ORDOVICIAN AND SILURIAN STRATA IN THE GENESEE VALLEY AREA SEQUENCES, CYCLES AND FACIES

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INTRODUCTION

Upper Ordovician and Silurian strata in New York State are well-known from their spectacular exposures in the Niagara and Genesee River Gorges. Because of the excellent exposures in western New York, the descriptive stratigraphy of these units is well-refined, and the interval has recently been used as a test case for models of eustatic and tectonic stratigraphic dynamics. Important modern works concerning the litho- and biostratigraphy of these strata include Gillette (1947), Fisher (1953, 1960, 1966), Kilgour (1963), Rexroad and Rickard (1965), Zenger (1965, 1971), Rickard (1969, 1975), Martini (1971), Brett (1983), Duke (1991) and LoDuca and Brett (1991). Allostratigraphic analyses have been performed by Duke and Fawcett (1987), Brett et al. (1990a, b; 1991) and Goodman and Brett (1994).

The Upper Ordovician and Silurian strata of the Genesee Valley and surrounding areas were deposited near the northern reaches of a dynamic and rapidly evolving Appalachian foreland basin. The striking patterns of unconformity and lateral basin axis shift are striking given that the Late Ordovician and Silurian Periods are generally considered to be times of tectonic quiescence between the Taconic (late Middle Ordovician) and Acadian (Middle to Late Devonian) Orogenies. Foreland basin flexure produced asymmetric marginal unconformities, but the differential subsidence did not obscure relative sea-level trends in litho- and biofacies that correlate with patterns in other basins. Thus, the stratigraphic interval exposed in the Genesee Gorge is an excellent field laboratory for the interaction between tectonic foreland basin flexure and eustatic sea-level changes.

During the Late Ordovician and Silurian, the northern Appalachian Basin was situated within a subtropical climatic belt, probably at about 20 to 25 degrees south latitude (Van der Voo, 1988, Witzke, 1990). Climates apparently oscillated from relatively arid during the Late Ordovician to humid during the Early Silurian and back to very arid during the Late Silurian. During the Late Ordovician and Early Silurian, the bulk of the basin fill in western New York represents marginal marine to nonmarine settings. Siliciclastic sediment that infilled the basin appears to have been shed from rejuvenated Taconic source areas primarily located to the east and

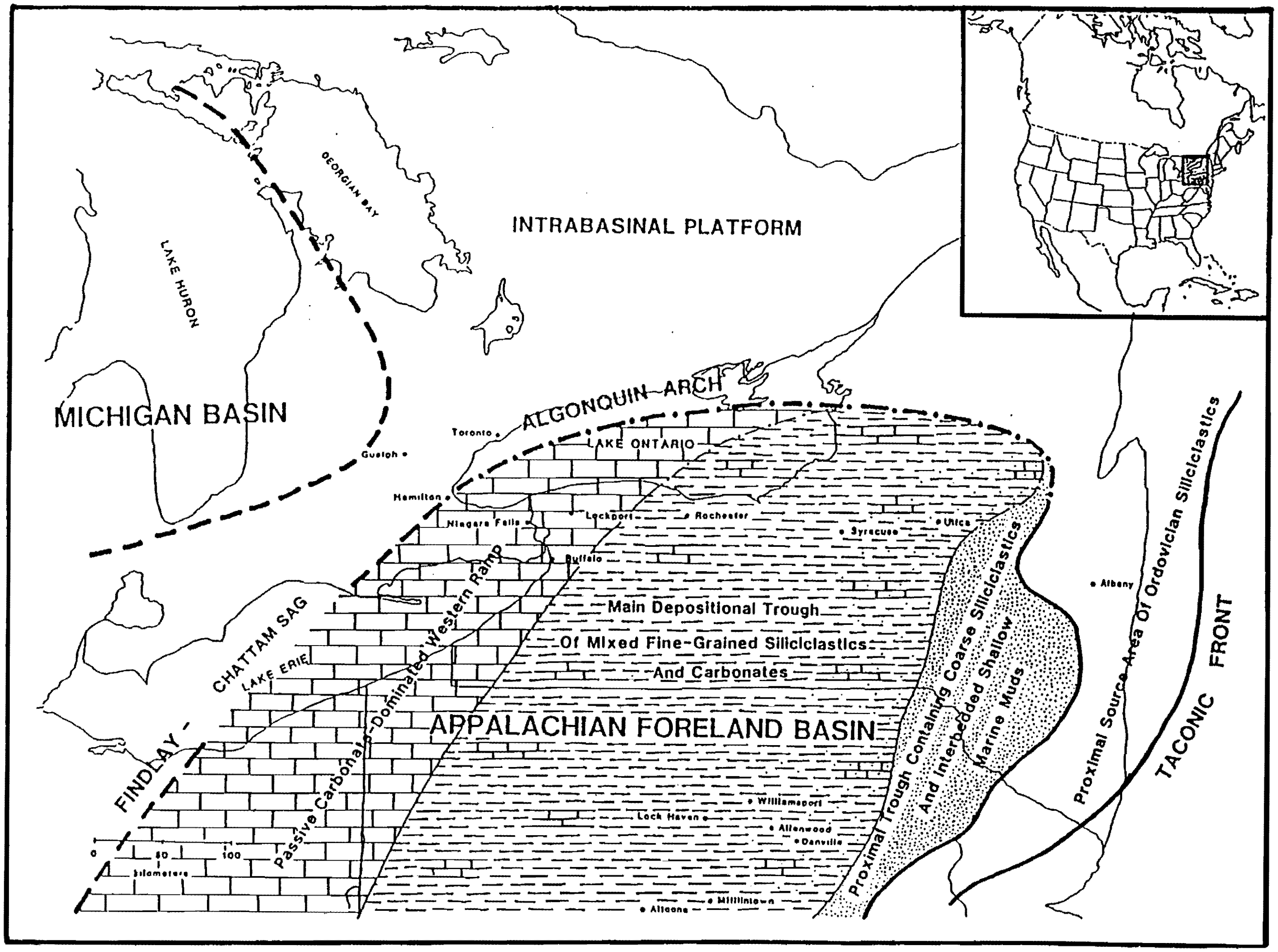

Figure 1. Paleogeographic map of the northern Appalachian foreland basin during medial Silurian time; inset map shows position of the study area within North America. From Brett and others (1990).

southeast. Open marine facies that are time-correlative to the Queenston Shale and Medina Group are situated northwest of the Niagara region.

A low forebulge, Algonquin was intermittently uplifted along to northwestern rim of the basin (Figure 1).

Subtidal ramp carbonates are preserved in the lower Clinton Group between Niagara and Wayne Counties, New York. The onset of clean carbonate deposition stratigraphically above a low angle, regional unconformity at the top of the Medina Group suggests structural uplifting of the Algonquin Arch during lower Clinton time. Unfortunately, a late Llandoverian unconformity that divides the Clinton Group into two units removed a significant portion of the lower Clinton stratigraphic record in western New York. Consequently, paleogeographic reconstructions can only be indirectly inferred from biofacies and textural trends in the truncated carbonates and siliciclastic facies belts situated farther east.

During the Late Silurian (Wenlockian and Ludlovian Epochs), upper Clinton and Lockport carbonates accumulated on the western basin ramp. Except for the Wenlockian eustatic sea-level highstand during which the fossiliferous Rochester Shale accumulated over significant portions of the basin, persistent siliciclastic sedimentation was restricted to the eastern ramp and basin center. Shales and mudstones commonly occupy the central, offshore facies belt. The eastern strandline facies belt is dominated by sandstone and conglomerate.

Late in the Silurian (Pridolian Epoch), circulation within the basin became restricted in response to increased aridity and fringing reefs of the Guelph Formation (Rickard, 1969). Increased siliciclastic sedimentation associated with the formation of the Bloomsburg-Vernon deltaic complex may signal rejuvenation of the eastern basin flank and cannibalization of Upper Ordovician and Lower Silurian strata during the Salinic Disturbance. Following accumulation of deltaic red beds across western New York, a thick sequence of peritidal carbonates, mudstones and evaporites (Salina Group) accumulated in western New York and surrounding areas. Resumption of more normal shallow marine conditions is recorded in the Cobleskill biohermal dolostone which is the youngest pre-Helderberg Silurian unit preserved west of Cayuga County.

In this paper, details of upper Ordovician and Silurian stratigraphy are provided in a regional context so that a framework may be established for the Rochester area facies. Where interpretations of allostratigraphy have been developed, depositional sequences and smaller, component cycles are discussed. This presentation proceeds in ascending stratigraphic order.

QUEENSTON FORMATION

The Upper Ordovician Queenston Formation is the oldest formation that crops out in western New York. In western New York and Ontario, the Queenston Formation consists of predominantly red shales and subordinate fine-grained sandstones, in contrast to the sandstone-dominated facies of the Queenston of central New York and of the correlative Juniata Formation in Pennsylvania.

The Queenston Formation represents the accumulation of molasse during late stages of the Taconic orogeny. In New York and Ontario, the Queenston Formation conformably overlies unfossiliferous peritidal to nonmarine sandstone (Oswego Sandstone) and fossiliferous grey and green marine shales and

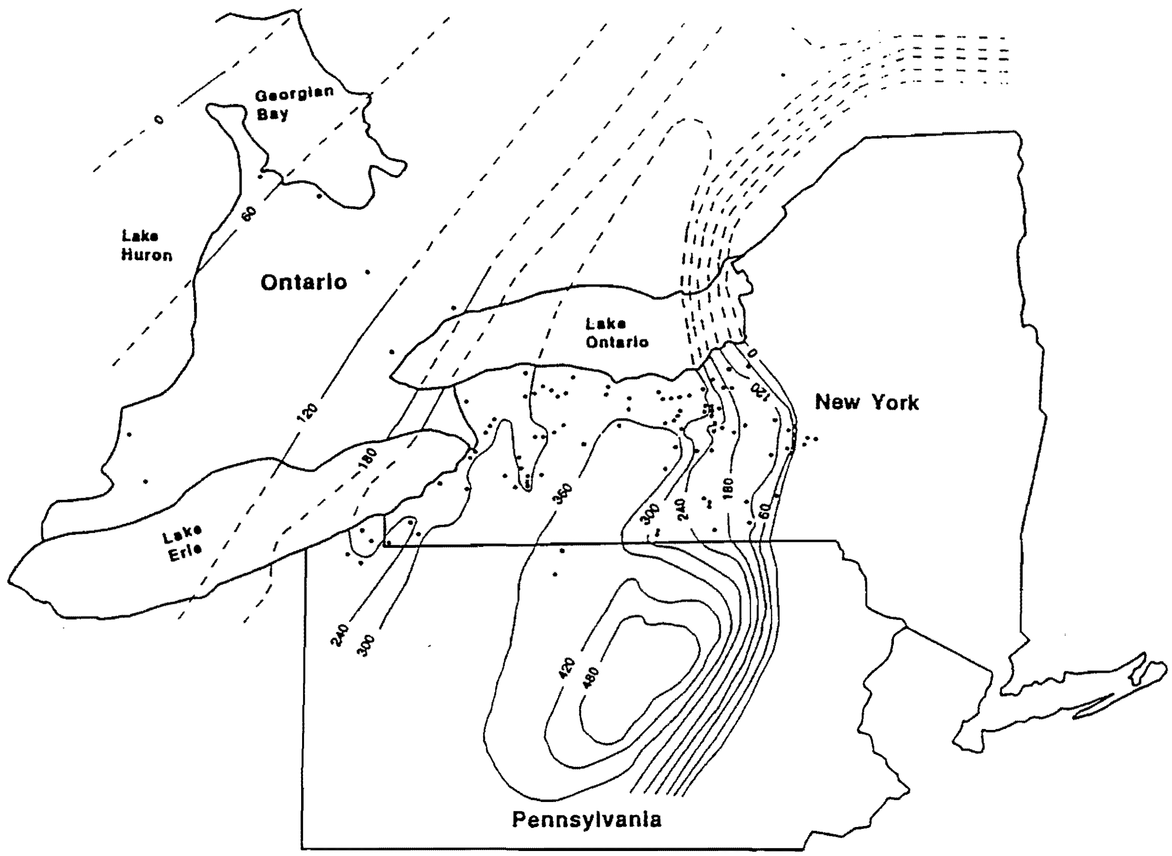

Figure 2. Isopach map of the Queenston Formation. Dashed lines are conjectural. Isopachs in Pennsylvania are based primarily on work by Swartz (1946).

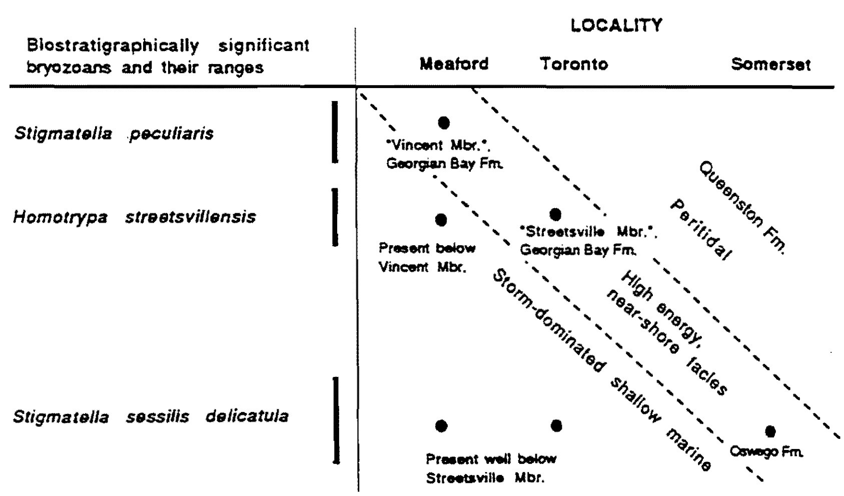

Figure 3. Bryozoan biostratigraphy of Queenston and correlative strata. High energy nearshore facies and Queenston red-bed facies appear to be older to the southeast. Uppermost Oswego strata at Somerset, N.Y. are time-correlative with middle Georgian Bay strata at Meadford, Ontario.

sandstones. The base of the Queenston, defined by the lowest occurrence of red beds, largely corresponds to the onset of peritidal conditions. The Queenston reaches a maximum thickness of approximately 360 m in western New York (Fig. 2).

The Queenston Formation is part of a progradational succession that filled the Appalachian foreland basin during the Late Ordovician glacioeustatic sealevel fall. The regressive maximum is recorded by the Cherokee unconformity that serves as the Queenston-Medina contact in western New York and Ontario. Queenston strata comprise transgressive-regressive cycles of a number of scales. These cycles are most apparent in the lower part of the formation in western New York and throughout the section in Ontario where green and red shale facies are interbedded. For example, in the Bruce Peninsula region, a green calcareous tongue of the Queenston is sandwiched between gypsum-rich, red shales containing desiccation-cracks. These green calcareous strata include biomicrites and biosparites that contain a normal marine fauna. In the Toronto area, this "mid-Queenston" marine incursion is represented by peritidal, gypsum-rich, calcareous strata bounded by non-marine, deltaic deposits (described below). This mid-Queenston transgressive interval can be divided into three, smaller, transgressive- regressive cycles which are manifested as alternating fossiliferous and gypsum-rich strata in the Bruce Peninsula region and as alternating gypsum-rich and non-gypsiferous, unfossiliferous strata in the Toronto area.

Although the Queenston strata in New York are generally unfossiliferous, the age of the Queenston can be constrained by the biostratigraphy of fossiliferous deposits which directly underlie it. Fritz (1926, 1982) noted that different stratigraphic levels in the underlying Georgian Bay Formation of Ontario contained characteristic bryozoa and, to some degree, defined a bryozoan biostratigraphy. Her work indicates that the uppermost marine strata below the Queenston Formation in the Toronto area contain a slightly older bryozoan assemblage than do lithostratigraphically correlative strata from farther northwest (Meaford, Ontario). Fossiliferous, lower Queenston bryozoa beds from Somerset, New York (RG&E core, stored at the University of Buffalo) contain an even older bryozoan fauna, indicating that the base of the Queenston is slightly diachronous, becoming progressively younger to the northwest of Somerset (Figure 3).

The depositional settings of the Queenston strata in western New York and Ontario include storm-dominated normal marine, tidal flat, and delta plain environments. The tongues of normal marine strata are restricted to the lower part of the formation. For example, a *Hebertella-* and bryozoan-rich bed is present 3 m above the base of the Queenston in the Hamilton, Ontario area. This bed, in which some fossils are oriented in life position, is bounded by red mudstones containing desiccation cracks.

A similar lower Queenston marine incursion is represented in drill cores from eastern Niagara County, New York. At Somerset, the basal 9 m of Queenston strata consists of unfossiliferous, cross-stratified sandstone and mudstone containing desiccation cracks. These peritidal strata are overlain by 4.5 m of red and green shale with interbeds of white, fossiliferous, calcareous sandstone, which, in turn, is overlain by unfossiliferous Queenston strata. This tongue of calcareous sandstone contains bryozoans and brachiopods, some oriented in life position. In general, fossiliferous beds are more closely associated with green shale than with red shale, although rip-up clasts of red shale are present in some fossil beds. Based on the presence of large (>7 cm) rip-up clasts and the vertical proximity of these beds to peritidal deposits, we postulate an extremely shallow shelf depositional setting for this marine tongue.

Red and green, gypsum-rich, variably calcareous mudstone and cross-stratified fine- to very fine-grained calcareous sandstone are characteristic of the middle Queenston strata in the area between Meaford and Toronto. This same facies assemblage is characteristic of the lower and upper Queenston strata of the Bruce Peninsula. In these rocks, laminae around gypsum nodules are typically distorted, suggesting that the nodules formed in unlithified sediment and displaced over- and underlying sediment during nodule growth.

Imbricated shale clasts are present at the base of some sandstone beds, and the top of sandstone beds contain current-, wave-, and interference ripple marks. Some mudstone beds contain desiccation-cracks, and birdseye structures are present in calcareous mudstones. Sandstones with interference rippled tops and mud-cracked bases are common, indicating that sands were deposited during flood tides or during storms.

In general, beds are not heavily bioturbated, and body fossils, with the exception of rare leperditiid ostracodes, are absent in these gypsum-rich strata. Along Workman's Creek near Meaford, Ontario, a small, partially dolomitized algal mound is present near the base of the Queenston. A leperditiid ostracod and algae-dominated biota seems to be characteristic of marginally hypersaline settings throughout the middle Paleozoic (Walker and Laporte, 1970).

These middle Queenston strata represent muddy tidal flat and sabkha settings in which periodic or episodic arid climatic conditions led to the precipitation of gypsum nodules. Well-developed, stable channels may have been lacking in this setting; we have not seen any large channel or bar forms from these intervals in outcrop.

Whereas the gypsum-rich lower Queenston strata of Ontario seem to represent hypersaline tidal flat conditions, normal marine tidal flats are represented in the lower Queenston strata of western New York. Unfossiliferous peritidal facies occur in the basal 9 m and the upper 40 m of Queenston formation in the Somerset drill cores. These peritidal successions, separated by the aforementioned 4.5 m of marine Queenston, include intervals of variably bioturbated, cross-stratified sandstone (often containing imbricated shale clasts) up to 15 cm thick interbedded with green and red shale. Intervals of predominantly red mudstone with minor, thin, soft sediment-deformed sandstone beds are also present. Recognizable trace fossils include shallow *Skolithos* (<6 cm deep) and small *Chondrites*. Within individual trough cross-stratified sandstone beds, trough size increases upwards indicating sand was deposited during times of increasing water velocity and/or decreasing flow depths; these sandstones may record unusually strong ebb tides. Load casts are relatively common at the bases of sandstones, especially in mudstone-rich intervals. Desiccation cracks are also present, indicating periodic subaerial exposure of tidal flat muds.

Mudstone-dominated strata are characteristic of the Queenston as a whole in western New York and are characteristic of lower and upper Queenston in the area between Toronto and Corbetton, Ontario. Four facies comprise these strata: 1) intensely bioturbated, arenaceous mudstone; 2) hackly-fracturing mudstone; 3) thin (<8 cm) couplets of fine sandstone and shale; 4) cross-stratified, upward-fining sandstone beds up to 70 cm thick.

