MIDDLE – UPPER DEVONIAN STRATA ALONG THE LAKE ERIE SHORE, WESTERN NEW YORK

D. Jeffrey Over, Dept. of Geological Sciences, SUNY-Geneseo, Geneseo, NY 14454;
Gordon C. Baird, Dept. of Geosciences, SUNY-Fredonia, Fredonia, NY 14063;
William T. Kirchgasser, Dept. of Geology, SUNY-Potsdam, Potsdam, NY 13676;

INTRODUCTION

The Middle and Late Devonian succession along the New York State Lake Erie shoreline and exposures in adjacent creeks includes numerous dark gray and black shale units that record dysoxic to near anoxic marine substrate conditions near the northern margin of the subsiding Appalachian foreland basin. Contrary to common perception, this basin was often not stagnant; evidence of current activity and episodic oxygenation events are characteristic of many units. Lag deposits of detrital pyrite roofed by black shale, erosional runnels, and cross-stratified deposits of tractional styliolinid grainstone are evidence of episodic, moderate to high energy events within the basin. This trip will highlight the transitions in the basin from gray shales to dark shales, often characterized by pyrite-rich lag deposits, phosphate, conodont, fish beds, and concentrations of carbonate material, as well as the Naplesites epibole surface associated with the Belpre Ash suite in the lower Rhinestreet Formation. Three stops will showcase strata associated with Middle and Late Devonian extinction events – the Taghanic Onlap and the “Conodont Bed” of the North Evans Limestone that marks the Givetian-Frasnian boundary in western New York – a truncation of the more conformable transition to the east, and the Frasnian-Famennian boundary interval, one of several Late Devonian extinctions and the marker of a significant global crisis that led to the demise of the widespread and diverse Devonian reef community.

GEOLOGIC SETTING

During the late Middle Devonian western New York was located in the southern hemisphere tropical realm and covered by an epicontinental sea (Scotese, 1990). Strata seen on this fieldtrip accumulated on the northern margin of a subsiding foreland basin that periodically expanded and deepened during phases of oblique collisional overthrusting (tectophases) associated with the ongoing Acadian Orogeny (Ettensohn, 1987, 1998; Fig. 1). The most pronounced thrust loading event (tectophase three) coincided with the onset of the deposition of the Genesee Group; this flexural drowning event was also largely coincident with a major rise in sea level (within T-R cycle IIa of Johnson et al. 1985). In west-central New York this deepening is expressed by lithologic change from shelf carbonates of the Tully Formation into basinal black shale deposits of the Geneseo Formation (Heckel, 1973; Baird and Brett, 2003; Baird et al., 2003). In western New York the Tully Formation is absent due to erosional/corrosional processes, and progressively younger divisions of the Genesee Group: Geneseo Formation with Leicester Pyrite at its base, Penn Yan Formation, and condensed North Evans/Genundewa deposits, are observed to successively onlap the Taghanic Unconformity, a major regional disconformity, in a westward direction (Fig. 2). This disconformity, separating fossiliferous neritic facies of the late Middle Devonian (Late Givetian) Windom Member of the Moscow Formation, Hamilton Group from overlying dysoxic, pelagic limestone and lag debris of the North Evans/Genundewa deposits at the base of the Genesee Group, will be seen at STOP 1A. In west-central New York localities, the gradational transgressive change from Tully carbonate facies into black shale of the Geneseo Formation coincides with the beginning of the upper Givetian substage of the late Middle Devonian (Huddle, 1981; Kirchgasser et al. 1989). Proceeding westward along the Taghanic disconformity, the ages of the onlapping black shale deposits become progressively younger into eastern Erie County; this reflects the regional flexural-eustatic Taghanic event (Kirchgasser et al., 1989; Baird and Brett, 1986). A younger erosion surface, associated with the North Evans Limestone conodont – bone lag below the Genundewa Limestone, oversteps the Taghanic disconformity in Erie County, thus merging the two discontinuities into a composite unconformity (Fig. 2). Hence, at STOP 1A, the Late Devonian (early Lower Frasnian) North Evans Limestone rests directly on late Middle Devonian (middle Givetian, ansatus Zone) shales of the Windom Member (Moscow Formation; Hamilton Group) with several conodont chronozones missing or whose representatives were reworked and transported. The effective chronostratigraphic (taphonomic) age of the North Evans is early Frasnian upper MN Zone 2 (Figs. 2, 3).

Acadian orogenic uplift in New England and the central Atlantic region was associated with progradational developmemt of the Catskill Delta Complex which filled the foreland basin from east to west (Woodrow and Sevon, 1985; see Kirchgasser et al., 1997). Catskill Delta progradation began in earnest during deposition of the Middle Devonian Hamilton Group following the onset of the second collisional tectophase, but accelerated significantly during the third tectophase (Ettensohn, 1998). Not only do strata above the Taghanic disconformity thicken greatly to the east, but they also grade spectrally eastward and shoreward into variably fossiliferous neritic facies which are typically much coarser (Fig. 2).

Generally, the units seen on this field trip represent very fine grained detrital facies of the Catskill Delta representing deposition in deeper water slope and basin settings both at and beyond the delta margin (Fig. 2). Units such as the Rhinestreet Formation of the West Falls Group (Late Devonian, Frasnian) are typically expressed along Lake Erie as organic-rich, fissile to massive, black shale facies recording near-anoxia during phases of transgressive highstand (Rhoads and Morse, 1971; Murphy et al., 2000). However, thinner intervals of gray-green, typically bioturbated shale occur within the Rhinestreet (see STOPS 1C, 2). Shale of this type thickens greatly eastward toward the depocenter and sediment source. Black shale units, including the Rhinestreet, typically split into eastwardly splaying black shale tongues (Fig. 1). The black shale facies is often laminated, but actually, typically displays small flattened burrows, indicating the bottom setting was not exclusively anoxic.

Baird and Brett (1986, 1991) discussed a variety of mechanisms to produce coarse tractional lags in black shale settings in the context of a basinal, deeper-water setting interpreted for such facies. Processes including: deep-storm wave impingement, bottom current processes, and internal waves were examined as mechanisms capable of moving coarse particles at depth. We tentatively settled on a model of internal wave-shoaling against a sloped basin substrate as a possible traction mechanism; in this scenario by internal waves generated along the pycnocline

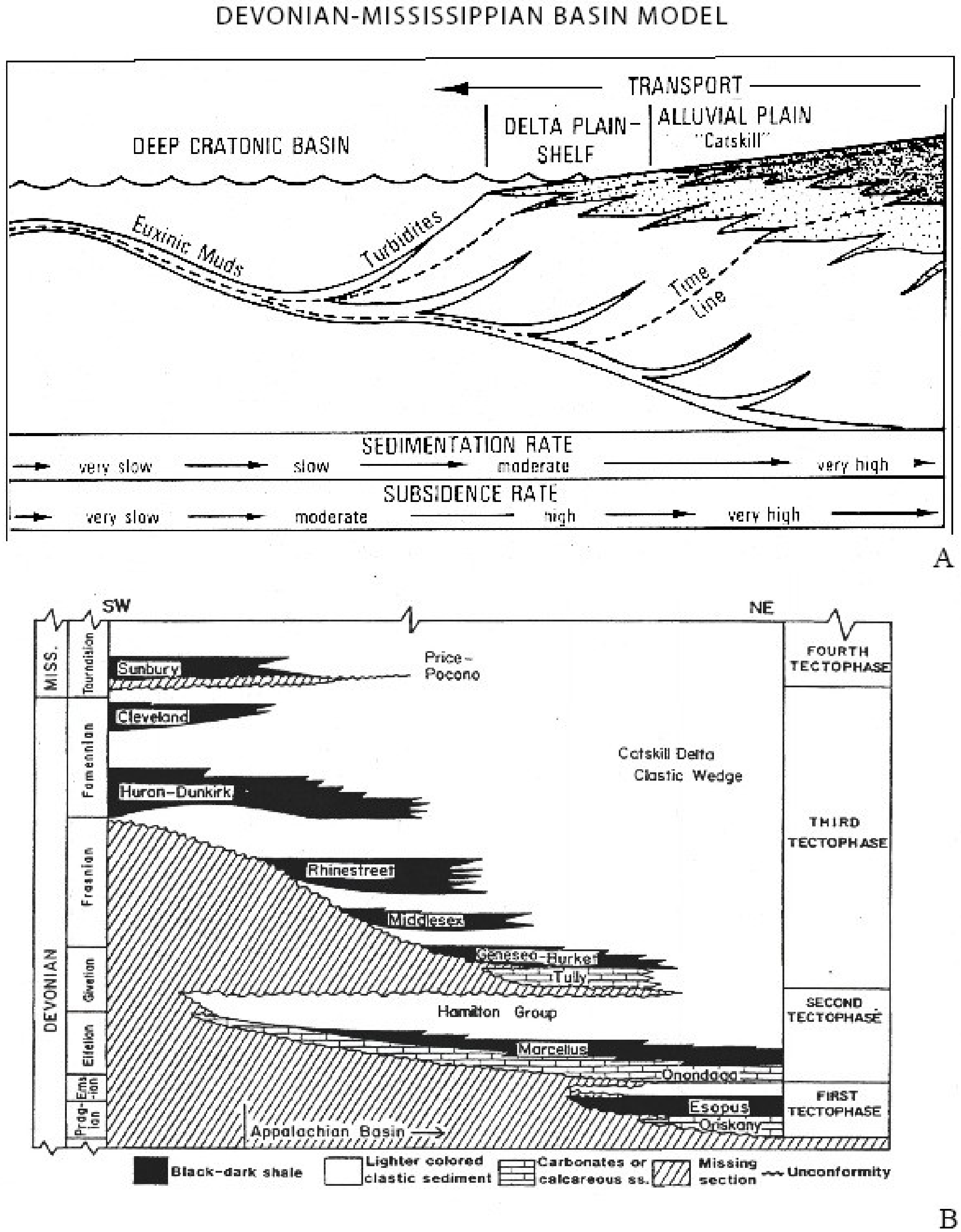


Figure 1. A. Idealized depositional model of the Catskill Delta complex (from Broadhead et al., 1982). B. Composite stratigraphic section from east-central New York to north-central Ohio in the northern Appalachian Basin showing distribution in time of pre-tectophase unconformities and unconformity-bounded flexural sequences of black shales and coarser clastic sediments attributed to four Acadian tectophases. Note progressive southwestward (cratonward) basin migration of successive black shale strata (from Ettensohn, 1994).

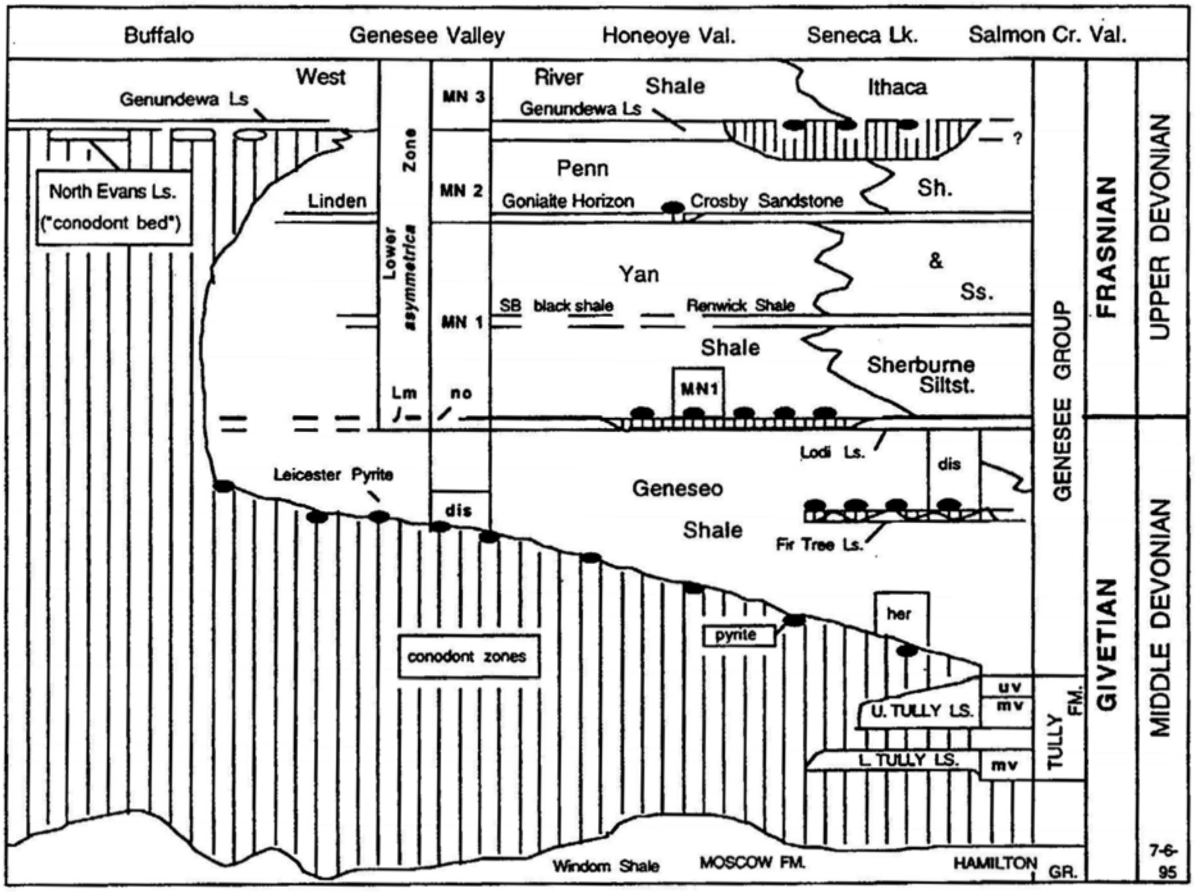


Figure 2. Generalized chronostratigraphic cross section of lower Genesee Group and subjacent Moscow Formation (Hamilton Group, Windom Shale Member). Large hiatus below Genesee Group marks position of compound Taghanic Unconformity, Genesee onlap succession and sub-Genundewa unconformity. The pre-Tully erosion- Hamilton erosion surface marks a major sequence and tectophase (III) boundary. The lenses of detrital Leicester Pyrite are derived from this erosion but were deposited through a long period of diachronous onlap of Genesee black muds from this discontinuity during the Taghanic transgression. The locally beveled beds with pyrite and fish debris include condensed styliolinid limestones and nodules (Fir Tree, Lodi, Abbey, Linden, Crosby, Genundewa) associated with surfaces of maximum sediment starvation formed during pulses of sea level rise. In this report, these horizons have been traced to the most highly condensed westernmost sections. The North Evans Limestone ("conodont bed") in the Buffalo area in western Erie County is a lag deposit of crinoid, fish and conodont debris that accumulated in shallow water over the peripheral bulge at the west margin of the basin where of the gap of the compound unconformity is greatest. Lenses of North Evans debris with ansatus Zone (Middle varcus) to upper MN Zone 2 conodonts and Frasnian goniatites (Koenenites) are traceable beneath the sub-upper Genundewa disconformity as far east as the Genesee Valley. (From Kirchgasser, Brett and Baird, 1997, fig. 7). See Fig. 3 for names of conodont zones.

