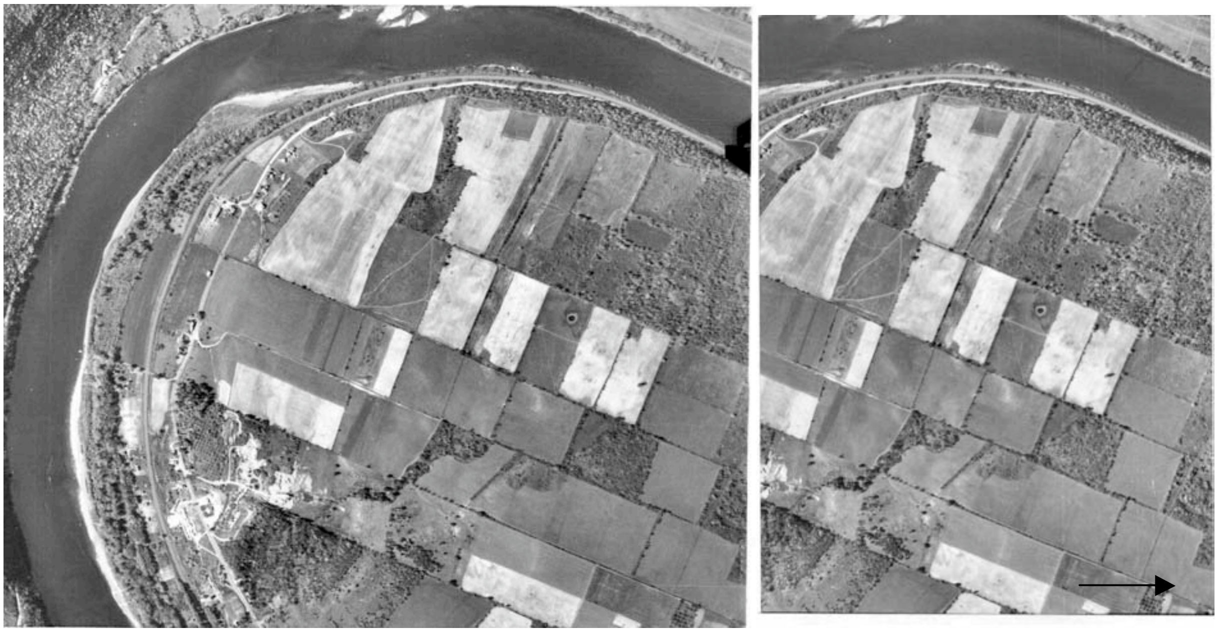

Figure 59. Stereo pair of the moraine just above the outwash terrace in the Susquehanna valley. North is to the right.

		Leave Stop 10 and retrace route back US 6 at Tunkhannock.
0.2	50.8	Turn LEFT onto Ironwood Street, go around 90^0 turn onto Birch Drive, cross terrace tread, and then turn right to descend terrace riser.
0.5	51.3	Turn RIGHT onto PA 92.
2.0	53.3	Turn RIGHT at traffic light onto US 6 east and immediately cross Tunkhannock Creek.
0.8	54.1	Descend the slope and cross Tunkhannock Creek.
0.3	54.4	On left is the Shadowbrook Inn & Resort and Perkins restaurant.
0.4	54.8	Cross Tunkhannock Creek again.
0.2	55.0	Esker on right.
0.7	55.7	Turn LEFT on PA 92 and retrace route to Nicholson.
3.2	58.9	Enter East Lemon and recross the tornado track.
1.9	60.8	On right is the outwash terrace under the power line pictured earlier (Figure 51).
1.4	62.2	On right is the stone house with the water fall behind it.
1.1	63.3	Welcome to Nicholson sign on right.
1.7	65.0	Turn LEFT following signs to US 11 south.
0.1	65.1	Bear LEFT to Stop sign. Turn LEFT onto US 11 south.
0.2	65.3	Cross Tunkhannock Creek, Tunkhannock Viaduct now on your left.
0.1	65.4	Turn RIGHT into parking area behind guide rails. Disembark.

Stop 11. Tunkhannock Viaduct

Leader: Jon D. Inners and William S. Young.