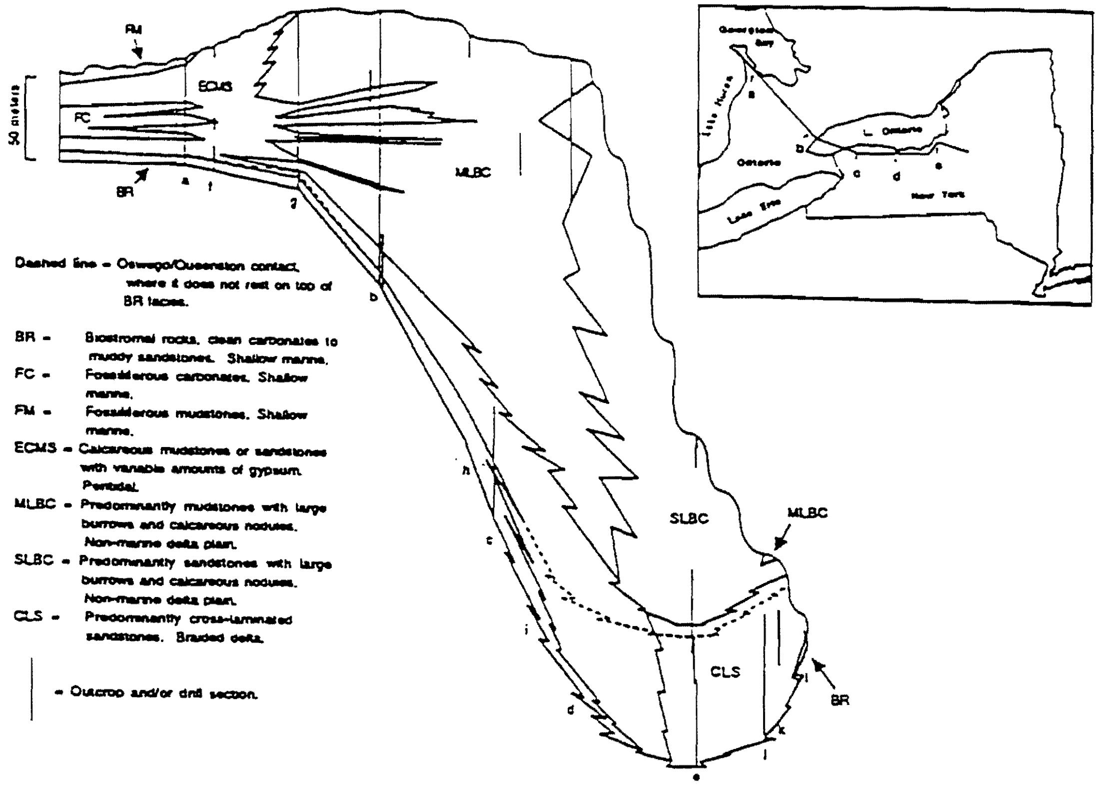

Figure 4a. Paleoenvironmental interpretations of the Streetsville (and Vincent) Mbr., Georgian Bay Fm; Oswego Fm, and Queenston Fm. Outcrop and drill sections are shown as vertical lines.

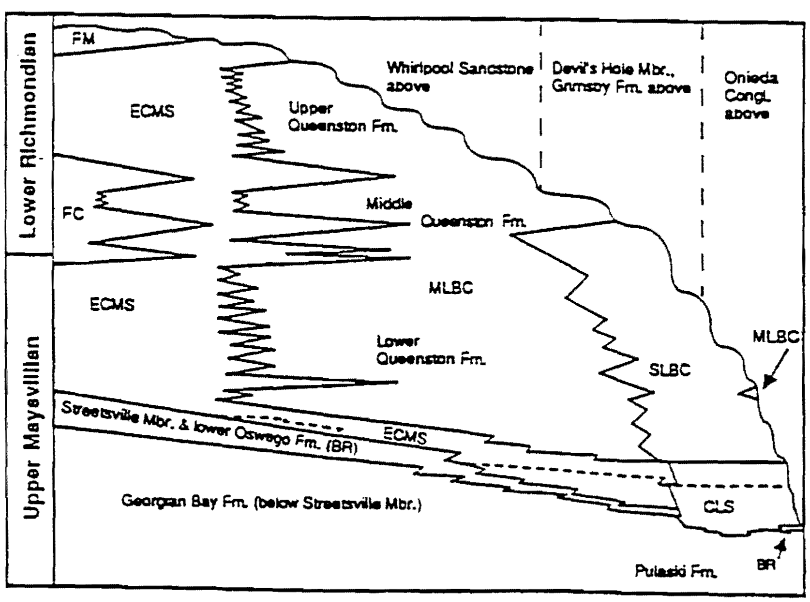

Figure 4b. Chronostratigraphic relationships of Upper Maysvillian and Lower Richmondian Strata of New York and Ontario.

The intensely bioturbated mudstones contain small (<2 cm) nodules of micrite and calcite-replaced detrital quartz sand and silt. These features are characteristic of caliche (Sakar, 1988). The upper surfaces of mudstone intervals typically contain desiccation-cracks, indicating that the mudstones were subjected to sub-aerial conditions. Hackly fracturing mudstones, gradational in character with the intensely bioturbated mudstones, contain sub-horizontal to sub-vertical slickensides. In outcrop, these mudstones weather to prismatic, angular blocks. This weathering pattern, in conjunction with possible caliche nodules, suggests that these bioturbated and hackly-fractured mudstones may be paleosols. They have characteristics of B-horizon soils, as outlined by Retallack (1988). We have not yet recognized distinctive A-horizons within these mudstones, but this, in part, may be due to erosional truncation of the upper horizon.

Sandstone/shale couplets form successions up to 7 m thick. Sandstones typically exhibit some degree of grading and are cross-stratified. Superified cross stratification (climbing ripples) is common in thicker (>2 cm) sandstone beds indicating rapid deposition. We interpret couplets as representing flooding events in a delta plain setting, somewhat proximal to distributary channels.

Upward-fining sandstones, up to 70 cm thick, occur as both individual and amalgamated beds, forming arenaceous intervals up to 2.5 m thick. Within the thicker upward-fining sandstone beds, a consistent internal stratigraphy is present. Graded intervals containing imbricated shale rip-up clasts and/or calcareous nodules are present at the bases of most sandstones. These graded lag deposits are overlain by cross-stratified sands. Sandstones typically form distinctive accretionary bar forms (up to 1.5 m high), shallow (<75 cm) sand-filled channels, and distinctive sheets. Orientations of accretion surfaces and foresets from cross-stratified sheet sands at Rochester, New York, indicate northward directed paleoflow (Zerrahn, 1978).

Sandstone beds contain distinctive sub-vertical to sub-horizontal trace fossils, essentially identical to putative terrestrial arthropod burrows (Retallack, 1985; Feakes and Retallack, 1988) described from the correlative Juniata Sandstone of Pennsylvania. These burrows are up to 25 mm in diameter and may penetrate 30 cm or more of strata.

Low-Mg calcite ensheathes mud-filled burrows and also decreases upward from the bases of sandstone layers, so that sandstone beds typically exhibit downward color gradations from white to pink. The gradational, downward increase in these calcite cements is reminiscent of groundwater dolocretes described from the Triassic strata of the Paris Basin by Spotl and Wright (1992). The preferential cementation around burrows and the thinness of calcite-cemented sandy intervals, however, leaves open the possibility that the Queenston cements had a pedogenic origin.

The upward-fining sandstone beds represent tidally-influenced, non-marine distributary channel deposits. The presence of mud drapes within accretionary bar forms indicates periodic or episodic cessation of channel flow, possibly associated with slack tides, and the lack of thick channel deposits suggests that the distributary channels were migratory.

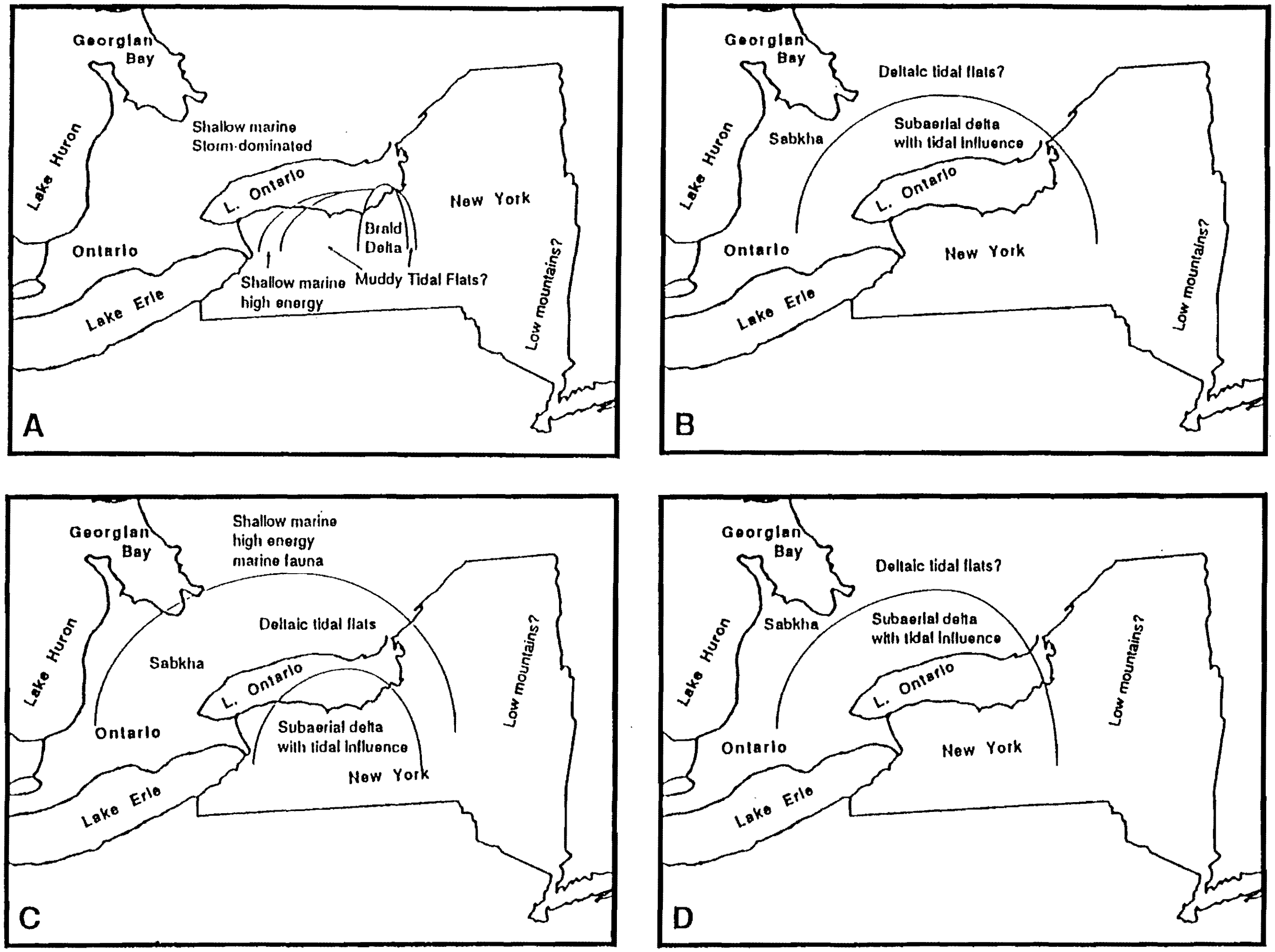

Figure 5. Paleogeographic reconstructions of the Queenston delta. A) During Oswego deposition in north-central New York. B) During lower Queenston deposition in southwestern Ontario. C) During middle Queenston transgression. D) During upper Queenston deposition in southwestern Ontario.

Thus, sedimentologic, stratigraphic, and biostratigraphic data indicate that the Queenston Formation represents a northward prograding complex of shallow marine to non-marine environments (Figures 4, 5). The presence of synsedimentary to very early diagenetic evaporite minerals in tidal flat deposits indicates hypersaline conditions in southwestern Ontario, whereas similar evaporite minerals are generally absent in peritidal paleoenvironmental settings in New York. It seems likely that proximity to freshwater (i.e., the Queenston/Juniata delta) may have influenced evaporitic mineralization.

Regional trends in stratal thickness, maximum grain size, and paleocurrent data suggest that the molasse present in New York and Ontario is part of a clastic wedge which prograded from southeastern Pennsylvania (Figure 1; see Lehmann, 1993, for discussion). The molasse accumulated in a gently north-plunging elongate basin. Based on correlation of gypsum beds and facies relationships, sabkhas were greater than 40 km in width, and tidal effects influenced sedimentation on delta plains more than 400 km inland from fully marine settings. The gentle topographic gradient responsible for these expansive facies belts was presumably created and maintained as sediment supply overcompensated for accommodation space produced by basin subsidence.

The Queenston red beds represent a large deltaic complex that prograded into a shallow marine basin. At Manitoulin Island, approximately 120 km northwest of Wiarton, Ontario, blue-gray to buff colored limestones and dolostones are time correlative with the Queenston red beds which are present to the southeast. Reports of fossiliferous Queenston strata at Russel, Ontario (27 km southwest of Ottawa) suggest that fully marine conditions existed to the northeast of Rochester along the basin axis as well (Wilson, 1946).

The lobe of the Queenston-Juniata siliciclastic wedge that prograded from Pennsylvania into Ontario is presumably one of many coalescing red bed lobes which developed adjacent to Taconic highlands along eastern North America. Although the deltaic complex discussed herein apparently thins and grades into marine-dominated facies to the north, at least 400 to 600 m of Upper Ordovician non-marine red beds (Becancour Formation) have been reported from the subsurface of the St. Lawrence lowlands, approximately 35 km northwest of Montreal (Belyea, 1952). The thickness of the Becancour Formation suggests that a regional depocenter, and perhaps a local sediment source, also existed in that region.

Additional work on the physical stratigraphy of the Queenston Formation remains to be completed before a detailed sequence stratigraphy may be interpreted. The facies analyses presented in this paper serves as a prerequisite for synthesis of the regional-scale physical sequence stratigraphy of the Queenston Formation.

SILURIAN SEQUENCES

Because of good exposure, the litho- and biostratigraphy of the Silurian strata in western New York and Ontario have been progressively refined over the past 150 years (Figure 6). Because of the vast amount of knowledge that has accumulated on the Silurian strata, the interval is an ideal laboratory for the testing of various stratigraphy-based models. In recent years, the present authors have evaluated prevalent models of allostratigraphy and foreland basin dynamics underlying the Silurian strata of the northern Appalachian basin (Brett et al., 1990a, b,; Goodman and Brett, 1994).

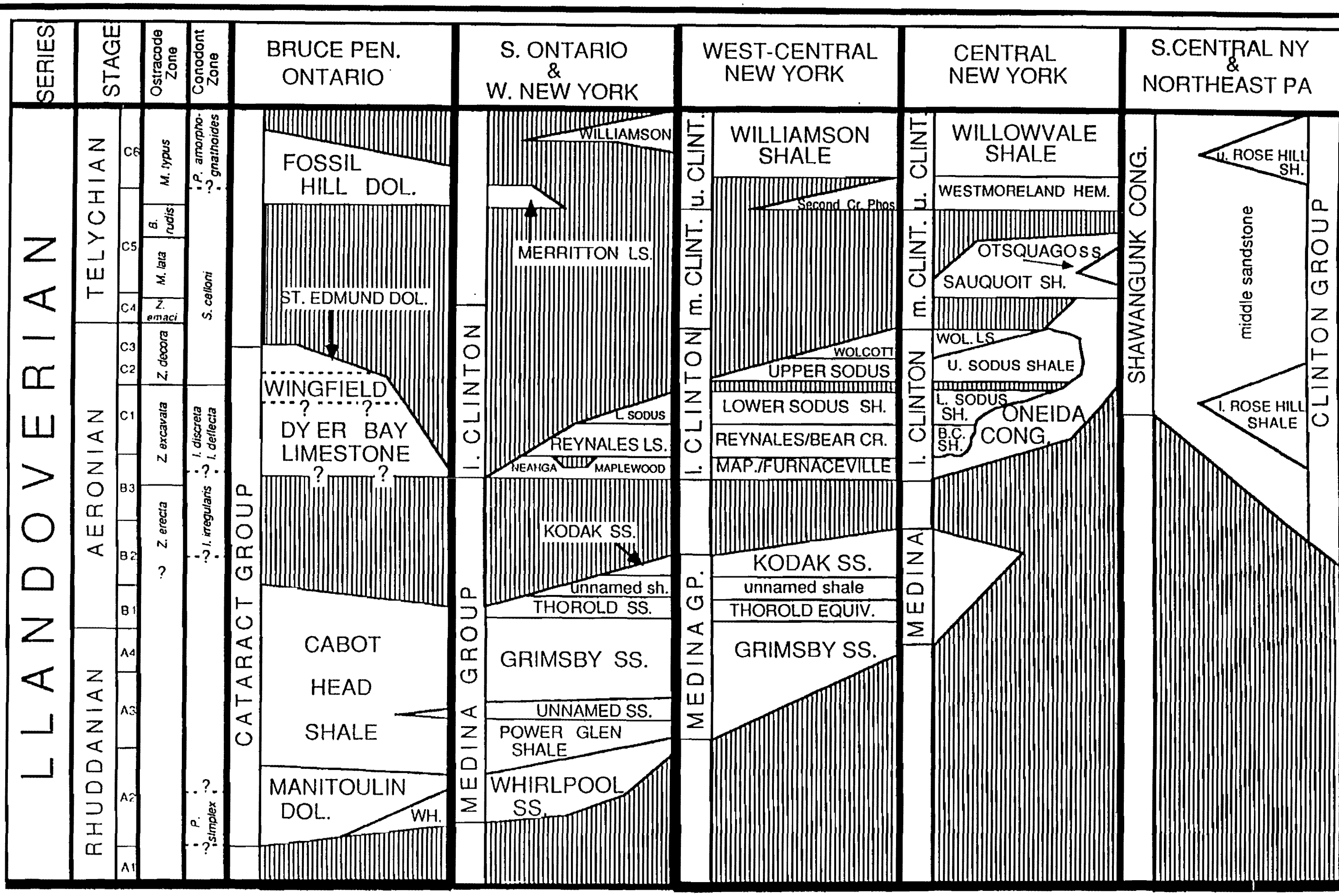

Figure 6a. Chronostratigraphic relationships of Lower Silurian (Llandoverian) strata of sequences I and II in Ontario (Bruce peninsula), western, central and eastern New York State. Vertical ruling indicates unconformities.

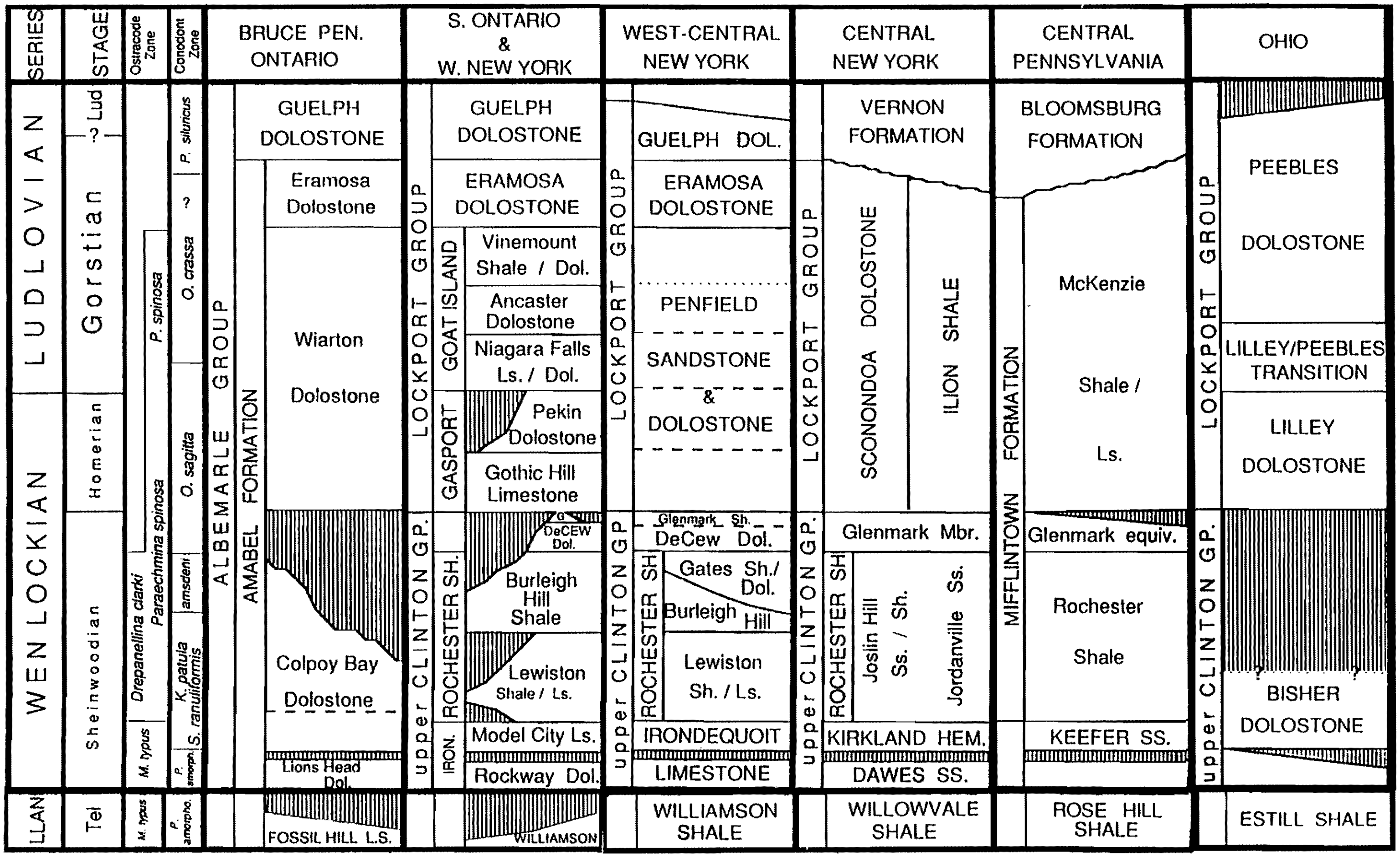

Figure 6b. Chronostratigraphic relationships of units within the upper Clinton (Sequences IV, V) and Lockport (Sequences VI) Groups in Ontario, New York, Pennsylvania and Ohio. Formation names are listed in upper case, members in lower case.

