

Although the Kinzua Viaduct has been destroyed and the Tunkhannock is suffering steady deterioration of its concrete, the cut-stone masonry Starrucca Viaduct stands as beautiful and useful as when it was built more than 150 years ago.



Figure 37.
The Starrucca Viaduct at Lanesboro, Susquehanna County, looking northwest from "The Hole," a large "bluestone" quarry (elev. 450 feet A.T.) on Taylor Hill, south of the viaduct.



Figure 38.
The Starrucca Viaduct looking east up the Starrucca Creek channel.

Site Geology. The Starrucca Viaduct is located on the glaciated Allegheny Plateau at the confluence of Starrucca Creek and the North Branch Susquehanna River in the borough of Lanesboro (Figure 39). Elevation of the valley floor at the viaduct site is about 900 feet, with rounded hills on all sides standing more than 800 higher. Bedrock outcropping on the higher slopes and summits of the adjacent hills consists of interbedded deltaic sandstones and silty shales of the Catskill Formation, while fossiliferous, marine sandstones and shales of the subjacent Lock Haven Formation underlie the lower hillslopes and valley bottoms. Bedding is subhorizontal in these Late Devonian rocks, this part of Susquehanna County lying north and east of the region affected by Alleghanian folding (Faill, unpublished map). Glacial deposits in the area are entirely of Late Wisconsinan age and consist of silty clay till on the uplands and complexly interstratified till, outwash and ice contact gravel, and lacustrine sediments in the North Branch and Starrucca Creek valleys (Braun, 2004d). In the North Branch valley, a once continuous esker can clearly be traced through gravel pits north of Lanesboro to just west of Oakland (STOP 6)(Figure 39). Thickness of glacial (and postglacial fluvial) deposits beneath the viaduct is at least 3 meters (9 feet) (the maximum depth of the pier foundations) and may be considerably more.

The stone of the Viaduct. Ralph Stone (1932) in his classic *Building stones of Pennsylvania*, provides as good a description of the Starrucca Viaduct as anyone:

The high arch stone viaduct of the Erie Railroad at Lanesboro is built of [Catskill] bluestone which has weathered to greenish gray and rusty color. The stone was quarried at Stevens Point [STOP 2] and dressed to joint-face and rock-face random ashlar. The blocks are all sizes up to 6 feet by 10 inches, 3 feet by 20 inches, and some may be up to 24 inches thick. They are sound and it looks as if it would stand for centuries.

Note that the drill marks on the sandstone blocks are identical to those seen on the quarry wall at Stevens Point. A few blocks have numbers carved in them that date from the time of quarrying (for example, a block in the second pier from the south along SR 1009 contains a weathered, upside-down “3”). Such numbers may have indicated the workman or work crew responsible for quarrying certain individual blocks or “skids” of stone.

History and engineering. The New York and Erie Railroad was designed to connect New York with the Great Lakes Region. Although ground was broken for the railroad in 1835, it was not until 1846 that construction really got under way. The final route passed up the Delaware River from Port Jervis to Deposit, NY, cut across the Delaware-Susquehanna divide at Gulf Summit, and then followed the North Branch Susquehanna River down into Pennsylvania—through Lanesboro (Figure 33), Susquehanna Depot (now Susquehanna) and Great Bend—and back into New York. Plans to run the railroad directly through the newly opened Northern Anthracite field at Carbondale and Slocum Hollow (now Scranton) were stymied by the Delaware and Hudson Canal interests, who wanted to maintain their short-lived monopoly on coal transportation (Young, 1995). The viaduct was designed by Julius Adams (1812-1865), a New Englander, and built mainly under the supervision of James Kirkwood (1807-1877), a New Yorker (who had been born in Scotland) and brother-in-law of Adams. It was constructed over a two-year period (1847-48) and was the most ambitious and expensive railroad bridge built up to that time (Figures 72 and 73). Stone was obtained from quarries two miles north of Lanesboro (1847 and late 1848) and at Stevens Point (STOP 2) in the Starrucca Creek valley. Rosendale cement (from limestone quarries in Ulster County, NY) was used for concrete in the pier footings and for mortar in the viaduct. (This use of concrete footings is one of the earliest uses of structural concrete known). Brick for supporting arches within the hollow spandrels was made on site from clay found nearby—probably at Brandt (STOP 3) where a thick deposit of lacustrine clay was utilized for brick making about 30 years later (Young, 1995). Wrought iron T-rails for the broad-gage railroad were manufactured at the new Lackawanna iron works 40 miles to the south, the first large order for T-rail in the country and a contract which marked the industrial birth of the city of Scranton (Perry, 1994). The foundations of the viaduct were dug only 6 to 9 feet deep, where Adams encountered “a course hard gravel, pervious to water” (Young, 1995)—apparently a cobbly outwash gravel. The shallow foundations of the piers were a cause of concern in later years, but Adam’s rather daring decision has stood the test of time.

ENGINEERING STATISTICS OF THE STARRUCCA VIADUCT

(Young, 1995; Historic American Engineering Record)

<i>Pier material</i> - dimension stone (sandstone)	<i>Depth of pier footings</i> - 6 to 9 feet
<i>Length</i> - 1040 feet	<i>Pier centers</i> - 58 feet
<i>Height</i> - 100 feet	<i>Height of piers</i> -65.67 feet
<i>Width of deck</i> - 26 feet	<i>Arch radia</i> - 25.5 feet
<i>Number of arches</i> - 17	<i>Work force</i> - ~800 men

Leave STOP 5, turning LEFT onto Depot Street and passing again under the viaduct.

0.2 32.5 Turn LEFT onto SR 1015.

0.1 32.6 Bear to RIGHT at stop sign after crossing Starrucca Creek. You are back on SR 1009.

0.6 33.2 Intersection with PA 171 under the Canawacta Viaduct. Continue straight on PA 171 North.

0.4 33.6 At the top of the hill to the right across North Branch Susquehanna River is the 24 meter (80 ft.) cut in the Lanesboro-Oakland esker.

0.1 33.7 Enter borough of Susquehanna.

0.5 34.3 Traffic light. Continue straight ahead following PA 171 North/PA 92 South. The shopping center and parking lot to right occupy the site of the extensive Erie Railroad yards and shops(1848-1960's).

0.1 34.4 Turn RIGHT at the traffic light and cross North Branch Susquehanna River.

- 0.2 34.6 Turn LEFT at the Stop sign at the end of the bridge, staying on PA 171 North.
 0.9 35.5 Turn LEFT onto access road to Red Oak pit of Masters Ready Mixed Concrete Co. Proceed to the right and park next to the weighing station.

Stop 6. The Lanesboro-Oakland Esker, exposed at the Red Oak Sand & Gravel Pit
 Leaders: Duane D. Braun, Jon D. Inners

