A tale of two terranes

A river guide to the geology of the Yellow Breeches Creek from Spangler's Mill to New Cumberland

Rose-Anna Behr, Bureau of Geological Survey

Trail of Geology
21–125.1

COMMONWEALTH OF PENNSYLVANIA
Tom Wolf, Governor
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Cindy Adams Dunn, Secretary
OFFICE OF CONSERVATION AND TECHNICAL SERVICES
Lauren Imgrund, Deputy Secretary
BUREAU OF GEOLOGICAL SURVEY
Gale C. Blackmer, Director

Cover Photo: View looking downstream at the St. Paul Formation outcrop at Green Lane Farms. Photo by Tom Pawlicki.

This report can be obtained through the Bureau of Geological Survey website at
https://www.dcnr.pa.gov/Geology/

Suggested citation: Behr, Rose-Anna, 2021, A tale of two terranes–A river guide to the geology of the Yellow Breeches Creek from Spangler's Mill to New Cumberland: Pennsylvania Geological Survey, 4th ser., Trail of Geology 21–125.1, 30 p.

Introduction

This kayak trip explores the Yellow Breeches Creek from Spangler's Mill in Camp Hill to the New Cumberland Borough Park (Figure 1). The Yellow Breeches Creek originates on South Mountain in Michaux State Forest (Susquehanna River Basin Commission, 2007). It meanders 49 miles through the Cumberland Valley to the Susquehanna River. Upstream, the stream traverses Cambrian to Ordovician limestones and Ordovician shales before entering the Mesozoic rift basin (see Behr, 2015). It then exits the Mesozoic basin and returns to the older rocks. Our trip will take us through the entrenched meandering lower stretch in the limestone and shale valley, over the Yellow Breeches Thrust and Allendale Faults, alternating between the Cumberland Valley and Lebanon Valley terranes (Figure 2).

Figure 1. Aerial photograph showing river route and stops.

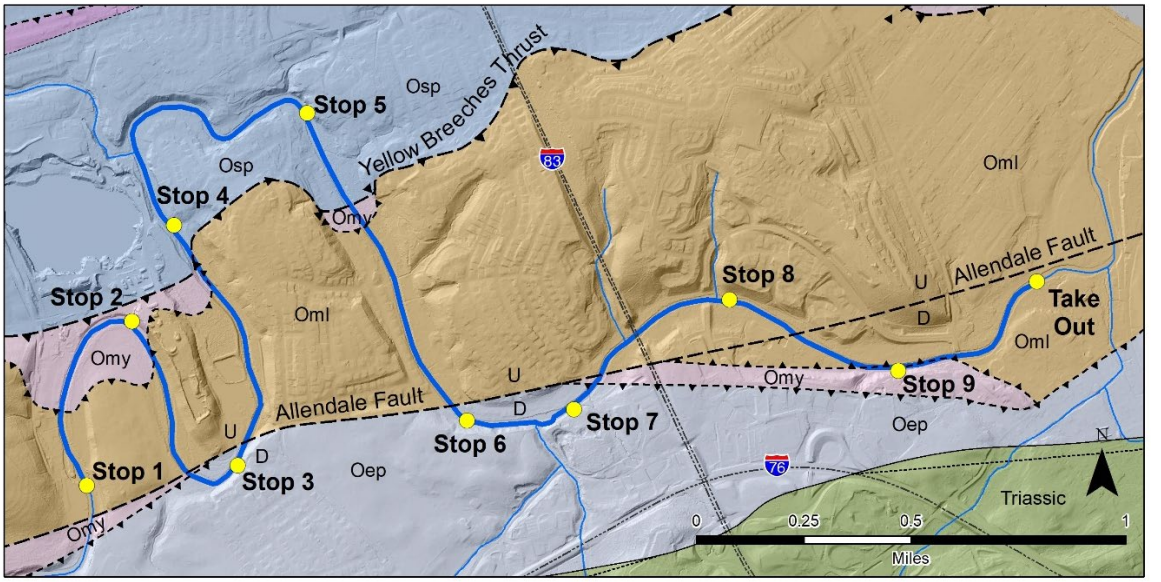


Figure 2. Map showing geologic formations, faults, river routes and stops. The Cumberland Valley terrane is north of the Yellow Breeches Thrust. The Lebanon Valley terrane is south of it. Modified from Root (1977). See Figure 3 for formation abbreviations.

Deposition

Our trip will cover four rock formations, all deposited during the Ordovician time period 485.4 to 443.8 million years ago (Figure 3). During this time, Pennsylvania was located south of the equator and was covered by a warm, shallow sea with a stable carbonate shelf, much like the Bahamas today. However, the sediments accumulated in two widely separate parts of the shelf (Root, 1977). Therefore, they are grouped into two stratigraphic sequences: the Lebanon Valley sequence and the Cumberland Valley sequence. Though similar in age and rock type, the two different areas have subsequently undergone very different deformation events.