The Llandoverian to Ludlovian (Medina through Lockport Group) succession of the northern Appalachian foreland basin has previously been divided by Brett and others (1990a, b) into at least six large-scale, unconformity-bounded stratal packages comparable in many respects to *depositional sequences* of Vail and others (1977, 1991). For the most part, these sequences correspond to previously recognized group-level stratigraphic units. The first sequence corresponds to the Medina Group, the second and third sequences to the lower and middle portions of the Clinton Group, respectively, the fourth and fifth sequences to portions of the upper Clinton Group, the sixth sequence to the lower Lockport Group. A newly recognized seventh sequence corresponds to the upper Lockport Group and Vernon Shale (Figure 7).

The sequences recognized herein are at least crudely divisible into *systems tracts* that are analogous to those within depositional sequences of seismic stratigraphers (e.g. Vail et al., 1977; Van Wagoner, 1988; Posamentier and others, 1988). In terms of temporal magnitude, Silurian sequences, like those of seismic stratigraphers, encompass approximately 1 to 5 million years and, therefore, can be classified as third-order cycles (Vail et al., 1977).

The Silurian sequences are divisible internally into very prominent and basin-wide *sub-sequences*, which are of lesser temporal magnitude and display sharp, slightly erosive disconformities. Sub-sequences are considered to reflect shorter duration, roughly 1.0 to 1.5 million year cycles in the range referred to by Busch and Rollins (1984) as fourth-order cycles. Sub-sequences are also comparable to Carboniferous mesothems described by Ramsbottom (1979) that apparently record rapid regressions followed by progressive, stepwise transgressions. Other researchers, including Vail and others (1991), have recently broadened the temporal range of third-order cycles to approximately 0.5 to 5.0 million years. This broader definition of third-order cycles would also include sub-sequences of Brett and others (1990b). We choose to retain the Busch and Rollins (1984) classification of allocycles and to consider the smaller-scale sub-sequences as a discrete scale in a hierarchy, because of the following: a) the bounding discontinuities (except those which also coincide with sequence boundaries) involve less erosional truncation than do third-order sequence boundaries; and b) two or more sub-sequences consistently occur within each interpreted Silurian sequence, suggesting a nested hierarchy of allocycles. Sub-sequences are, in turn, divisible into smaller-scale cycles that correspond roughly to members or submembers in lithostratigraphic terminology. Each sub-sequence, thus, is divisible into two to three cycles that are analogous to *parasequence sets* or fifth-order cycles. The smallest scale cycles that can be correlated over significant portions of the basin tend to be arranged within parasequence sets in groupings of two to five. These *parasequences* commonly exhibit an asymmetrical upward-shallowing motif and correspond to sixth-order cycles or PACs (Goodwin and Anderson, 1985).

In the following sections, we describe the seven major sequences and their internal cyclicity. Details of the outcrops in the Genesee Valley are emphasized.

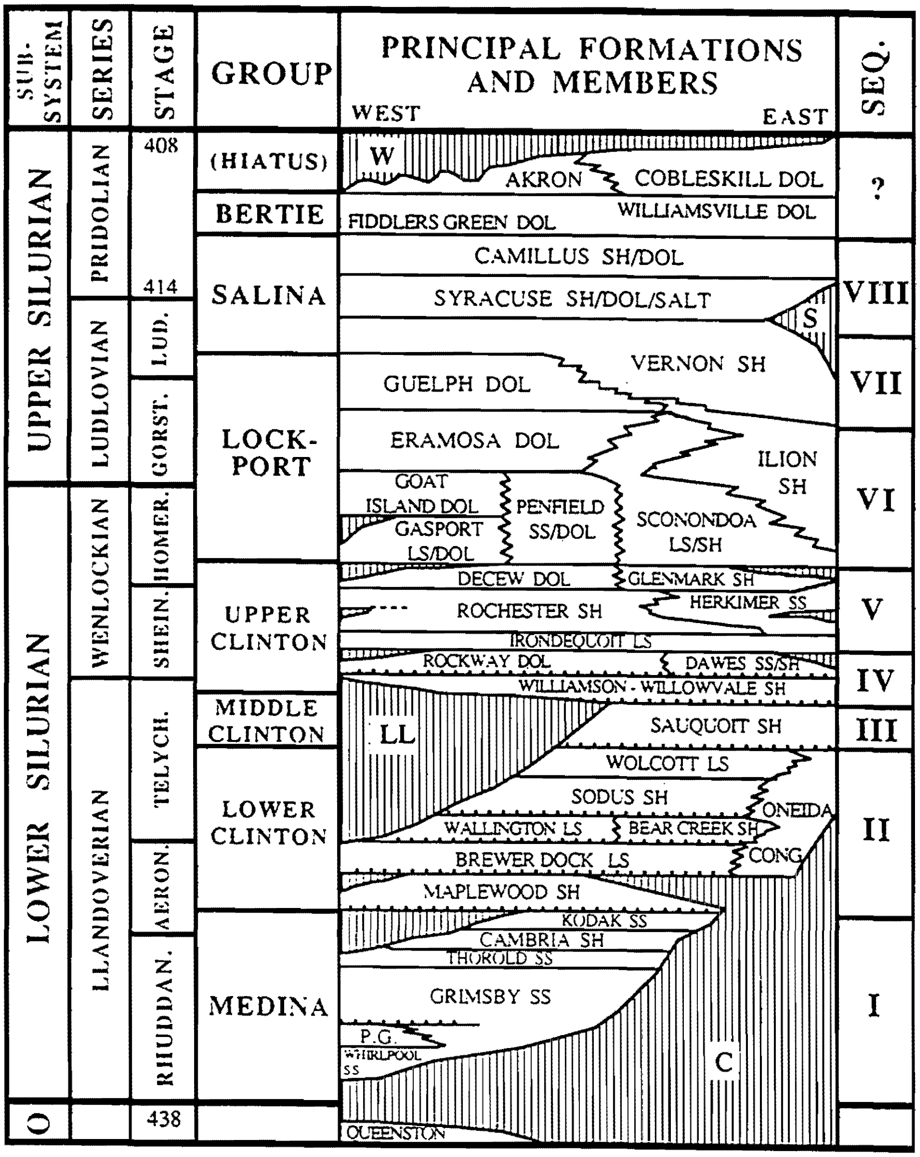

Figure 7. Generalized Silurian stratigraphy of New York State illustrating division into third-order depositional sequences. Vertical axis is scaled to time; horizontal scale is west to east distance along the New York outcrop belt from Niagara Gorge to near Utica, N.Y., approximately 300 km. Abbreviations: O = Ordovician; Rhuddan. = Rhuddanian; Aeron. = Aeronian; Telych. = Telychian; Shein. = Sheinwoodian; Homer. = Homerian; Gorst. = Gorstian; Lud. = Ludfordian. Ages listed are estimates for beginning and end of Silurian Period and end of Ludlovian (in millions of years). For formations and members: P.G. = Power Glen Shale, DOL--dolostone, LS = limestone, SH = shale, SS = sandstone; dotted lines indicate persistent hematitic/phosphatic beds; major unconformities are labeled with upper case letters C = Cherokee (basal Silurian): LL--Late Llandovery; S = Salinic, W = Wallbridge; SEQ. = sequences. Chart modified from Rickard (1975).

Sequence I: Medina Group

The Medina Group at Rochester Gorge consists of 17 m (50 ft) of red- and white-mottled, interbedded sandstone, siltstone and mudstone (Figure 8). Prior to recent allostratigraphic analyses (Duke and Fawcett, 1987; Brett and others, 1990a, b; Duke, 1991; Goodman and Brett, 1994), the Medina Group strata near Rochester were assigned to only two units, the Grimsby and Kodak Formations. The refined correlations that have resulted from recent investigations suggest that the Rochester area section contains intervals equivalent to at least four newly defined formations in the Niagara region (Figure 9).

The basal three meters of red, coarse-grained sandstone appear to correlate with the upper half of a thick basal sandstone interval quarried near Albion, Orleans County and with the Devils Hole Sandstone which overlies the Power Glen Shale in Niagara County. At Rochester, the Devils Hole Sandstone is a massive bed of planar laminated to cross-stratified, subarkosic, medium to coarse-grained sandstone. The bed also contains iron and phosphate-rich ooids and scattered crinoid ossicles. The sharp, slightly undulatory, basal contact with the Ordovician Queenston Formation is a low angle regional unconformity of considerable magnitude. This contact is the Cherokee Unconformity of Dennison and Head (1975).

The unconformity and unusual petrography of the Devils Hole Sandstone are readily understood in the context of the regional sequence stratigraphy (see Figures 8 and 9). The Medina Group has recently been interpreted to be a single depositional sequence sensu Wilgus and others (1988) and to represent stratigraphic accumulation during a single, third-order cycle of sea-level rise and fall (Brett and others, 1990a, b; 1991; Duke, 1991). The Cherokee Unconformity at Rochester is the surface of maximum starvation that separates strata of the transgressive systems tract (Whirlpool Formations of the Niagara region) from overlying strata of the highstand systems tract. In the Niagara region, both transgressive and highstand strata can be observed in the same stratigraphic section. Because marine transgression progressed from west to east through the Rhuddanian and Aeronian Stages, the oldest Medina Group strata pinchout west of Rochester. Only after the maximum sea-level highstand did sufficient accommodation space exist on the local paleotopographic high of the Rochester area for accumulation of condensed, onlapping, marginal marine strata. Ten km to the east at Webster, the Medina section expands to approximately 25 m (Fred Amos, personal communication). The increased thickness is attributable to increased preservation of basal strata. This pattern reflects the regional-scale paleotopographic relief of the Cherokee Unconformity that, for the most part, appears planar at the outcrop scale.

Medina Group strata that overlie the Devils Hole Sandstone, therefore, comprise the highstand systems tract of Silurian Sequence I. These strata are now assigned to the Grimsby (restricted sense), Thorold, Cambria and Kodak Formations (see Figure 8). These formations comprise three (subsequence) coarsening cycles on the scale of 3-5 m that record a pulsed, westward progradation of the eastern strandline during a late Rhuddanian to early Aeronian sea-level highstand. The basal sandstones of each cycle are intensely bioturbated by *Daedalus* and *Arthrophycus* which probably are mining traces (fodinichnia) of large annelid worms. Where primary sedimentary structures are preserved, however, the sandstones contain lateral accretion surfaces (Thorold Formation) or alternating tabular beds of sandstone and shaley siltstone (Kodak Formation).

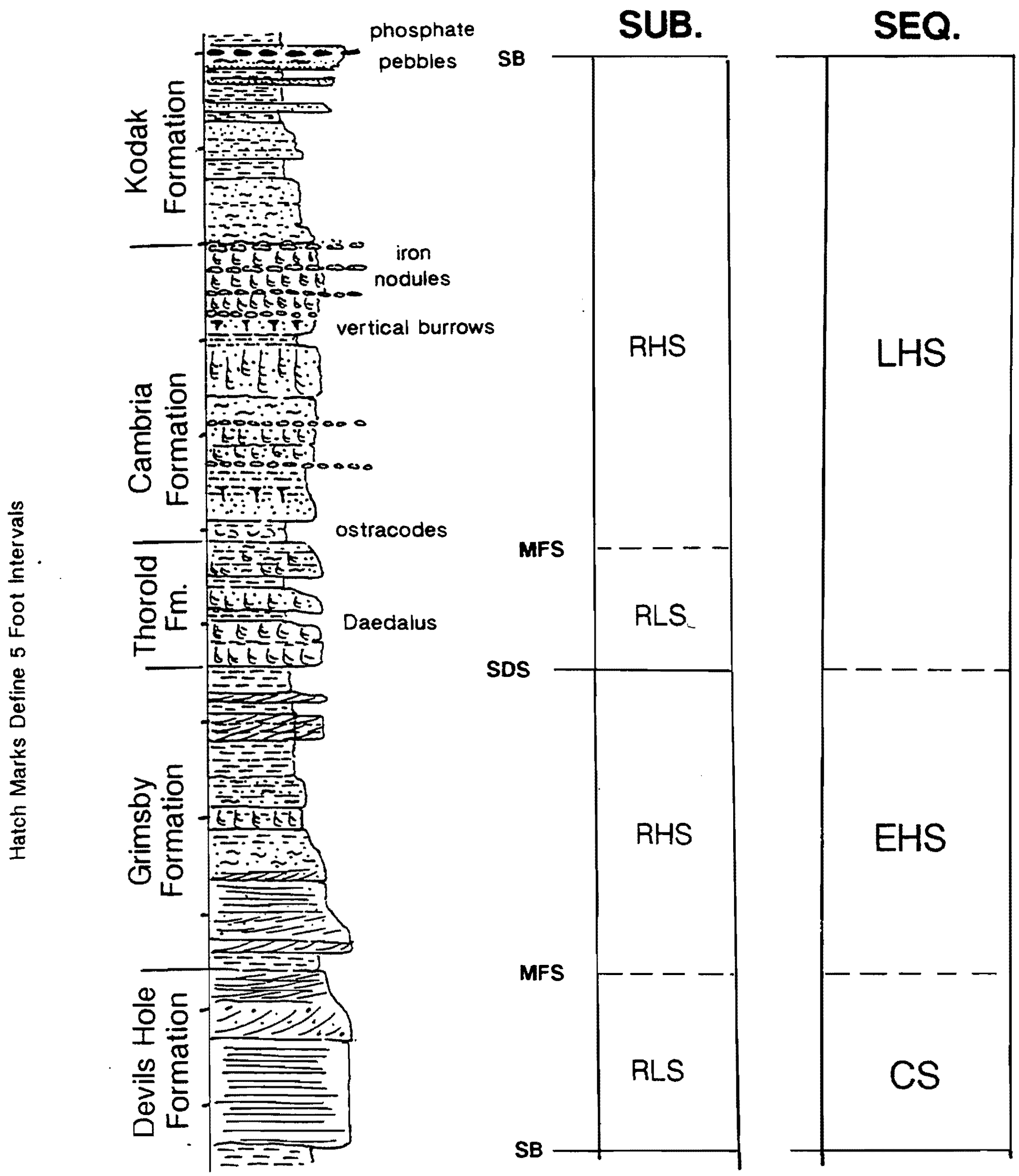

Figure 8. Stratigraphic column for the Medina Group (Sequence I) from a drill core in Rochester, N.Y.

Bars on right side of figure indicate subdivisions of subsequences (SS; left bar) and for systems tracts the sequence as a whole (SEQ; right bar). Abbreviation for subsequences: NM = non-marine lowstand deposit; RLS = relative lowstand (shallow marine deposit); RHS = relative highstand; MFS = marine flooding surface; SDS - sealevel drop surface; CI = condensed interval. For sequences SMT = shelf margin systems tract (lowstand deposit); TST = transgressive systems tract; MFS = marine flooding surface; CS = condensed section; EHS = early highstand; LHS = late highstand; SB = sequence boundary; TS = transgressive surface.

The Grimbsy consists primarily of red and white mottled sandstones, commonly with basal lags of shale pebbles interbedded with maroon silty shales. At Rochester marine shelly fossils are absent. Lingulids are abundant tot he west near Lockport. Minor coarsening-upward cycles, capped by tidal channel sandstones were recognized in the Grimsby by Duke (1991).

Consequently, the regressive phases of the sea-level cycles resulted in the progradation of tidal channel and tidal flat facies over muddy subtidal to lower intertidal facies that contain ostracodes, lingulid brachiopods, pelecypods, trilobite trace fossils (*Rusophycus*), and, possibly, hematized stromatolites.

In the Genesee Gorge, the upper boundary of the Medina Group is placed at the contact between the Kodak Sandstone and the overlying Maplewood Shale of the Clinton Group. A phosphate pebble bed marks a low angle, regional unconformity at this contact. To the west, upper Medina strata (Thorold, Cambria, Kodak) are beveled beneath this unconformity. The area of maximum erosion may be located between Hamilton and Guelph, Ontario. Conversely, this region was close to the basin center (deepest water facies during deposition ofthe lower Medina (Cabot Head) strata. This region appears to have become a cratonic arch that separated a subsiding foreland basin with an eastward migrating depocenter in New York from the more stable-positioned, southeast margin of the intercratonic Michigan Basin near the end of Medina deposition. Consequently, although this unconformity is likely to have been formed during a sea-level lowstand following progradational infilling of the Appalachian Basin by upper Medina strata, strong evidence of early Aeronian foreland basin flexure with concomitant uplift of the cratonic arch is apparent in the stratigraphic architecture of the region.

Sequences II-V: Clinton Group

The Clinton Group at Genesee Gorge consists of a diverse assemblage of shale and carbonate formations with associated hematitic ironstones and phosphatic beds. The total thickness of the Clinton Group is approximately 55 m (170 ft). The Clinton strata span the upper Aeronian through Sheinwoodian stages in the Niagara region. In western New York, the Clinton Group is divided into upper and lower halves by a major unconformity (Gillette, 1947; Rickard, 1975; Lin and Brett, 1988). Farther west in Ontario, Canada, the entire lower Clinton is truncated beneath the major unconformity. Farther east in the type Clinton area of east-central New York, the lacuna of the unconformity decreases; lower and middle Clinton strata only briefly present at Rochester are preserved. The middle Clinton strata are only briefly discussed in this paper but have been studied in detail by Gillette (1947) and Muskatt (1972).

Sequence II: Lower Clinton Group

The lower Clinton Group has been previously interpreted as a discrete depositional sequence (Sequence II of Brett et al., 1990a, b, Figure 10). Lower Clinton strata, however, have proven to be a challenge to interpret in terms of systems tracts because of the following attributes: 1) undulatory onlap surface (Medina-Clinton contact) and resultant local, lateral discontinuity of basal Clinton units; 2) complete absence of lower Clinton strata west of St. Catharines, Ontario, due to truncation beneath the middle Clinton unconformity; 3) lack of a diagnostic benthic assemblage (sensu Boucot, 1975) in the Maplewood Shale; and 4) inverse relationship between benthic assemblages used to define relative sea-level by

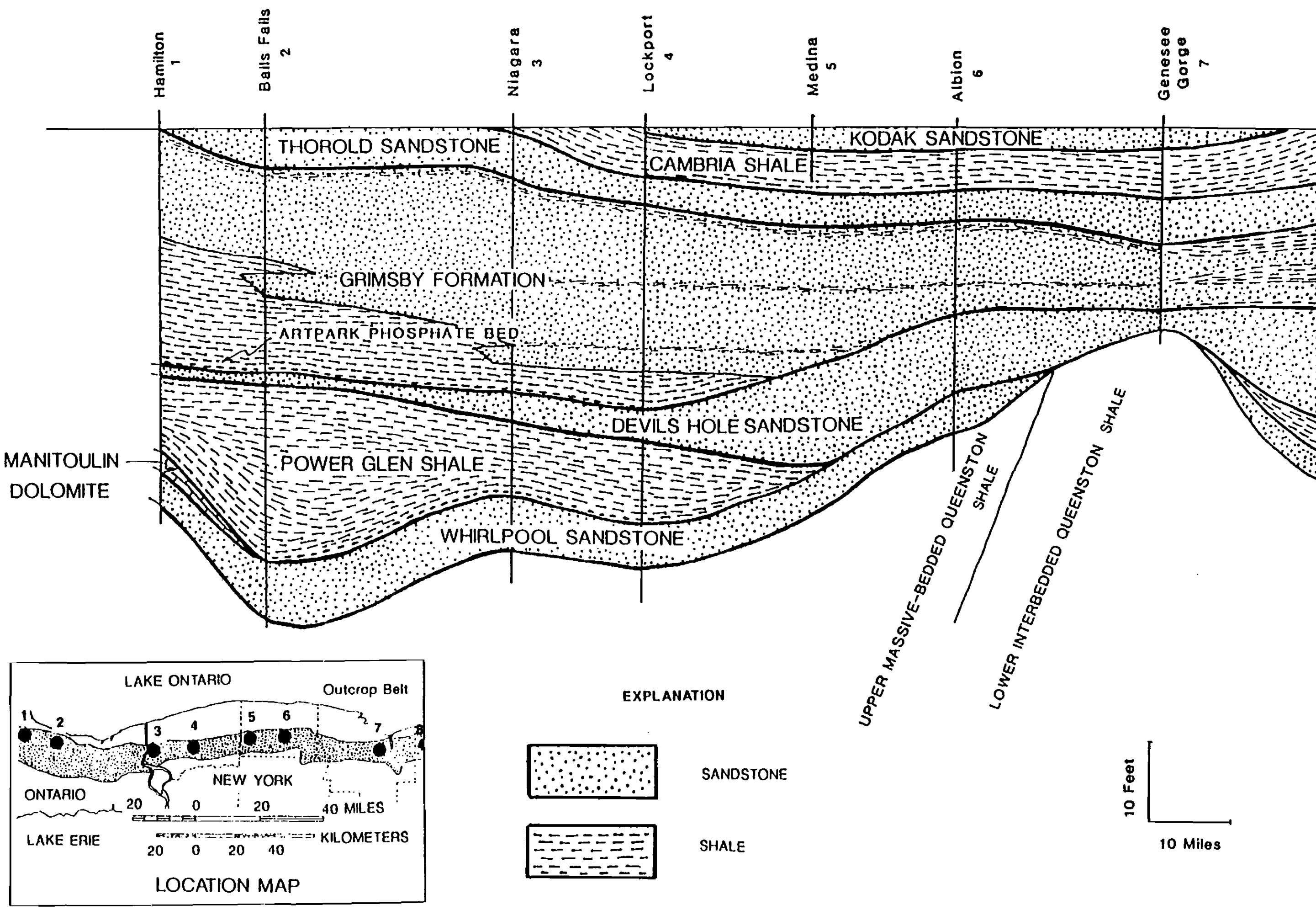

Figure 9 -- Diagrammatic stratigraphic relations in the Medina Group, with regional correlations between Hamilton, Ont. and the Genesee Gorge in Rochester, N.Y. Length of vertical line at each locality indicates units observed in the field or in drill cores. (Modified from Brett and others, 1991, fig. 7.)

paleontologists and carbonate grain-size trends used for the same purpose by sedimentologists. Detailed stratigraphic performed by LoDuca and Brett (1994) has clarified some of the relationships between strata at Rochester and those in Wayne County. Additional work with drill cores between Wayne and Madison Counties will be helpful in completing the correlations across the basin. Drill cores were once available (see Gillette, 1947), but they were apparently lost in a fire at the office of the state geological survey.