By way of introduction, the Historical Marker on the opposite side of the highway reads:

> *TUNKHANNOCK VIADUCT.*
>
> *This reinforced concrete structure was the largest of its kind ever built when it went into service in 1915 on the Delaware, Lackawanna & Western Railroad. The bridge, 2,375 feet long and rising 240 feet above Tunkhannock Creek, was the focal point of a 39.6 mile relocation between Clarks Summit and Hallstead. The novelist Theodore Dreiser called this viaduct "one of the true wonders of the World."*

This short paragraph says quite a bit--and perhaps more than enough—as this most monumental of structures needs no explanation in order to take away the breathe of a first-time observer—or even to continually astound someone who sees it every day (Figure 62)!

Figure 60. STOP 11 Location and Geologic map of the region around the Tunkhannock Viaduct (large arrow). Note the numerous deep cuts and fills—as well as the Nicholson (Factoryville) Tunnel —on the labeled Erie-Lackawanna grade (part of the "Summit Cutoff" of the old DL&W. (surficial geology after Braun, manuscript map).

f= artificial fill
d = quarry dump
Qw = wetland
Qa = alluvium
Qwoic = Wisconsinan outwash and ice-contact deposits (undifferentiated)
Qwt = Wisconsinan till
Dck = Catskill Formation.

Geology. The Tunkhannock Viaduct, or "great white bridge" of Dreiser (Figure 63), crosses the Tunkhannock Creek valley where the valley itself is about 1300 feet wide and the creek is only about 100 feet wide (Figure 60). Surrounding hills to the north and south of Tunkhannock Creek reach elevations of 1200 to 1300 feet, with the stream level about 700 feet. Joining the creek from the north at Nicholson is Martins Creek, the tributary valley that was deepened by meltwater erosion when it functioned as the New Milford Sluiceway (STOP 7).

Bedrock over the entire area consists of interbedded gray sandstones and red shales, siltstones, and mudstones of the Late Devonian-age Catskill Formation (Dck, Figure 60). Extensive exposures of these rocks can be seen along US 11 and on the active railroad line north and south of the viaduct. The sandstones are typically crossbedded and locally contained lenticular beds of calcareous breccia/agglomerate and (rarely) pods of massive pyrite. Bedding is subhorizontal, but may locally attain dips as high as 12°. Jointing is well developed in the sandstones, a smooth north-south set (occasionally with quartz mineralization) and a somewhat uneven east-west set being "ubiquitous."

Late Wisconsinan glacial deposits exposed in the Nicholson area consist of silty glacial till in the hills and mixed outwash and ice-contact stratified drift in the valleys of Tunkhannock and Martins Creeks (Figure 60). At the site of the Tunkhannock Viaduct, glacial and glacio-fluvial deposits are at least 15 mters (50 ft. deep across the entire valley and locally extend down to nearly 30 meters (100 ft.). Upstream and downstream of Nicholson, kettled outwash/kame terraces occur intermittently on either side of Tunkhannock Creek 6 to 9 meters (20 to 30 ft.) above relatively continuous alluvial terraces. An excellent exposure of folded and faulted ice-contact deposits in one of the higher terraces can be seen in an old sand pit on a farm 0.5 mile east of Nicholson (1 on upper right of Figure 60, Figure 61A-B).

