, 1958) Southern Ontario (Terasmae, 1960; Goldthwait et. al., 1965), Ohio (Goldthwait et. al., 1965) and in Cattaraugus and southwestern Erie Counties, New York (Muller, 1964; 1965) indicate a very complex history of glacial fluctuation during the Wisconsin Glaciation. In the London to Toronto area of southern Ontario, four distinct Wisconsin advances prior to the Port Huron are represented by the Sunnybrook, Southwold, and Port Stanley tills which in turn help define the St. Pierre, Port Talbot, Plum Point and Lake Erie interstades. Finite dates of 52,000 B.P. and 63,000 B.P. by the Groningen (Netherlands) Laboratory on peat beneath gravel, till, and thin lacustrine beds at Otto, Cattaraugus County (Muller, 1964) may suggest correlation respectively to Scarborough (St. Pierre interstade) beds and Sunnybrook till of the Toronto area.

Elsewhere in southern New York, the Olean Moraine (MacClintock and Apfel, 1944) and the Kent (Binghamton), Lavery, and Hiram tills of Chautauqua County (Muller, 1963) may be correlated with the drifts of southern Ontario. Till and interstade beds exposed in banks of Clear Creek near Gowanda in southernmost Erie County have been dated at greater than 38,000 years and may correlate with the Otto or St. Pierre interstade beds (Muller, 1960; 1965).

#### Valley Heads (Port Huron?) and Later Time

##### End Moraines

The last significant glacial readvance in western New York is probably marked by the outstanding, Valley Heads/Lake Escarpment end moraine ridges of southwestern New York (plate 2). This morainal system, the most continuous in New York State, is characterized by strong topographic expression with conspicuous kame knobs and kettle depressions. It is presently considered to be of Late Cary age and probably in part equivalent to the Port Huron Moraine of Michigan. Analysis of spruce from many sites overlying gravel near a mastodon site in southwestern Erie County, yields a minimum date of 12,020 B.P. for recession from this terminal moraine (Muller, 1963). Muller (1963, p. 48) notes "that this date may be measureably younger than the Valley Heads maximum is afforded by --" an average of 12,370 B.P. for two dates taken on spruce from proglacial Lake Iroquois deposits at Lewiston, New York. Evidence from western New York, of recessional history from Cary (Kent) terminal moraine provides no adequate demonstration of the magnitude of the readvance to the Port Huron

(Valley Heads Moraine) [Muller, personal communication]. However, the probable correlatives of the Valley Heads Moraine near Hamilton, Ontario the Paris and Gait Moraines (Goldthwait et. al., 1965; Muller, 1963) may have followed a pronounced retreat of the Erie Lobe (Karrow, 1963).

Retreat from the Valley Heads border is marked in western New York by a series of recessional moraines, from south to north: Gowanda, Hamburg, Marilla, and Aiden Moraines of Leverett (1902); the Buffalo Moraine of Kindle and Taylor (1913); and the Barre and Aibion Moraines of Leverett (1902). In most cases, the tracing of these moraines is difficult. In the Erie and Ontario Lowlands, they were laid down in proglacial lakes resulting in subdued topographic expression and poor continuity (see Fairchild, 1932). Because of the lacustrine deposition and heavy proglacial drainage, much of the moraine material is very sandy and kame moraine ridges are common.

The Gowanda Moraine is probably related closely in age to the Valley Heads and has been reduced in most areas to an erosional boulder remnant of Lake Whittlesey action. The Aiden and Marilla Moraines may be distinguished from the Hamburg Moraine largely through glacial marginal drainage channels (Fairchild, 1932). The latter extends from Hamburg 25 miles into the northwestern part of the adjoining Wyoming County where it connects with the interlobate (Erie/Ontario Lobes) moraine of the Valley Heads system near Batavia. With sharp knolls of 20 to 50 feet relief, together with inclosed basins and sloughs; and also with its great width near Batavia (plate 2), the Hamburg Moraine is by far the most conspicuous ridge in northwestern New York. The other moraines for the most part show relief of much less than 50 feet or are identified by slight boulder concentrations on y.

The extent to which these moraines represent advances or significant halts in recession of ice from the Valley Heads moraine in western New York is not known. However, the glacier had retreated north of the Niagara Escarpment by 12,370 B.P. and probably north of the Ontario Basin, never to return into western New York, by 12,500 to 10,500 B.P. according to bracketing dates of Lake Iroquois (Karrow et. al., 1961).

#### Glacial Great Lakes

The correlation of events in the Erie - Ontario Lake Basin with "Late" Pleistocene chronology of the upper Great Lakes has posed a serious problem to some (See Hough, 1963; Bretz, 1964; Wayne and Zumbege, 1965; Hough, 1966), but most workers now agree that proglacial Lakes Whittlesey, Warren, Wayne, Grassmere, Lundy and/or possibly Dana and an Early Algonquin existed prior to the Two Creeks Interstade and formation of Lake Iroquois.

The highest Great Lakes strandline recognized in Erie County and western New York rises from 778 feet at the Pennsylvania State Line to 910 feet, 73 miles northeast at East Aurora (plate 2). Here it dies out at the position of the former ice border. This dated strand is dated as 12,660 B.P. in southern Ontario (Goldthwait et. al., 1965; Hough,

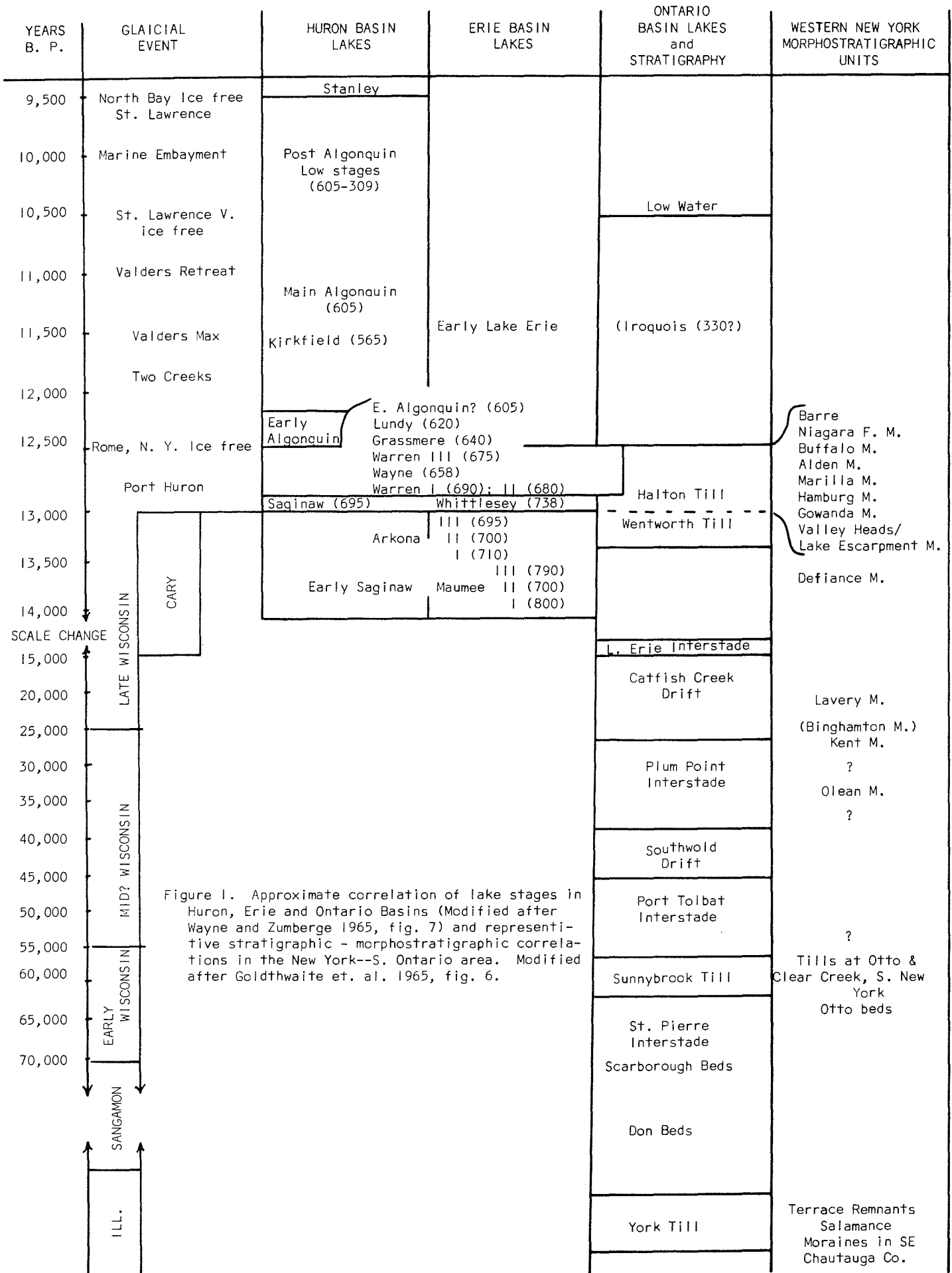
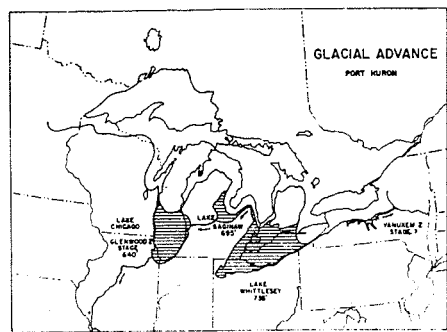
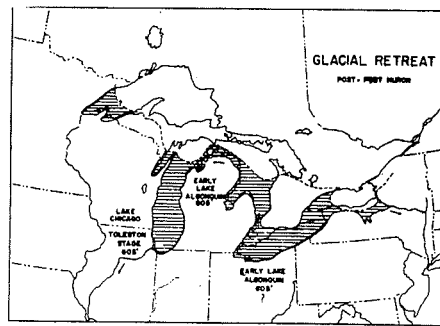


Figure 1. Approximate correlation of lake stages in Huron, Erie and Ontario Basins (Modified after Wayne and Zumberge 1965, fig. 7) and representative stratigraphic - morphostratigraphic correlations in the New York--S. Ontario area. Modified after Goldthwaite et. al. 1965, fig. 6.

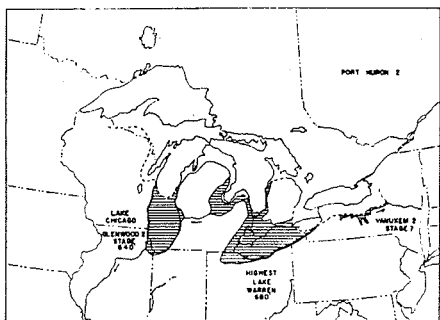




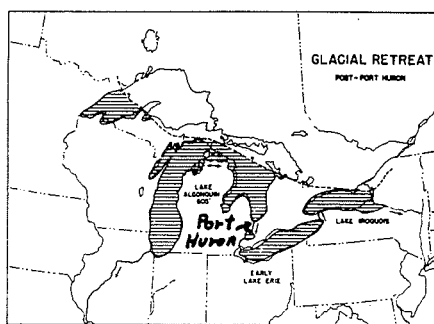
2A



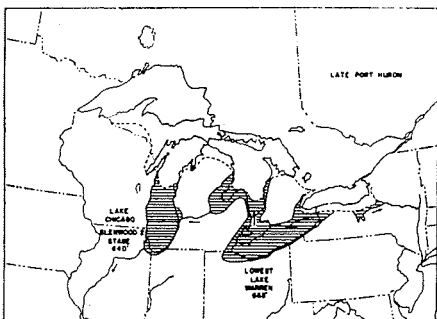
2D



2B



2E



2C

Figure 2. Some stages of the Great Lakes. After Hough (1963).

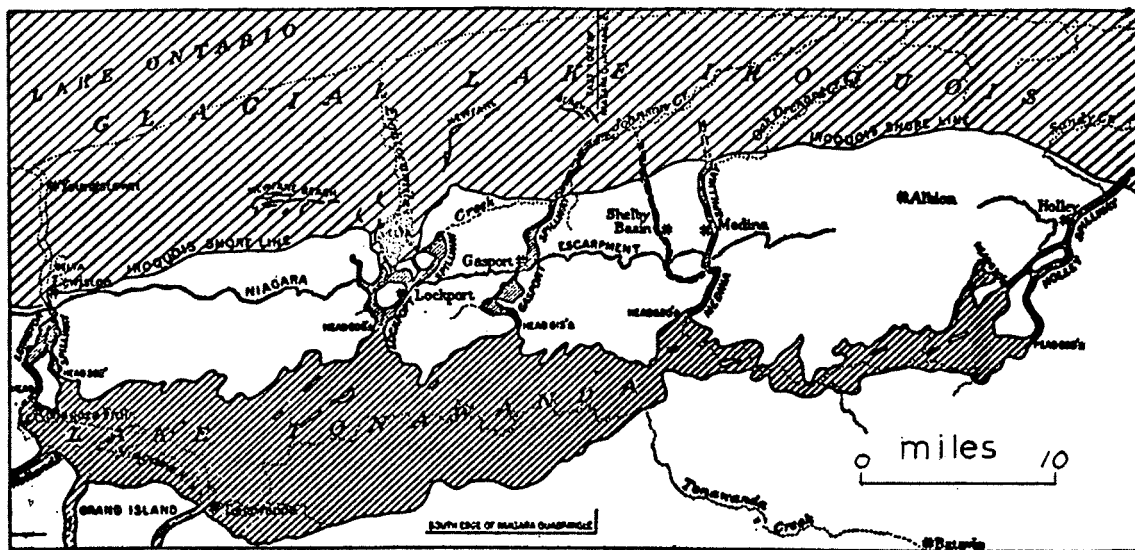


Figure 3. Sketch map of Lake Tonawanda and spillways. Shoreline of Lake Tonawanda approximate. After Kindle and Taylor (1913).





