GEOLOGY AND ARCHAEOLOGY OF MEADOWCROFT ROCKSHELTER

Meadowcroft Rockshelter (photo from Anonymous, 2018b).

AND THE MULTIPLE ICE AGES OF SOUTHWESTERN PENNSYLVANIA

Pittsburgh Geological Society

Field Trip

September 7, 2019

Guidebook

PGS Spring Field Trip

September 7, 2019

Geology and Archaeology of Meadowcroft Rockshelter and the Multiple Ice Ages of Southwestern Pennsylvania

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WASHINGTON COUNTY, PENNSYLVANIA

ABOUT 19,000 YEARS AGO

Well, so much for global warming!

GEOLOGY AND ARCHAEOLOGY OF MEADOWCROFT ROCKSHELTER AND THE MULTIPLE ICE AGES OF SOUTHWESTERN PENNSYLVANIA

Welcome to the 2019 Pittsburgh Geological Society Field Trip! On this trip, we will examine the impact that two separate ice ages, one in the Carboniferous and the other in the Pleistocene, had on southwestern Pennsylvania. Among the six stops we will visit are: 1) two very important and influential sites, both located just southwest of Pittsburgh; 2) the former site of a bygone Pleistocene peat bog that left a very interesting record; and 3)a stop to look at the Late Pennsylvanian Monongahela and Waynesburg formations.

The first important and influential site is the internationally acclaimed Meadowcroft Rockshelter in Avella, western Washington County, PA, recognized to be the oldest continuously-used shelter for human habitation in North America, going back as early as 19,000 bp. Dr. James M. Adovasio, Ph. D., lead archeological excavator of this site since he opened it at Albert Miller's request in 1973, will present a lecture and tour. After lunch at beautiful Cross Creek Park several miles to the east of Meadowcroft, we will travel to a second important site in this area, the MarkWest Houston extraction plant outside of Houston, Washington County, PA. We will tour this facility to learn how natural gas liquids (NGLs) are extracted from locally produced hydrocarbon-rich "wet" Marcellus gas. The Shell Oil Company ethylene cracker plant, currently being constructed along the Ohio River near the interchange of Interstate 376 and PA Route 18 in Potter Township, Beaver County, will use products from the MarkWest Houston Plant.

From Houston, we will travel north to Bridgeville in southern Allegheny County, PA, to discuss the implications of a Pleistocene bog that, unfortunately, no longer exists. Although long gone, the bog provided much data that are important in studying the Late Pleistocene Wisconsinan Stage outside the limits of glaciation. Our last stop, just a few miles west of Bridgeville, will be a look at the upper beds of the Late Pennsylvanian Monongahela Formation and the lowest beds of the overlying Waynesburg Formation of the Dunkard Group exposed in a roadcut in Collier Township, Allegheny County, PA. Although more than 250 million years old, these rocks represent a small portion of the 90 -million-year record of cyclical climate changes in the Appalachian basin that were driven by repeated glacial-interglacial episodes in the southern hemisphere during the Carboniferous Period.

Pennsylvanian rocks of the Monongahela Formation exposed along PA 50 near Bridgeville provide information on the Carboniferous Ice Age.

THE PLEISTOCENE IN SOUTHWESTERN PENNSYLVANIA

John A. Harper

Introduction

When Louis Agassiz (1840), the great Swiss paleontologist and geologist, announced that large parts of North America and Europe had once been covered by ice as much as two miles thick, his hypothesis upset many people who had preconceived notions about icebergs being responsible for features we now call tills, moraines, and glacial striae in bedrock. Agassiz' hypothesis, originally presented to the Helvetic Society of Switzerland in 1837, stated that ancient glaciers not only had flowed outward from the Alps, but that even larger glaciers had covered the entire northern hemisphere in a prolonged ice age. After arriving in the United States in 1846, he found that large portions of North America had been covered by glacial ice that extended from the northern pole across Canada and down across much of the midwest (Figure 1). He was very familiar with glaciers, having studied them in careful detail in his native Switzerland. When he came to America, he found nothing but mountain glaciers in the west, but in the east and midwest he recognized the signs of glaciation he had studied in Switzerland. We now recognize the brilliance of Agassiz's work, and the existence of the Pleistocene, or Ice Age, the lowest epoch of the Quaternary Period of geologic history.

Figure 1. Generalized diagram of North America during the Wisconsinan glaciation showing the directions of ice flow of the Laurentide and Cordilleran ice sheets.

The international geological community recognizes the Pleistocene Epoch as beginning at 2.588 million years ago and ending 11,700 years ago. The epoch has four stages in North America, the pre-Illinoian, Illinoian, Sanga-monian, and Wisconsinan, with the pre-Illinoian representing most of the epoch (Figure 2). For many years, North American geologists had recognized four glacial stages, Kansan, Nebraskan, Illinoian, and Wisconsinan, but detailed studies revealed that the concepts on which they were defined were incorrect and the Kansan and Nebraskan stages have been abandoned. The Wiscon-sinan and Illinoian are now the only two officially named glacial stages. All earlier ones, labeled A to K, are part of the pre-Illinoian stage. In western Pennsylvania, Pleistocene glacial tills and moraines are restricted to the northwestern counties. The maximum glacial advance reached only as far south as Butler and

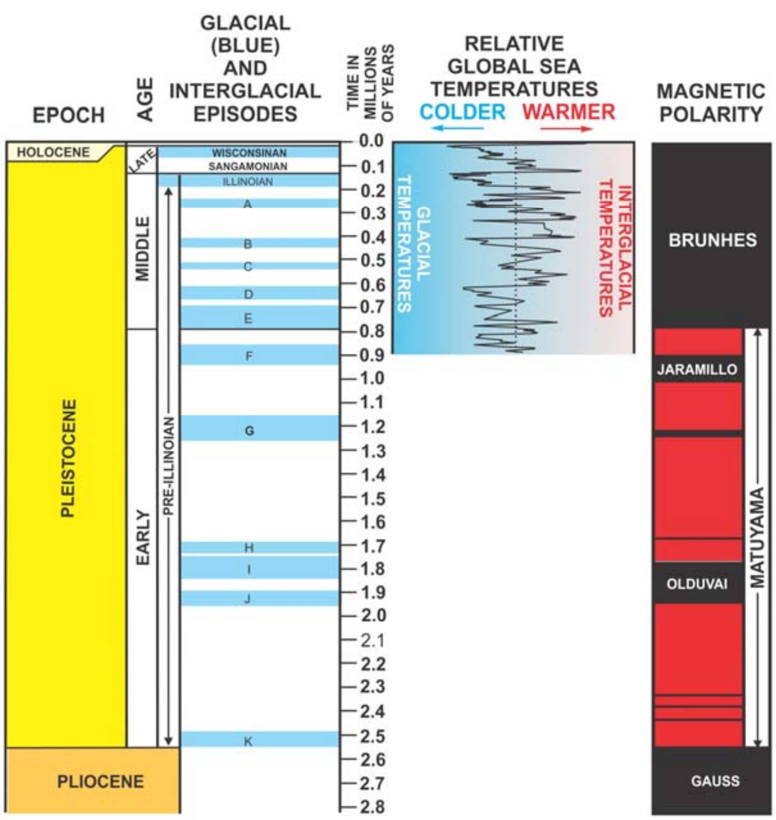


Figure 2. Glacial (blue) and interglacial stages of the Pleistocene Epoch correlated with reversals of the earth's magnetic field (normal polarity is shown in black, reverse polarity in red) and the temperature record for the last 800,000+ years.

