BLACK RIVER AND TRENTON GROUPS, NORTHWESTERN NEW YORK STATE

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INTRODUCTION

Black River and Trenton Group strata in eastern North America record the last phases of deposition on the "Great American Bank" (Sloss, 1963), the long-lived Cambrian through late Ordovician cratonic-passive margin carbonate depositional system. Carbonate deposition ended with tectonically-driven foreland basin deepening, coupled with the influx of terrigenous clastics from Taconic Orogenic source lands to the current east of the continental interior. The change from carbonates to clastics was diachronous across the basin in the New York State region, with Utica Formation muds derived from the orogenic hinterlands progressively flooding the platform from east to west. This facies transition, and the structural framework of basin development linked to collisional mountain-building, were critical to the plate tectonic model elucidated by Bird and Dewey (1970), which was among the very first studies to document the link between plate collision and basin development on ancient continental margins.

The Black River and Trenton Groups have also been central in the historical development of our understanding of the relationships of stratigraphic patterns such as lateral facies changes, stratal continuity and chronostratigraphic correlation, and abrupt vertical contacts, to basin dynamics, including tectonic, eustatic and climate forcing factors. Following the early descriptive work of Vanuxem (1838, 1842) and Hall (1847), subsequent paleontological (Young 1943a, b) and stratigraphic analyses (Kay, 1939, 1960; Fisher, 1962, 1977, for example) documented large-scale facies relationships, biostratigraphic correlations, and established a workable stratigraphic nomenclature. Sedimentological analyses and actualistic facies models were also developed, including, for example, the work of Winder (1960), Textoris (1968), and Walker (1973). Integrated paleoecological-stratigraphic studies (Cameron and Mangion, 1977; Titus and Cameron, 1976; Brookfield, 1988; Brookfield and Brett, 1988), and continued refinement of graptolite and bentonite-based regional correlations (e.g. Mitchell, et al, 1994, 2004) provided important new understandings of the Black River-Trenton-Utica system. Within the last 20 years, revision of the global time scale has resulted in assignment of the Black River-Trenton-Utica sequence to the Upper Ordovician, whereas in older literature, these rocks were considered Middle Ordovician. This sequence is placed within the Caradoc Stage, with deposition spanning the interval 457- 449 million years ago.

In the last two decades, the framework established formed the basis of studies that further documented regional temporal and spatial depositional patterns, and placed these within a modern depositional systems framework. In a series of excellent papers published by Carleton Brett and Gordon Baird, and co-workers (e.g. Baird, et al, 1992; Brett and Baird, 2002, Baird and Brett, 2002; Brett et al, 2004), a modern depositional systems model for the Black River-Trenton-Utica system was developed. Additionally, the fine work of Cornell (2001, 2008, Cornell, et al 2005) deserves special mention, as much of the information in this guidebook article is derived from those studies.

The Black River-Trenton-Utica interval has also received attention as an economic resource system. Important natural gas reservoirs hosted by Black River/Trenton carbonates – so-called hydrothermal dolomite (HTD) reservoirs – were developed in the southern Finger Lakes region of New York State. The origin of these high-permeability systems is linked to burial diagenetic processes, with saline, higher-temperature fluids derived from underlying rocks, associated with basement faulting (Smith, 2006). Some of these reservoirs host exceptionally productive wells; however, there have been few new discoveries in the New York HTD play in the last decade. Application of horizontal well and hydraulic fracturing technology has promoted development of gas and gas-condensate extraction in the Trenton-Utica interval in western Pennsylvania, Ohio, and West Virginia. The Point Pleasant Formation, for example, is age-equivalent to the upper Trenton Group in New York, and has seen significant recent hydrocarbon production in Ohio (Wickstrom, et al, 2012). Organic carbon content and thermal maturation play key roles in determining the production potential for these unconventional resource intervals.

This field guide focuses on the Black River Group and basal Trenton Group exposed in northwestern New York State, in the area south of the St. Lawrence River, and east of Lake Ontario, extending south to the Black River Valley. This guide provides only a brief overview of these units. Interested readers are referred to the bibliography, and the extensive resources available online at http://www.mcz.harvard.edu/Departments/InvertPaleo/Trenton/Intro/trentonintro.htm

GEOLOGIC OVERVIEW

The Black River and Trenton Groups are exposed, in the area of this field trip, in a broad outcrop belt north of the Tug Hill Plateau region, extending to the Lake Ontario Plain and southwestern St. Lawrence Valley. In that area, basal Black River strata rest disconformably on the Lower Ordovician Theresa Formation. To the south-southeast, in the Black River Valley, the outcrop belt narrows, and the Black River Group directly overlies Proterozoic rocks of the Adirondack Massif. Locally, outcrops are found in watercourses and lake shorelines, and in portions of the area where glacial cover is limited. Outcrops tend to form linear terraces that interrupt topography, and road cuts through these terraces provide fresh exposures.

The Upper Ordovician units in the region are generally flat-lying, although localized folding and faulting is present. These structures may be linked to basement faults which were active during and after foreland basin development related to Taconic orogenesis, a pattern which has been well-documented in the Mohawk Valley (Jacobi, et al, 2000; Jacobi and Mitchell, 2002). Importantly, some of these faults are mineralized, and localized dolomitization and vein development associated with faults and minor folds are likely related to fluid movement, perhaps analogous, on a small scale, to the hydrothermal dolomitization seen in the subsurface in southern New York State. Regional joint patterns in the Trenton-Utica interval responded to stress patterns during later stages of the Taconic Orogeny, with later overprinting by Acadian (Devonian) and Alleghanian (Carboniferous-Permian) (Garrand, et al, 2011). Locally, joint patterns reflect stress systems related to basement faults.

PALEOGEOGRAPHIC AND TECTONIC SETTING

The Late Ordovician Black River and Trenton Group carbonate system, and adjacent Utica Formation basin formed a platform-to-foredeep setting on the southern margin of Laurentia during the collision of island arc system(s) that characterized the Taconic Orogeny (Figure 1). At this time, the margin faced south, with New York State at approximately 30^{o} south latitude. The interior of the craton to the north of this area was of generally of very low relief; however there were likely areas where Proterozoic basement and overlying Cambrian-Middle Ordovician sedimentary rocks were exposed in uplifted horsts, and broad upwarps, to the current west and northwest, were also present. During lowstands, terrigenous clastic debris would have been supplied to the platform from these land areas, perhaps by aeolian processes.

