Refining the Timing of Faunal Turnover in the Middle Devonian Appalachian Basin: Paleoecological Analysis of the Earliest Hamilton Fauna and a Revision of the Base of the Givetian Stage in Eastern North America

Alex Bartholomew[1], Thomas Schramm[1], Charles Ver Straeten[2] and Jeffery Over[3]

[1]*State University of New York at New Paltz*
[2]*New York State Museum*
[3]*State University of New York at Geneseo*

INTRODUCTION

The Middle Devonian of the Appalachian Basin has long been a testing ground for various evolutionary and paleoecological hypotheses (Eldredge and Gould, 1972; Brett and Baird, 1995; etc.). Units such as the Onondaga Limestone and Hamilton Group contain an excellently preserved invertebrate fauna spanning a wide array of marine facies ranging from shallow, reefal environments with diverse faunas to deep-water, dysoxic settings typified by nearly monospecific assemblages. The well-documented nature of the stratigraphy of the Middle Devonian rocks of New York State in particular makes this interval the perfect area in which to investigate the spatial and temporal nature of paleoecology and faunal turnover during this critical interval in Earth history.

Workers such as Cleland (1903) recognized early on the presence of patterns of extended intervals of faunal stability within the Middle Devonian of New York State, patterns that lead Brett and Baird (1995) to the formation of the hypothesis of Coordinated Stasis. Their hypothesis states that there are extended intervals of compositional faunal stability, termed evolutionary-ecological subunits (EE subunits), within various environments throughout geologic time, that are bounded by relatively rapid pulses of faunal turnover with very low amounts of taxonomic hold-over between stable intervals.

More recent investigations on the topic of Coordinate Stasis have focused on gaining a better understanding of the type interval from which Brett and Baird formed their hypothesis within the Middle Devonian of the Appalachian Basin. Bonnelli et al. (2006) documented the nature of abundance patterns within the Hamilton EE subunit, noting that faunas from similar paleoecological settings had high levels of compositional stability but low levels of stability when taking abundance of the taxa into consideration; although the composition of the top ten taxa changed little from bed to bed, the abundance ordering between beds was quite different. A more recent study by Brett et al. (2007) focused on patterns of biofacies tracking within the Hamilton EE subunit, noting high levels of similarity of taxonomic relative abundance within biofaces through depositional cycles. While these studies have documented the nature of the intervals of faunal stability, the intervening periods of faunal turnover remain as yet poorly understood. The present study aims to shed light on the details of the faunal turnover between two of the EE subunits with the Middle Devonian of the Appalachian Basin, the Stony Hollow and Hamilton EE subunits, specifically examining how rapid was that turnover and how quickly were the previously documented suit of biofaces from the Hamilton interval established within the basin.

GEOLOGIC SETTING

Sediments of latest Eifelian-earliest Givetian age in the Hudson Valley were deposited in a retroarc foreland basin that was formed on the eastern margin of Laurentia, situated at about 20˚ south of the equator (Blakey, 2009, Figure 1), cratonward of the advancing Acadian Terrain. A large wedge of sediment, known as the Catskill Delta, was beginning to prograde out into the basin, affecting sedimentation and sea floor topography in the Hudson Valley at this time. The eastern margin of the current Middle Devonian Appalachian Basin sediments is undoubtedly artificial in nature, being the result of erosion during the last 300 mya, and the basin most likely extended far to the east during this time. However, as will be demonstrated below, the shoreline of the basin was most likely located near the present-day eastern boarder of New York State during the deposition of the interval under investigation.

Deposition within the Appalachian Foreland Basin during the Acadian Orogeny has been interpreted as being episodic in nature, with major pulses of clastic sedimentation, termed tectophases by Ettensohn (1985), punctuated by intervals of carbonate-dominated sedimentation during periods of tectonic quiescence. The strata of the Hamilton Group were deposited during Tectophase II of the Acadian Orogeny that began with a major deepening event in the late Eifelian. During this time there was a drowning of the shallow-water carbonate platform that had existed during the deposition of the Onondaga Formation associated with loading and downwarping of the eastern margin of the North American craton that lead to the deposition of deeper-water, dysoxic shales of the late Eifelian-early Givetian Marcellus sub-Group.

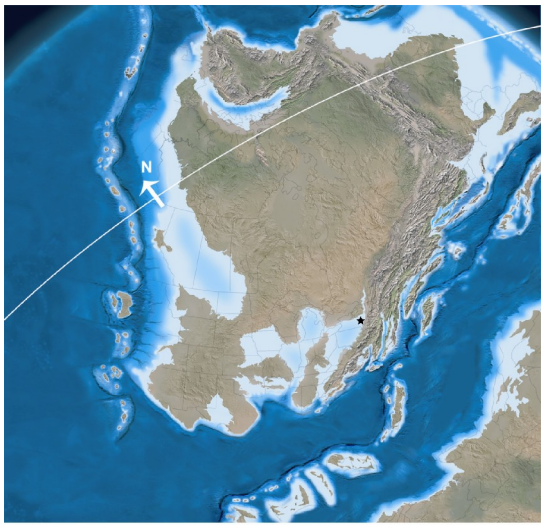

Figure 1. Paleogeographic reconstruction of the North American craton during the Middle Devonian. Star marks study area. Modified form Blakey (2009).

Most previous studies of the Hamilton Group strata have taken place in western and central New York State as these areas preserve relatively thin packages of fossil-rich sediment containing alternating packages of limestone and shale. Correlative sections in eastern New York State remain poorly understood due to their great thickness and the more homogeneous nature of their sediments. There is a drawback, however, to focusing only on sections in west-central New York in that these sections are much more condensed in relation to time, resulting in a loss of temporal resolution; thick sections in the east allow for a much great understanding of the precise timing of change within the basin, however careful attention must be paid to stratigraphic detail. The stratigraphic interval containing the Stony Hollow Fauna, in western-central New York ranges from nearly nil at Lake Erie to about 10 m around Syracuse, while in eastern New York in the Hudson Valley this interval spans well over 300 m (Rickard, 1975).

BACKGROUND

In their initial paper on Coordinate Stasis, Brett and Baird identified only three EE subunits within the Middle Devonian of the Appalachian Basin: the Onondaga, Hamilton, and Geneseo subunits. Within the lower Hamilton EE subunit they recognized the presence of a short-lived, anomalous fauna within the basin, parsing this interval out as a sort of sub-subunit; another such interval was recognized within the upper Hamilton EE subunit as well with the incursion of the Lower Tully Fauna. Subsequent investigation of these intervals has led to the recognition of these two periods of anomalous faunas within the Hamilton EE subunit as their own unique EE subunits. The fauna from the interval between the Onondaga and Hamilton EE subunits, termed the Stony Hollow Fauna, has been well-documented as an incursion of warm-water, dysoxic-tolerant taxa from arctic Canada that invaded all across eastern North America during the latest Eifelian Stage (Koch and Day, 1996) associated with the initial deepening of tectophase II of the Acadian Orogeny (Ettensohn, 1985). Similarly, the interval of anomalous fauna within the upper portion of the Hamilton EE subunit, known as the Lower Tully EE subunit, has been identified as a dysoxic-tolerant fauna that replaces the Hamilton Fauna in many areas around the basin (Baird and Brett, 2003). Both of these EE subunits are recognized as being associated with bioevents on a global scale; the faunal turnover between the Stony Hollow and Hamilton EE subunits represents the local manifestations of the Kacak Bioevent while the turnover at the end of the Lower Tully EE subunit marks the onset of the Taganic Bioevent.

The incursion of the Stony Hollow Fauna (Figure 2) occurs during the initial deepening associated with Tectophase II of the Acadian Orogeny. The first appearance of the Stony Hollow Fauna occurs in the Bakoven Member of the Union Springs Formation, interpreted to have been deposited during the highstand of a third-order depositional sequence. The fauna recurs with increasing diversity through the Stony Hollow Member which represents falling stage portion of the sequence and continues into the transgressive phase of the next overlying third-order sequence in the Cherry Valley Member of the Mount Marion and Oatka Creek formations (Figure 3). The first appearance of the

Hamilton Fauna (Figure 4) within the Appalachian Basin was long recognized as occurring in the Halihan Hill Bed, or *Meristella*-coral bed as it was originally known (Goldring, 1935), of the Mount Marion and Oatka Creek formations (Figure 3). In west-central New York, the Halihan Hill Bed is the first abundantly fossiliferous horizon above the Cherry Valley Member, observed as lying approximately a meter above the Cherry Valley Member in outcrops just south of Syracuse.

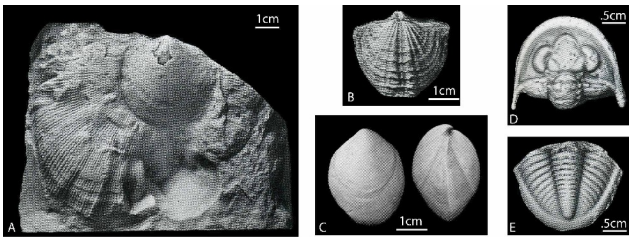

Figure 2. Stony Hollow Fauna: A) *Variatrypa*, B) *Carinatrypa*, C) *Subrennselandia*, D, E) *Dechenella* (modified from Ehlers and Kessling, 1970)

The interval between the Cherry Valley Member and the Halihan Hill Bed is known as the East Berne Member (Ver Straeten and Brett, 2006, Figure 3) and where present in west-central New York is most often represented as dark-gray shale with little to no fauna. The stratigraphy of the East Berne Member in the Hudson Valley has been well studied by Ver Straeten (1994) where it preserves facies ranging from dark-gray shales near its base, grading upwards into siltstone interbedded with thicker and thicker sandstones (>1 m) near the top. The lower portions of the East Berne Member are relatively barren of fauna with infaunal bivalves being rarely found. Approximately 15-20 m down from the top of the unit is a distinct fossiliferous horizon known as the Dave Elliot Bed (Ver Straeten, 1994). This bed is traceable throughout the Hudson Valley where it is underlain by a layer of distinctive vertically-oriented concertions and represents a small-scale transgressive interval within the East Berne Member. Together, the East Berne Member and Dave Elliot Bed sit within a critical interval between two EE subunits and the description of the fauna of this interval represents the bulk of the data examined in this paper.

