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FIELD TRIP GUIDEBOOK

Donald N. Peterson, Editor

Contributors

Gordon Baird, Dept. of Geological Sciences, Univ. of Rochester, Rochester, NY 14627
Carlton E. Brett, Dept. of Geological Sciences, SUNY, Buffalo, NY 14207
Donald J. Crowley, Dept. of Geology, S.U.C., Fredonia, NY 14063
Robert K. Fahnestock, Dept. of Geology, S.U.C., Fredonia, NY 14063
William Kirchgasser, Dept. of Geological Sciences, S.U.C. Potsdam, NY 13676
William J. Metzger, Dept. of Geology, S.U.C., Fredonia, NY 14063
Ernest H. Muller, Dept. of Geology, Syracuse University, Syracuse, NY 13210
Richard Z. Poore, Dept. of Geological Sciences, Brown University, Providence, RI 02912
Irving H. Tesmer, Geosciences Dept., S.U.C., Buffalo, NY 14222
Arthur M. VanTyne, Senior Scientist, N.Y. State Museum and Science Service, Alfred, NY 14802

Department of Geology, State University College at Fredonia
Fredonia, New York 14063

Additional copies of this guidebook are available from the permanent secretary of the New York State Geological Association: Dr. Daniel F. Merriam, Department of Geology, Syracuse University, Syracuse, NY 13210

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EDITORS NOTE

On behalf of the Department of Geology, State University of New York, College at Fredonia, I extend a cordial welcome to the participants of the 46th annual meeting of the New York State Geological Association. We hope that your participation will prove to be both enjoyable and educational.

I would like to acknowledge the contributors for taking the time to assist in the preparation of this guidebook. Although I was working with a slight handicap this year (the contributors represent eight different institutions), most of the deadlines were met with a minimum of prodding. Without their cooperation, our hosting of the NYSGA meeting would not have been possible, so, thank you.

I would like to express my gratitude to our departmental secretary, Mrs. Nancy Jagoda, who perservered with me in the preparation and typing of this guidebook, answered correspondence, and performed numerous and sundry jobs in helping to organize the meeting. Thanks also go to Mssrs. Don Burdick and Ron Warren of the Fredonia State Instructional Resource Center who helped in the preparation of some of the illustrations for this guidebook. Last, but not least, I would like to thank Mr. Joe Woloszyn and his staff at the campus print shop who did such a fine job of printing and binding the guidebook.

LOCKPORT (MIDDLE SILURIAN) AND ONONDAGA (MIDDLE DEVONIAN) PATCH REEFS IN WESTERN NEW YORK

Donald J. Crowley, State University College, Fredonia, N.Y. (Field Trip Leader) and Richard Z. Poore, Brown University, Providence, R.I.

INTRODUCTION

A recent flourish of oil and gas exploration in the Appalachian Basin has increased the interest in Silurian and Devonian reefs in New York and surrounding states. Although the companies do not expect to find reefs as large as those in the Michigan Basin, recent production of natural gas from Onondaga reefs around Stuben County, N.Y. has been sufficient to bring about a search for other Devonian reefs as well as Silurian reefs.

Patch reefs in the Lockport Formation (Middle Silurian) and Onondaga Limestone (Middle Devonian) are exposed along the northern edge of the Appalachian Basin in Western New York and have been studied in detail. Lockport reefs, occurring in the Gasport Member have been studied by Crowley (1973) and one Onondaga reef near LeRoy, N.Y. has been studied by Poore (1969). The object of this paper and accompanying field trip is to compare the Gasport reefs with the Onondaga reef.

LOCKPORT REEFS

Stratigraphy

The following is a condensed version of a lithofacies and biofacies analysis of patch reefs in the Gasport Member of the Lockport Formation of Western New York and Ontario (Crowley, 1973).

The stratigraphy of the Lockport Formation has been well established in New York State by Zenger (1965) and in Ontario by Bolton (1957) and Sanford (1969). Although there is some change in nomenclature across the border there are no major problems of correlation in the study area (Fig. 1). The Gasport Member can be traced as a distinct unit from just west of Hamilton, Ontario eastward to Brockport, N.Y., a distance of 110 miles along the Niagara escarpment (Fig. 2). It is separated from the underlying Rochester Shale by the DeCew Member and is overlain by the Goat Island Member. Sanford (1969, p. 12) states that the Gasport is an eastward extension of the crinoid-rich Wiarton Member, and is defined as a separate member only where the DeCew separates it from the Rochester Shale. Sanford's statement is true only for the lower crinoidal facies of the Gasport and, as this study shows, does not apply to the other facies which are lithologically distinct.

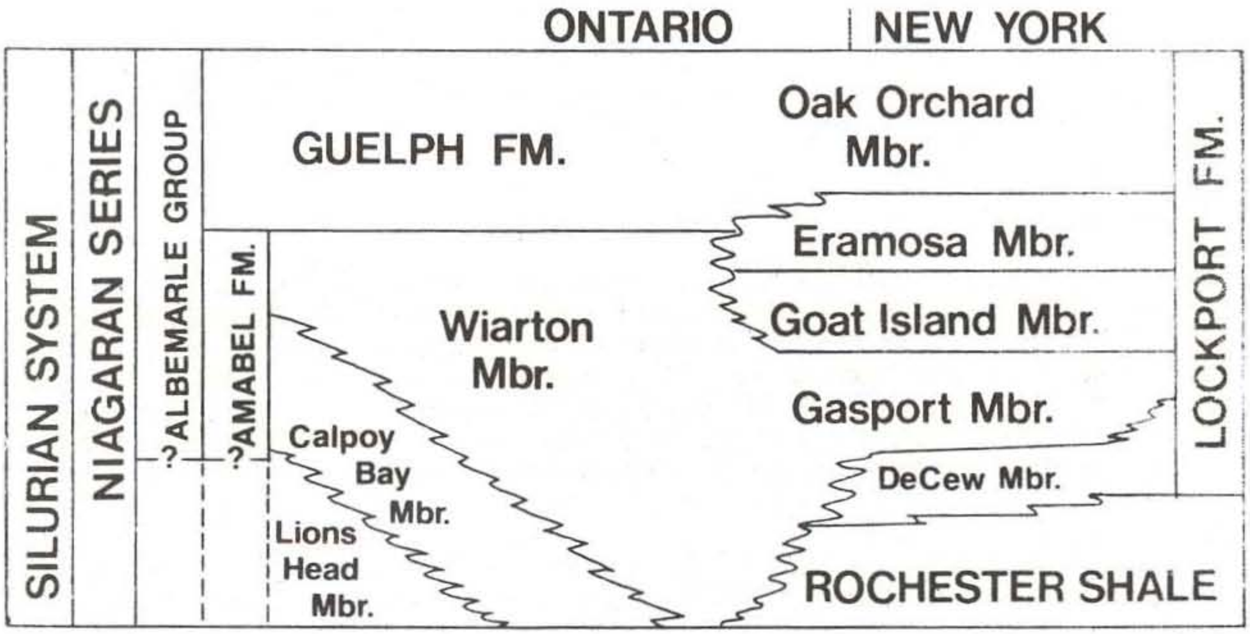

Fig. 1 - Stratigraphic equivalents of Lockport Formation in New York and Ontario. Exact placement of the lower boundaries of Albermarle and Amabel is in disagreement. However, Lions Head is member of Amabel Formation. From Crowley, 1973, (Compiled from Bolton, 1957; Sanford, 1969; and Zenger, 1965).

Gasport Facies

Crinoidal Bar Facies. This facies, which is the most widespread facies throughout the area (Fig. 2), is easily recognizable because of its crinoidal content, although it does also contain fragments of cystoids, corals, bryozoans and brachiopods. In fact, the crinoidal composition is usually the basis for recognition of the Gasport in the subsurface. The facies is 3 ft. thick near Hamilton, Ontario and generally becomes thicker to the east. Maximum thickness is 21 ft. just west of Niagara Falls, but averages about 10 ft. in the eastern half of the study area. Beds of coarse crinoidal sand 2 to 3 ft. thick grade laterally into thinner beds of finer crinoidal fragments 3 to 4 in. thick. Internal stratification is usually apparent in the thicker beds, whereas the thinner beds, which are usually, but not always finer grained, show less planar orientation of the fragments and are more homogeneous, suggesting that they have been reworked by burrowing organisms.

The thicker beds show cross-stratification dipping at angles of less than 10°, although individual sets are not well-defined. According to Imbrie and Buchanan's (1965) terms for describing carbonate sands, these are accretion deposits. The low amplitude, symmetrical ripples less than one foot high and at least 20 ft. in wavelength, seen at Lockport, N.Y., would probably be classed as para-ripples. Most cross-stratified beds occur from Lockport, N.Y. (loc. Z-29) west to Grimsby, Ont. (loc. B-9). Internal stratification is emphasized by weathering and subtle textural variations. In a few places, packed crinoidal biomicrite and sparsely-fossiliferous micrite form alternating inter-beds about one inch thick.

A few, very small bioherms are found in the crinoidal bar facies near Lockport, N.Y. STOP #2 of Field Trip These bioherms are lenses 1 to 10 feet in diameter and up to 10 feet thick and are composed of fine-grained dolomite with abundant massive, encrusting, and branching tabulate corals, as well as branching rugose corals, bryozoans, brachiopods and crinoids. Many of the corals are in growth position and numerous long segments of crinoid stems indicate less breakage and reworking by currents than elsewhere in the crinoidal facies. This lithology and fossil assemblage is essentially the same as that of the initial-reef subfacies discussed below. These localities are the only ones where bioherms are found <u>within</u> the crinoidal sand. The surrounding sand is composed of debris of most of the organisms found within the bioherms except that crinoidal fragments are more abundant. This same general mixture of organic debris is present throughout the study area with no noticeable trends in the relative abundance.

Additional constituents of this facies include the intraclasts of the DeCew lithology found in the basal one foot as well as other smaller intraclasts, pellets, and subhedral quartz grains found at all horizons. The amount of quartz increases significantly toward the east.

There is no significant trend in the amount of micrite present in the sand. Biosparites grade vertically and laterally into biomicrites. Where micrite is absent, the skeletal material is mostly calcite and well-preserved. Micrite matrix has undergone varying degrees of replacement by dolomite. In some samples only a few dolomite rhombs are present; whereas, in others the matrix has been replaced so much that it is difficult to recognize any of the original rock.

The crinoidal bar facies was a platform sand blanket much like those described by Ball (1967) in the Bahamas. The Gasport crinoidal sands are spread out for a distance of 110 miles and show many of the features found in the broad expanses of Bahama oolitic sand. Most of the Gasport sand blanket was probably subjected to storm waves producing submarine bars and low amplitude para-ripples like those described by Imbrie and Buchanan (1965).

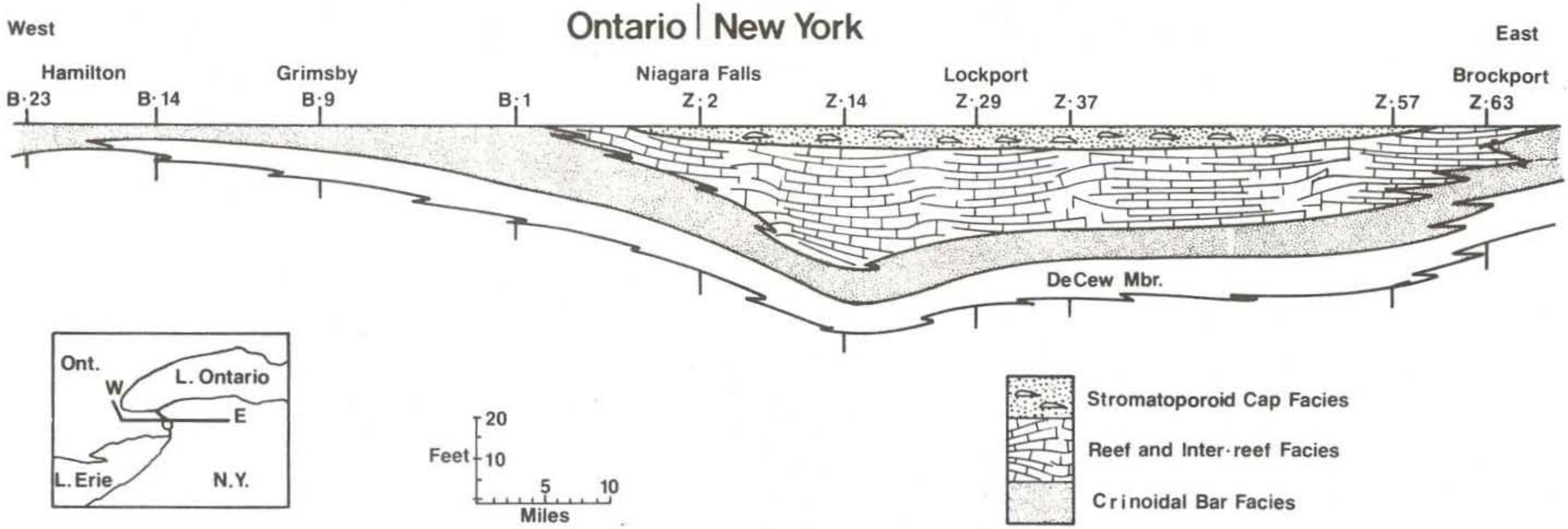

Fig. 2 - Gasport facies of New York and Ontario. Critical sampling localities are referred to in text. In this figure and in text, B-localities are described in Bolton (1957); Z-localities are described in Zenger (1965). From Crowley (1973).

Inter-layered storm lag deposits of fine and coarse material are also present. More cross-stratification in the Gasport sands than Ball describes for the blanket sands in the Bahamas indicates exposure to more frequent high-energy conditions. The finer grained portions of the unit are burrowed and poorly-sorted, whereas the sandier portions are better sorted and show well-formed internal stratification. Subaerial lithification features were not found in this facies indicating that the crinoidal bar platform was below low tide level but still near enough to the surface for frequent reworking by waves.

Prolific growth of crinoids, along with branching tabulate and rugose corals, bryozoans, brachiopods and motile benthos such as gastropods and trilobites provided the skeletal debris for the sand. A uniform faunal assemblage throughout the area indicates that, although small bioherms were found preserved only in one small local area, they probably grew in other places as well but were broken up before the sand was finally buried.

Reef Facies. The Gasport reefs and associated facies crop out in a zone 60 miles long, from Clarendon, N.Y. (Loc. Z-57) to just across the border in Ontario (Fig. 2). Inter-reef facies and overlying stromatoporoid cap facies are developed only within this reef zone leaving the crinoidal bar facies as the only lithology of the Gasport extending eastward and westward.

The reefs are easily seen from a distance at the outcrop because they stand out as slightly lighter gray, massive lenses inter-reef dolomite. They vary in height from 10 to 35 ft. and average 25 ft., commonly stand slightly above the top of the inter-reef facies, and depress the crinoidal bar facies beneath. The contact of the reef facies with the underlying crinoidal sand is commonly sharp except where the upper layers of the crinoidal bar facies are fine-grained. The width of the reefs vary from about 10 ft. up to about 100 ft. but most commonly is approximately 25 ft.

Dolomitization has completely obliterated all primary textures and fossils of most of the reefs, but a few have been relatively unaltered. This selective dolomitization occurs even within the confines of a single quarry (Loc. Z-29) where as many as 10 reefs are exposed a few yards to 300 yards apart. (STOP #3 of Field Trip) Perhaps only 2 out of 10 reefs in any one locality will have fossils preserved even though the shape of the reefs and their massive-bedded character are the same. The cause of this selective dolomitization is now known.

Where preservation is good, it is possible to delineate subfacies of the reefs and demonstrate systematic, vertical changes in the growth forms and assemblages of the reef-forming organisms.

Initial-reef subfacies - As the name implies, this subfacies represents the lower, beginning part of the reef (Fig. 3). Compared to the surrounding flank subfacies and inter-reef facies, the initial reef subfacies contains fossils in growth position and is thicker and more irregularly bedded. The initial-reef subfacies can be distinguished from the upper, reef-core subfacies by the fossil assemblage--mainly small, delicate, branching corals instead of the large stromatoporoids that later become the dominant reef former. Ecologically the fossil assemblage of this subfacies might be considered the pioneer reef community.

Fossils found in growth position are Halysites, branching tabulates (mainly Cladopora), branching, colonial rugose corals (Palaeophyllum), and branching trepostome bryozoans (Hallopora). Fragments of these as well as other tabulate rugose corals, bryozoans, brachiopods, and crinoids are mixed with the fossils still in growth position. Encrusting forms of Girvanella algae, trepostome bryozoans, and the tabulate coral, Alveolites fibrosus are also part of this assemblage. Interstitial material is micrite and fine-grained dolomite.

Girvanella is probably the only one of the encrusting forms that effectively bound the skeletal debris. It is almost everywhere associated with black, clotted interstitial micrite. Recrystallization and replacement by dolomite makes it difficult, in many instances, to distinguish micrite from recrystallized Girvanella. In fact, some of the micrite may have been derived from algae as has been suggested by Wolf (1965) and Klement and Toomey (1967). The initial-reef assemblage is also found where Girvanella and dark micrite are rare or absent so that the binding function does not appear to be necessary for the initiation of reef development.

The other interstitial material of this subfacies is fine-grained, greenish-gray dolomite that is common in the reef-core subfacies as well. Transition from micrite to this fine-grained dolomite has been noted in thin section. The origin of the dolomite, therefore, is assumed to be from micrite. The dolomite contains burrows whose outlines are accentuated by very fine-grained pyrite. In many cases the original, burrow-mottled sediment appears to have been plastically deformed and squeezed into voids between the skeletal framework. Similar burrowed textures have been reported in limestones and dolomites by Roehl (1967, Fig. 15) in the Ordovician, Metherell and Workman (1969, Plate 3) in the Devonian, and Rupp (1969, Fig. 4) in the Mississippian. None of these reports, however, describes this type of burrow-mottling associated directly with reefs, or mentions plastic deformation of the burrows.

The establishment of this pioneer coral thicket on the underlying crinoidal sand bar presumably slowed down the sediment-laden current resulting in the accumulation of fine-grained carbonate mud. As the mud settled within this organic lattice,

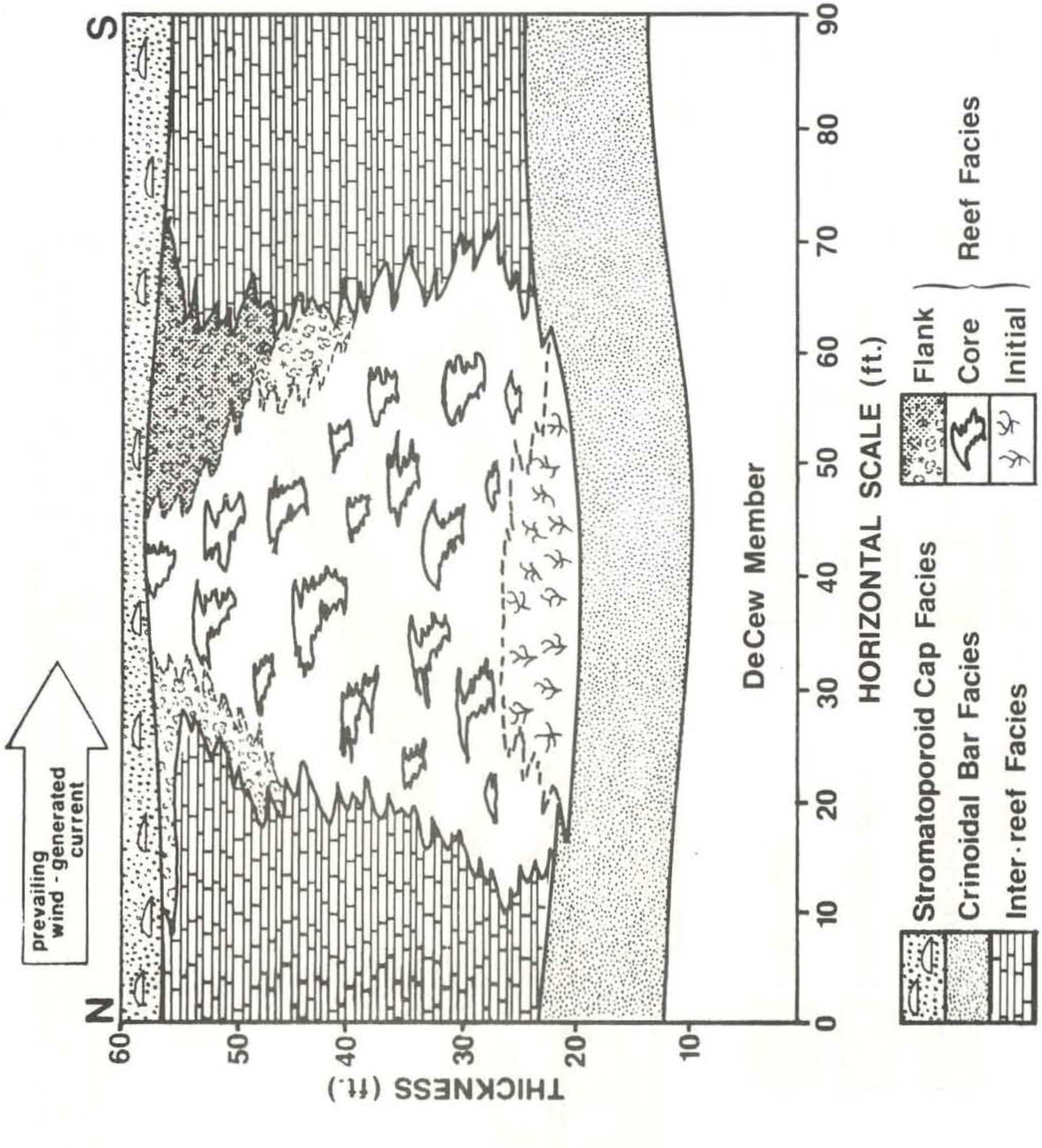

Fig. 3 - Diagrammatic illustration of Gasport facies and reef subfacies. Shaded part of flank subfacies represents detritus in dark dolomitic matrix. Stromatoporoids are shown developed asymmetrically into prevailing wind-generated current from north. Vertical and horizontal scales are for average Gasport reef. From Crowley (1973).

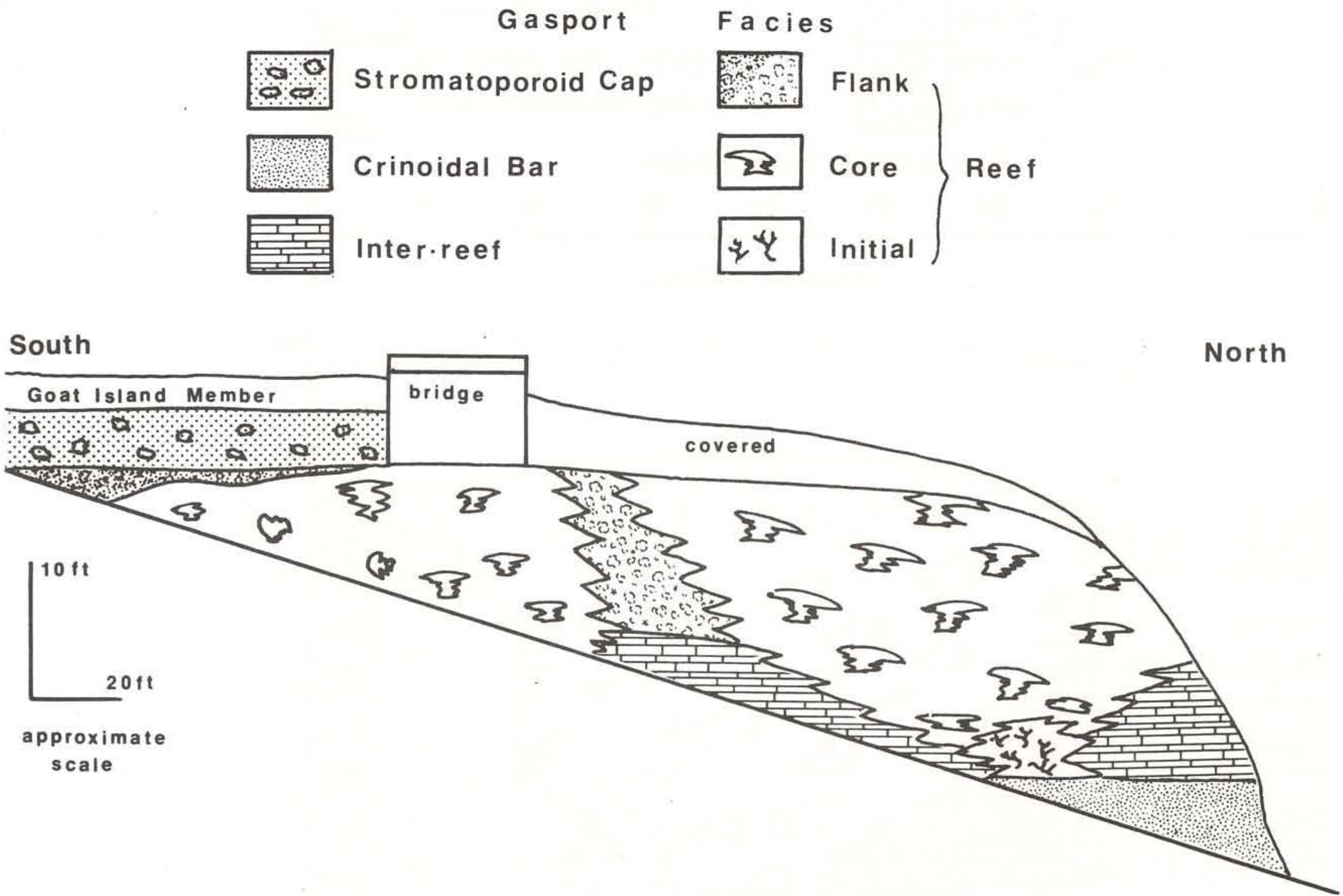

Fig. 4 - Diagrammatic view of two Gasport reefs exposed in road cut at Pekin, New York. Symbols for corals and stromatoporoids are like those in Figure 3. Scale is distorted because of vertical exaggeration. STOP #1 of field trip.

skeletal debris from the breakdown of these organisms also accumulated. The various encrusting forms of corals (Alveolites fibrosus), bryozoans (Hallopora) and girvanellid algae partially bound the mixed interstitial material in place.

Parallel pioneer reef communities are found in the Ordovician of Texas (Toomey, 1970) and Lake Champlain region (Pitcher, 1964); in the Silurian of the Michigan Basin (Lowenstam, 1950); and Devonian of New York (Poore, 1969), Western Canada (Embry and Klovan, 1970), and Belgium (Lecompte, 1959). In each case the actual biota is different, but there is similarity of form and function. Delicate, branching colonies trapped the mud and contributed skeletal material, while mud and debris were stabilized by other forms with an encrusting or tabular growth habit. In all these examples just cited, as well as in the Gasport, the result was the establishment of an organic mound that stood above the surrounding sea floor and was self-perpetuating as it grew upward into shallower water where increased wave and current action necessitated assemblage and form modifications if growth was to continue.

Reef-core subfacies - The initial-reef subfacies grades vertically upward into more massive- and irregularly-bedded, lighter-gray rock in which stromatoporoids are the dominant fossils (Fig. 3). The first stromatoporoids upwards in the reefs are small colonies (4 to 6 inches in diameter), of irregular shape, with latilaminae separated by thin layers of fine-grained dolomite. Within 3 or 4 ft. above the initial reef facies the stromatoporoid colonies reach heights of 2 to 3 ft. They become more columnar and somewhat umbrella-shaped. At irregular intervals the latilaminae spread laterally and encrust the surrounding dolomite. Asymmetrical growth toward the north occurs in one of the reefs at Peking, N.Y. (Loc. Z-14). Broadhurst (1966), describing Silurian reefs of southern Norway, postulates that such asymmetry faced into the prevailing current. A second reef just 25 ft. south of the one at Pekin (Fig. 4) contains stromatoporoid colonies that show much less asymmetrical growth. STOP #1 of Field Trip

Two genera of stromatoporoids have been identified as Stromatopora and Clathrodictyon, but further identification to species is not possible because of poor preservation. So far, no correlation between growth form and genus has been detected in the stromatoporoids. Ecologic control of growth form, however, has been pointed out by Broadhurst (1966), Galloway (1957), Harper (1970), Fischbush (1969) and Lowenstam (1950).

A few domal-shaped favositid colonies occur along with the stromatoporoids and some have latilaminae similar to those described in Silurian reefs of Iowa by Philcox (1971). The favositid colonies in the Gasport are, however, not the major reef framework builders in the Gasport reefs. Branching tabulate and rugose corals, branching bryozoans, crinoids, and brachiopods, are also present within the reef core, usually as fragments miced with the fine-grained, interstitial sediment that surrounds the stromatoporoids. The distribution and quantity of these fragments is irregular, both within one reef and between reefs. These fragments represent essentially the same fauna as that of the initial-reef subfacies, with the exception that Girvanella is rare within the reef core.

The interstitial sediment of the reef core is burrow-mottled, fine-grained dolomite like that previously described in the initial-reef subfacies. As in the initial-reef subfacies, it appears to have been plastically deformed and squeezed into almost every void of the stromatoporoid framework. Point counts from photographs of large blocks and exposures of the core in place show that this interstitial dolomite makes up 52 percent to 75 percent of the reef volume. Estimates of framework corals of Pleistocene reefs, arrived at by similar methods, show that they comprise approximately 30 percent of the reefs leaving 70 percent interstitial sediment of which 40 percent is calcilutite and 60 percent is skeletal sand or voids (Stanley, 1966). Roy (1970) described coral thickets growing in the muddy water of Fanning Island in the South Pacific Ocean. There the carbonate mud probably makes up most of the interstitial sediment in the coral framework, as is typical in the Gasport reefs.

Reef flank subfacies - The flanks of the Gasport reefs (Fig. 3) are neither as detrital-rich nor as steeply-dipping as the flanks of the Niagaran reefs in the Michigan Basin (Lowenstam, 1950; Textoris and Carozzi, 1964). Maximum dips are 15°, but most are less than 10°. Part of this dip results from the inter-reef sediments compacting more than the reef. Some indication of the height of the reef core above the surrounding flank and inter-reef deposits is given by the 3 to 4 ft. of thinning of the stromatoporoid cap facies over the tops of the reefs. The 3 to 4 ft. should be considered a minimum height, however, because the tops of some of the reefs were eroded before being covered by the cap facies.

Fragments of stromatoporoids, tabulate corals and other reef-derived detritus are found in dark gray to black dolomitized micrite extending a few feet or tens of feet out from the edge of the core. These fragments are commonly replaced by anhydrite or dolomite, but enough structure remains for general identification. Most reefs do not have extensive detrital fringes. An exception to this is in two closely-spaced reefs at Pekin, N.Y. (Loc. Z-14) which are separated by a zone of detritus 25 ft. wide (Fig. 4). This zone is a light yellow-brown, coarsely-crystalline dolomite that contains numerous crystal-filled, or partially-filled, vugs representing skeletal fragments. The initial porosity of this zone apparently allowed increased water movement resulting in more solution and replacement by coarsely-crystalline dolomite.

Flank deposits are thicker and more extensive near the tops of the reefs just beneath the stromatoporoid cap facies. These were produced by erosion of the tops of the reefs before they were covered by the stromatoporoid cap facies. In addition to reef-derived rubble, these uppermost flank deposits also contain fragments of more robust tabulate coral species than those corals within the reefs. These robust tabulate corals were either indigenous to the flank zone or were a transitional fauna adapted to the increasing higher-energy conditions which partially produced the overlying stromatoporoid cap facies.

Lenses of nearly black, fine-grained dolomite enclosing fragments of reef fauna are found at several localities. The dark color is due to the presence of microcrystalline pyrite possibly indicating small areas sheltered from oxygen-bearing water where organic-rich muds accumulated without oxidation. At the Pekin reefs (Loc. Z-14), these dark lenses are on the flank of a reef opposite the direction of preferred growth of the stromatoporoids. Perhaps deflection of the currents by the reef produced local pockets of poorly-oxygenated water and sediment on the lee side of the reef. Reef detritus accumulated in these organic-rich carbonate muds which subsequently became pyrite rich. This further supports the hypothesis that the dominant current direction was from the north.

Inter-reef Facies. Inter-reef lithology is found only between the reefs, above the crinoidal bar facies and below the level of the stromatoporoid cap facies. The inter-reef facies pinches out east of locality Z-63 and to the west in Ontario where there are no reefs (Fig. 2), thus leaving the Goat Island Member directly overlying the crinoidal bar facies.

The crinoidal bar facies grades upward into the finer grained inter-reef facies through a transition zone one to two feet thick. The upper contact of the inter-reef facies with the stromatoporoid cap facies is abrupt. The well-bedded, inter-reef lithology grades laterally into the massive reef facies.

The inter-reef facies is a dark-gray, dolomitized micrite and biomicrite. Replacement by dolomite is almost complete with only a few calcite fossil fragments remaining. The 4 to 8 in. thick beds are separated by black, shaly partings on bedding-plane surfaces. Most of the fine-grained dolomite has been partially homogenized by burrowing organisms but some internal stratification is still present. Intraclasts, with poorly-defined shapes, are common in these fine-grained rocks. Where beds are composed of alternating thin layers of crinoidal biomicrite and dark micrite, burrowing is absent.

The very reduced fauna of this facies consists of pelmatozoans along with a few brachiopods, small solitary rugose corals and burrowing organisms. All fossil debris has either been recrystallized to coarse-grained calcite or replaced by dolomite making more specific identification impossible.

Since the relief of the reefs was no more than a few feet, current and wave action over the reefs would have been about the same as between the reefs. Within the reefs, however, water movement near the sediment-water interface was slowed by the upward growth of the reef's organisms, which acted as baffles, allowing fine-grained sediment to accumulate. Lateral growth of the stromatoporoids then bound the sediment in place. In contrast, the currents between the reefs were unrestricted and thus could shift the sediment and produce stratification. The layers of crinoidal sand within the micrite probably represent storm lag deposits within the normally-muddy, inter-reef sediment.

Submarine consolidation of carbonate mud probably accounts for the intraclasts since no other evidence supporting subaerial dessication has been found. Partially-consolidated carbonate sediments have been reported in shallow, sub-tidal sediments of Florida (Jindrick, 1969) and the Bahamas (Ball, 1967)

Burrowing is confined to the fine-grained sediments which probably were deposited slowly. The coarse-grained layers were deposited rapidly and were reworked by currents and, hence, burrows are absent.

Stromatoporoid Cap Facies. The stromatoporoid cap facies of this study corresponds to the lower part of what Zenger (1965) calls the Goat Island Member and describes as "saccharoidal dolomite containing stromatoporoids" (p. 61). He suggests, however, that "...there is probably at least a slight facies relationship between the uppermost Gasport and the lowermost Goat Island" (p. 51). Lithologic continuity at the lower boundary of the cap facies with the Gasport and the erosional discontinuity at the upper boundary, however, makes it logical to include it with the Gasport facies.

The stromatoporoid cap facies forms a 4 to 6 ft. layer that caps both the reef and the inter-reef deposits and pinches out both to the east and west where reefs are not developed (Fig. 2). Although the lower contact with the reef and inter-reef facies is conformable in most places, the tops of some reefs have probably been eroded before being covered by the stromatoporoid cap sediments. Erosion is indicated by the presence of increased flank detritus immediately beneath the cap facies of some of the reefs. However, dolomitization has obliterated any direct evidence of an erosional surface on the tops of the reefs. Dark-gray, well-bedded, cherty Goat Island dolomite overlies an erosional upper surface of the stromatoporoid cap facies. This erosional surface truncates fossil fragments which must have been firmly cemented in place.

Lithologically, this facies is a light-colored, fossiliferous, vuggy dolomite which was originally a biosparudite and biomicrudite. Fragments of stromatoporoids and favositid corals along with other fossil debris have been leached out and the voids filled or partially filled with crystals of dolomite, gypsum, galena, and sphalerite. The light-colored, vuggy nature of this facies makes it easy to see from some distance and should make a recognizable marker in the subsurface.

At most localities the fossils of this facies are fragmented and the debris well-bedded. At Gasport, N.Y. (Loc. Z-37), however, stromatoporoids and coral colonies have been preserved in growth position. Exposure of a bedding-plane surface made possible an analysis of their size, density, and distribution. Most of the fossils found in place are dome-shaped or massive stromatoporoid heads ranging from a few inches to 4 ft. in diameter. Most of these heads show a preferred growth towards the NNW which nearly coincides with the northward-preferred growth of the stromatoporoids in the reefs. Some heads continued to grow after they were overturned while others formed larger masses by the coalescing of a clump of several small heads. Branching tabulate colonies of Cladopora ordinata (Davis, 1887) are also in growth position at this same locality and also have a preferred growth toward the north-northwest. Together, the stromatoporoids make up 14 percent of the surface area with colonies spaced close enough together so that it would be possible to jump from one to another. A similar study of a Devonian biostrome (Kissling and Lineback, 1967) showed that coral and stromatoporoid colonies also covered 14 percent of the surface area, but stromatoporoids make up only 26 percent of the colonies in contrast to nearly 100 percent in this study. The stromatoporoid colonies in the Gasport are surrounded by a well-bedded, carbonate sand composed of crinoids, Cladopora and stromatoporoid fragments. Some fine-grained dolomite matrix is present, but is not as abundant as in the reef and inter-reef facies.

Massive, dome-shaped stromatoporoids, coarse, organic rubble, well-bedded coral-crinoidal sand, and little fine-grained carbonate matrix all suggest a higher energy environment than the reef and inter-reef environments. The vuggy texture along with erosional surfaces within and on top of the unit suggest subaerial exposure of part of the unit resulting in lithification, solution and wave erosion.

One of the best Recent and Late Pleistocene analogs of this facies is found in Shark Bay, Australia described by Logan and Cebulski (1970) and Logan, et al. (1970). Part of the Late Pleistocene Bibra Formation of Shark Bay is a 1 to 3 ft. thick coral biostrome with coral heads ranging from 1 to 4 ft. in diameter surrounded by a pelecypod coquina. Lithoclasts are found on the weathered, upper surface of this formation indicating that is has been wave beveled previous to burial beneath tidal-flat deposits. (Logan, et al., op. cit.). Logan and Cebulski (op. cit., p. 35 report sheets of lithified sediments forming today in the upper intertidal zone of Shark Bay. Logan, et al. (op. cit., p. 79) report that the environment in which the Bibra Formation was formed was similar to that found on the rocky intertidal platforms in northern Shark Bay today.

The portion of the stromatoporoid cap facies of the Gasport where stromatoporoids and coral heads are in place and surrounded by coral-crinoidal sand is analogous to the sediments of Shark Bay forming in shallow subtidal channels and pools. As in Shark Bay, this portion of the Gasport was bordered by intertidal flats covered by stromatoporoid, coral and crinoidal rubble carried above the low tide level by currents and storms. Once exposed to air and rain water, this rubble was lithified, leached, and subsequently eroded. Dominant current direction (probably wind generated) was from the north-northwest as indicated by the preferred-growth orientation of the stromatoporoids and coral colonies.

Gasport Facies and Reef Development

A model that explains the deposition of Gasport facies involves a combination of lateral and vertical facies development on a discontinuously-subsiding, shallow marine platform. Lateral facies progression during the transgression, such as that proposed by Irwin (1965) and illustrated by Laporte (1967, 1969) in the Devonian Helderberg Group, accounts for the general development of the Gasport reef zone on the transgressing crinoidal sand bar complex. Vertical facies development of reefs into shallower more agitated water, such as has been well documented by Lowenstam (1950) and Textoris and Carozzi (1964), accounts for the vertical changes noted in Gasport reefs, including the stromatoporoid-cap biostrome. Variation in regional subsidence and consequent changes in basin circulation, however, are required to more fully explain the initiation and termination of Gasport deposits.

The following summary of Gasport facies development should be read with reference to the series of diagrams shown in Figure 5 illustrating the various developmental phases.

DeCew-Gasport Transition. DeCew carbonate mud was deposited on the northern flank of the Allegheny Basin which was at that time receiving mostly clastics from the east (Zenger, 1965, p. 143). The fine-grained, well-bedded character of the DeCew, along with the general lack of fossils indicates a restricted, low-energy environment sheltered behind the Wiarton crinoidal bank complex with which it interfingers near Hamilton, Ontario (Sanford, 1969, p. 12). The Wiarton bank complex, which coincides with the Algonquin Axis, was in existence throughout the deposition of the lower-half of the Lockport (Sanford, op. cit., p. 12). The Wiarton bank complex, which coincides with the Algonquin Axis, was in existence throughout the deposition of the lower-half of the Lockport (Sanford, op. cit., p. 12).

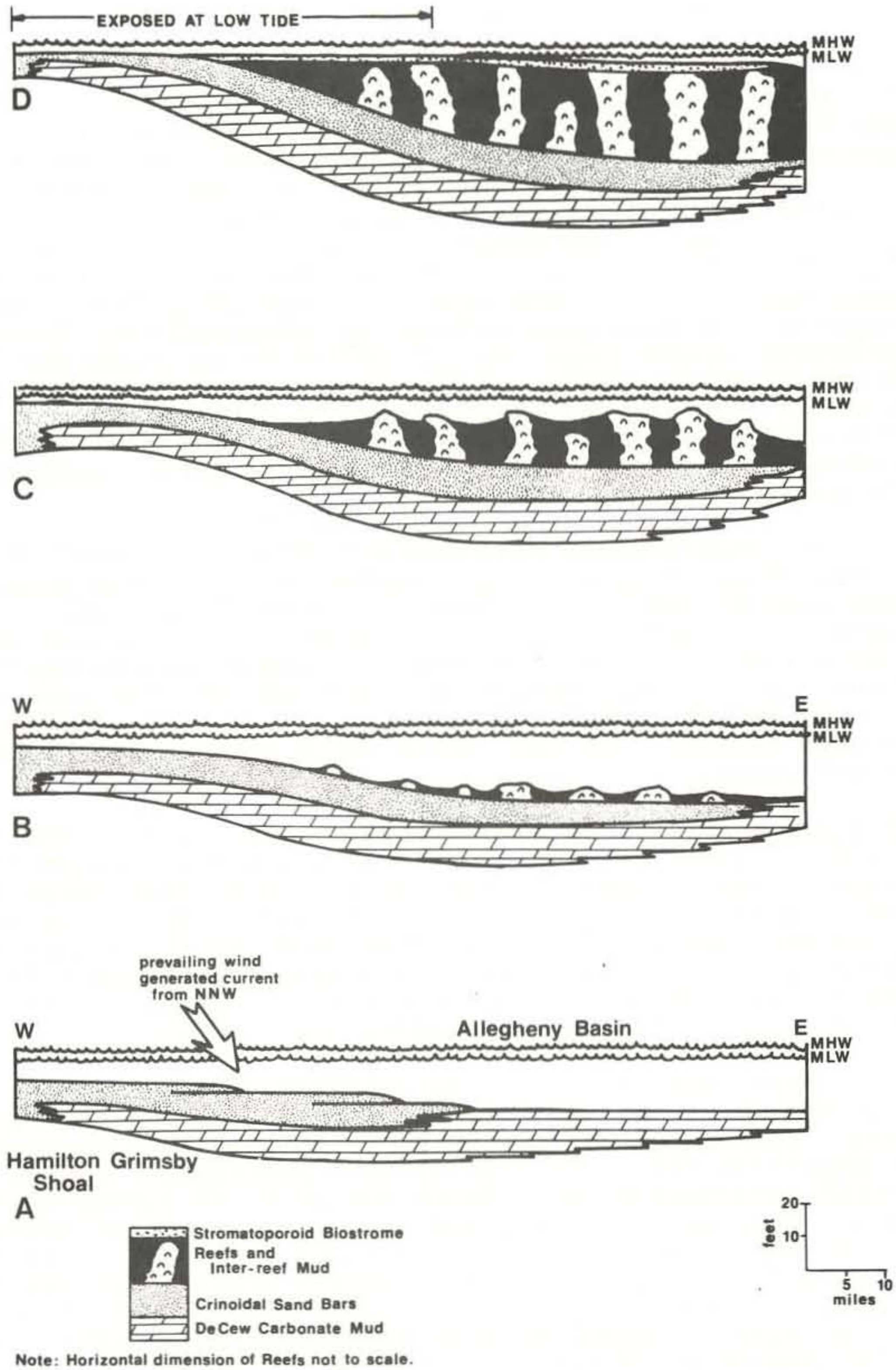

Fig. 5. Series of diagrams illustrating Gasport facies development. Sections parallel east-west outcrop belt of study area. Arrow indicates prevailing wind-generated currents from north and north-northwest throughout deposition of Gasport. Horizontal dimensions of reef are not to scale. From Crowley (1973).

Encroachment of the crinoidal bank complex southeastward into the area of DeCew deposition apparently was in response to increased regional subsidence allowing more open circulation from the north across the Wiarton bank. Increased current and wave activity caused submarine, crinoid sand bars to migrate into the once-quiet, muddy environment much as the oolite bars are migrating over the top of carbonate mud on the Bahama Platform today (Ball, 1967). The upper few feet of the DeCew mud were eroded and carried away before the crinoidal sand covered the remaining layers (Fig. 5A). Intraclasts of DeCew mud found in the lower few inches of the sand remain as evidence of this erosion. Interbedded sand and mud at the eastern end of the crinoidal bar facies represents the intermediate condition of contemporaneous sand and mud deposition at the leading edge of the encroaching sand bar.

The area between Hamilton and Grimsby, Ontario (Loc. B-23 to B-9, Fig. 2) apparently subsided less than the Allegheny Basin resulting in the sands thickening to the east. The area around Hamilton, Ontario acted as the hinge axis during the subsidence that allowed the sand to sweep into the Allegheny Basin from the Wiarton bank to the northwest. The Gasport crinoidal sands thicken eastward from the shoal area in response to increased current activity and subsidence while little sand accumulated on the shoal.

Reef Development. As the southeastern portion of the Gasport crinoidal platform subsided, small patch reefs began to grow in slightly deeper areas in the lee of the Wiarton-Gasport shoal near Hamilton, Ontario. The first reefs began to grow while crinoidal sand was actively being produced by crinoid meadows fluorishing on the submarine sand bars. Although a few of these reefs have been preserved, most were destroyed and the debris incorporated into the surrounding skeletal sand.

There seems to have been a threshold period when reefs gained a permanent foothold on the southeastern part of the area. This threshold was probably reached when carbonate sand accumulation failed to keep up with subsidence causing the depositional interface to move below the level of strong current agitation. Less agitation allowed the reefs to become firmly established and develop close together which further constricted water circulation. The result was a sudden vertical change from crinoidal sand, deposited in a highly agitated environment, to reefs growing on the sand in muddy, relatively quieter water (Fig. 5B). The reefs probably did not all appear at once, but lateral spreading of the patch reefs was rapid enough so that there was very little intermixing of the two facies.

Vertical development of the reefs from quiet-water, pioneer clumps of delicate, branching corals and bryozoans upward to massive, stromatoporoid-dominated patch reefs indicates that they were either growing into shallower water or the environment was becoming more rigorous (Figs. 3 and 5 C). Increased flank detritus and the capping stromatoporoid biostrome would favor the first interpretation. At any one time the reefs did not stand more than 3 to 4 ft above the surrounding muddy bottom. As they continued to build upward, mud filled in all voids within the reefs and continued to accumulate around them. Oriented growth of the stromatoporoid heads indicates that the prevailing current, probably wind generated, was from the north across the Wiarton-Gasport shoal.

During the period of reef building, no sediment was accumulating on the Wiarton-Gasport shoal. In fact, the crinoidal facies thins down to 3 ft. just east of Hamilton, Ontario where the top contact is leached, stained with limonite and a shaly parting separates it from the overlying Goat Island cherty dolomite. This probably is evidence for subaerial weathering, possibly occurring after deposition of the stromatoporoid cap facies to the east. It is also possible that the Wiarton-Gasport shoal was exposed during the period of reef building, thus inhibiting strong currents from the northwest and allowing acceleration of patch reef growth.

Stromatoporoid Biostrome. The vertical change from reef-associated facies to stromatoporoid cap facies is abrupt throughout the 60 mile wide reef zone (Fig. 5 D). This could be attributable to a change in energy as the reefs built upward into the wave-agitated subtidal and intertidal zones. There are, however, several features that argue for a slight drop in sea level placing most of the reef area in very shallow water at about the same time: (a) The transition from muddy reef and inter-reef sediments to coarse biosparrudites is abrupt although it appears to be conformable in most places; (b) The tops of some of the reefs have been eroded before being covered by the cap facies; (c) The unit maintains a uniform thickness of 4 to 6 ft. over a 60 mile wide area; (d) The adjacent crinoidal shoal to the northwest and portions of the cap facies show evidence of subaerial weathering and erosion.