Figure 3. Late Devonian succession in New York State showing alignment to international conodont zones (Standard and Montagne Noire [1-13], goniatite cephalopod divisions, and New York regional zones (12-28). MN Zone assignments follow Kirchgasser and Klapper (1992),

Kirchgasser (1994), Klapper et al. (1995) and Over (1997, 2002). New data indicate MN Zone 8 is represented in Rhinestreet Shale (see text) From House and Kirchgasser (2008, fig. 63).

within the water column, eventually shoal against the basin margin slope resulting in erosion and sediment traction (Baird and Brett, 1991). This fits into the black shale onlap scenario in that this erosion occurs on the Taghanic Unconformity slope prior to slope burial by black mud; as water deepens, owing to sea level-rise and/or flexural subsidence, the zone of pycnoclinal erosion continually migrates westward in the upslope direction ahead of black mud onlap which takes place within a lower energy, lower dysoxic substrate regime below the pycnocline (Baird and Brett, 1986, 1991). Westward flexural basin expansion during Geneseo Shale deposition would account for east-to-west slope drowning and conveyor belt-type pycnocline migration and subsequent sediment onlap along a 100 km lateral distance across western New York. Calcareous fossils and diagenetic carbonate debris reworked from the underlying Windom Shale on the east-sloping, sediment-starved, Taghanic erosional ramp would start out as calcareous lag material in a shallower water wave-influenced, oxygenated regime. Subsequent slope drowning with consequent overspread of dysoxic water below the pycnocline was believed to explain the dissolution and transformation of the lag material to a residual placer of pyrite and other insolubles. Since the zone of pycnocline impingement was always upslope from the mud onlap limit during Geneseo time, the basal Geneseo lag would always be made up of insoluble material (Baird and Brett, 1986).

It is significant that the Leicester example is not isolated; coarse insoluble lags associated with Devonian black shale-roofed unconformities have been examined elsewhere (see summary in Baird and Brett, 1991; Schieber, 1994, 1998; Brett et al., 2003). Moreover, in the Rhinestreet Formation (STOPS 1C, 2), Angola Formation (Stop 3) and in the Hanover Formation (STOPS 4, 5), we will observe numerous gray-black shale alternations where thin black layers, some only millimeters-thick, rest sharply on gray shale units. Some of these contacts display thin lags of reworked wire-like, pyritic burrows, flattened goniatites, some with pyritized sutures, and geopetally pyrite-filled, spherical cysts of the algal taxon Tasmanites (Schieber and Baird, 2001). Lags flooring these thin black layers are much thinner and finer than those associated with the major contacts.

Juergen Schieber, by contrast, argues for a shallower water origin of these discontinuities and associated black shale facies based on his work on the Ohio, Chattanooga, and New Albany shales (Schieber, 1994, 1998). Coarse tractional siltstones, sandstones, and shell beds within the very condensed black, Chattanooga Shale are interpreted by him as being the result of storm wave impingement. Calculations of orbital wave velocities accounting for coarse sand and detrital pyrite transport, as well as the scouring of consolidated shale, yielded velocities in excess of 150 cm/sec. suggesting water paleodepths of as little as 10 meters (Schieber, 1994, 1998). These contrasting models revive the long-standing “black shale paleodepth controversy.” Grit-grade pararipples and sheet sands occur within black shale facies of the Dowelltown Member of the Chattanooga Shale west of Nashville, Tennessee; not only does cross-laminated, grit-grade, quartz and phosphatic sand rest on the sub-Chattanooga disconformity, but this distinctive concentrate recurs at numerous overlying levels within the Dowelltown [G.C. Baird and A.J. Bartholomew (SUNY – New Paltz), unpublished observations]. Clearly, Schieber’s storm model appears to have some credibility in explaining black shale features on the Nashville Dome. The coarse-grained Dowelltown beds, as well as the Leicester and its analogs, pose a key question;

how does one reconcile “basinal,” widely-distributed, and near-anoxic, organic-rich shale with evidence for high energy current activity? Are these units truly shallow with a pycnocline maintained just below the sea surface, to be disrupted intermittently by storms? Does a shallow-to-deep spectrum of Devonian black shale types exist within the Appalachian Basin and beyond? If shallow Devonian black shales exist, are these maintained by enormous surface productivity or by purely physical mechanisms? Until a good actualistic (modern) example of Leicester-type deposits is found forming, they will remain an intriguing enigma, but also a key insight in our overall understanding of sedimentary processes in the rock record.

The model of regional bed onlap and deeper-water pycnoclinal erosion can also be applied to the younger North Evans bone/conodont lag bed flooring the Genundewa Limestone (see STOP 1A; Fig. 4). The Genundewa Formation of the Genesee Group is a condensed pelagic limestone unit almost entirely composed of the conical microfossil Styliolina fissurella [Order Dacryoconarida Fisher, 1962], a problematic 1-2 mm-long calcareous conical shell of uncertain affinities. It was originally described erroneously from flattened material, hence the specific name “fissurella” (see Hall, 1843, 1879). Subsequent workers placed these organisms in a variety of groups: pteropod mollusks, tentaculitids, protista, and convincingly a form of lophophorate (see Lindemann and Yochelson, 1994; Lindemann, 2002; Vinn and Zaton, 2012). The abundance of this taxon in the Genundewa constitutes a major regional bioevent, or epibole; this organism appears to have been a form of extinct plankton that must have undergone periodic “blooms” in the epicontinental sea. In the Genundewa, these shells are uncompressed and are sometimes replaced or casted by pyrite. Although this unit is volumetrically almost entirely composed of Styliolina, other fossils include coalified plant material, the diminutive bivalve Pterochaenia, conodonts, and goniatites, including Koenenites.

This stratum seems to mark a transgression from a eustatic or tectonically induced lowstand event recorded by a regional unconformity marking the top of the Penn Yan Shale and an associated coarse lag unit known as the North Evans Limestone bone/conodont bed (“Conodont Bed” of Hinde, 1879; Fig. 2). The dysoxic Genundewa styliolinid carbonate grainstone facies onlaps the unconformity surface to the northwest, the inferred foreland basin margin, to the point of near bed-extinction in eastern Erie County. The North Evans Limestone, similar to the Leicester Pyrite, is very coarse; it contains reworked fish teeth, bones, spines, scales, abundant pelmatozoan debris, pyritized mollusks, including early whorls of goniatites, and a rich and famous concentration of conodonts, an amalgamation of late Givetian and early Frasnian elements spanning several conodont zones (Baird and Brett, 1982; Brett and Baird, 1990; Bryant, 1921; Huddle, 1974, 1981; Kirchgasser, 1994; Hussakoff and Bryant, 1918; Over et al., 1999). The important difference between the North Evans and Leicester is the dominantly carbonate nature of the former and the overwhelmingly insoluble character of the latter. We believe that the North Evans lag accumulated under conditions that were less dysoxic and, by implications, shallower than those applying to the Leicester. In essence, the North Evans lag is what the Leicester may have looked like at an upslope position on the Taghanic ramp prior to its subsequent dissolution at greater depth (Brett and Baird, 1982; Baird and Brett, 1986). The biota is of low diversity and suggests a dysoxic stressed environment, particularly, when compared to the rich, high diversity benthic fauna of the Tichenor Limestone, a carbonate unit of comparable thickness 6 meters below the Genundewa along Eighteenmile Creek, Erie County. Devonian styliolinid limestone facies is also known from European and North African sections where it is understood to represent condensed pelagic facies which accumulated in sediment-starved settings on the order of tens to hundreds of meters of water depth (see Tucker and Kendall, 1973; Tucker,

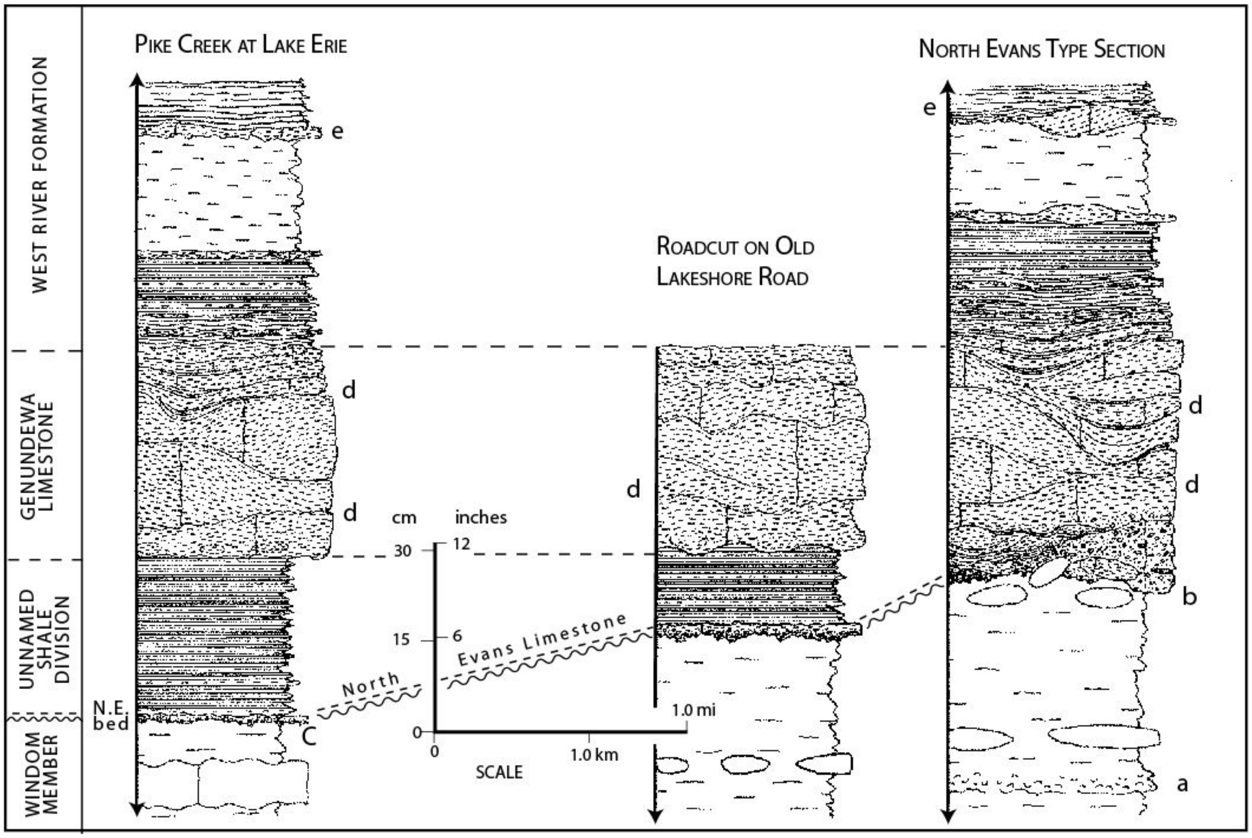


Figure 4. Genundewa Limestone and associated units in the vicinity of Lake Erie. Note prominent westward thinning of the North Evans lag deposit coupled with westward appearance of an unnamed black shale unit that separates the North Evans from the overlying Genundewa. Also visible is distinctive pinching and swelling of beds with associated localized channeling within the Genundewa. Lettered units include: a, Amsdell Bed of Windom Member yielding abundant Emanuella praeumbona; b, thick, pelmatozoan-rich subfacies of the North Evans Limestone; c, thin, pyrite-rich subfacies of the North Evans Limestone; d, Genundewa styliolinid grainstone-packstone carbonate facies; e, thin, lenticular, styliolinid limestone bed in the West River Formation yielding glauconite and abundant conodonts; this is sample-bed USGS 8122-SD Fall Brook, Geneseo (Livingston County) of Huddle (1981) and named the Huddle Bed in his honor (Baird et al., 2006).

1974; Bandel, 1974). The Genundewa compares most closely to the “cephalopodenkalk” (cephalopod limestone) facies of the German Rhenohercynian region; this carbonate accumulated on structural “highs” (schwellen) where styliolines, goniatites, diminutive bivalves, and ostracodes accumulated in a sediment-starved regime (Tucker, 1974; House and Kirchgasser, 1993). Basins between these swells received contemporaneous accumulation of thick shale units where turbiditic facies yield mainly ostracodes and little else. Compared to descriptions of the Rhenohercynian cephalopodenkalk, the Genundewa notably lacks micrite and is much more nearly a styliolinid grainstone (Fig. 4). However, it is locally packed with goniatite phragmocones in a manner typical of many cephalopodenkalk units. Acanthoclymenia, Koenenites, and Tornoceras , crinoid ossicles, and wood debris, can be found (see Kirchgasser et al., 1994, fig. 7, for sketches of the goniatites).

The Genundewa in Erie County is usually massive, but when weathered, the limestone typically splits apart into nodular and flaggy beds (Sass, 1951; Baird and Brett, 1982; Brett and Baird, 1982). Nodules occur as laterally linked to separate zones of sparry styliolinid limestone surrounded by muddy styliolinid partings. Bedding in the Genundewa is usually laminar with some evidence of bioturbation. Preparation for the present field trip led to discovery of cross stratification within the Genundewa along the Lake Erie shore bluffs southwest of Pike Creek and nearby on Eighteenmile Creek (Fig. 4). Several stacked sets of low angle cross stratified styliolinid grainstone can be seen with distinct thickening and thinning of beds in the cleaner, longer sections (Fig. 4). Locally, beds are distinctly cut out where channelization has occurred. This pattern resembles small-scale hummocky cross-stratification, suggesting the influence of deep-storm wave impingement at the substrate.

LATE DEVONIAN BASINAL FACIES AND EVENT HORIZONS

A sequence of alternating black and sparsely fossiliferous gray shale units, West River Formation-through-Dunkirk Formation, characterize the Late Devonian Frasnian and basal Famennian succession in southern Erie County. Inferred paleoenvironments range from nearly anoxic for portions of black shale units to more broadly dysoxic for the gray facies. No unit in this succession yields a significant benthos, though, as we will see, some strata yield a variety of pelagic taxa.

On the Lake Erie shore southwest of Eighteenmile Creek we will examine the lower part of the black Rhinestreet Formation, a major division of the West Falls Group (Fig. 6). Within the larger black shale interval is a 2.2-2.4 m-thick interval of predominantly gray shale with thin "pinstripe" black shale bands at several levels (Fig. 6). This is well exposed on the lakeshore (STOP 2) where a basal turbiditic? siltstone bed marks the base of the interval. Although some bioturbation can be seen in the gray shale, much of it is fine grained, conchoidal "satin shale," suggestive of turbiditic or hemipelagic origin. Hence the gray shale complex appears to be the distal "toe" of prodelta sediments within the basin. At STOP 1C a 1.0 cm-thick K-bentonite can be seen about one meter below the gray shale unit (Fig. 6). The pyroclastic character of this bed is revealed by an abundance of mica-rich clay which is suffused with diagenetic pyrite. This K-bentonite was reported by Levin and Kirchgasser (1994) to be the Belpre Ash of Tennessee, since confirmed by Lanik et al. (2013) to have the same radiometric date and similar conodont fauna. Some 40 cm above the gray shale interval exposed northeast of Sturgeon Point (STOP 2) is a 4 – 8 cm-thick interval of Styliolina–rich black shale that yields the zonally significant goniatite Naplesites (Fig. 7B), previously known in New York from a few specimens, presumably from the Rhinestreet Shale, that were reported by Clarke (1898) from around Naples in Ontario County. The discovery of conodonts in Styliolina concentrations associated with the goniatites, offers an opportunity to link conodont, ammonoid chronostratigraphic, and zircon derived U/Pb radiometric age from the underlying ash bed. The goniatites are notable for their poor, ghost-like preservation in the black shale, suggesting that the aragonite of the phragmocone may have dissolved before significant mud compaction had taken place, but that the organic periostracum survived after compaction, leading to the flattened, composite impressions of these fossils; the edges of some of the septa (chevron-pattern suture lines) are replaced by pyrite. The goniatite clusters include a variety of ontogenetic stages from juveniles to adults with shell diameters exceeding 100 cm.