METHODS

The outcrop belt of Middle Devonian sediments exposed along the present-day Hudson Valley provides a transect nearly parallel to the hypothesized shoreline that existed during deposition. Nine outcrops of the upper East Berne Member were examined in the between Kingston in the south to East Berne in the north, with a single outcrop from western New York examined at the Seneca Stone Quarry located between Seneca and Cayuga lakes (Figure 5). At each section, the location of the Dave Elliot Bed was determined and volumetrically standardized samples were taken from multiple locations along the outcrop if possible. Samples were taken back to the lab where they were processed and all possible specimens identified to the species level and counted. Raw counts were standardized to the level of relative abundance using the categories: rare (0-4 specimens), moderately common (4-10 specimens), common (10-19 specimens), and abundant (>20 specimens). This method allows for the standardization of samples across various environments, downplaying the sometimes large numbers of certain taxa (i.e. the infaunal bivalve *Nuculoidea*), which in some samples are found almost to the exclusion of all other taxa. Additional presence-absence data from the northernmost locality for this study (location 9, Figure 5) was taken from Goldring (1935) as the Dave Elliot Bed is now covered at this section. Faunal and sedimento-

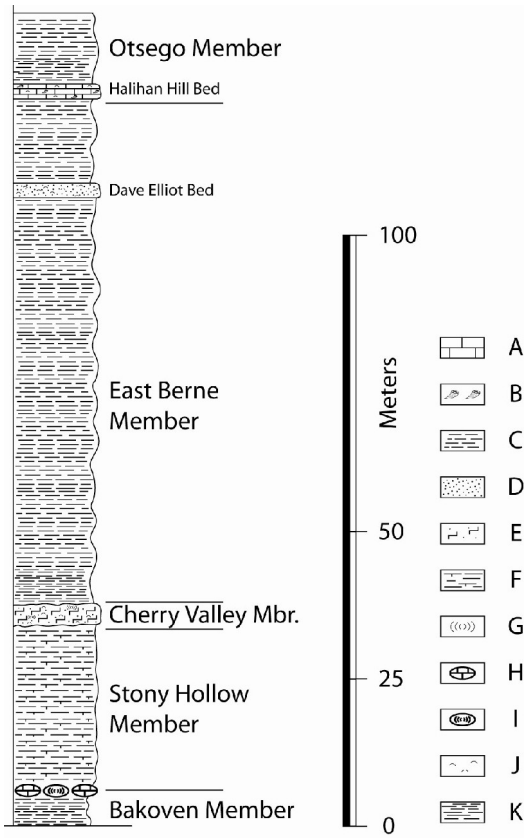

Figure 3. Simplified stratigraphic column for the study area. A) limestone, B) coral bed, C) gray shale, D) sandstone, E) calcareous sandstone, F) siltstone, G) goniatites, H) calcareous concretion, I) goniatite bearing concretion, J) shell bed, K) dark gray shale.

logic data were used to prepare paleoecological reconstructions of each of the 10 localities (see below).

Various statistical methods were used to examine the data from the Dave Elliot Bed. Comparison of faunal composition of individual samples from the Dave Elliot Bed was made using similarity coefficients and Detrended Correspondence Analysis using both relative abundance data and presence absence data as locality permitted. Similar methods were also used to compare samples from the Dave Elliot Bed to samples from the Centerfield Member cycle described in detail by Brett et al. (2007) to determine the similarity of biofacies through the Hamilton Group.

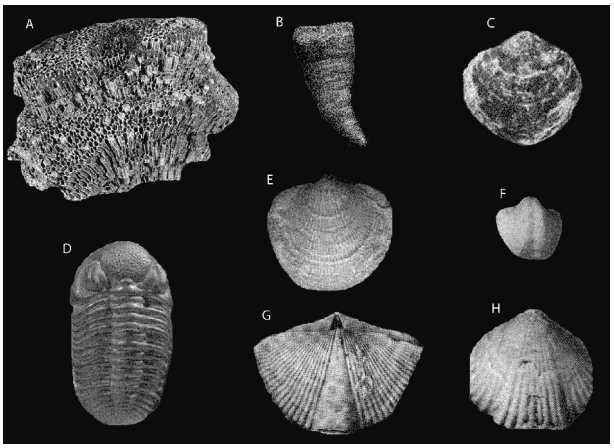

Figure 4. Hamilton Fauna: A) *Favosites*, B) *Stereolasma*, C) *Athyris*, D) *Eldredgeops*, E) *Pseudoatrypa*, F) *Ambocoelia*, G) *Mediospirifer*, H) *Eumetabolotoechia*.

DATA

Descriptions of the localities examined in this study will be discussed from south to north, beginning with

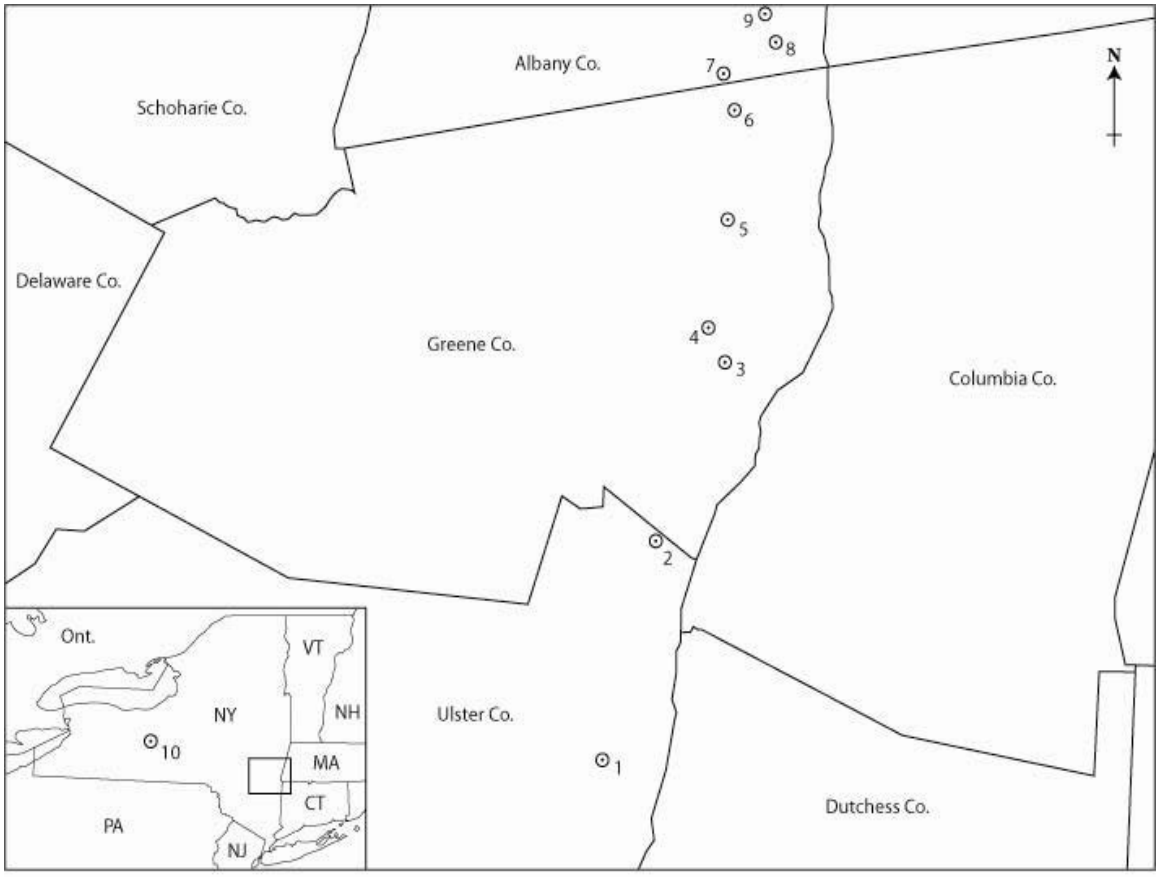

Figure 5. Map of sampling localities for the Dave Elliot Bed. Inset shows larger regional view, interal box represents enlarged area of mid-Hudson Valley. 1) Rte. 209; 2) Dave Elliot Rd.; 3) Sandy Plains Rd.; 4) Buttermilk Falls; 5) Earlton Quarry, Earlton; 6) Stanton Hill Rd.; 7) Gedney Hill Rd.; 8) Hannacroix Creek; 9) Cole Hill Rd., East Berne; 10) Seneca Stone Quarry.

Taxa \ Locality	Kingston 209	Dave Elliot Rd.	Sandy Plains Rd.	Buttermilk Falls	Earlton Quarry	Stanton Hill Rd.	Gedney Hill Rd.	Hannacroix Creek	Seneca Stone
Ambocoelia			•	•					•
Arcuaminetes			•		•	•	•		
Athyris	•	●	•	•	●	•	•	•	
Cyrtina		•	•		•				
Cupulorostrum			•	•	•	•	•		
Emmanuella		●							
Eoschuchertella		•			•	•	•		
Eumetabolotoechia	●						•	●	•
Hallinetes		●	•			•			
Lingula					•		•		
Longispina			●	•			●	•	●
Mediospirifer			•	•	●	●	•		
Mucrospirifer		●	●	●	●	●	●	•	•
Nucleospira			•	•					
Orbiculoidea					•	•		•	
Protoleptostrophia						•	•		
Psuedoatrypa					•	•			
Sinochonetes		•	•						
Tropidoleptus			•	●	●	●	●		
Trunculosia					•			•	
Actinopteria					•				
Goniophora					•				
Grammysia		•					•		
Leiopteria					•				
Modiomorpha		●			●		•	•	
Nuculites			•						
Nuculoidea	●	●	•			•	•	●	
Paleoneilo			•	•	•				
Paracyclas							•		
Pseudaviculopectin		•			•				
Bellerophon					•				
Bembexia			•	•					
Platyceras	●	•			•				
Tornoceras	•							•	
Straight Cephalopod	●							•	
Hyoliths	•		•						
Tentaculitids					•				
Aulocystis					•	•			
Favosites					•				
Heliophyllum					•				
Heterophrentis			•		●		•		
Stereolasma					•	•			
Conularia							•	•	
Bryozoan			•	•	•				
Crinoid ossicles			●		•		•		

● Abundant (>21)
● Common (11-20)
• Moderately Common (5-10)
• Rare (<4)

Table 1. Faunal list for all localities.