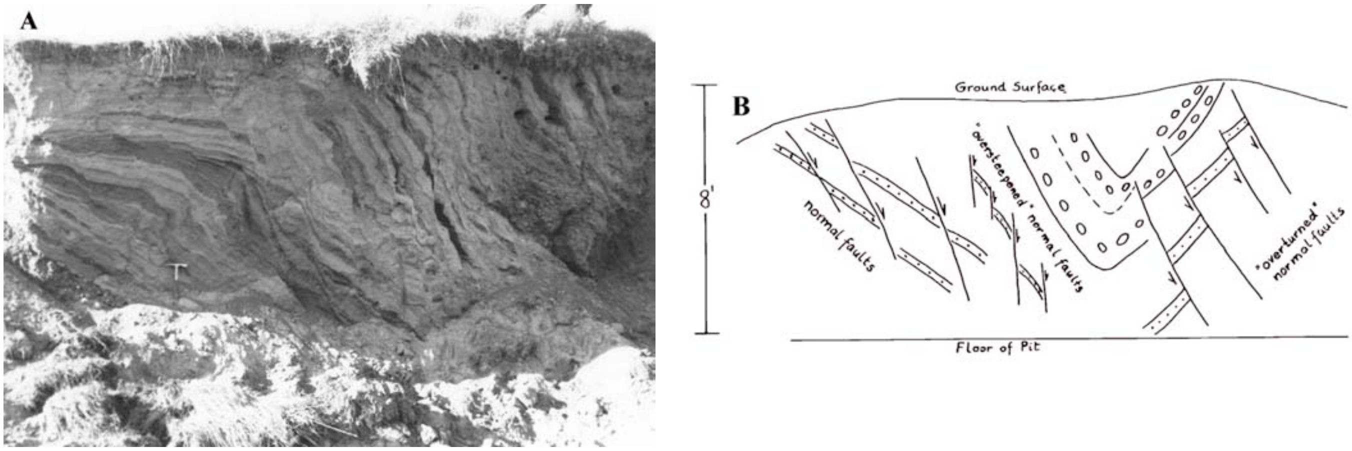

Figure 61. A. Faulted and folded ice-contact deposits in a kame terrace on the south side of Tunkhannock Creek, 0.5 mile east-southeast of Nicholson. B. Diagrammatic cross section of intensely deformed ice-contact deposits pictured in the photo above. The picture (Figure 61 A) shows the left two-thirds of the diagram.

Figure 62. The “great bridge” towers over houses in the borough of Nicholson in this view looking south from SR 1025. To locals the viaduct will always be the “Nicholson Bridge.”

The viaduct. To conform to the lessened grades of the new "Cutoff" route north of Clarks Summit, the elevation of the crossing of Tunkhannock Creek on the new alignment was set at 947.0 feet (Inners,2002; Braun et al., 1999). This necessitated a structure 240 feet above the floor of the valley. Since the DL&W had gained considerable experience with new reinforced concrete designs on previous projects (involving not only bridges, but company houses and breakers as well), choice of construction material for the bridge at Nicholson followed naturally. A. Burton Cohen designed the great viaduct in the monumental Beaux Arts style, which characterized many public buildings in the period between 1885 and 1930 (Young, 1968; McAlester and McAlester, 1984). George J. Ray and F. L. Wheaton supervised its construction (Engineering News, 1913), which began in May of 1912.

Construction of the pier foundations. A 49-ton Marion steam shovel with a 1¼-yard bucket was delivered by rail and commenced excavation of the upper portion of pier 6 in July 1912. It subsequently moved on to piers 5, 8, 9, and 10, excavating downward until groundwater was encountered. Spoils were delivered to narrow-gauge dump cars for movement away from the excavations. Approximately 2,000-feet of 3-foot gauge service tracks comprised of 60-pound rail and 6% slopes were constructed for the bridge project. While the steam-shovel excavation was in progress, a concrete plant with capacity of 40 cubic yards per hour, and a cableway that spanned the entire width of the valley, were installed.

The end abutments and piers 1 and 11 are located on the hillside where bedrock was only a few feet below grade and groundwater was not encountered. The foundations for piers 9 and 10 encountered bedrock approximately 20 to 30 feet below grade. The remaining piers (2 - 7, and 8) required much deeper excavations to encounter bedrock. Most of the middle pier footings are founded on bedrock about 60 feet below creek level (but see below). These deeper excavations were accomplished through use of cofferdams constructed of interlocking steel-sheet piling.

The typical frame for each cofferdam consisted of a 43 x 49-foot base spliced together from 12 x 12-inch timber. Vertical posts were set-up on each base and a second rectangular frame comprised of 12 x 12-inch timber was built 16 feet above the base. This large box-shaped frame, known as a waling, was then completely surrounded by an outside frame of similar construction so that the interior and exterior walings were separated by a 6-inch space. A continuous row of 12-inch wide, 30-feet long, 45-pound Lackawanna steel sheet piling was driven between the exterior and interior walings. Driving was accomplished using Vulcan steam hammers suspended from derricks located adjacent to each excavation. The hammer continued to rotate around the structure, driving the piling about 2 to 3 feet with each pass.