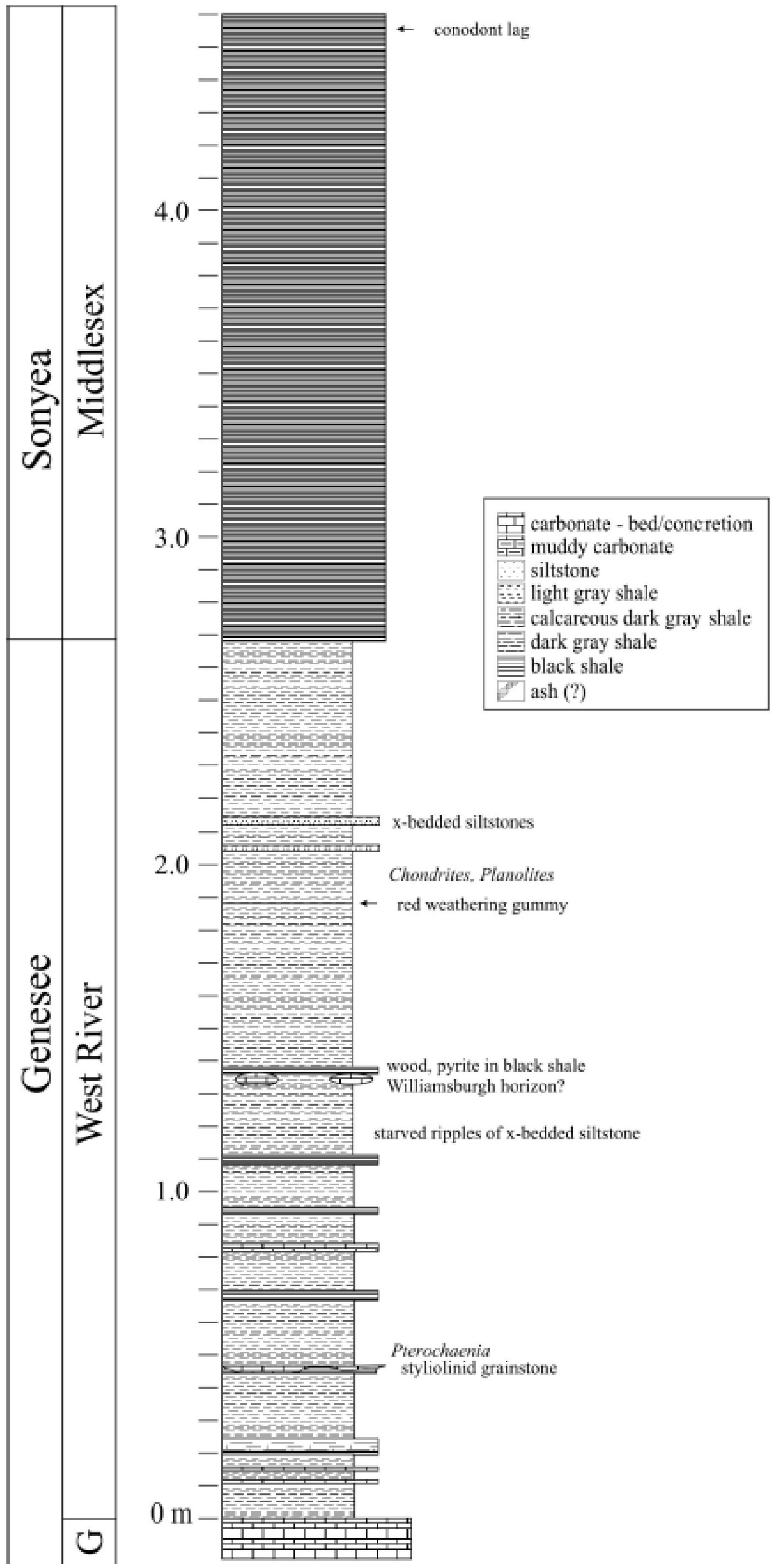


Figure 5. Stratigraphic section of the West River Formation and Middlesex Formation at Eighteenmile Creek. G = Genundewa Limestone.

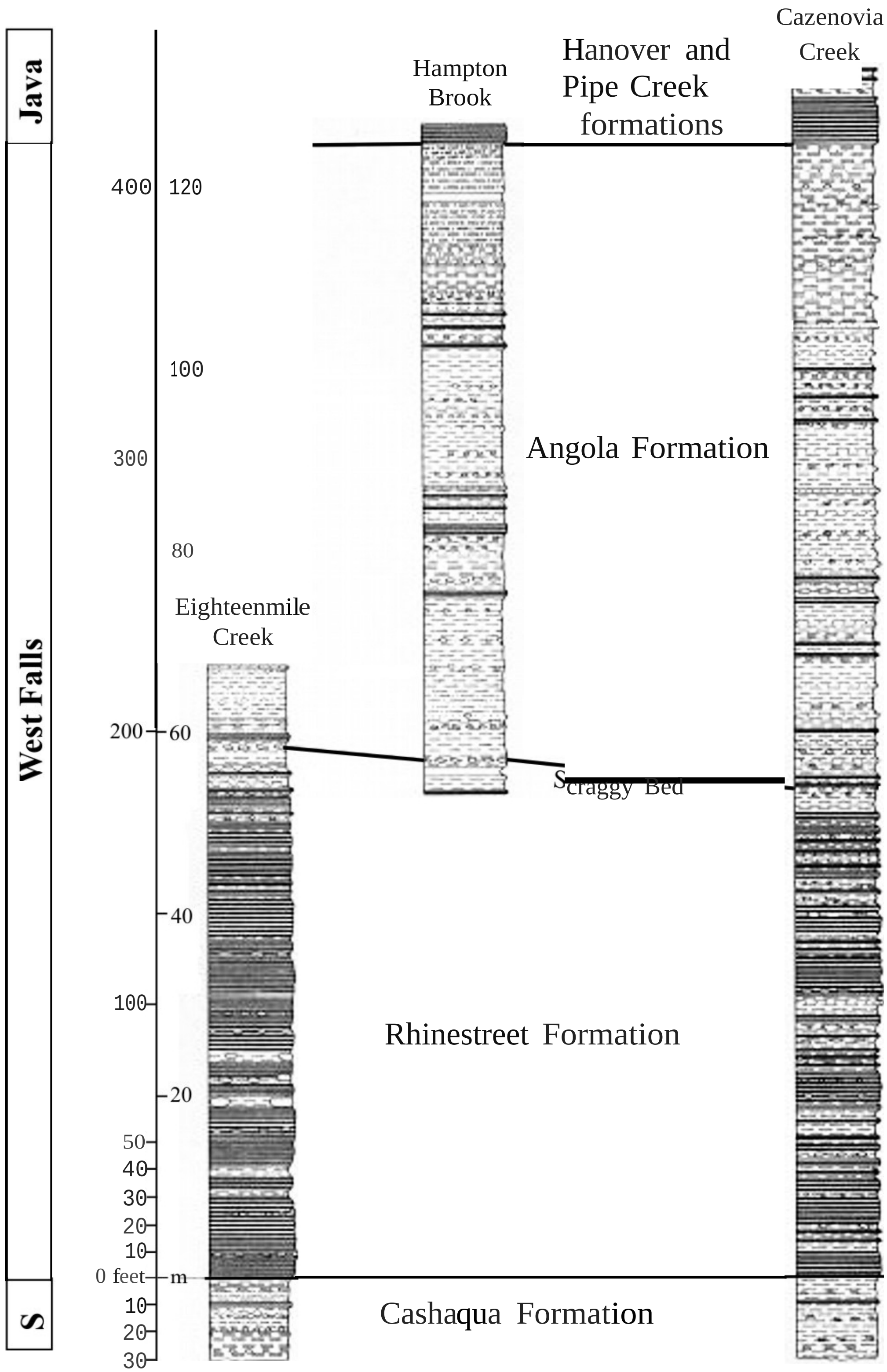


Figure 6A. General stratigraphy of the West Falls Group – Rhinestreet and Angola formations - on the Lake Erie shore and adjacent creek exposures, from Pepper et al. (1956). S = Sonyea Group. See Figure 5 for key to symbols.

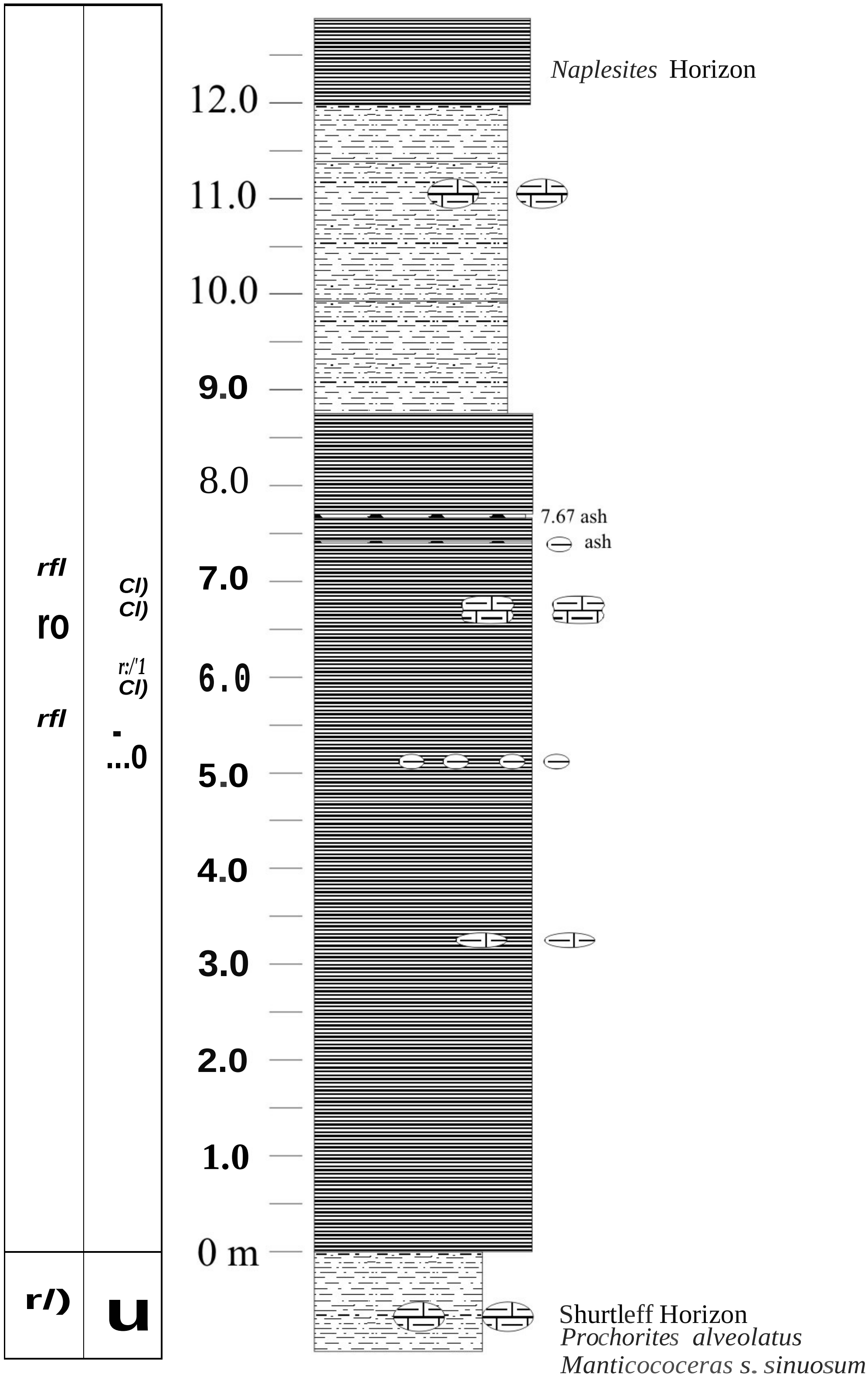


Figure 6B – Detailed section of the basal Rhinestreet Formation at Eighteenmile Creek. S = Sonyea Group; Ca = Cashaqua Formation. See **Figure 5** for key to symbols.

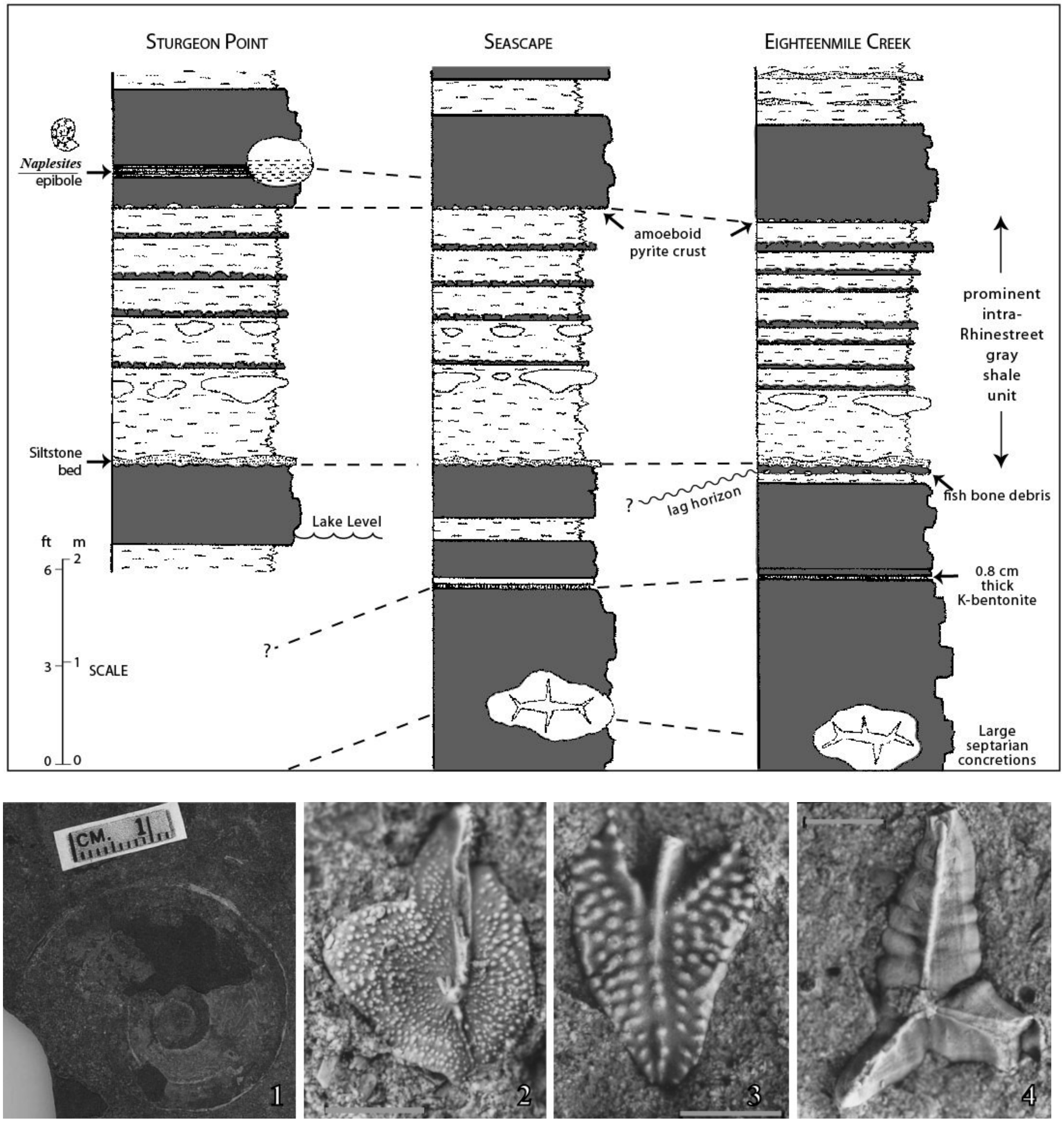


Figure 7A. Unnamed gray shale division within the lower part of the Rhinestreet Formation in the vicinity of Lake Erie in southern Erie County. Note the numerous gray-green shale alternations within the gray shale division, the K-bentonite bed below, and the Naplesites goniatite epibole above. B. 1. Goniatite Naplesites with characteristic chevron-pattern suture line preserved in pyrite from the Naplesites epibole. 2-4. Conodonts from the fish-conodont lag beneath the siltstone at base of gray shale division; 2, Palmatolepis punctata; 3, Ancyrodella nodosa s.s.; 4, Ancyrognathus sp. L of G. Klapper. Scale bar = 0.5 mm.