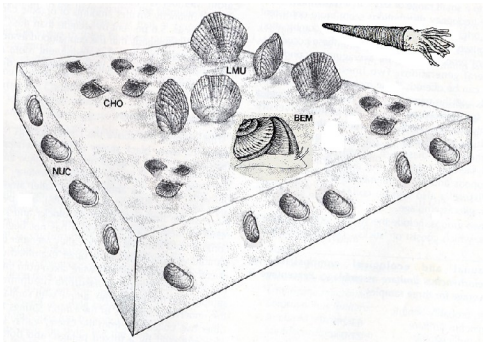

Figure 6. Paleoecological reconstruction for Rt. 209 locality. LMU: *Eumetabolotoechia*, NUC: *Nuculoidea*, BEM: *Bembexia*, CHO: *chonetids*.

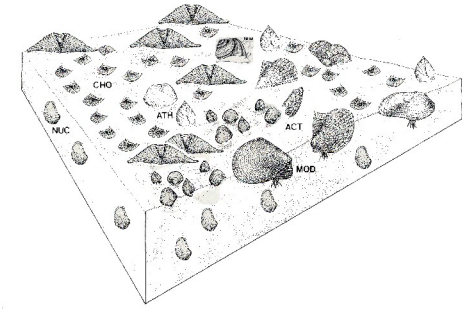

Figure 7. Paleoecological reconstruction for Dave Elliot Road. MOD: *Modiomorpha*, ATH: *Athryis*, ACT: *Actinopteria*

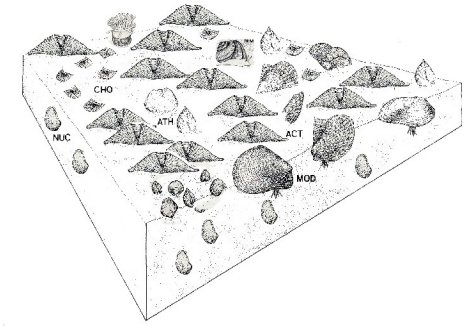

Figure 8. Paleoecological reconstruction for Sandy Plains Rd.

outcrops along the western side of Rte. 209 just west of Kingston where nearly the entire East Berne Member (all but the lowest ~10 m) is exposed in a large cliff (Figure 5). At this locality the East Berne Member consists of dark-gray shale grading upward into fine-grained silts with interbedded thin- to medium-bedded fine-grained sandstones. The bulk of the East Berne Member is relatively barren here with very rare, scattered infaunal bivalves and pyritic thread-burrow. There are two ~5 cm thick, compact, pyritic fossiliferous beds exposed near the middle-upper portion of the member separated by ~5 m of barren silty-shale. The upper fossiliferous bed has been identified as the Dave Elliot Bed, being underlain by the typical vertically-elongated concretions. Both beds are faunally similar, being dominated by large numbers of nuculid bivalves with rare leiorhynchid brachiopods, gastropods, and cephalopods (Table 1, Figure 6).

The next outcrop of the Dave Elliot Bed to the north is at the type locality at Dave Elliot Road west of Saugerties, a distance of 20 km north of Rte. 209 in Kingston (Figure 5). At this locality there is only one shell bed exposed within this portion of the East Berne. The Dave Elliot Bed here is a ~15 cm thick siltstone with fossil scattered throughout. The fauna of the Dave Elliot Bed is moderately diverse being dominated by small chonetid brachiopods along with abundant *Mucrospirifer*, *Athyris*, and *Emmanuella*. (Table 1, Figure 7).

~15 km. north of Dave Elliot Road, the Dave Elliot Bed examined is well-exposed along Sandy Plains Road just northwest of the village of Leeds (Figure 5) At this locality the Dave Elliot bed is preserved as a ~30 cm thick shelly sandstone at the top of an approximately 2 m coarsening upward succession. The fauna of the Dave Elliot Bed is dominated here by abundant spiriferid brachiopods along with abundant scattered crinoid columnals and moderately common bryozoans. This locality also contains the southernmost example of the typical Hamilton brachiopod *Tropidoleptus* (Table 1, Figure 8).

Just west and north (~2 km) of the exposure along Sandy Plains Road, the Dave Elliot Bed is exposed in a waterfall on Buttermilk Creek (Figure 5) The East Berne Member is well exposed in an abandoned quarry and in the creek here consisting of a coarsening upward succession of silty shale grading upward into thin- to medium bedded sandstones. Lithologically the Dave Elliot Bed closely resembles the exposure along Sandy Plains Road, however there are some distinct faunal differences between the two outcrops. The Dave Elliot Bed here contains abundant *Tropidoleptus* along with a greater abundance of chonetids and spirifereds (Table 1, Figure 9).

The next outcrop of the Dave Elliot Bed to the north is an exposure in an abandoned quarry at Earlton, ~10 km north of Buttermilk Creek (Figure 5). Most of the East Berne Member is covered at this outcrop, however it is possible to determine the stratigraphic location of the Dave Elliot Bed as an active quarry containing the Halihan Hill Bed is located just uphill from exposures of the Dave Elliot Bed. The Dave Elliot Bed at this outcrop consists of scattered fossils within the upper ~10 cm of a ~1.5 m thick very hard sandstone. This outcrop preserves the most diverse assemblage of taxa found to date within the Dave Elliot Bed including abundant *Tropidoleptus, Mediospirifer,* and *Mucrospirifer* brachiopods, moderately common to common rugosan corals including *Stereolasma* and *Heterophrentis*, and rare favositid corals (Table 1, Figure 10).

Continuing ~10 km north, the next outcrop of the Dave Elliot Bed examined is a creek exposure in Stanton Hill Ravine (Figure 5). The middle through upper East Berne is well-exposed in this ravine and consists of medium- to thick-bedded sandstones interbedded with siltstones. The Dave Elliot Bed is lithologically very similar to the exposure at Earlton, however the fauna is noticeably less diverse and lacks the distinctive coral taxa seen at Earlton. The fauna is

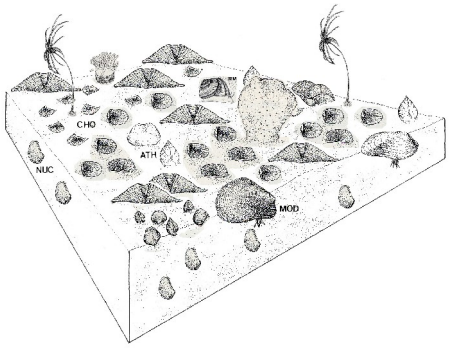

Figure 9. Paleoecological reconstruction for Buttermilk Falls.

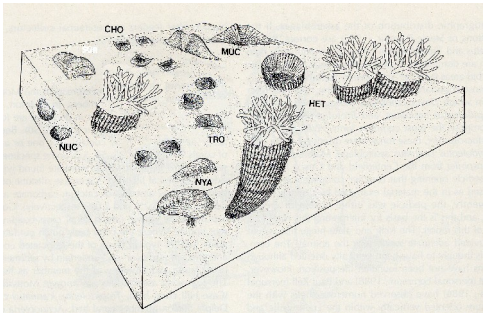

Figure 10. Paleoecological reconstruction for Earlton quarry. HET: *Heterophrentis*, MUC: *Mucrospirifer*, TRO: *Tropidoleptus*, NYA: *Nyassa.*

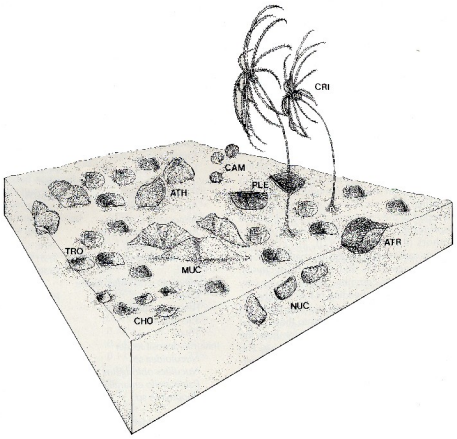

Figure 11. Paleoecological reconstruction for Stanton Hill Ravine. CRI: crinoids, ATR: *Pseudoatrypa*, CAM: *Camerotoechia*, PLE: *Prototoleptostrophia*.

dominated by abundant Tropidoleptus and Mediospirifer brachiopods along with rare atrypids (Table 1, Figure 11).

The Dave Elliot Bed is next encountered in exposures along Gedney Hill Road, ~4 km north of Stanton Hill Ravine (Figure 5). The East Berne Member is moderately well-exposed along Gedney Hill Road from the Dave Elliot Bed down toward the bottom of the unit; glacial erosion has removed the upper East Berne Member above the Dave Elliot Bed sandstone with only till being found sitting directly on the bed. The Dave Elliot Bed here consists of ~1.5 m of resistant sandstone with fossils being scattered through the upper ~30 cm of the bed with a fauna dominated by *Tropidoleptus*, *Mucrospirifer*, and chonetid brachiopods along with rare *Heterophrentis* corals and conulariids (Table 1, Figure 12).

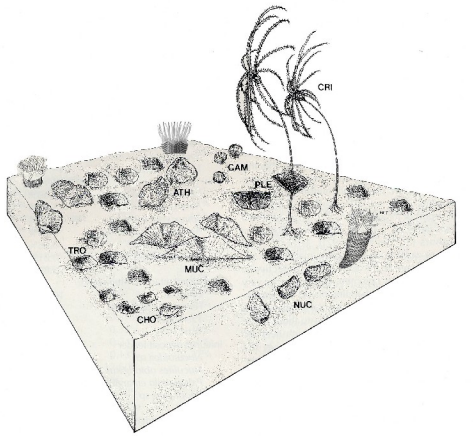

Figure 12. Paleoecological reconstruction for Gedney Hill Rd.