The interior of the cofferdam was then excavated at an average rate of one foot per day by a Mead-Morrison one-yard, clamshell bucket suspended from one of the adjacent derricks. Deep excavation was aided by a Williams special one-yard, toothed clamshell bucket which provided excellent results in the compact, hard soil encountered. As excavation continued, the piles were driven to their full length (30 feet) and were braced with successive horizontal tiers of 12 x 12-inch longitudinal and traverse struts. Each horizontal tier was made from yellow pine with openings, measuring 7 x 10 feet, to provide clearance for excavating tools and concrete buckets. Successive tiers were spaced between 3 1/2 to 5 feet apart. Vertical braces were made from 12 x 12-inch posts. The entire structure was held together with slice boards, or fishplates, and ¾-inch connecting bolts.

Once the inner sheet piling was driven its full length, a second set of double walings were erected so that they were concentric with and 4 feet 8 inches outside of the inner wall. An outside set of pilings was then driven to a depth of 12 to 15 feet. The inside set of pilings was subsequently encountered in the glacial sediments. When encountered, they were usually undermined and rolled into the excavation. Large boulders were drilled and blasted to facilitate removal. Frequently a 2-inch pipe was driven into the hardpan or between boulders and one or two sticks of dynamite was used to loose the materials so that it could be removed by the clam-shell buckets. Considerable leakage occurred during the early stages of the excavation. This leakage usually diminished as the joints filled-up with sand. Tunkhannock Creek was subject to flooding during the early phase of the project and, in turn, filled pits 3 and 4 located adjacent to the stream. Fortunately no great damage was done. The excavations were pumped out within a day or two. Most of the water entered through the bottom of the excavation. Two 8-inch centrifugal pumps and two 10-inch Emerson plunger pumps, supplied by a 150 horsepower boiler, were used to dewater pit 4, which was located adjacent to the stream. For general dewatering purposes, two of the pumps were sufficient to control groundwater infiltration. Upon completion of excavation activities, the interior sheeting lined with tarpaper and the cofferdams were completely filled with concrete using 2-yard capacity, Lockwood bottom-flap buckets.

Once the pour began, work continued day and night without break to ensure a monolithic foundation. In pier 3, 2,400 yards of concrete were poured without interruption in one seven-day period. Considerable groundwater infiltration was encountered during the excavation of pier 8. The problem was handled by constructing a wooden drain around the base of the cofferdam using 2 x 12 inch planks cleated together. Water was drained to a sump excavated into the bedrock floor and removed by an 8-inch centrifugal pump. Concrete was poured over the wooden drain, permanently entombing the wooden drain. As concrete was carried up, a full-size shaft was left open above the sump. This sump was later sealed with concrete when the pier was completed to the surface. Once most of the foundation was prepared, mammoth towers were built at each end of the viaduct from which cement ran on an aerial tramway to dump their contents at the appropriate arch under construction. However, one pier—at the site of which quicksand was encountered at 60 feet—had to be extended down to 92 feet and was not completed until the spring of 1915. To complete this pier footing (No. 5), compressed air was used to keep the foundation forms from bulging, and workers had to be lowered through compressed air chambers to muck out the bottom (Young, 1967; Williams, 1990). The foundation difficulties at this pier delayed completion of the viaduct for at least six months. The “great bridge” was finally completed in late September 1915 (Figure 98).

Construction statistics. (Anonymous, 1976):

Construction material - reinforced concrete - 163,000 cubic yds. concrete, 2,280,000 lbs. of reinforcing steel;
Elevation of railroad grade - ~940 feet
Length - 2,375 feet
Height - 240 feet above stream level; over 300 feet above bedrock.
Spans **-** 12 (10 spans of 180 feet visible; 2 spans of 100 feet buried in approach fills.)
Depth of pier excavations - 60 to 138 feet, 48,000 cubic yds excavated.
Workforce - 500 men