A likely modern analogue for this Late Ordovician setting is the north Australia lithospheric plate collision with the Timor Arc (Cornell, 2008). In this scenario, the broad carbonate and mixed-siliciclastic platform offshore of northern Australia represents the ‘Great American Bank’ of the Laurentian continent. Timor is the analogue of the arc system that was actively colliding with the Laurentian margin during the Late Ordovician. The foredeep of the Timor Trough is the analogue to the Utica mud basin that progressively deepened east to west as the collisional margin migrated westward, depressing the continental crust. This basin development (the ‘seafloor inversion’ of Bird and Dewey, 1970) continued as older passive margin sediment and accretionary prism material was overthrust onto the margin, further loading the crust, and providing uplifted source regions for terrigenous clastic sediments. These terrigenous muds and sands eventually prograded across the foreland basin, ending carbonate-dominated deposition, and progressively infilling the basin by the end of Ordovician time.

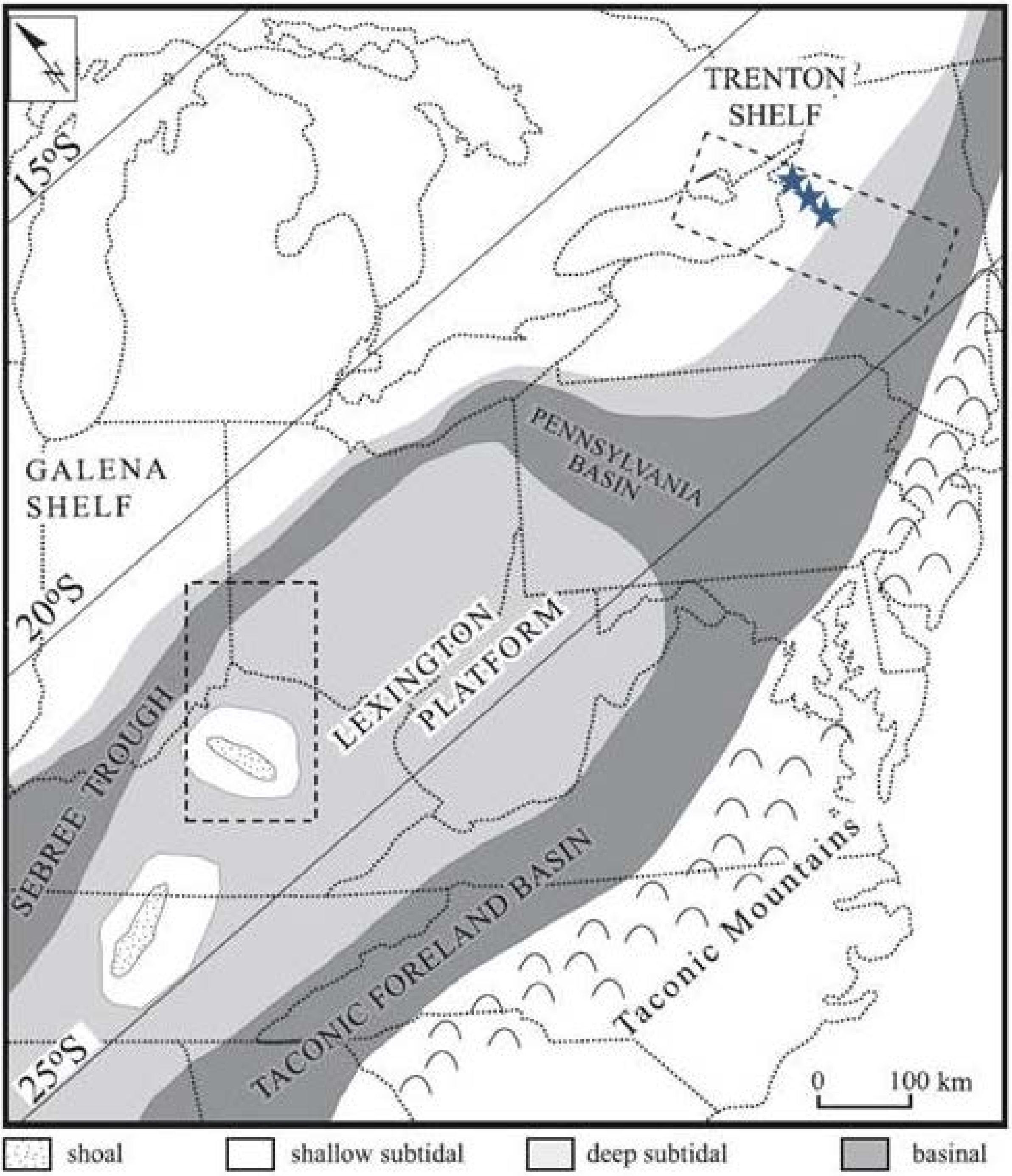


Figure 1. Schematic regional map showing location of the Trenton carbonate shelf relative to the Taconic Foreland Basin. Stars indicate approximate location of sites seen on this field trip. (from Brett, et al, 2004).

