FRASNIAN (UPPER DEVONIAN) STRATA OF THE GENESEE RIVER VALLEY, WESTERN NEW YORK STATE

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INTRODUCTION

History of Investigation

The Frasnian section in the Genesee Valley is located in the western part of the central Devonian outcrop belt of New York State that stretches from the Catskill Mountains to Lake Erie. The Genesee Valley was close to the center of the Fourth Geologic District of the first state survey, the district between Cayuga Lake and Lake Erie, covered by James Hall. Hall's final report, the monumental Part IV of the Geology of New York (Hall, 1843), is the starting point for Devonian studies in the region (Figure 1). The rocks of the classical Genesee, Portage and Chemung divisions consist of a succession of marine siliciclastics beginning with dark basinal shales (Genesee) that contain a pelagic molluscan fauna, which are overlain by lighter colored shales and siltstones that contain a pelagic and benthic fauna (Portage and Naples to the east) that were deposited in basin-and-slope environments. These strata are overlain by siltstones and sandstones bearing a benthic brachiopod fauna (Chemung) that were deposited on the slope and outer-shelf. Most of the fossils in these units were described in monographs by Hall (1879) and Clarke (1899, 1904). The excellent exposures in the Genesee Valley made this section a center for geological studies of the distal rocks of the Catskill Delta, which record stages in the filling of the Appalachian Foreland Basin. Beginning with Hall's (1843) observation of the lateral changes in lithology within each division ("constant increase of arenaceous matter" to the east and "increase in mud or shale" to the west) the Genesee Valley section came to play a central role in the application of the facies concept to the Appalachian Devonian.

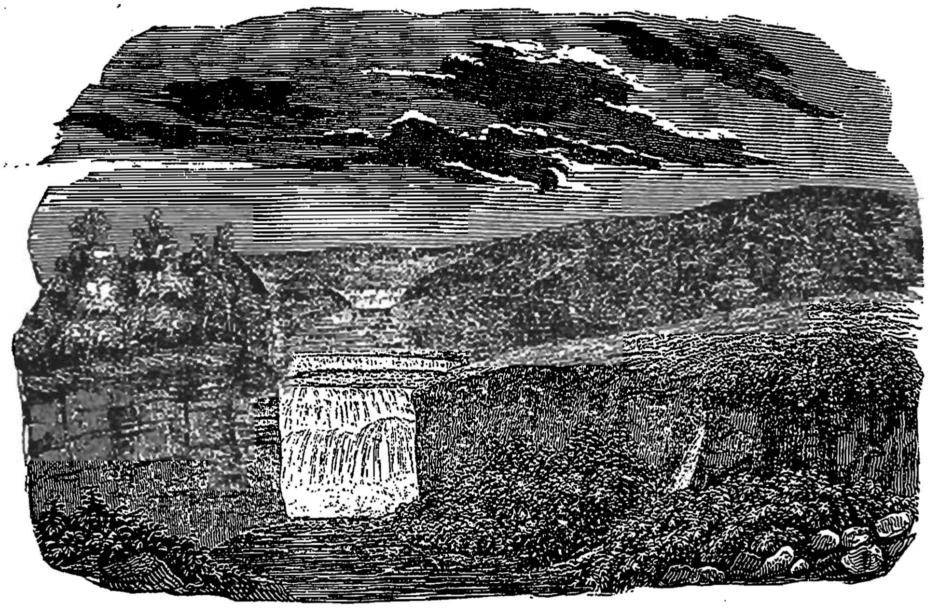

Figure 1. "Upper and Middle Falls of Portage". From a sketch by Mrs. James Hall. From Hall (1843).

Application of facies concept

When Chadwick (1935) declared that "Chemung is Portage" he could have added "Portage is also Genesee" to the title of his paper. It was recognized that the original divisions were facies-equivalents of each other, each one thickening shoreward (eastward) and grading into and interfingering with the adjacent facies. The dark shales of the offshore basin facies of the Genesee were seen to pass shoreward into the lighter colored shales and sands of basin-margin and slope facies (clinoform/ramp) of the Portage (and Naples). The Portage, in turn, intertongued with the sandy Chemung facies of the outershelf, which grades into nearshore shelf and shore deposits. The broadly upward-coarsening and vertical stacking of the facies seen in the Genesee Valley region (in the order Genesee-Portage-Chemung) is a manifestation of the upward shallowing and the seaward (westward) shift of each the facies as the Catskill Delta built into the basin. Rickard (1981) provided a concise review of the general relations and Kirchgasser (1985) and Kirchgasser et al. (1986) reviewed aspects of the history of correlations and stratigraphic classification.

Black-shale correlations

While the names Genesee, Portage and Chemung (and Catskill for the terrestrial deposits) survive as useful general descriptors of the major facies, only the name "Genesee" survives as a unit (group) in the modern lithostratigraphic classification (Figure 2). The boundaries of the major stratigraphic divisions and subdivisions employed today are defined by the sequence of key black shales. Each black shale records a deepening event or transgression, and can be correlated from the basin shoreward toward the shelf. Robert Sutton and his students at the University of Rochester and James Pepper, Wallace deWitt, Jr. and George Colton of the U.S.G.S. were instrumental in the recognition of the black shale correlations. These correlations led to the development of modern classification which were synthesized in the correlation charts of Rickard (1964, 1975) and employed in the revised Geologic Map of New York State (Rickard and Fisher, 1970).

Major subdivisions

The major subdivisions of the New York Frasnian (Genesee, Sonyea, and West Falls groups) consist of similar cyclic sequences of basal black shale (respectively Geneseo, Middlesex, and Rhinestreet) overlain by gray and green shales [e.g,. Penn Yan-West River shales in the Genesee Group; Cashaqua Shale in the Sonyea Group; Angola and Hanover shales in the West Falls Group (Figure 2)]. Each group (cycle) thickens and coarsens shoreward (eastward) as the shales of the basin grade into and interfinger with the leading edges of clastic wedges of turbiditic silt and sand. The major units of the coarse clastics from the Genesee Valley and eastward are the Ithaca (Genesee Group), Rock Stream (Sonyea) and Nunda-Wiscoy (West Falls). The Genesee and Sonyea cycles, which together are about 90 meters thick in the Genesee Valley, thin westward to less than 18 meters at Lake Erie, and thicken eastward to almost 500 meters at Cayuga Lake. The cyclicity of black shale-gray shale couplets, so apparent in the major divisions, is also seen at smaller scales down to centimeters and millimeters. Within the succession, numerous thin and widely traceable "event horizons" have been identified (including carbonates, erosional pyrite and distal tubiditic siltstones; Figures 3, 4). All of these subdivisions provide the stratigraphic framework for defining the biostratigraphic sequences of ammonoids (goniatites) and conodonts. They are also the starting point for discussion of the role of eustatic sea-level change, basin subsidence, and tectonics in explaining the cyclicity and facies migrations.

Lithostratigraphy

The Genesee Valley Frasnian lithostratigraphy is based on data from exposures in the deep canyon of the Genesee River at Letchworth Park, from scenic glens and gorges tributary to the Genesee River, wells drilled for

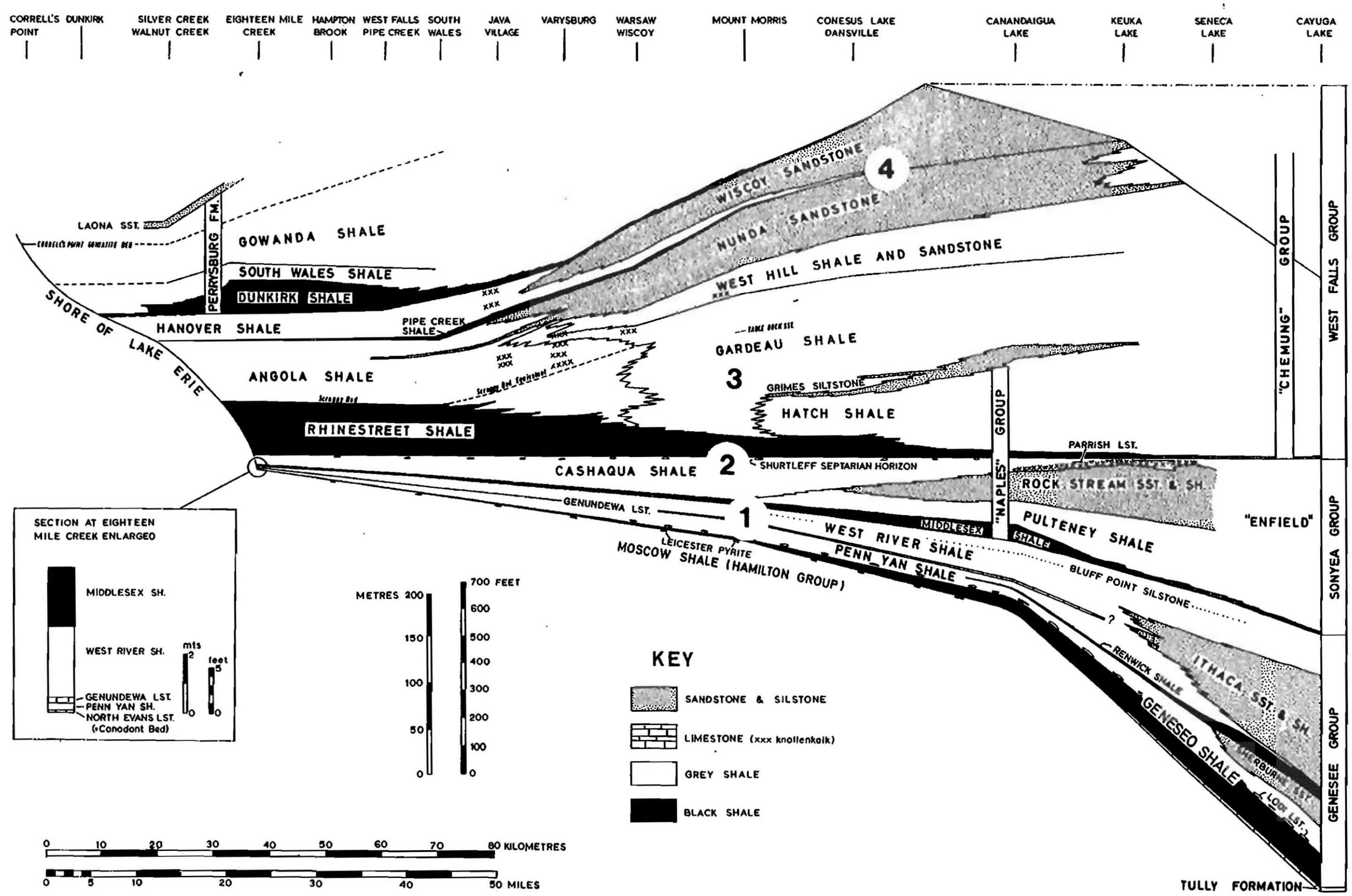

Figure 2. Frasnian facies in New York State from the Finger Lakes to Lake Erie showing stratigraphic position of field-trip stops. Modified from House and Kirchgasser (1993).

hydrocarbons, salt, water and engineering studies, and along road-cuts. Taken together, data on rock type, sedimentary structures, fossils, rock unit sequence, rock unit thickness, and other parameters facilitate a reasonable and broadly applicable lithostratigraphy, one which forms the basis both for stratigraphic correlations within the Appalachians and beyond, and for geologic mapping.