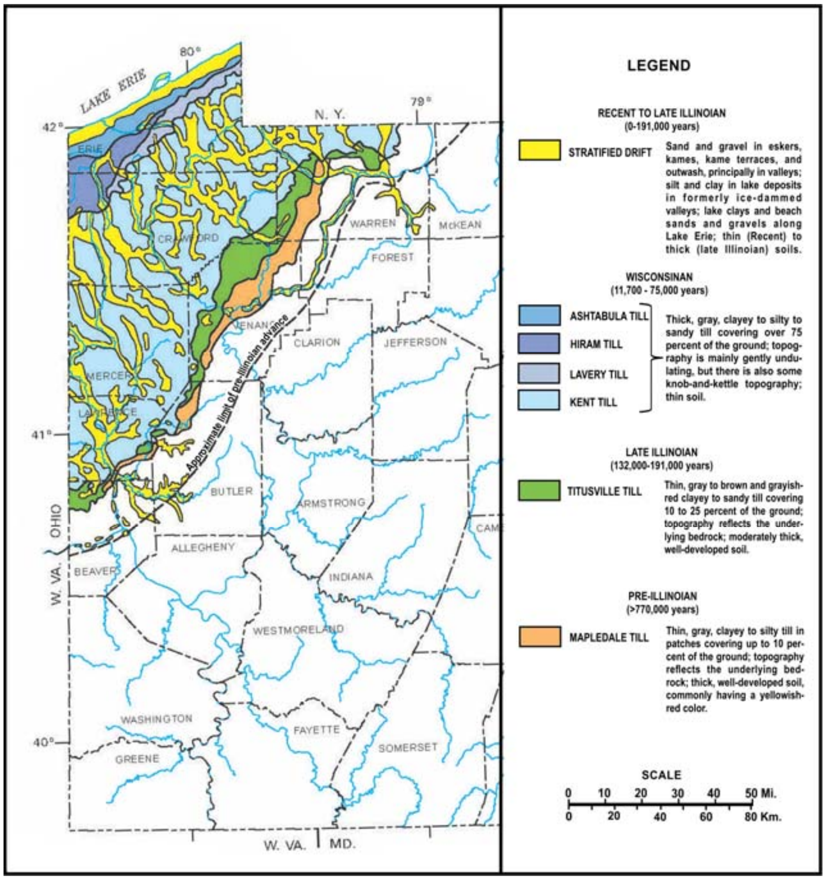


Figure 3. Map of western Pennsylvania showing the names, descriptions, and extents of Pleistocene tills and drift (modified from Sevon and Braun, 2000).

Beaver counties; recognized glacial sediment consists of the pre-Illinoian Mapledale till, the Illinoian Titusville till, and four separate tills deposited during the Wisconsinan (Figure 3).

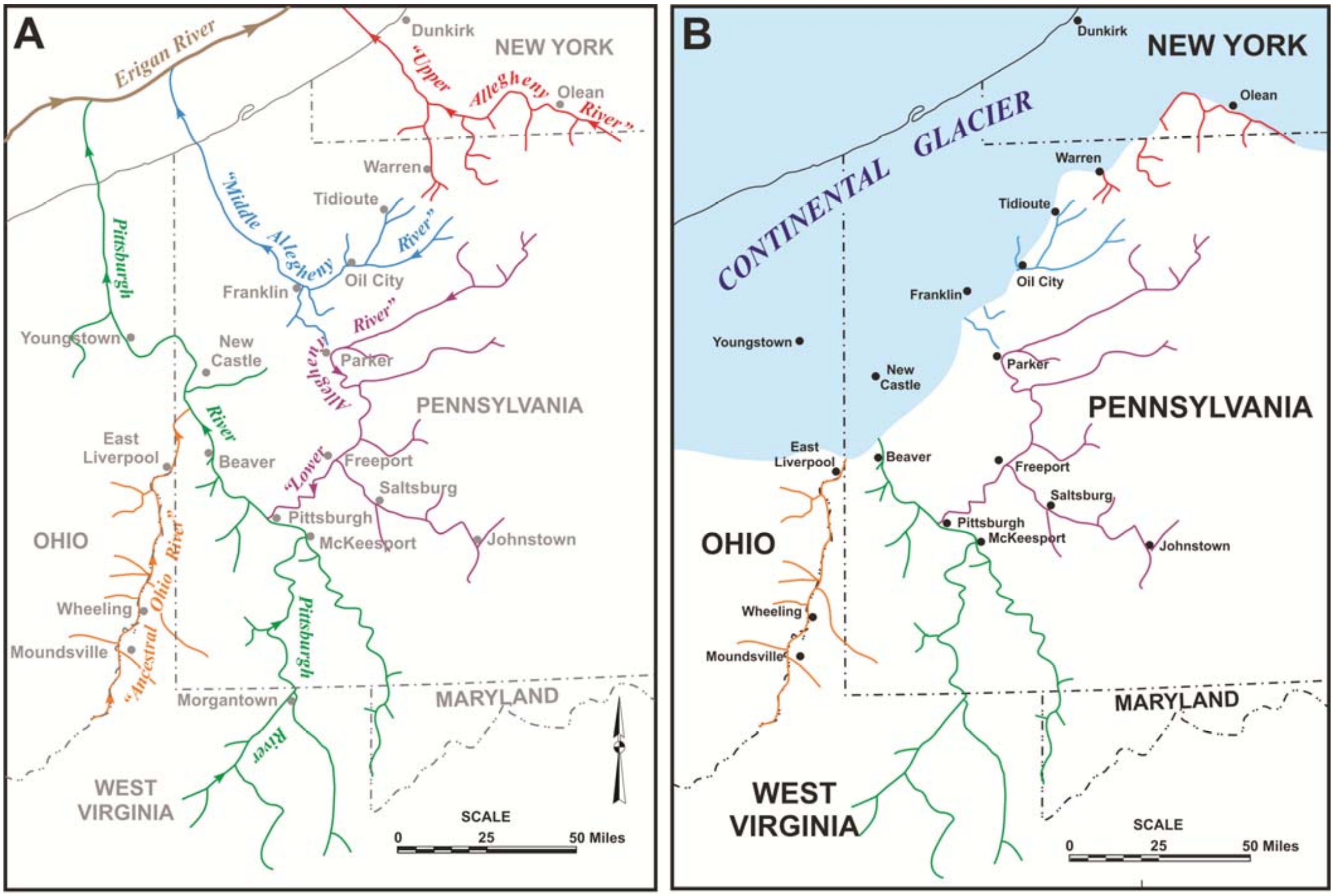
Pleistocene Drainage in Western Pennsylvania

During the Early or Middle Pleistocene, West Virginia and southwestern Pennsylvania were drained by the Pittsburgh River system (Figure 4A). Drainage direction generally was north-westward toward Canada rather than south and west into the Mississippi Valley. The Pittsburgh River flowed north out of West Virginia in a meandering channel to the present site of Pittsburgh. From there it followed the channel of the present Ohio River to Beaver where it bent northward and flowed up what is now the Beaver River valley, past New Castle and Youngstown, and finally into what some Pleistocene geologists call the Erigan River, the forerunner of the St. Lawrence River. The Pleistocene Ohio River was merely a tributary of the Pittsburgh that flowed northward to East Liverpool, Ohio, and entered the Pittsburgh just south of New Castle. The Allegheny River consisted of three separate and unrelated drainage systems, two of which drained into the Erigan River whereas the third was a tributary of the Pittsburgh River.

At some point in the Pleistocene, possibly even when the earliest glacier moved into northwestern Pennsylvania over 770,000 years ago, the south-flowing ice blocked the northwest-flowing streams (Figure 4B), causing the rivers to pond along the leading edge of the glacier. As the ponded waters rose they eventually crested their drainage divides, and the water eroded notches in the divides. The escaping waters scoured the landscape, formed new drainage channels that flowed southwestward, closely paralleling the front of the glaciers, and permanently reversing the ancient drainage directions of the Pittsburgh, "Middle Allegheny", and "Upper Allegheny" rivers (although it is possible that the reversals occurred prior to glaciation – see Sevon, 1992, p. 88). Ponding occurred each time a glacial advance blocked the rivers, but there is some disagreement as to how many such episodes occurred in western Pennsylvania. The ponding that formed during each succeeding glacial advance never reached the level of the previous ponding. The outlets, however, continued to be cut down each time a pond or lake formed and the water found an outlet and the river channels became entrenched (Marine, 1997). Each time a glacier advanced into the region, it dammed the existing drainage and the waters backed up to form an enormous lake called Lake Monongahela (White, 1896) (Figure 5). It was not a "lake" in the normal sense of the word, but rather a ponded drainage system similar to man-made lakes like Deep Creek Lake in western Maryland, only on a much larger scale. The lacustrine sediments deposited in the various iterations of Lake Monongahela constitute the Carmichaels Formation.