1963) and is correlated with the Lake Whittlesey stage (fig. 2A). This lake may have been initiated at Port Huron (Valley Heads) time and discharged westward across the thumb of Michigan. Lake Whittlesey, at its peak twice the size of Lake Erie, was slowly extinguished with retreat of ice from the Hamburg Moraine to the position marked by the Alden Moraine (Leverett, 1895). Its waters escaped westward through the Grand River channel to Lake Chicago (fig. 2A).

A lower outlet allowed formation of Lake Warren (fig. 2B), which according to Hough (1963) had three phases, the last (fig. 2C) following an intervening lower water stage of Lake Wayne. The lowest Lake Warren strand may be dated about 12,000 B.P. or 11,860 by organic material from a Tupperville, Ontario site (Dreimanis, 1964). In the area of East Aurora (plate 2), the first Lake Warren beach occurs as a single ridge at about 840 feet and "lower" Warren beaches occur as short, multiple ridges from 810 to 840 feet (Blackmon, 1956).

Weakly developed strandlines from 810 to 770 feet in the East Aurora area may relate to, respectively, Lake Wayne, Grassmere, and Early Lake Lundy. Occurrences of beaches assigned to these Great Lake stages are not plentiful in northwestern New York and levels are of uncertain correlation (see Kindle and Taylor, 1913).

The assignment of a number of beach ridges at about 700 feet and lower is uncertain. Fairchild's (1906) and Hough's (1958) Lake Dana stage, an assumed intermittent stage between Warren and Iroquois, may well be Kindle and Taylor's (1913) low stage of Lake Lundy or Hough's (1963) Early Lake Algonquin (fig. 2D [See Wayne and Zumberge, 1965]). The outlets for these lakes is not well defined (Hough, 1963), but may have been eastward to the Marcellus Channels near Syracuse (Fairchild, 1906).

As the ice margin retreated from the Niagara Falls Moraine and subsequently from the Barre Moraine positions in western New York (plate 2), and from the divide between the Oneida and Mohawk basins to the east (Muller, 1965), the Mohawk outlet to the Hudson River was opened. The resulting gradual lowering of the lake level (Early Lake Algonquin--fig. 2D) to below the Niagara escarpment initiated formation of Early Lake Erie and Lake Iroquois and necessarily, the Niagara River, Niagara Gorge, and Falls at Lewiston, New York (fig. 2E). Dates for this event from New York and Ontario average about 12,370 B.P. (Goldthwait et. al., 1965). Glacial ice still blocked drainage east toward the St. Lawrence Valley (Karrow et. al., 1961).

Ridge Road (U. S. Route 104) which follows the Iroquois beach ridge gives clear demonstration of postglacial isostatic tilt as it rises eastward from about 377 feet at the Niagara River to about 450 feet above sea level 180 miles away near Rome, New York (Muller, 1965). Further ice retreat uncovering the northern end of the Adirondacks (MacClintock and Terasmae, 1960) and opening of the St. Lawrence

Valley caused draining of Lake Iroquois about 11,000 years ago. Because of isostatic depression by ice in the St. Lawrence Valley, the water level in Ontario Basin first dropped to 230 feet or more below the present level of Lake Ontario, an event dated at about 10,150 B.P. (Goldthwait et. al., 1965). Postglacial uplift of the outlet near Kingston, Ontario, has brought the lake to its present level of about 246 feet.

#### Lake Tonawanda

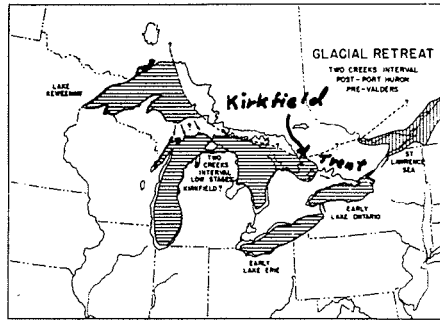
With glacial recession and lowering of the water level to Lake Iroquois, the Onondaga and Niagara escarpments were uncovered and waters pouring from the newly formed Detroit, St. Clair and Niagara Rivers respectively (fig. 2E), were impounded between the two cuestaform ridges forming Lake Tonawanda (fig. 3). During its early history, Lake Tonawanda extended nearly 58 miles from near Rochester to beyond Niagara Falls, Ontario and averaged 6 miles in width. The best developed beaches are at about 629 feet.

Lake Tonawanda had five outlets (fig. 3), each forming a falls and gorge where it drained over the Niagara escarpment to Lake Iroquois. Because of isostatic tilt, illustrated by Ridge Road, and because of its proximity to Lake Erie, outlets at Lewiston and Lockport carried most of the discharge. At Lockport, the largest spillways were the Gulf and the northeast trending gorge now utilized by the Erie and New York State Barge Canals. Subsequently, because of more rapid incision of the Lewiston outlet and because of sedimentation, Lake Tonawanda decreased in size. Oak Orchard swamp east of Lockport, and other swamps now surrounding Tonawanda Creek are successors of Lake Tonawanda.

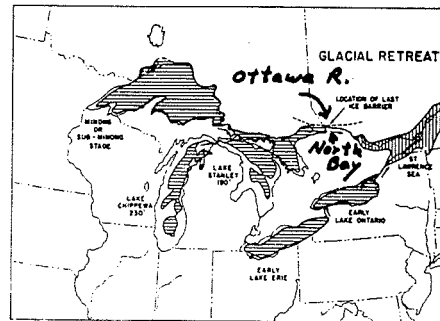
#### Formation of Niagara Falls and Gorge

Niagara River and Falls formed, and cutting of the Gorge into the escarpment began at Lewiston with the opening of the Mohawk Valley and subsequent draining of Early Lake Algonquin? water to form Early Lake Erie and Lake Iroquois. The initiation of gorge-cutting, previously dated by Lake Iroquois at 12,080 to 12,600 B.P., occurred at Lewiston, N. Y. rather than at the mouth of the buried St. Davids' Gorge, Ontario a few miles to the west (fig. 5). The reason for not using the old channel appears to be that its drift fill and the overtopping Barre Moraine (Plate 2) put its effective floor some 60 feet above the escarpment level at Lewiston (Taylor, 1933).

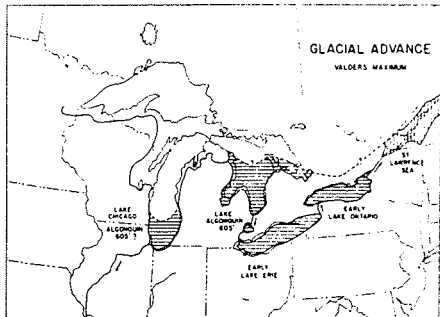
Thereafter, through more than 12,000 years the notch of the Falls has retreated approximately seven miles to its present position. The height of the Falls has been maintained through this period by the tough, Middle Silurian, Lockport Dolostone caprock, while undermining through the weaker Rochester Shales and other, less competent formations



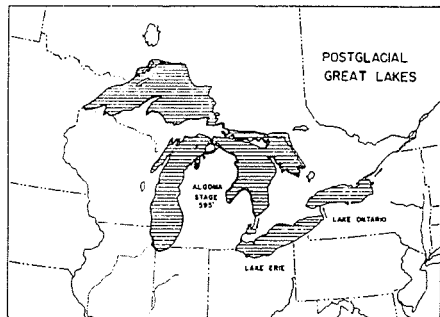
4A



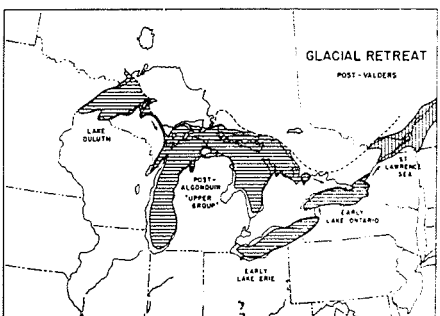
4D



4B



4E



4C

Figure 4. Some stages of the Great Lakes. After Hough (1963).

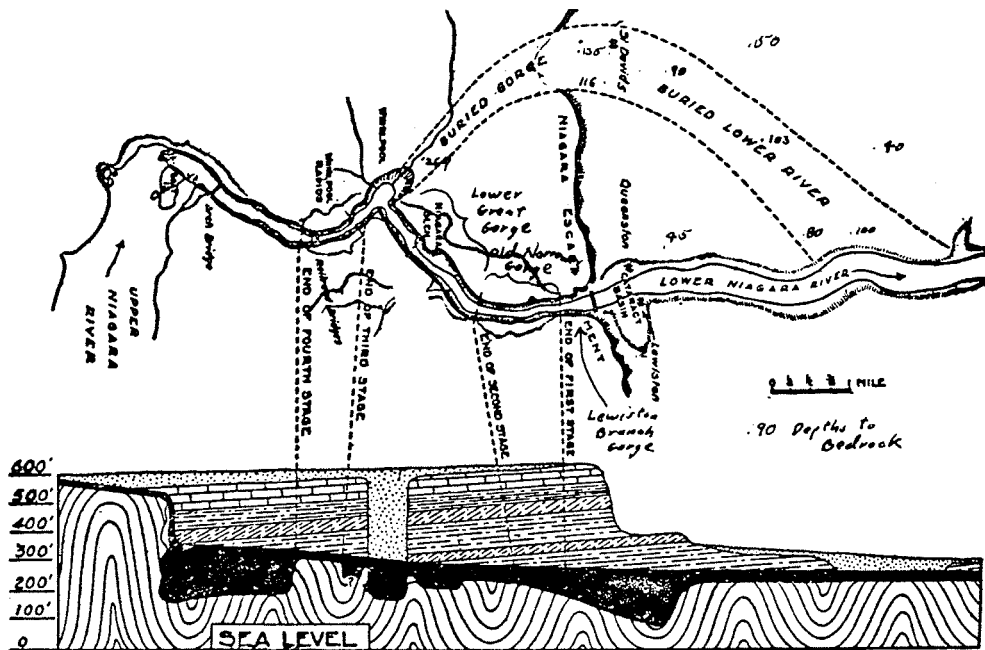


Figure 5. Sketch map of Niagara Gorge showing the varying width and depth. Vertical section is along Gorge and River with Vertical scale greatly exaggerated. Depth of water shown in black. Modified after Forrester (1926 & 1928).



below caused a joint block by joint block recession (see associated papers for stratigraphic column).

### Correlation of Niagara Gorge Enlargement With Great Lakes History

The time involved in the cutting of the Niagara Gorge was at one time considered a reasonably accurate measure of the duration of time since deglaciation. Estimates of postglacial time obtained in this manner vary by a factor of ten, ranging from as little as 3,000 years to more than 35,000 years (Kindle and Taylor, 1913). The principle complicating factor comes with the realization that the volume of water discharging through the Niagara River has varied considerably since its initiation. Such changes resulted from the varying size and number of outlets, other than through Lake Erie, afforded the upper Great Lakes waterbodies by action of the former ice margin. The various sections of the Niagara Gorge shown in figure 5, were correlated with the Great Lakes History by Kindle and Taylor in 1913 and by Taylor again in 1933. Since this time, radiocarbon dating and more detailed research elsewhere in the Great Lakes Basin makes this correlation out of date and a new interpretation, based on the present data available, is given below. Although such correlation is highly conjectural and based on meager proof, it may serve as a very temporary base of reference and help to illustrate how variation of discharge controlled the rate of Niagara Falls, recession. The interpretation below is based on the Great Lakes History according to Hough (1963) and others as outlined below and is partially illustrated in figures 2 through 5.

#### 1. Cataract Basin and Lewiston Branch Gorge Sections

Moderate discharge required is correlated with formation of Lake Tonawanda outlets and Chicago outlets for Lake Algonquin and Early Lake Erie (12,000 B.P. to 11,850 B.P.) See figures 2E and 5.

#### 2. Old Narrow Gorge Section

Decrease in volume of discharge is correlated with ice recession, the Two Creeks Interstade, and consequent opening of the Trent River outlet at Kirkfield, Ontario. The upper lakes (Algonquin/Kirkfield) then drained directly into Lake Iroquois. Carrying only discharge of Lake Erie, a narrow and shallow gorge section was cut. See figures 4A and 5.

#### 3. Lower Great Gorge Section

Increase in volume is correlated with: a) Valdres ice advance and subsequent blocking of outlet to the Trent Valley (Hough, 1963); or with b) isostatic rebound of the outlet at Kirkfield. Either event subsequently returned the Main Algonquin discharge through Lake Erie. At Niagara University (head of Old Narrow Gorge) the gorge widens

perceptably and deepens slightly, the greater width continuing southward nearly to the Whirlpool. At the Whirlpool, the south-westward retreating Falls intersected the previously cut, but drift filled St. Davids' Gorge at right angles thereupon turning sharply southeastward to reexcavate the head of the older gorge. See figures 4B and 5.

#### 4. Whirlpool Rapids Section

The decreased volume at this stage is correlated with recession of the ice front from the Valders terminal moraine and opening successively of outlets at Kirkfield to the Trent Valley and at North Bay, (9,500 B.P. after Terasmae and Hughs, 1960) to Lake Ontario and to the St. Lawrence River respectively (see Chapman, 1954). See figures 4C, 4D and 5. It is possible that as the ice front reached North Bay, the Trent River outlet at Kirkfield was closed by isostatic recovery. A narrow gorge may have been cut south of the area shown in figure 5; however, this section would have been enveloped by cutting of the Upper Great Gorge.