		Leave STOP 11, turning LEFT onto US 11 north, cross Tunkhannock Creek and enter Nicholson.
0.3	65.9	Intersection with PA 92. Continue straight ahead on US 11 north. Retrace route to Kingsley.
5.7	71.6	Hop Bottom, intersection with PA 167, continue straight on US 11 north
2.9	74.5	Go under Martins Creek Viaduct.
1.1	75.6	Enter Kingsley and continue past the PA 106 intersection.
0.2	75.8	Turn RIGHT onto PA 547 and IMMEDIATELY TURN LEFT onto gravel Stevens road (T574). Begin driving up the east side of East Branch Martins Creek, a "beaded valley" sub-parallel to ice flow.
0.9	76.7	Bear LEFT onto Grinnell road and descend slope.
0.7	77.4	Continue past Miller road (T479) on the right.
0.4	77.8	Turn LEFT onto Beaver Meadow road (T554) and cross the valley to continue along its west side. Entering south edge of Figure 63.
0.1	77.9	On the right is a water fall where the stream has been diverted by the till knob ahead and has just “caught” the east bedrock wall of the valley (southeast corner of Figure 63).
0.2	78.1	To right, gently rounded till knob in fields behind the barn, southern most knob on Figure 63.
0.1	78.2	Lake on north side of the till knob before the stream enters the bedrock gorge beside the till knob. Today the lake is dammed by humans but looks like the situation shortly after glaciation and before the stream incised beside the till knob.
0.6	78.8	Turn LEFT at T onto unnamed road.
0.1	78.9	Turn RIGHT onto Three Lakes Road (continuing on T554).
0.1	79.0	To right, second gently rounded till knob. To left is a bluestone quarry waste dump.
0.1	79.1	Pass White road (T487) on the right, continuing on Three Lake road (T 554).
0.1	79.2	Artificial lake on north side of the second till knob(Lower Lake, Figure 63).
0.6	79.7	To right, third till knob and artificial lake on it's north side (Middle Lake, Figure 63).
0.9	80.6	To right, fourth till knob and artificial lake on it's north side (Upper Lake, Figure 63).
0.5	81.1	Turn RIGHT at T onto unnamed T603 and continue uphill past where T554 goes to the left.
0.2	81.3	At the top of the hill, pull over into a wide pull-over on the right side of the road for Stop 12.

Stop 12. A view down a “beaded valley” - a chain of lakes separated by till knobs

Leader: Duane Braun

We have just driven up the “beaded” valley of the East Branch Martins Creek (Figure 63). The view to the south shows Upper Lake, the till knob to the south of it, and the top of the next till knob farther to the south. We are standing on yet another till knob (Figure 63) and the well at the house on the north side of the road goes through 30 meters (100 ft.) of till before reaching bedrock. Behind the house and barns is a shallow depression holding a wetland that would have been another lake shortly after glacier recession.

The heavy dashed lines on Figure 63 are my interpretation of the position of active ice margins that built the till knobs as the glacier receded across the region in stagnation zone retreat mode. The lobation I show of the glacier from valley to valley is relatively “short”, but that is what one is “forced into” when one starts connecting knobs across the region. The short lobes suggest a steep ice surface gradient and high basal shear stress. I think the glacier was “working hard” to cross this landscape, having an average basal shear stress of more than 100 kPa (1 bar). The glacier crossing the Appalachian Plateau of northeastern Pennsylvania is the antithesis of the low basal shear stress, low gradient glacial lobes of the Great Lakes region. While many valleys in the region are sub-parallel to ice flow, much of the base of the glacier is obliquely sliding over the bedrock ridges between the valleys and repeatedly having to go uphill across the obstructions in its path (Figure 63).