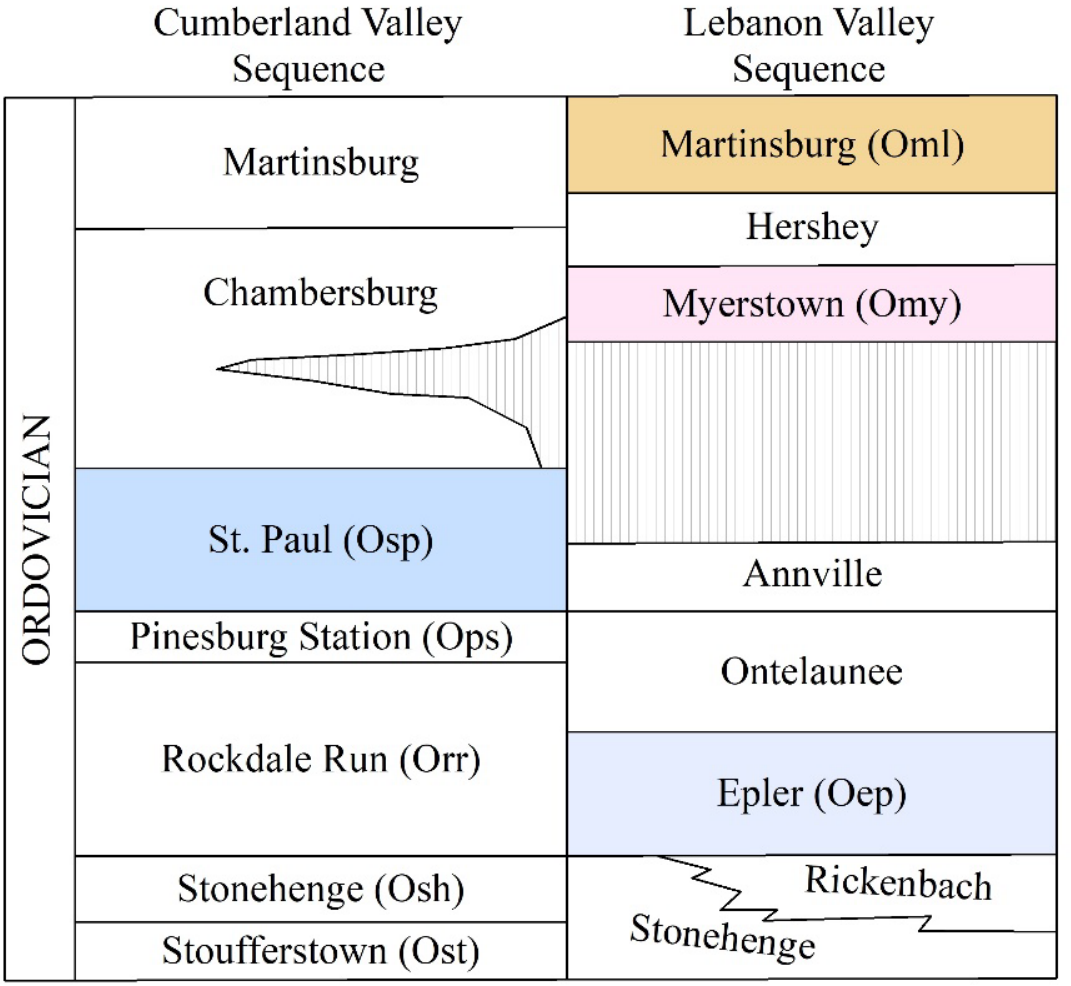


Figure 3. Generalized table of Ordovician formations in the Harrisburg area. Those highlighted will be visited on this trip. Letters in parentheses relate to the map and cross section. Striped pattern indicates time period without deposition. After Root (1977).

The Epler Formation limestone was deposited in one location, called the Lebanon Valley terrane, during the early Ordovician. Though similar in nature, the St. Paul Formation limestone was deposited in a much different location, called the Cumberland Valley terrane, during the mid-Ordovician. After the mid-Ordovician, the shelf became

less stable and the water deeper due to the impending mountain-building event called the Taconic Orogeny. The Myerstown and Martinsburg Formations were deposited above the Epler in the Lebanon Valley terrane. The Myerstown Formation was deposited on the less stable shelf and consists of limestone and shale. As the plate edge was depressed by the approaching microcontinent, the waters deepened, and the Martinsburg Formation, which is predominantly shale with rare limestone and siltstone, was deposited off the edge of the shelf.

Deformation

As the late Ordovician (458 to 443.8 million years ago) Taconic mountain-building event continued, faulting took place within the Lebanon Valley terrane in the solidified rocks. Rocks of an older age were thrust up and over younger rocks. The age sequence is Epler-Myerstown-Martinsburg, but due to faulting there is an inversion of the layers, and now the Epler sits on top of the Myerstown which is on top of the Martinsburg (Figure 4). These thrust faults dip about 20 degrees south and can be seen on the map as lines with pointy teeth. The teeth are on the upthrown side, and none of the faults are named. We will cross these faults six times on our trip. In places, the Martinsburg has been slightly metamorphosed changing the original shales into phyllite, a low-grade metamorphic rock with a slight shine to it.

Approximately 120 million years later, another mountain-building event took place. During the Alleghanian orogeny, which took place 325 to 260 million years ago, the Pangea supercontinent was assembled. Early on, the St. Paul Formation and other rocks of the Cumberland Valley were folded. We won't see these folds on the tour today. However, in the late Alleghanian, the aptly-named Yellow Breeches Thrust fault placed the Lebanon Valley terrane on top of the Cumberland Valley terrane. The fault is very shallow, dipping only 3-5° south. We will cross it twice on our trip as we enter and leave the St. Paul Formation rocks near Green Lane Farm.

Not long after Pangea was assembled, it began to tear apart. In Pennsylvania, Triassic rifting formed the Gettysburg and Newark Basins about 250 million years ago (Glaeser, 1966). This third and final tectonic event altered our study area. The pulling apart, or extension, created steep normal faults. The majority of them are at, or in, the Triassic basin which is marked by red rocks seen between northern York City and the Turnpike to Interstate 83 interchange. However, the Allendale Fault, which shows 650 feet of offset, is within the Lebanon Valley terrane and is a result of Triassic rifting. We will cross the fault five times on our float, and once more on the way to the parked cars.