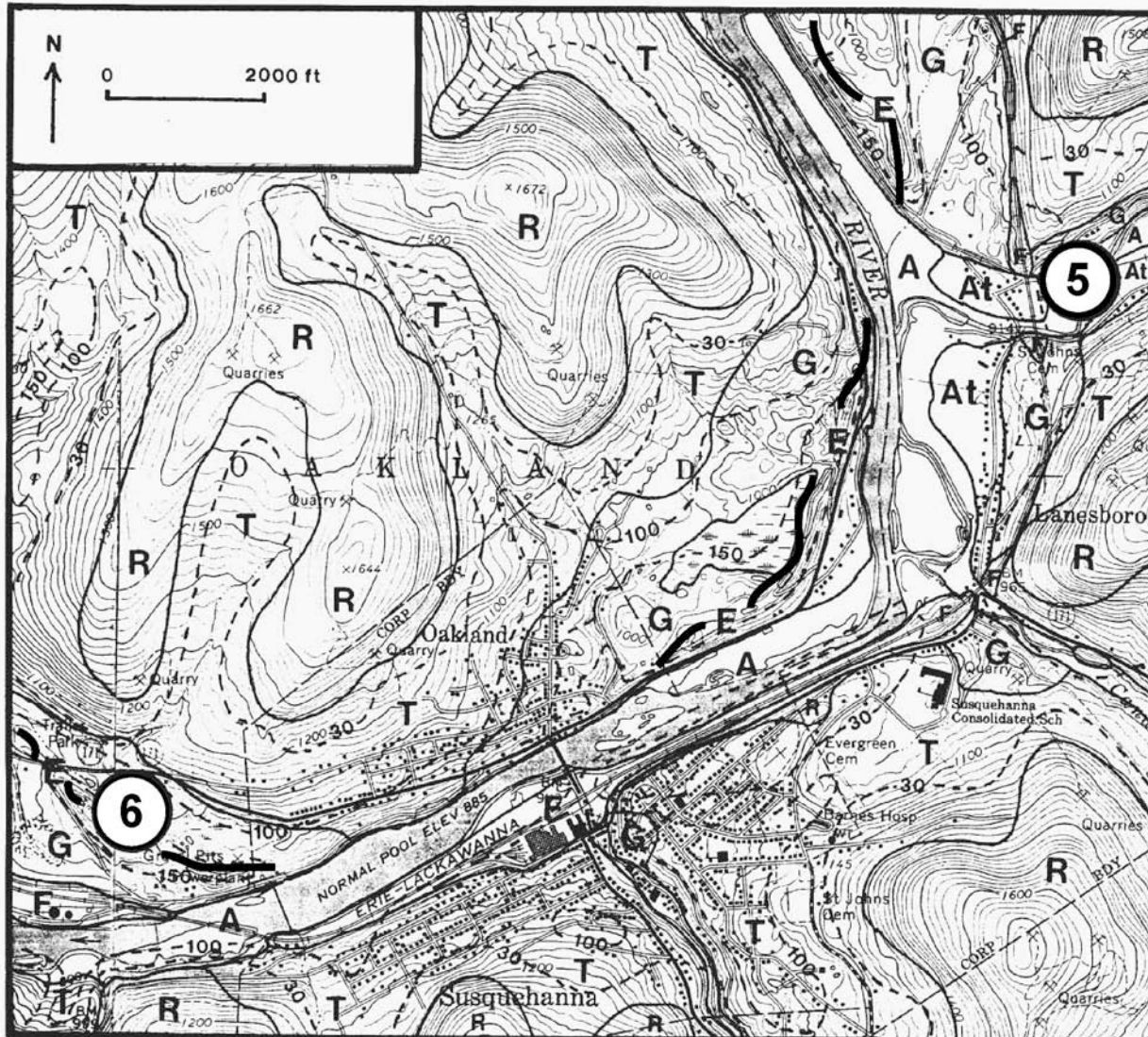


Figure 39. Map of surficial deposits in the area of the Lanesboro-Oakland esker, showing the three segments of the esker (E) and the other extensive and thick sand-and-gravel deposits (G) in the North Branch Susquehanna valley. A = alluvium, At = alluvial terrace, F = fill, GL = gravel underlain by varved sediments, R = rock, T = till, TL = till underlain by varves, W = wetland. Isochores of surficial deposits at 30, 100, and 150 feet. (From Braun, 2004c)

The Red Oak pit is located in a Late Wisconsinan esker on the north side of the North Branch Susquehanna River in Oakland Township (Figure 39). The mining of sand and gravel at this location has a long and varied history. During the 1920's, excavation was conducted by Madison Sand & Gravel Corporation of Hamilton, NY. This was a relatively small-scale excavation, removing material from the toe of the slope and trucking the product offsite via River Road, a narrow, dead-end secondary road. The operation ceased during the Depression. In 1946, Richard Masters acquired the land and adjacent mineral rights. Mr. Masters is the owner of Masters Ready Mixed Concrete Co. of Kingsley, PA. At that time, the site was not reopened due partially to significant development constraints. The resource was held in reserve until the early 1990's when the economics of permitting and development

were re-evaluated, and the permit process was initiated.



Figure 40. Segment of the Lanesboro-Oakland esker looking southwest, with the North Branch Susquehanna River valley to the left (Fairchild, 1925, Plate 33, Fig. 1). This is the part of the esker just northeast of Oakland.



Figure 41. Cross-section of the Lanesboro-Oakland esker at the Red Oak sand-and-gravel pit. View to west.

Geology. The deposit has long been recognized as part of the Lanesboro-Oakland esker, one of the largest such deposits in the region (Figure 39; Coates, 1981). . In places the esker exceeds 30 meters (100 ft) in height in places and its side slopes are steep. The esker was first described by White in 1881 and named the Lanesboro esker by Fairchild in 1925. White recognized that the feature was a type of glacial kame deposit. He noted that it was opposite the town of Susquehanna on the north side of the river and described it as long, sharp ridges 12 -15 meter (40 - 50 ft) high “running generally parallel to the river” (Figure 40). Fairchild correctly identified the feature as an esker and named it after the town of Lanesboro that lies across the river to the east of the esker. Fairchild incorrectly identified the separate segment of the esker west of Oakland at STOP 5 as a drift dam, cut by two channels that held in a shallow lake in the Susquehanna valley upstream of the site. Harrison (1966) mapped an esker at STOP 5 with a knobby kame area on its north side and an outwash terrace on its south side, features confirmed by the recent mapping by Braun (2004d). The Lanesboro esker is more than four miles long and consists of three distinct segments, a western segment at STOP 5 (Figure 41), a middle and longest segment opposite Susquehanna and Lanesboro, and a northern segment on the east side of the river north of Lanesboro (Figure 39). At each of these sites the esker is on top till or ice-contact “stratified drift” and surrounded by much more extensive ice-contact sand and gravel deposits (Figure 42). Those other deposits show well-developed knob and kettle topography with many wetlands.

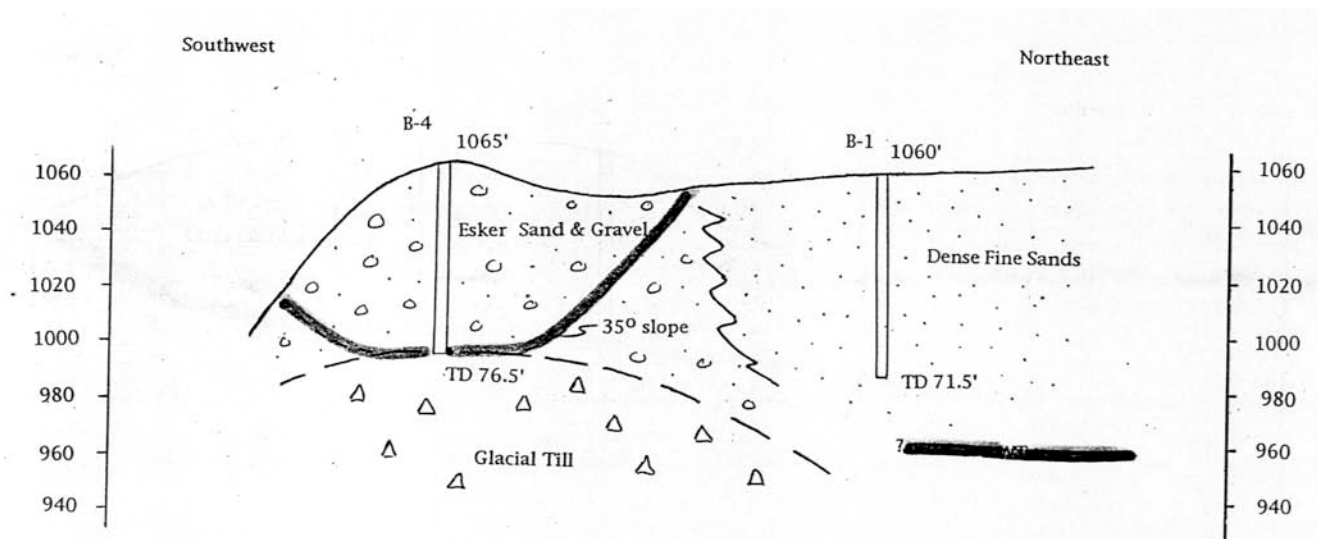


Figure 42. Cross-section of the Lanesboro esker at the Red Oak pit showing lacustrine fine sand on the north side of the esker and till under the esker. Pit floor is heavy line on left. Water table is heavy line on lower right. (from Harrington, 1991)

Exposures of sand and gravel within the Red Oak pit and at other nearby sites show the chaotic bedding (Figure 43 A), abrupt grain size changes (Figure 43 B), and collapse structures typical of deposition on top of stagnant ice. The bulk of the deposit is sand, with gravel occurring mainly in thin discontinuous bands (see Figures 43 A). More than 90 percent of the pebble- and cobble-size clasts are locally derived, with exotic lithologies such as granite gneiss, pink quartzite, and gray pebbly quartzite being relatively rare. The sand fraction contains a high percentage of lithic fragments. The esker is not overlain by till anywhere along its length. This suggests that the meltwater channel was near or at the glacier surface or the ice overlying the esker tunnel was exceptionally "clean". The esker may have just been a surface channel across the stagnate ice at the apex of the Great Bend in the Susquehanna valley. Glacial Lake Great Bend was also in front of the retreating active ice front and was probably flooding the esker site during the deposition of the esker material. This would account for the fine sands on the north side of the esker (Figure 42).

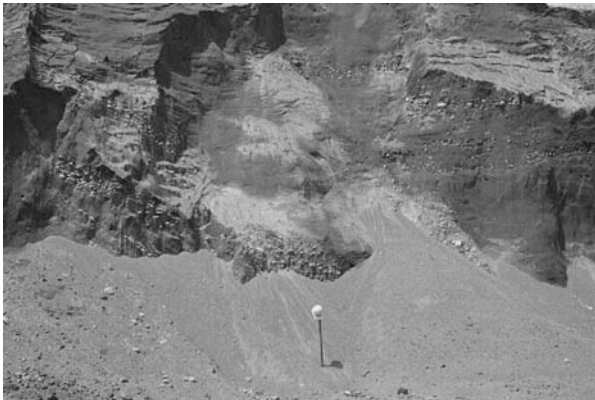


Figure 43 A. Chaotic bedding in sandy and gravelly beds.