The Carmichaels Formation

Although southwestern Pennsylvania was never glaciated, Pleistocene-age fluvial and lacustrine deposits constitute what little variety there is of "Ice Age strata" in the area. The oldest Pleistocene deposits in southwestern Pennsylvania are called Carmichaels Formation. Campbell (1902) named the formation for, primarily, lacustrine deposits preserved in an abandoned Monongahela River meander channel at Carmichaels in Greene County. The channel is now a remnant terrace about 300 feet above the Monongahela River (Figure 6).



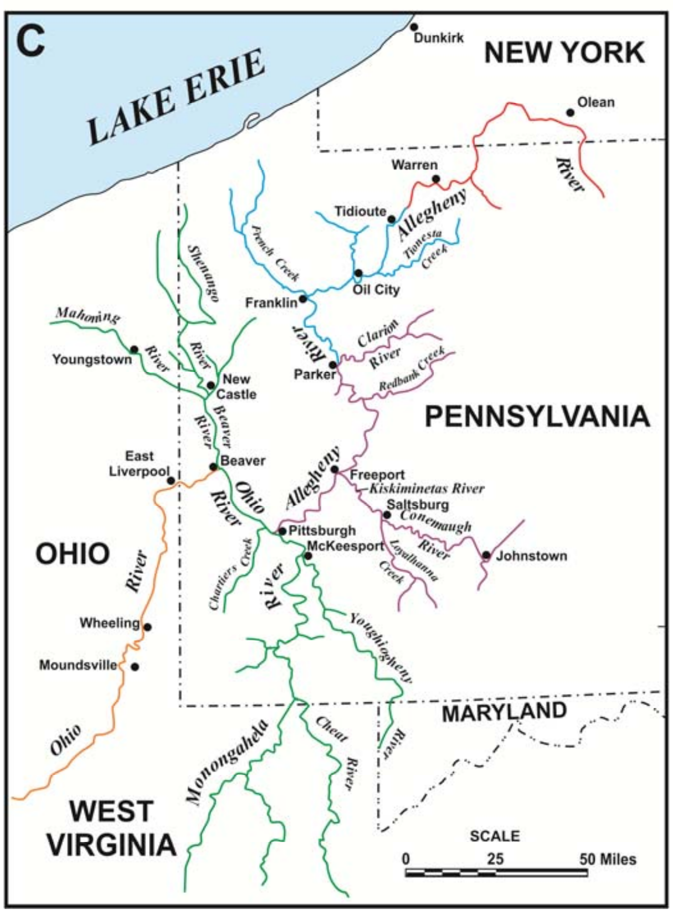


Figure 4. Maps of western Pennsylvania before, during, and after the Pleistocene. A, the stream pattern of western Pennsylvania before the first glacial advance, as determined from geologic mapping over the past 120 years (modified from Harper, 2016). Notice that the major stream in western Pennsylvania was the Pittsburgh River, which flowed up the Monongahela, Ohio, and Beaver valleys, there were three Allegheny rivers, and all of the streams drained northward toward Canada. B, as a glacier advanced into northwestern Pennsylvania (modified from Harper, 1997), the ice block the north-flowing stream, which backed up until the water was able to top the drainage divides and flow down the leading edge of the glacier. This forced western Pennsylvania drainage to flow southwest to the Mississippi River and Gulf of Mexico. C, the drainage of western Pennsylvania as we see it today. All major drainage systems have been color-coded, consistent in each map.

Figure 5. Reconstruction of Lake Monongahela based on a water-surface elevation of 1,100 feet above current mean sea level (generalized from Marine, 1997). Total extent of the lake in the Ohio and Allegheny River valleys is not shown. Modern towns and state boundaries are included for

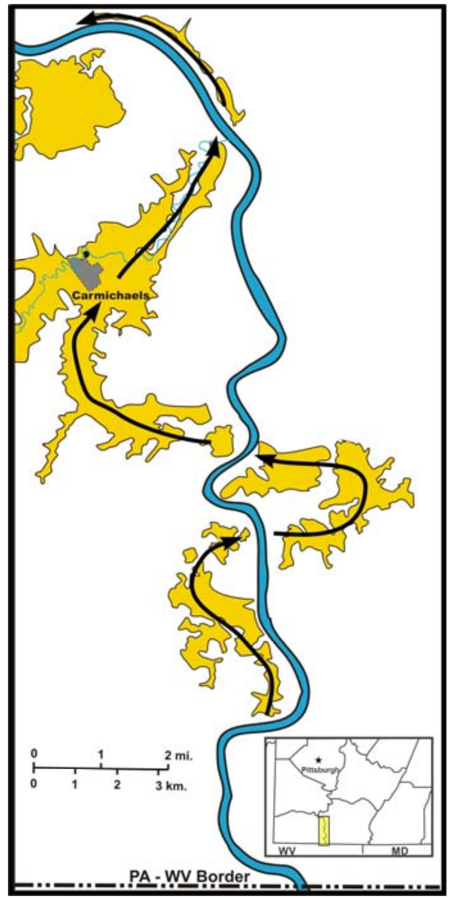


Figure 6. Extent of the existing Carmichaels Formation at Carmichaels, Greene County, showing the direction of flow of the Pleistocene Pittsburgh River. The small inset map shows the location of the illustration in southwestern Pennsylvania. Redrawn from Harper and Prellwitz (2013).

The name Carmichaels Formation often is used incorrectly for ALL Pleistocene terrace deposits in western Pennsylvania. In fact, most of the terrace sediments along the Allegheny and Ohio rivers are glacial outwash deposits (Figure 7A) that are distinctly different from the sediments of the Carmichaels.

The Carmichaels Formation is a lacustrine unit composed of clay, silt, and sand with subangular to well-rounded clasts ranging in size from pebbles to boulders (Donahue and Kirschner, 1998) (Figure 7B). The clasts typically are various Mississippian, Pennsylvanian, and probably Permian sandstones derived from bedrock exposed south and east of Pittsburgh. The formation occurs as sedimentary deposits capping a series of remnant terraces along the rivers and older, larger streams in western Pennsylvania and northern West Virginia (e.g., Chartiers Creek – see Plate 1).

Carmichaels Formation terraces within the Monongahela River drainage have been grouped by elevation into three distinct levels representing three different glacial damming episodes (the highest three in Table 1). The Fifth, or highest terrace, at approximately 1,040 feet above mean sea level (more than 300 feet above the current stream levels), is higher than any of the glacial outwash deposits in the Allegheny River valley. They represent the abandoned channels of the Pittsburgh River system prior to the earliest pre-Illinoian glacial advance that affected the eastern U.S. The Carmichaels deposits covering them probably represent the highest level reached by Lake Monongahela sometime later. The Fourth terrace, approximately 1,000 to 1,100 feet above mean sea level, represents a later pre-Illinoian glaciation. The Third terrace, at approximately 900 to 970 feet above sea level, represents Illinoian glaciation (White, 1896 Jacobson and others, 1988; Marine, 1997). The ages of the lower two terraces were based on correlation of outwash and drift with

Figure 7. Photographs of Pleistocene terrace deposits in southwestern Pennsylvania. Rock hammers for scale. Top, glacial outwash deposit of sand and gravel in O'Hara Township, Allegheny County, (photo by W. R. Wagner). Deposits such as this are found along the Allegheny, Ohio, and Beaver River drainages but have never been formally named. Bottom, sandstone cobbles and boulders in red sand, silt, and clay characterize the Carmichaels Formation at Speers, Washington

remnant paleomagnetism in Carmichaels sediments at widely scattered localities and will probably require revision based on future studies (Donahue and Kirschner, 1998). The Second terrace, which is not covered in Carmichaels Formation, occurs at approximately 900 to 970 feet above mean sea level. White (1896) interpreted this terrace as being Wisconsinan in age. An even lower terrace, the First, lies at an elevation of 740 feet above mean sea level in downtown Pittsburgh, and climbs in elevation to about 830 feet on the upper Monongahela River while maintaining a distance above river level of 30 to 40 feet. This is the modern floodplain, composed primarily of Wisconsinan glacial outwash in the Allegheny and Ohio valleys and sand, silt, and mud containing locally derived cobbles and boulders in the Monongahela valley. This terrace level has been capped by, and mixed with, Holocene alluvium.

Table 1: Levels of terraces above the three rivers in the vicinity of Pittsburgh (from Marine, 1997).

