

Life on the Edge: Death and Transfiguration in Mud

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SUMMARY

The hypothesis of Coordinated Stasis posits that paleocommunities were relatively stable associations of species that tracked together through cyclical changes in their regional environment. When this tracking capacity was exceeded, they experienced relatively abrupt turnover in species composition, leading to a new interval of relative stability. This fieldtrip will focus on changes in community structure within the dysoxic, *Ambocoelia*-chonetid biofacies through the Wanakah and Lower Windom depositional cycles. We will also discuss the implications of the observed patterns for habitat tracking and community stability over longer time scales.

INTRODUCTION

Recent work on the causes underlying patterns of biofacies distribution in time and space have lead to a set of hypotheses referred to as Coordinated Stasis (Brett et al. 1996). Basic postulates of this model are that relative stability in the species composition of biofacies assemblages is a consequence of the ability of species communities to track preferred habitats and thereby avoid selection pressures that would otherwise disrupt community stability. When, on rare occasions, extraordinarily pervasive and abrupt environmental changes overwhelm the ability of species assemblages to track their preferred habitats, communities undergo a cascade of species turnover during which a substantial fraction of the formerly characteristic species go extinct and new species join the survivors to form a new and markedly altered community (Brett and Baird, 1995 and Brett *et. al.*, 1996). Habitat tracking is most easily generalized as an effect of sea level change. As sea level fluctuates through transgressive - regressive cycles, it follows that environments will synchronously fluctuate along an onshore - offshore gradient. If communities of organisms that share a preferred environment are to remain in this environment, then they will be forced to migrate up and down depositional slope through time with sea level. A critical issue for the testing of Coordinated Stasis, therefore, is the degree to which we can observe habitat tracking through the fossil record that is preserved within stratigraphic sequences.

The geographic setting of this trip is Western New York, with four outcrops from the Wanakah and Lower Windom Shale Members of the Hamilton Group, northern Appalachian Basin (Figures 1 and 2). The Middle Devonian Hamilton Group (Givetian Stage) is a dominantly fine-grained marine deposit. The sediments originated from the erosion of a mountain belt to the east that formed during the Acadian Orogeny. Most of the Hamilton Group records the interval between the second and third phases of mountain building that occurred from the collision of microcontinents into New England and the central Atlantic United States (Ettensohn, 1985; Ver Straeten and Brett, 1995); more specifically, the oblique convergence between the Laurentian and Avalon terranes (Ettensohn *et al.*, 1988). This well-documented stratigraphic succession provides an ideal setting in which to examine the predictions of Coordinated Stasis. Indeed, it is the setting in which Brett and Baird (1995) developed the hypothesis.

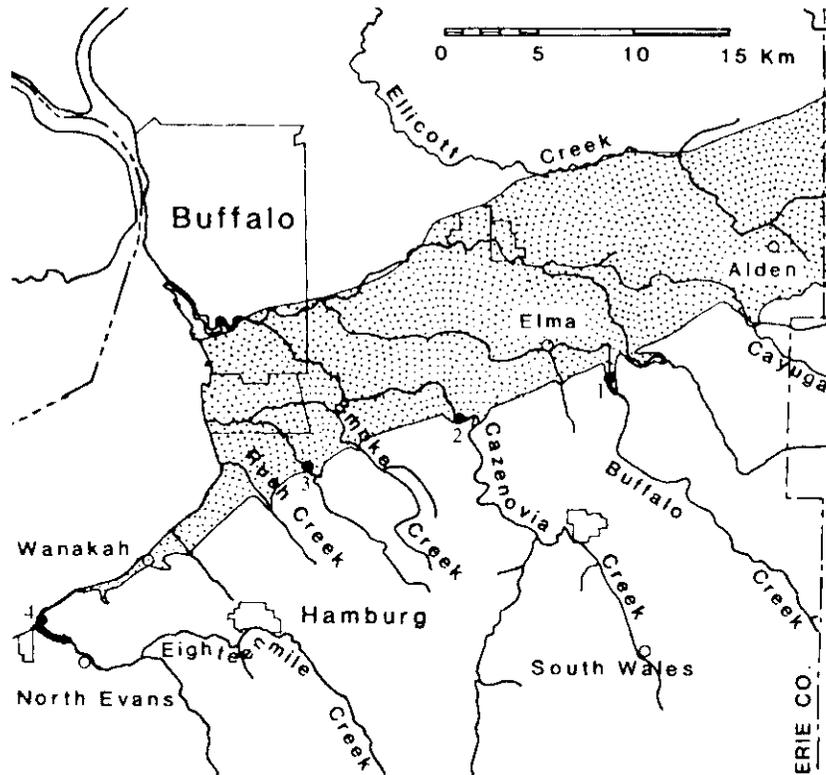


Figure 1: Map of a portion of Erie County, showing geographic location of the localities visited on this fieldtrip. Stippled area is the outcrop belt of the Hamilton Group, Middle Devonian. Locality 1: Buffalo Creek at Bullis Road; 2: Cazenovia Creek at US 20; 3: Smoke Creek (South Branch) at Milestrip Road; 4: Lake Erie Shore at Eighteenmile Creek. (Modified from Goldman and Mitchell, 1990).

