SURVEY OF THE GEOLOGY OF THE NORTHWESTERN ADIRONDACK MOUNTAINS AND BLACK RIVER VALLEY

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INTRODUCTION

The geological history of New York State may be conveniently divided into four major phases, each represented by rocks or sediments or geomorphic features. These major phases include:

- Proterozoic orogenesis (represented primarily by exposed mid-crustal metamorphic and igneous rocks of the Adirondack region)
- Paleozoic events (represented by exposed and deformed sedimentary rocks throughout the state)
- Early Mesozoic crustal extension (represented by basaltic dikes and sills, and by sedimentary rocks in southeastern NY)
- Pleistocene glaciation and subsequent events (represented by sediments and geomorphic features throughout the state).

Exposures in the northwestern Adirondacks and the Black River Valley permit the examination of relics of most of these events, although Mesozoic events are represented poorly at best The current trip is designed as a north-south transect from the Northwest Lowlands, across the Carthage-Colton Mylonite Zone into the Adirondack Highlands at their western margin, up onto the Tug Hill Plateau, and along the Black River Valley (Figures 1 and 2). The Black River Valley, which separates the Tug Hill Plateau from the Adirondack Highlands, provides a wonderful opportunity to examine rocks, sediments, and structural features with ages ranging over a billion years.

PROTEROZOIC OROGENESIS

Proterozoic metamorphic rocks of New York State are all part of the Grenville orogen, which welded together a supercontinent that predated Pangaea. This supercontinent 1.09 billion years ago contained a mountain range to rival the modern Himalayas (Mezger and others, 1991). The collisional events that produced this range occurred over a period 150-200 million years long, and left a complicated record composed primarily of highly deformed metamorphic rocks. The complete story may be deciphered with difficulty, using field relationships, interpretation of rock types, isotopic studies and dating, and chemical petrologic methods.

Various workers, especially Bohlen and others, (1985), and Mezger and others (1991), have shown that metamorphic grade is not equal across the Adirondacks. Rocks exposed in the Northwest Lowlands (Stops 1-6) were metamorphosed at generally slightly lower pressures and temperatures than those of the Adirondack Highlands (Stops 10- 11 and Stops 14-16). Additionally, there are more rocks of sedimentary origin, such as marble (Stops 1 and 2), in the Northwest Lowlands than in the Highlands, and metamorphism in the Lowlands ended before that in the Highlands (Mezger and others, 1991). All of the rocks currently at the surface in the Lowlands and the Highlands were metamorphosed at mid-crustal depths, with nearly 20 km of rock now missing from above the Lowlands, and at least 28 missing from above the Highlands.

The Carthage-Colton Mylonite Zone (CCMZ), a broad (3-5 km wide; Geraghty and others, 1980) belt of intensely deformed gneisses (stops 7-9) separates the Lowlands to the northwest from the Highlands to the southeast. Rocks within the shear zone have penetrative foliations and well developed lineations that plunge to the northwest. The interpretation is that the Lowlands were once over the Highlands, but essentially slid off along the Carthage-Colton

