Pittsburgh's Geoheritage: A Legacy of Late Paleozoic and Pleistocene Glacial Events

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When thousands of geologists gather in Pittsburgh this October for GSA Connects 2023, their scientific discussions will unfold at the nexus between Carboniferous land and sea and between Pleistocene water and ice. These nexuses, separated by 300 million years of geologic time and both resulting ultimately from global glacial episodes, sculpted western Pennsylvania's landscape and shaped Pittsburgh's human history. A delightful day trip 65 km northwest of Pittsburgh to McConnells Mill State Park puts this geological heritage on scenic display.

Western Pennsylvania's bedrock consists exclusively of upper Carboniferous sedimentary rock so noteworthy that the upper Carboniferous in North America is named the Pennsylvanian Period. The cyclic repetitions of interbedded sandstone, shale, coal, marine and lacustrine limestone, and chert horizons, associated with layers and nodules of siderite, an iron carbonate mineral, are textbook examples of the famous cyclothems (Riegel, 1991; Hannibal et al., 2011) exposed across vast portions of the American Midwest.

During Pennsylvanian time, what is now western Pennsylvania consisted of a huge delta that straddled the equator and was fed by rivers draining the actively rising Appalachian Mountains (Fleeger et al., 2003). Because of Pittsburgh's equatorial position, the Late Paleozoic Ice Age affected Pittsburgh indirectly, albeit profoundly. Repetitive growth and shrinkage of ice caps at Gondwana's high latitudes, driven by 100 ky and 400 ky Milankovitch Cycles, triggered repeated transgressions and regressions across the delta (Brezinski and Kollar, 2011). Those sea-level fluctuations produced the repetitive cyclothems, which included valuable coal, oil-producing black shales, chert, and iron ore—raw materials that Pittsburgh's human inhabitants would harness 300 million years later and that would eventually fuel Pittsburgh's rise as a great industrial city in the 19th and 20th centuries.

McConnells Mill and the nearby covered bridge. Photo by DodgeDart via Wikimedia Commons. https://creativecommons.org/licenses/by-sa/4.0/deed.en.

During the last 2.7 million years—the Pleistocene Ice Age—the globe once again cooled to the threshold temperature necessary for Milankovitch orbital forcing to trigger glacial-interglacial cycles. During each glacial advance, the Laurentide ice sheet crept south out of Canada into northwestern Pennsylvania, stopping each time just short of Pittsburgh. The region's preglacial river network flowed generally northwestward, so as the penultimate Pleistocene ice sheet retreated northward ~135 ka, its glacial ice dammed those preexisting valleys, which filled with meltwater to create a series of glacial lakes. As lake levels rose, they overtopped local drainage divides and carved canyons through them, thereby stitching together today's Ohio River network that drains southward to the Gulf of Mexico.

HOW HUMANS HARNESSED CARBONIFEROUS CYCLIC SEDIMENTATION

Western Pennsylvania's first human inhabitants used the cyclothems for shelter 14,000 years ago. The Meadowcroft Rockshelter, 48 km southwest of Pittsburgh, contains the oldest record of human habitation in North America (Swaminathan, 2014). A shallow cave, excavated from Birmingham shale, one cyclothem component, is sheltered by an overhang made of resistant Morgantown sandstone, another component deposited on a river point bar (Benyon and Donahue, 1982). The abundant stone tools recovered from the ^{14}C-dated cave sediments were fashioned from chert and jasper components of regional cyclothems (Goodyear, 2005).

Descendants of the Meadowcroft people have occupied the Pittsburgh area ever since. When the first Europeans arrived in the 1600s, the area's two dominant Native American cultures belonged to two distinct language groups—the Algonkian and the Iroquoian (Pennsylvania Historical and Museum Commission, 2015). Both groups relied on the geologic raw materials they derived from the Pennsylvanian cyclothems. For example, for hundreds of years members of the Seneca Nation, part of the Iroquois Confederacy, collected oil from seeps for use as a salve, insect repellent, and tonic (Ginsburg, 2009). When the Europeans arrived, they weren't interested in the oil—yet. They focused instead on the chert, to make millstones (Hannibal et al., 2011), and on the siderite iron ore; Pennsylvania's first iron smelter was erected in 1692 (Gray et al., 2015).

Over time, tensions rose over resource access, between both the Euroamericans and Native Americans and the English-speaking and French-speaking colonists. Pittsburgh got its start in 1754 when, at the recommendation of a young military commander named George Washington, the English constructed Fort Prince George at the strategic confluence of two mighty rivers, the Allegheny and Monongahela, which together form the Ohio River downstream.