Southwest of the Sturgeon Point marina and car park is a low, resistant bench of Rhinestreet black shale. At the top of the bench and above a band of massive septarial concretions are two closely-spaced zones of small, 0.3 – 3.5 cm- diameter phosphatic nodules which occur interspersed among larger limestone concretions. Close examination of the phosphatic nodules shows that they selectively grew around fish bones, spines, and scales. The high proportion of fish- nucleated nodules in this location suggests a time of significant water column productivity and/or sediment condensation. This horizon may be one of many similar beds yet to be recognized in the Devonian basinal succession. Recently G. Baird reconnoitered past the phosphate-bearing outcrop and around the shore bend to the southwest. Outcrop commences again with appearance of gray-green shale, gray discoidal concretions, and thin black shale layers both at and below water-level. Capping this is a bench of black shale yielding numerous Naplesites. It seems that the northward-projecting Sturgeon Point brings up older strata and that the section, north of the marina, is repeated once again. This would mean that the phosphatic beds should be present at Seascape, at our Eighteenmile Creek stop, and, possibly, locally at lake-level northeast of the Sturgeon Point marina.

Overlying the Rhinestreet in westernmost New York is the Angola Formation, which represents a return to Cashaqua-like conditions of predominantly gray silty shales and interbedded black shales and concretionary beds (Fig. 7). Eastward the Angola interfingers and grades into the Gardeau and Nunda formations, which represent more near shore turbiditic and sandstone facies of the deep shelf and shoreface (Pepper et al., 1956; Baird and Jacobi, 1999). Along the Lake Erie shore the Angola is on the order of 60 m thick. We will look at a lower portion of the Angola at Point Breeze (Stop 3) where goniatite-bearing concretions – Pt. Breeze Bed of House and Kirchgasseer (2008) and a distinctive black shale are exposed, as well as the uppermost Angola at Walnut Creek (Stop 4). The sedimentary microcycles seen in the Rhinestreet are continued in the Angola; these cycles and key beds can be traced well into Wyoming County to the east (House and Kirchgasser, 2008, fig. 15). The concretionary beds in the lower Angola are rich in well preserved goniatites. The type materials of Sphaeromanticoceras rhynchostomum (Clarke, 1898) and Carinoceras sororium (Clarke, 1898) come from the lower Angola. Other goniatites from the Pt. Breeze Bed include Sphaeromanticocera oxy, Carnioceras vagans, Manticoceras lamed, M. aff. M. lamed, Playfordites cf. P. tripartitus, Linguatornoceras aff. L. linguum, Aulatornoceras pacistriatum, and Crassotornoceras aff. C. crassum. These place the lower Angola in Devonian Goniatite Division Neomanitcoceras UD I-J; conodonts from this interval have not provided a distinct zonation (House and Kirchgasser, 2008), but are probably in MN 11.

The closing of the Late Devonian Frasnian stage was marked by two major episodes of ecological disruption and faunal extinction. The second of these, marking the Frasnian- Famennian boundary and associated mass extinction, was the greater crisis globally. This extinction, in part, probably explains the lower diversity and more generalized ecological character of Famennian neritic faunas seen higher in the Devonian succession in Chautauqua and Cattaraugus counties, south of the field trip area. In Europe, North Africa, and elsewhere the two extinction events are marked by black shale or black limestone beds within slope and basin successions. These are known respectively as the “lower Kellwasser Bed” and “Upper Kellwasser Bed” in the literature (see Over, 2002; Racki, 2005; Schindler, 1993; Schindler and Königshof, 1997). Recently, both the lower and Upper Kellwasser equivalent beds have been found in western New York on the basis of lithology correlated to conodont zonation (Over, 1997, 2002; Day and Over, 2002; Over et al., 1997). The lower Kellwasser event is now linked to the Pipe Creek Formation, marking the base of the Java Group; we will see this unit at Walnut Creek (STOP 4; Figs. 8, 9). The Upper Kellwasser event correlates to a black shale bed in the upper part of the Hanover Shale Formation near the top of the Java Group (Over, 1997, 2002); we will see this bed at Point Gratiot (STOP 5; Fig. 10).

The Pipe Creek Formation at Walnut Creek (STOP 4) is a 0.6 meter-thick, very hard, black shale that abruptly overlies the softer, gray Angola Formation (Fig. 8, 9). The laminated microfacies of the Pipe Creek contrasts dramatically with a subjacent zone of gray, pyritic Angola mudstone; this 15 cm-thick mudstone interval is thoroughly penetrated by networks of pyritic burrows which can be dramatically seen through x-ray imaging (Fig. 9). The Pipe Creek can be traced regionally southwestward into Chautauqua County where it is approximately 0.6 meters thick in its westernmost section (Tesmer, 1963). To the east, it thickens to about 6 or 7 meters near Warsaw, then becomes more depositionally complicated and interbedded with turbiditic silts and sands of the underlying Nunda Formation (Baird and Jacobi, 1999). The actual ecological reorganization-extinction event, best seen in neritic facies, is cryptic in Erie County; study of this faunal change will be the domain of work in equivalent silty-sandy facies in central New York. However, tentative discovery of a 1.2 cm-thick K-bentonite bed rich in pyroclastic micas in the Eighteenmile Creek section offers the possibility that this interval can be dated radiometrically. Given that the Pipe Creek Formation is succeeded by gray, goniatite-bearing nodular shales of the basal Hanover Formation (STOP 4 description; Fig. 8), the combined radiometric date and the goniatite - conodont information will constitute a key point for the global Lower Kellwasser Event.

The lower Hanover Formation shows distinct meter-scale cyclic packages of black shale - gray shale with concretion horizons that is seen elsewhere in the offshore faices of the Frasnian strata. The base of the black shales represents a starvation surface and condensed interval of a flooding surface, possibly accumulating pyrite – see Baird and Brett (1987) as well as volcanic ash. The black shales then represent the condensed early highstand and time of organic preservation under relatively deeper or quiet water conditions. The concretion horizons are believed to develop prior to significant compaction within the substrate, probably at the time of sediment starvation of the overlying black shale base (see Raiswell, 1971; Raiswell and Fisher, 2000).

The Upper Kellwasser Bed is exposed in upper Hanover Shale at numerous localities in western New York from the Genesee River Valley to Point Gratiot on the Lake Erie shore (Over, 2002). At Point Gratiot it occurs within the upper part of the Hanover Formation 0.15 m below the base of the Lower Famennian Dunkirk Formation. Along Eighteenmile Creek near New Oregon Road the bed is 2.4 meters below the base of the Dunkirk. Generally, the Hanover Formation is predominantly gray mudstone with a few rhythmic bundles of thin black shale units. Above the Pipe Creek and at several higher levels, this unit is spectacularly nodular with repeating bands of calcareous concretions and distinctive beds of irregular, closely crowded, beige nodules resembling calcrete (Fig. 8). Generally the Hanover yields only a low diversity fauna of ostracodes, small gastropods, bivalves, sparse goniatites, and small rugosans despite its light color, pervasive bioturbation, (including Zoophycos), and numerous carbonate layers. It appears to record relative sedimentary condensation under dysoxic conditions. However, compared to

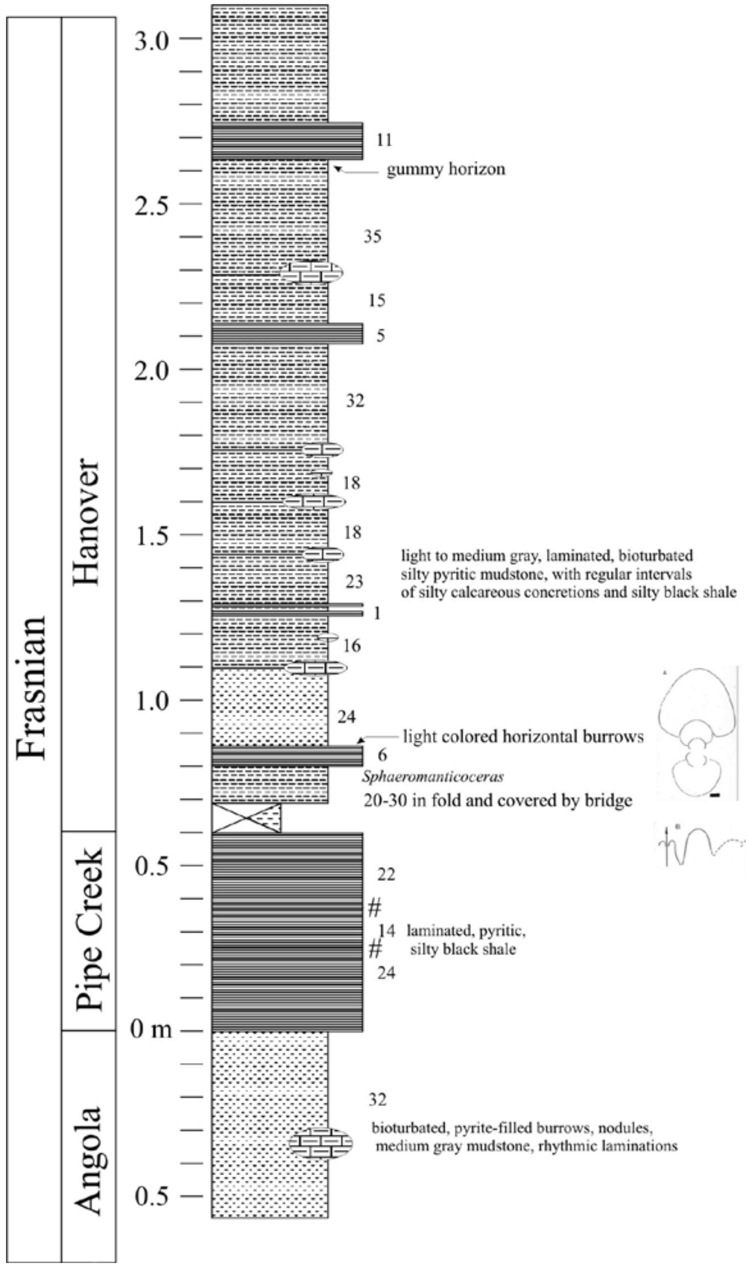


Figure 8. Pipe Creek Formation ("Lower Kellwasser Bed") and synjacent units at Walnut Creek (STOP 4). A, B are cross section and suture pattern of Crickities lindneri which enters at approximately 1 m in this section marking the base of the Crickites Geozone and Division UD I-L. Gummy horizon is a possible ash bed. See Figure 5 for key to symbols.

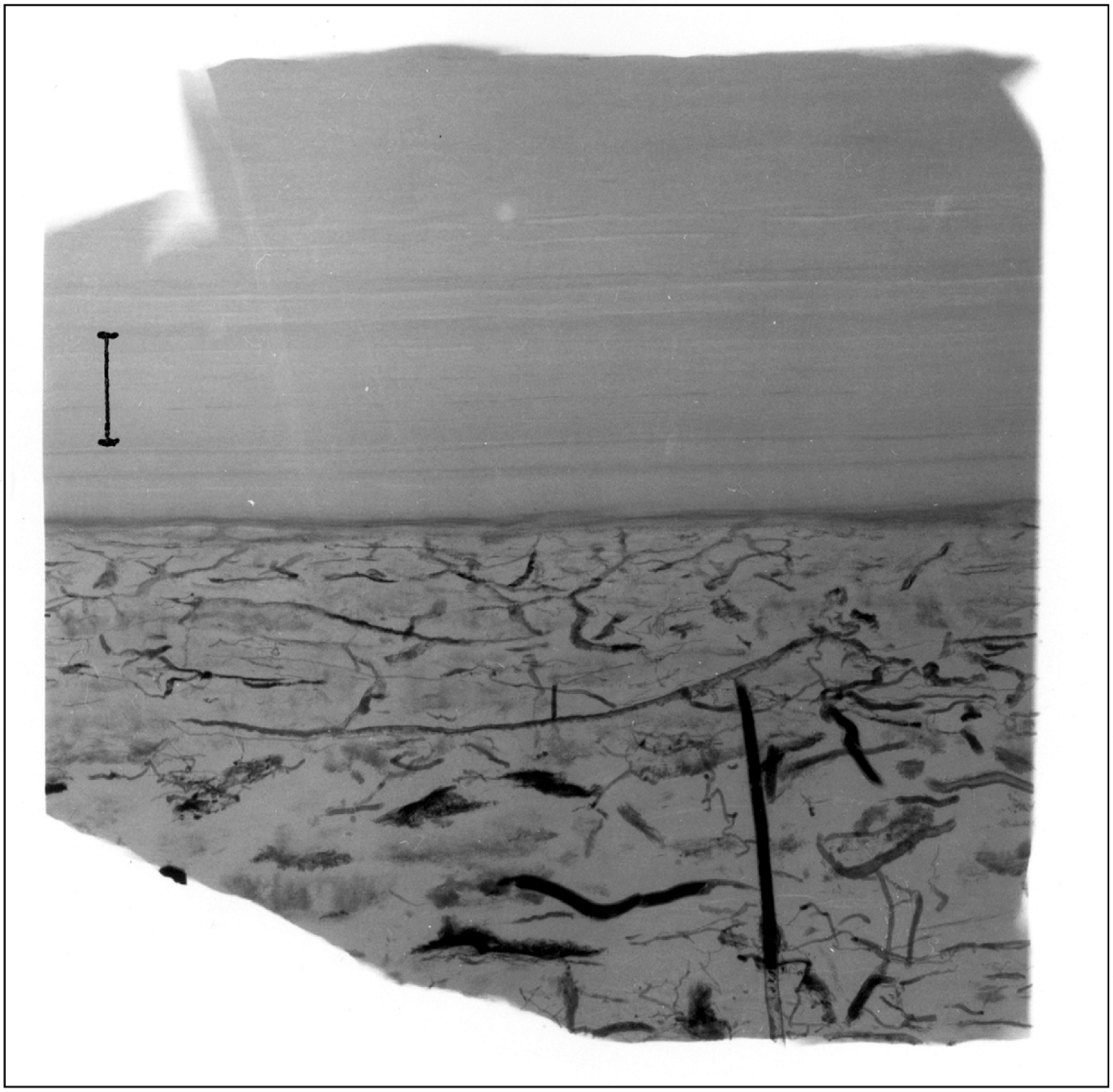


Figure 9. X-radiographic image of the contact between the Angola Shale and the overlying Pipe Creek Formation. Although this specimen is from the type Pipe Creek section near West Falls, Erie County, that contact is essentially identical to the one seen at STOP 4. Note the conspicuous vertical change from the bioturbated gray Angola into the laminated Pipe Creek lithology. Scale is 1.0 centimeter.

dysoxic – minimally oxic units in the Middle Devonian Hamilton Group (Levanna Member, Ledyard Member), the facies is markedly poorer in shelly benthos and richer in bands of small and irregular nodules. This suggests some dynamic geochemical-evolutionary changes across the Givetian and Frasnian that have yet to be identified or quantified.