Figure 43 B. Poorly sorted cobble bed underlain and overlain by pebbly sand and gravel on "sublevel" at east end of pit. Imbrication of the cobbles indicates current flow from the right (east).

Pit operation. In 1991 a series of test borings were drilled and standard split-spoon sediment samples were recovered (Harrington, 1991). This investigation indicated that over most of the property, useable sand-and-gravel deposits extended to a depth of over 75 feet and were underlain by till or flow till. Based on these borings, a process plant and mine layout were developed which took into account the specific site limitations. Its intent was to minimize the cost of production, while meeting state and local permit requirements. Material is excavated from the side of the esker and conveyed up to the processing plant, where individual aggregated products are separated. The office, scales, and stockpiles areas have all been developed on fine-grained lacustrine deposits that will not be excavated in the future. Material is readily transported offsite through access onto PA 171. Therefore, use of the lower secondary road is no longer required. Water for the wash plant comes from the adjacent pond. Secondary makeup water can be obtained directly from the Susquehanna. Fines from the washing plant are temporarily stored in settling basins along the mined-out toe of the deposit until the material is sold. Daily production is about 100 tons.

As soon as the mine was reactivated, it became evident that the deposit was more variable than subsurface borings had suggested. This has been an advantage in the material production. At present, five individual lifts have been developed. Each exposes material with differing grain size characteristics. This allows Red Oak Sand & Gravel to operate with a considerable range of flexibility without creating excess waste material. On a daily basis, material is screened at the process plant and gradations of individual products are recorded. If adjustments have to be made, the loader operator can then quickly alter the size and nature of material being fed to the conveyor.

When producing construction aggregate, two characteristics are of utmost importance—grain-size gradation and material soundness. The first is a function of several factors (e.g., the depositional characteristics of the material, excavation methods, and processing). Soundness is related almost exclusively to the mineralogy of the material. In this deposit, approximately 90 percent of the material is locally derived Upper Devonian graywacke.

Red Oak produces material mainly for its own use at the Masters Concrete plants at Kingsley and elsewhere in northeastern Pennsylvania, including work for road construction projects. On a regular basis, PennDOT samples material from this pit and conducts a series of tests to evaluate the quality of the individual products and their anticipated performance. This includes grain-size distribution as well as a range of physical tests, including specific gravity, percentage absorption, crust count, Los Angeles Abrasion testing, loss in a sodium sulfate solution, etc. The material passes all such tests. It is acceptable for a full range of products, including Type A Fine Aggregate for Concrete Sand, #57 Type A Coarse Aggregate, and Type 6S Anti-Skid Material for road surfacing. Consequently, this mine should continue to provide quality construction materials to the northeastern Pennsylvania area for many years.

It is estimated by Braun (2004d) that the three esker sites noted above and a fourth north of the area shown on Figure 34 contain on the order of 50 million cubic yards of sand and gravel in areas not yet covered by housing.

- | | | |
|-----|------|--|
| | | Leave STOP 6, returning pit entrance and turning LEFT onto PA 171. |
| 0.7 | 36.2 | To left is where Joseph Smith (1805-1844), the founder of Mormonism, translated most of the book of Mormon in 1828. |
| 1.0 | 37.2 | Enter Great Bend Township. |
| 1.0 | 38.2 | Village of Hickory Grove. |
| 1.5 | 39.7 | Village of Red Rock. |
| 0.4 | 40.3 | To left is the post-glacial gorge cut by the North Branch Susquehanna through the bedrock spur of a preglacial incised meander loop (the old valley swings around in the background to the south |
| 1.2 | 41.5 | Great Bend Township Municipal Building to left. Brant's Dairy Bar to right. |
| 0.8 | 42.3 | Pass over Norfolk Southern Railroad tracks (the old Erie grade from the Starrucca Viaduct). |
| 0.2 | 42.5 | Pass under I-81. |
| 0.1 | 42.6 | Straight ahead at traffic light into the Colonial Brick Parking lot. End of first day. |

At 6:30 pm the cash bar opens at Dodd's restaurant, banquet at 7:30.

Sunday's Field Trip Route Map after Stop 7, the first stop

Refer to Saturday's Field Trip Route Map
for the route to the first stop

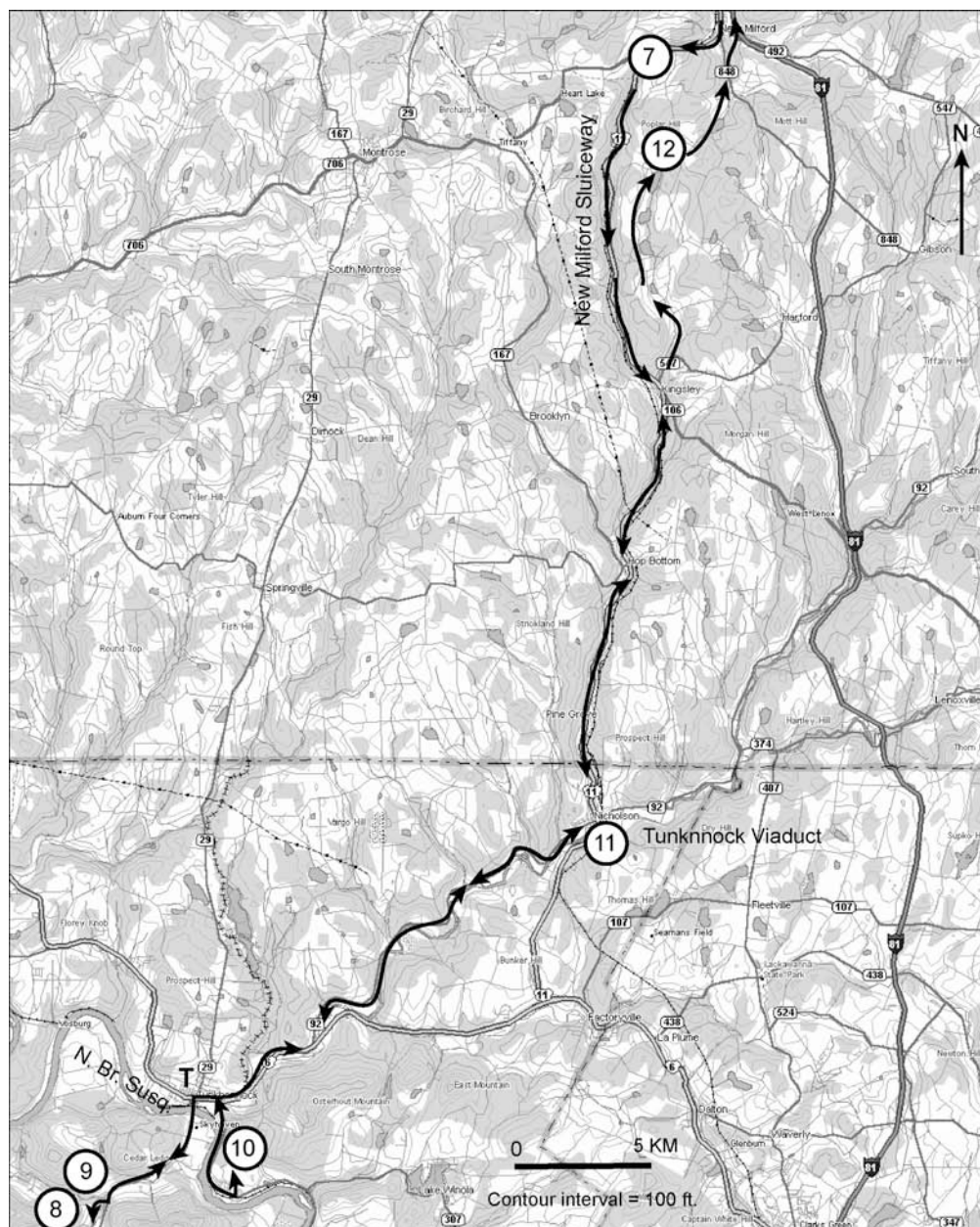


Figure 44. Second day (Sunday) trip route down the New Milford meltwater sluiceway to the Tunkhannock area and return northward.

