FIELD STUDIES OF THE MIDDLE DEVONIAN LUDLOWVILLE-MOSCOW SEQUENCE IN THE GENESEE AND SENECA VALLEYS, NEW YORK STATE

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INTRODUCTION

Numerous authors have studied and described in detail the unique depositional environments and the excellent fossil preservation found in the Middle Devonian Hamilton Group sediments of New York State (Grabau, 1899; Cooper, 1930; Grasso, 1973; Brett and others, 1986; Savarese and others, 1986). The advancement of high resolution stratigraphic mapping has permitted detailed correlations of facies divisions in the uppermost Ludlowville Formation across western and central New York (Mayer, 1989; Mayer and others, 1994). The focus of this field trip is to examine the spatial and temporal sedimentary relationships as well as the abundant and well preserved fossils in the Upper Ludlowville-Lower Moscow Formations of the Hamilton Group; in particular, the uppermost Wanakah Shale, Jaycox Shale and Tichenor Limestone Members in the Genesee and Seneca Valleys (Figure 1).

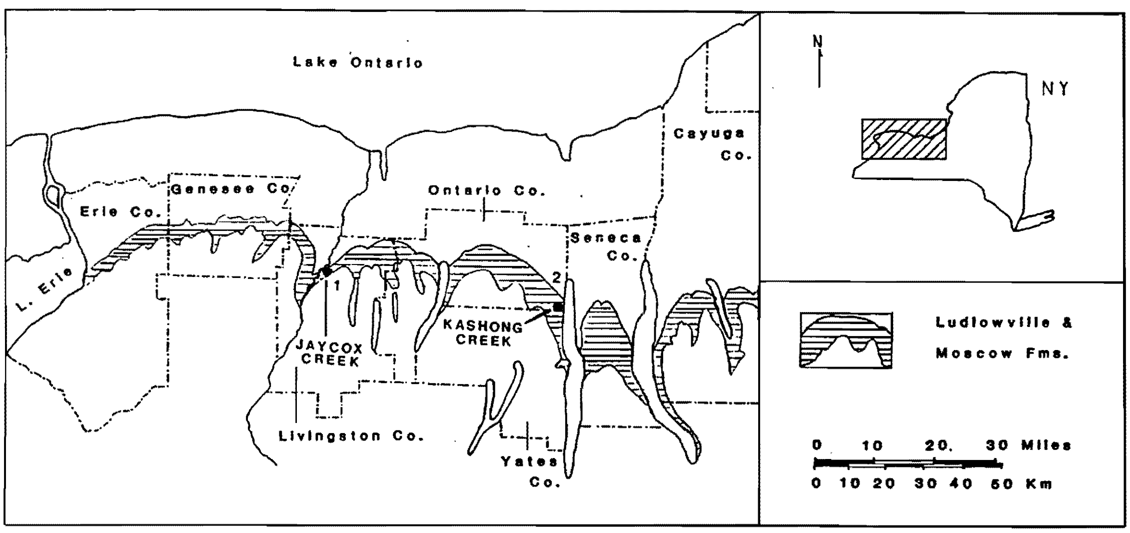

Figure 1. Key Ludlowville - Moscow outcrops in the Genesee Valley and Seneca Valley region. Modified from Baird (1979).

GEOLOGIC SETTING

The sediments of the Hamilton Group were deposited as part of the prograding Catskill Delta Complex at the northern margin of the Appalachian Basin in North America. Reconstruction of North American paleolatitudes, based on paleomagnetic studies, have placed the continental landmass across the paleoequator with the Hamilton deposition occurring at approximately 0-30° S latitude (Oliver, 1976; Ettensohn, 1985; Van der Voo, 1988). The sediments comprising the Ludlowville-Moscow Formations accumulated across a shallow epeiric sea. The seafloor extended across a western and eastern shelf separated by a central subsiding basinal trough, centered around the present-day Seneca Valley (Figure 2).

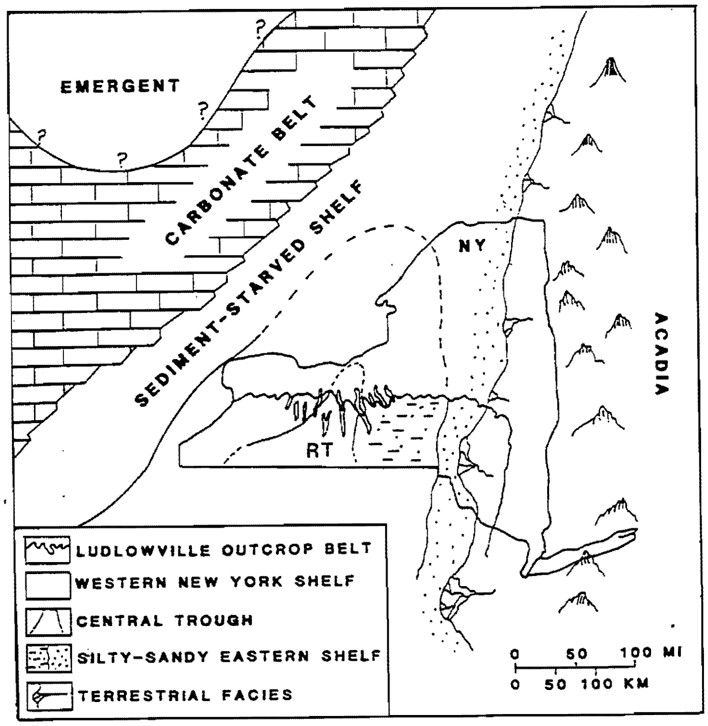

Figure 2. Generalized depositional setting and paleogeography of New York and adjacent areas during Middle Devonian (Givetian) time. RT= Romulus Trough. Modified from Mayer (1989).

The Jaycox Shale Member is an eastwardly thickening sequence of fossiliferous mudrock extending from Erie County to Seneca County and reaching its maximum thickness in the northern Cayuga Valley. However, the Jaycox discernably thins southeastward across Cayuga County with apparent litho- and biofacies changes. In western Onondaga County, Skaneateles Lake region, the Jaycox has been directly correlated to the Owasco Siltstone while the subjacent shales are directly correlated to the Spafford Member (Mayer and others, 1990,1994).

Stratigraphy of Jaycox Shale Member, Jaycox Creek Type Section, Genesee Valley

The type section for the Jaycox Shale Member is at Jaycox Creek, 2 miles north of Geneseo, New York. Here the stratigraphy was originally defined as shown in Figure 3. The Jaycox is bracketed at the base by the Hill's Gulch Bed and at the top by the Tichenor Limestone. The Jaycox strata contain two prominent coral horizons as well as variably fossiliferous mudstone intervals.

Downstream along the floor and in the banks of the creek, dark grey shales of the Wanakah Member are exposed. The uppermost layers contain a diminutive fauna of the brachiopod *Ambocoelia umbonata* var. *nana.* These fossils occur in such great numbers that they impart a granulated texture to the bedding planes and form a particularly distinctive marker horizon which is traceable throughout the region. In addition, chonetid brachiopods, the bivalves *Nuculites* and *Paleoneilo*, as well as the gastropod *Palaeozygopleura*, which is typically highly compressed laterally due to sediment compaction, occur in the uppermost Wanakah shales.

Directly overlying and gradational with the upper Wanakah Shale, is a 32 cm thick, medium grey fossiliferous silty mudstone originally designated the Limerick Road Bed (Mayer, 1989). Within the lower 7 cm of the Limerick Road Bed, cephalopods encrusted by the tubuliporate bryozoan *Reptaria stolonifera* commonly occur and form an important marker horizon throughout the study area. The Limerick Road bed also contains a conspicuous fauna of robust brachiopods including *Mediospirifer audaculus*, *Athyris spiriferoides*, and *Mucrospirifer mucronatus*. These fossils are preserved uncrushed and in life positions in many cases. Also, bivalves and the coral *Pleurodictyum* comprise part of the faunal assemblage.

The Limerick Road Bed is, in turn, overlain by a 45 cm thick interval of medium grey, silty shale which lacks fossils. The Limerick Road Bed and overlying barren shales are the westernmost equivalent of the Spafford Shale Member of the Owasco and Skaneateles Lake Valleys in central New York (Mayer and others, 1990).

The Hill's Gulch Bed (originally designated by Kloc, 1983, for exposures at Hill's Gulch Creek) marks the base of the Jaycox Shale Member. At Jaycox Creek, the unit is a 30 cm thick silty limestone. This unit forms the upper lip of the second falls along the creek. Fossils are abundant and include numerous species. Representative brachiopods are *Athyris spiriferoides*, *Devonochonetes coronatus*, *Tropidoleptus carinatus*, *Douvillina inequistriata*, *Mediospirifer audaculous*, and *Mucrospirifer mucronatus*. Additional fossils include the corals *Amplexiphyllum hamiltoniae* and *Stereolasma rectum*, the trilobite *Phacops rana*, the gastropod *Mourlonia* sp., the bivalves *Cypricardella bellistriata* and *Modiomorpha concentrica,* as well as various fenestrate bryozoans.

The Hill's Gulch Bed correlates directly with the Owasco Siltstone Member of central New York. (Mayer and others, 1990). The unit was mapped across the thick shale deposits of the central trough region of the Seneca and Cayuga Valleys and into the thinner deposits of the eastern shelf region of the Owasco and Skaneateles Valleys.

The Hill's Gulch Bed is overlain by a 50 cm thick interval of thinly bedded, grey mudstone, which is, in turn, overlain by the Green's Landing Coral Bed. This interval contains a shelly fauna but the fauna is not as diverse as the overlying coral bed fauna. Brachiopods, bryozoans, and pelmatozoans are common; however, corals are rare and tend to first appear just below the Green's Landing Coral Bed. The *Tropidoleptus-Longispina* pavements observed further east in the Seneca Valley originate in this interval, but at Jaycox Creek, these brachiopods are scarce.

The Green's Landing Coral Bed, the first of two coral-rich units in the Jaycox, is exposed along the banks and floor of this creek. The 32 cm thick, grey, crumbly mudstone contains a high diversity of corals, brachiopods, bryozoans, pelmatozoans, bivalves, gastropods, and trilobites, all of which can be readily collected. Conspicuous corals include *Heliophyllum halli*, *Heliophyllum confluens*, *Eridophyllum subcaespitosum*, *Favosites hamiltoniae* and *Favosites argus*. Dominant brachiopods include *Douvillina inequistriata*, *Elita fimbriata*, *Pentamerella pavillionensis*, *Parazyga hirsuta*, and

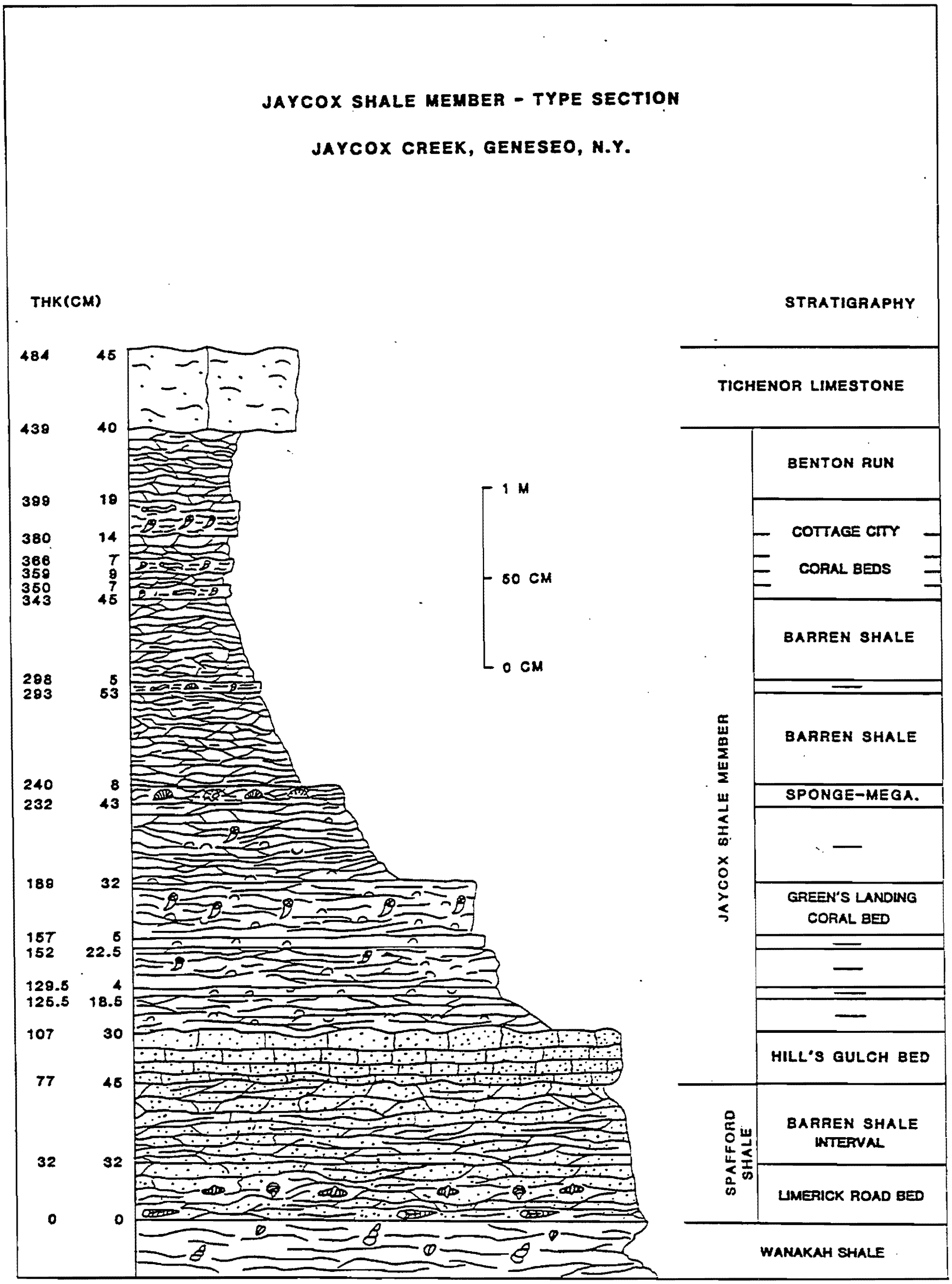

Figure 3. Stratigraphy of the Jaycox Shale Member, Genesee Valley.

Rhipidomella spp. Also common are fistuliporoid and fenestrate bryozoans, large crinoid holdfast systems and camerate crinoids such as *Dolatocrinus liratus* and *Megistocrinus depressus*, bivalves including *Modiomorpha concentrica* and *Plethomytilus oviformis*, gastropods such as *Naticonema lineata* and various platyceratids, as well as the trilobite *Phacops rana*.

The Green's Landing Coral Bed is overlain by a 43.5 cm thick interval of sparsely fossiliferous grey mudstone. This mudstone, in turn, grades upward into an 8 cm thick, hard, slightly calcareous, grey mudstone designated the Sponge-*Megastrophia* Bed (Mayer, 1989) due to a conspicuous fauna of unidentified "lithistid" demosponges and the brachiopod *Megastrophia concava*.

The Sponge-*Megastrophia* Bed is overlain by two approximately 50 cm thick intervals of unfossiliferous calcareous shales separated by a thin (5 cm) fossiliferous calcareous mudstone bed. This intervening bed contains organisms similar to that of the Green's Landing Coral Bed; however, fossils are less abundant.

The Cottage City Coral Beds, the second of the two coral-rich units in the Jaycox, immediately overlie these barren shales (Mayer, 1989). The Cottage City Coral Beds are 56 cm thick and comprise three distinct fossiliferous calcareous mudstone layers; each bed is overlain by a layer lacking fossils and each bed contains a greater abundance of fossils than the preceding bed. The Cottage City Coral Beds contain a diverse fauna very similar to the Green's Landing Coral Bed; however, the coral *Heliophyllum confluens* has never been observed in the Cottage City Coral Beds.

The uppermost division of the Jaycox is a 38-40 cm thick, light grey, calcareous shale that contains a very sparse fauna of brachiopods. These may include *Mesoleptostrophia*, *Mucrospirifer*, *Athyris*, and chonetids. The Jaycox upper contact with the Tichenor Limestone is sharp, irregular and erosional.

The Tichenor Limestone is the basal unit of the Moscow Formation (Baird, 1979). At Jaycox Creek, the upper falls are formed by the hard Tichenor limestone. The unit is a massive, calcarenitic, crinoidal grainstone. The Tichenor contains a diverse fauna including the rugose corals *Heliophyllum halli* and *Eridophyllum subcaespitosum*, the tabulate coral *Favosites hamiltoniae*, and the brachipod *Meristella*. Large holdfast systems, many over 12 inches long and one-half inch in diameter, as well as camerate crinoids including *Dolatocrinus* are plentiful.

The Tichenor Limestone grades quickly upward into the Deep Run Shale Member. The Deep Run is a medium grey-blue silty shale with numerous individual fossiliferous beds similar to the Jaycox. Well preserved fossils are abundant in the lowermost Deep Run strata, however; fossils become less plentiful stratigraphically upward. Fossils include the corals *Heliophyllum halli*, *Eridophyllum subcaespitosum*, and *Favosites* sp. as well as the brachiopods *Douvillina*, *Elita*, and *Parazyga*. Large fistuliporoid bryozoan mounds and large specimens of the trilobite *Phacops rana* occur in the Deep Run beds. Moreover, platyceratid gastropods attached to crinoid calyces have been collected from the floor and banks of the creek.

The Deep Run Shale Member grades stratigraphically upward into the Menteth - a very hard, rubbly, fossil-poor limestone. The Menteth is exposed furthest upstream and is the first rock ledge visible in outcrop.

Stratigraphy of Jaycox Shale Member, Kashong Creek, Seneca Valley

The beds of the Jaycox Shale Member as exemplified at the type section have been correlated into Yates County and can be observed directly at Kashong Creek (Figure 4) in the Seneca Valley. The Jaycox thickens significantly from 3.62 m at Jaycox Creek to 11.51 m at Kashong Creek. Both lithologic and faunal changes accompany this thickening. Jaycox shales contain more silt and are less calcareous in the Seneca Valley than in the Genesee Valley. Faunas are less diverse and represent those species more tolerant of higher sedimentation rates (see Mayer, 1989; Mayer and others, 1994).

The Limerick Road Bed remains sharply defined at Kashong Creek where the unit contains bioencrusted hiatus concretions. These concretions form a mappable horizon throughout the Seneca and Cayuga Valleys. The barren shale interval separating the Limerick Road Bed from the Hill's Gulch Bed thickens to approximately 2 m at Kashong Creek. From Seneca Lake eastward the unit contains unidentified discoidal fossils that can be traced into the Spafford Shale Member of the Skaneateles Lake region.

The lithology of the Hill's Gulch Bed grades laterally across a facies spectrum from a limestone on the western shelf in Erie County, to a silty limestone in the Genesee Valley, and to a calcareous siltstone in the trough region in the Seneca and Cayuga Valleys. As the unit is correlated out of the depocenter and onto the eastern shelf in the Skaneateles Valley, it exhibits the siltstone lithology of the Owasco Member. At Kashong Creek, the Hill's Gulch Bed is 24 cm thick and caps the second falls downstream from the Tichenor falls. Biofacies present in the unit also grade laterally from communities containing the corals *Favosites hamiltoniae* and *Heliophyllum halli* in Erie County to communities containing the brachiopods *Tropidoleptus carinatus* and *Mucrospirifer mucronatus* and lacking most corals in Yates County. These biofacies change further east to communities dominated by the brachiopod *Allanella tullius* indicative of the Owasco Siltstone facies in the Skaneateles Valley.

The mudstone interval above the Hill's Gulch Bed at Jaycox Creek extends east to the Seneca Lake Valley, forming a unique marker interval rich in the brachiopods *Tropidoleptus carinatus* and *Longispina mucronatus*. These brachiopods occur concentrated along bedding planes. Also, large specimens of the trilobite *Dipleura dekayi* occur associated with these brachiopods.

The Green's Landing Coral Bed undergoes litho- and biofacies changes eastward of Canandaigua Lake. The unit grades from a crumbly mudstone in the Canandaigua Valley to a silty mudstone in the Seneca Valley. At Kashong Creek, the bed is approximately 36 cm thick. Although, the bed still contains an abundant and diverse fauna, the corals *Heliophyllum*, *Eridophyllum*, and *Favosites* are absent and instead have been replaced by the corals *Amplexiphyllum hamiltoniae* and *Stereolasma rectum*. Also the brachiopods *Productella spinulocosta* and *Tropidoleptus carinatus* are present in the fossil assemblage.

The Sponge-*Megastrophia* Bed observed at Jaycox Creek also grades laterally eastward from a calcareous mudstone to a silty mudstone in the Seneca Valley. At Kashong Creek, the bed is approximately 51 cm thick. The demosponges are absent and *Megastrophia concava* is rare while *Tropidoleptus* and *Mucrospirifer* are more abundant.

The middle Jaycox "barren shale" interval progressively thickens eastward from less than 1 m in the Genesee Valley up to about 2 m in the Canandaigua Valley.

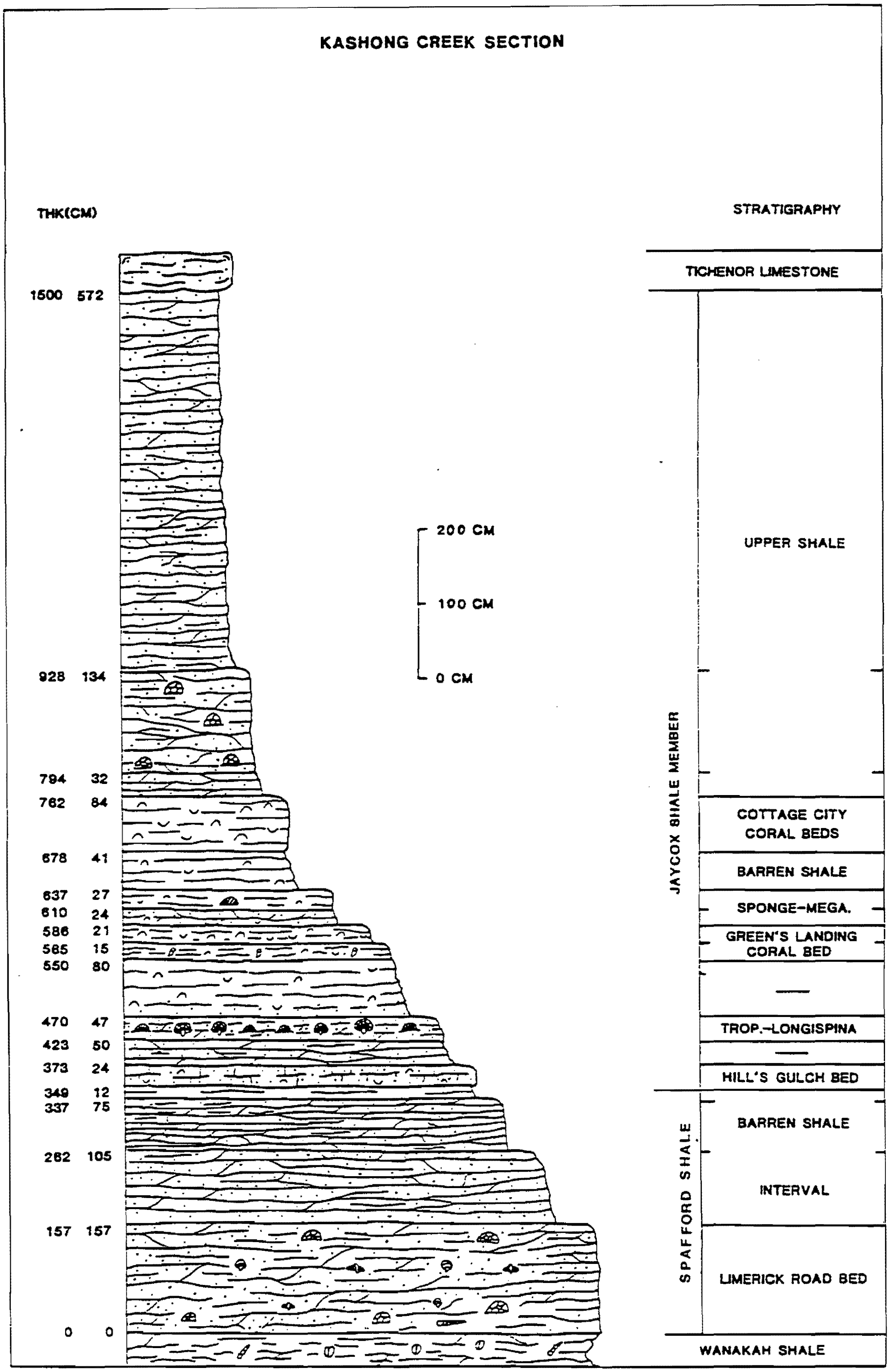

Figure 4. Stratigraphy of Jaycox Shale Member, Seneca Valley.

However, in the Seneca Valley, these shales thin to less than one-half m. The shales in the Seneca Valley contain more silt and are less calcareous than in the Genesee Valley. The interval still contains a very low diversity of fossils including *Tropidoleptus*, a few bivalves and the trilobite *Greenops boothi*.

The Cottage City Coral Beds also undergo eastward facies changes similar to the Green's Landing Coral Bed. At Kashong Creek, the unit is approximately 80 cm thick. The lithology changes from a calcareous mudstone to a silty mudstone. The faunal assemblage remains abundant and diverse in the Seneca Valley; however, the large rugosans and tabulates are absent and have been replaced by *Amplexiphyllum* and *Stereolasma*. Also *Productella* and *Tropidoleptus* are part of the biota and occur with *Parazyga*, *Pentamerella*, *Elita*, and *Douvillina*.

The uppermost shale division of the Jaycox has thickened exponentially from 40 cm at Jaycox Creek to 740 cm at Kashong Creek. The division is composed principally of *Zoophycos*-swirled calcareous siltstone. Bedding planes typically contain a sparse fauna of brachiopods consisting primarily of *Mesoleptostrophia*, *Athyris*, *Mucrospirifer*, *Mediospirifer* and chonetids. Also, large *Pleurodictyum* corals and articulated *Greenops boothi* trilobites occur in an interval in the lower part of this division.

The upper contact of this division with the Tichenor Limestone of the overlying Moscow Formation is sharp and irregular. The uppermost Jaycox shale thins dramatically both northward and westward. The Tichenor Limestone is predominately a calcareous siltstone in the Seneca Lake Valley but still contains very large crinoidal holdfast systems, as well as brachiopods and other fauna.

The Tichenor grades upward into the overlying Deep Run Shale Member. Like the Jaycox in the Seneca Lake Valley, the Deep Run is a slightly calcareous, silty mudrock containing shell-rich layers separated by unfossiliferous zones. Perhaps through additional research, the stratigraphy of these beds can be further refined and correlated westward.

DISCUSSION

Key fossiliferous marker beds facilitated detailed correlation of the Jaycox Shale Member across western and central New York (Figure 5A). Important correlative units include the Hill's Gulch Bed and the Green's Landing and Cottage City Coral Beds. Species diversity is high in Jaycox coral and shell beds but decreases basinward from both eastern and western shelves probably reflecting increased turbidity in the Middle Devonian trough setting. Rapid, episodic, storm-induced deposition is believed to explain the excellent fossil preservation and the occurrence of many organisms in life position in these beds. The Green's Landing Coral Bed seems to represent many rapid burial events. Except for smothered bottom assemblages, fossil assemblages reflect the biota as it persisted through time; that is, they represent "time-averaged" communities (*sensu* Walker and Bambach, 1971). Moreover, these assemblages or biofacies can be tracked and compared to the paleoecological model for Ludlowville biofacies put forth by Brett, Baird and Miller (1986) which relates biofacies to inferred depths, turbidity conditions and rates of sedimentation (see Mayer, 1989; Mayer and others, 1994).