Upward-coarsening of the section

Upper Devonian strata of the Genesee Valley demonstrate the upward coarsening characteristic of the Late Devonian throughout the central and southern Appalachians (Figure 2). When considered with the Onondaga/Hamilton sequence below, the strata exposed in the Genesee Valley south of Rochester represent the classic sedimentary response to tectonics envisaged by many pre-plate tectonics workers and summarized by Pettijohn (1975). Friedman et al. (1992) provide a more current summary based on plate tectonics and note that the Appalachian Devonian sequence exemplifies a foreland basin where sediments were derived from a thrust faulted orogen that resulted from plate interactions. Deposition was in a basin floored by subsiding continental crust. Correlation of the Genesee Valley Frasnian strata across New York and Pennsylvania demonstrates the displacement of deeper water facies by the lateral shifting of shelf, shore, and coastal plain facies to the west and northwest as basin-filling proceeded.

Stratigraphic marker-beds

Though clearly developed, upward coarsening and lateral displacement of facies is complicated by recurring cyclic sequences that make a simple regional pattern locally more complex. Correlation within and between complex stratigraphic sections is made possible through use of the black and dark gray shales (Geneseo, Middlesex, Rhinestreet, Pipe Creek, and Dunkirk) as marker beds. Additional secondary stratigraphic control is based on thin carbonates (e.g., Genundewa, Parrish) and distinctive thin siltstones (e.g., Bluff Point Siltstone), sandstones (e.g., Crosby Sandstone), and less obviously on ash beds.

Black and dark-gray shales serve as the primary basin-wide stratigraphic markers and are utilized as Frasnian formation and group boundaries across New York and throughout the Appalachian Basin (Rickard, 1975; Woodrow, 1985; Woodrow et al., 1989). The shale-bounded rock units, thus defined, enclose sequences of coarser-grained strata, which are also recognized in the stratigraphic terminology. Localized compaction and tectonic effects notwithstanding, the black and dark gray shales are thought to represent a deepening of basin water with resultant transgression of the shore.

Unlike the black shales, thin carbonates have restricted distributions within the basin, but whenever developed they make excellent stratigraphic markers and yield fossils of primary importance to biostratigraphy. Of lesser importance, or of indeterminate value as stratigraphic markers in this sequence, are distinctive

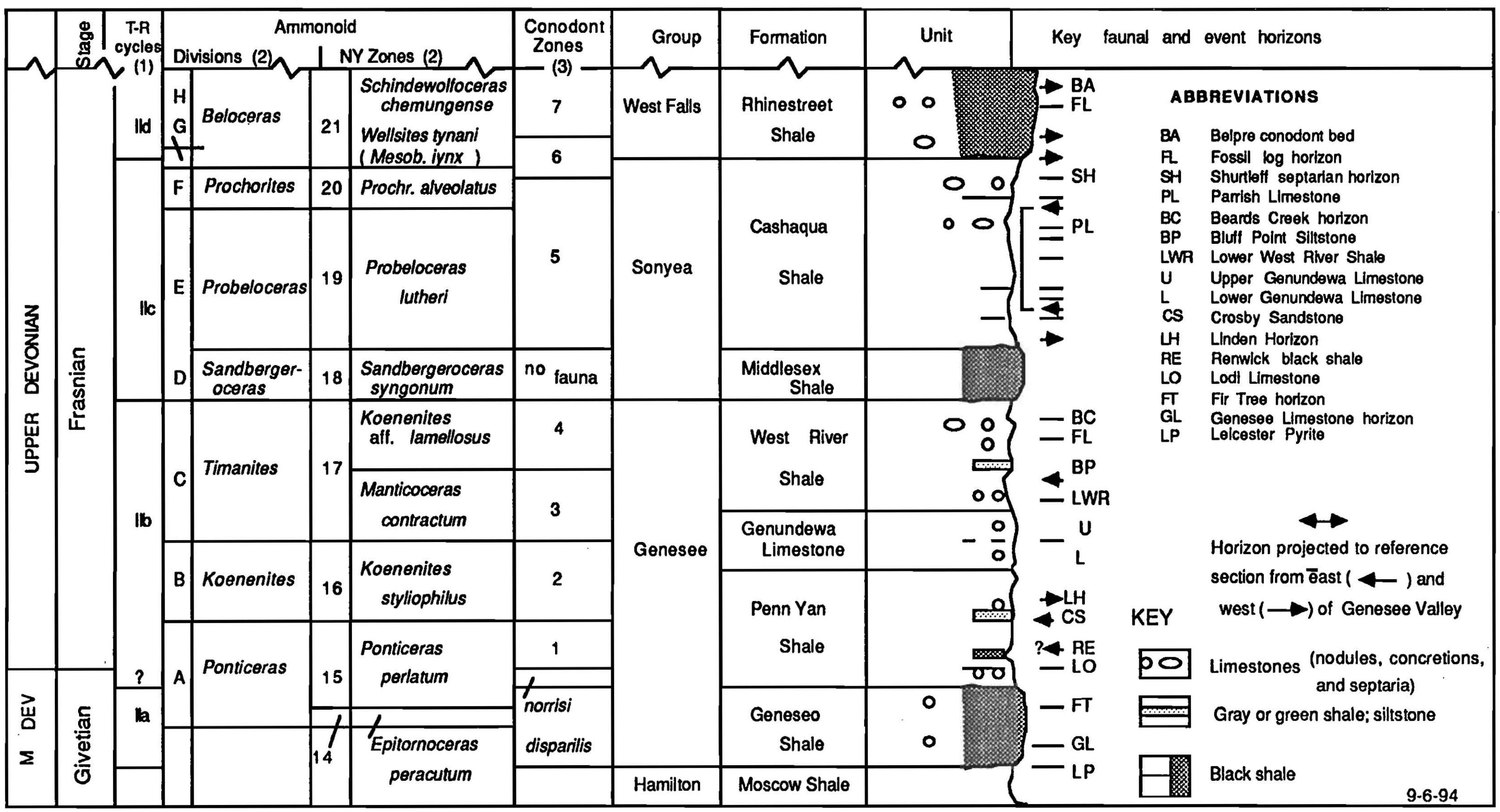

Figure 3. Idealized lower Frasnian section in Genesee Valley based on a composite of sections between the Finger Lakes and Lake Erie. 1. Transgressive-regressive cycles (T-R cycles) from Johnson et al. (1985); 2. Ammonoid (goniatite) sequence follows House and Kirchgasser (1993); 3. MN (Montagne Noire) conodont zones of Klapper (1989; et seq).

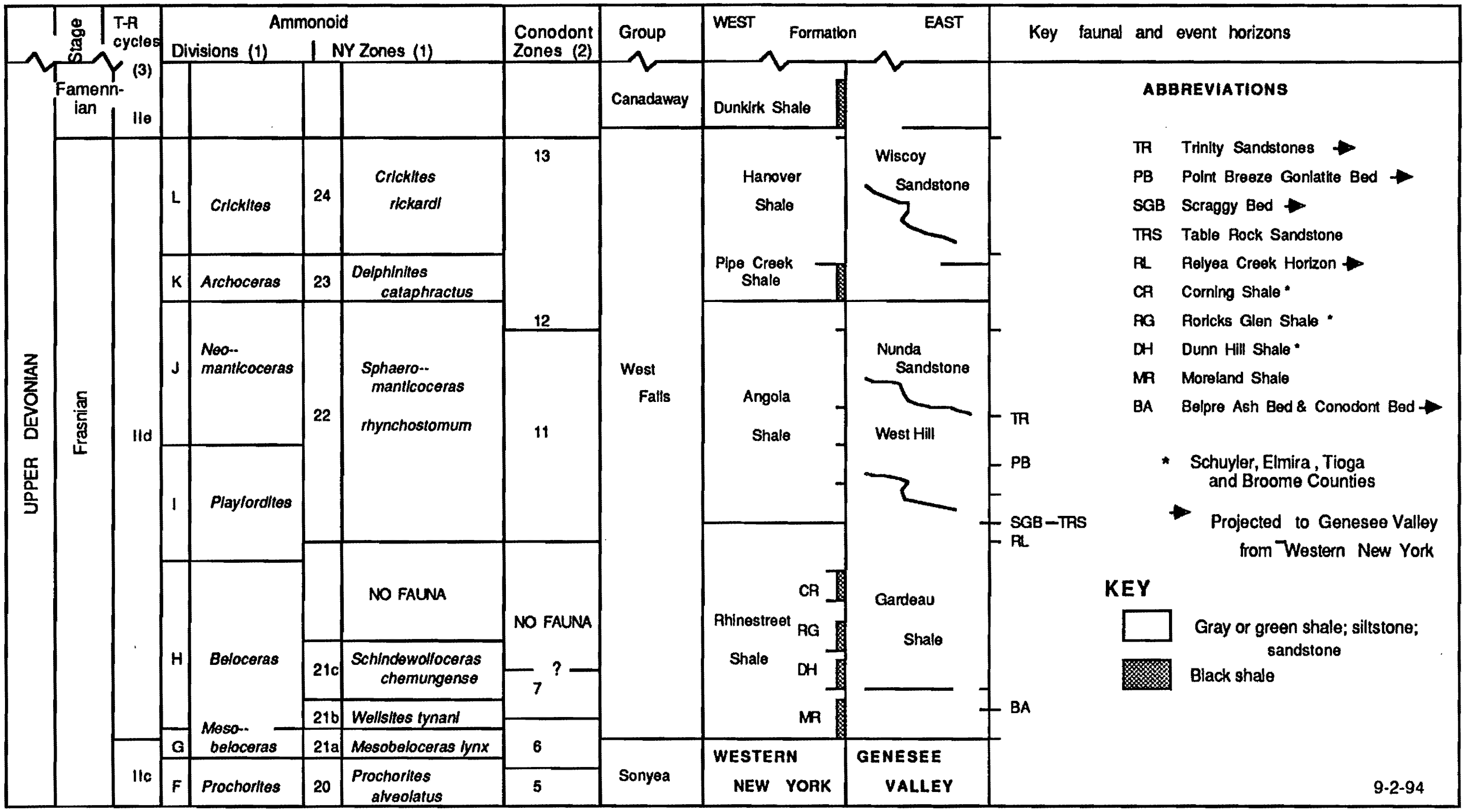

Figure 4. Idealized upper Frasnian section in western New York based on a composite of sections between the Finger Lakes and Lake Erie. Sources as in Fig. 3.

locally traceable siltstones or sandstones and volcanic ash beds. The Bluff Point Siltstone, a single stratum characterized by clear cross-lamination, much of it convolute, was originally recognized by Sutton and Lewis (1966) and correlated within the valley of Keuka Lake. Later, Colton and deWitt (1978) correlated the Bluff Point into the Genesee Valley. Frasnian ash beds, although well known from the surface and subsurface in other states (e.g., Belpre and Chimney Hill in the Chattanooga Shale; Roen, 1980; Roen and Hostermann, 1982) have not been identified with certainty in New York State. The Belpre Ash Bed is apparently represented in the Rhinestreet Shale at Stop 2, the Mount Morris Dam (Wahler, 1984; Levin and Kirchgasser, 1994).

Unique rock types and erosion surfaces

The entire late Devonian sequence thins markedly across western New York (Figure 3) and erosion surfaces developed within the sequence are more pronounced in that direction. Some of these surfaces are marked by phosphate nodules, quartz pebbles, pyritized shells and burrow fills, fish bones, inarticulate brachiopods (orbiculoids and lingulids), conodonts, and various features of erosion and dissolution typical of dysoxic and anoxic environments (Baird and Brett, 1986a, 1986b; Baird et al., 1989; Brett and Baird, 1982). The most prominent example is the Leicester Pyrite which is developed on an erosion surface west of the erosional edge of the Tully Limestone (Figure 5).