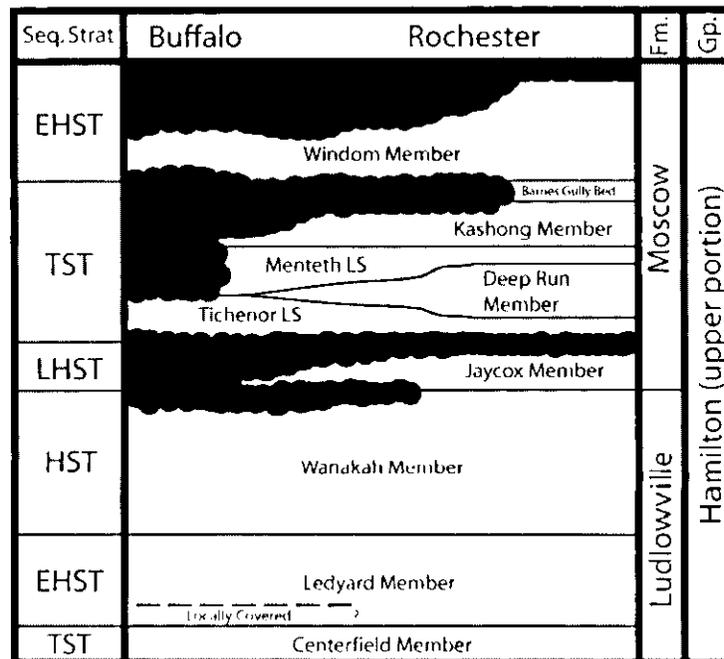


Figure 2: General stratigraphy of the upper portion of the Middle Devonian Hamilton Group in western New York. Column on left represents position within third-order sea level cycles. TST: transgressive systems tract, EHST: early highstand systems tract, HST: highstand systems tract, and LHST: late highstand systems tract. (Modified from Brett and Baird, 1996).

Sea level change can occur at different magnitudes. Fifth- or sixth-order cycles are typically seen as 0.5-meter thick intervals in the study area. These consist of subsymmetrical alternations of gray mudstone with concretionary, calcareous mudstones; an example of the latter is seen as the various trilobite beds of the Windom and Wanakah Shale Members. If these cycles were the product of Milankovitch forcing, they may have had a duration of ~20 to 100 ka each (Brett and Baird, 1996). Fourth-order cycles commonly display a biofacies spectrum (described in more detail below) from a low diversity "*Leiorhynchus*" fauna, through the *Ambocoelia*-chonetid biofacies, to either a diverse brachiopod or coral-rich community (Brett and Baird, 1996) and, correspondingly, may have had an approximate duration of 0.1 to 1.0 m.y. Third-order cycles, representing 0.8 to 2.0 m.y., correspond fairly well to previously described formations in New York State, primarily because Cooper (1930, 1933) used the thin and widespread limestones in New York as the bases of formations. These limestones have subsequently been interpreted as third-order transgressive systems tracts (TST) by Brett and Baird (1996).

Both the Ludlowville and Moscow Formations, therefore, represent distinct third-order depositional sequences. On this trip we will examine the relationship between observed faunal changes and the early highstand systems tract (EHST) and highstand systems tract (HST) portions of these third-order cycles. Previous work suggests that both of these systems tracts are aggradational, whereas the late highstand systems tract (LHST, which we will not examine here) is dominantly progradational (Brett and Baird, 1996). These comparisons provide an opportunity to gauge the degree of change in biofacies composition that accompanies sea level changes of various magnitudes. Unlike the case for the third-order cycles, fourth-order systems tracts have not been delineated for all of the intervals studied. Thus, fourth-order cycles are described here simply in terms of relative sea level change; that is, as fourth-order transgressive and regressive facies, rather than in terms of systems tracts. See Brett and Baird (1996) and Batt (1996) for full description of sequences and systems tracts addressed on this fieldtrip.

The *Ambocoelia*-chonetid biofacies is one of numerous recurrent fossil assemblages, or biofacies, described within the Hamilton Group of New York. These biofacies are representative of relatively narrow ranges of benthic environmental conditions (Figure 3). The *Ambocoelia*-chonetid biofacies represents conditions of low oxygen in a relatively quiet offshore setting below maximum storm wave base. Apparent habitat tracking through fourth-order sea level cycles results in symmetrical community replacement from "*Leiorhynchus*" to *Ambocoelia*-chonetid, to *Athyris* biofacies and vice versa (Figure 3). *Ambocoelia umbonata*, *Crurispina nana*, *Devonochonetes scitulus*, *Sinochonetes lepidus*, *Longispina mucronata*, *Mucrospirifer mucronatus*, *Styliolina fissurella*, *Phacops rana*, *Greenops boothi* and Auloporid corals are all commonly present in this biofacies along with numerous other, less common taxa (Figure 4). For a more detailed list of taxa found within this biofacies, see Zambito (2006).

