Stratigraphic and Structural Relationships of the Ordovician Flysch and Molasse along the Western Boundary of the Taconic Allochthon near Kingston NY

Gerald Pratt

New York State Department of Environmental Conservation

Overview

This trip will visit recently described exposures of the allochthonous Ordovician Normanskill Group juxtaposed against autochthonous Quassaic and Martinsburg sedimentary rocks. Exposures in the Kingston and Esopus Townships demonstrate through stratigraphic position, sedimentary structures and fossils, the collapse of a foredeep basin and subsequent down warping of a foreland basin during the latest stages of the Taconic Orogeny. The trip includes several stops at outcroppings of the allochthon strata, Taconic Unconformity and the later arenites of the Quassaic, which contain an unusual molasse facies.

Introduction

Sandstone petrology of compositions of the strata in the field trip area indicate Ordovician formations originate from a volcanic terrain and are classified as recycled orogen blocks directly or indirectly. It is likely that these formations were formed proximal to one another. A structural inlier consisting of fossiliferous thin shale and siltstone is identified and delineated within unfossiliferous massive arenites. Structural geometry, biostratigraphy and sedimentology were analyzed to constrain the inlier stratigraphic boundaries to the Martinsburg Formation. Massive Ordovician arenites in the study area are uncharacteristic of those of the Normanskill Group, lacking fauna and allocyclic characteristic. Bedding is massive, exceeding 5 meters containing laminate sets and contained greater amounts of quart and lesser amounts of calcite and lithic fragments as well. Sedimentology of the massive arenites suggests this formation is an alluvial or olistostrome deposit and its structural position would place it above the Normanskill Group. However, analysis distinguishing structural domains potentially places the arenites within the Normanskill Group. Thus, the arenite strata are proposed as a new formation for the uppermost position of the Normanskill Group. The stratigraphic sequence of the Ordovician strata within the study area represents a transgressive progression from an older flysch to a younger molasse facies. This is interpreted as a tectonic depositional loading to a flexural extension of underlying continental blocks.

Geologic Setting

The study area topography is the result of multiple orogenic events and created several notable landmarks in the region. The largest and most prominent landmark is Hussey Hill, which is a northern extension of the Marlboro Mountains and overlooks the low-lying village of Port Ewen to the east. This range of 'mountains' originally named "Marlborough Mountain" (Mather 1843) extends due south approximately 40 kilometers from Connelly to the city of Newburg in Southeastern New York and attains its highest altitude of just over 300 meters at Illinois Mountain. Hussey Hill is formed by a large north plunging syncline consisting of the Quassaic Group, a late-Ordovician arenite sequence (Waines 1986).

Another prominent and more important landmark is Hasbrouck Park, this lies immediately north of the Rondout Creek within the Rondout district of Kinston. It is the southernmost point of a well-exposed, eastward facing steep ridge called North Hill that separates Rondout and points west from the low-lying Ponck Hockie fronting the Hudson River, and extends north approximately 1 kilometer to the Terry survey station of the USGS and attains an average height of 76 meters. The ridge is capped with the folded and faulted late Silurian and Early Devonian Rocks. Mining of this ridge during the latter half of the 19th and early 20th centuries for dolostones and limestones of the late Silurian Rondout Formation, of which the Rosendale Member was the most sought after, have in large part contributed to the ridge's steep and exposed face. Underlying the dolostone and limestone formations are Ordovician silt-

stones and shales of the Austin Glen the Normanskill Group's upper member. The Austin Glen is overturned and thrust between repeating layers of the later Silurian and Devonian limestones. At the base of Hasbrouck Park exposed on the east side are massive quartz arenites. Unlike the Austin Glen, sandstones the arenites consist of massive coarse-grained sandstone light grey-bluish to buff in color and overturned. Also out of character are lenticular conglomerates less than one foot thick of semi to sub angular large to small pebbles of possible Normanskill origin are set into the quartz matrix. These characteristics place the arenites potentially above the Normanskill Group. This carbonate ridge extends south and west crossing the Rondout Creek at Connelly where it meets and overlies the Quassaic Group in angular unconformity to the west of Connelly. The contact continues southwest towards the town of Rosendale and there is buried under postglacial alluvial sand deposits. To the east of North Hill and Hussey Hill are low-lying sand plains that underlie Connelly, Ponck Hockie, and Port Ewen and extend east to the Hudson River. These plains are underlain by highly faulted and folded thrust slices of a medial to Late Ordovician phyllarenite sequence belonging to the highest sequence of the Normanskill Group. The Normanskill Group of rocks extend contiguously south to city of Newburgh and north to the city of Albany and as far east as Pine Plains New York. Locally, the Normanskill sequence lies in angular unconformity with the overlying younger Silurian carbonate sequence and thrust upon and over younger Ordovician Quassaic Group. The angular unconformity and the fault suggest at least two orogenic events took place, the first described by the Normanskill- Quassaic contact, a named fault known as the Esopus Thrust (Dames and Moore 1973) where two Ordovician layers are tilted, overturned and thrust upon themselves. The second is an unconformity located in Hasbrouck Park identified by a Normanskill-Silurian contact. The folded and tilted Silurian beds overly already deformed Ordovician beds, this is typically referred to as the Taconic Unconformity. Another structure of interest lies within the largely overturned thrust sheets of Ordovician arenite beds. Upright beds of fossiliferous thin-bedded sandstones and siltstones are bounded above and below by the massive arenites. The low-lying shales contrast against the ridges of the arenites. This positioning of the inlier also implies it is of Ordovician age. Fossils identified from the shales would indicate an age later than the Normanskill and fauna in kind with ones found within the Martinsburg Group. The Martinsburg inlier is not completely exposed within the Ordovician layers, it is partially submerged under younger Silurian and Devonian strata to the North.