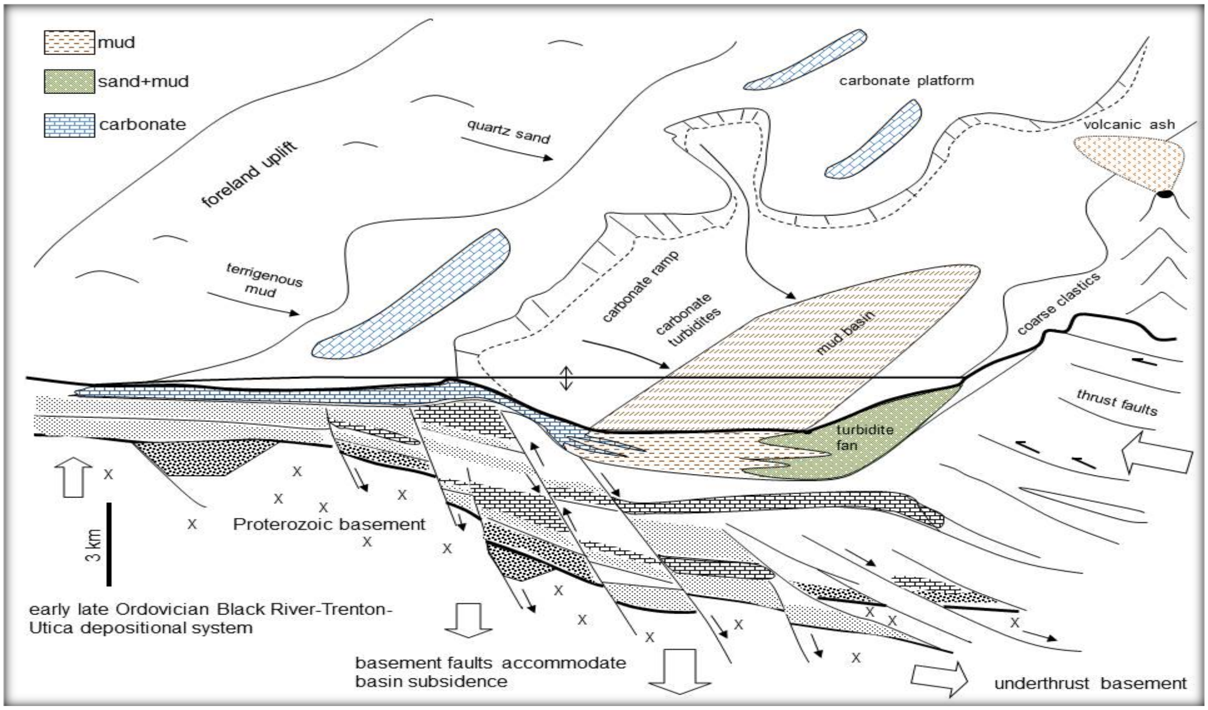
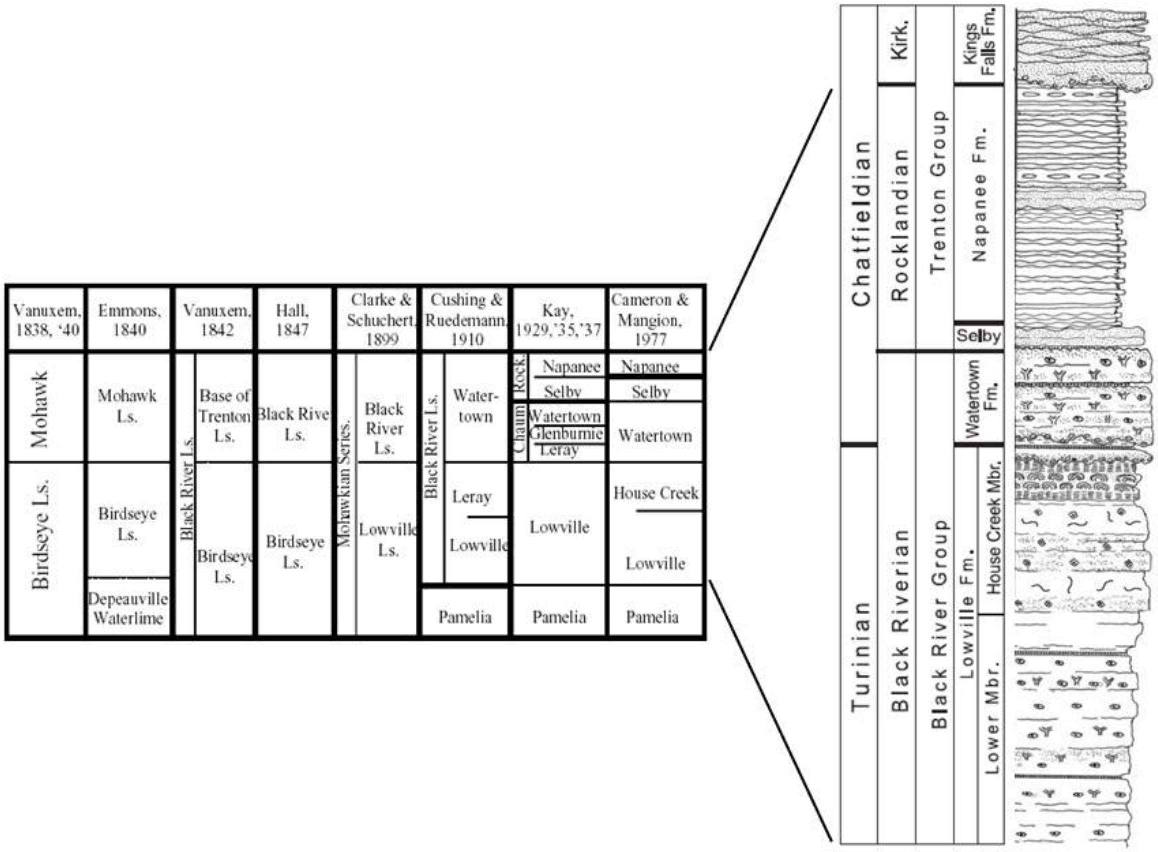


Figure 2. Schematic diagram illustrating facies relationships, collisional tectonics and basin development during the Late Ordovician of eastern Laurentia. Note that minor sea level changes would have significant impact on location of facies belts on the carbonate platform. Overall, basin deepening, and transition from carbonate to terrigenous clastic deposition progressively from east to west (current geography) across the basin. Note that basin subsidence was accommodated by basement faulting, as well as crustal flexure. These normal faults were active during deposition.

BLACK RIVER GROUP STRATIGRAPHY

Pamelia Formation: The Black River Group in the area of this field trip is traditionally divided into three formations. The basal Pamelia Formation, which reaches about 45 meters in thickness in northwestern New York, includes terrigenous sandy and muddy carbonates with purer grey lime mudstones and dolostones. The Pamelia Formation thins to the south in the Black River Valley, and is absent south of Boonville, NY, where basal Lowville Formation beds rest directly on Proterozoic basement.

Lowville Formation: The uppermost Pamelia Formation is overlain by the lower unnamed member of the Lowville Formation. The contact is marked by a widespread unit, the Pittsburgh Quarry Bed, which documents a lowstand event characterized by increased terrigenous clastic input, succeeded by transgressive to highstand facies deposited in intertidal to shallow subtidal settings (Cornell, 2008). The lower Lowville consists of grey lime mudstones and wackestones, plus shaley to massive dolostones and contains a sparse marine fauna, dominated by ostracods and gastropods. The lower member of the Lowville (10-13 meters thick in the area north of the Tug Hill Plateau) is overlain by the House Creek Member, consisting of generally more fossiliferous mudstones, wackestones and packstones. Typical House Creek fossils include the tubular coral *Tetradium*, gastropods, bryozoans, brachiopods, tabulate corals, stromatoporoids and trilobites. Some beds are dominated by in place thickets of colonial *Tetradium* set in fine-grained lime mudstone. The uppermost House Creek Member consists of shaley, dolomitic mudstone with mudcracks and algal structures, termed the Weaver Road Beds (Cornell, 2008) documenting a regressive interval.