Terrace	Feet above river (normal pool) level	Feet above mean sea level
First	30	740
Second	160	900
Third	220	960
Fourth	260	1,000
Fifth	330	1,040

Periglacial Features of Southwestern Pennsylvania

Washburn (1980) used the term "periglacial" to refer to cold climate environments both with and without permafrost. Tundra conditions dominated southwestern Pennsylvania during the glacial episodes (Figure 8). Tundra refers to a biome where low temperatures and short growing seasons hamper plant growth, and rainfall is scant. Snow typically covers the surface soils of tundras for much of the year and the subsoil is permafrost. Permafrost is ground whose temperature remains at or below 32^{o}F (0^{o}C) for two or more years in a row. Continuous permafrost occurs in regions with mean annual air temperatures less than about 17^{o}F to 21^{o}F (-6^{o}C to -8^{o}C); discontinuous permafrost occurs in regions with mean annual air temperatures less than about 28^{o}F to 31^{o}F (-0.5^{o}C to -2^{o}C) (Merritts and others, 2014). Relatively few plant and animal species can live in the tundra because of environmental stresses. Although we typically think of tundra as an environment close to ice conditions (think Canada above the Arctic circle), even areas many tens of miles from the edge of a glacier can experience deep freezing conditions. As a result, evidence of Pleistocene tundra conditions can be found in many places in southwestern Pennsylvania, especially in the highlands where alpine tundra conditions prevailed (Figure 8). Brezinski and Kollar (2004), for example, documented patterned ground, rock cities, and bogs, all resulting from tundra conditions, in the Laurel Highlands of Fayette, Somerset, and Westmoreland counties. Patterned ground is a permafrost condition where repeated freeze-thaw cycles of the ground surface caused rocks, shallow fractures, and vegetation to form polygons, rings, or stripes. Rock cities are areas where intense freeze-thaw conditions separated blocks of fractured sandstone into patterns that vaguely resemble city buildings separated by streets (Figure 9). Even most of the peat bogs that occur in southwestern Pennsylvania are relics of Pleistocene periglacial environments (see below). Today, geologists recognize all of these periglacial environments and features exist in various places in southwestern Pennsylvania, over 10,000 years since the last glacier retreated into the Arctic.

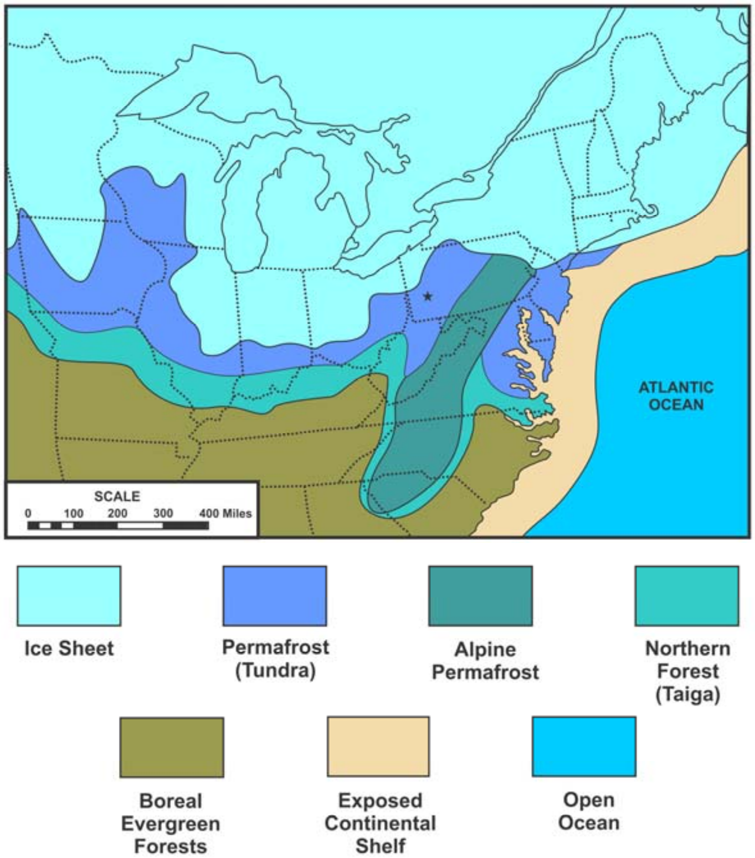


Figure 8. Generalized map of eastern North America during the Wisconsinan glaciation showing the Laurentide ice sheet and various biomes associated with it. While the ice sheet covered parts of northern Pennsylvania, the rest of the state was a tundra. The taiga environment, farther to the south, presumably converged north into Pennsylvanian during retreat of the glacier. Based partly on Merritts and others (2014, p. 51, fig. 1). The star indicates the present position of Pittsburgh.

Figure 9. Photographs of rock cities in southwestern Pennsylvania. A, Wolf Rocks in Laurel Summit State Park, Westmoreland County (from AllTrails, 2019). B, Baughman Rocks near Mt. Davis, Somerset County (not to be confused with Baughman Rocks in Ohiopyle State Park) (from Cheney, 2018).

Taiga refers to a biome where coniferous forests consisting of pines, spruces, and larches are the dominant plant growth. They are often referred to as "boreal forests." Most of Canada and Alaska today occurs in a taiga environment. Taiga soils tends to be young, poor in nutrients, and lacking deep, organically-enriched profiles typical of temperate deciduous forests. Soil thinness results from the cold climate that hampers both soil development and plant uptake of nutrients. Fallen leaves lying on the forest floor, moist climate, and acids from evergreen needles leach the soil. Thus, only lichens and mosses grow on the forest floor. Herbs and berries only grow in clearings or where boreal deciduous trees grow. In Pennsylvania, the Pennsylvania spruce- and eastern hemlock-dominated forests of northwestern Pennsylvania are relicts of taiga forests that covered the region following glacial retreat (Gross, 2010). They are found primarily on those areas of the Allegheny Plateau that had been glaciated; they were once far more extensive than they are today. They typically are associated with forested wetlands and peatlands, or are part of wetland complexes at headwaters of high-quality cold-water streams (Gross, 2010). In all likelihood, southwestern Pennsylvania experienced taiga conditions during the interglacial episodes.

Peat Bogs – Very Interesting Periglacial Features

The peat bogs that are scattered throughout western Pennsylvania, Maryland, and northern West Virginia developed when increased precipitation during glacial episodes inundated poorly-dained low areas. The bogs still in existence, such as Spruce Flats Bog (Figure 10A), located at the crest of Laurel Hill in Somerset and Westmoreland counties, preserve localized pockets of unusual plant communities as refuges (Brezinski and others, 2005). It is only one of many bogs that still sustain relict plant communities in western Pennsylvania (Figure 11).

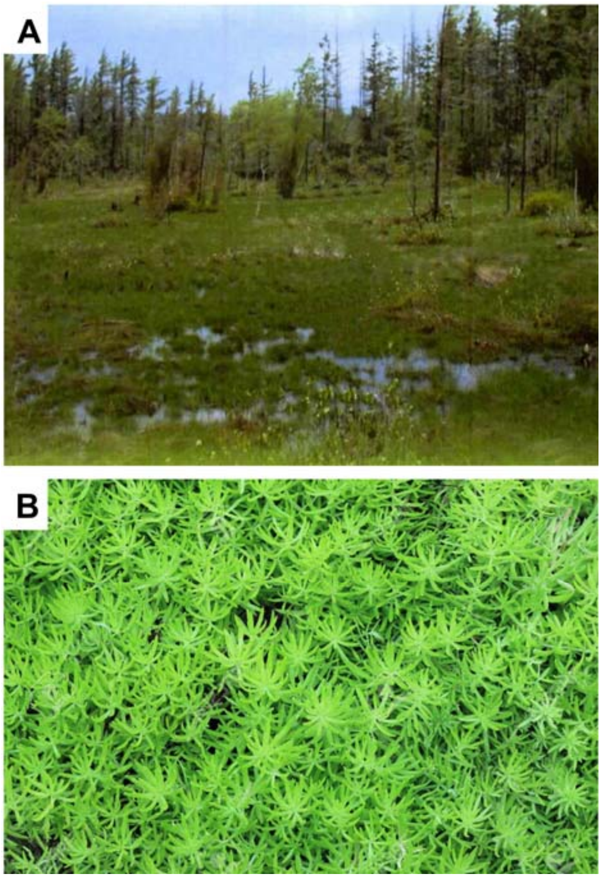


Figure 10. Photograph of A, Spruce Flats Bog in Laurel Summit State Park, Westmoreland and Somerset counties (from Hamilton and Sillman, 2008). See Figure 11 for the location of the bog. B, Photograph of sphagnum, or peat moss.