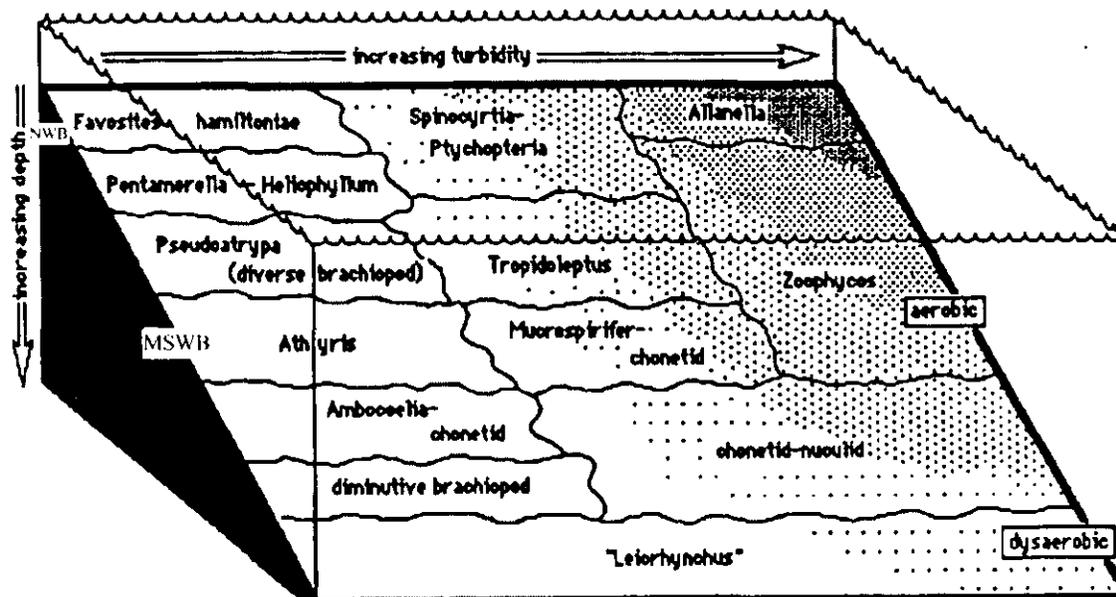


Figure 3: Biofacies model for the Middle Devonian Hamilton Group. Relations to water depth, (and corresponding turbulence and oxygen content) and turbidity (rate of sedimentation) are illustrated. NWB: normal, or fair-weather, wavebase; MSWB: maximum storm wave base. (Taken from Brett *et al.*, 1990).

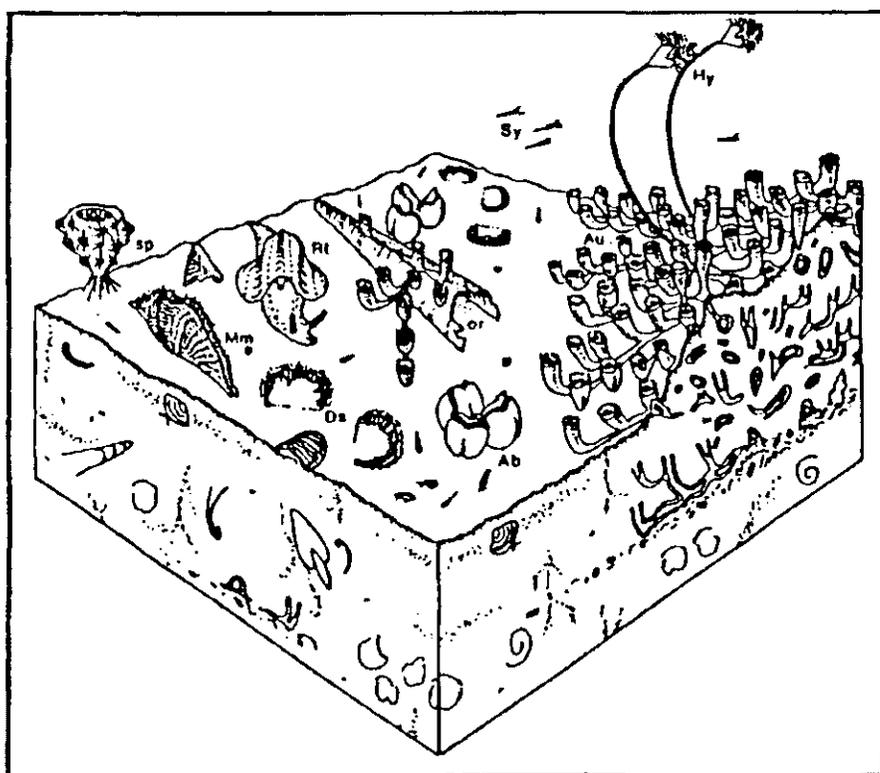


Figure 4: *Ambocoelia*-Chonetid biofacies reconstruction. Ab: *Ambocoelia umbonata*, Ds: *Devonochonetes scitulus*, Mm: *Microspirifer mucronatus*, Au: *Aulocystus jacksoni*, Hy: *Hyperoblastus*, Rt: *Retispira leda*; Sy: *Styliolina fissurella*, or: orthoconic nautiloid, sp: sponge. (Taken from Brett *et al.*, 1990).

Complicating any test of ecological stasis is the need to sample similar environments over time. This trip outlines the effects of sea level change, at the scale of both third- and fourth-order cycles, on organisms found within the dysoxic *Ambocoelia*-chonetid biofacies. Differences in community membership are described, and possible explanations for these differences are discussed. The primary application of this trip is a better understanding of considerations to be taken into account for studies that test communities for prolonged stability over time utilizing samples of from relatively small stratigraphic intervals.

STRATIGRAPHIC UNITS EXAMINED

Lower Wanakah Shale Member, Ludlowville Formation—The section of the lower Wanakah Shale Member examined in this study extends from approximately the top of the Fargo Bed (Kloc, 1983) to 1 meter above the Bidwell Bed (Kloc, 1983; Figure 5). Contained within this interval are up to 4 distinct limey bands (Murder Creek and Bidwell beds) that are rich in trilobites, including *Phacops rana* and *Greenops boothi*. The calcareous nature of these beds may reflect carbonate diagenesis below the sediment-water interface during the deposition of the overlying transgressive, sediment-starved, shales (Batt, 1996). This interval contains a number of species of ambocoeliids and chonetids and will be observed at Stop 4, along the Lake Erie shoreline at the mouth of Eighteenmile Creek (Figures 1 and 5). These sediments were deposited during a fourth-order regression within the third-order, Ludlowville HST (see Fig. 2, 6).