#### 5. Upper Great Gorge Section

The large increase in discharge through the Falls necessary to initiate this section is correlated with abandonment of the North Bay outlet to the Ottawa River due to isostatic rebound. For the first time, the entire discharge of the three upper Great Lakes flowed through two southern outlets (Hough, 1963). The Chicago outlet, resting on bedrock, could not cut deeper; however, the Port Huron outlet to Lake Erie, resting in till, was cut down and further concentrated the flow through Lake Erie and over the Falls (4,200 B.P. after Dreimanis, 1958; Farrand, 1962). Separation of the Horseshoe and American Falls is estimated to have taken place from 600 to 700 years ago (Taylor, 1933).

#### Origin of St. Davids' Buried Gorge

Another problem of the Niagara Falls area is the origin of the drift-filled St. Davids' Gorge (fig. 5). Apparently as deep and nearly as wide as the Upper Great Gorge (Kindie and Taylor, 1913; Forrester, 1926; International Joint Commission, 1953), it extends from the Whirlpool to the town of St. Davids, Ontario at the Niagara escarpment. As evidenced by deep drilling in the Iroquois Plain, it extends northward from St. Davids across the Iroquois Plain to the Lower Niagara River. Its length and apparent cross section would suggest that it was carved by a discharge approaching that of the present Niagara River and may have taken more than 4,000 to 8,000 years to form. Recent palynological study by Dr. Paul Karrow may suggest an "Early" Wisconsin or Sangamon origin for some units of the drift fill (J. Terasmae, personal communication). Geophysical survey and stratigraphic drilling are being undertaken currently by Dr. Terasmae of the Geological Survey of Canada.

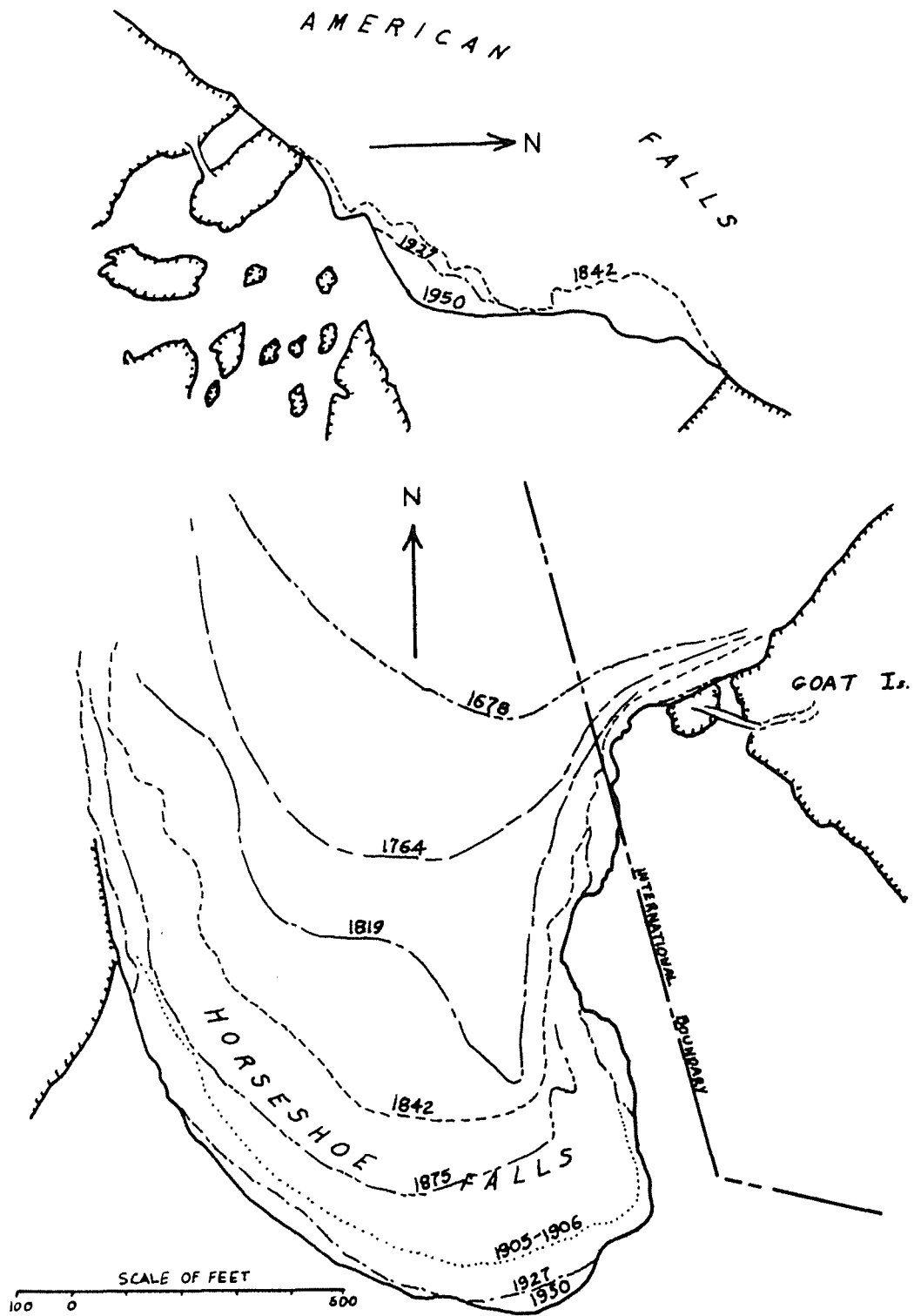


Figure 6. Comparative crestlines of Horseshoe and American Falls. After International Niagara Falls Engineering Board, 1953.





## Niagara Falls in Recent Time

The Niagara River and hence the Niagara Falls continues to carry the surplus water of the upper Great Lakes seaward from Lake Erie to Lake Ontario. The mean flow of the river is about 200,000 ft<sup>3</sup>/sec. and because of the immense storage capacity of the upper lakes, the flow is remarkably steady. The normal flow is measured by a few thousand cubic feet per second which are diverted into Lake Superior from the Albany River watershed in Canada, and it is reduced by somewhat similar amounts diverted by the Chicago Sanitary and Ship Canal from Lake Michigan into the Mississippi River, and by the Welland Canal and the New York State Barge Canal directly into Lake Ontario (International Joint Commission, 1953).

A considerable body of information regarding recent rates of recession of the Horseshoe and American Falls is summarized in figure 6. Average recession for the Horseshoe Falls has apparently decreased from an average of 4.2 ft/yr between 1842 and 1906, to 3.2 ft/yr between 1906 to 1927, to 2.2 ft/yr from 1927 to the last survey in 1950. Several factors contributing to this reduction of cutting include: 1) the regional dip of the capping Lockport Dolostone, diminishing the height of the Falls by about 20 ft/mile; 2) a southward thickening of the capping Lockport Dolostone; 3) diminishing discharge of the Niagara River as a result of increased diversion for power purposes (10,000 ft<sup>3</sup>/sec. in 1906, to greater than 100,000 ft<sup>3</sup>/sec. at present).

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## THE ECONOMIC GEOLOGIC SETTING OF WESTERN NEW YORK

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## Introduction

The geologic setting of western New York State does not support a diversified production of economic minerals. The somewhat austere local setting is not conducive to the production of large quantities of metallic minerals although such species as sphalerite, galena, cerussite and pyrite are known in the local stratigraphic column. Just a few miles to the north and across the international border a distinguished list of produced metallic minerals can be compiled, but these minerals occur in the crystalline rocks of the Canadian Shield. Nevertheless, western New York is a producer of some natural mineral and rock products and is a major consumer of a wealth of natural mineral products from throughout the world. It is the intent of this paper to point up some of these considerations.

## Production

Excluding natural gas, petroleum and sand and gravel, mineral products which have been and are being commercially exploited in the eight counties of western New York include: dolomite and limestone, gypsum, salt, building stone (sandstone and bluestone) and silica. Gypsum is considered in another article in this guidebook.

## STONE PRODUCTS

Crushed limestone—Crushed limestone is produced for use as concrete aggregate, road metal, asphaltic cement, railroad ballast, riprap and roofing material. Erie County in 1962 was the fourth largest producer of broken and crushed stone in the state. In 1965 the estimated production of crushed stone by the three major producers in Erie County is somewhat over one and three quarter million tons. At the current production rate, the largest producer estimates a reserve of material sufficient for 350 years. All production in Erie County is from the Onondaga limestone, the silica content of which ranges from 25-30%. Niagara County has three commercial producers of crushed stone who produce from the Lockport dolostone and Genesee County also has three commercial producers.

At one time natural cement rock was both quarried and mined in the Buffalo area, but this is no longer an active industry. Natural cement rocks or waterlimes are those which when burned, finely ground

and mixed with water yield cement. Recovery from natural cement rocks was the major source of cement until about 1918 when use of manufactured Portland cement became dominant. In 1926 a natural cement rock quarry was activated near Akron, New York and produced for several years. Natural cement rock for this operation came from the upper Salina (Bertie) formation (Newland, 1939).

Shale-Erie County lead the state in shale production until 1962 when it fell to second place. Most of the produced shale is used in the cement manufacturing industry but some is also used in the manufacture of building bricks and specialty products.

Dimension Stone- Although this commodity once supported a flourishing industry in western New York State, its importance has largely been replaced by the development of manufactured products including cement and asphalt.

Sandstone curbing blocks from quarries located near Albion and Medina and situated in the Medina sandstone were in common use throughout this area and also were shipped throughout the state and to such places as Cleveland and Cincinnati, Ohio and Indianapolis, Indiana. Around the turn of the century the quarries at Albion employed hundreds of men. Some of the Medina sandstone has been used in the construction of buildings and the Asbury Delaware Methodist Church at the corner of Delaware Avenue and Tupper Streets in downtown Buffalo is constructed of Red Medina sandstone from a quarry at Huiberton in Orleans County. This quarry is still in operation and supplies replacement curbstone for the City of Buffalo.

The term "bluestone" was originally applied to the blue colored dimension stone which occurs in Ulster county in eastern New York, but it gradually evolved to cover most of the flagstone used in building which was produced in New York State irrespective of its color. At one time the counties of western New York had many bluestone quarries the greatest number of which were situated in Wyoming and Allegany Counties. Wyoming County had the only large operations and these were located near Warsaw and produced from the West Falls Group. Actually bluestone for use on the St. Joseph's School on Main Street in Buffalo as well as the lower portion of the National Guard Armory on Delaware Avenue in the City of Tonawanda are products of the Warsaw quarries. Some bluestone operations were located in Cattaraugus and Chautauqua counties, but similar to the operations in Allegany County, they were quite small and often supported the efforts of only one or two men.

Through the years the demand for this type of building material has gradually declined to the point where sources in this area are now almost non-existent. It is interesting to note, however that in 1962 a small operation near Portageville was still actively quarrying bluestone for use in buildings and monuments. Part of that year's production was used in facing of a hospital in New York City and some was used for monuments in Arlington National Cemetery.

Limestone was at one time quarried as a building stone, but quantitatively was of limited significance primarily because of the varying quality of the Onondaga limestone. Among other things, the locally high chert content of this formation makes the material difficult to process. At one time the Buffalo area had several active limestone quarries however which supplied local construction as well as some export. Hayes Hall, the administration building on the Main Street campus of the State University was constructed from native stone taken from a quarry which was located at the northeast corner of the campus near the intersection of Main Street and Bailey Avenue. Many of the other older buildings on the campus are also constructed of Onondaga limestone.

## SALT

Salt holds the distinction of being one of the earliest commercially produced minerals in the State of New York. Although the first recorded recovery of usable salt from brine was in the vicinity of Syracuse, the quantitative center of salt production moved toward the west with the discovery in the 1860's that rock salt was present in the stratigraphic column. This discovery was made first in a well drilled at Vincent, New York and later in the drilling of a wild cat oil well at Wyoming in Wyoming county. The recorded thickness in the Wyoming well was 70' at a depth of 1270'. Several years following this discovery the first shaft was sunk to the salt horizon at Retsof, New York in Livingston County. Other shafts were opened to the salt horizon in the period from 1885 to 1900, but most of these did not survive. The Retsof mine is still producing and is alleged to be the largest producer of rock salt in the world.

The Salina formation of Silurian age yields all of the salt produced in western New York. Salt horizons within the Salina are found below the Camillus and apparently thicken to the east (Newland, 1919). All of the accumulated data on the salt beds comes from either drill cores or mines and much still remains to be learned of its total organization.

The salt horizons thin and terminate toward Lake Erie and subsurface data indicate that any recovery of salt in Erie County is not likely. Alling (1928) indicated his belief that the salt beds of New York State were probably continuous with those of Ohio, but that the Salina salt of Michigan comes from a different basin. He thus hypothesized at least two major basins of accumulation for the salt and related the genesis of the salt to an upwarping which isolated portions of a shallow saline sea. Recharge of water was believed to be from intermittent contact with the sea and by stream drainage into the saline basin. Evaporation of water from the basin took place under desert conditions but it was never evaporation to completion and Alling appeals to a number of interrupted cycles. Whether accumulation in each of these major areas occurred in a single basin or in numerous isolated basins cannot be defined without further subsurface data. In a later more detailed study, Alling and Briggs (1961) define three distinct evaporite basins separated totally or in part by a massive reef complex which physically isolated them from the sea but allowed saline recharge through intermittent connection with the sea according to the reflux hypothesis.

