Non-Fossiliferous and Fossil Rich Beds in the Hamilton Group; Indicators of Sedimentation Rates

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The Hamilton Group siliciclastic rocks are part of the progradational sequence formed at the onset of the Acadian Orogeny. Mountain building occurred to the east of New York state on a NNE/SSW trend. Paralleling the mountains to the west was the axis of the depositional basin which ran approximately through the Finger Lakes region. This is reflected by the thickening trend of Hamilton Group rocks from west (100 m) to east (1000 m). Throughout most of the Givetian Stage, eastern New York was close to the depositional source. This can be seen in the Albany area and immediately to the south where Hamilton Group equivalent rocks such as the Plattekill and Monorkill Formations preserve evidence of fluvial depositional environments (Willis 1990). To the west of the fluvial facies is the Panther Mountain Formation which contains nearshore marine sandstones which extend to the Unadilla valley area. The Panther Mountain Formation is the eastern equivalent of the Skaneateles and Ludlowville Formations of Central New York. In western New York the Hamilton group is predominantly dark shales and siltstones with rare carbonate units. The dark shales represent environments distant from the depositional source and in deeper water conditions than the sandstones of the Panther Mountain Formation. The rocks of central New York are a mixing and interfingering of the basinal and nearshore marine environments (Fig 1).

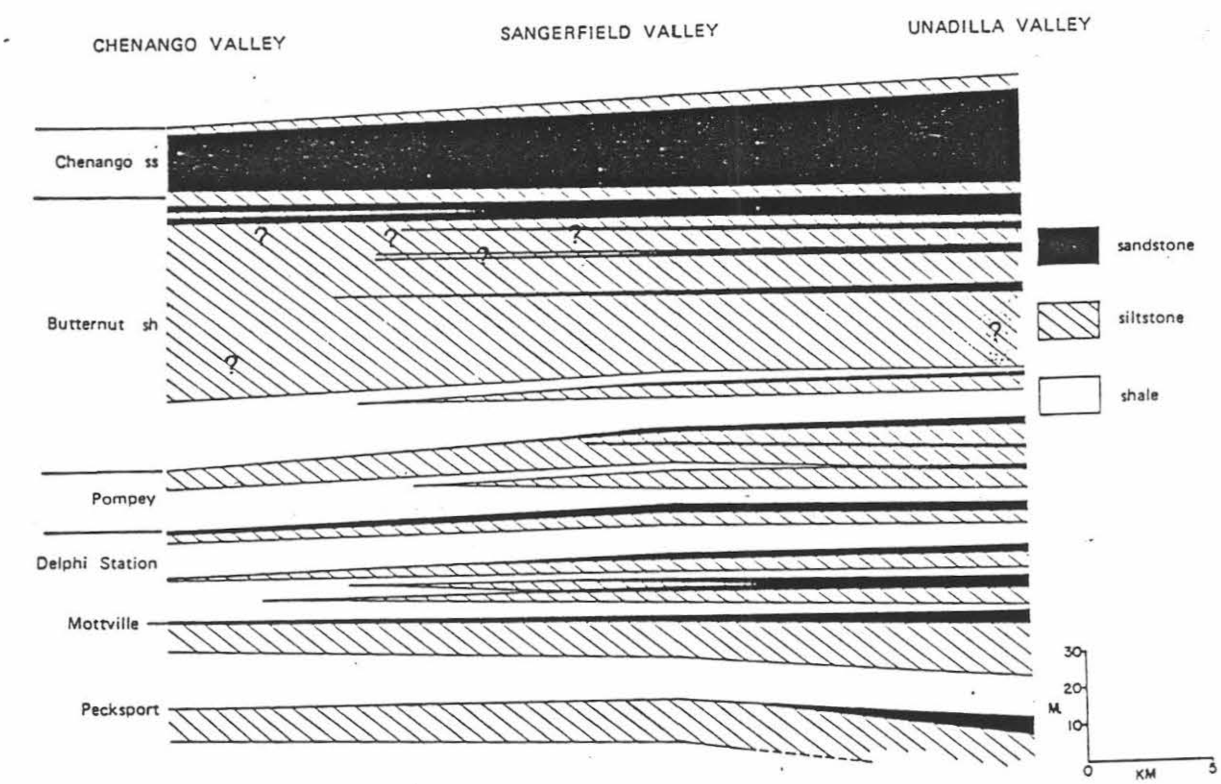


Figure 1. Interfingering of Panther Mountain Sandstone of Eastern New York with basinal shales of Western New York from the Chenango Valley to the Unadilla Valley.

The formations of the Hamilton Group were defined in part by Lardner Vanuxem and James Hall during the geologic survey of the state begun in 1836. The members the Hamilton Group were defined by Cooper (1929, 1930, 1934). In central New York Cooper defined members on the basis of rock type (Chenango sandstone, Butternut shale, Sollville sandstone) and on a recognizable coarsening interval such as the Delphi Station and Pompey members (Fig 2).

The stratigraphy of the Hamilton Group is comprised of a series of coarsening upward cycles. In central New York the base of the Marcellus through the top of the Skaneatelles Formations could be considered a single large-scale coarsening cycle. Within this large coarsening sequence smaller coarsening sequences can be observed; examples of these are the Chittenango Shale through Solsville Sandstone, or the Butternut Shale through Chenango Sandstone. Within each of these intermediate coarsening sequences are the coarsening sequences visible at the outcrop scale such as the Pecksport, Delphi Station and Pompey Members. Finally, meter- scale coarsening sequences on a scale equivalent to the punctuated aggradational cycles of Goodwin and Anderson (1986) can be seen within a single outcrop. These depositional cycles are heirarchical (Busch and Rollins 1984, Busch and West 1987). Johnson and others (1985) consider the Skaneateles to the top of the Moscow to be a third order transgressive-regressive sequence within the Vail (1977) system. The Marcellus can be divided into two third order cycles, one from the base of the Unions Springs to the top of the Cherry Valley and the second one from the Chittenango to the top of the Pecksport, cycles Id and Ie of Johnson and others (1985). Within the third order cycles are the fourth order cycles of Bush and Rollins (1984). These would correspond to a coarsening sequence from the Butternut through the Chenango Sandstone or the entire Ludlowville Formation. Fifth order cycles are what can be seen as coarsening cycles on the outcrop scale and in central New York have thicknesses of 10-20 m. Sixth order cycles are meter scale coarsening sequences which can be seen within one fifth order or outcrop scale cycle. Each scale of cyclicity has an approximate duration. Sixth order cycles are thought to represent tens of thousands of years, fifth order cycles a few hundred thousand years and so on. The coarsening sequences observed on this trip will be fifth and sixth order cycles.