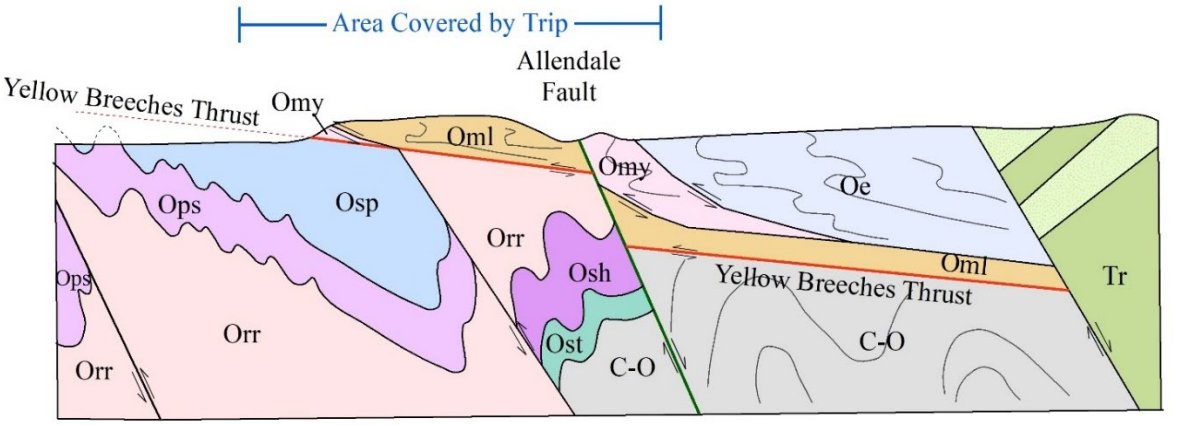


Figure 4. Cross section of rocks in the subsurface with Taconic faults, early Alleghanian folds, late Alleghanian Yellow Breeches Thrust fault (red), and Triassic-rift-related Allendale Fault (green). The dark blue line shows the area traversed by the meandering creek on this trip. Modified from Root (1977). See Figure 3 for formation abbreviations. C-O is Cambrian to Ordovician rocks undivided, Tr is Triassic rocks.

Geomorphology

Geomorphology is the study of patterns and processes acting at the earth's surface over time. The Yellow Breeches Creek is an entrenched meandering stream along this lower stretch. This means that the stream wanders back and forth, as we will note when we paddle. The outside of the curve is called a cut bank and is the location of

the most active erosion. Several of our stops are in cut banks, where fresh rock is exposed. Inside the curve, water moves slower, and often deposits a point bar of gravel and sand. The creek is a series of pools and riffles. This variation leads to increased habitat for the critters that live in the stream. The deepest part of the stream is called the thalweg. Here the water is deeper and faster. You will need to seek it out in some of the shallow areas. Over time, the stream has cut down in this position, leaving former stream banks high and dry.

Stream terraces are benches above the creek, marking these former water levels. Some terraces are well-developed surfaces. Others are simply marked by rounded rocks of the former streambed. There is a terrace of Quaternary age 80 to 100 feet above the creek (Stose and Jonas, 1939; Root, 1977)! The deposit is a thin discontinuous veneer of well-rounded siltstone, sandstone, and quartzite clasts, with minor vein quartz pebbles in a poorly solidified reddish-brown silt-clay matrix that is only a few feet thick (Root, 1977). It is mapped near the intersection of Spangler's Mill Road and Limekiln Road.

Floodplains are similar to terraces, but in active flood zones. Several different horizontal areas may parallel the stream, each used in successively higher floods. During Hurricane Agnes in 1972, the floodplain immediately downstream of the Spangler's Mill bridge was inundated by water. The adjacent floodplain on the remainder of the float trip was under successively deeper flood water during that event, which has a 1% chance of reoccurring each year (Pennsylvania Emergency Management Agency, 2020). The take-out point was under 25 feet of water (Page and Shaw, 1973)!

Alluvium is cobbles, gravel, and sand of recent depositional age, found along the modern stream. Keep an eye out for these deposits as you float the creek. The stream valley is a dynamic place, shifting within its bounds over time.

The Journey

The river log begins at the Pennsylvania Fish and Boat Commission's Spangler's Mill launch and continues 4.9 miles to the New Cumberland Borough Park take-out (Figure 1). The Yellow Breeches Creek is designated a Class I-II stream on the International Whitewater Rating System (Cumberland County Planning Department, 2015). A Class I stream is characterized by easy moving water with few riffles while a Class II stream contains some obvious obstacles to maneuver around. Be especially wary of downed trees.

The USGS gage height near Camp Hill should read at least 1.4 feet to navigate the stream successfully. It can be done with stream levels as low as 1.05 feet, with minor scraping.

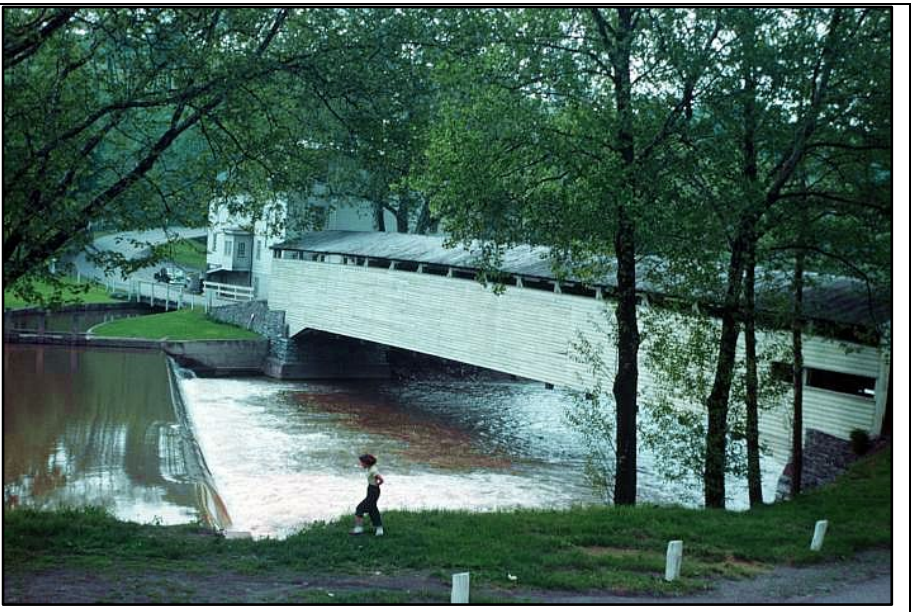
At Spangler's Mill Road, park in the parking lot. Carry boats down to the creek, selecting the launch upstream in the pool with access to the outcrops on the far side of the creek. To shuttle a vehicle to the take-out place from Spangler's Mill launch, turn right out of parking lot, travel 0.7 mile, turn left onto Limekiln Road. As you make this turn, note the flat area behind you. This is the Quaternary terrace (Root, 1977). Follow this road 2 miles to the T-intersection with Poplar Road. Turn left, proceed 0.3 mile, then turn right on Second Street. After 0.35 mile, turn right onto Geary Avenue, in less than 0.1 mile enter the Borough Park, and follow the drive 0.3 mile to park.