The Maplewood Shale, lowest of the Clinton units, consists of 6 m (18 ft) of soft, green-gray, clay shale (Figure 11). Despite its prominence in the Genesee Gorge, the unit pinches out at Webster, only 10 km east of Rochester (Fred Amos, personal communication). The Maplewood thins to about 2 m at Albion, Orleans County and to less than 30 cm at Lockport, Niagara County, where it is mapped as Neahga Shale. The Maplewood-Neahga Shale is about 2 m thick in the Niagara Gorge.

The Maplewood Shale is bounded both at its base and top by phosphatic pebble beds. The basal bed, designated the Densmore Creek Phosphate Bed by LoDuca and Brett (1994), may be up to 10 cm thick and contains large clasts of phosphatized, arenaceous carbonate and black, fossil steinkerns of fluorapatite (Paxson, 1985). Phosphatic clasts and fossils are often piped downward 5-10 cm into burrows that penetrate the underlying uppermost bed of the Medina Group. The phosphate bed is traceable westward from Rochester to St. Catharines, Ontario where it is represnted by phosphatic limestone. The Densmore Creek Phosphate Bed grades eastward from Rochester into the base of the hematitic and phosphatic carbonate intraclast and oolite facies (Webster Bed) of the Furnaceville Formation (LoDuca and Brett, 1994). In a sequence stratigraphic context, this lower phosphate bed records the basal Clinton marine transgression over the beveled upper Medina surface. No nonmarine strata are preserved immediately above the unconformity along the New York-Ontario outcrop belt. Consequently, if a lowstand systems tract exists within the basin, it may be found in the sections of central Pennsylvania and/or in the subsurface of southern New York. The Maplewood Shale has been tentatively interpreted as part of the transgressive systems tract of Silurian Sequence II (Brett and others, 1990a, b).

The upper phosphate bed, designated the Budd Road Phosphate Bed, occurs at the contact of the Maplewood Shale with the overlying Brewer Dock Member of the Reynales Formation. The upper phosphate bed is well developed at the Genesee Gorge but is generally less distinctive than its lower counterpart. In a sequence stratigraphic context, the upper phosphate bed may signify the onset of clear-water, carbonate deposition with progressive sea-level rise during the middle Aeronian (C_1) stage.

Macrofossils are very rare in the Maplewood Shale and most that have been reported likely come from the basal phosphate bed (Fisher, 1953a). Nonetheless, fully marine conditions are suggested by the fauna. Fisher 1960 reported a nektonic trilobite from the shale. More recently, Sam Ciurca (personal communication) has obtained lingulid brachiopods, nautiloids, eurypterid fragments, and complete specimens of a new species of crinoid from the Maplewood Shale. The authors have observed gastropods and brachiopods (*Eocoelia, Hyattidina* and *Leptaena*) preserved as steinkerns in the lower phosphate bed. The shale also contains a diverse and well-preserved microflora of acritarchs and chitinozoans (Fisher, 1960; Miller and Eames, 1982). Based upon the paleontology and lateral stratigraphic relationships, the Maplewood-Neagha Shales were probably deposited

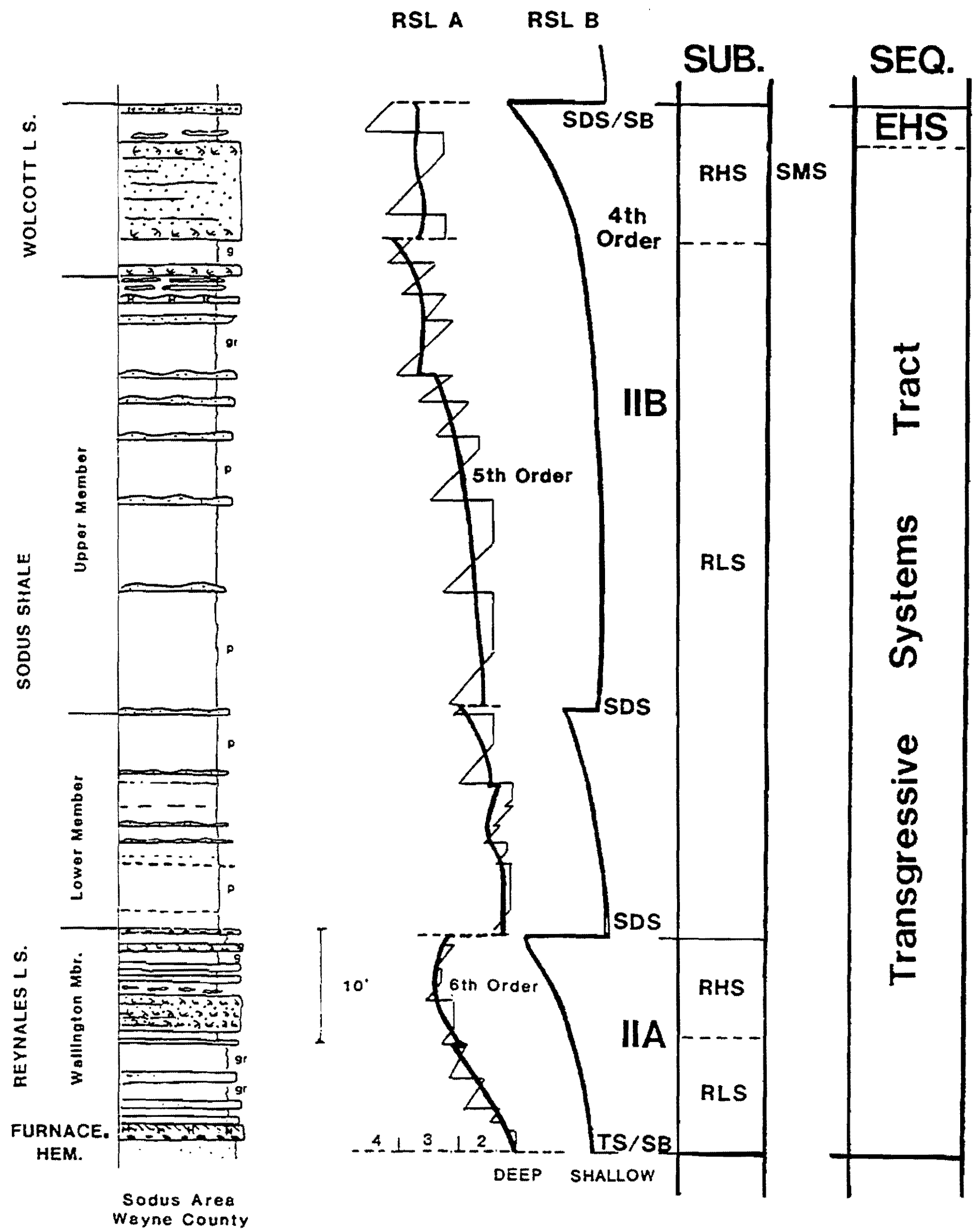

Figure 10. Lithostratigraphy, inferred relative sea-level, and sequence terminology of the lower Clinton Group (Sequence II) near Sodus, Wayne County, N.Y.: RSLA = relative sea-level curves for the 5th- and 6th-order cycles. Calibration based on biofacies: 2 = *Eocoelia* association (BA-2); 3 = pentamerid association (BA-3): 4 = stricklandid association (BA-4).

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in a variably deep, stagnant trough immediately offshore of a high energy strandline located near Webster, Monroe County. The thinness of the unit near Lockport, Niagara County may suggest that the Neahga and Maplewood Shales were deposited in weakly differentiated sub-basins separated by a minor topographic high.

The Reynales Formation is a carbonate-rich interval that is well exposed along the RG&E access road locality, (Stop 1A) within the Genesee Gorge. The age of the Reynales has been the subject of some debate (see LoDuca and Brett, 1994). On the basis of ostracodes and extensive conodont sampling in recent years, however, the entire Reynales Formation is presently believed to be Aeronian (C_{1-2}) in age (Maxwell and Over, 1994;Mark Kleffner, personal communication). To the west, the formation (Hickory Corners Member) has been recognized only as far as Queenston, Ontario. To the east of Rochester, the Reynales Formation grades laterally into the type Furnaceville Hematite and overlying Bear Creek Shale.

In the Rochester area, the formation has been divided into three units which are in ascending order: the Brewer Dock Member; the Furnaceville Hematite Bed; and the Wallington Member. The name of the hematite bed at Rochester has been changed to Seneca Park Bed by LoDuca (1988) and LoDuca and Brett (1994), because the distinctive bed within the Reynales correlates with only part of the type Furnaceville Hematite exposed in now flooded quarries near Ontario, Wayne County. The type Furnaceville Hematite represents a thoroughly hematized equivalent of the entire Brewer Dock Member at Rochester.

In the Genesee Gorge, the Brewer Dock Member is approximately 60 cm thick and consists of the basal Budd Road Phosphate Bed, and interbedded pelletal calcisiltites and green-gray shale. Soft sediment deformation features (ball and pillow structures) are locally exposed in the gorge. The member is fossiliferous; the fauna consists primarily of bryozoans, brachiopods and crinoid ossicles. The primary brachiopods are *Eocoelia* and *Hyattidina*.

The Seneca Park Hematite Bed overlies the Brewer Dock Member. In the Genesee Gorge, the hematite stands out as a striking red bed within the light gray carbonate sequence. The bed is approximately 30 cm thick and consists of hematited, bryozoan-rich grainstone. The hematite bed is distinctly cross-bedded. The direction of bedform migration was to the northwest. The Seneca Park Hematite and the Furnaceville Hematite likely represent sandwaves deposited on the interior margin of storm wave-base environments. These bioclastic beds differ petrographically from phosphatic, oolitic hematite beds such as the Webster Bed that appear to have been generated during sediment starvation associated with marine flooding surfaces (LoDuca and Brett, 1994).

The Wallington Member is a 5-6 m (16-18 ft) thick interval of medium- to thick-bedded brachiopod packstones and pelletal grainstones. At the Seth Green Drive section, imbricated beds with sigmoidal geometries occur at one level. Although large bioclasts disrupt internal patterns of lamination, similar beds in the Devonian Becraft Limestone have been argued to be tidal bundles by Ebert (1987). Thin partings of green-gray, silty shale occur near the base of the member. Several beds in the lower portion of the member also contain blue-gray chert nodules. Sedimentary structures and biofacies suggest deposition at and above storm wavebase. Fossils include the brachiopods, *Eocoelia* and *Pentamerus*, stromatoporoids, and complete specimens of an unusual crinoid *Stipatocrinus* (Eckert and Brett, 1987). Stromatoporoids are common in the uppermost beds.

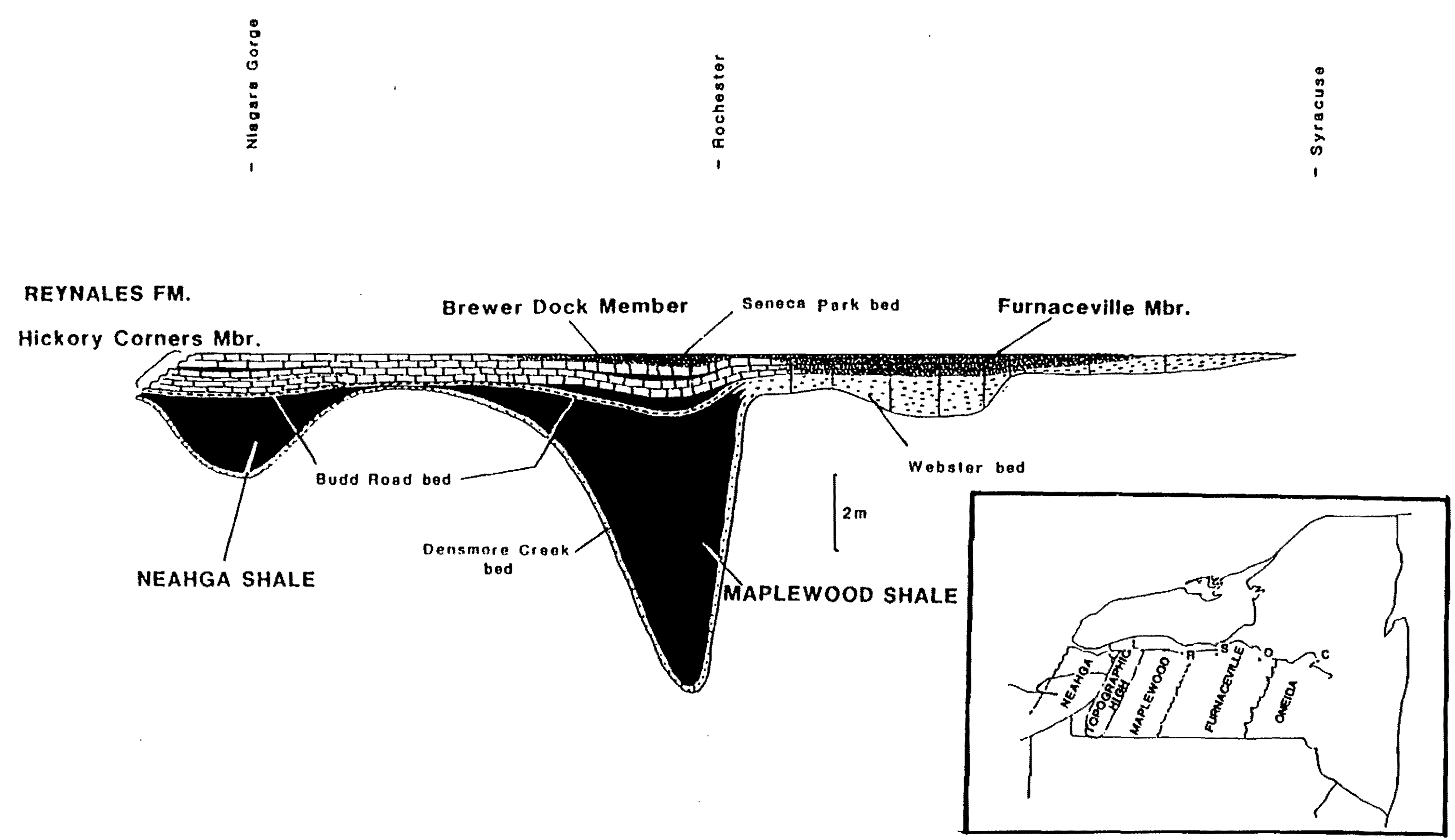


Figure 11. Regional cross-section of the lower part of the Clinton Group between Syracuse, New York, and St. Catharine's, Ontario. Note the presence of two minor depocenters (for Neahga and Maplewood Shales, respectively) separated by a minor arch. Also, note eastward passage of Maplewood Shale into a highly condensed, multigenerational phosphatic conglomerate (Webster Bed). West of Niagara Gorge, the Neahga Shale is truncated by the major mid-Clinton Group angular unconformity.

One distinctive carbonate bed containing stromatoporoids is separated from the main carbonate body of the Wallington Member by a prominent purple shale bed that resembles the overlying Sodus Shale Formation. Thus, although the lithologies of discrete beds are distinct, a stepped transition in bedding sequence occurs at the Wallington-Sodus Shale contact. The formation boundary is typically placed at the upper contact of the distinctive stromatoporoid-bearing bed.

Six pentamerid-rich grainstone beds recognized within the Wallington in the Genesee Gorge define the bases of small-scale, asymmetrical carbonate-to-shale cycles that resemble punctuated aggradational cycles (PACs). The pentamerid beds are positioned at the base of the Wallington Member, and at approximately 1.4 m, 2.0 m, 2.8 m, 3.2 m and 4.0 m above the base. The uppermost cycle of the Wallington in the Genesee Gorge consists of the condensed, dark-stained stromatoporoid bed referred to previously. This distinctive bed appears to grade eastward into the 10-20 cm thick Sterling Station Hematite.

Westward from Rochester, outcrops of the Wallington Member are rare although pentamerid-rich limestones are known from scattered patchy outcrops in the bed of Salmon Creek between Spencerport and Brockport. At least one distinctive pentamerid bed has also been observed in drill cores near Albion, Orleans County. At Middleport and Lockport, however, pentamerids are not present; equivalent strata consist of crinoidal pack- and grainstone. Neither the Brewer Dock nor the Wallington Member have previously been recognized in Niagara County. These strata have been collectively assigned to the Hickory Corners Member.

The Sodus Shale consists of alternating green and purple, fossiliferous shales. At the Genesee Gorge, approximately 4.4 m (13 ft) of Sodus Shale are preserved beneath the middle Clinton (Sequence II-IV) unconformity. The western pinchout of the Sodus Shale has not been precisely located, but occurs east of Albion, Orleans County. To the east in Wayne County, the full thickness of the formation as well as younger, lower Clinton strata (Wolcott Limestone, Wolcott Furnace Hematite) are preserved beneath the unconformity. All of these strata appear to condense farther east and grade into the Oneida Conglomerate.

The predominant fauna of the Sodus Shale consists of *Eocoelia* brachiopods and diminutive ostracodes. The litho- and biofacies are reminiscent of the much thicker and, in part, time correlative strata of the Rose Hill Formation of Pennsylvania (see Cotter, 1983; 1988; 1990).

In the Rochester area, a major unconformity below the Williamson Shale progressively bevels, the upper and lower Sodus Shale. This shale-on-shale unconformity is easily missed in local sections without careful inspection.

Sequence III: Middle Clinton Group

The middle Clinton Group, as defined by Gillette (1947), consists of 35-45 m of green Sauquoit Shale in the Clinton type area of east-central New York. These same strata have been designated as Silurian Sequence III by Brett et al. (1990a, b). A thin tongue of greenish shale, possibly assignable to Sauquoit occurs between the Furnace beds and Williamson Shale at Second Creek (Stop 6). No strata correlative to the Sauquoit Shale are preserved west of central Wayne County along the New York outcrop belt. These strata have been truncated beneath the unconformity at the base of the Williamson Shale.