SEA-LEVEL CHANGES IN THE LATE DEVONIAN

The cyclic alternation of facies so characteristic of the Genesee Valley Upper Devonian is taken to represent variations of water depth. Johnson et al. (1985) proposed the most comprehensive hypothesis of Devonian sea-level fluctuations. House and Kirchgasser (1993) provide a more recent consideration of the evidence for sea-level fluctuations within the New York Frasnian (Figures 3, 4, 8).

Johnson et al. (1985) recognize within the Upper Devonian of New York cyclic deposition at three scales: 1) long-term "depophases" which span more than a stage; 2) shorter-lived, shallowing-upward, transgression-regression cycles ("T-R cycles") which span 1 to 4, or as many as 14, conodonts zones; and 3) PAC-like, small-scale, 1-5 m thick T-R cycles. In the view of Johnson et al. (1985) the cyclicity in Frasnian strata cannot be a response to glacially-induced eustatic sea-level changes because there is no evidence for glaciation at that time. Instead, the large-scale depophases are thought to reflect changes in the volume of the ocean basins caused by the "...growth and decay of oceanic ridge systems." The smaller scale T-R cycles are thought to reflect " ...mid-plate thermal uplift and submarine volcanism..." The apparent synchroneity of transgressions over parts of North America and western Europe is considered in the analysis to rule out the local effects of tectonics, basin subsidence, compaction and climate.

In New York State the Geneseo, Rhinestreet, and Pipe Creek black shales, as well as the Genundewa Limestone, represent the deepening phase of major T-R

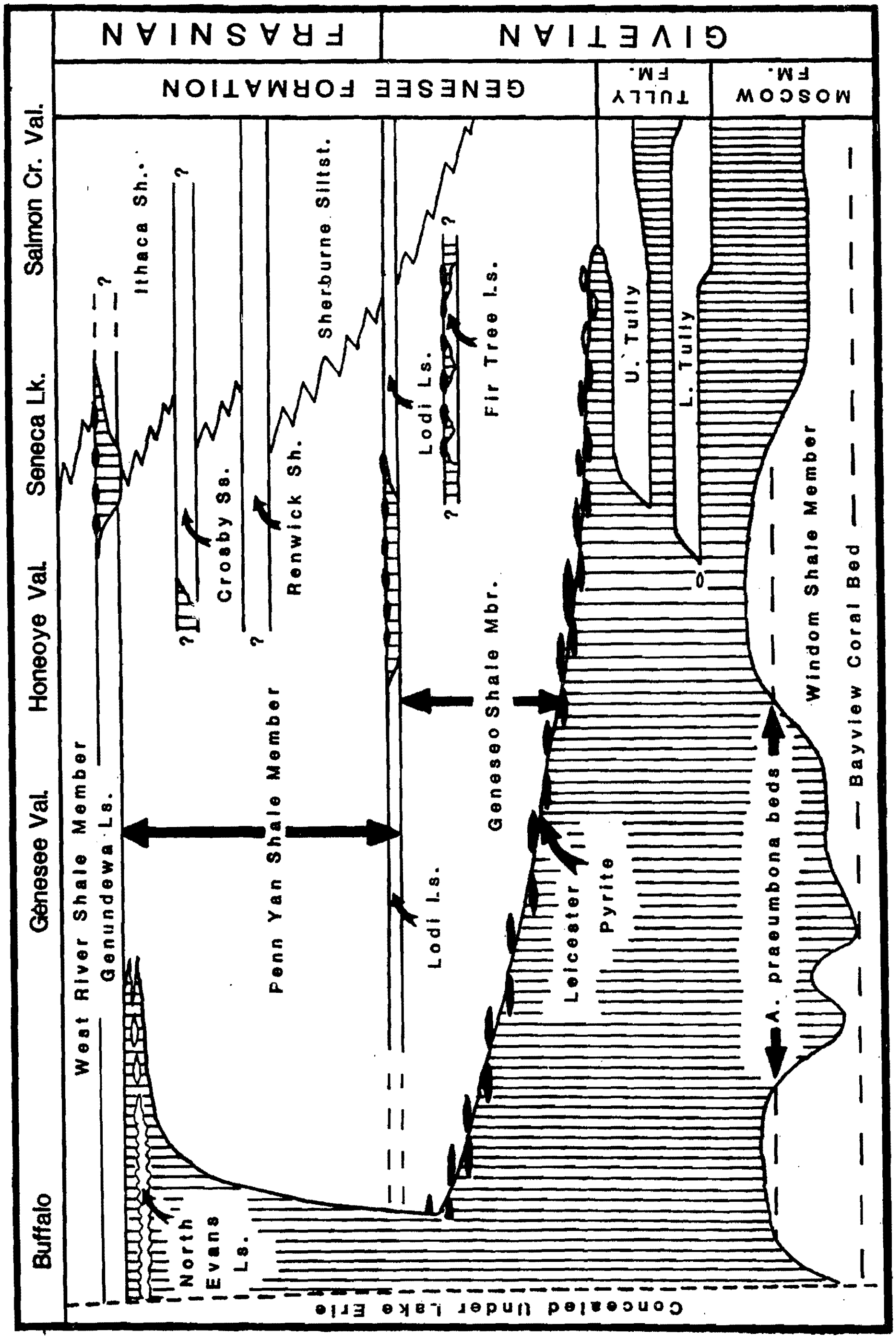

Figure 5. Cross-section of lower Genesee Group showing sub-Genesee Taghanic Unconformity. Lenses of detrital Leicester Pyrite record this long period of submaine erosion prior to burial during the Taghanic onlap of the black muds of the Geneseo Shale. A similar black-shale roofed discontinuity above the Lodi Limestone is at the Givetian-Frasnian (Middle-Upper Devonian) boundary to the east of the Genesee Valley (Kirchgasser et al., 1989). From Baird et al. (1989) and based on Brett and Baird (1982) and Baird and Brett (1986a).

cycles. The coarser clastics within each cycle are the shallowing or fill-in phase (House and Kirchgasser, 1993). The relatively sharp basal contacts of the shales may indicate that deepening (with its attendant shoreline transgression) occurred relatively rapidly while the gradational tops of the black shales indicate relatively slower shallowing as clastics were introduced to the deeper water. Minor T-R cylces are based on the Middlesex and Renwick black shales.

In the cycles based on black shales, it is inferred that deepening brought the pycnocline up the clinoform/ramp and on to the shelf, thus spreading poorly oxygenated or anoxic water across sediment interfaces which were previously relatively well-oxygenated. Benthic faunas were greatly reduced in variety and number, or were displaced entirely. Along the shore, transgression trapped clastics in newly established estuaries or along streams in which gradients had been reduced, effectively cutting off the introduction of clastics to the clinoform/ramp and deeper basin.

Not every episode of deepening resulted in broadly extensive black shales as demonstrated by the development of the Genundewa Limestone, other styliolinid limestones in the Genesee Group, and a few scattered limestones that contain a pelagic fauna higher in the Frasnian [e.g., pre-Middlesex Beard's Creek septarian horizon (BC) and the pre-Rhinestreet Shurtleff Septarian horizon (SH)]. In situations when clastics were cut off from the shelf and clinoform/ramp, and a pelagic fauna flourished, a limestone developed. The formation of carbonates during an episode of deepening (instead of black shale) suggests cut-off of clastics to the basin and the enhanced production of pelagic fauna, perhaps due to upwelling. The limestones are condensed strata that contain evidence of erosion, reworking of shelly materials, and scattered phosphate nodules and lag accumulation of conodonts.

In the terminology of sequence stratigraphy, the Taghanic Onlap of the Genesee Group onto the pre- and post Tully unconformity (Figure 5) is clearly a first order sequence boundary. However, it is not clear how the multi-scale cycles higher in the succession fit into the hierarchy of sequence cycles (the numbered orders). The regional episodic influx of turbiditic silt and sand and the erosive effects of bottom currents and submarine dissolution all would serve to disrupt the accumulation of uniform and symmetrical sequences that might be related to a particular scale of eustatic cyclicity.

BIOSTRATIGRAPHY

Conodonts and goniatite (ammonoid) cephalopods are the principal groups for age determination of marine rocks of the late Devonian age, and both groups are well represented in the New York section. Most of the key goniatites were described by Hall (1843, 1879) and Clarke (1899) and re-illustrated by Miller (1938; see also Linsley, 1994). Modern work dates from House (1962), and the sequence is outlined in Kirchgasser and House (1981) and House and Kirchgasser (1993). Modern work on conodonts in late Devonian strata of New York begins with Huddle (1968, 1981). The sequence is reviewed in Klapper

(1981), and an outline of recent collaborative work with Gilbert Klapper (University of Iowa) is presented here. Work on other important biostratigraphic groups [e.g., miospores, dacryoconarids (styliolines, nowakiids)] is still in a preliminary stage (see Woodrow et al., 1989).

Faunal horizons and "event beds"

While fossils are scattered through the various marine facies of the New York Frasnian, the sources of most identifiable goniatites and conodonts are the "event beds" identified in Figures 2-4. Key fossil beds include the thin styliolinid limestones, argillaceous limestones, concretionary (septarian) or nodular bands, or calcareous siltstones and sandstones. The offshore styliolinid bands (e.g., Genundewa Limestone), which yield datable faunas from the pelagic conodont biofacies, are condensed levels condensed (as well as current-reworked) believed to have accumulated during times of low clastic influx. By comparison, the concretion, septarian, and nodular carbonate horizons may have accumulated in somewhat shallower water during times of "normal" sediment influx. The calcareous siltstones and sandstones are distal siliciclastics carried down the slope and into the basin. The black shales that represent the deepest facies are mostly devoid of macrofossils, but the transgressive lower boundaries of some black shales overlie discontinuity horizons of carbonate dissolution and lag-concentrations of reworked pyrite (including goniatite interiors and burrows), phosphate and quartz pebbles, fish scales and bone, inarticulate brachiopods (orbiculoids, lingulids) and conodonts. The major basal Genesee disconformity is the Leicester Pyrite, similar but thinner "cryptic" horizons occur through the succession.

New York and Frasnian Composites

The idealized sections for the Frasnian of the Genesee Valley illustrated in Figures 3 and 4 are composites of the sequence of units and "event beds". The sections are aligned to the Montagne Noire (MN) conodont zonation of Klapper (1989, et seq.) and are correlated to the global ammonoid divisions following House and Kirchgasser (1993).

For the lower Frasnian of New York, the lithostratigraphic (black shale boundaries and other "event beds") and biostratigraphic data (ranges of conodonts and goniatites) from 20 sections have been compiled into a single New York Composite by the method of graphic correlation based primarily on the positioning of key beds (Klapper and Kirchgasser, 1992). The section in the Genesee Valley at Beard's Creek, Leicester, N.Y., between the base of the Geneseo black shale and the base of the Middlesex, was selected as the reference section for the lower Frasnian. The resulting New York biostratigraphic composite is a compilation of the ranges of 28 conodont species and 24 ammonoid genera and species. The New York Composite in turn has been correlated by graphic correlation into a developing Frasnian Composite that consists of data from some 27 sections from around the world (Klapper et al., 1993; in press). The ranges of key zonal conodonts from the lower Frasnian in the New York and the Frasnian Composites are illustrated in Figure 6; note that the ranges in New York (white bars) mostly fall "within" the ranges in the Frasnian Composite, reflecting the obvious "facies control" of occurrences of conodonts and goniatites in New York State. Construction of a New York Composite for the New York upper Frasnian (Rhinestreet to Dunkirk) is in progress. Some of the characteristic goniatites of the Genesee, Sonyea and West Falls groups are illustrated in Figure 7. Many of the key goniatite horizons also yield datable conodonts. The T-R cylces shown in Figures 3 and 4 were aligned by Johnson at al. (1985) by conventional correlation to the conodont zonal scheme proposed by Ziegler (1962) and most recently revised by Ziegler and Sandberg (1990).