Upper Wanakah Shale Member, Ludlowville Formation—The most pronounced feature of the upper Wanakah section, seen during this trip at the stops at Cazenovia Creek and Lake Erie Shore, are the numerous concretionary horizons that can be grouped into two major intervals separated by approximately 2 to 3 meters of shale that contains sporadic concretions. In descending order, these are the Spring Brook Concretion Bed and the Walden Cliffs Concretion Bed of Kloc (1983). The Spring Brook and Walden Cliffs concretionary intervals comprise a series of concretions, which sometimes overlie one another, that reflect diagenetic enhancement of marker beds similar to the trilobite beds described above. The Spring Brook and Walden Cliffs concretionary intervals are similar both sedimentologically and faunally: both contain abundant pyrite, sometimes in the form of pyritized fossils and as pyritized shell hash horizons (Kloc, 1983); and both contain a number of species of ambocoeliids and chonetids. This interval of the upper Wanakah can be observed at stop 2, Cazenovia Creek at US 20 (Figures 1 and 5). The upper Wanakah Shale Member was deposited during a fourth-order transgression within the third-order, Ludlowville HST (see Fig. 2, 6).

Lower Windom Shale Member, Moscow Formation—The portion of the lower Windom Shale Member examined in this trip includes the lowermost *Ambocoelia*-rich shales. This is a medium gray, sometimes concretionary interval representative of an early highstand phase within the Windom Member depositional cycle (Brett and Baird, 1994). Horizontal, and sometimes vertical, pyritized burrows are common, indicating deposition under dysoxic conditions. This shale interval contains up to four species of chonetid brachiopods, only one species of ambocoeliid. We will examine this interval at stops 1 (Buffalo Creek at Bullis Road)

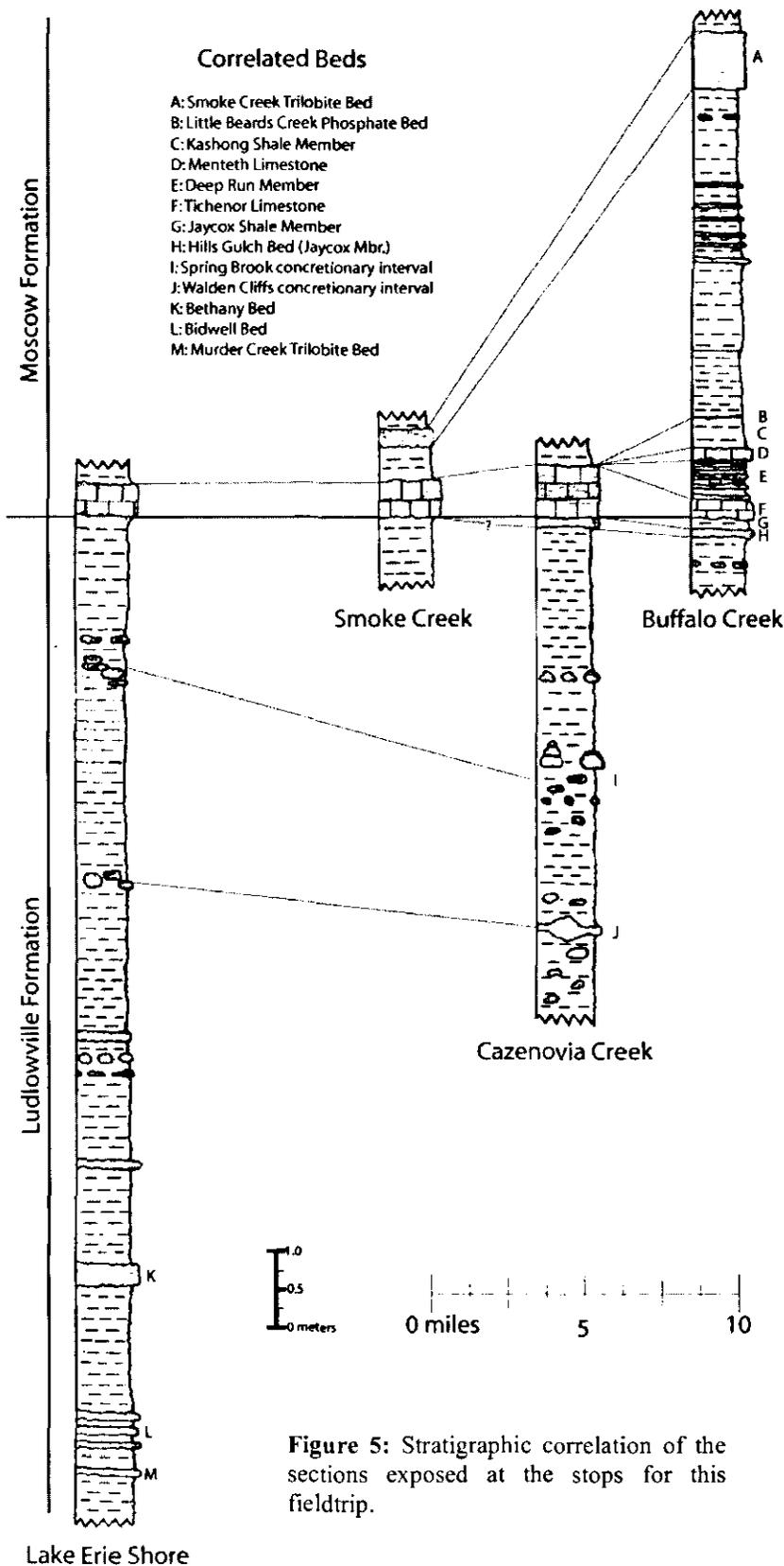


Figure 5: Stratigraphic correlation of the sections exposed at the stops for this fieldtrip.