Mileage is estimated based on aerial photos and GPS coordinates. **Stop** refers to the numbered locations shown on Figures 1 and 2. **Inc.** refers to the incremental mileage between points of interest, whereas **Cum.** refers to the total mileage from the boat launch. River Right refers to the right side of the river, when looking downstream. River Left is the converse. It will take 2.5 hours of easy paddling to travel the 4.75 river miles. Allow additional time for exploring the rocks and enjoying the scenery and wildlife.

River Log

Inc	Cum	Things to See
0	0.00	Spangler's Mill Launch, 40.21179/-76.90703 River Left This launch is operated by the Pennsylvania Fish and Boat Commission. Launch permits required.
0	0.00	**Stop 1. <u>Martinsburg Formation</u>** 40.21163/-76.90623 River Right Five fins of semi-resistant rock emerge approximately two feet above water level. The fins are ten feet wide. Beds appear to dip upstream at a 50° angle. Rock types include medium light gray limestone, medium gray sandy silty limestone and siltstone, and dark greenish gray shale to phyllite. All of these rocks were deposited in a marine setting, with fluctuating sediment input and water depth.  The shale has a phyllitic shine to it, indicating it has been slightly metamorphosed. Look for little tiny wrinkles, called crenulations, in the shale, indicating it has gone through multiple mountain building events. Our first three stops are in the Lebanon Valley terrane. Root (1977) reported only sparse clasts of limestone in the Martinsburg Formation in this terrane. However, in the Cumberland Valley sequence he reports up to 4-inch beds of limestone with silty shale interbeds, especially in the lower Martinsburg. Outcrops of Martinsburg are sparse, and this one was under water when he mapped the area.

		 This is the only Martinsburg outcrop we will see on the entire trip, unless you brought your snorkel. The character of the rocks in the Martinsburg makes them more susceptible to weathering and erosion, resulting in subdued relief. You may notice that in the areas underlain by the Martinsburg, there tend to be quiet waters, low floodplains, and less often cliffs adjacent to the creek. Downstream of Interstate 83, you will cross over long creek-bottom outcrops, but viewing the rocks themselves will be challenging.
0.03	0.03	Spangler's Flour Mill You may have noticed the buildings across the street from the parking lot. They are the remains of a flour mill built in the early 1900s (Mill Pictures.com). However, there has been a mill at this site since 1750 (Miller, 1909). There was a concrete dam, to power the mill, upstream of the bridge. It was 135 feet long and 8 feet high. It was rebuilt in 1911 by George Spangler to replace the crib dam that was built earlier. The dam was removed in 2008, because the water power was no longer needed, and the dam was an impediment to fish movement, water flow, and recreation (Turner, 2008). The State Route 2031 bridge was replaced in 2018 (York Dispatch, 2018) during the Rapid Bridge Replacement Project. Utilizing a standardized design, PennDOT contracted to replace 558 bridges in just three years. Most of the bridges were small and rural like this one (http://parapidbridges.com). The previous bridge was an open grate metal bridge, and that was a replacement for the covered bridge that was here when the mill was in operation.



Looking west at Spangler's Mill dam, bridge and flour mill. Slide photograph taken by Clyde Martsolf circa 1950. Photo used by permission from Jim Miller, www.millpictures.com.

Downstream of the bridge, look for the remains of the mill race rejoining the creek on the left.

0.3	0.33	 Near the creek, there are some historical water pipes for the Hempt Brothers Quarry, where they have been mining limestone from the St. Paul Formation since before 1937. The St. Paul limestone is a high-calcium limestone and is used in Portland cement, agricultural lime, steel flux, blast furnaces, glass manufacture, and paint filler (Root, 1977). Watch the left bank and see if you can pick out the stone walls from the original farms. They are built of the locally available limestone.  **Photos by Tom Pawlicki**

0.15	0.48	**Stop 2. <u>Myerstown Formation</u>** 40.21730/-76.90435, River Left This outcrop is exposed in the cut bank of the meandering river. As the stream flows past, it attacks the outside edge of the curve, causing erosion. Along the inside of the curve, the water slows down, often depositing sediment. You may notice a low peninsula of sand and gravel covered in vegetation on the inside of the curve, unless a storm has washed it away. Root (1977) only saw a few tens of feet of Myerstown Formation when mapping the Harrisburg West area. This outcrop is part of a sliver of rocks caught up between two major thrust faults. The stress of being sandwiched caused significant folding. There are several well developed fractures in the outcrop as well. The outcrop consists of beds of limestone forming slightly resistant, small ledges in a dark gray calcareous shale. Some of the beds are impossible to trace due to extensive folding. 

A close-up look at some of the limestone beds will reveal algal laminations or mats. Layers of algae would have formed on the floor of the warm tropical sea, in quiet areas undisturbed by waves. The algae would form a trap for sediment, and just like dirt in your carpet, it would accumulate over time.

Look near water level at the upstream end of the outcrop and see if you can find veins of white quartz. The veins of quartz indicate that warm water was circulating, likely bringing silicon dioxide from depth. This hydrothermal activity is probably associated with one of the faulting events.

		 You may be hearing the activities at the quarry north of you. They are not mining the formation you see here, as this material makes poor aggregate due to the shale beds. As you paddle to the next stop, take note of the quiet water and low floodplain on either side of the creek. We have crossed over a thrust fault in the Lebanon Valley terrane into the Martinsburg Formation.
0.52	1.00	**Stop 3. <u>Fin of Epler Formation</u>** 40.21251/-76.89968, River Right The rapids you just navigated are underlain by the Epler Formation. The cut bank of the creek is rather steep, and plenty of boulders make for a bouncy ride! When we crossed from the Martinsburg to the Epler Formation just before the curve, we crossed over the Allendale Fault, a normal fault of Triassic age, associated with rifting of the supercontinent Pangea. This outcrop forms a resistant fin that stretches from the creek to the hill crest. Downstream for about 300 feet you will note a few more outcrops in this elevated position, until we cross the Allendale Fault again.