Any one of these features would not be sufficient evidence for a drop in sea level. Together, however, they indicate that a lower stand of sea level left the Wiarton-Gasport crinoidal shoal to the northwest out of the water causing such an abrupt change in conditions in the reef zone that reef growth ended. The reef zone, now in the wave-agitated zone was covered by an assemblage of isolated, domal stromatoporoids, branching tabulate coral colonies, and crinoids. Skeletal debris from these animals accumulated above low tide where exposure to air and rainwater caused cementation and weathering. Both subtidal areas with colonies still in growth position and intertidal areas where skeletal rubble accumulated are found within the stromatoporoid cap facies.

The top of this facies is an erosional surface as is the top of the adjacent crinoidal shoal in Ontario. Immediately overlying this erosional contact is the dark, well-bedded, cherty dolomite of the Goat Island Member. Although the Goat Island has not been studied in detail, fossils found mainly in the chert nodules (Zenger, 1965) indicate that the area was again submerged, but that the sea was more restricted than during Gasport time.

ONONDAGA REEF

Introduction

This study is based on a Master's thesis submitted by Richard Poore to the Department of Geological Sciences at Brown University in 1969.

The Onondaga Limestone (Middle Devonian) of New York State crops out almost continuously from Buffalo east to Albany, and then south and southwest to Port Jervis (Fig. 6). Along most of this outcrop belt, the lowest member of the Onondaga Fromation is a light-gray, coarsely-crystalline, crinoidal and coralline limestone. This unit has been named the Edgecliff Member of the Onondaga Limestone (Oliver, 1954).

The Edgecliff Member contains more than thirty irregularly-distributed, small bioherms that provide an excellent opportunity for paleoecological studies. This study concerns one of these bioherms, the Leroy Bioherm which is located in an abandoned quarry approximately two miles northwest of the Town of Leroy, New York (STOP #4 of Field Trip).

Fig. 6 - Outcrop belt of Edgecliff Member of Onondaga Limestone, and location of the Leroy bioherm. Modified from Oliver (1956).

Stratigraphy

The Onondaga Formation in western New York rests unconformably upon the Bois Blanc Formation (upper Lower Devonian, Emsian) or Upper Silurian dolomite (Oliver, 1966). There is a gradational contact between the Onondaga Formation and the overlying Oatka Creek Shale Member of the Marcellus Formation (Rickard, 1964).

Oliver (1954) divided the Onondaga Formation into four members, these being, in ascending order, the Edgecliff, Nedrow, Moorehouse and Seneca. Ozol (1964) renamed the Nedrow Member in western New York, the Clarence Member, on the basis of its high chert content. Lindholm re-studied the Onondaga Limestone in 1967 and, along with Oliver, showed that bioherms occur in the Edgecliff Member (Fig. 7).

As an incidental part of the study of the stratigraphy of the Onondaga Limestone in New York, Oliver (1954) listed the fauna of the Williamsville Bioherm in western New York, and the Thompson Lake Bioherm in eastern New York. Later, Oliver (1956b) listed the location of over twenty bioherms in eastern New York. Oliver (1966) provides a short discussion of the Edgecliff bioherms and gives a generalized diagram of the relationship of the core and flank facies of these bioherms to the surrounding non-biohermal rocks.

Mecarini (1964) and Bamford (1966) provide the only detailed studies that have been done on Edgecliff bioherms. Mecarini studied the Mt. Tom Bioherm and Bamford worked on the Albrights Reef, both in eastern New York. These workers found that the bioherms were best described as patch reefs, and that they displayed a remarkably similar, but not identical, vertical sequence of ecological succession.

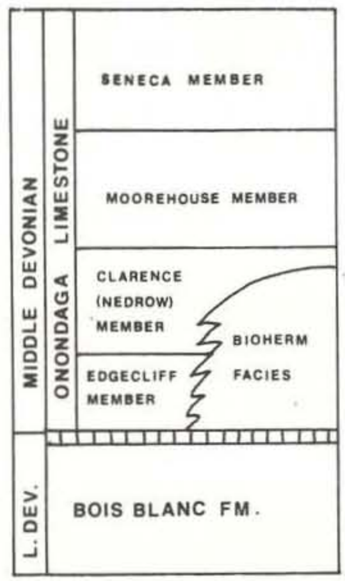

Fig. 7 - Stratigraphy of the Onondaga Limestone showing subdivision into Members and stratigraphic equivalents of the Leroy bioherm. Modified from Oliver (1966).

Bioherm Facies

Detailed analysis has resulted in the division of the Leroy Bioherm into nine facies. These are in order of discussion: the Acinophyllum facies, the Core facies, which includes the Inner Core subfacies and the Outer Core subfacies, the Transitional facies, the Heliophyllum facies, the Near Reef Edgecliff facies, the Flank facies, the Protocap facies, the Flank-Cap facies and the Modified Flank-Cap facies. These facies can be seen on two sides of the reef exposure and are illustrated in a cross section of the south side (Fig. 8). Table 1 is a summary of point count data for several of the facies and Table 2 contrasts the coral fauna of the biohermal units.

Both Oliver (1954), (1956a) and Lindholm (1967) agree that the deepest part of the Onondaga basin was in central New York. Lindholm (1967) suggests that the axis of the basin ran from Syracuse roughly southwest into Pennsylvania. The authors have adopted this viewpoint, and in the following discussion the western side of the bioherm is toward the platform and the eastern side of the bioherm is toward the basin.

Coelenterate classification follows Stumm (1964), except in the case of Synaptophyllum where McLaren (1959) is followed.

Acinophyllum Facies. This facies is a biomicrudite which crops out very discontinuously at the east end of the south side of the bioherm (Fig. 8) and at the base, near the center of the north side. The lower contact of this facies was not observed, and the maximum thickness observed was 2 ft.

This facies is characterized by a large number of Acinophyllum in a dark matrix of micrite and fine-grained fossil hash. Point count analysis of thin sections shows that Acinophyllum comprises from 31 to 60 percent of the rock volume. Most of these corals are strongly oriented in an east-west direction.

Crinoids, auloporids, ostracods and gastropods are present in meager amounts. With the exception of the ostracods, these accessory organisms occur as broken fragments.

Spar is present in most skeletal voids and in secondary voids such as fractures. Occasional patches of pseudospar can be found in the micrite, fossil hash matrix.

This facies is interpreted as a basal platform or substrate on which the core of the bioherm was built. Acinophyllum acts as a pioneer population which colonizes the area and traps mud*

*In the remainder of this paper, mud refers to everything less than 20 microns which includes both micrite and silt-sized particles.

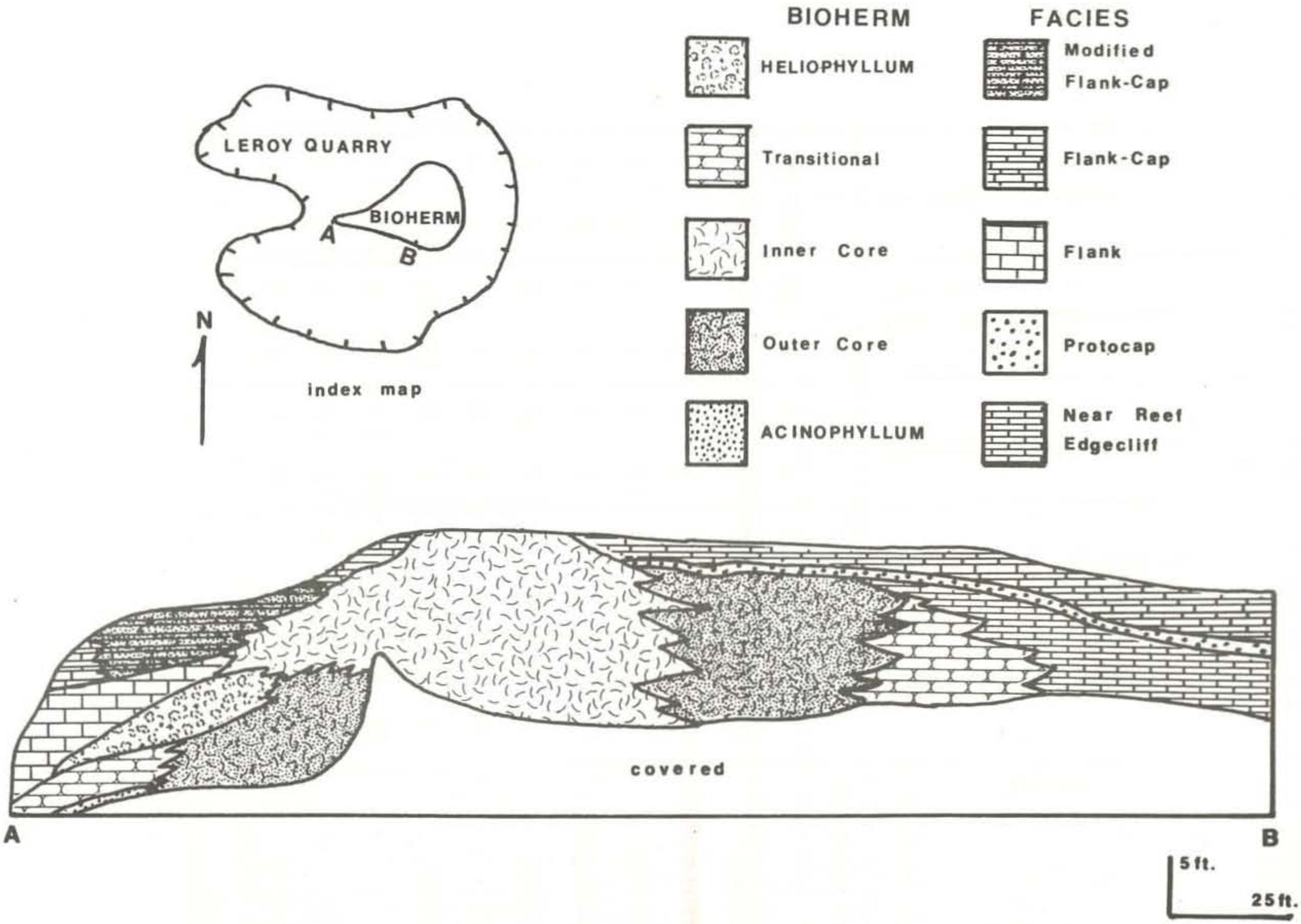

Fig. 8 - Cross section of Leroy bioherm showing facies. Cross section is along the south side of the core of the bioherm which is exposed in the middle of the Leroy quarry (see index map).

Table 1: Summary of point count data for selected biohermal facies and subfacies. A average; SD standard deviation; x not seen in facies; - too minor to be counted

Facies	Inner Core subfacies		Outer Core subfacies		Transitional facies		Near Reef Edgecliff facies		Protocap facies	
Number of samples	9		14		4		5		5	
Percent	A	SD	A	SD	A	SD	A	SD	A	SD
"cladoporids"	14	7	20	8	9	3	2	1	6	5
other tabulates	3	4	2	3	3	2	8	6	2	2
Acinophyllum	1	-	2	3	12	4	-	-	26	8
Synaptophyllum	x	x	-	-	2	3	-	-	8	12
other rugose	1	-	1	3	7	10	4	8	2	2
ectoproct	4	3	2	2	5	4	1	1	2	1
pelmatozoan	13	7	13	7	8	4	56	13	15	13
mud	34	11	35	9	28	10	6	6	21	12
spar	21	8	17	9	13	12	4	6	8	3
unidentified skeletal debris	6	4	5	3	8	5	9	8	9	4
other	5	3	2	2	3	1	1	1	1	1

Table 2: Relative abundance of tabulate and rugose coral genera in Leroy Bioherm facies and subfacies. A abundant - crowded in rock; C common - easily found; P present - can be found; R rare - rarely found; x not seen; ? questionable identification

Facies	Acinophyllum	Outer Core	Inner Core	Transitional	Heliophyllum	Near Reef Edgecliff	Protocap	Flank	Flank-cap	Modified Flank-cap
Heliolitidae										
PROPORA (?)	X	X	P	X	X	X	X	X	X	P
Favositidae										
FAVOSITES	X	P	C	C	X	C	P	C	A	A
EMMONSIA	X	C	C	X	X	X	X	P	R	X
THAMNOPORA	X	A	A	C	P	C	C	?	C	C
CLADOPORA	X	A	A	A	C	C	A	C	C	C
COENITES	X	P	X	C	X	X	?	X	X	X
Auloporidae										
ROMNIGERIA	R	C	P	P	R	P	X	X	P	X
AULOCYSTIS	R	C	C	C	C	C	C	P	C	C
Streptelasmatidae										
HETEROPHRENTIS	X	X	X	X	X	X	?	P	P	X
SIPHONOPHRENTIS	X	P	P	X	X	?	X	C	?	?
Zaphrentidae										
HELIOPHYLLUM	X	R	X	C	A	C	R	C	A	A
BETHANYPHYLLUM	X	R	X	?	X	C	R	C	C	?
Stauriidae										
SYNAPTOPHYLLUM	X	R	X	C	C	X	A	X	P	P
Phillipsastraeidae										
CYLINDROPHYLLUM	X	X	X	?	?	X	P	X	P	X
ACINOPHYLLUM	A	P	P	A	A	P	A	?	A	P
Digonophyllidae										
CYSTIPHYLLOIDES	X	A	A	X	X	C	R	C	C	X
EDAPHOPHYLLUM	X	R	X	X	X	?	X	R	R	X

and other organic debris between its elongate cylindrical coralites, resulting in a compact or firm substrate.

This platform building stage took place in low energy conditions where the mud and other organic debris was able to filter down between the Acinophyllum corallites. Acinophyllum with its elongate, cylindrical and laterally-connected corallites is better adapted to a turbid environment than massive sheet-like or head-like favositid corals would be. In addition to this, the compound, interconnected Acinophyllum provides an excellent framework, which, once packed with mud and other debris, becomes a suitable foundation for the bioherm-building organisms.

The Acinophyllum facies is analogous to the initial-reef subfacies of the Gasport reefs. The biota of the Gasport is different but the effect was the same, that of providing the framework in which sediment accumulated. The resulting mound then acted as the base on which other organisms grew.

Core Facies. A casual examination of this facies in outcrop would probably not result in further subdivision. However, detailed examination of lithology and faunal abundance, summarized in Table 3, has resulted in identification of two subfacies.

Inner Core Subfacies - The Inner Core subfacies (Fig. 8) is a cladoporid-crinoid sparse biocalcisiltite to a poorly-washed biosparudite. The maximum thickness observed for this unit is 20 ft. The Inner Core subfacies is characterized by its dark-gray color, vuggy weathering appearance, and complete lack of bedding.

The tabulate corals present fall into two natural groups. The first is composed of members of the genera Favosites, Emmonsia, Thamnopora, (larger species than counted in cladoporids) and Propora (?) with reptant and phaceloid growth forms. The second group is composed of cladoporids and auloporids. The latter are much smaller and their growth form is predominantly ramose. These cladoporids commonly grow in thickly-entwined, anastomosing clusters and make up 14 percent of the rock volume.

Cystiphylloides americanum is the most abundant large rugose coral. Two other types of rugose corals, one of the subfamily Acrophyllinae and the other resembling Placophyllum (?) (Fagerstrom, 1961) are present in this subfacies.

Platyceratid gastropods are fairly common, and one portlockiellid gastropod was seen in this unit. Cyclostome ectoprocts are found encrusting cladoporids and matrix. Other organisms present are molluscs, trilobites, ostracods, brachiopods, fenestrate cryptostome ectoprocts, and other rugose corals.

The matrix is composed of 34 percent lime mud, which includes micrite as well as silt-sized grains less than 20 microns in diameter, and other larger skeletal debris (Table 1).

Outer Core Subfacies - The Outer Core subfacies is a cladoporid-crinoid packed biocalcisiltite to a poorly-washed biosparudite. It, in part, underlies and laterally interfingers with the Inner Core subfacies.

On outcrop this unit is dark gray, does not exhibit a well-developed, vuggy-weathering surface, and has highly-irregular, discontinuous bedding.

The same two natural grouping of tabulate corals mentioned for the Inner Core subfacies are present, but with modifications (Table 3). Propora (?) is not present, and Emmonsia is more abundant, especially on the outer and upper edges of the unit. These larger tabulates are, as a whole, more abundant than in the Inner Core subfacies. There are three noticeable changes in the second group. Individuals of the genera Coenites are found in the Outer Core subfacies, but not in the Inner Core subfacies, and the cladoporids do not form as many anastomosing clusters in the Outer Core subfacies. In addition to this, Romingeria is more abundant.

Cystiphylloides americanum is still the dominant rugose coral, but Edaphophyllum, Heliophyllum and Bethanyphyllum are also present.

These two subfacies are interpreted as being the major topographic building unit of the bioherm with the Inner Core subfacies acting as the main growth center. The thickly-entwined cladoporids provided a framework or upward-reaching siève, which trapped organic debris and mud. Larger favositid corals helped to buttress the cladoporid framework, and in conjunction with encrusting ectoprocts, helped stabilize the skeletal debris.

Away from the main growth center (Outer Core subfacies), the larger tabulates increased in abundance and played more of a major role in upward building. The cladoporids in this subfacies are more evenly distributed and form fewer clusters. Thus it seems that deposition was slightly slower in this subfacies, allowing more of the cladoporids to be broken and mixed in with the other organic detritus. This is in contrast to the Inner Core subfacies, where most of the cladoporids were incased in organic detritus while still in growth position.

Squires (1964) describes a coral thicket of Upper Miocene age in New Zealand, in which the framework-building organism is Lophelia parvisepta, a deep-water scleractinian coral with a highly-reticulate growth pattern. The writers do not wish to suggest that the Leroy Bioherm is a deep-water structure, but rather that Squires' (1964) thicket, coppice, and early bank stages are probably analogous to the first stages of the Core facies development.

Table 3: Basis for subdividing Core Facies

Inner Core subfacies	Outer Core subfacies
weathers very vuggy	weathers slightly vuggy
massive	irregular and discontinuous bedding
low abundance of *Emmonsia* trace amounts of *Acinophyllum*	higher abundance of *Emmonsia* more *Acinophyllum*
Synaptophyllum not present	*Synaptophyllum* present
presence of *Placophyllum* (?) and member of subfamily *Acrophyllinae*	Placophyllum (?) and member of subfamily *Acrophyllinae* not present
Cystiphylloides dominant almost to exclusion of other large rugose corals	Cystiphylloides dominant, but *Edaphophyllum*, *Heliophyllum* and *Bethanyphullum* present

The spar content of the core facies is considerably greater than that of the underlying Acinophyllum facies thus suggesting better circulation and a higher energy environment for the Core facies. This facies, then, represents the semi-rough water stage of development.

Although "stick" or "finger" tabulate corals are commonly known to build mounds and biohermal structures during Devonian time (Stumm, 1969, Dumestre and Illing, 1967), they usually do so in concert with stromatoporoids. Only two stromatoporoids were seen during this study.

Transitional Facies. This facies in part overlies the Acinophyllum facies and interfingers laterally with the Outer Core subfacies and the Near Reef Edgecliff facies. On the western or platform side of the bioherm, it has a gradational contact with the overlying Heliophyllum facies (Fig. 8).

This unit is a packed, cladoporid-Acinophyllum biocalcisiltite. On outcrop this facies is light-gray, non-vuggy, and exhibits moderately well-developed bedding. Large tabulate and rugose corals are not very abundant in this unit. On fresh exposures this unit has a speckled appearance caused by the color contrast between the matrix and the lighter colored Acinophyllum, Synaptophyllum and cladoporids.

In thin section this unit is characterized by the Acinophyllum, Synaptophyllum and cladoporid association. Mud content is still high averaging 28 percent. Associated organisms in order of decreasing abundance are brachiopods, gastropods, trilobites and ostracods. Many of the organisms present in this facies are either broken, or are not in growth position.

This facies represents the narrow band that separated the Outer Core subfacies from the Near Reef Edgecliff facies and is composed of the detritus that was, in part, transported from the Outer Core subfacies. The area was not a prolific growth area for the cladoporid group, except perhaps for Coenites, and because of this Acinophyllum was not crowded out as it was in the Core facies.

Heliophyllum Facies. This facies is developed only on the western (platform) side of the bioherm. It interfingers laterally with the Outer Core subfacies and the Flank facies. It has a gradational contact with the underlying Transitional facies and the overlying Modified Flank-Cap facies (Fig. 8).

On outcrop this unit is very distinctive and is dominated by Heliophyllum and Acinophyllum horizons in a black, dense matrix. The Heliophyllum display a weakly-aggregated growth habit. Westward dips ranging from 8 to 12 degrees were recorded for this unit.

In thin section this unit is best described as a sparse to packed Heliophyllum-Acinophyllum biomicrudite. Synaptophyllum occurs irregularly within the Acinophyllum-rich horizons, and an occasional Cladopora-rich zone was encountered.

The matrix is a mixture of fine fossil hash and micrite. Occasionally, pockets of crinoid ossicles and spar can be found, but on the whole, both of these components are minor. Ectoprocts, ostracods, brachiopods, gastropods, trilobites and auloporids are also found in this facies.

This unit is thought to represent an "energy shadow" deposit accumulated on the platform side of the bioherm as it built up into the semi-rough water environment.

The Heliophyllum-rich zones are well-defined and continuous. The weakly-aggregated individuals are most often found lying on their sides forming, in places, a white band of rock that closely parallels the dip of the unit. Another feature of the occurrence of these corals is that very few broken or abraded individuals were found. These observations indicate that these corals have not been transported to any significant degree and, in addition, are probably very near their original growth position with only a minor amount of compaction.

The zonation seen in this unit is probably due to turbidity changes. During times of high turbidity Acinophyllum was better adapted for this quiet, muddy environment. During times of reduced turbidity and concomitant, slower deposition of fines, Heliophyllum was able to dominate over Acinophyllum.

Near Reef Edgecliff Facies. This facies interfingers laterally with the Transitional facies and is overlain by the Protocap facies or the Flank-Cap facies. It is exposed on the east and north-east side of the bioherm (Fig. 8). On the western side of the bioherm it has been quarried out.

On outcrop this unit is a light- to dark-gray, medium-crystalline crinoid sand. It is fairly well-bedded, with individual beds ranging from 2 - 6 in. in thickness. Favositid and solitary rugose corals are common in this unit. The growth forms of the favositids are usually reptant or sheetlike and they appear to be in life position. Occasional hemispherical (2-4 in. diam.) Favosites were seen. Heliophyllym, Bethanyphyllum and Cystphylloides are common. The latter are sometimes concentrated on the lowermost bedding planes of this unit.

In thin section this unit is a crinoid biosparudite. Mud content is low, averaging only 6 percent and virtually no micrite was seen. The crinoid content averages 56 percent. Brachiopods and platyceratid gastropods are found throughout this unit. Fragmented Acinophyllum, Synaptophyllum and ectoprocts are minor components of this facies.

The Near Reef Edgecliff facies is very much like that of the normal Edgecliff and represents only a slight modification of normal Edgecliff conditions. The most obvious difference between the two is that the Near Reef Edgecliff facies does not contain the black chert beds and nodules that are present in the normal Edgecliff. The normal Edgecliff also has less spar, and more large spherical to hemispherical Favosites than the Near Reef Edgecliff.

Flank Facies. This is present on the western or platform side of the bioherm. It is a wedge-shaped unit that overlies the Transitional facies and, in part, the Heliophyllum facies. It is in turn overlain by the Modified Flank-Cap or the Flank-Cap facies. It laterally interfingers with the Heliophyllum facies (Fig. 8).

On outcrop this unit is a light-gray to pink, medium crinoid sand which is massive- to poorly-bedded. Large and small Favosites are present as are large solitary rugose corals. Most of the Favosites are reptant or in a semi-sheet growth form, however, some larger head or semi-hemispherical forms were seen. Rugose corals include Compressiphyllum, Edaphophyllum, Siphonophrentis, Heliophyllum, Bethanyphyllum and Cystiphylloides.

In thin section this unit is a crinoid biosparudite. Cladopora is the only cladoporid found in this unit and aulo-porids are relatively lacking. With the exception of the larger rugose and the reptant or sheet-like favositids, most of the organisms present in this facies show some degree of breakage or abrasion. The mud content of this facies (9 percent) is higher than that of the Flank-Cap facies, and some micrite is present in this category.

There is a prominent and continuous bedding plane on the north side of the bioherm that separates this facies from the overlying Flank-Cap facies and the Modified Flank-Cap facies. On the south side of the bioherm, where this area of the outcrop is more severely weathered and partially overgrown, this relation-ship is not as well developed. It is possible that this facies should be considered as part of the Modified Flank-Cap facies rather than as a separate unit, however, the "Flank-Cap" desig-nation is used to imply that a unit both flanks and overrides the core facies.

This unit is thought to have been deposited during the initial stages of the formation of the "crinoid garden," which later draped the area and formed the Flank-Cap facies. As this crinoid garden was forming, the individuals would be initially widely-spaced, perhaps in patches, and therefore susceptible to being broken up. They then could be washed over and around the bioherm and deposited in the slight energy shadow on its platform side. The larger rugose corals and sheet-like or reptant favositids probably were growing in this area along with some crinoids and their associated platyceratid gastropods. The larger Favosites were washed into the area along with other crinoid and skeletal debris during times of storm activity.

Protocap Facies. This facies is found only on the eastern or basin-side of the bioherm. It overlies the Core facies, the Transitional facies and the Near Reef Edgecliff facies. It is, in turn, overlain by the Flank-Cap facies (Fig. 8). The thickness of this unit varies from 4 to 6 in. This unit is best developed on the south side of the bioherm and was seen at one point on the north side. The lower contact of this unit is sharp, but the upper contact is gradational into the Flank-Cap facies.

On outcrop this facies is dominated by Acinophyllum oriented parallel to the lower contact. Shaley partings are more obvious in this facies than in any other biohermal unit.

The Protocap facies is thought to represent the very beginning of the wave-resistant or rough water stage in the development of the bioherm. It would seem that this unit was developed just below or right at the lower limit of normal wave base.

Flank-Cap Facies. This facies overlies the Protocap facies, the Near Reef Edgecliff facies, the Core facies and, in part, the Flank facies. It also interfingers with the Modified Flank-Cap facies.

On outcrop this unit is a whitish-gray to pink, extremely-coarse, crinoid sand. As is indicated by its name, it both flanks and caps the core of the bioherm. The unit has a bedded appearance which is caused by zones or horizons of concentrations of rugose and tabulate corals. The larger, tabulate corals present are head-shaped and semi-hemispherical Favosites, and heavy ramose Thamnopora. Some of the Favosites are several feet in diameter and 6 to 8 in. thick.

The rugose coral zones are composed of Acinophyllum or Heliophyllum. Cladopora is usually present in the Acinophyllum zones, and in some cases Cladopora and auloporids make up a coral horizon. Bethanyphyllum and Cystiphylloides are common in this unit, but they do not form coral horizons or zones.

The rock between coral zones is an extremely-coarse, pink and white crinoid sand with abundant crinoid columnals up to an inch in diameter. Brachiopods and gastropods are associated with these crinoid sand layers. The unit dips away from the core of the bioherm at angles up to 15 degrees.

In thin section this unit is a crinoid biosparudite. Point count data are strongly affected by the location of the sample in relation to the coral-rich horizons, therefore no attempt was made to obtain average amounts of the various components. Skeletal debris is abundant in this facies and mud is usually minor, occurring in significant amounts only in the coral horizons.

The Flank-Cap facies is interpreted as being the culminating stage in the development of the Leroy Bioherm. The crinoids equipped with holdfasts and flexible stems, are well-suited to living in a near-surface, high-energy environment. There organisms formed a crinoid garden, that draped the bioherm and the surrounding area. The lower flanking portions of this unit formed during the early period of the wave-resistant stage, probably contemporaneously with the higher portions of the core. As the core built up into the zone of normal wave action, the crinoid garden migrated up and over the core, and finally capped the structure.

The coral horizons represent times of relatively low-energy conditions, when corals were able to grow in great profusion in and around the crinoid stalks. During times of relatively high-energy conditions, these coral beds were buried by crinoid and other skeletal debris. In his dicussion of Niagaran reefs, Lowenstam (1957) describes typical reef-flank sections in the following manner:

> "...Reef-flank sections denoting an early stage of the wave-resistant phase commonly show cyclical interlayering of frame-building organisms and bioclastics reflecting periodic storm-induced burial by reef-derived fragments and hence temporary retraction of the building sphere..."

The Flank-Cap facies seems to represent a similar situation to that seen in some large Niagaran reefs; however, it is not similar to the flank subfacies of the Gasport reefs.

Modified Flank-Cap Facies. This facies is found on the western side of the bioherm. It overlies the Flank facies and the *Heliophyllum* facies, and interfingers laterally with the Flank-Cap facies (Fig. 8).

On outcrop this unit varies from a rugose coral-rich, dark, dense rock to a light-gray, coarse crinoid sand. Favositid corals are irregularly present and are of the same assemblage as that of the Inner Core subfacies. Mud content is generally quite high (average 33 percent) and the facies contains many entwined *Heliophyllum* and subordinate *Acinophyllum*.

In thin section this facies varies from a rugose coral, sparse-to-packed biocalcisiltite to a crinoid biosparudite. The matrix trapped by the Heliophyllum contains micrite and silt-sized skeletal debris. Associated organisms include ectoprocts, trilobites, ostracods, gastropods, and brachiopods.

The facies is thought to represent a combination of a second generation energy-shadow deposit and a shifting of the core out of the high-energy zone. Even after the bioherm was built up into the rough water zone, and was overgrown by the crinoid garden, it initially had enough relief to provide a slight energy-shadow on its platformward side. Heliophyllum became established in the area, along with corals characteristic of the Inner Core subfacies. The Heliophyllum, in this case, acted as the major framework building organism, and was able to trap fines.

As the Flank-Cap unit began to reduce the relief of the area the Modified Foank-Cap facies was soon smothered by the encroaching crinoid garden.

Surrounding Rocks

The stratigraphic succession exposed in the quarry walls surrounding the Leroy Bioherm can be divided into four units. These units can be traced around the entire quarry and show little variation from place to place.

1. The lowest unit exposed is a vaguely-bedded to massive, medium-grained, dark, crystalline crinoid limestone. There are a few solitary rugose corals in this unit along with brachiopods and occasional gastropods and cladoporids. The maximum thickness seen for this unit was 3 ft. The upper contact is sharp and is overlain by a 2 in., dark chert bed at the base of the overlying unit. The lower contact with the Lower Devonian, Bois Blanc Formation was not observed.

2. This unit is a well-bedded, medium-to-coarse, dark-gray crinoid sand. The individual beds which are 2 to 8 in. thick commonly exhibit considerable lateral variations in thickness. The total thickness of the unit is about 7.5 ft. The unit is very fossiliferous, containing abundant rugose and tabulate corals, brachiopods and some gastropods. The favositid colonies are up to a foot in diameter and are either head-shaped or reptant. Cladoporids and auloporids are found scattered throughout, along with the dominant rugose corals, Heliophyllum and Bethanyphyllum.

Chert is very abundant in the lower portion of this unit, occurring in 1 to 3 inch discontinuous beds, or as nodular horizons. Towards the top of the unit, chert content decreases and no chert beds are present. The upper contact with the overlying unit is gradational. Chert content for the unit as a whole is approximately 30 percent.

3. This unit is a well-bedded, light-to-gray, coarse crinoid sand. Individual beds are 1 to 8 in. in thickness, and often a thick bed will split laterally into two thinner ones. The total thickness is 9 ft.

This unit is extremely fossiliferous, containing two species of Heliophyllum along with Bethanyphyllum, Cystiphylloides, Acinophyllum, Siphonophrentis and Edaphophyllum. Tabulate corals are represented by several species of Favosites, auloporids and the cladoporids. Brachiopods are abundant in this unit with spiriferids, pentamerids and several species of Atrypa being common. Gastropods are also abundant in this unit.

Coral beds of Acinophyllum and Heliophyllum are present as are auloporid and favositid-rich zones. The coarse crinoid sand between these coral horizons is packed iwth the other solitary rugose corals, brachiopods and gastropods.

Beds of Favosites measuring 2 ft. in diameter are not uncommon in this unit. Reptant and smaller hemispherical Favosites are also present. Chert content of this unit is less than 5 percent.

The lower limit of this unit is set at a marked ledge on the southern quarry wall and the upper limit is set at the first occurrence of a continuous chert bed at the bottom of the overlying unit.

4. The topmost unit is well-bedded, dark gray, medium crinoid sand. The bedding is very similar to that in the underlying unit. The maximum observed thickness is 6 ft.

This unit is also very fossiliferous, but differs from the underlying unit in that rugose corals are less abundant, Heliophyllum still forms coral beds. Again, two species of Heliophyllum are present, one forms the coral beds and the other is irregularly distributed. Acinophyllum does not occur in beds, but rather in circular clumps. Large head-shaped Favosites are not as common and small spherical favositids are more abundant.

The most notable faunal change from the underlying unit is in gastropod abundance and diversity. Two species of euomphalids, several platyceratid, and many large unidentified gastropods are found in this unit. These gastropods are often found in association with the chert beds. Brachiopods are still common. Chert in this unit is approximately 45 percent and occurs as irregular 2 to 4 in. beds, or as chert nodule horizons. Rock debris looking very much like this unit was found on top of the bioherm. It seems reasonable to assume that this unit once overlay the Flank-Cap facies at the bioherm.

Units 2 and 3 compare favorably with description of the Edgecliff Member by Oliver (1954, 1966) and Lindholm (1967) although unit 3 is influenced considerably by the proximity of the flank-cap facies of the reef. Unit 4 is probably equivalent to the Clarence Member (Nedrow of central New York). However, its fossil content indicates that the nearby reef was still an active influence during the initial phases of Clarence sediments.

Reef Development Model

There is a marked vertical community succession or seral succession (as used by Nicol, 1962) exhibited by the Leroy Bioherm. The main communities are, in ascending order, the Acinophyllum community, the cladoporid community, and the crinoid garden community.

The Acinophyllum community is characterized by low taxonomic diversity and is dominated numerically by one species, Acinophyllum baculoideum. This community forms a pioneer community, and the controlling factors in its development are water energy and turbidity. This community represents the quiet-water stage of the bioherm.

The cladoporid community is characterized by a high taxonomic diversity and, as far as could be determined, no one species is numerically dominant. This community is the major topographic building unit of the bioherm. The cladoporids and subordinate larger favositids (except perhaps in the upper portions where Emmonsia and other Favosites may have become more important) constructed a framework which provided many niches for other organisms and provided a trap which retained debris created in and around this growth center, thereby facilitating its upward growth. The controlling factor is again water energy. This community represents the semi-rough water and, in part, the rough water stage of the bioherm.

The crinoid garden community is characterized by a moderate-to-high taxonomic diversity and is possibly numerically dominated by crinoids. When it is seen directly over the core of the bioherm, it does not contain the diverse fauna that it shows away from the core. This is to be expected as the point over the core was, for a time, the topographically highest position of the crinoid garden and, therefore, in the area of highest energy. It is reasonable to expect a slight reduction of diversity in a stress environment.

The controlling factor is once more water energy. The initiation of the crinoid garden was caused by the bioherm penetrating up into the surf zone, where the cladoporid community could not survive. The crinoid garden community was then able to take over the area. This stage of the bioherm was not very important in upward building of the structure. The growth of the bioherm during this stage was mainly in a horizontal direction and was soon able to level the relief of the area. The crinoid garden community is considered to be the rough water stage of the bioherm.

Organisms acting as sediment binders within the bioherm are cyclostome ectoprocts, crinoids, sheet-like and reptant favositids. The framework builders are the cladoporids, Acinophyllum, auloporids, and larger favositid corals. The sediment-producing organisms are crinoids, cryptostome ectoprocts, gastropods, brachiopods, trilobites, ostracods, and to some degree all of the coral present in these rocks.

In an effort to construct a general model for Edgecliff biohermal development, the detailed facies of the Leroy reef can be grouped into four basic units (Fig. 9). The first unit is the platform-building or Acinophyllum facies. The matrix of this unit is mainly micrite. The lower extent of the Acinophyllum facies and its relationship to underlying rocks is now known.

Overlying the Acinophyllum facies is the Core facies which is the main relief-building unit of the bioherm. The framework builders are delicate "finger" corals and to a lesser degree other larger favositids. The matrix of this unit is a mixture of micrite and silt-sized organic debris. The top of this unit may or may not be channeled. On the platformward side of the core, the energy-shadow facies is developed. This unit has more micrite in its matrix than the Core facies, but less than the Acinophyllum facies. Organisms with a high tolerance for mud are found living in this area. Fluctuations of turbidity experienced by this environment are indicated by a zonation of organisms, which are interpreted as having different levels of tolerance to turbidity.

The last basic unit is the Flank-Cap unit which both flanks and overrides the structure bringing its upward growth to a half. The change from the upward-building, core facies to the lateral-building, Flank-cap facies is brought about by the penetration of the bioherm into the wave zone. As a result, the Flank-Cap facies is extremely coarse and virtually mud free.

Reconnaissance field work in 1969 indicated that most of the bioherms exposed in eastern New York fit the model suggested in Fig. 9. Observations made during this time support the interpretation that "finger corals" are important in the framework of the main relief building facies of these bioherms.

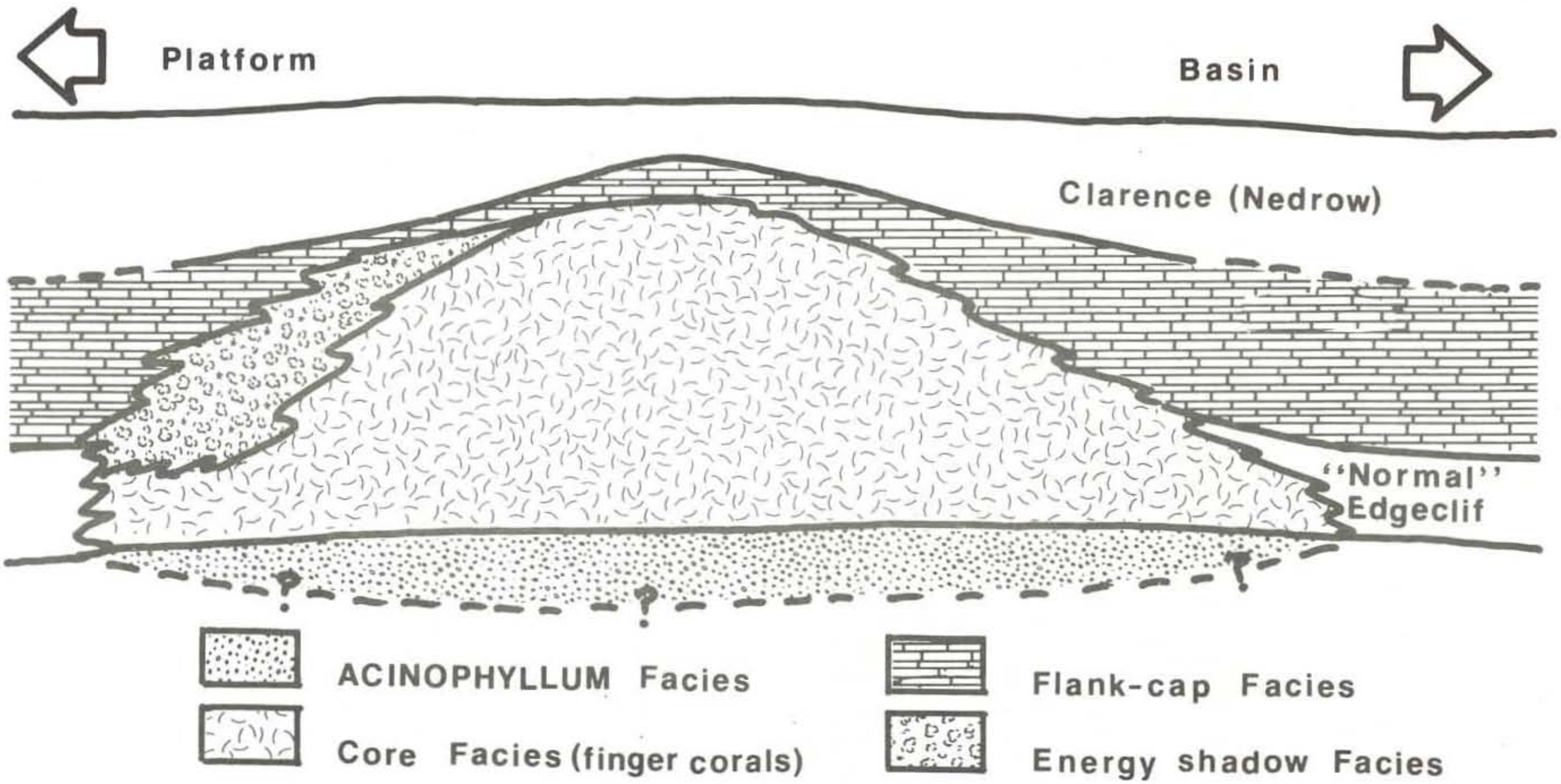

Fig. 9 - Diagrammatic cross section of a "typical" Edgecliff bioherm. See text for discussion of facies.

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TRIP A - LOCKPORT (MIDDLE SILURIAN) AND ONONDAGA (MIDDLE DEVONIAN) PATCH REEFS IN WESTERN NEW YORK

Donald J. Crowley (Field Trip Leader) and
Richard Z. Poore

Location of Stops

STOP 1.

Road cut on escarpment in the village of Pekin, 1.8 miles north on route 429 from intersection with route 31. Ransomville 7½' quad.

Two patch reefs in the Gasport Member (Lockport Fm) are exposed on the west side of the road cut (See Fig. 4 in report). Lower few feet of the overlying chert-bearing Goat Island Member are also exposed.

STOP 2.

Railroad cut on the east side of "The Gulf", 1.3 miles east on route 31 from intersection with route 78 in Lockport. Lockport 7½' quad.

DeCew Member and the crinoidal bar facies of the Gasport (Lockport Fm.) are exposed. This is the most fossiliferous exposure of the Gasport and preservation of fossils is also good. Coral thickets form lenses in the crinoidal bar facies.

STOP 3.

Frontier Stone Products quarry, 1.4 miles southwest of intersection of routes 31 and 78 in Lockport. Lockport 7½' quad.

All Gasport facies (Lockport Fm.) are exposed including several patch reefs. Stromatoporoid cap facies forms light band near the top of the quarry walls. A few feet of the Goat Island Member is exposed above the light band and the floor of the quarry is the top of the DeCew Member.

STOP 4.

Abandoned quarry ("LeRoy quarry"). From the intersection of routes 5 and 237 in the village of Stafford (Stafford 7½' quad.) go north 2.2 miles on route 237, turn right and go 2.6 miles to the east end of Britt Road (to the point where the road turns south and crosses the Leigh Valley Railroad tracks). Turn north into entrance road to quarry. Byron 7½' quad.

Patch reef in Onondaga Limestone exposed in the middle of the quarry. Edgecliff and the lower part of the Clarence member exposed around the outside quarry wall. (See Fig. 8 in report for cross section of reef).

A BRIEF DESCRIPTION OF UPPER DEVONIAN UNITS TO BE OBSERVED ON CHAUTAUQUA COUNTY FIELD TRIP

Irving H. Tesmer, Geosciences Department, SUNY College, Buffalo, NY 14222

PREVIOUS WORK

The first major work related to the geology of Chautauqua County appears in James Hall's (1843) Survey of the Fourth Geologic District. Chautauqua County stratigraphy was later studied in greater detail and modified by such workers as Clarke (1903), Chadwick (1923; 1924), Caster (1934), Pepper and de Witt (1950; 1951) and de Witt and Colton (1953). New York State Museum Bulletin 391 (Tesmer, 1963) describes the stratigraphy and paleontology of Chautauqua County.

Devonian stratigraphic nomenclature pertinent to this region his been subject to various interpretations (e.g., Rickard, 1964 and Oliver *et al.*, 1969). In this guidebook, the present author follows the stratigraphic terminology used in his other publications (Tesmer 1963; 1966; 1967; 1974; Buehler and Tesmer 1963).

DESCRIPTION OF UNITS

Hanover Shale Member of the Java Formation

Only a few feet of the uppermost portion of the Hanover Shale can be observed on this field trip (STOP 2). The Hanover Shale was named by Hartnagel (1912, p. 76) for exposures that occur in Hanover Township, northeastern Chautauqua County. This unit is about 90 ft. thick and consists mostly of gray shales with some interbedded dark-gray shales and thin limestones as well as several zones of calcareous nodules (Tesmer 1966, p. 48). The unit contains some pyritized algae, conodonts and a few cephalopods. The Hanover has been traced from the Lake Erie shore at Dunkirk eastward across Cattaraugus Creek between Irving and Versailles through Pipe Creek Glen in Colden Township, Erie County to exposures in Beaver Meadow Creek at Java village, Wyoming County and eastward (Pepper and de Witt 1950; de Witt 1960).

Dunkirk Shale Member of the Canadaway Formation

An excellent view of this unit may be seen at STOP 2 which is the type locality for the Dunkirk Shale named by Clarke (1903, p. 24). Here, one may observe most of the unit which is composed of about 40 ft. of black shale (Tesmer 1963, p. 15) containing some pyrite nodules and septaria that vary from 1 to 5 ft. in diameter. The sharp contact between the light-gray Hanover beds and the overlying black shales of the Dunkirk makes a well-defined base for the Canadaway Formation. Pepper and de Witt (1951) assigned the Dunkirk, South Wales and Gowanda Members to a Perrysburg Formation which the present author does not recognize as it has an ill-defined top to the east in southern Erie and northern Cattaraugus Counties. Instead, Tesmer (1963, p. 14) considers the Dunkirk as the basal member of the Canadaway of Chadwick (1933, p. 355) and Caster (1934, p. 136). The Dunkirk has been traced from Lake Erie exposures in Dunkirk (Stop 2) across Cattaraugus Creek at Versailles, eastward to Pipe Creek Glen in Colden Township, Erie County, and beyond. Fossils include pyritized algae, higher plant fragments and conodonts.

South Wales Shale Member of the Canadaway Formation

Overlying the black Dunkirk Shale is a sequence of interbedded light- and dark-gray shales which vary from about 60 to 80 ft. in thickness (Tesmer 1963, p. 15). The South Wales was named by Pepper and de Witt (1951) for exposures in a small tributary to the East Branch of Cazenovia Creek, three miles south of South Wales in southern Erie County. South Wales strata contain some algae and conodonts. This member has been traced from the Lake Erie shore near Van Buren Point across Chautauqua Creek between Versailles and Gowanda eastward to Pope Creek Glen in Colden Township, Erie County, and beyond.

Gowanda Shale Member of the Canadaway Formation

The Gowanda Shale, originally named by Chadwick (1919, p. 157) after exposures at the village of Gowanda, was later redefined by Pepper and de Witt (1951), who selected outcrops along Walnut Creek in Hanover Township, Chautauqua County, as a standard reference section. The original Gowanda of Chadwick (1919, p. 157) is now divided into an older South Wales Member and a younger Gowanda Member (restricted sense). Thus, the Gowanda Member as now defined, contains interbedded gray to black shales, silty shales and light-gray siltstones, as well as many zones of calcareous concretions and septaria. The thickness varies considerably, ranging from about 120 ft. to well over 200 ft., generally increasing to the east (Tesmer 1963, pp. 18-22). Many of the strata seem quite barren but the Gowanda Member contains some fossiliferous zones such as the Corell's Point Goniatite Bed of House (1967, p. 1066). This will be seen at STOP 3 and is described by Kirchgasser in this guidebook. In addition to cephalopods, several pelecypods and some gastropods are present (Clarke 1904) and conodonts have been collected from dark shale bands near the top of the unit. The Gowanda occurs in Lake Erie cliffs in Portland Township, Chautauqua County, and has been followed eastward across Walnut Creek and Big Indian Creek (Pepper and de Witt 1951). This member cannot be easily differentiated in most of southern Erie and northern Cattaraugus Counties as the younger Laona Siltstone Member pinches out making the contact between the similar Gowanda and Westfield Shale Members indistinct east of the village of Perrysburg (Tesmer 1974).

Laona Siltstone Member of the Canadaway Formation

This unit was named by Beck (1840, p. 57) for strata that occur along Canadaway Creek at Laona, Chautauqua County. It has been traced across Chautauqua County from Lake Erie cliffs at Barcelona into western Cattaraugus County where it apparently pinches out in the vicinity of the village of Perrysburg (Tesmer 1963, pp. 25-27; 1974). The Laona attains a maximum thickness of about 25 ft. and consists principally of light-gray, quartzose siltstones up to one foot thick, with increasing interbedded gray shales toward the top of the unit. Usually barren, at one locality near Nashville, eastern Chautauqua County, this member contains a basal coquinite comprised primarily of brachiopods and pelecypods, several species of which first occur in the Laona but continue upward into younger units such as the Northeast Shale Member.