Genesee Group

In the Genesee Valley section, late Givetian conodonts occur in the Leicester Pyrite (with the goniatite *Tornoceras uniangulare*) and at levels within the Geneseo Shale associated with poorly preserved *Ponticeras* (Huddle, 1981; Figures. 3, 10). In the Lodi Limestone in the lower Penn Yan Shale, *Ponticeras perlatum* (Figure 7) and rhynchonellid brachiopods occur with *Skeletognathus norrisi,* the indicator of the latest Givetian *norrisi* conodont zone (Klapper and Johnson, 1990). In the Genesee Valley, the Lodi horizon projects by graphic correlation into Montagne Noire (MN) Zone 1 of the Frasnian (Figure 6). East of the Genesee Valley, MN Zone 1 conodonts (*Ancyrodella rotundiloba* early form) occur in black shales immediately above the Lodi (Kirchgasser et al., 1989; Kirchgasser, 1994; Figure 5). In the Genesee Valley, MN Zone 1 conodonts occur in the SB black shale higher in the Penn Yan Shale, and still within the range of *Ponticeras* (Stop 1: Fall Brook and Dewey Hill; Figure 10).

MN Zone 2 conodonts with *Ancyrodella rotundiloba* (late form) enter in the middle of the Penn Yan Shale. The goniatite *Koenenites styliophilus* first appears near the level of the lowest entry of *Acanthoclymenia.* The key horizons are a styliolinid band, locally with white barite, called the Linden Horizon (LH), and the equivalent or approximately equivalent Crosby Sandstone (CS) around Keuka Lake. The characteristic bivalve in the dark Penn Yan Shale and West River Shale is *Pterochaenia fragilis.*

The Genundewa Limestone is an important key bed in the middle of the Genesee Group, and this prominent condensed styliolinid limestone is thought to record a short-lived deepening event of possible eustatic origin (Figure 8). The upper Genundewa marks the entry of the MN Zone 3 conodonts *Ancyrodella rugosa* and *Ad. alata,* and a distinctive group of short ranging species of *Ancyrodella* represented by *Ad.* sp. B (Kralick, 1991, in press). The upper Genundewa also marks the entry of *Manticoceras* and *Acanthoclymenia genundewa* (Figure 7).

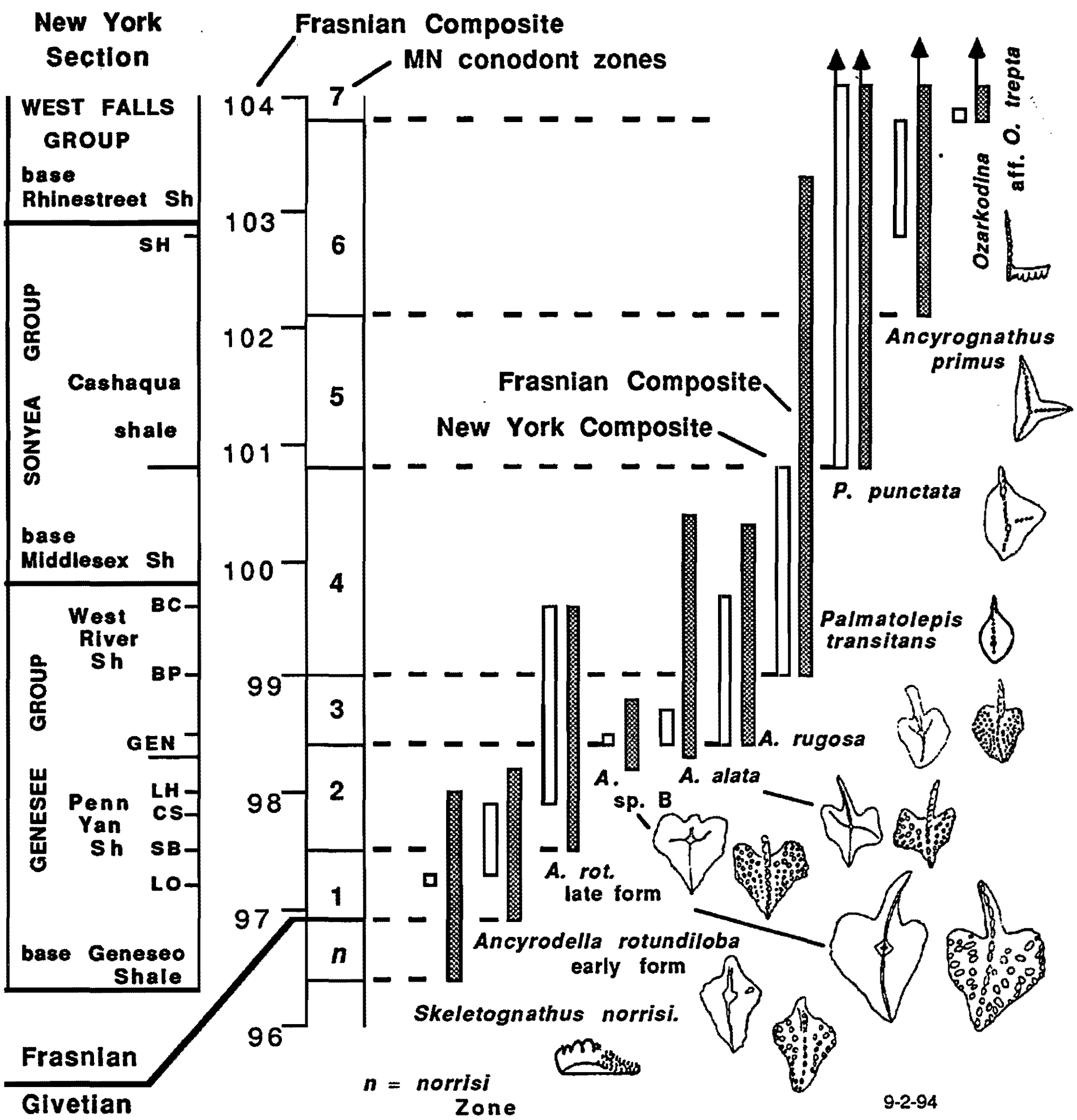

Figure 6. Correlations of lower Frasnian conodont sequence in New York with Montagne Noire (MN) conodont zones (Klapper, 1989; et seq.) and Frasnian Composite (Klapper et al., 1993; in press). The New York seqence is a composite of range-data from 20 sections compiled by graphic correlation (see text). The Frasnian Composite is compiled by graphic correlation of 27 sections from the around the world. Note that in most cases the species ranges in New York fall within the ranges in the Frasnian Composite. The distibution of New York species are strongly controlled by facies, and the ranges are restricted because of the frequent facies shifts.

MN Zone 3 conodonts continue into the lower West River Shale. Faunas are characterized by *Ancyrodella alata* (Figure 10). In the middle West River Shale conodonts of MN Zone 4 (with *Palmatolepis transitans*) enter just below the Bluff Point Siltstone (BP) in a bed with *Koenenites* aff. *Ko. lamellosus*. The MN Zone 4 fauna also occurs in the Beards Creek horizon (BC) near the top of the West River Shale in concretions with species of *Koenenites, Acanthoclymenia* and *Manticoceras* (House and Kirchgasser, 1993). Huddle (1981) illustrated many specimens of conodonts from this level at Keuka Lake.

Sonyea Group

Conodonts are unknown in the black Middlesex Shale and only one ammonoid species has been identified. MN Zone 5 with *Palmatolepis punctata* begins in New York at the base of the Cashaqua Shale. *Probeloceras lutheri* and *Manticoceras sinuosum* are present at several levels within the unit and will likely be seen at Stop 2 (Figure 7).

The facies sequence of the Sonyea to basal Rhinestreet is strikingly symmetrical and follows the pattern ABCBA, with A being black shale (Middlesex and Rhinestreet); B, dark gray shales interbedded with thin black shales (lower and upper Cashaqua); and C, green shale and mudstone (middle Cashaqua). The B facies and distinctive olive green shale and mudstone facies of the middle Cashaqua (facies C) have argillaceous concretions, burrowed horizons, and a moderately diverse molluscan fauna, sometimes with large bivalves (*Lunulicardium*). This fauna and sedimentological changes suggest the middle Cashaqua records a shallowing event (Figure 8). In the upper Cashaqua, fissile dark gray shales (facies B), like those of the lower Cashaqua, recur. This dark shale suggests renewed deepening that precedes the major highstand recorded by the lower black shale of the overlying Rhinestreet Shale (Moreland Shale). The lower Rhinestreet may be the deepest water facies in the entire section (Figure 8).

The styliolinid and baritic Shurtleff Septarian horizon (SH) within the upper dark shale facies of the Cashaqua is the source of *Ancyrognathus primus,* the zone indicator of MN Zone 6, although by graphic correlation with the Frasnian Composite, MN Zone 6 aligns to a position lower in the Cashaqua (Figure 6). In addition to its rich conodont fauna of *Palmatolepis punctata* and *Ancyrodella nodosa*, the Shurtleff Horizon locally contains a diverse molluscan fauna. Cephalopods, preserved in pink and white barite, were described by Clarke (1899) and include *Manticoceras sinuosum* and *Acanthoclymenia neapolitana*, and the distinctive *Prochorites alveolatus* with its concave ventral margin (Figure 7). *Probeloceras lutheri* and *Prochorites alveolatus* occur in western Australia, aligned with the same conodont sequence as in New York (Klapper and Kirchgasser, 1992; Becker et al., 1993; Figure 8.).

