

GEOLOGIC

River Segment(s): UPDE

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Area Of Expertise: Geology

OVERVIEW

When describing geologic values, consider features that are rare, unique, or present in an unusual combination, related factors contributing to significant geologic features or attractions within the region. Geologic features may be highly diverse over the river corridor. Please describe these variations by river segment as necessary.

NARRATIVE

Describe the Abundance of Feature

Consider landforms with unusual, unique, or outstanding geologic features (e.g. gorges, arches, badlands, oxbows, caves, relic shorelines, bogs, waterfalls, deep canyons, hot springs, unique rock formations, and outcrops). River corridors with an abundance of unusual, unique, and distinctive geologic features in the region are highly valuable.

The 73.4-mile segment of the upper Delaware River Scenic and Recreational River (UPDE) is an exceptional example of a deep, narrow river valley cutting across the glaciated portion of the Appalachian Plateau. It is the only large river that crosses the Small Lakes Section of the glaciated Appalachian Plateau. The overall landscape is a fluvial or stream cut landscape modified by stream derangements from glacial deposits burying portions of preglacial valleys. The UPDE valley is 500 to 1000 feet deep with a floor typically only a 1000 feet or so wide. The narrowness of the valley is due to the river having to cut into Devonian-aged sedimentary rock that is mostly sandstone with minor amounts of shale.

The sandstone layers, mostly composed of quartz with varying amounts of feldspar, dip gently upstream along much of the UPDE with variable gentle dips occurring in the northern portion of the UPDE. The sandstone layers have a variety of bedding features, trace fossils and plant fossils. They were deposited in sand bed braided streams that drained to the northwest from about 380 to 360 million years ago. The lowest few miles of UPDE cut through shallow marine shale, siltstone, and sandstone layers that have a moderate upstream dip. Those layers often have abundant marine benthic fossils such as brachiopods and mollusks. The total thickness of sedimentary rock layers along the UPDE is on the order of 10,000 feet. (Note: The formal stratigraphic nomenclature differs between New York State and Pennsylvania and within Pennsylvania. Currently there is considerable disagreement among the stratigraphers that have worked in the UPDE as to how to subdivide the sandstone units. So use of specific formation names has been avoided.

The UPDE has a very unusual drainage pattern whose explanation has generated a wide variety of hypotheses by a number of geologists over the last 100 years. At the north end of UPDE is the confluence of the East and West Branches of the Delaware River. Both of those branches flow primarily westward from the Catskill Mountains. The UPDE itself trends southeasterly across the Appalachian Plateau. In the upper part of UPDE from Hancock to Milanville there are several "barbed tributaries", streams that enter the river in an upstream direction, forming a sharp bend that points upstream. The UPDE below that contains no barbed tributaries. At the south end of UPDE

the river enters the Valley and Ridge physiographic province and turns abruptly to the southwest to follow a strike valley.

Some geologists have hypothesized that the overall southeast trend of UPDE represents the course of a river that continued across New Jersey to the Atlantic Ocean in late Cretaceous time, about 70 million years ago. That river flowed on a low relief erosion surface above the present mountain tops (a peneplain) or on a cover of coastal plain sediments that covered the area. Other geologists have focused on the westerly trend of the East and West Branches of the Delaware River and the barbed drainage pattern of the upper UPDE. They proposed that the entire Delaware drainage north of Milanville used to flow westerly to the Susquehanna or a river that continued northwesterly to the Saint Lawrence River. Headward erosion of the Delaware in the lower UPDE gradually reversed the drainage in the upper UPDE to its present direction sometime within the last few tens of millions of years (mid to late Cenozoic).

The UPDE is also unusual in that for such a narrow-deep valley the river channel rarely exposes the sandstone bedrock across its bed though sandstone cliffs run along its banks for much of its course. This is due to partial infilling of the valley by deposits from the last glacial recession at around 20,000 BP or so (calendar years). The UPDE valley runs essentially transverse to the flow of the continental glacier. Such valleys act as glacial sediment traps and become partially to completely filled by glacial deposits. Typically there is 100 feet or more of glacial sediment below the present river channel. In places there is more than 200 feet of glacial sediment on the flanks of the valley. At several sites the river has incised through the glacial fill and cut into the bedrock of the valley side, in essence missing its preglacial channel. These are where there are bedrock rapids across the river channel.