Westfield Shale Member of the Canadaway Formation

Overlying the siltstones of the Laona is a sequence of gray shales 100 to 220 ft. thick with a few interbedded siltstones. Chadwick (1923, p. 69) named it the Westfield Shale for exposures along Chautauqua Creek at the village of Westfield. This member can be traced from the Lake Eire shore near the New York - Pennsylvania line across Chautauqua County to the east branch of Big Indian Creek in northwestern Cattaraugus County (Tesmer 1963, pp. 27-29). As both the underlying Laona Siltstone Member and overlying Shumla Siltstone Member apparently pinch out a short distance east of here, the intervening Westfield Shale Member merges with the similar older Gowanda and younger Norteast Shale Members and is not recognized as a distinctive unit eastward in southern Erie and northern Cattaraugus Counties (Buehler and Tesmer 1963, pp. 93-94; Tesmer 1974). Most strata appear to be relatively barren although a few brachiopods and several conodonts have been reported (Hass 1958, p. 767).

Shumla Siltstone Member of the Canadaway Formation

This member was named by Clarke (1903, p. 25) for siltstone beds exposed along Canadaway Creek at Shumla (STOP 1). Lithologically, the Shumla is similar to the older Laona Siltstone Member of the Canadaway, consisting of up to about 35 ft. mainly of light-gray, quartzose siltstone with beds seldom more than a few inches in thickness. Various sedimentary structures may be observed at our field stop. An increasing percentage of interbedded shales occurs toward the top of the unit. Strata assigned to the Shumla are usually quite barren, but Hass (1958, p. 767) collected and identified conodonts from the type locality. This lens-like member has been traced from Lake Erie shore exposures near the New York - Pennsylvania line across Chautauqua County into Perrysburg Township, northwestern Cattaraugus County, where it apparently pinches out.

Northeast Shale Member of the Canadaway Formation

The Northeast Shale, named by Chadwick (1923, p. 69) for excellent exposures in Northeast Township, Erie County, Pennsylvania, is the youngest member of the Canadaway Formation. This unit, which varies in thickness from about 400 to 600 ft., is exposed in a band across northern Chautauqua County, particularly along Chautauqua Creek south of Westfield and in Canadaway Creek upstream from Shumla. With the pinching out of the Laona and Shumla Siltstone Members in northwestern Cattaraugus County, the Gowanda, Westfield and Northeast Shale Members merge into a single unit east of Persia Township, Cattaraugus County, and are treated as undifferentiated Canadaway by Tesmer (1974). Lithologically, the Northeast is a sequence of mostly medium-gray shales with some light-gray siltstones from 1 to 4 in. in thickness. The percentage of interbedded siltstones varies within the unit as well as geographically. The Northeast is quite barren in many places but the upper Northeast becomes quite fossiliferous in easternmost Chautauqua and northwestern Cattaraugus Counties. Bryozoans, brachiopods and pelecypods are typical forms (Tesmer 1963, pp. 31-35; 1974).

Dexterville Member of the Chadakoin Formation

This unit was proposed by Caster (1934, p. 63) for the fossiliferous, gray siltstones and shales of which about 100 ft. are exposed in quarries at Dexterville (now part of the city of Jamestown). They form a subdivision of the Chadakoin, previously named by Chadwick (1923, p. 69) for the same exposures which are adjacent to the Chadakoin River (STOP 6). The brachiopod "*Pugnoides*" *duplicatus* is confined to the Dexterville and has been collected in various parts of Chautauqua County as well as near the village of Randloph in southwestern Cattaraugus County. The Dexterville fauna contains many examples of brachiopods and pelecypods as well as numerous bryozoans. Exposures of this member occur in many part of central and eastern Chautauqua County (Tesmer 1963, pp. 37-38) where the member is usually less than 100 ft. in thickness. East of Randloph, the distinctive Dexterville brachiopod "*Pugnoides*" *duplicatus* is absent and Tesmer (1974) considers the Chadakoin Formation as a single unit here.

Ellicott Member of the Chadakoin Formation

Above the Dexterville is a sequence of fossiliferous, gray shales and interbedded siltstones which overlie much of central and southern Chautauqua County (Tesmer 1963, pp. 39-41). These strata are assigned to the Ellicott Member, proposed by Caster (1934, p. 66) for exposures in Ellicott Township, near Jamestown. An excellent locality for collecting Ellicott fossils occurs along the Erie-Lackawanna railroad cut (STOP 5) near Lakewood where Late Devonian brachiopods and pelecypods may be found. Murphy (1973) collected the alga *Protosalvinia* (*Foerstia*) near the base of the

Ellicott at Belsons Run in northwestern Chautauqua County as well as westward into northwestern Pennsylvania and northeastern Ohio. The Ellicott Member averages about 150 ft. in thickness in Chautauqua County, although complete sections are seldom exposed. In Cattaraugus County, to the east, the Dexterville and Ellicott Members are not differentiated, but are considered collectively as undifferentiated Chadakoin (Tesmer 1974).

Panama Conglomerate Member of the Cattaraugus Formation

The youngest unit to be observed on this field trip is the Panama Conglomerate lens that locally forms the base of the Cattaraugus Formation of Clarke (1902, p. 525). The Panama Conglomerate was proposed by Carll (1880, p. 58) for about 70 feet of conglomerate and buff sandstone exposed at the village of Panama is southern Chautauqua County (STOP 4). The Cattaraugus Formation contains a great variety of lithologies including red shales, several similar conglomerate lenses, as well as sequences of interbedded, gray siltstones and shales. Miller (1974) studied the petrology of the Panama and various other Cattaraugus conglomerate lenses in an attempt to differentiate them with regard to environment of deposition, provenance and dispersal.

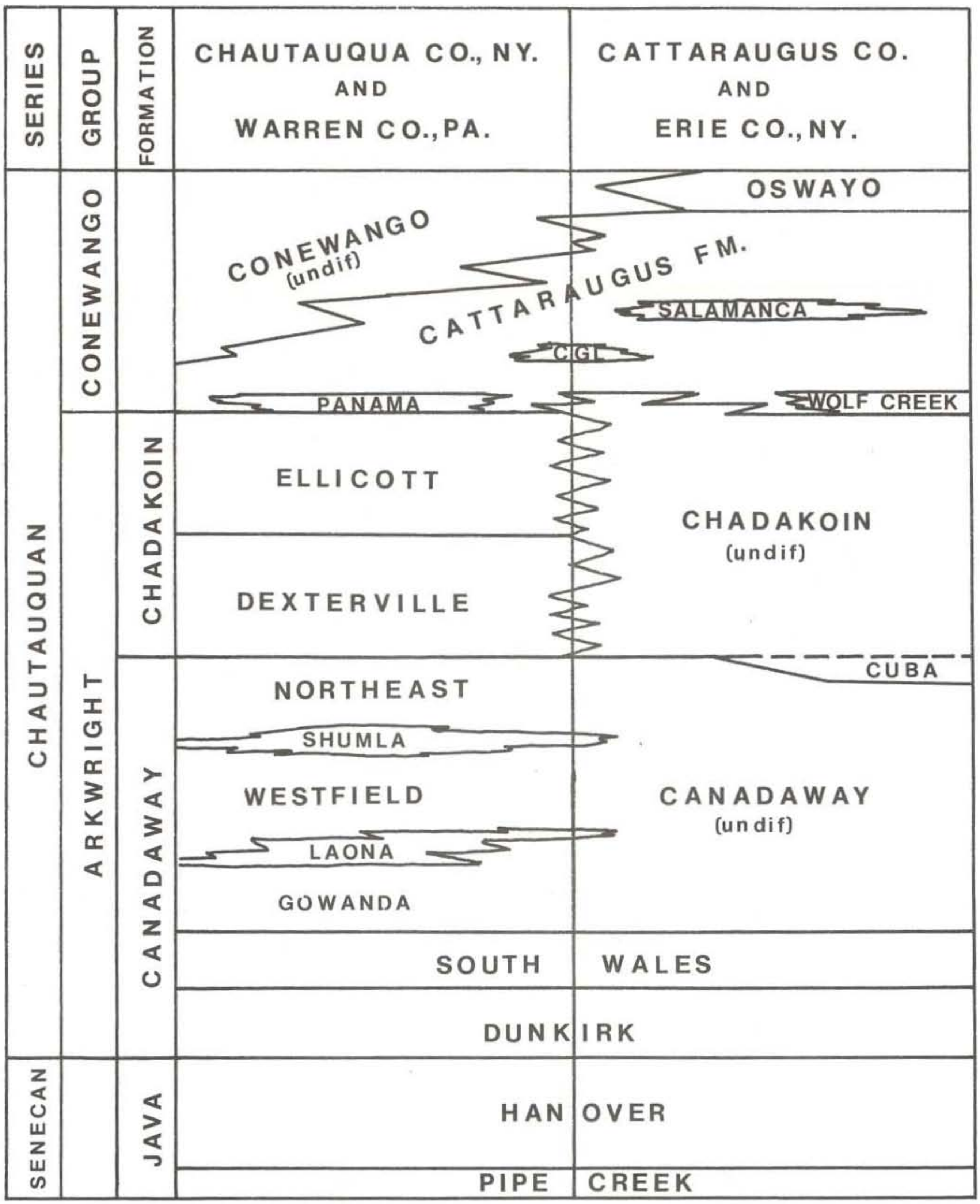

Plate 1. Correlation of the stratigraphic units exposed in Chautauqua, Cattaraugus and Erie Counties, NY and Warren Co., PA. The Chautauqua County column is modified from Tesmer (1963) and the Cattaraugus County column is modified from Tesmer (1974).

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NOTES ON THE AMMONOID AND CONODONT ZONATIONS OF THE UPPER DEVONIAN OF SOUTHWESTERN NEW YORK

William Kirchgasser, Department of Geological Sciences, SUNY College at Potsdam

INTRODUCTION

The sequence of zones currently recognized for the upper part of the Upper Devonian of New York is based on research by House (1962, et seq.) on the ammonoid (goniatite) cephalopods and by Hass (1958) and Huddle (in Oliver and others, 1968 and Klapper and others, 1971) on conodonts. During the course of their studies of the succession in southwestern New York the author has had the opportunity to work with Michael House and John Huddle and the notes which follow summarize their reports to date. The zonations and the horizons from which biostratigraphically important faunas have been recorded are shown in Figure 1. Although the New York record for the upper part of the Upper Devonian is far from complete, correlations have been made at several levels with the standard zonal sequences of Europe.

Above the Dunkirk Shale, horizons yielding determinable ammonoid and conodont faunas decrease in frequency as the offshore shales wtih calcareous horizons and pelagic faunas interfinger with and are overlain by thick sequences of silty shales, siltstones and sandstone with benthonic faunas, and non-marine units in the upper part. The Dunkirk is the highest major black shale in the succession and above this level the subdivision and regional correlation of the rocks have proved to be more difficult than lower down in the section where black shale horizons provide stratigraphic control. Because key faunal horizons are scattered and difficult to trace, the positions of many zonal boundaries are not known with certainty.

Ammonoids are rare in New York above the Gowanda Shale and, in this part of the succession, conodonts would seem to offer the most promise for further zonal refinement. As shown in Figure 1, the European conodont zones are named for species of the distinctive platform genus *Palmatolepis*. Illustrations of some of these species are found in the *Treatise* (Muller, 1962, fig. 47); see Klapper and others (1971) for additional references. Illustrations of ammonoid zone-fossils are found in the Treatise (Miller and others, 1957), Miller (1938), and House (1962).

Java Formation

The ammonoids of the Java Formation mark the last occurrences of manticoceratids (Zone of *Manticoceras* (I) in New York, but there are as yet no reports from sections in the fieldtrip area.

FIGURE I. UPPER DEVONIAN ZONES- SOUTHWESTERN NEW YORK (after Rickard, 1964)

	SERIES	STAGE	CONODONT ZONES (after Klapper & others, 1971)	AMMONOID ZONES (after House, 1962)		ROCK UNITS				
				EUROPE	NEW YORK		Published records of ammonoids (a) and conodonts (c).			
UPPER DEVONIAN	CHAUTAUQUAN	BRADFORD		*PLATY-CLYMENIA* (III): ? ; *Pseudo-clymenia sandbergeri* (IIIα)	? ; *Sporadoceras milleri*	CONEWANGO GROUP	↓	Venango Shale, Siltst., Sandst.		
							a (NW Pa.)	Panama Conglomerate		
		CASSADAGA	LOWER *Palmatolepis quadrantinodosa*	*CHEILOCERAS* (II): *Sporadoceras pompeckji* (IIβ)	*Sporadoceras pompeckji*	CONNEAUT GROUP	a,c	Ellicott Shale	Chadakoin Fm.	ARKWRIGHT GROUP
								Dexterville Siltst. & Sh.		
				? ; *Cheiloceras curvispina* (IIα)	? ; *Cheiloceras amblylobum*	CANADAWAY GROUP	c	Northeast Shale		
			Palmatolepis rhomboidea				c	Shumla Siltstone		
			UPPER *Palmatolepis crepida*				c	Westfield Shale		
								Laona Siltstone		
							a,c	Gowanda Shale	Perrysburg Fm.	
							c	South Wales Shale		
			UPPER *Palmatolepis triangularis*				c	Dunkirk Shale		
	SENECAN	COHOCTON		*MANT.* (I): *Crickites holzapfeli* (Iδ)	*Manticoceras cataphract-um*	JAVA FM	a,c	Hanover Shale		
								Pipe Creek Shale		

Manticoceras cataphractum occurs in the lower part of the Hanover Shale Member at Java, N.Y. (Wyoming County) and a form of the Crickites holzapfeli-type occurs in the upper part of the member in a nearby section (House, 1968, p. 1066). Conodonts reported from the upper Hanover include Palmatolepis triangularis and indicate the Upper P. triangularis Zone (Klapper and others, 1971, fig. 4).

Canadaway Group

No ammonoids have been reported from the Dunkirk Shale or succeeding South Wales Shale, but in the Gowanda Shale the Cheiloceras fauna (Zone of Cheiloceras (II)) is well developed in the Corell's Point Goniatite Bed (House, 1962, 1966, 1968). At the type locality at Corell's Point on Lake Erie (STOP 3), the cephalopods occur as small pyritic molds in a ledge of concretions up to eighteen inches thick, outcropping at lake level, and also in the overlying fifteen feet of shale. The fauna (Figure 2) includes Cheiloceras amblylobum (subglobular shell with broad, relatively flat suture across well rounded venter), Tornoceras concentricum (suture with steep dorsal face of lateral lobe concentric with the umbilicus) and Aulatornoceras bicostatum (prominent ventro-lateral furrow); the latter two species are the highest known tornoceratids in the Devonian of New York (House, 1965, p. 84, 1966, p. 55).

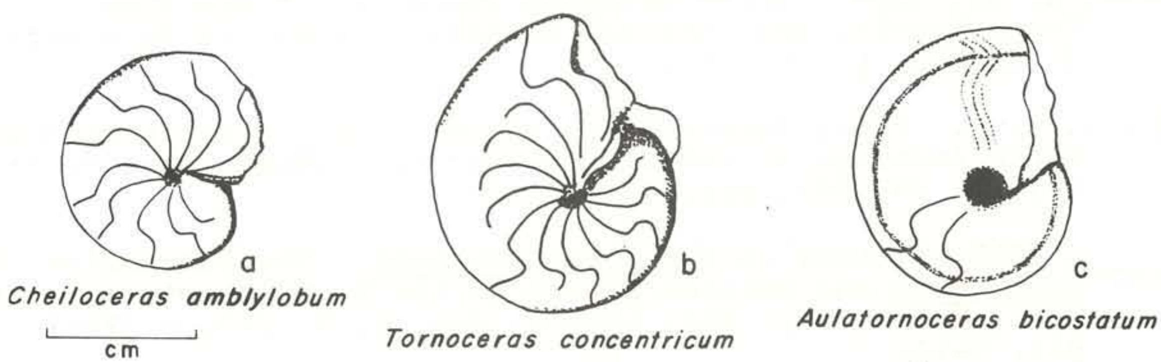

Figure 2. Ammonoids from Corell's Point Goniatite Bed (Gowanda Shale) at Corell's Point, Lake Erie (STOP 3). a: figured House (1962, pl. 46, fig. 4). b: figured House (1965, pl. 9, fig. 88). c: figured House (1965, pl. 11, fig. 128).

The Corell's Point Goniatite Bed has been traced inland through several sections as far as Holland, N.Y., in eastern Erie County. Localities near Fredonia include Little Canadaway Creek below Lamberton and Walnut Creek at Forestville (see House, 1966, 1968, for locality details). Faunal lists and locality data for the conodont faunas of the Canadaway Group and higher units are found in Hass (1958), Tesmer (1963), Oliver and others (1968) and Klapper and others (1971).

Conneaut and Conewango Groups

Few ammonoids have been found in the highest part of the New York succession and the biostratigraphically important clymenids are apparently missing. The only ammonoid identified from the Conneaut Group is *Sporadoceras* cf. *pompeckji* (*S. pompeckji* Zone) from the Ellicott Shale in Porter's Creek, Summerdale, N.Y. (Chautauqua County) (House, 1962, p. 277). No higher ammonoids have been reported in New York but *S. milleri* (*Pseudoclymenia sandbergeri* Zone) is known from near the Panama Conglomerate (Conewango Group) in northwestern Pennsylvania (Miller, 1938, House, 1962). There are six higher ammonoid zones recognized in the Upper Devonian of Europe (House, 1962, Table 3).

The highest conodont fauna reported from New York is also from the Ellicott Shale and represents the Lower *Palmatolepis quadrantinodosa* Zone (Klapper and others, 1971). There are eleven higher zones recognized by Ziegler (1971, Chart 4) in the standard sequence in Europe and many of these are recorded elsewhere in North America (Kapper and others, 1971, fig. 4).

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TRIP B - UPPER DEVONIAN STRATIGRAPHY OF CHAUTAUQUA COUNTY, NEW YORK

William J. Metzger, Irving Tesmer, and William Kirchgasser

Total Miles	Miles from last point	Route description
0.0	0.0	Leave the Fredonia campus at the Temple Street Exit.
		Turn left (S) onto Temple Street.
0.7	0.7	Intersection with Route 20. Proceed straight ahead on Water Street.
0.8	0.1	Cross Canadaway Creek.
0.9	0.1	Bear left at intersection of Water and Liberty Streets.
1.3	0.4	Several levels of river terraces are exposed on each side of the bus at this point associated with higher stages of Lake Erie.
1.8	0.5	Cross Canadaway Creek Bridge. Good exposures of the Gowanda shale at this point continue upstream to Laona, NY.
2.2	0.4	Cross Railroad tracks.
2.4	0.2	Enter Laona, NY.
		Well-defined stream terraces can be seen on the right side of the bus. An abandoned oxbow lake can be observed 25 feet above the present level of the creek.
2.6	0.2	Intersection with Webster Road; continue straight ahead. 100 feet to the right (west) of this intersection is the type section of the Laona Siltstone exposed in a small waterfall.
3.0	0.4	Intersection with Route 60. Turn right (S)

Total Miles	Miles from last point	Route description
4.1	1.1	Road cut through semi-stabilized land-slides on left of bus. Hill is composed of till overlying proglacial lake deposits. The creek flows in bedrock 200 feet to the right (W).
4.3	0.2	Exposures of the Westfield Shale are seen on the right side of the bus.
4.4	0.1	Junction with Shumla Road. Turn left (E).
4.9	0.5	Pull off onto shoulder before the bridge. Walk down to the Canadaway Creek down-stream from the bridge.
		STOP 1. Shumla Siltstone: Exposures examined here are the type section of this unit. The lower contact is exposed down-stream from the bridge. The underlying Westfield shale includes interbedded silt-stones and shales. The base of the Shumla is marked by a massive siltstone which grades upward into increasingly thinner bedded units. These strata in turn grade upward into interbedded siltstones and shales which characterize the overlying Northeast shale. Trace fossils are abundant in several zones in these outcrops as are sedimentary structures including ripple marks, flute casts, and soft sediment deformation. Dunkirk, NY, 7½' quad.
		Turn around and return to Route 60.
5.4	0.5	Junction with Route 60. Turn right (N).
8.7	3.3	Passing the crest of the Pleistocene beach ridge of Glacial Lake Whittlesey.
9.2	0.5	Intersection with Route 20. Proceed straight ahead. The bus will pass over the Lake Warren beach complex in the next 0.3 miles.

Total Miles	Miles from last point	Route description
9.5	0.3	Mobil station on the right is near the crest of Warren II beach and it displays the best topographic expression of all the beaches along this traverse. Dunkirk Ready-Mix plant is located in the beach deposit.
10.0	0.5	Thruway overpass.
11.0	1.0	Entering Dunkirk, NY
11.1	0.1	Cross Norfolk and Western Railroad Tracks.
11.5	0.4	Junction Route 60 and Main Street. Turn right (N) and proceed to Lake Shore Drive. (Route 5).
12.1	0.6	Intersection of Main Street (Route 60) and Lake Shore Drive (Route 5). Turn left (SW).
13.2	1.1	Turn right (N) onto Point Drive North.
13.6	0.4	Turn right into Cedar Beach Parking area.
13.7	0.1	STOP 2. Hanover Shale and Dunkirk Shale: Exposures allow the examination of the contact between the grey-green Hanover Shale and the black, fissile Dunkirk Shale. Numerous pyritized worm burrows and carbonized plant stems are seen at this locality. Rare specimens of the inarticulate brachiopod *Barroisella compbelli* have also been collected. Exposures of a "bedded" till are also exposed along the eastern side of the headland overlying a striated surface of Dunkirk Shale. Dunkirk, NY 7½' quad. Leave parking lot. Turn left (S) onto Point Drive North.
14.1	0.4	Intersection with Route 5. Turn right (SW).

Total Miles	Miles from last point	Route description
19.8	5.7	On left is gas wellhead, one of approximately 60 wells drilled during the past 2 years in Chautauqua County. Production comes from the Silurian Medina Sandstone.
20.0	0.2	Bridge over Little Canadaway Creek. Exposures are in the South Wales Shale.
21.1	1.1	Entrance to Lake Erie State Park.
23.1	2.0	Bridge over Slippery Rock Creek. Exposures include the South Wales at the lake shore and Gowanda Shale at the bridge and upstream.
24.0	0.9	Bridge over Corell Creek. Exposures are the Gowanda Shale.
25.1	1.1	Park on shoulder beyond the entrance to the trailer park on the right (N) side of the road. Walk down to the beach turn to the left (SW) and proceed approximately 100 yards.
		STOP 3. Gowanda Shale, Corell's Point Fauna: Exposures at about lake level continue for approximately 100 yards. Cephalopods are pyritized and concentrated in bands, the most prominent of which is approximately 2 feet below a conspicuous zone of very large septarian concretions. This exposure is also notable for the bedrock-till contact which includes till injected along bedding planes and the incorporation of large blocks of bedrock in the till. Brocton, NY, 7½' quad.
		Return to the bus. Continue straight ahead on Route 5 towards Barcelona, NY.
26.3	1.2	On the left of the bus (S) observe the elongate glacial landforms which characterize this specific portion of the lake plain. These deposits may represent reworked sand deposits of higher lake stages.
26.8	0.5	Bridge over unnamed creek. Exposures of Gowanda Shale include a 15 foot waterfall at the lake.

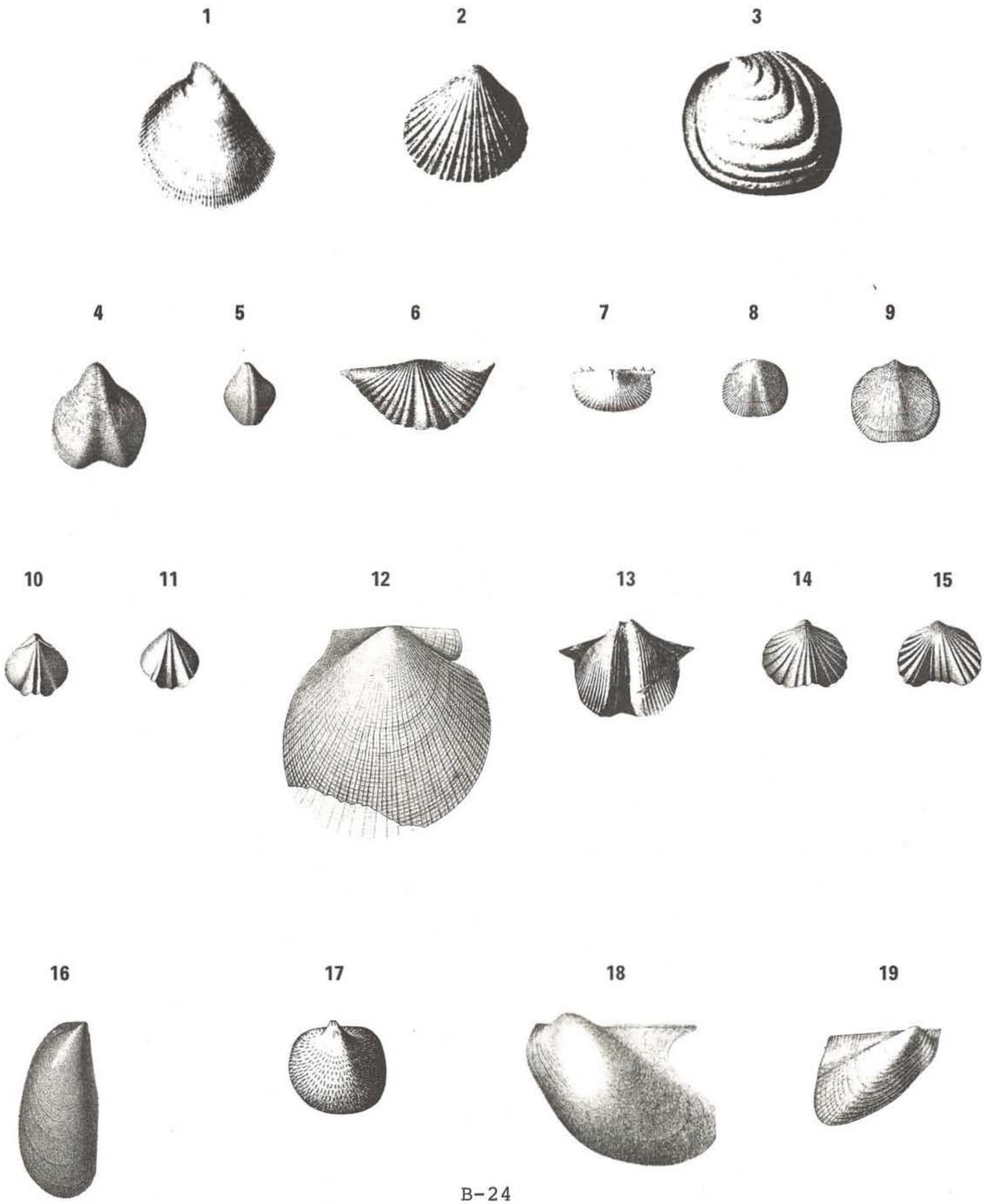
Total Miles	Miles from last point	Route description
28.8	2.0	Bridge over Bournes Creek. Exposures of Gowanda Shale and Laona Siltstone.
31.0	2.2	Entering Barcelona.
31.2	0.2	First Lighthouse illuminated by natural gas in U.S.A.
31.3	0.1	Intersection of Route 5 and 17. Turn left (S) onto Route 17.
31.6	0.3	Pass Thruway entrance on left.
31.9	0.3	Entering Westfield.
32.9	1.0	Intersection of Route 17 and 20. Continue straight towards Mayville.
	?	Crossing Glacial Lake Whittlesey beach crest.
34.0	1.1	Bridge over Little Chautauqua Creek gorge.
35.4	1.4	Pull off road onto shoulder for overview. Stop is located on the lake escarpment moraine. Optional lake plain overview.
38.5	3.1	Entering Mayville, NY
38.9	0.4	Intersection of Route 17, 430, and 394. Proceed straight ahead on Route 394 East.
39.7	0.8	Chautauqua Lake. Field trip route will traverse over Pleistocene and Recent Alluvial sand and silt for the next several miles.
42.6	2.9	Junction of Route 394 and Road to Panama, NY. Bear right. Route now travels over Kent ground moraine.
44.5	1.9	Cross Prendergast Creek and drive onto Kent end moraine.
46.4	1.9	Elm Tree Y intersection. Bear right towards Panama, NY.

Total Miles	Miles from last point	Route description
51.3	4.9	Enter Panama, NY
52.0	0.7	Intersection with Route 474. Turn right (W).
52.2	0.2	Junction with Rock Hill Road. Bear left up the hill.
52.4	0.2	Enter Panama Rocks Park on left.
		STOP 4. Panama Conglomerate Member of the Cattaraugus Formation: Exposures examined here constitute the type section of this unit. A thickness of approximately 70 feet is exposed. The conglomerate is crossbedded in part and consists predominantly of milky quartz with occasional jasper pebbles averaging less than one inch in diameter. Localized weathering and erosion along joints account for the various "dens", "alleys", and special shapes which characterize Panama Rocks Park. Panama, NY, 7½' quad.
		LUNCH STOP
		Leave parking lot and turn right onto Rock Hill Road.
52.6	0.2	Junction with Route 474, turn right (E) Continue on 474 towards Jamestown, NY Route between Panama, NY and Ashville traverses over a Kent end moraine which is somewhat older than the one observed at mile 44.5.
56.2	3.6	Entering Blockville, NY.
58.5	2.3	Entering Ashville, NY.
58.9	0.4	At flashing yellow light turn right (S) onto Maple Road.
59.2	0.3	Junction with Hunt Road, turn left (E)
60.2	1.0	Pull off on shoulder east of the Erie Lackawana Railroad tracks.

Total Miles	Miles from last point	Route description
		STOP 5. Ellicott Member of the Chadakoin Formation: Exposures in this Erie-Lackawana railroad cut are very fossiliferous. The fauna includes brachiopods *Camarotoechia*, *Cyrtospirifer* and *Productella* and pelecypods *Leptodesma* and *Mytilarca*. Lakewood, NY, 7½ quad.
		Proceed straight ahead on Hunt Road to Jamestown, NY
64.7	4.5	Entering Jamestown, Bear right on Hunt Ave.
64.8	0.1	Y intersection of Hunt Ave. and Third Street. Bear right onto Third Street and proceed through downtown Jamestown.
66.2	1.4	Turn right onto Prendergast Street.
66.3	0.1	Turn left onto Second Street.
67.5	1.2	Turn right onto Buffalo Street.
67.8	0.3	Turn back sharply to the right onto Allen Street.
68.0	0.2	Turn left into parking area of abandoned shale quarry.
		STOP 6. Dexterville and Ellicott Members of the Chadakoin Formation: The exposures in this inactive quarry represent the type section of both members. The lower unit, the Dexterville, is predominantly shale. Good fossil collecting is possible from both members at this location. *Pugnoides duplicatus* is restricted to the Dexterville strata and has been used as an index fossil for that unit. Rare specimens of very poorly-preserved glass sponges have been collected from these exposures. Jamestown, NY, 7½' quad.
		Leave parking lot and turn right onto Allen Street.
68.2	0.2	Turn back sharply to the left onto Buffalo Street.
68.5	0.3	Intersection with Second Street. Turn left.

Total Miles	Miles from last point	Route description
69.3	0.8	Bear right onto E. Fourth Street (Route 394 West).
69.6	0.3	Turn right on Prendergast Street.
69.7	0.1	Turn left onto Sixth Street.
69.9	0.2	Turn right onto Route 60 North.
71.4	1.5	Junction Route 17. Continue North on Route 60.
73.8	2.4	Airport overview. Panoramic view of the glaciated terrain. Uplands are predominately Kent ground moraine. Glacial streamlining is very obvious.
76.0	2.2	Entering Gary, NY.
76.6	0.6	Flashing stop sign. Turn left and continue on Route 60.
		Between Gary, NY and Sinclairville, Route 60 traverses a series of Kent stratified drift deposits. The flood plain of Cassadaga Creek observed on the left (W) of the bus is recent alluvium and stream gravels.
		Between Sincliarbille and Cassadaga the route traverses primarily Kent ground moraine.
87.8	11.2	Entering Cassadaga, NY.
88.5	0.7	Outwash plain of lake escarpment moraine complex.
88.8	0.3	Bedded sands and gravels in pits behind trailers.
89.2	0.4	Lake escarpment moraine front.
90.1	0.9	Typical morainal topography.
90.9	0.8	Landslides in complex glacial deposits which include varved clays deposited in a proglacial lake as well as till of Lake escarpment age.

PLATE I



CONTACTS OF THE WINDOM MEMBER (MOSCOW FORMATION) IN ERIE COUNTY, NEW YORK

Carlton E. Brett, Department of Geological Sciences, SUNY at Buffalo

INTRODUCTION

Since the time of Cooper's (1930) survey of the Hamilton Group in New York State, it has been well established that the stratigraphic sections exposed in Erie County are relatively incomplete compared to the section in Central New York, particularly in the upper Hamilton Group. Clastic sediments derived from highlands to the east often failed to reach western New York. Thus, thin lag deposit limestones and scoured contacts between members or individual beds may be time equivalent to thick sequences of shales and siltstones in the east.

In western New York the Windom Member of the Moscow Formation is bounded above and below by unconformities representing two fairly major periods of nondeposition. Careful examination of the contacts provides evidence that these were also periods of erosion suggesting local shoaling of the seas. These discomformities are described in some detail in the present paper because of their implications in the interpretation of the depositional environments of the Moscow and overlying (Upper Devonian) Genesee Formation.

The study area covered in this report (Fig. 1) includes all outcrops form Cazenovia Creek at Spring Brook (Orchard Park 7.5 min. quad.) to Pike Creek near Derby, NY (Eden 7.5 min quad.) a total distance of about 20 miles.

LUDLOWVILLE/MOSCOW DISCONFORMITY

Stratigraphy

In New York the Moscow Formation (Hall, 1939) comprises the fourth and youngest formation of the Middle Devonian Hamilton Group. In western New York it consists of 10 to 150 ft. of calcareous, medium-grey shales and thin limestones. Cooper (1930) recognized three members of the Moscow in the Genesee Valley (Fig. 2): (1 ft.), basal Menteth Limestone, about 80 ft. of fossiliferous bluish-grey, calcareous Kashong Shale, and some 50 ft. of medium-grey, fossiliferous Windom Shale. The basal Menteth and Kashong Members thin rapidly westward and pinch out in Erie County. The Menteth can be traced west to Buffalo Creek at Bullis Road, whereas, the Kashong diminishes in thickness to about 16 in. at Cazenovia Creek in Spring Brook, N.Y. to an irregularly bedded mass of calcareous shale and argillaceous limestome packed with crinoid columnals and the branching tabulate coral _Trachypora_ _romingeri_.

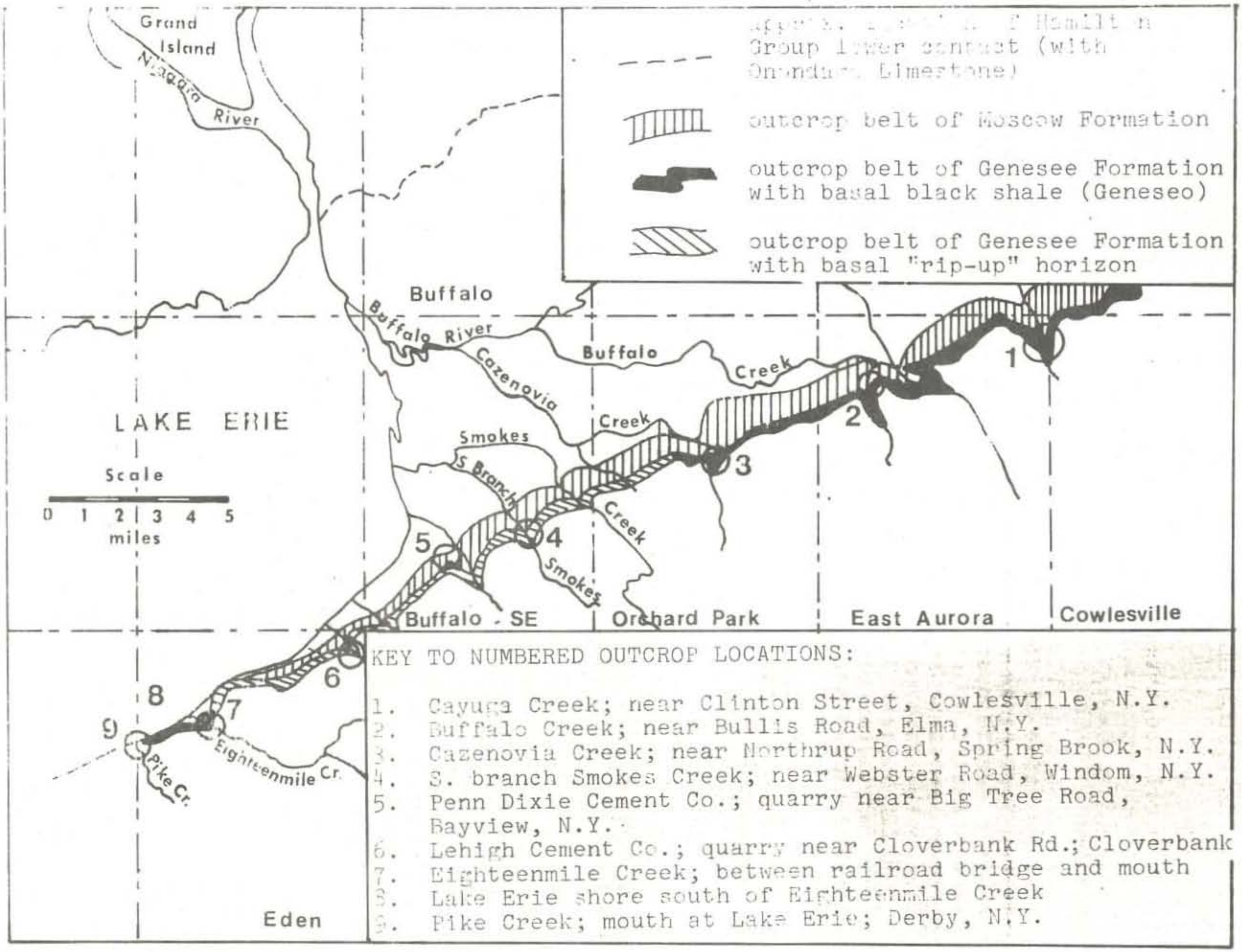
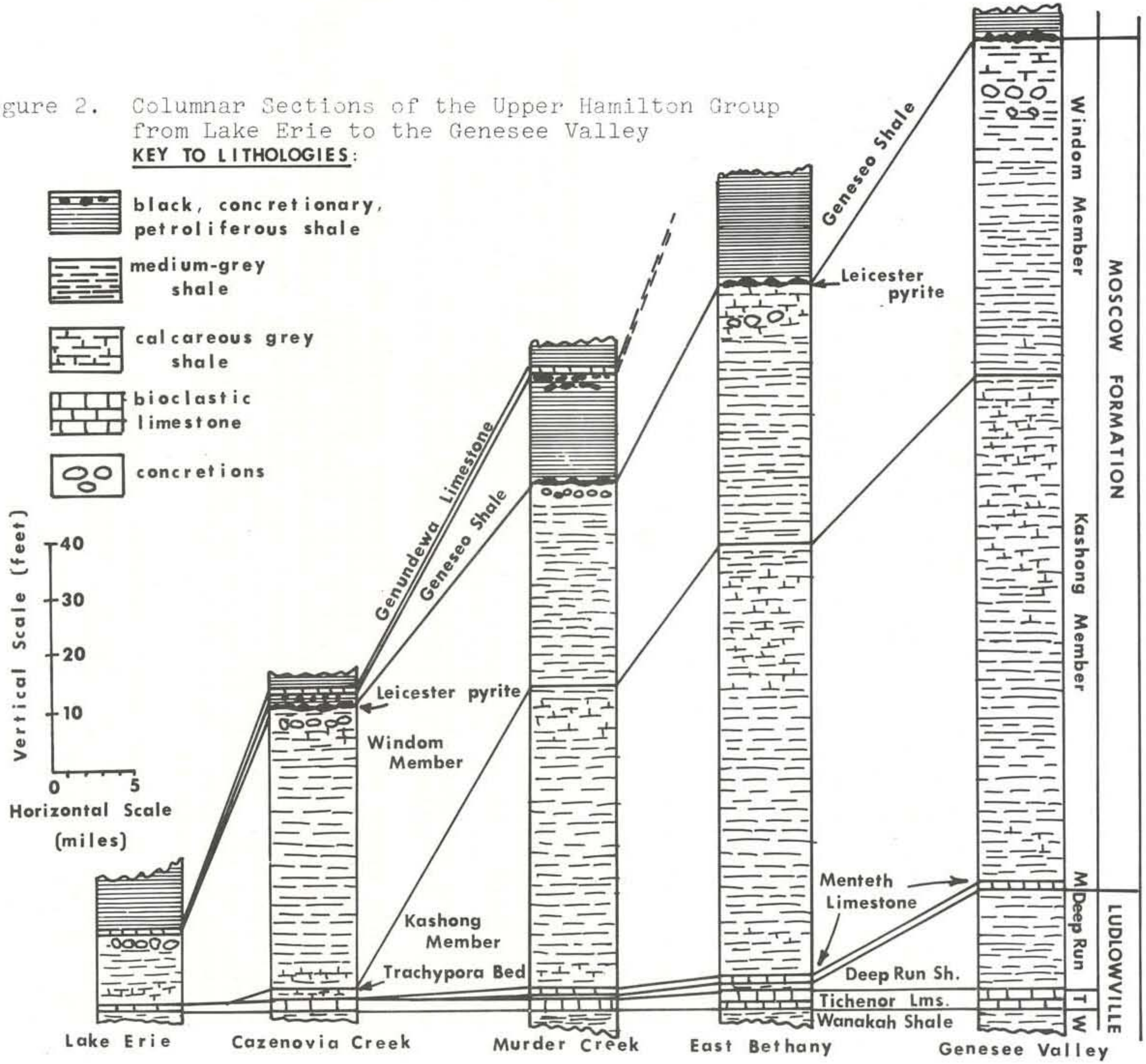


Figure 1. Location and prominent outcrops of Upper Hamilton and Genesee contact in Erie County, New York

Figure 2. Columnar Sections of the Upper Hamilton Group from Lake Erie to the Genesee Valley

KEY TO LITHOLOGIES:



data from Cooper, 1930

Two miles southwest of the Cazenovia Creek exposure, lenses of shaley limestone with the same fauna crop out in a small stream near Reserve Road. West of this locality the Moscow Formation is represented solely by the Windom Member which thins to 9 ft. on the Lake Erie shore. In exposures of Hamilton strata west of this, in Ontario and Ohio, Moscow equivalents are absent altogether.

In the Genesee Valley the Moscow is underlain by a thin layer (5 ft.) of Deep Run Shale, the uppermost member of the Ludlowville Formation in that region; but, the Deep Run also pinches out near Leroy in Genesee County. Thus, in all of Erie County, the Moscow Formation comes to rest on the next lowest Ludlowville unit, the Tichenor Limestone Member. Here the Ludlowville/Moscow contact is a disconformity representing the time-span during which portions of the upper Ludlowville and lower Moscow sediments were accumulating farther east. Careful examination of this contact has provided evidence for at least two (possibly more) periods of erosion during this time interval in western New York. At least part of the time the upper Tichenor surface was an exposed indurated hardground surface.

The Upper Tichenor Surface

At Cazenovia Creek where the calcareous Kashong shale overlies the Tichenor limestone, the upper contact between the two units, appears gradational and difficult to pinpoint. However, west of the Orchard Park quadrangle, the Kashong is absent and the Windom-Tichenor contact is sharply defined. Here the basal Windom shale containing abundant *Ambocoelia umbonata* rests on a Tichenor surface which is irregularly pitted suggesting erosive sculpture.

This upper portion of the Tichenor contains abundant fossils including numerous corals, brachiopods, bryozoans, and, locally large pelecypod valves. Nearly all bivalve shells are disarticulated; Many of the fossils are broken and/or abraded and burrows and borings are abundant. Thus, the deposit was considerably reworked prior to lithification. More significant, however, is the evidence that certain of the fossils lying in or on the upper surface of the Tichenor have been subjected to abrasion *after* the lime muds were indurated (Plate 1).

At the Tichenor upper surface, specimens of the larger, more robust fossils such as rugose corals and valves of the brachiopod *Spinocyrtia granulosa* frequently show differential abrasion. Exposed convex surfaces are often quite smooth and polished, whereas portions of the fossils imbedded wholly within the matrix of the Tichenor show considerable surface detail. On some of the large concavo-convex shells, protruding portions have been beveled off or faceted to nearly planar surfaces. Occasionally, the most convex central portions of the valves have been breached through entirely, exposing internal structures (Plate 1, Fig. 1.2).

Obviously, such extreme cases of faceting could only have developed on shells which were fixed rigidly in one position, as otherwise the valves would certainly have been plucked from the matrix by vigorous scouring of the bottom. Thus, during a period prior to the deposition of the Windom, the Tichenor sediments must have been partially or wholly indurated.

Encrustations of epifaunal organisms directly on the Tichenor upper surface provide additional evidence for induration of this surface. Rarely, crinoid holdfasts (Plate 1, Fig. 10) and inarticulate brachiopods are found to be attached to the surface of the Tichenor. A specimen of rugose coral, Heliophyllum halli was found in probable growth position (calyx facing upward) in the basal Windom shale at Eighteenmile Creek apparently cemented by its base to a shell fragment imbedded in the Tichenor (Plate 1, Fig. 8). The surface of this coral is only slightly worn and it was evidently preserved in situ rather than being reworked. Such organisms undoubtedly required firm substrates on which they could attach. It seems very unlikely that they would have cemented onto unstable crinoidal sand.

Basal "Conglomerate" of the Windom

In several localities the basal layers of the Windom contain reworked fossils and rock fragments from the underlying beds. No report of this zone has been made aside from a note by Grabau (1899) on the discovery of a "well-worn quartz pebble and a worn fragment of Spirifer granulosus, both of which were found in the lower part of the Moscow".

The reworked material is particularly common in section 5 of Eighteenmile Creek (Grabau's specimens came from this locality) where extremely worn fragments of fossils derived from the underlying Tichenor surface occur in association with well-preserved delicate shells of Ambocoelia, Choenetes, and other characteristic lower Windom species. Very smooth triangular fragments derived from halves of Spinocyrtia valves (Plate 1, Fig. 3,4) as well as worn pieces of rugose coral and crinoid stems, can often be recognized from this horizon. Rounded limestone pebbles, a few mm. to several cm. in diameter, with characteristic Tichenor lithology and fauna also occur within the basal Windom at this locality. They are evidently derived from the underlying scoured surface of the upper Tichenor and "incipient" pebbles can be seen on the Tichenor upper surface. These consist of rounded knobs of limestone which have been partially undercut. In some instances, Windom shale with Ambocoelia can be found filling in around such knobs, so their form was obviously produced prior to the deposition of the latter.

The limestone pebbles appear to be associated with shiny black phosphatic nodules 1 in. in maximum dimension) which are also common in the basal Windom in this locality. In some cases these nodules appear to be homogeneous, whereas others show a dark crust of phosphatic material around limestone pebbles or fossil fragments.

EXPLANATION OF PLATE 1: Fossils from the Tichenor Windom Contact.

1. Faceted specimen of *Spinocyrtia granulosa*, from the upper surface of the Tichenor Limestone at section of Eighteenmile Creek, Erie County, N.Y. x1.

2. a. b. Diagrammatic cross section of a brachiopod shell embedded in indurated rock demonstrating the way in which faceting takes place.

3. 7. Various typical reworked fragments from the basal Windom Shale at Eighteenmile Creek and the original skeletal elements from which they were derived.

3 & 4. Internal and external views of fragment derived from the pedicle valve of *Spinocyrtia granulosa*. x1

5. A bored, phosphatic steinkern from the cephalon of the trilobite *Phacops rana* x 1

6. Bored and rounded crinoid pluricolumnal x1

7. Fragment from a rugose coral x1

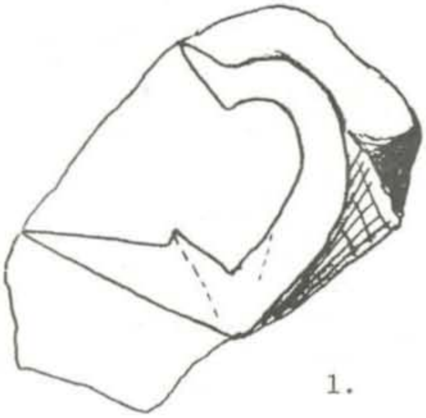
8-10. Attachments of epifaunal organisms, directly to limestone or pebbles.