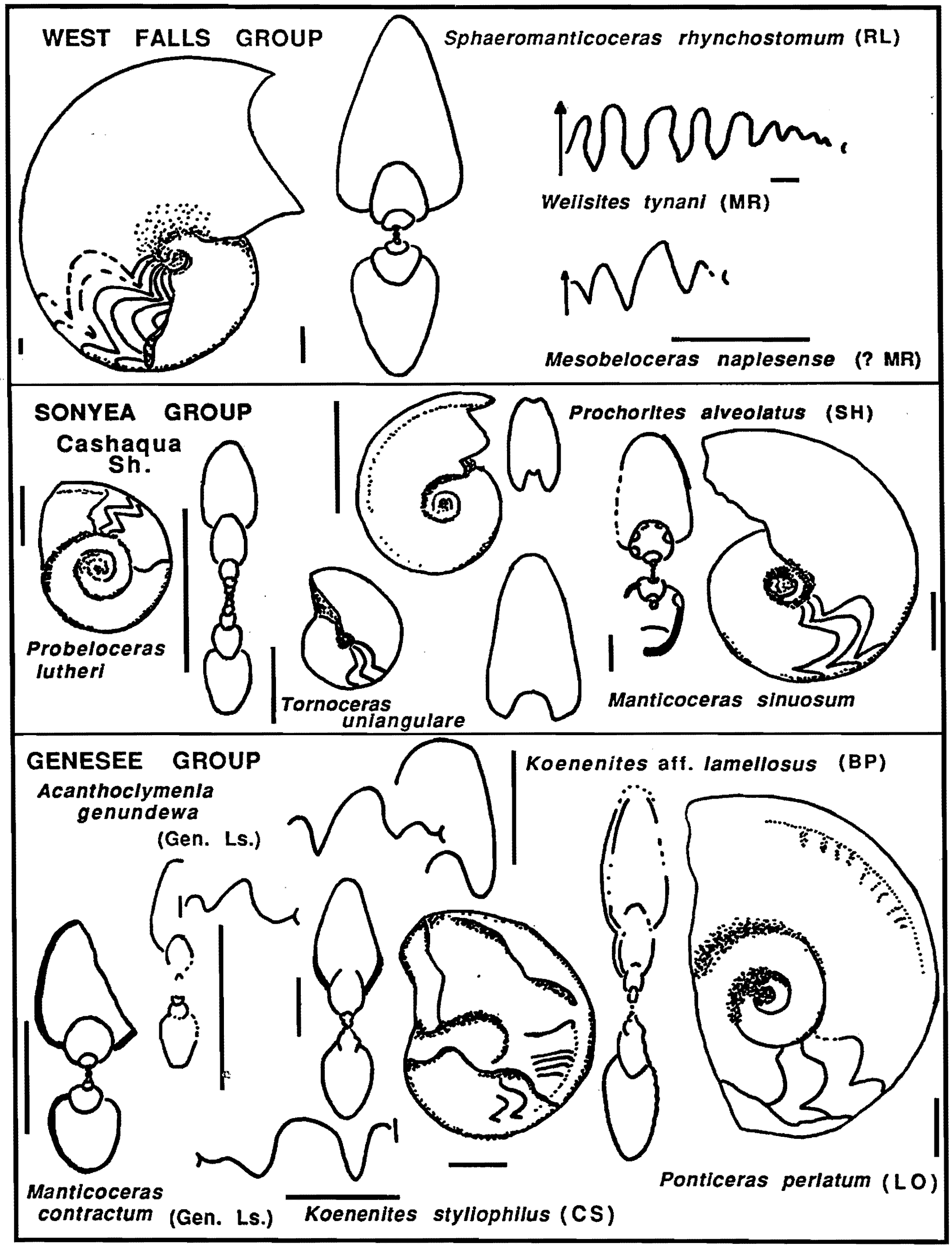

Figure 7. Characteristic goniatites in the Genesee, Sonyea and West Falls groups. Abbreviations of horizons as in Figs. 3 and 4. Bar scale is 1 cm. Modified from Kirchgasser (1973) with revisions based on House and Kirchgasser (1993).

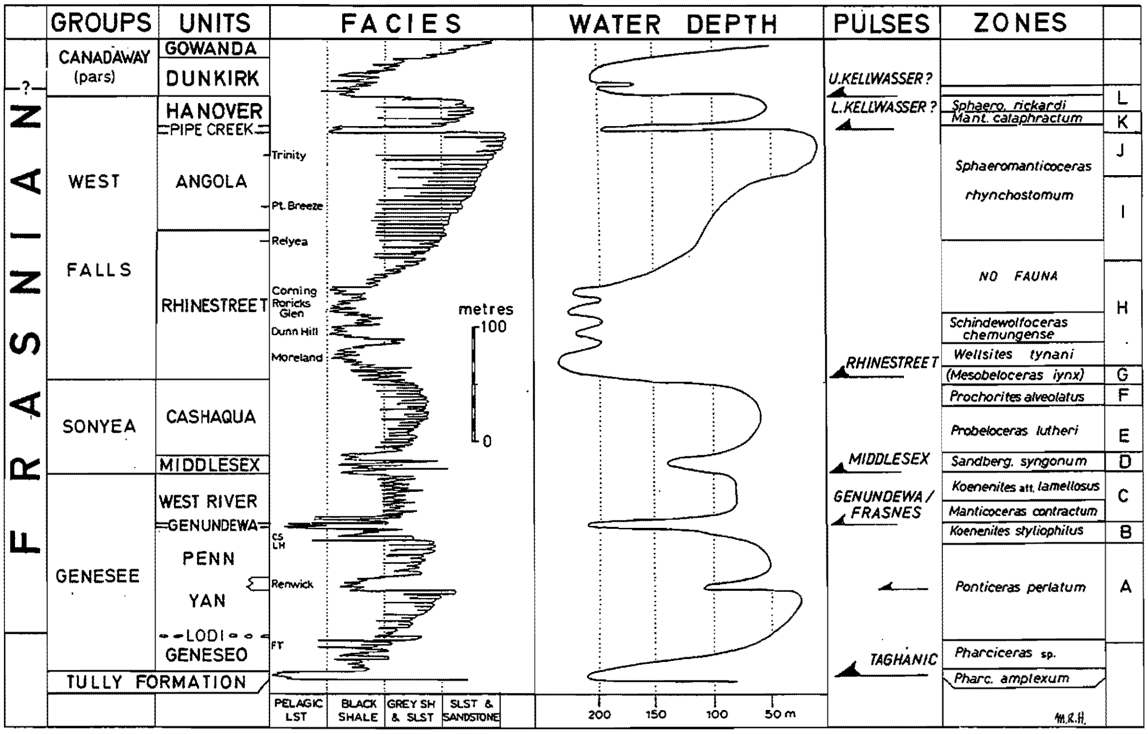

Figure 8. Facies shifts and major sea-level changes in the New York Frasnian. The major transgressive pulses are aligned to the goniatite divisions and zones illustrated in Figs. 3 and 4. From House and Kirchgasser (1993).

West Falls Group

Conodonts recovered from the base and lower part of the Rhinestreet black shale suggest that the Rhinestreet deepening begins in the interval of MN Zone 6. MN Zone 7, marked by the entry of *Ozarkodina* aff. *Oz. trepta*, begins about 6 meters above the base of the Rhinestreet at Cazenovia Creek in western New York. An MN Zone 7 fauna occurs 8 meters above the base at the Lake Erie shore, about a meter below the Belpre Ash Bed (Levin and Kirchgasser, 1994). These Zone 7 occurrences correspond to the Moreland Member of the Rhinestreet Shale.

Identifiable goniatites are rare in the black and gray shales of the Rhinestreet, and only a few crushed specimens are known in the Genesee Valley. However, to the southeast toward the Finger Lakes and the Southern Tier, there are records of distinctive evolute and multi- lobed genera and species from just below, within, and just above the Moreland Shale, as well as from middle levels within the Rhinestreet (House and Kirchgasser, 1993; Figures 4, 7).The occurrence of these cosmopolitan "belocerids," known elsewhere in the Old World and Australia, suggests that the Rhinestreet records a major eustatic deepening.

Near the top of the Rhinestreet in the Oatka Creek Valley (Warsaw, N.Y.), the Relyea Creek concretionary horizon (RL) contains a MN Zone 11 fauna and the large manticocerid *Sphaeromanticoceras rhynchostomum* (Figure 7). Based on conodonts from over- and underlying strata the middle and upper Rhinestreet interval corresponds to MN Zones 8, 9 and 10, but no faunas of these zones have been found. The top of the Rhinestreet in western New York is the pyritic-concretionary Scraggy Bed. A black shale beneath that horizon is believed to project into the Genesee Valley section to about the level of the Table Rock Sandstone, the siltstone bed that caps the Table Rock observation platform in Letchworth Park near the Lower Falls (Kirchgasser, 1973; Kirchgasser and House, 1981; Figure 2). This correlation indicates that the Gardeau Shale below the Table Rock correlates westward with the Rhinestreet, and that the Gardeau above the Lower Falls correlates westward with the Angola Shale (sections in Pepper et al., 1956). The section at Stop 3 is within the Gardeau Shale in strata equivalent to the Angola.

In the Genesee Gorge at Letchworth Park, the base of the 107 foot high Middle Falls is in the upper Gardeau Shale, and the section from the top of the Middle Falls to the top of the 70 foot high Upper Falls is within the West Hill Shale and Sandstone (Figure 2). The massive beds of the Nunda Sandstone (the Portage Sandstone of earlier workers) begin at the top of the Upper Falls. In western New York, the Angola Shale equivalents of the West Hill and Nunda have concretion horizons that contain Zone 11 conodonts and goniatites of the *Sphaeromanticoceras rhynchostomum* Zone. Above the Nunda, in a tongue of the upper Angola at Varysburg, MN Zone 12 conodonts have been recovered in a nodular (knollenkalk) horizon associated with burrowed shales. The Angola Shale and equivalent Nunda Sandstone in western New York is succeeded by the black Pipe Creek Shale, which, in turn, is overlain by the green-gray Hanover Shale (Figures 2, 4). Over (1992, 1994) has recovered conodonts of MN Zone 13 (the highest Frasnian Zone) and Lower and Middle *triangularis* Zone (lowest Famennian) in the upper Hanover Shale, several meters below the base of the black Dunkirk Shale, the horizon where the Frasnian/Famennian boundary has traditionally been drawn.

At the south end of the Genesee Valley towards Dansville, the Pipe Creek Shale separates the Nunda Sandstone from the overlying Wiscoy Sandstone, the coarse-grained (sandstone) equivalent of the Hanover Shale. The section on I-390 near Cohocton (Stop 4) is believed to be close to the Nunda-Wiscoy boundary. Conodonts of the *Polygnathus* biofacies characteristic of Zone 12 or younger have been recovered from a channel-fill, but none of the indicator species of the MN zones have been recovered. The brachiopod fauna is also typical of Mn Zone 12 (Day, pers. comm, 1994). The goniatites recovered so far from the channel fill bed are small and not well enough preserved to be compared to any of the late Frasnian zone fauna (Figure 4).

SUMMARY

The predominantly marine siliciclastic Frasnian strata exposed in the Genesee River Valley record the fine-grained offshore filling of the central Appalachian Basin. Cyclic sequences consist of black shale that grade upward into lighter colored shale and coarser clastics that record large- and smaller scale regional and eustatic sea level fluctuations and westward progradation of the Catskil Delta. Conodonts and cephalopods from key marker horizons allow regional and global correlation of Frasnian strata, as well as timing of cyclic sequence events.

ACKNOWLEDGEMENTS

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ROAD LOG

(Begin at I-390 South, Exit 8 (Geneseo), stop sign at US 20A; distances in miles)

00.0	0.0	US 20A West.
03.1	3.1	Village of Geneseo.
04.9	1.8	Junction Rt. 39, SUNY-Geneseo to right, continue around sharp left turn on US 20A.
05.9	1.0	Rt. 63 and US 20A/Rt. 39 split, turn right and continue on US 20A/Rt. 39. The highway was closed in March 1994 due to road and bridge damage west of the Genesee River near Cuylerville that resulted from roof collapse of the Retsof salt mine and subsequent subsidence and formation of sink holes. The salt beds are approximately 300 m (1000 ft) below the valley floor in the Upper Silurian Vernon Formation.
06.6	0.7	Cross Fall Brook and turn left into alfalfa processing plant, turn around, recross Fall Brook.
06.7	0.1	Pull off road and park at uphill (east) end of guard rail. Walk down path, cross fence, and follow paths or stream up to high banks and falls.