DAY 2 ROAD-LOG AND STOP DESCRIPTIONS

Miles		Description
Int.	Cum.	
0.0	0.0	Leave the Colonial Brick Motel, turning RIGHT at the traffic light onto US 11 south.
0.1	0.1	To left between the McDonald's and the river bank is the site of the Great Bend archeological site (Thieme, 2002), studied in 1999 as part of the engineering investigation for the new bridge. The base of the 4.5 meter thick Holocene alluvial sequence yielded a radiocarbon date of $8,840 \pm 50$ BP. That date is about 0.5 meter below the low water mark of the River and shows the river has done little incision during the Holocene at this site.
0.1	0.2	Cross North Branch Susquehanna River and enter Hallstead. Downstream to the right the river turns sharply to the north to enter New York State and complete the Great Bend of the North Branch Susquehanna River. The recently completed four-span concrete bridge here is the sixth at this spot since 1814, Susquehanna County's oldest principal bridge crossing. Previous structures were completed in 1814, 1822, 1832, 1846, 1874, and 1926. The first four (wooden covered bridges) were destroyed by ice-jam floods. The fifth, originally a four-span wood truss, went through extensive changes over many years as individual spans were modified and replaced. The sixth, a 600-ton, steel, Platt-truss was toppled into the river on December 11, 2001, serving for 75 years "to the day" (Young, 2002).
0.1	0.3	Borough of Hallstead, built on the high outwash terrace of the North Branch Susquehanna River. Originally part of Great Bend, which once occupied both sides of the river, Hallstead was renamed in honor of DL&W General Manager W. F. Hallstead at the turn of the 20th century.
0.3	0.6	On left is Humbie's Diner, where you can get "lost in the 50's" while enjoying hot cider and "humbeans." We will now ascend the Salt Lick Creek valley and head for the outlet of Glacial Lake Great Bend, the New Milford meltwater sluiceway.
1.4	2.0	To left, on the hillside above I-81 is a distinct notch cut by the overflow from a proglacial lake in the Little Egypt Creek Valley into Glacial Lake Great Bend (Figure 45). The notch is also shown on the upper right of Figure 46 as an arrow marked with the elevation of 1410 feet.



Figure 45. Notch cut by meltwater flowing westward from a high-level proglacial lake in Little Egypt Creek valley into an early phase of Glacial Lake Great Bend in Salt Lick Creek valley. Below the notch is a hanging delta (upper-right KD on Figure 94) that was mostly quarried away for embankment material during construction of I-81. The topset - foreset contact was exposed at about 1200 feet, the elevation of Glacial Lake Great Bend.

1.4	3.4	PENNDOT storage area on right.
0.1	3.5	To right on the hillside, partly hidden by trees, is another gravel pit in a "hanging delta" showing a foreset-topset contact at an elevation of about 1200 feet (Figure 46, KD site on west side of map).
0.4	3.9	To right are "mucky" fields that may mark the site of the "bottomless" Summersville swamp, which caused considerable trouble during railroad construction through here in 1912-1915.

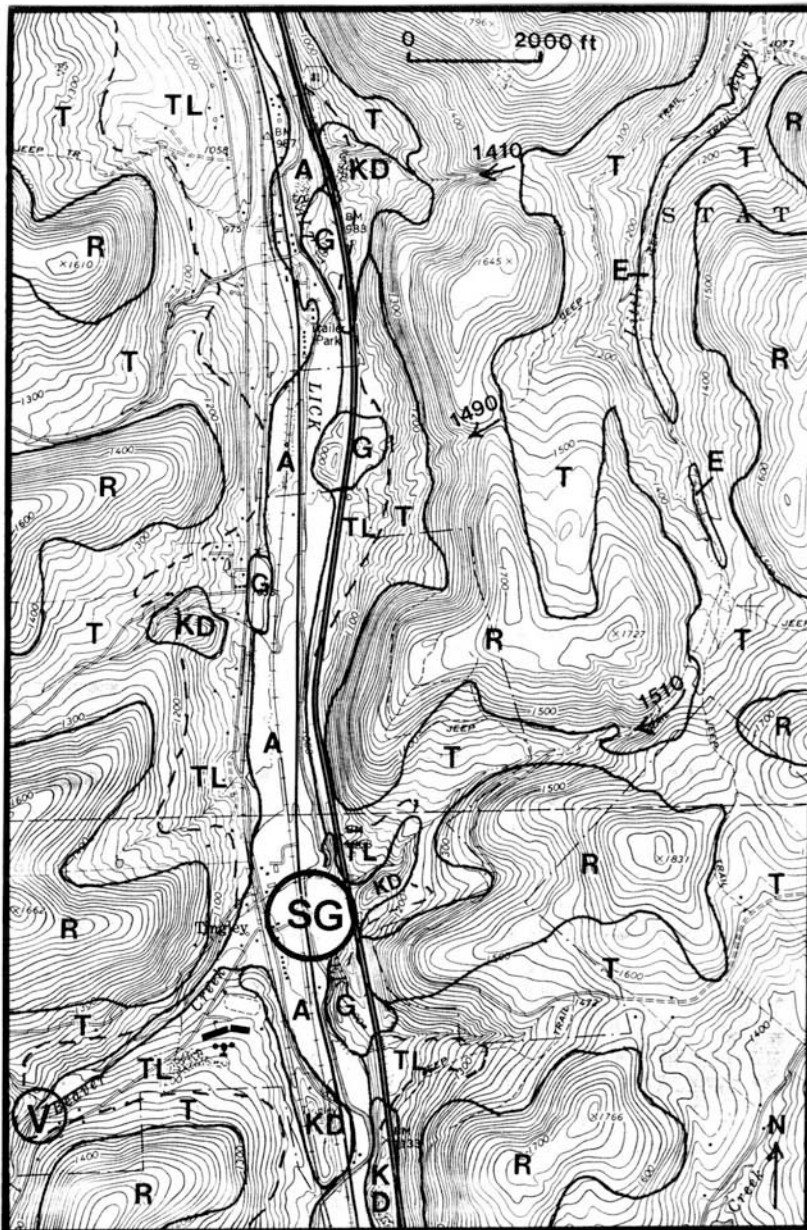


Figure 46. Map showing sluiceway notches from Little Egypt valley to Salt Lick Creek valley and surficial deposits in the area. (from Braun, 2004a).

A = alluvium
 G = ice-contact gravel
 KD = kame delta
 R = bedrock
 T = till
 TL = till underlain by lake sediments
 Circled V = exposures of varves overlain by till

Arrows with numbers = location and elevation of sluiceways (in feet) from the Little Egypt valley

- 0.4 4.3 Pit to left (with a cell phone tower in it) is that of the New Milford Sand and Gravel Co (site SG on map above). It is developed in ice-contact stratified drift. To the right is the sandstone quarry (lowermost Catskill Formation) of the New Milford Sand and Gravel Co. The ice-contact deposit is adjacent to and overlain by a kame delta that was fed by a sluiceway from the next valley to the east (Figure 46, arrow with 1510 elevation label). The top of the ice-contact deposit at this site is below the level of Glacial Lake Great Bend so it was once capped by a relatively thin sequence of glacial lake sediments from the final recession of the ice from the area. Postglacial erosion has removed the lake sediments and much of the kame. As noted at STOP 2 and 3, within the area of Glacial Lake Great Bend, there is another glacial lake sediment unit observed under the glacial deposits that typically form the present ground surface. Opposite this site, Beaver Creek enters the west side of the Salt Lick valley. In that tributary valley, varved sediments were observed under thick till deposits (circled V on Figure 46). Presumably varves underlie the sand and gravel at this site but are below the present valley floor level and so do not cause slumping in this area.
- 0.3 4.8 To the right, old US 11 (SR 1018) crosses the railroad. Out of sight beyond the railroad is another gravel pit that exposes foreset bedding dipping south, the southernmost KD patch west of US 11 on Figure 46.
- 0.3 5.1 To left behind the New Milford Township Building is an occasionally active gravel pit in ice-contact stratified drift (Figure 46, southernmost KD site; Figure 47 on the next page).



Figure 47. Inclined (25° SE) and faulted sand-and-gravel beds in ice-contact stratified drift. Many clasts are coated with travertine derived from the weathering of calcareous fossils in the clasts.

- 0.3 5.4 New Milford Borough sign on right.
- 0.8 6.2 Cross Salt Lick Creek. To left is the turn-of-the-20th-century Pratt Memorial Library building.
- 0.3 6.5 Intersection of US 11 with PA 429 East and PA 848 East in borough of New Milford. Continue on US 11 South. You are now rising above the water level of Glacial Lake Great Bend.
- 0.5 7.0 On the right the cattail swamp is the outlet channel of Glacial Lake Great Bend, with the railroad in the middle of it.
- 0.5 7.5 Intersection of US 11 with PA 706 West (to Montrose). Continue on US 11 South.
- 0.1 7.6 Pull over on the RIGHT into the parking lot just beyond the restaurant on the right for Stop 7.

Stop 7. The deeply incised New Milford meltwater sluiceway

by Duane D. Braun

New Milford sluiceway is a deep breach in the drainage divide between streams heading north to the Susquehanna River in New York and streams heading south to the Susquehanna River in Pennsylvania (Figure 1, Quaternary History section). As ice initially receded north of Scranton, Pennsylvania, meltwater was free to drain southward and formed extensive outwash terraces. Once the ice receded north of the east-west trending divide though, a series of proglacial lakes would have been impounded between the ice and the divide. Usually the lake in each individual north-trending valley would have had its own sluiceway. Thanks to the “Great Bend” in the overall course of the Susquehanna River, the New Milford sluice was positioned to receive drainage from 40 kilometers (25 miles) of ice front and adjacent north draining valleys (Figure 6 of the Quaternary History article). This permitted exceptionally deep cutting of the sluice (Figure 48). The 180 meters (600 ft.) of cutting in the divide is a composite of all the ice and meltwater erosion from the 3 or 4 glaciations that have crossed the area. Other saddles along the divide that acted as only local proglacial lake sluiceways show incision on the order of 30 meters (100 ft.) or so (Figure 48).