Description of Strata

Normanskill Group

Austin Glen Formation

This formation is the only formation of the Normanskill Group present in the study area and its thickness is estimated at less than 300 meters, based on observed outcrops. Estimates of its thickness are difficult due to the ubiquitous faults, lack of marker beds, and incomplete stratigraphic sequence within the study area.

Beds consists of alternating sequences of laminated and cross-stratified thin grey phyllarenites, calcareous grey to dark-grey siltstones interspersed with thin argillaceous dark-grey siltstones and blue-grey and black shales. Arenite and siltstone beds are typically less than 1 meter thick but can range from several centimeters to two meters. Shale is often lenticular and varies in thickness from a few centimeters to less than a meter. Erosive contacts of the hummocky cross-stratified beds with underlying dark gray shales are common. Occasionally shale and siltstones occur in shallow troughs less than a meter in depth. Much of the beds are bioturbated virtually obliterating nearly all fossil evidence in most of the outcrops observed. Limited shelly fauna was found in thin siltstones and shales in detrital assemblages at Hasbrouck Park at the contact with Silurian beds. Additionally shelly and planktonic fossils are reported to be found at Kingston Point (Howell 1942). They include *Sowerbella sericca* and *Dalmanella testudinaria* brachiopods as well as graptolites; *Corynoides gracilis perungulatus, Climactograptus bicornis, C. modestus and Diplograptus (Orthograptus) acutus*.

Clastic sedimentation and presence of fossils indicates marine depositional facies. Sandstone-shale contacts show abundant ripples, load casts, tool and sole marks indicating active margin deposition. A number of these sedimentary structures were determined to indicate a paleocurrent direction of northeast-southwest with a provenance likely to the east. Furthermore the sequence of interbedded sandstones siltstones and shales describe a synorogenic origin.

Modal analysis of siltstone thin section samples show abundant amounts of quartz (>90%) and lithic fragments (<6%) followed by lesser amounts of plagioclase (<3%), calcite (<1%), mica (<1%) and traces of potassium feldspar as dominate detrital mineral phases in a calcareous matrix. Quartz grains display morphological variation in the form of recrystallization and suturing. The Austin Glen deposits originate from clastic flows resulting from the uplift of older formations. Turbidite sequences are evident in a number of outcrops, sandstone grading into shales that form laminate couplets a few millimeters to a centimeter in thickness. Locally the Austin Glen was restricted to a narrow exposure along the western banks of the Hudson River.

Thrust faults are numerous and no continuous sections larger than 20 meters were found. Orientation of thrust faults would indicate westerly beds are generally younger than those to the east. Beds lie unconformably against younger Ordovician sandstone beds of a proposed formation (Ulster Park) at the western boundaries. To the north, the Austin Glen also lies against the Silurian limestones of the Rondout Formation in angular unconformity. Bedding is upright and occasionally overturned, sometimes bedding is overturned and upright within a single outcrop preventing a definite correlation of beds. Erosive contacts of the hummocky cross-stratified beds with underlying dark-grey shales are common. Regionally the Austin Glen formation is part of the Normanskill Group, which the Austin Glen is the highest stratigraphically (Rudemann 1908). To a greater extent, the Normanskill Group is part of the Taconic Sequence. The overall extent of the Austin Glen member of the Taconic Sequence is contiguous from Southwestern Vermont to the lower Hudson Valley of New York (Zen 1967, Rowely and Kidd 1981).

Dominant bedding is moderately to steeply east dipping, homoclinal and generally strikes 000-030 degrees. Much evidence of tectonism is found in the Austin Glen Formation. Recumbent to moderately inclined folds and bedding parallel reverse faults are common. Reverse faults often cut through the recumbent fold axis and then are also subsequently faulted again into smaller segmented thrusts or slices. Brittle shear zones occur in reverse faulted shale and siltstone layers. En echelon tension fractures or gashes often forming sigmoidal vein filled fractures are common. Shear zone rock fragments exhibit brecciation and crushing. Slickensides evident on sandstone bedding planes and are often in-filled with quartz and calcite. Small thrust segments can be less than 25 feet in length though most are greater in length but could not be determined in outcrops due to limited exposure. The reverse faulting occurs so frequently that discerning a stratigraphic sequence and relative thickness is difficult. Adding to the already difficult sorting of the slice segments the younging direction occasionally flip flop on account of the cut off recumbent folds. This was evident in outcrops which beds would be overturned in the footwall of a fault and upright in hanging wall.

Occasional high angle normal faults were found and often at high angle and oblique to bedding planes. Multiple shale and sandstone cleavage planes often oblique to structural trend are common. Shale and siltstone cleavage is common on two planes and the shale exhibits penciling in a few outcrops. Sandstone layers demonstrate fracture cleavage limited to one plane predominately trending in a northeast southwest direction, limited to Hasbrouck Park. Orthogonal jointing and plumose structures are common in sandstone beds. Cleavage planes exist in shales and more competent siltstones orientations are NNE in shales and NE in siltstones. They are similar to those indicative with the foliation structures in the Taconic allochthon seen elsewhere and agree with Zen (1967), Rowely and Kidd (1981), Stanley and Ratcliff (1985), and others.