The coarsening upward cycles are interpreted to represent shallowing upward depositional environments. The top of each coarsening sequence is followed by an abrupt return to deeper water conditions or by an effect equivalent to a rapid distancing from the sedimentary source. Many of the larger scale cycles are traceable over hundreds of kilometers indicating that the cause of cyclicity is operating over a very large area of the basin. Some workers have attempted to tie the larger-scale cycles to global sea level curves (House 1983, Johnson and others 1985). If the cycles are allocyclic and are driven by climate change or tectonism, they could be used to correlate with a much finer resolution of time than is currently available with biostratigraphy.

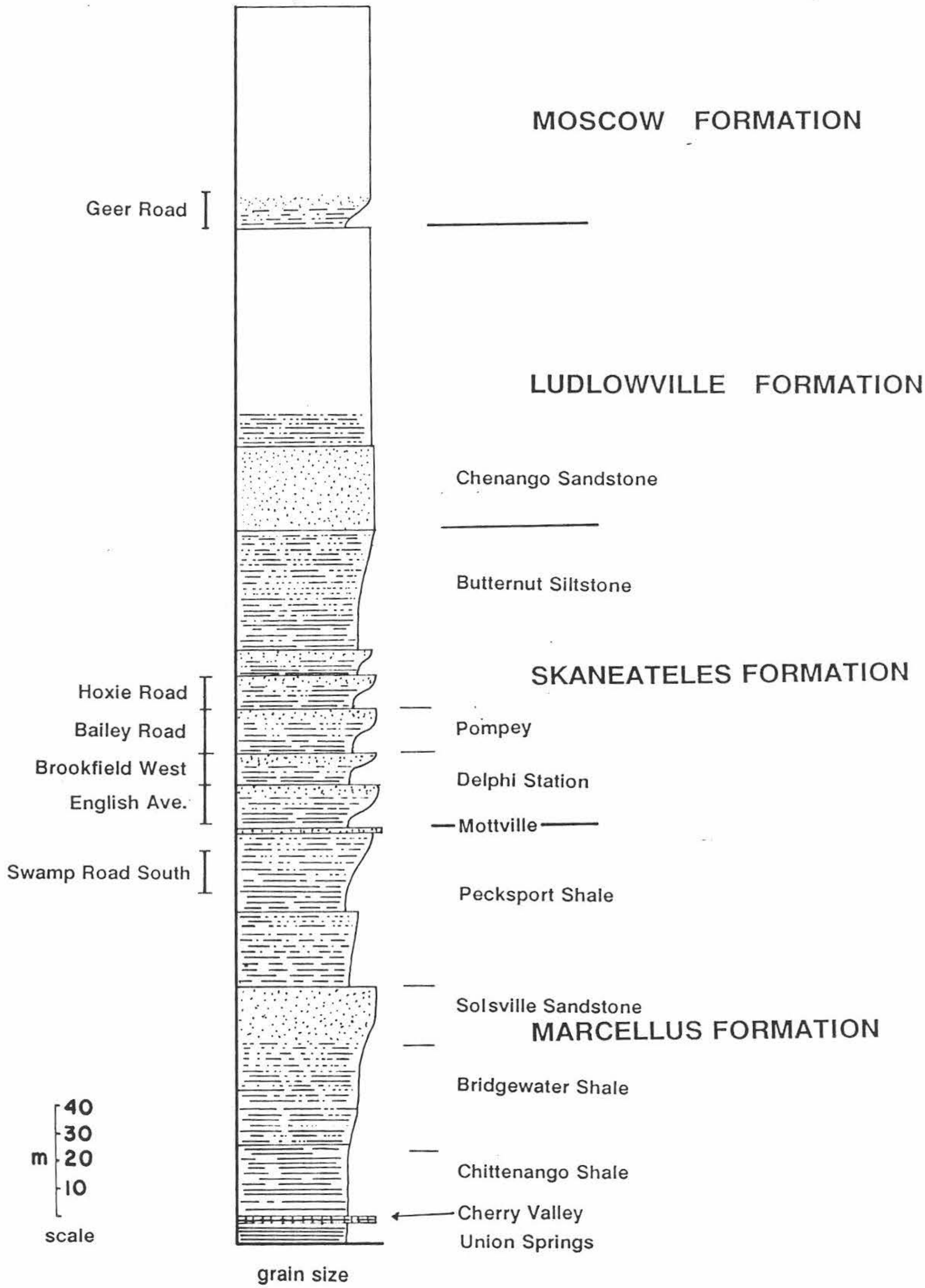
The Hamilton Group is famous for its well preserved and abundant fossils. Fossils occur in rock types from shale through sandstone and in rare beds of bioclastic packstone. In central New York it is unusual to find stratigraphic intervals where fossils are absent. Since non-fossiliferous units are the exception rather than the rule, by examining vertical and lateral changes from fossiliferous to non-fossiliferous zones it may be possible to determine what factors control the diversity and abundance of benthic faunal assemblages in the Middle Devonian of central New York.

The coarsening sequences are interpreted to be shallowing sequences. The basal shales contain a faunal assemblage different from the sandstones at the top of the cycles, and the mudstones in between the shales and sandstones have their own characteristic faunal assemblages. The faunal composition of these assemblages is presumably controlled by different water depths, turbidity conditions, and substrates.

Non-fossiliferous zones can be observed in both the basal shales and the mid-cycle mudstones. There are several possible explanations for the presence of non-fossiliferous zones within otherwise fossiliferous rocks. Exclusion of benthic organisms may result from anoxic or dysoxic conditions, from rapid sedimentation rates which produce water saturated and highly unstable substrate, or from hypo- or hypersaline conditions.