At many valley side sites there are large mounds of sand and gravel called kames or ice-contact stratified drift deposits. At other sites glacial till containing a mix of all sizes of material mantles the valley sides. These materials are almost never exposed at river level and infrequently exposed in road cuts or gravel pits. Immediately upon deglaciation of the UPDE, periglacial frost activity eroded material on the upper hillsides and deposited it as till like materials (gelifluction deposits) on the toeslopes.

Glacial deposits also partially to completely fill a number of the tributary valleys to UPDE. Many of the tributary valleys have narrow, deep gorges with a series of waterfalls dropping down to the UPDE valley. These gorges are also due to the tributary streams cutting through the glacial fill and into the bedrock valley flank. Most the gorges are on the south side of the valley with the preglacial valley buried by a "till shadow" on the north side of the valley.

The present floor of the UPDE has a narrow to nonexistent floodplain of Holocene age with a few sites having glacial outwash terraces. Smaller, steeper sloped tributaries have deposited alluvial or debris flow fans on the floodplain. The present river has three basic channel patterns. In some reaches it has an anastomosing (branching) pattern of relatively stable boulder bar islands, particularly where the floodplain is the widest. In those reaches there are a number of abandoned channel swales, most of which are farm fields today. In other reaches it has a relatively stable pool-riffle pattern within a channel that is relatively straight. In yet other reaches it has large incised meanders that have a pool and riffle pattern where particularly large pools occupy the "outsides" of the bends.

Describe the Diversity of Features and Processes

Consider the number and variety of special geologic features and processes, and the value of these to the region. Consider the unique or rare combination of geologic features (e.g., erosional, volcanic, glacial). River corridors that contain the greatest diversity of geologic or hydrologic features are highly valuable.

The convoluted drainage pattern of the Delaware River system provides a rare combination of drainage anomalies that challenge various explanations of how Appalachian River systems evolved over geologic time. The diversity of valley orientations has produced an equal diversity of geologic hypotheses that try to explain how the pattern came to be.

The sandstone cliffs along UPDE expose ancient river channel deposits that have a wide variety of bedding features such as three types of cross-bedding, ripple marks, current lineation, tool marks, mud cracks, and intraformational conglomerate. Fossilized plant remains of woody debris and leaf material occur on some bedding surfaces. Rare fossilized animal material is usually found on some bedding planes as accumulations of bony plates from the armored fish of Devonian times. More common evidence of animal activity are trace fossil animal trails, tracks, and burrows. At the downstream most part of UPDE shallow marine sediments are exposed that contain a wide variety of shell remains, mostly brachiopods and mollusks, a few types of coral, bryozoans, cephalopods, and rare trilobites.

The variety of valley trend orientations provide a large diversity of settings in which glacial erosion and deposition take place. Surficial deposit maps display a complex pattern of deposits in the valleys. Valleys oriented near parallel to ice flow, like many of the valleys tributary to UPDE, are scoured out and then partly backfilled as the glacier retreats. Valleys oriented near perpendicular or transverse to ice flow, like the UPDE and a few tributary valleys, are little eroded by the glacier and are mostly in filled by glacial deposits that the stream incises into in post glacial times. These transverse valleys are often so filled by glacial deposits that the post glacial stream incises down into the valley wall or flank and forms a bedrock gorge. There are a number of such bedrock gorges with a diversity in form in the UPDE valley and adjacent tributary valleys.