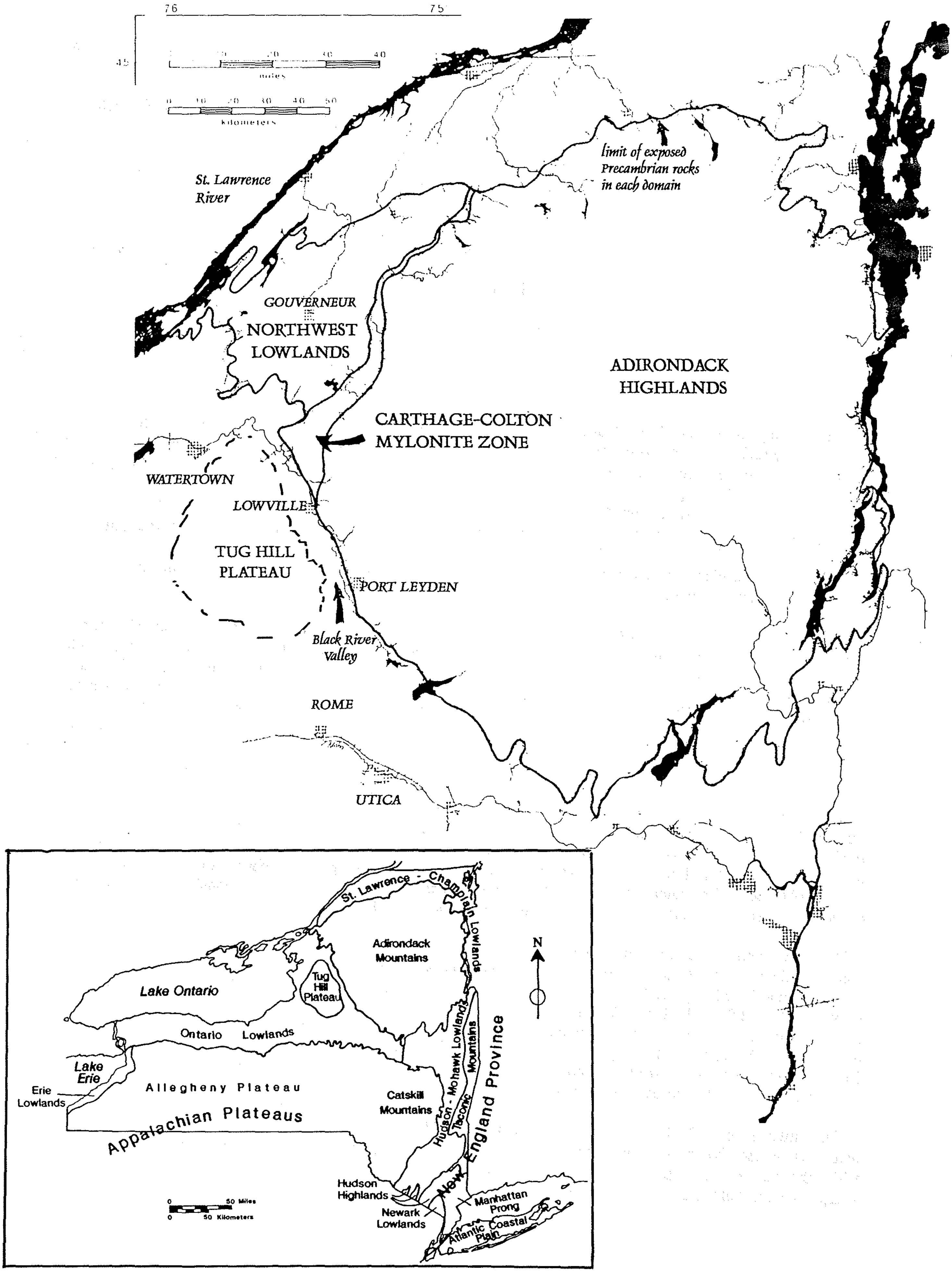
76
75
45
miles
kilometers
St. Lawrence River
limit of exposed Precambrian rocks in each domain
GOUVERNEUR
NORTHWEST LOWLANDS
ADIRONDACK HIGHLANDS
CARTHAGE-COLTON MYLONITE ZONE
WATERTOWN
LOWVILLE
TUG HILL PLATEAU
PORT LEYDEN
Black River Valley
ROME
UTICA
St. Lawrence - Champlain Lowlands
Adirondack Mountains
N
Tug Hill Plateau
Lake Ontario
Ontario Lowlands
Lake Erie
Erie Lowlands
Allegheny Plateau
Appalachian Plateaus
Catskill Mountains
Hudson - Mohawk Lowlands
Taconic Mountains
New England Province
Hudson Highlands
Newark Lowlands
Manhattan Prong
Atlantic Coastal Plain
0 50 Miles
0 50 Kilometers

Figure 1. Map showing major geographic and geologic features of the State of NY. The current field trip runs fro outside Gouverneur south to the village of Port Leyden. Figure is modified from figures in Isachsen and others, 1991.