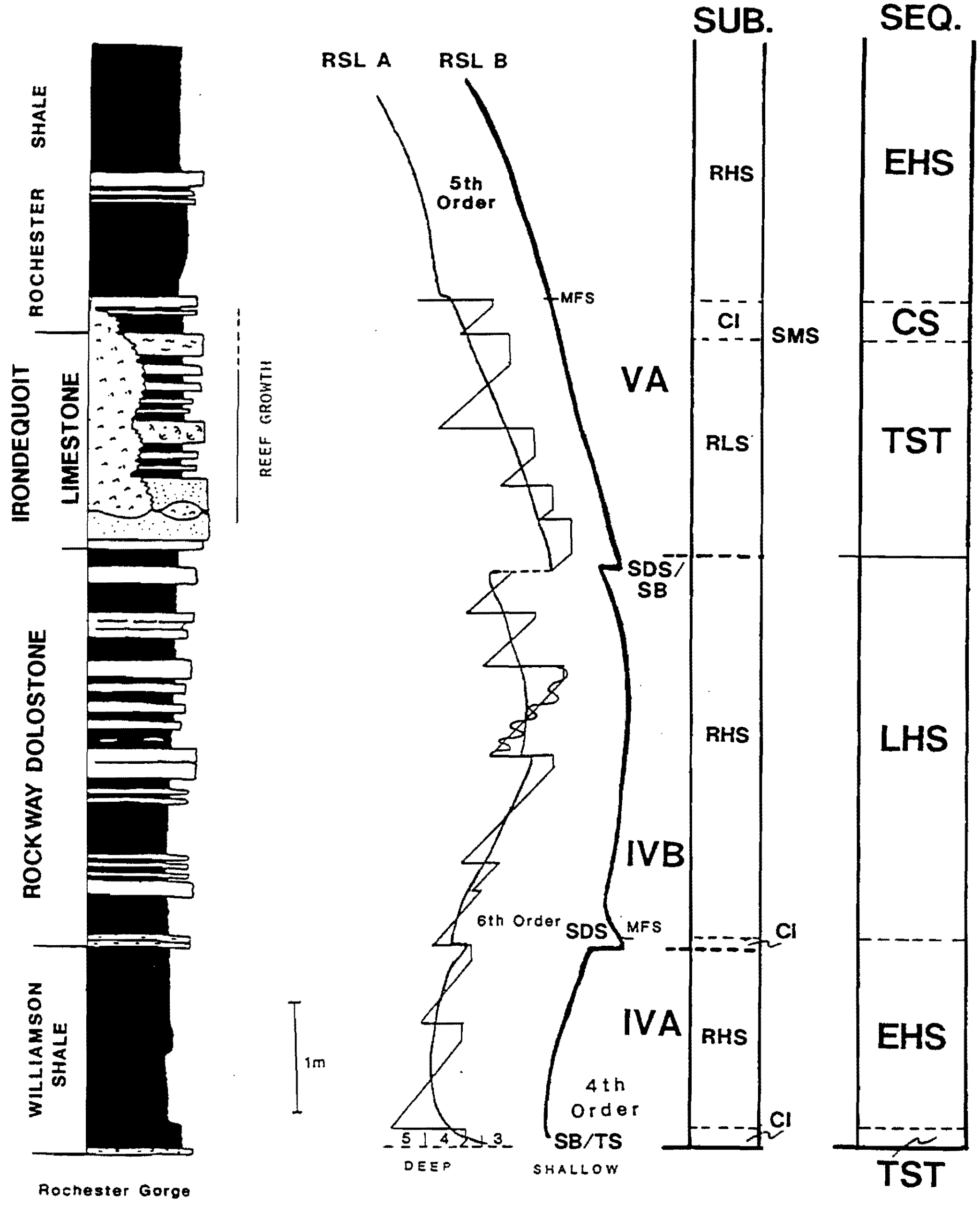


Figure 12. Lithostratigraphy, inferred relative sea-level and sequence interpretation of the late Llandoverian to early Wenlockian upper Clinton Group (Sequence IV and lower V) at Genesee Gorge, Rochester, New York. Sharp but nearly conformable sea-level drop surface (SDS) separates Sequences IV and V at base of the Irondequoit Formation. Calibration of relative sea-level curves (RLS) based on biofacies as follows: 3 = large *Whitfieldella* association. benthic assemblage 3: 4 = diverse brachiopod *(Dicoelosia-Atrypa)* association (BA-4): 5 = deep-water, dysaerobic shales with graptolites and

Sequence IV: Upper Clinton Group (Williamson Shale-Rockway Dolostone)

Sequence IV contains the basal two formations of the upper Clinton Group in western New York. These two formations, the Williamson Shale and Rockway Dolostone, are a mixed carbonate and siliciclastic mudstone succession of latest Llandoverian to early Wenlockian age. The basal boundary of Sequence IV has long been recognized (Gillette, 1947; Kilgour, 1963) as a major, albeit cryptic, unconformity. The shale-on-shale unconformity may be observed at on the west side of the Genesee Gorge at Maplewood Park and at the Tryon Park locality along Browncroft Creek. The surface is commonly overlain by a 1-10 cm thick phosphate and quartz pebble bed designated by Lin and Brett (1988) as the Second Creek Phosphate Bed. The bed is traceable for approximately 240 km between Syracuse and Niagara Falls, New York. East of Syracuse, the Second Creek Bed grades laterally into the Westmoreland Hematite which has been interpreted by Brett et al. (1990a, b) to be a condensed transgressive systems tract. Thus, the Second Creek Bed records a marine flooding surface at the top of the transgressive systems tract of the same sequence. The Williamson Shale is interpreted to be the early highstand systems tract of Sequence IV (Figure 12). West of Niagara Falls, the bed appears to be represented by a glauconitic zone at the top of the *Pentameroides*-bearing Merritton Dolostone. The Second Creek Bed yields conodonts indicative of the *P. amorphognathoides* Zone that establish it as late Telychian C_5 to C_6 age. The biostratigraphy and stratigraphic relationships also suggest correlation of the Merritton Dolostone and the Westmoreland Hematite. Both units represent the condensed transgressive systems tract of Sequence IV.

In the Rochester area, the Williamson Shale is a 2-6 m thick sequence of black and greenish-gray, graptolite- and brachiopod-bearing clay shale. The Williamson Shale contains the deepest marine biofacies in the Silurian System of western New York. The graptoloid-*Eoplectodonta* biofacies of the Williamson Shale represents a transitional BA-5 to BA-6 benthic assemblage (sensu Boucot, 1975). In polished drill core, small *Chondrites* burrows are also visible.

Polished drill cores also reveal decimeter-scale rhythmic alternations of shale beds exhibiting different shades of green and gray that are reflective of varying oxidation states of iron. These color alterations must be primary depositional features, because the *Chondrites* burrows in one bed are infilled by clay that is the same color as the overlying bed. These small-scale rhythms are reminiscent of limestone-marl couplets that have been interpreted elsewhere to record 10 ka. precessional cycles in the Milankovitch band (Hallan, 1986; Ricken, 1986). A similar bedding motif is also apparent in the overlying Rockway Dolostone (Figure 13).

The Rockway Dolostone is marked at its base by a thin (10-30 cm), quartz and phosphate pebble bed, designated the Salmon Creek Phosphate Bed by Lin and Brett (1988). The Rockway Dolostone consists of rhythmically alternating green-gray shales and fine-grained carbonates. Both lithofacies are generally fossiliferous and contain brachiopod assemblages dominated by *Costistriklandia* west of Niagara Falls and *Eoplectodonta* and *Clorinda* at sections in western Monroe County and Wayne County. These brachiopods suggest that the *Chondrites* -rich shales and carbonate mudstones were deposited in below-wave-base environments that were slightly shallower than the Williamson Shale paleoenvironment. Thus, the Rockway is interpreted to represent the late highstand systems tract of Sequence IV.

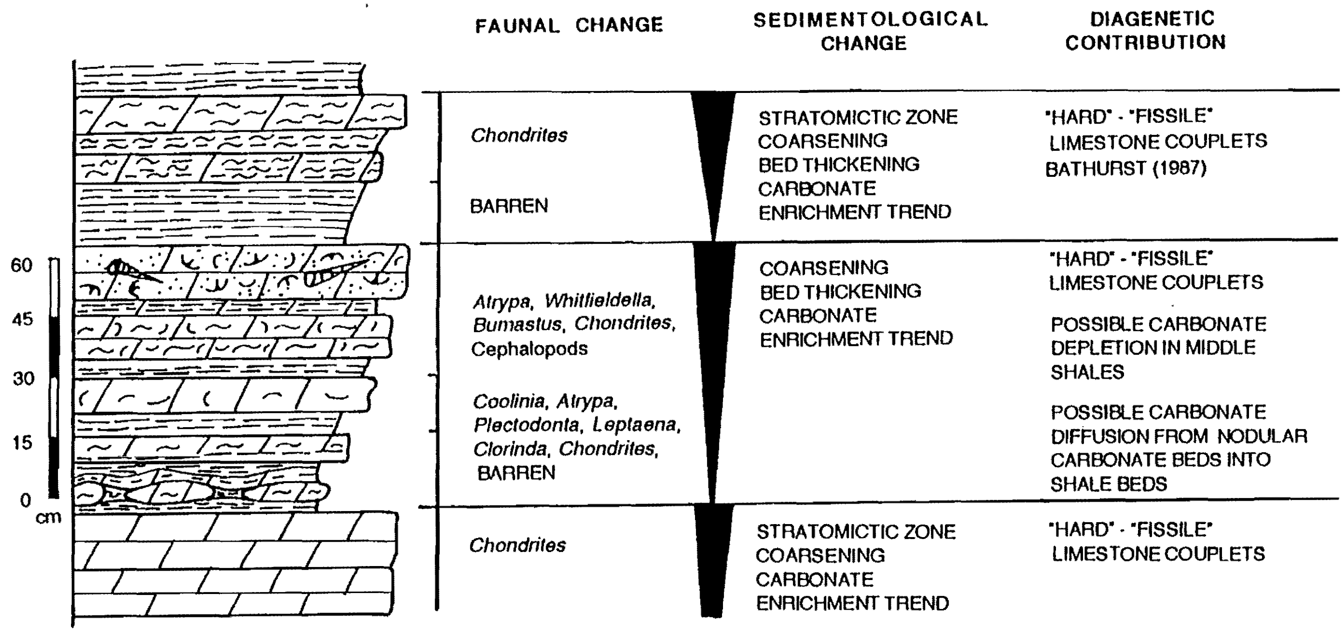


Figure 13. Example of Rockway sixth-order cycle in the Genesee River Gorge, Rochester, NY. Description of faunal, textural, and diagenetic components of same sixth-order cycle are provided to the right of the stratigraphic column.

The decimeter-scale rhythmic couplets seen in the Rochester area sections of the Rockway are stacked into meter-scale asymmetric to subsymmetric cycles reminiscent of Punctuated Aggradational Cycles (PACs) of Goodwin and Anderson (1985). These meter-scale or parasequence cycles are apparently traceable as discrete allocycles between Hamilton, Ontario and Wayne County, New York. Tentative correlation of these cycles with similar bedding patterns in the Dawes Sandstone of central New York and the upper Rose Hill Shale of Pennsylvania suggests that these are circumbasinal allocycles.

Sequence V: Upper Clinton Group (Irondequoit Limestone-Rochester Shale-DeCew Dolostone-Glenmark Shale)

The Rockway Dolostone shares a sharp, distinctive contact with the overlying Irondequoit Limestone. This contact may be traced basin wide as a distinctly sharp surface between equivalent formations and was recognized by Dennison and Head (1975) as representing a basin-wide sea-level drop surface. In east-central New York, the sharp surface occurs between the Dawes Sandstone and the overlying Kirkland Hematite. In Pennsylvania, the surface generally has been used to mark the contact between the Rose Hill Shale and Keefer Sandstone. Given the ubiquity of the distinctive surface across much of the basin, the Rockway-Irondequoit contact has been interpreted to be the Sequence IV-V bounding unconformity.

The Irondequoit Limestone consists of buff-weathering, crinoidal and brachiopod packstones and wackestones with green-gray shale interbeds. Small, bryozoan-rich bioherms are intercalated in the bedding sequence. The bedding sequence generally reflects a stepped, retrogradational facies trend. The shallowest facies appear to be in the basal beds of the formation and consist of crinoidal packstone. Beds of relatively shallow water, packstone facies that are intercalated with calcareous shales and bioherms appear to cap meter-scale allocycles. These cycles are traceable westward to Niagara County where they coalesce into a massive formation of well-sorted, crinoid and brachiopod grainstone reflecting wave-base shoal environments. The better articulation of body fossils and the diverse biofacies dominated by the brachiopod *Whitfieldella* in the Rochester area suggest that the sections observed in the Genesee Gorge reflect a more basinal setting than the classic section at Niagara Gorge.

The retrogradational trend initiated in the Irondequoit Limestone continues into the lower member of the overlying Rochester Shale. The basal bed of the Lewiston Member contains a diminutive brachiopod fauna (Tetreault, 1994) and consists of an intensely bioturbated calcareous shale. Drill cores reveal a profusion of highly compacted, millimeter-scale *Chondrites* burrows. The bed appears to represent a period of slow net accumulation of siliciclastic muds and may be interpreted as a condensed section at the base of the Sequence V highstand systems tract. Given this interpretation, the basin-wide, nearly isochronous facies change from coarse-textured carbonates and siliciclastics to shale records a major Wenlockian marine transgression. A major Silurian sea-level highstand in the early Wenlockian (Sheinwoodian) is also apparent in other marine basins. (Johnson, 1987; Johnson et al. 1985, 1991).

The strong evidence of eustatic control on the major facies change, however, cannot explain regional stratigraphic relationships in lowermost Rochester Shale strata that suggest that differential subsidence of the basin continued to

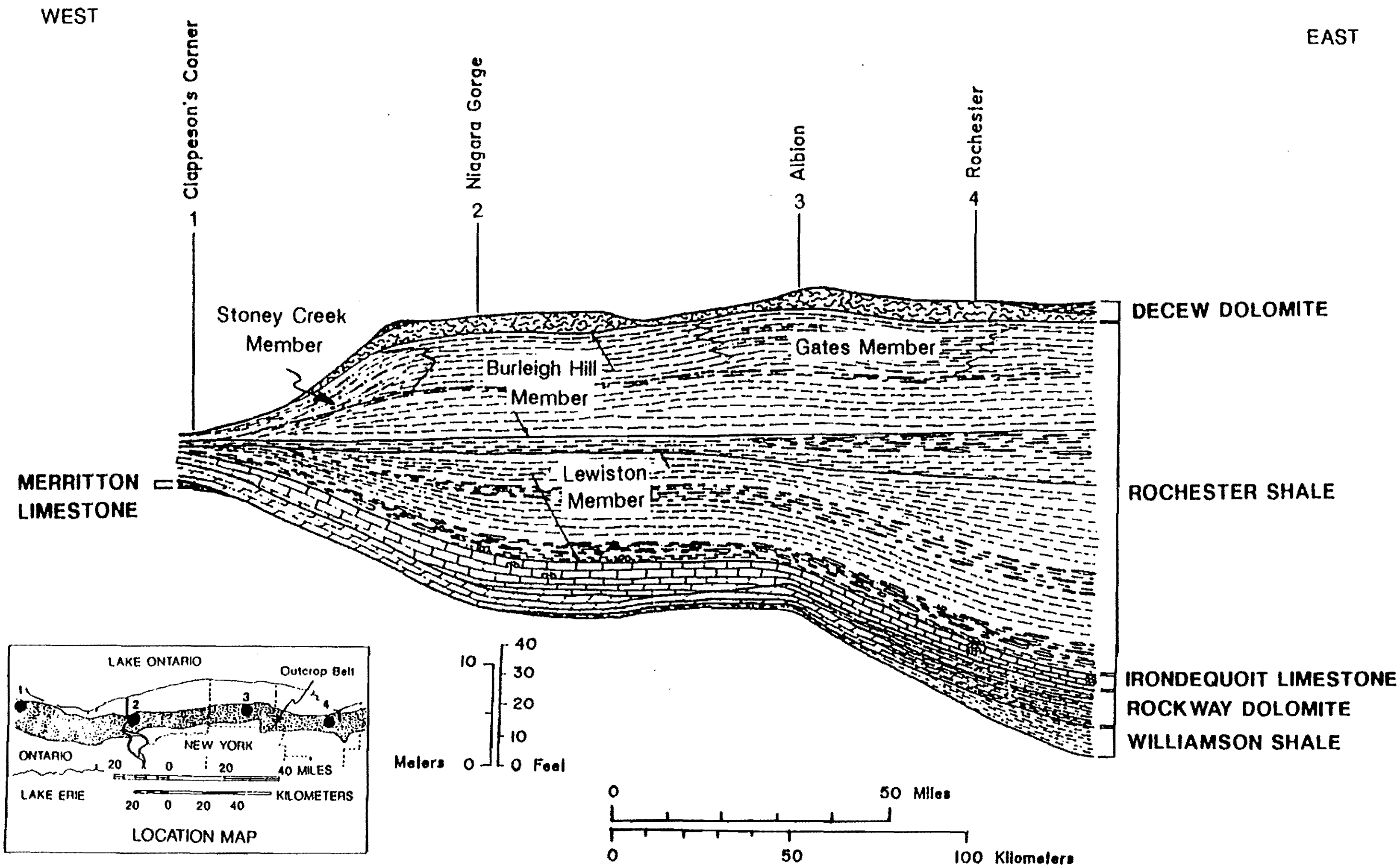


Figure 14. Diagrammatic stratigraphic relations in the upper part of the Clinton Group, with regional correlations between Clappison's Corners, Ont., and Rochester, N.Y. Reference datum is the contact between the Lewiston and Burleigh Hill members of the Rochester Shale.

operate. First, complex pinch and swell architecture of basal beds in the Rochester Shale of Pennsylvania suggest the formation of intraformational saddles and sags. Second, the retrogradational pattern of the Irondequoit continues beyond the condensed section for approximately 10 meters higher into the lower Lewiston Member before maximum relative sea-level is attained. This pattern may be explained by an episode of basin subsidence that outpaced deposition of siliciclastic muds and bioclastic carbonates that comprise the Lewiston Member.

The top of the Lewiston Member of the Rochester Shale is capped by a bryozoan biostromal layer that extends far into the basin off the western ramp. A mirror image fossiliferous and hematitic sandstone tongue extends into the basin from the eastern basin margin. This horizon, designated the Lewiston E submember by Brett (1983a, b), has been interpreted by Brett and others (1990a, b) to mark the boundary between the early and late stages of the highstand systems tract.

The beds overlying the Lewiston E submember at Rochester were assigned to the Gates Member by Brett (1983a, b). These strata consist of silty clay shale and are only sparsely fossiliferous. The paleontology of these beds is less noteworthy than that of the Lewiston Member except for some spectacular crinoid (*Dimerocrinites*) pavements observed at the Penfield Quarry (Stop 3).

The Rochester Shale attains thicknesses of approximately 35 m in the Rochester area (Figure 14). Consequently, the formation does not crop out completely at any one locality. The most complete section, albeit an inaccessible one, occurs at the Upper Falls on the Genesee River. At this section, river level below the falls occurs in the lower beds of the Lewiston Member. At the crest of the falls, the contact between the Gates Member and the DeCew Dolostone may be seen on the east bank.

Numerous exposures of the Rochester Shale-DeCew Dolostone contact are exposed along the area expressways and in the Erie Barge Canal. Although apparently conformable, the contact is always distinctive because of the often spectacular soft-sediment deformation in the basal beds of the DeCew Dolostone. The horizon of soft-sediment deformation is commonly overlain by hummocky cross-stratified calcisiltite and pelletal calcarenite beds. This association of bedding features is suggestive of submarine slumping of storm-generated beds due to widespread liquifaction and remobilization of sediment it may represent a seismite.

The DeCew Dolostone is only sparsely fossiliferous. The fauna includes mainly disarticulated crinoid ossicles and lingulid brachiopods. At Rochester, arenaceous beds in the DeCew contain bulbous *Skolithos*-like vertical burrows. Locally, both the Gates Member and the DeCew Dolostone apparently accumulated on the platform of an intrabasinal paleotopographic high referred to by Don Crowley (unpublished manuscript) as the Penfield Shoal. Brett and others (1990a, b) interpreted these strata as part of the late highstand systems tract of Sequence V. In Monroe County, the DeCew Dolostone is unconformably overlain by the Gasport Limestone-equivalent part of the Penfield Formation of Sequence VI.

Thin remnants of Sequence V strata that overlie the DeCew Dolostone can be observed in Wayne County. These younger strata consist of fossiliferous shales and thin brachiopod-rich limestones. The diagnostic brachiopod of this interval is *Nucleospira pisiformis*. This interval of *Nucleospira*-rich black limestones extends eastward into the type Clinton area of central New York and into Pennsylvania and

Maryland where it has previously been mapped as the basal unit of the McKenzie Shale (Brett et al. 1990).

Sequence VI: Lower Lockport Group (Gasport Limestone, Goat Island Dolostone equivalents of the Penfield Sandstone)

Identification of the Glenmark Shale in Wayne County confirms that the sharp, erosional contact between the DeCew and Gasport Formations in the Niagara region is a low angle unconformity. Thus, the unconformity defines the base of Silurian Sequence VI in western New York and Ontario outcrop belts. This sequence includes the formations of the lower Lockport Group. In the Rochester area, the Lockport carbonates are particularly arenaceous. For this reason, Zenger (1965) defined the Penfield Sandstone Member of the Lockport Formation to include all strata between the underlying DeCew Formation and the overlying Oak Orchard Formation. Recent work by Brett and others (1994) has demonstrated the need for substantial nomenclatural revision for three strata because of the following reasons: 1) the Lockport strata are presently given group strata because of internal, mappable units which are larger in scale than beds and, thus, may be defined as members and formations; these member- and formation-scale units are recognizable within the Penfield Sandstone. For example, the Gasport Limestone and Goat Island Dolostone horizons may be readily identified at the Penfield Quarry; 3) the name "Oak Orchard" must be abandoned and substituted by the names "Eramosa" and "Guelph" because of miscorrelation of strata across the United States-Canada border and the fact that none of the strata previously designated as "Oak Orchard" are actually exposed along Oak Orchard Creek. The nomenclature for Lockport strata in the Rochester area is in the process of being revised (Brett and others, 1994). Brett and others (1990a, b) have promoted use of the Niagara region formation names to identify allostratigraphic units that are relatively time-parallel and cross-cut local facies belts. The benefit of defining allostratigraphic as opposed to purely lithostratigraphic units lies mainly in improved correlations and more precise paleogeographic reconstructions (Figure 15).