*UPDE also has a variety of channel patterns ranging from pool-riffle chains in straight reaches to elongated pool-riffle chains in incised meander reaches to anastomosing channel reaches with a number of islands to short bedrock gorge reaches. Where the river undercuts the sandstone valley side, especially deep pools form. Nearly all these forms are composed of cobble to boulder bed material sometimes with a top layer of finer sediment and are relatively stable compared to sand bed channels. Large flood flows move gravel through the pool-riffle pattern with pool scour and riffle deposition occurring on the rising flood and pool deposition and riffle scour occurring on the falling flood so that the overall form is maintained. **The relative stability of all the channel forms in UPDE produces a relatively stable and diverse aquatic biologic habitat.***

Describe Educational or Interpretative Opportunities

Consider geologic features and processes that clearly and graphically reveal an interesting or unique education or scientific story of earth's history. River corridors that represent the best example of a feature and processes are more valuable for education and interpretation.

Overall the UPDE contains a number of interesting geologic features that can provide valuable educational and interpretive opportunities. A series of geologic features are described below going in a downstream direction from Hancock to Sparrow Point and are keyed into approximate river miles.

Mile 331 Point Mountain

The mountain is an isolated bedrock knob or umlaufberg bordered on the east by the East Branch Delaware River, on the west and south by the west Branch Delaware River, and on the north by glacial deposits in an abandoned incised meander of the Delaware river. Umlaufbergs are usually formed by glacial meltwater erosion cutting through a ridgeline between a confluence of two streams. At this site glacial meltwater probably did not cut the channel on the north side of the knob that isolated it in the middle of the West and East Branch confluence. The valley north of the umlaufberg, occupied by the town of Hancock, has the arcuate form and size of an abandoned incised meander loop of the East Branch Delaware River now partly filled in by glacial deposits. It is likely that in preglacial time an incised meander of the East Branch made a counter clockwise flow loop just north of Hancock and undercut the east side of a meander spur (ridge inside an incised meander loop) that once connected Point Mountain to the higher ridge just to the northwest. At the same time an incised meander of the West Branch at the position of the present one undercut the west side of the meander spur. The two meanders cut through the spur and isolated Point Mountain. Immediately after the incised meander cutoff, the East Branch flowed into the

West Branch on the north side of Point Mountain and the valley on the west side of Point Mountain was abandoned except where Shehawken Creek occupied it. Glaciation partly buried the West Branch incised meander loop and diverted the West Branch along its pre-cutoff valley west of Point Mountain. (Map to illustrate the preglacial channel pattern to be attached here.)

Mile 330.5 West Branch Delaware River and Shehawken Creek confluence

Shehawken Creek is a barbed tributary that enters the river in an upstream direction, forming a sharp bend that points upstream. Such barbed tributaries are considered evidence that the drainage system used to drain north and has been reversed to the south by a stream eroding headward from the south.

Mile 330.5 to 333 Anastomosing reach with several islands.

Mile 333.5 Stockport

An alluvial fan from Stockport Creek projects out onto the floodplain to the river's edge. A side road goes up Stockport Creek through a narrow bedrock gorge. A till shadow buried the creek valley and the post glacial creek cut a new channel in the bedrock wall of the south side of the preglacial valley.

Mile 325 Buckingham access point at Dillontown

A small fan projects out onto the floodplain from an unnamed tributary draining Nabbys Lake. A well there went through 170 feet of glacial deposits to reach bedrock. The stream draining Nabby Lake has a "one sided" bedrock gorge (south side in bedrock, north side in till). The preglacial valley just north of the present gorge is filled with at least 150 feet of glacial deposits.

Mile 322.5 Equinunk

The Equinunk valley is near parallel to glacial ice flow and has been deeply scoured and widened by glacial erosion and then partly back filled by glacial deposits during glacial recession.

Mile 322.5 to 316 Well developed incised meanders

In this relatively narrow, roadless reach, the river has carved excellent bedrock exposures along the right bank from mile 320 to 321 and mile 317 to 316.

Mile 313 Kellams bridge kames

Just east of the Kellams bridge are a series of knobs and wetland- filled kettles underlain by ice-contact stratified drift and glacial till.

Mile 306.5 - 299.5 Anastomosing reach with a number of islands

This mostly straight reach has some of the widest floodplain and the greatest number of islands of any reach along the river.