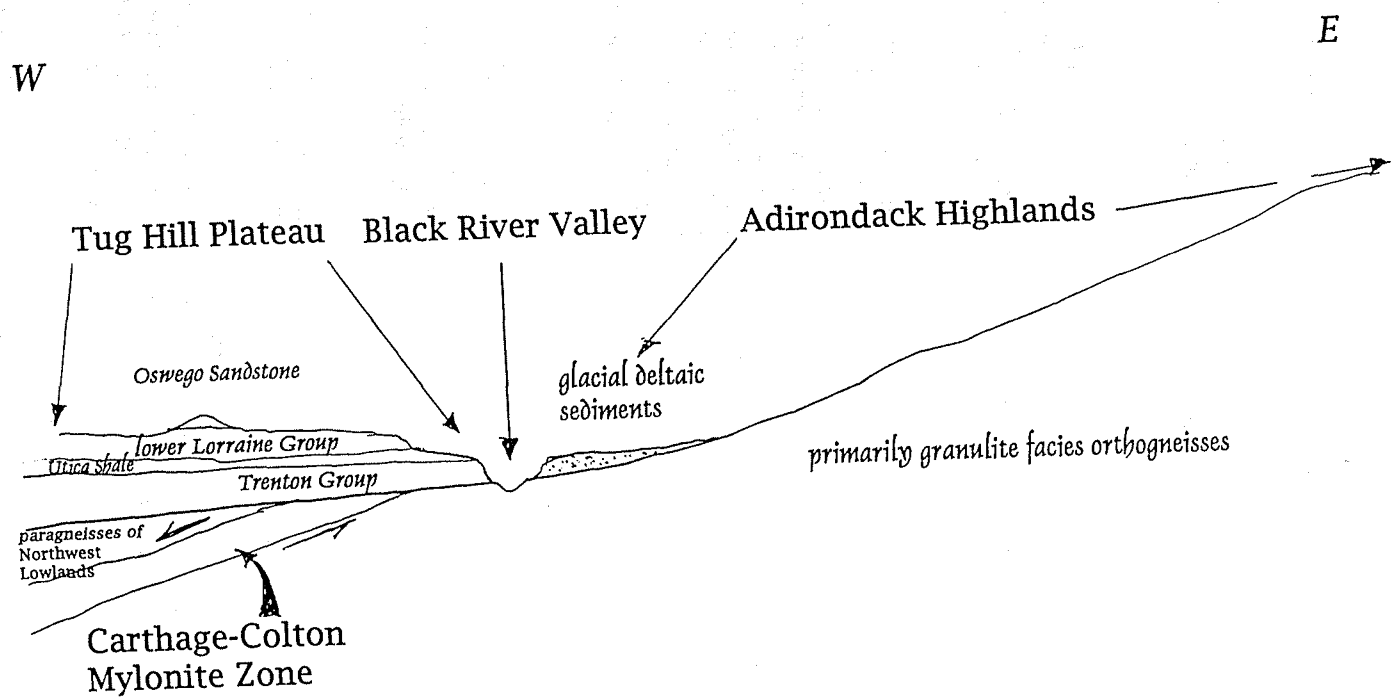

Figure 2 Schematic cross-section from west to east across the Black River Valley, between Lowville and Port Leyden. The figure is meant only to illustrate gross relationships between features and units; vertical scale has been grossly exaggerated, and the horizontal scale is not reliably linear. Note that rocks of the Northwest Lowlands are exposed only well north of the line of section.

Mylonite Zone shortly following high-grade metamorphism. This model accounts for the structural features of the CCMZ, as well as the differences between the Highlands and the Lowlands.

At some time after Grenville orogenesis and before Paleozoic sedimentation, sub vertical basaltic dikes were emplaced in the gneisses, perhaps as a response to the break up of the supercontinent. An example of one of these dikes may be seen at Stop 1.

PALEOZOIC EVENTS

Over much of the Adirondack region, the oldest preserved Paleozoic unit is the Late Cambrian Potsdam sandstone. It is a relatively near-shore passive margin deposit of quartz sandstone. We will see only erosional remnants preserved in sinkholes in Proterozoic marble at Stop 1. Originally more extensive deposits, along with any Early Ordovician sediments were eroded away in Middle Ordovician time (and/or in Mesozoic time), as the seas retreated from the area.