There remains a 60 meter (200 ft.) rise from the Susquehanna River at Great Bend to the sluiceway at New Milford. If during the next glaciation the ice has a significant stillstand just north of the town of Great Bend, the deposits from that stillstand may be thick enough to continue to block and permanently divert the Susquehanna River down the New Milford sluiceway. This is how the Susquehanna River was diverted out of its preglacial valley in the Bloomsburg area, blockage by 60 meters (200 ft) of head-of-outwash deposits marking the Late Illinoian (or older) terminus (Braun and others, 1984, Braun, 1994).

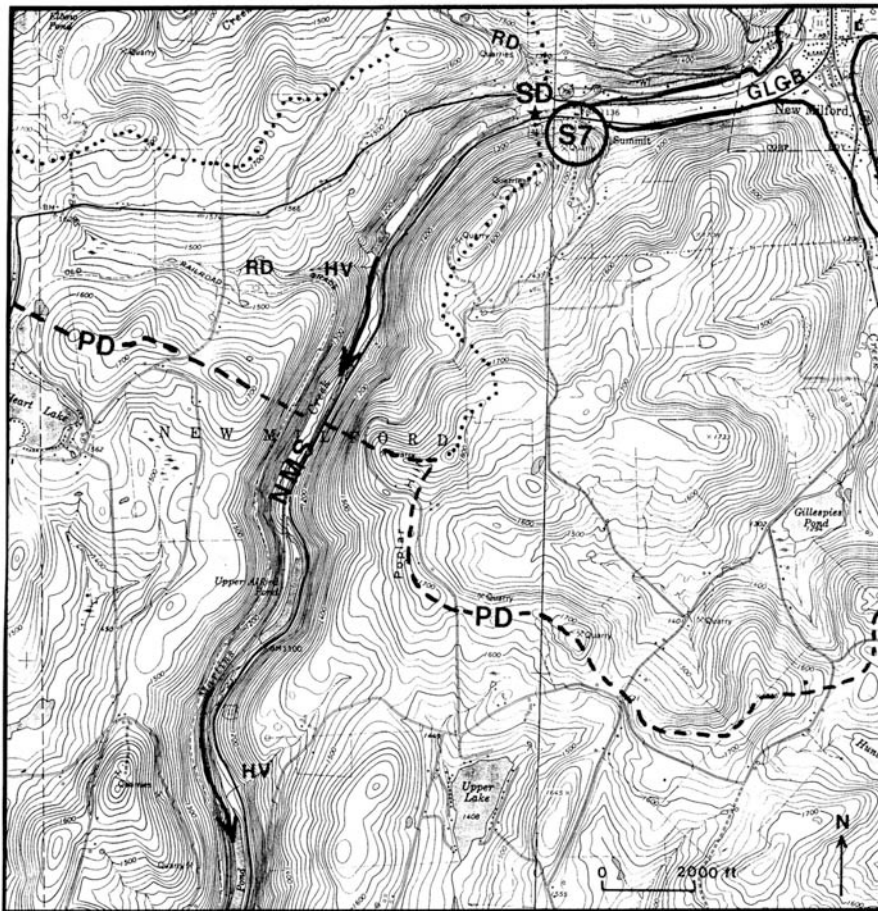


Figure 48. Map showing the New Milford sluiceway (NMS) cutting across the preglacial east-west divide (dashed line labeled PD). SD = Present Summit Divide 350 meter (1140-1150 ft) RD = Streams with reversed drainage Dotted line = area of reversed drainage HV = hanging valleys GLGB = Glacial Lake Great Bend.



Figure 49 View northeast toward New Milford from the hillside on the northwest side of the sluiceway. STOP 7 at the Summit divide lies at the base of the slope below the vantage point with the New Milford sluiceway entrance and the regional divide to the right. Glacial Lake Great bend occupied the floor of the valley in the middle distance and extended northward out of sight to the left.

Leave STOP 7, continuing south on US 11 through the sluiceway.

- 0.9 8.5 To right, across the valley beside a power line and hidden by trees on the hillside, is a 60 meter (200ft.) water fall “cascade” (a number of 2 to 5 meter (5-15-ft)-high waterfalls, one after the other) of a tributary that once drained north. The tributary has now been left “hanging” above the floor of the sluiceway and its drainage has been turned southward.
- 0.1 8.6 From this point for next five miles are numerous cuts in well-jointed, flaggy Catskill sandstone. The prominent, smooth joints are the ubiquitous north-south set.
- 0.3 8.9 From here for the next 7 miles US 11 runs on top of the old Delaware, Lackawanna and Western Railroad (DL&W) railroad bed. The old railroad bed is such a good base that when US 11 was concreted in the 1930’s, it did not require major repair and resurfacing until 2001.
- 0.3 9.2 US 11 crosses what was once the regional east-to-west-trending divide between streams draining north and south to the North Branch Susquehanna River. The glacial sluiceway here is cut 180 meter (600 ft.) deep through the divide.
- 0.8 10.0 To the right for the next several miles, two long, narrow artificially dammed lakes occupy the floor of the sluiceway.
- 2.6 12.6 Dirt road to right leads to Alford Junction, where a branch railroad line to Montrose led off the new “Summit Cutoff” grade of the DL&W.
- 2.9 15.4 To left is a cut in flaggy Catskill sandstone. It is capped by several feet of gravel (ice-contact stratified drift). Wide pull-over on the right.
- 0.2 15.6 Intersection with PA 547 North. On the right side is a Historical Marker that reads:
Galusha Grow. Father of the Homestead Act, opening western lands to free settlement in 1862, lived at nearby Glenwood. Speaker of the House, 1861-1863, and member of Congress, 1893-1903. Died in 1907; buried in nearby Harford Cemetery at few miles from here.
- 0.1 15.7 To left are low ledges of flaggy, crossbedded, gray, fine- to medium-grained, micaceous and calcareous Catskill sandstone containing a large, calcareous breccia shale ball 5 feet long and 3 feet high. Such “breccia balls” often form some of the largest boulders in the till in this region.
- 0.2 15.9 Intersection with PA 106 in borough of Kingsley. Down-valley of this point there is much less bedrock incision of the Martins Creek valley, often just the glacial till deposits have been removed from the valley floor.
- 0.9 16.8 To left, opposite the PENNDOT storage area, is a long cut exposing one complete, 40-foot-thick, alluvial fining-upward cycle in the Catskill Formation and the base of another. Weathering has accentuated the crossbedding in calcareous sandstone units.
- 0.2 17.0 Pass under Martins Creek Viaduct. Approximately 1600 feet long, 125 feet high, and “three-tracks” wide (wider than the Tunkhannock Viaduct at Stop 11), it is basically a smaller version of the reinforced-concrete Tunkhannock structure and has the same Beaux-Arts design (Inners, Stop 11).



Figure 50. Martins Creek Viaduct. View to the south.

- 2.0 19.0 To left behind a house is a 6 meter (20 ft) high cut in reddish-brown, silty-matrix, stony till.
- 0.3 19.3 Hop Bottom Borough sign on right.
- 0.6 19.9 Intersection with PA 167 in borough of Hop Bottom, named for the wild hops that grew along nearby Hop Bottom Creek two centuries ago (Blackman, 1873). On left is the old DL &W railroad grade now above the level of US 11.
- 0.5 20.4 To left is an abandoned channel of Martins Creek, cut-off by construction of US 11.
- 1.2 21.6 To left is another cut-off channel of Martins Creek.
- 1.8 23.4 Martens Creek Antiques to left preserves the original spelling of Martins Creek, which was named for