8. Specimen of *Heliophyllum halli* found in growth position in the basal Windom Shale at Section Five, Eighteenmile Creek. The base of the coral was cemented to a shell fragment in the upper surface of the Tichenor Limestone. x1

9. Fenestellid bryozoan holdfast on a phosphatic pebble from the lower Windom Shale. x2

10. Scutella-type holdfast of crinoids on a pebble of Tichenor Limestone x2.

PLATE 1



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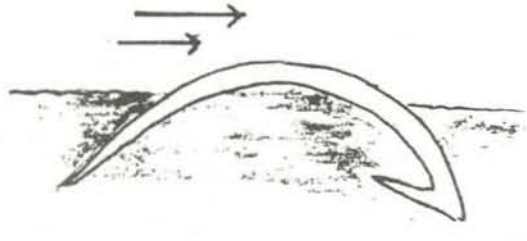

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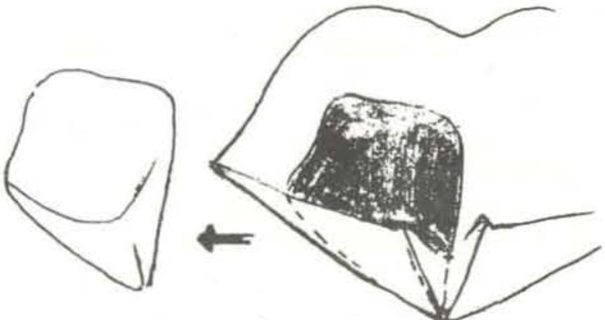

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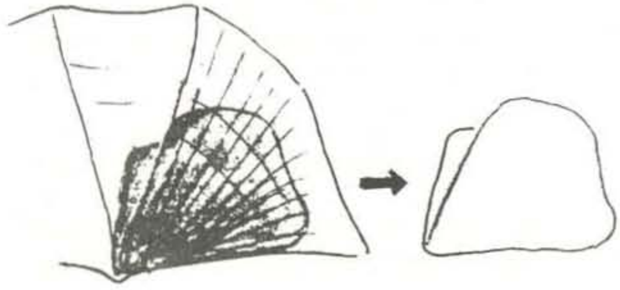

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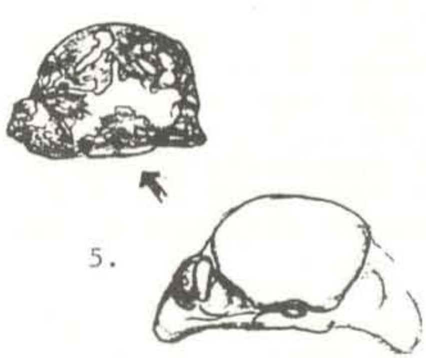

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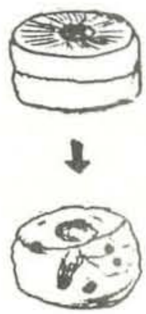

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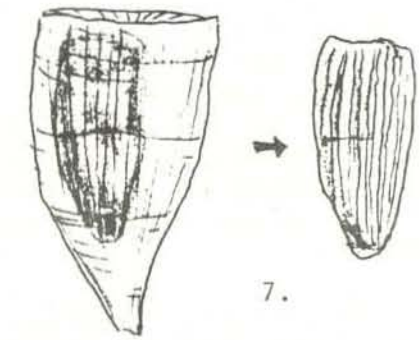

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Some fossils in the basal Windom also occur as phosphatic replacements. Brachiopods, including Tropidoleptus, Mucrospirifer, Camarotoechia, bellerophontid gastropods, fragments of trilobites, and bryozonas occur as internal molds, steinkerns of black phosphate. Most specimens lack surface details and may have originated as reworked Tichenor fossils. Others such as the bellerophontid gastropods are rather well preserved. As these are also forms which are not characteristic of either the Tichenor or the Windom, it can be speculated that they represent the remains of some otherwise unknown fauna which existed during the interval between the deposition of these two units.

Dietz, et al. (1942, p. 837) suggests that porous limestone may become replaced by phosphorite by infiltration with phosphatic solutions, "precipitation of phosphorite out of these solutions (could produce) a rock with a high percentage of phosphorite". The impure nature of some of the phosphatic nodules from the basal Windom suggests that these may have originated by replacement of Tichenor pebbles.

The phosphate nodules were themselves reworked for they are typically rounded and polished. Furthermore, they occasionally were bored. One phosphatic steinkern of a Phacops cephalon from Eighteenmile Creek shows a number of pits evidently produced by boring organisms (Plate 1, Fig. 5).

The assortment of limestone pebbles and phosphatic nodules which accumulated on the upper surface of the Tichenor provided hard substrates for the attachment of encrusting epizooites as did the surface of the limestone itself. The author has collected a piece of the lower Windom Shale from Eighteenmile Creek which contains a partial specimen of a fenestellid bryozoan with its holdfast cemented to one of the phosphatic pebbles (Plate 1, Fig. 9). A more spectacular specimen from the contact at Penn Dixie quarry near Bayview is a subangular, ellipsoidal limestone pebble 1.5 x 2.2 in. which shows eight minute crinoid holdfasts attached to its surface.

The basal reworked bed is not equally well developed in all localities, but at least a few worn fossils have been collected from the Ambocoelia bed in most outcrops. Secondary (derived) fossils in the lower Windom are not restricted to reworked Tichenor forms. At Cazenovia Creek where the Windom is underlain by the Trachypora bed" of the Kashong Member, reworked Trachypora specimens occur in the basal Ambocoelia bed. At Reserve Road where the Trachypora bed is very thin and lenticular, a mixture of Tichenor pebbles and Trachypora is found in the basal Windom. Phosphate nodules are very rare in these two localities, but occur abundantly at the Windom/Kashong contact farther east in Genesee County (discovered by Gordon Baird, University of Rochester).

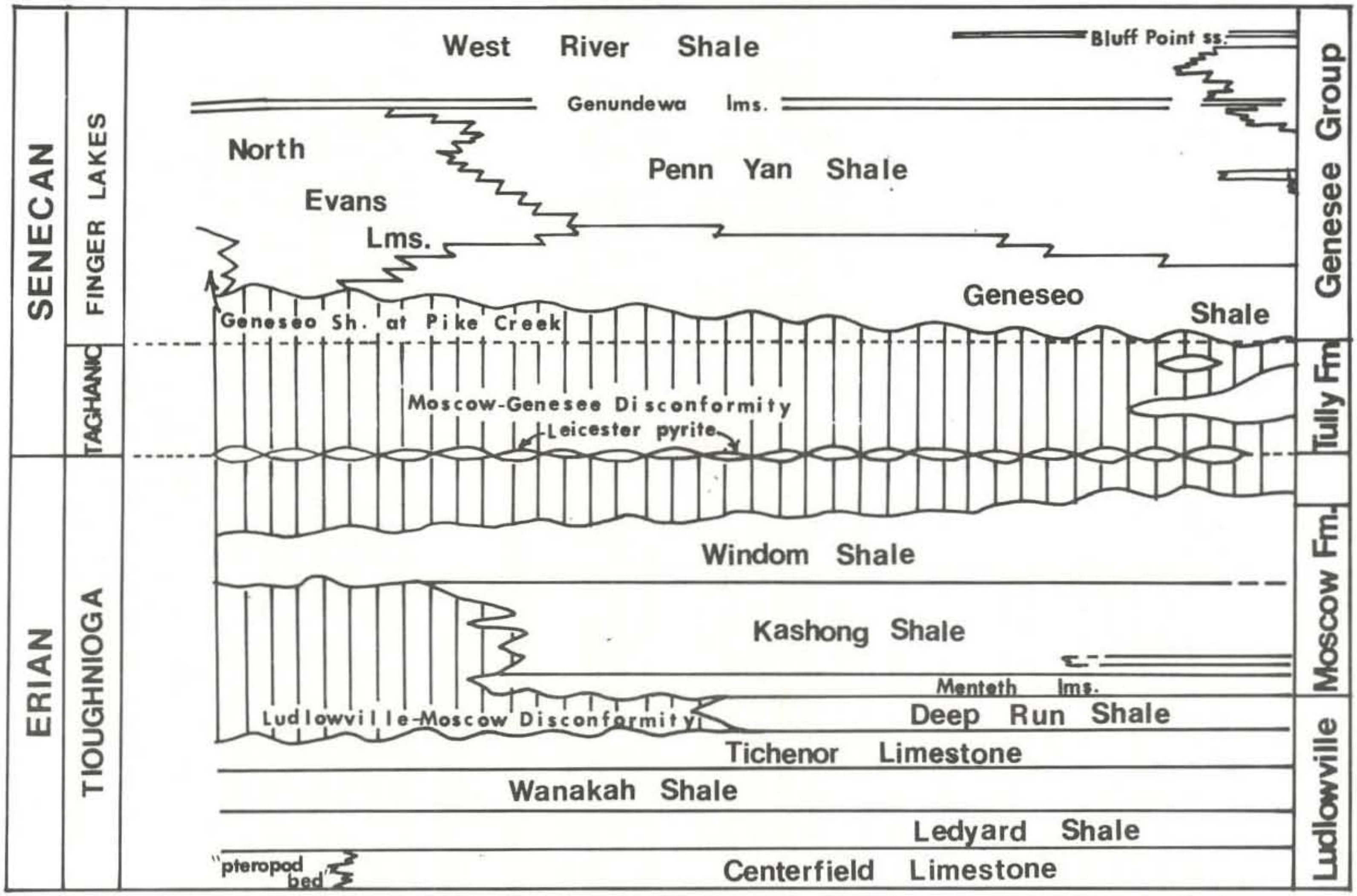


Fig. 3 - Stratigraphic relationships of the Upper Hamilton and Genesee in Western New York (adapted from Rickard, 1964)

Summary and Interpretation

During the interval of time between the deposition of the Tichenor and Windom sediments in western Erie County, the upper surface of the Tichenor became cemented to form an indurated hardground as is indicated by faceting of fossils, direct attachments of organisms, and pebbles in the overlying Windom shale. This hardground surface was exposed to shallow water above wave base. Pebbles of limestone were torn from the surface and slightly rounded by waves, holes were scoured in the upper surface (possibly initiated from solution of the rock), and fossils imbedded in the upper surface of the hardground were abraded and faceted. Limestone pebbles and fossil fragments torn from the limestone surface accumulated on the seafloor along with scattered fish plates and other debris. Phosphatic nodules may have formed by replacement of porous limestone, although in some cases, phosphatic material filled cavities within skeletal material.

The formation of the nodules probably occurred in quiet water where phosphatic solutions could concentrate. This seems to imply a period of deepening following the initial erosive phase. However the nodules were also reworked as they are generally smooth and rounded. Certain very smooth brachiopod fragments found in the lower Windom show traces of faceted surface also suggesting at least two periods of abrasion. Phosphate nodules found at the Windom-Kashong contact east of Erie County indicate that the second period of reworking may have occurred at least in part after the deposition of the Kashong in these areas.

Following the latest period of erosion, the water again deepened. A few benthic organisms such as fenestellid bryozoans, crinoids and rugose corals settled on pebbles or directly on the scoured surface of the Tichenor.

UPPER MOSCOW/GENESEE DISCONFORMITY

General Stratigraphy

Overlying the Moscow Formation in the central Finger Lakes area of New York is the massive, light-grey Tully Limestone which contains Late Middle Devonian (Taghanic) fossils (Fig. 4). At Canandaigua Lake the Tully pinches out abruptly and west of this locality rocks of the Taghanic Stage, if present at all, are represented by thin, discontinuous lenses of Leicester Pyrite (the Leicester actually may belong with the Upper Devonian Genesee Formation). In all of western New York from Canandaigua to Cazenovia Creek in Erie County, the basal black shales (Geneseo and Penn Yan Members) of the Upper Devonian overlie the Windom or the Leicester lenses when present. These units, like the underlying Moscow, show considerable westward thinning from about 80 ft. in the Genesee Valley to only 2 ft. at Cazenovia Creek. In Erie

County west of Cazenovia Creek, contrary to what is generally believed, the black Genesee shales and the Leicester pinch out entirely for a distance of nearly 20 miles along the outcrop belt. The Leicester may grade into the "Conodont bed" (North Evans Limestone), but the black shale reappears at the Lake Erie shore in the vicinity of Eighteenmile Creek (Fig. 5) and actually thickens in a southwesterly direction (opposite to most other units) in a short section along Lake Erie from Eighteenmile to Pike Creek.

Thus, in western New York, the upper contact of the Moscow Formation with the Genesee Formation represents another disconformity spanning all of late Middle Devonian and earliest Late Devonian time. Once again, in Erie County there is evidence for erosion as well as non-deposition during this interval. Particularly in the portion of the outcrop belt between Cazenovia and Eighteenmile Creeks, where the Geneseo and Leicester are missing. The basal Genesee "Conodont bed" contains abundant pebbles and shales of argillaceous limestone torn up form the underlying upper Windom Members. This "rip-up" zone and other evidence suggests that portions of the upper Moscow were truncated by erosion in western New York prior to the deposition of the Upper Devonian sedimentary units.

Description of Units

Several units of the Genesee Formation as well as the Windom Shale are involved in the Moscow/Genesee contact in Erie County. Because an understanding of the stratigraphic relationships is necessary for the interpretation of the disconformity, these units are briefly discussed in the following section. The upper Windom (Praeumbona bed) is described in a second paper in this guidebook by the author. In this paper the Genesee Formation is equivalent to the Genesee group of Rickard (1964).

Leicester Pyrite: Along most of the outcrop belt of the Moscow, the upper Windom is overlain by lenses of solid pyrite up to 6 in. thick containing a dwarf fauna of over 50 species, mainly brachiopods and pelecypods (Loomis, 1903)- the Leicester Pyrite. The bulk of this rock is made up of replaced crinoid columnals. Black fragments of bone and wood are also abundant.

This problematical unit has been correlated with the Tully Limestone (Cooper 1942), but the discovery of interbedded black shale within some lenses supports the view expressed by Hass (1959) and recently by Huddle (1974) that the Leicester represents replacement of a transgressive, basal lag concentrate of the Genesee Formation. The latter two authors also correlate the Leicester with the North Evans Limestone (or Genesee Conodont bed). This seems reasonable in view of the fact that the two have similar framework grains, "bone-bed" characteristics and lensatic nature. Furthermore, while the Leicester disappears west of Cazenovia Creek the North Evans can be traced from Lake Erie east to within four miles of the Cazenovia Creek in the same stratigraphic position.

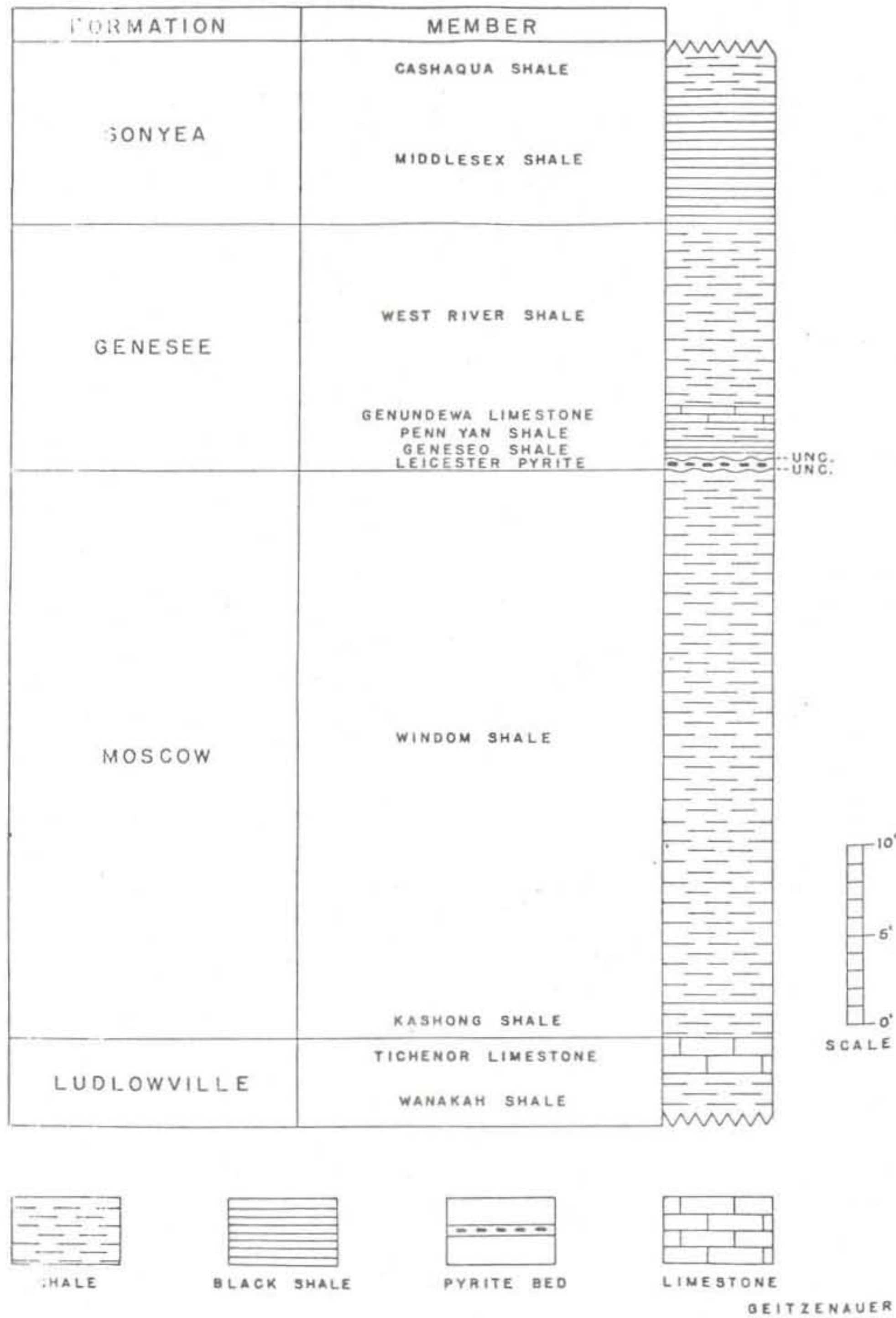


Fig. 4 - Stratigraphic column Tichenor-Middlesex (from Buehler and Tesmer, 1963)

North Evans Limestone Member: The name North Evans has been applied by and suggested by Wells (Rickard, 1964) for the thin (maximum 4") lensatic biocalcarenite occurring at the base of the Genesee Formation at Section 1 of Eighteenmile Creek near the town of North Evans. This lensatic bed which was formerly termed "Conodont bed" (Hinde, 1879) is well described by Hussakof and Bryant (1918, p. 12): "Lithologically, the "Conodont bed" is an impure limestone containing large numbers of quartz grains, small pebbles, crinoid stems, fragments of fossil wood, and other matter. Here and there are fragments of pyrite and more or less broken remains of fishes and invertebrates." Buehler and Tesmer (1963) list 41 species of conodonts and 43 species of vertebrates including arthrodire plates, cladodid teeth and acanthodian spines. The density of conodonts in this limestone has been discussed by Bryant (1921) who reports that in places they make up nearly half of the rock.

The relationship of the North Evans Limestone to other stratigraphic units is somewhat obscure. The Devonian correlation chart (Rickard, 1964) shows the North Evans as a distinct unit, distinct from the Genundewa Limestone which directly overlies it in most sections of Eighteenmile Creek and time equivalent to the Geneseo and Penn Yan Members of the Genesee Formation farther east. Interbedding of typical "Conodont bed" lenses with black shale in section 5 of Eighteenmile Creek supports this interpretation. The author has traced the North Evans Limestone from its type locality northeast to the north branch of Smokes Creek near Orchard Park. The next exposure of the Moscow/Genesee contact is at Cazenovia Creek about 4 miles to the east. Here North Evans is apparently absent. However, a thin (0.5 in.), crinoidal layer rich in fish bones which coats the underside of the Genundewa limestone of this locality may be partly equivalent. At Pike Creek southwest of Eighteenmile Creek, the North Evans Member is represented by a persistant 0.5 in. crinoidal bone bed. This thin bed which is separated from the Genundewa Limestone by 9 in. of dark-chocolate-colored Geneseo shale is quite pyritic and suggests the Leicester although it is apparently not lensatic. Everywhere along its outcrop belt of about 20 miles, the North Evans lies directly on the Windom Shale Member. Near Pike Creek, the contact is flat, but elsewhere, the upper surface of the Windom appears to be highly eroded.

Geneseo and Penn Yan Shale Members: West of Cayuga Creek in Erie County the two lower shale members of the Genesee Formation are not distinguishable from one another (see Kirchgasser, 1973). At Cazenovia Creek the two members are represented by 2 ft. of black and dark-grey, unfossiliferous concretionary shale. These members do not appear in outcrops in the Buffalo Southeast Quadrangle nor in most of the Eden Quadrangle where the compressed lower Genesee sequence includes only the North Evans Limestone and about 6 in. of typical Genundewa Limestone. At section 1 of Eighteenmile Creek, thin (2 in.) tongues of black shale are interbedded with the North Evans member and separate this unit from the Genundewa. However, these tongues appear to pinch out when traced southwest along the creek exposures. Under the bridge of N.Y. 5 on Eighteenmile Creek a thin (2-3 in.), black shale layer again separates the North Evans Member from the Genundewa. This appears to be continuous with the dark-chocolate bed at Pike Creek noted above. This unit, which was termed Penn Yan by deWitt and Colton (1939), can be traced for a distance of almost 2 miles along the shore of Lake Erie below Eighteenmile Creek and can be seen to thicken toward the southwest from 2 in. to 2 ft.

Genundewa Limestone Member: The Genundewa Member of the Genesee Formation is a dark, nodular, petroliferous limestone made up almost entirely of the minute shells of *Styliolina fissurella*, thus called the *Styliolina* bed by Grabau (1899). The Genundewa is about one foot in thickness at Cazenovia Creek where its undulating undersurface rests on dark concretions of the Geneseo-Penn Yan. Farther west the Genundewa is about 6-9 in. thick and generally rests with undulatory contact on the North Evans Limestone. In some localities such as at the Cloverbank Quarry, the contact between the two members is obscure. Whereas, at Eighteenmile Creek, thin shale partings may be present between the two. Elsewhere along the same exposure, the North Evans Limestone is present only as a thin veneer on the undersurface of the Genundewa.

The Genundewa appears to grade upward into the dark silty West River Shale in most exposures.

The Moscow Genesee Contact:

Huddle (1974) suggests that the western shore of the Tully sea may have stood near Canandaigua. If this is so, the remainder of western New York would have been as emergent area of exposed Windom muds. Whether or not this interpretation is correct, there is generally little direct evidence of erosion at the upper Windom surface. In most outcrops the Leicester or Geneseo paraconformably overlie the Windom. However, in western Erie County, there is abundant evidence of scouring of an indurated upper Windom surface.

Eroded upper Windom surfaces are best displayed in outcrops of the Windom Genesee contact in the Buffalo Southeast and Eden quadrangles, particularly in the Penn Dixie quarry at Bayview and the Lehigh quarry in Cloverbank. In all outcrops in these quadrangles from the north branch of Smokes Creek southwest to Eighteenmile Creek, the black Geneseo Shale is either missing or reduced to very thin discontinuous partings, and the Genundewa (*Styliolina* Limestone) rests directly on the North Evans (typical "Conodont bed").

The Windom North Evans contact in this section is highly irregular and may be characterized as a "rip-up" horizon. The Cloverbank exposure shows this feature very plainly (see Fieldtrip C discussion). Here slabs of the upper Windom argillaceous limestone 1 in. thick and up to 3 ft. across have been torn up and redeposited in the "Conodont bed" (North Evans). In a few instances, slabs of Windom, still partly bedded in the upper Windom, appear to bend up at one end into the overlying North Evans. Such slabs typically

Explanation of Plate 2. North Evans Contacts and "Rip up" Horizon. (all photos from Lehigh quarry at Cloverbank, N.Y.)

1. Upper and lower contacts of the North Evans Limestone (marked by arrows) note undulatory contact with Genundewa Limestone.

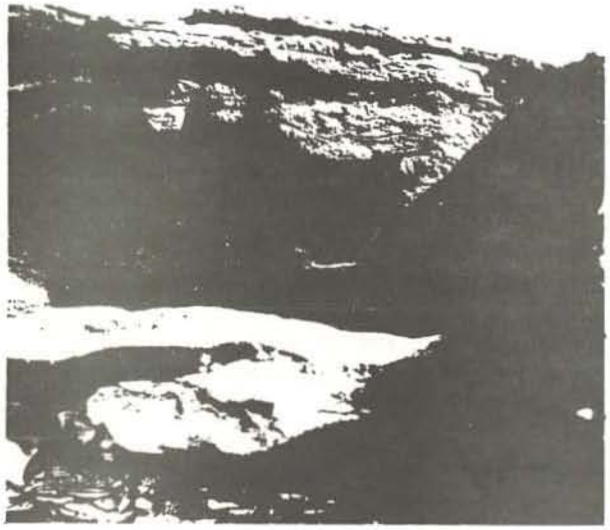
2. Characteristic "rip up" horizon showing both rounded and angular fragments of Windom argillaceous limestone incorporated into North Evans Limestone. (Conodont bed)

3. A fractured slab of Windom which bends up into the overlying North Evans.

4. Stacked slabs of Windom argillaceous limestone within the "Conodont bed.

5. Plan view of the underside of the North Evans showing incorporated concretionary limestone pebbles.

6. Windom/North Evans contact with a discontinuous layer of concretionary argillaceous limestone lying just below the "rip-up" horizon.



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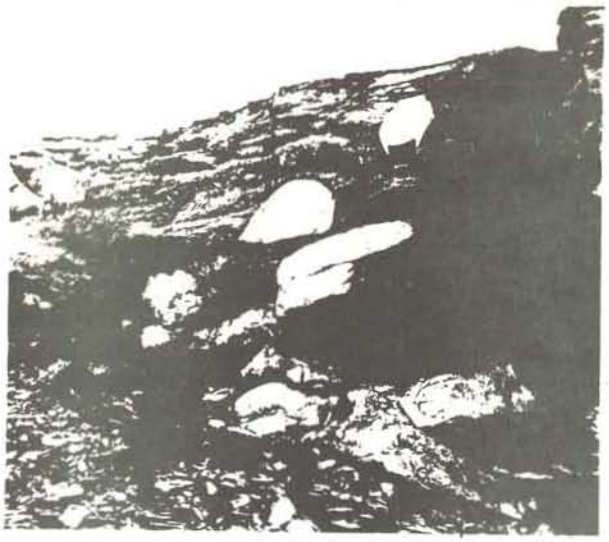

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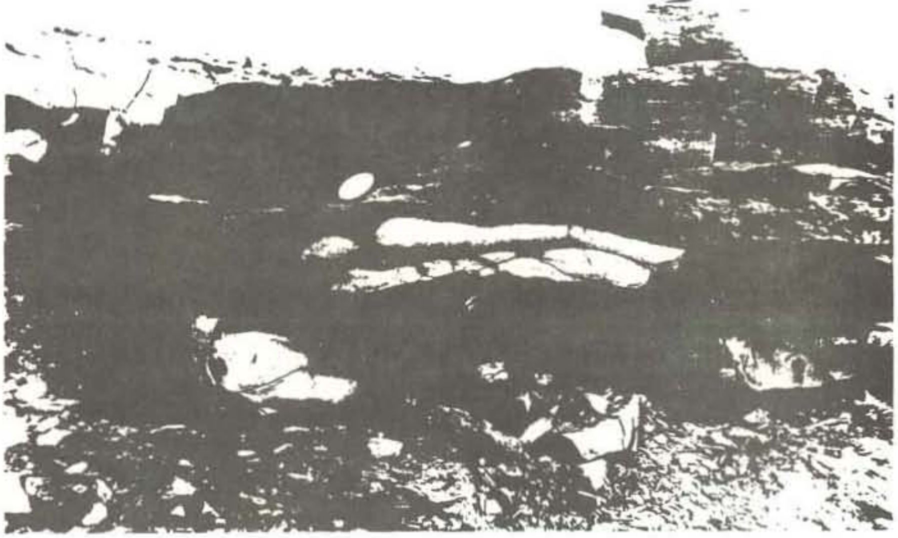

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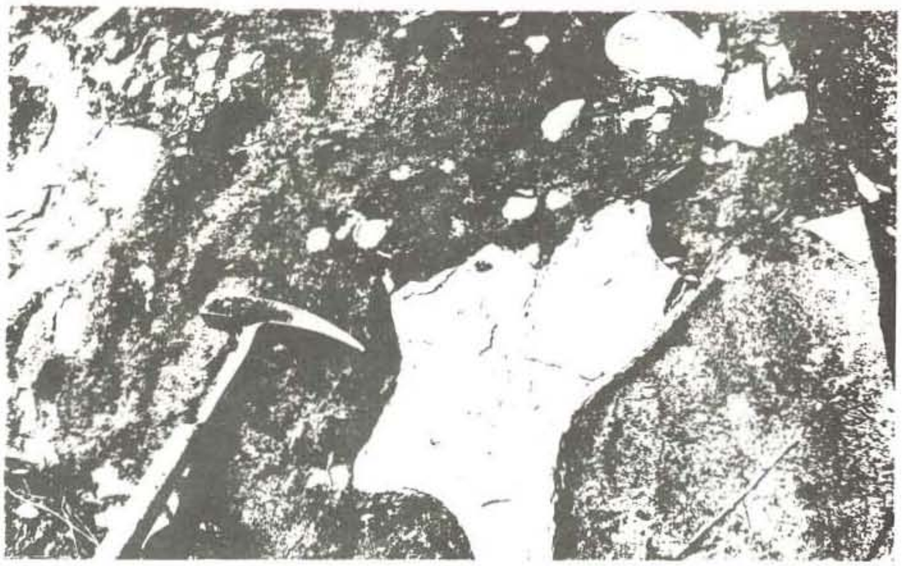

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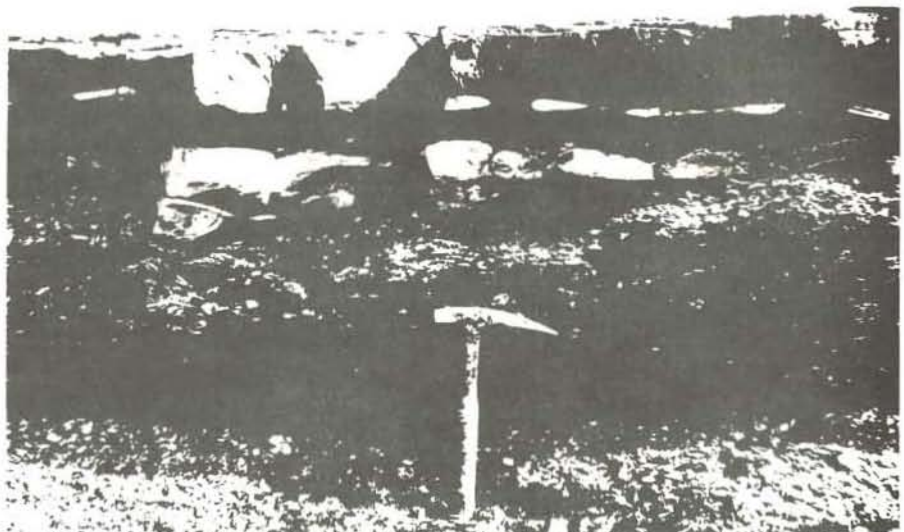

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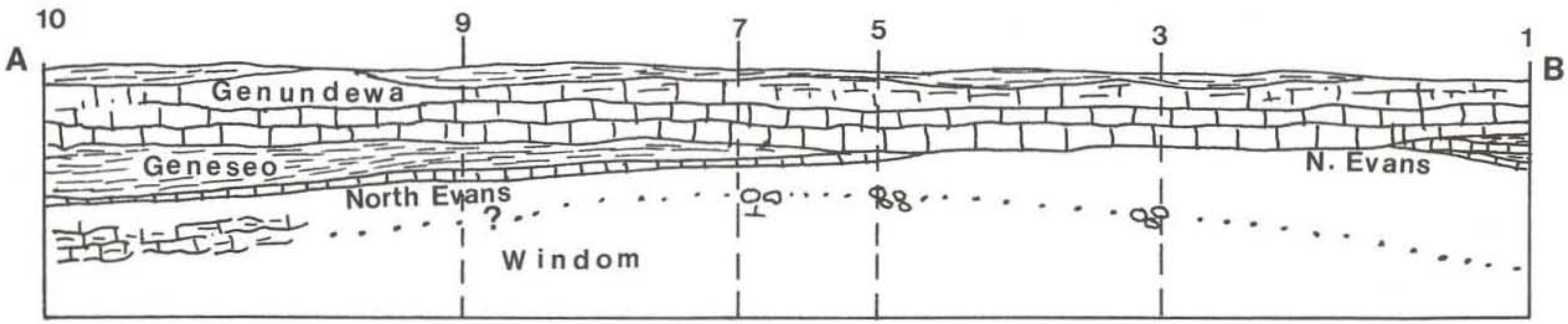
exhibit sharp angular breaks indicative of brittle fracture, and the fractures are usually filled with "Conodont bed" material. In some cases even the finest hairline cracks are "injected" with fine debris such as minute crinoid ossicles. The slabs of Windom are variously oriented and may be stacked one upon another. In contrast to the angular Windom slabs are subangular to rounded fragments, some of which probably represent reworked concretionary structures, while others generally overlying the angular fragments, appear definitely abraded and rounded by the action of water.

At Penn Dixie quarry the uppermost calcareous bed of Windom is rather fossiliferous, containing abundant brachiopods of which A. praeumbona is predominant. The overlying "Conodont bed" also contains numerous specimens of this species. Thin sections show the articulated valves of specimens of A. praeumbona with grey, micritic fillings which resembles the matrix of the underlying calcareous upper Windom suggesting that at least some of the fossils in the "Conodont bed" are reworked from the upper Windom. Specimens of typically Hamilton (Mid Devonian) fossils such as Atrypa reticularis, Mucrospirifer mucronatus, Mediospirifer audaculus, and undetermined rugose corals have been obtained from the Conodont bed in the "rip-up" horizon at Penn Dixie which also contains a mixture of "Middle and Upper Devonian conodont species (Huddle, 1974).

Truncation of the upper beds of the Windom is further indicated by tracing of persistant concretionary horizons below the contact. Gravau (1898) notes that a persistant double layer of concretions and shale containing the brachiopod Schizobolus truncatus can be traced along sections three and four of Eighteenmile Creek for a distance of about 500 ft. in each section (Fig. 5). The concretionary layer is about a foot below the Genesee contact in the southern ends of both sections and approaches the contact as it is traced northwesterly. Grabau concludes (1898, p. 23). "This layer therefore dips to the south at a higher angle than does the Styliolina limestone". A cross section (Fig. 5) constructed from measurements of the upper Windom and Genesee Formation at several exposures along Eighteenmile Creek similarly suggests the presence of a slight angular unconformity between the Moscow and Genesee at this location.

Detailed examination of exposures of the Moscow/Genesee contact in the vicinity of Eighteenmile Creek indicates that a complex series of depositional and erosional events took place at this surface in this area. Near the bridge of NY 5, the uppermost Windom is immediately overlain by a thin crinoidal-conodont bed about 1-2 in. thick, followed by 2 in. of black or chocolate-brown shale. There is little evidence of scouring at the base



KEY TO SYMBOLS:

- dark-grey to black, fissile petroliferous shale
- medium-grey, calcareous shale
- irregularly bedded, nodular, impure limestone (Styliolina)
- biocalcarenite; bone bed (Conodont bed)
- concretionary, argillaceous limestone
- probable position of a distinct, double layer of concretions in the Windom

Horizontal scale:

1 in.= 1960 ft.

Vertical scale:

1 in.= 2 ft.

KEY TO NUMBERED SECTIONS:

1-8 Grabau (1899)
9 cut on Lakeshore Road
10 Lake Erie cliff

Map scale
in feet
0 1000 2000

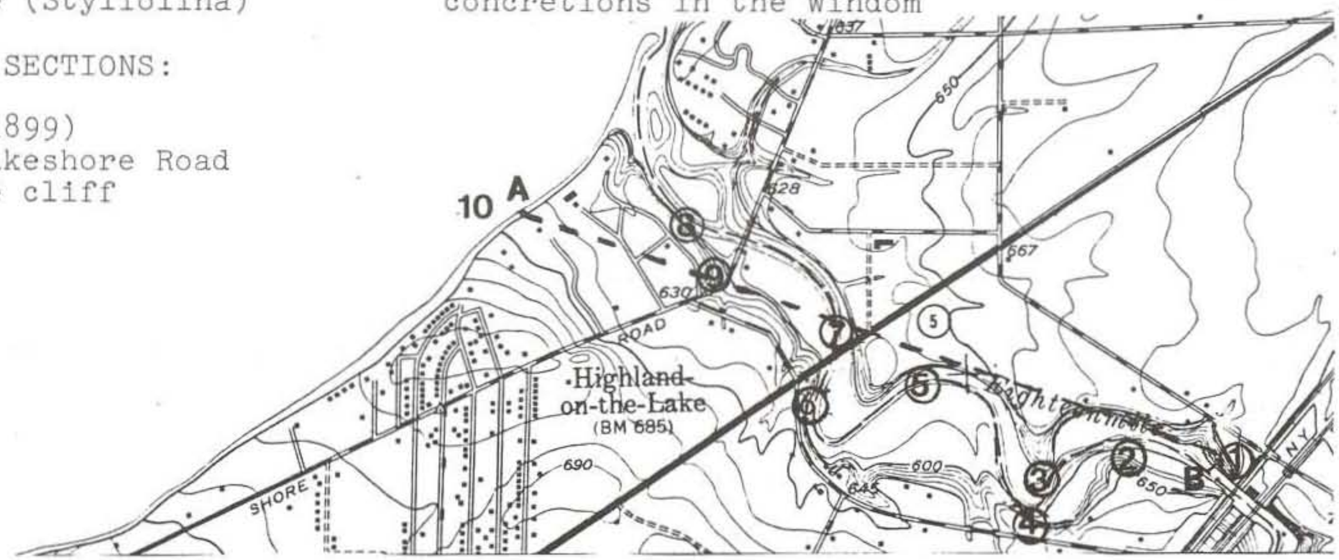


Fig. 5. Cross section of the Moscow/Genesee contact in the vicinity of Eighteenmile Creek and index map showing the locations of the numbered sections.

of the North Evans and reworked Windom pebbles have not been found here. The North Evans here has roughly the same characteristics as the thin pyritic band which lies between the Windom and the 9 in. of black shale one mile farther south at the mouth of Pike Creek. Acetic acid residues have revealed similar conodont assemblages from both localities. Thus, if previous interpretations of the Pike Creek limestone band as Leicester are correct, it must be concluded that, at least in this last locality, "Conodont bed" is "Leicester pyrite".

At section 5 (Fig. 5) the black shale is reduced to a parting, or is absent, and here, and in all the exposures to the NY 5 bridge, the "Conodont bed" occurs as a coating on the undersurface of the Genundewa Limestone, or is lacking altogether. Patches of crinoidal "Conodont bed" on the underside of the Genundewa frequently contain rounded to subangular pebbles of light-grey, concretionary limestone evidently derived from the upper Windom. Smaller poorly-defined pebbles and chips of dark-chocolate-colored shale also occur within the crinoidal bone-bed martix. This suggests a tearing up of previous deposited, but still soft black shale and well-indurated upper Windom concretionary rock.

At section 1 of Eighteenmile Creek, where the North Evans limestone is interbedded with black shale, distinct fragments of "Conodont bed" lithology can be found within the rock of a similar nature. These have evidently been scoured from previously deposited and partially cemented "Conodont bed". The thickness of the North Evans at its type locality may be related to "cannibalism" of nearby deposits of the same sediments.

Thus, along the Eighteenmile Creek a full spectrum of contact types is exhibited, ranging from paraconformable contact of the Windom with a layer of North Evans limestone to "rip-up" horizons with Windom and black shale pebbles and even reworked pebbles of "Conodont bed" within the North Evans.

Summary and Interpretation

A portion of western Erie County roughly delimited between the present Cazenovia and Eighteenmile Creeks was apparently subjected to greater erosion during the interval of Windom to North Evans than adjacent areas. The "rip-up" horizon characteristic of the Moscow Genesee contact in this area suggests scouring of a partially indurated and cracked, calcareous Windom muds. That such evidence of erosion is restricted in geographic extent suggests that a topographic high (possibly a localized island or arch) may have existed in this area.

Discovery of reworked Windom fossils in the North Evans, the "rip up" horizon and detailed tracing of distinctive upper Windom beds suggests truncation of portions of the upper Windom in this area by pre-North Evans erosion.

The contact in the Eighteenmile Creek area is complex. Dark Geneseo muds deposited in this region on top of a basal lag concentrate were locally scoured, torn up, and elsewhere were blanketed by reworked "Conodont bed" sands. West of this locality, conditions were similar to those existing east of Spring Brook, N.Y. where dark muds were probably gradually accumulating in quiet water, because there is little or no evidence of erosion.

Similarity of the Leicester pyrite lithology and its interbedding relationship to the black Geneseo shales suggests that it was formed under similar conditions to the thin North Evans layer at Eighteenmile Creek. The two units may in fact be stratigraphic equivalents.

Hassakof and Bryant (1918) interpreted the "Conodont bed" as a sandbar deposit citing as evidence, vague cross bedding, waterworn pebbles and wood fragments, and the mixture of marine and non-marine vertebrate fossils. Huddle (1964) similarly suggests that the North Evans is a transgressive lag deposit. These interpretations are in accord with observations of the Moscow Genesee contact in western Erie County.

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A special thanks to my wife Bettylou and my mother who helped in the preparation of the manuscript, and to Dr.'s Edward J. Buehler and G. Gordon Conally of SUNY, Buffalo who have given advice and encouragement for my independent studies of local paleontology.

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TRIP C - LATE MIDDLE AND EARLY UPPER DEVONIAN DISCONFORMITIES AND PALEOECOLOGY OF THE MOSCOW FORMATION IN WESTERN ERIE COUNTY

Carlton E. Brett and Gordon Baird

Total Miles	Miles from last point	Route Description
		We will take the N.Y. Thruway to Exit 54 where the road log begins.
0.0	0.0	Take Exit 54 for N.Y. Rt. 400. Turn right (west) onto exit for 400 south.
		BEGIN ROAD LOG WHERE THE EXIT RAMP MEETS THE AURORA EXPRESSWAY.
4.4	4.4	Exit for Transit Road south (N.Y. 78, U. S. 20). Turn right onto exit and bear southeast.
4.9	.5	Transit Road. Turn right (south) and proceed for a short distance.
5.2	.3	Intersection with N.Y. 16 (Seneca St.). Turn left (east) Town of Elma.
6.0	.8	Intersection with Northrup Road. Turn right (south)
6.2	.2	Bridge over Cazenovia Creek

STOP 1. Cazenovia Creek at Northrup Rd., Spring Brook, N.Y. (Orchard Park 7.5 min. quad.): A good exposure of Ludlowville Moscow contact can be seen on the left bank just downstream from the bridge. A thick section of Tichenor Limestone with basal shaley layer containing large favositids is overlain by the *Trachypora* bed of the Kashong Member about 11-14 in. thick containing abundant crinoid columnals, the coral *Trachypora*, large pelecypods, and gastropods. The base of the Moscow is the contact between the Kashong and Tichenor. The Kashong-Windom contact is marked by a rusty layer containing abundant crinoidal debris and *Ambocoelia umbonata* with occasional reworked specimens of *Trachypora* from the

Total Miles	Miles from last point	Route Description
		underlying Kashong. About 74 in. of *Ambocoelia* beds are present in the lower Windom here followed by (inaccessable) ledges of the calcareous *Spinatrypa* and coral-trilobite beds. At tne falls east of Northrup Road, the Tichenor lower contact with the fossiliferous Wanaka shale can also be seen. High cliffs which can be seen in the distance upstream from the falls exposes about 40 ft. of Windom capped by the black Genesee shales and Genundewa limestone.
		Continue southwest on Northrup Road.
7.2	1.0	Intersection of powerline which passes over the road.
		STOP 2. Proceed down dirt path on the left side of the road near utility poles. At the bottom turn left and walk to exposure on Cazenovia Creek bank. Here the upper Windom Shale is at water level, the Genundewa Limestone of the Genesee Formation forming a projecting ledge. About .1 mile downstream is a good exposure of the Moscow/Genesee contact. About 20 in. of black Geneseo shale separates the upper Windom (Praeumbona Beds) from the Genundewa. At intervals, lenses of Liecester Pyrite 0.5-6 in. thick occur at the contact. These are fossiliferous and contain an assemblage of diminutive brachiopods and mollusks. One lens along this section shows interbedding of the pyrite with black Geneseo shale. The basal layer of the Genundewa at this locality contains abundant, well-preserved fish bones.
		Return to Northrup and continue on Northrup southwest.
7.5	.3	Intersection of N.Y. 187 (Transit Road) turn right (north)
7.9	.4	Intersection of first road on the left side to U.S. 20 (sign to Silver Creek) Turn left (west).

Total Miles	Miles from last point	Route Description
8.0	.1	Intersection of U. S. 20 (Southwestern Blvd.); turn left (southwest)
	5.1	Bridge on U. S. 20 over Smokes Creek (Type locality of the Windom is north, downstream) Orchard Park Stadium on left side.
18.4	5.3	Intersection of Rogers Rd. Turn right (northwest)
18.8	.4	Intersection of Cloverbank Rd. Turn left (west)
19.5	.7	Intersection of railroad tracks. Turn left onto gravel driveway just before tracks.

STOP 3. Cloverbank Quarry. (Eden 7.5 min. quad.): Leased quarry of Lehigh Cement Co., on east side of Versailles-Pennsylvania R.R. tracks about .3 miles southwest of the intersection of the tracks and Clover Bank Road.

The Quarry walls about 50 ft. high expose the Upper Devonian Middlesex-Cashaqua Shale, floored mainly by the shaley upper contact of the Genudewa limestone and the West River shale. In a narrow pit the Genundewa is breached and a section extends down some 8-10 ft. to, or just below, the Praeumbona bed of the Windom shale. The Windom here is in contact with the North Evans Limestone and the contact is an erosion surface showing characteristic "rip-up" horizon. The uppermost Windom bed is a concretionary, calcareous, grey (1-3 in.) shale or argillaceous limestone. It appears to be unfossiliferous. The upper layer is undulating and pieces of this layer have been incorporated into the overlying North Evans as "slices" which appear to be cracked and torn up. Others occur as rounded chunks. The crinoidal debirs of the North Evans appears within cracks in the Windom upper layer as if injected. Some of the pieces of the upper Windom bed have greenish stains on the surface suggestive of glauconite. The North Evans contains much debris including abundant

Total Miles	Miles from last point	Route Description
		fish plates and teeth, phosphatic nodules, much pyrite (note rusty stains), and a few invertebrate fossils: crinoid plates and rugose corals. The Genundewa itself is only about 6 in. thick and quickly grades into a somewhat sandy shale (West River). It is in direct undulating contact with the underlying North Evans although in places this contact is obscure.
		Return to Cloverbank Road and turn left (west)
19.9	.4	Intersection N.Y. 5 (Lake Shore Rd.). Turn Left (southwest).
20.2	.3	Town of Wanakah. Type locality for the Wanakah shale (Ludlowville Formation).
21.4	1.2	Fork of N.Y. 5 and Lake Shore Rd. Continue straight on 5.
24.0	2.6	North Creek Road, proceed straight on 5 for a short distance.
24.3	.3	Private drive on left side just before the bridge of N.Y. 5 over Eighteenmile Creek. Turn left onto this drive. Please park at the turn around area near the end of the private drive. Walk down the dirt road to the bank of Eighteenmile Creek (Grabau's 1898 section 5 - see Fig. 5 in text).
		Section 5 STOP 4. Eighteenmile Creek (Eden 7.5 min. quad.): About 1/4 mile south of the bridge at route 5 over Eighteenmile Creek, the creek makes a major U-bend and swings around from southwest to northeast. Due south from the bridge on the left side of the stream is a large meander scar, then the bank rises steeply where the stream is actively cutting into the Tichenor Limestone. Here the Tichenor forms a slightly undercut ledge about 1-2 ft. from the water edge, for about 1/4 mile to a small falls. The lower beds of the Windom Shale (here about 17 ft. thick) are easily studied here. The upper 1-3 ft. or so of the Wanakah which is exposed here is quite fossiliferous. The Tichenor is 1 foot thick, massive and contains abraded crinoid columnals and other fossils. Its upper surface is notably rich in the pelecypod *Plethomytilus* here, and contains traces of

Total Miles	Miles from last point	Route Description

burrows. At this locality a zone of shale about 3 in. thick in direct contact with upper Tichenor Limestone contains waterworn fragments of brachiopods (Spinocyrtia), limestone pebbles eroded from the underlying Tichenor, and rounded black pebbles (0.2-0.5 in.) probably phosphatic. A large crinoid root (scutella-form) was in place on the upper surface as well as bored and abraded shells. The lowest 2 ft. of the Windom contain the extremely rich Ambocoelia beds, and these are overlain by classically developed coral beds (3 in. thick) with large Cystiphylloides and the brachiopods Atrypa, Spinatrypa, followed by one foot of calcareous shale containing Amplexiphylloides, Stereolasma, Mucrospirifer consobrinus, and well-preserved trilobite remains. Poorly preserved Nuclulites are found in the middle of these shales and just a few inches above the "trilobite-coral" layer a few pyritized fossils (Bucanopsis and nautiloids) were obtained. Associated with these (just below) was a thin unfossiliferous, calcareous lens and above some Mediospirifer and corals were collected.