During the Pleistocene glacial episodes, increased rain in summer months and snowfall in winter months filled low-lying areas with cold water. These ponds and lakes froze in the winter but were open water in the summer. The cold water, which could support only specialized plants able to withstand the intensely cold conditions, prompted plants such as sphagnum (peat moss) (Figure 10B) to grow in dense floating mats on the surface of the water where they produced acidic and low oxygen conditions in the open water below. The moss accumulated over time to produce thick deposits. Such bogs are interesting ecological features supporting unusual low diversity, acid-loving plant communities that are rare elsewhere (Brezinski and Kollar, 2004). Through time, the bogs would fill from the sides and top down rather than from the bottom up. When they fill, they typically take on a grassy, or even an arboreal, biota and became meadows. Fort Necessity in Fayette County sits on the Great Meadow, a former peat bog (Brezinski and others, 2005) (Figure 12).

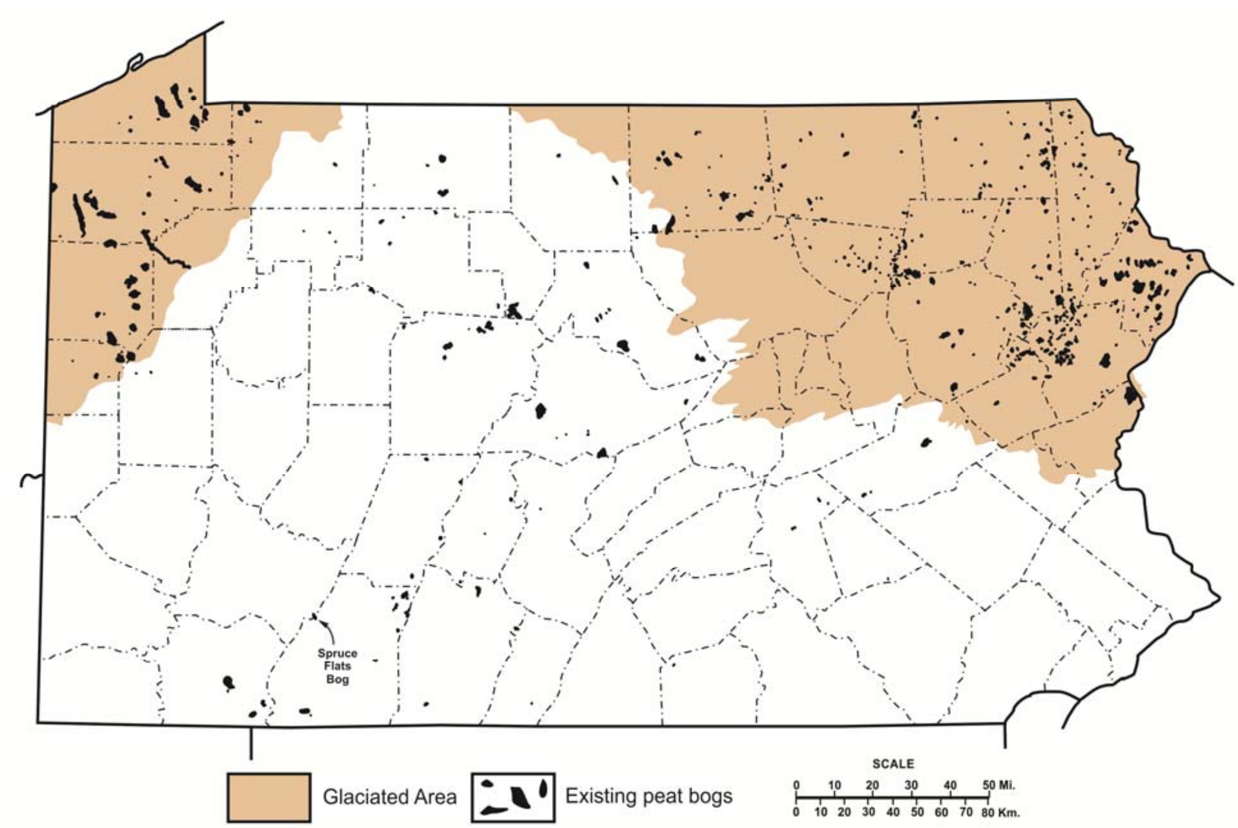


Figure 11. Map of Pennsylvania showing the locations of known peat bogs (redrawn from Western Pennsylvania Conservancy, 2019). Notice that the majority of peat bogs occur on formerly glaciated land.

Figure 12. Photograph of the Great Meadow at Fort Necessity in Fayette County (from National Park Service, 2019).

Figure 13. Historic photograph of a mastodon tusk John Clouse found at Sharpsburg on May 3, 1909. The tusk was once on display at the Carnegie Museum, but now resides in the Big Bone Room out of sight of museum visitors.

Pleistocene Biota of Southwestern Pennsylvania

We are not completely sure what plants and animals were native to southwestern Pennsylvania during the Pleistocene as only a few records exist and the ages of much of the data are uncertain. Archeological excavations at Meadowcroft Rockshelter documented . . . *sections of tree trunks and limbs, with and without bark, minute seeds and seed coats, fruits, charcoal, and small amounts of pollen, as well as 151 species of vertebrate remains in the many of the strata exposed* (Adovasio and others, 1984, p. 358), but these were mostly from Holocene strata. The only extinct animal remains found were those of passenger pigeons. Schopf and Cross (1947) documented a few species of plants from the Wisconsinan-age Bridgeville peat bog (see Stop 5), including an assemblage of mosses, ferns, club mosses, and seed plants. They also mentioned that insect remains were found in the peat, as well as some bones of a mastodon. Other fossils from southwestern Pennsylvania include: 1) a mastodon tusk found at Sharpsburg, Allegheny County, in 1909 (Figure 13) that currently resides in the Carnegie Museum; 2) the lower jaw of a mastodon found in the bed of the Grays Fork of Tenmile Creek, Greene County (reported by Hay, 1923); and 3) a mastodon tooth found at Lone Pine, Washington County (reported by Hay, 1923). Most of what we know of the flora and fauna of the Pleistocene in the region, however, comes from outside of southwestern Pennsylvania.

***Flora.* –** White (1883) first mentioned the existence of leaves of forest trees in clays of the Carmichaels formation in the Morgantown, WV, area. Gillespie and Clendening (1968) compiled a catalog of about 1,500 specimens from a heavy clay deposit in the Carmichaels about 240 feet above the Monongahela River (the fourth terrace of Lake Monongahela – see Table 1) outside of that city. This "Carmichaels megaflora" is essentially identical to the current flora of West Virginia and surrounding states, suggesting that the vegetation was growing during temperate climatic conditions – an interglacial stage. The pollen flora from the deposit, however, indicates an upward change from a mostly coniferous forest to a mostly hardwood forest, suggesting that a boreal (colder) climate existed in the early years of deposition, transitioning to a somewhat warmer climate later (the aforementioned interglacial?). Gillespie and Clendening (1968) had some of the woody material in the deposit radiocarbon dated; the results indicated an age of 23,000 ± 1,000 years BP, suggesting a late Wisconsinan age. Since this is essentially the same age as the peat deposit at the Bridgeville bog (see Stop 5), which occurred at the elevation of the second terrace of Lake Monongahela (Table 1), it seems unlikely that one or both dates are accurate. Therefore, we know as little about the Late Pleistocene flora now as we did before.