- the large population of Martens that once lived along its banks (Blackman, 1873).
- 0.7 24.1 To left, behind the homes, is a stonewall that is part of the old grade of the DL&W.
- 0.3 24.4 Wyoming County and Nicholson Township sign on right.
- 0.7 25.1 Nicholson Borough sign on right.
- 0.4 25.5 To right, Wood-frame DL&W Weigh House. This structure is along the old, pre-viaduct grade of the railroad. Today the site is a bluestone storage yard. You are now entering the Tunkhannock Creek valley, where meltwater from the sluiceway deposited a large amount of outwash from here to the Susquehanna River, 11 miles downstream.
- 0.1 25.6 Turn LEFT and descend exit road to SR 92. Ahead and to the left is the great reinforced-concrete Tunkhannock Viaduct, commonly known as the Nicholson Bridge (see STOP 11). The structure was built by the Delaware, Lackawanna and Western Railroad (DL&W) in 1912-1915.
- 0.1 25.7 Turn RIGHT onto SR 92 and drive under US 11.
- 0.1 25.8 Cross Martins Creek.
- 0.1 25.9 Ascend riser to the high outwash terrace that stands about 30 meters (100 ft) above present creek level. This is where meltwater from the New Milford sluiceway first entered the Tunkhannock Creek valley.
- 0.2 26.4 To right is an un-reinforced bluestone or flagstone wall that soil creep is now beginning to tilt towards the road and topple parts of it.
- 0.1 26.5 Descend the terrace riser and cross bridge for Horton Brook Creek.
- 0.6 27.1 To right is a cut in red and olive-green Catskill sandstone and shale (at bend in road).
- 0.1 27.2 To right is a cut showing frost-riven Catskill ledges and large "colluviated" sandstone blocks.
- 0.5 27.5 Cross low alluvial terraces of Tunkhannock Creek.
- 0.2 27.7 Cross bridge for Field Brook.
- 0.4 28.1 To left are broad, low alluvial terraces of Tunkhannock Creek.
- 0.3 28.4 To right is a stone farmhouse with a bedrock gorge and waterfall cascade behind it. The preglacial valley, buried by more than 30 meters of till, is immediately to the right of the waterfall.
- 0.5 28.9 To right is a cut exposing gray and grayish-red Catskill strata that exhibit several features typical of the formation, including sandstone channel cutouts, calcareous breccia/agglomerate lenses, and calcareous nodules in red mudstone (paleosol concretions).
- 0.3 29.2 Cross valley of Monroe Creek, incised through the Tunkhannock Creek terraces and ascent riser onto the outwash terrace.
- 0.6 29.8 To left along the power line is an excellent view of high outwash and low alluvial terraces along Tunkhannock Creek. The high-terrace riser is particularly distinctive (Figure 51). To right is a high cut in complexly interbedded and channelized, gray and grayish-red sandstone and shale and grayish-red mudstone of the Catskill Formation. At the west end a thick pod of calcareous breccia/agglomerate occurs at the base of a cross-bedded channel-sandstone.



Figure 51. Outwash terrace and lower alluvial terrace along Tunkhannock Creek.

- 0.3 30.1 The road now starts crossing the high outwash terrace.
- 0.3 30.4 To left is a small cemetery; relatively easy digging in the outwash.
- 0.1 30.5 Descend terrace riser and cross broad terraces of Tunkhannock Creek. To left are Holocene alluvial terraces and to right are forested risers of the outwash terraces.
- 0.4 30.9 To right behind a building and other stuff is a partly reclaimed gravel pit in glacial outwash.
- 0.5 31.4 East Lemon sign on right. Then ascend riser onto the high outwash terrace that East Lemon is built on and cross the track of a 1998 tornado.

- 0.2 31.6 To right are flat-lying ledges of Catskill sandstone at base of a hillside with a number of broken off trees rising above dense brush. The trees were snapped off by the F-3 Lake Carey tornado of June 2, 1998, that traveled from right to left across the valley and through the village of East Lemon. This is near the end of the 38 mile long track of the tornado that destroyed 42 homes and killed 2 people at Lake Carey to the west of here. We mapped this area in 2002 and the characteristic criss-crossed downed-tree signature of the tornado made the track almost impossible to penetrate unless it had been salvage logged.
- 0.2 31.8 Tunkhannock Township sign on right.
- 0.3 32.1 To right is a large "colluviated" block of grayish-red, calcareous sandstone from ledges upslope. For the next several tenths of a mile there are a number of such blocks projecting from a colluvial mantle that covers the till on most of these hillslopes.
- 0.4 32.9 To left are the wide alluvial terraces and active floodplain of Tunkhannock Creek.
- 1.1 34.0 To right is a narrow post-glacial bedrock gorge with a waterfall cascade over a sandstone ledge in the Catskill Formation. Just to the right of the gorge is the preglacial valley now buried by more than 30 meters of till.
- 0.6 34.6 On left is a lumber mill with a large log yard. The hardwood products industry is thriving in northeastern Pennsylvania, cutting the now mature second growth forest in the region. This makes mapping more "challenging" due to large tracts of logging slash.
- 0.3 34.9 Turn RIGHT onto US 6 entrance ramp.
- 0.1 35.0 To left is Osterhout Mountain (summit elev. 1900 feet A.T.), capped by the Spechty Kopf Formation of Late Devonian-Early Mississippian age (Berg and Dodge, 1981).
- 0.3 35.3 Esker on left paralleling road and undercut by Tunkhannock Creek on its other side.
- 0.2 35.8 Cross Tunkhannock Creek. On right is the Shadowbrook Inn and Resort that occupies the inside of a large meander loop of Tunkhannock Creek.
- 0.7 36.5 Cross Tunkhannock Creek again and ascend slope onto a kame of ice-contact stratified drift.
- 0.5 37.0 On right is an abandoned gravel pit in the ice-contact stratified drift. It is now used as a bluestone storage yard.
- 0.2 37.2 Bear left across Tunkhannock Creek, staying on US 6.
- 0.1 37.3 Traffic light, continue straight ahead across terraces of Tunkhannock Creek. The skyline ahead is the top of the highest part of the Appalachian Plateau in northeastern Pennsylvania at an elevation of 760 meters (2500 ft.). The Susquehanna River here is at 180 meters (600 ft.) elevation, giving a local relief of almost 600 meters (2000 ft.) in the area to the west of here.
- 0.2 37.5 To left is a distinct terrace-riser scarp separating two terrace levels. The upper terrace is about 7.5 meters (25 ft) above present river level and is considered to be of post-glacial, earliest Holocene age. All these low terraces are covered by silts and sands mapped as the Tioga soil and are considered to be of Holocene age. The higher outwash terraces tend to be gravel covered and have a Chenango soil mapped upon them. Peltier (1949) thought the Valley Heads terrace (ice at the Valley Heads in the Finger Lakes) was at the 8.2 meter (27 ft) level above the river here.
- 0.3 37.8 Cross Tunkhannock Creek again.
- 0.1 37.9 Traffic light, turn LEFT onto PA 29 South. US 6 continues ahead.
- 0.1 38.0 Begin crossing the North Branch Susquehanna River, now a much larger river than where we crossed earlier today at Great Bend. Downstream 70 channel miles at Bloomsburg, the Susquehanna has a mean annual discharge equal to that of the Colorado River at Grand Canyon. Along this reach of the river are a series of large incised meander bends (Figure 5 in introduction). Upstream to right, rock ledges are visible at low water on the south bank where the river is undercutting the mountain. You are now entering the northeast corner of the Figure 48 map.
- 0.3 38.3 To left is a broad outwash terrace that rises 18-20 meters (60-65 feet) above present river level. In this area, Peltier (1949) placed the Olean terrace (recession from late Wisconsinan terminus) at 23 meters (75 feet) and the Binghamton terrace (ice at PA - NYS line) at 14 meters (45 feet). Our mapping of the area showed an extensive 30 meter (100 feet) terrace (Peltier's 29-33 meter (95-110 ft.) kame terrace) and then this 18-20 meter (65-60 feet) terrace.
- Peltier's 30 meter (100 feet) level terrace is not a kame terrace but the highest outwash terrace deposited by meltwater from glacial margins north of the map area. If the feature was as ice-marginal kame terrace, the surface should slope from Tunkhannock northeast to southwest across the river valley and have at least some kettle depressions. What is observed is a lack of kettles, the top surface sloping from west to east parallel to the river, and the entire feature elongate parallel to the river. In addition, there are several other extensive remnants of the 30 meter (100 feet) high terrace over a distance of 24 kilometers (15 mi.) along the channel both downstream and upstream of this site. Two miles downstream of Tunkhannock on the north side of the river, there is a remnant of the 100 feet high terrace that is 1370 meters (4500 ft.) long by 230 meters (700 ft.) wide that is now

occupied by a housing development (just below STOP 10). Two miles upstream of Tunkhannock, on the south side of the river, is another 30 meter terrace remnant that has been partly removed by a gravel pit. There are several other 30 meter terrace sites upstream on the adjacent Meshoppen Quadrangle. These other sites show that the 30 meter level is continuous through the area and is not just a kame feature at Tunkhannock.

Peltier's 23 meter (75 ft.) Olean terrace is actually the next to highest glacial outwash terrace and is more properly related to ice margin positions farther north than those ice positions that produced the 30 meter terrace discussed above. In essence Peltier's Olean terrace is more properly related to ice margin positions at the Pennsylvania – New York State line and be better called the Binghamton terrace. At the south edge of the Tunkhannock 7.5' quadrangle, on the south side of the river, is a broad terrace at 22-23 meters (70-75 ft.) above the river. These terrace remnants are as extensive as the 100 feet terrace remnants and suggest a significant stillstand or readvance of the glacier north of this area.