The Upper Kellwasser Bed is expressed as a fissile black shale unit with some silty laminations in the upper part (Fig. 10). This bed is designated the Point Gratiot Bed for the excellent exposure along Lake Erie at Point Gratiot at the southwest edge of Dunkirk, Chautauqua County (Stop 5). This layer, which is 15 cm-thick at Point Gratiot, is traceable eastward to the vicinity of Hornell and Canisteo in Steuben County where it is approximately 2 meters-thick (Over, 1997, 2002). At Point Gratiot and at Beaver Meadow Creek at Java Village the upper part of this layer has yielded articulated fish remains. At Beaver Meadow Creek, Spathiocaris, a probable cephalopod anaptychus, is common. It is important to note that the Point Gratiot Bed does not mark the base of the Dunkirk Formation of the Canadaway Group as was indicated by Baird and Lash (1990) and Baird and Brett (1991); the Point Gratiot Bed actually marks an apparent change to finer grained, more basinal facies within the upper part of the Hanover Formation [see revised schematic (Fig. 11) clarifying this relationship]. Between Point Gratiot and Java Village the interval between the Upper Kellwasser Bed and the overlying Dunkirk thickens from 15 cm to 7 meters with addition of numerous alternating black and gray-green shale beds (Fig. 11). The occurrence of reworked pyrite in the form of wire-like detrital burrow fragments at the bases of the black Dunkirk Shale and underlying upper Hanover black bands indicates that these contacts are of erosional character; some of the southwestward thinning of the upper Hanover is apparently due to collective overstep at such contacts (Baird and Lash, 1990).

The Upper linguiformis (MN Zone 13)/Lower triangularis chronozonal conodont boundary and inferred Frasnian-Famennian contact (Fig. 3) is crossed near or at the top of the Upper Kellwasser Bed based on work at Point Gratiot in Dunkirk, Irish Gulf, and at Beaver Meadow Creek in Java Village (see Over, 1997, 2002). Again, the major extinction event, observed globally at this level, is cryptic in the black shale facies except for the microfossil changes. However, one of us, Jeff Over, has described a bed of shelly taxa containing earliest Famennian brachiopods and bivalves in a thin, anomalous layer only one meter above the extinction horizon near Java Village (Day and Over, 2002). This "recovery layer" sheds important clues as to the nature of macrofossil changes in western New York following the mass extinction. Moreover, new fieldwork by Over in neritic deposits at this level further east near Hornell, by Boyer and students, and work by Baird in southern Chautauqua County, is shedding light on the more visceral effects of the extinction on shelly benthos and bioturbators in lower Famennian neritic deposits.

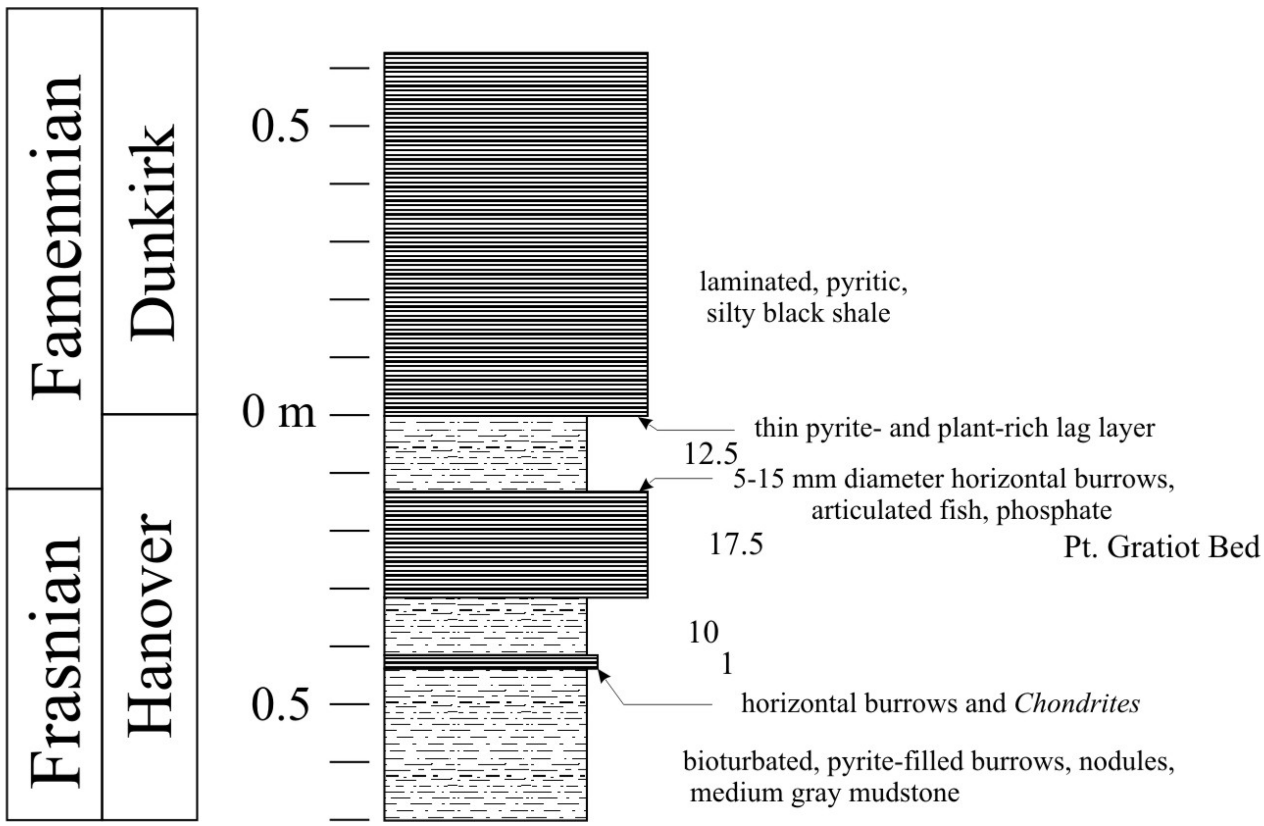


Figure 10. Frasnian-Famennian boundary horizon within the upper part of the Hanover Shale on the Lake Erie shore at Point Gratiot. Note that the local Frasnian-Famennian boundary unit, corresponding to the global "Upper Kellwasser Bed" of chronostratigraphic literature, designated the Point Gratiot Bed. See Figure 11 for lateral changes in the Hanover Shale, especially the inflation of the 12 cm interval between the Pt. Gratiot Bed and the Dunkirk Formation. See Figure 5 for key to symbols.

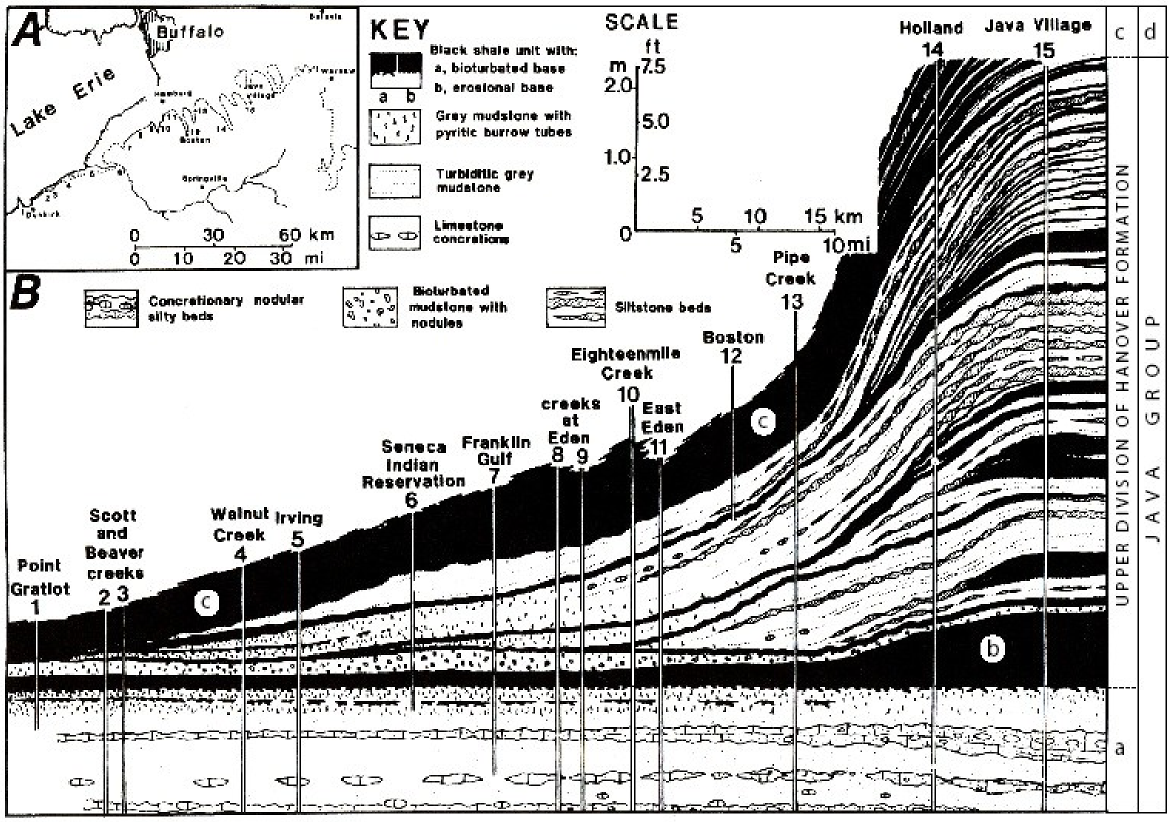
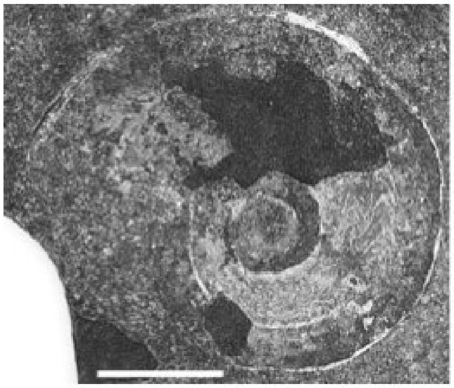
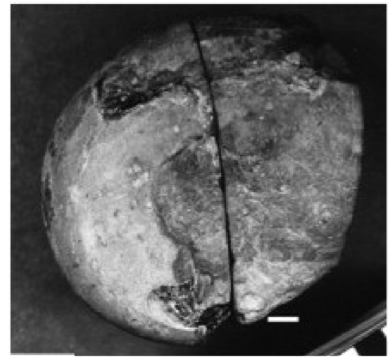


Figure 11. Regional stratigraphy of units within the upper part of the Hanover Formation across Chautauqua, Erie, and southwest Wyoming counties. Note conspicuous eastward thickening of the upper Hanover unnamed division of alternating thin gray and black shale with eastward splaying of units into a distal deltaic wedge and westward erosional overstep of underlying units by Dunkirk and upper Hanover black shale beds. Note also that the upper medial Hanover Formation below the newly named Point Gratiot Bed (= "Upper Kellwasser Bed") is notably more calcareous, bioturbated, and lighter colored than overlying units (see discussion in text). This figure is modified from Baird and Lash (1990) and Baird and Brett (1991) in that the Point Gratiot Bed is shown to be a division within the upper Hanover succession rather than the base of the Dunkirk Formation as shown in these earlier reports. Lettered units include: a, calcareous bed in upper medial part of Hanover Formation; b, Point Gratiot Bed; c, basal strata of Dunkirk Shale.



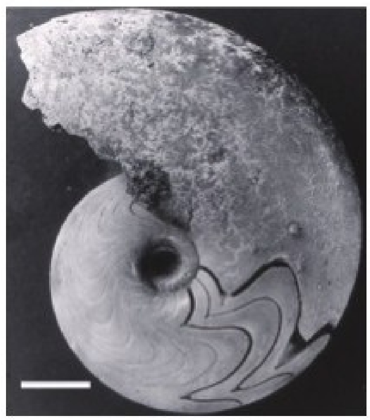
7

8



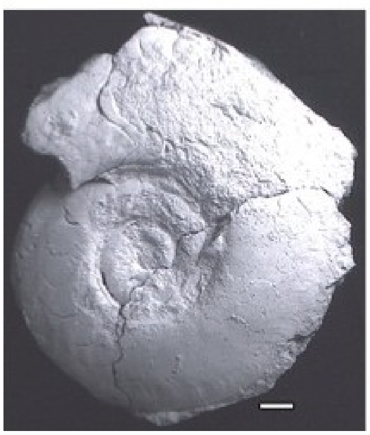
9

4



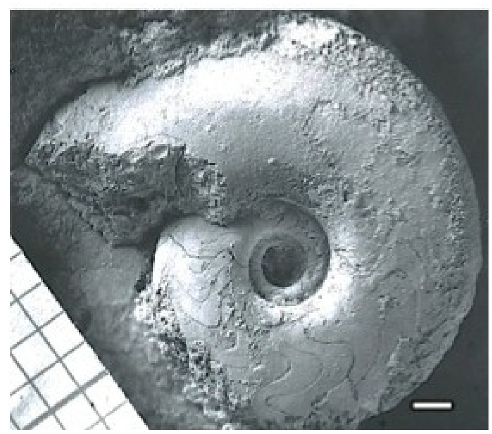
5

6



1

2



3

Figure 12. Goniatite cephalopods from Late Devonian of western New York: in stratigraphic order [Givetian (1) and Frasnian (2-9)]. Specimens illustrated in House and Kirchgasser (2008) and reposited in New York State Museum, Albany. Bar scales: 1 cm. 1. Ponticeras perlatum, Lodi Limestone, Lodi Glen, Seneca Lake. 2. Koenenites styliophilus styliophilus, Penn Yan Shale, Sartwell Ravine, Keuka Lake. 3. Koenenites styliophilus kilfoylei, Genundewa Limestone, Bethany Center, Genesee County. 4. Probeloceras lutheri, Cashaqua Shale, Eighteenmile Creek, Erie County (pyrite replacement). 5. Manticoceras sinuosum sinuosum, Cashaqua Shale, Beards Creek, Livingston County (pyrite replacement). 6. Prochorites alveolatus, Cashaqua Shale, Honeoye Lake, Ontario County (barite replacement). 7. Naplesites naplesense?, Rhinestreet Shale, Sturgeon Point, Lake Erie shore, Erie County (pyrite replacement). 8. Sphaeromanticoceras oxy, Angola Shale, Kennedy Gulf, Wyoming County. 9. Crickites lindneri, Hanover Shale, Walnut Creek, Chautauqua County.