Stratigraphic column from Brett, et al, 2004

Figure 3. Stratigraphic nomenclature. Table on left from Cornell, et al (2005). Note the various nomenclature used for the upper Lowville-Chaumont-Watertown interval. In this report, Chaumont Formation is used for the uppermost formation in the Black River Group; it is subdivided into the LeRay, Glenburnie and Watertown Members. The LeRay and Glenburnie Members are well developed only in the northern Black River Valley area, and to the north in southern Ontario. The Black River-Trenton Group contact is the base of the Selby Formation, atop the Watertown Member of the Chaumont Formation.

Chaumont Formation: In the northern Black River Valley, the upper contact of the House Creek Member of the Lowville Formation with the basal Chaumont Formation is marked by ~1 meter of bioclastic grainstone containing crinoids and bryozoans (LeRay Member) overlain by ~1 meter of shaley, nodular limestone (Glenburnie Member). The overlying Watertown Member consists of 2-3 meters of thick bedded to massive bioclastic grainstone/packstone with large tabulate corals, rugose corals, crinoids, stromatoporoids and other typical open marine fauna. The LeRay and Glenburnie are progressively truncated to the east and south of the northern Black River Valley (Cornell, 2008). South of Lowville, NY, the massive Watertown is directly underlain by the House Creek Member of the Lowville Formation. The term Watertown Formation is sometimes used to represent the Chaumont Formation interval in regions where the LeRay and Glenburnie Members are absent. The Watertown Member also thins to the south and east in the southern Black River Valley, and becomes less fossiliferous, changing to muddy peritidal facies with more Lowville-like aspect (Cornell, et al 2005).

TRENTON GROUP STRATIGRAPHY

Selby Formation: In the northern Black River Valley and adjacent southern Ontario, the upper Watertown Member of the Chaumont Formation is overlain by 1-3 meters of dark, irregularly bedded bioclastic packstone to grainstone known as the Selby Formation. This base of the Selby Formation interval is marked by a prominent bentonite in the Lowville, NY area, where the Selby is thinned to 20-50 centimeters. The Selby Formation appears to represent a period of limited sediment accumulation on a marine subtidal platform. Large gastropods and orthocone cephalopods are sometimes found in the Selby.

Napanee Formation: Overlying the Selby Formation is the Napanee Formation, which consists of thin to medium bedded silt-grade lime mudstones with abundant brachiopods and bryozoans. Thin terrigenous mud interbeds are characteristic of the Napanee Formation, and some beds are relatively organic rich and slightly cherty. The Napanee Formation records a major deepening event, with the establishment of deeper shelf to carbonate ramp depositional environments.

Kings Falls Formation: The Napanee Formation is sharply overlain by relatively coarse, medium to thick bedded bioclastic grainstones of the Kings Falls Formation. The basal Kings Falls beds occupy erosional channels cut into the top of the underlying Napanee, with some truncation of upper Napanee strata. Typical Kings Falls Formation structures include large wave rippled beds, coquinas of well-sorted brachiopod and crinoid debris, and laterally lensing grainstone beds. Thin, very dark shale interbeds separate the coarse bioclastic strata. These coarser, wave-dominated facies fine upward into darker, shaley, more organic rich lime mudstones, to be succeeded by coarser bioclastic intervals. A number of these higher order deepening-shallowing intervals are present in the Kings Falls (Cornell, et al 2005).

Upper Trenton Group: The remaining stratigraphic units in the Trenton Group, (Sugar River, Denley, Rust, Steuben and Hillier Formations) will not be seen on this trip. These units comprise a sequence documenting shallowing and deepening intervals on a subtidal carbonate shelf, coupled with variations in terrigenous clastic input. The Hillier Formation is abruptly overlain by the Indian Castle Member of the Utica Formation in the northern Tug Hill Plateau region. Interested readers are referred to the field guide article by Cornell, et al (2005) for additional information and field localities for the upper Trenton Group units.

BURIAL DIAGENESIS

The burial diagenetic history of the Black River-Trenton-Utica sequence has received considerable study in the last two decades, spurred by the interest in hydrocarbon potential of the sequence. Localized hydrothermal dolomitization, related spatially to basement faults and fluid flow, is recognized as the origin of important Trenton-Black River gas reservoirs in the subsurface of southern New York State (Smith, 2006). While early (pre-stylolite) dolomitization of carbonate appears to have been a common process in the Pamelia and Lowville Formations, as we will discuss at Stop 1 today, this process did not lead to significant porosity enhancement. In the Chaumont Formation, and generally in the overlying Trenton Group facies, minor amounts of dolomite are present, and widespread, but rarely form discrete beds. Coarsely ferroan crystalline dolomite is associated with vertical fractures that appear to post-date stylolites, and, as seen at Stop 2, coarse dolomite is often localized in areas of inferred faulting and folding. Horizontal veins of calcite and dolomite, as seen at Stop 5, document fluid-related mineralization developed during layer-parallel thrusting, or during episodes of elevated fluid pressure related to hydrocarbon maturation.

Chert is common in the Watertown Member of the Chaumont Formation, as seen at Stop 3. Chert nodules often contain poorly-preserved sponge spicules, suggesting that biogenic opaline silica from sponges may have served as a source of dissolved silica. Sparse to common certification of carbonate bioclasts is present in most Trenton lithologies, with more abundant chert associated with deeper-water facies. Petrographic studies show that echinoderm bioclasts are most likely to show chert replacement. Chert replacement involved initial precipitation of watery opal-CT, followed by recrystallization to quartz. This recrystallization causes a reduction of solid volume (related to dewatering of opal-CT), and often the chert is finely fractured as a result. In the Trenton Group, hydrocarbon staining often follows the microfractures in chert, suggesting that fluid hydrocarbons were generated during the chert recrystallization.

In the area of this field trip, thermal maturity indicators (vitrinite reflectance, conodont alteration index) and fluid inclusion studies of horizontal veins suggest that the Trenton Group strata reached burial temperatures in excess of 145°C. These rocks are thus overmature in terms of petroleum hydrocarbons, but would like be gas-bearing in the subsurface. Trenton Group strata served as gas reservoirs for small fields in the central and southern Tug Hill region.