***Fauna.* –** As with the flora, what we know about the fauna comes mostly from collections from areas outside of southwestern Pennsylvania. Bedford and Blair counties in south-central Pennsylvania,

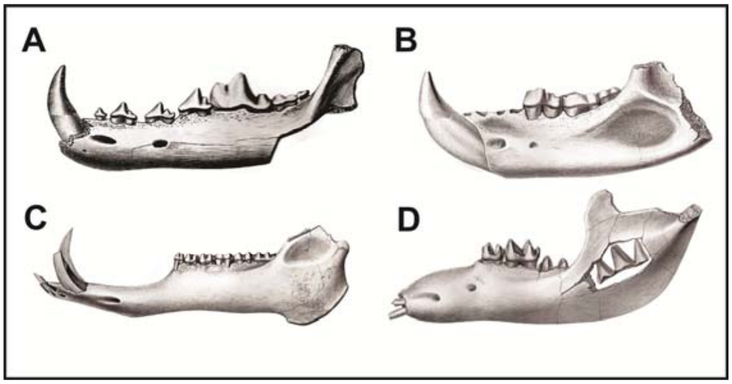


Figure 14. Comparisons of the fossil jaws of some now-extinct animals documented from Blair County that probably roamed the tundra in western Pennsylvania as well (all illustrations from Peterson, 1926, not to scale). A, *Canis dirus*, the dire wolf. B, *Arctodus pristinus*, the short-faced cave bear. C, *Mylohyas nasutus*, the long-nosed peccary. D, *Mammut americanum*, the mastodon.

in particular, are among the closest localities where Pleistocene faunas have been found, although certainly not the only ones; e.g., skeletal remains of both wooly mammoths and mastodons have been found in Erie and Crawford counties. The Bedford and Blair county faunas, discovered in sinkholes, fissures, and caves in Devonian and Silurian limestones, have yielded large numbers of invertebrates and the bones of vertebrates. In Blair County, for example, a cave at Frankstown (Holland, 1908; Peterson, 1926) and a fissure at Hollidaysburg (Cuffey and others, 1976; Fonda, 2003) provided an impressive list of animals, from insects and mollusks to reptiles, amphibians, birds, and a variety of mammals, including extinct dire wolves, cave bears, ground sloths, musk oxen, peccaries, and elephants (Figures 14 and 15). See Table 2 for a list of documented species from Blair County localities (and those are just the ones that could be identified). Other localities from northern and eastern Pennsylvania and from nearby states have provided comparable faunas.

Megafaunal Extinctions. **–** There has been much argument and discussion about the causes of the extinction of large animals such as ground sloths and mastodons. Most hypotheses tend to prefer single causes such as overhunting by humans or climate. Some merely suggest that the record of Pleistocene/early Holocene animals is too poor to support viable hypotheses. Overall, the major divisions of thought fall into two categories, exogenous and endogenous (Haynes, 2009). Exogenous hypotheses blame the extinctions on . . . *external stresses imposed on the ecosystem by the environment*, whereas endogenous hypotheses blame extinctions on . . . *the dynamics of the ecosystem* such as . . . *overzealous predators or the introduction of new competitors into formerly stable systems* (Newman and Palmer, 2003, p. 2). The primary exogenous theory is climate change at the end of the Pleistocene, which suggests that the largest land animals died out quickly (within a relatively few millennia) as a result of climate shifts causing stress that fragmented regional populations. This would have resulted in reducing gene flow and decreasing genetic diversity. Other hypotheses range from a bolide impact to a hypervirulent disease organism. The primary endogenous hypothesis suggests the cause was rapidly dispersing human hunters. Uncertainty about how long humans co-existed with the animals is the major conundrum affecting this hypothesis. If humans co-existed with the animals for millennia, and very slowly changed the ecosystem by a combination of altering habitats and low-intensity hunting, they were already part of the existing ecosystems (endogenous). If human co-existed only briefly, however, and killed the fauna quickly by active hunting, they were exogenous.

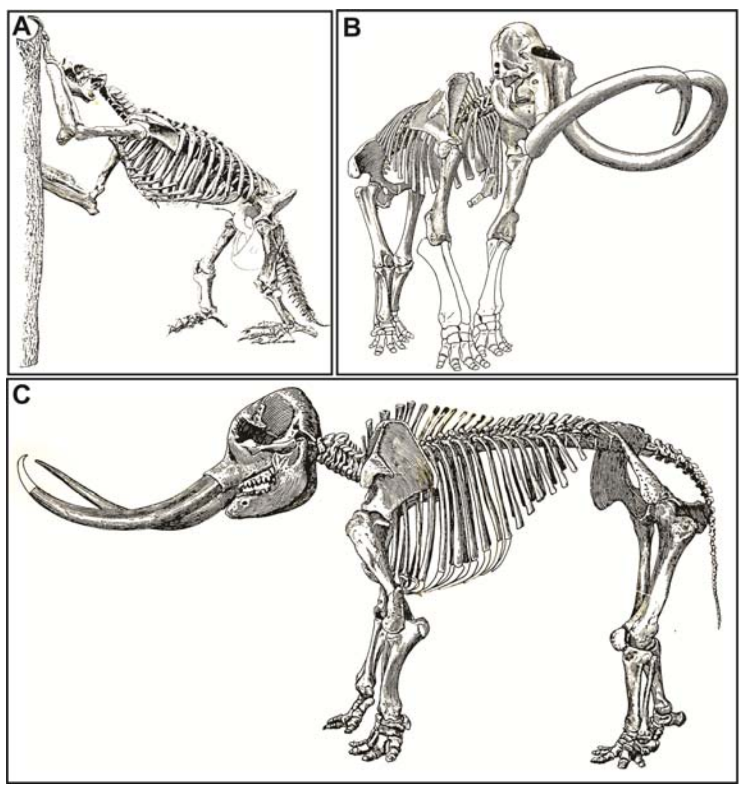


Figure 15. Some of the larger now-extinct animals that roamed the tundra of western Pennsylvania during the late Pleistocene and, possibly, very early Holocene (all illustrations from Moodie, 1929, not to scale). A, *Megalonyx jeffersoni*, the giant ground sloth. B, *Mammothus primogenius*, the wooly mammoth. C, *Mammut americanum*, the mastodon.

Basically, although there are many hypotheses concerning Pleistocene extinction, no one is actually certain what the primary driver or drivers of those extinctions were. All we know for certain is that there are no more giant ground sloths, wooly mammoths, or mastodons (Figure 15) roaming the world.

Table 2. List of biota (species and their common names) from Pleistocene localities in Blair County, Pennsylvania (modified from Peterson, 1926, Cuffey and others, 1976, and Fonda, 2003).

Species	Common Name	Species	Common Name
Round spores	Fungi	*Pitymys pinetorum*	Pine Vole
Bisaccate pollen	Conifers	*Ondatra zibethicus*	Muskrat
Stenotrema fraterna	Land snail	*Zapus hudsonicus*	Meadow Jumping Mouse
Gastropods indeterminate	Other land snails	*Napeozapus insignis*	Woodland Jumping Mouse
Insects indeterminate		*Peromyscus* sp.	Deer-mouse
Fish indeterminate		*Neotoma floridana*	Eastern wood-rat
Cryptobranchus sp.	Hellbender	*Neotoma* sp.	Wood-rat
Plethodon sp.	Salamander	*Synaptomys cooperi*	Southern bog lemming
Rana sp.	Frogs and Toads	*Erithizon dorsatum*	Porcupine
Clemmys insculpta	Wood turtle	*Lynx* sp.	Bobcat
Plestiodon anthracinus	Coal skink	*Canis latrans*	Coyote
Lampropeltis triangulum	Eastern Milk Snake	**Canis dirus*	Dire Wolf
Coluber constrictor	Northern Black Racer	*Canis lupus*	Gray Wolf
Heterodon platyrhinos	Eastern Hognose	*Urocyon cinereoargenteus*	Gray Fox
Crotalus cf. *horridus*	Timber Rattlesnake	*Ursus americanus*	Black Bear
Agkistrodon contortrix	Copperhead	**Arctodus pristinus*	Short-faced cave bear
Thamnophis sirtalis	Common Gartersnake	*Martes Americana*	Pine Marten
Bonasa umbellus	Ruffed grouse	*Mustela rixosa*	Least Weasel
Meleagris gallopavo	Wild turkey	*Mustela frenata*	Weasel
Anas sp.	Teal	*Mustela vison*	Mink
Mergus sp.	Merganser	*Mephitis mephitis*	Striped Skunk
Bubo sp.	Great Horned Owl	*Brachyprotoma obtusata*	Short-faced skunk
Dendrocopos sp.	Hairy Woodpecker	*Parascalops breweri*	Hairy-tailed Mole
**Megalonyx* sp.	Giant ground sloth	*Condylura cristata*	Star-nosed Mole
Sylvilagus transitionalis	New England Cottontail	*Blarina brevicauda*	Short-tailed Shrew
Lepus americanus	Snowshoe Hare	*Sorex fumeus*	Smoky Shrew
Sylvilagus floridanus	Eastern cotton-tail	*Sorex cinereus*	Masked Shrew
Marmota monax	Woodchuck	*Microsorex hoyi*	Pygmy Shrew
Citellus tridecemlineatus	13-lined Ground Squirrel	*Eptesicus fuscus*	Big Brown Bat
Tamias striatus	Eastern Chipmunk	*Myotis* sp.	Little Brown Bat
Glaucomys sp.	Flying Squirrel	*Plecotus* sp.	Big-eared bat
Tamiasciurus hudsonicus	Red Squirrel	**Mylohyus nasutus*	Long-nosed Peccary
Castor canadensis	Beaver	*Cervus elaphus*	American Elk
**Castoroides ohioensis*	Giant Beaver	*Odocoileus virginianus*	White-tailed Deer
Peromyscus maniculatus	Deer Mouse	*Sangamona furtive*	Caribou-deer
Neotoma floridana	Eastern Woodrat	*Rangifer tarandus*	Caribou
Phenacomys cf. *ungava*	Spruce Vole	*Cervalces americanus*	Stag-Moose
Synaptomys cooperi	Southern Bog Lemming	**Cervalces* sp.	Stag-Moose
Synaptomys borealis	Northern Bog Lemming	**Bootherium bombifrons*	Wood Musk Ox
Dicrostonyx hudsonius	Collared Lemming	*?Bison* sp.	Bison
Clethrionomys gapperi	Red-backed Vole	*Equus* sp.	Horse
Microtus pennsylvanicus	Meadow Vole	**Tapirus* cf. *veroensis*	Vero Tapir
Microtus chrotorrhinus	Rock Vole	*Tapinis* sp.	Tapir
Microtus xanthognathus	Yellow-cheeked Vole	**Mammut americanum*	Mastodon