Ulster Park (Proposed)

The stratum named the Ulster Park is proposed as the upper formation of the Normanskill Group. Within the Kingston and Rondout areas, it lies juxtaposed as a fault contact against the Austin Glen, the contact is exposed at the base of Hasbrouck Park extending west to the base of the Quassaic where it rests in angular unconformity. The formation continues south of the study area and outcrop in the towns of Ulster Park and Lloyd (Cunningham 1990). The formation lies completely to the west of the Austin Glen. Thus, based on the assumption its placement follows the presently accepted tectonic model of thrust slice emplacement, where the leading edge of younger slices were emplaced prior to later aged slices which still mobile, over rode the trailing edge of the younger aged slice, (Stevens 1970) thus the proposed formation is presumed younger than the Austin Glen. Homoclinic with bedding largely overturned and moderately to steeply dipping, total strata thickness is reported to range from 1000 to 3400 meters (Cunningham 1990). A far less thickness was found in the study area, likely represents a partial stratigraphic representation of the formation. The formation as reported is described as having brown shales as its lowest member, overlain by increasing intermittent laminated sandstones and siltstones and lesser shale layers (Cunningham 1990). Sand-

stones increase up-section in frequency and thickness, often exceeding 5 meters and weather brown, black and rust yellow. Sandstones include lenticular conglomerates of limestone and clays. In some instances, the clays weather out of sandstones creating pocks in jointing planes. Fossils reported include several genera of trilobites, brachiopods, asterozoa, bryozoa, ostrocoda and crinozoa of the Middle Ordovician (Kirkfieldian) from two locations. Fossils of shelly fauna exist sporadically in shale layers. Initial petrographic analyses seem to indicate a significant sodic-rich plagioclase and K-bentonite content. The feldspar and other mineral grains are detrital and subangular, thus may represent an eastern provenance and orogenic terrene. Numerous shallow turbidites less than 0.5 meter deep, ripple marks, and lode casts exist throughout the sequence. The entire sequence represents a transgressive sequence. The lower beds contain calcareous muddy silt, an offshore relatively low sediment influx rate, which was the favorable environment to sustain the abundant shelly fauna. The silt and muds rapidly gave way to thick coarse sands from a upslope high sediment influx environment represented by the numerous turbidity structures. A type section within the township of Ulster Park was established (Cunningham 1990).

Outcrops within the study area absent of the fossiliferous shales and are predominately massive quartz arenite in most exposures, thickness of beds varies from <1 to 5 meters. Minor dark shale and siltstone beds vary in thickness from several centimeters to two meters. Color ranges from light to buff in fresh exposures to orange brown to black in weathered exposures. Erosive contacts of the hummocky crossstratified beds with underlying dark gray shales are common. Beds are often graded or cross graded, faint laminae sets are also present and vary from 5 mm to a centimeter in thickness. Laminae sets vary little in exposure, often absent of cross set pairs or truncated pairs make it difficult to determine younging direction. Found in outcrops located east of Esopus Fault and west of Normanskill beds bordering the Hudson River. A large outcrop near the base of the Wurt Avenue bridge location yielded 250 meters of exposed section; with a representative dip of 50 degrees, this gives a thickness of about 100 meters. Several other poor outcrops serve to identify the extent of the beds laterally but without any additional discernable thickness. Total thickness 300-400 meters, however, may be more representative of the unit within the study area. The arenite beds become thicker and more abundant to the east presumably higher in section. Ulster Park is similar in structural complexity to the Austin Glen but varies slightly in foliation, generally striking 010-050 degrees, beds dip east moderately (30 degrees) to steeply (>45 degrees) in outcrop. Faulting is ubiquitous; numerous reverse faults that follow structural trend of beds are common. As found in the Austin Glen, reverse faults often cut through fold axes or are subsequently faulted again into smaller thrusts or slices. Normal faulting occurs occasionally in larger outcrops, strike of these faults are approximately 060 and often at high dip. Faulting bounds the upper and lower contacts of the formation so that discerning a stratigraphic sequence and thickness is difficult. Outcrops near the contacts with Silurian and younger Ordovician beds are nearly devoid of shales as opposed to more frequent layers away from contacts. It is likely that there is an increase in shear stress as beds near the contact thus during deformation and less competent shales were squeezed out leaving behind arenites. Where observed cleavage planes orientations in shales is NNE. Generally this structural trend coincides with the Normanskill Group. A synclinal fold with axial plane striking 075 degrees was observed at one location along Connelly Rd. The orientation of this fold is not typical to those generally associated with Taconic orogeny, which folding and faulting occur generally north south. Folds are symmetric and fold axis is oblique to strike and plunge north. The fold orientation and intact structure suggest these folds are post Taconic in age. The fold orientation follows similar trends to those folds in Silurian strata and is more likely that these folds are associated with the later Acadian orogen. The Acadian effects are often seen to the southwest of the Hudson Valley demonstrated in the folding of the Silurian Shawangunk Conglomerate and rise of the Catskill Mountains. Therefore, while finding these folds was surprising they were not completely unexpected.

Martinsburg Formation

The Martinsburg Formation is a mapped bedrock unit with extents in, New York, Pennsylvania, New Jersey, Maryland, Virginia and West Virginia. It is named for the town of Martinsburg, West Virginia for which it was first described. The Upper Ordovician Martinsburg Formation of eastern Pennsylvania consists of mudstone, siltstone, and sandstone turbidites, which are also seen along the western edge of the study area. The beds are gray to dark gray, and infrequently tan and purple shale and slate. Localized sandstone, thin, argillaceous limestone or phyllitic shales are present. The mudstone-rich Bushkill Member, the stratigraphically lowest unit of the Martinsburg exposed to the south and west of the study area in the townships of New Paltz and Rosendale, grades upward into approximately equal proportions of mudstone, siltstone, and sandstone of the Ramseyburg Member, which closely coincides with