		 The Epler Formation is medium to thick bedded, laminated, finely crystalline limestone with rare dolostone layers. Notice how much thicker these limestone beds are than the Myerstown Formation at Stop 2. Bedding dips 30° to the south, and joints, or brittle fractures dip 60° north. Some of the joints are closely spaced and visible directly at eye level. Some of the limestone beds in this fin have a bluish cast whereas others have gash weathering. In places it looks as if someone has slashed the outcrop with a very sharp knife.
0.53	1.53	Cross the Yellow Breeches Thrust into the Cumberland Valley terrane.
0.09	1.62	**Stop 4. <u>Potholes in the St. Paul Formation</u>** 40.22053/-76.90247 River Right The St. Paul Formation is light gray, medium to thick bedded high-calcium limestone. It may contain black chert, dolostone interbeds,

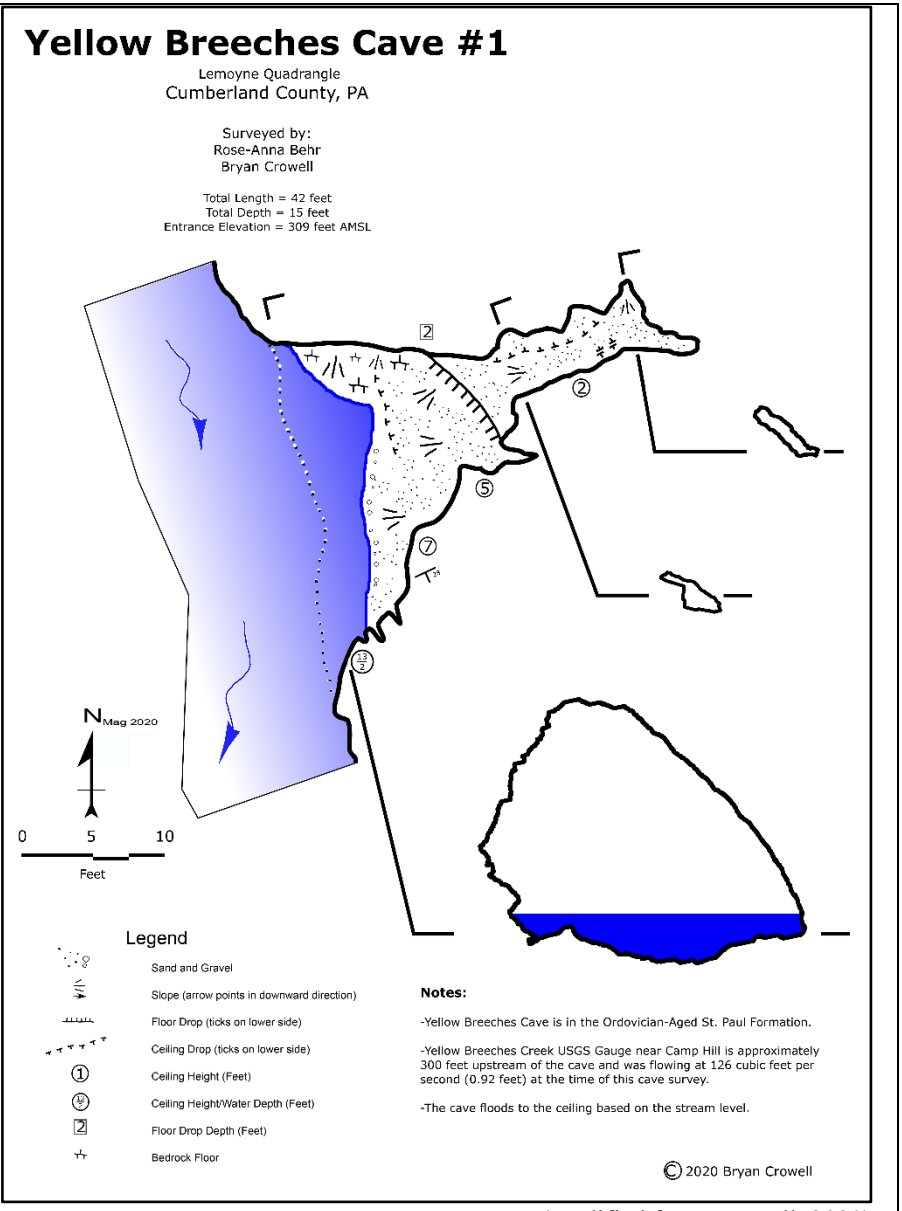
and be burrowed by the feeding patterns of ancient marine life. If you look closely at this outcrop, you will see the burrows on bedding, as a color contrast between sandy limestone and pure limestone. Two well developed sets of fractures also can be observed. The sculpting of the rocks commonly follows these planes.

This outcrop contains several potholes. These pockets are a product of mini whirlpools of swirling sand and air bubbles during floods. Plucking, abrasion, and cavitation remove bits of rocks from the walls and floor of the hole making it deeper over time. The river takes advantage of the weaknesses in the rock caused by the fractures, especially where two fractures intersect. This erosion can be purely physical, however with limestone, some chemical erosion may also be taking place.

		 **Photo by Tom Pawlicki**
0.2	1.82	Cedar Run The next mile of the creek will be marked by nearly continuous patches of outcrop of the St. Paul Formation. A few of the outcrops are really spectacular. These are all Ordovician in age, part of the Cumberland Valley terrane, and all occur below the Yellow Breeches Thrust fault. As you paddle downstream, you may notice some docks high and dry. There was a dam approximately 70 yards upstream of the bridge, but it was removed in 2009 (Turner, 2009). The dam was used to power a mill built before 1858 and eventually owned by Calvin Etters and John Shanklin (Miller, 1909). Photo shows one of the outcrops near the original dam.  Photo by Tom Pawlicki

0.46	2.28	 Etters Bridge, also known as Green Lane Farms Bridge, was built in 1889. It was designed by Dean and Westbrook, of New York, and fabricated by Phoenix Bridge Company of Phoenixville, Pennsylvania. It is a metal, eight-panel, pin-connected, Pratt Through-Truss bridge. It was built to replace a wooden bridge that washed away in the spring floods of 1889. At that time, it connected thriving communities of farms, lime kilns, grist and saw mills, distilleries, and warehouses (National Historic Registry, 1985; Historic Bridges, 2020; CRGIS, 2020). The USGS stream gage is located 50 feet downstream of the bridge on the left.