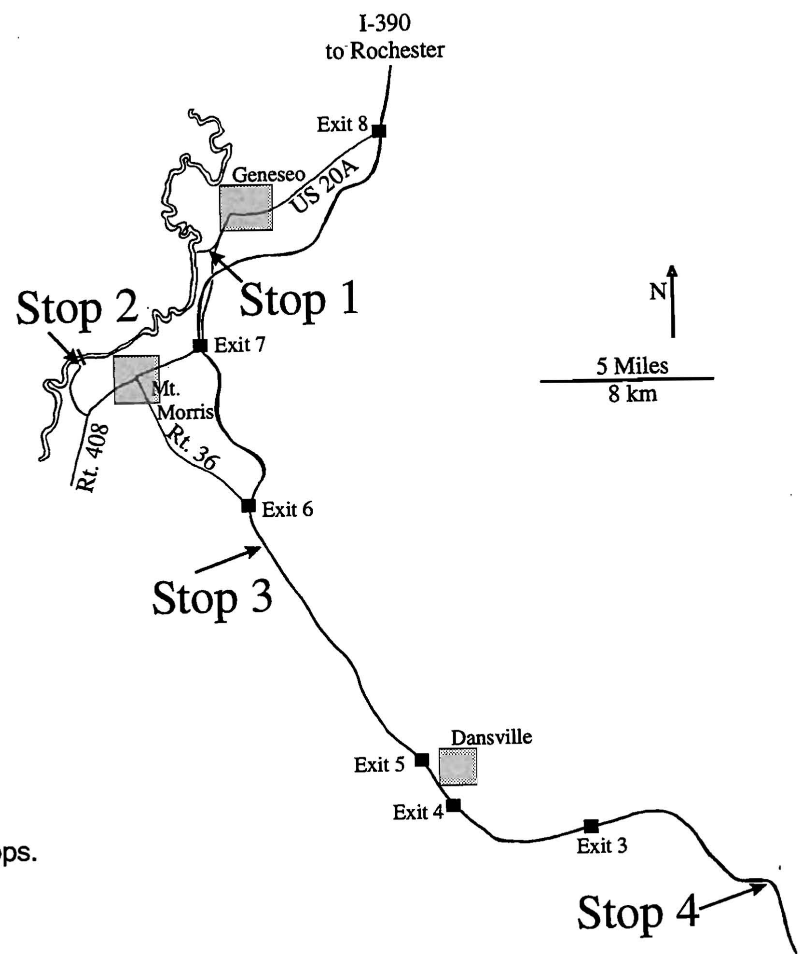


Figure 9. Map of field-trip stops.

Stop 1A - Fall Brook (Property is posted, access by permission only.): Erosional base of Genesee Group, pyritic lag, dark colored petroliferous shales, interbedded carbonates, Givetian-Frasnian boundary, and major deepening of the basin represented by planktic-fauna carbonates. Leicester Pyrite, Geneseo Shale, Penn Yan Shale, Genundewa Limestone (Figures 9, 10).

Strata of the Moscow Formation (Hamilton Group) are exposed in the stream bed and banks below the falls. Fossiliferous bluish-gray shales of the Kashong Member are overlain by bioturbated fossiliferous medium gray calcareous shales and carbonate beds of the Windom Member (Figure 10). The steep banks prevent close investigation of Genesee strata. Stratigraphic relationships and fallen debris can be examined in the gorge, in place collections can be made from a side creek or Stops 1B (Dewey Hill) and 1C (above falls) where strata are more accessible. **Caution: large blocks have been known to fall from overhangs and strike eminent geologists.**

The Genesee Group consists of the Leicester Pyrite, Geneseo Shale, Penn Yan Shale, Genundewa Limestone (resistant bed forming falls), and West River Shale. The base of the Genesee Group is marked by the Leicester Pyrite, a 0-20 cm thick sharp based accumulation composed almost entirely of pyrite nodules, pyritized burrows, and pyrite replaced fossils that represents a condensed lag accumulation above a major disconformity. The bed contains a mixed conodont and cephalopod fauna of Hamilton, Tully, and Genesee nature (Figure 5). The unconformity is the result of submarine erosion, corresponding to the Taghanic Onlap (Baird and Brett, 1986a). Look for pyritized cephalopods (*Tornoceras uniangulare*), crinoids, bivalves, burrow fills and rare brachiopods and trilobites in fallen blocks of the Leicester, which is distinctive due to the orange-brown weathered surface.

The Geneseo Shale gradationally overlies or is locally interbedded with the Leicester Pyrite. Here at Fall Brook the Geneseo is 8.2 m thick (base of lower black shale to top of upper black shale), characterized by a lower 1.7 m thick and an upper 1.4 m thick dense black petroliferous shale units separated by 5 m of medium-dark gray shale and thin carbonate mudstone beds. [In deWitt and Colton (1978) only the lower black shale is considered to be the Geneseo.] The Geneseo black shale thickens eastward, absent at Lake Erie (possibly represented as a parting between the North Evans Limestone and Genundewa Limestone) to about 30 m thick in the Finger Lakes (Figure 2).

The continuous limestone band in about the middle of the gray Geneseo shale interval is the Genesee Limestone (GL), with *Pharciceras* and a *disparalis* Zone conodont fauna that includes *Polygnathus linguliformis* gamma and *Po. dubius*. The Fir Tree Limestone, represented here by a thin carbonate mudstone bed 1.2 m above the Genesee Limestone, is a distinctive horizon in the Finger Lakes region that contains a pyrite-bone bed lag developed on the corroded surface of a carbonate bed (Baird et al., 1989).

The Penn Yan Shale lies above the upper thick black shale of the Geneseo and is characterized by medium-dark shale and interbedded thin carbonate

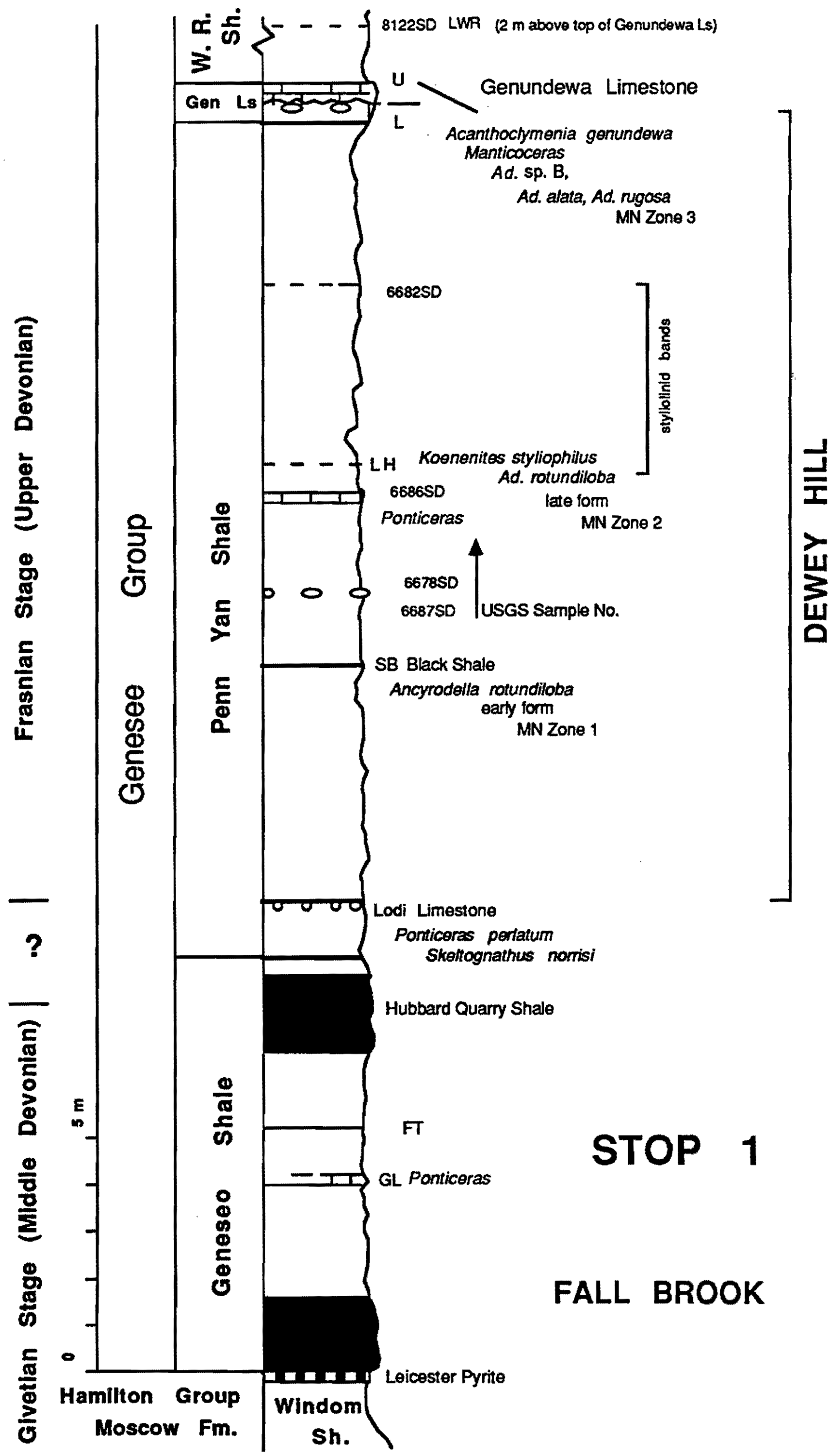


Figure 10. Section of Genesee Group at Stop 1, Fall Brook and Dewey Hill, near Geneseo, New York. Revised from Oliver and Klapper (1981). USGS Samples Numbers (SD) from deWitt and Colton (1978) and Huddle (1981).

mudstones, styliolinid packstone/grainstones, and thin black shale beds. The Lodi Limestone, a nodular carbonate 1.1 m above the base of the Penn Yan, marks the local first occurrence of *Ponticeras perlatum* and *Skeletognathus norrisi*, indicative of the *norrisi* Zone, the latest zone of the Givetian. *Ancyrodella rotundiloba* early form, which defines the base of the Frasnian and MN Zone 1 of Klapper (1989), and the Givetian-Frasnian boundary, occurs just above the Lodi Limestone east of the Genesee Valley (Figure 3, 5). Based on graphic correlation with the Frasnian Composite Standard of Klapper et al. (1993), however, the Givetian-Frasnian boundary would lie in the Geneseo-Penn Yan transition (Figure 6). The Lodi Limestone can be collected from the side creek, and will also be seen at Dewey Hill (Stop 1B).

The Genundewa Limestone caps the water fall of Fall Brook. The Genundewa is a 0.3 to 0.5 m thick, wood-bearing, cephalopod styliolinid packstone-grainstone that consists of several amalgamated beds separated by discontinuous shale laminae. The grainstone consists almost entirely of the small conical shells of *Styliolina fissurella*, an enigmatic organism that may be a protist (Yochelson and Lindemann, 1986). The lower surface is irregular, indicating scouring of the sea floor prior to or during deposition. Reworking and erosion are indicated by current alignment of the styliolinids and corrosion/wear features. The Genundewa is interpreted as the result of deepening of the basin; consequent flooding of the terrigenous sediment source and near shore sediment trapping resulted in accumulation of planktic organisms, without dilution by siliciclastics. Several styliolinid laminae and thicker packstone-grainstones occur in the upper Penn Yan indicating cyclic deepening and consequent sediment starvation. The base of the Genundewa is recognized by a regionally persistent, thin (10 cm) black shale bed that underlies the prominant carbonate band. The Genundewa will be viewed in place at Stop 1C; however, samples can be easily collected from large slabs in the stream bed.