In the Late-Middle and Upper Ordovician, sedimentation resumed over the entire Adirondack region (Rickard, 1969; 1973). In the Black River Valley, limestones of the Black River Group were laid down directly onto exposed Precambrian granitic gneisses. The unconformity is well exposed in Roaring Brook, at Stop 12. The unit here is conglomeratic, with pebbles of crystalline rocks in a sandy matrix. The depositional environment of the Black River Group is thought to be shallow to intertidal. The Trenton Group limestones were deposited over the Black River Group. Deeper water conditions followed, in response to loading of the eastern edge of proto-North America at the onset of the Taconic Orogeny. Thick (up to hundreds of meters), black, sulfidic, shales of the Utica Formation were deposited. The contact between the Trenton and the Utica is sharp. In the Black River Valley and Tug Hill Plateau region, the Utica Shale in turn grades upward into the Lorraine Group, a stack of siltstones and shales, beautifully exposed in Whetstone Gulf. The siliciclastic nature of this unit reflects filling in of the basin and westward transgression of the incipient Queenston delta.

MESOZOIC EVENTS

While the Mesozoic rifting, intrusion, and deposition seen elsewhere in New York State had little effect on the western Adirondacks and the Black River Valley, the terrain was still affected by Mesozoic events. Recent work by Roden-Tice and others (2000) proves that denudation of the Adirondack Mountains occurred in Mesozoic time. Apatite fission-track ages for the Northwest Lowlands range from 135-126 Ma, slightly younger than those from the High Peaks region of the Highlands.

The actual age of the current domal form of the Adirondack Mountains, and the dips on the unconformity which overlies them, may be still younger. According to Isachsen (1975, 1981), doming is Tertiary.

GLACIAL EVENTS

Nearly two million years ago the northern hemisphere underwent an Ice Age. There is evidence in North America for four major pulses of ice advance. In New York most of the features we see are related to the last ice advance, called the Wisconsin. By about 20,000 years ago nearly all of New York (although probably not the Adirondack Highlands, which were elevated by then, and were affected by valley glaciers) was under the Wisconsin ice sheet. About 10, 000 years ago, the ice retreated again.

The remains of this ice sheet in the Northwest Lowlands consist of polished and striated rock surfaces, and widespread, relatively small sand and gravel deposits. In the Black River Valley, there are deltas of sediment shed off the Highlands into proglacial Lake Port Leyden, at a time when ice blocked both the Mohawk Valley and the St. Lawrence Seaway.

ROAD LOG FOR GEOLOGY OF THE NORTHWESTERN ADIRONDACK MOUNTAINS AND BLACK RIVER VALLEY

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Parking Lot of Day's Inn, Watertown on Rte.3. Turn east on Rte. 3.

1.3	1.3	Turn north on Rte. 11.
37.0	35.7	Pass McDonalds on Rte. 11, village of Gouverneur.
37.1	0.1	Turn north (left) on Rock Island Street.
41.4	4.3	STOP 1, Roadcuts on either side of Rock Island Road, immediately south of bridge over Oswegatchie River.

STOP 1. ROCK ISLAND ROADCUT

This large roadcut is one of the best places to observe the contact between Proterozoic marbles of the Adirondack lowlands and the Cambrian Potsdam sandstone. The marbles were highly deformed, intruded by basalt dikes (also exposed here), and deeply eroded. The Potsdam sandstone here was apparently deposited into sinkholes formed on the pitted marble surface. A clear and detailed description of this outcrop is provided in Van Diver (1976).

Turn around and head back south on Rock Island Road

45.65	4.3	Turn south on Rte 11, village of Gouverneur.
45.95	0.3	Turn south on Route 58, toward Fowler.
47.4	1.45	STOP 2. Large white roadcut at intersection with Hailesboro entry road

STOP 2 HAILESBORO ENTRY ROAD ROADCUT

This outcrop exposes white marble of the Northwest Lowlands, enclosing trains of dark amphibolite blocks. The rocks are complexly folded. According to Shoenberg (1974), the sequence of events that accounts for the features of this outcrop is:

foliation formation
folding
intrusion of basalt as dikes and sills
further folding and metamorphism, converting basalt to amphibolite, and folding and dismembering the dikes

Marble and basalt have considerably different mechanical properties, accounting for the difference in behavior during deformation; marble can flow at conditions that cause silicate materials to break.

There is also abundant evidence for chemical interaction between the two rock types. The grain-size in the marble increases toward the dikes, and minerals such as tourmaline and feldspar, absent elsewhere, occur there.