The next outcrop of the Dave Elliot Bed to the north (~10 km) from Gedney Hill Road is found in Hannacroix Ravine (Figure 5). Exposed within the ravine is a nearly complete section of the East Berne Member, however this section is markedly different from those to the south and multiple visits to the section were needed to determine the nature of deposition within the study interval. The East Berne Member has thickened quite a bit in this area and the lower and middle portions of the unit are distinctly finer-grained than sections to the south. The upper portion of the unit is approximately 25 m thick and contains a number of well-developed, coarsening-upward cycles, each approximately 3 m in thickness, that are capped by thicker and thicker sandstone beds with more and more diverse shell beds at the top of each cycle, continuing up to the exceedingly diverse Halihan Hill Bed. Additionally, the Dave Elliot Bed is not the lowest fossiliferous bed within the succession, mirroring the pattern seen at Rte. 209 in Kingston, except that there are three additional horizons of concentrated shells below the Dave Elliot Bed within the ravine. The Dave Elliot Bed is again here marked by a well-developed horizon of vertically-oriented concertions underlying the bed. The bed itself consists of a silty-sandstone with *Zoophycus* burrows and contains a moderately diverse fauna dominated by leiorhynchid, chonetid, and rarer spriferid brachiopods along with conulariids (Table 1, Figure 13). The next shelly bed just below the Dave Elliot Bed in Hannacroix Ravine we have informally termed the Hannacroix Ravine Bed as it is well-developed and contains the zonally important goniatite *Tornoceras* aff. *mesopleuron* that pins this horizons to be just above the base of the Givetian stage within the Middle Devonian; previously this goniatite's lowest known occurrence was in the Halihan Hill Bed. The Hannacroix Ravine Bed contains a fauna dominated by nuculid bivalves with very rare leiorhynchid brachiopods and relatively common goniatites and nautiloids, much resembling the Dave Elliot Bed and lower bed at Rte. 209 near Kingston. The Hannacroix Creek Bed is marked by a zone of flattened concretions below it as well as two interesting 'gummy' clay horizons that are being currently investigated as to whether or not they may be bentonitic clay horizons.

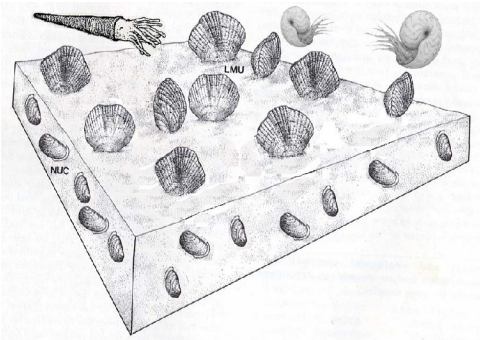

Figure 13. Paleoecological reconstruction for the Dave Elliot Bed at Hannacroix Ravine.

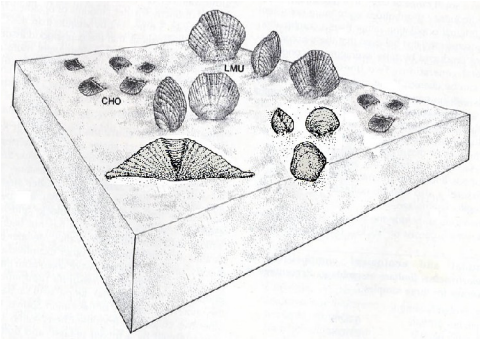

Figure 14. Paleoecological reconstruction of the Dave Elliot Bed at Seneca Stone.

Just ~5 km to the north and west of Hannacroix Creek is the type locality of the East Berne Member exposed along Cole Hill Road (Figure 5). Currently, the Dave Elliot Bed is covered at this locality; however Goldring (1935) de-

scribed the outcrop when the road was newly cut. It is possible from Goldring's detailed description of the lithology and fauna of the Halihan Hill Bed, which sits ~22 m above what was then the base of the outcrop, to estimate the level of the Dave Elliot Bed. The lowest ~6 m are described as relatively barren, blocky shales with concretions and rare nautiloids and goniatites. The next ~6 m were described as containing a fauna consisting of the brachiopods *Mucrospirifer*, *Mediospirifer*, *Arcuaminetes*, *Nucleospira*, along with nuculid bivalves and *Modiomorpha* in blocky shales with thin sandstone beds becoming thicker near the top. Continuing up to the Halihan Hill Bed (~10 m) Goldring reports fossils becoming more abundant along with thicker sandstone beds, with the Halihan Hill Bed positioned within the upper 30 cm of a ~2 m sandstone. From her description of the section the Dave Elliot Bed most likely sits somewhere within the second 6 m of the section; this is consistent with patterns seen just to the south at Hannacroix Ravine. However, the fauna reported by Goldring for the hypothesized Dave Elliot interval at East Berne is markedly different from that observed at Hannacroix Ravine, containing a more diverse fauna composed of taxa interpreted to exist in somewhat shallower water conditions than those found at Hannacroix Ravine.

The Dave Elliot Bed has yet to be found north and west of Hannacroix Ravine throughout the outcrop belt of the East Berne Member except for a small exposure in the southwestern corner of the Seneca Stone Quarry south of Seneca Falls, a distance of ~200 km west of Hannacroix Ravine (Figure 5); a search is currently underway for exposures of the Dave Elliot Bed in the intervening area between these two widely separated areas. In between Hannacroix Ravine and Seneca Stone Quarry, the East Berne Member thins dramatically to little over approximately one meter in thickness and consists of dark-gray, fine-grained shale. The Dave Elliot Bed was discovered at Seneca Stone Quarry by Jeff Over of SUNY Geneseo and consists of a thin shell lag ~1-2 cm thick containing common chonetid, relatively common ambocoeliid and leiorhynchid and rare spirifereds brachiopods about 10 cm below the Halihan Hill Bed (Table 1, Figure 14).

DISCUSSION

Faunally, all of the taxa encountered within the Dave Elliot Bed to date have been elements of the Hamilton Fauna; no taxa of the underlying Stony Hollow Fauna have been encountered within the Dave Elliot Bed. With the existence of fossiliferous horizons below the Dave Elliot Bed within the East Berne Member (see discussion of Hannacroix Ravine section in road log), it is additionally possible to determine the content of the middle-lower East Berne in at least the Helderberg area and again, the fauna of this portion of the unit, though much less diverse than the overlying Dave Elliot and Hannacroix Ravine beds, contains no taxa distinctive of the underlying Stony Hollow Fauna. From these observations it is possible to postulate that the turnover between the Stony Hollow and Hamilton E.E. sub-Units is very rapid with little to no mixing of the two faunas.

With the identification of what is now the lowest known abundant and diverse example of the Hamilton Fauna it is possible to determine to what extent the extremely stable biofacies that typify the middle and upper Hamilton Group are developed (Figure 15), *i.e.*, how rapidly to the typical biofacies establish themselves within the basin after the rapid faunal turnover. Samples of the Dave Elliot Bed were compared with the typically developed sequence of biofacies seen through the Centerfield Cycle from the middle Hamilton Group (data from Gray, 1991) using Detrended Correspondence Analysis (DCA) to determine if the inferred sea floor

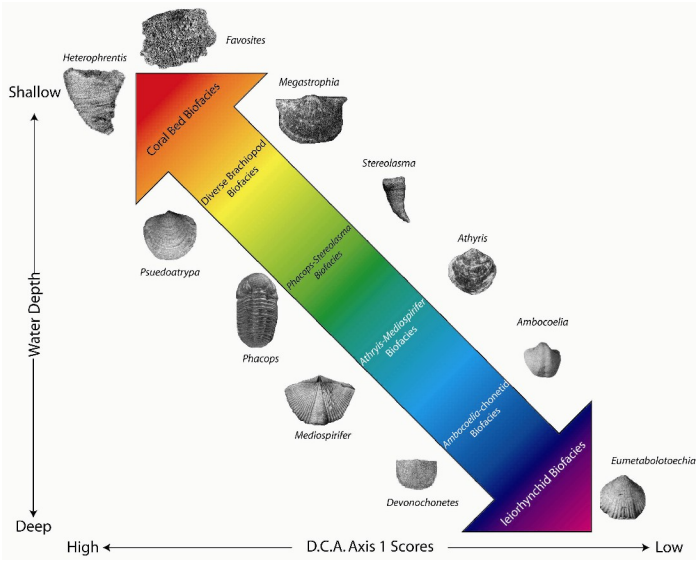

Figure 15. Diagram showing hypothesized gradient that existed along the sea floor during the Dave Elliot interval.

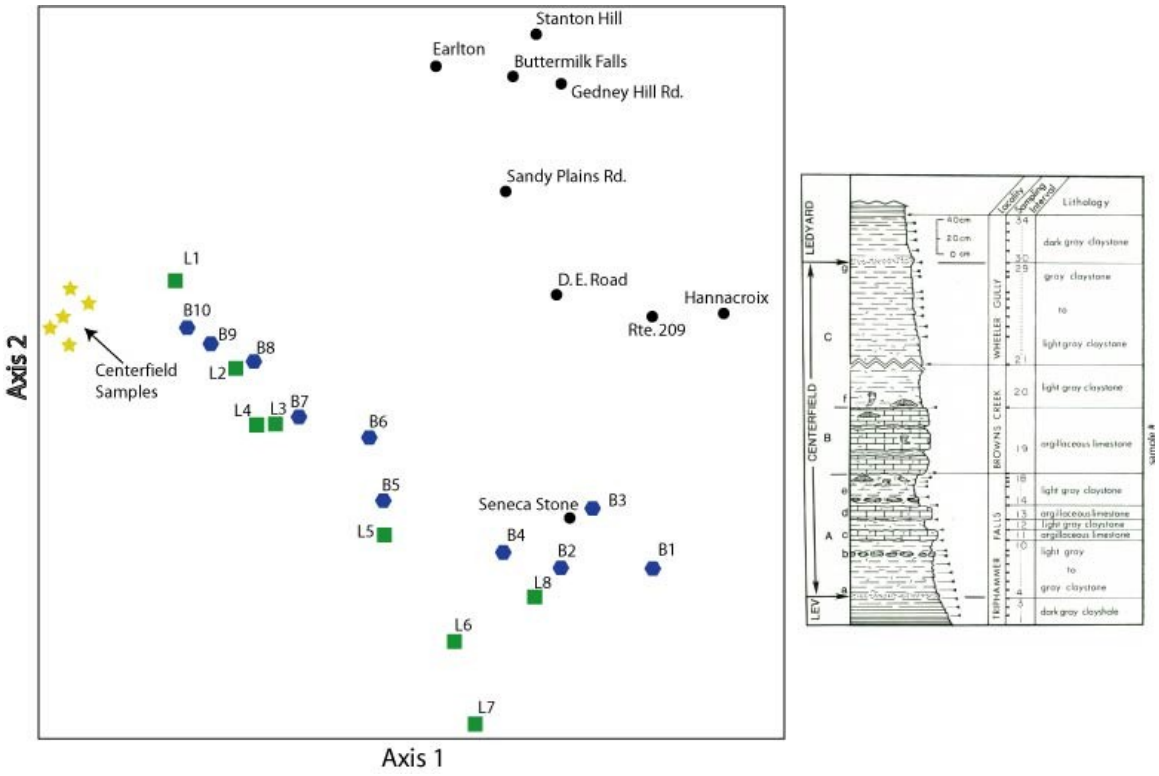

Figure 16. DCA plot for Dave Elliot Bed and Centerfield cycle samples. Stratigraphic column on right is for the Centerfield cycle (Gray, 1991). Black circles represent Dave Elliot Bed samples, blue hexagons represent the upper Levana Shale (LEV on column) samples of Gray, yellow stars represent the Centerfield Limestone samples of Gray, and green squares represent the Ledyard Shale samples of Gray.

gradient qualitatively hypothesized from field observations was statistically valid and how it compared to that seen through the Centerfield cycle.