- 0.4 38.7 Traffic light for Wal-Mart, continue straight ahead.
- 0.2 38.9 Descend outwash terrace riser to broad Holocene alluvial terraces developed where Bowman Creek cuts across the outwash terraces to enter the river to the left.
- 0.4 39.3 To right is a school bus parking lot in an abandoned gravel pit at the mouth of a buried tributary valley. To the right of the pit and the partly disassembled house is a cascade of waterfalls on bedrock. We are now driving upstream in the northeast-draining Bowman Creek valley. The northeast-retreating glacier dammed a continuous series of proglacial lakes in this valley from its head at Ricketts Glen State Park to this point.
- 0.1 39.4 To right is a cut in Catskill sandstone, gravel overlies the ledge.
- 0.6 40.0 Cross Bowman Creek.
- 0.9 40.9 Turn RIGHT onto Sugar Hollow road (SR 3003), beside the Sugar Hollow Diner.
- 0.1 41.0 Cross Bowman Creek and turn LEFT onto Jadick Lane (T376).
- 0.2 41.2 Pull over onto broad shoulder on left side of road for Stop 8.

STOP 8. BOTTOMSETS OF THE DELTA BUILT INTO GLACIAL LAKE BOWMAN

Leader: Duane D. Braun

A large delta was built into the final phase of Glacial Lake Bowman when the edge of the glacier occupied the Susquehanna valley and just blocked the mouth of Bowman Creek (Figure 5, Quaternary History section). The delta is marked by two broad flat areas at 244 to 250 meter (800 - 820 ft) on the north side of Bowman Creek (Figure 52). The delta was fed by two sluiceways, Sugar Hollow on the west and Benson Hollow on the north. Broad terraces on the top of the delta graded to Sugar Hollow suggest that the delta was beginning to be incised while meltwater was still coming in from the west. Meltwater escaped eastward along the north flank of Miller Mountain and then down the southwest side of the Susquehanna valley. Two flat topped remnants of that valley train remain on the flank of Miller Mountain. The more than 60 meter (200 ft) thick delta originally extended all the way across the Bowman Creek valley and dammed a post glacial lake in the Bowman valley. Post glacial incision of Bowman Creek and its tributaries carved the delta into its present two part landform.

The overall stratigraphic sequence at the stop is gravel overlain by sand that is in turn overlain by gravel capped by sandy silt. The lower gravel is interpreted to be an ice-contact, sub-lacustrine fan unit deposited when the ice-front was retreating past the site. The overlying rippled sands, with clay drapes that become more widely spaced upward in the sands, represents the progradation of the delta bottomsets and foresets across the site. The upper horizontally bedded gravel represents the topsets of the delta. The capping of sandy silt is windblown loess deposited when the delta top was beginning to be incised. Only the lower gravel and clay draped sand will be examined at this stop (Figure 53). The upper gravel and loess will be examined at STOP 9.

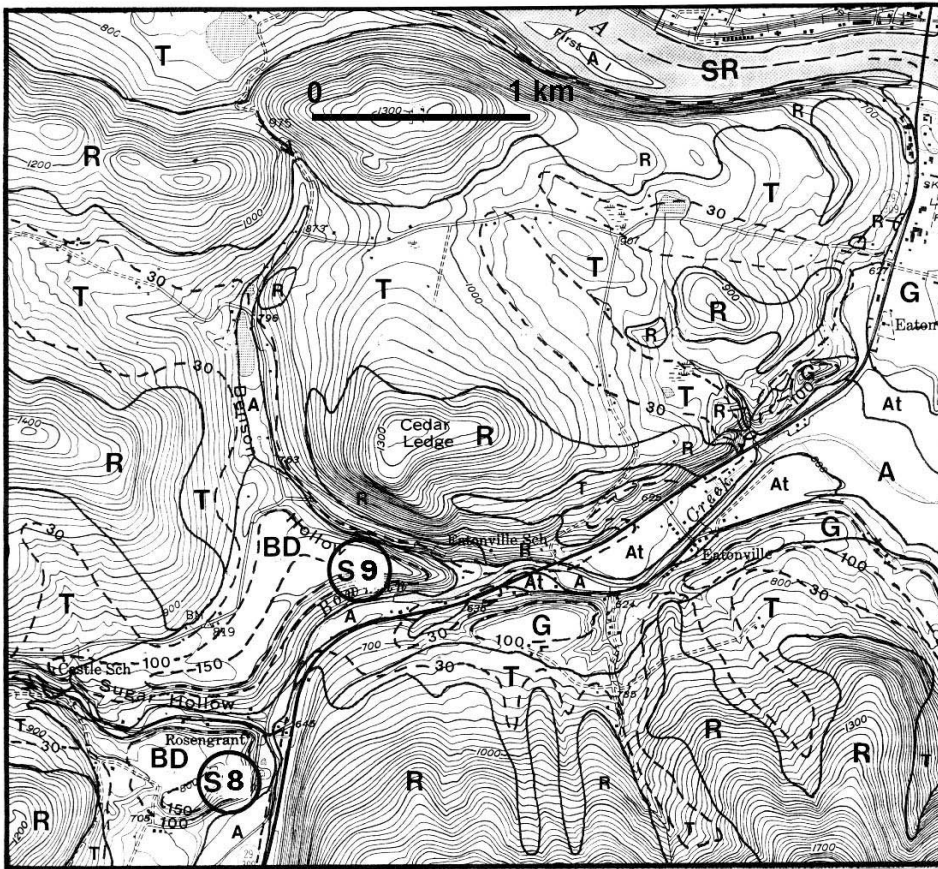


Figure 52. The Glacial Lake Bowman delta marked by two broad flat areas at 800 to 820 feet on the north side of Bowman Creek (BD) (from Braun, 2004d).

Circled S 8 = STOP 8
 Circled S 9 = STOP 9

A = alluvium
 At = alluvial terrace
 G = outwash gravel
 R = bedrock
 T = till

SR = Susquehanna River

Isochores at 30, 100, & 150 feet.



Figure 53. Picture of the outcrop face showing the lower gravel overlain by rippled, clay draped sands. View to south into the Bowman Creek valley once occupied by Glacial Lake Bowman.

The clay draped sands (Figure 53 and 54) are lake sediments that are near to or proximal to the sediment source. Some call such clay draped sands proximal rhythmites. During the summer melt season several meters of sand are deposited. Then during the winter season the clay settles on top of

the sand to form a thin clay drape. As the delta progrades across the site each season's sand layer gets thicker and the clay drapes get farther apart (upper part of the exposure).

At this site the bedding is off set by faults and tilted strongly to the west. Figures 54 and 55 show a small scale offset of the bedding. The bedding should be tilted down towards the south in the direction that the delta was prograding into the lake. The faulting and westward tilt of the bedding has been caused by slumping of the outcrop as Bowman Creek cut into the deposit in post glacial times.

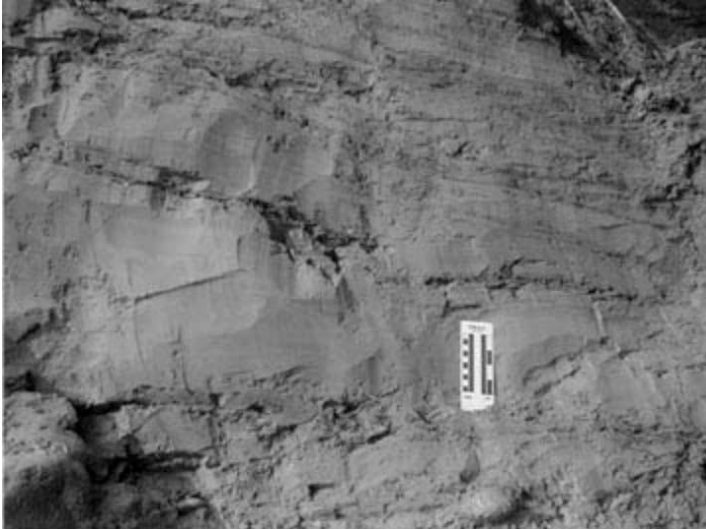


Figure 54. Closeup picture of the clay drapes (darker) and sand (lighter). Also shown is a small scale fault offset of the bedding caused by slumping of the outcrop.



Figure 55. Close-up of one of the offset clay drapes. Clay drape has a darker color as compared to the sands.

- 0.2 41.4 Leave STOP 8, turning around and proceeding back the way you came.
- 0.1 41.5 Turn RIGHT and cross Bowman Creek.
- 0.9 42.4 Turn LEFT onto PA 29.
- 0.9 42.4 Cross Bowman Creek and immediately turn SHARPLY LEFT onto Sand Bank road that runs beside the creek. At the intersection another road, Gople Hill road, goes directly uphill.
- 0.5 42.9 On left across a narrow valley are slide scars that expose sand and gravel of the delta. The stream valley the road follows runs along the contact between the bedrock hill on the right and the delta gravels on the left.
- 0.3 43.2 Turn LEFT, continuing on Sand Bank road and crossing the small stream.
- 0.4 43.6 Turn LEFT into entrance road to American Asphalt & Paving Co. Eatonville gravel pit. You are now on the top surface of the delta that extends to the right (Figure 52 and 56).
- 0.3 43.9 STOP 9. Top edge of pit, disembark for overview of the site before descending into the pit.