The sparsely fossiliferous "barren shale" intervals within the Jaycox are heavily bioturbated and display abundant spreiten of *Zoophycos*. Fossils are rare and scattered but typically well preserved. It is believed that this facies represents rapid deposition of muds as a result of storm activity. These muds were probably winnowed from high

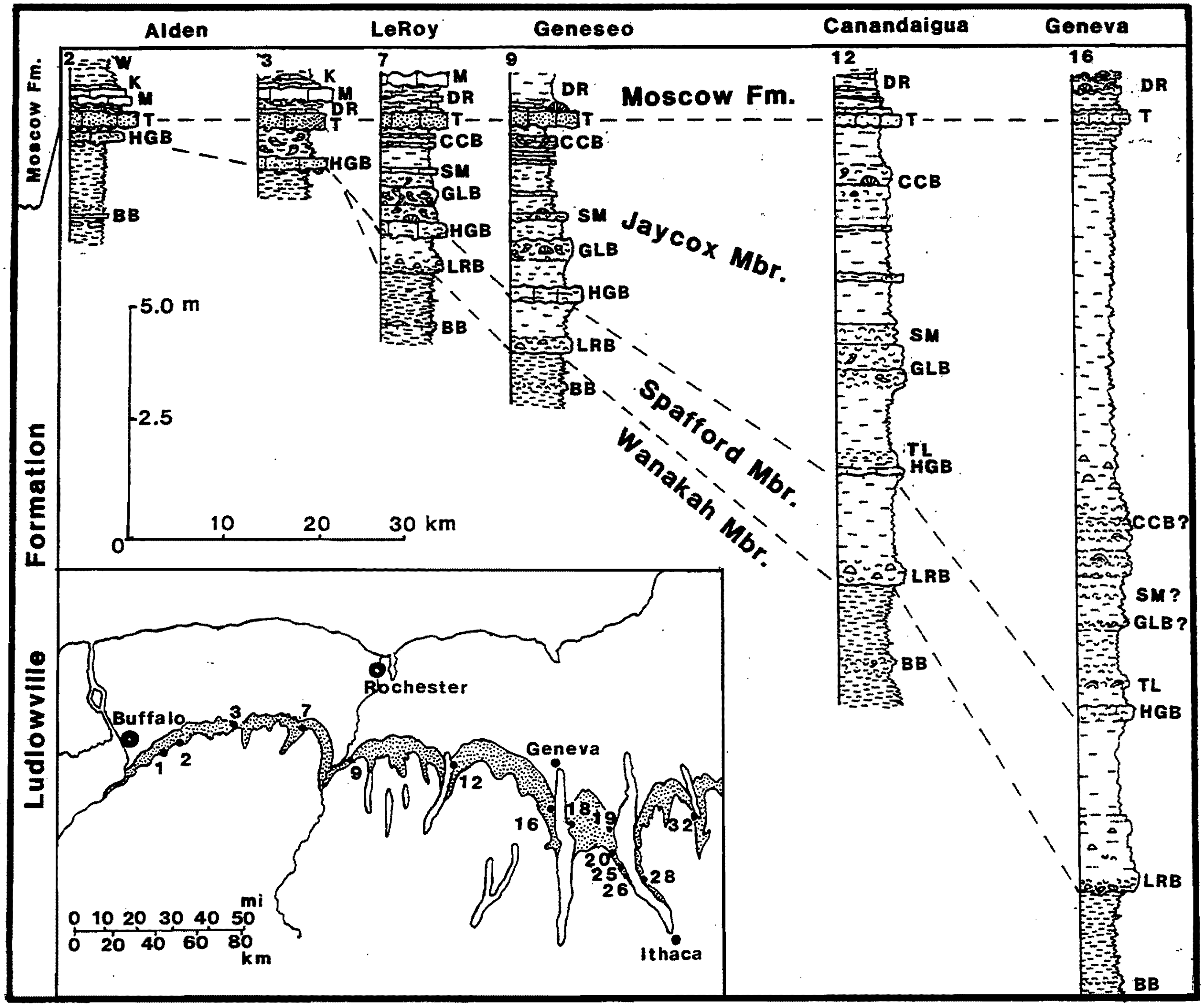

Figure 5A. Correlation of facies divisions of the Upper Ludlowville - Lower Moscow Formations across western New York. Units include BB=Bloomer Creek Bed; LRB=Limerick Road Bed; HGB=Hill's Gulch Bed; TL=*Tropidoleptus-Longispina* mudstone interval; GLB=Green's Landing Coral Bed; SM=Demosponge-*Megastrophia* Bed; CCB=Cottage City Coral Beds; T=Tichenor Limestone; DR=Deep Run Shale Member; M=Menteth Member; K=Kashong Member; and W=Windom Member. Locality numbers can be referenced to Mayer and others (1994).

energy shallow shelf regions and were transported into lower energy settings, with subsequent bioturbation destroying most primary bedding (Brett and others, 1986).

Moreover, Aigner's (1982, 1985) model of tempestite proximality allows one to make inferences of depositional environments. Ideally, proximal storm beds (generally shallow water) are thick, bioclast-dominated amalagamated beds with erosional bases; conversely, distal beds (generally deeper water equivalents) are thin, mud-dominated discrete beds with non-erosional bases. These characteristics are exhibited by the Hill's Gulch Bed. The unit shows evidence of multiple winnowing and reworking of fossil and sediment accumulations as a result of proximal storm deposition on the western shelf as well as evidence of less reworking of lithoclasts and bioclasts distally or basinward. Furthermore, deposition of the Hill's Gulch Bed on the western shelf probably was characterized by high energy direct wave impingement on the seafloor as evidenced by scour-and-fill structures resulting in a highly irregular basal surface of the bed (Brett and Baird, 1985; Brett and others, 1986). Conversely, deposition of the Hill's Gulch Bed within the basinal trough was probably characterized by low energy sediment accumulations.

The upper contact of the Jaycox with the Tichenor is sharp and irregular at most localities. Although westward thinning of the Jaycox is due in part to sedimentary condensation, more importantly it is due to sub-Tichenor erosional overstep of the Jaycox. This erosional truncation removed upper portions of the Jaycox, superimposing the Tichenor on the Hill's Gulch Bed or uppermost Wanakah in western Erie County. However, the Jaycox consists of thick deposits in the Seneca and northern Cayuga Valleys, where sediment accumulations were greatest. To the southeast of the northern Cayuga Valley, Jaycox equivalent beds become markedly condensed and are erosionally truncated; the Tichenor disconformably overlies the Owasco Siltstone in the Owasco and Skaneateles Lake regions (Figures 5A-B). These regional stratigraphic patterns reveal a northeast-southwest trending structural belt of differential subsidence and deposition, (Romulus Sag) that was centered in the Seneca Valley and northern Cayuga Valley region during Ludlowville-Moscow time (Mayer and others, 1994).

Jaycox Creek and Kashong Creek are two key outcrops of the Upper Ludlowville-Lower Moscow strata exposing the Wanakah, Jaycox, Tichenor, and Deep Run Members. Numerous other outcrops were studied to reveal the stratigraphic trends of the Jaycox-Spafford deposition. This research is presented in greater detail in a recent paper by Mayer, Baird and Brett (1994).

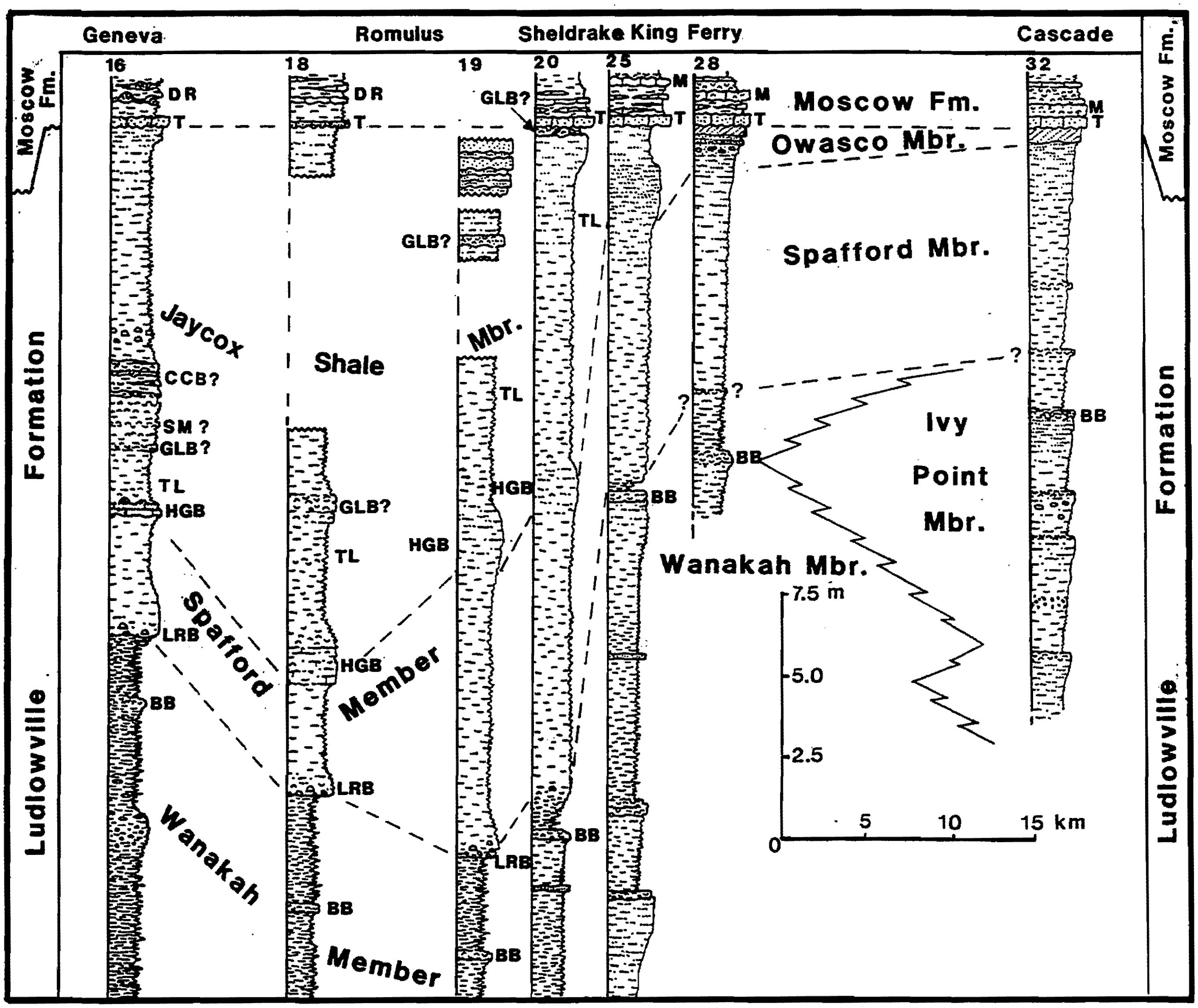

Figure 5B. Correlation of facies divisions of the Upper Ludlowville-Lower Moscow Formations across west-central New York. For abbreviations see Figure 5A.

ACKNOWLEDGMENTS

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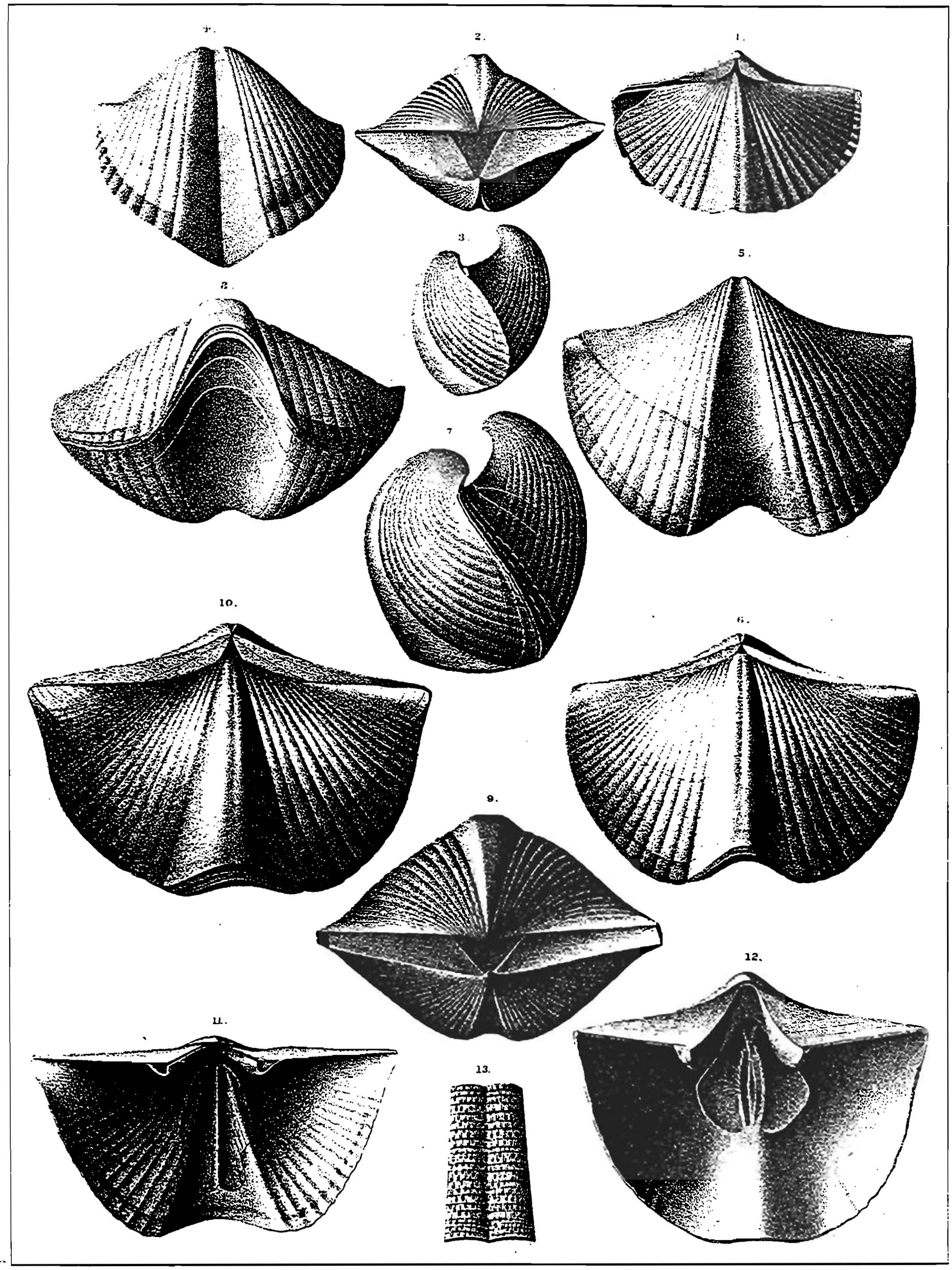
Note: Road log and stop descriptions accompanying this article follow paper by Brett and Baird (this volume).



Spinocrytia granulosa. Hamilton Group.
From Hall, 1867, Plate 36.

DEPOSITIONAL SEQUENCES, CYCLES, AND FORELAND BASIN DYNAMICS IN THE LATE MIDDLE DEVONIAN (GIVETIAN) OF THE GENESEE VALLEY AND WESTERN FINGER LAKES REGION

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INTRODUCTION

Late Middle Devonian (late Givetian) deposits in the Genesee Valley - central Finger Lakes region are represented in ascending order by the Moscow Formation of the Hamilton Group, the Tully (Limestone) Formation, and the lower third of the Genesee Formation. This succession records a dramatic facies transition from fossiliferous subtidal shelf mudstones in the Moscow Formation through outer lagoonal-to-shelf carbonate deposits in the Tully Limestone, into black shales recording anoxic basinal conditions in the Genesee Formation. The Tully-Geneseo succession records a dramatic shift from carbonate platform conditions to a deep-water, anoxic foredeep setting due to inferred flexural loading of the craton by a pulse of orogenic thrusting (Ettensohn, 1985, 1987).

The Moscow-lower Genesee stratal succession yields abundant and diverse fossils ranging from robust, shallow water forms to delicate taxa that lived under conditions of near-anoxia. Moscow and Tully biotas are highly diverse and have been well known since the publication of James Hall's "fourth district" report in 1839. Well preserved fossils can be collected at all of the field stops.

Strata discussed herein were deposited as muds in a foreland basin setting linked to a key phase of the Acadian Orogeny, a collision event involving the "docking" of one or more microcontinents in what is now New England and the central Atlantic states (Faill et al., 1978; Woodrow 1985; Ettensohn, 1985, 1987). Orogenic uplift and overthrusting in the tectonic settings to the east and southeast of New York State led to flexural downbending of the craton in eastern North America (Quinlan and Beaumont, 1984; Beaumont et al., 1988). This loading produced a foreland basin characterized by greater regional subsidence and often greater water depths (Figure 1). Erosion of orogenic highlands in the east led to the formation of progradational complexes ("Great Catskill delta") which filled in the Devonian shelf seas associated with the foreland basin, thus producing the Devonian stratal record in New York State, Pennsylvania, Maryland, and Virginia. In actuality, several inferred collision and overthrusting events are believed to have produced tectophases of overthrust-induced basin deepening and progradational basin-filling (Ettensohn, 1987; Ettensohn and Elam, 1985). A mainly quiescent phase at the end of Tectophase II is recorded by the upper Hamilton Group (Moscow Formation). However, the Tully-Genesee transition records a grand deepening and progradational pulse associated with the onset of Tectophase III.

The Devonian ("Catskill") clastic wedge provides a classic example of an ancient deltaic complex. Because orogenic events took place to the east,

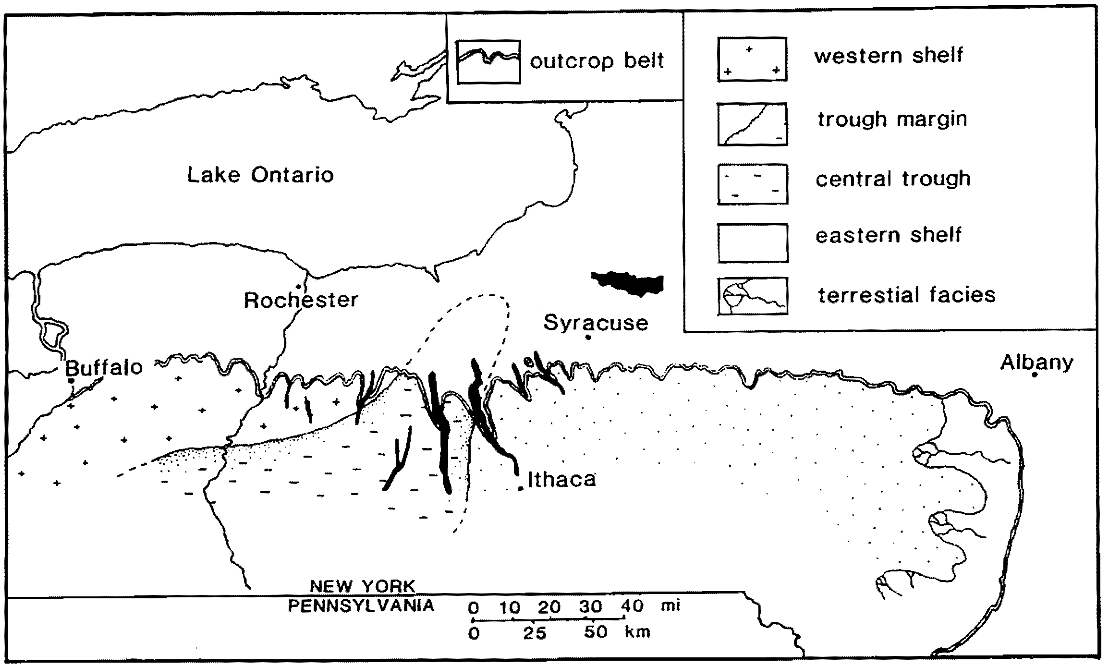

Figure 1. Geological setting of the northern Appalachian Basin during the Middle Devonian Givetian Age. Note the position of the Finger Lakes through (area of maximum subsidence) relative to the present outcrop belt. Dashed lines indicate conjectural positions of facies belts north of the outcrop belt.

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sediments supplied to the basin came from the eastern Acadian mountain belt. This is typically, though not always, reflected in the eastward-thickening of sediments within the Catskill clastic wedge. It is also reflected by west-to-east facies changes (limestone-to-terrigenous sediment, shale-to-siltstone, siltstone-to-sandstone, etc.) at almost all stratigraphic levels. These diachronous facies shifts are well displayed in the Devonian time-rock stratigraphic chart for the state (Rickard, 1975). The Catskill Delta is also a story of numerous isochronous events: evolutionary and immigration (epibole) events, volcanic eruptions, and sea level changes can be traced stratigraphically over long distances.

In this paper, we will focus on the record of sea level oscillations which have left a detailed record of sedimentary cycles during the Late Givetian Age (approximately 380-375 million years ago). Numerous thin limestones, marine erosion surfaces, and stratigraphically condensed intervals record sediment-starvation events associated with transgression events; these are well displayed in strata discussed herein. Recent advances in our understanding of Catskill Delta depositional processes involve the use of principles of sequence stratigraphic mapping.

The purpose of the present paper and associated field trip is fourfold: first, we document a rich assortment of shelf-to basin facies which is characterized by a broad array of Devonian fossils; second, we illustrate advances in stratigraphy which have been developed with the past few years, particularly involving application of sequence stratigraphy concepts to Paleozoic foreland basin deposits; third, we illustrate patterns of differential subsidence and migration of the foreland basin centers; finally, we illustrate several excellent Late Givetian sections within two hours' drive of Rochester which yield abundant, diverse, and well preserved fossils for the Devonian enthusiast.

We have chosen to describe Moscow subdivisions in some detail in the present paper in order to provide the details upon which our interpretations are based and as a guide to the various fossil bearing levels to aid paleontologic studies. Beacuse most horizons are laterally traceable for tens of kilometers we have followed the practice of assigning many bed names for those divisions. This is not intended to overwhelm the reader with detail but to facilitate unambiguous communication about the many levels. The more general reader may wish to bypass these sections and read the sections on sequence and cycle interpretation.

DETAILED STRATIGRAPHY AND SEQUENCE INTERPRETATION OF THE MOSCOW FORMATION, UPPER PART OF HAMILTON GROUP, WEST CENTRAL NEW YORK STATE

The Middle Devonian Moscow Formation is the uppermost of five major packages or formations in the Hamilton Group (Figure 2). The term "Moscow" was first applied to bluish gray shales (mainly Windom Member) exposed along Little Beards Creek in the town of Moscow (later renamed Leicester), Livingston County, New York, by James Hall (1839). In western New York, the Moscow consists of gray to black shales; calcareous mudstones and thin limestones. The Moscow Formation can be construed as a single major depositional sequence, representing perhaps 1.5 to 2 million years of geologic time and bounded above and below by relatively important and regionally angular unconformities. The basal sequence boundary coincides with the erosion surface below the Tichenor Limestone. The upper boundary is the disconformity below the Tully Limestone, or, where that unit is absent, below the Genesee Formation black shales. However, within a sequence context, the Moscow Formation can be subdivided into two unequal packages or fourth order sequences which constitute groups of previously named members. The lower portion, which might be termed the Portland Point "subformation," consists of the Tichenor, Deep Run, Menteth and Kashong members, as defined by Cooper (1930, 1933). In the Cayuga Lake region and, again, in Erie County, members thin dramatically and merge into a thin limestone-rich interval previously termed the "Portland Point Member" (Cooper, 1933); however, Baird (1979) demonstrated that individual limestone members can still be recognized within the Portland Point. Overall, this is a retrogradational or deepening-upward succession that involves several internal cycles ("fifth order cycles in the terminology of Busch and Rollins, 1984). The upper and thicker portion of the Moscow Formation consists of a single member in western New York, the Windom Shale and its lateral equivalent, the Cooperstown Siltstone in central New York. In the Central Finger Lakes region another thin, silty, fossil-rich interval, herein informally termed the "unnamed member" is interposed between the Kashong and Windom members (Figures 2,3). This interval consists primarily of shales and thin concretionary limestones in western New York, but farther to the east, it can be subdivided into coarsening-upward mudstone to siltstone packages, which have been mapped in some detail by Zell (1985). The Windom Shale overall is interpreted as the highstand portion of the Moscow sequence. Uppermost regressive portions of the sequence (or late highstand

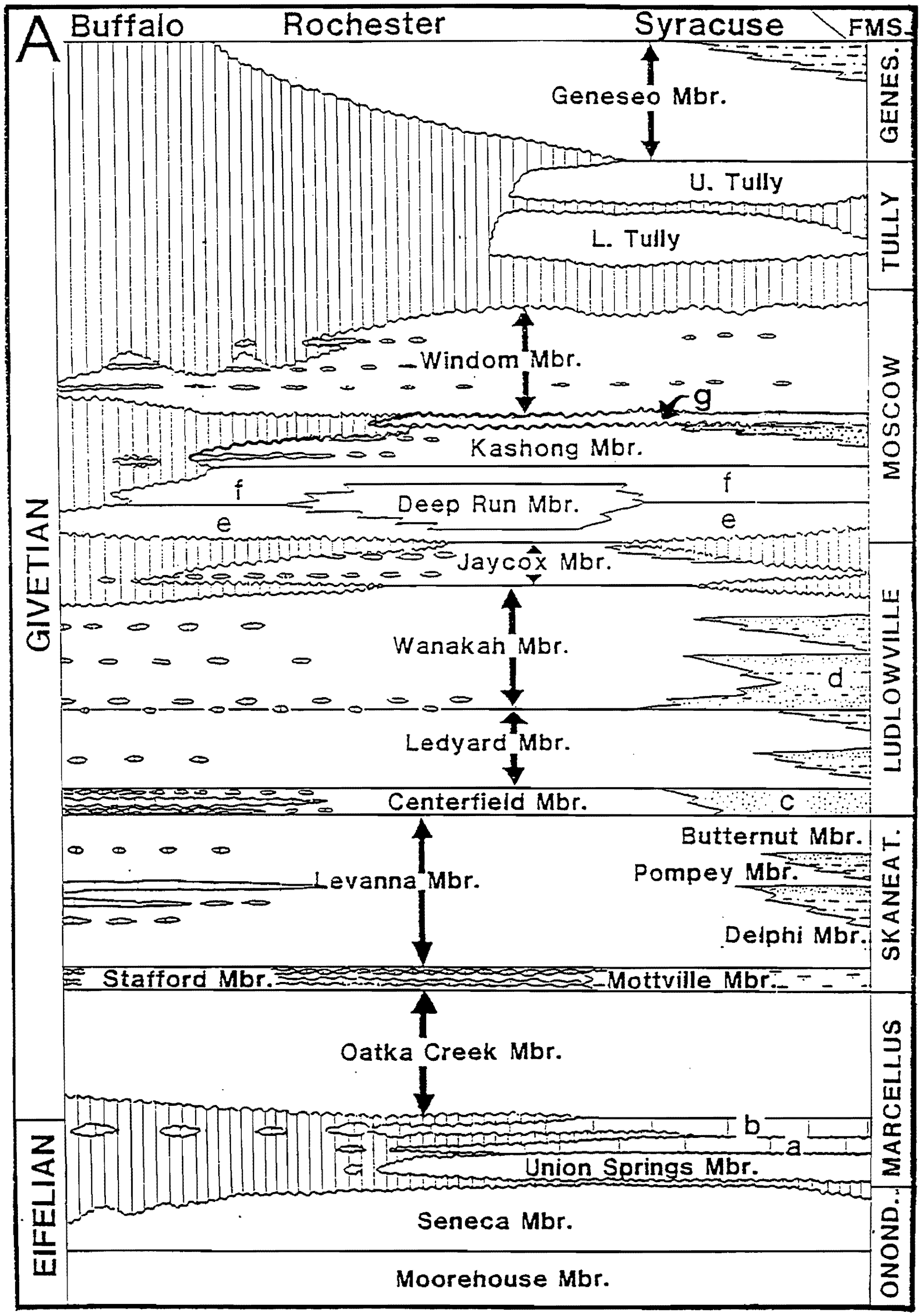

Figure 2A. General stratigraphy of the Middle Devonian Hamilton Group and under and overlying units in western New York. Lettered units include: a) Chestnut Street beds; b) Cherry Valley; c) Chenango Sandstone; d) Ivy Point Siltstone; e) Tichenor Limestone; f) Menteth Limestone; g) unnamed member (Barnes Gully bed to Geer Road bed, see text).

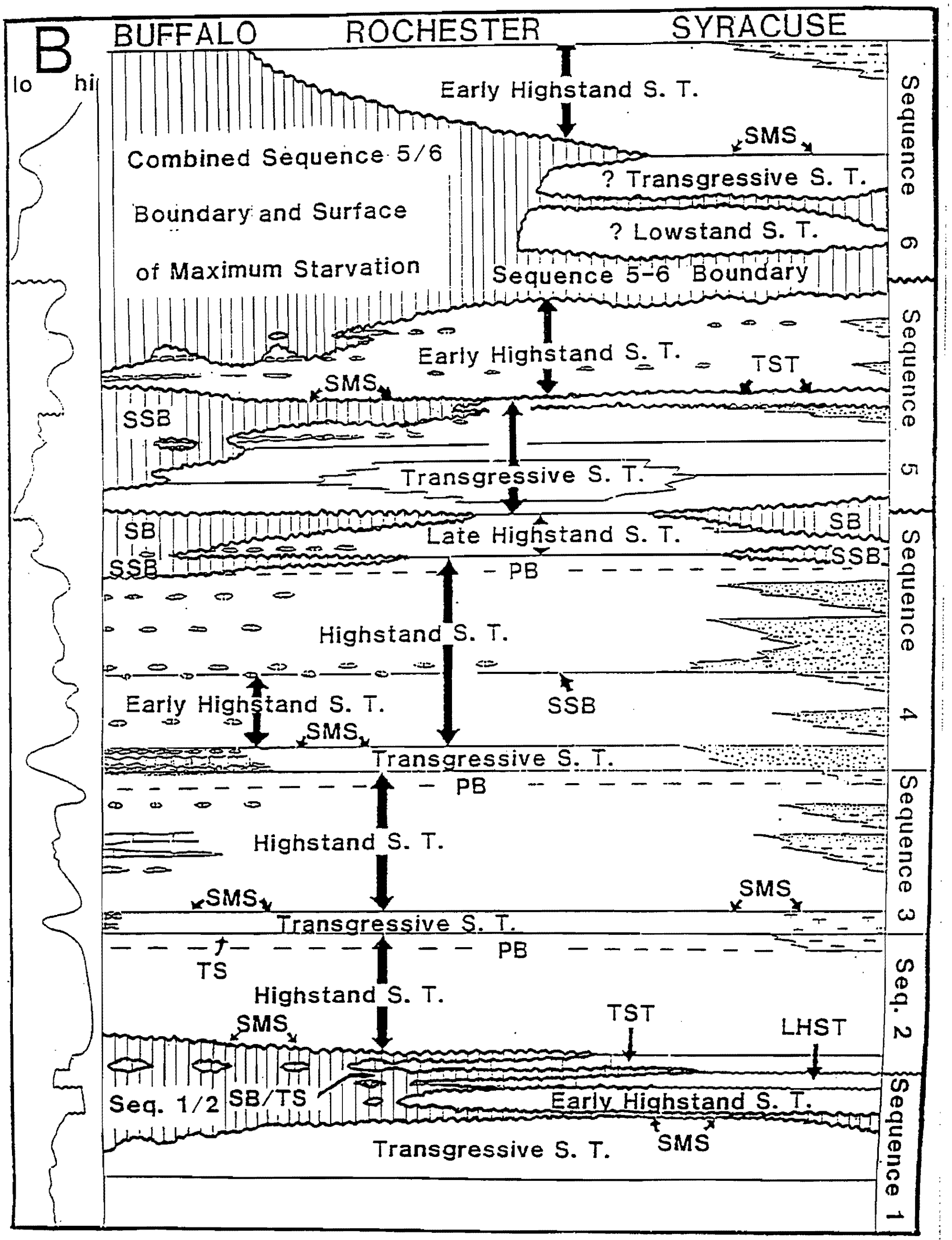

Figure 2B. Sequence interpretation of the Middle Devonian. Curve on left illustrates inferred sea level fluctuations. Abbreviations. SB = sequence boundary; SSB = subsequence boundary; TS = transgressive surface; PB = precursor bed; ST = systems tract; SMS = surface of maximum starvation.