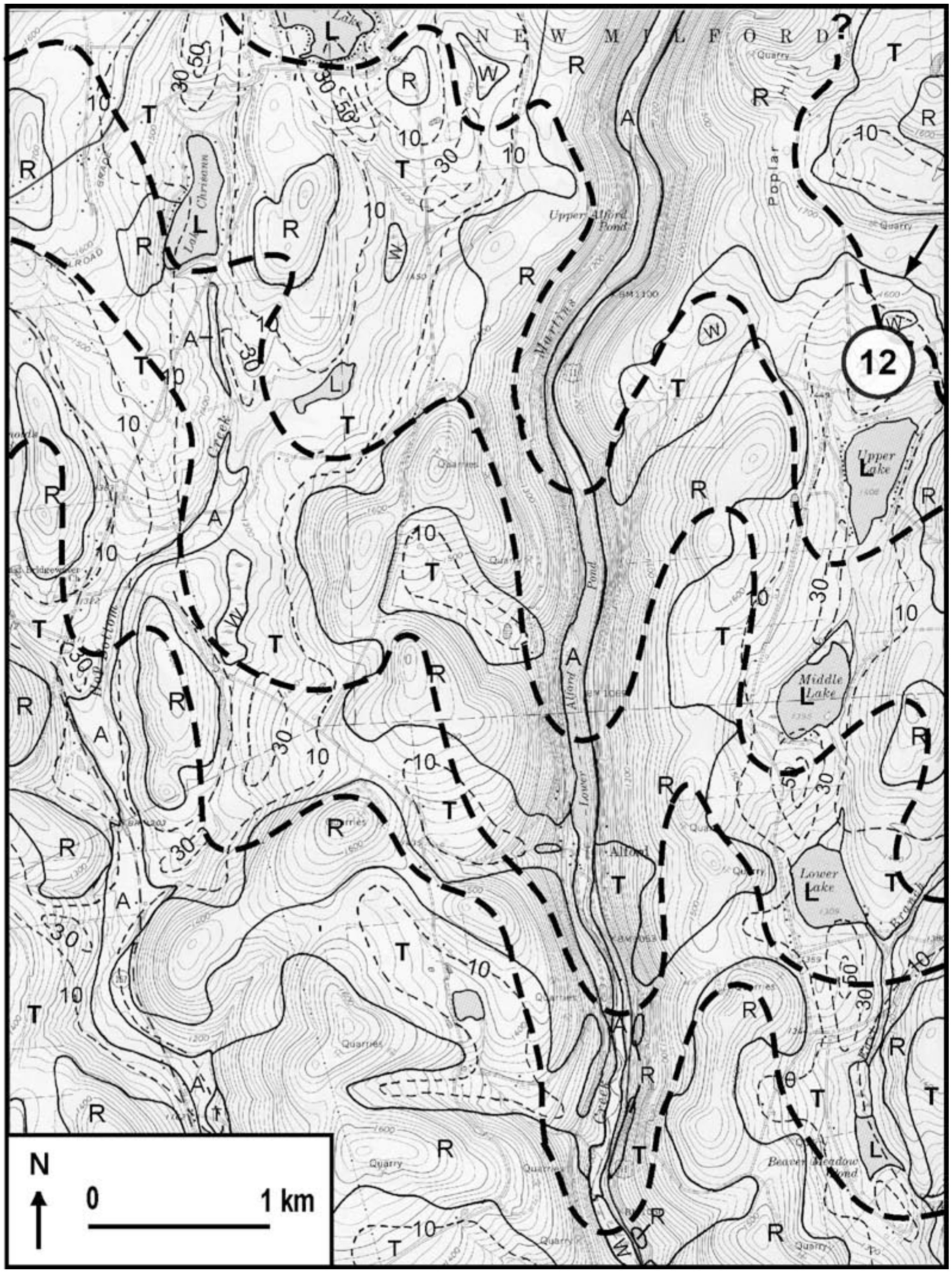

Figure 63. Surficial deposit map of the area around STOP 12. Immediately south of the site is the beaded valley with a chain of lakes that the field trip has just ascended. The next valley to the west is the New Milford sluiceway.

Heavy dashed lines are proposed active ice margins that deposited the till knobs in each of the valleys across the area.

Striation - Arrow north of STOP 12

A – Alluvium
G – ice-contact gravel
L - Lake
R – Bedrock
T – Till

(From Braun, 2004, Surficial Geology of the Harford and Montrose West 7.5' quadrangles).

		Leave Stop 12, continuing ahead on T603.
0.4	81.7	Ascend onto bedrock hilltop area with sandstone ledges to either side of the road.
0.2	81.9	Turn LEFT onto unnamed SR 2061 and descend into a north flowing stream valley that should have contained a short lived proglacial lake. We have not found any lake sediments in the valley, but the slopes below lake level are covered by colluvium derived from the slopes that lie above lake level.
0.4	82.3	Continue on SR 2061 past T576 on the left.
0.3	82.6	Till knob on left, bedrock ledges in stream to right.
0.2	82.8	Continue on SR 2061 past T556 on the right. Just beyond that on right is Gillespies Pond, another artificial lake replicating the scene immediately after glaciation. Till knob is ahead and on the left.
0.4	83.2	On left is the till knob dam for Gillespies Pond.
0.5	83.7	Turn LEFT at the T with PA 848 at Wellmans Corners.
0.4	84.1	On right is the Old Mill Village, part the Pennsylvania Historical and Museum Commission system.
0.7	84.8	Enter New Milford. To left is the entrance to the New Milford sluiceway.
0.2	85.0	Turn RIGHT at T onto US 11, IMMEDIATELY TURN RIGHT onto Jackson Street (SR 492).