Figure 2

HAMILTON GROUP STRATIGRAPHY IN THE SANGERFIELD VALLEY AREA



The non-fossiliferous, organic-rich, black shale of the Oatka Creek and Levanna Members of western New York are stratigraphically equivalent to the highly fossiliferous mudstone and sandstone members of the Marcellus and Skaneateles formations of central New York. The model of a density stratified basin (Woodrow and Isley 1983, Ettonsohn and Elam 1985) has been used to explain the absence of benthic fauna and presence of abundant carbon in the Marcellus and Skaneateles of western New York. This model postulates that the Appalachian Basin may have been density stratified due to differences in temperature and salinity. The lower colder bottom waters were anoxic and higher in the water column were followed by dysaerobic zone called the pycnocline. The upper part of the water column maintained fully oxygenated normal marine conditions. In the Upper Devonian of Kentucky in the central Appalachin Basin the following sequence is interpreted for different water depths (Ettonsohn and Elam 1985): black non-fossiliferous shales were deposited below the pycnocline in the deepest part of the basin, gray bioturbated shales with no hard shelled fossils in the dysaerobic zone of the pycnocline and abundant benthic fossils above the pycnocline. In western New York the black non-fossiliferous shales of the Oatka Creek and Levanna members grade eastward into the gray mudstones and fossil rich siltstones of the Marcellus and Skaneateles Formations. Western New York can be interpreted as the deeper water dysaerobic zone while central New York could be the transition from the dysaerobic zone into the oxygenated zone.

If this model is applied to the shallowing up cycles of central New York then the deposition of black shales must have occurred below the pycnocline where anoxic conditions made habitation by benthic organisms impossible. Progradation of the shoreline and an infilling of the basin to a depth above the pycnocline then allowed benthic organisms to inhabit the substrate. From here on up in the shallowing cycle benthic fauna are present unless some other variable prevented them from colonizing the substrate. The lower Marcellus of central New York is probably an excellent example of basinal infilling producing a shallowing upward sequence. The anaerobic, dysaerobic and aerobic zones are clearly observed in the shallowing trend formed by the Chittenango, Bridgewater and Sollsville members and again in the Pecksport through Mottville sequence. It is not so clear whether this model is applicable to the Skaneateles cycles because water depths as interpreted by the thickness of the sedimentary cycles are too shallow. In the coarsening cycles of the Skaneateles Formation the basal shales may be highly fossiliferous and yet fossils may be absent from the mudstones in the middle of the cycle. Fossils are found both above and below the non-fossiliferous zones and often in rare beds within them. Deposition rates which create unstable substrates may be a better explanation for the absence of benthic organisms but do not provide a complete solution.

Hoxie Road Quarry

This coarsening cycle is interpreted to be at the base of the Butternut Member in the Skaneateles Formation. The quarry exhibits the repeated coarsening-upward trend observed at most localities in the Hamilton Group. The rock type at the base of the quarry is shale interlaminated or thinly interbedded with fine siltstone. Close inspection reveals repeated 1-2 cm thick couplets of fine siltstone and shale. The siltstone contains low angle cross laminae and planar laminae. The base of the siltstone units is abrupt and the contact with the shale above is gradational. In the middle part of the exposure the silt beds become thicker (5 cm) and preserve rare articulated crinoid columnals typically on the upper surface of the siltstone beds. No fossil lag deposits are observed at the base of the siltstone beds and fossils are otherwise rare in this part of the outcrop. The upward increase in thickness of the siltstone beds indicates a closer proximity to the source of sediment and an increase in energy conditions on the substrate, both of which reflect the shallowing upward nature of the depositional cycles. The upper part of the outcrop is bioturbated very fine sandstone and contains a normal Hamilton assemblage of bivalves and brachiopods.

Fossils in the lower part of the exposure are rare and when observed are concentrated on single bedding planes. At vertical intervals of 1-2 m discontinuous lenses, meters in width and 1-2 cm in

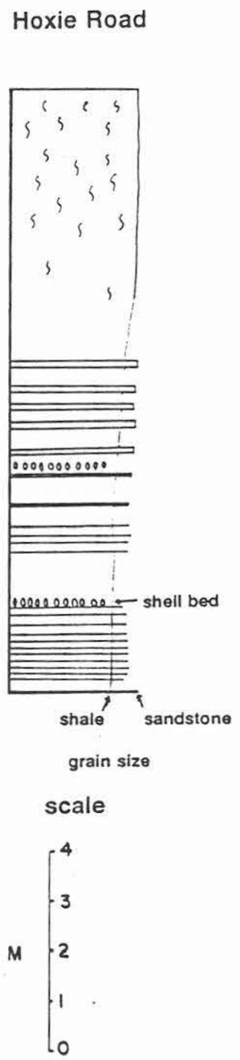


Figure 3

height, contain articulated bivalves, brachiopods, and the crinoids Gilbertsocrinus and Acanthocrinus. The bivalves Leiopteria conradi, Actinodesma erectum and Actinopteria boydi are numerically the most abundant taxa and are all epifaunal, possibly byssally attached forms. The brachiopods Tropidoleptus carinatus and Camarotoechia congregata are associated with the bivalves but are less abundant. The crinoids are articulated and appear to be using the bivalve shells as a substrate. The unusual aspect of these shell beds is that they are not storm accumulations and the fossils are articulated and in life position. Rocks above and below the fossil beds are nearly barren and preserve only rare brachiopods and bivalves.

The presence of small-scale sedimentary structures in fine grained sediments is rare in Hamilton Group rocks in central New York. Infaunal and semi-infaunal organisms disturb the substrate and destroy sedimentary structures. If sedimentation rates are low enough for the organisms to continually rework the sediment, no sedimentary structures will be preserved and the mud and silt layers are homogenized into the bioturbated mudstone commonly observed in Hamilton Group rocks. At this and other localities there is a conspicuous absence of fossils associated with the stratigraphic intervals where sedimentary structures are preserved. An absence of fossils may be explained by rapid deposition rates which create an unstable substrate, by a lack of oxygen, or by non-normal marine salinities. The pycnocline model is applicable in relatively deep water settings; however central New York is closer to the depositional source and in presumably shallow water depths.