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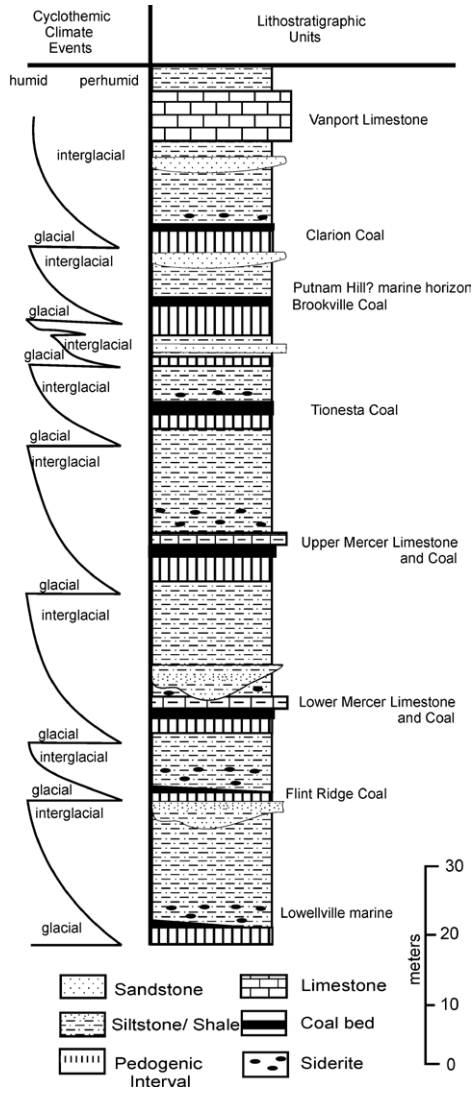


Stratigraphic section of upper Pottsville Formation and lower Allegheny Formation rocks exposed along U.S. 422 at Moravia Street Interchange, New Castle, Pennsylvania (modified from Skema, 2005). This interval is interpreted to have been deposited during the early Pennsylvanian humid period. Climatic cycles (left column) are interpreted to be the Appalachian equivalent to Midcontinent cyclothems produced during repeated advances and retreats of high-latitude continental glaciers. (From Brezinski and Kollar, 2011.)

The French captured the fort just one month later at the beginning of the French and Indian War (Gray et al., 2015).

The war ended in 1763 with the British firmly in control of Pennsylvania. English-speaking American colonists began moving to western Pennsylvania in large numbers. The area's first industries were sawmills and gristmills. McConnells Mill, the centerpiece of the eponymous state park, is a picturesque example of an early gristmill. Mills were constructed wherever a sufficient drop occurred on a river to turn the wheel; McConnells Mill was built in 1870, sited where Slippery Rock Creek tumbles over a ledge of resistant Homewood sandstone. The mill is equipped with a buhrstone grinding wheel. Burhstone is a light-colored chert abundant in the local cyclothems; it was the premier material used for making millstones (Hannibal et al., 2011).

THE RISE OF PITTSBURGH AS AMERICA'S IRON AND STEEL CAPITAL

Iron smelters quickly followed the mills as economic engines thanks to the abundance of 30–40%-pure siderite iron ore and limestone—another legacy of the cyclothems—and expansive hardwood forests from which the colonists made charcoal to fuel the furnaces. More than 60 iron furnaces were operating by the onset of the Revolutionary War (Gray et al., 2015).

The growing economy's voracious appetite for trees used in smelting and building meant that the once-extensive forest nearly vanished by the 1850s. But the region's abundant coal easily replaced charcoal as fuel for the blast furnaces (Hannibal et al., 2011). By the 1870s, Superior Province iron ore supplanted the local siderite, sounding the death knell for many rural smelters (Fleeger et al., 2003). But Pittsburgh's iron industry was already firmly established, and the city's abundant coal reserves ensured that it continued to flourish. By 1911, Pittsburgh-produced steel accounted for nearly half of total U.S. production (Gray et al., 2015).

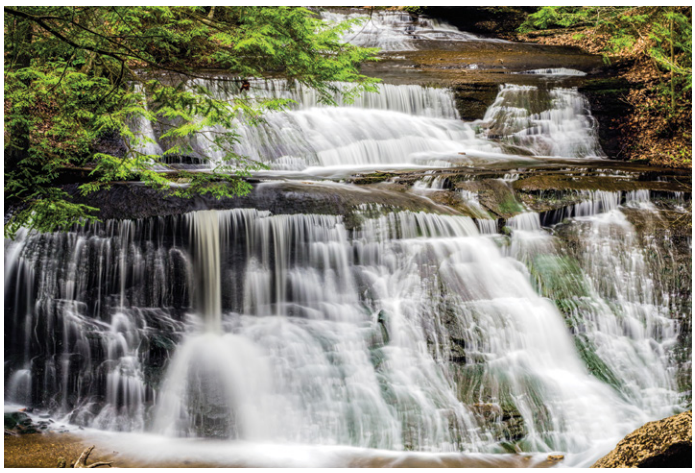
Hells Hollow in McConnells Mill State Park is a scenic place to see remnants of western Pennsylvania's early iron industry. A gentle creekside trail traverses Vanport limestone, an especially thick marine limestone deposited during a particularly high sea-level stand. The Vanport is called a "ferriferous limestone" because of the high iron content at the top of the formation (Fleeger et al., 2003). The Lawrence iron smelter was built here in 1846 because of this convenient juxtaposition of iron ore and limestone, the latter used as flux to remove impurities. The smelter lies on private land, but the trail passes a shallow quarry and adjacent lime kiln. The Vanport limestone has developed karst drainage, with disappearing streams that gave the Hollow a fearsome reputation (Hannibal et al., 2011). A narrow, flume-like section of creek flows along a collapsed karst cave (Fleeger et al., 2003). The trail ends at Hells Hollow Falls, which cascades over a ledge of resistant Clarion sandstone.