Most of the overlying shales are barren, although near the top, the slightly concretionary calcareous Praeumbona bed contains abundant brachiopods. The Genundewa Limestone overlies the Windom about 17 ft. above the Tichenor. Fallen blocks reveal a thin coating of "Conodont bed" adhering to the underside of the Genundewa. This unit contains pieces of upper Windom argillaceous limestone as well as dark shale pebbles.

The section is capped by about 20 ft. of Genesee Formation and massive jointed Middlesex black shale fallen blocks of the yield plant remains.

Section 4. Proceeding upstream from the falls at section 5, Eighteenmile Creek bends to the south. About 500 ft. above the falls a steep bank on the south (right) side of the creek exposes a section of some 75 ft. (Section 4). At the top of the bank the black Rhinestreet Shale (Upper Devonian, West Falls formation) forms a nearly vertical wall.

Total Miles	Miles from last point	Route Description
		Below it is the greenish-grey Cashaqua, blocky black Middlesex Shale (two members of the Sonyea formation), and a dark-grey West River Shale. The Genundewa limestone forms a projecting ledge at the base of the cliff. The "Conodont bed" (North Evans) is either missing or occurs as very thin patches on the underside of the ledge. A few feet of Windom crop out beneath the ledge. The creek is very deep next to this section and therefore it is difficult to examine in detail.
		Section 3. Opposite the upper end of section 4 the creek swings back north and cuts the end of a promontory on the north side of the channel. Here an easily accessible section of upper Windom to Cashaqua can be seen. Note the double concretionary layer in the upper Windom. The basal Genundewa has black shaley seams, but the "Conodont bed" is apparently absent here.
		Section 1. It time and creek conditions permit, we will proceed around the end of the promontory and upstream (east) about 500 ft. to exposures on the left bank near the trestle of N.Y. Central Railroad. Here in the type locality, the North Evans Limestone thickens to a maximum of about 4 in. In places, interbeds of dark shale separate the North Evans limestone into two bands. The unit is also separated from the overlying Genundewa by a black shale seam.
		Return to the bus via a dirt path running from the end of the promontory at section 3 to the end of Basswood Drive. Access to sections of Eighteenmile Creek from private lands has been provided by kind permission of the owners, Mr. S. Prahovic and Mr. W. F. McLimans. Please respect this privilege.
		Return to N.Y. Rt. 5 and turn left (southwest).
26.8	2.5	Intersection of Delamater Road. Turn left (south).

Total Miles	Miles from last point	Route Description
27.6	.5	Intersection of Derby-Sturgeon Pt. Rd. Turn left (east).
28.5	.9	Railroad crossing.
29.1	.6	Intersection of Versailles-Plank Rd. Turn right (south)
	1.3	Rt. 20. Go straight through this intersection.
30.9	.5	Intersection of Evans Ctr-Eden Rd. Turn left (east)
	.9	Proceed over Thruway to Interchange 57A.
32.2	.4	Thruway tollgate. Turn left. Proceed on ramp to Westbound lane of Thruway.
		Thruway to Fredonia.

LOOKS AT THE PRESENT AND THE RECENT PAST

Ernest H. Muller, Dept. of Geology, Syracuse University and
R. K. Fahnestock, Dept. of Geology, S.U.C. Fredonia

A WORD TO THE FORE

We wish to acknowledge the stimulus provided by our respective chairpersons, Daniel Merriam of Syracuse and Olcott Gates of Fredonia who volunteered our services, and the gentle prodding of the guidebook editor. All were essential to the completion of this manuscript. The cooperation of the New York State Geological Survey and its director, Dr. James Davis, in permitting the use of appropriate portions of a draft of Muller's Glacial Geology of the Niagara Sheet and materials is appreciated. Drafting help with maps was provided by John Walton of Fredonia. Illustrations were prepared by Don Burdick and Ron Warren of the Fredonia Instructional Resource Center.

E.H.M. was wise enough to leave for New Zealand immediately upon hearing of the assignment. R.K.F., having no place to go, has proceeded to reproduce Muller's 1960 Friends of the Pleistocene Field Guide with few improvements and all the controversies and inconsistancies dictated by the western New York geologic record. Some new stops have been added in light of recent local geologic events and RKF's orientation toward processes and predilection for scenery, buried and otherwise. Due to RKF's slowness in producing a manuscript, EHM has had no opportunity to recant or to correct the errors of omission or commission found in the present attempt. We all look forward to EHM's explanations on the outcrops in the fall.

WESTERN NEW YORK GLACIAL GEOLOGY: CHAUTAUQUA AND CATTARAUGUS COUNTIES (see fold out map at end of section "F")

Drift borders in western New York were described by Chamberlin (1883) and Lewis (1884), but Leverett's massive monograph (1902) is still the most extensive summary of glacial geology of the region.

Knowledge of the landscape at the onset of glaciation is based on interpretation of erosion levels and through-valleys. Tarr (1902) assigned upland remnants in southern New York to a Cretaceous peneplain. Campbell (1903) and Cole (1938) identified multiple erosion levels. Denny (1956a) examined evidence of structural control during equilibrium reduction of the former erosion surface in Potter County, Pennsylvania. Carll (1883) and Leverett (1902) discussed evidence of the northward course of the Ancestral Allegheny River.

Evidence of pre-Wisconsin glaciation is limited. MacClintock and Apfel (1944) describe Illinoian terrace remnants in the Allegheny Valley near Salamanca. Bryant (1955) and Muller (1957b) traced ice marginal features in the Quaker Bridge and Red House areas indicative of pre-Wisconsin glaciation across Allegheny Valley. The stratigraphic section at Otto probably indicates pre-Wisconsin glaciation, whether the organic zones are interpreted as Sangamon (MacClintock and Apfel, 1944) or as post-Sangamon, pre-Farmdale (Muller, 1957a, 1960).

Features of the Wisconsin drift border mapped earlier (Lewis, 1884; Leverett, 1902; Lobeck, 1927) were interpreted by MacClintock and Apfel (1944) as including two drifts, the Olean drift of the Winconsin border east of Little Valley and the younger, brighter Binghamton drift at the Wisconsin border west of Little Valley. The present detailed interpretation of the drift border is based on soil survey work (Pearson et al., 1940; Bryant, 1955). Two recessional positions of the Binghamton ice margin, incorrectly identified as the Inner and Outer Cleveland moraines by Leverett (1902) are renamed the Clymer and Findley moraines (Shepps et al., 1959; Muller, 1963). Proglacial lake history in the plateau valleys is related to recessional positions of the ice border (Chadwick and Dunbar, 1924; Fairchild, 1896; 1928; Cuthbert, 1927).

Lavery and Defiance moraines mapped on the basis of texture and weathering profile (White and Shepps, 1952; Shepps 1953; 1955; Muller, 1956a) in western Pennsylvania (Shepps et al. 1959) and Chautauqua County (Muller, 1963) appear to mark glacial readvances intermediate between the Binghamton recessionals and the Lake Escarpment moraines. Eastward correlation into Cattaraugus County is uncertain.

The Lake Escarpment moraines (Leverett, 1902) were correlated with the Valley Heads moraine (Fairchild, 1932) of the Finger Lakes region and have been dated at more than 12,000 years B.P. (Merritt and Muller, 1959). Shepps et al. (1959) have applied to this complex of moraines in western Pennsylvania the name Ashtabula moraine, initially proposed by Leverett (1902) for one of the several Lake Escarpment moraines.

The succession of proglacial lakes imponded between the receding ice border (Leverett, 1902; Taylor, 1913; and Fairchild, 1932) and the northern margin of the Appalachian Plateau was described by Leverett and Taylor (1915), Fairchild (1932), Leverett (1939) and Taylor (1939). Correlation based on radiocarbon dating (Flint, 1956; Hough, 1959) has associated proglacial Lake Whittlesey with the Cary ice recession and at least the latest phase of Lake Warren with a post-Two Creeks readvance.

Calkin (1970) presented the summaries of the chronology of deglaciation and lake succession reproduced here as Tables 1 and 2. Table 3 is reproduced from Muller (in press). It is hoped that these dates will provide a basis for discussion and an understanding of the rapidity of some glacial processes. They present a picture of extremely rapid deglaciation and the development of major beaches and deltas within a period of a thousand years beginning about 13,000 years ago.

TABLE 1
Correlation of Late Wisconsin lakes† and moraines, western New York **from Calkin (1970)**

Years B.P.	Glacial Event	Lakes of Erie Basin (* evidenced in N.Y.)	Moraines in N.Y.
	St. Lawrence ice-free		
−11,000			
	Valders Advance		
	Two Creeks Interstade	Iroquois (Ontario basin)	
		*Early Erie (473?)	
−12,000	Rome, N.Y. ice-free		
		*Dana (570)	Albion M.
		*Early Algonquin (605)	Barre M.
		*Lundy (620)	
		*Grassmere (640)	Batavia M.
		*Warren III (675)	Niagara Falls M.
		*Wayne (660)	Buffalo M.
		*Warren II (680)	Alden M.
		*Warren I (690)	Marilla M.
			Hamburg M.
	Port Huron Advance	*Whittlesey (738)—?	Gowanda M.
			Lake Escarpment M.
−13,000	Cary/Port Huron	Ypsilanti? (543-373)	
		III (695)	
		II (700)	
		Arkona I (710)	
	Cary Advances		Moraines of SW New York (see Muller, 1963)
−14,000			

†Elevations of glacial lakes south of respective zero isobases, (after Wayne and Zumberge, 1965).

Pre-Wisconsin glaciation

No direct evidence remains as to details of early glaciations. Prior to glaciation the Ancestral Allegheny River, rising in Pennsylvania flowed generally northwestward in a valley past Salamanca toward Steamburg, Randolph, Conewango, Dayton and Gowanda, with outflow into the Erie basin (Figure 1). A left-bank tributary of this stream flowed north from near present Kinzua, Pennsylvania to confluence with the Ancestral Allegheny between Salamanca and Steamburg. Although the Labradoran ice sheet may have experienced subordinate development during the Kansan and Nebraskan stages, it must have extended into New York far enough to block the Ancestral Allegheny, diverting its flow southward. The former divide at Kinzua had been reduced essentially to its present elevation before deposition of the earliest preserved glacial materials in Cattaraugus County.

TABLE 2 **from Calkin (1970)**

Summary of radiocarbon dates† defining late glacial history of the Lake Erie basin

Event	Date Number	Age-Years B.P.	Remarks	Reference
A) Specifically Dating Pleistocene Great Lake Stages				
Lake Arkona III	*W-33	13,600 ±500	Tree fragments from lagoon deposits (689 ft. A.T.) overlain by Whittlesey sand and silt.	Hough, 1958 (D)‡
Lake Whittlesey	*W-430	12,920 ±400	Wood from a peaty zone below Whittlesey gravels at Parkerstown, Ohio.	Alexander and Rubin, 1958 (D)
	I-3175	12,900 ±200	Wood in Whittlesey beach, Elyria, Ohio.	T. Lewis and R. Goldthwait, 1963 personal communication
	*Y-240	12,800 ±250	Wood fragments in Whittlesey sediments 4.5 miles southeast of Bellevue, Ohio.	Hough, 1958 (D)
	*S-31	12,660 ±440	Driftwood from Lake Whittlesey gravel near Ridgetown, Ontario (minimum date).	McCallum, 1955 (D) A. Dreimanis, 1966 personal communication
Lake Warren or Lake Wayne	I-2918	11,200 ±170	Wood from Lake Warren—Wayne beach, Cleveland, Ohio.	T. Lewis and R. P. Goldthwait, 1969, personal communication
Early Lake Erie	S-172	12,000 ±200	Plant remains at 581 ft. near Tupperville, Ontario below beach deposits of Early Lake St. Clair 590-600 A.T.	Dreimanis, 1964 (D)
	GSC-211	11,860 ±170	Same as above.	Goldthwait *et al.* 1965 (D)
	GSC-382	11,300 ±160	Buried plant detritus western Lake Erie	Lewis *et al.* 1966
	GSC-330	10,200 ±180	Buried driftwood central Lake Erie	Lewis *et al.* 1966
Lake Iroquois	W-861	12,660 ±400	Organic material from Lake Iroquois sediments, Lewiston, N. Y.	Rubin and Alexander 1960 (D)
	I-838	12,100 ±400	Wood in the Iroquois sediment 4.5 mi. north of Lockport, N. Y.	Buckley *et al*, 1968
	W-883	12,080 ±300	Organic material from Lake Iroquois sediments, Lewiston, N. Y. (previously run as W-861).	E. H. Muller, 1956a
	Y-391	11,570 ±260	Wood from Lake Iroquois bar, Hamilton, Ontario	Dreimanis, 1966
B) Defining Glacial Recession on Northwestern N. Y.				
Minimum for recession from:				
Gowanda and Lake Escarpment M. (may also date late Whittlesey early Warren I)	I-3665	12,730 ±220	Organic detritus in lake silts, at 810 ft. A.T., 2.4 miles south of North Collins, Erie Co., N. Y.	Calkin and McAndrews, 1969
Lake Escarpment M. (distal side)	W-507	12,020 ±300	Wood over outwash, southeastern-most Erie Co., N. Y. (Nichols Brook at Cherry Tavern).	Muller, 1960, 63, 65a
"	I-4043	13,800 ±250	Same as above except specimen of organic detritus taken 25 cm above outwash. Stratigraphically below spec. W-507.	This report
"	I-4216	14,900 ±450	Same location as above (I-4043) except dated material from 2 cm above outwash (23 cm below I-4043).	This report

†Dates reported are based on the standard half-life value for C-14 of 5568 years. Dates above must be increased by 350 to 400 years based on the more accurate half-life of 5730 years.

*According to Dreimanis (1966, this journal) these date the transition from Lake Arkona to Lake Whittlesey.

‡(D) in reference column notes that date is also referenced in summary of Dreimanis (1966, this journal).

Table 3. Radiocarbon Sites of the Field Trip Area (from Muller, in press)

Site No.	Site Name Town Name	Quadrangle, County	Years B.P.	Lab Ident.	Remarks: Material, Stratigraphy, Location, Significance	References
A	Otto, Otto	Cattaraugus, Cattaraugus	63,000 ±17,000	GrN-2634 GrN-3213	Peat beneath gravel, lake clay, 2 tills; left bank, S. Br. Cattaraugus Cr., S edge of Otto. Dates Otto Interstadial.	6, 5, 4
			52,000	GrN-2565	Carb. silt in gravel beneath lake clay, 2 tills; left bank, S. Br. Cattaraugus Cr., S edge of Otto; Picea and Pinus dominate pollen spectra.	6, 5, 4
B	Clear Ck, Collins	Gowanda, Erie	48,400	GrN-5486	Wood, probably Picea, in firm silty clay imbedded in 6.5 m till beneath 4 tills; left bank, Clear Ck. Rt. 39, 62 bridge. Minimum age of interstadial.	7, 5
C	Winter Gulf, N. Collins	N. Collins Erie	12,730 ±220	I-3665	Organic detritus in gray clay beneath 1.08m of shale shingle, 14 m. below max. level of Lake Whittlesey; at level of Warren I; 3 km S of N. Collins limits.	1
D	Sheridan, Forestville	Sheridan, Chautauqua	9200 ±500	M-490	Mastodon rib in Lake sand beneath 60 cm muck in basin landward from Warren beach; Dahlman Farm; postdates Lake Warren.	2, 3

References for Table 3.

1. Calkin, P. E., 1970, Strand lines and chronology of the glacial Great Lakes in northwestern New York; Ohio Jour. Sci. 70:78-96.

2. Crane, H. R. and J. B. Griffin, 1959, University of Michigan Radiocarbon dates IV: Radiocarbon Suppl. 1:173-198.

3. Hartnagel, C. A. and S. C. Bishop, 1922, The mastodons, mammoths and other Pleistocene mammals of New York State, N.Y.S.M. Bull. 241-242, 110 p.

4. MacClintock, Paul and E. T. Apfel, 1944, Correlation of the drifts of the Salamanca re-entrant, New York; Geol. Soc. America Bull 55:1143-1164.

5. Muller, E. H., 1960, Glacial geology of Cattaraugus County, N.Y. Guidebook 23rd Reunion, Friends of Pleistocene, Geology Dept. Syracuse Univ. 33 p.

6. Muller, E. H., 1963, Geology of Chautauqua County, New York, Part II: Pleistocene geology; N.Y.S.M. Bull 392, 60 p.

7. Rubin, Meyer and Corinne Alexander, 1960, U. S. Geological Survey radiocarbon dates V; Radiocarbon Suppl. 2:129-185.

These deposits include terrace remnants mapped by MacClintock and Apfel (1944) as Illinoian (Figure 2). Three saddles north of Quaker Run, aligned generally north-south were pointed out by Bryant (1955). These aligned notches, together with glacial deposits blocking valleys of Quaker Run, Hotchkiss Hollow and Meetinghouse Run, are evidence that pre-Wisconsin glaciation extended southeast across the Allegheny Valley (Muller, 1957b). The Illinoian gravels typically contain about 5 percent of igneous and metamorphic pebbles, and below the leached zone, 25 to 30 percent carbonate and associated rock types derived from north of the plateau. The depth of leaching averages about 15 ft. Secondary cementation is not uncommon at greater depth. Granitic boulders with one-half inch thick, kaolinitized weathering rinds occur on some of these benches. Illinoian terrace remnants stand 120 to 180 ft. above present river level, as opposed to 10 to 30 ft. for Wisconsin terraces. Those able to read fine print may discover some of these terraces on Plate 1.

Pre-Farmdale organic sites

Stratigraphic sections exposed by Clear Creek near the Gowanda State Hospital *(STOP F3, Muller, 1960, Stop 3) and by South Branch Cattaraugus Creek near Otto (STOP D6, Muller 1960 Stop 4) contain organic zones dated by radiocarbon as older than 38,000 years B.P. Both are overlain by one or more tills and underlain by evidence of earlier glaciation. Neither contains the strong paleosol or evidence of climate warmer than the present which would be conclusive evidence of the Sangamon interglacial. Both, however, contain evidence of an interval of subaerial erosion, which may in part account for absence of the more conclusive evidence.

The Otto high bluff is exposed where the South Branch of Cattaraugus Creek cuts sharply against its left bank in the southern outskirts of the village of Otto, Cattaraugus County, New York (STOP D6). The exposures extend a couple of hundred yards downstream from the highway bridge, from which they are clearly visible. Although the upper portion of the bluff is slumped and disturbed, the lower portion containing organic deposits is exposed in a face 40 to 100 ft. high.

MacClintock and Apfel (1944) first described the exposures at Otto. Quoting a brief characterization of the peat flora by Paul B. Sears, they interpreted the section as representing from the base up, Illinoian glaciation, Sangamon peat, Olean outwash and Binghamton till and proglacial lake deposits. (Muller, 1957a) suggested that the Otto interglacial beds may represent a post-

*The lettered stops refer to the glacial field trips for this meeting. The Saturday all-day trip is Trip D and Sunday's half-day trip is Trip F.

Sangamon, pre-Farmdale interval of partial deglaciation. In connection with present investigations, the Otto organic material has been studied and interpreted by Clair A. Brown of Louisiana State University, William S. Benninghoff of the University of Michigan, Edward H. Ketchledge of the New York State College of Forestry at Syracuse and Howard Crum of the Canadian National Museum. Radiocarbon dating has been attempted by the Washington and Groningen Laboratories.

Pollen analyses show complete dominance of coniferous species, with Pinus generally in excess of Picea. Abies is present in the lowest horizons, comprising less than 4 percent at maximum abundance, but is missing above blocky peat, Unit 3-c (refers to a unit in STOP F3 description). The complete lack of Tsuga is in contrast to its typical presence in post-glacial boreal pollen counts. Brown (written communication) suggests that two species of spruce may be present, for the smaller pollen grains suggest identification as Picea mariana (black spruce). Some of the pine pollen is small enough to suggest Pinus Banksiana (jack pine). Isolated grains of oak (Quercus), birch (Betula), maple (Acer), linden (Tilia) and (Carya) are too sparse and erratic in distribution to be representative.

Non-arboreal pollen grains are not abundant, perhaps because they are derived from a more restricted area than are grains of the taller trees. Sparsely represented in the lower horizons are vegetation of drier upland sites. The uppermost horizon on the other hand shows predominance of marsh and lake shore elements such as cat-tail (Typha), arrowleaf (Sagittaria) and pond-weed (Potamogeton).

Two moss zones are separated by about 4 ft. of sediment and peat (Units 3-b to 3-g). The general pollen spectrum of the upper moss zone suggests close relationship to the lower in which E. H. Ketchledge (written communication) identified the following assemblage:

> Tomenthypnum nitens about 95 percent
> Drepanocladus of D. aduncus, about 5 percent
> Paludella squarrosa, distinctive, but very subordinate.

Of these species, Paludella squarrosa is essentially lacking in the active flora of New York, and Tomenthypnum is not encountered in the rather pure stand suggested by this assemblage. These species suggest a wet environment, whether fen (marsh) or steambank, with waters of relatively high pH and climate slightly colder than present.

The botanical assemblage represents the southern aspect of the boreal forest, such as grows today near Ottawa, for instance, under climatic conditions which suppress hardwood species. No clearcut change in environment is indicated during deposition of Units 2-4 inclusive but Benninghoff (written communication) reports an internally consistent upward decrease in spruce-pine ratio, suggestive of slight climatic amelioration.

No strictly lacustrine deposits occur in this portion of the Otto sequence. Units 2-5 inclusive include blocky peat, moss and twig layers, muck, slit, sand, channery gravel and a coarse boulder layer. This range of stratified deposits can be accounted for best, perhaps by a floodplain situation. The side of the bedrock valley is within a few hundred feet south and east. Shifting of channels playing occasionally against till bluffs at the base of the section, but with increasing regularity against bedrock bluffs upward in the section, may account for the coarser beds. Oxidation of peat prior to burial is suggested near the base, but deposition was generally in reducing environment under conditions of high water table. Oxidation of the boulder layer is almost surely attributable to ground-water seep in recent years, rather than to pedological processes during deposition. For intervals probably measured in centuries, the channel was situated across the valley, permitting development of boreal forest with peat accumulation favored perhaps by nearby seep conditions of cold carbonate-charged waters.

Glaciation predating deposition of the organic sediments is indicated by a basal boulder gravel (Unit 1) in which crystalline erratics are conspicuous. This deposit is a lag concentration resulting from stream erosion of till banks. Although no till is now exposed, a trace of blue-gray clay, suggestive of till matrix is to be seen in places between tight-fitting boulders and in bedrock joints. Striae are distinguishable on a few boulders in Unit 4, but not bedrock beneath the basal gravel, which is not surprising in view of the closely-spaced jointing and incompetence of the rock. This glaciation is Illinoian or advance Wisconsin, depending on interpretation of the magnitude of the non-glacial interval. This, in turn, must depend on dating, on inferred depth of erosion or volume of subaerial deposition, on intensity of pedologic development, and on inferred climate during the interval of non-glaciation.

No floral indication of climate as warm as postulated for the maximum of Sangamon climatic amelioration has been recognized at Otto. Radiocarbon dating has failed to establish a finite age for this material. Initial assay by the U. S. Geological Survey Laboratory (Suess, 1954) established peat (probably Unit 3-g) as radioactively inert, with age given as greater than 35,000 years. Analysis of carbonaceous silt midway up in Unit 5 by the Groningen Laboratory yielded age greater than 52,000 years (Gro 2565). The organic section is older than most of the Port Talbot section in Ontario (Dreimanis, 1959) where gyttja near the base of the bluff has been dated at 47,500 B.P. (Gro 2597 and 2601)

(Dreimanis, 1964). It is hoped that isotopic enrichment of the more carbon-rich material near the top of Unit 3 may establish or disprove the tentative correlation of this unit with advance Wisconsin refrigeration as represented by the St. Pierre interval in Quebec (Terasmae, 1958).

The bluff near Gowanda State Hospital (STOP F3) exposed by undercutting at a bend of Clear Creek, 50 yards west of U. S. Route 62 reveals a succession of tills separated by stratified sand and silt and underlain by flood plain deposits comparable to those at Otto, though less rich in organic remains. Wood (from Unit 2) submitted for radiocarbon dating is older than 38,000 years (W-866). Initial pollen analyses have shown the presence of *Picea* and *Pinus*, but pollen was too scarce for statistical treatment (Brown, personal communication). Sparse tests of *Ostracoda*, *Pelecypoda* and *Gastropoda* occur in a marly layer in Unit 2, but have not yet been studied by suitable specialists. Preliminary indications are that the non-glacial interval represented at this site, like that at Otto may well represent advance Wisconsin conditions.

Olean and Binghamton drifts - Includes Kent of Chautauqua County Figure 3.

MacClintock and Apfel (1944) distinguished drift of relatively high lime content, relatively shallow leaching of carbonates and unmodified constructional topography from drift of very low lime content, deeper leaching of carbonates and somewhat greater modification of constructional topography. The latter they mapped at the Wisconsin drift border from Little Valley eastward. They named it the Olean drift for exposures near that city. The former they distinguished at the Wisconsin border west of the Salamanca reentrant. By reconnaissance mapping and spot-checking eastward, they correlated it with kame gravels near Binghamton, assigning them the name Binghamton drift.

Olean drift and the Olean drift border have been correlated with the Iowan or the Tazewell substage of the Wisconsin (MacClintock and Apfel, 1944) the Iowan-Tazewell complex (Flint, 1953), the Tazewell (MacClintock, 1954) and the pre-Bradyan Wisconsin (Denny, 1956b). These authorities concur in assigning pre-Cary, Wisconsin age to the Olean drift and moraines. No more specific basis for dating or correlation has been recognized to date (1960).

In 1956, Denny questioned the existence of Binghamton till in the Elmira area, thereby casting doubt on the validity of correlation of till west of the Elmira area with kame deposits near Binghamton. Merritt and Muller (1959) point out the close association of upland drift of Olean lithology adjacent to valley-filling drift of Binghamton lithology south of the Valley Heads drift border in central New York in situations where no creditable glacier margin could be drawn between the two contrasting drifts. For these reasons serious reservation is felt regarding long distance correlations based on similarity of till constitution, particularly with respect to the coarse fraction. Merritt and Muller (1959) suggested using the term "Binghamton drift" in a purely lithological sense, without necessary connotation of time equivalence, pending resolution of the "Binghamton problem".

Objections to the criteria for distinguishing between Binghamton and Olean drift were not unforeseen by MacClintock and Apfel who wrote in 1944: "The question naturally arises as to whether the Olean is not simply the outermost part of a single drift sheet containing fewer erratic stones than the part of the same drift sheet back nearer the outcrops from which the stones were derived. There seems little unanimity of opinion among glacialists on whether or not there should be more concentration of erratics at the margin of a drift sheet or farther back. However, in either case change of lithology has not been found; the change from one type of drift to the other is sharp and abrupt. The Olean drift has the same lithology from its margin northward to a sharp line of demarcation at which line the limestone and igneous content of the drift suddenly increases. The contrast is so sharp that in the field even the first glance at a good exposure reveals the difference."

The Binghamton moraine where it borders the Salamanca re-entrant on the west has been correlated with the Kent moraine of Ohio and Pennsylvania (Shepps et al., 1959) on the basis of continuous tracing. On the basis of present correlations Binghamton is Kent (Muller, 1963).

The age of Kent (=Binghamton) moraine in Pennsylvania is approximately demonstrated by radiocarbon dating of material from the Corry bog, northwest of Corry, Pennsylvania (Droste, et al., 1959). Internally consistent dates on marl and basal peat collected by drill-coring and analyzed in the Washington Laboratory indicate probable abandonment of the terminal Kent moraine slightly prior to 14,000 B.P. (W-365) (Rubin and Alexander, 1958) (see Tables 1, 2, and 3). This dating is consistent with the assignment of Kent to early Cary (Shepps et al, 1959) and Binghamton to Cary (Flint, 1953; MacClintock, 1954) or early Cary (Muller, 1957a).

Lavery and Defiance moraines

Shepps (1955) applied the name Lavery moraine to part of Leverett's (1902) Cleveland moraine. Associated till typically has silt matrix, and is light gray, moderately pebbly and leached to average depth of 45 in. Eastward, the Lavery moraine has been traced across northwestern Pennsylvania (Shepps et al., 1959) and into Chautauqua County, N.Y. (Muller, 1963). In eastern Chautauqua County it cannot be distinguished with any confidence from the Lake Escarpment moraines.

The sparsely pebbly, calcareous gray clay to silty clay till above the Lavery till in northeastern Ohio and Pennsylvania has been mapped as the Hiram till (Shepps et al., 1959). The principal end moraine composed of Hiram till is correlated with a certain amount of reservation with the Defiance (= Blanchard) moraine of Ohio (Leverett, 1931; White, 1953). Similar till is mapped in several discontinuous areas in Chautauqua County where it projects south from beneath overlying till into through-valleys. Till with characteristics similar to the Hiram till composes the moraine at Markham and south of Zoar Valley. No Lavery drift occurs south of these two moraines and it is therefore concluded that the Lavery till is overridden and concealed in this area.

Shepps et al. (1959) consider the Lavery moraine to represent middle Cary glaciation, but there is indication of closer relationship to the succeeding Late Cary (= Mankato(?)) moraines in Chautauqua County.

Lake Escarpment morainic system

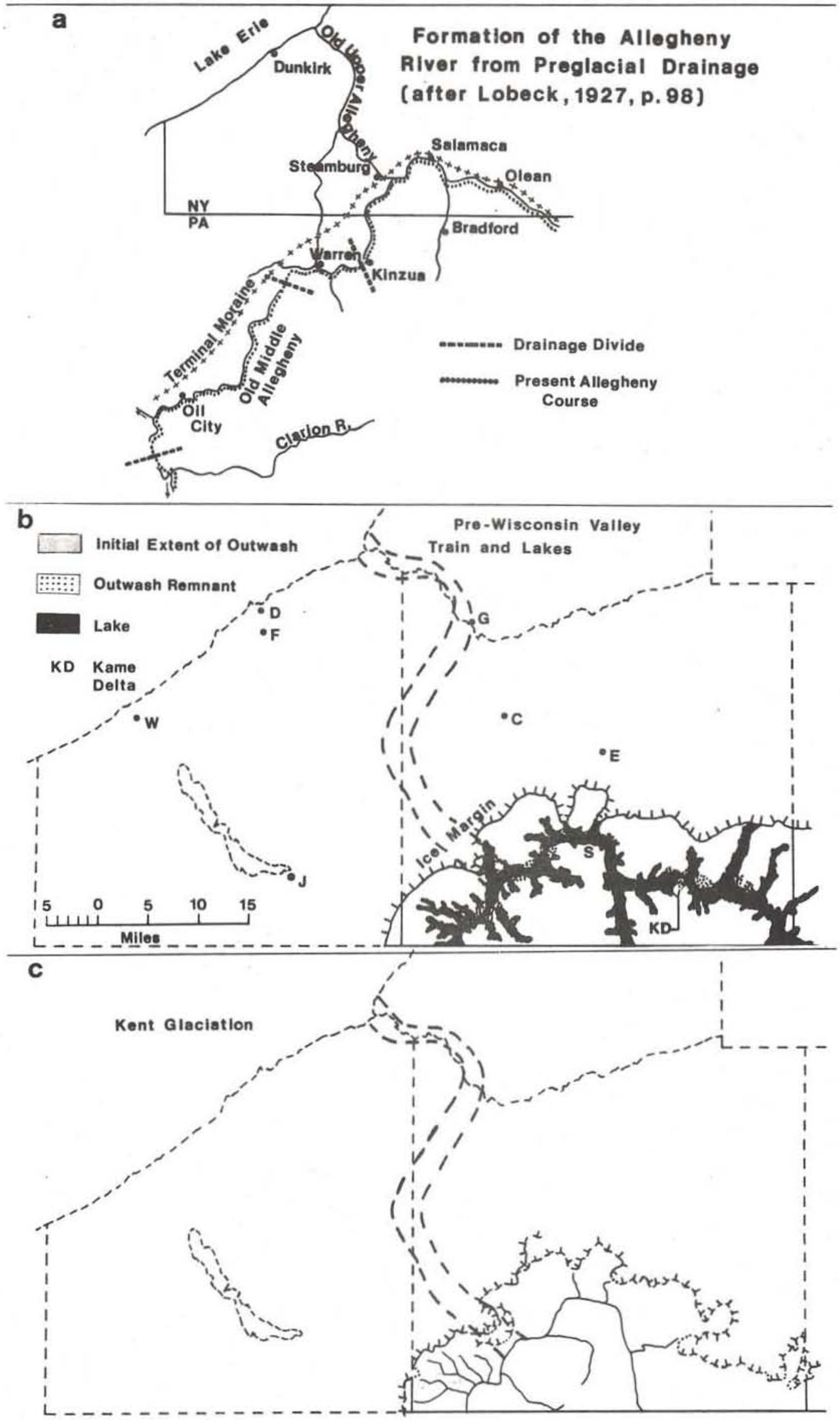
Leverett (1895) applied the name Dayton moraine to the massive valley-stopper moraine at the village of Dayton, New York. In 1902 he supplanted this name, discussing the overlapping moraine ridges of the north margin of the plateau, under the term Lake Escarpment morainic system, in recognition of the complexity of the belt. Westward in Ohio and Pennsylvania he mapped diverging ridges of the complex as the Euclid, Painesville, Ashtabula and Girard moraines. Shepps et al. (1959), following White (in press) apply the name Ashtabula moraine to the entire complex as mapped in northeastern Ohio and Pennsylvania. In New York the belt is characterized by multiple ridges, but because they are so closely spaced, continuous tracing is unreliable and, following Leverett, the complex is referred to as the Lake Escarpment morainic system.

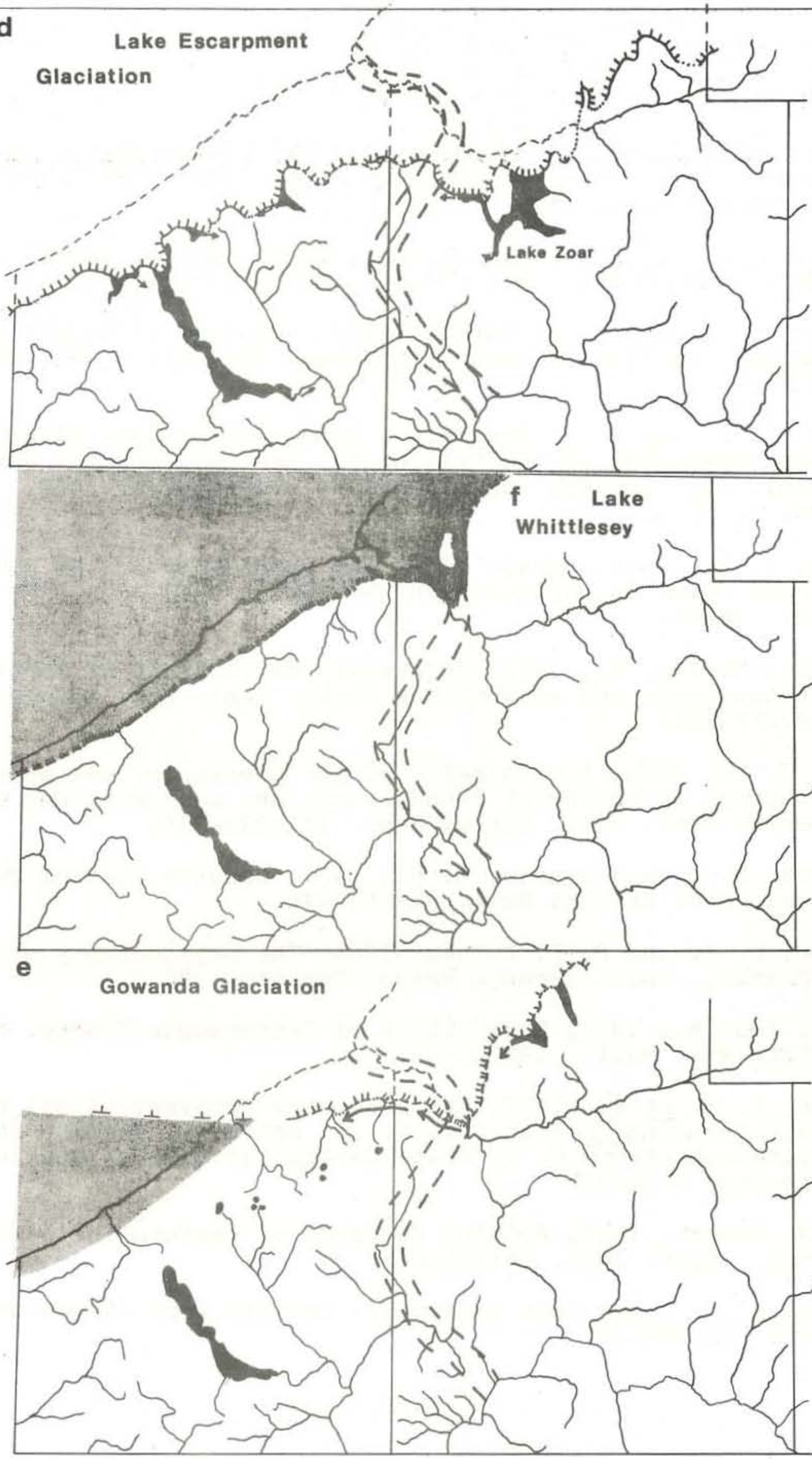
The Lake Escarpment morainic system has been considered equivalent to the Valley Heads moraine of central western New York. Radiocarbon dating of spruce wood from marly silt overlying outwash gravel near a mastodon site in the southeastern corner of Erie County yields a minimum age for recession from the terminal moraine at 12,020 B.P. (W-507). Confirmatory evidence which seems to indicate rapid recession of the ice border is found in the 11,410 year age (Y-460) for wood associated with mastodon remains north of King Ferry east of Cayuga Lake and about 30 miles north of the Valley Heads moraine.

Recession from the Lake Escarpment morainic system is marked by a series of moraines of which only the Gowanda moraine is seen on the field trip route. Like the succeeding Hamburg and Marilla moraines it imponded waters of proglacial Lake Whittlesey which predated the Two Creeks interval (Plate 2, e and f).

The youngest glacial feature in the field trip area is the Lake Warren strand. Although Lake Warren has been considered to have existed during Valders time, recent lines of evidence suggest that the proglacial lake history of the eastern Great Lake basins may have terminated during the Two Creeks interval (MacClintock and Terasmae, 1960; MacClintock 1960; Terasmae, 1959; Flint, 1956; Karrow, 1963).

Plate 2. Stages in the evolution of the Western N.Y. Landscape




d
Lake Escarpment Glaciation
Lake Zoar
f
Lake Whittlesey
e
Gowanda Glaciation

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APPENDIX

These are stops from Muller (1960). They may be added to or substituted for listed stops on either Trip D or F. The locations are shown on Plate 1.

STOP ONE. Twenty minutes. Weathering profile in silty clay till of moraine southeast of Markham. Dayton town, Cattaraugus quadrangel, Cattaraugus County (78°56'42"W, 42°26'10"N).

Till, chocolate brown, very sparsely pebbly; matrix silty clay. Leached to about 40" except deeper where overlain by selvage of sand and gravel. Washed selvage ranges from 0 to 4 ft. Soil is mapped as Mahoning silt loam with very limited patches of Otisville gravelly loam on a few knolls.

This moraine lies south of the massive, composite Lake Escarpment moraines. Similar till is at the surface in Chautauqua trough and near the Pennsylvania State Line where it seems to protrude south from beneath Lake Escarpment till. Topographic expression at this stop is similar to that of the Defiance moraine in Ohio and weathering profile of the till suggests correlation with the Hiram till of Ohio and Pennsylvania.

Stop One is over axis of bedrock valley of the Ancestral Allegheny River. A well drilled for gas 2 miles northeast was abandoned at depth of 935 ft. without encountering bedrock. Maximum thickness of drift probably exceeds 1000 feet. From Steamburg and Randolph the Ancestral Allegheny had its course northward past Dayton and Gowanda to the present Erie basin.

Question: Does the character of this till reflect incorporation of lacustrine silt in basal load of the glacier during flow up axis of Ancestral Allegheny River? If so, is till character a valid criterion for correlation with similar till north of Chautauqua Lake and at Pennsylvania State Line? To what extent is this topography characteristic of clay-rich till and therefore only as valid as texture in relating this to Defiance moraine and Hiram till?

STOP TWO. Forty minutes. Please park close to car in front and off pavement. Keep highway clear. This is a major highway. Late Wisconsin stratigraphy.

Gowanda high bluff section. Stream bluff, West Branch Thacher Brook. Persia town, Cattaraugus quadrangle, Cattaraugus County. (76°56'44"W, 42°26'10"N).

Unit	Lithology	Thickness
8	Stratified sand and gravel; leached to 6 ft. oxidized to 14 ft.	17.0 ft.
7	Till (?) silty-clay matrix, calcareous, sparsely pebbly; includes sand parting	9.0 ft.
6	Stratified sand and gravel; oxidized in part	19.0 ft.
5	Till, blue-gray, calcareous throughout; matrix silty-clay; pebbles very sparse; basal contact undulatory; compact; silty toward base	9.0 ft.
4	Stratified, well-sorted gray silt; lamination obscure; very sparsely pebbly; bedding contorted in part; basal 8 ft. sandy grading to gravel	25.0 ft.
3	Till, silty-clay matrix; calcareous at top; sparsely pebbly; contains obscure silt partings	30.0 ft.
2	Stratified sand and gravel	12.0 ft.
1	Till, silty to silty-clay, chocolate blue-gray; pebbles very sparse; base obscured	6.0 ft.

Questions: What criteria distinguish basal till from glacionatant till (deposited beneath shelf ice) and from lacustrine deposits at the ice margin? What history of fluctuation is represented by this section? What interval is represented by these four similar tills? Has the situation here a modern analog in, for instance, Moreno Glacier's intermittent sealing of Canal de los Tempanos in Argentina?

STOP THREE. of Muller, 1960, is STOP F3 of this guide.

STOP FOUR. of Muller, 1960, is STOP D6 of this guide.

STOP FIVE. Fifteen minutes. Binghamton till.

Roadcut, Cattaraugus-New Albion Road (County Road 6), New Albion town, Cattaraugus quadrangle, Cattaraugus County (78°52'45"W, 42°18'N).

Till in roadcut contains numerous pebbles of bright appearance, e.g. carbonates, crystallines and red sandstone. MacClintock and Apfel (1944) characterized Binghamton drift and especially kame gravel as possessing typically 5-7% crystallines and 12-25% carbonate pebbles.

The New Albion outlet of Lake Zoar, with controlling level at approximately 1435 feet is visible due east, up-valley. This outlet is intermediate in elevation between the primitive southeastward overflow toward Little Valley and the subsequent Persia outlet marginal to the Lake Escarpment moraine. Note truncated kame at channel edge. Was the confined gorge of the easternmost .6 mile of this channel cut by rapid nick-point migration or even plunge-pool drilling, while the southwestward portion involved only filling and widening of an existing valley?

STOP SIX. Fifteen minutes. Postulated location of divergence of Binghamton and Olean moraines.

Constructional topography, .8 mile north of The Narrows, Napoli town, Randolph quadrangle, Cattaraugus County (78°51'W, 42°14'N).

West of the Salamanca re-entrant, MacClintock and Apfel (1944) mapped the Binghamton moraine (Kent moraine of Pennsylvania and Ohio) at the Wisconsin border. From The Narrows eastward they mapped the Olean moraine at the Wisconsin border, emerging from beneath the Binghamton drift. The Binghamton border is marked northeastward by massive valley-choking deposits of calcareous drift. Although topography and drift lithology support this interpretation the interpretation will be strengthened when superposition of Binghamton over Olean deposits is demonstrated.

STOP SEVEN. Fifteen minutes. Evidence of periglacial frost action.

Boulder nets, .8 mile WNW of Bucktooth School, Little Valley town, Randloph quadrangle, Cattaraugus County (78°48'W, 42°13'N).

The Wisconsin drift border has been drawn along the ridge crest of this stop. It is suggested that these boulder nets originated in rigorous climatic conditions at the Olean ice margin. Although most of the boulders are of local lithology, sparse crystalline boulders suggest that an earlier glaciation, or an attenuated margin of Olean till extended south of the boulder net locality.

STOP EIGHT. of Muller, 1960, is STOP D6 of this guide.

STOP NINE. of Muller, 1960, is STOP D5 of this guide.

STOP TEN. Vista of Upland peneplain

Observation Tower, Allegany State Park, Salamanca town, Salamanca quadrangle, Cattaraugus County (78°43'15"W, 42°7'50"N).

Upland peneplain at 2300-2400 feet above sea level. Uplands, well-wooded with second growth show no signs of glaciation. Soil mapped widely as DeKalb and Ernest silt loams. Salamanca conglomerate occurs below summit. Red House Lake and Allegany Park Headquarters visible to south in basin.

TRIP D - FROM LAKE ERIE TO THE GLACIAL LIMITS AND BEYOND (or What the Glaciers Did For Us)

E. H. Muller, Geology Department, Syracuse University
and R. K. Fahnestock, Geology Department, SUNY, Fredonia

Today's trip will take us from Fredonia southeastward to Olean returning by way of Otto (The route and features of this trip will be found on Plate 1). Leaving the Erie lake plain in the morning, the route crosses the glaciated plateau to the edge of the unglaciated Salamanca re-entrant. Topographic features and surface glacial deposits are progressively older southward, ranging from nearshore deposits of Lake Warren across moraines of the plateau margin to early Wisconsin features of the Olean drift border. Deposits of post-Sangamon, pre-Farmdale age will be studied in exposures at Otto.

The road log narrative begins at Barker Commons (town square) in downtown Fredonia. Proceed south on Water Street crossing Canadaway Creek. Continue up the Water Street hill, climbing above the creek terraces graded to the Lakes Warren and lower levels of the glacial Great Lakes. At the top of the hill the level plain is a beach-delta complex formed at the Lake Whittlesey level, 830 ft. at this point. Lake Whittlesey shoreline rises about 1 foot per mile toward Buffalo.

To the Southwest a drift-free bench (1) (The circled numbers refer to location on Plate 1.) marks one of the many ice marginal drainage channels. The north wall of this channel must have been the glacier. Beyond the bench lies the escarpment. The escarpment which separates the lake plains from the plateau has been called the Portage Escarpment, but it is developed on the Canadaway Formation in this area. The escarpment bears no relationship to the Portage Group, which does not crop out in Chautauqua County. The Canadaway Formation totals about 950 feet and is composed dominantly of shale. The Laona and Shumla Members, each about 30 feet thick are largely siltstone and somewhat thicker-bedded than the other members. These two siltstone members may account for details of the character of the scarp as developed eastward toward Forestville.

Question: In view of the dominantly shale lithology exposed in this portion of the escarpment, is structural control an adequate explanation of the origin of this scarp? Regional dip is very gentle toward the south. If the topography be truly cuestaform, where are the resistant capping strata responsible for the scarp which is 700 to 1100 feet high in eastern Chautauqua County?

Turn east, crossing Canadaway again in the village of Laona. On the south side of the bridge, (2) a mill dam, its pond now filled with debris, raises the height of the waterfall over the Laona siltstone under the bridge. One hundred and fifty years ago Laona, like all towns was a major user of water power. The county historian points out that about 35 factories drew their power from the Canadaway and it is said that there were at least seven dams in Laona alone. Anyone considering floodplain landforms must keep in mind both man and beaver as geologic agents.

Turn right (S) in Laona onto Rt. 60 and continue south to Cassadaga.

Heading south on Route 60 we pass through a broad, open valley with only isolated patches of bedrock exposed (3). This is a post-glacial excavation of a complex of buried valleys. The streams of this area have made similar excavations each time the glacier retreated from the escarpment. The buried valleys (also featured on tomorrow's trip F) have a variety of forms from steep-walled canyons (Fig. F1) to broad, open valleys with gentle walls (Fig. F5).

The landslides along the road involve tills and lake clays.

STOP D1. Route 60 Landslide Area. This area will also be visited tomorrow on Trip E, Environmental Geology. You may wish to consult the descriptions of the landslides and associated problems with the Fredonia Reservoir.