An alternate explanation for non-fossiliferous units could be viewed as follows: assuming that the depositional cycles are shallowing up sequences one method of deposition may have been basinal infilling. If sea level is stable and sediment is transported to the basin, progradation of the shoreline will occur. The part of the basin proximal to the shoreline will become infilled with sediment and a shallowing upward depositional sequence will be produced. By this model the muddy siltstones would be less than ten meters below the sandstones. The water depth of the sandstones is equivocal but they are definitely within storm wave base, and given the proximity to the shoreline, probably in less than ten meters water depth.

Brett (1985) has postulated that periods of maximum deposition occur in the middle of the depositional cycles in the siltstone/mudstones and that while the sandstones are deposited in the shallowest water, they are also periods of low deposition rates. The sandstones are possibly reworked or winnowed over long periods of time. If the siltstones and shales were deposited rapidly this could have created unstable water saturated sediment which would have kept epifaunal or semi-infaunal filter feeders from colonizing the substrate, thus creating non-fossiliferous intervals. However evidence from this locality suggests otherwise due to the presence of rare shell beds with epifaunal bivalves. Furthermore, the centimeter-scale siltstone beds, which should have been a relatively stable substrate, have no fossils associated with the upper surface. This suggests that a factor other than anoxia or substrate instability was preventing the colonization of the substrate by epifaunal benthic organisms.

The proximity of central New York to the fluvial environments in the east suggests that hyposaline conditions could be a factor in controlling faunal assemblages on the nearshore shelf. The northern end of the Appalachian Basin during the Devonian was a relatively enclosed basin. The uplands created to the east by the Acadian Orogeny were the major source of siliciclastic sediment.

Brookfield West

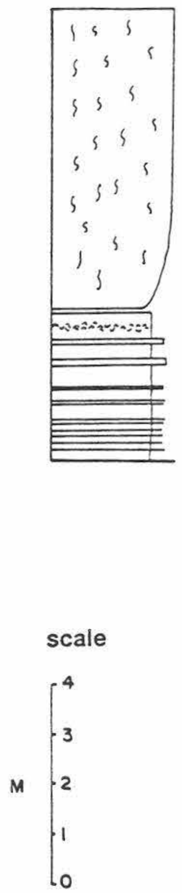


Figure 4

Fluvial depositional systems have been identified in Hamilton Group equivalent rocks in eastern New York. Rivers feeding the sediment to the basin may have had the effect of reducing salinity in the shallow, nearshore regions of the basin. If the siltstone/mudstone intervals were deposited during periods of maximum sedimentary influx, and the position of the ancient shoreline was less than 100 km to the east, it is possible that the nearshore or shallow part of the basin experienced periods of hyposalinity. During periods of low rainfall normal salinities would return to the nearshore part of the shelf and a normal marine fauna would colonize the substrate. If the sandstones were deposited or reworked during periods of low sedimentary influx this may also have been a time of relatively low rainfall and consequently normal marine salinities.

Fossil evidence in the form of thin lenticular shell beds containing in place articulated bivalves and crinoids suggests episodic colonization of the substrate followed by an abrupt event which preserved the fossils without disruption. The rare fossils, typically Camarotoechia congregata, Tropidoleptus carinatus, Grammysia bisulcata and Pterochaenia fragilis in the intervening layers between shell beds are found on single bedding planes with only Grammysia appearing to be in life position. In the middle part of the outcrop siltstone beds preserve articulated crinoids on the upper surface of the beds. The fossils between the shell beds in the interbedded siltstones and shales are the best indicators of the typical paleo-environment. Fossils such as Camarotoechia, Tropidoleptus and Grammysia could have been salinity tolerant. Only Grammysia and Pterochaenia are found articulated and in place. The brachiopods could have been transported although they are not found associated with sedimentary lag deposits. The crinoids associated with siltstone layers could have been transported, although not over long distances since they are still articulated. The shell beds contain dominantly bivalves which may have been salinity tolerant (Brower and Osborne 1991) but also contain articulated crinoids which are much less likely to have been salinity tolerant.

The rarity of both fossils and bioturbation in the thinly interbedded siltstones and shales suggests that some factor was preventing colonization of the substrate. Dysoxia has been suggested as a possible factor but the fossils that are present tend to be salinity tolerant species rather than species typical of the deeper water dark shales associated with dysaerobic conditions. When periods of normal marine conditions occur the substrate is apparently rapidly colonized by bivalves, brachiopods and crinoids. These brief periods of colonization are equally rapidly ended by an event which preserves the fauna intact and articulated. The proximity of central New York to the ancient shoreline and accompanying river systems suggests that fresh water flooding of the nearshore shelf may account for some non-fossiliferous intervals in the interbedded silts and shales.

Brookfield West Quarry

This section is tentatively placed as the fourth or uppermost coarsening cycle of the Delphi Station member of the Skaneateles Formation. The lower two meters of section contain 5-20 cm thick interbeds of shale and siltstone. Siltstone beds have an abrupt base and grade upward from planar laminae into small scale, high angle cross laminae. The upper surfaces of some siltstone beds preserve symmetrical ripples. The siltstone units are interpreted to be event beds, probably storm deposits. The absence of infaunal and epifaunal organisms with the related bioturbation is discussed in the section on the Hoxie Road quarry. The shale separating the siltstones is fissile, lacks lamination and contains no fossils with the exception of rare cephalopods.