Mile 304 Callicoon Creek confluence

The Callicoon Creek East Branch is a barbed tributary that enters the river in an upstream direction, forming a bend that points upstream.

Mile 295.5 Skinners Falls and Milanville

At Milanville, Calkins Creek is another barbed tributary that enters the river in an upstream direction, forming a bend that points upstream. Skinners Falls is a bedrock-floored rapids in the river. The preglacial channel of the river is buried by glacial deposits just to the west of the present channel. Just above

Skinnners Falls, glacial till is exposed in the right bank after a flood event. The buried channel's bedrock floor is about 100 feet deeper than the present channel. The river in post glacial time has recently cut into the bedrock on its east valley wall. Future down cutting of the river may form a bedrock gorge at the site or the channel may just incise along the east side of the buried valley, excavating the buried valley. The bedrock at Skinnners Falls is the control on the down cutting of the river for a considerable distance upstream of the site.

Mile 290 Narrowsburg preglacial incised meanders and post glacial incised meander cutoff

There are three elongate incised meanders at Narrowsburg that were cut in preglacial times. The Narrows at Narrowsburg is the post glacial cutoff of the abandoned middle incised meander, partly filled by glacial deposits, that extends from the Narrows to Hunts Corner. The Narrows is a short gorge cut through the bedrock of the preglacial incised meander spur ridge that once occupied the site. The river there abruptly narrows to about one-third or one-fourth of its normal width. There is about 150 feet of glacial deposit fill under present river level both immediately upstream and downstream of the Narrows. Today there is a plunge pool at the downstream end of the Narrows from an "underwater waterfall" that forms during flood flows. The water shoots through the narrow, shallow bedrock channel at the Narrows and then deeply scours the glacial deposits in the buried preglacial channel. During the rising stages of a large flood, the river may scour down the full 150 feet and then on the falling flood stages backfill 50 feet or more. The bedrock channel at the Narrows is the control on the ability of the river to erode down upstream of the site to Skinnners Falls.

Mile 288 Triangular Eel trap (cultural feature).

Mile 277.5 Lackawaxen River confluence

The later stages of Glacial Lake Wallenpaupack drained easterly through a series of ice marginal channels cut in the hills above the south flank of the Lackawaxen River valley. There was a short lived, a few decades to a century or so, proglacial lake in the lower Lackawaxen valley that drained easterly in a series of ice marginal channels cut in the hills above the south flank of the Delaware River valley from the Lackawaxen confluence to near the southern end of UPDE. Those channels also received meltwater drainage directly from the adjacent ice front that at the time still buried the UPDE downstream of the Lackawaxen confluence.

Mile 273 Shohola bedrock gorge rapids

In preglacial times the Delaware River flowed through the village of Shohola and curved sharply to the left through what is now the saddle that the railroad presently goes through. Just upstream of the present Shohola Creek gorge, Shohola Creek used to turn right and flow easterly to the river at Handsome Eddy. The abandoned course, now partly filled by glacial deposits, is the deep saddle now followed by Bee Hollow Rd. In preglacial or early glacial times the Delaware River undercut the ridge separating it from the Shohola Creek valley and had almost cut into ("captured") Shohola Creek at the Shohola bedrock gorge site. Glaciation partly filled in both the Delaware River and Shohola Creek valleys. The post glacial Delaware River cut down at least 200 feet into the bedrock on the north side of its preglacial valley at the site of the Shohola rapids. Shohola Creek's easterly valley segment, blocked by glacial deposits, was abandoned by post glacial Shohola Creek for a lower route northward through a deeply notched saddle to the river at Shohola village. In postglacial times Shohola Creek incised down to cut a 200 feet deep bedrock gorge. Both upstream and downstream of the gorge, Shohola Creek's floodplain abruptly widens where the creek has eroded the glacial fill of the preglacial valleys. (Note: If the bedrock floor of the Delaware River gorge at the Shohola Rapids is more than a few feet below the boulder mantle of the rapids (I don't remember seeing ledges across the entire bed there), the gorge may have been cut after an

older glaciation. At least four different glacial advances have crossed UPDE over the last one million years.) (Map to illustrate the preglacial channel pattern to be attached here.)