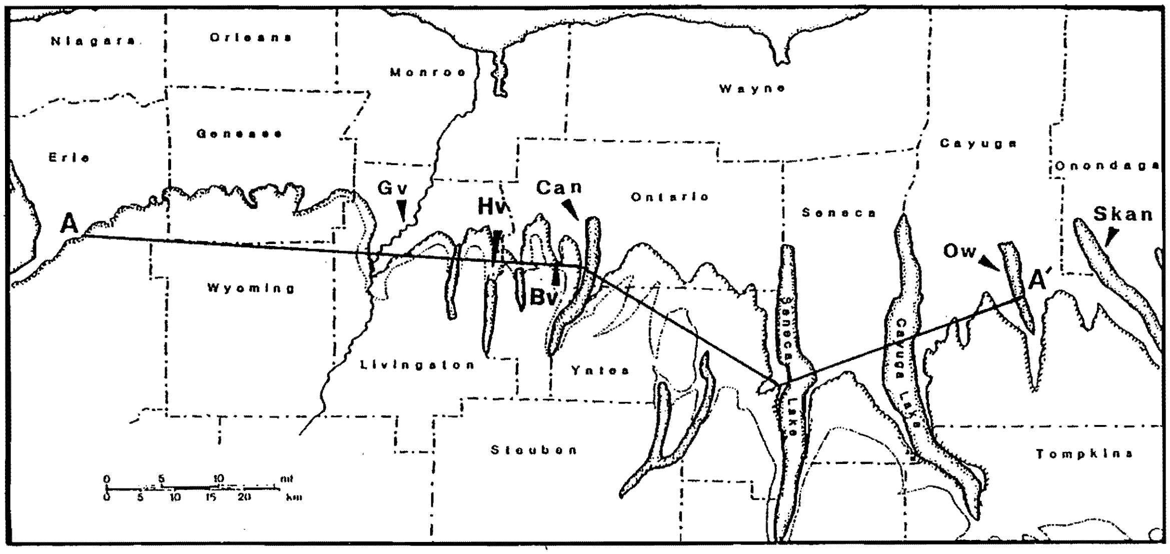

Figure 3. Map of western New York State showing location of key geographic features referred to frequently in the text. Counties are named; abbreviations include: Bv, Bristol Valley; Can, Canandaigua Lake; Gv, Genesee Valley; Hv, Honeoye valley; Ow, Owasco Lake; Skan, Skaneateles Lake. Cross section of Figure 5 is indicated at line A-A'.

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progradational succession), representing the Windom-into-Tully facies transition, have been removed by erosion at the sub-Tully unconformity. Details of various increments of this sequence are described in the following sections. For location of counties and other features referred to in these sections, see Figure 3.

Tichenor Limestone

Description: In west-central New York State the Tichenor Limestone is a thin, 30-50 cm- (1 to 2 foot-) thick compact limestone bed; its western facies seen primarily in Erie to Livingston counties consist of coarse crinoidal skeletal grainstone. However, eastward in the vicinity of Canandaigua Lake the Tichenor becomes slightly thicker and considerably finer-grained, represented by a styliolinid and crinoidal packstone (Griffing, 1994).

Interpretation: The Tichenor is considered to represent the first transgressive limestone of the Moscow sequence (Figures 2,4). It overlies a distinct disconformity which bevels the underlying Ludlowville Formation in both a westward, and probably an eastward, direction from the central Finger Lakes region. In the vicinity of Seneca and Cayuga Lakes where the boundary becomes most nearly conformable, the Tichenor still sharply overlies upper silty beds of the underlying Jaycox Shale Member (Figures 2,4). Indeed, an upper transitional coarsening-upward cycle culminating in medium- to coarse-grained siltstone deposits has been located at Big Hollow Creek just west of Cayuga

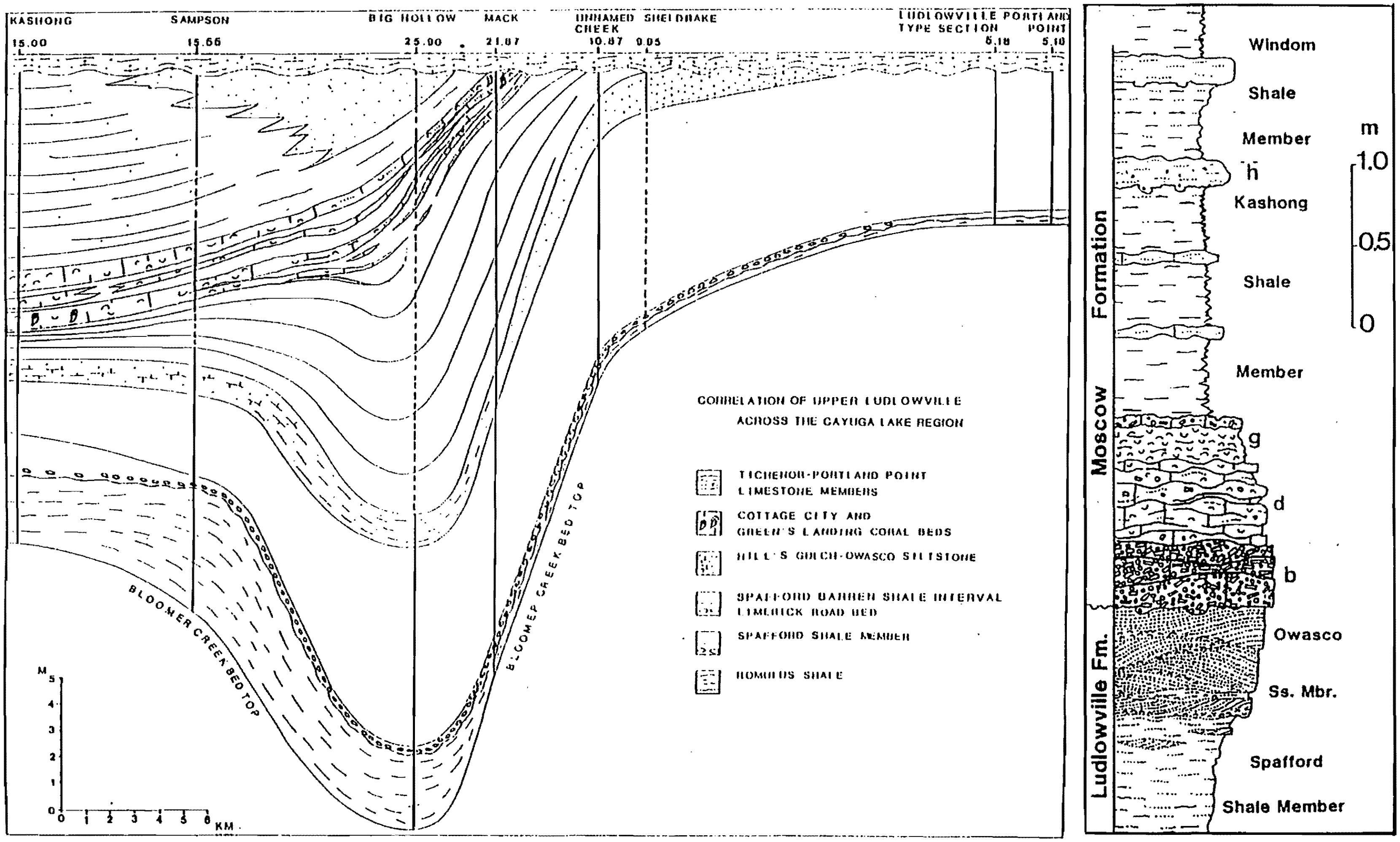

Figure 4. Schematic northwest-southeast cross section of the uppermost Ludlowville Formation and overlying Tichenor Member of the Moscow Formation; position of cross section in Seneca-Cayuga Lake region is shown in Figure 3. Note depocenters of upper Ludlowville in vicinity of Big Hollow Creek. Inset shows stratigraphic section of upper Ludlowville and Lower Moscow Formations of Portland Point. Symbols include: b, Tichenor Limestone; d, Deep Run-Mentith; g, condensed lower Kashong Member; h, Barnes Gully phosphatic bed. Modified from Mayer et al., (1994).

Lake in the Town of Ovid. This latter may be interpreted as the late highstand or progradational package of the underlying Ludlowville sequence (Figures 2,4).

To the west, the basal sequence boundary of the Moscow Formation (base-Tichenor disconformity) progressively bevels beds of the middle to lower Jaycox Member; in western Erie County the Tichenor rests locally on the basal Hills Gulch limestone bed of the Jaycox Member, and even on the underlying Wanakah Shale Member where the Hills Gulch Bed has been removed by erosion. A comparable pattern of progressive erosive overstep is observed beneath the Tichenor southeastward from the Ovid area both across and along Cayuga Lake (Figure 4). The upper silty beds of the Jaycox Member have been progressively removed and the Tichenor comes to be juxtaposed sharply, but with a welded contact either on the Owasco Siltstone (lateral equivalent of Hills Gulch bed), or, where that has been removed, on the underlying Spafford Shale (Mayer et al., 1994; Figure 4, herein). This "mirror image" unconformity on either side of the Cayuga Seneca Lake region defines a trough of most active subsidence during early Moscow deposition in which lowstand siltstones apparently were dumped into the basin at the same time that erosion took place along the margins. The sub-Tichenor lowstand was sufficiently strong that in most places at least a minor disconformity underlies the Tichenor.

The Tichenor, in turn, is readily interpretable as a transgressive, sheet-like, lag deposit of crinoidal, coral, and other fossil debris, except near the basin center (McCave, 1969, 1973; Brett and Baird, 1985, 1990; Griffing, 1994). The Tichenor grainstone was deposited in relatively clear, shallow water environments during an initial transgression that took place after maximal sea level lowstand.

The upper contact of the Tichenor in most localities is relatively abrupt, although apparently gradational and conformable with the overlying Deep Run mudstones. At Jaycox Run near Geneseo small mounds of fistuliporoid bryozoans occur at this surface and extend upward into the mudstone. This appears to reflect a minor sea level rise, during which time these minature bioherms built upward. Tichenor thus records two scales of process. On the one hand, it represents the basal transgressive carbonate of the overall Moscow sequence; however, at a smaller scale, the Tichenor, in many localities, appears to represent an abbreviated small-scale cycle (parasequence) which is capped by a marine flooding surface at its contact with the overlying Deep Run mudstone.

In western New York a second crinoidal packstone ledge occurs somewhat above the main coarsely crystalline Tichenor ledge. Eastward, this bed appears to splay outward, being separated from the Tichenor proper by up to a meter of Deep Run mudrock. This then is interpreted as the capping bed of a second parasequence which eventually merged together with those of the underlying minor cycle in up-ramp basin margin sections.

Deep Run Member

The Deep Run Member was named by Cooper (1933) for exposures on Deep Run Gully just south of Kipp Road on the east side of Canandaigua Lake. At this locality, the Deep Run attains a thickness of approximately 18 meters, this being one of its thickest sections. A somewhat lower thickness of 11 meters occurs at Kashong Glen in the Seneca Lake Region. The interval thins markedly both to the southeast along Cayuga Lake, where the Deep Run (or

Deep Run-equivalent) Interval ranges from 4.0 to 0.5 meters, as well as west of the Canandaigua Lake area where the interval rapidly thins to approximately 2.5 meters in the Genesee Valley, and less than one meter in central Genesee County (Figure 5). Hence, the overall geometry of the Deep Run is that of a large-scale lens in cross section with its maximum thickness in the west central Finger Lakes Region and thinning both to the east and west to a feather edge (Figure 5).

The Deep Run consists of hard bluish gray, calcareous, and typically highly bioturbated (*Zoophycos*-bearing) silty mudstones. In many areas, particularly in the eastern outcrops, the Deep Run becomes a calcareous silty mudstone or siltstone with well preserved *Zoophycos* spreiten. The basal 0.5 to 1.5 meters of the Deep Run is somewhat richer in fossils, particularly the branching coral *Heliophyllum proliferum*, which is diagnostic of this interval, as well as large camerate crinoid columns and fenestrate and cryptostome bryozoans. Calyces of the crinoids *Dolatocrinus* and *Megistocrinus*, platyceratid gastropods, the brachiopods *Pentamerella, Protodouvillina*, and *Elita*, and relatively large specimens of the trilobites *Phacops*, *Greenops*, and *Monodechenella* are also typical of these basal beds. As noted above, in many localities a 20 to 30 centimeter, compact, crinoid coral-rich limestone occurs some 0.5 to 2 meters above the Tichenor Limestone. This latter bed resembles the Tichenor and has sometimes been included within that unit, although it is separated from the typical Tichenor by the interval of more characteristic Deep Run mudstone.

The upper beds of the Deep Run are relatively homogenous in appearance and contain only scattered fossils. However, well preserved crinoids, brachiopods, large bivalves and large trilobites may be encountered rarely. The Deep Run appears to become somewhat more silt-rich (coarser) upward. Narrow prod like structures (burrows or gutter casts?) filled with laminated silt occur sporadically within these beds. Near the basin center, the Deep Run appears to grade upward into the overlying silty Menteth Limestone; however, towards the basin margins, near Cayuga Lake and in western New York the contact is sharp.

Menteth Limestone

Description: The Menteth Limestone consists of about 30 to 40 centimeters of thoroughly bioturbated (*Zoophycos*-churned), hard, silty, calcareous mudrock or very silty limestone. This uniformly thin limestone bed separates the Deep Run and Kashong members (Figure 5). On the whole, the unit appears to be sparsely fossiliferous. Thin sections show abundant sponge spicules in some areas (Griffing, 1994). In western New York, the Menteth displays very scattered small bluish-gray chert nodules.

The fossils in the Menteth are dominated by brachiopods and relatively large trilobites, some of which may be silicified. Large specimens of *Spinocyrtia*, *Mucrospirifer*, *Tropidoleptus*, *Athyris*, and *Nucleospira* are abundant; this fauna resembles that of the overlying Kashong Shale, except for the abundance of *Spinocyrtia*. The upper surface of the Menteth typically displays a somewhat richer biota that may include occasional rugose corals and fairly abundant coralla of the branching tabulate coral or *Thamnoptychia* (= *Trachypora*) as well as large camerate crinoids.

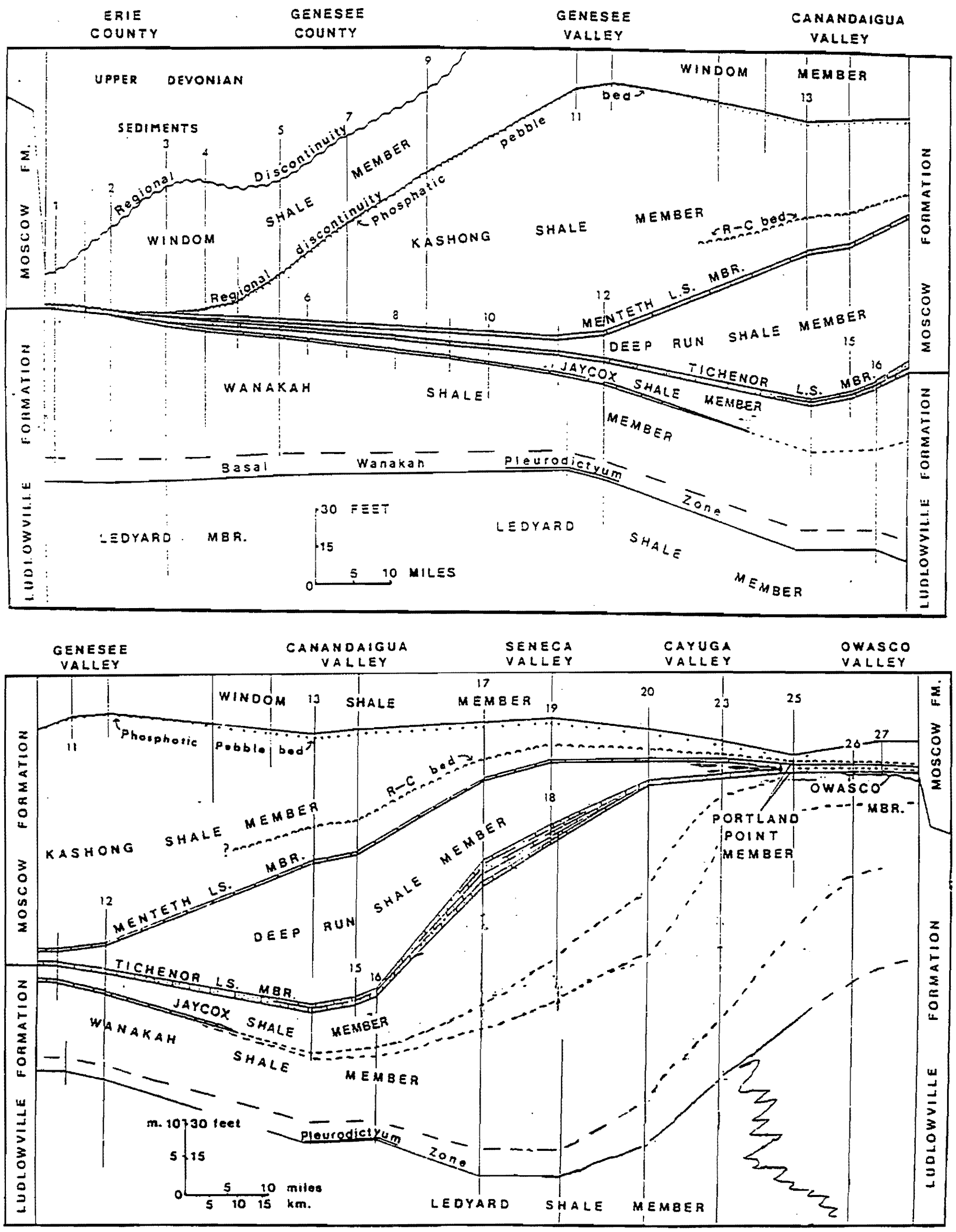

Figure 5. Regional east-west cross sections of upper Ludlowville and lower Moscow Formations. A) Western panel, Erie County to Canandaigua; B) Eastern panel, Genesee Valley to Owasco Lake. See figure 3 for approximate cross section lines. Numbered locations are described in Baird (1979).

Interpretation of the Deep Run and Menteth Members: The Deep Run-Menteth succession is interpreted as representing two intermediate-scale, shallowing-upward cycles. The first begins above the Tichenor Limestone flooding surface and culminates in the lower Deep Run unnamed limestone. This interval, contains sparsely fossiliferous, calcareous mudstone at its base and passes upward into fossiliferous, calcareous mudstone and limestone. It is interpreted as a small-scale, shallowing-upward succession or parasequence. The second cycle commences with the flooding surface above the unnamed lower Deep Run limestone and passes upward into the Menteth Limestone. Shallowing was accompanied by an increased influx of muds and silts from eastern source areas. The Menteth Member, which caps the cycle, is locally a calcareous siltstone.

There is some ambiguity to the interpretation of the Menteth capping beds. In particular, a sharp contact which separates the limestone from underlying Deep Run mudstone on both eastern and western margins of the central Finger Lakes trough or basin suggests that the carbonate should not be thought of as occurring in the shallowing or progradational phase of a cycle, but rather subsequent initial deepening phase. The carbonate overlaps a regionally, slightly angular beveled surface, which therefore more closely resembles a boundary of a small-scale sequence than a marine flooding surface of a parasequence.

Kashong Shale Member

General Description: The Kashong Shale Member was recognized by Cooper (1933) for exposures along Kashong Glen east of Bellona and about 1 kilometer west of Seneca Lake. More recently, Lukasik (1984) provided a detailed, updated study of Kashong member stratigraphy, sedimentololgy and paleoecology (Figures 5,6). At its type locality, the Kashong is a soft, bluish gray mudstone with some thin but regionally widespread limestones and nodular concretionary horizons. The Kashong interval thickens to a maximum of about 25 meters (80 feet) in the Genesee Valley and thins westward to a feather-edge in Erie County; the Kashong also thins towards the southeast and east (Figure 6). The Kashong somewhat resembles the Deep Run in lithology, but it is a softer, less calcareous, and typically less silty mudstone.

The Kashong mudstones carry a very distinctive fauna dominated by the concavo-convex orthid brachiopod *Tropidoleptus carinatus,* as well as *Mucrospirifer*, *Nucleospira concinna*, *Devonochonetes coronatus*, the tabulate coral *Pleurodictyum americanum* relatively large bivalves such as *Orthonota undulata*, and the trilobite *Dipleura*. Component limestone beds contain a much more diverse biota, dominated by small twig-like bryozoans such as *Taeniopora* and *Sulcoretepora*, crinoids as well as a variety of brachiopods, especially rhynchonellids.

Lower Kashong: The Kashong Member can be subdivided into three intervals, of which the lower usually constitutes a third or less of the total thickness of the Kashong (Figure 6). The lower division of the Kashong Shale consists of about 0.5 to 3 meters of bluish-gray mudstone with abundant small concretions in its upper third. The base of this interval sharply overlies the Menteth Limestone, but the basal 30 centimeters. contains a highly diverse fossil assemblage, including abundant large crinoids, bryozoans, brachiopods, and bivalves. Overall, the fauna closely resembles that seen in the more fossiliferous beds of the older Deep Run Member. The remainder of the lower division is more

The Fisher Gully interval displays a reciprocal thickness pattern with the underlying Bear Swamp beds--thinning to the southeast as the latter interval thickens (Figure 9). For example, the Fisher Gully interval is 7 m-thick at Bloomer Creek but only 3 m (10 ft) at Willow Point, along the west side of Cayuga Lake. Fisher Gully beds display a sharp contact with the underlying beds, which, as noted above, is locally an erosional unconformity that has removed substantial portions of the Bear Swamp beds. This basal contact is typically overlain by a thin, cryptic shell hash bed that displays a concentration of varied fossils reworked from underlying shales, hiatus concretions, and even reworked tubular pyrite clasts in at least one locality. This reworked debris is variably commingled with the typical fauna of the Amsdell Bed which includes specimens of the ambocoeliids *Emanuella praeumbona*, *Ambocoelia umbonata*, and the leiorhynchid *Eumetabolotoechia multicosta*. The overlying 1 to 2 m of shale are typically quite dark gray and platey and range from nearly barren to highly fossiliferous on certain bedding planes. The latter are typically crowded with nearly monospecific assemblages of *E. multicosta*. However, toward the upper portion of the interval, thin beds rich in *Emanuella praeumbona* appear at several levels, together with a somewhat more diverse fauna that may include chonetids, small *Athyris*, rare *Mediospirifer*, various nuculid and modiomorphoid bivalves, the cephalopod *Spyroceras* and various gastropods. The trilobite *Phacops rana* may be present as well. One or two beds near the middle of the interval are also rich in diminutive specimens of the brachiopod *Allanella tullius*. In the eastern Finger Lakes area, this interval becomes silty medium gray and may contain small ellipsoidal concretions. To the west, near Canandaigua Lake and the Genesee Valley, the interval again tends to be medium gray, loses its platy nature, and contains more abundant *Emanuella* and other brachiopods and fewer specimens of *E. multicosta*.

The upper boundary of the Fisher Gully beds varies from apparently gradational in areas around Seneca and Cayuga Lakes and eastward to very sharply defined in the Canandaigua to Genesee Valley area where the Fall Brook coral bed rests with sharp and apparently unconformable contact on the underlying *E. praeumbona*-rich shales.

No trace of the *E. praeumbona*-rich interval has been found in outcrops in Genesee or eastern Erie Counties. However, the apparently corresponding interval reappears in western Erie County (Figure 8). Here, the *Emanuella praeumbona*-rich zone is contained within an interval, up to about 2.5 m in thickness of medium gray, light weathering, highly calcareous and somewhat petroliferous mudstone. Very argillaceous limestone occurs at the base of the interval and near the top of the Windom Member in outcrops between Cazenovia Creek and the Lake Erie Cliffs near Hamburg. This bed, previously termed the "*Praeumbona* bed" by Grabau (1898, 1899), and more recently the Amsdell Bed (Brett and Baird, 1982), is a highly distinctive marker in Erie County. Its lithology somewhat resembles the basal part of Unit 11 in the Canandaigua-Genesee Valley area. The Amsdell bed is believed to have been formerly coextensive with the lower *E. praeumbona* dark shales of the Finger Lakes area (Figure 8b). However, the absence of this bed in Genesee and eastern Erie counties is accounted for by the presence of two unconformities. In previous work, we have documented the northeastward removal of the Amsdell bed in Erie County as a result of the Windom-Genesee unconformity (Brett and Baird, 1982). This contact was demonstrated to be regionally angular, truncating not only the Amsdell bed, but also underlying mid Windom shale units in the eastern Erie County and Genesee outcrop area. However, this disconformity surface does not account for the absence of the Amsdell bed in eastern Genesee and western Livingston County areas west of the Genesee Valley. In these areas, the Fall Brook bed (Unit 12) is still present below the Windom-Genesee unconformity. Consequently, it is necessary to postulate that a lower erosion surface beneath the Fall Brook coral bed has locally beveled out the Fisher Gully strata (Unit 11) in the area of northwest of the Genesee Valley.

Indian Creek Bed and "Willard Channel": A highly distinctive crinoidal pack- and grainstone bed, up to 20 cm-thick, occura along Indian, South Indian, and Simpson Creeks in the town of Willard on the east side of Seneca Lake. For this bed, the informal term Indian Creek bed is proposed herein. At these localities, especially along South Indian Creek, the bed is compact, highly fossiliferous, pyritic, packstone layer containing extremely abundant, corroded crinoid ossicles, *Stereolasma* (rugose corals), and brachiopods, as well as reworked, although non-encrusted, concretions, derived from the underlying shales. This compact bed, which locally resembles the Tichenor Limestone, is obviously lenticular. No similar thick bed has been located beyond the east Seneca Lake region. At South Indian and Simpson Creeks, the base of the bed is razor sharp and overlies an erosion surface that has beveled out units 4, 5 and 6 and cut down into concretionary levels at the top of the *D. coronatus* interval (Figure 9). Indeed, the upper concretions protrude into the bed and have been reworked as isolated clasts within the base of the skeletal pack- and grainstone. This is the lowest of three important mid-Windom erosion surfaces which display complex relationships with respect to one another. However, the erosion at this level was relatively localized, evidence being limited to the area of thick development of the Indian Creek bed around Willard.

The Indian Creek bed is overlain in the Willard area by 2.1 to 3.9 m (7 to 13 ft) of sparsely fossiliferous, medium gray shale with a distinctive satiny sheen. The lowest 0.5 m of the shale contains thin stringers of crinoid debris; upper beds carry chonetids and rare *Eumetabolotoechia* and *Emanuella*. The interval is capped by a thin brachiopod-rich bed that may be coextensive with the lag bed at the base of the Fisher Gully beds near Cayuga Lake.

Detailed measurements of this shale indicate that it is lenticular and probably fills a channel-like depression cut into the lower Windom Shale (Figure 9). The stratigraphic affinities of this shale are somewhat enigmatic; we offer two possible alternatives in Figure 9. The first model (Figure 9a) assumes that the Indian Creek bed is correlative with the mid-Windom conodont bed and that the shell bed above the "satiny shale" is the base of the Fisher Gully interval. Hence, the "satiny shale" is a local expression of the Bear Swamp shale.

The alternative correlation (Figure 9b) implies that the Indian Creek bed is a local thickening of the basal Fisher Gully shell lag; the channel-like erosion surface would be coextensive with the discontinuity beneath the Fisher Gully beds documented in the vicinity of western Cayuga Lake. By this interpretation, the "satiny shale" would be a locally expanded facies of the Fisher Gully beds and the shell bed at the top would be a minor bed within the Fisher Gully interval. Resolution of this issue will require still more detailed study.