The rock salt recovered from the New York mines is dark whitish gray and makes up about 95% of the recovery. It is interlayered with and contains isolated pieces of shale, limestone and calcium sulphate which total about 5% of the recovered volume. Although halite is the dominant salt, Alling (1928) indicates occurrences of sylvanite, carnallite, and polyhalite in the overlying and underlying rock units.

Mining at Retsof follows the room and pillar method with the pillars about 30' x 30' in size and spaced about 30' apart. This allows 75% or more removal from the desired horizon. The thickness of individual horizons in the Livingston County area are reported to be from six to twelve feet (Newland, 1919).

Salt has many obvious uses in its natural or purified state and everyone recognizes the importance of household salt, the salt used in agriculture and that used in refrigeration and curing. The use of salt as a raw material in the manufacture of chemical products such as sodium hydroxide, sodium carbonate, sodium and chlorine to mention but a few, and as a chemical in manufacturing processes is often lost sight of however, Much of the rock salt produced at Retsof is shipped directly to the chemical producing plants of the Niagara Frontier.

#### Mineral Consumption

Although the counties of western New York State have long contributed to the economic community in production, the geographic environment of this portion of the state has allowed it to burgeon in the use of mineral products from throughout the world. The Niagara Frontier is that somewhat loosely defined area in western New York which supports so much of the state's industrial wealth.

A complete tabulation of consumption data would be most revealing, but there are certain limitations to such a compilation, the greatest of which is the reluctance of consumers to publicly divulge their annual consumption figures. Over and above this, in addition to the most obvious consumers, the largest industries, there are a great number of local smaller consumers the evaluation of which would take a great deal of time. Therefore, only some of the more interesting and significant statistics are considered here.

Any industrial area requires a great amount of coal and the total annual consumption of coal in the Niagara Frontier must be extremely large. The Huntley Station of the Niagara Mohawk Power Corporation located on the Niagara River just opposite the south end of Grand Island was put into operation in 1916. At that time it was the largest steam generating plant in the United States and it is still the largest of four steam generating plants operated by Niagara Mohawk. Coal is brought to this station by train and lake freighter. In 1964 the consumption of coal at this plant was in excess of 1 1/4 million tons. Power generated at this plant is fed into a giant system and is disseminated throughout the state by the use of computers.



The Niagara Frontier supports several steel manufacturing companies among which the largest are the Bethlehem Steel Corporation's Lackawanna plant and the plant of the Republic Steel Corporation. The Bethlehem plant is the third largest steel manufacturing operation in the world and as such is a major consumer of raw materials. These two companies consumed in excess of 4 million tons of coal in 1964 and Bethlehem's 1965 estimated tonnage of coal consumption is over 3 1/2 million tons.

In addition to this, the steel companies use great quantities of iron ore and the major producer in this area used over 5 1/2 million tons of ore in 1964 with 1965 tonnage estimated to be nearly 1 million tons over this. Limestone and dolomite consumption by Bethlehem is in excess of 1 1/2 million tons annually and fluorite ranges between 7,000 and 10,000 tons, all of which are impressive figures.

The Niagara Frontier supports a large abrasive production industry and in 1964 the tonnage of bauxite consumed was 269,360 tons. This was used in the local production of abrasive alumina grain. Approximately 99% of the tonnage of abrasive grade bauxite coming into the United States is shipped into the Niagara Frontier for processing. Over and above this, large quantities of emery, garnet (mostly from Gore Mountain, New York) and natural abrasive diamonds are brought into this area each year to support producing consumers.

Silicon carbide is another abrasive which has long been manufactured locally. This hard crystalline material has the distinction of being the first man-made abrasive and its occurrence in nature is still debated. It is manufactured in huge electric furnaces from 40' to 50' long which are charged with coke and sand along with some sawdust and salt. These furnaces are brought to 2000°C and held for approximately 36 hours to allow the crystallization of silicon carbide.

Although the above considers some of the major contributions to the consumption of naturally occurring mineral and rock products in this area, it is far from complete. These considerations could be further developed but what is presented here should emphasize the importance of the western New York setting in the total evaluation of certain aspects of economic geology.

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## THE GYPSUM DEPOSITS OF THE SALINA GROUP OF WESTERN NEW YORK

by C. V. Clemency  
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## Introduction

Although New York is the richest state in the Union, its mineral production accounts for only a fraction of the total wealth. Because of this New York is not usually associated with significant mining production. It is not generally known, even by geologists, that New York leads the country in the production of titanium, talc, soapstone, pyrophyllite, emery, abrasive garnet and calcined gypsum, besides being the third largest producer of zinc and salt (Minerals Yearbook, 1962). Significant contributions are made in the production of lead, silver, iron, cement, lime, peat, petroleum, natural gas, stone, sand and gravel. New York ranked approximately eighteenth among the states in the production of total mineral wealth.

## Gypsum Mining in New York

One of the least known of these mineral products is gypsum, which is produced only in the western part of New York from the Salina Group of late Silurian (Cayuga) age. Only five gypsum mines are now operating in New York, three in Erie County, and one each in Genesee and Monroe Counties. All are underground operations, working at shallow depths ranging between 30 and 60 feet below the surface. The three mines in Erie County are located about 15-20 miles due east of the city of Buffalo; two are near the town of Clarence Center and the other near Akron. The Bestwall Gypsum Division of the Georgia-Pacific Corporation operates the mine at Akron and manufactures plaster of Paris, which is processed into plaster wall board, lath and other finished building products. The National Gypsum Company operates a mine at Clarence Center which also produces gypsum for manufacturing building materials. The Universal Atlas Cement Division of the U. S. Steel Corporation produces mostly raw gypsum for use as a retarder in Portland cement at its Clarence Center plant. Near the town of Oakfield in Genesee County, the U. S. Gypsum Company produces gypsum for conversion into plaster building products, as does the Ruberoid Company in Monroe County at the town of Wheatfield.

The gypsum is mined by room and pillar methods from a 4 foot thick [about 3-1/2 to 4-1/2 foot thick] layer of gypsum which is interbedded between limestone layers. The room and pillar technique leaves pillars of gypsum about 30 feet square standing to hold up the roof while 30-foot squares around the pillar are removed. This permits recovery of about 75% of the gypsum. Because the workings extend under the towns and adjoining valuable farm lands, the pillars are not removed later as is often done in coal mining.

After the gypsum rock is blasted, it is loaded into electric shuttle cars, then transferred to mine cars which convey the gypsum to the primary crusher. The coarsely crushed rock is taken to the surface by bucket where it is further crushed and delivered to large calcining kettles where the dihydrate of calcium sulfate is converted to the hemihydrate,  $\text{CaSO}_4 \cdot 1/2 \text{H}_2\text{O}$ , known as plaster of Paris or "stucco". From the calcining kettles the plaster is sent to storage and later either bagged as plaster or processed into finished building products of which plaster wall board comprises by far the greatest volume.

The wall board is made in a continuous process on large machines. The plaster is mixed with water, spread on a sheet of paperboard which is fed from giant rolls, passed between rollers which squeeze the plaster to the desired thickness, and a second layer of paperboard placed on top. The "sandwich" is then carried along a conveyor belt at such a speed that by the time the end is reached, the plaster has set. The continuous sheet is cut to length, edges are bound and the boards are conducted through a continuous drying oven. The wall-board moves along these conveyors at a speed about equal to a rapid walk, and the machines run 24 hours a day. On emerging from the oven they are thoroughly dry and are ready for shipment. Other machines make the lath and block by automatic casting in molds.

#### History of Gypsum in New York State

The first discovery of gypsum in the United States occurred in 1792, near the town of Camillus, New York, a few miles west of Syracuse, followed shortly by discoveries to the east near Chittenango, New York (Newland, 1929; Withington and Jaster, 1960). These deposits were brought into commercial importance during the War of 1812 when Nova Scotia gypsum supplies were cut off. Later, the low cost transportation available in the Erie Canal led to the opening of markets along the Hudson Valley and shipments were made as far as Philadelphia. Almost all the early production was used in agriculture as a fertilizer, providing needed sulfate to the soil. In 1835 gypsum was first calcined (dehydrated) in small quantities in the U. S. It was used for making figurines which were cast, painted and sold on the spot by itinerant peddlers. These figurines, the most famous of which are called the "Rogers' Group", achieved great popularity, rivaling the lithographs of Currier and Ives, and are now highly valued by antique collectors.

By 1838, when the first geological survey of N. Y. was under way, gypsum quarries had been established in Monroe, Ontario, Cayuga, Onondaga and Madison Counties. The yearly production at that time was estimated at 50,000 tons.

Because pure gypsum plaster sets in only 5 or 6 minutes, it was not much used for interior wall and ceiling coatings; builders preferred to use lime instead. However, in 1888, it was discovered that the

addition of animal glue retarded the setting to a more practical length of time. Soon, by proper mixing of additives, plaster with any setting time between 5 minutes and 5 hours was made available. In 1892 the first large scale calcining plant in New York was built for the manufacture of plaster of Paris. This product soon displaced lime in the construction industry and by the turn of the century almost all interior walls and ceilings were being coated with gypsum plaster. Since 1890 the value of gypsum products has increased from \$412,000 to almost a half billion dollars a year in 1965.

### Occurrence

In New York State, workable deposits of gypsum occur only in the Salina Group (old "Onondaga salt group" of early writers) of evaporite deposits formed during late Silurian (Cayugan) age. The large salt production of New York also comes from the Salina Group. The type locality is in the vicinity of Syracuse, New York, formerly known as Salina (Buehler and Tesmer, 1963). Near Syracuse the Salina includes three formations, the Vernon shale (oldest), the Syracuse formation, and the Camillus shale (youngest). Only the Camillus is found in western New York where the thickness is about 400 feet; the thickness increases to the east. The Camillus in western New York is largely shale with intermittent thin layers of limestone, gypsum and anhydrite. Outcrops are rare and contacts with the overlying Bertie formation and underlying Lockport formation are few and difficult to define.

The outcrop belt of the Salina group (see map in Newland, 1929, fig. 3) extends from Madison County, near Albany, westward to the Niagara River and well into Ontario. It also extends from Albany southward along the west side of the Hudson River into New Jersey. The outcrop area of the Salina beds is represented by a topographic depression across the state, with few outcrops visible. The beds dip gently to the south at the rate of 20 to 50 feet per mile. Gypsum is present from Herkimer County in the east into Ontario to the west. In only a few places are the gypsum beds of sufficient thickness and purity to justify mining at present. A drill hole in the Buffalo area penetrated three beds of gypsum 4, 2 and 4 feet thick, respectively, at a depth of about 35 feet. They are of high quality and remarkably uniform in thickness. When traced eastward, these gypsum beds thicken to about 30 or 40 feet but become more impure and more discontinuous, occurring as pods or lenses.

### Origin

The gypsum is thought by Newland (1929) and by most later workers to be an alteration product of anhydrite, although Dana and Grabau favored the theory of alteration of limestone beds by acid sulfate water. The latter theory is not generally accepted for extensive sedimentary beds of gypsum. Below a cover of about 100-150 feet, only

anhydrite is found in the Camillus shale. It appears (Newland, 1929) that ground-water has caused the hydration of the uppermost portions of anhydrite beds to form gypsum. Below depths of 100-150 feet no gypsum is found when the beds are traced southward down dip. It is apparently not possible, therefore, to add to future supplies of gypsum by simply following extension of the beds at depth. As of 1951, reserves of gypsum in western New York were estimated at 66 million tons, although some producers refuse to give any information at all about their operations or reserves. The actual amount is undoubtedly greater.

Although gypsum is sometimes found associated with ore deposits where it has evidently formed by the action of sulfate-bearing waters on calcium carbonate, by far most gypsum and anhydrite is found as sedimentary deposits interbedded with other sedimentary rocks. Gypsum and anhydrite are classified among the evaporites, the rocks formed by the deposition of the salts which were once dissolved in sea water. Many authors have studied the origin, significance and mechanism of formation of evaporite deposits (see Withington and Jaster, 1960). It is the consensus of modern opinion that evaporite deposits form when a portion of the sea is isolated, as in restricted lagoons or embayments, where high rates of evaporation and a continuous inflow of sea water to replace that evaporated, cause a gradual increase in salinity. Eventually, the water will become saturated with the various components in solution, and precipitation will occur.

Actual crystallization of a natural brine is very complex, and depends not only on the solubility of the salts involved, but also upon the concentration of the salts present, the temperature of the solution, material brought in by feeder streams, intermittent replenishment by sea water, climatic change, etc. Hence, many exceptions are known to the ideal sequence or order of precipitation, which is believed to be iron oxide, calcium carbonate, calcium sulfate, sodium chloride, magnesium salts, and lastly potassium salts (Pettijohn, 1957).

Sea water contains about 3.5% of dissolved solids, of which 3.6% is calcium sulfate. This means that to produce a four foot thick bed of gypsum, as is found in western New York the equivalent of about 8,000 feet of sea water would have to be evaporated.

Departures from a normal evaporation cycle are common in the geologic column. A common deviation is alternating beds of limestone and gypsum and shale, indicating intermittent replenishment of sea water and inflow of clastic sediment, seldom reaching the stage where the original volume is reduced to 1/10 at which point salt would be deposited.

One of the puzzling problems of gypsum-anhydrite formation is the difficulty of determining which formed originally or if one form has inverted to the other. It is well known that gypsum can be dehydrated at low temperatures to form anhydrite and that anhydrite can form gypsum by taking up water. Experiments by MacDonald (1953) on the

equilibrium relations between gypsum and anhydrite in pure water and brine solutions lead to a clear picture of the reasons why either gypsum or anhydrite or mixtures of the two can form under natural conditions.