observations made at a number of locations locally. Outcrops are generally upright though some overturned beds were found. Disconformities of the hummocky sandy beds with underlying dark grey shales are common, and ripple marks are infrequently developed on these beds. Individual cross beds reach a thickness of 30 to 50 cm. Several Pebble to cobble sized (10 cm), rounded mudstone clasts are found at locations with similar lithofacies. Bound structurally top and bottom by Ulster Park Formation by faulting; thus the stratigraphy is incomplete. The Bushkill-Ramseyburg sequence is reported to be approximately 2000 m thick, though its total section in the study area is approximately 40 m. Thus represents a partial section of the formation. The Martinsburg lies above and below erosional unconformities regionally. The Shawangunk Formation (New York), lie unconformably atop the Martinsburg. Below it, the Middle Ordovician Chambersburg and Myerstown Formations (Pennsylvania) lie in unconformity and it is unknown what lies below the Martinsburg Formation locally. The following descriptions represent a partial sequence of the formation. Bedding is generally homoclinic, striking north to northeast and dipping east low to moderately, 020 to 040 degrees. Undulating bedding and sedimentary structures are common as well as shallow turbidites typically fining-upward. Hummocky character of beds sedimentary structures are interpreted as reflecting the influence of external or allocyclic controls such as variations in the intensity of tectonic activity in shelf/slope areas, thus exhibit a flysch facies. In the study area, the Martinsburg exists as an inlier within the Ulster Park Formation of slightly older if not similar age. It is likely the turbidites are caused by underwater landslides stirring up sediments that accumulated on a slope along the periphery of a tectonically active foreland basin. The variation of argillaceous and limestone beds within calcareous matrix, these variations reflect the local rate of sea-level rise and/or variations in the intensity of tectonic activity in shelf/near shore or hinterland areas from a deepening trough or formed upon peripheral bulges due to the closing of a sea rather than more commonly cited allocyclic mechanisms related to terrestrial events as subsidence and deltaic flooding (Lash 1988).

Quassaic Group

The Quassaic Quartzite was first named on the Geologic Map of New York State (Fisher 1971) and later described as a massive pink and green quartzite, sandstone with occasional conglomerates, quartzites, conglomerates having arkosic, peletic, occasional red argillaceous matrix. Beds grade upward into green-grey sandstones with tabular cross-lamination common and few green-grey shale interbeds. The red matrix is debris from erosional shoals of older material is transported to an upper slope environment. This matrix is best described as a molasse (Fisher 1977). Later work by Waines (1986) raised the Quassaic to Group status. The Quassaic Group is a late Medial to medial Late Ordovician marine arenite, 3000 meters in thickness. It is subdivided (oldest to youngest) into five formations: Creek Locks, Rifton, Shaupeneak. Slab Sides, and Chodikee. General lack of shales, and scarcity of fossils indicate that the average depositional environment of the formations was near the base of the slope of a sedimentary apron or delta. The Quassaic Group is at a stratigraphic high point or erosional shoal thus no known unit overlies it. It is similar or equivalent in age to the Bushkill Member of the Martinsburg Formation. Thus likely represents a transition point in the closure of the foredeep basin.

Stratigraphy

Folded siliclastic quartzite, mostly upright and occasionally overturned. All outcrops generally occur in the western portion of study area along a ridge line of hills noted as the Marlbourogh Mountains. Beds on western side of hills grade conformably into younger late Ordovician Martinsburg Formation shales (Waines 1986). Beds on eastern side of the Marlboro Mountains are truncated by a fault and lie in angular unconformity with older sandstones and shales of Ulster Park and Normanskill Group and the younger Devonian limestones of the Helderberg Group.

Structure

The Quassaic Group bedding generally strikes 010-030 degrees and forms the most intact structure within the study area. The Quassaic strata make up a large asymmetric syncline (Waines, 1983) which is continuous along strike for at least 40 km (Cunningham 1991). Eastern limb beds dip east moderately to steeply 40 to 90 degrees or are occasionally overturned, western limb beds dip west steeply moderately (>45 degrees) in outcrops. The eastern boundary of the Quassaic is bounded by The Esopus Thrust fault (Dames and Moore 1973) which was traced from Newburgh north into the township of Esopus but stopped south of the study area. Within the study area this fault is mostly covered except for a few outcrops along the railroad cut. The Ulster Park Formation abuts this fault on its western

extents. Foliation of strata indicates the syncline plunges north and under younger Devonian beds thus indicating at least two tectonic events. Rarely, faulting occurs as normal or strike slip faults oblique to strike often at high angle. Slumping of bedding at the Stop 12 location indicates a molasse facies. This outcrop, located at the most northern exposure of the Quassaic, consists of a 200m ridge that decreases in elevation from north to south 30m. The ridge is mostly covered in thin soil with little exposed bedrock outcrop. The northern most outcrop of the Formation was quarried historically, at this area it appears there is a significant slumping of beds in which thin 30 degrees west dipping sandstones to the east side of the outcrop are truncated by near vertical red conglomerate and thick bedded sands. An upslope outcrop to the south and west exposes bedding as thin sands oriented 30 degrees west dipping, similar to that found on the east side of the slump. While no west contact of the block was found, it is inferred that this is evidence of a molasse facies. Further study of this outcrop site would likely produce interesting findings.

Field Trip Stops

Note: There is significant rock scrambling and hiking so sturdy hiking shoes are recommended. Trials are typically overgrown and long pants and shirts are also recommended.

Stop 1. Rotary Park at Kinston Point. Within the park are several outcrops of Austin Glen lithology, which generally dip 55 degrees east. Thin to thick beds of alternating sequences of laminated and cross-stratified thin grey phyllarenites, calcareous grey to dark-grey siltstones interspersed with thin argillaceous dark-grey siltstones and blue-grey and black shales. Arenite and siltstone beds are typically less than 1 meter thick but can range from several centimeters to two meters. Shale is often lenticular and varies in thickness from a few centimeters to less than a meter. Erosive contacts of the hummocky cross-stratified beds with underlying dark gray shales are common. Shale and siltstone cleavage is common on two planes orientations are NNE in shales exhibiting penciling and NE in siltstones in a few outcrops at the park. Orthogonal jointing and plumose structures are common in arenite beds. Limited detrital fauna deposits are found in the shale and siltstone layers due to bioturbation.