ACKNOWLEDGMENTS

Tim Phillips of the University of Cincinnati was of essential assistance in lettering and cleaning up several of the figures used herein. Dr. Jonathan Muntz performed the X-radiography of the Pipe Creek Shale specimen at no charge. Fritz Ehmke graciously allowed access to Walnut Creek in Silver Creek.

REFERENCES

Baird, G. C., and Brett, C.E. 1982. Condensed sedimentary sequences and associated submarine hiatus within a cratonic basin setting – case study of Upper Devonian Genundewa Limestone of New York. Abstract, American Association of Petroleum Geologists, Eastern Section, 11th Annual Meeting, Buffalo, p. 1.

Baird, G. C., and Brett, C.E. 1986. Erosion on an anaerobic seafloor. Significance of reworked pyrite deposits from the Devonian of New York State. Palaeogeography, Palaeoclimatology, Palaeoecology, 57:157-193; Amsterdam.

Baird, G. C., and Brett, C.E. 1991. Submarine erosion on the anoxic seafloor, paleoenvironmental and temporal significance of reworked pyrite-bone deposits. In Tyson, R.V. and Pearson, T.H. (eds.), Modern and Ancient Continental Shelf Anoxia. Geological Society Special Publication, 58:223-257; London, England.

Baird, G. C. and Brett, C.E. 2003. Shelf and off-shelf deposits of the Tully Formation in New York and Pennsylvania. Faunal incursions, eustasy and tectonics. Cour. Forsch. Senckenberg, 242: 141-156; Frankfurt am Main.

Baird, G.C., Brett, C.E., and Bartholomew, A.J. 2003. Late Middle Devonian biotic and sedimentologic events in east-central New York – Tully Formation clastic correlative succession in the Sherburne – Oneonta area. In Johnson, E. L. (ed.), Field Trip Guidebook – New York State Geological Association, 75th Annual Meeting, 1-54; Oneonta, New York.

Baird, G. C. and Jacobi, R. 1999. “Nunda Sandstone” depositional event in the Pipe Creek black shale, South Wales-Varysburg area, New York, SUN B1-SUN B7. In Baird, G.C. and Lash, G.G. (eds.), Field Trip Guidebook, New York State Geological Association, 71st Annual meeting, Fredonia.

Baird, G.C., Kirchgasser, W.T., Over, D.J. and Brett, C. 2006. An early late Devonian bone-bed-pelagic limestone succession: the North Evans-Genundewa Limestone story. In Jacobi, R. (ed.), Guidebook, New York State Geological Association, 78th Annual Meeting, Buffalo, New York, p. 354-395.

Baird, G.C. and Lash, G.G. 1990. Devonian strata and paleoenvironments: Chautauqua County region: New York State. In Lash, G.G. (ed.), Field Trip Guidebook, New York State Geological Association, 62nd Annual Meeting, A1-A46, Fredonia, New York.

Bandel, K. 1974. Deep-water limestones from the Devonian-Carboniferous of the Carnic Alps, Austria, 93-116. In Hsü, K.J. and Jenkyns, H.C., Pelagic sediments: on land and under the sea. International Association of Sedimentologists Special Pub. No. 1, Blackwell, Oxford.

Brett, C.E. and Baird, G. C. 1982. Upper Moscow-Genesee stratigraphic relationships in western New York: evidence for regional erosive beveling in the late Middle Devonian, 19-65. In Buehler, E.J. and P.E. Calkin (eds.), Guidebook for field trips in western New York, northern Pennsylvania, and adjacent southern Ontario. New York State Geological Association, 54th Annual Meeting, Buffalo.

Brett, C.E. and Baird, G.C. 1990. Submarine erosion and condensation in a foreland basin: examples from the Devonian of Erie County, New York, SUN A1-SUN A56. In Lash, G.G. (ed.), Field Trip guidebook, New York State Geological Association, 62nd Annual Meeting, Fredonia, New York.

Broadhead, R.F., Kepferle, R.C., and Potter, P.E. 1982. Stratigraphic and sedimentological controls of gas in shale – example from Upper Devonian of northern Ohio. American Association of Petroleum Geologists Bull., 66:10-27.

Bryant, W. L. 1921. The Genesee condonts. Buffalo Society of Natural Science Bulletin, 13(2):1-59
Buehler, E. J. and Tesmer, I.H. 1963. Geology of Erie County, New York, Buffalo Society of Natural Sciences, Bull., 21(3), 118 p.
Clarke, J.M. 1898. The Naples Fauna (fauna with Manticoceras intumescens) in Western New York, Part 1. Albany, NY. 161 p.
Colton, G.W. and deWitt, W.Jr. 1958. Stratigraphy of the Sonyea Formation of Late Devonian age in western and west-central New York. U.S. Gelogical Survey, Oil and Gas Invent., Chart OC-54.
Day, J.E., and Over, D.J. 2002. Early Famennian post-extinction brachiopod and conodont fauna in western New York State. Acta Palaeontologica Polonica, 47(2):189-202.
deWitt, W., Jr. 1960. Java Formation of Late Devonian age in western and central New York, American Association of Petroleum Geologists Bull., 44:1933-1939.
deWitt, W. Jr., and Colton, G.W. 1959. Revised correlations of lower Upper Devonian rocks in western and central New York, American Association of Petroleum Geologists Bull., 43:2810-2828.
Ettensohn, F.R. 1987. Rates of relative plate motion during the Acadian Orogeny based on spatial distribution of black shales. Journal of Geology, 95:572-582; Chicago, Illinois.
Ettensohn, F.R. 1994. Tectonic control on the formation and cyclicity of major Appalachian unconformities and associated stratigraphic sequences. In Dennison, J. and Ettensohn, F.R. (eds.), Tectonic and eustatic controls on sedimentary cycles. SEPM Concepts in Sedimentology and Paleontology, 4:217-242.
Ettensohn, F.R. 1998. Compressional tectonic controls on epicontinental black shale deposition: Devonian-Mississippian examples from North America. In Schieber, J., Zimmerle, W. and Sethi, P.S. (eds), Shales and Mudstones, vol., 1 (Basin Studies, Sedimentology, and Paleontology), p. 109-128: E. Schweizerbart' sche Verlagsbuchhandlung (Nagele u. Obermiler); Stuttgart, Germany.
Fisher, D.W. 1962. Small concoidal shells of uncertain affinities. In Moore, R.C. (ed.) Treatise on Invertebrate Paleontology, Part W, Miscellanea, p. W98-W143. Geological Society of America and University of Kansas Press.
Hall, J. 1843. Geology of New York. Part IV, comprising the survey of the fourth Geological District (Natural history of New York, Div. 4, Geology Vol. 4).
Hall, J. 1879. Descriptions of the Gasteropoda, Pteropoda, and Cephalopoda of the Upper Helderberg, Hamilton, Portage, and Chumung groups. New York State Geological Survey, Paleont. Vol. 5, Part 2, Albany.
Heckel, P.H. 1973. Nature, origin, and significance of the Tully Limestone. Geological Society of America Special Paper, 139, 244 p.; Boulder, Colorado.
Hinde, G.J. 1879. On conodonts from the Chazy and Cincinnati Group of the Cambro-Silurian, and from the Hamilton and Genesee shale divisions of the Devonian, in Canada and the United States. Quarterly Journal of the Geological Society of London, 35:351-369.
House, M.R. and Kirchgasser, W.T. 1993. Devonian goniatite Biostratigraphy and timing of facies movements in the Frasnian of eastern North America. In Hailwood, E.A. and Kidd, R.B. (eds.), High Resolution Stratigraphy. Geological Society, Special Publication 70, p. 267-292.

House, M.J. and Kirchgasser, W.T. 2008. Late Devonian goniatites (Cephalopoda, Ammonoidea) from New York State. Bulletins of American Paleontology, v. 374, 285 p., Paleontological Research Institution (PRI), Ithaca, New York.

Huddle, J. 1968. Rediscription of Upper Devonian conodont genera and species proposed by Ulrich and Bassler in 1926. United States Geological Survey Professional Paper 578, p. 1-55.

Huddle, J. 1974. Middle/Upper Devonian conodont zonations in western New York. Abstracts with Programs, North-Central Section, Geological Socity of America. Vol. 6(6), p. 512.

Huddle, J. 1981. Conodonts from the Genesee Formation in western New York. U.S. Geol. Surv. Professional Paper, 1032 B, 66 p; Washington, D.C.

Hussakoff, L. and Bryant, W.L. 1918. Catalog of the fossil fishes in the museum of the Buffalo Society of Natural Sciences. Buffalo Society of Natural Sciences, Bull.Vol. 12.

Johnson, J.G., Klapper, G. and Sandberg, C.A. 1985. Devonian eustatic fluctuations in Euramerica. Geological Society of America Bulletin, 96:567-587; Boulder, Colorado.

Kirchgasser, W.T. 1994. Early morphotypes of Ancyrodella rotundiloba at the Middle-Upper Devonian Boundary. In Landing, E. (ed.), Studies in stratigraphy and paleontology in honor of D.W. Fisher. New York State Museum Bulletin 481:117-134.

Kirchgasser, W.T. 1998. Problems in sampling the North Evans and Genundewa limestones(Genesee Group of New York) and the development of the conodont zonation around the Middle-Upper Devonian (Givetian/Frasnian) boundary. Abstracts with Programs, North-Central Section, Geological Society of America, 30(2), p. 27.

Kirchgasser, W.T. 2001. Taphonomy and “sequence” of conodont and ichthyoliths in the North Evans remanié deposit at the Taghanic-sub-Genundewa Unconformity (late Givetian-early Frasnian) in western New York. In Königshof, P. and Plodowski, G. and Schindler, E. (eds.), Mid-Paleozoic Bio- and Geodynamics, The North Gondwana-Laurussia Interaction, 15th International Senckenberg Conference, Senckenbergische Naturforschende Gesellsdhaft, Frankfort am Main, Abstracts, p. 53.

Kirchgasser, W.T. 2002. Taphonomy of conodonts and microvertebrates in remanié horizons: new approaches to unraveling stratigraphic relations around the Middle-Upper (Givetian-Frasnian) boundary in western New York. Abstracts with Programs, Northeastern Section, Geological Society of America, vol. 34(1), p. A-58.

Kirchgasser, W.T. 2004. Conodonts in pyrite lag deposits at the Taghanic Unconformity in New York State: problems in dating faunas in highly condensed beds around the Middle(Givetian)-Upper (Frasnian) Devonian boundary. In Devonian neritic-pelagic correlation and events. Abstracts, IUGS Subcommission on Devonian Stratigraphy and Institut Scientifique, University Mohammed V, Rabat, Morocco, p. 27.

Kirchgasser, W.T., Baird, G.C. and Brett, C.E. 1989. Regional placement of Middle/Upper Devonian (Givetian-Frasnian) boundary in western New York State. In McMillan, N.J., Embry, A.F. and Glass, D.J. (eds.), Devonian of the World, Canadian Society of Petroleum Geologists Memoir 14 (3):113-117; Calgary, Alberta. [1988]

Kirchgasser, W.T., Brett, C.E. and Baird, G.C. 1997 Sequences, cycles and events in the Devonian of New York State: an update and overview. In Brett,C. E. and Ver Straeten, C.A., (eds.), Devonian cyclicity and sequence stratigraphy in New York State. Field Trip Guidebook for Subcommission on Devonian Stratigraphy (SDS) meeting July 22-27, 1997. Published through the University of Rochester, Rochester, New York. 369 p.

Kirchgasser, W.T. and Klapper, G. 1992. Zonal and graphic correlation of the New York and Australian Upper Devonian (Frasnian) conodont and ammonoid sequences. Abstracts with Programs, North-Central Section, Geological Society of America, 24(4):26

Kirchgasser, W. T. and Koslowski, D. 1996. North Evans conodont fauna at Cayuga Creek, Erie County, western New York: evidence of reworked conodonts during part of the early Upper Devonian. Abstracts with Programs, Northeastern Section, Geological Society of America, 28(3):72-73.

Kirchgasser, W.T., Over, D.J. and Woodrow, D.L. 1994. Frasnian (Upper Devonian) strata of the Genesee River Valley, western New York State. In Brett, C.E., and Scatterday, J. (eds.), Field Trip Guidebook. New York State Geological Association, 66th Annual Meeting, Dept. of Earth and Environmental Sciences, the University of Rochester, Rochester, New York, p. 325-358.

Kirchgasser, W. T. and Vargo, B. 1998. Middle Devonian conodonts and ichthyoliths in an Upper Devonian limestone in New York: implications for correlations around the Givetian-Frasnian boundary. In Bagnoli, G. (ed.), Abstracts, Seventh European Conodont Symposium (ECOS VII), Bologna-Modena, Tipografia compositori Bologna, p. 82.

Klapper, G., Kirchgasser, W.T. and Baesemann, J. 1995. Graphic correlation of a Frasnian (Upper Devonian) Composite Standard. In Mann, K.O and Lane, H.R. (eds.), Graphic Correlation, SEPM Society for Sedimentary Geology, Special Publication No. 53, p. 177-184.

Lanik, A., Over, D.J., Schmitz, M.D., and Hogancamp, N.J. 2013. Conodont biostratigraphy and new zircon dates for the Upper Devonian Belpre ashes, Chattanooga Shale, Tennessee and lower Rhinestreet shale, New York, eastern North America. Abstracts with Programs, Geological Society of America.

Lash, G.G. 2006. Top seal development in the shale-dominated Upper Devonian Catskill Delta Complex, western New York State. Marine and Petroleum Geology, 23:317-335, Amsterdam.

Lash, G.G. and Blood, D.R. 2006. The Upper Devonian Rhinestreet black shale of New York State – Evolution of a hydrocarbon system. In Jacobi, R. (ed.), Field Trip Guidebook, New York State Geological Association, 78th Annual Meeting.

Levin, P. and Kirchgasser, W.T. 1994. Petrography and conodont age of the Belpre Ash Bed (Upper Devonian; Frasnian) in outcrop in western New York. Abstracts with Programs, Northeastern Section, Geological Society of America, 26(3):31.

Lindemann, R.H. 2002. Dacryoconarid bioevents of the Onondaga and the Marcellus Subgroup, Cherry Valley, New York. In McLelland, J. and Karabinos, P. New England Intercollegiate Geological Conference (9th) and New York State Geological Association Meeting (74), Guidebook for Fieldtrips in New York and Vermont, Colgate Univ., Williams College, Skidmore College, p. B7-1-15.

Lindemann, R.H. and Yochelson, E. L., 1994. Rediscription of Styliolina [INSERTAE SEDIS]-Styliolina fissurella (Hall). In McLelland, J. and Karabinos, P. (eds.), New England Intercollegiate Geological Conference (9th)and New York State Geological Association Meeting (74), Guidebook for Fieldtrips in New York and Vermont, Colgate Univ., Williams College, Skidmore College, p. 149-160.