Below 40° C gypsum is the stable phase in the presence of pure water and above 40° C anhydrite is the stable form at 1 atmosphere. In a buried deposit, then, if the temperature goes above 40°C, gypsum will dehydrate to form anhydrite. An increase in pressure lowers the dehydration temperature 1°C for every 40 bars. At a pressure of 500 bars, the dehydration temperature is 270C.

If the water in contact with the gypsum is not pure, but is a brine containing about 29% NaCl (saturated brine contains about 36% NaCl at 20° C), the equilibrium temperature is reduced to 21°C. At temperatures below 21° C, gypsum is deposited. The greater the amount of salt in solution, the lower the transition temperature between gypsum and anhydrite. Normal sea water contains about 1.26 parts per thousand of calcium sulfate. In an environment of saturation, where the sea water has a chlorinity of 65 parts per thousand, gypsum will precipitate from sea water below 34°C, and anhydrite above 34° C. Pressure has little effect on this temperature, the effect of the salt concentration being predominant. As an example, the following history is given. At 25° C, salts are concentrated until the chlorinity reaches 65 parts per thousand. At this point gypsum is precipitated. In addition, gypsum that is in contact with sea water of chlorinity above 113 parts per thousand will be unstable and break down to form anhydrite. In saturated NaCl solutions, gypsum will precipitate only at temperatures below 14° C. The maximum depth in the earth at which gypsum will be found is controlled by the temperature gradient over a region, the composition of the water and the ratio of hydrostatic to lithostatic pressure.

Thus, it can be seen that either gypsum or anhydrite or both can be precipitated from sea water, given the proper temperature and/or composition. In addition, one form can invert to the other should conditions change. Scruton (1953), Sloss (1953), Douglas and Goodman (1957) and Pettijohn (1957) give excellent detailed discussions of the formation of evaporite deposits and their relation to climate, salinity, temperature of formation, and mechanism of reflux between the restricted basin and normal sea water (MacDonald in Withington and Jaster, 1960).

#### Uses of Gypsum

Today gypsum has three major uses and a score of minor ones. The major applications are in the manufacture of plaster building products, as a fertilizer in agriculture, and as a retarder in Portland cement. Some minor uses include: the manufacture of toothpaste, face powder, paint, rubber, sulfuric acid (in Europe), fireproofing, acoustical tiles, wine and beer. It is also used to make molds and casts for bathroom fixtures, dental plates, dinnerware and in the arts.

## Production

Today raw gypsum is produced in the U. S. at the rate of about 10 million tons per year, valued at \$127 million in the raw form. Of this, about 8.8 million tons are calcined into plaster and fabricated into construction materials valued at \$327 million. New York produced more calcined gypsum than any other state, its share amounting to 1,153,000 tons valued at about \$115 million (Minerals Yearbook, 1962).



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TECHNICAL SESSION

NEW YORK STATE GEOLOGICAL ASSOCIATION

Titles

Authors

Abstracts

Time of Presentation



Time: 2:00 P.M.

PETROLOGY AND STRUCTURE OF PRECAMBRIAN CRYSTALLINE ROCKS  
RUSTIC QUADRANGLE, MUMMY RANGE, COLORADO

Paul W. Kirst  
State University of New York at Buffalo

ABSTRACT

A study of the Precambrian metamorphic rocks in the southern half of the Rustic Quadrangle of the Mummy Range, Colorado, indicates that the gneiss and schists are dominantly of sedimentary origin. During metamorphism, these rocks attained the rank of sillimanite-almandine-orthoclase subfacies of the almandine amphibolite facies. The biotite-sillimanite schist contains lenses of amphibolite gneiss and calc-silicate gneiss rich in diopside, pistacite and grossularite which reflect calcium concentrations in the original pelitic sediments. These metasediments may be correlative with the Idaho Springs formation.

In the southwestern half of the study area, the metamorphic rocks are engulfed and locally permeated by granite which may be correlative with the Silver Plume granite. In the northeast, the metamorphic rocks are interfingering with granite which is believed to be a variety of the Silver Plume granite known as the Log Cabin granite.

Rhyolite porphyry occurs in several lens-like bodies concordant with the regional structure and may be of late Precambrian age. Rhyodacite porphyry occurs as an irregularly shaped volcanic plug of probable Tertiary age.

Long narrow discordant bodies of anthophyllite-cordierite-almandine gneiss are the result of magnesian metasomatism of Precambrian silicic dikes in contact with the granitic magma.

An early deformation caused the development of regional foliation in the metamorphic rocks and the folding of a long narrow unit of hornblende gneiss. The axial planes of this folded unit are concordant with the regional foliation. This unit is cross-cut by granite which is believed to have been emplaced along weakness planes defined by planar anisotropy of the metamorphic rocks. A final deformation produced vertically plunging folds of larger amplitude throughout the area.

Time: 2:15 P.M.

THE PANAMA CONGLOMERATE OF CATTARAUGUS  
AND CHAUTAUQUA COUNTIES, NEW YORK

William H. Miller  
State University of New York at Buffalo

ABSTRACT

A sedimentological study was made of the Panama conglomerate (Upper Devonian) in Cattaraugus and Chautauqua Counties, New York. Analysis of the data indicates the following preliminary conclusions:

Cross-bedding sets vary in thickness from six inches to three feet. Preliminary analysis of the vectorial properties indicates a direction of current flow from the south-east.

Average mean size of the Panama conglomerate is  $0.11 \phi$  units, with a range of  $-1.22 \phi$  to  $2.21 \phi$  units. Mean size decreases slightly from the base to the top. The average sorting coefficient is 1.38 (poorly sorted), with a range from 0.98 to 1.93. Sorting decreases from the base to the top due to a greater influx of the sand mode.

The Panama conglomerate in most cases exhibits positive skewness values, the average being 0.32 (very positively skewed). The range of skewness values is  $-0.54$  to  $0.59$ . Positive skewness values indicate an excess of fine size material, represented as tails of a normal curve. Kurtosis values ranged from 0.89 to 1.40 with a mean of 1.24 (leptokurtic).

The Panama consists of predominantly disk and rod-shaped quartz pebbles that are very well rounded. Occasional jasper and quartzite pebbles are also present. The matrix of sand, notably in the  $-1.0 \phi$  to  $1.0 \phi$  size, is predominantly sub-angular.

Heavy minerals consist of the following minerals in decreasing order of abundance: leucoxene, probable kyanite, tourmaline, magnetite-ilmenite, zircon, pyrite, hematite-limonite and accessory garnet, staurolite, epidote, sillmanite, rutile, hypersthene, kyanite, hornblende andalusite, and apatite. The dominant suite indicates a source from reworked sediments and/or metamorphics.

Time: 2:30 P.M.

DEPOSITIONAL ENVIRONMENT OF THE PARRISH LIMESTONE  
(LATE DEVONIAN) NEW YORK

William T. Kirchgasser  
Cornell University  
Ithaca, New York

ABSTRACT

The Parrish limestone is a lentil 3-15 inches thick in the lower Cashaqua shale (Chagrin Phase; Frasnian) extending 25 miles southeast from Canandaigua Lake to Seneca Lake. Petrographic analysis reveals a burrowed heterogeneous matrix of sparse biomicrite, fossiliferous micrite and clay, with nodules of fossiliferous micrite. The matrix is commonly truncated or scoured near the top of the Parrish and overlain by thin current-reworked fossiliferous lenses of packed biomicrite and poorly washed biosparite. These lenses accumulated in relatively agitated water during times of low terrigenous deposition.

From its northwestern outcrops in the vicinity of Canandaigua Lake, the Parrish changes in facies southeastward from a dark red and green stylolite-cephalopod limestone to a thicker, light gray, more impure nodular stylolite-crinoidal limestone in the Keuka Lake area. Accompanying this change, the Cashaqua thins and the Parrish horizon, the top of the Rock Stream siltstone (underlying Cashaqua), and the base of the Rhinestreet shale (overlying Cashaqua) converge toward the central Keuka Lake area. Here the water was shallower and more agitated than in the surrounding areas; the rate of accumulation of the Cashaqua sediments was lower and the degree of current and infaunal reworking of the Parrish sediment was more intense.

The facies relations suggest that the Parrish limestone and Cashaqua shale accumulated over a broad submarine swell on the Rock Stream siltstone that crested in the central Keuka Lake area. The depositional environment is analogous to the deep Schwelle (swell) environment that produced Late Devonian cephalopod limestone similar to the Parrish (Kramenzelkaike) in the off-shore condensed successions of the Rhenish Mountains, Germany.

Time: 2:45 P.M.

AN ALTERNATIVE METHOD FOR THE COLLECTION OF  
MATERIAL FOR HEAVY MINERAL STUDIES

Christopher B. Gunn  
University of Western Ontario  
London, Canada

ABSTRACT

In the course of prospecting for diamonds in West Africa the writer devised a simple method of collecting large amounts of heavy minerals in the field quickly, cheaply and easily, and has applied the system successfully to drift sampling in the United States. Field concentration has three main advantages over laboratory separation only. 1) It obviates the need to carry large amounts of material back to the laboratory; 2) it enables the geologist to gain a preliminary idea of his findings in the field so that he can use his time in the field more effectively; 3) it provides more heavy mineral concentrate for study which is more likely to be representative, since much larger samples can be taken in the field.

The method consists essentially of wet screening the sample in specially constructed sieve-boxes and collecting the minus 32 mesh material in a pan below water. This is then panned, observing a number of simple precautions, while the larger fractions are jigged in a way used by diamond washers to produce a heavy concentrate. The field product is a semi-concentrate which is then separated in the laboratory with heavy liquid in an open dish.



Time: 3:00 P.M.

PETROLOGY OF THE POUNDRIDGE LEPTITE

Peter Lessing  
Syracuse University  
Syracuse, New York

ABSTRACT

Detailed geological mapping and extensive chemical and petrographical analyses have been completed on the Poundridge leptite in Westchester County, New York. Structural data indicate that the leptite is concordant with the surrounding Fordham gneiss. Concordant and intercalated contacts support the idea that the Fordham gneiss and Poundridge leptite are integral stratigraphic sequences in the New York City group. The entire area is now in the sillimanite zone of regional metamorphism.

The leptite is a K-feldspar - plagioclase - quartz - biotite gneiss with perthite dominant in the medial zone and microcline dominant near the periphery. Except for the K-feldspar, no petrographic or chemical variation exists across the leptite. The leptite is also similar to granitic layers in the Fordham. The Poundridge leptite is interpreted to be the result of anatexis of pre-existing sedimentary units. However, petrological data would also support a varied choice of schemes for the enigmatic origin of granitic rock. The correlation of the Poundridge leptite with the Yonkers granite is doubtful, since they are distinctly different petrographically and are not correlated by field evidence.

Time: 3:15 P.M.

THE ORIGIN OF GLACIO-FLUVIAL AND ICE MARGINAL FEATURES  
IN THE CLINTON-ORISKANY FALLS AREA, CENTRAL NEW YORK

Jay D. Murray and W. Scott Baldrige  
Hamilton College  
Clinton, New York

ABSTRACT

In the Oriskany and Stockbridge valleys and on adjacent highlands no evidence for extensive lakes has been found. Instead the character and abundance of meltwater channels along the northern scarp of the Appalachian Plateau indicates that during the latest retreat an integrated ice-marginal drainage system existed with only local ponding and attendant delta building.

The Valley Heads moraine in both the Stockbridge and Oriskany valleys is a complex of kames and outwash plains, with little or no till. Evidence strongly suggest that the greater part of the drift came not from the ice tongues occupying the valleys, but from outwash deposited against and over these stagnant and fractured tongues by meltwater from adjacent ice-covered highlands and valleys. Perhaps for this reason the Valley Heads moraine is invariably found in the valleys, for although ice covered the highlands, the bulk of the moraine formed in the lowlands where meltwater was funneled and deposited its load.

Drumlins and drumlinoid hills on the outwash plain north and north-east of Waterville suggest that at one time the Mohawk Lobe reached a position at least as far west as the eastern edge of the Oriskany valley. The presence of a Valley Heads-type kame and kettle moraine in the Saquoit valley several miles to the east, within the area once covered by the Mohawk ice, may indicate that the Mohawk Lobe was pre-Valley Heads time.

Time: 3:30 P.M.

RESTUDY OF CERTAIN RHYNCHONELLIDS OF THE  
NEW YORK FRASNIAN: A PRELIMINARY REPORT

Jonathan W. Harrington  
Cornell University  
Ithaca, New York

ABSTRACT

Study of collections from the Big Bend and Smethport depositional phases, as well as materials from the extensive collections at Cornell University, indicates the need for more precise generic definition of certain forms. The internal structure of several forms preserved in coquinite layers has been determined by serial sectioning.

A species occurring in a sandy coquinite stratum in the lower Ithaca formation near Scott, New York, shows affinities with two species from western Canada, Leiorhynchus castanea (Meek) of the Givetian and L. carya (Crickmay) of the Frasnian. L. mesacostale (Hall) from the Ithaca formation at Ithaca, New York, lacks dental plates, and the validity of the generic designation is questionable. Specimens from a coquinite layer in the Cayuta shale at Owego, New York, previously described as Camarotoechia congregata (Conrad), are, on the basis of internal structures and external features, considered to be of a distinct genus, probably intermediate between Cupularostrum Sartanaer of the Givetian and Ptychomaletochia Sartanaer of the Famennian.

Preliminary results of this study of the taxonomy, morphologic variation, and distribution of the Frasnian rhynchonellids in New York indicate that what have previously been considered as a number of species with variable external expression may be a group of genetically related species with well defined specific characteristics and limited stratigraphic ranges. Furthermore, elements of the rhynchonellid zonation in Western Canada as worked out by McLaren, Sartanaer, and others may be applicable to the Upper Devonian of New York.