Stop 2. Hasbrouck Park. A path off the parking area continues along the base of an escarpment of Helderberg limestones. The path continues along the southwest side of a large vertical adit runs northeast southwest. The escarpment was extensively mined in the past for the dolostones of the Rondout Formation to make cement. Carefully continue past the adit and scramble down off the path to a cut in the slope. Here the Austin Glen is juxtaposed against the remnants of the Wilbur Limestone member of the Rondout Formation in angular unconformity.

Stop 3. Trolley Museum. Take a few minutes and peruse the museum. Follow the railroad cut west along base of Hasbrouck Park, Outcrop is exposed along its entire length. Massive sandstone layers include some lenticular conglomerates of chert and limestone. Clasts of semi-angular large and small pebble-sized black and green chert, grey shale and weathered laminated light to dark grey limestone. Approximately 100’ along the railroad bed from the museum the rock face gives way to a slope. Scramble up the slope to an abandoned road. Walk east along the road to the end of the chain link fence approximately 75’. Scramble up the slope toward a large rock fall. A section is cut out of the slope perpendicular to the mine adit. Here the upper Normanskill is in contact with Silurian or Devonian Limestone. The orientation of the unconformity has changed from a NNE strike to NE. This sight is also accessible from Hasbrouck Park. Beginning at the pavilion in the park, walk north along a sidewalk path toward an abandoned block building, continue though a break in the fence behind the building and scramble down a steep path through the talus. The ground levels and the contact is on the left approximately 50 feet from the base of the slope.

Stop 4. West Strand Street. Extensive exposure approximately 250 long at base of Wurts Ave Bridge exhibits large amounts of deformation and a few folds plunging northeast. Beds are both upright and overturned, generally striking N40W and dipping 50E. A number of low to high angle faults strike NE throughout the section. Orthogonal joints exhibiting plumose structures are common. Turbidite structures are used to determine overturned or upright sections of the outcrop. Pock marks eroded from joint faces generally run along bedding planes and are thought to be of soft mudstone pockets within the otherwise massive sandstone.

Stop 5. Slaughterhouse. Just West of Stop 4 this outcrop was recently uncovered after demolition of a large abandoned structure once used as a slaughterhouse. Massive quartz arenite in most of the exposure, thickness of beds exceeds 5 meters. Minor dark shale and siltstone beds vary in thickness from several centimeters to two meters. Cleav-

age planes orientations in shales is NNE. Color of arenites range from light to buff in fresh exposures to orange brown to black in weathered exposures. Beds are often graded or cross-stratified, faint laminae sets are also present and vary from 5 mm to a centimeter in thickness. A high angle normal fault occurs in the exposure, strike of this fault is approximately 060. Faulting bounds the upper and lower contacts of Street boarders the upper part of the exposure on the South side. Bordering the north side of Abeel Street is an outcrop of Devonian limestone outcrop in apparent unconconformity. Arenite beds near contact are nearly devoid of shales as opposed to more frequent layers away from contacts seen to the east. It is likely that there is an increase in shear stress as beds near the contact thus during deformation and less competent shales were squeezed out leaving behind arenites.

Stop 6. Apparent Taconic Unconformity. Top side of the Stop 5 outcrop, this part of the exposure demonstrates an apparent contact with the Devonian beds of the Coeyman limestone formation directly across the street.

Stop 7. Old 9W Roadcut. The proposed Ulster Park formation in the extensive road cut is exposed. Massive quartz arenites dominate the cut. Bedding displays graded and cross bedding and is overturned. The few thin shales exposed are cleaved in at least two directions. At least two major faults cut through the outcrop and is traceable across the highway. A high angle fault dominates the outcrop, its displacement effectively dissects the exposure into two distinguishable and different parts. Some shale and limestone pebble conglomerates are evident. Several lode casts are evident on bedding planes.

Stop 8. Connelly Road residence. Large outcrop behind residence exhibits plunging fold oriented N75W. This orientation is not typical of Taconian deformations that follow a NNE trend.

Stop 9. Intersection of County Route 25 and Millbrook Road. Locally fault-bounded above and below by upper massive quartz arenites and composed of low-to moderately-eastward dipping, 020 to 040 degrees, faulted and folded, medium to dark-grey sandstone and interbedded shale. Total section represented in this exposure is approximately 40 m. Dominate dark-grey to black mudstone with a few lenticular fine-grained, medium grey, sandstone turbidites, calcareous with mudstone clasts. Many of the turbidites observed are arranged in small-scale (1-2 m) fining-upward sequences demonstrating bedding is upright in position. Calcareous shelly fossils preserved primarily as molds and casts. Shelly fossils occur throughout the shale and sandstone with locally dense concentrations. There were several fossil localities along Millbrook Rd. Fossil localities chiefly contained disarticulated brachiopods, ostracods, crinoids, bryozoans, and trilobites. Genera and limited species of brachiopods found were identified as *Dalmanella sp.*, *Paucicrura rogata* sp., *Sowerbyella* spp. and *Rhynchonella* sp. articulate brachiopods, *Dilobella* spp. ostracod, trepostomate bryozoa zoaria, and a pygitium belonging to a trilobite tentatively identified as *Decoroproetus* spp. was found.

Stop 10. This outcrop contains calcareous thin-bedded siltstones and shales. Bedding is dark grey to black, and is moderately dipping east 50 degrees. These strata are similar in composition to Stop 9, though the fossils are absent.

Stop 11. East side of railroad cut is massive sandstone bedding overlooking extensive sand cover to the southeast.