ROAD LOG AND STOP DESCRIPTIONS FOR TRIP B-1
(UTM locations in NAD 83, Zone 18T)

Cumulative miles	Miles from last point	Depart from Bonnie Castle Resort Parking Area; follow Holland Street to Church Street, turn left (S) onto Church Street)
0.8	0.8	Intersection with NYS Route 12. Turn right (SW). Continue SW on Route 12 to Clayton, NY, crossing I81
13.1	11.3	Intersection of Rt. 12 and James Street. Turn left (S) on Rt. 12. Continue S on Route 12.
20.1	7.0	Depauville, NY. Roadcuts on Route 12 expose upper Pamelia Formation and lower Lowville Formation. Parking here is difficult and somewhat dangerous. Continue S on Route 12.
26.6	6.5	Stop 1 – Park on right shoulder adjacent to road cut approximately 300 meters SSE of Perch River WMU. Road cuts on both side of road; proceed cautiously to outcrop on E side of Route 12. Be very watchful of traffic.

STOP 1. LOWVILLE FORMATION AT PERCH RIVER GAME MANAGEMENT AREA (UTM 422131 m E, 4881179 m N)

The basal ~2 meters of the outcrop on the NE side of Rt. 12 exposes the contact interval between the uppermost Pamelia Formation and lower Lowville Formation of the Black River Group. This unit, known as the Pittsburgh Quarry Bed (Cornell, et al 2005: Cornell, 2008) is now considered to form the base of the Lowville Formation. It consist of weak-weathering dolomitic mudstone, overlain by thick laminated and occasionally cross-laminated, relatively massive brown to yellow weathering quartz sandy dolostone. Angular to subrounded polycrystalline quartz grains in the massive dolostone approach 4 mm in diameter, and must have been derived from exposed Proterozoic basement nearby. Overlying the Pittsburgh Quarry Bed, shaley dolostones and medium to thick bedded lime mudstones comprise the lower (unnamed) member of Lowville Formation.

Key sedimentary features to observe are cryptalgal/microbial laminations, bentonite (volcanic ash) beds, mudcracks, evaporite (gypsum/anhydrite) mineral casts, and storm event beds represented by mud rip-ups clasts, intraclast breccias, stylolites and solution voids. Grey limestone beds contain vertical "*Phytopsis*" burrows that are backfilled with grainy sediment or occasionally filled with calcite spare cement. Body fossils are relatively rare, but some beds contain abundance ostracodes; scattered gastropod and trilobite debris is present in some beds. The SE end of the outcrop is capped by a massive, tan-weathering laminated dolostone with abundant large mineralized voids. Immediately beneath the dolostone, beds of grey limestone are arrayed in a low amplitude fold with an axial trend approximately N80W, parallel to the highway. The basal beds of the overlying House Creek Member of the Lowville Formation are poorly exposed and partially hidden by brush at the summit of the exposure on the west side of the highway.

Thin (mm-cm thick) dolomite+calcite+pyrite+barite veins trending N70E are present in the limestone, and cm-scale calcite spar-filled voids are common in the dolostone and some limestone beds. The mineralized fractures here are small-scale hydrothermal features that may be related to the dolomitization and related mineralization. Note also that some of the larger voids have dark, hydrocarbon-stained calcite as the void fill.

Examine the limestone - dolostone contact and see if you can trace mineralized fractures into the dolostone. Is the dolomitization here 'early' (preburial – related to Mg-rich brines derived from seawater that had precipitated gypsum) or is the dolomitization related to the later mineralized fractures? What is the relationship between dolomitization and stylolitization? Why is some rock dolomitized whereas other rock remains nearly pure calcite limestone? Was there significant porosity in this rock at any time during its diagenetic history?

Is the folding related to the minor mineralization or a later phenomenon? When during the burial history were hydrocarbons generated?