Figure 16 shows the DCA plot for all the samples from the Dave Elliot Bed and the Centerfield cycle together. Previous analysis of the Centerfield cycle data has indicated that the samples shallow out of the Levana Shale into the Centerfield Limestone (shallowest water) and then deepen upwards through the overlying Ledyard Member (Brett et al., 2007). Within the DCA plot, this is shown as a distinct gradient along Axis 1, with the shallowest water samples plotting on one side of the axis and the deepest water samples The Dave Elliot Bed samples are separated off from the Centerfield cycle samples along axis 2, with the noted exception of the one sample of the Dave Elliot Bed from western New York (Seneca Stone). Along axis 1, the Dave Elliot Bed samples are arrayed from right to left in what was qualitatively determined to represent the deepest to shallowest water samples, thereby statistically supporting the field-based interpretation of a general shallowing from south to north, with a marked increase in water depth over a short distance between Gedney Hill and Hannacroix Ravine. The 'compression' of the Dave Elliot Bed samples along Axis 1 in relation to the Centerfield cycle samples and the separation of the two sets of samples along Axis 2 is most likely the result of the geographic location of the samples. The Hudson Valley area from which the Dave Elliot Bed samples were collected would have been much closer to the sources of sediment that were entering the basin during deposition and this probably had marked effects on which taxa could tolerate the higher amounts of sediment in the water column. It is interesting to note that the one Dave Elliot Bed sample that was taken in the vicinity of the Centerfield cycle samples plotted down amongst the Centerfield cycle samples along Axis 2, further supporting this interpretation. It is also possible that the shallowest Dave Elliot Bed sample (Earlton) was not as shallow as the core Centerfield cycle samples.

From these interpretations it is possible to now reconstruct the paleogeography of the shoreline within the basin during the time of deposition of the Dave Elliot Bed (Figure 17). From our analyses, we interpret an overall shallowing from Rte. 209 in Kingston to the samples from the Earlton Quarry. At Stanton Hill, just north of Earlton, no corals have been found and the sample is dominated by the brachiopod *Tropidoleptus*. Previous investigations have demonstrated that this association is consistent with shallow water-high sediment input, so Stanton Hill was most likely of a similar water depth as Earlton but was situated closer to a sediment source. Heading north from Stanton Hill we continue to see a pattern of high sedimentation; however the biofacies deepen somewhat towards Gedney Hill Road. Once north of Gedney Hill Road we see very rapid biofacies change with the next northerly sample from Hannacroix Ravine being exceedingly deep. This indicates the presence of some sort of paleovalley having existed on the sea floor in the vicinity of Hannacroix Ravine during sedimentation. This is further supported by the increased thickness of the upper East Berne Member in this area as there would have been additional accommodation space for sediment to have been deposited here.

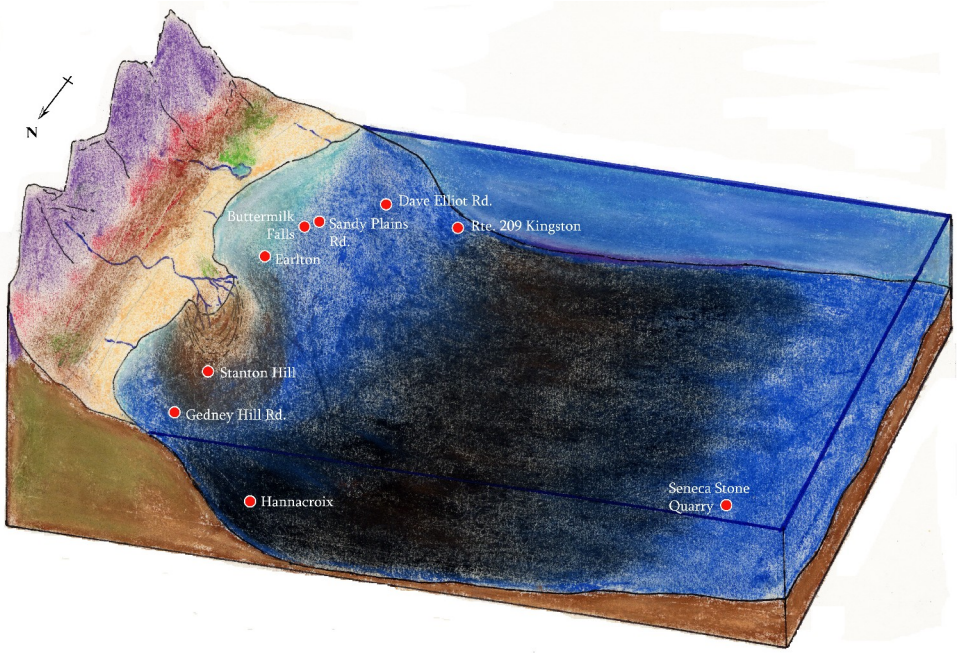

Figure 17. Paleogeographic reconstruction of the shoreline of the Appalachian Basin in the vicinity during deposition of the Dave Elliot Bed.

CONCLUSIONS

The Dave Elliot Bed represents the lowest known occurrence of the Hamilton Fauna within the Appalachian Basin and is of earliest Givetian age. None of the warm-water incursion taxa of the underlying Stony Hollow Fauna were found within the Dave Elliot interval indicting a full and complete replacement of those taxa by cold-water adapted forms of the Hamilton Fauna. Additionally, this indicates a very rapid rate of faunal turnover and wholesale replacement of faunas within the basin with a very short interval of time. The typical biofacies of the overlying Hamilton Group were established throughout the water depth gradient and persisted with little if any change for the entirety of the Hamilton Fauna interval. The Dave Elliot Bed provides us with an important and interesting sample of time within a World-wide bioevent that helps to elucidate many factors that controlled faunal change through the interval.

ROAD LOG

Tot.	Int.	
0.0 mi.	0.0 mi.	Exit Plattekill Parking Lot at S.U.N.Y. New Paltz, turn RIGHT
0.05	0.05	Turn LEFT onto Rte. 32 heading North
0.25	0.2	Turn RIGHT onto Rte. 299 heading East
1.25	1.0	Turn RIGHT onto NYS Thruway entrance ramp, head North
5.75	4.5	Upper Ordovician Martinsburg Shale outcrops
9.75	4.0	Cross Rondout Creek
11.0	1.25	Lower Devonian Port Ewen Fm. outcrops
13.25	2.25	Lower Devonian Port Ewen, Alsen, and Becraft Fm.'s
14.75	1.5	Lower Devonian Schoharie Fm.
15.45	0.7	Lower-Middle Devonian Onondaga Fm.
15.85	0.4	Onondaga Fm
16.65	0.7	Cross Esopus Creek
16.75	0.1	Exit 19 for Kingston, get off Thruway
17.15	0.4	Turn RIGHT onto Rte. 28 heading West
18.0	0.85	Turn RIGHT onto Forest Hill Rd. then take immediate RIGHT onto City View Terrace

STOP 1 - City View Terrace. Our first stop this morning will be used to set up the stratigraphic and faunal story that will be the focus of today's trip. The outcrop along City View Terrace consists of shales and siltstones of the middle Union Springs Fm. and is the type locality for the base of the Stony Hollow Member with the upper-most portion of the underlying Bakover Member also being exposed (Figure 5). The contact between the two formations is marked by a layer of carbonate concretions as well as a discrete color change from dark-gray to black shales below to lighter-gray shales above; the concretions contain rare goniatites (*Cabrieroceras*) (Figure 18). This outcrop is a good example of the sediments that were deposited during the initial phases of the second tectophase of the Acadian Orogeny (Ettensohn, 1985). The downwarping of the edge of the craton due to back thrusting of the magmatic arc to the east created an over-deepened basin containing dysoxic to anoxic bottom waters allowing little to no benthic faunas to exist. Associated with this initial tectonic deepening is an eustatic sea level rise that brought warm, equatorial waters and associated faunas down to the south into the Appalachian Basin during this time; this is the local manifestation of the Kacak Bioevent. We see the first influx of warm-water adapted taxa in the upper Union Springs with the appearance of pelagic cephalopodspreviously unknown in much of the basin, such as *Cabrieroceras*. Additional taxa invade into the basin, displacing the preexisting cold-water adapted taxa, with a moderately diverse benthic fauna being present in the overlying Stony Hollow Member; this fauna has been termed the Stony Hollow Fauna (Figure 2). Today we will be primarily examining the interval that records a return to more 'normal' conditions for the Appalachian Basin near the end of the Kacak Bioevent showing a return of cold-water adapted taxa into the basin (Figure 4) associated with basin shallowing and associated sea level fall within the overlying East Berne Member of the Mt. Marion Fm.

Figure 18. Outcrop along City View Terrace. Contact between Bakoven Member (below) and Stony Hollow Member (above) of Union Springs Fm. is at base of tree. Goniatite-bearing concretion at far right of picture marked by arrow.