Time: 3:45 P.M.

SHEAR STRENGTH EVALUATION OF SENSITIVE LAURENTIAL CLAY VIA  
UNCONFINED COMPRESSION, FALL-CONE AND VANE SHEAR TESTS

Thomas Summerlee  
Clarkson College of Technology  
Potsdam, New York

ABSTRACT

Three types of laboratory tests utilized to determine the shear strength of cohesive soils are the unconfined compression, fall-cone and laboratory vane tests.

The testing apparatus and laboratory procedures associated with each of these three methods of shear strength evaluation have their own advantages and disadvantages.

A series of twenty-five shear strength evaluations each were conducted utilizing the unconfined compression, fall-cone and laboratory vane test procedures. These tests were performed on "undisturbed" 3-inch tube samples of sensitive Massena (Leda) Clay obtained from the north bank of the St. Lawrence Seaway Canal, downstream from Snell Lock. Massena clay is a sensitive, slightly preloaded marine silty-clay commonly found in and adjacent to the St. Lawrence River Valley.

Statistical methods were used to analyze and compare the results of the shear tests evaluated by the three methods. Correlations were made between the shear strength and the natural water content, liquid limit, plastic limit and the non-homogeneous peculiarities of the various clay samples tested.

Time: 4:00 P.M.

X-RAY STUDY OF SEDIMENTARY PYRITE OF WESTERN NEW YORK

John E. Izard  
State University of New York at Buffalo

ABSTRACT

X-ray examination of a large number of iron sulfide samples collected from the sedimentary rocks of western New York showed the presence of only pyrite although some of this material has long been referred to in the literature as marcasite. Grinding experiments attempting to cause an inversion of marcasite to pyrite in the manner described by Anderson and Chesley (1933) were unsuccessful and it is believed that no such inversion by grinding occurs for these polymorphs. A few experiments in the synthesis of pyrite under sedimentary conditions are described and the possible role of organic decay products such as the amino acid cystine is discussed.

Time: 4:15 P.M.

A GROUND MAGNETIC STUDY OF THE PLATTSBURGH,  
NEW YORK GRAVITY ANOMALY

G. Myer and F. Tallman  
State University College  
Plattsburgh, New York

ABSTRACT

The Plattsburgh gravity anomaly, one of four along a NW line (Simmons, 1964) was studied by ground magnetics. Data from 234 stations revealed a 3000  $\gamma$  anomaly. The anomaly was reproduced from a model of vertical cylinders at depths of 0.45 to 1.9 miles. The source is presumably a vertical plug of irregular plan with susceptibility contrast of about  $2.5 \times 10^{-2}$  c.g.s. Shape, possible rock type, and distribution of the line of anomalies are roughly comparable with the Monteregian Hills, but the depth is greater. Irregularities in the basement surface account for part of the anomaly, but the major body does not reach this level.

References:

- Diment, W. H. (1966, Pers. Comm.) Dr. Diment originally suggested the similarity of the anomalies to the Monteregian Hills.
- Simmons, G. (1964) Gravity survey and geological interpretation, Northern New York. G.S.A. Bull. v. 75, pp. 81-98.

Time: 4:30 P.M.

SEISMIC REFLECTION PROFILING AT SEA

Bruce F. Molnia  
Harpur College  
Binghamton, New York

ABSTRACT

Seismic reflection profiling is one of the newest and most practical methods available to the oceanographer that permits study of the bottom and sub-bottom to as much as 4,000 fathoms. The methods and interpretation are described.

TRIP A: SILURIAN STRATIGRAPHY OF WESTERN N. Y.

LEADERS: Edward J. Buehler and William J. Kilgour

DATE: April 30, 1966, 8:30 A.M.

ROAD LOG

Time: approximately 10 hours

Total mileage: 115

TIME SCHEDULE: The large enrollment for this trip will probably necessitate two sections, the second of which will follow a different schedule.

Leave Treadway Inn . . . . . 8:30 A.M.  
 Arrive Decew Generating Station. . . . . 9:30 A.M.  
 Leave Decew Generating Station . . . . . 10:30 A.M.  
 Arrive Power Vista . . . . . 11:30 A.M.

Lunch and View exhibits

Descent into gorge . . . . . 12:45 P.M.  
 Leave Power Vista. . . . . 2:00 P.M.  
 Arrive Lockport. . . . . 3:00 P.M.  
 Leave Lockport . . . . . 3:45 P.M.  
 Arrive Akron . . . . . 4:15 P.M.  
 Leave Akron. . . . . 5:00 P.M.  
 Arrive Treadway Inn . . . . . 6:30 P.M.

MILEAGE SCHEDULE:

Miles from  
last point

Description

0.0	Leave Treadway Inn; turn left at Buffalo Avenue.
0.2	Left on Robert Moses State Parkway.
4.3	Arrive Niagara Falls; Continue on Parkway.
1.6	Pass Whirlpool park.
1.6	Pass Power Vista; follow road marked South-Canada.
1.1	Take route marked Canada.
0.7	Cross New Queenston Bridge; toll gate and customs; straight ahead on #405; toll gate on bridge over Welland Canal.
9.6	Turn off (left) at Ontario St. exit.
1.9	Cross St. Paul St. (Rt. 8); continue on South Drive.

<u>Miles from last point</u>	<u>Description</u>	
0.1	Turn right on Glen Ridge.	
1.7	Turn right at Brock University; continue to DeCew Generating Station	
1.0	STOP 1. Refer to papers by Fisher (p. 1), Kilgour (p. 10), and Zenger (p. 19). The following stratigraphic column for DeCew Falls is taken from Bolton, 1949.	
0 - 12	<u>Dolomite</u> , light grey dense nodular, weathering buff to white.	Lockport
12 - 25	<u>Dolomite</u> , as above, but with abundant nodules of chert.	Ancaster
25 - 56	<u>Limestone</u> , coarsely crystalline and porous, or sandy, with thin shale interbeds.	Gasport
56 - 64	<u>Dolomite</u> argillaceous to sandy, calcareous, dark grey, weathering buff to tan.	DeCew
64 - 120	<u>Shale</u> , fissile, green-grey to dark grey.	Rochester
120 - 127.5	<u>Limestone</u> , pink to dark grey, coarsely crystalline, crinoidal.	Irondequoit
127.5 - 134	<u>Limestone</u> , <u>dolomitic</u> , dense, light grey; top 0.5' sandy.	Reynales
134 - 142	<u>Limestone</u> , dense, light grey, massive, with thin sandy partings	Reynales
142 - 143	<u>Shale</u> , greenish grey to dark grey.	Neahga
143 - 148	<u>Sandstone</u> , fine grained, massive, white to light grey, with a few thin shale partings.	Thorold
148 - 148.5	<u>Shale</u> , dark grey.	Grimsby
148.5 - 152	<u>Sandstone</u> , as above	Grimsby
152 - 183	<u>Sandstone</u> , fine grained, red mottled with green, with interbedded red shale.	Grimsby



Miles from  
last point

Description

183 - 194	Shale, red and green, with minor beds of red sandstone.	Grimsby
194 - 242	Shale, dark grey to green, calcareous, with beds of sandy shale and light grey calcareous sandstone.	Power Glen
242 - 254	Sandstone, quartzose, white to light grey, massive to thick bedded with small scale cross-bedding. Thin zones of grey shale pebbles (intraformational conglomerate).	Whirlpool
254 -	Shale, brick-red with 0.3' of light green shale at top.	Queenstone

Leave DeCew Generating Station.

- 1.0 Turn left at Brock University (Glen Ridge Ave.).
- 1.7 Turn left at South Drive.
- 0.1 Turn right at St. Paul Street; left at William Street; left again.
- 0.2 Right onto Ontario Street, follow QEW signs.
- 1.7 Turn right onto QEW.
- 5.6 Take Rt. 405 - Queenstone Bridge to U.S.A.
- 5.0 U.S. Customs at Bridge; turn right at #104; follow #104 west.
- 1.2 Turn left at Power Vista.

STOP 2. Lunch. Examination of exhibits at Power Vista. Following is the stratigraphic section here. See papers by Fisher (p. 1), Kilgour (p. 10), and Zenger (p. 19), for details.

Eramosa	20'
Goat Island	19
Gasport	27.5'
DeCew	8'
Rochester	68'
Irondequoit	26'
Reynaies	8'
Neahga	6'
Thorold	7'
Grimsby	52'

Miles from  
last point

Description

Cabot Head, etc.	36'
Whirlpool	25'
Queenston	100' exposed

Leave Power Vista; turn right on #104 East.

1.6 Descend Niagara escarpment; follow 104E.

1.0 Turn left; continue of 104.

13.5 Arrive at junction with #93 (Warrens Corners); turn right.

2.0 Ascend Niagara escarpment.

0.6 Lockport dolomite outcrop.

0.5 Intersection; continue straight on 270.

1.6 Cross Rt. 31.

0.4 Turn left on Hinman Road.

2.1 Junction with Bear Ridge Road.

0.3 Enter Frontier Crushed Stone Quarry.

STOP 3. The following units of the Lockport are exposed here. See paper by Zenger (p. 19) for details.

Goat Island	24'
Gasport	29.5'
DeCew	8.5'

Leave Frontier Crushed Stone Quarry; turn left; bear right over bridge.

0.8 Cross Transit Road #78; continue ahead on Lincoln Road.

2.2 Turn right on Rt. 93; continue on 93 through Akron.

15.7 Turn left at Akron Park (Parkview Drive).

0.4 Turn right.

0.6 Park at Akron Falls.

Miles from  
last point

Description

STOP 4A. The following members of the Bertie dol. are exposed at the falls. See paper by Rickard (p. 24) for further details.

Scajaquada	8'
Falkirk (the massive Member)	20'
O-atka	20'

The reentrant of the base of the falls is identified as the top of the Camillus Shale.

STOP 4B. About 1/4 mile upstream from the falls. The Units here are:

Nedrow member of Onondaga	about 6'	exposed
Edgecliff member of Onondaga	5'	
Siluro-Devonian unconformity		
Akron dolostone	8'	
Williamsville member of Bertie	6'	

See papers by Rickard (p. 26), and Oliver (p. 32) for details.

Leave Akron Falls

- |     |  |
|-----|--|
| 0.6 | Turn left on Parkview Drive.   |
| 0.5 | Turn left on #93.  |
| 1.0 | Turn right on Rt. 5.   |
| 8.0 | Junction with 324 (Sheridan Dr.); straight ahead on Rt. 5.                     |
| 6.2 | Right turn on Youngman Highway, (290); Use through traffic rt. (290).          |
| 8.0 | Take 190 North - Niagara Falls.  |
| 0.8 | Grand Island Bridge toll booth; Cross East River onto Grand Island.            |
| 5.3 | North end of Grand Island; cross bridge onto mainland; bear right (N. Y. 384). |
| 0.5 | Arrive Treadway - End of trip.   |

TRIP B: UPPER DEVONIAN N.Y.S.G.A. FIELD TRIP

LEADER: Dr. Irving H. Tesmer

DATE: April 30, 1966

See papers by Tesmer (p. 47) and Buehler (p. 44) for stratigraphic details.

ROAD LOG

Time: approximately 9 hours

Total mileage: 136.5

MILEAGE SCHEDULE:

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
0.0	0.0	Leave Treadway Inn, Niagara Falls, New York at 8:30. Turn left on Buffalo Avenue, west on N.Y. 384.
0.4	0.4	Turn left on Interstate 190; south on Interstate 190 over North Grand Island Bridge.
6.5	6.1	Cross South Grand Island Bridge.
8.1	1.6	Junction with Interstate 290 (Youngman Highway); continue south on Interstate 190.
10.5	2.4	Enter city of Buffalo
12.7	2.2	Junction with N.Y. 198; continue south on Interstate 190.
14.1	1.4	Observe Onondaga Limestone to left (Buffalo NW quad)
14.3	0.2	Drive under Peace Bridge to Canada.
16.7	2.4	Junction with N.Y. 5; south on N.Y. 5 over Skyway Bridge.
19.5	2.8	Cross Father Baker Bridge
20.3	0.8	Leave city of Buffalo, enter city of Lackawanna.
22.3	2.0	Leave city of Lackawanna, enter village of Woodlawn.
24.2	1.9	Junction with N.Y. 75; continue southwest on N.Y. 5.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
25.8	1.6	STOP 1. Hamburg Park (Buffalo SE quad); exposures of Ledyard and Wanakah; depart 9:45.
28.5	2.7	Turn right on Lakeshore Rd.; southwest on Lakeshore Road.
31.7	3.2	Bridge over Eighteen-mile Creek.
31.9	0.2	Turn right at Home of Piarist Fathers  STOP 2. Arrive 10:00. Home of Piarist Fathers (Eden quad); exposures of Wanakah, Tichenor, Windom, Genundewa and West River; depart 11:00. Return northeast on Lakeshore Road.
32.3	0.3	Junction with N.Y. 5; continue east on Eighteen-mile Creek Road.
33.1	0.8	New York Central Railroad Bridge.  STOP 3. Arrive 11:15. Follow path to left along west side of railroad to banks of Eighteen-mile Creek (Eden quad); observe exposures of Cashaqua and Rhinestreet; depart 11:30.
33.9	0.8	Church Parking Lot  STOP 4. Walk 0.2 miles further east along Eighteen-mile Creek Road to U.S. 20 and then to bridge over Eighteen-mile Creek (Eden quad); observe exposure of Rhinestreet; depart 12:00.  Return west on Eighteen-mile Creek Rd. to Lakeshore Road.
35.8	1.9	Turn left on Lakeshore Road; continue southwest on Lakeshore Road.
37.8	2.0	Junction with Sweetland Road; continue straight ahead on Lakeshore Road.
40.3	2.5	Junction with Dennis Road; continue straight ahead on Lakeshore Road.
41.8-43.0	1.5	Observe prominent sand ridge to right (Angola quad).
46.5	4.7	Turn right into Evangola State Park.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
47.1	0.6	Evangola Parking Lot  STOP 5. Arrive 12:30. Evangola State Park (Farnham quad); lunch and rest stop; exposures of Angola Shale; depart 1:30.  East on Evangola Park Road
48.7	1.6	Turn right on N.Y. 5; southwest on N.Y. 5.
49.3	0.6	Junction with N.Y. 249, Farnham, N.Y.; continue on N.Y. 5.
51.4	2.1	Junction with U.S. 20.  STOP 6. Arrive 1:45. Niagara Trading Post and bridge over Cattaraugus Creek (Farnham quad); observe Angola Shale and preglacial course of Allegheny River; depart 2:00.  Continue southwest on U.S. 20 and N.Y. 5.
54.1	2.7	Continue straight ahead on U.S. 20.
54.5	0.4	Enter village of Silver Creek, New York
55.1	0.6	Turn left at stop light in center of village; continue on U.S. 20.
55.4	0.3	Junction with N.Y. 428; continue on U.S. 20.
55.5	0.1	Bear right on Main Street.
55.6	0.1	Turn right on Ward Avenue.
55.7	0.1	Turn right on Parkway.
55.8	0.1	STOP 7. Arrive 2:15. Walnut Creek (Silver Creek quad); exposures of Angola, Pipe Creek and Hanover; depart 2:45.  Return to center of Silver Creek village via same roads.
56.5	0.7	Turn left on Central Avenue at stoplight in center of village of Silver Creek; this becomes N.Y. 5.  Southwest on N.Y. 5.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
57.7-62.4	1.2	Observe various exposures of Hanover Shale Lake Erie cliffs to right (Silver Creek and North of Dunkirk quads).
64.6	6.9	Enter city of Dunkirk.
65.9	1.3	Junction with N.Y. 60; continue west on N.Y. 5.
67.0	1.1	Turn right on Point Drive North.
67.9	0.9	Point Gratiot Park (Dunkirk quad).  STOP 8. Arrive 3:15. Exposures of Dunkirk Shale; depart 3:30.  Continue along Point Drive to N.Y. 5.
68.5	0.6	Turn left on N.Y. 5; return east on N.Y. 5.
69.6	1.1	Turn right on N.Y. 60; south on N.Y. 60.
71.8	2.2	Turn left, enter Interstate 90 (Dewey Thruway) at Interchange #59; northeast on Interstate 90 toward Buffalo.
76.1	4.3	Observe abandoned lake beach to right, associated with glacial Lake Warren at Sheridan, New York (Dunkirk and Forestville quads)
83.9	7.8	Silver Creek Interchange #58; observe Hanover-Dunkirk contact (Farnham quad).
85.3	1.4	Bridge over Cattaraugus Creek.
97.4	12.1	Bridge over Eighteen-mile Creek.
102.9	5.5	Hamburg Interchange #57.
104.4-104.7	1.5	Observe exposures of Rhinestreet Shale (Buffalo Se quad).
106.9	2.5	Blasdel Interchange #56.
112.8	5.9	Interchange #53, junction with Interstate 190 (Niagara Section) to downtown Buffalo; continue straight ahead on Interstate 90 (Dewey Thruway).
118.5	5.7	Exit at Interchange #50, north and west on Interstate 290 (Youngman Highway).

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
128.5	10.0	Junction with Interstate 190; north on Interstate 190 toward Niagara Falls.
129.3	0.8	Cross South Grand Island Bridge.
135.2	5.9	Cross North Grand Island Bridge.
136.0	0.8	Turn right on N.Y. 384.
136.5	0.5	Arrive at Treadway Inn, Niagara Falls, New York at 5:00.



TRIP C: LATE PLEISTOCENE GEOLOGY AND GEOMORPHOLOGY OF NORTHWESTERN  
NEW YORK

LEADERS: Parker E. Calkin and Charles J. Cazeau

DATE: April 30, 1966

ROAD LOG

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
(Quadrangle Maps)		
0.0	0.0	<u>Assembly point:</u> Parking lot, Treadway Inn Buffalo Avenue, Niagara Falls, Near North Grand Island Bridge.
<u>Departure time:</u> 8:15 A.M. All travel by bus.		
(Tonawanda 15' Tonawanda W. 7 1/2')		Turn left (W) out of parking lot onto Buffalo Ave. and proceed west to North Grand Island Bridge entrance.
0.4	0.4	Turn left (S) immediately after passing under bridge ramp and proceed across Niagara River (east fork) onto Grand Island following U.S. Rt. 190, Niagara Expressway.
4.1	3.7	Pass south over very subdued Niagara Falls Moraine; 20-30 feet of relief at stream cuts on otherwise very flat plain of Lake Tonawanda. This is the lowland of Upper Silurian, Salina Group.
6.5 (Buffalo 15' Buffalo N.W. 7 1/2')	2.4	Proceed again across Niagara River (east fork) to Tonawanda.
7.8 (Buffalo NE 7 1/2')	1.3	Turn right at Exit N-16 onto U.S. Rt. 290, Youngman Expressway, and proceed east over plains of former Lake Tonawanda.
17.1	9.3	Rise south over Onondaga Limestone (M. Dev.) Escarpment. Exposure here in roadcut as you pass under Main Street.
17.5	0.4	Keep right at Thruway fork to remain on Thruway--"West Bound".

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
24.0 (Buffalo SE 7 1/2')	6.5	Pass beneath Niagara Expressway ramp and cross Buffalo River .6 miles beyond.
25.6	1.6	Turn right (W) at Exit 54 to N.Y. Rt. 16.
27.1	1.5	Turn left (E) at T onto N.Y. Rt. 16 and immediately bear to right (S) off Rt. 16 at fork .2 miles beyond. Cazenovia Creek, a tributary of the Buffalo River at your right.
28.1	1.0	Turn left (E) onto Main St. and proceed along well defined morainal ridge at 660-670' through Ebenezer. Ridge is a probable westward extension of Leverett's (1902) Alden Moraine.
DeCew 15' Orchard Park 7 1/2'		It has been mistaken for a Lake Dana beach ridge but has probably been altered by Lake Dana waters (680-700'). Cellar cuts reveal a dense till, rich in large, striated boulders of Onondaga Limestone.
30.2	2.1	Join Seneca St. and proceed along subdued morainal ridge.
31.7	1.5	Turn right (SE) onto N.Y. Rt. 16, still continuing on Seneca Rd. At right, lateral migration of Cazenovia Creek has caused collapse of paved road.
33.6	1.9	Turn right (S) onto Northrup Rd. and cross Cazenovia Creek .2 miles beyond. Note at left the falls formed by resistant and fossiliferous Tichenor Limestone Member.
34.3	0.7	Beyond intersection with Kingsley Rd., Northrup crosses shaley gravel of glacial Lake Warren beaches, 800-830'. At left, 7 miles beyond is gravel beach ridge, 830', behind green house.
35.2	0.9	Intersection with N.Y. Rt. 187, Transit Rd. (BE CAREFUL, BLIND CORNER) Proceed left (S) on Transit Rd. rising up to glacial Lake Whittlesey features, 900'.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
36.1	0.9	STOP 1. Cancer Prevention Research Center. View postulated, (Fairchild, 1906) Lake Whittlesey, wave-cut beach and scarp at left and right on north side of hill. Ridge appears to be largely shale, but its north side is partly flanked by well sorted sand.
36.3	0.2	Turn left (E) onto Mile Strip Rd. Cross ridge crest (880') after .3 miles. Cellar of Barren house at right, was dug in Lake Whittlesey (?) gravel. Bear right (S) beyond ridge onto Willardshire Rd.
37.0	0.7	Proceed past probable kame moraine gravel ridge at right on north side, Hamburg Moraine.
37.5	0.5	Cross Cazenovia Creek and proceed on Willardshire Rd. across typical hummocky topography of Hamburg Moraine.
40.0	2.5	Turn left (N) onto Seneca Rd.
42.0	2.0	Proceed through intersection of Jamison and Conley Roads with Seneca Rd. which overlies a Lake Whittlesey beach and split at 900'. Beach topography is now nearly obscured except for minor sand ridges on grounds of Moog Plant at right (N). Descend from split, .3 miles west of Moog Plant.
43.4	1.4	Turn right (E) beyond Church onto Rice Rd. which follows beaches of glacial Lake Warren (lower or second Lake Warren). Observe prominent beach ridge at left of intersection with Dellwood Dr. An abandoned gravel pit 1.3 miles beyond Seneca Rd. cut in the beach exposes 20' of well sorted gravel.
45.6	2.1	Turn left (N) onto Bowen Rd.
46.2 (East Aurora 7 1/2')	0.6	Pass under R.R. tracks and turn right (E) onto Woodward Rd. Note again at least two prominent ridges of Second Lake Warren (Blackmon, 1956) left, .7 miles from Bowen Rd.
48.0	1.8	Turn left (N) onto Girdle Rd. and .1 miles beyond turn right onto Bullis Rd.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
48.5	0.5	Cross Buffalo Creek. Pipeline trenches adjacent to creek here revealed 2' of gravel over blue shaley till.
48.8	0.3	Turn left onto Stille Rd. noting well formed beach ridge of Lake Warren on right. Cross at least 3 NE-SW trending ridges of Second Lake Warren 835'-800'.
50.0	1.2	Turn right onto Clinton Rd. and pass across delta of Buffalo and Little Buffalo Creeks formed in Lakes Whittlesey and/or Warren.
50.8	0.8	STOP 2. Turn right into Huber and Huber sand pit. Observation and discussion of exposed Lake Warren beach and delta structures. On leaving, turn right (E) onto Clinton Rd.
51.0	0.2	Turn left (N) onto Town Line Rd. and pass across beaches of Second Lake Warren, possible Lake Wayne 800' (.4 miles), and Lake Grossmere, 790';, (0.8 miles) beyond Clinton Rd.
52.8 (Clarence 7 1/2')	1.8	Cross unidentified beach ridge, 760', and Cayuga Creek, the eastern most river draining into Erie Basin. Proceed south over very subdued remnants of Alden Moraine. Borrow pits and cellar cuts reveal red, stony silts and normal clay till in this general region.
57.8	5.0	Cross Ellicott Creek and turn left (W) onto N.Y. St. 33, Genesee St. Pass gravel pits in ice-contact deposits on right.
59.7 (Lancaster 7 1/2')	1.9	STOP 3. Pine Hill Concrete Co. sand and gravel pit. Over 45' of ice-contact, stratified drift is exposed on the northeast corner. Thin layers of flow (?) till occurs at some horizons and the deposit is overlain by 7-10' of cobbly till in the northwest corner. This together with cross-bedding data suggest a possible (a) kame delta or (b) ice margin! stream origin. These and adjacent deposits may be related to the Buffalo Moraine of Kindle and Taylor (1913).

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
64.6	4.9	Cross Ellicott Creek and turn right (N) onto N.Y. Rt. 78, Transit Rd. Proceed north under Thruway, .8 mile, and across Main St., 2.0 miles beyond Genesee St.
67.4 (Lockport 15' Clarence Center 7 1/2')	2.8	Proceed under Sheridan Dr. overpass and down Onondaga Escarpment to Lake Tonawanda plain, 630' t. This area is largely underlain by lacustrine red silts and clays overlying Camillus Shale (U. Silurian). Scattered till ridges and drumlins project above its surface.
69.2	1.8	Cross over crest of Niagara Falls Moraine.
75.5	6.3	Proceed north across Tonawanda Creek and from Erie into Niagara County.
76.3	0.8	Turn right (E) onto Branz Rd. and proceed up onto NE-SW trending drumlin. This and next drumlin have no more than 35' of relief but stand out clearly from flat Lake Tonawanda plain.
78.4	2.1	Turn left (NW) onto Raymond Rd. (formerly Rapids Rd.) and immediately (.3 mile) left again onto Rapids Creek Rd.
79.1	0.7	Crest of NE-SW trending drumlin.
80.2 (Lockport 7 1/2')	1.1	Turn right onto N.Y. Rts. 78 and 263, Transit Rd.
82.4	2.2	Pass up over hummocky ridges of Barre Moraine with good crests 1 mile beyond, near stop light at Lincoln Ave., City of Lockport.
84.2	1.8	Cross N.Y.S. Barge Canal/Erie Canal at Lockport. Canal leads NE through one of Lake Tonawanda outlet spillways. Continue north on Transit Rd.
85.1	0.9	STOP 4. Turn left onto Outwater Dr. and proceed to Outwater Park for lunch. The park lies on the Lockport Dolostone (M. Sil.) forming the prominent Niagara Escarpment overlooking glacial Lake Iroquois plain to north. Lake Ontario lies 11 miles to the north.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
		Proceed to Trow bridge and make a U turn, returning (E) on Outwater Dr. to Transit Rd. Turn left (N) onto Transit Rd.
86.3	1.2	Turn right (E) onto Glenwood Ave.
86.6	0.3	Turn sharp left (NW) onto Gooding St. and in .2 mile bear left after crossing tracks at fork onto W. Jackson St. After .5 miles at fork, bear right along creek onto Plank Rd. You are passing down from Niagara Escarpment through one of many spillways cut by water draining from Lake Tonawanda to Lake Iroquois.
88.1 (Tonawanda 15' Cambria 7 1/2')	1.5	Turn left (W) at intersection across Eighteen-mile Cr. onto Old Niagara Rd./Stone Rd.
91.3	3.2	At Warrens Corners (Junction of Stone Rd. with U.S. Rt. 104, Ridge Rd.) turn right and immediately left (W) proceeding west on U.S. Rt. 104 and N.Y. 93, Ridge Rd. Ridge Rd. follows the Lake Iroquois beach ridge, 390'+; Lake Ontario stands at 246'.
93.7	2.4	Bear right following N.Y. Rt. 93 at fork onto bar of Lake Iroquois.
94.1	0.4	STOP 5. Abandoned gravel pit exposes shingled gravel of Iroquois bar, lightly cemented with secondary calcium carbonate as to preserve details of imbrication, bedding, and cut-fill structure. Continue west on Rt. 93.
95.1	1.1	Turn left (S) onto N.Y. Rt. 425 Cambria-Wilson Rd.
95.9 (Ransomville 7 1/2')	0.8	Turn right (W) onto Rt. 104 Ridge Rd. and proceed along Iroquois beach to Lewiston. Note Niagara Escarpment prominently displayed at left is reached at Dickersonville, where rise begins from Iroquois plain, 400' to Tonawanda Plain at 600'+.