Murphy, A.E., Sageman, B. B., Ver Staeten, C.A., and Hollander, D.J. 2000. Organic carbon burial and faunal dynamics in the Appalachian Basin during the Devonian (Givetian-Famennian) greenhouse: an integrated paleoecological and biogeochemical approach. In

Huber, G.T., MacLeod, K.G. and Wing, S.L. (eds.), Warm Climates in Earth History. University of Cambridge Press, p. 351-385.
Over, D.J. 1997. Conodont biostratigraphy of the Java Formation (Upper Devonian) and the Frasnian-Famennian boundary in western New York State. GSA Special Paper 321:161-177.
Over, D.J. 2002. The Frasnian-Famennian Boundary in the Appalachian Basin, Michigan Basin, Illinois Basin, and southern continental margin, central and eastern United States. Palaeogeography, Palaeoclimatology, Palaeoecology, 181(1-3):153-170.
Over, D.J., Conaway, C.A., Katz, D.J., Goodfellow, W.D., and Grégoire, D.C. 1997. Platinum group element enrichments and possible chondritic Ru:Ir across the Frasnian-Famennian boundary, western New York. Palaeogeography, Palaeoclimatology, Palaeoecology, 132:399-410.
Over, D.J., Hopkins, T.L., Brill, A., and Spaziani, A.L. 2003. Age of the Middlesex Shale (Upper Devonian, Frasnian) in New York State: Cour. Forsch.-Inst. Senckenberg, 242:217-223.
Pepper, J.F., de Witt Jr., W., and Colton, G.W. 1956. Stratigraphy andof the West Falls Formation of Late Devonian age in western and west-central New York. US Geological Survey Oil and Gas Investigations Chart OC 55.
Racki, G. 2005. Toward understanding Late Devonian global events: few answers, many questions, 5-36. In Over, D.J., Morrow, J.R., and Wignall, P.J. (eds), Understanding Late Devonian and Permian-Triassic biotic and climatic events: Towards an integrated approach. Elsevier, Amsterdam.
Raiswell, R. 1971. The growth of Cambrian and Liassic concretions. Sedimentology, 17:147-171.
Raiswell, R., and Fisher, Q.J. 2000. Mudrock-hosted carbonate concretions: a review of growth mechanisms and their influence on chemical and isotopic composition: Journal of Geological Society of London, 157:239-251.
Rhoads, D.C. and Morse, J.W. 1971. Evolutionary and ecologic significance of oxygen-deficient marine basins. Lethaia, 4:413-428.
Sass, D.B. 1951. Paleoecology and stratigraphy of the Genundewa Limestone of western New York. Unpublished M.S. Thesis, University of Rochester, Rochester, N.Y., 113 p.
Schieber, J. 1994. Evidence for episodic high energy events and shallow water deposition in the Chattanooga Shale, Devonian, central Tennessee, U.S.A. Sedimentary Geology, 93:193-208.
Schieber, J. 1998. Sedimentary features indicating erosion, condensation, and hiatuses in the Chattanooga Shale of central Tennessee: relevance for sedimentary and stratigraphic evolution, 187-215. In Schieber, J., Zimmerle, W., and Sethi, P.S. (eds.), Shales and Mudstones I: Basin studies, Sedimentology, and Paleontology, E. Schweizerbart'sche Verlag., Stuttgart.
Schieber, J. and Baird, G.C. 2001. On the origin and significance of pyrite spheres in Devonian black shale of North America. Journal of Sedimentary Research, 71:155-166.
Schindler, E. 1993. Event-stratigraphic markers within the Kellwasser crisis near the Frasnian/Famennian boundary (upper Devonian) in Germany. Palaeogeography, Palaeoclimatology, Palaeoecology, 104:115-125, Amsterdam.
Schindler, E. and Königshof, P.1997. Sedimentology and microfacies of Late Devonian Kellwasser limestones in relationship to palaeobathymetery (Upper Kellwasser Horizon, Late Frasnian). Zbl. Geol. Palaont., Teil I, Vol. 5/6, 597-607, Stuttgart.
Scotese, C.R. 1990. Atlas of Phanerozoic Plate Tectonic Reconstruction. International Lithophase Program (IUU-IUGS), Paleomap Project Technical Report 10-90-1; Chicago, Illinois.

Sutton, R.G. 1963. Correlation of Upper Devonian strata in south-central New York. In Shepps, V.C. (ed.), Symposium of Middle and Upper Devonian stratigraphy of Pennsylvania and adjacent states. Pennsylvania Geological Survey, 4th series, Bulletin, G-39:87-101.

Tesmer, I. H. 1963. Geology of Chautaugua County, New York. Part I, Stratigraphy and Paleontology (Upper Devonian). New York State Museum and Science Service, Bull. No. 391, 65 p.

Tucker, M.E. 1974. Sedimentology of Palaeozoic pelagic limestones: the Devonian Giotte (southern France) and Cephalopodenkalk (Germany), 71-92. In Hsü, J. and Jenkyns, H. C. (eds.), Pelagic sedimentation: On land and under the sea. International Association of Sedimentologists, Special Publication, No. 1, Blackwell, Oxford.

Tucker, M. E. and Kendall, A. C. 1973. The diagenesis and low grade metamorphism of Devonian styliolinid-rich pelagic carbonates from West Germany: possible analogues of recent pteropod oozes. Journal of Sedimentary Petrology, 43:672-687.

Vinn, O. and Zatoń, M. 2012. Phenetic phylogenetics of tentaculitoids – extinct, problematic calcareous tube-forming organisms. GFF, 134(2):145-156.

Woodrow, D.L., and Sevon, W.D. 1985. The Catskill Delta, Geological Society of America, Special Paper 201, 246 p., Boulder.

ROADLOG AND STOP DESCRIPTIONS

Accum-ulated Miles	Incre-mental Miles	Road log description
0.0	0.0	Central Avenue at entrance to SUNY-Fredonia; turn south (right) and proceed to Temple Street; turn left (southeast) and proceed to E. Main Street/US 20. Turn east (left) and proceed on US 20 from Fredonia, through Silver Creek, to North Evans and the traffic signal at South Creek Road just before the bridge over Eighteenmile Creek.
28.4	28.4	Turn left (north), proceed under railroad overpasses and park on west side of road.
1.0	29.4	Stop 1A – Eighteenmile Creek at stone bridge.
1.1	30.5	Proceed south on South Creek Road, cross US 20 and park on side of road by cemetery. Stop 1B – Eighteenmile Creek at US 20 bridge.
0.6	31.1	Proceed south on South Creek Road/Shadagee Road to where gas line crosses road and park on east side of road. Stop 1C – Eightreenmile Creek at "gas line."

STOP 1A. Conrail Bridge over Eighteenmile Creek, South Creek Road near North Evans, south of NY 5, north of US 20. Proceed from parking area eastward on old railroad grade and down slope on south side to creek. This section exposes the upper Windom Shale, North Evans type section, very thin Penn Yan, Genundewa Limestone, West River Shale, Middlesex, Cashequa, and the lower Rhinestreet on either side of the stone bridge (Figs. 4-7).

This section shows the Windom Member-North Evans Limestone contact as a knife-sharp boundary separating gray Windom Shale bearing light gray concretions from dark, dysoxic beds of the Genesee Group (Fig. 4). The North Evans Limestone is a 6-12 cm thick lag accumulation dominantly composed of crinoidal debris, but also characterized by abundant conodonts, glauconitic grains, fish debris, and reworked concretions (Fig. 4). The North Evans grades into styliolinid grainstone facies of the overlying Genundewa, sometimes separated by thin styliolinid-rich shale assigned to the Penn Yan. However, further downstream from that bridge to the northwest, a succession of creek bank sections shows dramatic thinning of the North Evans Limestone with the appearance of the feather edge of the dark shale as a nodular parting above the lag unit. Moreover, the North Evans undergoes a lateral, spectral change from a thick crinoidal unit to a thin layer of mixed carbonate grains and detrital pyrite that is distinctly more "Leicester"-like (Fig. 4). In the next key section (Fig. 4) along the Old Lakeshore Road the intervening shale is 10-11 cm-thick and the North Evans Limestone is only about 2-3 cm-thick. This intervening shale unit is herein interpreted as being a local basinal facies of the Genundewa Limestone in that its upper contact is conformable (non erosional) with the Genundewa Limestone. The westward North Evans allochem transition from dominantly calcareous to largely insoluble grains, accords closely to the appearance of the overlying dark shale, and it suggests that carbonate dissolution of the exposed lag was more intense in the more basinal subenvironment of STOP 1 than at localities further to the northeast.

At STOP 1 the North Evans Limestone rests on the Taghanic Composite Unconformity, a disconformity of large time-magnitude. Based on comparison with more continuous Devonian sections further east, the section at Lake Erie is severely truncated; approximately one third of the Windom Member, the entire overlying Tully Formation, and all of the succeeding Geneseo and Penn Yan formation successions are absent at STOP 1 (Figs. 3, 4). The North Evans Limestone is a complex lag blanket famous for its fish material (Hussakoff and Bryant, 1918, Bryant, 1921, Turner, 1998) and conodonts (Hinde, 1879, Bryant, 1921, Huddle, 1974, 1981). North Evans conodonts are exceedingly abundant and diverse in species and types of elements. Elements of the North Evans fauna, both its fish debris and conodonts, can be traced from Erie County to the Genesee Valley. Preservation of the conodont elements is distinctive and varies from complete and pristine (light amber-colored) to broken, dark (almost black), and degraded (Color Alteration Index is 2 to 3). Colors of some of the fish debris are red, orange, gray and blue. The taphonomic history of the North Evans debris is complex and tests the limits of chronostratigraphic resolution (Kirchgasser and Koslowski, 1996; Kirchgasser and Vargo, 1998; Kirchgasser, 1994, 1998, 2001, 2002, 2004). The final taphonomic (burial age) of the North Evans material correlates to the youngest zone conodont in the mix, which is Ancyrodella recta of the upper part of Lower Frasnian MN Zone 2 (Kirchgasser, 1994); early whorls of the Lower Frasnian goniatite Koenenites (also MN 2 age) have been recovered from North Evans conodont residues at the type section at Eighteenmile Creek (Fig. 4) and in lenses within the Genundewa Limestone at Linden in Genesee County. The North Evans, as with most lag beds, poses a depositional paradox; even though the lag content records an enormous span of time, the actual final depositional event producing the bed may have been geologically instantaneous.

The Genundewa Limestone at STOP 1 is a 30-40 cm-thick ledge composed of styliolinid grainstone-packstone carbonate (Fig. 4). It is typically brownish gray, massive to nodular, limestone which sometimes weathers into thinner, flaggy beds. Aside from Styliolina and the small bivalve Pterochaenia, fossils are scarce, usually small, and of low diversity. The goniatites Koenenites, Acanthoclymenia, and Tornoceras, as well as Manticoceras at the very top, occur in the Genundewa, but are rare or poorly preserved here; the conodont Ancyrodella recta of upper MN Zone 2 occurs in the North Evans Limestone and at the base of the Genundewa Limestone at Linden in Genesee County (see Sunday illustrations). As noted, the Genundewa is a pelagic limestone that probably represents oxygen-stressed, sediment-starved, basin slope conditions. However, at this locality, local erosional channelization is evident locally within the limestone (Fig. 4). These channels, as well as pervasive small-scale hummocky cross-bedding and widespread alignment of Styliolina throughout the Genundewa, attest to significant current activity at the substrate, probably caused by deep-storm waves. The top of the Genundewa is gradational with the overlying shaley West River Formation; the topmost Genundewa becomes shaley and flaggy before giving way to the typical alternation of thin black and gray shale normally seen in the West River (Fig. 4). We herein interpret the interval from the sub-North Evans disconformity upward into the lower medial West River Formation is a Transgressive Systems Tract, starting with an erosional lowstand event recorded by the disconformity. The succeeding Genundewa is a condensed interval recording transgressive deepening within the basin and sediment-starvation on slope. A possible Maximum Flooding

Surface is represented by a recurrent conodont-glauconite-bearing styliolinid bed within the basal West River Shale (Fig. 4); this conodont-rich bed has been traced westward from the Genesee Valley and is Huddle (1981) sample horizon 8122SD at Fall Brook, Geneseo (Kirchgasser et al., 1994, A-4, STOP 1, Fig. 11); it has been named the Huddle Bed in his honor (Baird et al., 2006). Early highstand facies are represented by succeeding alternations of black and gray shale. This overall transgression probably represents a hybrid eustatic and flexural event within the basin.

Proceeding up-section the West River Shale is composed of 2.5 m of dark gray shales, black shale beds, and silty interbeds that are cross bedded (Fig. 5). Horizons rich in the the pelagic bivalve Pterochaenia are common, as are beds that preserve dacryoconarids and Planolites. The Williamsburg Bed, a carbonate, wood, and conodont-rich pyritic horizon in the upper 1.5 m of the West River marks a sequence boundary and condensed interval before the onset of persistent black shale deposition in the Middlesex. The Williamsburg Bed can be traced to the Finger Lakes region (Over et al., 2002).

The Middlesex is exposed upstream from the railroad bridge. Here the Middlesex is xx m thick, composed of dense silty black shales. A lamination of pyrite and conodonts in the upper 5 cm contains Ancyrodella gigas and the lowest Palmatolepis punctata, which marks the base of MN Zone 5.

In a narrow gully on the east side of the creek the entire Cashaqua Formation is exposed. The Cashaqua is 13 m thick, consisting of light gray shale and abundant concretions that contain goniatites and dacryoconarids. Toward the top are several thin black shales and an ash bed, which is possibly part of the Belpre Ash Suite, but this has not yet been tested. The Rhinestreet Formation sharply overlies the Cashaqua – Stop 1B.

Return to vehicles.

Cashaqua-Rhinstreet contact, Belpre Ash.

STOP 1B. Cashaqua Shale/Rhinestreet Shale contact and overlying Rhinestreet strata exposed on Eighteenmile Creek and on access road leading to that creek, town of North Evans, Erie County (see Fig. 6). Enter access path opposite from North Evans Cemetery. Proceed on foot down sloped path to valley bottom. Cross flat area to edge of Eighteenmile Creek.

The Cashaqua Formation of the Sonyea Group in southern Erie County is characteristically composed of gray fissile shale with a rhythmic succession of discoidal concretion bands (Buehler and Tesmer, 1963; Kirchgasser et al., 1997; Fig. 6). The fauna of this unit consists of small mollusks and brachiopods, indicative of a dysoxic setting. Most notable, is the occurrence of numerous, often poorly preserved, goniatites belonging to the genera Manticoceras and Probeloceras which are flattened within the shale and variably three dimensional inside of concretions (conodont Zone MN 5). Probeloceras is the ancestral genus of the family Beloceratidae and is followed by the genus Naplesites in the Rhinestreet Shale seen at Sturgeon Point, Lake Erie (Stop 2; Fig. 12 and Kirchgasser et al., 1994, fig. 7 for illustrations of Sonyea and West Falls Group goniatites). The prominent concretion layer with MN Zone 6 conodonts in the dark shales of the upper Cashaqua Shale is a septarian band with white or pink barite filling the shrinkage cracks and in places east of the Genesee Valley in Livingston County, replacing the shells of a rich molluscan fauna including the goniatites Manticoceras, Prochorites, Acanthoclymenia and Aulatornoceras; conodonts in the bed indicate MN Zone 6. The Prochorites is a species (P. alveolatus) known elsewhere only in Western Australia.