18.0	0.0	Continue on City View Terrace to Potter Brothers' Ski Shop
18.1	0.1	Turn around in parking lot
18.3	0.2	Turn LEFT onto Forest Hill Rd. then take immediate LEFT onto Rte. 28 heading East
18.85	0.55	Turn RIGHT onto Rte. 209 entrance ramp heading North towards Rhinecliff
19.45	0.6	Middle Devonian Stony Hollow Member of Union Springs Fm.
20.75	1.3	Middle Devonian Otsego Member of Mt. Marion Fm.
20.8	0.05	Take exit for Sawkill Rd., turn LEFT, cross under Rte. 209 and immediately turn RIGHT heading back South on Rte. 209 towards Ellenville
22.25	1.45	Halihan Hill Bed in outcrop to right marking boundary between the East Berne Member (below) and Otsego Member (above) of Mt. Marion Fm.

STOP 2 - Route 209. At this stop we will be dropped off at the southern end of the outcrop and walk upwards through the section from the upper Stony Hollow Member, through boundary of the Union Springs and Mt. Marion Fm. at the base of the Cherry Valley Member, then into the overlying East Berne Member with a fine exposure of the Dave Elliot Bed, finishing up at the Halihan Hill Bed at the base of the Otsego Member where we will reboard the vehicles (Figure 5). Starting at the southern end of the outcrop we are in the upper siltstones and sandstones of the Stony Hollow Member (Figure 19). The unit is bioturbated and contains several shelly horizons including the lower and upper Proëtid beds containing a diverse example of the Stony Hollow Fauna (Figure 2). In the interval between the upper Proëtid Bed and the base of the Cherry Valley Member is the Hurley Member of Ver Straeten et al. (1994). This interval contains the distinctive goniatite *Agoniatites nodiferans*. Only the lower ~2 m of the Cherry Valley Member is exposed here consisting of thick-bedded sandstone with a depauperate fauna of dominantly leiorhynchid brachiopods (*Cherryvalleyrostrum*).

Sadly, the contact between the Cherry Valley Member and the overlying East Berne Member is covered here, but only for ~10 m or so. The lowest portions of the East Berne Member are medium-gray, fine-grained, very fissile shales that grade upwards with more and more silts. Near the middle of the member, we see the entrance of thicker-bedded siltstones and fine-grained sandstones. These beds are very homogenous inside and show little to no burrowing in nearly every instance at this outcrop. We interpret these beds to be storm-derived sediments that were most likely deposited nearly instantaneously into deep, dysoxic waters.

Continuing up section we first come to a distinct rusty horizon that contains an incredible abundance of infaunal nuculid bivalves (*Nuculoidea*) (Figure 20).

Approximately 2 m above this bed is a distinctive horizon of vertically-oriented concretions formed around tubular pyritic burrows. This bed is ~1 m below the Dave Elliot Bed, another rusty horizon with abundant nuculid bivalves and rare leiorhynchid brahiopods and cephalopods. This bed represents a 'dirtier' water version of the leiorhynchid biofacies of Brett et al. (2007) (Figure 15). Con-

Figure 19. Southern portion of outcrop along Rte. 209 just west of Kingston exposing Stony Hollow Member (below), Hurley Member (middle) and Cherry Valley Member (above). Students are collecting from the upper Proëtid Bed within the Stony Hollow Member. White line denotes base of Cherry Valley Member.

tinuing upwards we see thicker and thicker siltstone and sandstone beds until near the northern end of the outcrop we encounter the diverse Halihan Hill Bed that contains abundant spiriferid brachiopods and common small rugosan corals.

Figure 20. Rte. 209 outcrop. Arrows point to distinctive fossiliferous horizons. Upper arrow points to the Dave Elliot Bed.

23.25	1.0	Stony Hollow Member
23.85	0.6	Take exit for Rte. 28 heading East
24.85	1.0	Go ¾ the way around the traffic circle and exit onto NYS Thruway and head North towards Saugerties
25.55	0.7	Stony Hollow Member
27.75	2.2	Cross Sawkill Creek
27.95	0.2	East Berne Member
30.55	2.6	Cross Plattekill Creek
31.0	0.45	Otsego Member
32.25	1.25	Mt. Marion to west of Thruway
34.05	1.8	Big Quarry in East Berne Member on north end of Mt. Marion
34.75	0.7	Take Exit 20 for Saugerties, outcrops of Onondaga Fm. just beyond exit ramp
35.15	0.4	Stay in middle lane after going through toll booth
35.25	0.1	Turn LEFT at traffic light and immediately enter Stewart's parking lot REST STOP at Stewart's/MacDonald's
35.25	0.0	Turn RIGHT out of Stewart's parking lot, stay in Right lane
35.45	0.2	Turn RIGHT onto Rte. 32 North
36.35	0.9	Onondaga Fm.
37.25	0.9	Turn RIGHT onto King's Highway, Co. Rte. 34
38.25	1.0	Kaatsban Stone Church (Kaatsban is Dutch for tennis court)
38.65	0.4	Turn LEFT onto Dave Elliot Rd.
40.15	1.9	Dave Elliot Road Quarry. Pull into quarry and park

STOP - 3 Dave Elliot Quarry. Stop 3 is the type locality of the Dave Elliot Bed along Dave Elliot Road (Figure 5, 21). This small quarry exposes ~10 m of the upper East Berne Member and dip markedly to the west. The Dave Elliot Bed consisting of a ~20 cm siltstone bed containing an abundance of chonetid brachiopods exposed near the eastern end of the quarry, holding up a small terrace; many of the brachiopods in the bed are distinctly white in color at this locality. Also present in the fauna of the bed here are rare to common spirifers and common emmanuellid brachiopods. The biofacies preserve here would be consistent with the chonetid biofaces of Brett et al. (2007) (Figure 15).

40.15	0.0	Continue West up hill on Dave Elliot Rd.

40.35	0.2	Otsego Member
41.25	0.9	Turn RIGHT at 'T' onto High Falls Rd.
42.35	1.1	Otsego Member
42.75	0.4	Turn RIGHT, staying on High Falls Rd.
43.05	0.3	Stay STRAIGHT on Nelson Rd.
43.25	0.2	Cross Kaaterskill Creek just above High Falls, take immediate LEFT after bridge and bear LEFT onto Mossy Hill Rd.
43.35	0.1	Otsego Member
46.15	2.9	Turn RIGHT onto Rte. 23A
46.75	0.6	Stony Hollow and Cherry Valley members, base of Cherry Valley Member marks the base of the Mt. Marion Fm.
47.0	0.25	Stony Hollow Member
47.5	0.5	Upper Proetid Bed of Stony Hollow Member
48.1	0.6	Turn RIGHT at Stop Sign
48.7	0.6	Turn LEFT onto Vedder Mt. Rd.
49.7	1.0	Stony Hollow Member
51.2	2.5	Turn LEFT onto Co. Rte. 47
51.7	0.5	Cross Rte. 23
51.9	0.2	Turn RIGHT onto Co. Rte. 23B
52.2	0.3	Turn LEFT onto Green Lake Rd., Co. Rte. 49
52.7	0.5	Bear LEFT onto Sandy Plains Rd.
53.45	0.75	Pull over on side of road. Be careful as there is minimal shoulder here.

Figure 21. Dave Elliot Bed at Dave Elliot Rd.

STOP 4 - Sandy Plains Road. The Dave Elliot Bed at Sandy Plains Road (Figure 5) is exposed at the top of a ~1.5 m sandstone bed and is dominated by crinoidal debris, abundant spiriferid brachiopods along with with rare bryozoans. It is interesting to note that the upper portion of the East Berne Member has coarsened considerable in this area, with the sandstone containing the Dave Elliot Bed thickening by almost an order of magnitude (Figure 22). The biofacies preserved in the bed here most closely resemble a moderately diverse brachiopod assemblage of the Hamilton Group (Figure 15).

Figure 22. Dave Elliot Bed at Sandy Plains Rd.

53.45	0.0	Continue West on Sandy Plains Road
53.95	0.5	Otsego Member
54.0	0.05	Turn RIGHT onto Potic Mt. Rd.
55.95	1.95	Turn RIGHT onto Buttermilk Falls Rd.
56.7	0.75	Pull off for Buttermilk Falls

LUNCH STOP - Butter Milk Falls. Our lunch stop today is a picturesque spot at the Buttermilk Falls preserve just north of Leeds (Figure 5, 23). Exposed in the stream is the uppermost portion of the Stony Hollow Member and the overlying Cherry Valley Member. Continuing upstream the East Berne is exposed on private property and consists of silty shales with numerous thin-bedded sandstones. The main face of the falls where we will eat lunch is the upper Proëtid Bed and the distinctive brachiopods *Variatrypa arctica* and *Pentamerella* cf. *wintereri* have been found here representing the Stony Hollow Fauna. The smaller falls just upstream from the main falls is the Cherry Valley sandstone and is distinctly cleaved at this locality. The Dave Elliot Bed is present upstream and forms another ~4 m waterfalls and very closely resembles that seen at Sandy Plains Road just to the south (Figure 24).

Figure 23. Upper Stony Hollow Member at Butter Milk Falls.