and 3 (S. Branch of Smoke Creek at Windom, NY) (Figures 1 and 5). The lower Windom Shale Member sediments seen on this trip exhibit a fourth-order regression within the third-order, Moscow Formation EHST (Fig. 2, 6).

SAMPLING BIOFACIES

If we are to make a convincing test of community stability and habitat tracking, it is necessary to sample similar environments over time and to identify this habitat independently of the taxonomic composition of assemblages whose stability we seek to gage — that is, to control as nearly as possible for other sources of variation in community composition. Some environmental parameters of concern include sedimentation rate, redox conditions, and nutrient abundances (through measures of paleo-productivity), which are ultimately related, either directly or indirectly, to sea level fluctuations (Sageman *et al.*, 2003 and Tribovillard *et al.*, 2006). Thus, when testing for Coordinated Stasis it is essential to assess the relative position within sea level cycles at which the studied samples were deposited.

Data on the faunal composition and species abundance were collected through dysoxic intervals in the lower and upper Wanakah Shale Member as well as the lower Windom

Shale Member (Figure 2) to assess the effect that transgressive vs. regressive depositional settings may have on faunal composition. Accordingly, comparison of faunal constituents between these two depositional sequences also allows for insight into similarities and differences between two distinct third-order sea level cycles (Figure 2) within one Ecological-Evolutionary Sub-Unit (EESU; sensu Brett and Baird, 1995), or stable evolutionary block as described by the Coordinated Stasis hypothesis; and from this to gauge the degree to which this community is stable in its composition.

The intervals of the Wanakah and Windom Shale Members that will be discussed were bulk-sampled in contiguous, 10-centimeter thick increments. Species abundance was determined by counting the number of specimens of each of the taxa present. Absolute abundances are favored over relative abundances so that a change in one taxon does not affect the abundance of all other taxa (Finnegan and Droser, 2006). Confidence in these results, in particular the concern that rare taxa might be missed and counted as absent is sustained by agreement of presence/absence of taxa sampled in this instance with similar data from Zambito (2006), in which a rigorous sampling effort involving replicate samples and sub-samples was performed on the same intervals within both the lower Windom and upper Wanakah Shale Members. Those samples proved to be statistically indistinguishable estimates of a common underlying species abundance distribution, and that any species that was present at the site in at least a one percent relative abundance was recovered with a 95% confidence. Absolute abundances of the most common taxa, along with and typically including all ambocoeliids and chonetids, are presented in Figure 6 for discussion.

BIOFACIES COMPARISONS AMONG SEA LEVEL CYCLES

The Hamilton biofacies exhibit gradational boundaries between adjacent biofacies. Thus the presence of *Leiorhynchus*, in the upper Wanakah interval indicates that these sediments were deposited near the deep water limit of the *Ambocoelia*-chonetid biofacies (see Figure 3), whereas its absence in both the lower Wanakah and the lower Windom intervals suggest that these reflect somewhat shallower environments (Batt, 1996). Thus, the lowest Moscow Formation Kashong, Deep Run, and lower Windom member deposits deepen upward (Brett and Baird, 1994), but the lack of *Leiorhynchus* in the capping lower Windom Shale Member suggests that this deepening did not proceed to the extent needed to introduce this species' preferred habitat. These observations illustrate how the environmental extent within, and the gradational boundaries between, biofacies provide sources of variance in sampled assemblages. This is another aspect to consider when determining intervals for sampling in studies of community stability.

Notable differences in community membership are evident between the *Ambocoelia*-chonetid communities of the upper Wanakah fourth-order regressive interval and the lower Wanakah transgressive interval, both of which fall within a single third-order cycle. *Crurispina nana* occurs only sporadically in the lower Wanakah Shale, whereas it is present at much higher abundance in the upper Wanakah Shale (Figure 6), indeed, this species makes up nearly 50% of the specimens obtained from some levels in the Wanakah study interval. Conversely, the trilobites *Phacops rana* and *Greenops boothi* become less common in the upper interval. These dissimilarities in faunal composition imply that environmental differences associated with these transgressive vs. regressive facies affected faunal dominance and composition of this biofacies.