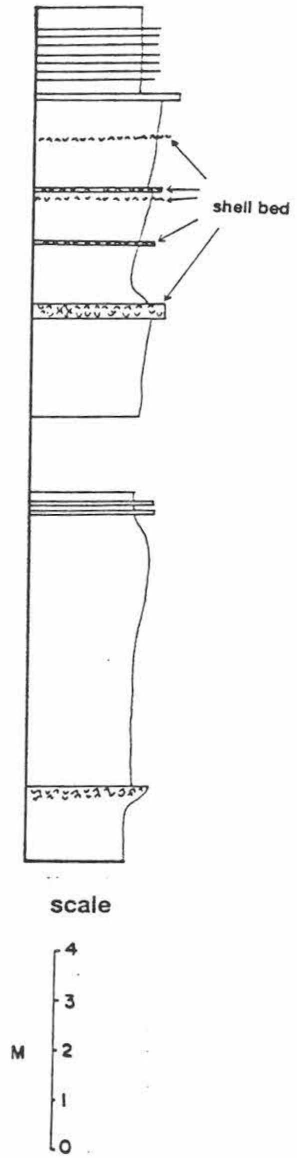


Figure 5

In the middle of the exposure is a noticable notch in the quarry wall. Above this the siltstone/shale interbeds disappear and bioturbated sandstone, with a normal Hamilton faunal assemblage of epifaunal bivalves and brachiopods, is observed. The notch in the quarry wall is a light gray clay, varies in thickness from 0.5-3.0 cm, and is tracable the length of the outcrop. X-ray analysis reveals the presence of illite and chlorite but no expandable clay minerals. The coarse fraction of the clay does contain some euhedral crystals. This bed is tentatively identified as a meta-bentonite.

Ten centimeters below the clay bed is a densly packed fossil-rich zone 1-4 cm thick. This is the first appearence of fossils in the lower part of the quarry. The assemblage is unusual in that it contains the monoplacophoran Cyrtonella and abundant infaunal bivalves, Nuculoidea, Nuculites and Modiella. Infaunal bivalves would not normally be found in a packed shell bed like this since when they die they are already buried. The presence of these shells together indicates that the sediment has been reworked and that this bed may be a sediment-starved omission surface. Phosphate pebbles are found with the shells in this bed which also suggests that the accumulation of shells took place during a depositional hiatus.

This section is somewhat unusual in that it does not follow the typical pattern of a gradual coarsening upward trend. The fossil rich sandstones at the top of the locality appear relatively abruptly following the appearance of the clay bed. Whether there is a tectonic connection between the two events is highly ambiguous.

Bailey Road Quarry

The seventeen meters of section at this locality represent the Pompey Member of the Skaneateles Formation. From the base of the section to the top there is an overall coarsening trend from shale through fine sandstone. Within this coarsening trend there are four, meter-scale coarsening upward units. In the terminology of Bush and Rollins (1984) the entire outcrop would be a fifth order cycle and the smaller coarsening sequences would be sixth order cycles. The base of the smaller cycles is indicated by topographically level areas within the quarry.

The lowest small-scale coarsening cycle is bioturbated shale with abundant, well preserved, articulated bivalves and brachiopods. The bivalve assemblage is dominated by Nuculites oblongata, N. triquiter, Modiella pygmaeaand Paracyclas lirata. The top of the first cycle grades upward into a packed silty shell bed containing Longispina, Mucrospirifer, and rare septate rugose corals. The second depositional cycle grades upward from a siltstone through a coarse siltstone. The finer grained interval is bioturbated but contains no fossils with the exception of rare cephalopods. The coarser part of the cycle contains a chonetid/Mucrospirifer assemblage. The third cycle is progressively coarser than the first two, grading from mudstone through very fine sandstone. The base is again bioturbated but relatively non-fossiliferous. The top of the cycle is capped by a packed shell bed containing the brachiopod genera Rhipidomella, Pseudoatrypa and Athyris. These brachiopods, particularly Pseodoatrypa, are relatively rare in the rocks of central New York and have been interpreted to represent clear non-turbid water conditions. The fourth cycle is again coarser than the previous three, grading from siltstone to fine sandstone. Brachiopods dominate the fauna though bivalves, particularly Cypricardinea indenta, Paracyclas lirata and Nyassa arguta, are quite abundant. Bryozoa and zoophycus are common in the upper part of the cycle but appear only occasionally below this.

Several packed shell beds are located within this cycle. Two are similar to the one capping the third cycle (i.e. dominated by Rhipidomella and Athyris) while several others are dominated by Spirifers and Ambocoelia, with lesser amounts of Chonetes and other organisms.

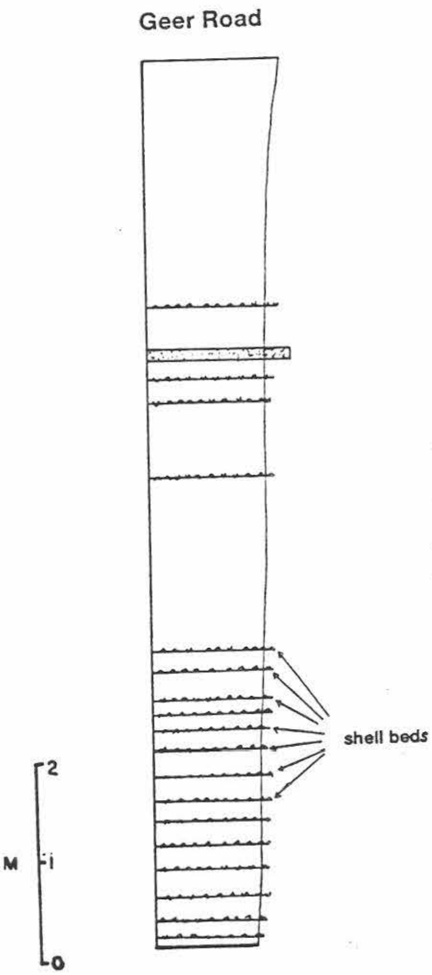


Figure 6

The depositional sequences at this locality provide some clue to sedimentation rates if the assumption is made that fossil preservation potential and biogenic productivity, in terms of shell production, is constant through time. The fossiliferous shaley interval of the lowest cycle can be interpreted to have relatively low sedimentation rates due to the presence of numerous infaunal and epifaunal organisms. The shell bed which caps this interval is a period of low siliciclastic deposition where fossils accumulated gradually through time. Evidence in the form of disarticulated shells suggests that the shell bed was affected by storm events; however, no sedimentary structures are visible to support wholesale transport or reworking of the shells as a lag deposit. The base of the shell bed is gradational with the underlying shale, further supporting an in place formation of the bed. The base of the second cycle is nonfossiliferous yet it is bioturbated. This interval probably represents a period of rapid deposition where epifaunal filter feeders would have had difficulty with an unstable and rapidly aggrading substrate. The absense of infaunal deposit feeding bivalves cannot be easily explained since the presence of bioturbation and rare cephalopods suggests that organisms were present and that fossilization was possible. The upper part of the cycle is coarser grained and preserves abundant brachiopods. This indicates a decrease in sedimentation rates. The third cycle is again non-fossiliferous at the base and is capped by a shell bed containing an unusual assemblage of brachiopods. The Athyris/Pseudoatrypa/Rhipidomella assemblage has been interpreted to represent a shallow, clear water depositional environment. This shell bed represents an absence of siliciclastic deposition. The abundant brachiopods of the fourth cycle again suggest fairly low sedimentation rates, while the shell beds, similar to those of the third cycle, most likely represent periods of non-deposition.