Continue south on Rte. 58

51.15	1.0	STOP 3. Large dark roadcut on either side of Rte. 58 at intersection of Poplar Hill Rd.

STOP 3. Popple Hill Gneiss

The Popple Hill Gneiss is a widespread unit in the Northwest Lowlands. It is locally migmatitic formation extensively studied by Carl (1988). This exposure on Rte 58 is the best example of the migmatitic phase of the unit. Here the dominant rock type is a dark gray quartzofeldspathic gneiss with biotite; subordinate rock types include concordant amphibolite layers, and leucosomes. As at Stop 2, the amphibolites as well as the leucosomes behaved differently from the surrounding gneiss and became folded and boudinaged in this case. Structural relationships demonstrate that the leucosomes formed in situ before or during major folding events.

Based on extensive chemical analysis, Carl (1988) proposed that the Popple Hill Gneiss originated as a dacitic volcanic rock.

Continue south on Rte. 58

52.1	1.05	Turn south on Rte. 812 toward Harrisville
53.4	1.3	Pass Gouverneur Talc mines.
62.2	8.8	Junction of Rte 3 and 812, turn west, staying on both 3 and 812.
66.7	4.5	Turn south on Rte. 812
69.0	2.3	STOP 4. Small brown outcrops, either side of 812

STOP 4 Deformed anorthosite in Carthage-Colton Mylonite Zone

The rock here is a brown-weathering, pink, very coarse-grained gneiss with large bluish-gray relict phenocrysts of plagioclase. The pink mineral which resembles K-feldspar is also plagioclase, colored pink for the same reason that K-feldspar appears pink: its cleavages are decorated by small inclusions of earthy hematite. Foliation is defined by parallel alignment of wisps and stringers of dark minerals. Also parallel to this crude layering are large somewhat irregular oxide schlieren.

70.5	1.5	STOP 5. Small outcrops either side of 812.

STOP 5. Mylonitic Gneisses of the Carthage-Colton Mylonite Zone

In these outcrops, mineral lineations are so well developed that lineation can easily be mistaken for trace of foliation. Lineation is defined by rods of quartz and K-feldspar, the latter occasionally forming rounded porphyroclasts. It is this moderately plunging, NNE-bearing lineation that is thought to represent the direction of tectonic transport, which slid lower-temperature rocks from the southeast and higher in the crust, down and to the northwest, and left them juxtaposed against deeper, higher-temperature rocks.

Continue south on Rte. 812.

73.2	2.7	STOP 6. Pink outcrops west side of Rte. 812.

STOP 6 Coarse-grained massive granitic gneiss.

The pervasive foliation and lineation present in rocks exposed along Rte 812 for 5 miles to the north is simply not present here. The rocks here are much coarser grained, and clearly have not experienced mylonitization in the CCMZ. You have crossed the southeastern edge of the CCMZ and are looking at rocks of the Adirondack Highlands.

76.9	3.7	Village of Indian River. Continue south on Rte. 812
82.9	6	Village of Croghan. Continue south on Rte. 812.
84.7	1.8	STOP 7. Long low pink and gray roadcut on either side of Rte. 812

STOP 7. Granitic gneiss and amphibolite of the Adirondack Highlands.

Rocks southeast and under the CCMZ are predominantly orthogneisses, and are at higher metamorphic grade than those northwest and above the CCMZ. The difference in grade is expressed primarily in the mineral chemistry and assemblages. Foliation here has fairly low dip and is defined primarily by the presence of amphibolite layers in coarse-grained pink granitic gneiss. While the rocks are not part of the CCMZ, they are still intensely deformed and contain lots of evidence for shearing, including: offset dikes, refolded folds, and augen feldspars, and local truncation of layering within the amphibolite against the granite.

There is fairly nice glacial polish with striae on the tops of outcrops on the east side of the road. Climb to top of outcrops on east side of road, and look to the east. There is a good-sized sand and gravel quarry, in a glacial deposit.

Continue south or Rte. 812.