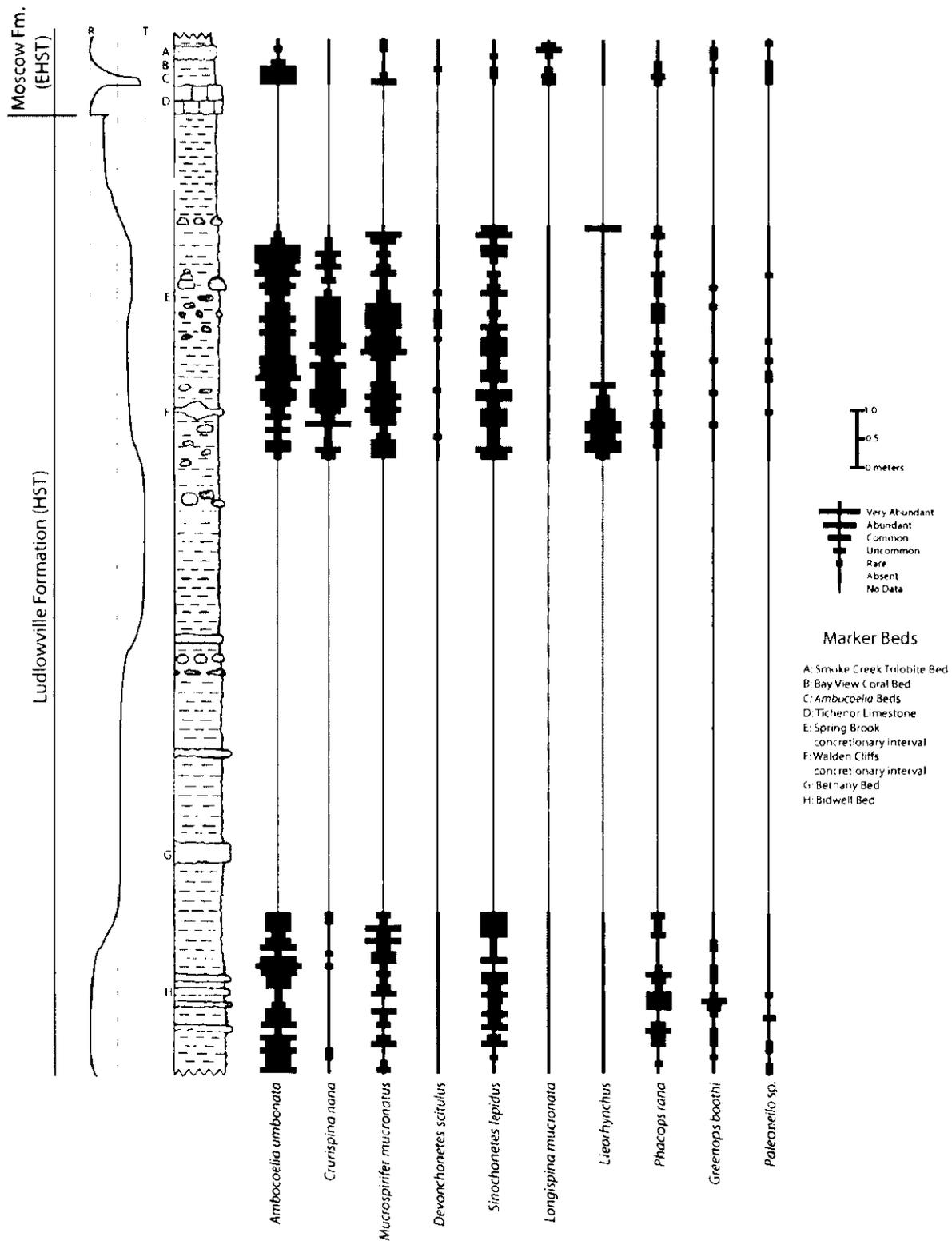


Figure 6: Composite Stratigraphic section for the stops of this fieldtrip, showing corresponding abundance of the main faunal components of the *Ambocoelia*-chonetid biofacies in the form of a spindle diagram. Lower Wanakah Shale Member faunal data collected at Stop 4; Upper Wanakah Shale Member faunal data collected at Stop 2; Lower Windom Shale Member faunal data collected at Stop 3. Column on left represents inferred sea level fluctuation of fourth-order cycles (curve) as well as third-order cycles (EHST vs. HST) (adapted from Batt, 1996 and Brett and Baird, 1994).

We tentatively suggest that *C. nana*, being spinose and therefore possibly specialized for environments with soft substrates, is better suited for regressive facies rather than sediment-starved transgressive facies in which sediment becomes trapped in more proximal environments.

The upper Wanakah Shale and lower Windom Shale members are both fourth-order regressive facies, and therefore, we might expect similarity in faunal composition and abundance. This is not the case, however. *Crurispina nana* again disappears within the lower Windom, *Sinochonetes lepidus* becomes relatively rare, and *Longispina mucronata* is present for the first time among the samples studied (Figure 6). Despite these faunal differences, upper Wanakah and lower Windom sediments are indistinguishable in trace metal studies of paleoenvironmental proxies for sedimentation rate, redox conditions, and paleoproductivity, as well as in measures of the degree of bioturbation (Zambito, 2006). This may imply a third-order sea level cycle control on this biofacies: the upper Wanakah corresponds to a level high in the preceding HST, whereas the lower Windom beds are part of the following EHST deposits and immediately overlie the maximum flooding discontinuity in Erie County (Figure 2). Possibly environmental differences associated with these systems tracts may include slight differences in the degree of aggradation versus progradation.

Although not recovered in our lower sample intervals, *Longispina mucronata* does occur at other levels in the Wanakah Shale Member, in particular in the interval up to and just below the Fargo Bed, which occurs slightly below the section present at Lake Erie Shore at the mouth of Eighteenmile Creek (Miller, 1991) — that is, slightly below the interval examined in this study. *Longispina mucronata* has also been observed in the lower Ledyard Shale Member (Savarese *et al.*, 1986; Brett and Baird, 1994). In the Penn Dixie and Buffalo Creek Pyrite beds of the upper Windom Shale in Erie County (see Dick and Brett, 1986), *Crurispina nana* is observed by the present authors to occur in abundances similar to those of the Spring Brook concretionary interval (unpublished data). *Crurispina nana* occurs even more abundantly at certain intervals in the uppermost fourth-order regression of the Levanna Shale Member (Zambito, 2006). These observations demonstrate that a similar representation of the *Ambocoelia*-chonetid biofacies (one that includes common *C. nana*) recurs during three different third-order depositional sequences: the uppermost Levanna, the Spring Brook concretionary interval of the upper Wanakah, and the Windom Pyrite beds. These observations also suggest that fourth-order systems tracts may be necessary to explain biofacies compositions at the thin intervals (10cm) sampled.