Geer Road Quarry

The nine meters of section at this locality represent the lowermost of the four coarsening upward cycles in the Moscow Formation (Selleck, personal comm.). Grain size ranges from very fine siltstone at the base of the quarry through very fine sand at the top, with most of the coarsening occurring in the upper three meters. The faunal assemblage is dominated by brachiopods (80%) and bivalves (10%) with gastropods, cephalopods, trilobites, bryozoans and crinoids also present.

Fossils are distributed abundantly and fairly uniformly throughout the section; however, flat bedding planes of densely packed shells, predominantly of the brachiopod Chonetes, also occur. In the lower three meters of the section these Chonetes shell beds occur at intervals of 20-25 cm. Above the first three meters Chonetes beds become rare. Orientation of the shells varies between the upper and lower beds. In the lower shell beds Chonetes are found 50% in life position and 50% overturned while in the upper beds 90% of the Chonetes are overturned. In the siltstones between the shell beds different taxa are present in approximately the same ratio as seen on the shell beds, but the density of fossils is much less. No sedimentary structures are visible.

The Chonetes beds may represent storm events during which transported siliciclastic sediment smothered the brachiopods. However, the sedimentary characteristics normally associated with tempestites, such as fining upward sequences or planar or cross laminae, are not visible. The presence of fossils in the sediment between the shell beds suggests that they are not winnowed lag deposits.

A more probable theory is that the shell beds represent periods of non-deposition allowing for the build-up of many shells over time. If the coarsening upward sequence reflects shallowing, the lower shell beds would have been in deeper water than the upper beds. The differing orientations of the Chonetes may then be explained; the lower, deep-water shell beds would have remained relatively unaffected by wave action, allowing half of the brachiopod shells to remain, even after death, in the less stable life position. The Chonetes of the upper shell beds, being in shallower water, would have been 90% overturned into a hydrodynamically stable position.

The most definitive evidence for storm deposited sediments is a 5-8 cm fine to medium grained sand bed located six meters above the base of the quarry. The sand bed has an abrupt base and contains small scale cross and planar laminations. Both shelled fossils and trace fossils are absent from this bed, appearing neither as storm lag deposits nor as colonizers of the post-storm surface. The position of this bed is near the top of the section, in the coarser part of the cycle. Assuming that the cycles represent shallowing upward, this part of the quarry may have been within the influence of storm wave base. The lower, finer grained part of the cycle was likely deposited in deeper water below storm wave base.

English Avenue Quarry

This quarry is situated in the Delphi Station member of the Skaneateles Formation. The gastropod species Bembexia sulcomarginata is abundantly represented at this locality and all specimens are either of the ornamented variety or the intermediate B variety. (See the discussion of Bembexia following the locality 6 description.) They are distributed from the finer grained siltstones at the bottom of the quarry through the coarser material at the top.

Peterboro South (Swamp Road South)

This locality is in the lower part of the Pecksport Member of the Marcellus Formation. The rock type is mudstone with very few sedimentary structures and abundant fossils. The preservation at this locality is quite exceptional for the Hamilton Group in that molluscs have their shells intact and are not preserved as composite molds as at Geer Road. Small amounts of original aragonite may still be found in some shells and the replacement of aragonite by calcite is so fine that the original shell microstructure is still preserved (Carter 1978).

All the specimens of Bembexia sulcomarginata that have been found in this quarry are of the unornamented type. They may be found throughout the entire quarry but are most abundant in the upper surface of the lower quarry face.

Ornamentation in Bembexia sulcomarginata

Bembexia sulcomarginata (Conrad 1871), one of the most common gastropods in the Hamilton Group, is characterized by great intraspecific variation in the amount of ornamentation on its shell. Workers have observed variation within the species but have failed to describe the range of variation or document the stratigraphic distribution of variants. An explanation for the observed variation is problematic due to an inability to determine variables such as temperature variations, food supply and predatory relationships. The only direct information available is from the sedimentary record and evidence of the depositional environment preserved in the coarsening up cycles.

Knight (1944) was the first to document variation in B. sulcomarginata. He described one variant with strong collabral and spiral ornamentation throughout ontogeny, and a selenizone always raised above the suture. Other specimens were unornamented, exhibiting faint growth lines across whorl faces parallel to the aperture. On these specimens, the selenizone was immediately subjacent to the suture and in some cases was completely or partially covered by it. Intermediate varieties exhibited collabral and spiral ornamentation early in ontogeny, loosing all ornament later in life. Rollins et. al. (1971) described variations concerned with overall shell form, position of the suture relative to the selenizone, strength of collabral and spiral ornamentation and duration of ornamentation throughout ontogeny. Rollins et. al. (1971) characterized B. sulcomerginata as ornamented, unornamented and intermediate.

Field work involved collecting specimens from localities distributed throughout the Marcellus and Skaneateles Formations of the Hamilton Group. Collections of approximately 600 specimens from these localities were analyzed and four morphologic variations of B. sulcomarginata were recognized:

1) Ornamented shells have collabral and spiral ornament throughout ontogeny, the selenizone is always raised above the suture and the shells tend to be more high spired than other forms.

2) Unornamented shells show faint growth lines and rarely subtle carinae growth. The selenizone is typically partly or completely covered by the suture.

3) Intermediate A has both collabral and spiral ornamentation on the early whorls with the collabral ornament being the first to dissappear. Spiral carinae typically extend past the early whorls.