0.6	85.6	Cross under I-81 and turn LEFT onto the north bound ramp of I-81.
0.2	85.8	Merge onto I-81 north.
0.2	86.0	View to left of entrance to the New Milford sluiceway.
1.1	87.1	Enter south edge of Figure 94.
0.7	87.8	To left on the other side of the valley is the rock quarry of New Milford sand & gravel. The gravel pit (SG on Figure 46) is just below I-81.
0.8	88.6	To left on the other side of the valley is the gravel pit the hanging delta on the west side of the valley.
1.5	90.1	To right, over-grown gravel pit beside I-81 in the delta supplied through the notch in the ridge above from the adjacent Little Egypt Valley as pictured in Figure 45.
2.0	92.1	Cross North Branch Susquehanna.
0.1	92.2	Bear RIGHT onto exit 230 ramp for Great Bend.
0.2	92.4	Turn LEFT onto SR171 and cross under I-81.
0.2	92.6	Continue straight ahead into the Colonial Brick parking lot.
		End of trip. Have a safe journey home and thanks for coming.

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FRIENDS OF THE PLEISTOCENE REUNIONS
1934-2004

Reunion	Leaders	Area
1. 1934	George White / J.W. Goldthwait	Durham to Hanover, NH
2. 1935	Dick Flint	New Haven to Hartford, CT
3. 1936	Kirk Bryan	SE Rhode Island to Cape Cod, MA
4. 1937	J.W. & Dick Goldthwait / Dick Lougee	Hanover to Jefferson, NH
5. 1938	Charlie Denny / Hugh Raup	Black Rock Forest, NY
6. 1939	Paul MacClintock / Meredith Johnson	Northern NJ (drifts)
7. 1940	Kirtley Mather / Dick Goldthwait	Western Cape Cod, MA
8. 1941	John Rich	Catskill Mtns., NY
1942-45	*no meetings during war years*	
9. 1946	Lou Currier / Kirk Bryan	Lowell-Westford area, MA
10. 1947	Earl Apfel	Eastern Finger Lakes, NY
11. 1948	D.F. Putnam / Archie Watt / Roy Deane	Toronto to Georgian Bay, ONT
12. 1949	Paul MacClintock / John Lucke	NJ ("Pensauken problem")
13. 1950	O.D. Von Engeln	Central Finger Lakes, NY
14. 1951	John Hack / Paul MacClintock	Chesapeake, MD (soils/stratigraphy)
15. 1952	Dick Goldthwait	Central OH (tills)
16. 1953	Lou Currier / Joe Hartshorn	Ayer quad, MA (outwash sequences)
17. 1954	Charlie Denny / Walter Lyford	Wellsboro-Elmira-Towanda, PA-NY
18. 1955	Paul MacClintock	Champlain lake and sea, NY
19. 1956	Nelson Gadd	St. Lawrence Lowland, QUE
20. 1957	Paul MacClintock / John Harris	St. Lawrence Seaway, NY
21. 1958	John Hack / John Goodlett	Appalachians, Shenandoah, VA
22. 1959	Alexis Dreimanis / Bob Packer	Lake Erie, ONT (till bluffs)
23. 1960	Ernie Muller	Cattaraugus Co., western NY
24. 1961	Art Bloom	SW Maine (marine clay; ice margins)
25. 1962	Cliff Kaye / Phil Schafer	Rhode Island (Charleston Moraine etc.)
26. 1963	Hulbert Lee	Lower St. Lawrence Lowland, QUE