*Extinct

PENNSYLVANIAN CLIMATE-DRIVEN SEDIMENTARY CYCLES WITH EMPHASIS ON THE MONONGAHELA FORMATION

Albert D. Kollar and John A. Harper

Introduction

Climate change greatly influenced the Pennsylvanian strata of North America and equivalent strata globally. The Late Carboniferous (Pennsylvanian) was one of the numerous Ice Ages that affected the world over geologic time. Although long-term (10^7 y [years]) climate trends were related to plate tectonics and intracratonic tectonic events, changes of much shorter duration (100-400 ky [thousand years], and 10-20 ky) (Milankovitch cycles) overprinted the longer term changes (Brezinski and Kollar, 2011).

The Appalachian basin was situated about 5^o south of the equator during the Carboniferous, so the local climate would have been subtropical to tropical. The cyclical nature of cyclothems, which were first recognized in the Pennsylvanian rocks of North America, have been linked to alternating high and low sea level stands that, in turn, have been related to the cyclical advance and retreat of glaciers, something not in existence in the tropics. Instead, glaciation during the Carboniferous occurred in the southern continent of Gondwana (Figure 16) where tillites many hundreds of feet thick have been discovered. The Carboniferous glacial period lasted approximately 90 million years, even reaching into the Permian. This was the longest glacial epoch in Phanerozoic history. Only the Precambrian "Snowball Earth" supposedly was greater; icehouse conditions occurred over most, if not all the Earth's surface sometime prior to 650 Mya (million years ago).

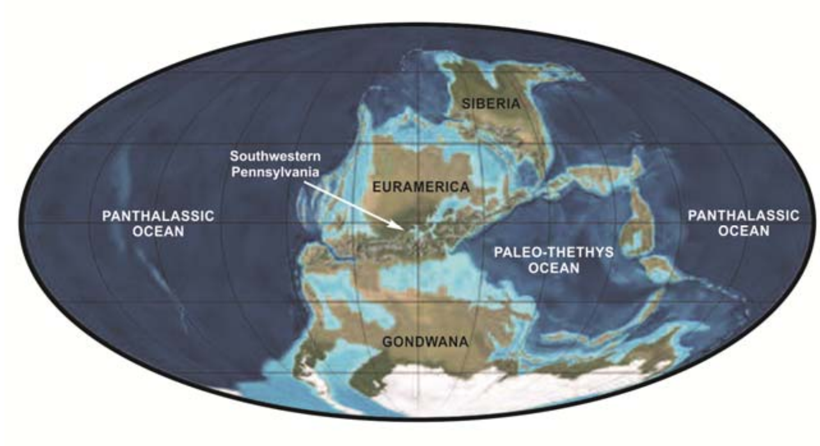


Figure 16. Paleogeographic map of the Early Pennsylvanian (~300 Mya) during peak icehouse conditions in southern Gondwana (modified from Montañez and Poulsen, 2013). Notice that what is now southwestern Pennsylvania was situated about 5^o south of the equator.

Brezinski and Kollar (2011) demonstrated the profound influence Gondwanan glaciation had on the Appalachians, affecting the cyclical climate and classic cyclothemic stratigraphy for which the Pennsylvanian Period is justly famous. For example, the climate in the Appalachian basin during deposition of the Pottsville and Allegheny formations (Figure 17) changed from perhumid to humid conditions during periods of glacial advance, and from humid to dry subhumid conditions during glacial retreats. Climates during deposition of the Conemaugh Group (Glenshaw and Casselman formations) became progressively drier with dry subhumid conditions during glaciations and semiarid to arid during deglaciations. During deposition of the Monongahela Formation, Appalachian climates returned to the humid conditions prevalent during glaciations. Unlike the depositional periods of the Pottsville and Allegheny formations, however, the evidence points to drier subhumid conditions during the intervening interglacial episodes. The latest Pennsylvanian and/or early Permian strata of the lower Dunkard Group exhibit a return to Conemaugh-like deposition as evidenced by the pervasiveness of redbeds, dry climate floras, and highly terrestrial vertebrate faunas.

The Monongahela Formation

Rogers (1840) named the "Monongahela series"[1] for what informally had been called the "Upper Coal Measures" exposed in the valley of the Monongahela River. In Rogers' terminology, this series rested on the Allegheny series. He separated the two series at the . . . *final outcrop of the shales which are exposed just above the Ohio River at Pittsburg* (Rogers, 1840, p. 150). If this definition

[1] Most of the stratigraphy of western Pennsylvania has changed over the years, so the Monongahela "series" later became the Monongahela Formation. Berryhill and Swanson (1962) raised the Monongahela to group rank in western Pennsylvania and divided it into the Pittsburgh and Uniontown formations. Since many of the strata forming these two "formations" can be difficult to trace over mappable areas, we prefer to use the term Monongahela Formation.