Mile 271 - 259 Incised meander reach

Good exposure of sandstone at several sites where the river actively undercuts the valley side and there is not a railroad embankment.

Mile 268.5 Cutoff incised meander at Hillside Cemetery

This incised meander loop whose apex is one mile north of the present river was cutoff in preglacial time and then partly filled in by glacial deposits. The cemetery is at the site of the meander spur cutoff. Turn onto Van Tuyl Rd. and ascend the glacial fill. Turn right onto Bloom Rd. and cross the glacial fill. Where Bloom Rd. ascends the next slope and intersects with Mapes Rd. is the "headwall" of the outside of the abandoned incised meander loop.

Mile 263 Stairway Rapids

Sandstone ledges project out into the river from the right bank. A good site to look at bedding plane and river scour features at low water.

Mile 262 Triangular Eel trap just downstream of mid channel island (cultural feature).

Mile 261 Mongaup Rapids

Mongaup River bouldery sediment forms the rapids just like some tributary junctions do on other rivers like the Colorado River in Grand Canyon.

Mile 260 Butlers Rift

Sandstone ledges along the left bank.

Describe Region of Comparison

Consider the geographic area that is larger than local and smaller than national that provides an effective backdrop for comparative analysis of geologic resources and reveals the significance of this river corridor on a regional scale. The region of comparison should generally include similar types of physiographic resources as this river corridor and be an area with which resource experts are familiar.

Glaciated Appalachian Plateau region

The North Branch Susquehanna River also cuts across the glaciated Appalachian Plateau but has a relatively broad valley carved in Devonian-aged sediments that contain as much shale as sandstone. It received a great deal of glacial meltwater drainage from the Finger Lakes region and has broad glacial outwash terraces that rise above the present floodplain. This broad, terraced valley has been intensively used by humans for agriculture and commercial-industrial activity.

In contrast, the UPDE, with its much narrower and often steeper sloped valley, was less conducive to human activities and thus remains in a much more wild and scenic state.

Overall Delaware River valley region

The East and West Branches of the Delaware River above UPDE trend southwesterly, subparallel to glacial ice flow. Glacial erosion has widened those valleys and glacial recession has left a number of glacial outwash terrace sites. So there are broad floodplain areas where extensive agricultural activity takes place. The narrowest, most scenic part of each valley is occupied by a drinking water supply reservoir.

The Delaware River valley below UPDE is a broad southwest trending valley of the Valley and Ridge Physiographic province. The valley is underlain by relatively erodible shale and limestone and is oriented near parallel to glacial ice flow. So the valley there has been glacially eroded and as the glacier retreated up the valley, broad glacial outwash terraces were left on the valley floor. The valley has been extensively used by humans for agriculture and other commercial activities.

In contrast to the uppermost and lower Delaware River valley, the UPDE has a narrow-deep valley that provided less opportunity for human activities and thus retains a much more wild and scenic state.