The glacial sequence consists of till, lake rhythmites, and till. The landslides start with a failure at or near the lower contact of the lake beds. Although the upper contact of the lake beds has not been observed, it is thought to be relatively undisturbed. If so, a till flow, a la Hartshorn (1958, 1960) may be a possibility.

There are about 20 feet of interlayered clays and silts which may represent (A) annual pairs (varves) or (B) storm pairs resulting from disturbance and more rapid settling of the silts; or (C) maybe you have an idea. If (A), this small lake lasted longer than some or all of the Glacial Great Lakes. If (B) it didn't. Cloture will be invoked after 10 minutes to allow vote of all present to be taken to settle the matter for all time.

Continuing South on Rt. 60, a brief side trip to the Cassadaga Lakes will be made to show the evidence of formation from the melting if ice blocks buried in outwash. The Cassadaga Lakes (5) lie between the Lake Escarpment (4) moraines to the north and remnants of a slightly older moraine to the south.

Continue south on Rt. 60 through the Cassadaga Valley along the route shown on Plate 1 and Figure D1 which is filled about half way from the bedrock floor to the adjacent summits. A well near Gerry has penetrated 600 feet of fill. In contrast to the thickness of fill in the valleys, the streamlined drumlinoidal topography of the uplands is covered in most places by a veneer of ground moraine (basal till plastered on under the glaciers). Figure D2 shows the evolution of some of the morainal belts and lake and outwash deposits which make up the valley fill.

At Gerry leave route 60 and continue straight (SE) on Rt. 604.

Crain (1966) recognized that the Jamestown water supply was independent of the flow of Cassadaga Creek as heavy pumping of adjacent wells had no effect on the creek. This is thought to result from lake silts and clays near the surface of the valley fill acting as an aquiclude. The pumping did, however, show effects on permeable zones within the valley fill. These zones known as the Jamestown aquifer occur at lower elevations as one goes northward raising the question of what permeable deposit would dip northward, up glacier or up valley.

Obvious water losses, of the streams tributary to Cassadaga Creek, occur as they flow across the "alluvial fan-deltas" which occur along the valley margin where the relatively steep streams emerge onto a flat valley floor. These water losses suggested to Crain the relationships between the tributary stream deposits and the aquifer shown in Figure D3. The losses are not as obvious if one follows the streams out onto the valley floor where a major part of the "lost" water reappears. Here it flows in tightly meandering channels as the "deltas" thin toward their margins and the effects of the lake deposits are felt.

The Sinclairville (8), Gerry (6), Holmquist (9) and Folsom (10) "deltas" are among the "recharge" areas mapped by Crain.

Agnes caused considerable damage in many areas of New York, but a study of Holmquist Creek by Winter (1974) revealed that very little erosion or deposition occurred. The spring meltwater flows appeared to be significantly more effective in moving sediment and causing change. On high gradient streams with small drainage basins like Holmquist Creek, intense events covering much smaller areas are the prime movers and land sculptors. Events with a recurrence interval of 100 years or more play a much more important role than do events like Agnes with a 25 to 50 year interval.

On NY 394 (old route 17) we will head eastward crossing ice contact stratified drift (11) and skirt the north edge of the Hartson Swamp (12) which lies atop the Poland aquifer, a permeable zone in the Conewango-Cassadaga valley fill. Aside from the permeable

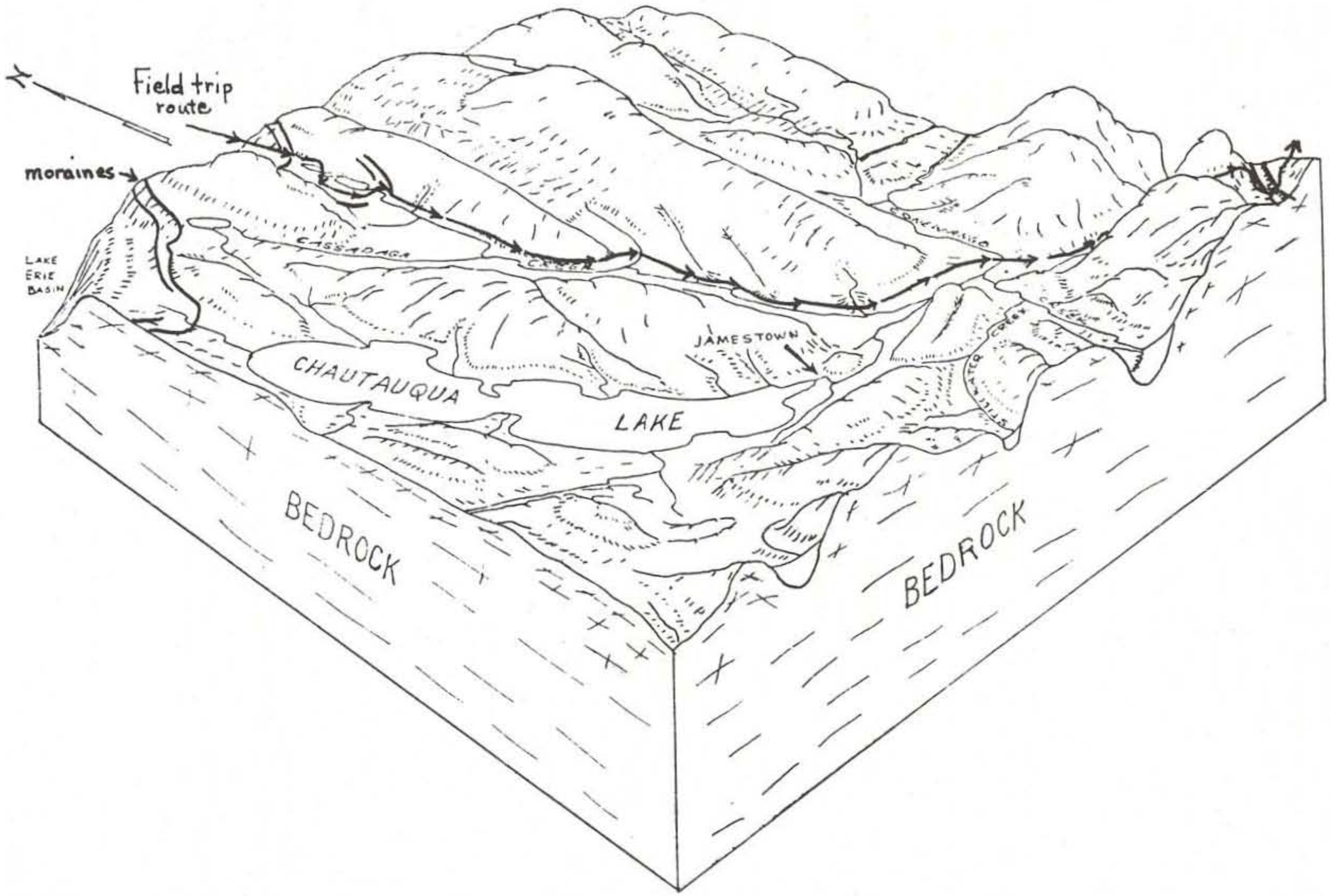
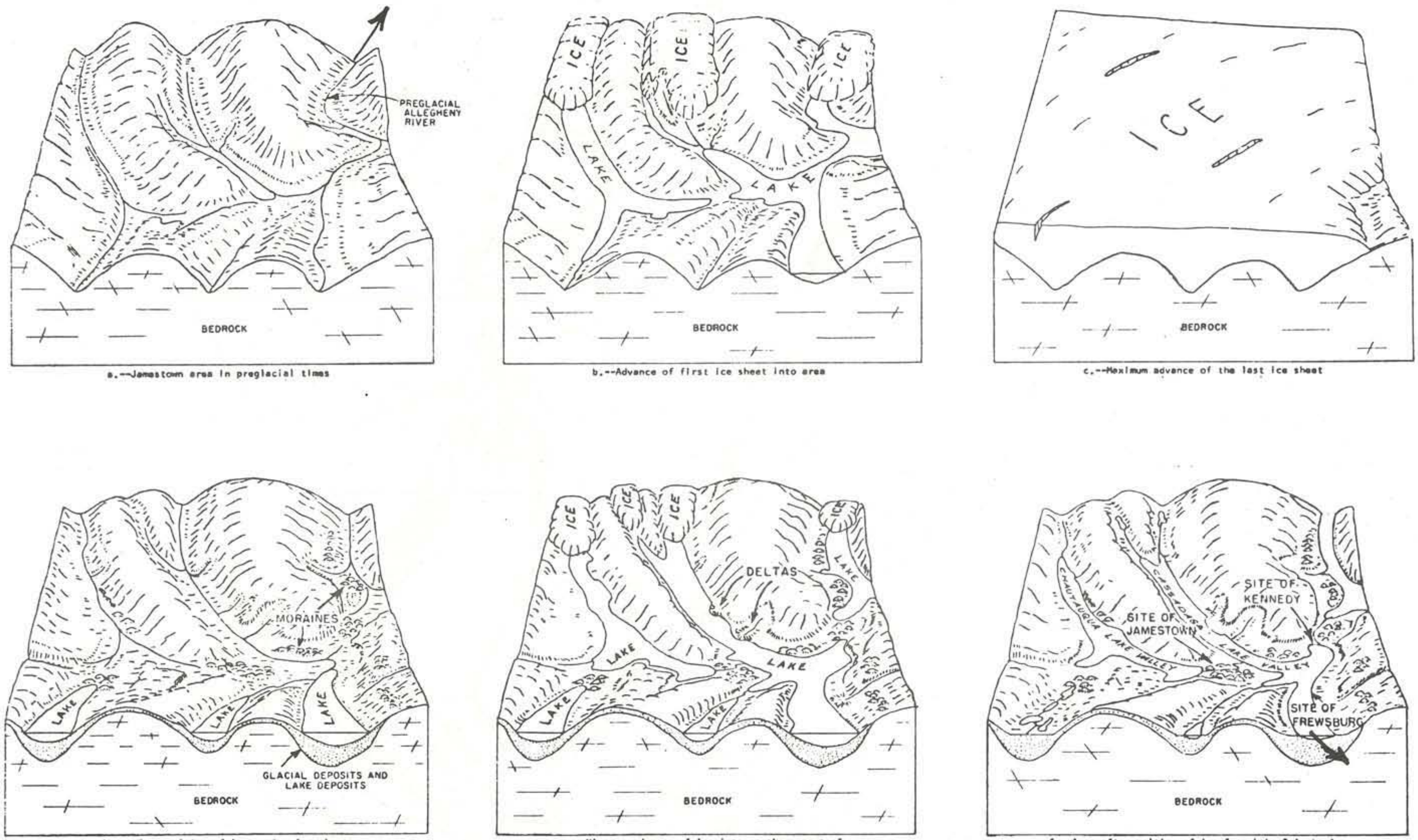


Figure D1. Topographic features of the Jamestown area (from Crain, 1966, Fig. 5)



a.--Jamestown area in preglacial times

b.--Advance of first ice sheet into area

c.--Maximum advance of the last ice sheet

d.--Area after melting of last major ice sheet

e.--Minor readvance of ice into northern part of area

f.--Area after melting of ice from Lake Erie basin

Figure D2. Glacial history of the Jamestown area (after Crain, 1966, Fig. 6)

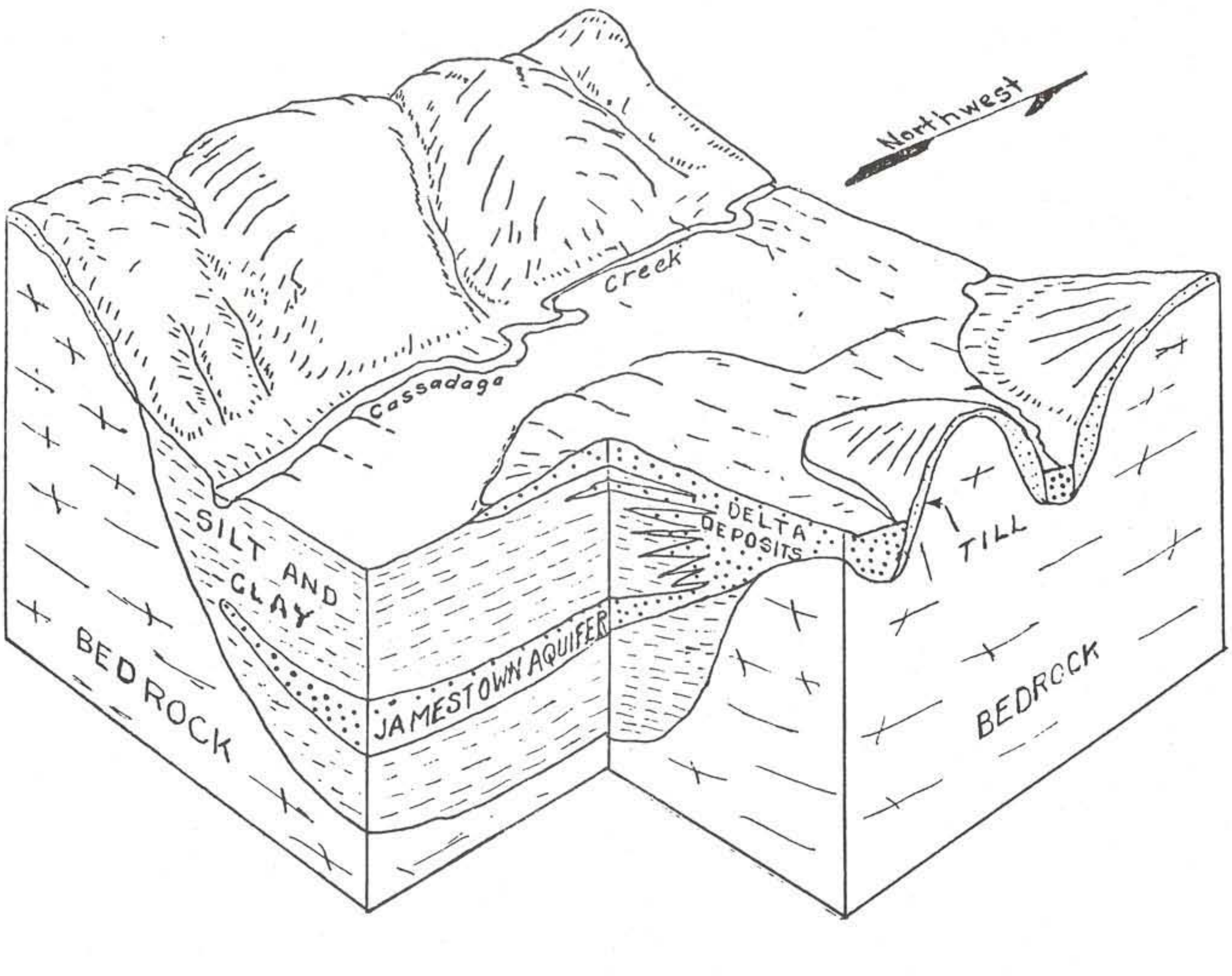


Figure D3. Cassadaga Creek valley in the vicinity of Folsom Creek (from Crain, 1966, Figure 22).

zones in the valley fills, groundwater is not abundant. In the uplands limited quantities can often be produced from zones of broken bed rock at the contact with overlying drift. Where the drift is thin or lacking and ground water must be produced from the local shales and siltstones, there is little of it and the quality leaves much to be desired.

Crossing the Conewango from Poland Center the route climbs the valley of Mud Creek (13). Note the gradient and character of the stream and valley floor. We will attempt to compare this valley with that of Elkins Brook (14), the next one to the north, in order to determine whether the present streams fashioned either valley.

On the upland, the route will traverse the glacial boundary crossing and recrossing it at several places. At some points we will be in knob and kettle topography with as much relief as any of the younger moraines to the north (15). While there are some evidences of glaciation such as foreign cobbles and boulders a few hundred yards beyond the obvious moraine, the changes in relief in the upland are not as striking as in the valleys. We will travel beyond the region affected by glaciation and along its fringes and then return through the sequence of moraines and filled valleys typical of New York State. A major point of this field trip is the contrast between unglaciated, marginal, and repeatedly-glaciated terrain.

Large quantities of gravel for the new route 17 (The Southern Tier Expressway) were removed from a large kame delta which has since been landscaped.

STOP D2. Refer to Plate 2c and d and the Steamburg and Randolph 7½ minute maps.

Dropping off the north side of the glaciated upland into the Ancestral Allegheny Valley now occupied by minor tributaries of the Conewango, we will pause for a view of the ice contact face (17) of the Kent terminal moraine and related features on the valley floor. The valley before us is the site of the reservoir advocated by Arthur Morgan (1971, Dams and other Disasters) as an alternate to the Kinzua Reservoir we will cross later. While Morgan was careful to not publish any maps, his plan would appear to make sense increasing the safety of the Allegany drainage while living up to George Washington's promises to leave the Indian lands untouched "so long as the sun rises and the river runs" in the works of the Pickering Treaty, the oldest existing U. S. Treaty (Morgan, 1971, p. 318).

The route winds by the most direct path now available, through the town of Steamburg on Rt. 394 (old Route 17) and south along the Kinzua Reservoir (18) on Reservoir Rd. in the post-glacial Allegany valley to Hotchkiss Hollow.

STOP D3. Quarry just into Hotchkiss Hollow. Refer to Plate 2b. "Devil's concrete" (conglomerate) has preserved the bedding of this quarry in striking contrast to most gravel deposits. What does the bedding indicate about the direction of the gravel source? What is the significance of the lithologies present in the gravel? What can you make of the feature blocking the mouth of the valley and of the form of its surface from which we just descended?

If the bus can turn around here, we will procede to Bradford, PA and to Rock City near Olean. If not...

In this portion of the trip we will traverse the glacial margin, but the final route has not been established as of this writing. In any case, we must return north to cross the Allegany on new Route 17. Wisconsin valley train has been quarried for the Route 17 fill (19). A terrace remnant of valley train (20) is deeply cut for the new route on the SE side of the river (Expletive deleted Landscaping!) (21) The new highway construction has triggered numerous landslides, rockfalls and mudflows. A route through Salamanca, Kilbuck, and Limestone, or an alternate route along the reservoir and south of the Allegany State Park may be taken (NY Rt. 220 to PA Rt. 346).

On either route, contrasts between glaciated valleys and valleys in which the only effects are those of lakes like the one in Hotchkiss Hollow and valleys untouched by any glacial effects will be seen.

As we approach Bradford (the home of Kendall Oil Co.), many wells producing in the manner of the early oil industry can be seen. A pump house and wells of this type will be seen at STOP D4 in Rock City. Turn east onto PA Route 646 at Foster Brook (22), staggering through Derrick City and up over the Knapp Creek (23) summit to Rock City. The route becomes NY 16 at the state line. It follows the old right-of-way of the Western New York and Pennsylvania RR interurban between Bradford and Olean which followed the route of a narrow gage railroad built in 1878 to haul oil.

Turn to the northwest into the private drive leading to "nature's own scenic wonder" at Olean Rock City Park.

STOP D4. Olean conglomerate weathering escarpment.

Olean Rock City, Allegany town, Olean quadrangle, Cattaraugus County (78°28'30"W, 42°1'N).

This is the type locality for the Olean conglomerate (Lesley, 1875), exposed in weathering scarp 64 ft. thick. Cross-bedding, joint cracks and ellipsoidal quartz pebbles to more than 30 mm in length are characteristic. This unit occurs on summit remnants of the Upland peneplain as far east as Alma Hill in Allegany County at 2548 feet above sea level, the Highest elevation in western New York. Southward into Pennsylvania, the formation loses its conglomeratic character in 20 to 30 miles.

This ledge consists of joint blocks separated by interconnecting passages which widen toward the exposed scarp face. Near the parent ledge, the joint blocks show a minimum of rotation and subsidence, but outwards they show varying amounts of tilt and downward movement. Noting that the blocks appear now to be immobile and disintegrating in place, Smith (1953) identified this and other nearby "rock cities" as periglacial features. A similar, though less striking, rock city in the area of Early Cary glaciation is at Panama Rocks, Chautauqua County.

Question: What evidence is there as to the relative importance of weathering, wedging, creep, sapping or other processes to produce this display of joint enlargement? What evidence shows the blocks to be immobile and the rock cities to be relics of periglacial environments?

The following paragraphs from Cochran (1957) on the production of oil is applicable to the oil fields around Rock City.

> In the Allegany (Bradford area) field primarily two different means are used in pumping wells, that is the individual well jack and the Oklahoma style jack pumped by a central power. The main difference in these tow methods is that the individual well jack is a unit complete in itself with a motor to supply power to the jack for lifting the rods and bottom hole equipment. The power to the Oklahoma style jack is supplied by a cable or rod line from the eccentric of the central power.
>
> Two different types of central powers are in use today, the gear power and the bandwheel power. The gear power uses a gear and pinion powered from the engine by a belt to motivate the eccentric whereas the bandwheel power uses a horizontal band wheel powered by a belt running from the engine to motivate the eccentric.
>
> Generally about 25 wells are pumped off of one central power. About four barrels of fluid per hour can be pumped from each well. Since this is normally more than will flow into the well bore it is not necessary to pump all the wells simultaneously, and the pumping times of the individual wells may be staggered throughout the pumping period.

Note: See Cochran (1957) for information on water flooding, well shooting and other aspects. A detailed and readable account of the early New York oil industry is contained in Herrick (1949).

Return (south) on NY Rt. 16A to Knapp Creek.

In village of Knapp Creek, turn right (north) onto County Road 61 which drops sharply into valley of Four Mile Creek. Harbell Farm Well no. 1 the state's oldest oil well which has produced continuously since 1877 (Herrick, 1949) lies in this valley.

Rockview (24) the first of six boom towns to spring up in and around the Four Mile valley in 1877 had 6 stores and 70 homes. Other towns included Rock City, Knapp Creek and Stateline.

West Brank Four Mile Creek lies to the west across the valley. Distribution of erratic pebbles and cobbles suggests that this is the approximate limit of glaciation in the valley of Four Mile Creek (25).

Turn left (W) onto River Rd. (County Rd. 60). Cross Four Mile Creek.

Turn left (W) onto Birch Run Rd. toward Birch Run Country Club.

Foundation excavations at left exposed terrace gravels with several per cent of crystalline pebbles, leached more than 8 ft.

To the right, ahead, a flat-topped ridge extends northwest, confining the flood plain to one-third of the valley width. This terrace remnant is poorly exposed, but is believed to consist of gravel, leached to 8 or 10 feet and overlain by several feet of yellow-brown silt and silt loam. The elongate form of the ridge suggests ice-marginal deposition, perhaps as an outwash delta. A tempting explanation for ponding in the Allegheny Valley is by glacial damming. Such imponding did not occur downstream from this point in Olean or later time.

Bear left at fork. Unmarked road to left leads to abandoned rock quarry and upper levels of STOP D5.

STOP D5. Kame delta complex.

Allegany Sand and Gravel Pit, Buffalo Slag Company. Birch Run at edge of Allegheny Valley, .9 miles SE of Russell, Allegany town, Salamanca quadrangle, Cattaraugus County. (78°32'50"W, 42°5'25"N).

Exposures in kame delta at several levels. Gravel is leached 9 to 12 ft. Carbonate content low, comprising only a few per cent of pebbles. Cementation by secondary carbonate is limited. Cobble imbrication, forest bedding and slump structures suggest deposition toward west. In upper level as exposed in 1959, 40 feet of boulder-free cobble gravel overlay 15 feet of sand over 10 feet of till. Till is olive brown, silt loam matrix, low in lime, with coarse fraction consisting primarily of streamworn pebbles and flaggy boulders.

Search for erratic pebbles revealed none more than a mile south up the valley of Birch Run, nor could any be found on the south side of valley of Birch Run. A few erratics in the saddle at 1760 feet, 3/4 mile southeast of the pit confirm the inference that proglacial meltwaters drained across the saddle south from Allegheny Valley into the valley of Birch Run.

Continue west on Birch Run Road.

Turn Right (N) following dirt road.

Turn left (W) on Ninemile Rd. Lippert Sand and Gravel Pit about one mile east produces from outwash gravel below river level.

Single lane bridge will not handle bus, continue west along south side of river.

Turn north on Rt. 219 to Bradford Junction (26).

Bradford Junction. Turn west on N.Y. Rt. 17 through Salamanca noting terrace remnants along the way. Salamanca is one town that cannot be given back to the Indians; they already own it and the lease does not have many years to run.

On the west side of town, turn north on NY 353 toward Little Valley. As we procede, try to spot the outermost evidence of ice action, the remnants of outwash terraces, the terminal and recessional moraines.

About 5 miles north of Little Valley we will bear right on Lovers Lane Rd. passing on the east side of the valley opposite the town of Cattaraugus to the East Otto Rd. and the Town of Otto.

STOP D6. Wisconsin stratigraphy.

Otto high bluff section, stream-bluff of South Branch Cattaraugus Creek, Otto town; Cattaraugus quadrangle, Cattaraugus County. (78°50'W, 42°21'15"N).

The Otto site was initially described (MacClintock and Apfel, L944) as exposing Binghamton till, Olean outwash and Sangamon interglacial deposits. As exposed in recent years (Muller, 1957) the lower portion of the section has been alternatively interpreted as evidence of post-Sangamon, pre-classical Wisconsin environments. Both interpretations are permitted by radiocarbon dating of the uppermost organic zone, 15 ft. above the river at an age of greater than 52,000 years (GRO 2565). See discussion in text section on pre-Farmdale organic sites.

Upper part of the section is obscured by slump. Units 6 through 11 below were measured at the south end of the exposure. Units 2 through 6 were measured nearer the north end where material for radiocarbon and pollen analyses was also collected. Bedrock is exposed only at the south.

Unit	Lithology	Thickness
11	Stratified sand, silt and clay	3 ft.
10b	Till, gray-brown, sparsely pebbly silty clay loam matrix. Oxidized but unleached; bright pebble lithology; silt streaks	20 ft.
10a	Till as above, unoxidized	10 ft.
9	Stratified sand, silt and clay with very sparse pebbles	3 ft.
8	Till, gray, sparsely to moderately pebbly, silt to sandy silt matrix; includes partings of washed drift suggestive of oscillatory conditions of deposition	40 ft.
7	Pebble gravel, grading downward with decreasing coarseness	5 ft.
6	Lake clay, contorted, laminated; red and "fat", in part.	3 ft.
5	Gravel, coarse, consisting largely of angular to sub-rounded pebbles and cobbles of plateau rock (sandstone and siltstone). Carbonate and crystalline cobbles are very sparse. What current direction is suggested by imbrication? A thin but continuous layer of silt and carbonaceous silt about midway up in this unit was dated at greater than 52,000 years (Gro-2565).	20 ft.
4	Stratified silt, muck, sand and pebbly silt. Both contacts transitional, not indicative of abrupt change of environment.	4 ft.
3	Boulder gravel, in a lens with maximum thickness at north end of exposure. Exact position in the organic sequence of units 2 and 4 is not certain. Boulders are tightly wedged with coarse sand to pebble gravel matrix. Platy cobbles and flatstones are dominant. Erratics and glacial striae are very sparse. Top of this unit is discolored by hydrous iron oxide deposition. Difficult to obtain effervescence with hydrochloric acid except on cobble coatings, which suggests secondary deposition	3 ft.

2	Stratified silt, muck, peat, suggestive of floodplain deposition. Twigs are flattened and peat highly compressed. Imbrication suggests deposition from southwest. Base of section concealed below river at north. Pollen from near the base (2a-7) includes primarily <u>Picea</u> and <u>Pinus</u> (Brown and Benninghoff, personal communication, see p. 25f.)	7.0 ft.
1	Boulder gravel, coarse with abundance of crystalline boulders, apparently lag concentration in channel which eroded preexisting drift. A smear of till may exist beneath and among the boulders.	3.0 ft.
0	Bed rock; blue-gray siltstone with gradient northward	6.0 ft.+

<u>Questions</u>: What is the significance of the oxidized horizon at the top of Unit 3? How is the Sangamon represented? What is the character of the interval(s) represented by Units 1 through 4? What change caused the transition deposition of cobble gravel, Unit 5?

Return to the southwest on East Otto Rd. to the town of Cattaraugus. This valley served as the outlet to Lake Zoar (Plate 2d). The first outlet [5] continuing further south and the later outlet turning north at Cattaraugus following the present course of the South Branch of Cattaraugus Creek and the route of the Erie RR westward through the low at Persia. No roads and few trains follow this route today.

If time permits we will stop at Muller Stop 1, [1] (Appendix A) on the Markham Rd.

The return trip will be through Markham (28) (a well penetrated 1100 ft. of fill near here), across the Conewango Valley (29) (the Ancestral Alleghany) to such famous places as South Dayton, Skunks Corner, Hamlet, Chicken Tavern, and Loana to Fredonia.

SELECTED PROBLEMS OF ENVIRONMENTAL GEOLOGY IN CHAUTAUQUA COUNTY, NEW YORK

William J. Metzger, State University College, Fredonia, NY

LAKE ERIE SHORELINE EROSION

The problems of shoreline erosion in the Lake Erie basin as well as the other Great Lakes have received wide publicity during the past two years. As Table 1 indicates, the highest monthly averages of levels of Lake Erie on record were observed during 1973 (9 months) and 1972 (3 months). These record-high lake levels have a significant effect on the intensity of wave erosion and are probably the primary cause of the extensive erosion which has been observed during the last 2 years. At the time this paper is being written (June, 1974) the Chairman of Chautauqua County Civil Defense Unit is attempting to have the lake shore area of Chautauqua County declared a national disaster area. He suggests that there is a potential of $14 million damage to private property by lakeshore erosion.

Although the problem of erosion along the shoreline is very complex, several important variables can be demonstrated by the simple model indicated in Figure 1. Note that at times of normal lake levels, the water at the shoreline is in contact with bedrock which has a very low erosion rate under normal circumstances. The lake bottom area over which the wave energy is dissipated (indicated by X in Fig. 1.) is very large. This condition produces a stable beach and wave erosion is not a serious short-term problem. In contrast to this, however, a high-water lake level will result in much more rapid erosion. In many places along the Lake Erie shore in Chautauqua County, the water level is presently very close to the top of the bedrock and is in contact with till in many others. As the lake level reaches this till-bedrock contact, and the waves can attack the unconsolidated till, the rate of erosion increases very rapidly. The wave action is now directed at the steepest portion of the shore zone and the lake bottom area over which wave action is dissipated reaches its lowest value (indicated by Y in Fig. 1). These factors combine to produce intensified erosion in the most easily-eroded materials exposed along the shoreline.

However, this is not the whole story. Figure 2 illustrates an additional factor which must be considered when trying to understand the increased rate of erosion along the shore. Notice in Figure 2 that the undisturbed (stillwater) level indicates that water will be in contact with bedrock and therefore result in low rates of erosion. This may be true for a given shore area even if the stillwater level is at a record high. However, short-term

TABLE 1. Summary of Average and Extreme Level of Lake Erie at Cleveland, Ohio. (Modified from data published by U. S. Department of Commerce NOAA - National Ocean Survey, Lake Survey Center, Detroit, Michigan.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
MONTHLY AVERAGE FOR PERIOD 1860 THRU 1970											
569.85	569.81	570.02	570.56	570.90	571.05	571.01	570.83	570.54	570.21	569.95	569.88
MONTHLY AVERAGE FOR PERIOD 1900 THRU 1970											
569.61	569.58	569.80	570.37	570.70	570.84	570.80	570.61	570.32	570.00	569.72	569.64
MONTHLY AVERAGE FOR PERIOD 1960 THRU 1970											
569.61	569.73	569.97	570.46	570.78	570.87	570.83	570.68	570.39	569.99	569.78	569.78
HIGHEST MONTHLY AVERAGE (1860-1973) WITH YEAR											
573.39	572.53	572.88	573.50	573.25	573.51	573.34	573.03	572.51	571.95	572.17	572.35
(1973)	(1973)	(1973)	(1973)	(1973)	(1973)	(1973)	(1973)	(1973)	(1972)	(1972)	(1972)
LOWEST MONTHLY AVERAGE (1860-1973) WITH YEAR											
567.62	567.49	567.65	568.20	568.43	568.46	568.46	568.36	568.23	557.95	557.60	557.53
(1935)	(1936)	(1934)	(1934)	(1934)	(1934)	(1934)	(1934)	(1934)	(1934)	(1934)	(1934)

INTERNATIONAL GREAT LAKES DATUM (1955)

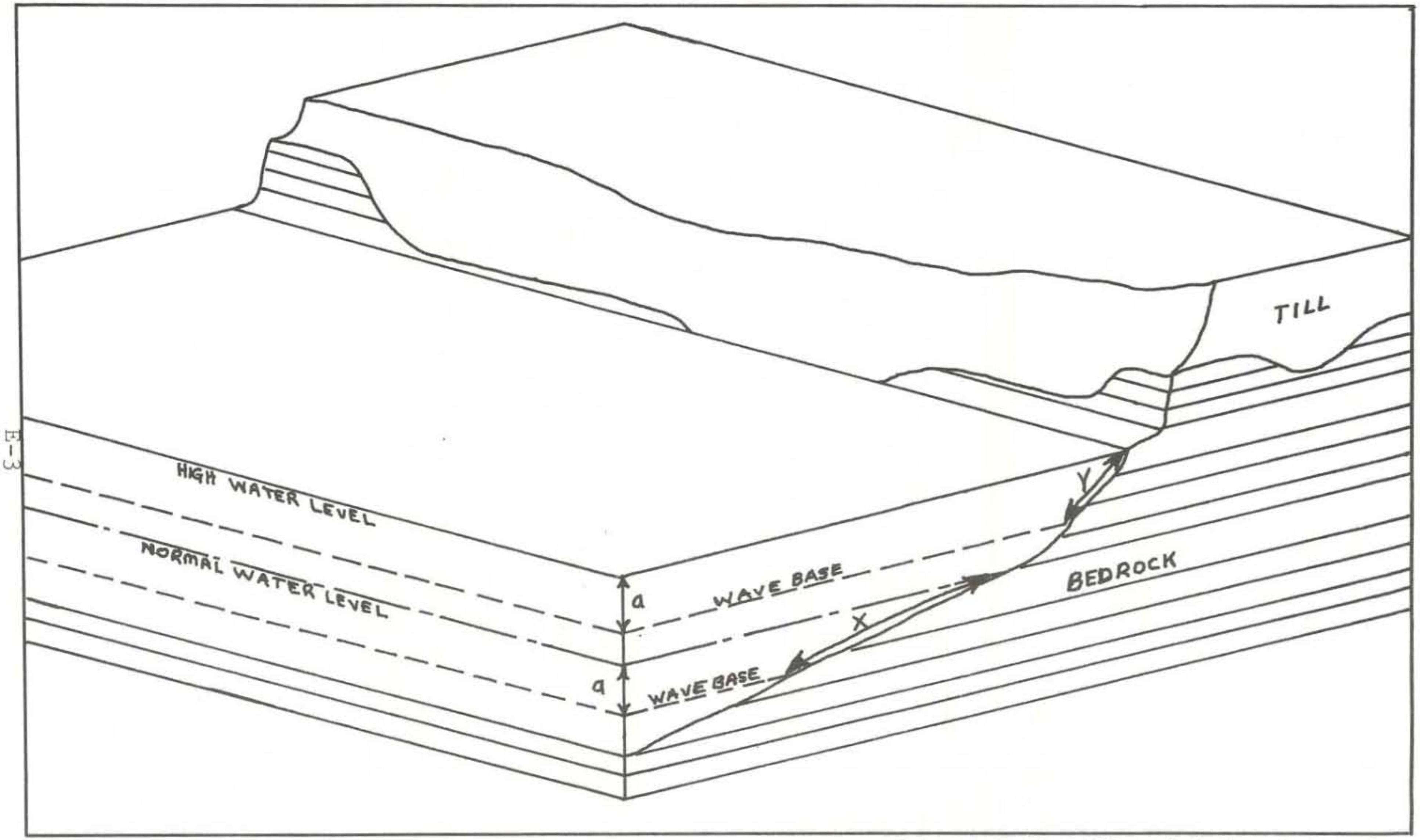


Figure 1. This diagram illustrates a hypothetical lake shoreline. Both till and bedrock are in contact with the water. Both normal and high water lake levels are illustrated. The effective wave depth is the same in both cases and indicated by the letter a. The area over which the wave energy is dissipated at the normal lake level is indicated at x while the area at the high water level is indicated at y.

meteorological activity such as rapid barometric changes and storms may cause strong, prevailing winds to develop in the lake basin. This will result in a phenomenon called setups which causes the water to pile up on one side of the lake and the surface of the water to tilt in the basin. This is known as the storm setup. The amount of setup observed at any time varies with such factors as the intensity of the storm, the length of fetch associated with the prevailing winds, the bottom topography and the depth of water. The maximum setup values for Lake Erie are not constant, but they generally range from about 1.5 feet near Cleveland, Ohio to nearly 6 ft. at Buffalo. (Corps of Engineers, 1973).

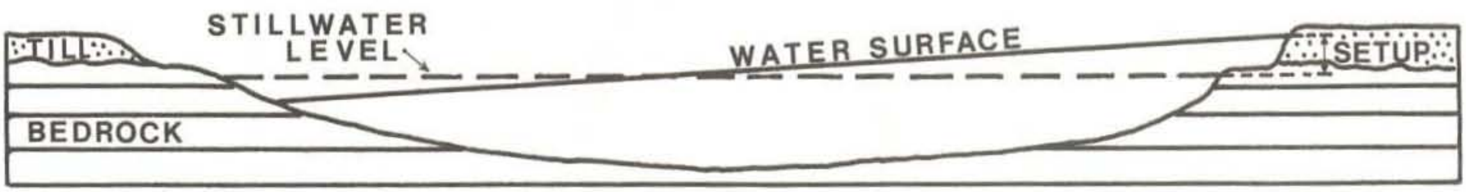


Figure 2. This diagram illustrates the tilted water surface that develops during prolonged prevailing wind conditions. The increase in the elevation of the water surface on the windward shore is called the setup. Note that in this case the stillwater surface is in contact with bedrock while the setup surface is in contact with the much more easily eroded till.

With record-high water levels, a storm which results in the maximum setup for a given area is generally accompanied by large waves with amplitudes greater than 5 ft. These large waves, in combination with the high water levels, can result in extremely rapid shoreline erosion.

When the lake water levels are at the maximum, as we presently observe them, the higher intensity waves erode the sand on the beach and carry these sediments offshore. The beaches are narrowed by both the encroachment of the water and the removal of the sand to the offshore beach area. When the lake levels return to normal, this sand should be pushed back onto the beach by the lower energy waves.

FLY ASH AND BOTTOM ASH DISPOSAL

One of the major problems facing all municipalities today is the disposal of solid wastes and cities in Chautauqua County are not exceptions. However, there is an additional problem here. Two bituminous coal-fired electric generation plants located in the county produce substantial quantities of ash which add considerably to the total solid waste tonnage that requires disposal.

According to a study by Havens and Emerson (1971), the total solid wastes produced in Chautauqua County during 1970 exclusive of ash amounted to 189,900 tons. The total ash produced during the same year was approximately 163,000 tons, or 46 percent of the total solid wastes produced in the county.

The principle ash source is the Niagara Mohawk electrical generation plant located in Dunkirk, New York. This is a 600 megawatt installation which is fired by bituminous coal. The total ash which is being produced at the present time is significantly greater than the figures quoted above for 1970. In 1973, new and more efficient electrostatic precipitators were installed on all the stacks at this plant. While this resulted in a very desirable and commendable improvement in the air quality, it also greatly increased the amount of fly ash that was trapped by the precipitators. Presently the plant burns 4000 tons of coal daily and produces 250 tons of bottom ash and 550 tons of fly ash (Leo O'Sullivan, Plant Superintendent, Dunkirk, NY, personal communication. During the spring of 1974, Niagara Mohawk announced plans to construct within 15 miles of Dunkirk, NY an additional 1700 megawatt generating plant also to be fired by bituminous coal. It is clear that the problem of the disposal of these wastes will increase as this new plant begins operation in 1979 or 1980.

In order to assess the current trench-and-fill method of ash disposal, the present landfill site was visited during the spring and early summer of 1974. Samples of water were taken from several locations on the site itself as well as from an adjacent abandoned disposal area. The stream which drains both areas was sampled approximately 1,000 ft. downstream from the landfill. We were interested in determining the concentration of several ions which were expected to be high in leachate derived from the fly ash deposits. Low concentrations of these ions would suggest that the leachate was being contained on-site, whereas high values downstream would indicate that this method of ash disposal was not successful in containing the leachate on-site. We were also interested in comparing the relative quality of the water from the present operation with that of the abandoned area located adjacent to the present site. Finally, all of these measurements were compared to data taken from Canadaway Creek which was the nearest stream that could be used as a control. All these data are summarized in Table 2.

The data demonstrate that the artificial pond (Location 1, Fig. 3) constructed in 1973 has significantly lower values of iron and manganese than Canadaway Creek. The conductivity of the water in the pond is almost twice as great as the creek but this may be related to the fact that the pond is primarily recharged by

TABLE 2. Conductivity and Ion Concentrations From Fly Ash and Bottom Ash Disposal Sites

Location	Conductivity mhos	Mn g/L	Fe g/L	Cd g/L
Location 1: Artificial Pond Surface Sample West End	615	18	70	22
Location 2: Leachate from former landfill operation	3514	7300	96600	32
Location 3: Ponded Leachate adjacent to Fredonia Airport runway	602	2600	3100	35
Location 4: Surface water downstream from former landfill	1216	Not determined	Not determined	Not determined
Canadaway Creek: averages for entire drainage basin June 13, 1973	287	91	660	Not determined

Unpublished data from W. M. Barnard and R. A. Levey with permission

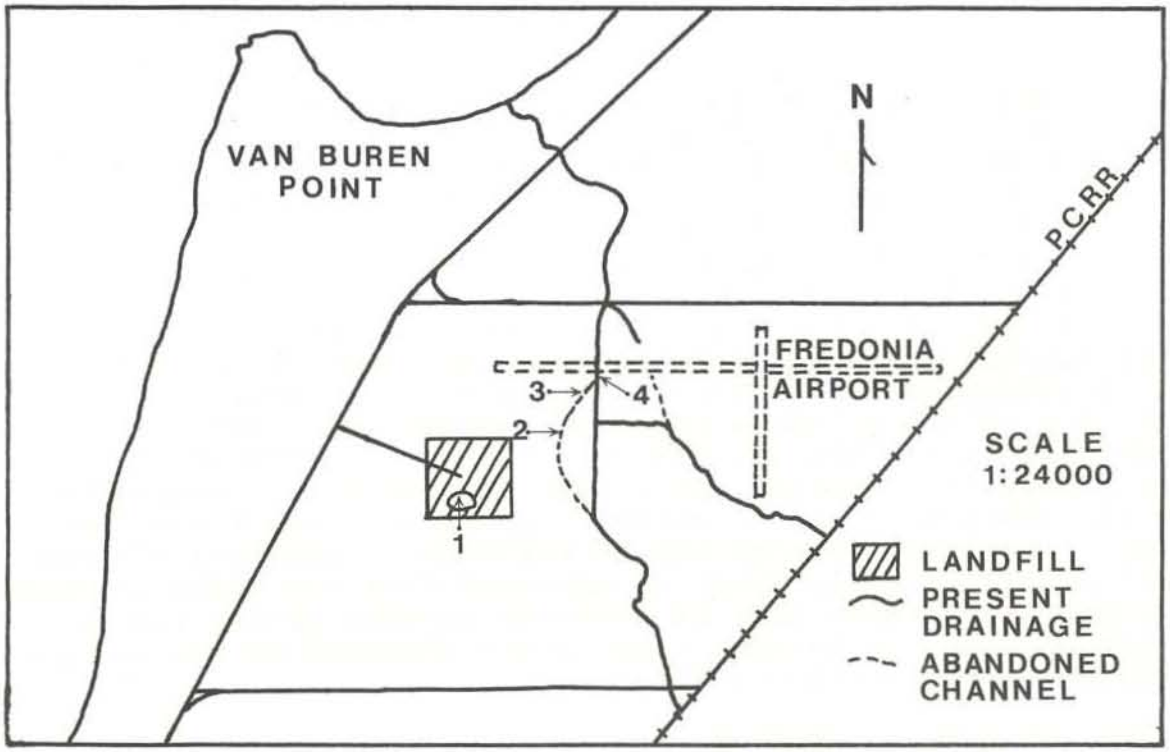


Figure 3. Map showing the location of the numbered sample sites listed in Table 2. Base map is USGS Brocton 7½' quadrangle.

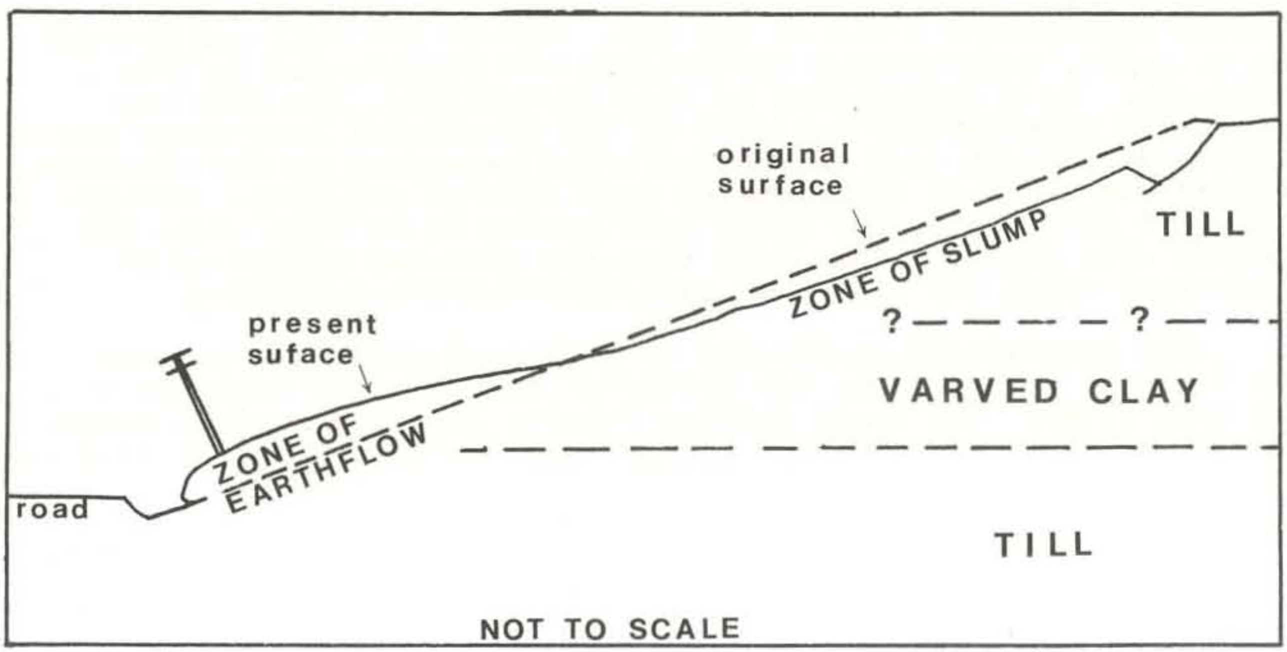


Figure 4. Morphology of the landslides along Route 60 near Laona, NY. The diagram indicates the relative position of the zone of slumping and the zone of earthflow. The generalized glacial stratigraphy is indicated at the right.

groundwater which typically has higher ion concentrations than surface water. From this information it appears that for the relatively short period of the pond's existence, the disposal methods currently being employed at this site are controlling the concentrations of ions in the groundwater moving away from the site. However, the leachate which was taken from the abandoned site (Location 2) represents a completely different situation. In the water drainage from this site, there is approximately 300 times the concentration of iron and over 100 times the concentration of manganese as is found in the pond. The increased concentration of these ions represents the partial solution of the improperly-buried fly ash and the lack of containment of this leachate within the disposal site. The intermediate conductivity reading at Locations 3 and 4 (Table 2) which are downstream from Locations 1 and 2 are interpreted to represent a physical mixture of normal runoff with the leachate produced from the older disposal site. Continued efforts must be directed towards proper burial of the ash so that the present area is not degraded to the level now observed at the abandoned site.

LANDSLIDES AND BADLAND EROSION

The section of NY highway 60 which is affected by landslides was completed in 1958. The cut, which is approximately 0.3 mile long, was excavated through a series of glacial deposits which include a varved proglacial lake deposit which is both underlain and overlain by till (see Fig. 3). The material removed from the excavation was incorporated into a large fill which spans the valley immediately south of the cut. Before the fill was brought up to grade, considerable instability was experienced in this material. As a consequence of this instability, the fill was partially re-excavated and some of the proglacial lake clays and till were brought back to the north and deposited on the hillside behind the crest of the ridge on each side of the road. Within the road cut itself, the sides were graded to an even slope and seeded with grass. Since that time the area has served as an excellent model for both mass wasting and erosion studies.