PLEISTOCENE CREATION OF THE OHIO RIVER SYSTEM

Pittsburgh owes its location to its strategic geography at the head of the Ohio River, but prior to establishment of the modern drainage network 135 kyr, its location wouldn't have been especially strategic. The scenic gorge of Slippery Rock Creek in McConnells Mill State Park puts this reorganization on scenic display.

The gorge's deepest (at 120 m) and narrowest point is seen from the Cleland Rock scenic vista. The vista is particularly spectacular during peak fall foliage, which should occur during GSA Connects 2023. Gorge depth decreases to both north and south of Cleland Rock, as does the stream gradient—28 ft/mile in the gorge, diminishing to 8 ft/mile outside it (Fleeger et al., 2003). Both characteristics result from the gorge's position on the Pleistocene drainage divide. Back then, the section of modern Slippery Rock Creek south of Cleland Rock was a small, south-flowing drainage that geologists call Wurtenburg Run. The section to the north was an equally small, north-flowing drainage named McConnells Run. The Laurentide ice sheet blocked northward-draining McConnells Run, filling it with glacial meltwater to form Lake Prouty. When the lake reached the height of Cleland Rock, it spilled southward into Wurtenburg Run, linking the upper and lower portions of today's Slippery Rock Creek and cutting the modern gorge.

Today, Muddy Creek, a west-flowing Slippery Rock tributary 10 km northeast of McConnells Mill State Park, is impounded by a



Hells Hollow Falls at McConnells Mill State Park. Photo by J7u via Wikimedia Commons. https://creativecommons.org/licenses/by-sa/4.0/deed.en.

dam to form Lake Arthur, which is the centerpiece of Moraine State Park. Lake Arthur is a smaller modern version of Pleistocene Lake Watts, which was dammed by the Laurentide ice sheet. Progressive ice-sheet retreat caused Lake Watts to spill southward through a succession of low points on the intervening drainage divide. Geologists call these spill points Alpha, Beta, and Gamma passes (Fleeger et al., 2003). Alpha Falls tumbles over a resistant ledge of Homewood sandstone at the first Lake Watts spill point. Even larger glacial lakes—Lake Edmund to the north and Lake Monongahela, which covered Pittsburgh itself, to the south—formed similarly in response to glacial damming of the preexisting drainage (Fleeger et al., 2003; Kollar and Noe, 2022). The cumulative effect of multiple glacial lake spillover events stitched several previously separate river segments together to form today's Allegheny River, which joins the Monongahela at Pittsburgh to form the Ohio.

BIRTH OF THE U.S. OIL INDUSTRY

Moraine State Park is a great place to learn about the history of Pennsylvania's oil industry, yet another legacy of the Carboniferous cyclothems thanks to their oil-producing black shale components. The most famous chapter of the story unfolded 110 km to the north in Titusville, where in 1859 Edwin Drake drilled the first commercial oil well. Drake was inspired by the existence of abundant oil seeps across western Pennsylvania in the 19th century. Slippery Rock Creek's name comes from an oil-covered rock at a Native American ford 10 km downstream of McConnells Mill (Fleeger et al., 2003). Similar seeps fouled Samuel Kier's salt brine wells at Tarentum, 30 km north of Pittsburgh. One day Kier noticed that the oil closely resembled a potion his wife used regularly, so in 1852 he began marketing it as "Rock Oil" for medicinal purposes. He later distilled it for use in oil lamps (Gray et al., 2015), generating a market.

A drilling boom quickly followed Drake's success, and by 1862 Pennsylvania produced 3 million barrels of oil per year, surpassing Russia as the world's largest oil producer (Gray et al., 2015). The Muddy Creek Field was discovered at modern Moraine State Park in 1891. Well #19 has been transformed into the Muddy Creek Oil Well Living History exhibit, which includes a Bessemer gas engine, the type that powered late 19th century wells. Volunteers periodically rev it up so visitors can witness how America's early oil industry operated (Carter and Sager, 2010).

Taking a day trip to McConnells Mill State Park from GSA Connects 2023 is an opportunity to admire fall foliage at the rim of a scenic gorge carved by spillage of Pleistocene glacial lakes. It's also a great way to acquaint yourself with Carboniferous cyclothems, their abundant raw materials, and the industries that relied on them. We can think of no more graphic illustration of geoheritage—the recognition that geologic processes sculpt all landscapes and that every human activity is fueled by resources that are a legacy of local geologic history.

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