The Rhinestreet Formation is one of the thickest Late Devonian black shale divisions in western New York. The base is sharp and marked by a seam of diagenetic pyrite which weathers to a rusty band in bank sections. No detrital pyrite has been found on the contact, but a rich association of conodonts is reported from the basal few centimeters of black Rhinestreet shale (Huddle, 1968; Kirchgasser and Klapper, 1992; Klapper et al., 1995). Hard, well-jointed, black shale makes up most of this section. Less organic-rich, recessive weathering dark gray shale intervals, as well as, beds of greenish gray shale, can also be seen (Fig. 6, 7). Conspicuous at several levels within the black shale intervals are large, often massive, septarial concretions. The black shale facies within the Rhinestreet records intervals of severe dysoxia to near-anoxia within the Devonian basin associated with a broad time interval associated with global sea level highstand (Johnson et al., 1985). This organic-rich lithofacies accumulated in a relatively deep-water, stratified basin setting west of the prograding Catskill Delta in a foreland basin already maintained by collisional thrust loading (Ettensohn, 1998; see Fig. 1). Contemporaneity of Catskill Delta progradation is splendidly shown by the eastward splaying of Rhinestreet black shale divisions into the deltaic clastic wedge and by eastward passage of organic-rich basinal facies into shoreward, coarse, fossiliferous neritic facies and terrestrial red beds (Woodrow and Sevon, 1985; see deWitt, 1960; deWitt and Colton, 1959; Colton and deWitt, 1958; Sutton, 1963, and Kirchgasser et al., (1994) for evolution of correlations and unit terminology pertaining to eastern Rhinestreet and other West Falls Group subdivisions). The 2.3 meter to 2.4 meter-thick gray shale unit above the band of large concretions is the western distal "toe" of a progradational clastic pulse extending westward from the delta complex; this fine grained turbiditic or hemipelagic sediment was probably deposited during a sea level lowstand event which allowed prodelta muds to be exported far into the basin (Fig. 1). A turbiditic origin for part of this interval is suggested by the presence of a 2 – 5 cm-thick siltstone bed at its basal contact (Fig. 6, 7); the basal surface (sole) of this layer displays erosional groove cast impressions and the top of the bed fines upward into featureless gray shale, suggestive of a turbiditic event. At the Seascape section, the basal lag of the siltstone bed yields conodonts typical of MN Zone 7-8 (Levin and Kirchgasser, 1994; Kirchgasser et al., 1994; Kirchgasser and Klapper, 1992; Fig. 7B).

Upstream on the west bank - STOP 1C - about one meter below the green-gray shale units an excellent exposure of the Belpre Ash Suite. Two ash beds and a concretion horizon are exposed here. A third ash, possibly related, is found in the uppermost Cashaqua. The thickest altered ash bed is characterized by gray brown clays (kaolinite and mixed layered clays), bleached (pyroclastic?) micas, minor quartz, calcite, plagioclase and apatite, as well as secondary pyrite. The ash bed is graded with clay flakes in the upper part with even stronger parallel orientation than the clays in the overlying black shale. Lenses with the distinctive color and fabric of the ash occur intermittently for a few centimeters above the ash bed. The upper "thick" ash was recently dated using single zircon chemical abrasion U/Pb analysis at the facility at Boise State University to 375.32 +/- 0.14 Ma. This is statistically identical to the date from ash "6" at Little War Gap, Tennessee, of 375.40 +/- 0.13 Ma (Lanik et al., 2013). The shales between the ash beds in a 1 m interval at Little War Gap include Palmatolepis punctata, P. housei, P. ljaschenkoae, Ancyrognathus barba, and Ancyrodella nodosa, which indicate placement in MN Zone 8. Conodonts within a 4 meter thick interval from the adjacent shale and concretions in the Rhinestreet Shale above the ash horizons include Palmatolepis ljaschenkoae, P. punctata, Polygnathus dubius, Ancyrodella nodosa s.s., and Ancyrognathus sp. L? of Klapper (Fig. 7B). The conodonts and absolute dates indicate the middle Frasnian ashes in New York State are Belpre and provide a precise date for MN Zone 8.

Return to vehicles.

0.6 31.7 Proceed north on Shadagee Road to junction with US 20, turn west (left).

1.7 33.4 Procced west on US 20 to Sturgeon Point Road, turn northwest (right).

5.0 38.4 Enter Sturgeon Point Park and Marina, park on northernmost berm. Stop 2 – Lake Erie shoreline

STOP 2 and LUNCH. Rhinestreet Formation in Lake Erie shore bluff succession, both to the northeast of-, and southwest of, the Sturgeon Point marina and car park complex near Derby, Erie County (see Figs. 6, 7). We will, first, proceed on foot from the northeast end of the car park to the beach and follow the beach and continuous shale cliff section to a position near the outflow pipes from the Derby waterworks. The K-bentonite is not accessible here, but the gray shale unit is much easier to examine at this outcrop. Moreover, the black shale interval above the gray unit can be examined (Figs. 6, 7).

Within the gray shale unit in this locality are very thin, 0.2 – 6 cm-thick, black shale beds that often display sharp contacts and strong visual definition within the thicker gray succession. Buff gray concretions occur at two levels within the gray shale interval; these are concentrated closely below black shale bands and appear to be controlled by the presence of the bands. However, in a few places along the exposure, the thin, overlying black shale bands pinch out over the tops of the subjacent nodules. This suggests that concretion growth may have created differential paleorelief , perhaps due to early dewatering and differential settling of mud. The sharply defined thin, black bands pose an interesting question: Do they represent slow background deposition between turbiditic gray mud pulses, or do the thin black bands, themselves, represent some alternative type of rapid depositional event involving sedimentation, or resedimentation, of organic-rich sediment? Is it possible that the organic-rich sediment, instead, may have been originally pelletal, hence mobile and easily transported on the seafloor? This latter scenario, yet untested, could explain these sharp pinstripe bedforms as rapidly deposited, current-traction-generated features.

To the immediate northeast of the second waterworks outlet is a problematic structural displacement or offset at the level of the gray shale unit. At the lake edge, several fractures in the lower black shale division can be seen that are filled with gray shale that displays soft-sediment shearing and fracturing. Directly across from the area of shore fractures in the cliff face the gray shale unit thins to less than a third of its normal thickness across a distance of about

80 meters. However, debris on the beach conceals the intervening area and the full nature of this structure. The shore cliff and lake edge exposure displays excellent examples of joint networks, particularly for the black shale bands. These joints are believed by Gary Lash to have evolved during thermal-burial maturation of the black shale unit as the black shale units began to function as hydraulic top seals for moving fluids migrating up from below (see Lash, 2006.) The different orientations of the various joint sets are believed to correlate to a series of far-field stress phases associated with the Allegheny orogeny (Lash and Blood, 2006).

Between 40 and 45 cm above the gray shale interval, within black shale facies, is a styliolinid-rich, hashy layer that is associated with widely-spaced, spheroidal concretions (Figs. 6, 7). Close examination of the layer shows the presence of numerous, flattened goniatites (some partially pyritized), spotty concentrations of Styliolina, fish debris, large horizontal (arthropod?) trace fossils and scattered conodonts. The goniatites first identified during a survey of this section in 2006 belong to the genus Naplesites in the family Beloceratidae. The lineage is characterized by compressed (discoidal), evolute shells with increasingly numerous, distinctly pointed lobes (and saddles) forming chevron-like patterns. The ancestor of the family is Probeloceras which in New York occurs below the Rhinestreet in the Cashaqua Shale (Sonyea Group; MN Zone 5); the group culminates with the extremely multilobed Beloceras, a genus still unknown in North America (Fig. 3). The discovery of the Naplesites horizon at Sturgeon Point is important in that its presumed position in the lower Rhinestreet (House and Kirchgasser, 1993, 2008) is confirmed and the conodonts in the bed may prove to be datable. Naplesites is otherwise rare in New York and is known only from a few specimens (two species) described by Clarke (1898) far to the east from unspecified horizons and sections in the shales around Naples in Ontario County (Canandaigua Lake meridian). Probeloceras and Naplesites (as Mesobeloceras) are illustrated in Kirchgasser et al., 1994, fig. 7).The close stratigraphic coincidence of useful conodonts, Naplesites, and the K-bentonite bed is important geochronologically and is the subject of ongoing work.

Return to vehicles and proceed by car around to the southwestern most parking area near the Sturgeon Point pier.

Proceed on foot to beach below car park and follow beach southwestward for approximately 120 meters to a low outcrop bench of black Rhinestreet shale at the lake edge.

This exposure of black shale is believed to be the top of the lower Rhinestreet and phosphatic level below the “false Cashaqua” interval. The huge septarian concretions correspond to the conspicuous level at Seascape and the level studied by Lash and Blood at Eighteenmile Creek, but the precise match of beds can not yet be made owing to the long covered interval between the two sections. Notable in this outcrop are several bands of concretions including a line of massive septarial concretions below the bench of very resistant black shale. At the top of the black shale bench are two closely-spaced horizons of small spherical to ellipsoidal, 0.3 – 4 cm-diameter, phosphatic nodules. Phosphatic nodules, well known from the upper part of the New Albany Shale and the Cleveland Shale, have not been reported from the Rhinestreet. The occurrence of nodules of this type has been interpreted as evidence of nutrient upwelling and high productivity in surface waters (see Robl and Barron, 1989). What is striking here is that many, if not most, of the nodules are nucleated by fish spines and scales. Small, sand-size grains within some of the nodules may be radiolarian tests.

Return to vehicles and follow one-way road around to exit of Sturgeon Point Marina.

0.8 39.2 Proceed from the marina eastward on Sturgeon Point Road to Lake Shore Drive, turn southwest (right).

5.5 44.7 Proceed to Lake Erie Beach Park – Stop 3 – Point Breeze on Lake Erie shore.

Stop 3 – Lake Erie Beach Park. Lower Angola Formation at Point Breeze. From parking lot walk northeast up the beach to the cliffs on the point.

There is approximately 5 m of Angola Formation here. The lower Angola consists of light gray shale with interbeds of black shale and calcareous concretions. The Pt. Breeze Goniatite Bed is the first large concretionary bed at the water line, characterized by a diverse goniatite fauna – see text..

1.3 46.0 Proceed southwest on Lake Shore Drive, turn south (left) onto Evangola State Park Road.

1.1 47.1 Proceed southeast to NY 5, turn southwest (right).

7.0 54.1 Proceed toward Silver Creek on NY 5, merge with US 20 and continue on US 20 to Walnut Creek, cross bridge and park in Ehmke Drilling near the creek. Stop 4 – Walnut Creek

STOP 4. Section of Pipe Creek Formation ("lower Kellwasser Bed") and synjacent units at Walnut Creek, Silver Creek, NY Proceed from the parking area to Walnut Creek and exposure of the Hanover Formation and Pipe Creek Formation – base of the Java Group, and the underlying Angola Shale. The lowest strata at this site downstream from the US 20 bridge are the gray, silty, bioturbated Angola Formation of the West Falls Group. This is abruptly capped by the resistant, black, and well jointed Pipe Creek Formation of the Java Group (Fig. 8) that forms a bench in the stream. The 0.6 meter-thick Pipe Creek succession is followed upstream in the floor of the creek and bank by softer, nodule-rich, gray and black shale facies of the Hanover Formation (Fig. 8).

The black Pipe Creek shale consists of massive, organic-rich facies that contrasts markedly with both the underlying Angola and overlying Hanover. The base of the Pipe Creek is abrupt on the Angola with the development of abundant diagenetic pyrite in the uppermost Angola. No erosional, detrital pyrite has been found at the contact, but a profound change in microtexture is seen as one passes from the bioturbated, pyrite- suffused, uppermost Angola, into the laminated, black Pipe Creek (Fig. 9). As noted in the text, this unit has now been found to correlate to the "Lower Kellwasser Bed" which marks a major ecological reorganization and extinction event in global sections.

Fossils are common in the lower Hanover, but are usually very small. Diminutive gastropods, bivalves, and ostracodes make up most of the fauna found in concretions or as pyritized shells in the gray shale. Goniatites, important as chronostratigraphic markers, occur in the shales and concretions as well. There is a rich but still undescribed pyritic goniatite fauna at the Pipe Creek/Angola Shale contact beneath the US 20 bridge, over Walnut Creek, discovered years ago by G. Kloc; the pyrite lag is often covered in sediment and/or below water. Upstream of the bridge Crickites lindneri and Sphaeromanticoceras aff. S. rickardi occur in the first few meters of the Hanover Shale. Crickites lindneri is a species know also from Australia. In nodule bands in lowermost Hanover in nearby Silver Creek and in Beavermeadow Creek, Java Village, the goniatite Delphiceras cataphractum occurs. The lower Hanover goniatite levels are probably in the Crickites Goniatite Division UD I-L and probably in Conodont Zone MN 12 (House and Kirchgasser, 2008).

0.4 54.5 Head northeast on US 20 to intersection with NY 5, turn west (left)

10.5 64.9 Proceed west on NY 5 to Dunkirk and signal at Point Road, turn north (right).

0.4 65.3 Proceed north to sand road (unmarked) to Dunkirk Beach – Stop 5 – Point Gratiot on Lake Erie shore.

STOP 5. Upper Hanover and Dunkirk Shale type locality – Point Gratiot, Dunkirk, NY (see Figs. 9, 10).

Exit vehicles and proceed southwest along the lake shore to exposures. The interbedded gray and black shales of the upper Hanover are overlain by massive black shales of the Dunkirk (Fig. 10). The Point Gratiot Bed, a 15 cm thick black ledge, correlates to the "Upper Kellwasser Bed" of Late Devonian sections globally. The topmost part of this bed marks the Frasnian-Famennian extinction event of literature based on conodont work in western New York sections (see Over, 1997, 2002; Day and Over, 2002). Although the bed is composed of basinal black shale, fossils such as the probable anaptychus organ Spathiocaris, fish material, and wood debris can be found, particularly near the top of the bed. Moreover, elevated levels of Platinum Group elements occur at this level and other horizons in the boundary interval black shales (see Over et al., 1997). Above the Point Gratiot Bed is 10 cm of gray shale below the base of the thick black shale of the Dunkirk.. Eastward this interval expands to several meters of gray and black shale beds (Fig. 11). The upper Hanover interval closely resembles the lower Rhinestreet gray shale unit owing to several discrete, thin, black shale bands which contrast sharply with the thicker gray lithology. Reworked pyritic burrow clasts and exhumed geopetally pyritized Tasmanites half-spheres (sensu Schieber and Baird, 2001) have been found in thin lags at the base of the thin black beds and at the base of the Dunkirk Shale. Hanover deposits below the Point Gratiot Bed are markedly more calcareous, lighter colored, and more intensely bioturbated; upward changes across the Point Gratiot Bed probably reflect combined effects of transgressive deepening in the basin and adverse biological effects associated with the Frasnian-Famennian crisis.

End of Field Trip – return to Dunkirk and NY 98B south to SUNY Fredonia or NY 60 to I-90.