Stop12. Old quarry. This quarry lies the opposite side of the railroad cut west of Stop11. Here the Esopus Fault is presumed to lie within the railroad cut and plunges under the Silurian and Devonian limestone immediately north of the stop. The fault extends to the south with rocks of the upper Ordovician Quassaic Group sitting to the west of the railroad. Thin bedded sandstones are truncated by massive conglomerates of red clay clasts of pebble to cobble size. The bedding generally strikes N30 degrees dip east moderately 40 degrees. Slumping of bedding at the location indicates a molasse facies. An upslope outcrop to the south and west exposes bedding as thin sands oriented 30 degrees west dipping, similar to that found on the east side of the slump indicating a defined block of red clasts slumped into the sands.

Stop13. Railroad cut at County Route 25 and West Shore Railroad line. Here again lies the presumed exposure of the Esopus fault. Rocks on the west side of the railroad cut are massive steeply dipping and medium to thick quartz arenites and conglomerates. Conglomerates contain of rounded or subangular pink or grey (rarely banded) limestone and black or green chert and shale pebbles. In the railroad cut, the basal Shaupeneak Formation of the Quassaic group is exposed. To the east of this extend the proposed Ulster Park rocks of the upper Normanskill Group. They

are seen in numerous outcrops along the backstreets of Port Ewen and form low-lying ridges extending north to south.

Stop 14. Hussey Hill. A moderate climb up a steep slope is required to access this stop. Along the slope path are exposures of red clasts of the Shaupeneak. At the top are exposures of the Slabsides Formation of the Quassaic Group are found. They mostly occur as vertical beds of thin to medium quartz arenites. The Quassaic Group makes up the Hussey Hill at its northern point and extends south from the north to the Marlboro Mountains.

Road Log

Total Miles:	**Miles from last Stop**	
0	0	Start: Kingston Point, Battery Park Kingston N.Y. Parking lot. Looking North you will see North Hill a ridge running North South. It consists of deformed Helderburg Limestones resting on the Ordovician Normanskill strata.

Stop1. Enter Park through iron gate. Outcrop immediately along dirt path on right just after entering park. Cleavage face of Austin Glen formation. Continue south along dirt path to outcrop. Crossection of angular beds of Austin Glen formation consisting of alternating shales and siltstones. Siltstones substantially bioturbated. Continue along path to southern peninsula of park. Large outcrop of sandstones, siltstones and shales.

0	0.01	Turn right out of parking lot onto Delaware Ave. Ascend North Hill and take note of , then turn left onto Hasbrouck Park Rd.
0.7	0.7	Take immediate left into parking area. Hike 1/4 mile into **Stop2.**
0.71	0.01	Take right out of parking area to end of Hasbrouck Park Rd. Turn right on Delaware Ave.
0.72	0.2	Turn right at Abruyn St. though the hamlet of Ponck Hockie.
0.92	0.3	Turn right at East Strand St. A good view of the North Hill ridge to the right and Rondout Creek on the left.
1.22	0.6	Turn right into the trolley museum.

Stop 3. The Trolley Museum is part of and adjacent to an active railroad switchyard and permission is needed to access this location. The outcrop is located behind the museum buildings along the base of North Hill. This is the northern extents of North Hill and is truncated by Rondout Creek. The outcrop consists of massive arenites and thin lenticular conglomerated of the proposed upper formation of the Normanskill formation.

1.82		Turn right out of Trolley Museum at East Strand St. to Broadway
1.82	0.1	Turn right at Broadway
1.92	0.05	Turn left at West Strand St., parking area will be on left. Across the street is the road cut **Stop 4.**
1.97	0.05	Walk west down West Strand St. to **Stop 5**. Outcrop set back on north side of road. Walk back to car and turn left (West) out of parking lot on West Strand St.
2.02	0.1	Turn right at Abeel St.
2.12	0.05	Park in lot on north side of Abeel St. **Stop 6** outcrop is at back of lot. When leaving turn left from parking lot.
2.17	0.4	Turn right at North Broadway over bridge. Pull into industrial pipe supply company and park. Permission is needed. Note, the bridge has a pedestrian walkway and provides an excellent vantage point to observe several field trip stops are visible (2, 3, 4, 5, 12) . Several other outcrops and structures of interest not covered in the field trip are also prominent.
2.57		Walk north along road. Caution must be used when walking along roadway. **Stop 7** outcrop is both sides of the road. Return to cars and turn left (north) out of lot.
2.57	0.1	Turn left at Connelly Rd
2.67	0.2	Turn left at Connelly Rd residence. **Stop 8**. Large outcrop in back yard. Permission is needed to enter location. Return to Car, turn left out of driveway.
2.87	0.4	Turn left at Millbrook Dr.
3.27	0.6	Turn left into gravel lot.