88.2	3.5	Village of N. Bremen. Continue south on Rte. 812.
92.1	3.9	Large quarry on east side of Rte. 812. Unconformity with Precambrian rocks is at base of hill
93.2	1.1	Lowville. Stay on Rte 812. Turn south at the light where Rte. 26 intersects Rte. 812.
94.2	0.9	Intersection of Rte 12 with Rte. 26. Bear west, staying on Rte. 26.
94.3	0.1	McDonalds. Stop for drinks.
95.1	1.4	If weather is clear, glance out to east, across Black River Valley.
99.9	4.3	At sign for Whetstone Gulf State Park, turn to northwest onto West Road.
102.7	2.1	Turn west onto Corrigan Hill Road, which is unpaved.
104.1	2.3	STOP 8. Immediately beyond intersection, pull into grassy area and park. Cross Corrigan Hill to marked trailhead, and follow trail to brink of Whetstone Gulf

STOP 8. Overlook of Mid- to Late Ordovician Utica Shale and Lorraine Group in Whetstone Gulf

From this point at the brink of Whetstone Gulf, you can see a stack of late-middle to late Ordovician rocks, with the Utica shale at the bottom grading up into finely bedded shales and siltstones of the Lorraine Group on the top. These rocks represent early sediments shed from the Taconic Orogen 150 km to the east. Also, note the fracture sets shown in the canyon walls.

Note the large Pleistocene glacial erratics perched on the rim.

Return to cars. Turn around and head back down Corrigan Hill Rd.

105.6	1.5	STOP 9. Pull off to right as far as possible. Overlook of Black River Valley

STOP 9. Black River Valley Overlook

If the weather is clear, pull as far as possible of the road. Look out to east over the Black River Valley. You are standing on the Tug Hill escarpment. The valley below marks the boundary between Tug Hill and the western Adirondack Highlands. The Tug Hill escarpment consists of two distinct benches. The one on which you are standing is underlain by sandstones and siltstones of the upper Lorraine Group. The lower bench, marked by numerous dairy farms below you, is underlain by the Trenton and Black River Groups (limestones). Low in the valley and on the far (east) side, you may be able to distinguish a relatively level surface, created by the tops of deltas shed into glacial lake Port Leyden, during the Wisconsin deglaciation. Better views may be had further south, between Lyons Falls and Boonville. Beyond these and to the far horizon, metamorphic rocks of the Adirondack Highlands are exposed.

Continue down Corrigan Hill Rd.

106.2	0.6	STOP 10. Small borrow pit on south side of Corrigan Hill Rd.

STOP 10. Fossils in Utica Shale.

By gently prying open bedding surfaces, many samples of fossils may be collected. Fragments of trilobites, and pyritized cephalopods are common, whereas graptolites are rare.

Continue down Corrigan Hill Road

106.4	0.2	Turn south on West Rd.
106.8	0.7	Turn east on Lee Road.
107.5	0.4	Cross Rte. 26 on Lee Road.
108.5	1.0	Bear left at fork, staying on Lee Road.
109.1	0.7	Cross Glendale Road.
110.5	1.2	Cross Rte. 12 onto Cannan Road, at enormous dairy operation.
110.7	0.2	STOP 11. Pull over immediately before small bridge.

STOP 11. Unconformity between middle Ordovician sedimentary rocks and pink quartz-feldspar gneisses of Adirondack Highlands.

If the creek is high, then this outcrop is not accessible. If the creek is low, drop down and walk upstream until you encounter nearly flat-lying sedimentary rock lying directly on top of pink quartz-feldspar gneiss in which the foliation dips steeply. Notice the pebbles of gneiss enclosed in the basal sedimentary rocks. These sedimentary rocks are part of the middle Ordovician Black River Group (rather than the upper Cambrian Potsdam sandstone as at Stop 1), which means that the difference in age between the rocks above and below the unconformity is roughly 600 million years. Notice the evidence for spheroidal weathering in the pink quartz-feldspar gneisses directly below the unconformity. The evidence decreases downstream (i.e. farther structurally below the unconformity),. Consequently, we interpret this to be the result of middle Ordovician chemical weathering.

Continue north on Cannan Road.