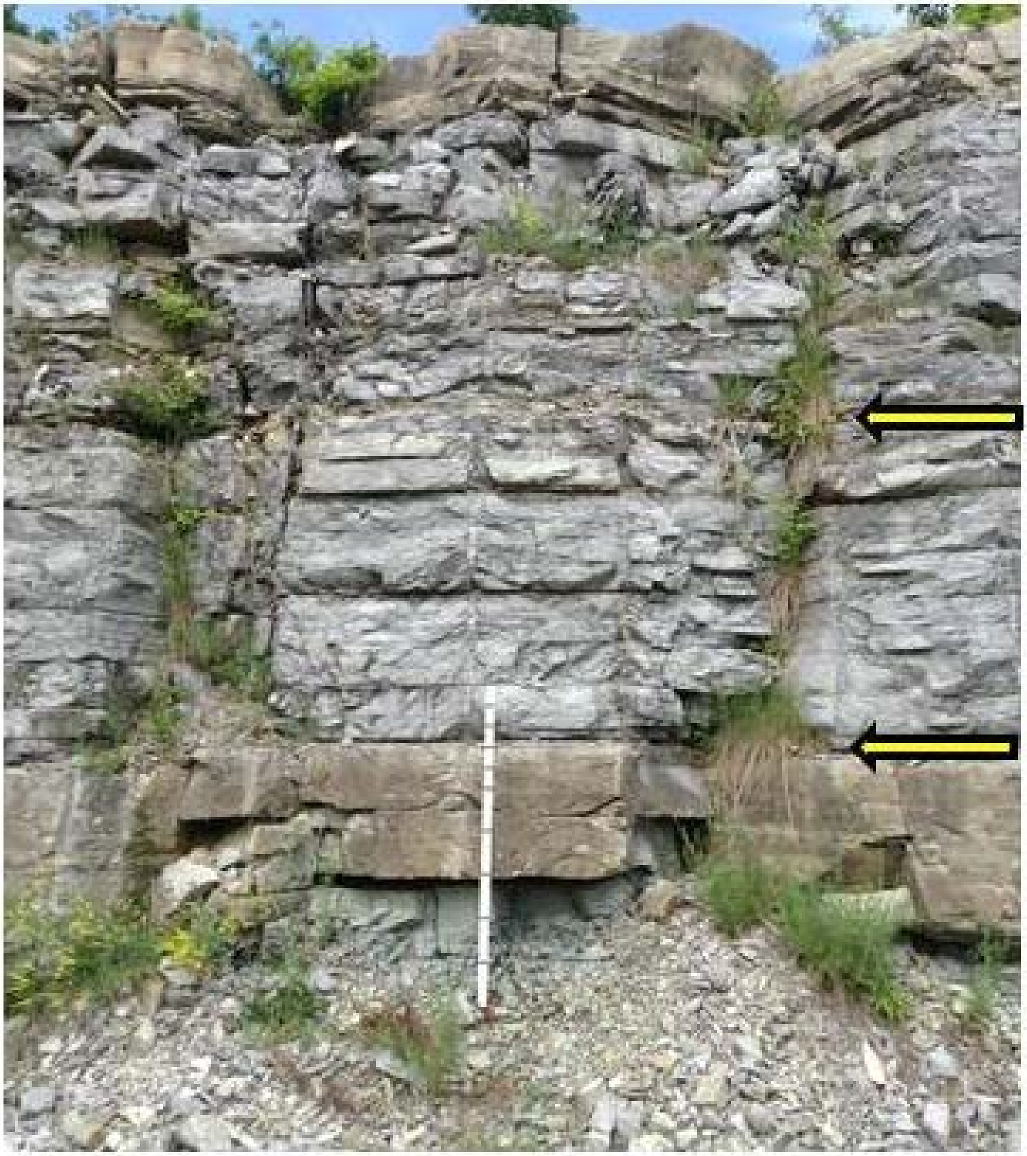


Figure 4. Lower unnamed member of the Lowville Formation at Stop 1. Rod is 1.5 meters, and rests on the Pittsburgh Quarry Bed and overlying lime mudstone. Note the prominent rentrants marking bentonite horizons (arrows). Additional thin shaley partings may represent other ash horizons.

Figure 5. Stop 1. Upper left. Tilted strata in east-dipping limb of minor fold. Upper right. Mm-scale evaporite crystal molds. Tip of hammer gives scale. Lower left. Calcite/hydrocarbon void fill. Lower right. Stylolite with stylocumulate dolomite.

26.9	0.5	Continue SSE on Rt. 12 to intersection with Star Schoolhouse Road. Turn right (SW) onto Star Schoolhouse Road; continue SW
29.8	2.9	Intersection of Star Schoolhouse Road and County Route 54 (Perch River Road). Turn left (S) onto Route 54; continue S.
33.2	3.4	Intersection of County Route 54 and NYS Route 12E in Village of Brownville (East Main Street). Turn left (E) onto Route 12E. Continue E on 12E to Glen Park
34.9	1.7	Stop 2 – Glen Park entrance to parking area for hydroelectric fishing access. Walk to gate entrance, crossing canal. Follow signs to fishing access site, descending path to river level. Watch for poison ivy along path. Be aware that warning sirens provide only 5 minutes before river level rises due to water releases. Be cautious – rocks are slippery.

STOP 2. UPPER LOWVILLE FORMATION AND CHAUMONT FORMATION AT BLACK RIVER GORGE, GLEN PARK, NY. (UTM 423767 m E, 4872115 m N)

The Black River Gorge from Great Bend to Brownville, NY exposes Black River and Trenton Group strata in a series of spectacular narrow river channel walls, waterfalls, and challenging rapids favored by rafters and kayakers. The river has been partially diverted and dammed for hydropower, and here at Glen Park the control structures provide access to riverside exposures along a foot path which descends to the natural channel south of the diversion canal. The strata exposed in the river gorge in the immediate vicinity of the access area include the upper portion of the House Creek Member of the Lowville Formation, including the Weaver Road Beds, the entire Watertown Formation, and the overlying Selby and Nappanee Formations of the basal Trenton Group.

At the river bank where the access trail ends, the outcrops consist of massive to thick-bedded bioclastic packstone/grainstone of the Watertown Member of the Chaumont Formation. The gorge wall across the channel exposes the Weaver Road Beds (House Creek Member of the Lowville Formation), and LeRay and Glenburnie Members of the Chaumont Formation, succeed by the massive Watertown. The Selby and Nappanee Formations of the Trenton Group overlie the Watertown. Looking west, downstream, it appears that the strata are downdropped to the north, although the perspective here is somewhat problematic. This could represent a tight monoclinal fold or high-angle fault. The course of the river here may be in part controlled by this structure. Coarsely crystalline ferroan dolomite in the Watertown here suggests hydrothermal fluids were active, perhaps related to the faulting/folding.

Figure 6. View downstream from fishing access site at Glen Park (Stop 2). The massive bed (upper arrow) is the Watertown Limestone Member of the Chaumont Formation. Note the apparent offset of the Watertown and underlying strata (Glenburnie, LeRay Members, Weaver Road Beds of House Creek Member of the Lowville Formation).