Gasport-equivalent strata in the Rochester area consist of brown-gray, medium- to thick-bedded, planar to bimodally trough cross-stratified, dolomitic sandstone and arenaceous dolostone. The thickness of the Gasport-equivalent, part of the Penfield averages approximately 5 m. At localities in western Monroe County, lenses of crinoidal grainstone, i.e. classic Gasport facies, are still common in the lower half of the interval. The upper half of the interval is often darker colored and slightly more argillaceous. The upper half is commonly intensely bioturbated. Small-diameter *Chondrites* burrows weather out in relief a render a "vermicular" texture to the upper half of the Gasport interval.

The Gasport equivalent units are overlain by more argillaceous, slightly deeper water Goat Island equivalents. The Goat Island interval contains a relatively massive bed of arenaceous dolostone at its base. LoDoca (1991) has mapped remnants of the *Medusaegraptus* epibole within this massive basal Goat Island equivalent at localities in western Monroe County. The massive bed is overlain by more argillaceous, thin-bedded, fossiliferous wackestones that probably represent the deepest water facies of the Lockport Group in the Rochester area. These facies are particularly well exposed at the Route 531 exit off of Route I-490 on the west side of the city. On this road cut and many others around the city, massive, vuggy, biostromal beds previously assigned to the Oak Orchard Member and now assigned to the Eramosa Formation abruptly overlie these relatively open marine, thin-bedded carbonates.

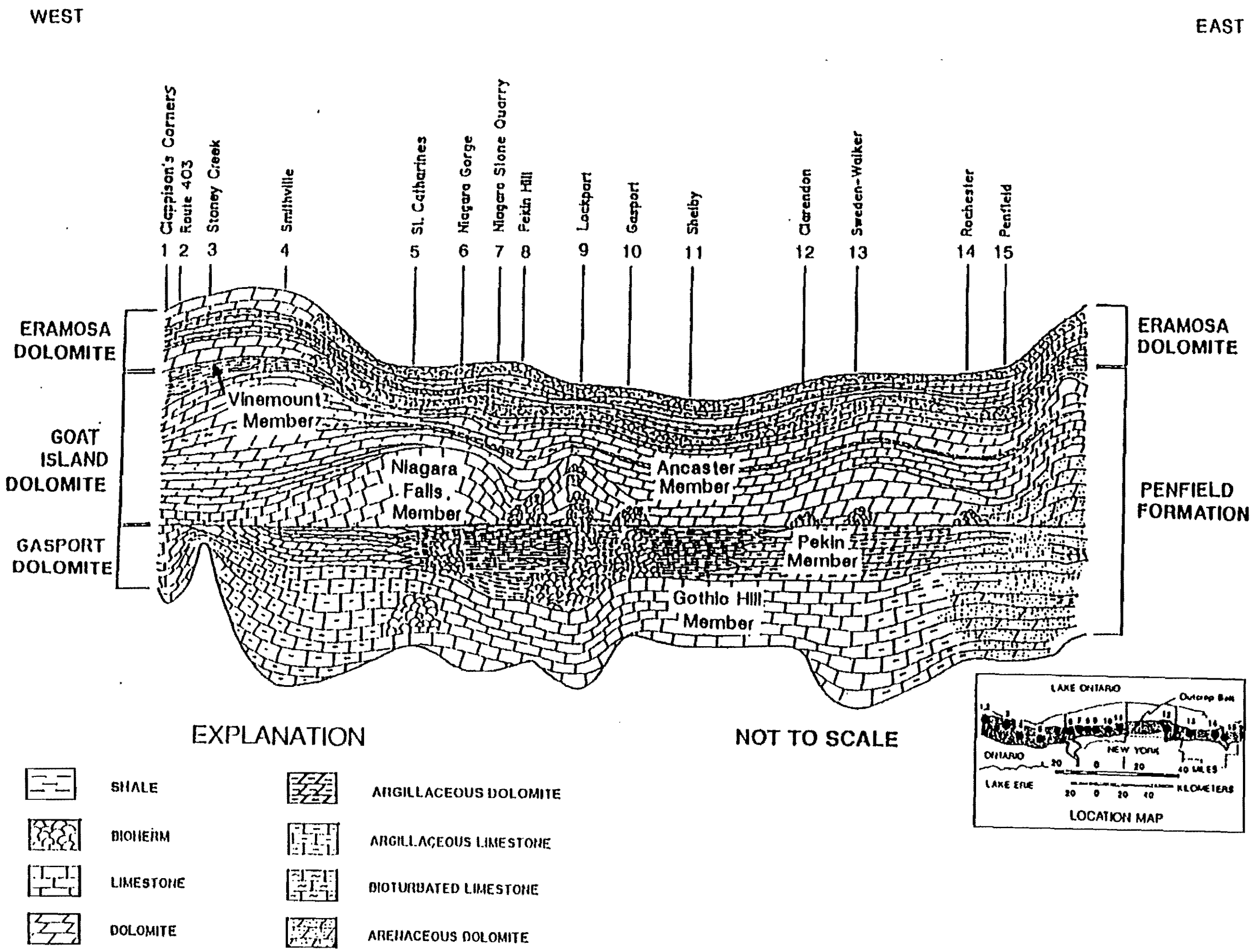


Figure 15 -- Diagrammatic stratigraphic relations in the Lockport Group, with regional correlations between Clappison's Corners, Ont., and Penfield, N. Y. Reference datum is the contact between the Gasport Dolomite and the Goat Island Dolomite.

Sequence VII: Upper Lockport Group (Eramosa and Guelph Formations) and Salina Group

The abrupt facies change from deep water, fine-grained carbonates of the upper Goat Island Formation to the shallow water, biostromal facies of the lower Eramosa Formation can be traced from Guelph, Ontario to Wayne County, New York. Although the interpretations are preliminary, this contact may define the base of a seventh Silurian third order Sequence. The Eramosa is the only unit within this tentatively defined sequence that crops out across western New York. The Eramosa generally contains a tripartite stratigraphy. The upper and lower portions of the formation consist of massive biostromal beds that are separated by a middle unit of medium-bedded, tabular, slightly more argillaceous dolostones. In the Niagara region, the Eramosa Formation is capped by distinctive stromatolite reefs of the Guelph Formation. These stromatolite reefs have not been documented in the Rochester area. In fact, Rickard (1969) suggests that the 20-25 m thick Guelph interval of the Niagara region grades eastward beyond Lockport, Niagara County into Vernon facies. Consequently, the sharp gamma ray inflection used to mark the Lockport-Vernon contact in the subsurface of the Finger Lakes region may correlate with the Eramosa-Guelph contact of the Niagara region.

DISCUSSION AND SUMMARY

The Late Ordovician to medial Silurian strata of the Genesee region represent marginal marine to deeper basinal deposits of mixed siliciclastics, derived from the erosion of the Taconic orogenic terrains, and intrabasinal carbonates. These strata record cyclic variations at several scales. The largest are equivalent to third order sequence (1 to 3 million years; Vail et al., 1991) that are bounded on one or both margins of the forehand basin by prominent erosion surfaces (see Figure 7). These large scale sequences are also subdivisible into two or more fourth order subsequences, (Bush and Rollins, 1984; Brett et al., 1990), which display a similar internal pattern to the large scale sequences of which they are a part, but also possess less significant erosion surfaces at their boundaries. We recognize a total of seven large scale or third order sequences, roughly corresponding to parts of originally defined lithostratigraphic groups in the Silurian of the Rochester area, and at least 15 subsequences. The erosional sequence boundaries correspond to relative low stands of sea level. Transgressive surfaces are generally superimposed upon the lowstand erosion surfaces with no intervening non-marine (lowstand) sediment. Transgressive or rising sea level phases are recorded in thin, but typically widespread intervals of reworked, clean sandstones (e.g., Devils Hole Sandstone) or carbonates (e.g., Irondequoit). Highstand deposition is represented by thicker shales such as the Williamson and Rochester, or by argillaceous limestones (Goat Island equivalent portions of the Lockport). Maximum flooding of shoreline areas and alluviation in estuarine environments are recorded in the offshore facies as highly condensed deposits and/or surfaces of sediment starvation near the tops of transgressive sandstone or limestone intervals. Such surfaces may be sharp discontinuities, even with evidence for erosion and are typically marked by phosphatic debris, or, in the medial, Silurian by hematitic or glauconitic beds.

The Silurian sequences and their bounding discontinuities recognized in western New York appear to correspond to those seen in other parts of the world, at least within the rather loosely constrained limits of biostratigraphy. (Johnson et al., 1985; Brett et al., 1991). Because of this, we argued that at least the larger cycles (third and fourth order) or 0.5 to 3-million year duration are global and reflect eustatic sea level changes.

Silurian sequences can also be subdivided into a number of smaller-scale cycles which range from nearly symmetrical limestone shale cycles to markedly asymmetrical, shallowing upward cycles. These fifth and sixth order cycles (100 to 400 thousand year cycles) also appear to correlate widely within the Appalachian basin. The shallowing upward shale to limestone cycles in western New York, for example, appear to correlate with coarsening upward shale to siltstone or sandstone cycles in the central New York type Clinton area. At present, we are unable to determine whether or not these cycles can also be correlated outside the Appalachian basin.

As a generality, the succession from Queenston Shale to Vernon redbeds represents one broad scale trend towards deepening culminating in the Williamson and Rochester Shales in the mid Silurian (late Llandoverian to Wenlockian) interval, followed by a general trend towards shallowing. This large scale, second order cycle is also observable within the Silurian in other parts of the world, and it may also reflect a global scale, perhaps tectono-eustatic driven cycle of rise and fall in sea level.

Three very broad scale trends are superimposed upon the cyclic patterns of the Silurian stratigraphic record. The first is a rather obvious trend toward a decreasing influence of siliciclastic sedimentation upward in the Silurian, at least to the middle portion of the Clinton group. Thus, Sequence 1, the Medina Group is almost entirely siliclastic sands and muds in western New York, whereas as Sequence 2, the lower portion of the Clinton Group, comprises mixed siliciclastics and limestones. A reversal of this trend occurs within the middle portion of the Clinton Group with deposition in central New York of relatively thick (30 to 40 m siliciclastic wedge of the Saquoit-Otsquago Formations Sequence 3). Siliciclastic-dominated sedimentation continued in the eastern and central New York through the accumulation of Sequences 4 and 5, (Willowvale-Williamson shale, Herkimer Sandstone and its lateral equivalent, the Rochester Shale). This pulse of increasing siliciclastic input, including relatively coarse sands in New York and Pennsylvania (Keefer Sandstone, Colter, 1983, 1988), is timed with a reorganization of the basin and a change in its direction of migration. The trend towards increasing siliciclastics is reversed through much of the later Wenlockian and Lludovian with deposition of the Lockport Group, at least in western New York. However, the appearance of dolomitic sandstone within the Penfield facies of the Lockport Group at Rochester, and their eastward gradation into finer-grained Ilion Shale may indicate that siliciclastics were largely trapped in the eastward portions of the basin due to partitioning associated with the development of a "Penfield high" or shoal area (Zenger, 1965; Crowley, 1973). In any case, the interval of carbonate-dominated sedimentation in the Lockport in the west was terminated in the later part of the Ludovian by the westward spread of the Vernon siliciclastics. These latter appear to have over-filled the shallow eastward portion of the basin, such that the upper parts of the Vernon and its equivalent in Pennsylvania, the Bloomsburg Formation, consist of nonmarine red beds.

A second, related trend, less obvious from the local frame of reference, is a large scale cycle in the migration direction of the Appalachian of the foreland basin axis. During the late Ordovician, (Ashgillian) to the mid Silurian (late Llandoverian) time, some 15 million years, the depocenter or area of thickest sediments, as well as the area of apparent deepest water facies appears to have shifted by over 300

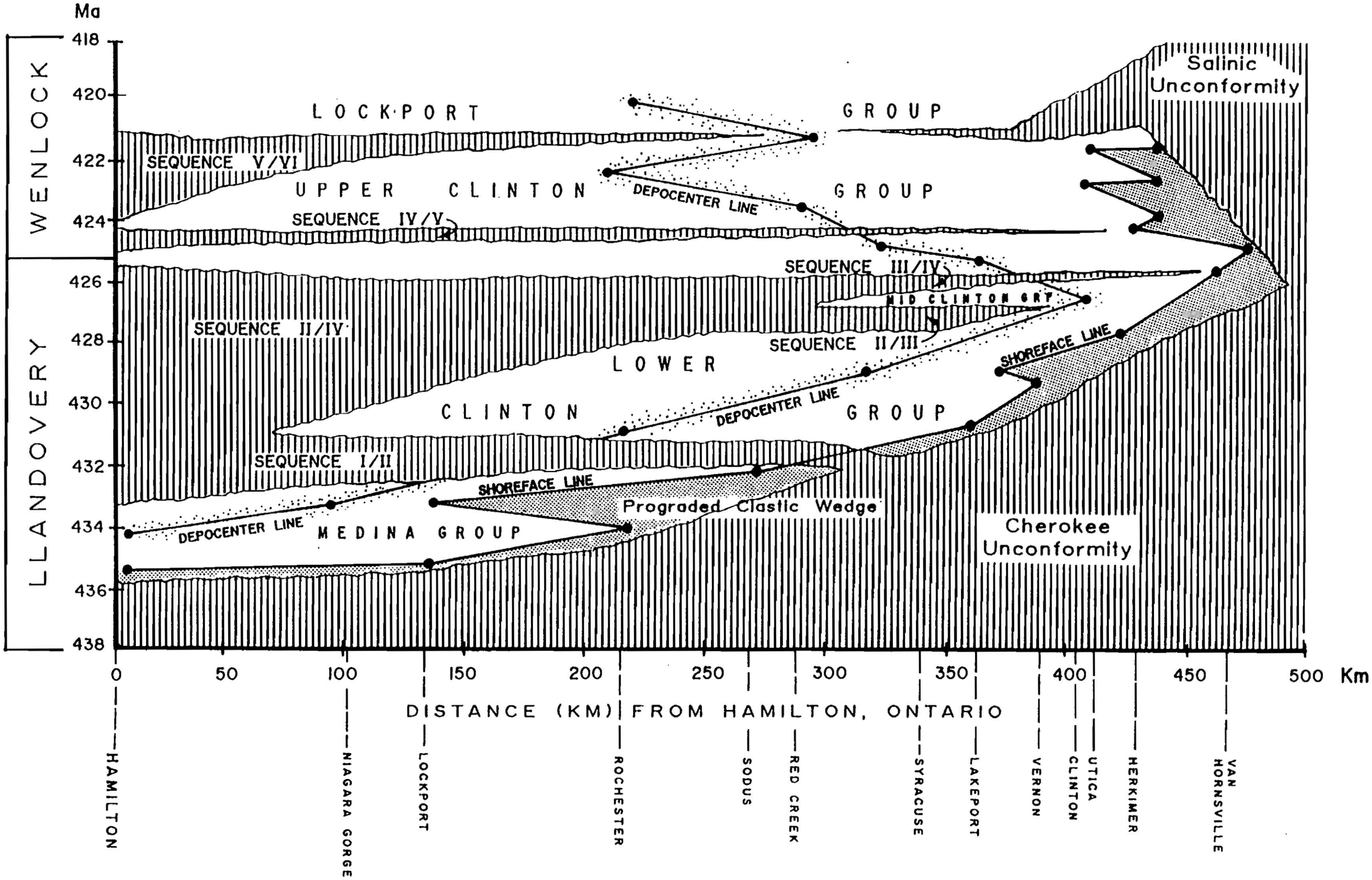


Figure 16. Migration of shoreface and depocenter for the Appalachian Basin during early to medial Silurian time in section along New York State outcrop belt. Major sequence-bounding unconformities are depicted by vertical ruling.

kilometers from western Ontario to central New York State (Figure 16). This was followed by an abrupt change during the latest Llandoverian, at which time the basin axis appears to have migrated back westward some 200 plus km during deposition of Sequences 4 and 5. A return to eastward shifting in the basin center is evident, starting within the upper portion of the Lockport Group, and certainly continuing into the time of deposition of the overlying Salina Group (late Llandovian to Pridolian times).

Finally, a third phenomenon relates to the development of unconformities that bound the Silurian sequences. Some of the sequence bounding unconformities become more extensive in an eastward direction (i.e., proximally or toward the source of the sediments), while others in the mid part of the Silurian open in a westward or Cratonward direction (Figure 17). The basal Cherokee unconformity opens eastward such that the Queenston shale and then the underlying Oswego, Lorraine, and parts of the underlying Utica siliciclastics are progressively beveled in central New York. Likewise, the Salina unconformity which is a minor discontinuity separating the Vernon Shale from the overlying Syracuse Formation in western New York bevels the Vernon and ultimately oversteps the underlying Herkimer, Willowvale and Otsquago siliciclastics in east central New York.

Conversely, unconformities bounding sequences 2, 4, 5 and 6 all appear to become more prominent toward the west, approaching the so-called Algonquin Arch; these discontinuities appear to decrease to conformities in central New York State. For example, the very major unconformity that underlies the late Llandoverian Williamson Shale throughout west central New York (Lin and Brett, 1988) is a regionally angular beveled surface. This unconformity appears to be a minor discontinuity between the West Moreland hematite and underlying Sauquoit-Otsquago shales in central New York. However, to the west the unconformity becomes more prominent and progressively bevels almost the entire Clinton Group between the area of Clinton, New York and Grimsby, Ontario.

This pattern suggests erosion of a differentially uplifted arch, perhaps centered in the region of Hamilton, Ontario during the medial Silurian. We interpret this feature as a transient forebulge, as predicted in most models of basin dynamics (e.g., Quinlan and Beaumont, 1984; Beaumont et al., 1988, Jordan and Flemings, 1991). Unconformities of the basal parts of the Medina Group, upper Clinton and Lockport Groups also display lesser, but still significant erosional truncation toward the west.

Thus, three phenomena appear to be interrelated: (1) the pattern of decreasing and increasing siliciclastic input, (2) the eastward to westward oscillation of basin axis migration over several tens of millions of years, and (3) the alternation of eastward opening and westward opening sequence bounding unconformities. Taken together, these observations suggest the action of a long term tectonic cycle.