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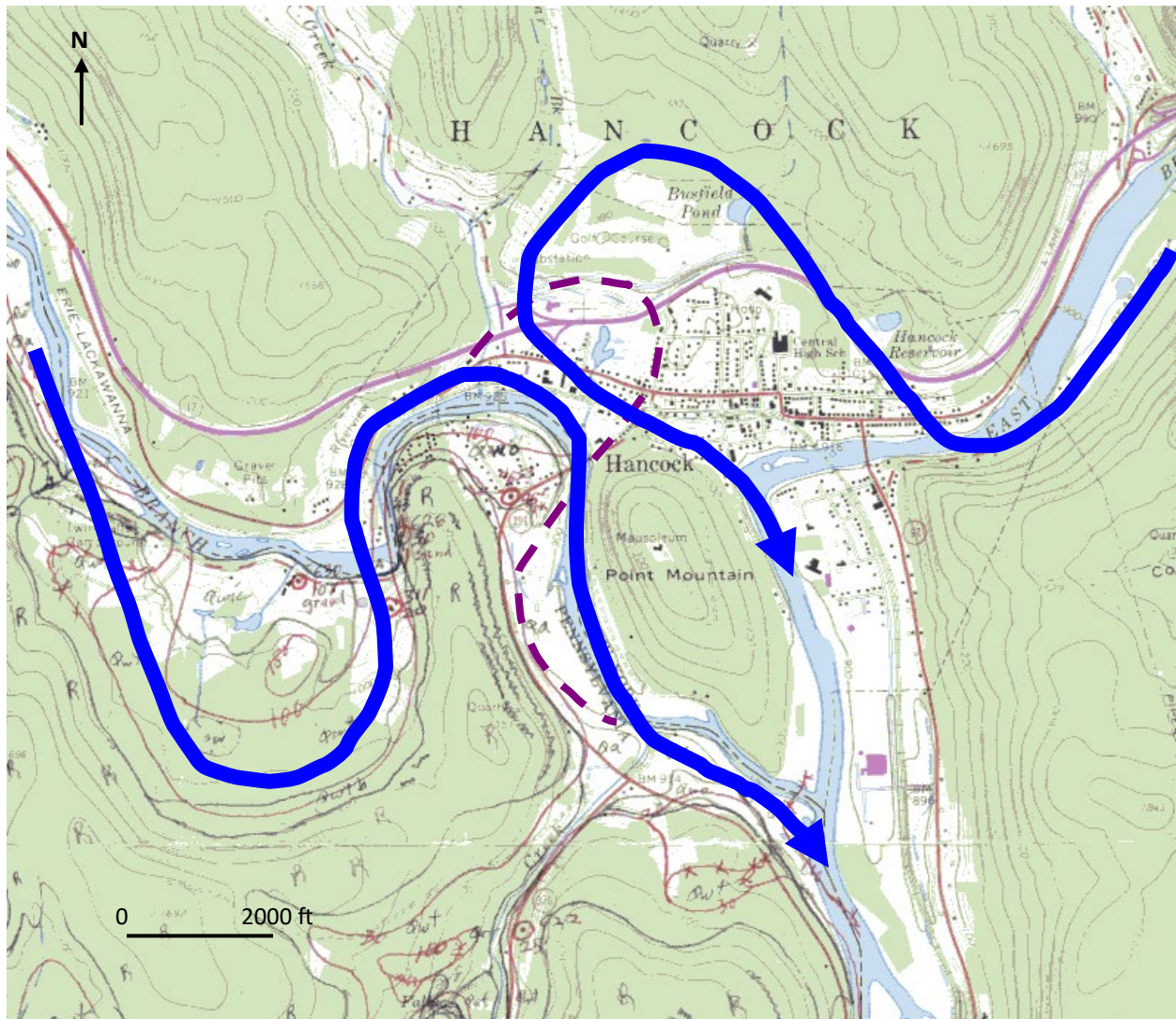
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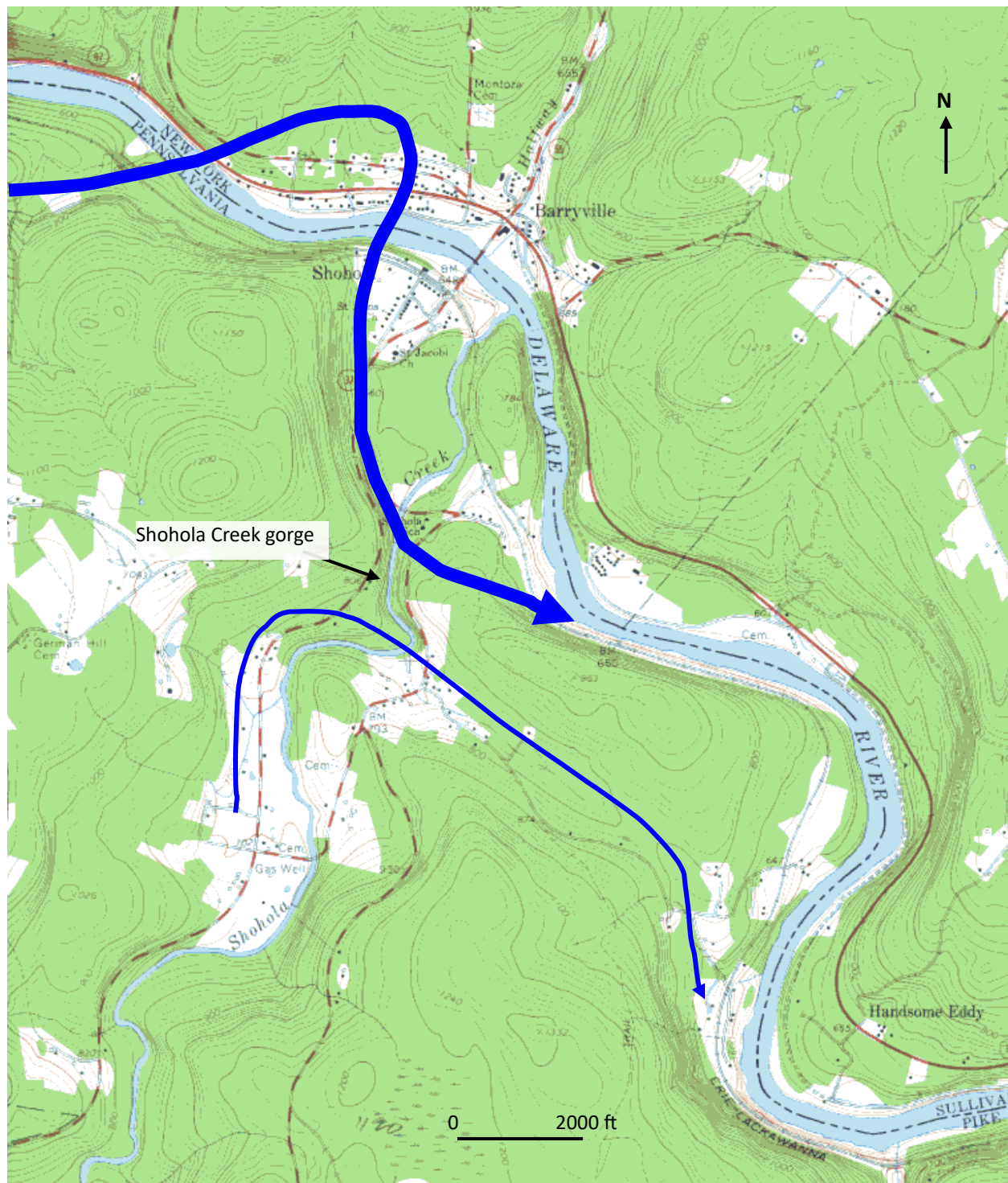
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River Mile 331 Point Mountain