Unit 12. Fall Brook Coral Bed: The Fall Brook coral bed was defined and described by Baird and Brett (1983) for an interval of approximately 0.5 to 2 m in thickness overlying the *E. preaumbona*-rich dark gray (Fisher Gully) shales in the Genesee-to-Canandaigua and Seneca Lake area (Figure 8). This interval is characterized by an abundance of large rugose corals, especially *Cystiphylloides*, *Heliophyllum*, and *Heterophrentis*. An extremely diverse associated fauna, comprising over 70 species of brachiopods, bryozoans, small-to-medium sized tabulate corals, mollusks, trilobites, and echinoderms was also discussed in detail by Baird and Brett (1983) and a regional gradient of faunal change was also noted in that publication. The Fall Brook bed contains the greatest number of corals and displays the highest proportion of skeletal debris in the more western sections. To the east of the Genesee Valley, the Fall Brook bed displays a marked decrease in the abundance of larger rugose corals, but an increase in overall faunal diversity.

The easternmost locality at which the Fall Brook bed can be readily recognized as a discrete interval is along Perry Ravine on the west side of Seneca Lake south of Dresden, New York. Here it is a somewhat thicker interval of fossiliferous mudstone (up to 3 m) that contains abundant small corals, such as *Amplexiphyllum*, as well as a high diversity of brachiopods, including forms such as *Tropidoleptus* which are rare or absent in the western sections. Also, accompanying an increase in thickness and decrease in density of fossils is the appearance of greater numbers of the trace fossil *Zoophycos* and semi-infaunal bivalves such as *Modiomorpha*. The Fall Brook bed is readily recognizable as a highly fossiliferous zone westward to Linden, Genesee County, where it occurs immediately below the Leicester Pyrite and succeeding Geneseo Shale. Westward of this locality regional truncation at the Moscow-Genesee contact has removed the Fall Brook bed and underlying strata downward locally as far as the upper Bay View beds interval (Figure 8). Although units 10 and 11 reappear beneath the unconformity in southwestern Erie County outcrops, the Fall Brook bed does not reappear in this area (Figure 8). Evidently the highest beds exposed just beneath the unconformity in areas of western Erie County belong to the *Emanuella praeumbona*-rich Unit 11.

It is notable that the latter interval had been removed by an unconformity below the Fall Brook bed in areas of eastern Genesee County prior to erosional truncation of the Fall Brook bed and subjacent shales by the post-Windom unconformity. However, in Erie County the unconformity beneath the Fall Brook bed, if ever present, must have been minor, as evidenced by the reappearance of Amsdell (Unit 11) bed, strata in that area.

To the east, the Fall Brook bed displays a less distinct basal contact, and eventually, near Seneca Lake, the bed appears to be conformable with underlying mudstones. At the same time, the bed loses its compact nature and splays into a series of thin, brachiopod and small coral-rich beds. These beds are exceptionally rich in *Mediospirifer* and *Athyris*, but also contain relatively abundant small corals, including *Pleurodicytum*. Intervening shales are relatively dark gray and may even contain specimens of the leiorhynchid *Eumetabolotoechia multicosta* This is a curious mixture of faunas as it is most unusual for small rugose corals to occur with leiorhynchids in the Hamilton Group. Cleland (1903) referred to this interval as a "transition zone" to his "*Spirifer-Atrypa*" Zone. Grasso (1966) and Zell (1985) traced this interval of *E. multicosta* eastward through the Tully and Chenango Valleys. Moreover, the Fall Brook interval becomes exceptionally pyrite-rich in outcrops in the Cayuga Valley. Relatively finely crystalline but euhedral pyrite occurs as crusts on shell, as irregular lumps and nodules, and occasionally as infillings in fossils; pyritized wood is relatively common in this interval. One or more levels of relatively large septarial concretions are also observed within the Fall Brook interval. Shell beds within the interval appear to become slightly more diverse upward. Beds 1.5 to 3 m above the apparent base of the Fall Brook interval contain rare specimens of the brachiopod *Spinatrypa*, which is generally common to the west in the Fall Brook bed. However, large rugose corals have never been found within this interval east of Seneca Lake.

The upper contact of the Fall Brook bed with the overlying Taunton beds is relatively distinct in the Genesee Valley area, where it is marked by a fairly abrupt change to moderately fossiliferous blue gray mudstones. However, this upper contact, like the lower, becomes diffuse and indistinct towards the east.

Unit 13. Taunton Beds: In the Genesee Valley area, the Fall Brook Bed is overlain by an interval, up to 3 m in thickness, of moderately fossiliferous bluish gray *Zoophycos*-burrowed mudstone with abundant large fossiliferous concretions (up to 30 and 40 centimeters in diameter). This interval has been termed the Taunton beds interval for excellent exposures in Taunton Gully north of Leicester (Baird and Brett, 1983). The lowest portion of the Taunton beds succession, directly overlying the Fall Brook coral bed tends to be blocky, sparsely fossiliferous mudstone, somewhat resembling the older Kashong Shale; like the Kashong the lower portion of the Taunton beds typically contains brachiopods such as *Tropidoleptus* and *Orthospirfer (?) marceyi*. Upward, the Taunton interval displays a general increase in thin (1 to 2 cm-thick) shell and bryozoan-rich beds.

Parsons et al. (1988) were able to correlate these thin shell hash beds at least regionally within sections of the Genesee Valley. Distinctive horizons in which shell layers are locally incorporated into the carbonate concretions, as well as pyritic shell rich beds provide useful regional markers. Crinoid columns and calyces also become abundant within this portion of the Taunton beds. Large camerate crinoids, such as *Megistocrinus*, *Dolatocrinus*, occasional blastoids, and inadunates occur sporadically in this interval. In the medial part of the Taunton interval beds of large (0.5 m) concretions typically display an abundance of crinoid and bryozoan material. This interval is the source of large clusters of crinoids, particularly *Clarkeocrinus*, found in the Bristol Valley and described in detail by Goldring (1923). This *Clarkeocrinius*-rich horizon, typically associated with fistuliporoid bryozoan mounds has now been traced from the Genesee Valley to the east side of Seneca Lake. It appears to be a widespread obrution or rapid burial horizon. It also represents an epibole, in that it displays a considerable abundance of the typically very rare species such as *Clarkeocrinus troosti*.

The upper Taunton beds are rich in the brachiopods *Pseudoatrypa*, and *Mediospirifer*, the small rugose corals, *Stereolasma* and *Amplexiphyllum*, the bryozoan *Sulcoretepora*. This fauna corresponds to Cleland's (1903) "*Spirifer-Atrypa* zone" in the Cayuga Lake region. The highest beds also are exceptionally rich in fenestellid bryozoans. Near Seneca Lake, this interval displays corals such as *Thamnoptychia* and occasional large rugosans such as *Heliophyllum*.

Eastward from outcrops near Seneca Lake, the Taunton interval becomes increasingly silty and displays a coarsening-upward cycle from soft, burrowed mudstones upward to heavily *Zoophycos* churned silty mudstones and/or siltstones. In sections east of Cayuga Lake, the creeks typically display a cascade or waterfall over these more resistant, silty upper Taunton beds.

Although the Fall Brook interval at the base of the Taunton submember becomes extremely diffuse and difficult to distinguish, the upper contact becomes increasingly sharp and is marked by a compact argillaceous limestone carrying abundant rugoans and the large tabulate coral, *Favosites hamiltoniae*. These beds, particularly well displayed in the area around Portland Point Quarry, South Lansing were termed the South Lansing coral bed by Baird and Brett (1983).

This South Lansing coral rich limestone bed displays a relatively abrupt lower and upper contact. This bed appears to correlate with a widespread coral-rich zone within the upper Mahantango (Sherman Ridge) shale in Pennsylvania (Ellison, 1966).

As the Taunton interval becomes increasingly silty, its fossil content decreases and becomes much more sparse, corresponding with a great increase in the abundance of *Zoophycos*. The increase in silt content is also accompanied by loss of the large, rather tabular horizontal concretions so typical of the Taunton, particularly the middle Taunton interval to the west.

The eastern limit of the Taunton beds interval is presently unknown; this highly silty portion of the Windom is distinctive and caps small waterfalls eastward at least to the Chenango Valley. To the west, the Moscow-Genesee unconformity has removed upper Windom beds, and the Taunton interval is missing at this erosion surface west of the Genesee Valley (Figure 8).

Unit 14. Spezzano Gully Beds: The Taunton interval is overlain in the Genesee Valley area by a series of calcareous shales and very argillaceous, somewhat concretionary to tabular limestone beds. This bundle of limestone and shale beds, up to about 1.5 m in thickness, is named the "Spezzano Gully beds" for exposures along Spezzano Gully near the town of Retsof, New York. The Spezzano Gully interval is rich in the small rugose corals, *Stereolasma* and *Amplexiphyllum*, and, in some layers, contains an abundance of partial, enrolled, and complete outstretched specimens of the trilobites, *Phacops rana* and *Greenops spp*. As such, the interval quite closely resembles the older Smoke Creek bed (Unit 6) of the lower portion of the Windom. The Spezzano Gully interval is roughly subdivisable into two parts near the type section. The lower portion contains a series of three tabular very sparsely fossiliferous argillaceous limestones, which can be correlated, at least, within the Genesee Valley Region. These closely resemble a bundle of three tabular micritic limestones found in the mid-Windom (Bear Swamp) interval in Erie County. Previous incorrect assumptions about the stratigraphy had led us to correlate the Spezzano Gully beds with these mid-Windom limestones. Shales immediately above and between these calcareous ledge-forming limestones carry an abundance of *Pseudoatrypa*, *Protodouvillina*, and small *Stereolasma* corals. The lower two ledges, appear to merge into a single calcareous band in the area of Fall Brook (Parsons et al., 1988). The upper portion of the type Spezzano Gully interval not does contain discrete carbonate beds, but is a rather platy, calcareous mudstone containing sparse, but commonly well preserved trilobites, scattered brachiopods, and even rare blastoids. The lower boundary of the Spezzano Gully interval is marked by abundant bryozoan-rich shell hashes which may be the stratigraphic equivalent of the South Lansing coral beds. The upper boundary is marked sharply in most localities by a thin, but very distinctive shell hash bed (Unit 15). To the east, in the central Finger Lakes area, the Spezzano Gully interval loses its discrete carbonate beds. However, it remains a distinctive fossil-rich mudstone unit.

The Spezzano Gully interval in west central New York rarely contains the brachiopods *Pustulatia*. This interval may be correlative with the well known "*Pustulatia* beds" high in the Sherman Ridge Member of the Mahantango Formation in Pennsylvania (Ellison, 1965). Like the Taunton interval below, the Spezzano Gully beds are truncated to the northwest of the Genesee Valley and do not reappear in any sections west of this area.

Unit 15. Simpson Creek Bed: The Spezzano Gully interval is everywhere abruptly terminated at a sharp contact with the overlying dark gray uppermost Windom Shale interval. This contact is overlain by a thin (1 cm-thick), yet highly persistent, shell-rich bed (Parsons et al., 1988). This bed, named for its excellent development along Simpson Creek near the Willard Psychiatric Center on the east side of Seneca Lake, is particularly rich in the small brachiopod *Emanuella praeumbona*. This brachiopod is otherwise seen only in the Fisher Gully (Amsdell) beds interval of the mid-Windom succession (Units 12 and 13). In the Simpson Creek bed, it is commonly mixed with abundant fragmentary brachiopod material, crinoidal hash and other debris. At Willard, the bed contains some pyritized nuculid bivalves and gastropods, including the high-spired forms *Palaeozygopleura* and *Glyptotomaria*. The bed locally carries evidence of being a lag deposit with some evidence of local scouring and minor removal of subjacent beds. This thin bed has been recognized from the Genesee Valley eastward to at least Barnum Creek on the west side of Cayuga Lake.

Unit 16. Gage Gully Beds: The highest strata of the Windom exposed in Western New York are medium to dark gray, typically somewhat petroliferous, chippy shales (Figure 8). These shales are characterized by a very distinctive fauna that includes small specimens of *Ambocoelia (?) nana*, and especially of the spiriferid brachiopod "*Allanella*" *tullius*. Small mollusks, especially nuculoid bivalves, gastropods, the nautiloid *Spyroceras*, and rarely *Tornoceras* are also present to abundant within the Gage Gully beds. In central New York, Grasso (1966) referred to this interval and perhaps the underlying Spezzano Gully beds, as the *Allanella-Pustulatia* zone.

This interval is named for one of its areas of maximum development, along Gage Gully on the east side of Canandaigua Lake. In this area, it is about 5-6 m-thick and consists of dark gray to nearly black, platy shale. To the west, the interval thins towards the Genesee Valley where it is at most about 2 m in thickness and is a medium dark gray mudstone containing an abundance of *Greenops* trilobites, small mollusks, and lesser numbers of *Allanella tullius*. Pyritized nodules, burrow tubes and fossil steinkerns, including those of large *Tornoceras*, occur sporadically in the upper portion of the Gage Gully beds. To the east, the interval is again truncated east of Canandaigua Lake such that it is only 2 meters thick at Kashong Creek at Bellona, less than 0.5 m in creeks along the northwest side of Cayuga Lake and absent altogether in the Owasco Lake-Ithaca region. However, the shale reappears eastward, being about 2 m-thick at Skaneateles Lake and up to 3 m-thick in the Tully-Chenango Valley region, where it is again a relatively dark gray, slightly rusty, weathering pyritic shale. Where present, the Gage Gully beds are everywhere capped by a marked disconformity flooring either the Tully Formation or the younger Genesee Formation, where the Tully is absent. This is a regionally angular bevel-surface which has removed the Gage Gully interval in the central Finger Lakes Region. Hence, the Gage Gully beds are the highest beds ever seen in the Windom within western and west central New York State. However, to the east in the

Chenango Valley area, still-higher gradational silty mudstone units occur at the top of the dark shale equivalents, recording the next shallowing cycle prior to the deposition of the Tully Limestone or its correlatives.

SEQUENCE AND CYCLIC INTERPRETATION OF THE MOSCOW FORMATION

Lower Moscow Formation

Overall, the Tichenor-to-top-Kashong interval which ranges from slightly over a meter on either side of the basin center to approximately 34 meters in the Canandaigua Lake region is inferred to represent a third-order transgressive systems tract (Figure 10). This package displays a generally upward-deepening pattern culminating with the *Ambocoelia*-rich mudstone interval of the basal Windom immediately above the Little Beards Creek phosphatic bed. However, it should be clear that this was a stepwise process and that it involved at least five lesser-scale shallowing-deepening cycles. These cycles, including two in the Deep Run and three in the Kashong Member, range from nearly symmetrical at the depocenter, for any given interval, to markedly asymmetrical toward the basin margins. In the latter areas, the cycles resemble small-scale sequences, in that their bases are sharply defined at erosion surfaces which underlie each of the thin condensed carbonate units, (i.e.; Tichenor, unnamed Deep Run limestone, Menteth, RC bed, upper Kashong siltstone, and Barnes Gully phosphatic bed). The latter beds probably formed at or near maximum lowstand in the basin center, but are slightly diachronous such that on the lateral ramps of the basin the carbonates formed during the immediately ensuing transgression and sediment-starved interval. The carbonate beds are of two types. First are skeleton-rich beds containing an abundance of fossil debris that include corroded brachiopods and corals. This type characterizes the Tichenor, unamed Deep Run limestone, RC bed and the Barnes Gully phosphatic bed. The alternate lithology is highly bioturbated to slightly laminated silty carbonate or calcisiltite represented by the Menteth and the upper Kashong unnamed silty limestone (Figure 10). It should be noted, however, that the latter lithology can assume the more shell-rich facies aspect near the basin center for these various limestones. In particular, the Tichenor limestone comes to take on this facies in the region around Canandaigua Lake.

Each of the limestones also displays a sharp upper contact with overlying shales which is interpreted as a flooding surface. Hence, the limestones appear to be small-scale analogs of transgressive systems tracts for each of the smaller-scale cycles. The overlying shaley beds (for example, the main body of Deep Run shale, lower and upper Kashong mudstones) constitute relative highstand to regressive deposits. The succession of five lesser cycles within the Tichenor Limestone-Barnes Gully bed interval displays a progressive relative deepening pattern with the upward passage of each cycle characteristic of an overall transgression with superimposed minor fifth-order cycles.

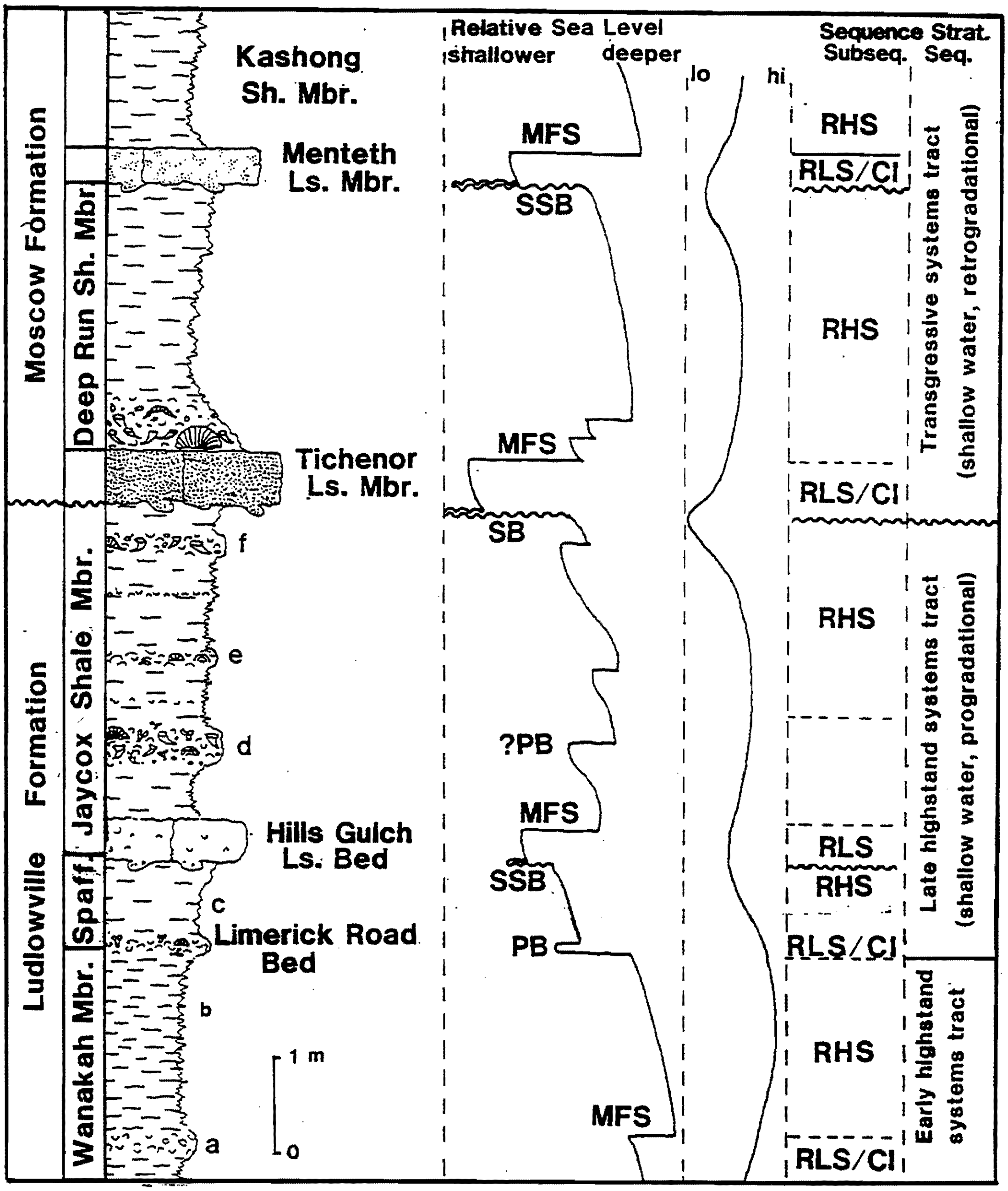

Figure 10. Sequence interpretation of the upper Ludlowville and lower Moscow Formations in the Genesee Valley area. Note sequence boundary at base of Tichenor Limestone. Symbols: RLS = relative lowstand; RHS = relative highstand; CI = condensed interval; MFS = Marine flooding surfaces; SSB = subsequence boundary; PB = precursor bed;

Windom Member Cycles

Parts of the Windom Shale appear to represent some of the deepest-water conditions within the upper part of the Hamilton Group. For this reason, and because it also shows a shoaling-upward pattern, as well as abrupt juxtaposition on shallow-water, somewhat condensed carbonates, the Windom is interpreted in the broadest sense, as the highstand systems tract of the upper Moscow depositional sequence. The informal "Unnamed member" represents a genetically-related transgressive systems tract separated from the Windom proper by a surface of maxiumum starvation (Figures 2,9).

However, it is equally clear that the Windom is subdivisible into a series of four cyclic packages (Figure 11), probably corresponding to fifth order cycles, or cyclothems (Busch and Rollins, 1984). These are, in ascending order: a) dark gray *Ambocoelia*-rich shales which pass upward through the *Devonochonetes coronatus* beds, and into the Bay View coral bed and Smoke Creek beds (Units 1 through 6); b) a previously unrecognized middle Windom cycle in western and central New York State comprising units 7 through 10 (i.e., the Bear Swamp chonetid- and *Ambocoelia*-rich shales) which pass upward to thin, calcareous, shell-rich beds overlain by diminutive brachiopod faunas (Penn Dixie pyritic beds); c) the Fisher Gully dark gray, *Ambocoelia*-and *Emanuella*-bearing shales (including Amsdell beds) upward through the Fall Brook coral horizon and overlying Taunton and Spezzano Gully beds (Units 11-15); d) an incomplete cycle comprising the uppermost Windom dark shales (Gage Gully beds) and hints of a final upward-shallowing package which is largely truncated by the sub-Tully (or sub-Genesee) erosion surface (Units 16, 17).

These cycles are widespread and even appear to be correlative from New York State into the upper Mahantango Formation of central Pennsylvania. For example, at Milesburg, Pennsylvania, exposures along the westbound entrance lane to Interstate 80 display a succession that appears to start in the *Devonochonetes cornatus* beds, continue up through the fossil-rich Bay View beds, through a sparsely fossiliferous, dark gray, middle Windom interval, and finally into beds associated with the Taunton beds-Gage Gully beds succession in New York. As such, this is the most complete Windom succession yet recognized in central Pennsylvania. Future work will attempt to extend these correlations.

Despite differences in detail, each of the Windom cycles shows several common elements. As noted below, these include a) basal lag beds, b) ambocoeliid shales, c) coarsening upward silty mudstones and siltstones, and d) thin, calcareous "trilobite beds" near the cycle top (Figure 11).

Basal Lag-Maximum Flooding Surface: The cycles begin with very thin condensed shell-rich beds: a) Little Beards - Geer Road phosphate, shell-rich interval, b) mid Windom conodont bed, c) unnamed basal lag of Unit 11; and, d) Simpson Creek bed (*E. preumbona*-rich phosphatic lag horizon). These inconspicous, thin (typically < 1 cm-thick) and widespread condensed horizons are interpreted as surfaces of maximum sediment-starvation associated with relatively rapid sea level-rise events. Presumably, these events flooded the shoreline and produced conditions of extreme siliciclastic sediment-starvation in offshore areas. Thin lag beds of variably disarticulated, fragmented, and

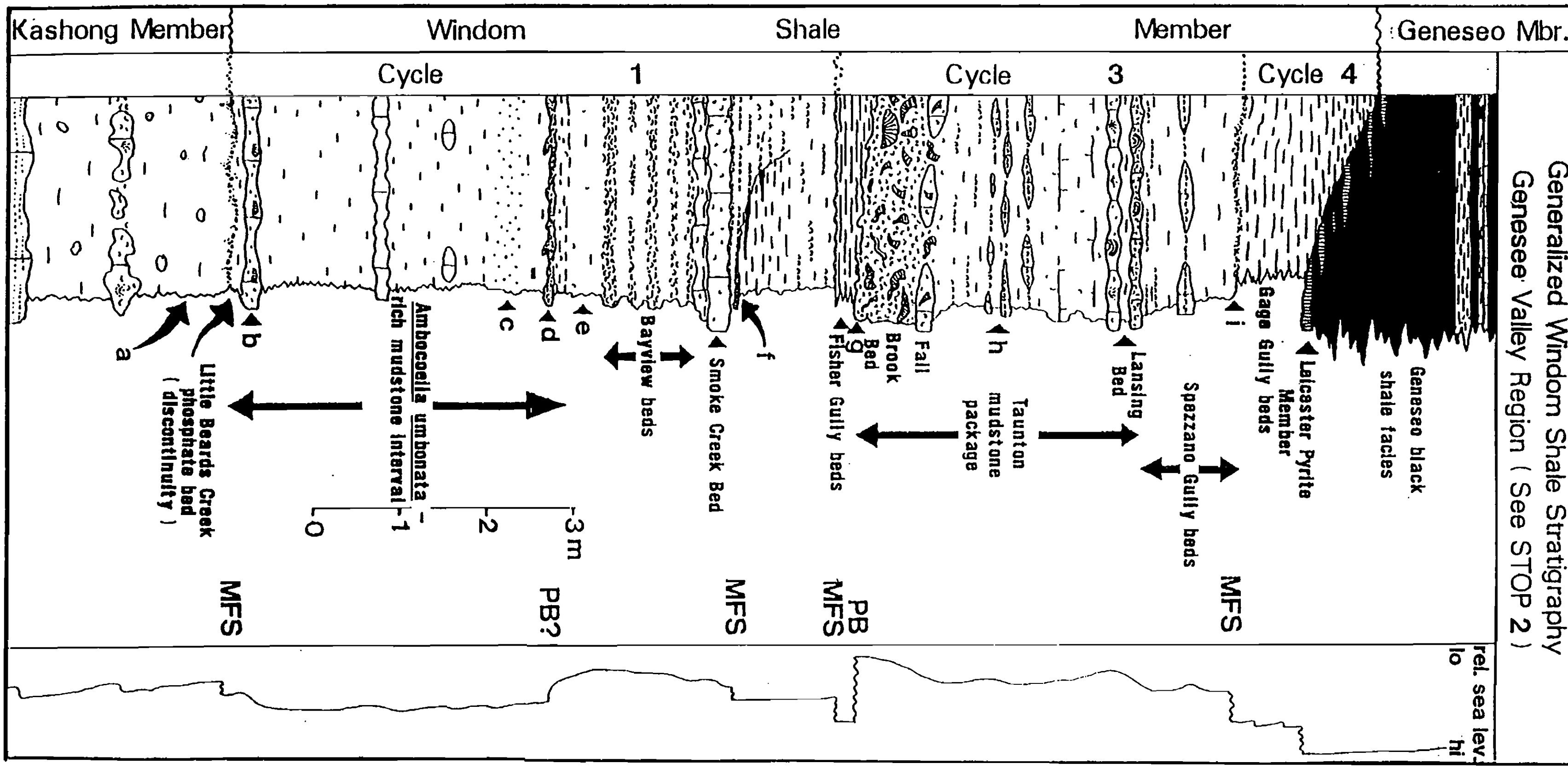

Figure 11. Windom stratigraphy generalized for the Genesee Valley region (Fall Brook, Little Beards Creek, Taunton Gully and Spezzano Gully sections). Inferred sea level changes and sequence stratigraphy units are shown on the right. Windom component cycles are also shown. Lettered units include: a) uppermost Kashong Member (phyllocarid epibole); b, *Phacops*, *Ambocoelia*, and demosponge-rich concretionary limestone bed; c, mudstone interval rich in pyritic nodules, *Phacops*, pyritized *Tornoceras*, *Athyris* and *Ambocoelia*; d, bed composed of concentrated *Ambocoelia* and displaying *Ambocoelia* filled hypichnial burrows; e, mudstone-rich in *Devonochonetes coronatus* and distinctive amplexiphylloid coral ("*D. coronatus* epibole"); f, erosional lag deposit composed of abundant conodonts, bone fragments and shell debris which is associated with discontinuity surface; g, discontinuity at base of Fall Brook Coral bed; h, bed yielding *Clarkeocrinus troosti* ("*Clarkeocrinus* epibole"); i, Simpson Creek transgressive shelly lag deposit rich in *Emanuella praeumbona*. Abbreviations as in Figure 10.

corroded skeletal debris, phosphatic nodules, and/or reworked concretions are mixed with better preserved shells representing a distinctly more offshore, dysaerobic community. Moveover, there is evidence associated with each of these beds for an interval of submarine erosion. The erosion appears to have produced minor discontinuities and in some cases possible furrowing of the underlying muddy sea floor.

Ambocoeliid Shales - Early Highstand Phase: The basal lag beds are overlain by intervals of medium to dark gray shales carrying diminutive brachiopod assemblages. In the lower three cycles *Ambocoelia umbonata* and two to three species of small chonetid brachiopods dominate the assemblages within these intervals; in the upper two cycles *Emanuella praeumbona*, diminutive *Allanella*, *Tropidoleptus*, and *Eumetabolotoechia multicosta* are mixed with less common *Ambocoelia* and chonetids. These intervals appear to represent somewhat more dysoxic conditions than those seen in underlying cycles. The ambocoeliid shales are interpreted to have accumulated under deepest water portions of each cycle.

Silty Mudstone Late Highstand-Progradational Phase: The ambocoeliid-bearing medium to dark gray shaley mudstones are in each case overlain by intervals of calcareous to silty mudstone. These appear to represent progradational shallowing intervals during which coarser siliciclastic sediments were transported further offshore than during most of the rest of the time interval. These silty sediments in the eastern Finger Lakes area generally appear to be transitional upward from the underlying medium gray mudstones.