0.09	2.37	**Stop 5. <u>Yellow Breeches Cave</u>** 40.22427/-76.89656 River Left  **Photo by Tom Pawlicki** Approximately 100 feet downstream of the bridge is a small cave, several crevices, and a rock shelter formed in the St. Paul Formation at the edge of the creek. In 1953, Stone reported the largest of these extended 50 feet. Recent surveying and mapping revealed that the cave is 15 feet wide and 15 feet tall at the opening and goes back 35 feet. Possibly it continues farther but is silted shut by stream sediments. Note the way bedding controlled dissolution, erosion, and cave formation at the back of the cave.



(modified from Crowell, 2020)

Within half a mile of the cave, a dozen sinkholes and two dozen closed depressions are reported (Kochanov, 1989). A drive through the local neighborhoods reveal several patched areas of macadam that disguise the on-going problems below due to sinkhole development (Christopher Catherman, personal communication, 2020).

		As you float downstream from the cave, you may notice a few limestone outcrops in the manicured lawns on your right. They give way to a bank that is more prone to erosion and armored by land owners with all sorts of materials. We cross the Yellow Breeches Thrust again, leaving the Cumberland Valley terrane, and enter the quiet water passing over the Martinsburg Formation in the Lebanon Valley terrane. As we near the meander bend, again we cross the Triassic Allendale Fault.
0.82	3.19	**Stop 6. <u>Cherty Epler Formation</u>** 40.21372/-76.88955, River Right The Epler Formation has the most variable rock types on this trip. Think back to Stop 3, the large fin of thick-bedded light-blue limestone. This looks nothing like it. Here the Epler Formation is laminated limestone with thin interbeds of black chert, at the tip of the finger in the photo below. Look closely for approximately one-inch-thick resistant beds of black chert. Chert forms in deep water on the sea floor from siliceous ooze. The source of the silica may be very fine grained silt washed down the continental slope or creatures such as sponges and diatoms. The multiple thin, evenly spaced layers in this rock seem to suggest a cyclical repetition of deposition. In several places along the outcrop, especially at the waterline, you can see dissolution features, like little tiny caves! 

0.25	3.44	**Stop 7. <u>Creekside Park</u>** 40.21419/-76.88495 River Right On the left side of the creek you will see Creekside Park, a New Cumberland Borough park with access to the creek. On the right side of the river you will see a gravel bar which has come from Lime Kiln Run. The creek itself is easy to miss. Then you come to an outcrop of Epler Formation that is about 10 feet tall and 50 feet long. You will again note how this Epler does not look like Stop 3 or Stop 6. Here the formation is a dark gray limestone with some thin beds, some thicker beds. On the hilltop above the outcrop and along Lime Kiln Run are several old limestone quarries, utilized to make agricultural lime. The remains of the kiln are located next to the Limekiln Road. You should be able to pick out a nice little anticline, or fold that arches up, and a partial syncline, or fold that arches down, and a faulted zone next to it, near the upstream end of the outcrop. There are no faults mapped in the immediate area, but this faulting is most likely related to the many thrust faults within the Lebanon Valley terrane.  The red line highlights the fold and the blue line marks the edge of the fault zone.

		At the downstream end of the park you cross the Allendale Fault again
0.22	3.66	Interstate 83 bridge
0.19	3.85	Beacon Hill Boulevard Bridge
0.05	3.9	**Stop 8. <u>Pools, Riffles, and the Martinsburg</u>** 40.21785/-76.87807 River Right then Left Not long after you pass under the Beacon Hill Boulevard Bridge, the pool you have been lazily floating through will encounter a nice riffle. Depending on the water level, you may well get stuck. On the right is a sycamore tree leaning over the creek, then a gravel bar. Stop to take a closer look at the gravel bar.  The pebbles to cobbles that make up this bar, and the riffle, are being eroded from an older deposit along the bank and recycled into the current stream and riffle. There are a range of rock types and roundness. How many rock types can you find? A quick survey may reveal vein quartz, quartzite, white sandstone, pink pebbly sandstone, and olive colored siltstone. Most of these are well rounded to rounded. They have traveled a long distance, some from as far away as South Mountain in Adams County where the headwater of the Yellow Breeches is located. The pink pebbly

sandstone is likely from the Triassic Gettysburg Formation which crops out more than 7 miles upstream!

You will also notice an assortment of subangular to angular rocks. Many are white vein quartz and a few are limestone or phyllite. Even though much of the upstream area is limestone and shale, you don't find many of those. The limestone tends to dissolve, and the shale tends to break up if transported very far. Finding these angular pieces tells us they didn't travel too far.

How can there be rounded *and* angular vein quartz? It has to do with travel distance. The ones sourced on South Mountain were rounded and smoothed by their journey across the county. The angular vein quartz is local. Very local! It seems these rocks are associated with the Allendale Fault.

There are of course a few bricks, pottery, and an old tire imbedded in the deposit, marking the Anthropocene Epoch.

On the opposite side of the creek, shortly downstream, you will notice an abundance of phyllite and calcareous phyllite in the creek bank and armoring the edge of the creek bottom. Nowhere is outcrop

		observed, but this abundance of one type of rock lets us know we are near the Martinsburg Formation outcrop. This concentration continues 450 feet downstream. You may notice a few boulders of white vein quartz as you float downstream, in addition to more outcrop on the bed of the creek.
0.24	4.14	Lower Allen Waste Water Plant. On the right bank of the creek is the treatment plant. Your nose may have informed you of this. About midway along the chain-link fence we again cross the Allendale Fault. In this case, it has faulted Martinsburg against Martinsburg, so it is difficult to trace due to limited outcrop and similar rock juxtaposition.
0.2	4.34	**Stop 9. <u>Cliffs of Myerstown</u>** 40.21541/-76.87061 River Right The cliffs of Myerstown start behind the treatment plant, but it is hard to see from the creek. As you pass the meadow at the downstream end of the plant, the cliff and creek join. As you pass you will notice several hillside outcrops of limestone. Where the limestone meets the creek, stop and take a closer look. There are several outcrops to examine from the comfort of your boat.  This Myerstown Formation outcrop has several characteristics similar to Stop 2 including dark color, shale interbeds, laminations, folding, and veins. The limestone is dark gray, thick bedded to shaley, locally finely crystalline. Some thin laminations can be seen on certain beds and lots of small-scale folding is evident. Several thick veins of quartz