<u>Cumulative Miles</u>	<u>Miles from Last point</u>	<u>Description</u>
106.6 (Lewiston 7 1/2')	10.7	Turn left (S) onto N.Y. Rt. 18, Creek Rd. at outskirts of Lewiston and proceed up Niagara Escarpment. After .4 mile note exposure of Lockport Dolostone at left and view to right of Escarpment, and the broad Lower Niagara River. Emerging from the Gorge at Cataract Basin, the river spreads out to a width of 2,000', flowing with a gradient of less than 0.16' per mile to Lake Ontario 6 miles to the north.
109.1	2.5	Turn right at exit immediately after passing beneath highway ramp, following signs to CANADA. After .4 miles take left fork, then .2 miles beyond take right fork to Lewiston-Queenston Bridge entrance.
110.3 (Niagara, 30 m/3)	1.2	Cross Niagara River into Canada with Old Narrow Gorge and power projects at left, Lewiston Branch Gorge Section and Cataract Basin at right.
110.6	0.6	Turn right (S) at first exit after paying toll, and after .4 mile turn right again at intersection with Niagara Park Commission, "River" Road. Brock Monument, and Niagara Escarpment are at your left (N). Proceed south over Barre Moraine represented by hummocky relief .5 mile from the bridge toll stop.
111.3	0.7	Pass Sir Adam Beck Niagara Generating Station No. 2, a facility of Ontario Hydro. From this area to the Whirlpool (Stop 7) we pass through a shallow channel of the Niagara R. from Lake Tonawanda to Lake Iroquois. The deposits are red silts with grey clay layers overlying bouldery till.
111.6	0.3	STOP 6. Vista overlooking Gorge and Robert Moses Niagara Power Plant. Both Canadian and American Power Stations take their water from the Upper Niagara River.

A clear view of the Niagara stratigraphic section is revealed here from Queenston Shale to the Lockport Dolostone at the top. Proceed south along River Rd.

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
112.9	1.3	Pass Wintergreen Flats and Niagara Glen at left. Large talus blocks, some 20' in diameter and cut by giant potholes, lie below massive dolostone cliffs which remained when the retreating former Falls narrowed and gorge cutting resumed to the east.
113.4	0.5	<p>STOP 7. Turn left off main road to the Whirlpool parking area. The Whirlpool is a basin 1,700' by 1,200' with a maximum depth of 125'. The water enters the Whirlpool at high velocities after moving up to 30' per second through the Whirlpool Rapids upstream. Most of the flow rushes past the outlet to the far side of the Pool, makes a complete circuit counter-clockwise, and escapes through the narrow outlet by passing under the incoming stream. Below the Whirlpool, there is another two miles of rapids with a drop of 40'.</p> <p>The feature responsible for the Whirlpool is the buried St. David's Gorge, intersected here by the Niagara Gorge. It is observed trending northwest from the opposite side of the Whirlpool and extends to the village of St. David on the escarpment west of Lewiston. Various excavations for road, canal, and power projects reveal that it has steep sides and a depth approximate to that of parts of the Niagara Gorge. It has been filled by till, mantled with red lacustrine silts and gray clays probably related to the former Lake Tonawanda.</p> <p>The Middle and Lower Silurian section is clearly revealed here. The Whirlpool Sandstone is at the river level.</p> <p>Continue south along River Road</p>
114.0	0.6	Cross Bowman River which has partially excavated St. David's Gorge.
114.6	0.6	Bear left at road fork and pass Whirlpool rapids observation area .8 miles beyond. Proceed beneath Lower Arch R.R. bridge .1 mile beyond fork and begin passage along Upper Great Gorge.
115.9	1.3	Continue south beneath Rainbow Bridge.



Cumulative Miles	Miles from last point	<u>Description</u>
116.6	0.7	<p>STOP 8. Refectory view of Upper Great Gorge, American Falls, Goat Island, and Horseshoe (Canadian) Falls at right.</p> <p>Goat Island divides the Upper Niagara River into two channels, one leading to the American Falls and the other to the Horseshoe Falls. In each channel the water flows over resistant ledges of the southerly dipping Lockport Dolostone Caprock to form rapids and cascades with a drop of about 50'. Before construction of a submerged weir above the Cascades (Horsehoe Rapids), only five per cent of the total flow went over the American Falls; a little more than one half the present percentage. The relatively small flow is distributed evenly along the 1,100 foot crest of the American Falls so that the discharge per foot rarely exceeds 20 cubic feet per second compared to a maximum of 200 at the Horseshoe.</p> <p>At the 2,500' wide crest of 510-520' above sea level, there is a straight drop of about 160'. The crest has been lengthened as much as 100' in the past 100 years because the central portion recedes faster than the ends. In some places along the crest, there are depths from 6 to 12' but there are several small islands and shoals. In particular, there is a large central shoal dividing the flow into two main channels, which converge toward the central part of the crest.</p> <p>The massive Lockport caprock of the falls is clearly shown beneath the observer and between the two falls. It is some 80' thick here, thickening to 130' south at the Cascades head. The black Rochester Shales beneath are hidden by the falls and the blocky dolostone talus. The latter is not removed from beneath the American Falls because of the low discharge. The recession of these shales has caused undermining and consequent joint block by joint block retreat of the Falls from Lewiston.</p> <p>The river in the Upper Great Gorge below the Falls, drops only five feet in its two and one quarter mile length.</p>

<u>Cumulative Miles</u>	<u>Miles from last point</u>	<u>Description</u>
		Soundings show maximum depths of from 100' to 187'.
116.9	0.3	STOP 9. Horseshoe Falls and Scenic Tunnels. Proceed south, passing the Cascades and Canadian Niagara and Toronto Power Plants successively on the left, and the river-cut cliff and shelf in the Niagara Falls Moraine at right. This latter cut, now occupied by Queen Victoria Park was probably made (Taylor, 1932) after the Falls had retreated past the high point of land just north of Stop 7. At this time the curved course of the river in the rapids threw a powerful current against the bank west and south of the fall.
117.7	0.8	Turn right (W) encircling Dufferin Is. and skirting 60' cliff of Niagara Falls Moraine. Return north toward Rainbow Bridge past Falls.
119.9	2.2	Bear left at fork across traffic light to Rainbow Bridge entrance.
120.2	0.3	Turn right (E) at Bridge and cross Niagara Gorge to the U.S.
120.6 (Niagara Falls 7 1/2')	0.4	Pass through American Customs. Turn left (E) to Rt. 625 and almost immediately left again (N & W) onto Robert Moses Parkway - Grand Island Bridge route. Pass Niagara Frontier State Park with observation tower, American Rapids, and Goat Island at right. Exit for Goat Island is on left .8 mile from American Customs.
123.8	3.2	Pass Niagara River and Power Intakes for Robert Moses Power Project. Twin conduits, each 46' by 66', carry water four miles beneath the city of Niagara Falls. The concrete bulkheads held the closing doors for these conduits.
125.0 (Tonawanda 15' Tonawanda W 7 1/2')	1.2	Keep right (S) at exit for INN and turn right .3 mile beyond at intersection with Buffalo Avenue.
125.3	0.3	Turn right (S) into Treadway Inn, Niagara Falls.

TRIP D: ONONDAGA LIMESTONE IN WESTERN NEW YORK

LEADER: Dr. Edward J. Buehler

DATE: May 1, 1966 8:30 A.M.

ROAD LOG

Time: approximately 5 hours Total mileage: 125

MILEAGE SCHEDULE:

<u>Miles from last point</u>	<u>Description</u>
0.0	Leave Treadway Inn at 8:30 A.M.; turn left on Buffalo Ave.
0.5	Turn left on 190 (bridge access); cross North Grand Island Bridge.
1.1	Toll booth.
5.3	Cross South Grand Island Bridge; continue on 290.
1.5	Exit on N-16 (Youngman Highway)
10.2	Take N.Y.S. Thruway - East Bound - Albany.
1.0	Toll booth.
2.3	Take exit 49; toll booth
0.7	Turn left on Rt. 78.
0.7	Turn right on Wehrle Drive.
1.2	Arrive Buffalo Crushed Stone Quarry, Onondaga limestone.  STOP 1. 9:00 A.M. See paper by Oliver (p. 32) for stratigraphic details. Leave Quarry at 10:00 A.M. Turn left on Wehrle Drive.
1.2	Turn left on Transit Road (78).
0.7	Take Thruway entrance; toll booth; Take Thruway Albany - East.
27.7	Take exit 48.
0.4	Turn left on 98.

<u>Miles from last point</u>	<u>Description</u>
1.1	Turn left on Rt. 5.
6.5	Turn left on 237.
2.2	Turn right on Britt Road
2.7	Turn left onto dirt path at end of Britt Road.
	STOP 2. Arrive at Quarry at 11:15 A.M. This quarry exposes an Onondaga Bioherm. See paper by Oliver (p. 32) for details. Leave quarry at 12:15 P.M. Return via Britt Road.
2.7	Turn left onto 237.
2.2	Turn right onto Rt. 5
6.5	Turn right on Rt. 98 to Thruway.
1.1	Right onto Thruway.
0.2	Toll booth; take Buffalo Lane.
29.5	Toll booth at Buffalo
0.3	Take Youngman Highway exit; use thru Traffic route 290.
8.5	Take 190 North - Niagara Falls.
1.0	Toll booth at South Grand Island Bridge.
5.3	Cross North Grand Island Bridge.
0.5	Arrive Treadway; end of trip; 1:45 P.M.

TRIP E: HAMILTON FOSSIL LOCALITIES

LEADER: Harvey Hambleton - Buffalo Museum of Natural Sciences  
(See paper by Tesmer (p. 47) and Buehler (p. 44) for detailed description and sections).

DATE: May 1, 1966

ROAD LOG

Time: approximately 5 hours

Total mileage: 66

MILEAGE SCHEDULE:

<u>Miles from last point</u>	<u>Description</u>
0.0	Leave Treadway Inn 8:30 A.M.; turn left on Buffalo Rd.
0.4	Turn left on 190; Cross North Grand Island Bridge.
6.0	Cross South Grand Island Bridge.
1.6	Exit on N-16 (Youngman Highway).
13.2	Exit Thruway at Walden Avenue. Proceed east on Walden.
0.5	Turn right onto Union Road.
1.0	Turn left on Como Park Blvd.
4.5	Pass Como Park School and turn left at Lake Avenue.
0.15	Bridge crossing Cayuga Creek. Park adjacent to bridge or on road trending east along the creek. Disembark.
	STOP 1. Oatka Creek shale and Stafford Limestone.
	Return to Como Park Blvd.
0.15	Turn right. Proceed west to Aurora Street.
0.4	Turn left. Proceed south on Aurora Street.
2.4	Turn right onto Clinton Road.
0.7	Turn left onto Blossom Road
0.25	Bridge over Buffalo creek. Park in front of house just east of bridge on north side of bridge. Disembark.

Miles from  
last point

Description

- STOP 2. Centerfield Limestone. This is the most western outcrop of Centerfield.
- 0.0 Continue southwest, bearing right along Blossom Road and passing Blossom Center. Proceed, crossing Transit Road, and approach Lein Road after traversing a rather sharp S curve in Blossom Road.
- 1.1 Turn left on Lein Road.
- 1.15 Junction with Rte. 16 (Seneca Rd.) and Bullis Rd. at East Seneca. Turn right onto Bullis Rd. and proceed west.
- 0.3 Turn left onto Leydecker Rd. which swings sharply left and crosses Cazenovia Creek. Park in area to west of bridge on north side of bridge. Disembark.
- STOP 3. Wanakah Shale and Ledyard Shale.
- 0.0 Return to Bullis Road. Turn right.
- 0.3 Junction with Rte. 16 (Seneca Rd.). Turn right onto Seneca Road and proceed southeast.
- 1.8 Turn right onto Northrup Road in Springbrook.
- 0.2 Bridge crossing Cazenovia Creek. Park in area on north side of bridge. Disembark.
- STOP 4. Tichenor Limestone and Wanakah Shale.
- 0.0 Return to Rte. 16.
- 0.2 Turn left on Rte. 16.
- 6.5 Turn onto Thruway - North - Albany. Continue north on Youngman Highway (290).
- 16.0 Take 190 North - Niagara Falls.
- 1.0 Toll booth at South Grand Island Bridge.
- 5.3 Cross north Grand Island bridge.
- 0.5 Arrive Treadway Inn; end of trip.