Two other major faunal members of this biofacies, *Ambocoelia umbonata* and *Paleoneilo* sp., exhibit only relatively minor differences in abundance and presence/absence in the intervals studied. All other observations, however, suggest a complicated interplay between third- and fourth-order cycles as presently defined for the Middle Devonian Hamilton Group. In some cases, deposits with similar third- and fourth-order cycle positions show some similarities in biofacies composition and abundance, as is the case for the upper Wanakah and the upper Levanna (see Zambito, 2006) (fourth-order regressive facies in a third-order HST), as well as the lower Windom and presumably the lower Ledyard (fourth-order regressive facies in a third-order EHST). Unfortunately, the observations along with the systems tract delineations to date do not form a unifying relationship between third- and fourth-order cycles and biofacies composition

and abundance, but rather they emphasize the complexity of obtaining similar samples for tests of faunal stability.

CONCLUSIONS

Of concern in studies of community stability is not only the reproducibility of samples collected, but also the reproducibility of the community to be sampled. Variability due to environmental fluctuations is a reality in any biological system, yet if every effort to sample a given biofacies results in subtle or not so subtle differences in faunal composition which must then be attributed to subtle differences in the sedimentary or environmental regime, then the hypothesis of habitat tracking becomes effectively untestable and degenerates into a tautological truism. This study focused on differences in the *Ambocoelia*-chonetid biofacies and changes in community structure through both transgressive and regressive facies, as well as at the scale of both third- and fourth-order sea level cycles. Differences in community structure were evident between fourth-order transgressive and regressive facies as well as between two fourth-order regressive facies at different positions within third-order cycles despite similarities in geochemical and ichnofabric indicators of environmental conditions. These differences are seen in not only the presence/absence of organisms, but also in their abundance. Furthermore, both third- and fourth-order sea level cycles appear to influence community membership as well as abundance, but a synthesis of the relationships of these two sea level cycle orders is not currently possible because of remaining questions about the differentiation of fourth-order systems tracts for all intervals studied.

Implications of the observed community patterns for the hypothesis of habitat tracking are that there are cases in which it appears that some organisms track a preferred habitat, as is the case with the upper Levanna Shale Member, Spring Brook concretionary interval, and upper Windom Pyrite beds; and the taxonomic composition and abundance of the biofacies is therefore somewhat reproducible. There may be other factors, however, either unresolved environmental (temperature?) or perhaps even biological, that affected the distribution of these organisms since there is no consistent relationship between faunal abundances or presence/absence and position in third- and fourth-order cycles given the currently available systems tract differentiations for the Hamilton Group.

The variability in the *Ambocoelia*-chonetid biofacies observed has important implications for studying community stability over longer time periods. Exactly what is the 'type' *Ambocoelia*-chonetid biofacies? Are tests of community stability more appropriate over longer time periods (member, formation, or group-level), and therefore higher order sea level cycles, rather than samples representing only a relatively small number of bedding planes (see Baugh *et. al*, 2005)? Further work is necessary to fully understand the effect that community variability at different scales may have on tests of faunal stability. The present study suggests that the starting point to any study, however, is to gain an understanding of this variance and the factors responsible prior to selecting limited horizons for samples that represent a variable biofacies.

ACKNOWLEDGMENTS

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ROAD LOG

<u>Mileage</u>	<u>Instructions</u>
0.0 0.0	Leave Adam's Mark Hotel, going west toward Bingham St.
0.1 0.1	Merge onto I-190 S
5.2 5.1	Merge onto I-90 W
6.8 1.6	Take Exit 54: Route 400, West Seneca/East Aurora
7.3 0.5	Merge onto NY Route 400 S
12.2 4.9	Exit US 20 E/NYS Route 78/Transit Rd heading northbound
12.6 0.4	Turn right on Bullis Road
15.5 2.9	Cross Bowen Road
17.0 1.5	Cross Girdle Road
17.2 0.2	Cross Buffalo Creek, take immediate right after bridge, park near barrier Proceed down old road toward creek bed

Stop 1: Buffalo Creek

This stop focuses on the lowermost Windom strata, an *Ambocoelia*-rich gray shale. The base of the Windom Shale Member at this locality occurs directly above the Little Beards Creek Phosphate Bed which marks the disconformable contact of the Kashong and Windom Shale Members. This contact and the lower portion of the *Ambocoelia*-rich interval is accessible on the east-facing bank of Buffalo Creek almost immediately downstream of the new Bullis Road Bridge. The upper portion of the *Ambocoelia*-rich mudstones as well as the Smoke Creek Trilobite Bed are most easily accessed on the west-facing bank immediately upstream of the old Bullis Road Bridge.