111	0.25	Take first available left turn, onto unmarked road (Williams Road intersects on right)
111.1	0.1	Intersection with Rte 12. Turn south on Rte. 12
121	10.1	Turn left onto ramp for Rte 12D, at Stewarts Shop, toward village of Lyons Falls. Proceed into village.
121.2	0.2	Turn right on McAlpine.St.
121.4	0.3	Turn right again, following signs to Lyon's Falls. Pass paper mill
121.8	0.4	Turn left on Lyonsdale Rd. Cross bridge over Black River.
124.3	2.5	Turn left into Ager's Falls Park. Bear left.
124.5	0.2	STOP 12. Parking lot below Ager's Falls.

STOP 12. Dated locality of Lyon Mountain Gneiss at Ager's Falls.

The origin of the rock exposed at Ager's Falls Park is somewhat controversial. The country rock is a pink, medium-grained and equigranular granitic rock, which is host to abundant quartz-sillimanite "nodules", veins, and stringers. These elongate bodies have a set of preferred orientations that make the rock appear to have a tectonic foliation. It was mapped as metapelite by Florence and others (1995). However, the interpretation of Orrell and McLelland (1996), following arguments originally made by Vernon (1979) is that the rock formed as a granitic melt which created its own hydrothermal system as it crystallized, such that fluid flow was channelized. In areas of high flow, alkalis were leached away, leaving behind the relatively immobile silica and alumina, as quartz and sillimanite. Orrell and McLelland (1996) state that the origin of the quartz-sillimanite features of the rock are thus metasomatic rather than tectonic and the rock is therefore interpreted as undeformed and post-tectonic, and McLelland includes the rock with the Lyon Mountain granitic gneiss of the northern and eastern Adirondacks. Evidence in support of an igneous origin for this rock is provided by zircons, which are typically finely oscillatory zoned.

A sample from Ager's Falls has been dated, with a concordant single zircon grain giving an age of 1031 +/- 8 Ma (Orrell and McLelland, 1996).

Turn around and head back out of park.

124.7	0.2	Turn east on Lyonsdale Road.
125.1	0.4	Turn north, cross Lowdale Road bridges.
125.3	0.2	Stop 13. Pull over and park immediately after bridge.

STOP 13 Dated locality of undeformed pegmatite cross cutting Lyon Mountain Granite

Leave cars and head south across the northern bridge, and drop down into the Moose River bed on the western, downstream side. Staying fairly close to road, locate roughly one-half meter wide, steeply-dipping, undeformed white pegmatite dike, trending N35W. The dike is zoned, with quartz-albite rims and granitic, magnetite-rich interiors. Sillimanite is an accessory phase. Such undeformed pegmatites are generally rare in the Adirondacks. This particular example cross-cuts the Lyon Mountain Granite with abundant quartz-sillimanite nodules, as at Ager's Falls. This dike has been dated (Orrell and McLelland, 1996). Zircons give a well-defined upper intercept of 1034 +/- 8 Ma. Monazites give a well-defined intercept age of 1027 +/- 8 Ma. Because of the undeformed and hence post-tectonic character of the dike, this is considered to represent a minimum age for the end of Grenville orogenesis in the region.

Turn around and recross bridges.

125.5	0.2	Turn east on Lyonsdale Road.
125.9	0.35	Bear east at fork, onto Marmon Road
128.8	2.9	Turn west, following signs into village of Port Leyden
129.3	0.5	Turn north on Lincoln Road, just past the school.
129.8	0.5	Turn right on North Street
129.9	0.1	STOP 14. Pull into grassy area in front of Cataldo Electric and park.

STOP 14 Nelsonite ore body. Note! There is both poison ivy and barbed wire in the woods. Proceed only with extreme caution!

Cross North Street, heading south and east, to outcrop visible from parking area. This gray rock is a pelitic gneiss with the assemblage quartz + plagioclase + garnet + sillimanite + biotite. Walk over the outcrop and down to the left. Proceed for about 40 meters downhill toward a few prospect pits and ultimately toward the water filled mineshaft at the base of the hill. The prospect pits are in weathered exposures of the nelsonite; fresh samples can be collected near the mineshaft. The nelsonite is described and interpreted by Darling and Florence (1995). It is a rare igneous rock commonly associated with rocks of the anorthosite-suite. Its mineralogy is dominated by fine-grained magnetite, fluorapatite, and ilmenite. Pyrite and pyrrhotite occur as well. Chlorite, pyrite and biotite are abundant near contacts with the country rock. Darling and Florence (1995) suggest the occurrence of this rock indicates anorthosite-suite rocks were once present in the western Adirondack Highlands.