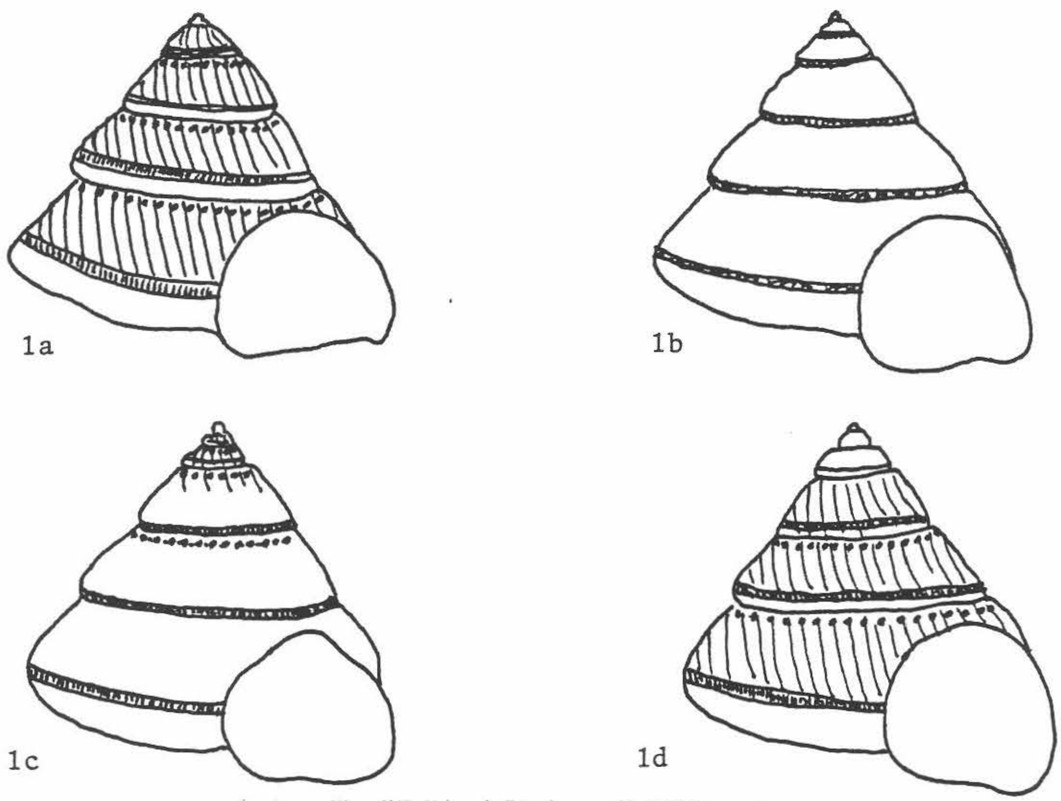
4) Intermediate B has the ornamentation reversed from that of intermediate A. The early whorls are smooth with collabral and spiral ornament developing on later whorls and continuing through ontogeny.

A series of ten measurements for each snail was developed based on different morphologies observed in hand specimen. Figures obtained from measurements were then entered into a spread sheet and graphed on a series of x-y plots and bar graphs. Significantly different trends resulted for unornamented and ornamented shells. These trends indicate the differing position of the selenizone relative to the suture between unornamented and ornamented varieties. As would be predicted from their morphology, both intermediate A and B samples showed characteristics of both unornamented and ornamented varieties.

Field observations demonstrate that the unornamented and ornamented varieties of B. sulcomarginata alternate in their occurence throughout the Hamilton Group (see Fig. 7). We may thus conclude that the differences are not the result of an evolutionary trend of unornamented to ornamented or vice versa. However, within any given horizon all of the individuals are either unornamented or ornamented morphotypes. Combinations of the two end member morphotypes were never observed on the same bedding plane. If intermediate forms are present, intermediate A is always associated with the unornamented variety. Thus whether the juvenile is ornamented or unornamented they all end up looking alike. (Likewise intermediate B is always associated with the ornamented variety). This suggests that the degree of ornamentation is an ecophenotypic adaptation to some environmental parameter. Perhaps the intermediates began life in one area and then migrated into an area which caused a change in their ornamentation. The shift in ornamentation type matched that of the individuals who had lived there all their lives.

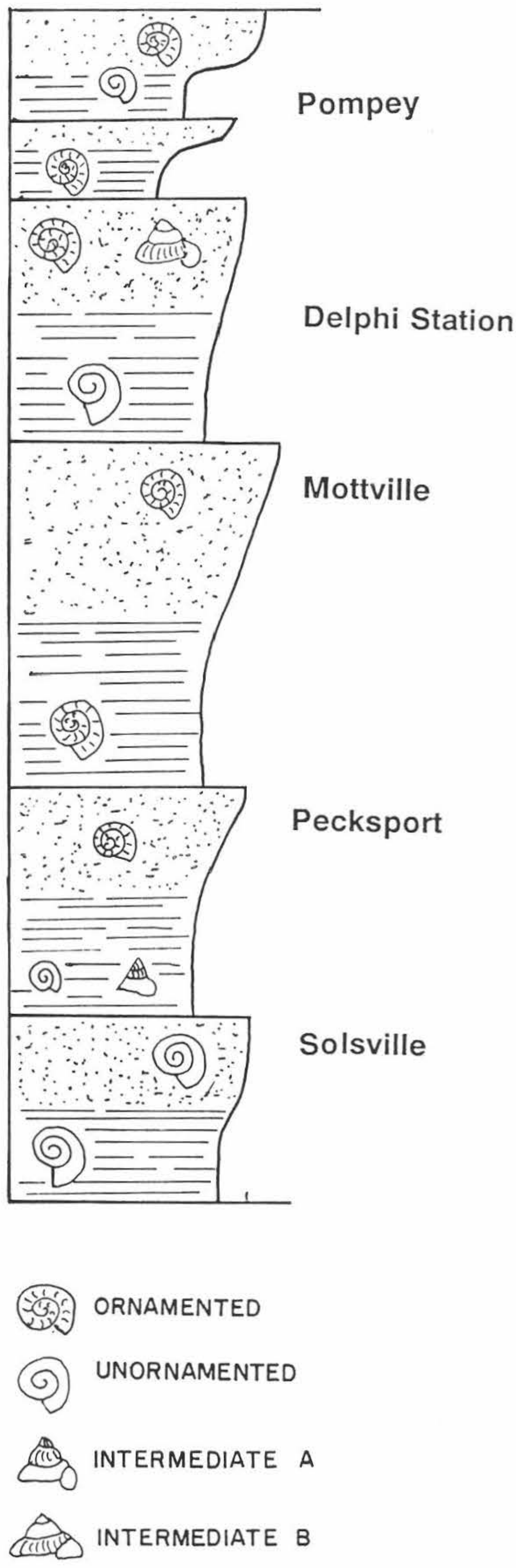
The obvious (and testable) environmental parameter which could account for the differences in ornamentation would be sediment grain size with its inferred parameter of turbulence. While there is a crude correlation between unornamented shells and fine grain size sediments (as will be seen at Peterboro south) it is not an invariant relationship (Fig. 7). At the English Avenue quarry all the individuals of B. sulcomarginata are either the ornamented variety or intermediate B, even though they may be found throughout the entire coarsening up cycle. Thus we feel compelled to reject the testable model of substrate grain size control on ornamentation and sugest that the causal factor is a variable such as salinity, food supply or a predator which we have not been able to document.