Following the viscoelastic thrust loading model of Quinlan and Beaumont (1984) and Beaumont et al. (1988), we have previously argued (Brett et al., 1981; Goodman et al., in press), that phases of tectonic thrusting alternating with intervals of quiescence are recorded in this long term pattern. Specifically, we have observed that intervals of westward basin axis shift, e.g. during the late Ordovician, and again during the mid part of the Silurian, are coincident with increasing coarse siliciclastic sedimentation and the development of minor

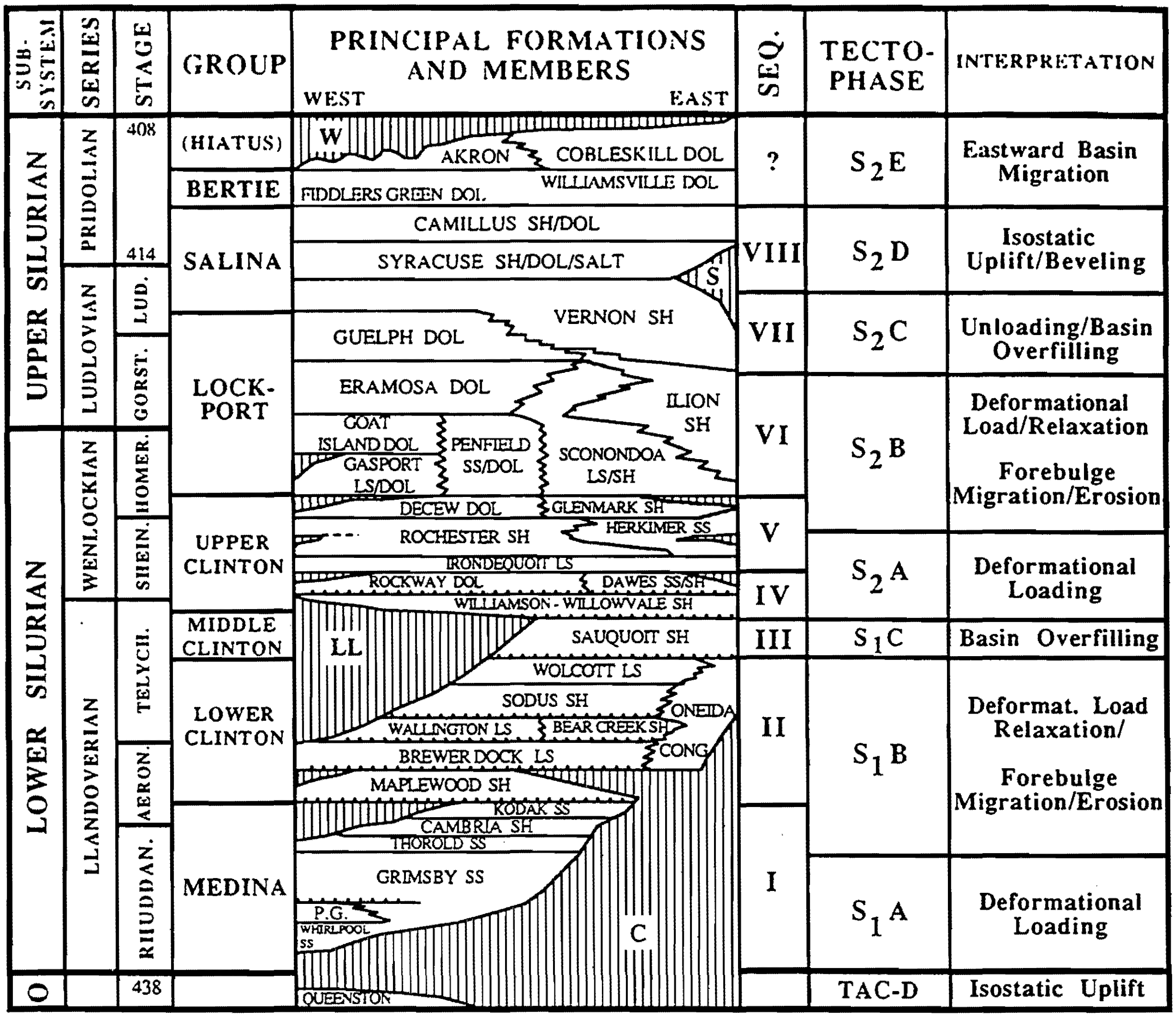


Figure 17. Tectophases of Sequences I-VIII across New York State. Rightside presents interpretation of phases of tectonic cycles. Tectophases designated as TAC-D=Taconic late phase; S_1A-S_1C and S_2A-S_2E are inferred phases of tectonic cycles during the Silurian.

westward opening unconformities. All these phenomenon may be related to one another and appear to have occurred during times of active thrust loading in the Taconic Orogen. Intervals of eastward basin shift, decreasing coarse siliciclastics, and westward opening major unconformities appear to be associated with interludes of tectonic quiescence and thrust load relaxation. A migration of the foreland basin toward the Hinterland and accentuation of the peripheral forebulge are predicted in the viscoelastic model of Beaumont et al., (1988). Accentuation of the eastern basin and the western forebulge is evident at times such as the early Silurian interval from at least the upper portions of the Medina Group deposition into the middle Clinton group.

A phase of basin overfilling by fine grained siliciclastics and some carbonates occurred during the later quiescent interludes. The Ordovician Queenston-Juniata and the late Silurian Bloomsburg-Vernon red mudstones would exemplify this phase. Finally, very late phases of uplift in the proximal clastic wedges were followed by an eastward erosive beveling of the proximal molasse. For example, major eastward opening unconformities cut the top of the Queenston and the Vernon red beds. In accordance with the Beaumont et al. (1988) model it is postulated that eastward uplift of the clastic wedge represents isostatic adjustment due to the redistribution of some of the thrustload. This took place by erosion and transport of sediments into more distal or cratonward parts of the basin. As such, the major eastward opening unconformities would record prolonged periods of relative quiescence between tectonic thrusting episodes.

We recognize that other models of foreland basin dynamics would make different, and in some cases, opposite predictions. For example, the elastic model of lithospheric behavior advanced by Jordan and Flemming (1991), would predict that episodes of eastward migration of the basin axis and of accentuated forebulge erosion would actually be times of active thrusting. Westward migration of depocenters would represent infilling of the foreland basin in the interludes following the thrusting episodes. In common with the Beaumont et al. (1988) model, Jordan and Fleming (1991) also postulate that uplift and erosion of the proximal side of the foreland basin will be greatest during times of tectonic quiescence. The main difference between these two models resides in the rate of response of the lithosphere to tectonic loading. In Jordan and Fleming's model the lithosphere is depressed relatively rapidly during tectonic thrust loading. This produces an asymmetrical deepened basin proximal to the thrust load. Conversely, in the viscoelastic model of Beaumont et al. there is a lag time in subsidence in the lithosphere such that the basin tends to contract toward the thrust load after the thrusting is over and during a phase of crustal relaxation. Although our observations are preliminary, they seem to support the views of the Beaumont et al. Clearly, the foreland basin appears to have been driven cratonward during known intervals of thrust loading, such as in the Taconic Orogency (Lehmann et al. in press). These are also intervals associated with increased input of coarse siliciclastics into the foreland basin. In contrast, times of accentuated western forebulge development and of eastward shifting of the basin axis appeared to coincide with intervals with little or no known tectonic activity as in the early part of the Silurian. Tectonic quiescence is also supported by the fact that these times of eastward shift are coincident with a decreasing input of coarse siliciclastic sediments. This might be expected during times of decreased erosion of an inactive tectonic source terrane. We have also made similar observations in the latter part of the Silurian, the early and Middle Devonian (Brett and Baird, this volume).

6.3 0.1 Intersection St. Paul St.; turn right (south)

6.7 0.4 Junction Driving Park Boulevard (or Avenue E), turn right(west) and cross Genesee River on new (1986) Driving Park Bridge

6.95 0.25 At west end of bridge turn left into driveway of YMCA and park. Proceed on foot back onto bridge for overview of Lower Falls.

STOP 1B - LOWER FALLS, GENESEE RIVER

This overlook provides a panorama of the Lower Falls of the Rochester Gorge. The Lower Falls, with a drop of 30 m (97 ft), is capped by resistant sandstones of the Upper Grimsby and Kodak Formations.

The stratigraphic units examined previously (Stop 1A; Queenston Shale to Reynales Limestone) are clearly visible near the base of the gorge beneath and immediately south of the Driving Park Bridge. Higher units of the Clinton Group can also be viewed from this vantage point although their limited accessibility precludes close examination during this trip.

The Reynales carbonates are observable immediately opposite this point near the base of the large water surge tank of the Rochester Gas and Electric Company. They are overlain by an interval of shales which actually constitute two distinct units. The lower 4.4 m (13 ft) of greenish to purple Lower Sodus Shale is unconformably overlain by 2 m (6 ft) of black to greenish-grey, graptolite-bearing Williamson Shale. The contact of these formations is cryptic but actually represents a significant, regional, angular unconformity that bevels successively older units in a westward direction (Lin and Brett, 1988). This erosional surface, which may reflect the eastward migration of a forebulge, is onlapped by a widespread dark shale of the latest Llandoverian Williamson Formation. The Williamson Shale is followed by thin-bedded dolomitic carbonates and grey shales of the Rockway Formation. The overlying Irondequoit Formation is thicker-bedded and contains small bryozoan-algal bioherms up to about 2 m in height. These can be seen to deform strata in the cliff near the deck level of the Driving Park Bridge. They were initiated on a single horizon of crinoidal packstone near the base of the Irondequoit Limestone. In turn, the Irondequoit Limestone is overlain here by about 3 m of brownish-grey, fossiliferous Rochester Shale, which is bevelled and overlain by glacial deposits.

Return to vehicles and retrace route across bridge , turning right on Avenue E.

7.2 0.25 Intersection of St. Paul, turn right and proceed south to Bausch St.

8.3 0.1 Genesee Brewery; look for access road on other south side of plant opposite Ward Street

8.7 0.4 Access Road for Upper Falls Terr Park, turn right and park in lot, walk to Pont de Rennes Bridge

STOP 1C- HIGH (UPPER) FALLS PARK, GENESEE RIVER

This park provides a view of the 25m (80 ft) High Falls, formerly a major source of water power for industry. Rochester developed as a grain milling center in the mid 1800's largely as a result of its location on the Erie Canal and the presence of this source of power (seeGrasso and Leibe article in this guidebook). Nearly vertical cliffs in the Genesee River Gorge below the High Falls display almost complete section of the Rochester Shale. This may be the oldest type locality in North America, the Rochester Shale having been named by James Hall in 1839. The Rochester Shale, here about 30 m (98 ft) thick, contains grey, calcareous shale with numerous thin calcisiltites (Brett, 1983a). The Rochester Shale is moderately to sparsely fossiliferous with an abundance of brachiopods and the trilobite *Dalmanites*. However, it is largely inaccessible at the type section. The Rochester appears to record a slight shallowing of relative sea level, with an increase in the number and thickness of dolomitic carbonate interbeds toward the top as it passes up into the predominantly carbonate DeCew and Lockport Formations. The upper unit of the Rochester Shale, comprising approximately a third of the cliff at this section, is the Gates Member. The Gates, DeCew, and Lockport units will be examined in greater detail at Penfield quarry (Stop 3). Rochester and DeCew strata represent shallow subtidal, muddy marine deposits, as indicated by the abundance of fossils and lack of tidal features.

8.75	0.05	Return to vehicles and turn around; <u>pull out and turn right onto St. Paul and proceed south</u>
8.8	0.05	Railroad overpass
8.9	0.1	Cumberland Ave.; continue south on St. Paul
9.15	0.25	Pleasant Ave.
9.25	0.1	Main St.
9.4	0.15	Broad St; bridge on old aqueduct (see Grasso and Leibe in this guide)
9.6	0.2	Note multiple junctions: Monroe, 490 East, 15 South, 490 East
9.7	0.1	<u>Take left exit to 490</u>
9.9	0.2	<u>Merge onto 490 East</u>
10.4	0.5	Exit 17, Goodman St. View of Pinnacle Hill with radio towers on right
10.9	0.5	Exit 18, Monroe Ave.
11.4	0.5	Exit 19, Culver Rd.
12.4	1.0	Exit 20, Winton Rd. View of Cobbs Hill to south; <u>stay to the right</u>
12.85	0.45	Fork of 1-490 and I-590; <u>bear right onto exit for I-590 North.</u>
13.1	0.25	Former "Can of Worms" area, minor low cuts in upper Penfield and Eramosa formations of Lockport Group formerlly biostromes were exposed near top of Penfield
13.5	0.4	"Can of Worms" ends
13.7	0.2	Exit 6 ; Blossom Road exit
14.2	0.5	Exit 7 ; Browncroft Boulevard (there are low cuts in DeCew dolostone along exit); <u>after passing under Browncroft overpass prepare to merge to the right, entrance ramp coming from Browncroft onto 390 pull right onto entrance ramp</u>
14.35	0.15	<u>Pull off and park immediately before I-590 N sign on shoulder</u> <u>Put flashers on vehicles. Walk into the field into the right of the highway and then straight paralleling the highway, down a bank, to ramp road of sewage treatment plant leading down to the level of small creek.</u>

STOP 2 PALMER'S GLEN (TRYON PARK)

This unnamed creek, informally referred to as Palmer's Glen, also serves as an overflow stream for the storm sewer system. The water in the creek is contaminated to some degree and should be dealt with cautiously.

Lowest exposures along the banks of this creek are at the lower part of the Sodus Formation. This interval is slightly above the upper beds viewed at the Genesee gorge along Seth Green Drive. The shales here range from greenish gray to light purplish gray in color. The purple colored shales appear to cap small shallowing cycles within the Sodus. These cycles commence with thin shelly and, in some cases, phosphatic beds and pass upward into greenish gray shales and these latter gray upward to purplish hued shales. Both green and purple shales contain a shallow marine fauna of the classic *Eocoelia* biofacies of (Boucot, 1975) Bedding plane assemblages are dominated by *Eocoelia cf.* E. *hemispherica*. These are mixed with small bivalves (pteriniids), rare *Leptaena*, small tabulate corals, *Tentaculites*, and abundant ostracods of the *Zygobolba decora* zone. At this locality thicker coquina beds of sandy limestone rich in *Eocoelia* also occur near the top of the Sodus.

The Sodus is capped by a major erosion surface, probably the largest unconformity within the Silurian. However, the unconformity is relatively cryptic at this locality, and is overlain by hard black shale of the Williamson Formation. The contact here is marked by a thin yellowish clay, which could be a bentonite. The basal Second Creek bed of the Williamson Shale is a thin phosphatic, skeletal rich sandstone generally less than one centimeter in thickness. Higher beds consist of an alternation of decimeter-scale hard dark gray shale and soft greenish gray shale beds. The black shales contain laminae of fine quartz sand, some of which possess small scale asymmetrical ripples on their tops. The black sandy shales also display well preserved graptolites of the *Monograptus clintonensus-Retiolites venosus* assemblage. These graptolites, together with abundant conodonts obtained from basal lags within the Williamson Shale, indicate a latest Llandovery (or late Telychian) age for these shales. The Williamson here is approximately four meters in thickness. It is overlain at a minor disconformity by the dolomitic limestones and greenish gray shales of the Rockway Formation. A thin bed at the base of the Rockway contains quartz granules and small pebbles as well as black phosphatic nodules, but these are highly scattered and the bed is difficult to observe. In turn, the Rockway is approximately 2.8 m-thick and is overlain by 3.2 m. of dolomitic crinoidal wacke- to packstones of the Irondequoit Formation. These rocks occur high in the bank at this section, and can be best viewed by walking downstream approximately 100 ft to the fork of Browncroft Creek, and walking upstream (south) into the Browncroft fork. Here the Rockway, Irondequoit and basal Rochester Shale can be viewed at a small waterfall section.

Return to vehicles

14.55	0.2	<u>Continue north after stop</u>
14.75	0.2	Overpass Tryon Park Road
14.85	0.1	Town of Irondequoit sign and sign for Exit 8, Empire Blvd.
15.25	0.4	<u>Bear right onto exit 8 for Empire Blvd.</u> (Route 404), to reverse directions. At stop light at junction of Empire, <u>turn left onto Rte. 404 west.</u>
15.65	0.4	Underpass under 590; <u>turn left onto entrance ramp back onto 590 S</u>
15.95	0.3	<u>Merge onto 590 South</u>
16.45	0.5	City of Rochester line

17.10	0.65	Browncroft Boulevard exit; bear right onto Exit 7
17.2	0.1	Stop light at junction Route 286 off exit lane; turn left onto Browncroft Boulevard (Route 286 East)
17.25	0.05	Stop light under bridge at entrance of 590; continue straight on Browncroft Blvd. (Route 286 East)
17.50	0.25	Small stream on right exposes upper portion of Rochester Shale
17.85	0.35	Bridge over Irondequoit Creek, Penfield town line
18.35	0.5	Ascending hill out of Irondequoit Valley; this is the old River Valley of the preglacial Genesee River , now occupied by underfit Irondequoit Creek
19.05	0.7	Stop light at Blossom Road; continue straight on Rte. 286 East
19.25	0.2	Panorama Trail stop light
19.65	0.4	Clark Road stop light ; continue straight on Rte. 286
20.15	0.5	Whalen Road; turn right
20.75	0.6	Bend in Whalen Road at Clark Road junction
20.95	0.2	Quarry entrance on left; enter and check in at office for permission to access quarry.

STOP 3-DOLOMITE PRODUCTS QUARRY, PENFIELD

This large, active dolomite quarry, about 30 m (100 ft) deep, exposes a nearly complete section of the Lockport Group and its contact with the underlying Clinton Group (Grasso and Friedman, 1989; Zenger, 1965). Crushed stone quarried at this location is used primarily for road-paving material. The quarry is famous among amateur mineral collectors as a source for euhedral crystals of saddle dolomite, calcite, sphalerite, galena, pyrite, celestite, selenite, and especially, clear bluish fluorite which occur in 20 to 50 cm. diameter vugs within the dolostone at several horizons. The source and timing of the mineralization is enigmatic but it occurred at temperatures of approximately 150°C. Mineralization occurred selectively within cavities produced during dolomitization, many of which represent former coral and stromatoporoid heads. Dolomitization in the Lockport Group is evidently of replacement type and has resulted in strong recrystallization and obliteration of much of the primary carbonate fabric. Dolomitization may have been produced by seepage refluxion of brines during deposition of the overlying Salina Group or may be of deep burial origin.

The Penfield Quarry was studied in detail by Zenger (1965), who designated this exposure as the type section of his Penfield Member, here comprising 19.2 m (63 ft) of sandy dolostone and dolomitic sandstone. Zenger also identified the upper 5.2 m (17 ft) of the section here as basal "Oak Orchard Member," which is now referred to as the Eramosa Formation. Recent deepening of the quarry and detailed regional correlation permit a reevaluation of this stratigraphy (Brett, et al., in prep.).

The Gates Member of the upper Rochester Shale is the lowest unit exposed in the quarry. It can be observed in a sump pit near the western edge of the quarry. The Gates contains dark grey, sparsely fossiliferous, bioturbated, silty, dolomitic mudstone and argillaceous dolostone. Planar and irregular (hummocky?) cross-stratification common in silty layers; many bedding planes contain the dendritic feeding trace *Chondrites* and oscillation/interference ripple marks aligned roughly NE-SW. Lingulid and rhynchonellid brachiopods and crinoid ossicles are present, a spectacular occurrence of over 1000 complete crinoids (*Dimerocrinites*) was discovered in this portion of the quarry.

The Gates Member is overlain at a sharp contact by about 3m (15') of thick-bedded to massive DeCew Dolostone. The lowest meter is a blocky bed of sandy, pale gray, buff-weathering dolostone with soft sediment deformation and hummocky cross-stratification that is prominently displayed in the main lower floor of the quarry. The hummocks are ellipsoidal, average approximately 1 m in length along their long axes, and are spaced about 0.5-1.0 m apart.

The basal DeCew was probably the lowest unit exposed when Zenger measured the quarry. Subsequent cutting of the sump pit revealed that the quarry floor was very close to the base of the DeCew, (whereas Zenger had apparently considered it the top of that formation). This bed is overlain by about 5 m (15 ft) of dolomitic sandstone and arenaceous dolostone with two prominent partings which display rusty staining due to ground water seepage. The DeCew is sparsely fossiliferous except for scattered stringers of crinoid columnals and occasional orbicerloid brachiopods, but sandy beds contain vertical *Skolithos*-like burrows. The Gates-DeCew interval is interpreted as mixed siliciclastic and allodapic carbonate sands and silts which were rapidly deposited basinward of shallow, winnowed platforms developed north (?) of this area. Gates-DeCew sediments accumulated in shallow subtidal areas below fair-weather wave base but subjected to frequent storm wave disturbance.

Most of the higher quarry wall is composed of brownish grey to medium grey, medium- to thick-bedded, sandy dolostone which displays planar and bidirectional cross-stratification. Layers and lenses of crinoidal grainstone occur in the lower 5 m which terminate at the top of the lower level of the quarry. The meter-thick bed just below the second bench of the quarry (approximately 12.5 m) is highly crinoidal and contains intraclasts as well as rare rugosan and favositid corals. It is overlain by a 9 m (28.5 ft) interval of medium and even-bedded, sandy dolostone, with thin shaley partings, that appears to correlate with the Goat Island and Eramosa formations of the Lockport Group.

The entire 15 m interval, corresponding to the members of the Gasport, Goat Island, and Eramosa formations, is enriched in quartz sand in the Rochester area, and the name Penfield Formation is perhaps useful in emphasizing this facies distinction. However, it should be noted that members, and even certain marker beds, in the Gasport interval can be traced across the facies change. Crowley (1973, unpubl.) emphasized the locally sandy nature of the Penfield and interpreted the unit as representing a shallow water sandy shoal or "Penfield island"; but the persistence of sedimentary cycles and elements of the typical Gasport marine fauna into the Penfield area indicates an environment similar to that of the typical Gasport facies. Crinoidal grainstones of the Gasport and sandy crinoidal dolostones of the lower Penfield represent similar environments, i.e., a shallow wave-winnowed and perhaps tidally-influenced (bimodal cross stratification) shelf with local shoals or bars, close to fairweather wavebase. The increased sand content of this facies in the Penfield area appears to indicate a local source of siliciclastics north of this region. Upper units are thinner-bedded and more argillaceous than the Gasport equivalents and record a transition to somewhat lower energy, probably deeper water environments similar to those in which the Gates-DeCew interval sediments accumulated.

The highest beds exposed in the Penfield Quarry consist of massive, highly fossiliferous and vuggy dolostones that were assigned to the lower 5.5 m (17 ft) portion of the "Oak Orchard Member" by Zenger (1965); recent study demonstrates that the term Oak Orchard is invalid, and we assign these beds to the Eramosa Formation Prominent, 0.5 m thick, light grey-weathering, dolostone beds occur about 2 and 3 m below the top of the quarry. Dark biostromal beds on eiter side of these horizons are rich in poorly preserved, and typically mineralized tabulate corals (*Favosites*, *Cladopora*), and small domal stromatoporoids. These beds contain numerous large vugs which are lined with nodular anhydrite, scalenohedral calcite, pink saddle dolomite, celestite, sphalerite, rare fluorite and sulfides; these vugs are the principal source of the Penfield minerals. Although the vuggy beds are inaccessible in the vertical quarry walls, they can be examined readily in large fallen blocks piled on the higher bench in the quarry.