56.7	0.0	Continue down hill on Butter Milk Falls Rd.
57.0	0.3	Turn LEFT onto Co. Rte 49, Green Lake Rd.
57.4	0.4	Stony Hollow Member
58.0	0.6	Stay straight (left) on Co. Rte. 49
59.0	1.0	Onondaga Fm.
59.2	0.2	Turn LEFT, the immediately RIGHT, the bear LEFT
60.0	0.8	Turn RIGHT onto Lime Street
61.2	1.2	Onondaga Fm.
62.3	0.1	Turn LEFT at Stop Sign
62.4	0.1	Turn RIGHT onto Bronk Rd.
63.1	0.7	Continue STRAIGHT through Stop Sign
63.4	0.1	Cross Rte. 81, continue STRAIGHT onto Vanderberg Rd.
64.4	1.0	Turn LEFT onto Co. Rte. 26 then immediately turn RIGHT onto Lime Kiln Rd. Onondaga Fm. outcrops all along this road
66.6	2.2	Turn LEFT onto Reservoir Rd.
66.8	0.2	Turn RIGHT onto Valley View Rd.
67.1	0.3	Turn LEFT onto Co. Rte. 54
67.7	0.6	Turn RIGHT onto Jenning's Rd.
69.2	1.5	Stay STRAIGHT (right) onto Co. Rte. 51
70.7	1.5	Turn LEFT onto Shady Lane
71.45	0.75	Turn RIGHT onto Gedney Hill Rd.
72.2	0.75	Quarry on left, Albany Co. line
73.2	1.0	Pull off to LEFT into small parking area at base of hill

Figure 24. Dave Elliot Bed capping a waterfalls on Butter Milk Falls Creek

STOP 5 - Gedney Hill Road. Stop 5 today is an exposure of the middle portion of the East Berne Member along Gedney Hill Road (Figure 5). We have skipped what are perhaps some of the most interesting exposures of the Dave Elliot Bed in the intervening area between Buttermilk Falls and here, however access to these exposures is limited at this time. We will walk up through the entirety of the exposure of the East Berne Member here as parking is limited. The Dave Elliot Bed is here represented by a ~1 m very hard quartz-rich sandstone bed (Figure 25) and contains an abundant fauna of brachiopods (*Athyris*, *Mediospirifer*, *Mucrospirifer*, *Tropidoleptus*) and rare corals and conulariids and would sit somewhere between the diverse brachiopod biofacies and the coral bed biofacies in the parlance of Brett et al. (2007) (Figure 15). In between here at Butter Milk Falls are the Earlton and Stanton Hill Ravine sections. The Dave Elliot Bed at Earlton contains the most diverse fauna yet discovered including rare tabulate corals, moderately-common rugosan corals, and abundant spiriferid and athyrid brachiopods. This biofacies is the closest we get within the interval to the coral bed biofacies of Brett et al. (2007) (Figure 15). The outcrop of the Dave Elliot Bed at Stanton Hill Ravine is similar in lithology to the exposure at Gedney Hill Road, however the fauna is less diverse (entirely lacking in corals) and almost entirely dominated by *Tropidoleptus*. This association would sit on the 'dirtier' side somewhere between the diverse brachiopod and *Athyris-Mediospirifer* biofacies of Brett et al. (2007) (Figure 15).

Figure 25. Dave Elliot Bed at Gedney Hill Rd.

73.2	0.0	Continue down hill (north) on Gedney Hill Rd.
73.7	0.5	Take hard LEFT onto Rte. 143 heading North
78.9	5.2	Turn RIGHT onto Rte. 32 heading NORTH
82.6	3.7	Turn LEFT onto Co. Rte. 301
82.7	0.1	End of Gulch Cave to right
82.8	0.1	Onesquethaw Cave to left
83.2	0.4	Turn RIGHT continuing on Co. Rte. 301
83.5	0.3	Onondaga Fm.
84.7	1.2	Cross Onequethaw Creek; nice fold in creek in upper Onondaga Fm.
84.9	0.2	Turn LEFT onto Rte. 443 heading West
85.0	0.1	Clarksville Cave
85.2	0.2	Cross Onesquethaw Creek
85.3	0.1	Onondaga Fm.
86.9	1.6	Turn LEFT into Stewart's parking lot
		REST STOP at Stewart's
86.9	0.0	Turn RIGHT out of Stewart's onto Rte. 443 heading East
88.6	1.7	Turn RIGHT onto Cass Hill Rd.
89.6	1.0	Otsego Member
90.0	0.4	Otsego Member
90.5	0.5	Turn LEFT into Nature Conservancy parking area for Hannacroix Ravine

STOP 6 - Hannacroix Ravine. The last stop today will be at Hannacroix Ravine (Figure 5). We consider this locality is somewhat of a 'Rosetta Stone' of sorts for the East Berne Member as it contains numerous individual fos-

siliferous horizons in addition to a number of well-developed small-scale cycles throughout the member. The abundance of thin, shelly horizons within this exposure confused us at first as to the proper identification of the true Dave Elliot interval, however this led to the discovery of some very important fossils that might have otherwise gone unnoticed. The actual Dave Elliot Bed consists of a ~0.75 m thick silty sandstone with *Zoophycus* burrows and a fauna dominated by spirifered brachiopods and conulariids and is underlain by the distinctive vertically-oriented concretions; the bed itself caps a small falls within the creek (Figure 25).

Figure 26. Author sitting on Dave Elliot Bed in Hannacroix Ravine.

We have, to date, found nine distinct fossiliferous horizons within the middle to upper East Berne Member at this locality (Figure 27, 28). Besides the Dave Elliot Bed, the horizon with the most well-developed fauna forms a ~30 cm interval with dispersed abundant nuculid bivalves, rare leiorhynchid brachiopods, and common nautiloid and goniatite cephalopods. This interval is underlain by two distinct 'gummy' clay horizons (possible bentonites, see discussion in main body of text). We have provisionally named this interval the Hannacroix Ravine Bed. Of great importance was the discovery at this site of the zonally important goniatite *Tornoceras* aff. *mesopleuron* (Figure 29, graciously identified for us by Dr. R. Thomas Becker of Muenster, Germany). At the standard section for the base of the Givetian in Morocco, this taxa first appears just above the base of the *P. hemiansatus* conodont zone that marks the base of the Givetian Stage and the occurrence of this taxa in the Dave Elliot Bed here marks it's lowest record in eastern North America to date and helps to establish the base of the Givetian Stage as occurring somewhere below this bed and above the top of the Cherry Valley Member which contains conodonts indicative of the upper Eifelian (*T. kockelianus* Zone) and puts the lower East Berne in the *P. ensensis* Zone (Figure 30).

Between the Dave Elliot Bed and the Halihan Hill Bed at the top of the East Berne, there are at least four distinct fossiliferous horizons, each becoming progressively more diverse as you proceed up-section. Between the Hannacroix Ravine Bed and the Dave Elliot Bed are two, thin fossiliferous horizons dominated by scattered nuculid bivalves. There are also two nuclulid-dominated horizons below the Hannacroix Ravine Bed that can be traced through the ravine and out onto the road where the lowest forms a ~2 m falls in a side gully entering from a ditch to the south of the main ravine; the upper of the two beds is visible further up the ditch to the south. A more detailed investigation of the entire East Berne Member is planned for this section. To date no fossiliferous horizons have been found downstream of the road culvert, although a picturesque waterfall is present about 100 yards downstream providing an accessible lower section that needs more work.

END OF TRIP

90.5	0.0	End of trip, return to New Paltz – Turn RIGHT out of parking lot onto Cass Hill Road
92.4	1.9	Turn RIGHT onto Rte. 443, cross Onesquethaw Creek
92.7	0.3	Turn RIGHT onto Co. Rte. 301
94.2	1.5	Turn LEFT continuing on Co. Rte. 301
98.7	4.5	Stay STRAIGHT continuing onto Co. Rte. 396
103.3	4.6	Cross Rt. 9W, stay on Co. Rte. 396
105.3	2.0	Turn LEFT onto Rte. 144 at 'T' intersection
105.7	0.4	Turn LEFT onto NYS Thru-way entrance ramp, head South
165.2	59.5	Take Exit 18 for New Paltz
166.1	0.9	Turn LEFT at light onto Rte. 299 heading West
167.1	1.0	Turn LEFT at light onto Rte. 32 heading South
167.3	0.2	Turn RIGHT onto Plattekill Ave. then immediately LEFT into parking lot

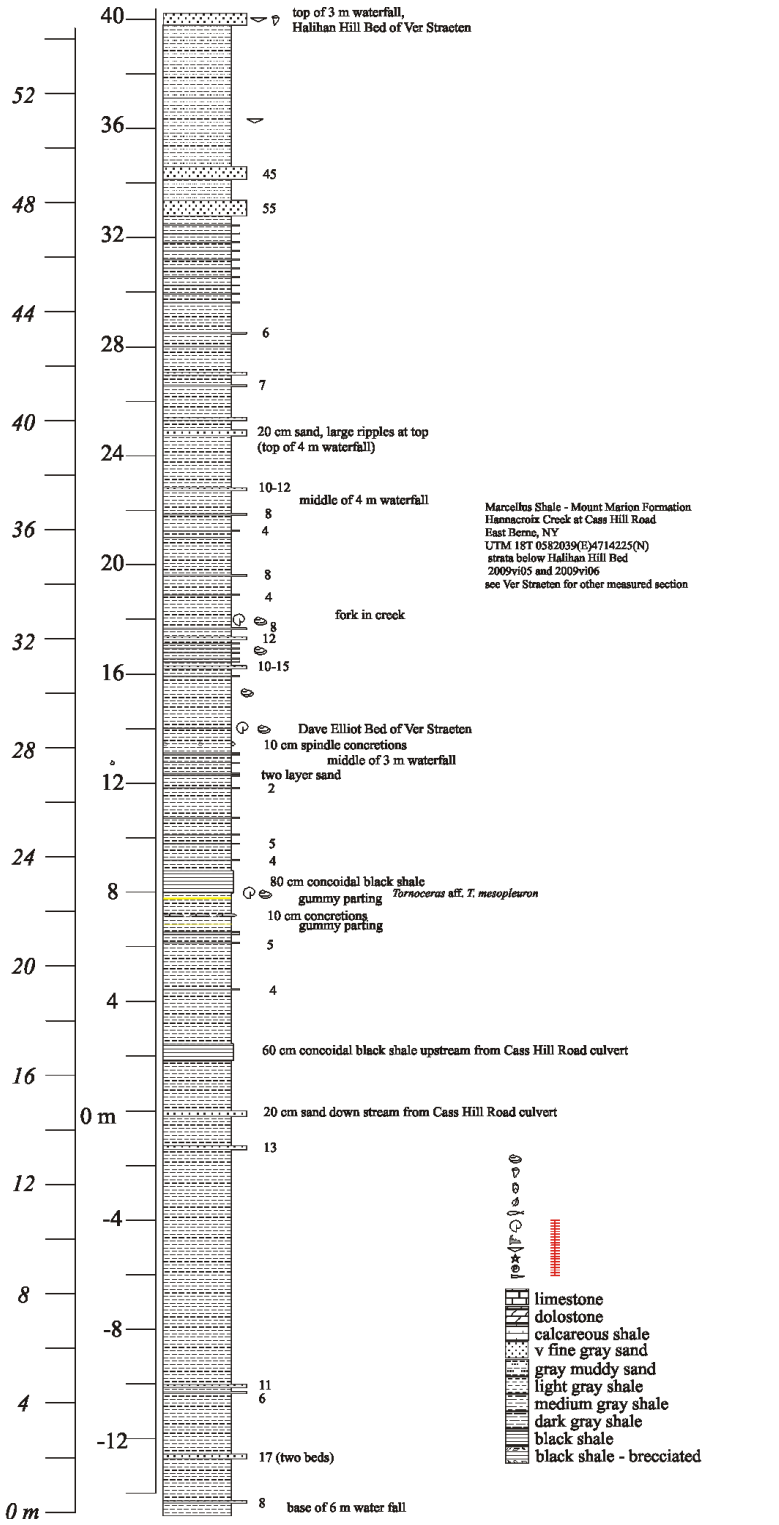

Figure 27. Stratigraphic column for Hannacroix Ravine (by Jeff Over and students).