Figure 7



1a - ornamented B. sulcomarginata; 1b - smooth B. sulcomarginata; 1c - intermediate A; 1d - intermedaite B.

Figure 8



Pompey
Delphi Station
Mottville
Pecksport
Solsville
ORNAMENTED
UNORNAMENTED
INTERMEDIATE A
INTERMEDIATE B

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ROAD LOG

Mileage Miles	Cum	
		From Cutten parking lot turn right (north) onto Broad Street (Rt. 12B)
.1	.1	Turn right at stoplight onto the Colgate Campus (College Street)
.3	.4	Stops sign with Oak Drive, turn right.
.1	.5	Turn left past Merrill House to leave campus.
.1	.6	Stop sign, turn right onto Hamilton Street. Continue straight on Hamilton Street.
.8	1.4	Gorton Road is on the right. Continue straight on Hamilton.
1.5	2.9	Hamilton Street curves right, continue straight on Kiley.
.6	3.5	Intersection with Poolville Road. Stop sign, continue straight on Larkin Road.
1.2	4.7	Stop sign. Intersection with Route 12, continue straight on Larkin Road.
3.2	7.9	Stop sign. Turn left onto Moscow Road.
.5	8.4	Turn right onto Skaneateles Turnpike.
3.0	11.4	Junction with Ouleout. Keep going straight on Turnpike.
1.0	12.4	Stop sign. Junction with Ouleout Road. Go straight.
.6	13.0	Village of Brookfield.
.7	13.7	Turn right onto Dougway Road.
1.4	15.1	Stop sign. Intersection with Hoxie Road, turn right.
.3	15.4	Settlement of Five Corners.
1.3	16.7	**Locality 1 on the right. Hoxie Road Quarry.** Leaving quarry, turn left onto Hoxie Road. Retrace steps to Brookfield.
1.3	18.0	Back through Settlement of Five Corners.
.3	18.3	Junction with Dougway. Turn left.
1.4	19.7	Stop sign. Turn left onto Main Street (Skaneateles Turnpike).
.9	20.6	**Locality 2. Brookfield Quarry.** Leaving Locality 2, turn right onto Skaneateles Turnpike.
.3	20.9	Junction with Ouleout Road. Continue straight on Turnpike.
1.1	22.0	Junction with Ouleout Road. Turn right.
3.3	25.3	Turn right onto Barnes Road.
.5	25.8	Turn left onto Main Street.
.8	26.6	Stop sign. Junction with Route 12. Continue straight onto Swamp Road.
1.3	27.9	Stop sign. Turn left onto Cole Hill Road.
	27.95	Turn right onto Bailey Road.
1.0	28.9	**Locality 3. Bailey Road Quarry.** Leaving Bailey Road turn right (east). Back to Cole Road.
1.0	29.9	Stop sign. Turn right onto Cole Hill Road.
2.3	32.2	Turn right onto Rhoades Road.
.7	32.9	Turn left onto Quarterline Road.
.8	33.7	Village of Hubbardsville. Keep straight on Quarterline.
1.7	35.4	Turn right onto Kiley Road.
.7	36.1	Stop sign. Junction with Hamilton Street. Continue straight.
2.2	38.3	Turn left onto Colgate Campus.
.1	38.4	Turn right onto Oak Drive
.1	38.5	Turn left onto College Street.
.4	38.9	Stop light. Junction with 12B. Continue straight on College Street.
.5	39.4	Stop sign. Turn left onto Lebanon Street (Randallsvilel Road).
1.2	40.6	Turn right onto Armstrong Road.
1.0	41.6	Stop sign. Turn right on River Road.
1.2	42.8	Turn left onto Chamberlain Road.
.8	43.6	Stop sign. Turn left onto Lebanon Hill Road.
1.0	44.6	Turn right onto Geer Road.
1.0	45.6	**Locality 4. Geer Road Quarry.** Leaving quarry, turn left (east) onto Geer Road.
.9	46.5	Stop sign. Turn left onto Lebanon Hill Road.

1.0	47.5	Intersection with Chamberlain Road. Continue straight on Lebanon Hill Road.
2.3	49.8	Stop sign. Junction with Rt. 26 in Eaton. Turn right onto Rt. 26.
.5	50.3	Turn left onto English Avenue.
.7	51.0	Bear left on English Avenue.
.5	51.5	**Locality 5. English Avenue Quarry.** Leaving quarry, turn right onto English Avenue.
1.4	52.9	Stop sign. Continue straight.
1.2	54.1	Junction with Route 20. Turn left onto Route 20 (note that Route 20 is a divided highway).
.7	54.8	Entering Village of Morrisville.
.6	55.4	Stop light. Turn right onto Swamp Road.
2.3	57.7	**Locality 6. Peterboro South.** Leaving quarry, turn right. Continue along Swamp Road.
.5	58.2	**Locality 6a. Peterboro North.**