However, in the case of the third cycle (Fisher Gully to Spezzano Gully beds succession) the appearance of this somewhat shallower water biofacies is abrupt, at least in western New York, and is marked by the highly fossiliferous, condensed Fall Brook coral bed. This interval displays a particularly interesting regional pattern. As noted, it overlies a sharp discontinuity that cuts out portions of the subjacent middle Windom beds in western New York State. However, to the east, the bed splays out into a series of thin and much less spectacular shell horizons and the base becomes transitional.

The Fall Brook bed is representative of a category of somewhat condensed skeletal debris-rich horizons that we have termed "*precursor beds*" (Brett and Baird, 1990). These are condensed beds that occur abruptly at the top of the early highstand shale intervals and at the bases of upward-coarsening parts of cycles. The Fall Brook bed appears at the base of the Taunton beds interval that reflects upward-shallowing conditions. To the east, this interval is capped by resistant *Zoophycos*-bioturbated siltstone beds which bear at their top a coral-rich interval.

The precise causes of sedimentary condensation associated with the beginning of upward-shallowing cycles remains rather enigmatic at this time. Precursor beds may reflect minor-sediment starvation occuring during an initial sea level drop (forced regression) due either to subaerial accommodation processes (i.e., regrading of streams to new equilibrium profiles with consequent reduction in detrital discharge of sediments to offshore regions; Posamentier et al., 1988), or the impingement of occasional deep-storm waves as a threshold of depth was obtained during a relatively rapid shallowing interval. If submarine erosion became prevalent prior to sediment progradation, then truncation of older beds would be expected. One of the curious features of the precursor beds is their tendency to downgrade in terms of faunal diversity and abundance in an upramp (easterly) direction. This eastward splaying of the precursor beds is probably the effect of greater proximity to the siliciclastic source area. Where the precursor beds are most condensed in the west, it is the result of the stacking of thin shell beds, each the cap of a minor shallowing- cycle, onto one another in a sediment-starved setting. Complex amalgamation of shell beds capping small-scale cycles produces the effect of the thin condensed precursor bed.

The precursor beds are overlain by a coarsening upward succession of mudstone to calcareous, highly fossil-rich siltstone deposits of the later highstand or progradational phase of the cycle. These intervals are typically heavily churned by *Zoophycos* and contain scattered lenticular brachiopod- and coral-rich shell debris horizons as well as concretions. The abundance of concretions in the upper part of this interval probably reflects a relative slowdown in sedimentation toward the end of the cycle; this enhanced diagenetic reactions. Each concretion horizon presumably reflects a minor episode of sediment cut-off to the western part of the basin. During such times, burrow peripheries became enriched with bicarbonate and sulfides, leading to growth of carbonate or pyrite concretions. Modern concretions, about 10 centimeters in diameter are thought to form within sediments during times of overall sediment-starvation and stability of the zone of sulfate reduction. (Hallam, 1986; Raiswell, pers. comm., 1993). Such nodules appear to have formed during a 3 to 5 thousand year period of general sediment cut-off.

In the case of Bay View and South Lansing coral beds, diverse brachiopods, bryozoans, crinoids and, in some cases, larger rugose and tabulate corals flourished over wide areas as a result of shoaling into the zone of turbulence, greater sunlight, and oxygen level. These organisms clearly also thrived in a sediment-starved regime associated with initial sea level-rise and or winnowing during peak sea level lowstand.

Trilobite Beds: Transgressive Phase : Finally, in each of the cycles, the early transgressive phases overlying thecapping shell-coral beds are expressed as thin, "trilobite beds" facies. This facies consists of variably fossiliferous intervals of thin bedded concretionary limestone (e.g., Smoke Creek and Spezzano Gully beds; Figure 11). The beds in these intervals are typically enriched in small rugose corals, and/or auloporids, brachiopods, including *Pseudoatrypa*, and trilobites. Trilobites are commonly articulated and may be found in clusters of complete and molted skeletal parts giving rise to the name "trilobite beds" for this facies. These calcareous, trilobite and small coral-rich layers appear to reflect times of minimal input of siliciclastic sediments. Traced in an eastwardly direction they appear to merge laterally into shell beds which overlie major progradational cycle. The enrichment of carbonate in the pore spaces of the sediment probably reflects prolonged stability the sediment-water interface, which permitted development of reducing, nonsulfidic conditions within the sediment.

These trilobite-rich, calcareous beds are one manifestation of marine sediment starvation associated with initial sea level-rise following a lowstand event. The trilobite bed interval represents a transition from regressive maximum to the maximum flooding surface for each cycle. The decimeter-scale nature of the bedding within these intervals is suggestive of a minor, but widespread climatic-eustatic signal. Either these small-scale fluctuations in carbonate content represent oscillation in relative sea level or variations in sediment-supply. The former contention is supported by lateral correlation of these small-scale cycles from western New York, where they are expressed as calcareous to concretionary mudstones alternating with shales, into central New York areas where cycles are manifested as minor (meter-scale) coarsening-upward successions. These latter asymmetric minor cycles are typically capped by siltstones and overlain by flooding surfaces, each marked with a thin shell-rich bed. These flooding surface beds are widespread and appear to correlate into the nodular concretionary carbonates of the western minor cycles (Brett and Baird, 1986).

This widespread nature of "trilobite beds" suggests rather uniform conditions over large tracts of the Devonian sea bottom. The calcareous and shell-rich nature of the beds over long distances further supports the notion of periodic episodes of widespread siliciclastic sediment-starvation. In central New York, these intervals are capped in each case by a sharp discontinuity which is overlain by a condensed, shell hash bed that begins the next larger (fifth order) cycle within the Windom Shale. These thin lag beds are associated with minor erosion surfaces and lie at the base of relative highstand deposits characterized by dark gray *Ambocoelia*-rich shale.

MOSCOW DISCONTINUITIES: PATTERNS AND PROCESSES

Careful stratigraphic correlation has revealed significant discontinuities within the Moscow Formation. The most prominent are associated with the major flooding surfaces, and thus appear to be associated with times of maximum sediment-starvation within the basin. They are overlain by the thin lag deposits at the bases of dark gray to black shale facies. These lag beds occur along sharp contacts at the tops of the underlying transgressive portions of the subjacent cycles. In several instances, portions of underlying cycles have been removed locally by these erosion surfaces. Although the regional geometry of these discontinuities is incompletely understood, it is clear that certain of these erosion surfaces locally cut more deeply than elsewhere and that these may represent broad channel-like scours in the top of the underlying mudstones (Figure 9).

Perhaps the most dramatic, but previously unrecognized example of such an erosion surface lies at the base of the Windom. As noted above, an erosion surface (Little Beards Creek Bed), which directly overlies Geer Road phosphatic bed of central New York, appears to truncate 3 to 4 m of underlying silty shale and concretionary limestone in the western Finger Lakes area (Figure 7).

At least two and perhaps three minor cycles are removed west of Canandaigua Lake by this erosion surface. The erosional truncation is particularly notable between Mud Creek in the Bristol Valley and Frost Hollow, 10 km to the west. Here about a meter of strata of the "Unnamed Member" is removed beneath a very cryptic discontinuity (Figure 7). These include, in descending order: a) the Geer Road bed; b, the "*Longispina-Mucrospirifer*-rich silty mudstone interval;" c, the Curtice Road bed; d, the "*Megastrophia* beds"; and, e) the Barnes Gully beds. This succession of beds, which is present and consistent from the central Finger Lakes west to the Bristol Valley is completely missing at Frost Hollow Creek, where typical *Ambocoelia*-bearing Windom Shale rests directly on Kashong mudstones below the level of the Barnes Gully shell bed. This contact is marked by the Little Beards phosphatic horizon. The source of the phosphatic nodules is apparently the Barnes Gully bed or the upper Kashong strata where the Barnes Gully bed is missing.

We postulate that the erosional process involved a combination of winnowing and dissolution which removed all fine grained siliciclastics and carbonates, but left a residue of phosphatic clasts on the erosion surface. Similar processes of erosive ablation have been described for reworked concretion beds by Baird (1981).

Two phosphatic-pyritic lag units in the middle Windom Member require further explanation. Because these beds occur at the sharp contacts of dark gray, typically dysoxic to anoxic shale facies, and contain materials such as reworked pyrite which would be unstable in a fully oxidizing environment, we have postulated a special mechanism of submarine erosion to account for the discontinuities. In part, the sharp surfaces relate to the high degree of sediment-starvation as evident from the overlying lag beds. For example, the high concentration of conodonts in a cryptic but important discontinuity above the Smoke Creek bed suggests a long interval of repeated winnowing, dissolution, and concentration of only the most stable,geochemically-resistant particles on the sea floor. In the absence of a renewed supply of sediment, deep-flowing bottom currents may well have been the agent of erosion. A variety of mechanisms can be visualized, including deep-storm waves, gradient currents, and contour-following currents. Turbidity currents seem unlikely in that little associated sediment was deposited following erosional episodes. An additional mechanism that may be of importance for explaining discontinuities roofed by dark gray shales has been advanced by Baird and Brett (1986, 1991). We hypothesized that internal waves were generated along water mass boundaries that separated denser, perhaps slightly cooler and/or slightly more saline waters below from the overlying aerobic and also lower density waters at a pycnocline. Similar internal waves have been documented in certain modern environments. We postulate that such waves, breaking against submarine slopes could erode the substrate in a sediment-starved regime.

In any event, the presence of these subtle shale-on-shale discontinuities has considerably complicated the correlation of an otherwise rather predictable layer cake type stratigraphy. For example, in certain areas of western New York, at least three different discontinuities interact to produce complex local patterns of stratigraphic preservation (Figure 12f). The mid-Windom Bear Swamp beds for example are locally very thin or absent in the Livingston County area as a result of a discontinuity underlying the superjacent Fisher Gully beds. However, in nearby Genesee County, the discontinuity surface evidently rises up sufficiently that beds of the Bear Swamp interval reappear. However, in this area, a still higher discontinuity below the Fall Brook coral bed has completely truncated the Fisher Gully horizon, such that the Fall Brook beds rests on the Bear Swamp interval. Still farther west, the Fall Brook bed appears to rise off this discontinuity once again preserving both the Bear Swamp and the Fisher Gully beds of the middle Windom. Moreover, in western New York, the top-Windom discontinuity locally bevels the Fall Brook Coral Bed and even the Bay View bed (Figure 12f). The result of this is a complex mosaic of preserved lenses of formerly widespread strata.

DEPOSITIONAL DYNAMICS AND BASIN AXIS MIGRATION

Compilation of thickness data from the rather precisely bounded packages within the Moscow formation reveals a distinctive pattern of westward migration of depocenters (areas of greatest thickness); study of litho-and biofacies relationships bears out this general pattern and indicates the deepest water areas in the basin also were subject to westward migration during the deposition of the late part of the Hamilton Group. The depocenter for the upper unit of the underlying Ludlowville Formation appears to be in the vicinity of Romulus, specifically on the upper end of Big Hollow Creek where a total of at least 18 m of silty mudstone representing the Jaycox Member have been measured (Mayer et al., 1994; Figures 4,5,10a). This area also appears to show the strongest degree of conformity between the Ludlowville and Moscow formations. In particular, an uppermost siltstone package within the Jaycox Formation, not represented in other localities, is present along Big Hollow Creek (Figure 4). This presumably represents the last major shallowing up cycle of the Ludlowville. Hence, evidence points to the most continuous and thickest deposition of the high Ludlowville in the area between Cayuga and Seneca Lakes.

The basal Tichenor Member of the Moscow Formation displays a change to calcareous silty mudstone in the vicinity of Seneca Lake; it is condensed to a compact pack- or grainstone bed both east and west of this location. The thickest development of the Tichenor appears to be in the vicinity of Sampson State Park on the east shore of Seneca Lake. The overlying Deep Run mudstone Member is among the most distinctly lenticular units in the Hamilton Group (Figures 5,12b). The Deep Run attains a maximum thickness of about 18 meters in the area of the type section at Canandaigua Lake. The Deep Run thins to a feather edge both to the west, in central Erie County and to the east, in the vicinity of southeastern Cayuga Lake. Hence, the Deep Run depocenter is subparallel to that of the uppermost Ludlowville Jaycox Member, but is shifted westward by approximately 35 km (Figures 5,12a,b).

The lower portion of the Kashong mudstone is rather ill-defined in the Genesee Valley, in part owing to the lack of a compact condensed horizon at its top (i.e., RC or TT bed). Consequently it is not possible to specify precisely the area of greatest development of the lower Kashong Shale. However, it is clearly in the vicinity of the Genesee River Valley, where the unit attains approximately 4.9 m in the Retsof drill core (Figures 6,12c). Lower Kashong shale thins to the west being only approximately 1 m (3 to 4 ft) thick in central Genesee County. In this area, it is overlain by the compact fossiliferous bed referred to herein as the *Thamnoptychia-Taeniopora* bed (see Lukasik, 1984).

To the east, the lower Kashong also thins as it is capped by the typical RC bed or *Rhipidomella-Centronella* bed. Again, lower Kashong mudstones appear to persist slightly east of Cayuga Lake before pinching out. In areas near Portland point, for example, the RC bed comes to rest essentially upon the Menteth Limestone in an almagmated series of beds referred to in the past as the upper part of the Portland Point Member (Baird, 1979).

The middle Kashong submember is very poorly exposed in the Genesee Valley region, but it is clearly considerably thicker than in the region of Canandaigua or Seneca Lakes. The unit may attain its greatest thickness near Geneseo where it is approximately 10.6 m in thickness (Lukasik, 1984).

Depocenters within the Windom Member, herein interpreted as the deepest portion of the overall Moscow sequence, are more complex and less readily interpreted. (Figures 8,12d,e). The Windom is not as distintinctly lenticular as are the Deep Run or Kashong. The lack of a well defined lenticular region of maximum thickness within the Windom may perhaps reflect the intensity of sea level rise during this interval which provided abundant accomodation space. Hence, slight topographic highs on the seafloor had relatively little influence upon sedimentation patterns, in contrast to the evident bypass and winnowing that took place along the basin margins during deposition of the Tichenor, Deep Run, and Kashong members. Nonetheless, some patterns are evident within the Windom that may suggest a continuation of the trends seen in underlying units. For example, the first cycle of the Windom Shale, constituting the *Ambocoelia umbonata* beds and overlying Bay View and Smoke Creek Beds, appears to thicken westward from Canandaigua Lake toward Erie County. Near the Erie-Genesee County border the total *Ambocoelia* beds portion of the section is on the order of 7 m in thickness, making this one of the thickest sections of *Ambocoelia* beds measured. However, *Ambocoelia* beds thin dramatically to the southwest along the outcrop belt within Erie County, reaching approximately 2 m (6 ft) at Cazenovia Creek and only about 0.5 m (1.5 ft) near Lake Erie. This westward thinning pattern appears to define a region of local subsidence and a regional north westward directed ramp within Erie County. However, the other margin of the lower Windom basin is not so well defined. In contrast to the lower Moscow Formation patterns, the lower Windom appears to thin to the east of Genesee County to a minimum of about 3 m (10 ft) in the western Finger Lakes (Figure 12d). From this point, the interval thickens somewhat to the east and southeast becoming silty and dividing into a series of coarsening-upward shale to siltstone cycles within the area of Chenango Valley (Zell, 1985). The lower Windom beds attain a thickness of about 25 m in the area of Chenango Valley. The middle portion of the Windom (i.e., beds above the Smoke Creek bed), display a complex pattern of thinning and thickening. The Bear Swamp Creek interval is about 15 m-thick at the type area on Skaneateles Lake. It is not known whether this interval thickens substantially to the east, although it does appear to pick up increasing amounts of siltstone. To the west, the interval thins to a minimum near Mack Creek on Cayuga Lake largely as a result of erosional down-cutting at a discontinuity that underlies dark gray Fisher Gully beds (Figure 8).

Age equivalent strata reappear in western Erie County and appear to thicken to the west of the depocenter for the basal Windom in central Erie County, (compare Figures 12d and 12e; Brett and Baird, 1982). Likewise, the Fisher Gully beds, with their distinctive *Emanuella praeumbona* fauna, appear to thicken both west and east of a region near the Genesee-Livingston County line at which point the Fisher Gully or Amsdell beds have been eliminated by erosion beneath the Fall Brook coral bed. The Amsdell bed thickens into southwestern Erie County, suggesting a local depocenter which has migrated 30 km to the southwest from the vicinity of Genesee County during this late interval. However, the Fisher Gully beds also thicken and become progressively darker and more platey in the vicinity between Canandaigua and Cayuga Lakes, the same region in which the mid Windom Bear Swamp Creek beds become thin or absent. Farther east (for example, at Skaneateles Lake), the Fisher Gully beds thin once again in concordance with the thickening of the underlying Bear Swamp beds (Figures 8,9).

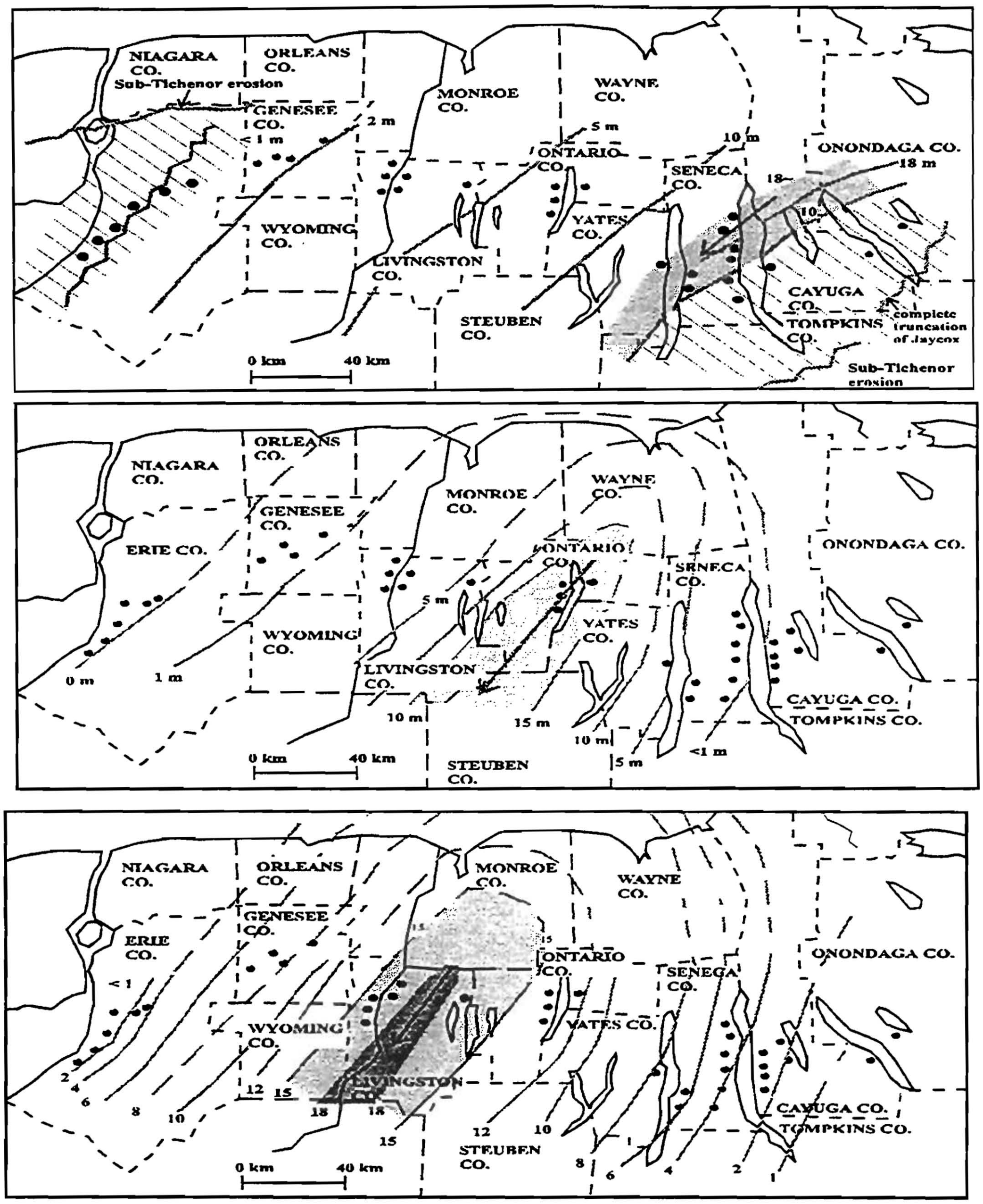

Figure 12. Schematic isopach maps for the Moscow Formation in western New York. Data indicate key localities; depocenter area shaded; approximate location and plunge of basin axis indicated by arrows; isopleths numbered in meters. A) Jaycox Member; B) Deep Run Member; C) Kashong Member. Note general westward shift of depocenters through this interval.

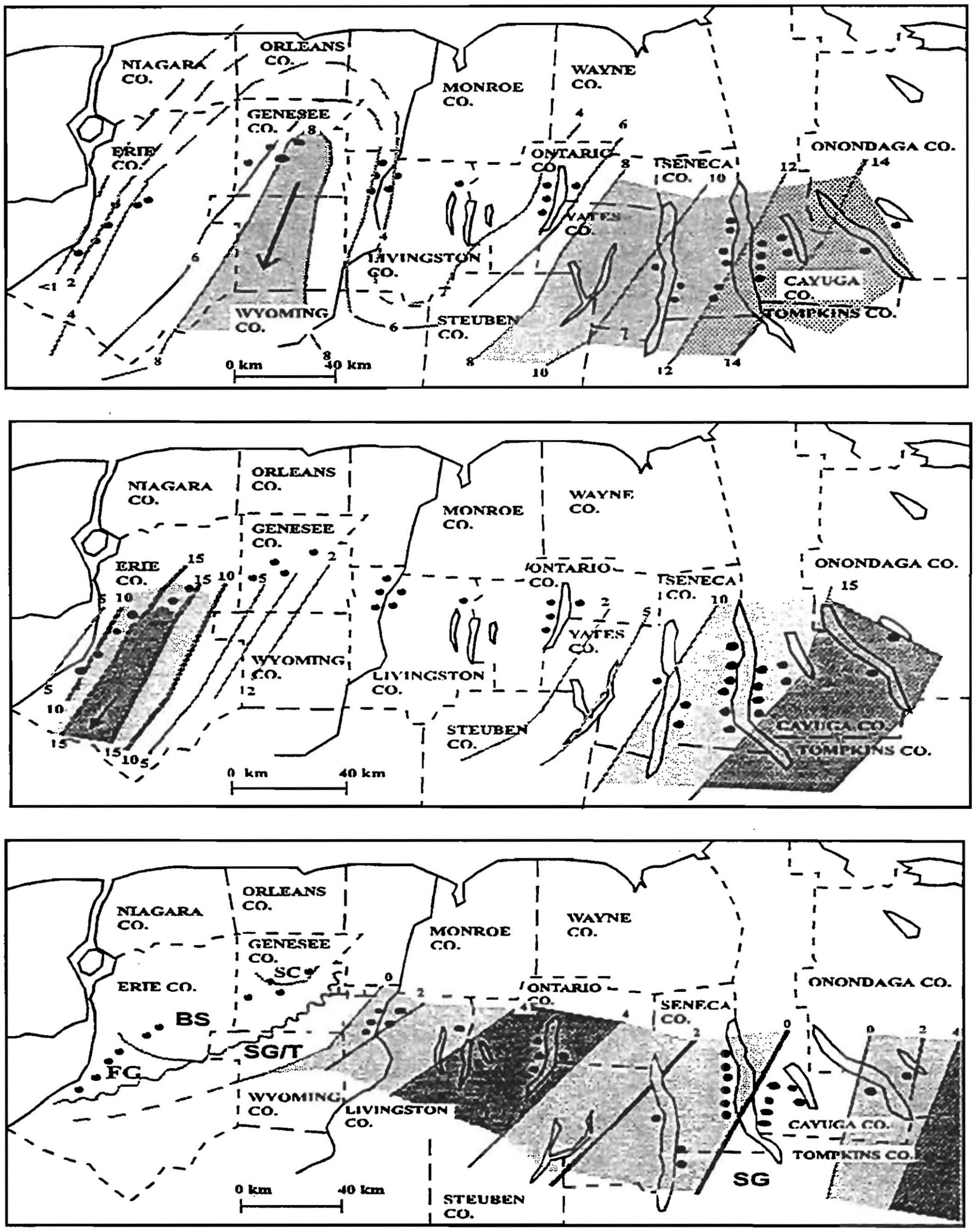

Figure 12 (Continued): D) Isopach map of lower portion of Windom Shale (up to Smoke Creek bed), note presence of two depocenters separated by thin area (arch) in Genesee-Canandaigua region. E) Isopach of middle Windom (Bear Swamp-Fisher Gully beds), note westward shift of western depocenter relative to "D." F) Isopach map of Gage Gully beds; thinning reflects erosional truncation; where Gage Gully beds completely removed lower units exposed beneath Taghanic unconformity. Symbols include: SG, Spezzano Gully; TG, Taunton beds; FG, Fisher Gully beds; BS, Bear Swamp beds; SC, Smoke Creek bed.

The Fall Brook coral bed, likewise, displays a pattern of increased skeletal content, increasing predominance of large rugose corals, and a thinning to the west near the Livingston-Genesee County line. Taken together these patterns suggest that the Windom sea floor carried at least two depocenters separated by a local swell or high region (Figures 12d,e). Perhaps this region became a bypass slope during this time and was subject to submarine erosion during the ensuing interval of sediment starvation. In any event, evidence from the successive more westwardly truncation of the Bear Swamp beds and then the Fisher Gully-Amsdell beds between Canandaigua Lake and west central Genesee County suggests that the local intrabasinal high as well as the sub-basins themselves display a westward migration pattern during the interval of the middle part of the Windom.

Patterns within the upper Windom, primarily the Fall Brook and Taunton cycles are less completely known, particularly due to major erosional removal of this portion of the section west of the Genesee Valley area (Figure 10). However, the evidence from remaining strata suggests that during this interval the eastern sub-basin of the Windom migrated into the vicinity of Canandaigua Lake. Here some of the thickest sections of the uppermost Windom unit, the Gage Gully black shales, are preserved (Figure 8). Correspondingly, the intra-basinal high area appears to have passed through the region of central Genesee County. At this location, the Windom Member, as a whole, displays maximum truncation by the pre-Tully erosion surface. Likewise, the eastern margin of the eastern sub-basin also migrated westward such that maximum truncation of the Windom Member, down to the level of the Taunton or Spezzano Gully beds occurs in the vicinity of Moravia or Portland Point.

At the close of Windom shale deposition, probably three separate centers or depocenters existed, separated by two intrabasinal highs as evidenced by the pattern of erosion of the sub-Tully unconformity (Figure 12f).

The paleogeography during this time would have included, from west to east: a) a relatively shallow western sub-basin centered in southwestern Erie County; b) a broad intrabasinal high region in north central Genesee County, at least partially separating the Erie County sub-basin from; c) a central and perhaps deepest sub-basin, with area of maximum subsidence at or near Canandaigua Lake where the uppermost Windom Gage Gully beds (Unit 17) are best developed as a black dysoxic shale unit (Figure 12f). In turn, this sub-basin was bordered to the southeast by a second low arch or submarine high which crested along a diagonal line approximately from Owasco Lake southeastward toward Portland Point, an area in which none of the Gage Gully beds have been preserved (Figure 12f). Still further to the east a shallow but actively subsiding sub basin existed in the region of Chenango Valley or perhaps further east in which region the upper Windom units become well defined, thick, and relatively silty.