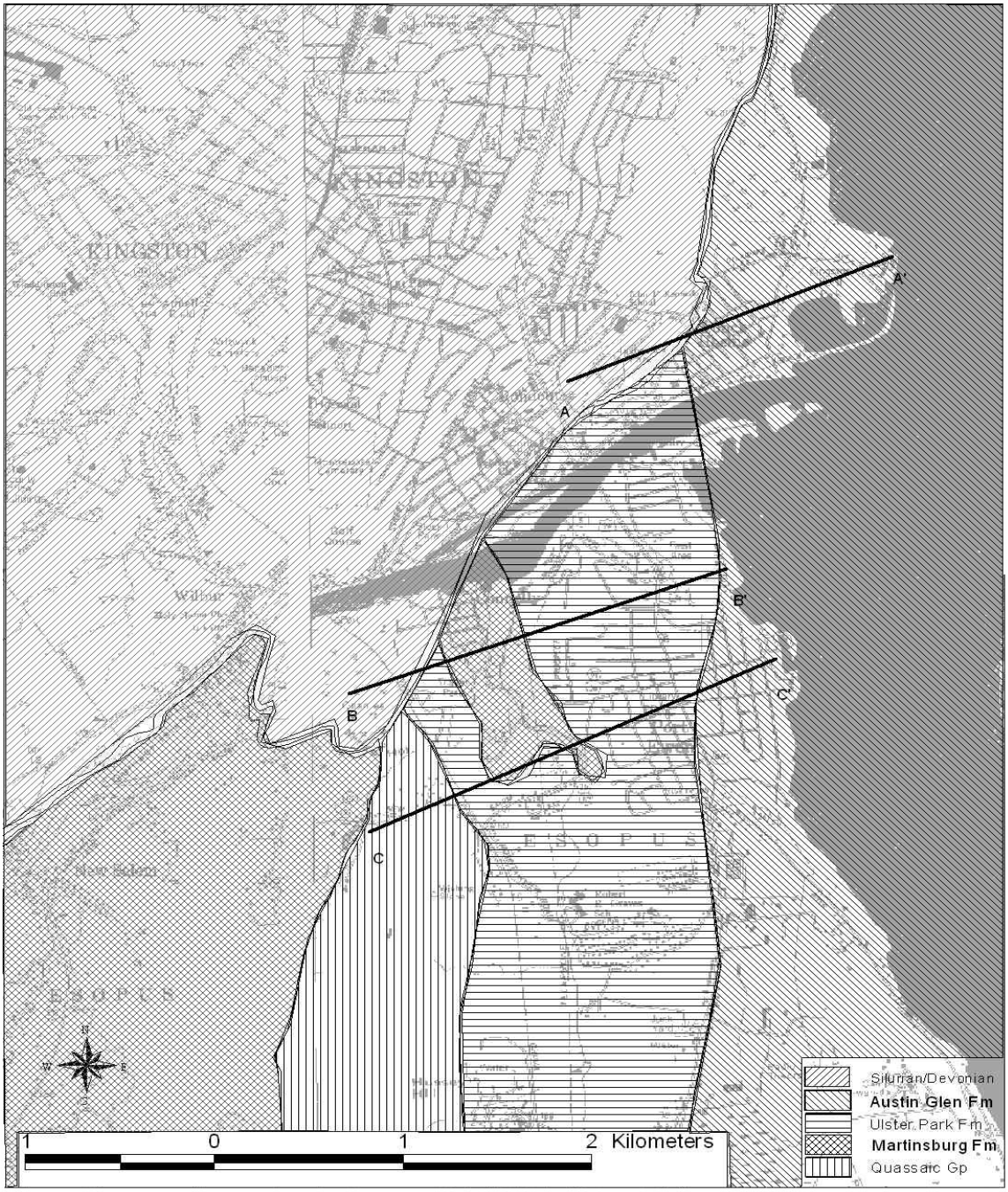
KINGSTON
Wilbur
A
A'
B
B'
C
C'
1 0 1 2 Kilometers
Silurian/Devonian
Austin Glen Fm
Ulster Park Fm
Martinsburg Fm
Quassaic Gp

Figure 1.

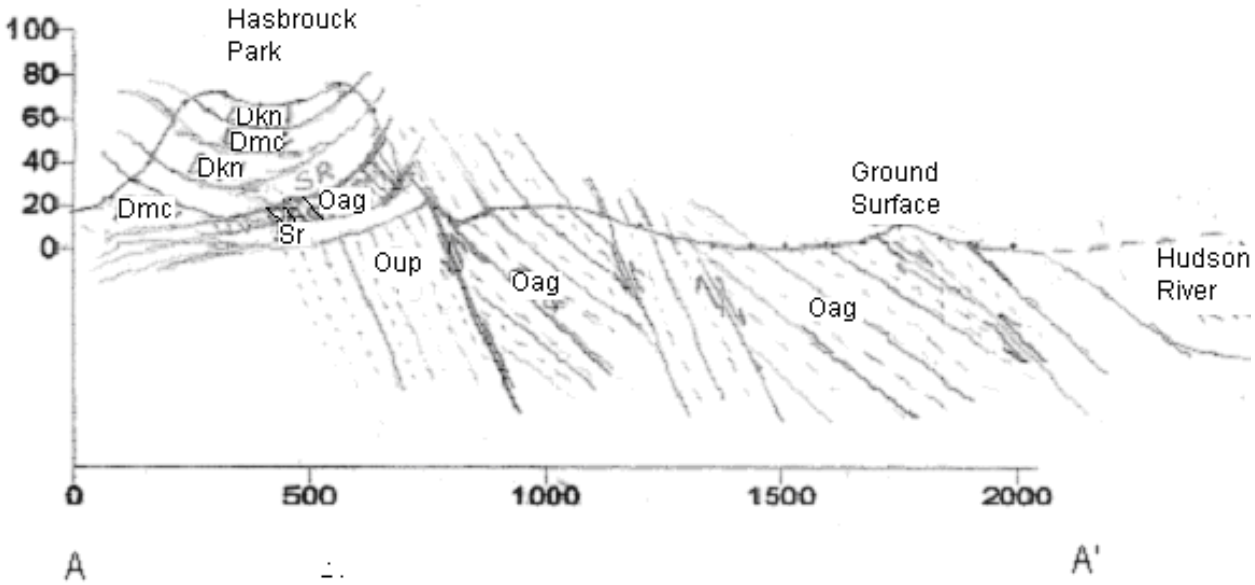

Figure 2. Units = meters. Cross sections x4 vertical exaggeration.