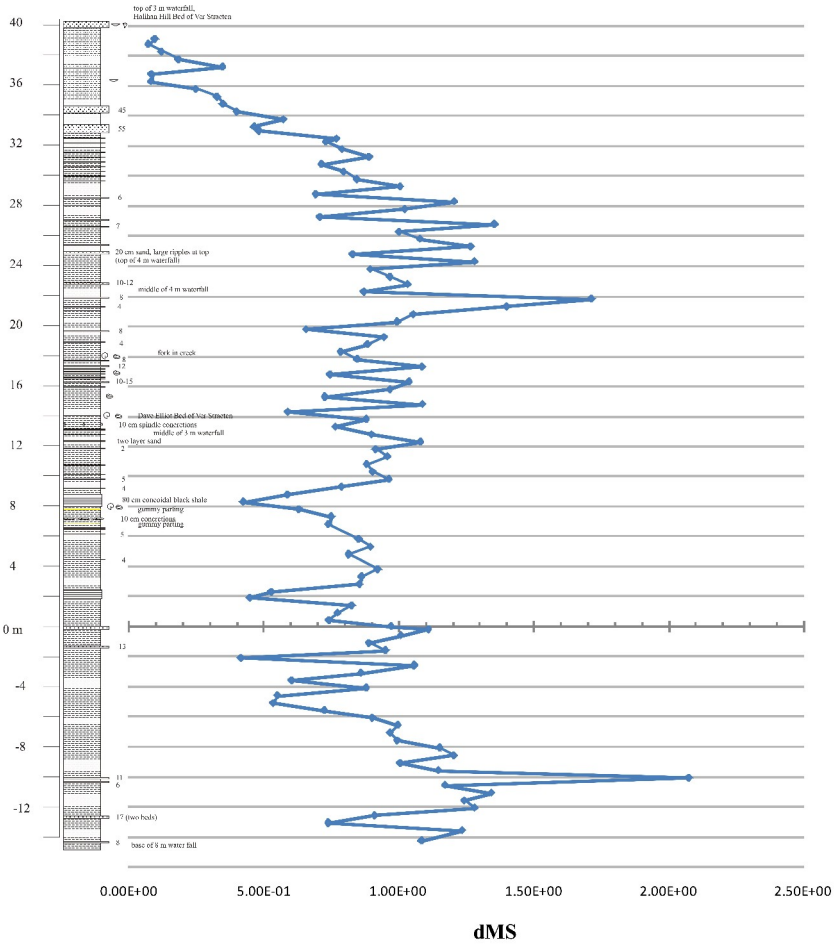

Figure 28. Magnetic susceptibility curve for Hannacroix Ravine section by Jeff Over and students.

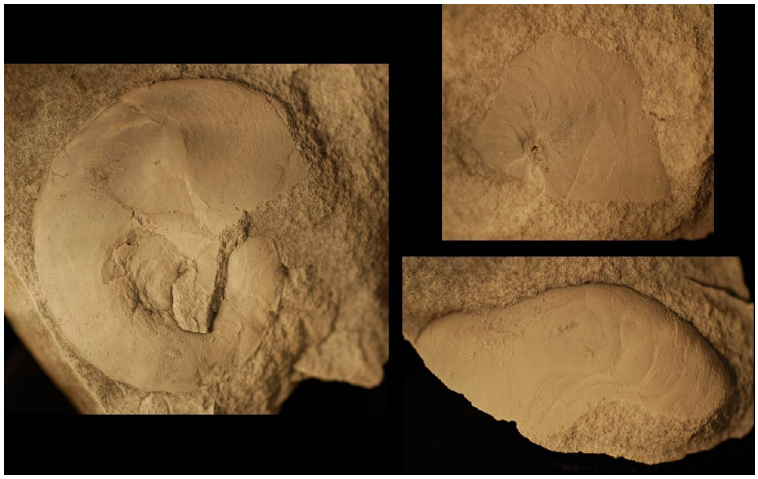

Figure 29. Goniatite Tornoceras aff. mesopleuron from the Hannacroix Ravine Bed. Full specimen is ~5 cm across.

REFERENCES

Baird, G.C., Brett, C.E., 2003, Shelf and off-shelf deposits of the Tully Formation in New York and Pennsylvania: Faunal incursions, eustasy and tectonics: Courier Forschungsinstitute Senckenberg, v. 242, p. 141-156.

Blakey, R., 2009, Paleogeographic maps, http://jan.ucc.nau.edu/~rcb7/

Brett, C.E., Bartholomew, A.J., Baird, G.C., 2007, Biofacies recurrence in the Middle Devonian of New York State; an example with implications for evolutionary paleoecology, Palaios, v. 33, no. 2, pp. 306-324.

Brett, C. E., Baird, G. C., 1995, Coordinated stasis and Evolutionary Ecology of Silurian to Middle Devonian Faunas in the Appalachian Basin, in New Approaches to Speciation in the Fossil Record, Erwin, Douglas, H., and Anstey, Robert, L. eds. pp. 285-315.

Bonelli, J.R., Brett, C.E., Miller, A.I., Bennington, J. B., 2006, Testing for faunal stability across a regional biotic transition; quantifying stasis and variation among recurring coral-rich biofacies in the Middle Devonian Appalachian Basin, Paleobiology, v. 32, no. 1, pp. 20-37.

Cleland, H. F., 1903, A study of the Fauna of the Hamilton Formation of the Cayuga Lake Section in Central New York: United States Geological Survey Bulletin, no. 206, 112 p.

Eldredge, N., and Gould, S. J., 1972, Punctuated equilibria: An alternative to phyletic gradualism. In: Schopf, T. J. M., (ed.), Models in Paleobiology, Freeman, Cooper, and Co., San Francisco, pp. 82-115.

Ettensohn, F. R., 1985, Controls on the development of Catskill Delta complex basin facies, in: WOODROW, D. L. & SEVON, W. D. (eds.): The Catskill Delta. Geological Society of America Special Paper, no. 201, p. 65-78.

Goldring, W., 1935, Geology of the Berne Quadrangle, New York State Museum Bulletin, no. 303, 238p.

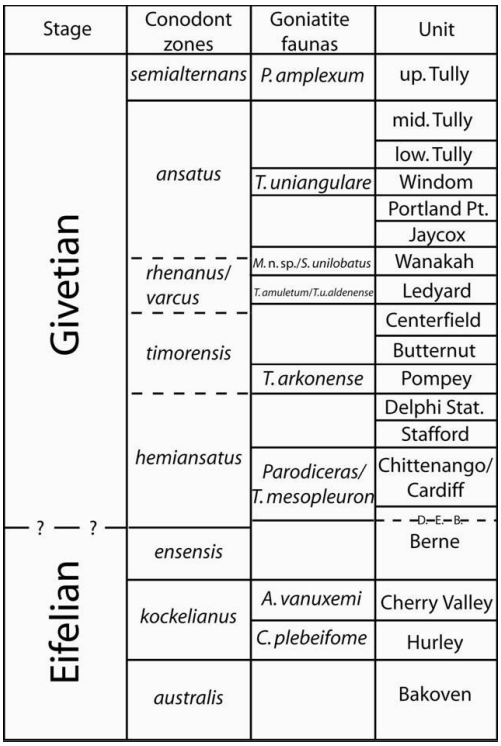

Figure 30. Current understanding of goniatite and conodont biostratigraphy for the Middle Devonian of New York.

Gray, L. M., 1991, The paleoecology, orogin, and significance of a shell-rich bed in the lowermost part of the Ludlowville Formation (Middle Devonian, Central New York), in: Landing, E., and Brett, C. E., (eds.), Dynamic Stratigraphy and Depositional Environments of the Hamilton Group (Middle Devonian) in New York State, Part II: New York State Museum Bulletin, v. 469, p. 93-106.

Koch, W.F., Day, J.E., 1996, Late Eifelian-early Givetian (Middle Devonian) brachiopod paleobiogeography of eastern and central North America, in: Proceedings of the International Brachiopod Congress, Copper, P., ed., v. 3, pp. 135-143.

Rickard, L.V., 1975, Correlation of Silurian and Devonian rocks of New York State, New York State Museum and Science Service, Map and Chart Series, no. 24.

Ver Straeten C.A., 1994, Microstratigrpahy and Depositional Environments of the Middle Devonian Foreland Basin: Berne and Otsego Members of the Mount Marion Formation in Eastern New York State, in: LANDING, E., (ed.), Studies and Stratigraphy in Honor of Donald W. Fisher, New York State Museum Bulletin, no. 481, p. 367-380.

Ver Straeten,, C. A., Brett, C. E., 2006, Pragian to Eifelian strata (middle Lower to lower Middle Devonian), northern Appalachian Basin; stratigraphic nomenclatural changes, Northeastern Geology and Environmental Sciences, v. 28, no. 1, pp. 80-95.

Ver Straeten, C.A., Griffing, D.H., AND Brett, C.E. 1994. The lower part of the Middle Devonian Marcellus "Shale," central to western New York State: Stratigraphy and depositional history, in: Field Trip Guidebook, New York State Geological Association, 66th Meeting, p. 271-322.