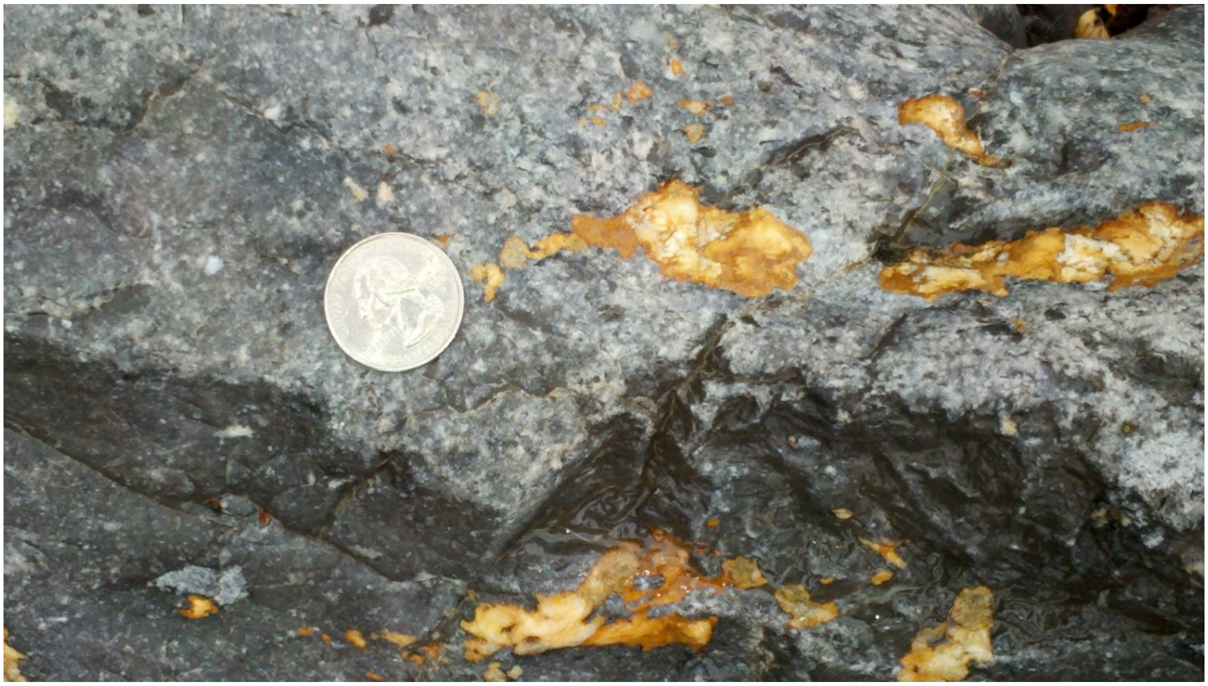


Figure 6. Close-up of Watertown Member bioclastic grainstone/packstone with large voids filled with ferroan dolomite. The proximity to the inferred fault may indicate that hydrothermal fluids were responsible for leaching of carbonate and subsequent precipitation of void-filling dolomite. U.S. quarter provides scale.

		Return to vehicles, exit parking area, turn right (E) on Route 12E, continue E.
35.8	0.9	Intersection of Route 12E with County Route 281 (Teal Drive). Turn left onto Route 281
36.5	0.7	Intersection of Route 281 with NYS Route 12. Turn left (N) onto Route 12. Continue N.
38.4	1.9	Intersection of Route 12 with NYS Route 342. Turn right (E) onto Route 342. Continue E.
45.2	6.8	Intersection of Route 342 with NYS Route 283 in Calcium, NY. Turn right (W) onto Route 283.
45.4	0.2	Stop 3 - Park on shoulder next to road cut on right (N) side of road.

STOP 3. HOUSE CREEK MEMBER OF LOWVILLE FORMATION OVERLAIN BY CHAUMONT FORMATION ON NYS ROUTE 283 NEAR CALCIUM, NY. (UTM 434297 m E, 4874691 m N)

The massive Watertown Member of the Chaumont Formation forms the resistant upper ledge at this road cutting. A prominent reentrant at the base of the Watertown is likely a bentonite horizon, with the underlying House Creek Member of the Lowville Formation forming the base of the exposure. Notably, the LeRay and Glenburnie Members of the Chaumont do not appear to be represented here (compare with Stop 2).

The House Creek Member beds here include typical *Tetradium*-rich wackestone with scattered, poorly-preserved ostracodes, gastropod and trilobite fragments. The moderately weathered faces of the overlying Watertown Member provide a good opportunity to examine this facies in some detail. Good examples of colonial tabulate corals (‘Hexagonaria”) and the small solitary rugose coral *Lambeophyllum* are relatively common. Brachiopods, crinoid plates, bryozoans and rare trilobites are also present. This fauna signals fully open marine conditions with normal salinity and well-oxygenated water.

Typical of the Watertown Member, chert nodules and certified bioclastic material is common in this outcrop. Nodular cherts are generally arrayed in laterally discontinuous horizons, perhaps related to the abundance of original siliceous skeletal material (sponge spicules, radiolarian) or possibly volcanic ash. Biogenic silica and volcanic ash are chemically unstable in seawater, and would provide dissolved silica for certification.

Are some fossil types here more likely to be chert-replaced than others? Use a hand lens to examine the void filling minerals in the tabulate coral fossils. What diagenetic minerals are present?

Figure 7. Stop 3. Massive bedded Watertown Member of the Chaumont Formation overlying ~60 centimeters of upper House Creek Member of Lowville Formation. Note the prominent reentrant (possible bentonite) at the base of the Watertown.

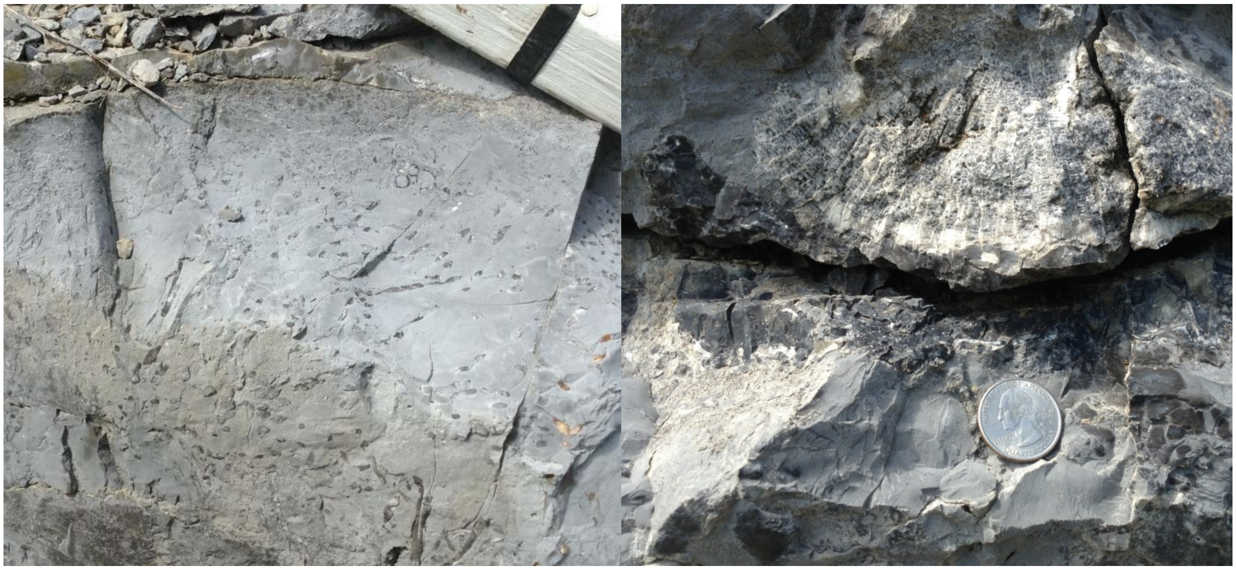


Figure 8. Stop 3. Left. Tetradium wackestone of the upper House Creek Member. Right. Overturned colonial tabulate coral head, partially chert-replaced.