The generalized morphology of a typical slide can be seen in Figure 4. Typically, two different areas can be distinguished on each slide. The upper portion behaves like a classical slump. The material moves downslope along a well-defined plane of dislocation.

The moving mass remains coherent for the most part and often displays the characteristic backwards rotation of slumps. During the spring rains, small ponds of water are often formed in these low areas contributing to the continued wetting of the downslope material. Over a period of 5 years scarps as much as 15 feet in height have been produced.

The lower portion of the slide behaves as a non-coherent, flowing mass typical of an earthflow. The first movement generally occurs at, or very near, the lower till-varved clay contact. The lower edge of the flow is marked by sod rolls which extend across the entire front of the portion of the hill undergoing mass movement. The flows move at rates which have been measured between 2 and 10 ft. per year. Most of the movement occurs as a more-or-less continuous event during the spring thaw.

The next transfer of material downslope is more rapid in the upper portions of the earthflow-slump. This movement results in a bulge of the surface of the ground wherein the surface is actually raised above the original elevation (see Fig. 3). Most of the flow of the soil material occurs below the rooted grass. Initially, the grass cover may not be disturbed as the flow begins. However, as the movement progresses, the sod is stretched and discontinuous bare patches of soil appears in the grass. As the amount of soil material is added to this area by flow from upslope and the bulging reaches a maximum, prominent areas of bare soil appear on the entire upper surface of the flow.

During May, 1970, a flow on the southwestern side of the roadcut moved downslope to the point that it reached a utility pole near the base of the hill. The earthflow initially flowed around the pole, but within two days the pole began to tilt outward towards the highway. The utility lines were relocated along the top of the hill where they are seen today. The State Highway Department became concerned that the flow would block off their drainage ditch at the roadside so they began an active program to remove the toe of the slide. This oversteepened the slope again and increased the potential for greater upslope activity. This readjustment is still continuing at the present time.

At the top of the cut on either side of the road good exposures exist of the excavated material that was "redeposited" by the contractor after it began to fail in the valley fill. These deposits are composed principally of till. But the significance of this location lies in the nature and extent of the soil erosion in this area that can be observed in the redeposited materials at this spot. The area represents a true badlands-type of topography that is primarily the result of construction activity. Grasses have failed to grow in this oversteepened area and erosion is very extensive.

The sediment which is being removed from this area is flowing into a tributary which eventually flows into the Fredonia water supply reservoir. This is obviously a problem area that offers good examples of man's interaction with environmental geology.

REFERENCES CITED

Corps of Engineers, 1973, Help yourself; a discussion of the critical erosion problems on the Great Lakes and alternative methods of shore protection: Department of the Army, Corps of Engineers, North Central Division, Chicago, Illinois.

Havens and Emmerson, 1971, Solid wastes in Chautauqua County; a comprehensive planning study: Havens and Emmerson, Consulting Engineers, Cleveland, Ohio.

TRIP E - ENVIRONMENTAL GEOLOGY OF THE FREDONIA-DUNKIRK AREA

William J. Metzger

Total Miles	Miles from last point	Route description
0.0	0.0	Leave the Fredonia campus at the Temple Street exit. Turn right (NW) onto Temple Street.
0.3	0.3	Intersection with Brigham Road; turn right (N).
0.8	0.5	New York State Thruway overpass. Route travels over lake bottom sediments of glacial Lake Warren.
1.5	0.7	Entering the city of Dunkirk.
2.7	1.2	Junction with Lake Shore Drive West (Route 5). Turn left (W). At this point on the north side of the road the Niagara Mohawk electrical generation plant can be observed. Power is produced by burning bituminous coal. The problems related to the disposal of the fly ash and bottom ash produced here will be discussed at STOP 3 of this trip.
4.0	1.3	Cross Canadaway Creek bridge.
5.8	1.8	Enter the parking area of the South Shore Motor Lodge. Walk north 150 yards to the lake shore.

STOP 1. Lake Shore Erosion Problems (Brocton, NY, 7½' quad.): This area allows a comparison of the extent of erosion between areas which have sea walls with those areas without any erosion control. In one unprotected zone over 10 feet of embankment has been eroded away during the past 20 months. One house which will be visited is seriously threatened by the active erosion which has been intensified by the high lake stages.

Return to the bus.

Total Miles	Miles from last point	Route description
5.9	0.1	Return to Route 5. Turn right (W) and proceed towards Van Buren Point.
7.8	1.9	Bear right onto Van Buren Bay Road at gas station.
8.0	0.2	Bear left at junction.
8.1	0.1	Junction with Van Buren Point private road. Turn right.
8.4	0.3	Intersection with Park Street. Turn right.
8.6	0.2	Pull well off road onto right shoulder in front of flood control wall.
		STOP 2. Flood control structure and shoreline erosion problem (Brocton, NY 7½' quad): The project you are examining was completed in the Spring of 1973 by the Corps of Engineers as a flood control measure to prevent the flooding of the low lying areas near the cottages along this portion of the beach. To the North of the wall, the elevation of the land is sufficient not to justify flood control. However this area is not protected from wave activity and rapid erosion is now taking place in that area.
		Return to the bus. Turn around and return along Park Street.
8.8	0.2	Intersection with Central Street. Turn left.
9.1	0.3	Junction with Van Buren Bay Road. Turn right.
9.2	0.1	Intersection with Route 5. Turn right (W).
9.6	0.4	Junction with unnamed dirt road. Turn left.

Total Miles	Miles from last point	Route description
9.7	0.1	Park in pull-off area at the left of the road before the gate. Walk into disposal area. STOP 3. Fly ash-bottom ash disposal site (Brocton, NY, 7½' quad): You will observe a trench and fill operation in relatively imperveous lake bottom sediments which overlie till. The fly ash is dumped first and later covered with coarser bottom ash to prevent blowing of the very fine particulates. The ash is then covered over by the soil and glacial deposits removed in the original excavation. Attempts to control and monitor leachate will be observed including an on-site measurement of the conductivity of the water entering the pond. Return to the bus. Turn around and leave the disposal site.
9.8	0.1	Junction with Route 5. Turn left (W).
10.4	0.6	Junction with Berry Road. Turn left.
10.5	0.1	Keep left at junction with The next segment of the trip will traverse a significant variety of glacial deposits and features. The highlights are noted in the log. At this point the bus is driving over lake bottom deposits of Glacial Lake Warren.
11.6	1.1	Penn Central railroad crossing.
12.4	0.8	Thruway overpass.
12.9	0.5	Junction with Farrel Road. Turn right.
13.1	0.2	To the left and front of the bus note the line of poplar trees in the distance. They mark the location of the Lake Warren II beach.
13.6	0.5	Driving up the front face of the Warren II beach.

Total Miles	Miles from last point	Route description
13.7	0.1	To the right of the bus observe the inactive sand and gravel pit. When in operation this pit is a good location to note the nature of the sediments and bedding characteristics of an ancient beach deposit.
13.9	0.2	Junction with Route 20. Jog to the right and continue on Farrel Road.
14.2	0.2	Unnamed, poorly defined beach ridge.
14.5	0.3	Driving up the front face of the Lake Whittlesey beach. This is the highest proglacial stage recognized in Chautauqua County.
14.6	0.1	Junction with Webster Road. Turn left (E). Webster Road follows the crest of the Lake Whittlesey for the next mile on the trip route.
15.7	1.1	Bear right to follow Webster Road.
15.8	0.1	Intersection with Chautauqua Road. Continue straight ahead on Webster Road.
16.9	1.1	Penn Central railroad (abandoned).
17.8	0.9	Intersection with the Fredonia-Stockton Road. Turn right (S). For the next 2 miles, the bus will travel over Lake Escarpment ground moraine as we gain elevation on the escarpment.
19.3	1.5	Penn Central Railroad (abandoned). To the right of the bus observe the deep gorge which was used as the railroad right of way. This is a glacial meltwater channel formed during the deglaciation of this area when the ice blocked the normal outlet downslope to the north.
19.7	0.4	Junction with Glasgow Road. Turn left. This intersection marks the approximate northern boundary of the Lake Escarpment end moraine complex.

Total Miles	Miles from last point	Route description
21.0	1.3	Penn Central railroad (abandoned).
21.3	0.2	Junction with Darby Switch Road. Turn left.
21.4	0.1	Pull off onto the far right shoulder of the road. Follow fence line down to the creek.

STOP 4. Agnes flood erosion and stream channelization problems (Cassadaga, NY, 7½' quad.): A very large landslide induced by greatly accelerated erosion during the Agnes Flood (1972) runoff is seen. The abundant supply of silt and clay from this material caused a serious siltation problem in the Village of Fredonia's Water Supply Reservoir located approximately 1.4 miles downstream. Agnes flood relief money allowed stream channelization upstream from this point to be completed in the summer of 1973. Since that time, extensive downcutting on this stream has occurred which has contributed greatly to further siltation problems in the reservoir.

Return to the bus. Proceed straight ahead on Darby Switch Road.

Total Miles	Miles from last point	Route description
22.0	0.6	Junction with Spoden Road. Turn left into parking area of New York State Highway Department. Leave the bus and walk 50 yards down Spoden Road.

STOP 5. Stream contamination problems (Dunkirk, NY, 7½' quad.): Two sources of water contamination are apparent in this area. The first includes clay and silt which is being dumped down the embankment by the highway department. The second involves the unprotected pile of bottom ash and salt which is locally used for ice and snow removal on the highways during the winter. The small stream is tributary to the Village of Fredonia water supply.

Return to the bus. Leave the parking area and turn right onto Spoden Road. Proceed uphill.

Total Miles	Miles from last point	Route description
22.5	0.5	Junction with Route 60. Turn left (N). The bus is now traveling over a series of deposits that include clays deposited in proglacial lake. They will be observed at the next stop.
23.3	0.8	Pull off the road to the far right. Leave the bus and proceed up the right hand embankment.
		<u>STOP 6</u>. Landslides and badland erosion (Dunkirk, NY, 7½' quad.): This section of Route 60 was completed during 1958 and since that time a combination of slumping and earthflows have affected both sides of this cut. The glacial deposits involved in the slides are proglacial varved clays and at least two tills. The highway department has removed much material at the base of the slope which has caused further instability problems. At the top of the hill an extensive "badlands" has developed where the soil has been removed or covered with clays taken from the road cut excavation. These clays are being washed into a tributary to the Village of Fredonia water supply reservoir.
		Return to the bus. Continue north along Route 60.
24.4	1.1	Semistabilized landslides in similar deposits.
25.6	1.2	Junction of Liberty Street and Route 60. Turn left and enter Laona, NY.
26.1	0.5	Entering Fredonia.
26.6	0.5	Bear right on Water Street and cross bridge over Canadaway Creek.
26.8	0.2	Intersection with Route 20. Continue straight ahead.
27.3	0.5	Temple Street entrance to the Fredonia Campus
		END OF TRIP

TRIP F - GLACIAL GEOLOGY AND BURIED TOPOGRAPHY IN THE VICINITY OF FREDONIA, GOWANDA, AND ZOAR VALLEY, NY

E. H. Muller and R. K. Fahnestock

Notes: The trip will be made in cars as there are several bridges that will not handle the weight of a bus.

Total roundtrip mileage is about 80 miles

The route of the fieldtrip is outlined on Plate 1, page D-13

Total Miles	Miles from last point	Route description
		Leave the Fredonia State campus by the Temple Street exit turning left (south) onto Temple Street. The road log begins at the intersection of Temple Street and Main Street (U.S. 20) at the town square. Turn left (east) onto Main Street and begin road log.
2.2	2.2	Cross Rt. 60 and continue along the Lake Warren Beach.
		Later Warren ridges are to the north (1) and the Lake Whittlesey (2) Ridge to the south. Note Warren strand along U.S. Route 20 in Sheridan (see plate 2f and Plate 1). The surface of this gravel terrace is at 755 feet above sea level. This beach trends east-northeast, rising about 50 ft. in elevation in 45 miles.
6.5	4.3	Turn Right (East) onto N.Y. Rt. 39. Gravel pits are in Lake Whittlesey beaches. The escarpment ahead and to right (south) which separates the lake plain from the plateau has been called the Portage Escarpment, but it is developed on the Canadaway Formation in this area. The escarpment bears no relationship to the Portage Group, which does not crop out in Chautauqua County. The Canadaway Formation totals about 950 ft. and is dominantly composed of shale. The Laona and Shumla Members, each about 30 ft. thick are dominantly siltstone and somewhat thicker-bedded than the other members. These two siltstone members may account for details of the character of the scarp as developed eastward toward Forestville.

Total Miles	Miles from last point	Route description
		Question: In view of the dominantly shale lithology exposed in this portion of the escarpment, is structural control an adequate explanation of the origin of this scarp? Regional dip is very gentle toward the south. If the topography be truly cuestaform, where are the resistant capping strata responsible for the scarp which is 700 to 1100 ft. high in eastern Chautauqua County?
12.8	6.3	Turn Left (north) on Center Rd. The road drops into a channel (3) formed either along the ice margin (Gowanda) or the beach ridge (Plate 2e and f).
13.5	0.7	Note Whittlesey strand at approach to King Road (Cook Rd. of Forestville 7½ minute Quadrangle). A shallow borrow pit 0.3 mile southwest off King Rd. in 1957 exposed the following: 3. Shingle gravel, stratified dipping southeast; dominantly of clastic pebbles; matrix coarse-textured; structure, open. — 10 ft. 2. Laminated lake silt with thin sand and pebble layers. — 4 ft. 1. Gravel, coarse, poorly-sorted with numerous erratics and rounded boulders suggesting derivation by wave washing of proglacial sediments. — 4 ft.
13.5	0.0	Turn right (East) onto Cook (King) Rd. For most of the way this road follows the beach ridge. To the south between the beach and the escarpment lie Gowanda moraine remnants (Plate 2e), kame terrace deposits and ice marginal channels. Plate 2f shows the geography of Lake Whittlesey time.
15.4	1.9	Cross Erie RR. This is the original right of way. The railroad completed in the early 1850s ran from Piermont on the Hudson to Dunkirk, avoiding such dens of iniquity as New York and Buffalo.

Total Miles	Miles from last point	Route description
17+	1.6	Look for the spit (4) built by the longshore drift into the Walnut Creek embayment coming up.
18.3	1.3	Cross Rt. 428.
19.0	0.7	Dennison Corners Left (N) on Dennison Rd.
20.1	1.1	STOP F1. Buried valley of Walnut Creek. Hanover Center Landslide. Figures F1 and F2 outline the general setting of this stop. A well at the house across the road from the "landslide" bottomed in "quick-sand" at 290 ft. and had to be abandoned because too much sand was pumped with the water. The landslide has appeared to result from groundwater sapping and liquifaction of the units exposed in the base of the amphitheater. Such active processes make for uneasy householders and highway departments.
20.4	0.3	Bridge over the Silver Creek Gorge. To the east is the open valley cut in the Walnut Creek valley fill and to the west is the bedrock gorge of Silver Creek which extends most of the way to Lake Erie.
20.7	0.3	Turn right (NE) onto Angell Rd.
20.9	0.2	Turn right again (SE) onto Hanover Rd. crossing the filled valley of Walnut Creek. Note the moraine remnants to the south of the road.
22.0	1.1	Turn left (E) on Versailles Rd. Again we are along the Whittlesey beach (6).
22.8	0.8	Intersection. Continue on Versailles Rd.
25.1	2.3	Enter Cattaraugus County.
28.9	3.8	Cross Bridge (5 ton capacity) over Cattaraugus Creek which is flowing over on bedrock part of which is the south wall of the old Allegany Channel (Figure 1-6).
		Bear Left.

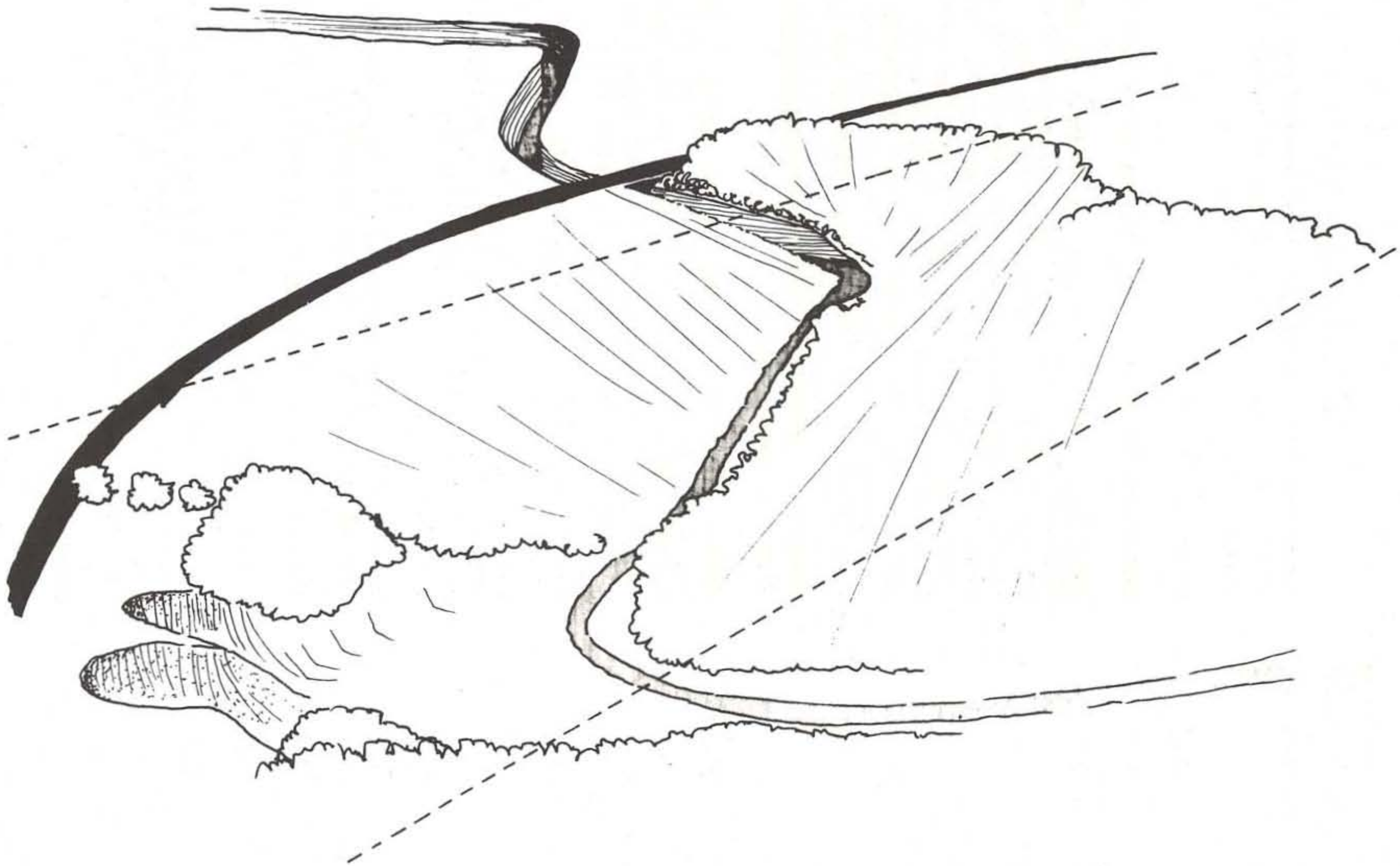


Figure F1. STOP F1, Post glacial Erosion. Broad valley is excavated in fill of buried valley of ancestral Walnut Creek (Wklson, 1974). Silver Creek enters in the foreground and leaves in the background in a postglacial bedrock gorge.

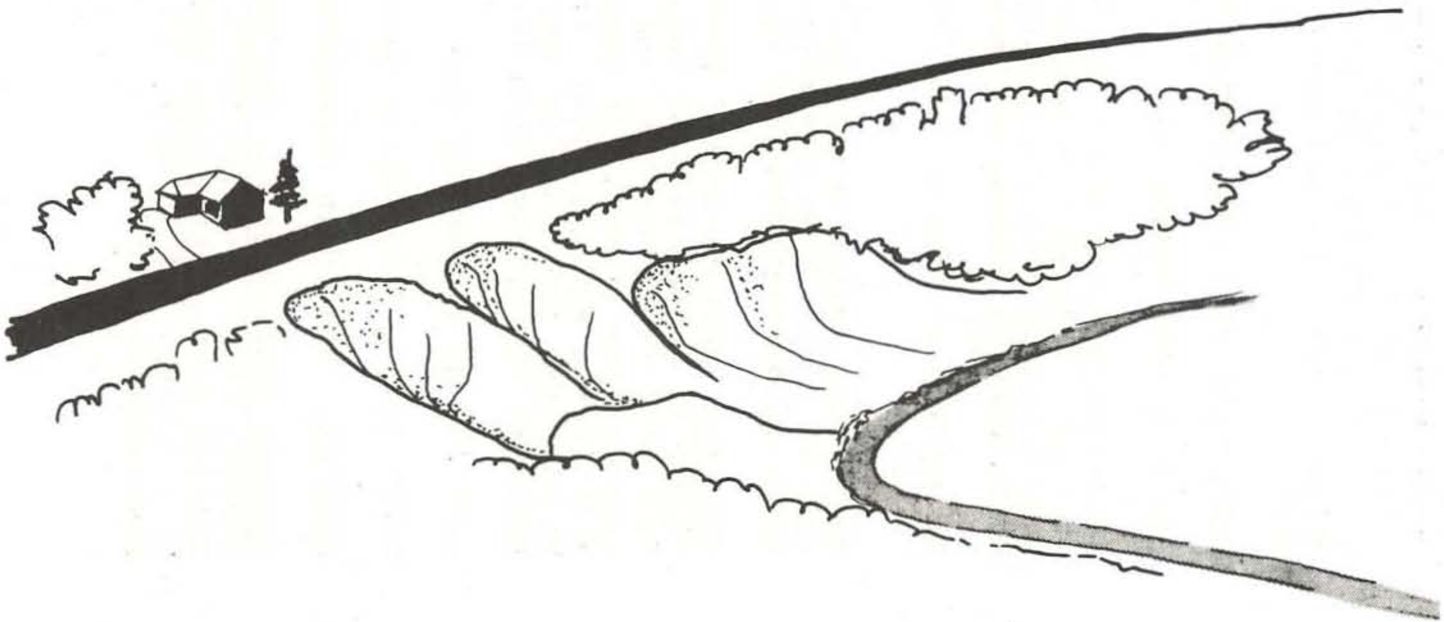


Figure F2. STOP F1. Landslides in the fill of the buried valley of Walnut Creek. These were active for about two years and have progressed only slowly over the past year.

Total Miles	Miles from last point	Route description
29.6	0.7	Cross Four Mile Level Rd. (Rt. 438) and continue north. In this area you are crossing the ancient Allegany valley (7) which has at least 500 ft. of fill near here.
30.2	0.6	Turn Right (NE) onto Seneca Rd.
31.6	1.4	Possible side excursion:
		Southeast on Long House Rd. 0.6 miles to end of road. This is a spit which extends southeastward from the island in Lake Whittlesey (8). Elevation 840+ ft.
32.9	1.3	At village of Lawtown turn Right (S) onto Rt. 62.
33.5	0.6	Right onto Raylor Hollow Rd. The road crosses Clear Creek and rises onto Four Mile Level (Elevation 800-840+ ft.).
35.5	2.0	STOP F2. Gernatt Gravel Products Pit. Figure F3 summarized the relation between Four Mile Level and the land form being quarried for gravel. If Four Mile is Whittlesey, what is this? If this Whittlesey, then what is Four Mile? What agencies can produce such level surfaces?
35.9	0.4	Left (E) on Richardson Rd.
36.7	0.8	Right (S) to Clear Creek Bridge.
37.0	0.3	STOP F3. Wisconsin Stratigraphy
		Gowanda State Hospital Section. Stream bluffs, Clear Creek at Route 63, 39, 18. Collins town, Cattaraugus quadrangle, Erie County. (78°55'50"W, 42°29'20"N). Composite section.

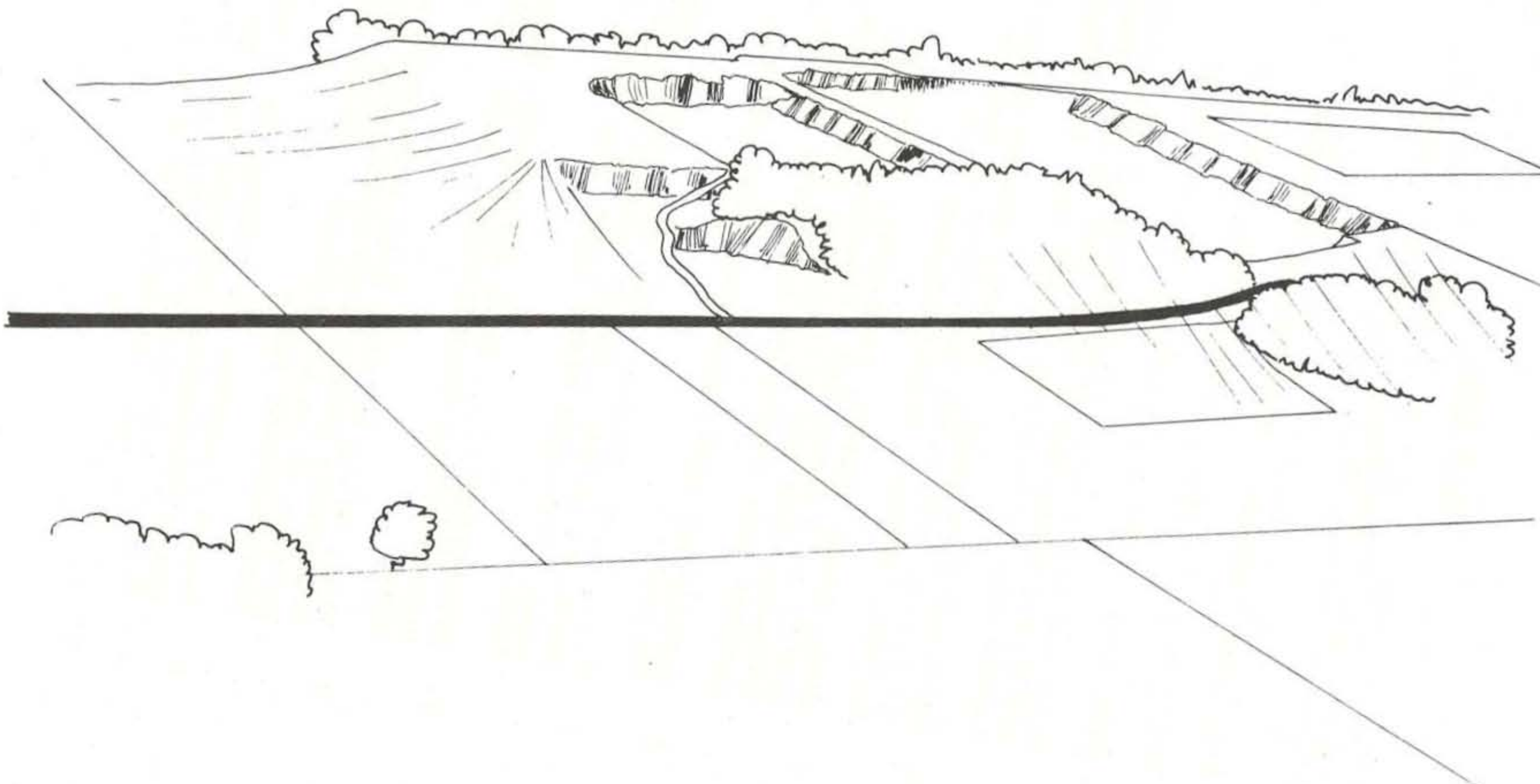


Figure F3. Gernatt Gravel Products Pit in
surface 20+ feet abo
level

Unit	Lithology	Thickness
11	Alluvial gravel; oxidized, many pebbles and cobbles deeply weathered; rounded to subrounded; exotic pebbles numerous	3.3 ft.
10e	Silt, dark olive-gray; stratified, includes fine sand laminae; oxidized and leached	1.0 ft.
10d	Silt, tan to olive, oxidized but unleached	1.3 ft.
10c	Fine sand, finely laminated, yellow-brown	1.2 ft.
10b	Clay and silty clay interlaminated with sand and silt; pairs are ½ to ¼ inch thick, finer toward top. Clay-rich layers are unoxidized.	6.5 ft.
10a	Silt and fine sand, light-to medium-gray; unoxidized, unleached; laminated to medium-bedded; sparsely pebbly towards base	10.0 ft.
9	Till, silty matrix, blue-gray, sparsely pebbly with shale and siltstone dominant. Includes sand and silt lenses but is more compact than overlying laminated units.	4.0 ft.
8	Stratified sand, silt and sandy gravel; unoxidized	1.0 ft.
7	Till, silty matrix, dark blue-gray, compact, sparsely pebbly. Upper contact marked by seep. Includes minor light gray silt partings.	8.0 ft.
6	Stratified silt, sand and gravel; unoxidized; upper contact transitional, lower contact sharp	2.0 ft.
5	Till, silty matrix, dark blue-gray, compact; moderately pebbly with relatively high proportion of exotic pebbles. Faint seep shows better-sorted lens.	6.0 ft.
4	Gravel, pebbles and cobbles in coarse sand. Crude imbrication suggests flow to northwest. Pebbles dominantly rounded with diverse lithology. Unit thickens southwest to about 20 ft. at the stream bend.	3.0 ft.

Unit	Lithology	Thickness
3	Till, calcareous throughout; color ranging from olive-brown to orange-brown, suggesting incomplete assimilation of diverse materials. Compact. Sparsely to moderately pebbly. Toward base appears to incorporate and deform underlying stratified sediments.	20.0 ft.
2	Silty and carbonaceous clay; stratification disturbed enough to suggest crushing and sliding. One layer contains sparse invertebrate tests and several contain twigs and other plant remains. Wood is more than 38,000 years old (W-866). This unit abuts northward against Unit 3.	15.0 ft.
1b	Till, pink, silty matrix, (Color 5Y 4/1), fairly pebbly. Surface rises east cutting out part of overlying stratified section. Relationship to Unit 3 not clear as contact is nowhere exposed. Base obscured west of bridge but transitional relationship to underlying is suggested 200 ft. upstream.	18.0+ ft.
1a	Till, medium blue-gray (5B 5/1), with abundant shanners and flaggy bits of local blue-gray siltstone. Basal contact concealed, but upstream a few hundred yards this unit rests on bedrock. This may be a color phase of the overlying pink till, different only in assimilation of abundant local rock.	6.0+ ft.

(Note: Sequence of deposition of lower, contorted and disturbed portion of bluff is not certainly established because of discontinuity of exposure and obscured relationships.)

About .8 mile west of highway bridge a well is reported to have penetrated 620 feet of unconsolidated material to about 240 feet above sea level. If correct, this information gives a measure of depth and sharpness of the bedrock valley.

Total Miles	Miles from last point	Route description
		From Clear Creek Bridge return toward Buffalo (N).
37.2	0.2	Turn right (E) following N.Y. Route 39 through Collins.

Total Miles	Miles from last point	Route description
38.6	1.4	Cross Gowanda moraine, (9) marking recessional position north of the Lake Escarpment moraines.
39.8	1.2	Turn right (S) onto Jennings Road.
41.0	1.2	Diagonal SE onto Foster Rd.
42.6	1.4	Begin rise onto proximal slope of massive Lake Escarpment moraine complex (10).
43.1	0.5	Commence descent into Zoar Valley following Zoar Valley Rd. CAUTION: This is a long, steep grade. USE LOWER GEAR Cattaraugus Creek flows across the grain of bedrock topography, crossing bedrock uplands through confined, steep-wall gorges and crossing drift-filled lowlands in broad, mature reaches. One such open reach is Zoar Valley ahead to the southeast, whereas due south at this point, Cattaraugus enters a 3-mile long gorge deeply incised in bedrock. (Figure F4). Silt and silty-clay till and lacustrine sediments in slumped moraine topography at left. Soil is mapped as Mahoning silty clay loam, steep phase.
44.7	1.6	Turn right (S) past Burt's Zoar Valley Park and across Cattaraugus Creek. Leave interval between cars in crossing wooden bridge (Three ton capacity). (11) Cross mature floodplain. Leave Erie County. Enter Cattaraugus County. Figure F4 is an aerial view of Zoar Valley looking west downstream.
46.0	1.3	Pass Girl Scout Camp. Waterfalls ahead mark the west edge of a drift-filled bedrock valley. Commence climb out of Zoar Valley on steep, winding road.
47.3	1.3	Turn Right (W) onto Wickham Rd.

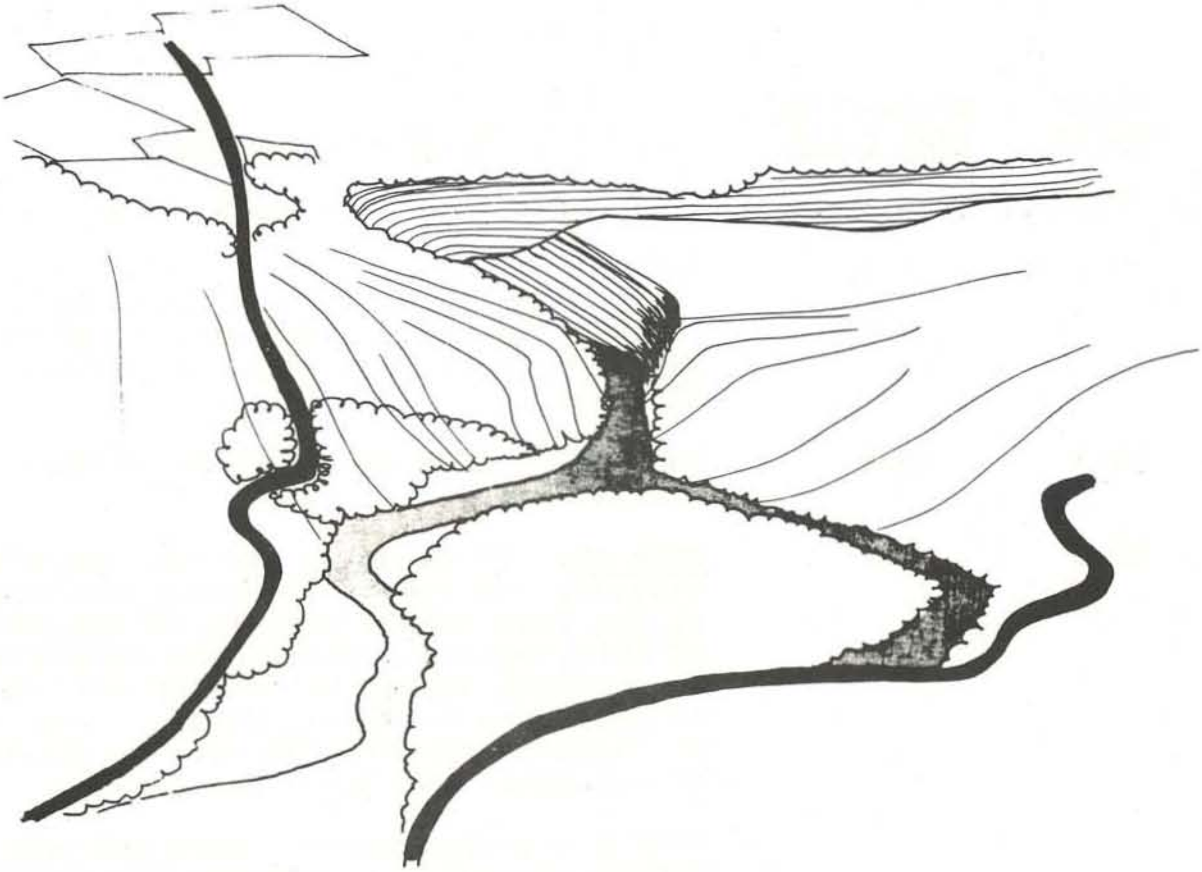


Figure F4. Aerial view of Zoar Valley and Gorge looking downstream on Cattaraugus Creek.

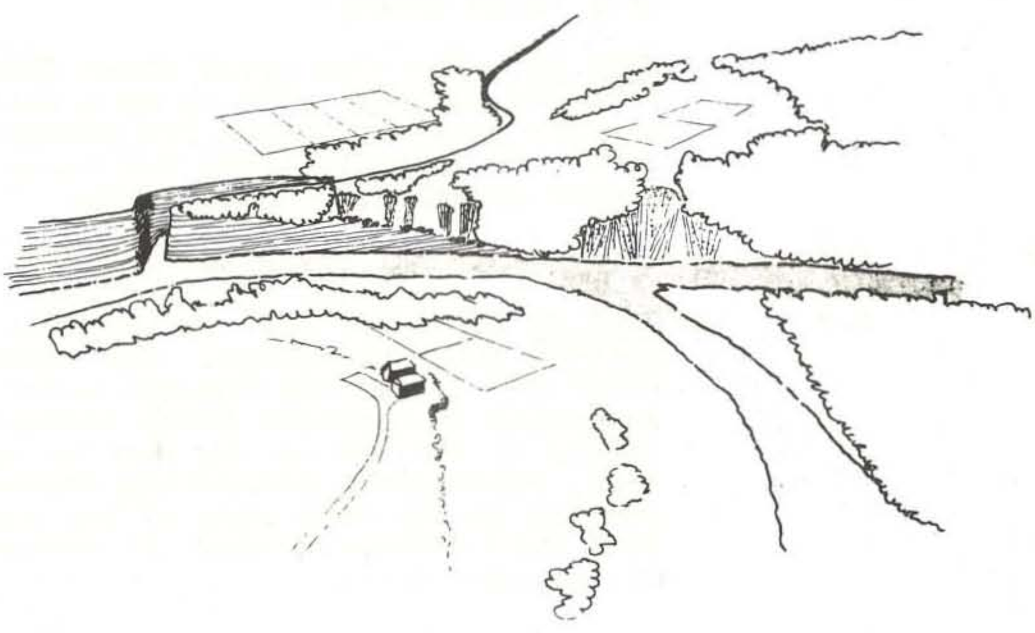


Figure F5. Aerial view of buried Allegany valley exposed in cliff making up the east wall of the Cattaraugus Creek Valley. Notice how the bedrock outcrop makes a diagonal across the cliff face. Above the line is unconsolidated valley fill.

Total Miles	Miles from last point	Route description
47.6	0.3	Crest of a Lake Escarpment moraine.
49.7	2.1	Turn Right on Forty Rd. to the 2-ton bridge over the South Branch of Cattaraugus Creek. The road climbs out of the valley. More spectacular views are available at STOP F5.
51.4	1.7	Turn Right (NW) on Point Peter Rd. to STOP F4.
51.5	0.1	STOP F4. If slumping has not obscured the bedding, the source direction and extent of the beds should clearly reveal the nature of this deposit. Should the relationships be somewhat vague, an attempt will be made to make them perfectly clear. There will be complete cooperation with no attempts to stonewall the investigators.
		Time permitting we will make two more stops before returning to Gowanda and going our separate ways.
52.4	0.9	Turn Right (NE) off Point Peter Rd. to the Zoar Gorge Lookout.
		STOP F5. The view point about 200 meters from the parking space is on a knife edge meander core well above the valley floor. There are friendly trees for those who prefer something to hold on to.
54.2	4.8	Return to Point Peter Rd. and turn right.
54.7	0.3	STOP F6 is on the east valley wall of the ancient Allegany valley. The small tributary which has filled the Gowanda water supply reservoir to spillway level leaves the broad valley at the cam on the west to enter a deep, entrenched, meandering channel in bedrock on the east side of the road. From this bedrock channel it emerges into Cattaraugus Creek.
		Brave souls may visit the meander core via a knife edge (without trees this time) or may peer into the broadening valley of Cattaraugus Creek and observe immediately below in the face of the cliff the diagonal line of the contact of fill and bedrock which is shown in Figure F5.
		Continue on Point Peter Rd.

Total Miles	Miles from last point	Route description
55.2	0.5	Turn Right on Broadway into Gowanda, astride Cattaraugus Creek in Erie and Cattaraugus Counties. Gowanda in the Seneca langauge means "a beautiful valley between hills". The Seneca Nation of Indians maintains its business office in downtown Gowanda, but the reservation is north of town, extending along Cattaraugus Creek to Lake Erie.

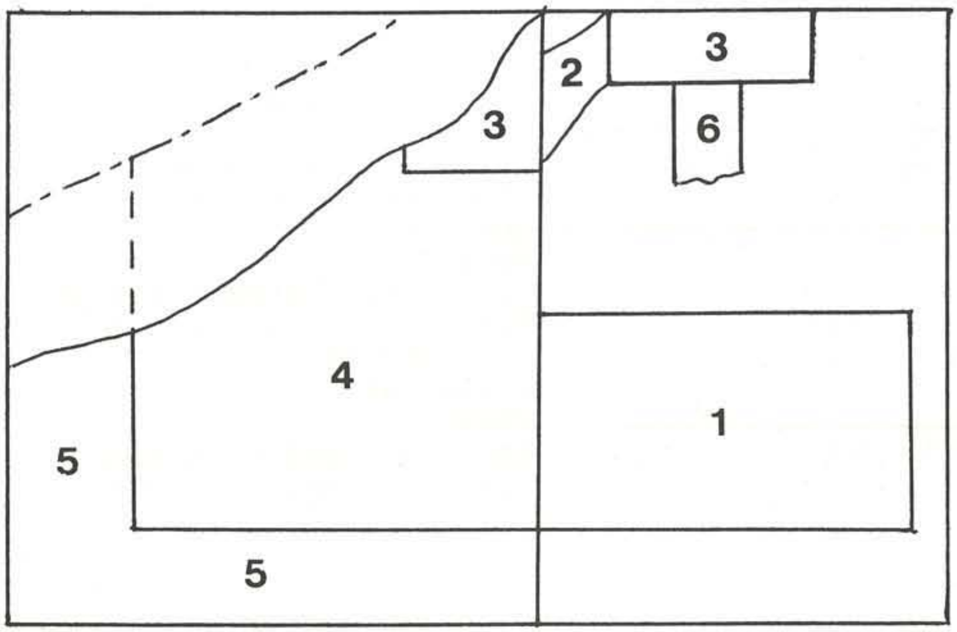
Cattaraugus in the Seneca language means "odorous waters", an epithet given new meaning by the white man's tannery and glue factory on the southern outskirts of Gowanda. Cattaraugus Creek is the largest creek in New York west of the Genesee River to flow north across the Lake Escarpment - Valley Heads moraines. In so doing, it has inherited the valley of the Ancestral Allegheny River where it descended from the plateau in a constricted gorge. Bedrock exposures on opposite sides of the valley at Gowanda are only 0.7 mile apart, yet a municipal well is reported to have penetrated 320 feet of drift. (Note: Well probably not on axis of valley as 7-800 ft. is reported elsewhere.)

END OF TRIP

Those returning to Thruway East may get on Thruway by following Rt. 62 North through Hamburg to the entrance.

Those returning to Fredonia and the Thruway west will hopefully make a Left turn at the base of the hill before entering downtown Gowanda and head west on Route 39 crossing hill and vale (buried) through Perrysburg and Forestville to Route 20 and Fredonia, approximately 25 miles.

PLATE 1. Glacial Map of western New York



Index Map of Published Data Sources Used in this Compilation. (Numbers refer to list below).

Map Data Sources

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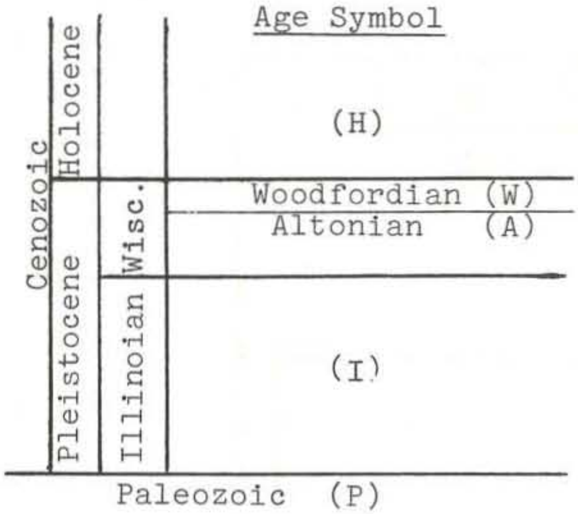
PLATE 1. Glacial Map of western New York



Deposit	
Alluvial sand and silt	as
Alluvial gravel	ag
Beach sand and gravel	ls
Lake silt and clay	lc
Peat, marl and muck	pm
Wind deposited sand	ws
End moraine	em
Ground moraine	gm
Ice contact stratified drift	kg
Outwash, terrace and delta gravel	og
Colluvium	cl
Shale	sh
Sandstone and siltstone	ss
Limestone and dolomite	ld

Symbols

Contact — Probable — Inferred

Glacier marginal positions (hachured toward glacier) — Probable — Inferred

Moraine ridges

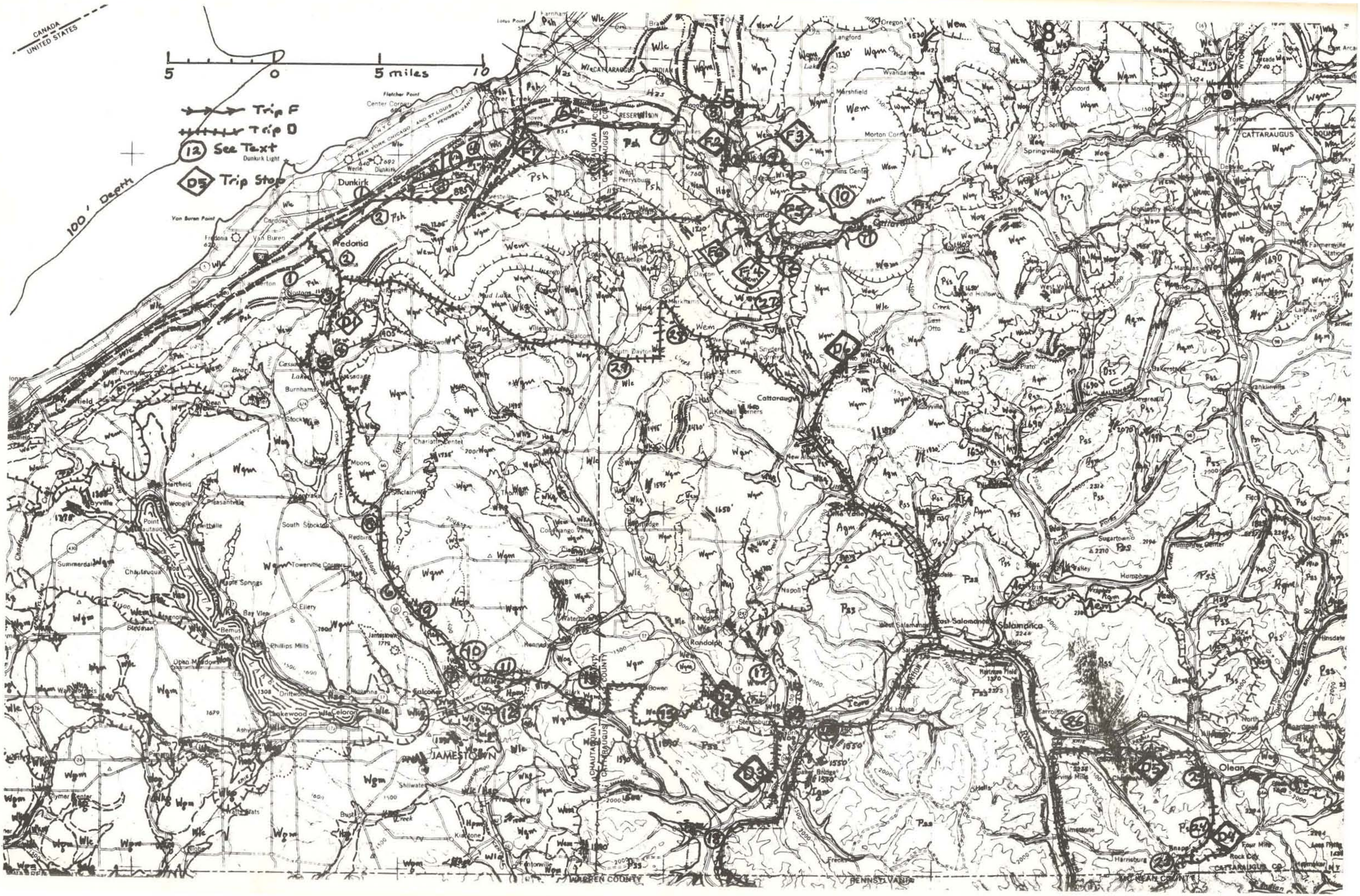
Wave-cut cliff
(hachured toward lake)

Beach, bar or strandline

Drumlins and fluted till plain
(symbol represents either individual drumlin or groups of drumlins)

Striae
(arrow head indicates sense of flow) — Sense of flow unknown

Glacial meltwater channels
(ool elevation in feet)


CANADA
UNITED STATES
5 0 5 miles 10
Trip F
Trip D
12 See Text
D5 Trip Stop
100' Depth
Dunkirk
Fredonia
Westfield
JAMESTOWN
Salamanca
Olean
Cattaraugus
Springville
CATTARAUGUS COUNTY
CHAUTAUQUA COUNTY
WARREN COUNTY
PENNSYLVANIA
McKEAN COUNTY

BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE WINDOM SHALE MEMBER (MOSCOW FORMATION) IN ERIE COUNTY, N.Y.