Thus, in a broad overview, the depocenter and axis of greatest subsidence for the Appalachian foreland displays a progressive, albeit complex pattern of east-to-west migration during deposition of the Moscow Formation, the last major sequence of the Hamilton Group (Figure 13). During an interval of no more than 1.5 to 2 million years of geologic time, the lower Moscow depocenter shifted its position some 90 km from the region between Cayuga and Seneca Lakes (upper Jaycox Member), to Seneca Lake (Tichenor Member),

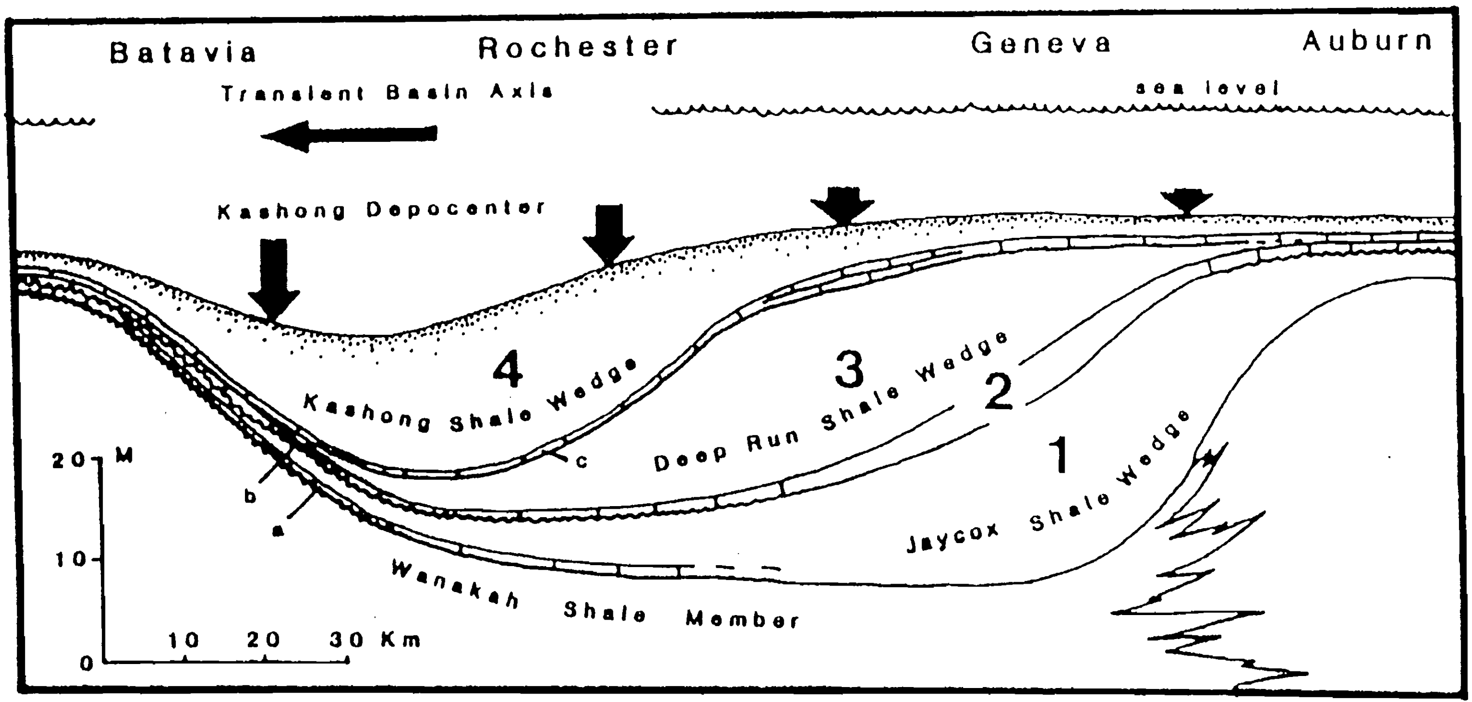

Figure 13. Diagrammatic east-west cross section of the upper part of Ludlowville and lower part of Moscow Formation. Note that successive wedges of mudstone, bounded by through-going carbonates display a progressive westward migration.

Canandaigua Lake (Deep Run Member), Livingston County (Kashong Member), and western Genesee County (lower Windom interval) (Figure 13). However, during deposition of the upper parts of the Windom Member, i.e., during the relative highstand portion of the overall sequence, the simple geometry observed in the earlier phases of the Moscow sequence gave way to a more complex topography in which at least two and perhaps three sub-basins were developed, each bounded by low broad submarine swells or highs. This suite of partitioned sub-basins and local highs also displayed a general westward drift throughout the remainder of the Hamilton deposition.

The minor "rippling" of the Hamilton foreland basin floor is a harbinger of more dramatic folding in the foreland basin that took place during deposition of the overlying Tully Formation. Heckel (1973) thoroughly documented development of a small scale anticline during deposition of the lower Tully and of a down-to-the-east monocline/fault that developed, perhaps along old lines of structural weakness in the region east of the Chenango Valley (Figure 14). This down-to-the-east subsided trough may have provided a clastic trap which starved the basin nearly completely of sililiclastic sediments and permited deposition of the unusual Tully Limestone over much of west central New York State. Furthermore, Heckel (1973) documented a mid-Tully interval of erosion during which the Chenango Valley high or anticline was breached and its center then became a locally subsided depocenter wherein the thickest part of the upper Tully Member was deposited.

The interval of partitioning and rapid westward migration of the basin during the later Moscow and into the pre-Tully interval suggests tectonic instability, perhaps associated with the beginnings of the third and strongest tectophase of the Acadian orogeny. It is notable that similar buckling, arching and erosion of the basin floor is also witnessed at the beginning of Onondaga Limestone deposition (see contribution by Ver Straeten et al., this volume). Ettensohn (1987) has suggesed that periods of docking of the microplates of Avalonia with North America produced tectophases of the Acadian orogeny and that times immediately following the docking were relatively quiesent intervals during which carbonates developed in sheet-like units over extensive areas of the craton, following the development of major unconformities such as the Wallbridge and the sub-Tully or Taghanic unconformity. Following a lag time, active tectonic thrusting from the east produced renewed pulses of major subsidence toward the hinterland. These deep underfilled basins were initially areas of dysoxic black mud accumulation.

STRATIGRAPHY AND INTERPRETATION OF THE TULLY AND GENESEO FORMATION

Sub-Tully Unconformity

The Hamilton Group is separated from the Tully Limestone in the Finger Lakes east of Canandaigua, and from the overlying Genesee black shale from Canandaigua westward, by a significant disconformity that has been termed the Taghanic Unconformity (Johnson, 1970). This disconformity serves to separate the early and later phases (holostromes) of the Kaskaskia megasequence. It displays significant although subtle, regional beveling as documented by Cooper & Williams (1935), Heckel (1973), and Brett and Baird (1982). This erosion surface is complex, having removed substantial amounts of the upper portion of the Windom Shale, particularly in areas of western Livingston, Genesee and eastern Erie Counties. However, the relatively condensed western Windom facies in the vicinity of Lake Erie display a much lesser degree of truncation at the top (Figure 12f). Maximum preservation of Windom strata occurs in the Canandaigua Lake Region, where 5-6 m of upper black to dark gray shale of the uppermost cycle occur beneath the Tully Limestone or the Genesee Formation where the Tully has been completely removed. Farther to the east, as well as to the west of the Canandaigua Lake area, significant amounts of the upper Windom cycle have been removed such that the Tully or Geneseo rests on the middle or even lower cycles of the Windom Member (Figures 8,12f,14).

During the interval between deposition of the highest Windom beds and initiation of the Tully Limestone, a major and apparently rather widespread sea level lowstand produced this erosion surface over much of New York State. Because of the complex topography, different portions of the upper Hamilton Group were preserved in different areas. Local topographic highs were exposed to greater amounts of erosion during the pre-Tully lowstand interval and we infer that regions of maximum cut out of the Windom permit delineation of these submarine highs (Figure 12f).

Farther west, into the mid craton, the sub-Tully unconformity removed a great deal of the upper part of the Hamilton Group. In many areas, Upper Devonian (Frasnian) strata rest directly upon beds equivalent to the lower part of the Hamilton Group in New York State, particularly the Centerfield Limestone or its lateral equivalents in the Beechwood of Indiana and the Boyle of Kentucky. Hence, this is a major erosion surface subdividing the Kaskaskia mesasequence into two portions or holostromes.

In central Pennsylvania, closer to the depocenter of the late Givetian times, the Mahantango Formation of the Hamilton Group is separated from the overlying Tully equivalent calcareous shales by a subtle unconformity. As in New York State, the patterns of units beneath the Tully *Emanuella* and *Hypothyridina*-rich calcareous shales is rather variable and complex. Units equivalent to the uppermost Windom Gage Gully beds downward through the South Lansing coral bed and parts of the Taunton beds may crop out beneath the sub Tully erosion surface in Pennsylvania.

Tully Limestone

General Stratigraphy: The Tully Limestone and its internal divisions have been documented in considerable detail by Heckel (1973). In most of west central New York east of Seneca Lake the Tully is subdivisible into two members separated from one another by a mid-Tully unconformity (Figure 14). The lower Tully consists primarily of micritic limestone (calcilutite) containing an unusual brachiopod assemblage characterized by forms such as *Hypothyridina*, *Emanuella* spp., *Rhyssochonetes aurora*, and others. The occurrence of possible stromatolitic lamination and desiccation cracks near the top of the lower Tully unit at Bellona suggests that these lime mudstones accumulated in shallow water, possibly a broad lagoonal setting and their contained brachiopod faunas reflect a distinctive nearshore biofacies not otherwise present in the Middle Devonian of the Appalachian Basin. In contrast, beds overlying the mid-Tully unconformity record a spectrum of facies closely similar to that of the portions of the underlying upper Hamilton Group (Figure 15). For example, the Taughannock Falls bed possesses a fauna typified by small rugose corals (*Stereolasma* or *Metriophyllum*), and the trilobites *Phacops rana*, *Dechenella* spp. and *Greenops* together with abundant *Pseudoatrypa*, *Protodouvillina* and other brachiopods that characterize the more calcareous portions [see preceding discussion of trilobite beds, (Units 6 and 13) of the Windom Member]. A similar biofacies spectrum is presented in the upper or Moravia bed in the Tully. Sandwiched between these is an intriguing interval displaying the highest Givetian coral bed. The Bellona bed contains a suite of fossils virtually identical to those found in many of the upper Hamilton coral beds, for example, in the Bay View, Fall Brook, and South Lansing coral beds discussed herein (Baird and Brett, 1983; Brett

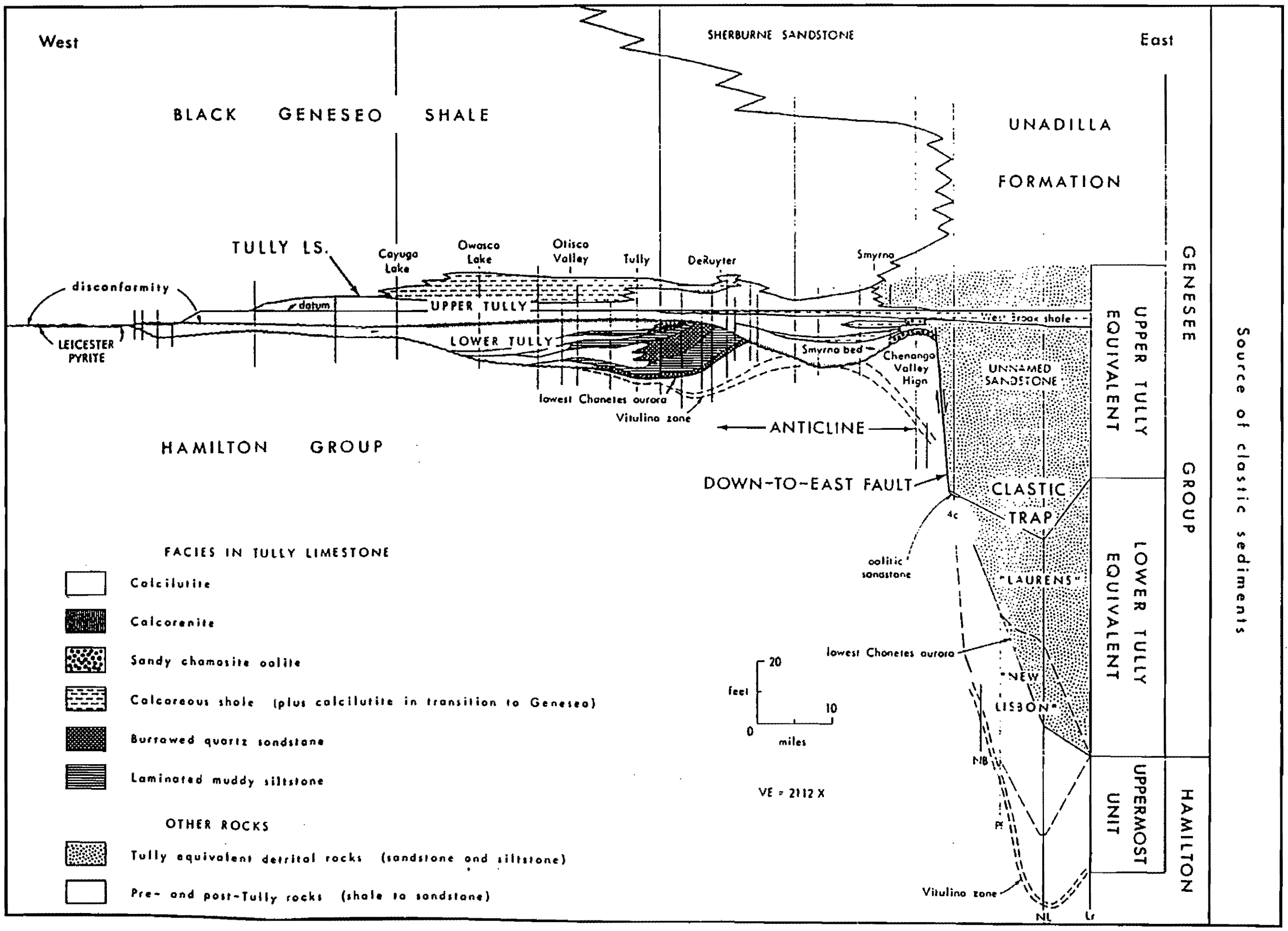

Figure 14. Regional cross section of Tully Limestone in western and central New York. Note truncation of upper Hamilton (Windom Shale) and adjacent units below Tully and, development of anticline which later becomes site of upper Tully depocenter west of Chenango Valley; from Heckel, 1973.

et al., 1983). The Bellona bed appears to reflect lowstand conditions within the upper Tully cycle. Its fauna of *Cystiphylloides*, *Heliophyllum*, favositids, and diverse brachiopods, including *Spinatrypa spinosa* strongly resembles those seen in the Windom beds. To the east, this unit and/or the immediately overlying shale carry a *Tropidoleptus* fauna not unlike that of muddier portions of the shallow water Hamilton Group such as the Kashong or Deep Run members discussed above. Hence the Tully appears to reflect a somewhat more siliciclastic-free version of facies well expressed in the upper Hamilton Group.

Interpretation: The Tully Limestone appears to record a reversal of the general pattern of siliciclastic input within the Appalachian foreland basin, and an abrupt "cleaning" of offshore marine environments. Tully carbonate is relatively siliciclastic free, which raises the significant question as to what processes temporarily shut down the influx of terrigenous sediments to the foreland basin. It may very well be that flexural folding and buckling within the basin, produced an arch-like barrier and sediment trap to the east of the Chenango Valley (Heckel, 1973; Figure 16, herein). On the other hand, the Tully interval is relatively carbonate-rich throughout much of the Appalachian basin suggesting that additional processes may have been at work. In many ways, the Tully (including its eastern equivalents which are quartz rich sand) appears to record a return to an orthoquartzite-carbonate succession characteristic of interval of relatively deep weathering of a diminished siliciclastic supply and, by inference, tectonic quiescence.

It is intriguing that both the Tully and underlying Windom display complex erosion surfaces as well as regionally angular bounding unconformities. Both of these phenomenona point to the presence of some activity within the foreland basin during this supposedly quiescent phase. Ettensohn (1987) has suggested that these effects record the initial docking of Avalon Terrain along the various salients of the North American margin. A broad uplift of arches might be predicted to occur during this time. Another significant factor is the apparent dramatic eastward shift in the depocenter and axis of greatest subsidence within Tully deposition. This amounts to a displacement of over 120 km of the basin center from near Canandaigua Lake during deposition of the black Gage Gully beds (Figure 12f) of the underlying Windom Shale back towards the Chenango Valley Region during deposition of the upper portion of the Tully Formation. The main center of the foreland basin during late Tully deposition is identified on the basis of evidence for most dysoxic facies, and relative thickness. These data tentatively indicate that the basin axis lies along a diagonal northeast, southwest trending line that ran approximately from southern Madison County in central New York through Williamsport, Pennsyvlannia. At the latter locality Tully equivalents exceed 30 m (100 ft) in thickness (Figure 16). In most areas, equivalent Tully strata are no more than 10 meters (25 to 30 ft) thick.

In the axial part of the basin, the upper portion of the Tully (Taughannock Falls bed) is represented by a rhythmic micritic limestone-dark gray shale succession, which may record a succession of carbonate turbidites. However, to the west of this area, the upper portion of the Tully thins into more highly fossiliferous shallow-water facies.

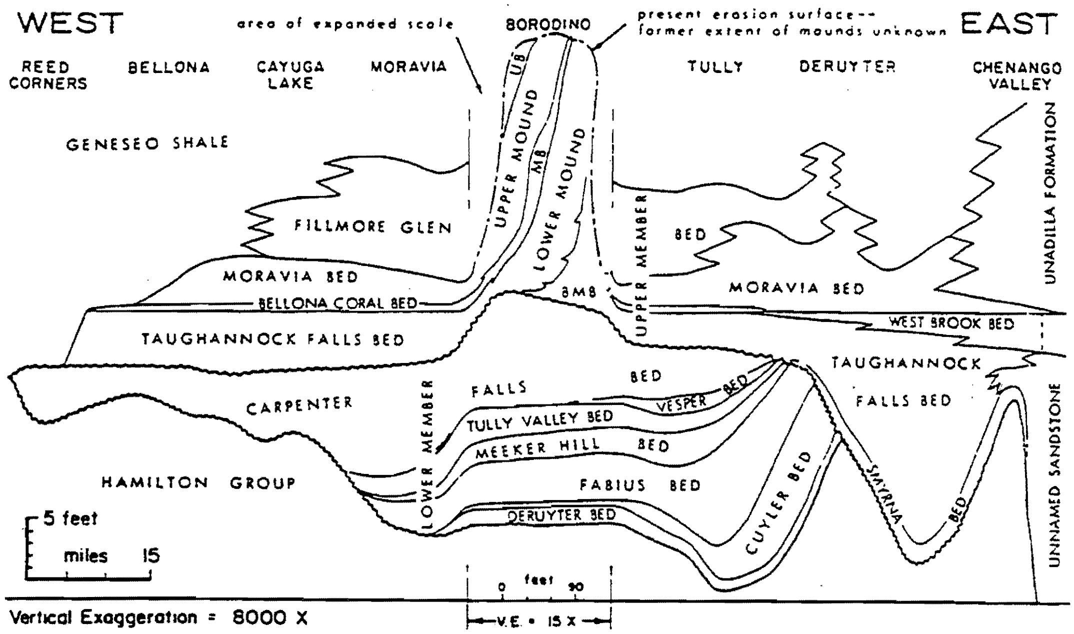

Figure 15. Stratigraphic units of the Tully Limestone, from Heckel (1973).

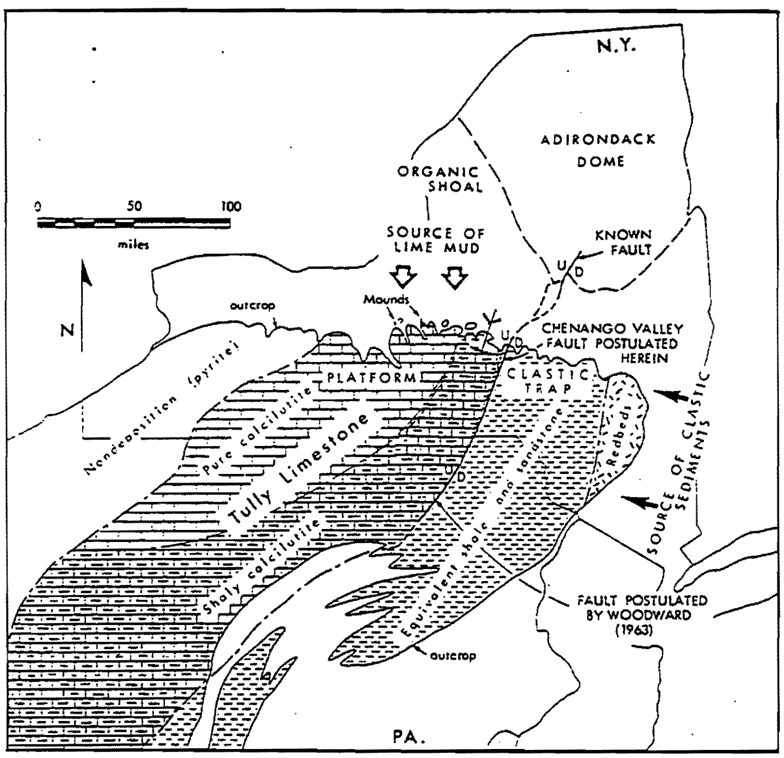

Figure 16. Map of structural and sedimentary features controlling Tully Limestone deposition, and resulting contemporaneous facies in New York and Pennsylvania. Note depocenter of upper Tully in region marked "shaley calcilutite;" from Heckel (1973).

Tully-Genesee Unconformity and Leicester Pyrite

In the area of southern Cayuga Lake, the uppermost Tully submember, i.e., Fillmore Glen beds, consists of argillaceous micritic limestones that alternate with black or dark grey calcareous shales. These grade upward into more and more sparsely fossiliferous dark shales. A sharpdiscontinuity (surface of maximum starvation) separates the upper Tully Fillmore Glen beds from the basal Genesee Formation black shales. In sections around Taughanock Falls, this surface of maximum starvation is demarcated by a thin (millimeters) lag of corroded fossil material and phosphatic diaclasts. The surface is merely a diastem between more calcareous, dark gray mudstones below and overlying black platey less calcareous shales above. However, to the west, between Cayuga and Seneca Lakes, this contact becomes sharp and erosive. The upper portion of the Moravia bed is successively beveled to the northwest from the region of Taughanock Falls in the southern area of Cayuga Lake northwestward to Seneca Lake (Figure 15). At Bellona (west side of Seneca Lake), black shale of the Geneseo Formation rests directly upon the Bellona coral bed in one area or on an erosional remnant of the Moravia bed in different banks of the Kashong Creek. This local scour surface at the base thus truncates the upper parts of the Tully and the nearly conformable successions seen in the southern and eastern Finger Lakes region passes into an important unconformity.

The Tully Limestone or the upper Windom Shale are abruptly overlain by black Geneseo shale west of Seneca Lake. In places this contact is marked by thin lines of reworked pyrite clasts, fish bones and conodonts, termed the Leicester Pyrite Member of the Geneseo Shale (Baird and Brett, 1986, 1991). In the vicinity of Gorham, between Seneca and Canandaigua Lakes, the sharp contact between black Geneseo Shale and the Bellona coral bed is marked by a thin lag of pyritic and crinoidal debris. This would appear to represent the easternmost locality at which the Leicester Pyrite can be recognized. Farther to the northwest, along the east side of Canandaigua Lake, even the lower Tully appears to be beveled beneath the sub-Geneseo unconformity. In the upper end of Gage Gully, small lenses of Leicester Pyrite have been observed overlying an erosional knob or remnant of the lower Tully Carpenter Falls bed. West of Canandaigua Lake, the Tully is missing altogether as a result of corrosion or erosion at this unconformity. In its place, are somewhat larger lenses of pyritic fossil and nodular debris, up to a meter across and in places 30 cm in thickness, occur along the otherwise knife-sharp contact between the Geneseo and the underlying Windom Shale (Figure 17). These pods of Leicester Pyrite interfinger with the black Genesee Shale and not with the Windom below (Baird and Brett, 1986).

Although the pyritic clasts are apparently derived from the erosion of the upper Windom beds, the Leicester Pyrite lenses are interbedded with laminated black shales of the basal Geneseo Member. We have previously argued (Baird and Brett, 1986, 1991) that the pyritic clasts derived from erosion of the underlying Windom muds were concentrated into windrows on the dysoxic sea bottom by internal waves or currents associated with a rising pycnocline. Hence, the pyrite and associated erosion surface at the base of the Geneseo muds provide an example of the processes associated with sedimentation during maximum marine flooding. In contrast to the basal Tully lowstand erosion surface, the disconformable upper contact of the Tully with the overlying black Geneseo Shale is of lesser magnitude and represents a highstand rather than a

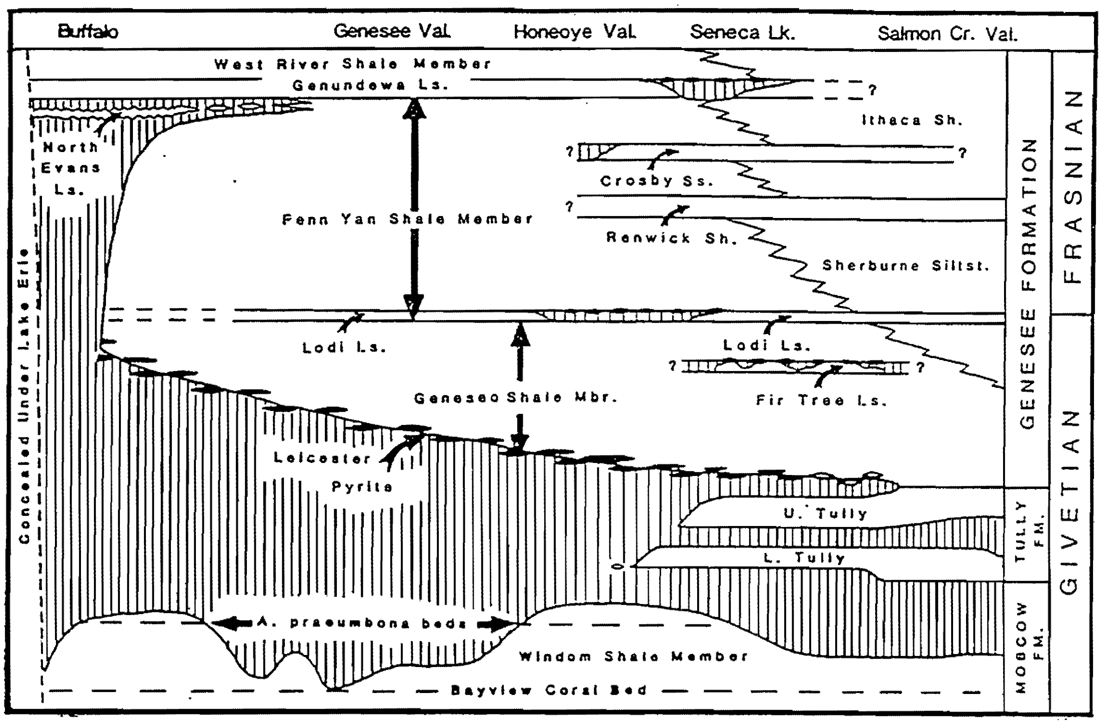

Figure 17. Chronostratigraphic cross section of lower Genesee Formation and subjacent Moscow Formation (Windom Shale Member). Note positions of the thin and locally beveled Fir Tree and Lodi Limestone submembers. Large hiatus below the Genesee Formation marks the position of the Taghanic Unconformity; lenses of detrital Leicester Pyrite are derived from this erosion but were deposited through a long period of diachronous overlap of Geneseo black muds from this discontinuity. From Baird et al., 1988.

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lowstand related unconformity. In previous papers (Baird and Brett, 1986, 1991; Brett and Baird, 1990), we have argued that these types of surfaces were developed at oxic-anoxic water mass boundaries and are related, in part, to intervals of sediment-starvation associated with maximum flooding surfaces. In areas to the west of Canandaigua Lake, where the Tully Limestone has been removed below this erosion surface, the discontinuity between the Hamilton and the Geneseo black Shale is a composite contact which has overstepped both the mid-Tully discontinuity and the sub-Tully erosion surface.

Removal of the Tully Limestone in the areas west of Canandaigua Lake juxtaposes the post-Tully, sub-Genesee unconformity on to the sub-Tully unconformity (Taghanic unconformity). However, the sub-Tully erosion surface occurred under fully oxygenated conditions. The basal surface of the Tully is characterized by casts of mega-burrows excavated into the still soft, but over-compacted muds of the Windom Member. Such distinctly burrowed irregular firmground contacts characterize lowstand sequence boundaries in parts of the Hamilton Group, as well. In contrast, the contact between the Tully limestone and the overlying Geneseo is associated with maximum flooding, the beginning of the highstand is a surface of maximum sediment starvation even where close to conformable near the basin center and the Cayuga-Owasco Lake region.

On the basin margin, erosion at this time, perhaps as a result of deep storm waves or internal waves (see discussion above under internal Windom erosion surfaces) produced beveling along a knife-sharp, gently furrowed surface lacking any type of burrow structure. In areas where the Tully was exposed on the sea floor during times of prolonged sediment starvation, submarine corrosion or dissolution may have been a critical factor in removal of the older carbonate sediments. Farther to the west, once the Tully had been breached, physical erosive processes must have worked to flatten and smooth the old pre-Tully erosion surface into a nearly planer or very gently furrowed surface. Furthermore, current velocities must have been sufficient to erode and aggregate pyrite from the underlying Windom beds, forming the Leicester Pyrite lenses. Hence, the basal Genesee contact in the area of the Genesee Valley and westward to Erie County is an excellent example of a combined or composite sequence boundary formed by lowstand erosion prior to the Tully and by erosion under deep marine conditions during a period of maximum sediment starvation at the base of the Genesee highstand.

The abrupt transition from Tully Limestone to Genesee black shale appears to record an interval of rapid subsidence of the Appalachian foreland associated with the influx of a large wedge-like body of black shales. This pattern, is closely comparable to the situation seen Tectophases I and II of the Acadian Orogeny in the Appalachian basin. One curious anomaly, however, is that in the case of the Tully-to-Geneseo transition, no bundle of thin K-bentonites (altered volcanic ash beds) is recognized. In the other examples of tectonic-flexural deepening (e.g., Oriskany-Esopus and Onondaga-Marcellus transitions), a distinctive bundle of bentonites occurs near the top of the carbonates. These clustered ashes suggest the onset of renewed orogenic activity. The change to Geneseo which undoubtedly records the strongest pulse or Tectophase III of the Acadian Orogeny is not apparently accompanied by the input of ash beds. However, this may reflect the absence of a concerted search for such layers.