		with thin internal calcite veins can be seen. Some of the veins exhibit gash weathering, so they look like someone sharpened a knife on them. Rare small grains of pyrite are visible on fresh pieces of rock. 
0.14	4.48	Poplar Avenue Bridge. As you pass below the bridge you will notice the water becomes slack and the land flat. The stream has entered a terrace of the Susquehanna River. Approximately 400 feet downstream of the bridge, where there are large rocks placed on the right bank to protect it from erosion, begins a creek bottom outcrop of Martinsburg Formation. If the water is clear, you can see this pavement outcrop of phyllite, limestone, and siltstone for another 450 feet downstream. Though the rock is not highly resistant to erosion, it forms the bed of the creek for a long distance.
0.27	4.75	**Take Out New Cumberland Borough Park,** 40.21835/-76.86452 River Left, under the power lines. Site of the former R. J. Ross Mill. As you carry your boats to your cars, you cross over the Allendale Fault one last time.

We hope you have enjoyed your geology tour!

Acknowledgments

The author wishes to acknowledge Caron and Tom Pawlicki and Bryan Crowell, who accompanied the author on kayak trips during data collection. Anne Muren and Robin Smith assisted on scouting trips and estimated travel time without thunderstorms. Jody Smale, of the Pennsylvania Geological Survey Library, located references. Debbie Remer and David Smith of the Society for Preservation of Old Mills located Jim Miller. Jim Miller graciously shared his photograph of Spangler's Mill, dam, and bridge. Bryan Crowell surveyed and mapped the Yellow Breeches Cave. Acadia and Christopher Catherman provided support and local knowledge for the chilly caving trip. The author appreciates photos contributed by Tom Pawlicki. The field trip guide was carefully reviewed by: Anne Muren; Robin Smith; Bryan Crowell; David Gillieson; and Kristen Hand, Stuart Reese, Caron Pawlicki, and Gale Blackmer of the Pennsylvania Geological Survey. Errors remain the author's responsibility.

Available River Guides

Geology Guide to the Yellow Breeches Creek from Messiah College to McCormick Road: Pennsylvania Geological Survey, 4th ser., Trail of Geology 16–115.0, 14 p., Behr, 2015.

http://elibrary.dcnr.pa.gov/GetDocument?docId=1751860&DocName=TG16-115_GeoTrail_YellowBreechesCr_MessiahCollege-McCormickRd.zip

A float through the Devonian—A river guide to the geology of Bald Eagle Creek from Milesburg to Dowdy's Hole: Pennsylvania Geological Survey, 4th ser., Trail of Geology 16–117.0, 14 p., Behr, 2016.

http://elibrary.dcnr.pa.gov/GetDocument?docId=1751862&DocName=TG16-117_GeoTrail_BaldEagleCr_Milesburg-DowdysHole.zip

Glossary

Anthropocene Epoch- an unofficial unit of geologic time used to describe the most recent period of Earth's history when human activity started to have a significant impact on the planet.

Cambrian- a geologic time period from 541 to 485.4 million years ago.

Carbonate shelf- a sedimentary environment where carbonate minerals such as limestone and dolostone come from seawater.

Chert- a hard, sedimentary rock made of quartz crystals that are microscopic.

Clast- a fragment of rock, such as a pebble or cobble.

Cut bank- the outside bank of a water channel in a meandering stream where erosion takes place.

Floodplain- the area of land next to the stream between the banks and the valley walls, which experiences flooding during high-water events.

Fracture- a break in the rock that does not experience any offset, as a fault would.

Hydrothermal- related to the action of heated water in the earth's crust.

Meander- a winding curve of a river.

Mesozoic- a geologic era from 251.9 to 66 million years ago.

Ordovician- a geologic time period from 485.4 to 443.8 million years ago.

Orogeny- a mountain building event.

Pangea- a super continent that assembled approximately 335 million years ago, and began to break up 175 million years ago.

Phyllite- a fine-grained metamorphic rock that was originally mudstone or shale.

Point bar-a stream deposit of sand and gravel on the inside of a meander bend.

Pothole- a hole in rock formed by plucking, abrasion, and cavitation during floods by mini whirlpools of swirling sand and air.

Quartzite- a metamorphic rock that was originally pure quartz sandstone.

Quaternary- a geologic time period from 2.58 million years ago to present.

Stratigraphic sequence- the order in which sedimentary rocks are deposited over time.

Tectonic- large-scale movements within the structure of the earth's crust

Terrane- a fault-bounded crustal block with distinct rocks and geologic history.

Thrust fault- a low-angle fault where the block above the fault has moved up and over the lower block.

Triassic- a geologic time period from 251.9 to 201.3 million years ago.

References

Behr, Rose-Anna, 2015, Geology guide to the Yellow Breeches Creek from Messiah College to McCormick Road: Pennsylvania Geological Survey, 4th ser., Open-File Report OFMI 15–21.0, 14 p.

Crowell, B. E., 2020, Yellow Breeches Cave #1: Nittany Grotto News, December 2020, v. 64, n. 1, p. 21.

Cultural Resources Geographic Information System (CRGIS), 2020, Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation, https://gis.penndot.gov/CRGIS, [accessed 8/10/2020].

Cumberland County Planning Department, 2015, Yellow Breeches Creek Water Trail-A Paddlers map and guide to boating, http://www.ccpa.net/DocumentCenter/Home/View/8814, [accessed 8/10/2020].

Glaeser, J. D., 1966. Provenance, dispersal, and depositional environments of Triassic sediments in the Newark-Gettysburg Basin, Pennsylvania Geological Survey, 4th ser., General Geology Report 43, 168 p.