45.7	0.3	Continue W on Route 283 to intersection with Five Corners Road (on right). Turn right (NE). Continue NE on Five Corners Road
46.1	0.4	Intersection with Route 342. Turn right (SE). Continue SE on Route 342
48.0	1.9	
53.3	5.3	Intersection with NYS Route 3. Turn left (E). Continue E on Route 3.
58.6	6.8	Intersection with NYS Route 26 in Great Bend, NY. Turn right (SE) on Route 26. Continue SE on Route 26.
72.8	14.2	West Carthage, NY. Continue SE on Route 26.
73.4	0.6	Intersection with NYS Route 12 in Lowville, NY. Continue SE on Routes 12 and 26.
74.3	0.9	Routes 12 and 26 diverge. Bear left (SE) on Route 12. Continue SE on Route 12.
		Stop 4 - Road cut on right (W) side of highway. Park on right shoulder adjacent to outcrop.

STOP 4. HOUSE CREEK MEMBER OF LOWVILLE FORMATION ON NYS ROUTE 12 NEAR LOWVILLE, NY. (UTM 462063 m E, 4846699 m N

The road cut on the west side of NYS Route 12 is developed in the House Creek Member of the Lowville. Only the uppermost House Creek Member was seen at Stop 3, and here a fuller range of lithologies is exposed. The subtidal facies in this exposure are typical of the House Creek, with grey-weathering *Tetradium* wackestones forming the basal portion of the interval, succeeded by a series of thick beds of bioclastic and intraclastic packstones and grainstones. There are relatively few large whole shell fossils in these units, but abundant fragmental ostracode, trilobite, bryozoan and coral material is present.

Note the wispy dolomite developed in the upper beds. Is the dolomite fabric-selective, that is selectively replacing a particular primary carbonate material, or are these wisps of stylocumulate origin? Carefully examine the intraclastic packstone bed. Is the fabric indicative of simple rip-up clasts, the result of bioturbation, or are these algal ‘clots’?

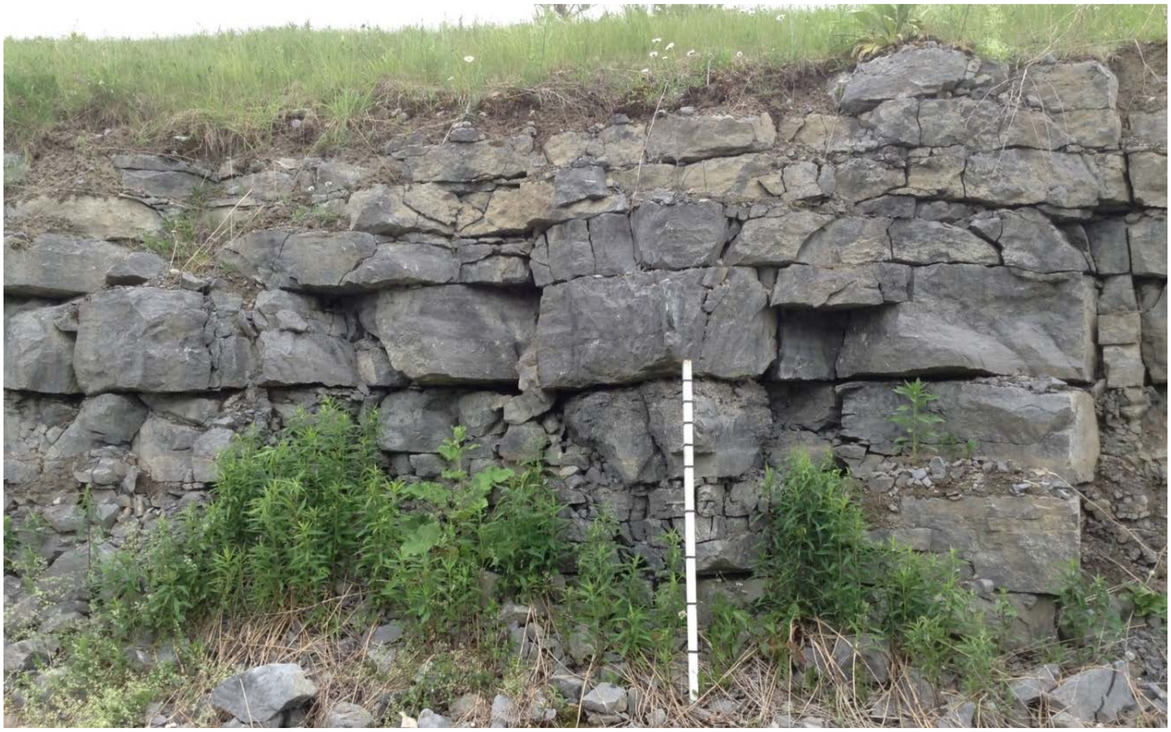


Figure 9. Stop 4. House Creek Member of Lowville Formation at Stop 4. Note the thick bedded character, generally lower terrigenous clastic content (less shaley), compared to the Lower Lowville seen at Stop 1.

Figure 10. Stop 4. Tetradium wackestone. Note wisps of dolomite.

		Continue SE on Route 12.
86.9	12.6	Village of Lyons Falls. Continue SE on Route 12.
93.7	6.8	Stop 5 - Road cut on right (W) side of Route 12. Park on shoulder (caution – broad road shoulder to right may be muddy).
		End of Trip.

STOP 5. KINGS FALLS AND NAPANEE FORMATIONS AT SUGAR RIVER ON NYS ROUTE 12. (UTM - 473796 m E, 4819529 m N)

Figure 11. Stop 5. Note the very sharp (erosional?) contact between deeper shelf Napanee Formation and wave-dominated grainstones of the basal Kings Falls Formation.

The road cuts on Route 12 and adjacent stream sections in the Sugar River at this locality allow observation of more or less continuous exposures of the lower and middle Trenton units. The Barrett Corporation quarry on the west side of Route 12 is developed in the upper Black River Group (upper Lowville and Chaumont Formations). On this trip we will limit our observations to the section exposed north of the Sugar River on the west side of Route 12.

Medium to thin bedded lime mudstones and silty shales of the Napanee Formation are overlain sharply by thick bedded, coarse bioclastic grainstones with thin interbedded shales of the basal Kings Falls Formation. The Napanee mudstones and shales are relatively organic-rich, and represent highstand facies. The succeeding wave and storm-dominated Kings Falls facies overlie a sharp, possibly erosional contact with the Napanee. Coarse , coquina-like brachiopod and crinoid grainstones are characteristic of the Kings Falls Formation. Many bedding surfaces show very fine preservation of brachiopods, crinoids, bryozoans and rare trilobites. Horizontal veins within shale horizons in the Napanee Formation document bed-parallel thrusting, perhaps related to high fluid pressure during burial diagenesis. Fluid inclusion temperatures in vein carbonate suggest burial heating to >145°C.

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