Geneseo Shale

The third and uppermost portion of the Givetian in New York State is represented by post-Tully clastic sediments of the lower part of the Genesee Formation (Figure 17). The lower Geneseo Black Shale, assignable to the *hermanni cristatus* conodont zone upward to the *disparalis* zone (Kirchgasser et al., 1988, this volume), records maximum deepening within the Appalachian basin for the Middle Devonian interval. Black laminated shales dominate the facies in the study area between the Genesee Valley type section and the Seneca Lake Region; however, we have recognized two significant, although subtle, cycles of shallowing within the Geneseo package (Baird and Brett, 1986; Baird et al., 1988). These cycles are capped by impure, nodular argillaceous concretionary limestones with abundant styliolinids, auloporid corals and goniatites. These two shallowing events are significant because the base of the lower *asymmetricus* conodont zone occurs at or near the top of the second nodular concretionary limestones cap. Thus, the top of this unit (Lodi Limestone) corresponds to the Givetian-Frasnian Stage boundary (Kirchgasser et al., 1988, this volume). The nodular limestones capping the two cycles are significant for a second reason; they are analogous to nodular cephalopod limestone facies described by Ver Straeten et al. (this volume) for the Cherry Valley limestone which characterizes a shallowing pulse associated with the earlier Tectophase II black shale depositional interval.

The major transgression, recorded by the change from Tully carbonate into basinal Geneseo black shale facies, is associated with a westward advance (onlap) of basinal deposits over the composite disconformity into Ohio and Ontario. It is referred to as the Taghanic Onlap or IIA transgression event (Johnson, Klapper and Sandberg, 1985), and it records the combined effects of eustatic and tectonic processes. Detailed stratigraphic relationships indicate that the transgressive record (Tully Formation) of this onlaps has been completely removed in the west by deep submarine erosion and corrosion prior to deposition of the overlying siliciclastics.

In certain ways, the abrupt deepening observed at the top of the Tully and the infilling of a local foreland trough with carbonate turbidites and dark shales is reminiscent of patterns observed in earlier Devonian tectophases. The Fillmore Glen beds at the top of the Tully are similar to thin bedded carbonates and dark shales in the upper Onondaga and lower Marcellus transition at the beginning of tectophase II at the base of the Hamilton Group (Ver Straeten et al., this volume). In the Tully example, as in the other cited instances, the carbonate appears to represent the transgressive deposits (systems tract) of a megasequence and the abrupt change to black shales at the top of the Tully mirrors that seen at the top of the Onondaga Limestone. As with the other cases, a transitional section of thinly-bedded carbonates and dark shales occurs in the area of maximum subsidence. Towards the margins of the basin, the carbonate to black shale contact is knife sharp and is marked in places on analogous surfaces (i.e., upper Onondaga and upper Tully), by a lag of phosphatic, conodont, bone and/or pyrite-rich debris. The Leicester Pyrite is one such thin lenticular lag deposit which accumulated under anoxic conditions in a deep-water setting (Baird and Brett, 1991).

DISCUSSION AND CONCLUSIONS

The highly predictable ("layer cake") carbonate-rich stratigraphy that characterizes the upper part of the Hamilton Group and the Tully Formation suggests an interval of relative quiescence between the second and third tectophases of the Acadian Orogeny (Ettensohn, 1975; Dennison, 1985). Widespread general lowering of relative sea level combined with diastrophic local flexural uplift within the foreland basin produced two relatively large and several lesser erosion surfaces that underlie widespread transgressive carbonate units. The most significant erosion surface within the Hamilton Group occurs at the base of the Tichenor Limestone which marks the sharp basal contact of the Moscow Formation: the Tichenor and overlying condensed carbonate deposits have been recently interpreted (Brett and Baird, 1990) as an initial transgressive systems tract of the Moscow third-order depositional sequence. Erosion at the sub-Tichenor surface-level occurred on both eastern and western ramps of the foreland basin producing a nearly symmetrical pattern of truncation of beds in the upper portion of the Ludlowville Formation both east and west of the central Finger Lakes (Mayer et al., 1994).

The Moscow Formation records a general deepening pattern from the basal skeletal grainstones of the Tichenor Limestone upward into dark gray to black shales of the Windom member which have been interpreted as highstand deposits. However, at least two fourth order sequences and a number of smaller scale cycles (fifth or sixth order cycles in the terminology of Busch and Rollins, 1984) are superimposed upon this general deepening pattern. Several member- or submember-scale shallowing-upward cycles, each capped by a thin silty to calcareous, bioclast-rich horizon have previously been documented. In ascending order these are: a) the Deep Run Member, calcareous mudstones which are capped by a silty, bioturbated Menteth Limestone; b) the lower Kashong Member blue gray mudstone overlain abruptly by the "RC" shell bed; c) the middle Kashong mudstones, capped by a Menteth-like unit; d) an upper Kashong cycle capped by silty shell rich and phosphatic Barnes Gully carbonate bed; e) two poorly developed presently unnamed cycles which range from shales to silty mudstones or siltstones depending upon location; the upper is capped by the Geer Road phosphatic shell bed; f) the lower *Ambocoelia*-rich shales of the Windom Member capped by Bayview shell and coral beds; g) the middle Windom ambocoeliid and chonetid bearing shales capped by unnamed shelly beds and h) dark grey Fisher Gully beds capped by the Fall Brook coral-rich bed and the overlying Taunton calcareous mudstones; and, i) the upper Windom dark gray shales which typically contain diminutive brachiopods, especially small spiriferids (juvenile ? "*Allanella*").

The dark gray to nearly black shales of the highest Windom Member appear to reflect some of the deepest water facies of the upper Hamilton Group, as a whole. This is rather enigmatic given the fact that they are overlain by a widespread erosive disconformity. Presumably, a still higher cycle of more profound shallowing originally occurred within uppermost Windom mudstones, but the upper, transitional, shallowing portions of this cycle have been removed everywhere throughout the New York outcrop belt by a sub-Tully unconformity of considerable magnitude.

Detailed mapping of the individual shallowing-deepening cycles within the upper part of the Hamilton Group has revealed a significant and intriguing pattern. The depocenters, areas of greatest thickness, as well as the areas of apparently deepest- water facies for each successive unit, display a displacement to the west relative to those of the underlying unit. This westward migration of the depositional axis of the basin has resulted, in part, from progradation of small siliciclastic wedges into the basin with consequent reduction of accommodation space progressively further to the west. However, the relative thinness of these wedge-like sedimentary bundles suggest that sediment loading was not a particularly significant effect. The pattern of westward migration seen progressively within the upper portion of the Hamilton Group appears to have been abruptly reversed during deposition of the overlying Tully Limestone.

Within the Moscow interval, relative lowstand erosion surfaces are overlain by two distinct types of somewhat condensed calcareous beds. The first type, well represented by the Tichenor limestone, the RC-TT bed of the Kashong Shale, Barnes Gully bed at the base of the unnamed member, and precursor beds, such as the Fall Brook Bed within the Windom. The beds rest sharply on the underlying mudstones with little or no hint of a shallowing upward cycle beneath them, and they are composed of extremely skeletal rich highly condensed lag deposits. These beds also overlie some of the more major erosional surfaces within the Hamilton Group. They are best interpreted as first transgressive lag beds that develop during initial sea level rise following a "forced regression" i.e., a time of relatively rapid sea level drop not associated with major progradation. This could be caused by either eustatic sea level fall or regional uplift; the latter would require that major portions of the northern Appalachian both east and west of the depocenter were more or less simultaneously uplifted. We suggest that eustatic sea level fall is the more likely alternative.

The second type of compact bed that overlies at least minor erosion surfaces, is exemplified by silty limestones and calcareous siltstones, such as the Menteth Limestone, unnamed calcisiltite beds in the upper Kashong shale, the Curtice Road bed of the unnamed member and perhaps capping siltstone beds within the Windom Member east of the Finger Lakes (Zell, 1985). These beds appear in depocenter areas to be gradationally conformable with underlying silty mudrocks (e.g. Deep Run, upper Kashong shales, *Megastrophia* beds silty mudstones). Towards basin margins, these beds display distinctly burrowed basal surfaces that evidently cut slightly into underlying mudstones, becoming slightly disconformable. Two factors seem particularly relevant in the interpretation of these beds and their associated discontinuities. First, they typically seem to alternate in position with the Type 1 lag beds (e.g., Tichenor vs. Menteth, RC bed vs. upper Kashong calcisiltites, Barnes Gully bed vs. Menteth Gully bed, Fall Brook precursor bed versus upper Taunton siltstone or Lansing bed). Secondly, these silty limestone beds do not show particularly dramatic lateral gradients. Indeed, they appear to run rather uniformly across the tops of wedge-like or lenticular bodies of silty mudstone which do show dramatic thickness changes, where as the silty beds display little or none. To that degree, these beds appear to be associated with times of "leveling out" of basin topography. More notably, the beds appear to separate episodes of basin axis shifting. For example, the Menteth Limestone separates large scale lenticular mudstone bodies (Deep Run and Kashong) which are offset from one another by ten of kilometers. Furthermore, the type 2 compact limestones are silty and heavily bioturbated, typically with swirly spreiten of *Zoophycos*, but they are not particularly shell rich, although they may display minor shelly basal lag deposits and/or thin shell hash beds at their tops.

We suggest the following model for the interpretation of the Type 2 (Menteth-like) silty limestones or calcareous siltstones. First, these beds developed only during intervals of generally shallow conditions over the northern part of the foreland basin. The shallowing episodes are probably represented by the Type 1 limestones or, more precisely, by the discontinuities that underlie the Type 1 limestones. Following shallowing by forced regression (relative sea level drop) minor sea level rise and/or development of a local subsiding basin provided accommodation space for the deposition of silty muds which were winnowed from basin marginal areas. These muds prograded into the most actively subsiding portions of the basin until those regions were filled to a threshold level, perhaps near the lower depth of storm wave base. At this depth, processes of winnowing and bioturbation became dominant, producing relatively compact deposits of heavily bioturbated silty and in some case limey sediment. Finer grained muds bypassed into more axial regions of the basin, presumably to the southwest into the western Pennsylvannia. Following the kinds of level filling of local basins, new episodes of subsidence, developed westward of the previous subsided basin axis and provided more accommodation space for a new package of mudstones. Note, for example the shift in position between the upper Deep Run and basal Kashong mudstones on either side of the Menteth Limestone. Minor sediment starvation associated with the deepening following deposition of the silty limestones produced thin shelly lags. It appears that shifts in the depocenters were also timed with intervals of true relative sea level rise which created widespread shelly lags. In some cases, the leveled out topography, created by the progradation of clastic wedges into the basins, persisted following the development of the silty capping limestones. In these instances, thin widespread calcareous beds showing relatively little lateral facies change also developed during the transgressive sea level rise interval; these include the widespread "trilobite beds" mentioned above.

Particularly strong pulses of relative sea level rise, with or without intervals of major shift in subsidence, produced the distinct, but very thin, phosphate, conodont- and/or bone-rich lag beds that lie at the bases of dark gray to black shales. We infer that these beds mark surfaces with maximum sediment starvation in the basin. A third type of erosional surface occurs beneath these maximum flooding surface lag beds. These erosion surfaces are typically channelized, and may remove major portions of the underlying transgressive sediments. We infer that this erosion in relatively deep water settings, was caused by basinward flowing currents and/or internal waves at water mass boundaries. Perhaps the most important factor in the development of highstand erosion surfaces was the absence of sediment input in offshore areas due to the trapping of siliciclastics near the source area. In the absence of new sediment input, even minor basinward flowing currents have been enough to initiate erosion, and over extended periods of time these currents could remove substantial amounts of the underlying sediment.

Hence, the stratal patterns of the upper portion of the Hamilton Group appear to reflect a mixture of actual relative sea level fluctuations and tectonic processes. The latter is recorded by the generally westward drift of the basin axis. This process appears not to have been steady, but rather episodic on a relatively long time scale, such that new basin depocenters were produced by local subsidence and largely infilled prior to their shifting to new and more westerly positions.

Finally, the processes which are recorded by subtle facies shifts and discontinuities in the upper part of the Hamilton Group were played out in a more extreme fashion during the deposition of the overlying Tully limestone and Genesee formations. A relatively major sea level drop or forced regression toward the end of the Windom deposition created a major unconformity that terminated the Hamilton Group. Moreover, it was not evidently preceded by a major or long-lasting shallowing-upward interval in the high parts of the Hamilton Group. Indeed, the beds that underlie this erosion surface represent some of the deepest water facies in the Moscow Formation. This erosion surface may have been produced, at least in part, by a relative uplift of the seafloor, and clearly somewhat more active diastrophic arching of the foreland basin floor did precede the sub-Tully erosion surface. This regionally complex pattern of uplift produced a complex paleotopography which was beveled during the erosive interval. Furthermore, development of anticline barriers on the seafloor, coupled with very low, but rising sea level may have produced one of the most highly sediment starved intervals during the Middle Devonian. This resulted in the deposition of clean, shallow water carbonates of the lower portion of the Tully over substantial areas of western New York, Pennsylvannia and perhaps as far south as Virginia. The basal Tully appears to represent a more extreme version of the Type 1 shallow water transgressive limestones discussed above. We agree with Ettensohn (1987) that this limestone and/or the erosion surface that underlies it may be in part the indirect result of renewed collision along the eastern margin of North America.

The Tully internal disconformity may represent another episode of forced sea level drop which eroded the lower Tully to some degree. A marked eastwardly migration of the basin axis is apparent in the deposition of the overlying upper part of the Tully. This eastwardly migration reverses the general pattern observed within the Hamilton Group below. It may signal either a time of renewed thrust-loading in the hinterland or an interval of load relaxation immediately following a thrusting episode (cf. Quinlan and Beaumont, 1984, Beaumont et al. 1988). The transition from the Tully into the Geneseo appears to initiate the third and most pronounced Devonian tectophase (Ettensohn, 1987). Again, as in the Moscow, but on a larger scale, the sediment starvation produced during this major relative deepening event is also associated with erosion. Westward beveling of the Tully Limestone beneath the Geneseo Black Shale is associated with development of the distinctive Leicester pyritic lag deposits. These lags were developed under stratified basinal conditions associated with the deposition of the initial black shales of the Catskill wedge. The abrupt pulse of deepening in the later portion of Tully deposition and into the overlying black shales of the Geneseo Formation is probably of both eustatic (Johnson et al., 1985) and tectonic (Ettensohn, 1987) origin. It is intriguing that precisely the same combination of probable eustatic sea level rise and enhanced basin subsidence is witnessed at each of the two earlier Devonian tectophases (i.e., Oriskany-Glenerie) into Esopus Shale and Onondaga Limestone into Marcellus black shale (Ver Straten et al., this volume).

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ROAD LOG FOR DEVONIAN MOSCOW-GENESEE FIELD TRIP

Mileage:		Instructions:
0.00	0.00	Leave University of Rochester parking lot, turn left onto Wilson Blvd.
0.10	0.10	Turn right onto Elmwood Avenue and cross Genesee River
0.30	0.20	Bear left at Scottsville Road
		Underpass under I-390
0.95	0.65	Turn right onto exit for I-390 south
1.05	0.10	Merge onto I-390
1.25	0.20	Crossing Genesee River
2.75	1.50	Overpass of Rt. 15 over I-390
3.25	0.50	Overpass of Rt. 15A over I-390
3.55	0.30	Cross Erie Canal
3.65	0.10	I-390/I-590 fork; bear right following I-390 South
4.15	0.50	Erie Canal on right; Monroe Community College to the west
8.55	4.40	Exit for NY State Thruway (I-90); continue south on I-390
9.05	0.50	Overpass of Thruway over I-390
13.35	4.30	Cross Honeoye Creek in approximate pre-glacial valley of Genesee River
16.95	3.60	Livingston County Line
19.05	2.10	Exit 8 for U.S. Rt. 20/Avon
19.30	0.25	Underpass under Rt. 20
20.55	1.25	Cross tributary of Conesus Creek
20.85	0.30	Minor hill slope exposures of Middle Devonian of Jaycox Shale; middle Devonian; excavation for I-390 in 1979 yielded a prolific fossil assemblage at this site.
22.15	1.30	Exit 9 for Lakeville; bear right onto exit
22.30	0.15	Junction Rt. 15; turn left (south)

22.40	0.10	Cross I-390
22.70	0.30	Railroad underpass over Rt. 15
23.25	0.55	Junction Triphammer Road (on right); turn right onto Triphammer Rd.
23.35	0.10	Cross Conesus Creek (swampy stretch)
23.95	0.60	Overpass over I-390
25.75	1.80	Side tributary of Conesus creek
25.95	0.20	Farm on right side borders Conesus Creek at Triphammer Falls, about 0.25 miles north of Triphammer Road; this is a classic locality for the Middle Devonian Centerfield Limestone
26.15	0.20	Junction Rt. 39; turn left (south) onto 39
27.10	0.95	Cross north branch of Jaycox Creek
27.90	0.80	Yellow barns on right are opposite Wheeler Falls of North Jaycox Creek. For optional stop pull off on shoulder of Rt. 39. Walk back to path along fence to west banks of Jaycox Creek

OPTIONAL STOP A. WHEELER FALLS
(See Description for Jaycox Creek)

Continue on Rt. 39

28.20	0.30	White Devon Farm on left, pull off on right shoulder near gateway into pasture, walk straight west from gate through pasture to clump of oak trees along Jaycox Creek, south branch for Stop 1. **Note: Visitors must obtain permission from the Wadsworth Estate,** Geneseo to study this locality.

STOP 1: JAYCOX RUN

Locality

Exposures along the south (main) fork of Jaycox Creek, on the property of William P. Wadsworth (White Devon Farm), 0.4 km (0.25 mi) west of NY Rt. 39 about 0.8 km. (0.5 mi) north of Nations Road, Geneseo, Livingston County, N.Y. (Geneseo 7.5 ft Quadrangle, 1950).

References

Cooper (1930), Grasso (1973), Baird (1979). The following description is from Brett and Baird (1981).

Descriptions of Units

Jaycox Creek exposes a nearly continuous section of the Ludlowville (Centerfield, Ledyard, Wanakah, and Jaycox members) and lower Moscow (Tichenor, Deep Run, Menteth, and basal Kashong members) formations (Figure 10). Exposures to be examined during the field trip are those in the upper portion of the Jaycox ravine associated with a series of three low waterfalls held up the thin limestone bands; a low upper falls is formed by the Menteth Limestone, a middle falls by the Tichenor Limestone, and the highest, lower falls by a calcareous band in the Jaycox Member.

The Jaycox through Menteth interval will be examined in detail. Faunal lists for these units are given by Grasso (1973). Units are described in ascending order as follows.

Ludlowville Formation

Wanakah Shale Member: The upper 4 m (13.2 ft) of the Wanakah Shale Member are visible below the lowest falls in Jaycox Creek. This constitutes an undifferentiated interval of medium gray fissile, friable shales with a low diversity fossil assemblage. *Ambocoelia umbonata*, *Mucrospirifer*, chonetids, and *Athyris*, the small rugose coral *Stereolasma*, trilobite remains (*Phacops* and *Greenops*), and various bivalves are common. No calcareous bands or concretions are present in this portion of the Wanakah Shale.

Jaycox Shale Member: Baird (1979) selected this creek exposure as the type section for his Jaycox Shale Member, the uppermost member of the redefined Ludlowville Formation. At this locality, the Jaycox consists of about 4 m (13.2 ft) of soft, bluish-gray shale with abundant thin fossil-rich horizons (biostromes) and calcareous bands (see article by Mayer, this volume).

The basal Hills Gulch bed of the Jaycox Member (Unit A) is a bioturbated, silty, argillaceous limestone band 30-35 cm (~1 ft.) thick, which grades upward from the calcareous uppermost Wanakah Shale (Figure 11). This blocky band which caps the lower falls of Jaycox Creek is notably rich in brachiopods (*Mucrospirifer*, chonetids, and *Mediospirifer*), bivalves (*Actinopteria*, *Modiomorpha*, *Paleoneilo*, and *Cypricardella*), and gastropods (*Mourlonia* and *Palaeozygopleura*). This bed has yielded exceptionally well preserved bivalves, including rare specimens in burrow positions. The bed contains numerous spreiten of *Zoophycos.* Westward this bed merges into a large coral-bearing unit resembling the overlying Tichenor limestone. Coral beds which occur at several levels within the Jaycox Member (Units B-C) contain assemblages very similar to those of older Centerfield Limestone, including a diversity of corals such as *Eridophyllum*, *Heliophyllum halli*, and the colonial form *Heliophyllum confluens* which is essentially restricted to this member. Large favositids and *Thamnoptychia* are also common at several levels within the Jaycox Member. Fossil layers contain abundant fenestellid bryozoans and large runner-like columns of crinoids modified as holdfasts (stolons). Diagnostic brachiopods of the Jaycox include *Parazyga hirsuta* and *Pentamerella pavillionensis*. These brachiopods are restricted to coral rich facies and recur only in association with biostromes (Centerfield Limestone, Jaycox Shale, Tichenor Limestone, and Windom coral beds).

Moscow Formation

Tichenor Limestone: The Tichenor Limestone (Unit D) constitutes a 30 cm ledge-forming band of medium gray, buff- to rusty weathering biomicrite (pack- or grainstone). As elsewhere, the Tichenor is an encrinite with abundant rugose and tabulate corals. The basal surface of the Tichenor Limestone represents a minor disconformity (Baird, 1979). Undersurfaces of projecting ledges, which can be examined in detail at this locality, show an irregular, sharp contact with the underlying Jaycox locality, show an irregular, sharp contact with the underlying Jaycox Shale. Very large hypichnia, probably crawling furrows similar to *Cruziana*, occur abundantly on the undersurface of the Tichenor.

The upper contact of the Tichenor Limestone at Jaycox Run is gradational through 15 cm of calcareous shale into the overlying Deep Run Member.

Deep Run Shale Member: Between the middle and upper falls, Jaycox Creek bed exposes 2.5 m (8.25 ft) of medium gray, calcareous mudstone of the Deep Run Member. These mudstones are distinctly harder (more calcareous) than most of the Jaycox Shale and break with irregular fractures due to the lack of fissility. Lower Deep Run shales (Unit E) contain a fauna similar to that of the Jaycox coral biostromes, including *Heliophyllum*, *Eridophyllum*, (but *H. proliferum* rather than *H. confluens*) and large favositid heads. Small mounds of fistuliporoid bryozoans project upward some 50 cm into the base of the Deep Run Member; these are exposed in the floor of Jaycox Creek. Associated with these mounds are abundant large stems and stoloniferous holdfasts of camerate crinoids; calyces of *Dolatocrinus*, *Megistocrinus*, and other crinoids occur rarely in the basal Deep Run. The Deep Run Member is particularly noted for the large size of its trilobites. Specimens of *Phacops rana*, *Greenops boothi*, and *Dechenella* sp. are abundant and are typically very large relative to those found in underlying and overlying shale units.

The upper beds of the Deep Run (Unit F) are sparsely fossiliferous bluish gray shale mudstones containing very abundant limonitized (pyritized) sinuous burrows. Occasionally, vague Zoophycos traces can be observed. These sparsely fossiliferous shales contain scattered stringers and lenses of large crinoid columnals and fenestellid bryozoans suggestive of storm lags. The Deep Run Member is gradational into the overlying Menteth Limestone Member.

Menteth Limestone Member: The Menteth Limestone (Unit G) which caps the uppermost falls in Jaycox ravine, consists of approximately 28-30 cm of light gray, buff-weathering irregularly bedded, strongly bioturbated calcisiltite (biomicrite). The lower contact of the Menteth is gradational, but the upper surface is sharply defined and hummocky suggesting a slight discontinuity or burrowed omission horizon. The Menteth contains a very abundant and often well preserved traces (*Zoophycos*) and scattered body fossils including spiriferid brachiopods, rare corals, and large trilobite fragments.

Kashong Shale Member: Only the lowest 30 - 50 cm of bluish gray, calcreous Kashong Shale (Unit H) crop out in Jaycox Run. These basal shales contain abundant fossils including the ramose tabulate coral *Thamnoptychia*, various bryozoans, brachiopods, camerate crinoids, and large trilobites.

Discussion

The basal Moscow Formation in the Genesee Valley represents a slightly different spectrum of environments. This sequence begins with the Tichenor Limestone which, as in most western N.Y. localities rests with marked disconformity on the Ludlowville Formation (Baird, 1979). Presumably, a portion of the upper Jaycox interval has been removed by submarine erosion prior to the deposition of the Tichenor. The Tichenor Limestone was probably deposited in a high energy, above wave base setting, as indicated by winnowing of fines, abrasion of fossil fragments, vague cross lamination, and overturned favosited coral heads. This unit is inferred to represent the shallowest water conditions in the entire sequence exposed at Jaycox Run. Gradation of the Tichenor into the overlying Deep Run calcareous mudstone indicates a return to lower energy, mud depositional conditions. The Deep Run thickens rapidly eastward into a lentil of calcareous mudstone which attains a maximum thickness of about 18 m. (59.4 ft) near Canandaigua Lake and then thins again eastward toward Cayuga Lake where the Deep Run pinches out (Baird, 1979). This lenticular configuration suggests active subsidence of a localized basin following the Tichenor deposition. The Deep Run locally contains cross laminated calcisiltite and calcarenite lenses which were probably transported into the depositional basin from nearby shoal regions during severe storms. Hence, the unit was deposited below normal wave base, but within reach of storm waves.

Deep Run mudstones grade upward into the Menteth Limestone, a uniformly thin (30-40 cm) but very widespread carbonate unit. The Menteth is a thoroughly bioturbated calcisiltite and is inferred to represent the terminal phases of infilling of the Deep Run depositional basin. Processes of sediment winnowing, probably aided by biological activity, became dominant over deposition of clays, resulting in a thin, lag deposit of skeletal debris and carbonate silt. Locally, coral beds developed on the upper surface of the Menteth. Menteth Limestone, in turn, grades upward into Kashong mudstones which faunally and lithologically somewhat resemble portions of the Deep Run. The entire Deep Run-Kashong interval (equals Portland Point of earlier workers; Baird, 1979) is inferred to represent deposition during a generally regressive interval. The sequence is bracketed by units which yield evidence of deposition under shallow water conditions. Minor oscillations of environmental conditions may have been the result of regional subsidence or downwarp of a shallow basin or trough.

Return to vehicles and <u>continue</u> <u>south</u> <u>on</u> <u>Rt.</u> <u>39</u>

28.70	0.50	Nations Road; to south is Wadsworth estate with ancient white oak trees

29.80	1.10	Village of Geneseo; Geneseo High School on right
31.00	1.20	Junction Rt. U.S. 20A; off south side of Geneseo, turn right onto 20A
31.35	0.35	South end of Geneseo State College dorms on right
31.70	0.35	Junction Rt. NY 63 on right, continue on 20A
31.95	0.25	US 20A turns to right; 63 goes straight. Follow 20A - turn right
32.25	0.30	Beginning of Dewey Hill roadcut; Genesee Formation (mainly Penn Yan dark gray shales)
32.55	0.30	Pull to right and park at guard rail for Stop 2. Walk across highway and enter pasture along Fall Brook at gateway. Proceed on foot upstream to exposures.

STOP 2. FALL BROOK, GENESEO

Locality

Exposures along the bed and banks of Fall Brook 0.2-0.6 km (0.1-0.37 mi) east of U.S. 20A and 39 and below Fall Brook Falls, Geneseo, Livingston County, N.Y. (Geneseo 7.5 ft Quadrangle, 1950).

References

Cooper (1930), Baird (1978), Baird and Brett (1983). The following description is from Brett and Baird (1981).

Description of Units: This stretch of Fall Brook exposes the upper portion of the Middle Devonian (Givetian) Moscow Formation (Windom and Kashong Shale Members) as well as the overlying Upper Devonian (Frasnian) Genesee Group (Figure 12).

Low cut banks along Fall Brook near U.S. 20A expose the upper 1.7 m (5.6 ft) of the Kashong Shale Member. This unit is comprised of sparsely fossiliferous, bluish gray mudstone with abundant pyritic tubular burrows. Body fossils include large ramose bryozoans, the brachiopods *Lingula* and *Tropidoleptus*, rare *Dipleura* trilobites, and phyllocarid fragments.

The disconformable contact with the overlying Windom Shale Member is exposed here and consists of a mudstone band approximately 10 cm-thick. This unit contains an admixture of reworked Kashong and Windom fossils and small phosphatic steinkerns and nodules (Little Beards phosphate bed). This heavily bioturbated sediment has been interpreted as a biogenically blurred unconformity or "stratomictic discontinuity" (Baird, 1978). The zone of phosphatic pebbles in the upper Kashong has been traced from Erie County, eastward to Owasco Valley, and is inferred to represent a widespread disconformity within the Moscow Formation (Baird, 1978). The informal "Unnamed Member" is absent here, having been cut out by erosion beneath the Little Beards bed.

Overlying the phosphatic pebble bed is typical basal Windom Shale: soft, medium gray shale with abundant specimens of *Ambocoelia umbonata*. A calcareous bed rich in trilobites occurs about 20 cm. above the Little Beards phosphatic nodule bed. Aside from the basal 30-50 cm, the lower 4.5 m (14.9 ft) of the Windom, are largely covered with slumped talus and are not accessible at Fall Brook. However, a complete Windom thickness of 15.63 m (51.6 ft) was measured at this locality.