Stop 9. Topsets Of The Delta Built Into Glacial Lake Bowman and evidence for large scale flooding across the delta surface

Leader: Duane D. Braun

At this stop at the eastern end of the delta, the topsets and loess cap are exposed. Most of the pit face is horizontally stratified pebble to cobble gravel with scattered boulders (Figure 56). At the top of the gravel is a boulder bed that may represent a lag left by the flood caused by the rapid, 180 meter (600 feet) lowering of Glacial Lake Mehoopany (Figure 57). That flood came down Sugar Hollow and out across the delta top. Above the boulder bed is a light brown layer of sandy silt that represents wind deposition of loess (Figure 57). There are a few pebbles in the loess probably caused by frost heaving from below during post glacial periglacial activity.

Most of the gravel clasts are sedimentary rock from the region northeast of the site. A few percent of the clasts are sedimentary, metamorphic and igneous rock from much farther north. The far traveled sedimentary material is gray chert from the Helderberg sequence in central New York. The metamorphic and igneous clasts are mostly quartzite, quartz rich gneiss, and granite. The far traveled erratic material is usually pebble sized though occasional cobbles are found.

The top of the pit stands at the highest level of the delta. To the west of the pit, there is a distinct step down to a lower level (Figure 56). This lower level represents the incision of the delta surface by meltwater from Sugar Hollow. As the glacier pulled back from the mouth of Bowman Creek a bit, lower channel ways along the southwest side of the Susquehanna valley opened up. This permitted incision of the delta surface and initial lowering of the lake level. This would also permit loess to be deposited on the highest part of the delta beside the active meltwater channel.



Figure 56. West facing view of the pit face and top surface of the delta. To right, before the ridge visible in the distance, is the Sugar Hollow valley (Figure 52), one of the two sources for sediment to the delta and the pathway for large floods from the lowering of Glacial Lake Mehoopany. The other source of sediment to the delta came from the immediate right, down Benson Hollow (Figure 52). The pile of boulders at lower left on the floor of the pit have been collected from the boulder bed at the top of the pit as mining as proceeded.



Figure 2. View of upper part of the pit face showing the boulder bed and loess cap. Boulders lower on the exposure have come from the boulder bed. In the upper middle part of the view the outcrop has been "cleaned off" to better show the loess cap. Trenching shovel for scale to right of "cleaned off" face.

The boulder bed suggests a large scale flood crossed the delta surface, winnowing out the finer material to leave a boulder lag and/or transporting boulders across the delta surface. To transport the larger boulder sizes of 1 to 2 meters suggests water velocity in the range of 6 meters/sec. to as much as 10 meters/sec. (Costa, 1983). Water depth to produce such velocities can be crudely estimated, given the slope of the delta surface of about 0.0067, by solving Manning's equation for depth using a moderate n -roughness value of 0.5. Such calculations yield water depths of 7 meters for the 6 m/s velocity and 15 meters for the 10 m/s velocity. The Bowman Creek valley is at its narrowest, 800 meters, between STOP 8 and 9 (Figure 52). Using the values above, first order estimates of discharges ($Q = V \times D \times W$) needed to transport the boulders are $3.36 \times 10^4 \text{ m}^3/\text{s}$ to $1.20 \times 10^5 \text{ m}^3/\text{s}$. If the boulder bed is just a lag with the less than 1 meter size clasts being transported, then a velocity as low as 2 m/s (Costa, 1983) may be all that is needed. Using that velocity and the other values above yields a water depth of only 1.35 meters and a discharge of only $2.16 \times 10^3 \text{ m}^3/\text{s}$.

Or are the boulders from Shaw's proposed $4.8 \times 10^6 \text{ m}^3/\text{s}$ catastrophic floods coming down the North Branch Susquehanna valley and spilling through the notches to the north?? Evidence that negates such catastrophic scale flooding will be examined at the next stop.

Leave STOP 9.

- 0.3 44.2 Turn RIGHT onto Sand Bank Road. Retrace route back to Tunkhannock.
- 1.1 45.3 Turn LEFT onto PA 29. Tunkhannock Creek bridge on the right.
- 1.0 46.3 Ascend riser onto 18 meter (60 ft.) terrace.
- 0.8 47.1 Start crossing North Branch Susquehanna River.
- 0.2 47.3 Turn RIGHT onto US 6 East at traffic light.
- 0.6 47.9 Turn RIGHT onto PA 92 at traffic light.
- 0.4 48.3 For the next mile or so we will be traveling along the undercut slope of Avery Mtn. with Catskill sandstone ledges on our left and the railroad and river to our right.
- 0.5 48.7 To right across the river are the alluvial and outwash terraces we crossed earlier to the way to Stop 8.
- 1.2 49.9 Turn LEFT into Ash Street (High Fields development) and ascend the riser of the 30 meter (100 ft.) outwash terrace.
- 0.1 50.0 Turn LEFT onto Birch Drive and tread surface of the 30 meter outwash terrace now covered by homes.
- 0.3 50.3 Go LEFT around a 90° curve and road becomes Ironwood Street.
- 0.1 50.4 Turn RIGHT onto Wellwood Road, curve left, and ascend the undercut slope of the till mantled side of the valley that rises above the terrace. Continue ahead onto dirt road where paved Jefferson Drive goes right.

- 0.1 50.5 Level off. Bouldery till outcrop on right side of road and in the fields beyond is well developed knob and kettle morainic topography. The moraine lies just 12 to 15 meters (40-50 ft.) above the terrace tread just crossed.
- 0.1 50.6 Pull into the driveway on the left for the Mother of God Convent and turn around. Park on the right side of the road.

Stop 10. Unscoured till surface in the North Branch Susquehanna valley, only 12 meters above the highest outwash terrace. Where is there evidence of Shaw's catastrophic floods from the Finger Lakes?

Leader: Duane Braun

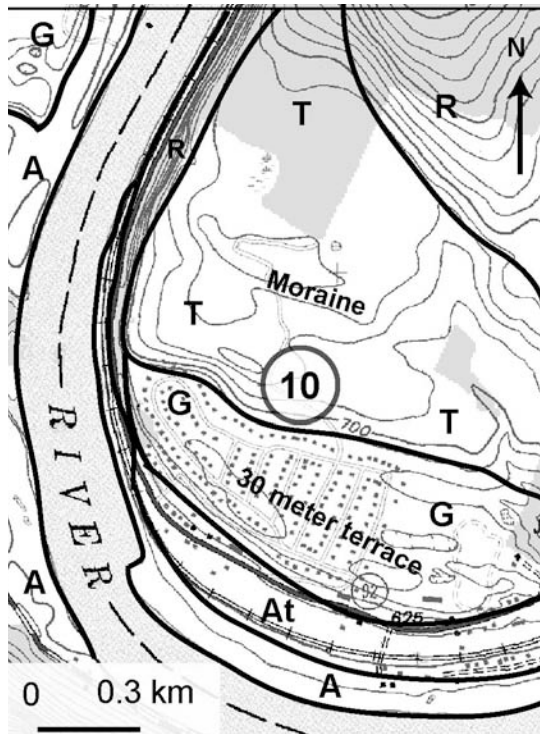


Figure 58. Moraine in the Susquehanna valley 12 meters above the outwash terrace. This limits potential catastrophic flood depths to less than 12 meters. (from Braun, 2004d).

Circled 10 = STOP 10

A = alluvium
At = alluvial terrace
G = outwash gravel
R = bedrock
T = till

Shaw (1989) proposed that $4.8 \times 10^6 \text{ m}^3/\text{s}$ ($1.7 \times 10^8 \text{ ft}^3/\text{s}$) catastrophic scale subglacial meltwater floods carved the drumlins and Finger Lake valleys in central New York State and then came down the Susquehanna valley. A flood of that size would require water depths in excess of 150 meters (500 ft.) above the Susquehanna valley floor given the cross-sectional area of the valley and given the highest velocities possible as calculated for the Channeled Scabland floods in the state of Washington.

Braun (1990) noted a number of features in the Susquehanna valley from Bloomsburg Pennsylvania to the Tunkhannock area that show that flood levels were never more than 10 to 15 meters (10's of ft.) above the surface of the highest outwash deposits. In the Tunkhannock quadrangle, as noted above, the highest outwash surface along the river is about 30 meters (100 ft.) above the river. That would have been the valley floor at the time of Shaw's proposed flood. At the 30 meter terrace level site two miles south of the town of Tunkhannock on the north side of the river, is an extensive area of knob and kettle morainic topography that lies just 12 meters (40 ft.) or so above the terrace surface (Figure 58 and 59). The knobs and kettles are random features in till. There is no evidence of meltwater scour of the features, no boulder lag surfaces, and no stream lining of the knobs. The preservation of the morainic topography limits flow depth above the 30 meter terrace to 12 meters, less than 10 % of that required for Shaw's proposed floods and it is a maximum that was probably never reached. The 12 meter high cut-bank does not require a flow that deep for it could have been undercut by much less deep flows as the braided outwash channel migrated laterally into the slope.