REFERENCES CITED

Bohlen, S.R., Valley, J.W., and Essene, E.J., 1985. Metamorphism in the Adirondacks. I. Petrology, pressure and temperature. Journal of Petrology, 26, 971-992.

Carl, J.D., 1988. Popple Hill Gneiss as dacite volcanics: A geochemical study of mesosome and leucosome, northwest Adirondacks, New York. Geological Society of America Bulletin, 100, 841-849.

Darling, R.S., and Florence, F.P., 1995, Apatite light rare earth element chemistry of the Port Leyden nelsonite, Adirondack Highlands, New York: Implications for the origin of nelsonite in anorthosite-suite rocks: Economic Geology, v. 90, p. 964-968.

Florence, F., Darling, R.S., and Orrell, S.E., 1995. Moderate Pressure Metamorphism and Anatexis due to Anorthosite Intrusion, Western Adirondack Highlands, New York. Contr. Min. Pet., 121, 424-436.

Geraghty, E.P., Isachsen, Y.W., and Wright, S.F., 1980. Extent and character of the Carthage-Colton Mylonite zone, northwest Adirondacks, New York: Nuclear Regulatory Commission, NUREG/CR-1865, 83 p.

Isachsen, Y.W., 1975. Possible evidence for contemporary doming of the Adirondack Mountains, New York, and suggested implications for regional tetonics and seismicity. Tectonophysics, 29, 169-181.

Isachsen, Y.W., 1981. Contemporary doming of the Adirondack Mountains: Further evidence from releveling. Tectonophysics, 71, 95-96.

Isachsen, Y.W., Landing, E., Lauber, J.M., Rickard, L.V., and Rogers, W.B., 1991. Geology of New York: A Simplified Account. NYS Museum/Geological Survey, Educational Leaflet No. 28.

Mezger, K., Rawnsley, C., M., Bohlen, S.R., and Hanson, G.N., 1991. U-Pb garnet, sphene, monazite and rutile ages: Implications for the duration of high grade metamorphism and cooling histories, Adirondack Mountains, New York. Journal of Geology, 99, 415-428.

Mezger, K, van der Pluijm, B.A., Essene, E.J., and Halliday, A. N., 1991. Synorogenic Collapse: A perspective from the middle crust, the Proterozoic Grenville Orogen. Science, 254, 695-698.

Mezger, K, van der Pluijm, B.A., Essene, E.J., and Halliday, A. N., 1992. The Carthage-Colton Mylonite Zone (Adirondack Mountains, New York): The site of a Cryptic suture in the Grenville Orogen? Journal of Geology, 100, 630-638.

Orrell, S.E., and McLelland, J.M., 1996. New Single Grain zircon and Monazite U-Pb Ages for Lyon Mt. Gneiss, Western Adirondack Highlands, and the End of the Ottawan Orogeny. Geol. Soc. Amer., 1996 Northeast Sectional Meeting.

RIckard, L.V., 1969. Stratigraphy of the Upper Silurian Salina Group, New York, Pennsylvania, Ohio, and Ontario. N.Y. State Museum and Sci. Service Map and Chart Series 12, 57p.

RIckard, L.V., 1973. Stratigraphy and structure of the subsurface Cambrian and Ordovician carbonates of New York.. N.Y. State Museum and Sci. Service Map and Chart Series 18, 26p.

Roden-Tice, M.K., Tice, S.J., Schofield, I.S., 2000. Evidence for differential unroofing in the Adirondack Mountains, New York State, determined by apatite fission-track thermochronology. Journal of Geology, 108(2), 155-169.

Shoenberg, M., 1974. Structure and Stratigraphy of the Adirondack Lowlands.near Gouverneur, New York.. Cornell University M.S. Thesis.

Van Diver, B., 1976. Rocks and Routes of the North Country. W.F. Humphrey Press, Geneva, NY, 204 p.

Vernon, R.H., 1979. Formation of Late Sillimanite by Hydrogen Metasomatism (Base-Leaching) in Some High-Grade Gneisses. Lithos, 12, 143-152.