27.	1964	Cliff Kaye	Martha's Vineyard, MA
28.	1965	Joe Upson	Northern Long Island, NY
29.	1966	Nick Coch / Bob Oaks	Southeast VA (scarps; stratigraphy)
30.	1967	Hal Borns	Eastern ME (moraines; glaciomarine)
31.	1968	Carl Koteff / Bob Oldale / Joe Hartshorn	Eastern Cape Cod, MA
32.	1969	Nelson Gadd / Barrie McDonald	Sherbrooke area, QUE
33.	1970	Dick Goldthwait / George Bailey	Mt. Washington area, NH
34.	1971	Gordon Connally	Upper Hudson Valley, Albany, NY
35.	1972	Art Bloom / Jock McAndrews	Central Finger Lakes, NY
36.	1973	Don Coates / Cuchlaine King	Susquehanna-Oswego Valleys, NY-PA
37.	1974	Bill Dean / Peter Duckworth	Oak Ridges-Crawford Lake, ONT
38.	1975	George Crowl / Gordon Connally / Bill Sevon / Les Sirkin	Delaware Water Gap to the Poconos, PA
39.	1976	Bob Jordan / John Talley	Coastal Plain, DE
40.	1977	Bob Newton	Ossipee area, NH
41.	1978	Denis Marchand / Ed Ciolkosz / Milena Bucek / George Crowl	Central Susquehanna Valley, NY
42.	1979	Jesse Craft	NE Adirondack Mtns., NY
43.	1980	Bob LaFleur / Parker Calkin	Upper Cattaraugus, Hamburg, NY
44.	1981	Carl Koteff / Byron Stone	Nashua Valley, MA
45.	1982	Pierre LaSalle / Peter David / Michelle Bouchard	Drummondville, QUE
46.	1983	Woody Thompson / Geoff Smith	Augusta-Waldoboro area, ME
47.	1984	Peter Clark / J.S. Street	St. Lawrence Lowland, NY
48.	1985	Ed Evenson / Jim Cotter / Dave Harper / Carl Koteff / Jack Ridge / Scott Stanford / Ron Witte	Great Valley, NJ-PA
49.	1986	Tom Lowell / Steve Kite	Northernmost ME
50.	1987	Carl Koteff / Janet Stone / Fred Larsen / Joe Hartshorn	Connecticut Valley-Lake Hitchcock, CT-MA
51.	1988	Ernie Muller / Duane Braun / Bill Brennan/ Dick Young	Genesee Valley, NY
52.	1989	Pierre LaSalle / Andree Blais / Denis Demers / Michel Lamothe / Bill Shilts	Mid St. Lawrence Lowland, QUE
53.	1990	Ralph Stea / Bob Mott	Halifax region, NS

54. 1991	Jack Ridge	Western Mohawk Valley, NY
55. 1992	Bob Dineen / Eric Hanson / Bob LaFleur / Dave Desimone	Lower Mohawk Valley, NY
56. 1993	Carol Hildreth / Richard Moore	Contoocook-Souhegan-Piscataquog Valleys, NH
57. 1994	Duane Braun / Ed Ciolkosz / Jon Inners / Jack Epstein	Eastern PA
58. 1995	Woody Thompson / Tom Davis / John Gosse / Bob Johnston / Bob Newton	Portland-Sebago Lake-Ossipee Valley, ME
59. 1996	Hal Borns / Chris Dorion / Joe Kelley / Karl Kreutz / Dave Smith / Woody Thompson/ Rick Will	Glaciomarine deposits, eastern ME
60. 1997	Scott Stanford / Ron Witte	Northern and central New Jersey
61. 1998	Les Sirkin	Long Island, NY
62. 1999	Ben Marsh	Periglacial landscapes, central PA
63. 2000	Julie Brigham-Grette / Tammy Rittenour / Janet Stone / Jack Ridge / Al Werner / Dena Dincauze / Ed Klekowski / Richard Little	Glacial Lake Hitchcock, MA
64. 2001	Najat Bhiry / Jean-Claude Dionne / Martine Clet / Serge Occhietti / Jehan Rondot	Quebec City region, QC
65. 2002	Woody Thompson / Carol Hildreth / Dick Boisvert / Chris Dorion / Brian Fowler	Northern White Mtns., NH
66. 2003	Fred Larsen / Steve Wright / George Springston / Richard Dunn	Central VT
67. 2004	Duane Braun / Jon Inners / Jack Ridge	Great Bend-Tunkhannock, northeast PA

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