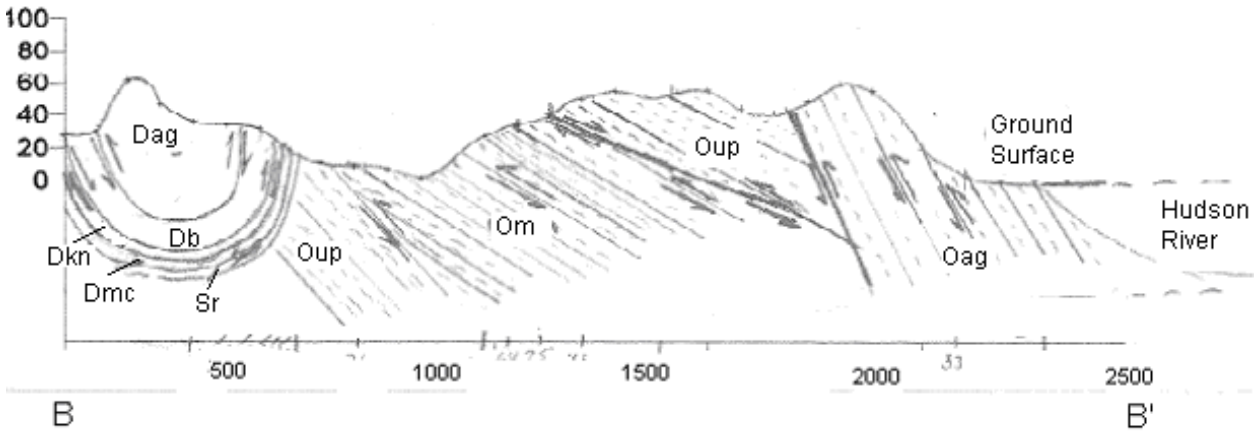

Figure 3. Units = meters. Cross sections x4 vertical exaggeration.

Stop 9 outcrop at back of lot. Facing east and up gradient along Salem St. a contact of Martinsburg with upper Normanskill strata is evident. Facing north, the outcrop continues for 0.76 miles along Millbrook Rd and within the stream gully that runs beside the road. The Martinsburg strata continues until it is truncated by the Rondout Creek. Facing west across the stream gully a steep slope rises, where outcrop of upper Normanskill is found. Leave lot north on Millbrook Dr.

3.87	0.3	North on Millbrook to right at Andorn Rd
4.17	0.1	Pull off road along shoulder at 1st culvert crossing. **Stop 10**. outcrop is northeast stream bank. Turn around.
4.27	0.1	Turn left at Millbrook Dr.
4.37	0.3	Turn left at Marys Ave.
4.67	0.1	Turn left at James St.

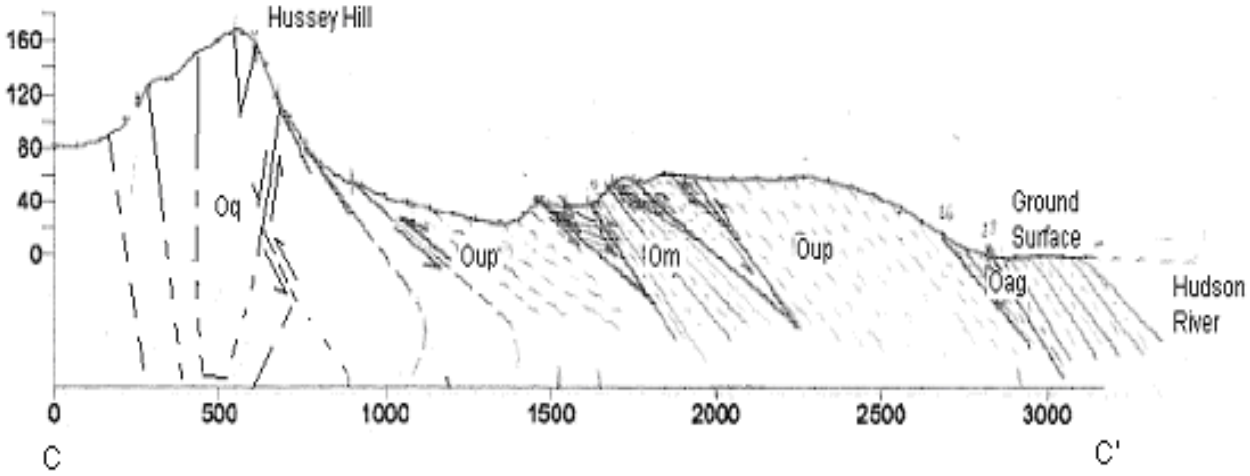

Figure 4. Units = meters. Cross sections x4 vertical exaggeration.

4.77	0.1	Turn left at Florida St.
4.87	0.3	Arrive at gravel lot on left between mobile homes. Walk behind mobile home to the right along ATV path about 200 feet, **Stop 11**. outcrop is low lying and may be difficult to locate in high vegetation. Continue along ATV path 300 feet toward railroad bed. Cross railroad bed and walk north west (left of path) 300 feet. Enter wooded area to right and down embankment. **Stop 12**, outcrop is on south side of large gully. Return to cars and back down hill.
5.17	0.3	Turn right at James St
5.47	0.1	Turn right at Marys Ave.
5.57	0.1	Turn right at Millbrook Dr.
5.67	0.6	Turn right at Salem St.
6.27	0.4	Turn left at Station Rd.
6.67	0.05	Turn into Town Highway Maintenance area. Park in an area clear of any ongoing work or town vehicles. Walk to railroad cut. **Stop 13**. outcrop both sides of railroad.
6.72	0.25	Walk back toward town maintenance area. Cross street opposite garage, to ATV path ascending slope of hill. Along ascent of path, note several outcrops of red clasts along path. Stop 14 outcrop along north south ridge of hill. Return to car.
6.97	0.05	Turn right at Salem St.
7.02	0.9	Turn right at Broadway/ 9W, through the town of Port Ewen. Return to SUNY New Paltz

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