The *Ambocoelia*-rich interval exposed at this locality represents the thickest exposure of this lower Windom unit on this trip, possibly representing a sub-basin (Gordon Baird, personal communication). The basal portion of these beds is a fissile and dark gray shale with only rare *Ambocoelia umbonata*, with a thickness of about 1 meter. This grades into a gray mudstone rich in both *Ambocoelia umbonata* as well as chonetids, including *Longispina mucronata*, *Sinochonetes lepidus*, *Devonochonetes scitulus*, and rare *Devonochonetes coronatus*. Near the top of the *Ambocoelia*-rich shales are at least six concretionary bands rich in styliolinids.

Ambocoelia umbonata becomes rarer above the second concretionary bed. The Smoke Creek Trilobite Bed attains a thickness of almost 1 meter at this locality and is underlain by approximately .5 meters of the Bay View Coral Bed.

The *Ambocoelia*-rich interval was deposited under regressive conditions, evidenced by the fissile dark gray shale below and the Bay View Coral Bed (requiring more oxygenated conditions) above. This interval is unique among those observed on this trip in that while it is representative of the *Ambocoelia*-chonetid biofacies, the absence of *Crurispina nana* and the presence of *Longispina mucronata* distinguishes this occurrence of the *Ambocoelia*-chonetid biofacies from the Wanakah Shale intervals described.

<u>Mileage</u>	<u>Instructions</u>
21.8 4.6	Return to vehicles and proceed west on Bullis Road
22.5 0.7	Turn left (southbound) on US 20/NYS Route 78/Transit Road
23.2 0.7	Cross NYS Route 16/Seneca Street
23.5 0.3	Cross over Cazenovia Creek
	Turn left onto Transit Road and park near Kinsley Road
	Proceed on foot back across US 20 Bridge over Cazenovia Creek
	Enter creek bed via driveway and trail on NW side of creek

Stop 2: Cazenovia Creek

The lower Windom and upper Wanakah Shale Members outcrop on the north-facing bank of Cazenovia Creek, on either side of the US 20 overpass. Only the upper Wanakah is readily accessible at this locality, specifically the strata of and between the Spring Brook and Walden Cliffs concretionary intervals; occurring from the bed of the creek to approximately midway up the outcrop. This medium to dark gray shale unit contains abundant pyrite in the form of burrow steinkerns, pyritized fossils, and also pyritized shell hash horizons, which are commonly encased in concretions. A detailed description of these units, in particular the Spring Brook concretionary interval and its diagenetic history is described by Jordan (1968).

Unlike the lower Windom Shale observed at Stop 1, the Upper Wanakah shale interval contains abundant *Crurispina nana*. The intervals in which there is a presence of *Leiorhynchus* are indicative of a deeper water and lower oxygen biofacies, which corresponds to a slight decrease in the abundance of ambocoeliids.

<u>Mileage</u>	<u>Instructions</u>
23.6 0.1	Return to vehicles and proceed west on US 20
25.9 2.3	Cross Michael Road
27.4 1.5	Turn right on Milestrip Road
28.9 1.5	Turn left on Abbott Road
29.0 0.1	Park behind medical office (first driveway on left)
	Proceed on foot to creek bed

Stop 3: Smoke Creek

The lowest strata exposed at this stop is the uppermost 1 meter of the Wanakah Shale Member. Overlying the Wanakah, where it has not been eroded, are pods of the Hills Gulch Bed of the basal Jaycox Shale Member. The cap of the falls at this locality is the Tichenor Limestone, a crinoidal grainstone containing many abraded fossil fragments indicative of a depositional depth near wave base (Brett and Baird, 1994). Immediately overlying this is the *Ambocoelia*-rich shales observed at Stop 1. No styliolinid-rich concretionary beds are present at this locality, and specimens of *Ambocoelia umbonata* are typically deformed, presumably due to compactional stress. The *Ambocoelia* shale interval is overlain by the Bay View Coral Bed and the Smoke Creek Trilobite Bed. This stop is the type section of the Smoke Creek Trilobite Bed, a well-developed calcareous gray shale interval with abundant *Phacops* and *Greenops*. Similar to the interval exposed at Buffalo Creek, this occurrence of the *Ambocoelia*-chonetid biofacies lacks *Crurispina nana* and contains *Longispina mucronata*.

<u>Mileage</u>	<u>Instructions</u>
	Return to vehicles and turn right on Abbott Road
29.1 0.1	Turn left on Milestrip Road
30.4 1.3	Cross I-90
31.8 1.4	Merge onto NYS Route 5 W
33.2 1.4	Cross Big Tree Road
34.7 1.5	Cross Rogers Road
35.9 1.2	Cross Amsdell Road
36.8 0.9	Turn right on Old Lake Shore Road
38.6 1.8	Cross Lakeview Road
39.9 1.3	Turn left into Eighteenmile Creek DEC pull-off
	Proceed across bridge back over Eighteenmile Creek
	Follow footpath downstream to north bank of creek mouth at Lake Erie

Stop 4: Lake Erie Bluffs

The exposure at the mouth of Eighteenmile Creek spans an almost complete Wanakah Shale section, with both the Tichenor Limestone and the basal Windom Shale Member visible when looking south along the shoreline. The interval examined, and easily accessible, at this section spans approximately 2 meters both above and below the concretionary trilobite beds of the lower Wanakah Shale Member.

Similar to the previous Wanakah Shale Member section examined at Cazenovia Creek, *Longispina mucronata* is absent from this interval. *Crurispina nana*, while present, is extremely rare and has only been observed by the present authors in a few horizons (Figure 6).

End of trip. Return to Adam's Mark Hotel via NYS Route 5 (Main Street) to Church Street.