The upper Lockport strata at Penfield (> 5m) are distinctly less sandy than the lower beds and more highly fossiliferous. The Eramose interval records a general decrease in the input of siliciclastic sediments and the development of coral-stromatoporoid biostomes and associated carbonate sediments in shallow, but relatively quiet water environments.

21.05	0.1	Exit from quarry
21.35	0.3	Five Mile Line Road (jog in Whalen Road); continue on Whalen Road at blinking light
22.85	1.5	Cemetary on right and court house on left
22.95	0.1	Baird Road stop sign; continue straight on Whalen
23.15	0.2	Junction Route 250 (Fairport-Nine Mile Point Road); turn left
24.60	1.55	Junction 286; continue north on Rte 250
26.15	1.65	Junction Plank Road; continue straight on Rte 250; Harris Garden Center on left
27.45	1.3	Junction State Road; stop light village of Webster; continue straight
28.25	0.8	Junction Route 404A; continue straight on Rte 250
28.55	0.3	Entrance ramp to Route 104 East; turn right onto entrance ramp and enter onto Route 104
28.75	0.2	Salt Road Exit
30.85	2.1	Basket Road
31.55	0.7	County Line Road; enter Wayne County, Town of Ontario
31.85	0.3	Switzers Auto Body shop on right; a small outcrop in ditch is the westernmost known exposure of Wolcott Limestone; the unit is truncated between this locality and Rochester.
32.45	0.6	Ontario Center Road intersection
33.45	1.0	Knickerbocker Road; turn left (north) at this light for optional Stop 4. (directions follow)
33.65	0.2	Cross railroad tracks
34.1	0.45	Entrance to Ontario Park on left; turn left (west) onto park road
34.25	0.15	Park in lot near building and walk to the right (north) past end of pond and then left (west) along the north side of the pond onto dump piles of rock dug from the pond

OPTIONAL STOP 4-OLD FRUITLAND ORE PITS PARK

The ponds in this park represent old pits dug in the Furnaceville ematite or iron ore bed for the production of red paint oxide (Gillette, 1947). Although in-place rock is no longer accessible within the flooded pits, dump piles provide an overview of the lithology of the Reynales Formation. Most slabs consist of dolomitic limestone with minor bluish gray chert nodules. Molds of pentamerid brachiopods are common on certain slabs. Pentalobate columns of the newly described inadunate crinoid *Haptocrinus* are relatively abundant. While most of the hematitic band was removed for the paint ore production, occasional blocks and slabs show the highly fossiliferous, oolitic hematite.

Return to vehicles and retrace route to Knickerbocker Road

34.4	0.15	Turn right (south) on Knickerbocker Road.
34.85	0.45	Junction NY 104; turn left (east) and proceed on 104.
35.05	0.2	Furnace Road (named for old blast furnaces for iron production from Furnaceville iron ore).
36.65	1.6	Fisher Road; eastern border of Ontario township
37.35	0.7	Apple Valley Speedway
38.30	0.95	Salmon Creek Road
38.35	0.05	Cross Salmon Creek, type section of the mid Silurian Williamson Shale is slightly upstream (south) of road.
38.55	0.2	Tuckahoe Road; enter village of Williamson
39.05	0.5	Williamson town garage on right; small exposure of yellowish weathering Rockway Shale is in ditch
39.35	0.3	Junction NY 21 (Lake Road)
39.45	0.1	McDonalds and Burger King (possible rest stop); continue east on Route 104.
39.85	0.4	Leaving Williamson
40.25	0.4	Cadbury's Company; Pond Road
41.35	1.1	Seneca Foods on left.
41.55	0.2	Townline Road
41.95	0.4	Very minor low outcrops of Rochester Shale in ditch to south.
42.55	0.6	Redman Road
43.45	0.9	Centenary Road
45.35	1.9	View of large wave modified drumlin on right (south)
45.55	0.2	Junction NY 88 (Alexander Road); continue east on 104. Enter Sodus
46.55	1.0	Maple Avenue (stoplight); eastern edge of Sodus

48.25	1.7	Old Ridge Road (stop light)
49.25	1.0	Barclay Road; Helluva Good Cheese factory on left
49.40	0.15	Cross Salmon Creek (East); Rochester Shale below road.
49.80	0.4	NY 240 (N. Geneva Road; blinking yellow light)
50.00	0.2	Note ditch to north (left) near Wallington town line; yellowish clay is weathered Glenmark Shale (formerly considered as upper part of Rochester Shale); This small exposure has yielded very abundant brachiopods, especially *Nucleospira pisiformis*, and small *Enterolasma* (rugose corals) *Stegerhynchus neglectum*. The Glenmark horizon with its distinctive fauna can be correlated from this small outcrop southward into the central Appalachians of Pennsylvania, Maryland, and West Virginia.
51.00	1.0	Bond Road
51.60	0.6	Junction NY 14; turn left (north) off NY 104 onto 14 toward Alton
51.90	0.3	T-intersection with Old Ridge Road, Rt. 143, Village of Alton; turn right onto Old Ridge and immediately (.025) left (north) onto Shaker Road (this is essentially a jog in the north south road).
52.90	1.0	Bend in road; prepare to stop
53.10	0.2	Park opposite southern fence line separating planted field to south from sheep pasture, on left (west) side of Shaker Road. This is the former Shaker Tract, or Alasa farms; white barns to the north now house the Lake Plains Wildlife Rehabilitation Center Follow along edge of fence back to woods bordering east side of Second Creek; enter woods and turn right following near top of bank for about 0.1 mile to where an old logging road descends to creek level; go downstream (north) for one major bend and walk across floodplain and creek to bank on west side.

STOP 5A-SECOND CREEK AT ALTON

This creek bank exposes a small but excellent section of the Clinton strata. Lowest beds exposed are in the Wolcott Furnace Formation, which consists of alternating greenish gray fossiliferous shales and limestones, containing an undescribed stricklandiid brachiopod, together with chaetetid sclerosponges, crinoid ossicles and small *Enterolasma* rugose corals. These beds also display thin fossiliferous hematitic limestone bands. At the top of this interval is a thin, but distinct bed containing granular black phosphatic material. About 20 cm of overlying greenish gray shale may represent the westernmost occurrence of the Sauquoit Shale, an interval which exceeds 30 m (100 ft) in thickness in east central New York, south of Utica. Here the interval has very nearly been truncated by an erosional surface. This unconformity is marked by a sharp surface and a very distinctive lag conglomeratic bed (the Second Creek phosphatic bed), best developed at this locality. This bed is approximately l to 2 cm in thickness, but in places, it contains clasts of dolomitic limestone, evidently derived from nearby exposures of the Wolcott or other lower Clinton carbonates. The clasts rarely exceed a cm in thickness, but may be up to 10 cm across. In places, these clasts are edgewise and may jut upward into the overlying Williamson Shale a few centimeters. The erosional clasts are packed in a matrix of dark gray, very pyrite- and phosphate-rich crinoidal grainstone. Pebbles of black phosphate and quartz up to 1 centimeter in diameter are present within the matrix. The lower surface of the bed is typically sharp and slightly irregular. Its upper contact is sharply overlain by black or very dark gray Williamson Shale and typically displays an abundance of the brachiopods *Eoplectodonta* and *Atrypa*. Current aligned specimens of the graptolite *Monograptus clintonensus* occur on the contact in some places. The unconformity here is the same one examined at Palmers Glen near Rochester (Stop 2). However, here the Williamson Second Creek phosphate bed unconformably overlies a remnant of the Sauquoit Formation, whereas at Rochester, the Williamson rests on the lower portion of the Sodus, some 10 m lower in the section. Hence, the unconformity is regionally angular and has truncated successively older Clinton strata to the west.

The overlying Williamson Shale includes alternating relatively hard, very dark gray to black graptolitic shale and soft greenish gray claystones. As at the Palmers Glen exposure (Stop 2), graptolites are generally confined to the dark gray layers and may occur on laminae of quartz sand or very coarse silt. Greenish gray layers are generally barren of fossils but may contain bedding plane assemblages of frilly *Atrypa* and *Eoplectodonta*. We will walk upstream along the bank of Second Creek to outcrops of the Rockway Dolostone and shale and the Irondequoit Limestone. The Rockway, well displayed in slabs recently ripped up during flooding from the creek floor, is fossiliferous, somewhat greenish gray silty mudstone, which weathers to a yellowish color. It contains an abundance of brachiopods, particularly *Clorinda,* (considered a classic deeper water, benthic assemblage 4 to 5 indicator), *Leptaena*, *Atrypa*, and others. The shales also contain scattered specimens of the small rugose coral *Enterolasma* and this locality has yielded specimens of the probable green alga *Ischadites*. Thin, muddy, micritic limestones interbedded with the shales contain scattered crinoid-bryozoan debris, including calyces of the tiny inadunate crinoid *Pisocrinus*. The contact with the overlying Irondequoit Limestone at this locality appears conformable, but relatively sharp. The Irondequoit consists of approximately 3 m of crinoid- and brachiopod-rich wacke- and packstone limestone. Small bioherms of bryozoans and possible algal bound micrite are also present at several levels in the creek bed and minor waterfalls here. The Irondequoit is interpreted as a relatively major sea level lowstand or shallowing event that separates the maximally transgressive Williamson and Rockway deposits from the overlying deeper water Rochester Shale. The small patch reefs appear to have grown upward during times of relative deepening as the Irondequoit passed upward into mudstones of the Rochester Formation.

If time permits, we may walk further upstream to sample from the richly fossiliferous lower Rochester Shale which contains a diversity of brachiopods, small corals, and trilobites. Most of these fossils, however, are present as disarticulated and somewhat fragmented material.

		Return to vehicles and continue north on Shaker Road, past buildings of the former Alasa Farms.
55.10	0.2	T-Intersection with Red Mill/Shaker Tract Road; turn left (west) onto Red Mill Road.
55.20	0.1	Pull to right and park in small bay; walk down path to banks of Second Creek

OPTIONAL STOP 5B-SECOND CREEK AT RED MILL ROAD

If time permits, we may look at the section along Second Creek at Red Mill Road. Immediately downstream from the road bridge are bank outcrops of green to purplish colored Upper Sodus Shale, containing a diverse *Eocoelia* brachiopod and ostracod rich *Zygobolba decora* fauna. These beds are sharply overlain by crinoid- and pentamerid-rich grainstones of the Wolcott Formation.

Return to vehicles and pull out to left, reversing direction (east) onto Red Mill Road.

55.30 0.1 Shaker Road intersection and Alasa Farms; continue east on Red Mill Road, which changes name to Shaker Tract Road

56.10 0.8 Good view of Sodus Bay to left (north)

56.60 0.5 Sharp bend in Shaker Tract Road at intersection with Hunter Road; follow Shaker Tract Road around to right (south)

58.00 1.4 Intersection of Old Ridge Road (Rt. 143).; continue on Shaker Tract which here changes name to Brick Schoolhouse Road

59.00 1.0 Intersection with NY 104; turn left (east) onto NY 104 and proceed.

59.50 0.5 Norris Road intersection; prepare to stop

59.60 0.1 Pull off to right and park on shoulder of NY 104; walk down into small gully immediately south of the highway at point where an exposed yellowish clay (Rochester Shale) is visible on bank above gully; you can then continue to the south into woods along the unnamed tributary of Sodus Creek

OPTIONAL STOP 6-UNNAMED TRIBUTARY OF SODUS CREEK IMMEDIATELY EAST OF NORRIS ROAD AND SOUTH OF US ROUTE 104

This small creek provides a relatively complete outcrop of the upper portion of the Rochester Shale. The section begins with the weathered bank parallel to and south of Route 104. This bank yields good specimens of weathered brachiopods, particularly *Eospirifer*, *Rhynchotreta*, and *Whitfieldella*. Upstream, along the main creek, are good exposures of the middle and upper portions of the Rochester Shale. Thick calcisiltite beds occur near the mouth of the stream in some of the lowest exposures. Upstream, a series of low waterfalls or riffles expose highly fossiliferous, bryozoan rich layers corresponding to the upper marker beds of the Lewiston Member (Lewiston E or bryozoan beds in Niagara County, New York).alternating shales and thin biostromal limestones, rich in the small ramose bryozoan *Chilotrypa*. Associated with these layers are abundant articulated and specimens of the brachiopods *Whitfieldella*, *Rhynchotreta*, *Eospirifer*, *Atrypa* and rarewell preserved specimens of the trilobites *Calymene*, *Bumastus* and others..

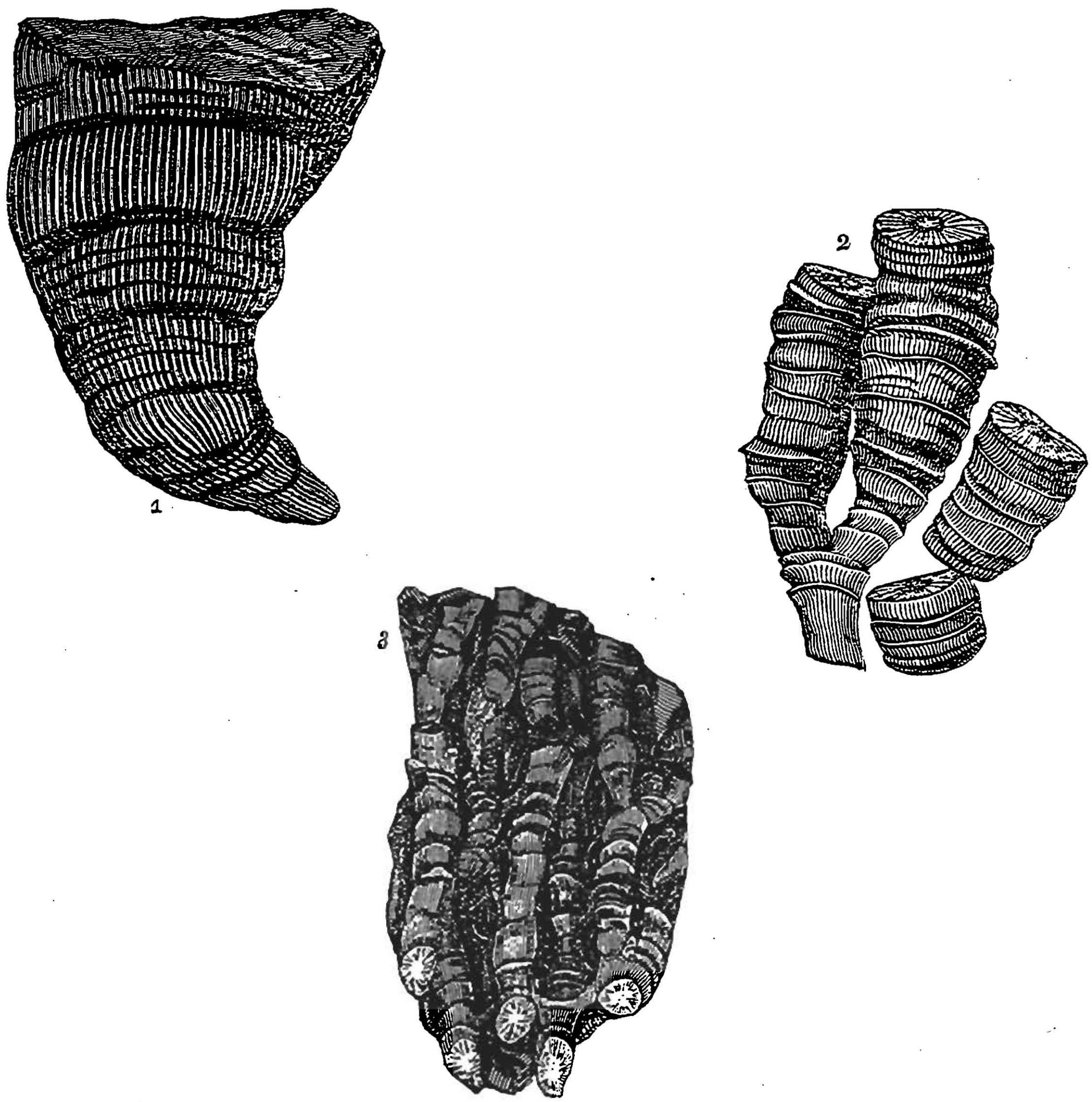
The change to more sparsely fossiliferous shales above this small falls marks the contact between the Lewiston and Burleigh Hill members. The upper beds, south to the bridge of York Settlement Road, are within the upper part of the Rochester Shale and consist of alternating mudstones, thin shell layers and calcisiltite beds. Some layers particularly near the top are rich in trilobites such as *Dalmanites*, and brachiopods such as *Stegerhynchus*, *Coolina*, *Dalejona* and occasional small rugose corals (*Enterolasma*). The change from bryozoan-rich biostromes to more sparsely fossiliferous shales marks a relatively major flooding surface within the Rochester Shale that can be identified throughout much of New York State and Pennsylvania. The upper shaly interval is more monontonous than the lower portion, reflecting highstand conditions. However, in the uppermost 2 to 3m the shales become increasingly interbedded with dolomitic calcisiltites.

The section is capped by a low waterfalls immediately north of the bridge on York Settlement Road. This falls is capped by a distinctive 40 cm-thick massive dolomitic limestone bed, referred to as the basal Glenmark bed. This bed, which contains small favositid and rugose corals, as well as the distinctive brachiopod *Nucleospira*, marks the approximate position of the DeCew Dolostone of western New York. This bed and the overlying shales, which are rich in distinctive brachiopods, particularly *Nucleospira*, and *Whitfieldella* (cf. *W. marylandica*) represent an important marker interval that is traceable from this area of New York State southward through much of central Pennsylvania Appalachians and into Maryland and West Virginia. This interval, previously unrecognized or treated as simply an upper portion of the Rochester Shale is herein recognized as a distinctive unit referred to as the Glenmark Formation. In nearby Sodus Creek, this 3 m interval is overlain by thinly bedded micritic limestones and very dark grey, fissile shales, as well as thrombolitic and intraformational conglomeratic horizons marking the base of Sconondoa Formation, the lateral equivalent of the lower part of the Lockport Group of western New York. It represents a distinctive shallowing to nearly peritidal or shallow lagunal conditions in the late Wenlock or early Ludlow time.

		Reverse direction on NY 104 by either backing to Norris Road, if traffic is not heavy, or by proceeding 1.7 miles to NY 414 to reverse direction. Mileage on return west-bound log is from Norris Road. Because most landmarks are noted in the eastbound log, only new sites will be noted in the return log
59.00.0		Norris Road
59.50	0.5	Brick Schoolhouse/Shaker Tract Road
60.50	1.0	Pre-Emption Road
61.50	1.0	NY 14 (Alton)
63.10	1.6	Wallington townline sign and Glenmark Shale in ditch
66.60	3.50	Sodus
73.70	7.10	Williamson
81.60	7.90	Monroe/Wayne Co. Line (Rte. 404)
84.60	3.0	Junction NY 250; Webster
86.60	2.0	Five Mile Line Road
87.10	0.5	Maplewood Shale was exposed in ditch between two lanes of Rt. 104
89.00	1.9	Bay Road (a turn left here would lead to Glen Edith Road and outcrops along road leading down to restaurant by Irondequoit.)
89.40	0.4	East side Irondequoit Bay; note slumps of soft lake silt; views of bay and bay mouth bar from bridge
89.90	0.5	West side of Irondequoit Bay
90.60	0.7	Routes. 104 and 590 divide ahead; bear left into entrance of I-590 South.
90.90	0.3	Enter onto I-590 South
91.50	0.6	Cross Densmore Creek; good exposures of Medina and lower Clinton outcrop along the Creek west of the highway to Densmore Road
92.40	0.9	Empire Boulevard exit

94.80	2.4	"Can of Worms," I-490 & I-590 junction; bear right continuing on I-590 South
101.0	6.2	Exit 16A for NY15A; bear right onto exit
101.3	0.3	Junction NY 15A; turn right (north) on 15A
101.4	0.1.	Cross Erie Canal
101.9	0.5	Route 15A forks with South Avenue; bear left on 15A
102.3	0.4	Junction NY Route 15; 15A ends; turn right (north) onto Rte. 15.
102.5	0.2	Junction Elmwood Avenue; turn left (west)
103.2	0.7	Elmwood curves to the right under old railroad overpass marked University of Rochester; follow to right and prepare for righthand turn
103.3	0.1	Junction Wilson Blvd.; turn right.
103.4	0.1	Univ. of Rochester parking lot.

End of Trip.



Corals of the Onondaga Limestone.

1. *Heterophrentis prolifica* 2. *Cylindrophyllum* sp. 3. *Syringopora* sp.

[From Hall, 1843, Geology of the Fourth District, Figure 33, p. 30.]