06.7 0.0 Proceed up hill on US20A/Rt. 39.
07.0 0.3 Pull off and park before guard rail on right. Exposures are in ditch and cuts on both sides of the road; the section described is on the south side.

Stop 1B - Dewey Hill: Penn Yan Shale including Lodi Limestone Member, SB bed, and Linden Horizon.

Here we will be able to closely examine beds below the Genundewa Limestone in the side walls of Fall Brook at Stop 1A. The Penn Yan Shale is comprised of dark to medium gray shale with interbedded carbonate and black shale. The Lodi Limestone, exposed in the road ditch, is the lowest key bed. The Lodi consists of thin (5 cm) discontinuous beds and nodules that are traceable to the Finger Lakes region and represents the latest Givetian (Middle Devonian) in New York State; *Ponticeras* is the predominant goniatite, but it is rare this far west. The Givetian-Frasnian (Middle-Upper Devonian boundary) is taken as the base of the shales overlying the Lodi, recognized by the first occurrence of *Ancyrodella* *rotundiloba* early form, which is used to define the base of MN Zone 1 (lowest Frasnian). Gastropods and rhynconellid brachiopods may be found in the nodular Lodi at this locality.

The SB bed is a 20 cm thick distinctive black shale interval that is characterized by a conodont and lingulid lag horizon in the lower few centimeters. The horizon interval represents a phase of benthic anoxia-dysoxia with preservation of organic material, as well as a hiatus/erosion surface and concentration of phosphatic bioclasts. Conodonts of MN Zone 1 can be recovered from the shale.

In contrast to the larger scale sequence marked by the disconformity at the base of the Genesee Group, smaller scale sequences in the Geneseo, Penn Yan, Genundewa, and West River formations (basin facies) seem symmetrical, preserving sediments that represent both the deepening and shallowing without development of a pronounced hiatus. The SB phosphate lag is an example of a cryptic disconformity within a minor cycle that marks a deepening maxima phase in the basin.

Nodular and continuous carbonate beds in the middle-upper Penn Yan contain cephalopods (genera include *Koenenites, Acanthoclymenia*, and *Tornoceras*) and conodonts. The key styliolinid bed is the Linden Horizon (LH) that contains *Koenenites styliophilus.* In this horizon the goniatite shells are often filled with crystalline pink and white barite. This level marks the base of MN Zone 2 in New York (*Ancyrodella rotundiloba* late form).

07.0	0.0	Proceed uphill (east) on US 20A/Rt. 39.
07.3	0.3	Turn right (south) at intersection onto Rt. 63.
07.8	0.5	Pull off to right and park at Fall Brook overlook.

Stop 1C - Fall Brook above falls: Genundewa Limestone and West River Shale.

Extreme Caution: the edge of the Genundewa is unmarked and the drop to the base of the falls is over 100 feet.

The Genundewa Limestone consists of approximately 35 cm of several amalgamated beds of styliolinid grainstones separated by discontinuous shale partings that can be traced from Lake Erie to Keuka Lake. The base of the Genundewa is marked by a persistent black shale bed that separates it from carbonate beds in the upper Penn Yan. Note here the irregular contacts in the Genundewa and proximal strata and apparent rippled surfaces. The styliolinids are aligned, indicating current orientation, however, the nature of the current(s) responsible is enigmatic: contourites, waves on pycnocline boundaries, storm waves, ocean gyres, or density currents are possible mechanisms.

The upper and lower Genundewa contain distinctive faunas. The lower beds are characterized by *Ancyrodella rotundiloba* late form, indicative of MN Zone 2. The upper Genundewa contains the first appearance of *Manticoceras* and conodonts of MN Zone 3, including *Ad. rugosa, Ad. alata*, and *Ad.* sp. B (Kralik, in press; Figures 3, 6).

The lower West River Shale is exposed in the creek bed and banks above the falls. The West River Shale consists of dark to medium gray shales and thin carbonate beds, lithologically similar to the Penn Yan Shale, that indicate shallowing and a return to fine clastic sedimentation following Genundewa deposition. A thin (3 cm) styliolinid carbonate bed approximately 2 m above the base of the shale contains numerous conodonts of MN Zone 3 [USGS Silurian-Devonian cat. No. 8122SD (Huddle, 1981)]. The upper West River Shale is exposed at the base of the Mt. Morris Dam at Stop 2.

07.8	0.0	Proceed south on Rt. 63.
10.3	2.5	Junction of Rt. 408, continue south on Rt. 408.
10.6	0.3	Junction I-390, continue south on Rt. 408.
12.0	1.4	Village of Mt. Morris.
12.5	0.5	Turn left at light.
12.6	0.1	Turn right at light, continue south on Rt. 408.
14.3	1.7	Mt. Morris Dam Road, continue to next intersection.
14.5	0.2	Turn right at park entrance to Mt. Morris Dam, continue to parking lot at dam overlook.
16.4	1.9	Park. Exposures are along the dam access road and "Burma Road" that descends gorge wall upstream from dam.

Stop 2 - Mt. Morris Dam (access by permission from US Corps of Army Engineers): Gorge overlook: dark gray shale of upper West River Shale at base above and below dam (river level); black shale of Middlesex Shale and green/gray shale of Cashaqua Shale, Sonyea Group; and gray/black shale of Rhinestreet Shale, lower West Falls Group to the top of the exposure (Figure 11). An apparent correlative of the Belpre Ash Bed may be visible.

The Letchworth Gorge of the Genesee River is a Pleistocene hanging valley cut into shales, siltstones, and sandstones of the Genesee, Sonyea, and West Falls groups. Three main waterfalls in the upper gorge are formed on resistant sandstones of the upper West Falls Group. The section exposed at the dam includes gray shale of upper West River Shale at the base above and below the dam (river level); black Middlesex Shale and green/gray Cashaqua Shale, Sonyea Group; and gray/black Rhinestreet Shale, lower West Falls Group up to the top of exposure. The two black shales represent major transgressions.

The lower Rhinestreet Shale and upper Cashaqua Shale are exposed in the access road to the top of the dam. The Cashaqua consists of green-gray shale and mudstone that are darker at the base, lighter colored and highly bioturbated in the middle, and darker gray at the top. This lithologic change indicates a shallowing cycle, superimposed on which there are numerous shorter-duration cycles indicated by darker shale bands and concretionary horizons. The medium gray shale of the upper Cashaqua exposed at the dam contains numerous bivalves and coalified plant fragments. The prominent concretionary band in the upper Cashaqua is the Shurtleff Septarian Horizon. These concretions contain a diverse conodont fauna of MN Zone 6 (*Palmatolepis punctata, Ancyrodella*

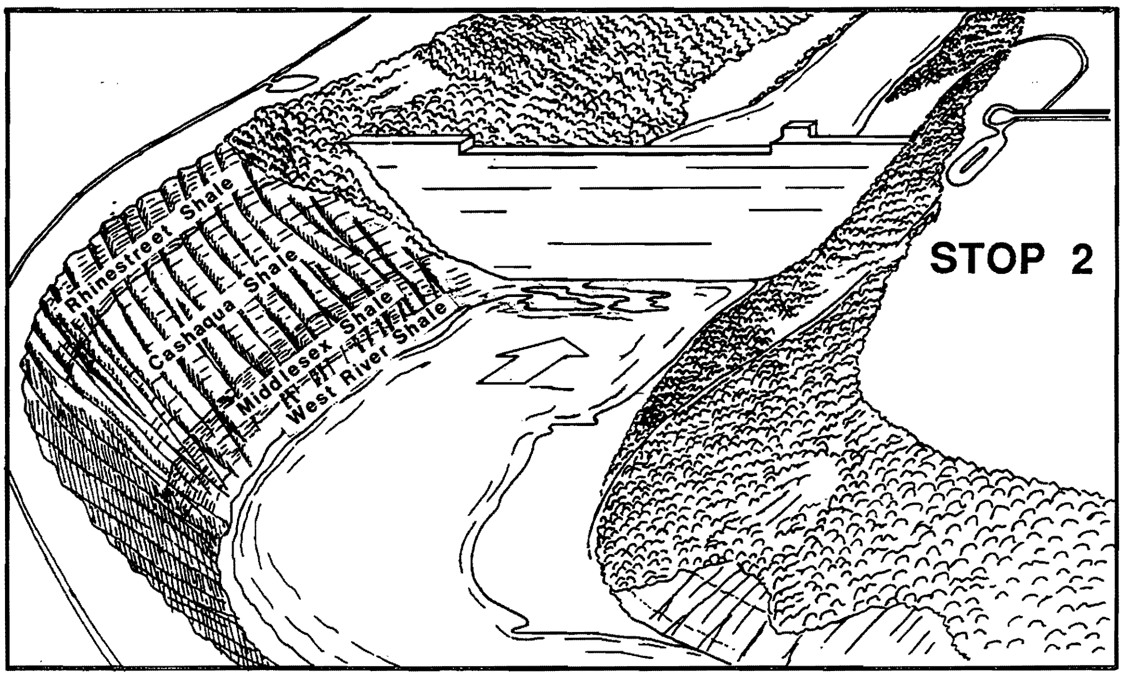


Figure 11. Schematic drawing of section of upper Genesee (West River Shale), Sonyea (Middlesex and Cashaqua Shales) and lower West Falls Group (Rhinestreet Shale) in the Genesee Gorge at Stop 2, Mount Morris Dam at Mount Morris, New York. From Van Diver (1980) with permission of the author.

nodosa), as well as mollusks replaced or filled with pink or white barite, including the goniatites *Manticoceras sinuosum* and *Prochorites alveolatus* (Figure 7; House and Kirchgasser, 1993).

The base of the Rhinestreet Shale and the West Falls Group is marked by a sharp transition from medium-to-dark gray shale below to thick black shale. The Rhinestreet is the thickest and most widely distributed black shale bed in the Upper Devonian of New York and represents a major transgression and deepening (Figures 2, 8). Plant remains, rare cephalopods, conodonts, and other fossils can be recoverd from bedding planes.

If time and weather permits the entire Cashaqua can be accessed on the "Burma Road" which enters the gorge upstream of the dam. If pool level is low the upper West River and Middlesex may also be exposed, however, out-croppings are likely to be partially covered by mud and debris. The base of the Cashaqua denotes the start of MN Zone 5 (*Palmatolepis punctata*) and *Probeloceras lutheri* Zone. A diverse molluscan fauna can be recovered from the greenish shales, including *Probeloceras lutheri* and numerous bivalves; among the most common are *Buchiola, Ontaria,* and *Pterochaenia* (see Clark, 1904).

16.4 0.0 Return to Rt. 408.
18.3 1.9 Turn left (north) on to Rt. 408.
19.3 1.0 Village of Mt. Morris.
20.1 0.8 Signal and junction with Rt. 36, turn right (south) onto Rt. 36.
23.7 3.6 Groveland Correctional Facility.
25.1 1.4 Junction with I-390 (Exit 6 - Sonyea), turn right and proceed south (toward Corning).
26.2 1.1 Pull off shoulder and park at Mile Marker 32, exposures are in road cut on both sides of highway; measured section is on the west side of the southbound lane.

Stop 3 - I-390 Mile 32: slope-basin muds and turbidites of Gardeau Shale, West Falls Group.