The Windom section continues upstream at the base of a high cliff face on the northern side of Fall Brook. The lowest unit exposed here is soft shale rich in *Ambocoelia* brachiopods which may occur in small prod-like concentrations. The overlying Bay View bed consists of medium gray calcareous and very fossiliferous mudstone. Abundant fossils include *Pseudoatrypa*, *Mucrospirifer consobrinus*, *Protodouvillina*, the rugose corals, *Stereolasma* and *Amplexiphyllum*, crinoid columnals, and abundant *Phacops* trilobites. This unit is gradationally overlain by a band of medium gray calcareous shale and argillaceous limestone, approximately 40 cm-thick, which forms a falls in the creek bed. This is gradational above and below into less calcareous mudstone and contains abundant crinoid columnals in stringers, the small rugose coral *Stereolasma*, and fragmentary and complete specimens of the trilobites *Phacops rana* and *Greenops boothi*. Trace fossils in form of pyritic, sinuous burrows are very abundant in this zone. This bed is traceable into the "Smoke Creek bed" of Erie County, NY (Brett, 1974; Baird and Brett, 1983). The unit, in turn, is gradationally overlain by gray, calcareous and relatively fossiliferous mudstone with a fauna resembling that of Unit A which grades upward into darker, less fossiliferous shale.

A band of darker gray, relatively hard, fissile shale, forms a slight projection in the bank in some areas about 8 m (26.4 ft) above the base of the Windom. This interval (the Fisher Gully beds) contains abundant *Emanuella praeumbona*, large specimens of *Ambocoelia umbonata*, and occasional *Leiorynchus* and *Spyroceras*. It is overlain abruptly by a bed of crumbly medium gray mudstone packed with fossils including *Cystilphylloides*, *Helioplyllum*, and other large rugose and tabulate corals, atrypid brachiopods (*Pseudoatrypa* and *Spinatrypa*), *Mediospirifer*, and at least 55 other species of invertebrate fossils. Unit E, which occurs 8.57 m (28.3 ft) above the base of the Windom at Fall Brook, has been designated the Fall Brook coral bed closely resembles that of the slightly older Bayview coral bed and indicates a recurrence of nearly identical environmental conditions under which coral biostromes developed widely in western N.Y. The Fall Brook bed has been traced from Central Genesee county, eastward to Seneca Lake, a distance of approximately 90 km (56 mi). Large rugose corals are restricted to a 30-40 cm-thick band, however, other fossils including small rugose corals (*Amplexiphyllum* and *Stereolasma*), *Pseudoatrypa*, *Mediospirifer*, *Douvillina*, abundant crinoid columnals, and bryozoans persist upward for approximately 1.5 m (5 ft) into the overlying mudstone. This richly fossiliferous, but non-coral bed assemblage has been termed the Taunton beds by Baird and Brett (1983). The upper portion of the Taunton interval bears three zones of large, calcareous, nonseptarian concretions. Fossil bands run continuously through concretions, which indicates possible relationship between carbonate diagenesis and organic remains.

A thin (30 cm-band) of argillaceous limestone containing abundant small rugose corals (*Stereolasma*) and a few atrypid brachiopods Spezzano Gully bed occurs about 11 m (36.3 ft) above the base of the Windom Shale at Fall Brook. This unit grades upward into dark gray, slightly calcareous, petroliferous shale with abundant pyritic sinous burrows and occasional nodules of pyrite and scattered fossils including *Stereolasma* and *Pseudoatrypa*.

The upper Windom Shale at Fall Brook consists of very dark gray fissile, pyritic shale (Gage Gully Bed). This shale is generally sparsely fossiliferous, but some layers contain abundant *Allanella tullius*, small *Ambocoelia*, *Devonochonetes*, and rare *Leiorhynchus* and *E. praeumbona*. A zone of pyritized fossils near the top of this interval has yielded nuculid bivalves, the trilobite *Greenops boothi*, the nautiloid *Spyroceras*, and rare large specimens of the goniatite *Tornoceras* cf. *T. uniangulare*. The highest beds of the Windom are black, platey shale with *Allanella tullius*. The contact between these beds and the overlying Geneseo Black Shale is often difficult to recognize in the Genesee Valley area because their lithologies are similar. However, the Geneseo is somewhat harder, weathers rusty and is more petroliferous than the upper Windom. The contact, here, as elsewhere in western New York, is sharp and unconformable.

Small lenses of Leicester Pyrite generally less than 10 cm-thick, occur at the Windom/Geneseo contact. The Leicester in this area contains abundant tubular pyrite, apparently reworked burrow fillings, as well as small brachiopods, nuculid bivalves, and rare nautiloids and goniatites from the erosionally truncated Windom (Brett and Baird, 1982). Return to vehicles, proceed straight to turn around.

32.65	0.10	<u>In driveway, reverse route back up Dewey Hill</u>
33.35	0.70	Junction NY 63/39 at Fall Brook fruit stand. <u>Turn right (south) on NY 63.</u>
33.80	0.45	<u>Pull off at wide area along shoulder</u>; walk up bank to right and proceed down dirt path to brink of Fall Brook Falls.

STOP 2A

Scenic overlook of Fall Brook Gorge: Dark shales on upper creek banks are West River Member of Genesee Formation falls is capped by Genundewa Limestone (20 in-thick). Caution: Stay back from edge, vertical drop of over 100 feet (Possible lunch stop).

Return to vehicles and proceed straight to turn around in farm drive.

34.30	0.50	Cross Fall Brook

34.40	0.10	Turn around at driveway.
34.90	0.50	Return to U.S. 20A junction; proceed straight on Rts. 20A/63/39 and continue to Geneseo.
35.90	1.00	Fork of Rts. 39/20A at edge of Geneseo. Proceed straight on US 20A.
37.10	1.20	McDonalds on right (possible rest stop).
39.10	2.00	Upper end of Jaycox Creek tributary; Genundewa Limestone in exposed south of road.
40.70	1.60	Entrance ramp to I-390 (northbound) on right; bear right onto ramp.
40.90	0.20	Merge onto I-390
43.20	2.30	Cross Conesus Creek; outlet from Conesus Lake flows into the Genesee River.
46.80	3.60	Exit for NYS-U.S. 20; Avon, Lima; bear right onto exit.
47.10	0.30	Junction; Rts. 5 & 20; turn right (east)
50.60	3.50	Village of Lima
51.10	0.60	Junction Rt. 15A; continue on Rts. 5-20.
53.85	2.75	Valley of Honeoye outlet creek.
54.85	1.00	Route 65; West Bloomfield
57.30	2.45	View of Bristol Hills to south
59.80	2.50	Route 64; East Bloomfield
62.80	3.00	Rt. 64 to right leads south into Bristol Valley and classic Windom localities; near this location the "Unnamed member" is becoming truncated
64.00	1.20	Village of Centerfield; type locality of the widespread Centerfield Limestone is on Schaeffer Creek north of Rt. 20
64.60	0.60	Cross Schaeffer Creek
66.80	2.20	Junction Rt. 5-20 bypass around Canandaigua; turn right onto bypass
67.50	0.70	Junction 21 south; (goes to Naples); continue on Rt. 5-20.

69.10	1.60	Junction 21 north (into Canandaigua) continue on Rt. 5-20
69.40	0.30	Driveway to McDonalds on right (possible rest stop).
70.30	0.90	Junction NY 364 (to east shore of Canandaigua)
70.95	0.65	Creek to left exposes Levanna black shale.
72.65	1.70	Cross Hopewell Ravine; creek just below 20 exposes Jaycox and Tichenor members, small but excellent outcrop.
75.30	2.65	Village of Alonquin
77.40	2.10	Village of Flint
77.60	0.20	Cross Flint Creek
78.40	0.80	Large landfill site on right
81.80	3.40	Commercial strip on western fringes of Geneva
82.50	0.70	Junction 14A-245 to Penn Yan; continue on Rt.5/20
82.60	0.10	Junction Pre-Emption Road (County Rt. 6) to Bellona; turn right (south); Pre-Emption line is an old western boundary line of Massachusetts territory.
85.30	2.70	Snell Rd. on left
85.40	0.10	Crossing Wilson Creek; downstream is a large waterfall over Centerfield Limestone; top phosphatic bed is exposed near the Pre-Emption Road bridge.
87.00	1.60	Benton Run on left exposes nearly complete Ludlowville Formation.
88.85	1.85	Junction Kashong Rd.; turn left (east).
89.40	0.55	Pull off in gravel parking area to right. Proceed on foot down path on bank to Kashong Creek.

STOP 3. KASHONG CREEK, LOWER FALLS

Locality

Exposures along the bed and banks of Kashong Creek just south of Kashong Road and 1.5-2.0 km (0.9-1.2 mi) west of NY 14, township of Geneva, Seneca County, NY (Geneva South 7.5 ft Quadrangle, 1953).

References

Cooper (1930), Baird (1978, 1979).

Description of Units

This creek section is, arguably, one of the most complete upper Hamilton sequences exposed in the Finger Lakes Region; it is a classic reference section and the type locality for the Kashong Shale Member. Nearly the entirety of the Ludlowville and Moscow formations are exposed on Kashong Gully. We will examine the Moscow Formation in detail, commencing with the Tichenor Limestone which caps the highest wateralls (10 m, 33 ft) in the glen; a somewhat lower (8 m, 26 ft) waterfall 400 m upstream from the latter, shield up the Menteth Limestone Member, and a third very low falls (approximately 2 m, 6.6 ft high) is formed by the resistant upper phosphatic shell bed at the top fo the Kashong member and the overlying basal siltstone beds of the Canandaigua Member. A short distance upstream from this uppermost falls the section ends and the creek flows on glacial till.

The Hamilton beds in this area are gently deformed by Alleghenian (?) folding and faulting. The creek cuts most perpendicularly through a small anticline-syncline pair near the Kashong shale type section; the axis of the syncline is approximately at the low falls over the Kashong/Windom contact beds (discussed above); this contact is exposed again about 100 m upstream on the opposite (western limb) of the syncline, at the position of the old bridge across the creek. The bulk of Kashong section is exposed downstream from the small falls on the strongly west dipping eastern limb of the syncline. The crest occurs just downstream (east) of the high Menteth waterfalls. Below that falls the creek flows down the gentle east limb dipslope on the lower Deep Run beds for about 100 m (330 ft) before descending over the high Tichenor capped waterfalls. A relatively large down-to-the east normal fault with about 20 m (66 ft) displacement and minor splay faults occur near the mouth of Kashong Creek, but will not be examined on this trip.

The Tichenor through basal Windom sequence will be described and examined in detail; lower stratigraphic units at the base of the high Tichenor waterfalls are accessible by a steep (dangerous!) pathway down the south side of the gully or by walking upstream from the mouth of the Kashong Glen; however, we will simply observe these units from the top of the waterfalls. Stratigraphic units are described below in ascending order.

Ludlowville Formation

Upper Wanakah Shales: The lowest stratigraphic units observable in this part of the gorge are medium to dark gray shales on the upper Wanakah Member. These shales outcrop below a smaller waterfall 100 m (330 ft) downstream from the large Tichenor-capped falls; this latter falls is capped by silty, calcareeous mudstones of the basal Jaycox Member (correlative with Unit A of the Jaycox run description; Stop 10, page 86). Upper Wanakah at the base of this falls consists of relatively fossiliferous, gray shale characterized by an abundance of small *Pleurodictyum* corals, brachiopods (such as *Athyris*, chonetids, and *Ambocoelia*), and *Phacops* trilobites. This sequence is capped by a fossil has bed, identified by Baird (1981) as the Bloomer Creek bed. Overlying this layer in the face of the small waterfall are 2 m (6.6 ft) of dark gray to nearly black shales, bearing *Leiorhynchus*, small *Tropidoleptus* and small ambocoeliids.

Jaycox Member: The face of the high waterfalls and the creekbed down stream to the cap fo the next small falls expose a light bluish gray mudstone of the Jaycox Member. The lower half of this sequence consists of alternating calcareous mudstone and fossil rich limestone layers; these latter have a diverse fauna of abundant fenestrate and fistuliporid bryozoans, corals, especially *Trachypora*, brachiopods such as *Tropidoleptus* and *Longispina*, andabundant crinoidal debris. The upper Jaycox beds (upper half of falls face) consist of sparsely fossiliferous, hard, blocky, calcareous mudstone containing scattered very large speciments of the tabulate coral *Pleurodictyum*. The uppermost few centimeters of the Jaycox beds are visible at the top of the waterfalls.

Moscow Formation

Tichenor Limestone: This is a very widespread, thin (0.5-1 m, 1.7-3.3 ft) carbonate interval, traceable from Lake Erie, eastward at least to Chenango Valley; east of Cayuga Lake. (Baird, 1979; Griffing, 1994). The Tichenor is sometimes referred to as the basal bed of the "Portland Point" Member (Baird, 1979) At Kashong Glen this member, which crops out just upstream from the brink of the highest waterfalls, consists of thin-bedded argillaceous, crinoidal packstone. The Tichenor is highly fossiliferous, characterized by large crinoid columnals and bryozoans with a few solitary, large rugose and tabulate corals.

In the Seneca Valley, the Tichenor does not form a compct, sharply based ledge, as it does at localities both east and west of this area. In fact, the basal disconformity which characterizes the Tichenor at all other locations here is either very crptic or absent, and the lithology closely resemble that of more fossiliferous beds in the under-and overlying Jaycox and Deep Run members.

Deep Run Member: Overlying the Tichenor is about 10 m (33 ft) of hard, blocky, calcareous mudstone referred by Cooper (1930) to the Deep Run abundant, poorly preserved *Zoophycos* trace fossils. However, beds occurring about 1-2 cm above the Tichenor Limestone are highly fossiliferous, biostromal, argillaceous limestones resembling the Tichenor. The creek flows on dip slope of these units exposing relatively large bedding planes; these display small mounds of fistuliporoid bryozoans and crinoid columns (up to half meter in length); some of these columns form rhizomatous ("runner") holdfasts. Other common fossils include fenestrate and sulcoreteporid bryozoans, varied brachiopods, bivalves, large trilobites and well preserved (but difficult to extract) calyces of crinoids and blastoids. The large size of many fossils (especially trilobites) indicates favorable environments in terms of food supply, as might be expected in shallow muddy areas; however, the rarity and scattered to patchy distribution of fossils in most of the Deep Run Member suggests that colonization of the sea floor by benthos was sporadic and probably limited by soft, unstable substrate and/or high turbidity near the sea floor.

Note the considerably greater thickness of the Deep Run at Kashong Glen than at Jaycox Run (Stop 1). The Tichenor and Menteth limestones converge and eventually merge both east west of this area.

The Deep Run wedges out abruptly both east and west of the Finger Lakes. This unit which closely resembles the calcareous mudstone facies of the older Mottville, Centerfield, and Jaycox carbonate intervals apparently characterizes deposits of a shallow rapidly subsiding trough bordered by very shallow (within wave base), crinoidal sandy shoals. The Deep Run facies is considered to represent a wedge of rapidly-deposited, fine-grained sediments which were winnowed from adjacent shallow tichenor-type shoal environments that bordered a central trough. Interfingering of Tichenor-like lithologies with the barren mudrock indicates close proximity of the two types of facies.

Menteth Limestone Member: This is compact, 30 cm-thick silty; siliceous, heavily bioturbated limestone which caps the moderately high waterfall west (upstream) of the Tichenor falls. This limestone is particularly characterized by an abundance of *Zoophycos* burrows, *Mucrospirifer*, *Spinocyrtia*, and large specimens of *Phacops*.

The undersurface of the Menteth in some areas appears gradational with the underlying Deep Run; elsewhere, as here, it is undulating and displays large scoured out burrow fillings indicating some erosion prior to its deposition.

This unit appears nearly identical throughout its outcrop despite thickening and thinning of synjacent shales (see Jaycox Run, Stop 1, descriptions). We have interpreted this unit as a winnowed, bioturbated calcisiltite reflecting reworking of Deep Run muds, following infilling of a subsided trough.

Kashong Shale Member: The Kashong Member abruptly overlies the Menteth. It consists of bluish gray mudstones which are somewhat softer, less calcareous and silty than the Deep Run Member, with horizons of small irregular ovoid to pipelike carbonate concretions, silty limestones and highly fossiliferous calcareous mudstones. Fossils are moderately abundant in the bluish gray mudstones and include, particularly, brachiopods (*Tropidoleptus*, "*Spirifer*" *marceyi*, and *Mucrospirifer*), the tabulate coral *Pleurodictyum*, bryozoans, bivalves, large trilobites, including *Dipleura*, phyllocarids, and crinoid stems.

The Kashong at this location, displays repetitive, cyclic motifs, consisting of: (a) sparsely fossiliferous blue gray shale, (b) zones of grotesquely-shaped carbonate concretions, capped by, (c) thin beds of burrowed calcisiltite resembling the Menteth Limestone, and/or (d) complex condensed shell beds. There are two complete cycles and two thin incomplete cycles within the member. These are interpreted as minor regressive, shallowing upward hemicycles, the complex shelly phosphatic pebble beds record sediment starvation and/or winnowing associated with cycle reversals.

A widespread, complex shell bed occurs within the Kashong Shale about 2.6 m (8.6 ft) above the base. Informally named the "*Rhipidomella*-

Centronella" bed (or R-C bed) this unit contains a great abundance and diversity of fossils including the nominal brachiopods and the large spiriferid *Spinocyrtia* (commonly highly corroded), *Douvillina*, varied bryozoans, bivalves, gastropods, trilobites, and crinoid debris. This bed, which locally approaches the appearance of the Tichenor Limestone (and was formerly considered to be the top of the Portland Point Member; Cooper, 1930; Baird, 1979) appears to represent a widespread interval of winnowing and shell concentration, perhaps associated with a minor shallowing cycle. It is overlain by bluish gray shale resembling the lower Kashong.

Unnamed Shale Member: Only the basal 2 m (6.6 ft) of this previously unrecognized member of the Hamilton Group are exposed at this section. The unit commences with the Barnes Gully phosphatic pebble bed, a slight discontinuity may exist. At eastern localities a tongue of typical Kashong mudstone with *Tropidoleptus* is present between the phosphatic bed and the Curtice Road bed. This bed resembles burrowed calcisiltites of the Menteth, and consists of *Zoophycos*-burrowed calcareous silt, with a fauna of *Spinocyrtia*, *Mucrospirifer*, chonetids, *Pholidostrophia* and other brachiopods.

Also, the basal "unnamed" unit locally displays a shell bed especially rich in strophomenid brachiopods and containing rare rugose corals. The silty bed shows a gradational top, passing upward into silty shales with a deeper water biofacies of small chonetids which then passes up into soft medium gray shales with very abundant *Longispina*. This reflects a deepening event, stronger than those of the lower Moscow, which resulted in a return of lower aerobic to dysaerobic, deeper water enviornments in western New York. This transgression apparently explains the recurrence of litho- and biofacies closely similar to those of the lower Hamilton formation. We presume that such facies coexised with the shallower water facies of the Moscow interval, but that they were displaced southwestward into the basin axis and do not appear anywhere within the New York outcrop belt during deposition of the Jaycox to Kashong interval.

Discussion: The upper Hamilton Group in the vicinity of Kashong Glen displays several differences from outcrops of the equivalent interval to the west (Genesee Valley, see Stop 1). Several units (e.g., upper Ludlowville, Tichenor, and Deep Run shales) show subtle differences indicating deeper water in the Kashong Glen area than at sites either east or west of this region. For example, the Wanakah and Spafford-equivalent shales which are represented by fossiliferous, gray mudstones at Genesee Valley, and by comparable but siltier facies at Cayuga Lake, here are composed mainly of dark gray, fissile shale with a low-diversity, *Leiorhynchus*-dominated fauna; this seems to indicate deeper, more dysaerobic water in an area centered in the Seneca Valley than in the bordering areas. Similarly, the Tichenor-Deep run units are differentially thicker here than at Genesee Valley or the Cayuga region; they are also less carbonate rich; in the case of the Tichenor the limestone is a pack- or wackestone in the Seneca Lake region but a grainstone both to the east and west. It is less rich in large corals and crinoids and appears to be nearly conformable above and below whereas to the east and west it is bounded by an erosional unconformity at the base and, locally, on the top. Again, this seems to indicate an area of differentially deeper, quieter water near the Seneca Lake meridian.

		Return to vehicles; reverse route on Kashong Road (west)
89.95	0.55	Junction Pre-Emption Road; turn left (south)
90.40	0.45	Rice Road; enter Bellona Village
90.70	0.30	Cross Kashong Creek; turn left to parking area adjacent to Old Mill building; cross bridge on foot and proceed east on path to foot of Falls over Tully Limestone

STOP 4: KASHONG CREEK AT BELLONA

Locality

Exposures at waterfalls along Kashong Creek 0.1 km east (downstream) from Pre-emption Road and upstream to 0.2 km west of road, town Bellona, Yates County, N.Y. (Stanley 7.5 ft Quadrangle, 1952).

Reference

Heckel (1973)

Description

This outcrop provides an excellent section of the top of the Hamilton Group (Windom Shale), the unconformable overlying Tully Limestone, and the basal Genesee Group (Geneseo Shale). This classic section was critical in Heckel's (1973) subdivision of the Tully Formation into the lower and upper members separated by an unconformity.

Moscow Formation

Windom Shale: Lowest units exposed in this portion of Kashong Creek are fossil-rich medium bluish gray shales of the upper Windom Member ("Taunton Beds"); this 7 m (23 ft) interval contains many thin, lenticular brachiopod-, rugose coral -, bryozoan-bearing shell beds, mutually separated by sparsely fossiliferous mudstones. Thicker beds probably record relatively long spans of slow deposition during which shells accumulated and were reworked by occasional strong storm waves; overlying mudstones apparently represent rapid influxes of mud that terminated shell buildup.

The uppermost 2 m (6.6 ft) of the Windom display marked change to dark gray or nearly black shale with diminutive brachiopods. This records a relatively strong transgressive (deepening event) that occurred near the close of Hamilton deposition.

These beds display a sharp, erosional contact with the overlying Tully limestone. An interval of diastrophic upwarp and erosional truncation, perhaps associated with subaerial exposure prior to Tully deposition.

Nonetheless, despite this evident break both the Windom and the lower Tully belong to the same conodont subzone (middle *P. varcus* subzone).

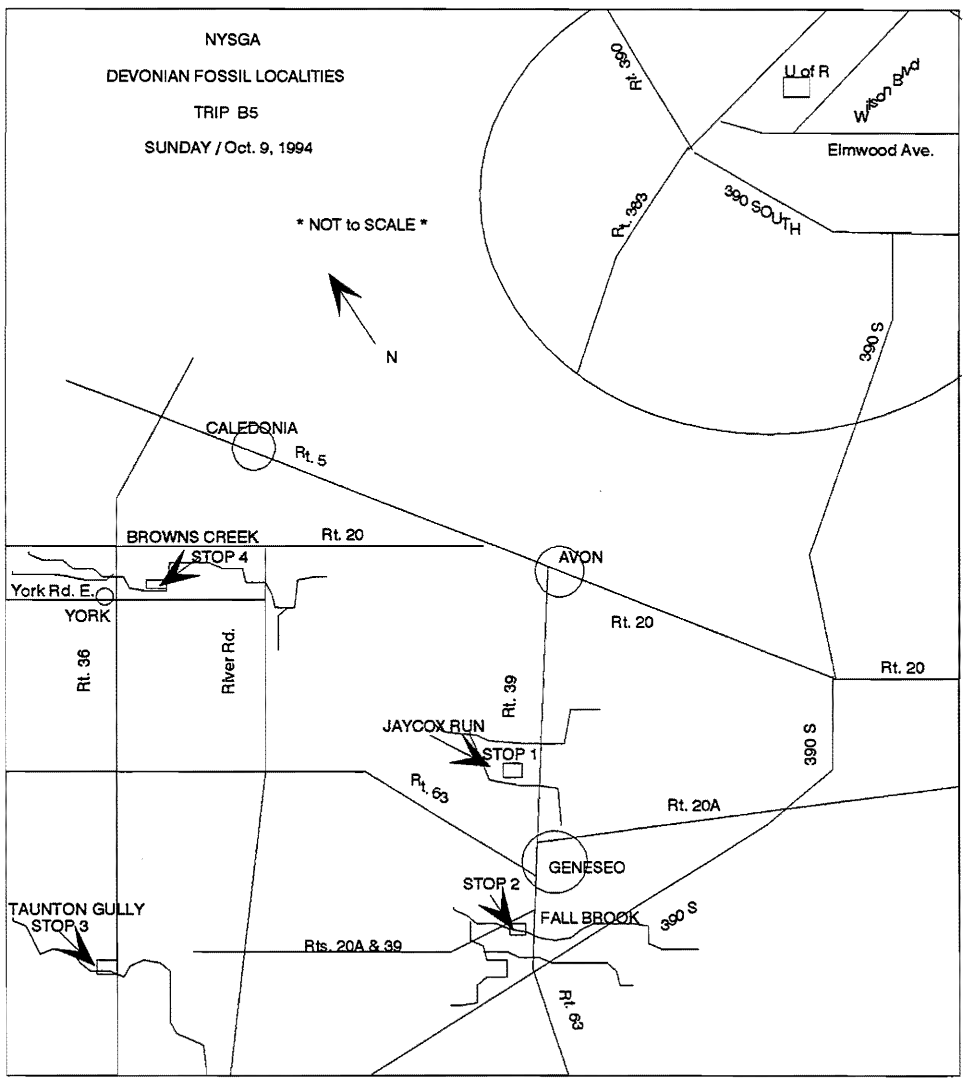
Tully Limestone: At the falls the light-gray, micritic Carpenter Falls bed (0.6 m-thick) of the Tully Lower Member, overhangs the Windom Shale; its basal surface displays large elongate burrows up to 8 cm. across, that were produced in overcompacted Windom muds and subsequently infilled with Tully matrix. The Carpenter Falls bed contains the index brachiopod *Hypothyridina*, as well as atrypids, small rugosans, trilobites, and crinoid debris. At the upper surface of this bed Heckel observed a widespread mid-Tully erosion surface, and, at this locality (upstream from Pre-emption Road Bridge), he noted possible truncated stromatolites at this surface. Hard fossiliferous wackestones, of the Taughannock Falls bed (Tully Upper Member) overlies this intraformational disconformity. The Taughannock Falls bed is capped by a thin, shaley bed with very abundant large rugose corals (*Heliophyllum* and *Cystiphyllolides*) and *Favosites* termed the Bellona coral bed for this excellent exposure. Upstream (west) from Pre-emption Road, the large corals are clearly visible on a large bedding plane on the creek floor. The Bellona coral bed has proven to be a key mappable unit. The Bellona bed is abruptly overlain by a thin (0.6 to 1.0 m) remnant of the Moravia bed; the upper Moravia bed and Fillmore Glen bed are absent here.

The top of the Moravia bed is marked by an erosion surface that, in this area, shows a thin layer rich in crinoidal debris, conodonts, fish bones, pyrite and glauconite; a few thin stingers of this lithology recur in the overlying black Geneseo Shale. This lag debris is believed to be a lateral equivalent of the Leicester Pyrite which is know to overlie the erosional top of the Tully about 12 km (7 m) northwest at Gorham. This bed has yielded conodonts diagnostic of the upper *hermanni-cristatus* subzone, whereas the underlying Moravia bed is of the middle *varcus* Zone age. Evidently, a considerable hiatus separates these units, during which time the upper Tully units were erosionally bevelled, prior to Geneseo deposition.

Geneseo Shale: The erosional upper surface of the Moravia bed, or, locally, the Bellona bed, is sharply overlain by platey, black Geneseo Shale, which is fossiliferous, except for the stringers of reworked crinoidal debris, men tioned above. This unit records major deepending of the Taghanic onlap. It is presently considered of the latest Middle Devonian (late Givetian) age.

		Return to vehicles
		<u>Reverse route and proceed north on Pre-Emption Road</u>
97.60	6.90	Junction US20 NY5, but <u>continue straight north on Pre-Emption Road</u>
102.80	5.20	Entrance to Oak corners Quarry on left. This is an excellent Onondaga Limestone section (Ver Straeten et al. trip - this guidebook).
103.70	0.90	Junction NY 96; <u>turn left (west)</u>
105.70	2.0	Town of Phelps

106.20	0.50	Cross Flint Creek; outcrops of upper Silurian dolostone
107.00	0.80	Junction NY88; a right turn here leads up to cuts below thruway in Bertie\Bois Blanc\Onondaga
107.10	0.10	Outcrops of Onondaga Limestone in Flint Creek left side
107.50	0.40	Driveway to left leads to outcrops of Nedrow shale along Flint Creek; (see Ver Straeten, this volume).
114.70	7.20	Cross Canandaigua outlet creek.
115.00	0.30	NY21; turn right (north)
115.05	0.05	Turn left into entrance to NY State Thruway (Manchester)
115.80	0.75	Merge onto I-90 (Thruway) westbound from entrance
117.20	1.40	Field exposure of Camillus Shale on left
124.60	7.40	Rising onto moraine; rest stop at top
126.30	1.70	Exit 45; I-490 eastern Rochester exit
137.50	11.20	Exit 46; I-390 north; exit onto 390 N and continue to university


NYSGA
DEVONIAN FOSSIL LOCALITIES
TRIP B5
SUNDAY / Oct. 9, 1994
* NOT to SCALE *
N
Rt. 390
U of R
Wilson Blvd
Elmwood Ave.
Rt. 383
390 SOUTH
390 S
CALEDONIA
Rt. 5
BROWNS CREEK
STOP 4
Rt. 20
York Rd. E.
YORK
AVON
Rt. 20
Rt. 20
Rt. 36
River Rd.
Rt. 39
JAYCOX RUN
STOP 1
Rt. 63
390 S
Rt. 20A
GENESEO
STOP 2
FALL BROOK
390 S
TAUNTON GULLY
STOP 3
Rts. 20A & 39
Rt. 63