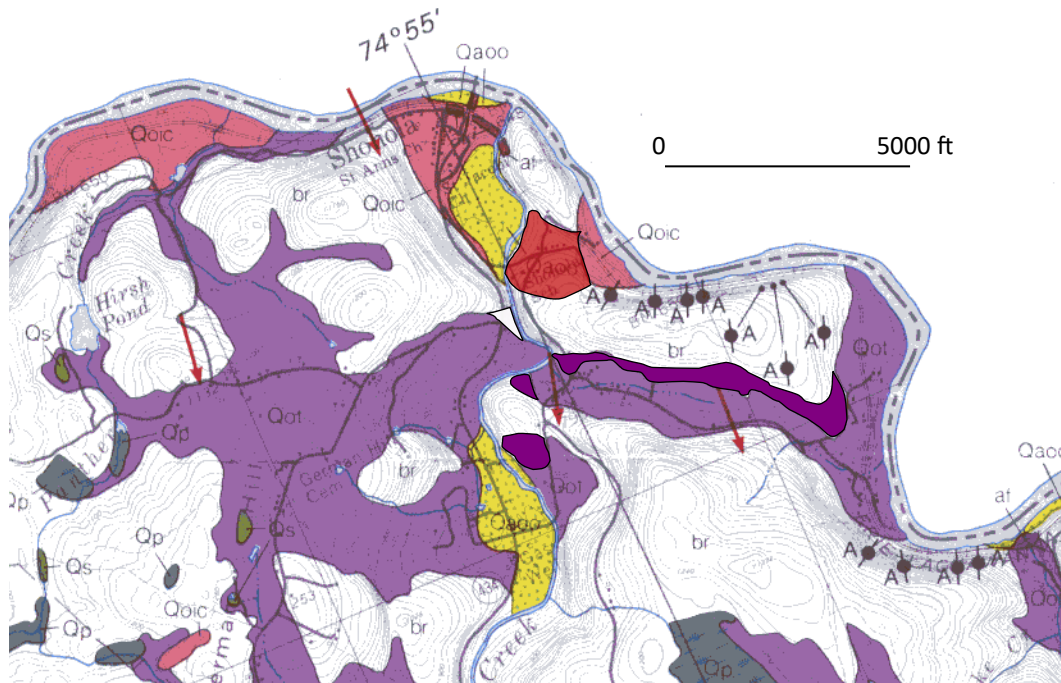
The preglacial incised meander pattern is shown by dark blue arrows of the East and West Branches Delaware River just prior to their cutting through the ridge separating them at Hancock. After the cutoff, the West Branch probably joined the East Branch to flow around the east side of Point Mountain. The West Branch channel on the west side of Point Mountain was abandoned except for Shehawken Creek draining through the southern end of it to reach the river. The West Branch meander pattern shown was when the river occupied the now abandoned meander loop west of Hancock. For the West Branch to occupy that loop, the river bed must have been at least 80 feet above present river level because there is a bedrock outcrop that high at the Twin Falls campground "underneath" the blue line preglacial channel. Since then the bedrock floor of the West Branch has been eroded down about 180 feet to 100 feet below present river level. That suggests that the cutoff at Hancock occurred several million years before glaciation. Since then the river has cut both down and laterally to cutoff the now abandoned West Branch meander loop and possibly the East Branch also cut off its meander at Hancock. Finally, glaciation occurred and glacial deposits partly infilled the incised meander loop at Hancock high enough to block the West Branch from joining the East Branch at Hancock. A now cutoff post glacial meander loop of the West Branch, dashed purple line, had cut about one-half way through the glacial deposit blockage. If the town of Hancock was not in the way, in the future the West Branch could reform that meander and erode through to the East Branch.