In the gorge section, the Gardeau Shale overlies the Rhinestreet and extends upstream to the Middle Falls, consiting of approximately 100 m of interbedded green-gray shale, black shale, and silts that represent an influx of fine and coarse clastic material into the basin. The exposure here of the Gardeau Shale consists of interbedded medium gray and dark shales that may represent small scale cycles that are overlain by interbedded silty shales and thin silt-sandstones that may also represent small scale cycles (Figure 12). The shales have yielded a low diversity and sparse fauna of nowakiids. Inarticulate brachiopods and trace fossils occur in the coarser (silt-sandstone) beds. The brachiopods and trace fossils in the silt-sandstone beds indicate development of dysoxic-oxygenated benthic waters and a suitable substrate for benthos. The silt-sandstones are graded, consisting of a scoured base, massive lower sand, and ripple to hummocky cross-laminated upper surfaces that are sharply overlain by gray shale. Scour features on the bases of silt-sandstone beds are oriented east-west. Many of the scours are laterally asymmetric, possibly the result of helical flow of the scouring current. The silt-sandstones are interpreted as turbidites, however, the upper surfaces have been reworked by subsequent currents.

26.2 0.0 Proceed south on I-390.
33.5 7.3 Dansville, Foster-Wheeler is a specialty steel plant.
41.4 7.9 Wayland (Exit 3), continue south on I-390.
44.0 2.6 High exposures on both sides of road between mile markers 15 and 14, pull well off shoulder at southern end of the exposures near the crest of the hill and park.

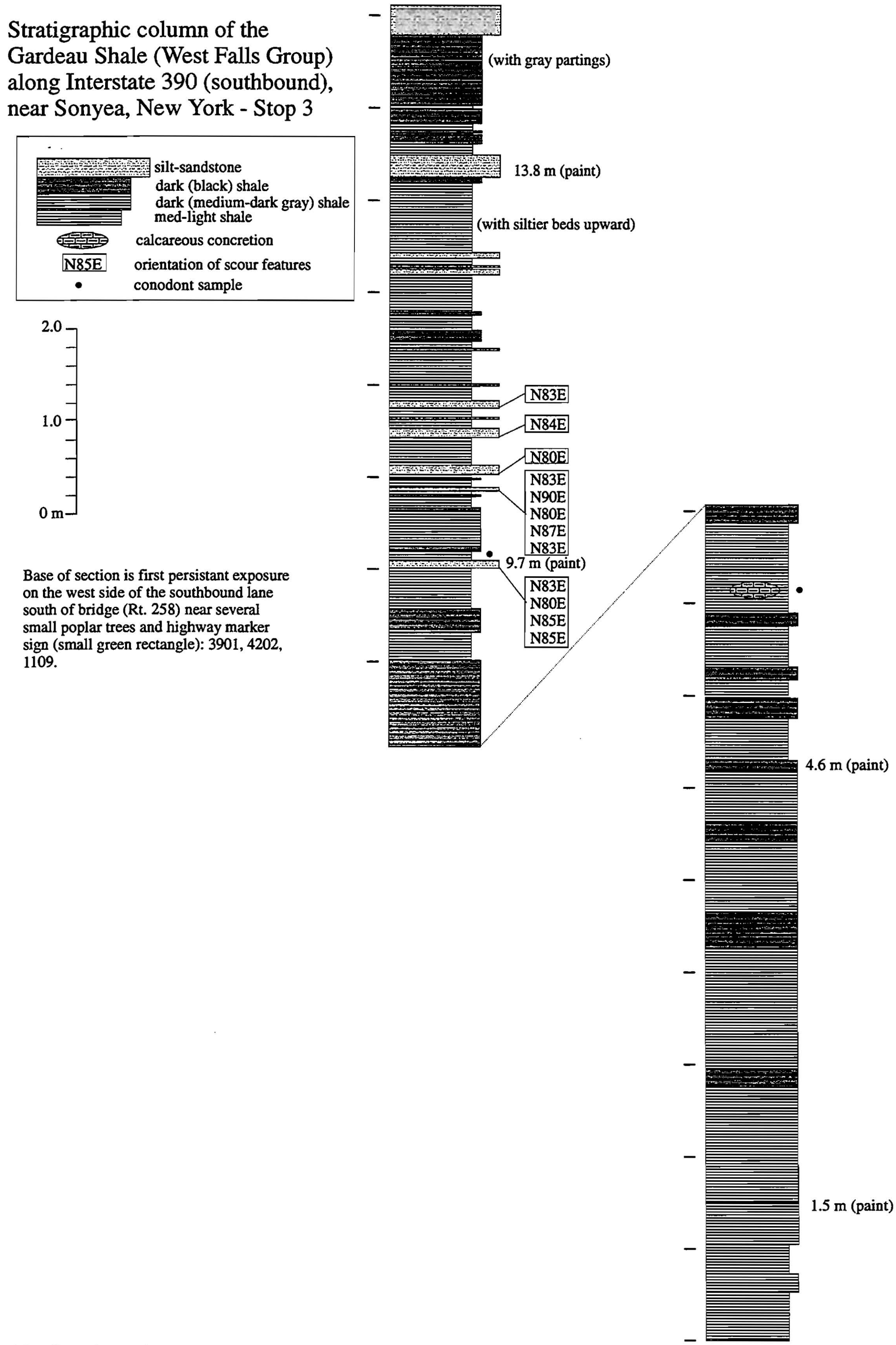


Figure 12. Section of Gradeau Formation at Stop 3, I-390 Mile 32.

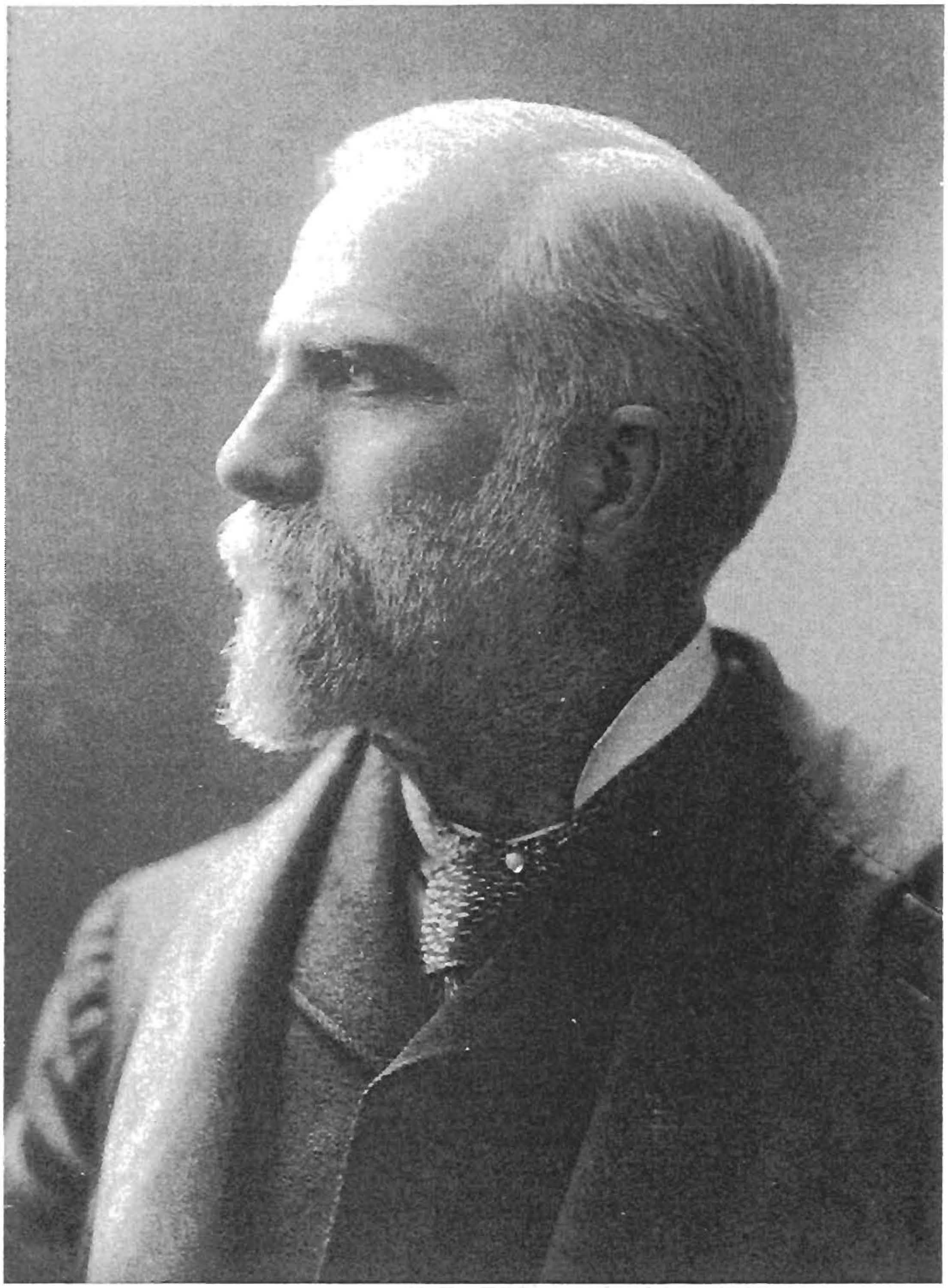
Stop 4 - I-390 Between Mile Markers 15 and 14 : Shelf sands of upper West Falls Group, Nunda or Wiscoy sandstone; ichnofossils, channel sand and shell-rich basal channel fill.

These sandstone exposures are questionably of the Nunda Sandstone which represents the upper West Falls Group and coarse-grained lateral equivalent of the Angola Shale in the Genesee River Valley. The sandstones are composed of tabular to lenticular thin to medium beds. Brown weathering sands are muddier, often low angle cross-laminated, and may contain rip-up clasts of brown mudstone and plant fragments. Medium blue-gray sands are ripple surfaced and cross-laminated, locally bioclastic (bivalves, brachiopods, and crinoids), and moderately to completely bioturbated. Identifiable trace fossils include *Skolithos, Diplocraterion, Scalarituba*?, and small *Chondrites*?, as well as poorly preserved lined and unlined horizontal to subhorizontal burrows. These sands are similar to the bluestones that were a common quarry stone near Portageville at the head of the Genesee gorge in the 1800's and early 1900's. Also notable in the section are resistant spherical weathering zones, suggestive of concretions developed in the sandstone.

In the southern most outcrop of the south bound lane is a channel cut filled with light gray weathering sandstone. The base of the channel consists of a 40 m long, 0.4-0.7 m thick dark-brown weathering fossiliferous sandstone to sandy carbonate. The stratum contains numerous brachiopods of a deepshelf environment *(Cyrtospirifer, Douvillina, Nervostrophia, Spinatrypa*), as well as cephalopods, crinoids, fish remains, and a diverse polygnathid conodont fauna. The fauna is characteristic of MN Zone 12.

The current reworked and bioturbated sands, brachiopod fauna, *Skolithos-Curziana* ichnofacies, and polygnathid conodont fauna are indicative of a moderate energy shelf environment. These sands correlate to finer grained green-gray and dark gray shale of the Angola to the west (Figure 2). The Pipe Creek Shale, a thin transgressive black shale unit, separates the Nunda from the overlying Wiscoy Sandstone, the lateral equivalent of the Hanover Shale (highest Frasnian). The Pipe Creek is not well developed in this region and has not been locally identified. More nearshore channel and deltaic sandstones are found to the south in Famennian strata. These shallow water shelf and near shore sandstones record the late stages of progradation of the Catskil Delta across New York State and the filling of the Appalachian Foreland Basin.

END OF ROAD LOG.



Herman Leroy Fairchild

Professor of Geology, University of Rochester
[1888-1920]