Carlton E. Brett, State University of New York at Buffalo

INTRODUCTION

The exposures of Hamilton strata along Lake Erie shore and in various creek beds in Erie County south of Buffalo are among the best-known and most thoroughly-studied Middle Devonian fossiliferous sequences in the world. The monumental studies of James Hall and A. W. Grabau (1898, 1899) provided a solid background for numerous later studies. Yet, in over a century of study, many biostratigraphic and paleoecological problems remain uninvestigated.

Recently, an exceptionally large and complete section of the Windom Shale (Moscow Formation) has been exposed in the shale quarries of Penn Dixie Cement Co. near Bayview, N.Y. This outcrop provides an excellent opportunity for detailed study of the fossil horizons of this upper Hamilton unit. Discovery of several new and little-known horizons at this quarry have led to the present restudy of biostratigraphy of the Windom in Erie County.

STRATIGRAPHY

From its type locality at Smokes Creek near Windom, Erie County N.Y., the Windom Member can be traced eastward nearly 200 miles to the vicinity of Skaneateles Lake (see Rickard, 1964) where the unit becomes sandy and grades into the Cooperstown shales and sandstones. Over most of this interval the Windom is a grey, calcareous shale. It is fossiliferous throughout most of its thickness and contains a characteristic "Moscow Facies" suite fossils.

In Erie County the Windom ranges from 9 to 50 ft. in thickness and is composed dominantly of soft, fissile medium-gray shale with thin bands of fossiliferous limestone. Thin calcareous beds containing abundant fossils occur only at the base and a few feet from the top of the Windom, intervening between these is a mass of nearly barren, grey shale 2 to 30 ft. thick. The presence of an undescribed pyritized assemblage of brachiopods and mollusks in the upper portion of this "barren interval" suggests a recurrence of the "Cleveland" (black shale) facies conditions (similar to those under which the Ledyard Shale of the Ludlowville Formation was deposited) existed in Erie County during the interval represented by the "barren" shales. The fossiliferous beds above and below suggest the occurrence of shallow, normal marine conditions during the early and late depositional phases of the Windom in Erie County.

DESCRIPTION OF FOSSIL HORIZONS OF THE WINDOM

The Windom shale member at the Penn Dixie Quarry, Bayview, N.Y. can be subdivided into six different units. In the following section each of these units, its characteristic fossils and paleoecology are described in stratigraphic sequence. The data are summarized in Figure 1.

Unit 1. Ambocoelia Bed

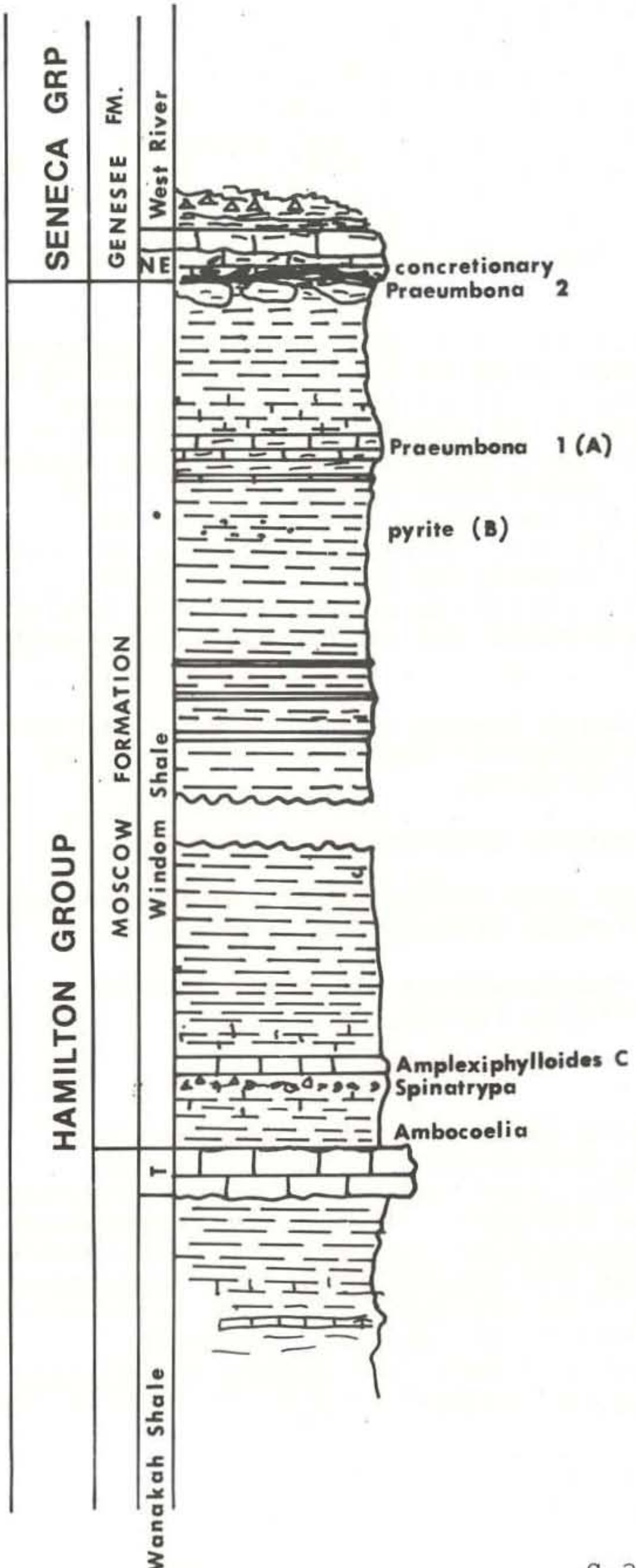
In much of western New York the base of the Windom Shale has been defined as the zone of abundant *Ambocoelia umbonata* (brachiopod). In places in Genesee County this species occurs abundantly throughout the lower half of the Windom, but in Erie County it generally is plentiful only in the lower 2-6 ft. The *Ambocoelia* bed consists of soft, fissile, grey shale. Its fauna, dominated by *Ambocoelia umbonata*, several species of choenetid brachiopods, *Athyris spiriferoides*, *Protoleptostrophia perplana*, and *Stereolasma rectum*, is very similar to that of the upper Wanakah. *Ambocoelia* occurs as "sheets" of very high density (several hundred individuals per square foot).

The preservation of fossils in the *Ambocoelia* bed is fairly good. A majority of the brachiopods (over 60 percent) are articulated and delicate, marginal spines of choenetids are generally intact. However, the fossils are often highly compressed. This suggests deposition of soft, soupy mud in a low energy environment followed by considerable compaction.

In addition to the main *Ambocoelia* fauna, the basal beds of the Windom often contain an assemblage of highly worn fossil fragments, limestone pebbles, and phosphatic nodules. This previously undescribed occurrence is discussed in greater detail in the other paper in this guidebook by the author.

Unit 2. Spinatrypa spinosa bed

Immediately overlying the *Ambocoelia* bed in western Erie County is a slightly to very calcareous band (1-6 in. thick) containing extremely abundant fossils. The brachiopod *Spinatrypa spinosa* occurs abundantly in this thin band and in western New York is almost entirely restricted to this unit. *Atrypa reticularis* and *Mediospirifer audaculus* occur with *Spinatrypa* in almost equal numbers. From the South Branch of Smokes Creek east to Buffalo Creek, this horizon is represented by a thin band of limestone composed of crinoid pluricolumnals and brachiopods. At Cazenovia Creek the tabulate coral *Pleurodictyum americanum* is a fairly common associate of the brachiopods and the association suggests a recurrence of the Wanakah *Pleurodictyum* bed fauna; whereas, at Penn Dixie quarry near Bayview and in the vicinity of Eighteenmile Creek, the brachiopod



North Evans: Crinoidal, bone bed limestone, grades up into shale; conodonts and arthrodire plates abundant in lowest layer; the limestone here rests uncomformably on a concretionary limestone in the upper Windom. Elsewhere the two are separated by about two feet of black and grey shale.

Upper Windom ("Praeumbona bed"): The upper portion of the Windom Shale is composed of soft fissile grey shale and on the whoel it is not very fossiliferous; however, a 6 inch calcareous bed marked A contains abundant brachiopods and trilobites; Ambocoelia praumbona is particularly common here and nowhere else in the Hamilton Group. Some pyritized fossils including pelecypods, gastropods, and cephalopods have been obtained from the shale (B) about two feet below the "Praeumbona bed". The remainder of the Windom down to about three feet from the base is barren of fossils.

Lower Windom (Trilobite beds): About 2 feet from the base of the member occur grey calcareous layers (C) which are richly fossiliferous and contain trilobites Phacops, rugose corals, and brachiopods.

Coral Layer: The lowest shale is very soft and friable; large rugose corals and Atrypid brachiopods are very common.

Tichenor Limestone: Hard crinoidal limestone; very fossiliferous (corals, crinoids, and brachs.), an upper layer of pyrite.

Upper Wanakah Shale (Demissa bed): soft fissile, grey shale much like the Windom, but with a different fauna.

Vert. Scale: 1"=4'

Figure 1. Stratigraphic section at Bayview, N.Y.

assemblage is supplemented by abundant, large, rugose corals. Heliophyllum halli, Cystiphylloides confollis and Heterophrentis simplex occur closely packed in a soft, shaley matrix. Although the large rugose corals actually occur in only a few localities, Grabau (1899) termed this coral-brachiopod assemblage the "Coral layer" and this name has generally been applied to the entire unit which in this report is called the Spinatrypa bed. The local nature of the coral fauna is well demonstrated in Windom shale exposures along the Lake Erie Shore south of Eighteenmile Creek. The large rugose corals are lacking in the Spinatrypa bed along most of the exposure, but suddenly reappear just north of Pike Creek.

In a group of 800 rugose corals collected from the S. spinosa bed at Penn Dixie Quarry, 107 were found to be attached to recognizable objects. Ingrown shell fragments and vague impressions on many others suggest that many or most of the corals initially attached themselves to hard objects. The majority grew on brachiopod shells. The fact that brachiopods are somewhat more common in the coral beds than elsewhere suggests that shell beds were selected as settling sites by coral planula larvae. Several specimens of corals were grown onto the interiors of brachiopod valves which must, therefore, have lain unburied in concave-up position on the seafloor. This suggests both low deposition rates and relatively little water movement near the seafloor.

The "Coral layer" fauna of large rugose corals occurs only as localized patch reefs. The circumstances favoring the formation of such patches seem to be the following:

1. A low rate of sedimentation, preventing smothering of corals.
2. Moderately shallow water with little or no turbulence on the seafloor, but sufficient circulation to prevent stagnation.
3. The presence of local accumulations of shells providing firm substrates for settling larvae.

Unit 3. Coral-Trilobite Bed

The Spinatrypa bed terminates abruptly and is followed by 1-6 ft. of resistant calcareous, medium-grey to purplish-grey shales which weather whitish. The lower portion of this calcareous band is quite fossiliferous, but contains a distinctive assemblage dominated by the brachiopod Mucrospirifer consobrinus, small rugose corals such as Stereolasma rectum and Amplexiphylloides hamiltonae, and the trilobite Phacops rana. The brachiopods are not as common in this bed as in the underlying beds of the Windom; although Mucrospirifer consobrinus is fairly common, and Atrypa reticularis Rhipidomella vanuxemi and Douvillina ineaquistriata are usually found.

The rugose corals which are extremely common in the basal foot of this unit, unlike the large forms found in the Spinatrypa bed, usually show no evidence of basal attachment. Instead, they are conical or horn-shaped with pointed bases. Presumably they were held upright by sinking into the firm, limey muds. Contorted shapes frequently observed in Amplexiphylloides from this horizon may have resulted form repeated toppling of the corallite.

The association of trilobites with corals in this horizon recalls the Wanakah "Trilobite beds" (Grabau, 1898). Specimens of Phacops, often in excellent condition, are abundant at this level. Occasionally, perfectly preserved trilobites occur in clusters of five or more individuals. These clusters appear to be segregated by species. Of four such aggregations examined, three were found to be exclusively Phacops rana. The fourth shows remains of five Basidechenella rowi on a small slab. This form is extremely rare in the lower Windom as a whole. Thus, such trilobite clusters appear to represent catostrophic death of intraspecific aggregations of trilobites.

Unit 4. Barren shales -"Spirifer" tullius bed

The calcareous shales of the coral-trilobite bed grade upward into fissile, medium-grey shales which in most localities in Erie County are almost completely barren of fossils except for rare Ambocoelia umbonata and choenetid brachiopods. An assemblage of fossils suggestive of the later Middle Devonian including "Spirifer" tullius, Schizobolus truncatus and Lieorhynchus multicostus occurs at Eighteenmile Creek in the upper portion of the "barren" shales. On the lake shore near Pike Creek where the Windom thins to about 9 ft., the author has found this fauna immediately overlying the coral-trilobite beds, suggesting that the intervening barren shales are totally absent here.

The maximum thickness of the barren shales is attained near the center of Erie County where about 30 ft. are exposed on Cazenovia and Buffalo Creeks. This suggests that a shallow basin with restricted circulation (and therefore conditions unfavorable to organisms) existed in this area.

Unit 5. Small Tropidoleptus Beds (Upper Windom Pyritized Assemblage)

An assemblage of pyritized fossils was discovered in an interval 2-3 ft. thick in the upper Window Shale underlying the Ambocoelia praeumbona beds at Penn Dixie Quarry in Bayview, Erie County. It has been possible to trace this assemblage southwest to Pike Creek where the Windom dips beneath the level of Lake Erie and east as far as Buffalo Creek, a total distance of about 30 miles along the outcrop. At present however, the geographic limits and the relationship of this fossil assemblage to other fossil beds occurring farther east are still undetermined. There is a close resemblance between this fossil assemblage and the older Ledyard pyrite fauna described by Fisher (1951) which suggests a recurrence of similar conditions.

Fossils in this horizon occur in soft, poorly-laminated, dark-grey shale which has a strong petroliferous odor when broken. Small twig-like pyrite nodules are very abundant in this horizon, but large nodules like those of the Ledyard are rare. Fossils occur free in the shale rather than as nuclei of pyrite nodules. Overall, the most abundant fossils in this interval are diminutive (probably immature) forms of the brachiopods Ambocoelia umbonata and Tropidoleptus carinatus. In some exposures at Cazenovia Creek near Spring Brook, nearly equal numbers of choenetids and small Tropidoleptus (which superficially resemble the former) are found. Elsewhere, Tropidoleptus is completely dominant, coating some bedding planes in great numbers.

Of other fossils, pyritized nuculoid pelecypods, nautiloids, the ammonoid Tornoceras uniangulare, and the gastropods Mourlonia itys and Bucanopsis leda are very abundant in local accumulations. The trilobite Greenops boothi is a moderately abundant member of the fauna, but Phacops rana is very rare. Rare specimens of the more "normal" benthonic species such as the brachiopods Mediospirifer audaculus and Mucrospirifer mucronatus and the corals Stereolasma rectum and Pleurodictyum sp. have been found. They are generally associated with pyritized wood fragments which suggests that they may have been rafted in or that they survived otherwise unfavorable conditions by attaching to waterlogged pieces of driftwood.

Fisher (1951) inferred a relationship between the unique assemblage of fossils (mainly diminutive brachiopods, mollusks and trilobites) and the occurrence of a band of pyrite, the "Marcasite horizon", in the upper Ledyard. He suggested that under conditions of restricted circulation, hydrogen sulfide resulting from fouling of the poorly-oxygenated seafloor by the organisms caused the precipitation of pyrite. It appears that similar conditions may have recurred in upper Windom seas in western Erie County; but at present, this hypothesis needs further study.

Unit 6. Praeumbona Beds

A series of calcareous shales and argillaceous limestones occurs in the upper Windom. In places the limestone occurs as a single massive band up to 2 ft. thick. Elsewhere, separate thinner beds or concretionary layers occur throughout an interval of about 5 ft. in the uppermost Windom. This calcareous interval contains a limited fauna dominated by the brachiopod Ambocoelia praeumbona, which is restricted to this portion of the Windom and to the overlying North Evans Limestone. The brachiopods, Lieorhynchus multicostus and Schizobolus truncatus, are associated with Ambocoelia praeumbona in the upper concretionary portion of this unit at Eighteenmile Creek. A few species of brachiopods, auloporid corals, crinoid fragments, and large Phacops rana make up the remainder of the Praeumbona bed fauna. This suggests a partial return to the more normal "Moscow" depositional conditions of the lower Windom. There is evidence that the uppermost beds of the Windom have been considerably eroded and that fossils of the Praeumbona Fauna have been reworked into the overlying North Evans Limestone of the Genesee Formation.

TABLE 1.

SUMMARY CHART
OF THE DISTRIBUTION
OF MEGAFOSSILS IN THE
WINDOM MEMBBR OF THE
MOSCOW FORMATION IN
WESTERN NEW YORK

	BASAL PHOSPHATIC ZONE	AMBOCOELIA BED	SPINATRYPA BED	CORAL TRILOBITE BED	SPIRIFER TULLIUS BED	SMALL TROPIDOLEPTUS INTERVAL	PRAEUMBONA BED	CONODONT BED (CONTACT)
	L	2	3	4	5	6	7	8
Plants:								
unidentified wood fragments	c			r	r	c		
Sponges:								
hexaxon spicules			c					
Coelenterates:								
Amplexiphylloides hamiltonae (Hall)				C*				
Aulocystis dichotoma (Grabau)			c_e					
A. jacksoni (Grabau)	c	c	c	c	c			
Cystiphylloides americanum (E.&H.)			L					
C. conifollis (Hall)			L					
Hadrophyllum woodi (Grabau)		c	c					
Heliophyllum halli (E.&H.)	R		L*					
Heterophrentis simplex (Hall)			L					
Pleurodictyum americanum (Romer)			L	c		R		
Stereolasma rectum (Hall)		c	r	C*		R		R
Stewartophyllum intermittens			c	c				
Streptalasma ungula (Hall)				c*				
Trachypora romingeri (Ross)	c_d		r					
Bryozoans:								
Fenestella emaciata (Hall)	r	r						
Leptotrypella ssp.			c					
Reptaria stolonifera (Rolle)						R_e		
Sulcoretipora incisurata (Hall)		c						
various encrusting trpostomes			c_e					
Echinodermata:								
Arthrocantha sp.				r				
Deltacrinus clarus (Hall)			r	r				
Hyperoblastus goldringae (Reimann)			r			R		
Synbathocrinus sp.			r					
plates		c	c	r		r	r	c
scutella-type holdfasts			c_e					

	1	2	3	4	5	6	7	8
Brachiopods:								
Ambocoelia praeumbona (Hall)							C*	c_d
A. spinosa (Clarke)						r		
A. umbonata		C*	c	c	c	L	L	
Athyris spiriferoides (Eaton)		c		r			r	
Atrypa reticularis (Linneaeus)			C	c			r	r_d
Camarotoechia c.f. horsfordi (Hall)	r_d							
Choenetes lepidus (Hall)							r	
C. vicinus (Castelnau)		c						
Craniops hamiltoniae (Hall)		c	c	c			?	
Cyrtina hamiltonensis (Hall)		r				r		
Douvillina inequistriata (Conrad)		r		c				
Elita fimbriata (Conrad)			r					
Emanuella subumbona (Hall)						c		
Leiorhynchus multicostum (Hall)							L	r_d
Longispina mucronatus (Hall)		c	c	c	c	L	c	
Mediospirifer audaculus (Conrad)		L	c			R	L	r_d
M. audaculus var. eatoni (Hall)			L					
Megastrophia concava (Hall)			c					
Mucrospirifer consobrinus (D'Orbrigny)		c	r	c				
M. mucronatus (Conrad)						r	r	r_d
Nucleospira concinna (Hall)		r						
Orbiculoidea doria (Hall)					L			
O. media (Hall)					L			
Petrocrania hamiltonae (Hall)			r_e					
Productella spinulcosta (Hall)					L			
Protoleptostrophia perplana (Conrad)		c	r	r				
Rhipidomella idonea (Hall)			r					
R. vanuxemi (Hall)		c	c	c				
R. penelope (Hall)			C					
Schizobolus truncatus (Hall)					L*		L*	
Schuchertella arctostriatus (Hall)		c	?	c			r	
Spinatrypa spinosa (Hall)			C*					
Spinocyrtia granulosa (Conrad)	c_d		r					
"Spirifer tullius (Hall)						L*		
Tropidoleptus carinatus (Conrad)						C*		
MOLLUSKS:								
Circoconarida:								
Hyolithes sp.	R					r		
Styliolina fissurella (Hall)				c		c	c	c
Gastropoda:								
Bucanopsis leda (Hall)					r	c		
unident. bellerophontids	c			r				
Cyrtolites sp.						r		
Loxonema hamiltonae (Hall)			r_i	r_i		R		
Mourlonia itys (Hall)						c		
Naticonema lineata (Conrad)	r		c	c		r	r	
Platyceras ssp.			r	r				

	1	2	3	4	5	6	7	8
Pelecypods:								
Cardiola sp.						R		
Cypricardinia indenta (Hall)		c						
Grammysia arcuata (Conrad)						r		
Modiella pygmaea (Conrad)						r		
Nucula corbuliformis (Hall)					r	c*		
N. oblongatus sp.						r		
Nuculites triqueter (Conrad						c		
Palaeoneilo fecunda (Hall)		r						
P. tenuistriata		c	r_i	c				
Pseudaviculopecten princeps (Conrad)			L					
Pterinopecten conspectus (Hall)						c		
Cephalopods:								
Bactrites arkonenesis						L		
Michelenoceras ssp.				c		L		
Spyroceras nuntium (Hall)				c				
Tornoceras uniangulare (Conrad)				R		c*		
Trilobites:								
Basidechenella rowi (Green)				R				
Dipleura dekayi (Green)				R				
Greenops boothi (Green)		r	r	c		c		
Phacops rana (Green)	c_d	c	c	C*		r	c	
Graptolites:								
Dictyonema hamiltonae				R				

Symbols: The following symbols are used in this chart to designate the abundance of various species.

- C - very abundant, making up a high percentage of a particular fauna
- c - common usually present (50 - 500 specimens have been observed at all outcrops)
- r - rare (5 - 10) specimens have been observed at all outcrops)
- R - extremely rare, (only 1-5 specimens have been collected)
- L - found commonly only in a few localized areas elsewhere rare or lacking

Various other notations used as subscripts in conjunction with abundance are:

- e - occurs as an encrusting epizoite or other fossils
- i - occurs as an impression on basal attachment of corals
- d - derived from some other unit; a secondary reworked fossil
- * - an index fossil of a particular bed; i.e. restricted nearly or entirely to one bed.

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Rickard, L. V., 1964, Correlation of the Devonian rocks in New York State, N.Y. State Mus. and Sci. Serv. Map and chart series No. 15.

TRIP G - A SELECTED MIDDLE DEVONIAN (HAMILTON) FOSSIL LOCALITY REFERENCE SECTION

Carlton E. Brett

Total Miles	Miles from last point	Route Description
		We will take the N.Y. Thruway to Exit 56 where the road log begins.
		Take Exit 56 from the N.Y. Thruway to Mile Strip Road. Bear right around ramp to toll booth, then straight ahead to intersection.
0.0	0.0	BEGIN ROAD LOG AT TOLL BOOTH.
.8	.8	Intersection Mile Strip Road turn right (west)
1.0	.2	Intersection of U.S. 62 South Park Rd. Turn left (south)
2.2	1.2	Intersection with Big Tree Road. Turn right (west) onto Big Tree Road.
2.6	.4	Intersection of first road on the left,near West Ave., which cuts across the intersection of Bayview and Big Tree Roads. Park along this road. Walk back (north) across Big Tree Road and through gate onto gravel road of Penn Dixie Cement Co. Proceed north into bare shale outcrop area and turn right into the east side of the quarry.

STOP 1. Penn Dixie Quarry, Buffalo Southeast quadrangle: The reference section that has been selected for this quadrangle is a large shale quarry (formerly owned by Penn Dixie Cement Co. of Woodlawn) north of Big Tree Rd. just west of the Erie-Lackawana tracks in the Town of Hamburg.

The main access road to this quarry is located near the corner of Big Tree Rd. and Bayview Rd. This road divides the quarry--actually a large shale pit--into east and west sides. The west side is older and has not been used for several years consequently it is highly weathered and is beginning to

Total Miles	Miles from last point	Route description

grow in with grass in a few spots. It is still owned by Penn Dixie Co. although this company is out of business in Buffalo. The east side is somewhat larger, is floored almost entirely by grey Windom Shale (Moscow Formation), and was actively used up to 1970 as a source of landfill. Presently it is owned by Sipprell Bros. Real Estate, Hamburg.

1A. East Side of Quarry - Upper Windom

The south side of the quarry forms a slight bank (8-10 ft. high). In places the uppermost Windom beds and the overlying Genundewa-West River are exposed. There is no Genesee black shale nor any Penn Yan exposed here. Rather, the Genundewa Limestone is in direct contact with the "Conodont bed".

The Conodont bed is a coarse-weathering, dark-grey (weathering yellowish-buff) limestone. Fish plates, teeth, and mandibles are very common in this limestone as are conodonts. This bed which is equivalent to the North Evans of Wells (1964)*yields abundant condonts and bone fragments when digested with diluted acetic acid. Worn, broken valves of brachiopods (Ambocoelia praeumbona, Atrypa reticularis, and Mucrospirifer mucronatus) also occur in this bed, apparently derived from the underlying limestone.

The uppermost Windom is a calcareous, concretionary layer about one foot thick, weathering light-yellowish, but light-grey when fresh, and containing fossils (Ambocoelia praeumbona, Phacops, Mucrospirifer) which are quite abundant in spots. Directly above this (in some places) is a thin (1-2 in.) layer of argillaceous limestone. It occurs on the underside of the Conodont limestone and is partly or entirely incorporated into the North Evans. Angular slabs as well as rounded pebbles, can be seen "floating" in the crinoidal bone-bed matrix of the latter. It appears brecciated and the fragments have cracks in them which are "squeezed" full of crinoidal matrix. Some greenish stains on the concretionary bed resemble glauconite.

*In Rickard (1964)

Total Miles	Miles from last point	Route Description

The upper Windom is shaley below the uppermost concretionary layer for about 3 ft. and is "barren" of fossils. The "Praeumbona bed", a calcareous, slightly concretionary interval about 1½ ft. thick caps the small knob in the southwest corner of the east side of the quarry. Abundant Ambocoelia praeumbona (in patches) as well as Atrypa, Athyris, Devonochocnetes, auloporid corals and large trilobites (Phacops) occur in this unit. Below this is a shale interval some 5 ft. thick extending down to the next thin calcareous bands. This interval contains pyritized fossils and a fauna similar to that of the Ledyard shale (Fisher 1951). Pyrite nodules also occur here, but they are almost always small twig-like bodies unlike the large nodules found at Alden. The most abundant fossils here are Nuculites, tiny Tropidoleptus and Ambocoelia, the ammonoid Tornoceras uniangulare, nautiloid fragments and the gastropod Mourlonia. Rarer items include coiled Greenops and wood fragments. At present, this undescribed occurrence of pyritized fossils is under study.

The remainder of the middle Windom which covers most of the quarry floor is barren of fossils down to the lower 3-4 ft. Three thin calcareous shale bands about 2 in. thick are exposed just below the pyrite zone and represents distinct traceable horizons (no fossils).

1B. Tichenor limestone and coral-trilobite beds

In the northeast corner of the quarry, mounds of bulldozed shale have been left. These mark the position of the fossiliferous lower Windom. Here the contact between the Windom and the Tichenor limestone is exposed in a few spots due to the occurrence of small swells* which dome the Tichenor up 5-6 ft. (in maximum relief) above its

*The cause of this structural feature is unexplained; such features are rare in Western New York

Total Miles	Miles from last point	Route Description

normal position. The upper surface of the limestone has a very rusty appearance due to large amounts of pyrite. Fossils in the Tichenor, of which Spinocyrtia and crinoid predominate, are somewhat abraded. There are not as many Favosites or other corals as elsewhere. The upper surface of the Tichenor limestone appears to have been subjected to erosion prior to Windom deposition. There are pockets in the surface of the Tichenor which are filled with soft, grey shale (Windom). The lowest beds of the Windom here are very soft, friable, grey shales containing Ambocoelia (though not in great abundance as at Eighteenmile Creek). These occupy the lower foot of the Windom.

The coral layer fauna of the Spinatrypa bed is well-developed at this locality, though not as rich in Heliophyllum or Cytiphylloides as that of Eighteenmile Creek. In 1970 when bulldozers were still working in this area, it was possible to collect literally bushels of excellently preserved Cystiphylloides, Heterophrentis, Atrypa, Spinatrypa, and Mediospirifer from this bed. Rhipidomella, Douvillina, Megastrophia and rarely Elytha are also found in this layer. The total thickness of this layer is probably only about 3-5 in.

Some 2 ft. up from the Tichenor limestone the shale becomes calcareous. These harder layers stand out in several spots surrounding the Tichenor "domes". This is the coral-trilobite horizon characterized by a low diversity fauna made up chiefly of trilobites and rugose corals. Phacops predominates here and occurs most frequently as somewhat distorted, coiled individuals when complete. Flat specimens can also be obtained though more rarely and occassionally they are found in clusters. I collected here a single slab with 11 complete individuals of Phacops rana. Greenops and Dechenella are also rarely found. Brachiopods are much reduced in this horizon, but Atrypa, Rhipodemella, Athyris and Mucrospirifer consobrinus are present. Trace fossils

Total Miles	Miles from last point	Route Description
		are particularly prevalent at this horizon, the surfaces of otherwise barren slabs show long sinuous "trails" of limonite suggesting worm or gastropod tracks. Typically, the lower beds are packed with rugose corals, but like the trilobites, their distribution tends to be patchy. Traces of nautiloids (Spyroceras, "Orthoceras") are fairly common and I have collected a very faint trace of a large goniatite here. The area around the outcropping edges of the "Trilobite-beds" are considerably worked by collectors who have made extensive "pits" and debris piles. These calcareous layers are about one foot thick and grade into barren middle Windom seen in section 1A.
		Return to the bus and retrace the route to Fredonia.

GEOLOGY AND OCCURRENCE OF OIL AND GAS IN CHAUTAUQUA COUNTY, NEW YORK

Arthur M. Van Tyne, Senior Geologist-in-Charge, Oil and Gas Office, Geological Survey, New York State Museum and Science Service, Alfred, New York

HISTORY-SHALE GAS DRILLING

The first natural gas well completed in New York State, and the United States, was drilled at Fredonia in 1821 to a depth of 70 feet. The owner and driller of the well, William A. Hart, was the first man to market natural gas in the United States and, through his efforts, Fredonia became the first community in the United States to be lighted by natural gas. During his visit to the village in June of 1825 General Lafayette is said to have been delighted by the gas light illumination. The well produced gas in declining volume for a number of years but no enlargement of service was possible. Therefore, in order to secure a new supply of gas, Mr. Preston Barmore drilled a new gas well during the year 1858. The well was located about one mile northwest of the Hart well and consisted of a dug cavity about 30 feet deep in the bottom of which two holes were drilled to depths of 100 and 150 feet. In the fall of 1858 Mr. Barmore, together with Elias Forbes, formed the Fredonia Gas Light Company and commenced supplying gas to the village. The first deep well was drilled by Alvah Colburn in 1871 at his mill located south of Main Street. The well which was drilled to a depth of 1,256 feet encountered gas between 130 to 300 feet, and reached the Onondaga limestone at 1,079 feet. A concerted effort to find more gas was initiated and it is estimated that 300 shale gas wells were drilled in Chautauqua County towards that end.

Medina Drilling

During the autumn of 1886, and the first half of 1887, the first Medina Sandstone well in the county was drilled about one-half mile southeast of the village by the Fredonia Gas and Fuel Company. This well reached a total depth of a little over 2,500 feet and obtained production of about 7,000 cubic feet of gas per day, with a maximum pressure of 160 pounds, from the Medina. Additional Medina drilling did not take place until 1903 when the South Shore Gas Company and the Brocton Gas Company began to drill Medina wells in the Brocton and Silver Springs areas. This development was probably spurred by successful Medina drilling to the north in Erie County around the turn of the century. Since 1903, drilling in Chautauqua County has continued on a sporadic basis with the majority of wells being drilled for Medina sandstone gas production. It appears that the present spurt in Medina drilling, commenced in 1973, will surpass all previous periods of drilling in the total number of wells drilled. It is estimated that about 700 Medina wells have been drilled to date in Chautauqua County.

Deep Drilling

The first of ten deep wells drilled in Chautauqua County was the Cassity #1 of Frost Gas located one-half mile east of Dunkirk. This well was originally drilled to a depth of 2,052 feet in 1908 and was re-entered and drilled deeper in 1916. The well topped the Trenton at 4,010 feet and was stoped at 4,035 feet. The Niehaus well, located two and one-half miles northeast of Dunkirk, was also an old well which was drilled deeper to 4,517 feet. The drilling was stopped in 1949 after encountering a good show of gas and considerable salt water in the Cambrian Theresa (Galway) Sandstone.

Since then, eight more deep wells have been completed all ending in Cambrian sandstones except one which stopped in the Trenton. No well has been drilled to basement rocks in Chautauqua County, but the deepest well in the county, the Harrington #1 of Wolf's Head Oil located six miles northwest of Jamestown and one-quarter mile east of Ellery was completed at 7,694 feet in the Cambrian Potsdam Sandstone which overlies basement rocks. Two of the deep wells had good shows of gas from Cambrian sandstones, but no commercial gas or oil production has so far been found in the Cambro-Ordovician rocks of Chautauqua County.

OIL EXPLORATION

During the drilling of the early shale gas wells, a small amount of oil was often recovered along with the gas. However, the first intensive drilling program to find oil in Chautauqua County did not take place until 1919 when the Poland Oil and Gas Company began to drill in Poland Township, about eight miles east of Jamestown. Three shallow wells were drilled on Mud Creek and some gas, but no oil, was found.

Subsequently, 19 wells up to 800 feet deep were drilled about one and one-half miles south of Clark. Although some oil was found only a small amount was ever produced and the wells were abandoned. Other operators drilled several wells three and one-half miles southwest of the Poland Township drilling, about two miles north of Frewsburg in Carroll Township. These wells produced a small amount of oil but were eventually abandoned.

In September, 1924 the Republic Light, Heat and Power Company, while drilling for gas on the Jacob Yonkers farm three and one-half miles northeast of Fredonia in Sheridan Township, encountered a flow of 100 barrels of oil per day together with a total flow of 2,400 Mcf (thousand cubic feet) of gas per day from the Onondaga limestone ("Flint" of the drillers). The Onondaga was topped at 1,315 feet and the oil flow occurred at 1,485 feet. One other well drilled nearby encountered some oil in this same zone but oil production from both wells declined rapidly and apparently only a few thousand barrels of oil were produced. One year later, in September, 1925, oil was found in this same zone in a well drilled on the Muscato farm located two miles east of Fredonia and two miles southwest of the Yonkers well. Several wells were eventually drilled on this farm, but total oil production is said to have been less than 10,000 barrels.

In 1945 Todd M. Pettigrew, backed by the Thomas brothers of Chicago, began a drilling program to develop oil production in the Busti area located about four miles southwest of Jamestown. Several wells were drilled over a three year period and a modest production was established from the Glade sand at about 700 feet in depth. However, the sand is tight and initial production declined rapidly making the operation uneconomic. By late 1948 the properties were abandoned or farmed-out to other interests who later abandoned them. An interesting aspect of the Pettigrew operation was the use of a "secret" electronic device to aid in locating oil bearing rocks.

The Pettigrew operation was somewhat premature in attempting to develop economic production in tight sandstones such as the Glade. It was not until the mid-1950's development of the hydraulic fracturing technique of well stimulation and its subsequent introduction into the Appalachian area that the oil in such rocks could be successfully produced. In New York the first wells were "fraced" in the late 1950's and early 1960's. The highly successful results of these early treatments caused a rapid increase in the useage of hydraulic fracturing so that by the late 1960's and early 1970's this procedure had almost completely supplanted shooting with nitroglycerin as a well stimulation method. Through the use of this technique the Busti area development has been revived. Starting in 1962, and still proceeding, some 315 oil wells have been drilled in the Busti Field. Total oil production from Busti, partly from actual production figures and partly estimated, is 775,000 barrels with estimated primary reserves of 500,000 barrels. It is estimated that 375 oil, or oil exploratory, wells have been drilled in Chautauqua County.

STRATIGRAPHY OF OIL AND GAS PRODUCING ROCKS

A generalized stratigraphic section of the rocks present on the surface and in the subsurface of Chautauqua County is shown in Fig. 1. About 2,100 feet of section, from the Knapp conglomerate of Mississippian age at the top to the Upper Devonian West Falls Group at the base, is exposed in outcrop. Beneath this there is an additional thickness of about 7,500 feet of sedimentary section above Pre-Cambrian rocks. The early shale gas wells were drilled in rocks of the Canadaway Group as are the oil wells in the eastern part of the county. The top of the major gas producing zone in the county, the Lower Silurian Medina Sandstone, is found at shallowest depths of 1,650 to 1,700 feet at a surface elevation of 600 feet in Hanover Township in the northeastern corner of the county. The deepest Medina penetration was registered in the Weiss #1 dry hole located in the Kiantone area about five miles southeast of Jamestown. Here the Medina top was found at 4,194 feet at a surface elevation of 1,244 feet.

Period		Group	Formation		THICKNESS	REPORTS OF
Devonian	UPPER	*CONEWANGO*		Sh, Ss, Cgl	0 - 600'	
		CONNEAUT	CHADAKOIN	Sh, Ss	0 - 600'	Oil
		CANADAWAY	UNDIFF.▪ •	Sh & Ss	700'-1200'	Oil
			PERRYSBURG#	Sh, Ss		Oil, Gas
		JAVA		Sh, Ss	100'-700'	
		WEST FALLS		Sh, Ss, Sh	415'-1950'	Gas
		SONYEA		Sh	45'-650'	Gas
		GENESEE		Sh, Ss, Sh	10'-900'	
	?		TULLY	Ls	0-50'	Gas
	MIDDLE	*HAMILTON*	MOSCOW	Sh	215'-790'	Gas
			LUDLOWVILLE	Sh		
			SKANEATELES	Sh		
			MARCELLUS	Sh		Gas
			ONONDAGA	Ls	20'-235'	Gas, Oil
	LOWER	*ULSTER*	SPRINGVALE	Ss	0-10'	
			ORISKANY	Ss	0-70'	Gas
		HELDERBERG	MANLIUS	Ls	0-220'	
			RONDOUT	Dol		
Silurian	UPPER	*BERTIE*	AKRON	Dol	0-45'	
		SALINA	CAMILLUS	Sh, Gypsum	403'-2295'	
			SYRACUSE	Dol, Sh, Salt		
			VERNON	Sh		
	MIDDLE		LOCKPORT	Dol	165'-250'	Gas
		CLINTON	ROCHESTER	Sh	123'-450'	Gas
			IRONDEQUOIT	Ls		
			SODUS	Sh		
			REYNALES	Ls		
	LOWER	*MEDINA*	THOROLD	Ss	0-15'	
			GRIMSBY	Sh, Ss	75'-125'	Gas
			WHIRLPOOL	Ss	0-25'	Gas
Ordovician	UPPER		QUEENSTON	Sh	715'-1010'	Gas
			OSWEGO	Ss	90'-675'	
			LORRAINE	Sh	560'-710'	
	MIDDLE	*TRENTON-BLACK RIVER*	UTICA	Sh	130'-270'	Gas
			TRENTON	Ls	410'-525'	
			BLACK RIVER	Ls	360'-470'	
	LOWER	*BEEKMANTOWN*	TRIBES HILL	Ls	0-50'	
Cambrian	UPPER		LITTLE FALLS	Dol	0-955'	
			THERESA	Dol & Ss	475'-860'	Gas
			POTSDAM	Ss	30'-365'	Gas & Oil-reported
PRECAMBRIAN			GNEISS, MARBLE, QUARTZITE, etc.			6/74 11/69

Fig. 1.--Composite Paleozoic stratigraphic section for western New York, west of long. 76°30'. (Auburn area)

•Includes Glade and Bradford 1st
▪Includes Chipmunk, Bradford 2nd, Scio, Penny
#Includes Bradford 3rd, Richburg, Humphrey, Clarksville, Upper Waugh 8 Porter, Lower Waugh 8 Porter, Fulmer Valley

The Medina averages 150 feet in thickness in Chautauqua County. From top to bottom the Medina Group consists of: Thorold Sandstone; a light-grayish-green, fine-grained sandstone which is 3 to 6 feet thick; Grimsby Sandstone, or Red Medina of the drillers, a fine- to medium-grained, red and grayish-white sandstone interbedded with red and green shales averaging 90 to 120 feet thick; Power Glen Formation of gray shale and interbedded gay sandstones which is 25 to 40 feet thick and wedges out towards the eastern part of the county and the Whirlpool Sandstone, or White Medina of the drillers, a light-gray to white, medium- to coarse-grained sandstone which is 8 to 14 feet thick in western Chautauqua County, but which thins towards the eastern portion of the county.

Productive Characteristics of the Medina Sandstone

Gas production occurs from scattered zones in the Grimsby in most fields, but high flows were encountered in the Whirlpool in Lake Shore and Sheridan Fields in Arkwright, Hanover and Sheridan Townships. Both Grimsby and Whirlpool produce gas in these two fields, but in the other 14 gas fields in Chautauqua County the Grimsby is the major gas producer with the Whirlpool producing only small amounts of gas. This is probably due to the thinness of the unit and also to the quartzitic nature of the Whirlpool. Gas accumulations occur where cementation of the sand grains has not obliterated porosity. Improved data from newer drilling indicates that minor structural features are imposed on the generally monoclinal, southeasterly dip and these appear, in some cases, to be related to the gas accumulations.

Gas flows reportedly have ranged from less than 100 Mcf per day to wells in Hanover Township which are recorded as having had natural flows of 8 to 12 million cubic feet of gas per day. Wells which were considered as dry holes in the early days are now routinely fracture treated to make successful producers. Many wells with natural open flows of 100 Mcf per day, or less, have been so treated to make producing wells. The porosity of producing zones in the Medina averages from 6 to 10 percent while rock (or surface) pressure in producing gas wells varies from 310 to 1200 psi, indicating that the Medina is an underpressured reservoir. Most rock pressures fall in the 550 to 850 psi range. It is estimated that at least 25 billion cubic feet of gas have been produced from the Medina in Chautauqua County to date.

Drilling and Completion Methods

Medina gas wells were drilled by cable tool rigs in the past but since the 1960's occasional Medina wells have been drilled by rotary rigs due to the declining numbers of cable tool rigs in service and to the greater speed of rotary drilling. In 1973, due to the commencement of a large-scale Medina drilling program in Chautauqua County, a number of rotary rigs were brought into the area and almost all Medina well drilling is now being accomplished by the rotary method. Current practice is to drill a surface hole through surficial, or weathered, material and run

11 3/4 inch, or 10 inch, casing cemented to surface. Some operators are drilling the surface hole with mud and are not running this surface casing or are using a temporary 12 inch galvanized iron casing. Intermediate, or water, string of 8 5/8 inch, or 7 inch, casing is then run to depths of 225 feet to about 400 feet (through known fresh water zones) and cemented in place. Finally, a 7 7/8 inch hole is carried to total depth and 4 1/2 inch production string is run through the Medina and cemented in place. The sand is then perforated through casing opposite productive zones determined by analysis of nuclear logs, fracture treated and shut-in for pipeline hookup and production. The size of current frac treatments averages 500 to 1000 barrels (21,000 to 42,000 gallons) of water and 30,000 to 55,000 pounds of sand. Breakdown pressures have varied from 2,000 to 4,000 psi. The total cost for a completed well varies between $40,000 to $50,000 per well.

Gas Prices

The wellhead price paid by the Utility companies for natural gas in New York remained stable at 30¢ per Mcf for many years but in 1972 was raised to 50¢ per Mcf and in early 1973 to 60¢ per Mcf. In the spring of 1974 this price was raised again to an annual average of 80¢ per Mcf. This price applies only to intrastate gas (gas produced and used within the state) and not to gas sold for interstate use. The Federal Power Commission, which regulates the price paid for interstate gas, has just approved an increase to 42¢ per Mcf for new interstate gas. In some cases higher prices than those mentioned have been obtained by selling gas to individual intrastate consumers.

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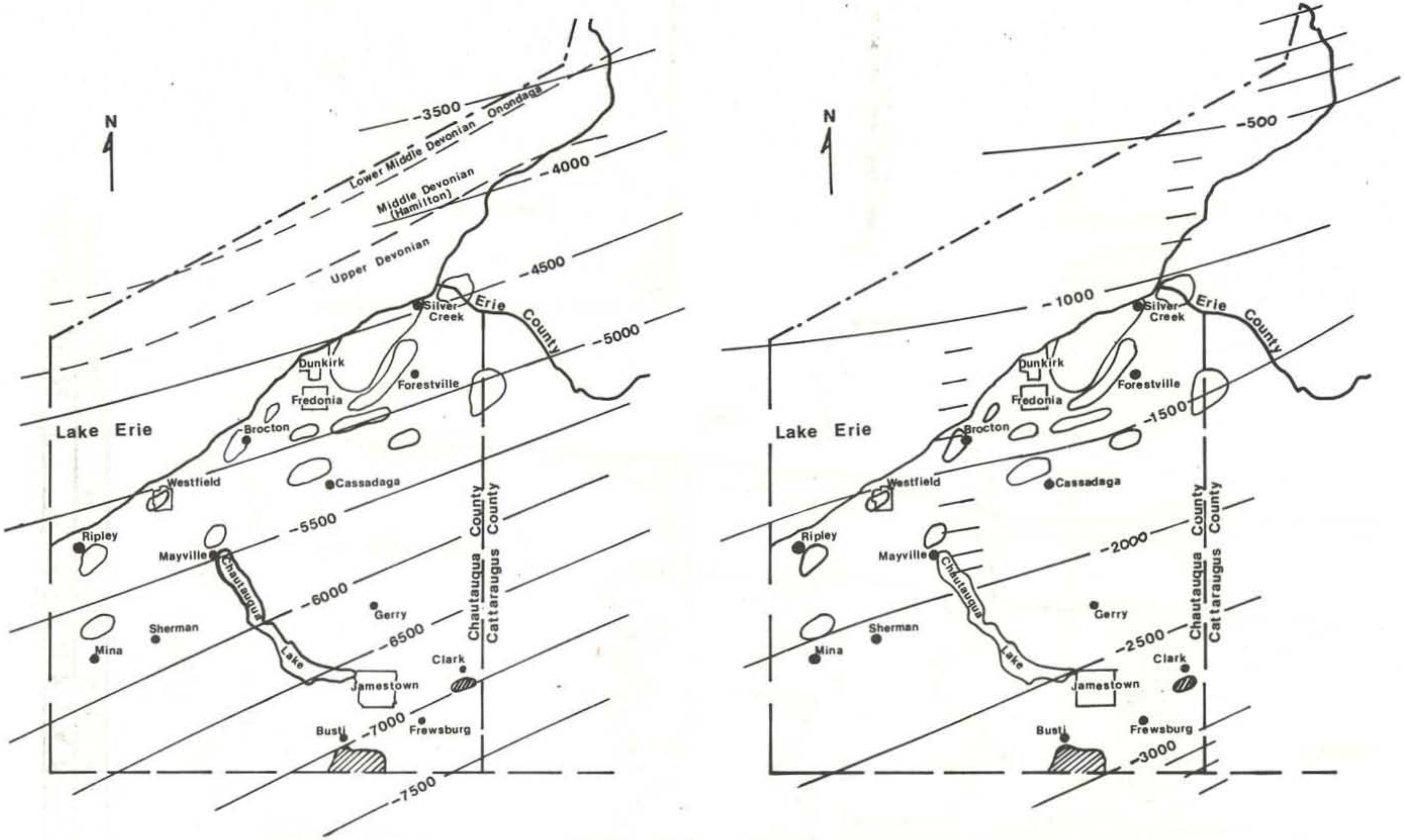

Figure 2. Subsea contours on top of (a) Pre-Cambrian and (b) Grimsby Formation

Gas field — Oil field

outcrop distribution, major units