Mile 273 Shohola bedrock gorge rapids



Topographic map showing the preglacial channel pattern of the Delaware River, wide blue line arrow, and of Shohola Creek, thin blue line arrow. The ridgeline between the two channels was being narrowed by erosion from both of the channels. A low saddle was formed at the present site of the Shohola Creek bedrock gorge. Glaciation then partly buried both valleys. The Delaware valley was filled to at least the top elevation of the present Shohola rapids bedrock gorge. Shohola Creek valley was filled above the level of the saddle leading northward to the

Delaware valley. The post glacial Delaware River incised down into its northern bedrock valley side to form the Shohola rapids. Shohola Creek incised into the saddle leading north to the Delaware valley to form the Shohola Creek gorge. The Creek also eroded out the glacial fill in the abandoned preglacial Delaware valley from the Shohola Creek gorge north to where the creek joins the river (yellow stippled area on the map).



Map showing the glacial deposits in the Shohola area (Surficial Deposit map of Pike Co., Sevon et. al., 198). Revisions by Duane Braun are shown in brighter colors on the map. Sand and gravel fill in the Delaware valley and till fill in the Shohola valley. Red color = Qoic = ice-contact stratified drift - sand and gravel, Purple color = Qot = glacial till, Stippled yellow color = Alluvium and outwash - sand and gravel, Gray or green-gray colors = Qs or Qp - wetlands, Red arrows = glacial striations, An A next to a dot with line = debris flow chutes.