Historic Bridges, 2020, https://historicbridges.org/b_a_list.php?ct=&c=&ptype=county&pname=Cumberland+County,+Pennsylvania, [accessed 8/10/2020].

Kochanov, W. E., 1989, Sinkhole and karst-related features of Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 89-02, 16 p., 9 maps, 1:24,000.

Mill Pictures, https://millpictures.com/mills.php?millid=1025&mill=Spanglers%,20Flour%20Mill-remnants, [accessed 8/10/2020].

Miller, J. R., 1909, Callapatscink- The Yellow Breeches Creek: delivered before the Cumberland County Historical Society, Nov 26, 1909. Reprinted in 1991, Cumberland County History, vol. 8, no. 1, p. 1-21. https://gardnerlibrary.org/sites/default/files/vol08n1.pdf, [accessed 9/8/2020].

National Historic Registry, 1985, National Register of Historic Places Inventory Nomination Form: Etters Bridge, https://gis.penndot.gov/CRGISAttachments/SiteResource/,H083684_01H.pdf, [accessed 9/8/2020].

Page, L. V., and Shaw, L. C., 1973, Floods of June 1972 in Harrisburg area, Pennsylvania: United States Geological Survey, Hydrologic Investigation Atlas HA-530, 1 plate.

Pennsylvania Emergency Management Agency, 2020, https://dced.pa.gov/local-government/pennsylvania-flood-maps, [accessed 9/2/2020].

Root, S. I., 1977, Geology and Mineral Resources of the Harrisburg West Area, Cumberland and York Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 148ab, 106 p.

Stone, R. W., 1953, Yellow Breeches Cave, *in* Reich, J. R., Jr., compiler, (1974) Caves of Southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 65, p. 115.

Susquehanna River Basin Commission, 2007, Lower Susquehanna Subbasin Small Watershed Study: Yellow Breeches Creek: Publication 250, 20 p. https://www.srbc.net/our-work/reports-library/technical-reports/250-lower-subbasin-yellow-breeches-survey/docs/lower-subbasin-yellow-breeches-survey.pdf, [accessed 9/10/2020].

Turner, Ford, 2008, Spangler's Mill dam removed from Yellow Breeches, Sept 10, 2008 https://www.pennlive.com/midstate/2008/09/spanglers_mill_dam_removed_fro.html, [accessed 9/2/2020].

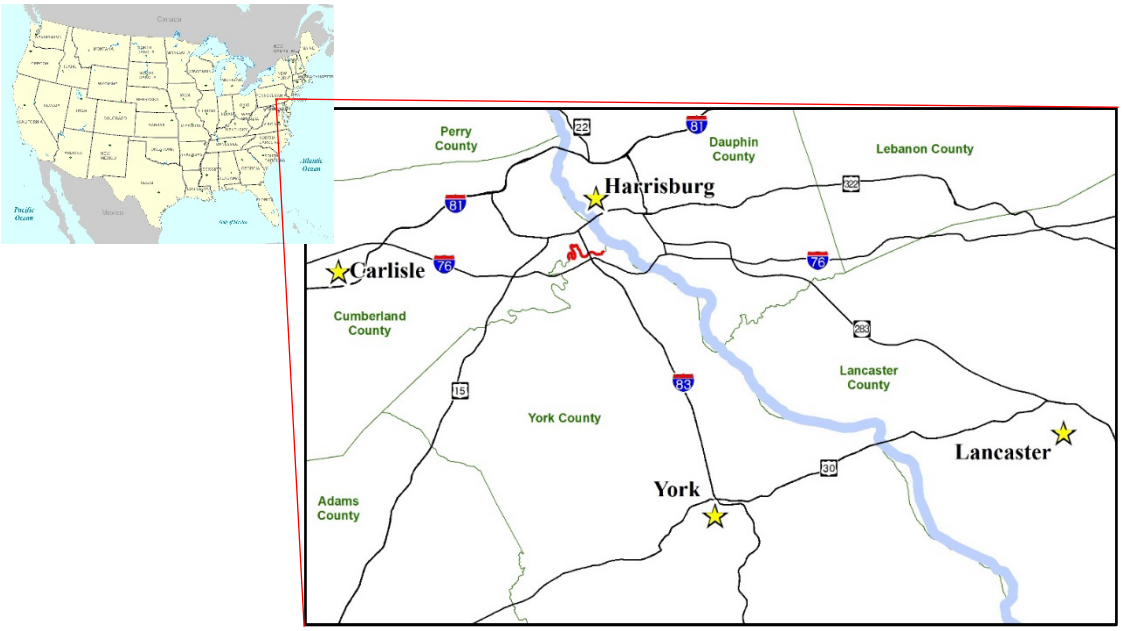
Turner, Ford, 2009, Green Lane Farms dam broken apart for removal, https://www.pennlive.com/midstate/2009/06/green_lane_farms_dam_broken_ap.html, [accessed 9/10/2020].

U.S.G.S. Gaging Station, https://waterdata.usgs.gov/nwis/uv?site_no=01571500, [accessed 9/10/2020].

York Dispatch, 2018, New Spanglers Mill Road bridge in Fairview Township open to traffic, Dec 1, 2018, https://www.yorkdispatch.com/story/news/local/2018/12/01/two-netwo-new-spanglers-mill-road-bridges-open-trafficw-spanglers-mill-road-bridges-open-traffic/2173707002, [accessed 9/2/2020].

River Rules

- This route is part of the Yellow Breeches Creek Water Trail (Cumberland County Planning Department, 2015). Launch areas are open year-round, dawn until dusk.
- Launch permits are required to use the Spangler's Mill launch.
- Anyone under age 12 must wear a personal flotation device at all times. From November 1st through April 30th, they must be worn by all. Cold water kills.
- A whistle or other emergency noise making device is required.
- Shoes are recommended, as sharp rocks and broken glass are common.
- Stream levels may be checked by visiting
  https://waterdata.usgs.gov/nwis/uv?site_no=01571500
  The water level at 1.2 feet is boatable but there will be some scraping. At a level of 3.0 feet, some of the outcrops may not be visible.
- Please stay on the creek, as property adjacent is privately owned.



pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

PENNSYLVANIA GEOLOGICAL SURVEY EST. 1836