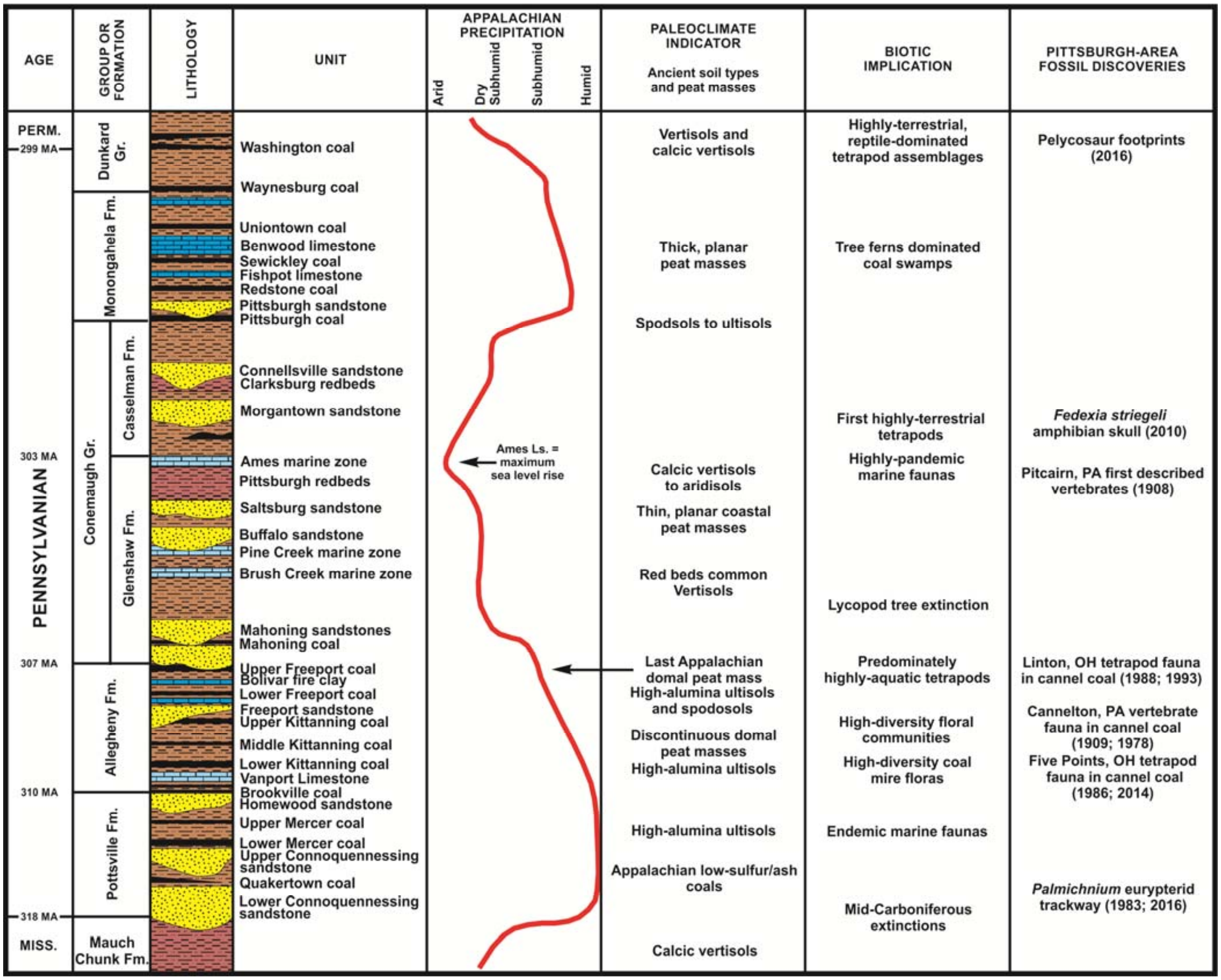


Figure 17. Pennsylvanian stratigraphy of the central Appalachian basin with interpreted precipitation curve (red), important paleoclimatic indicators, and notable biotic influences (from Brezinski and Kollar, 2011).

were still in effect, the Glenshaw Formation of current usage would be included in the Allegheny Formation and the Casselman Formation in the Monongahela.

Brezinski and Kollar (2011) included the Waynesburg coal (Figures 17 and 18) as part of the Monongahela. This traditionally had been considered the uppermost bed of the formation (e.g., Shaw and Munn, 1911) and is still accepted as such by many geologists (e.g., Rupert and others, 1999; Cecil and others, 2011, fig. 8 – but see p. 36 for a contradiction). Berryhill and Swanson (1962), however, revised the stratigraphy of the Monongahela and the Dunkard Group, including placing the Waynesburg coal at the base of the latter. According to Fedorko and Skema (2011), this was meant to conform to the concept of cyclothems prevalent in the early 1960s. Berryhill and Swanson (1962, p. C43) argued that the coal beds in this part of the section in southwestern Pennsylvania were basically key mapping beds and that . . . *the basic mapping unit for field classification, therefore, includes the several rock types between coal beds, and the basic unit represents a sedimentary cycle*. (Berryhill and Swanson, 1962, p. C43) These units gained the status of members; therefore . . . *the basal unit of a member as here defined is a coal bed, it follows that the basal unit of a formation must also be a coal bed* (Berryhill and Swanson, 1962, p. C45). In their revision, all the rocks from the base of the Waynesburg coal to the base of the Washington coal fall within the Waynesburg Formation. This arrangement has been accepted by the Pennsylvania Geological Survey.

The Monongahela Formation falls within the upper part of the Virgillian Stage (Late Pennsylvanian, equivalent to the Gzhelian International Stage; see Figure 18). According to Brezinski and Kollar (2011), this was a period when climatic conditions in what is now western Pennsylvania

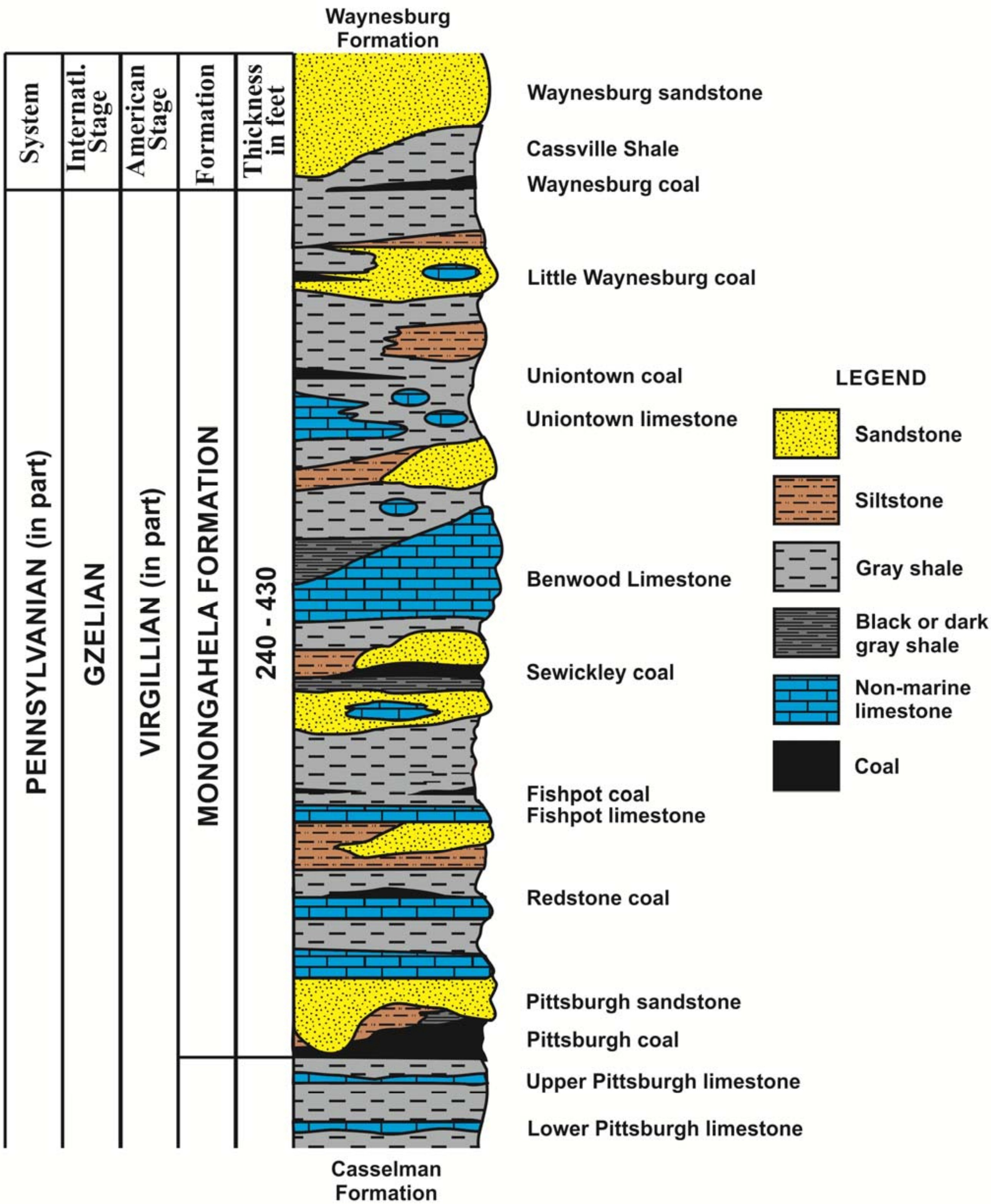


Figure 18. Generalized stratigraphic diagram of the Monongahela Formation in western Pennsylvania.

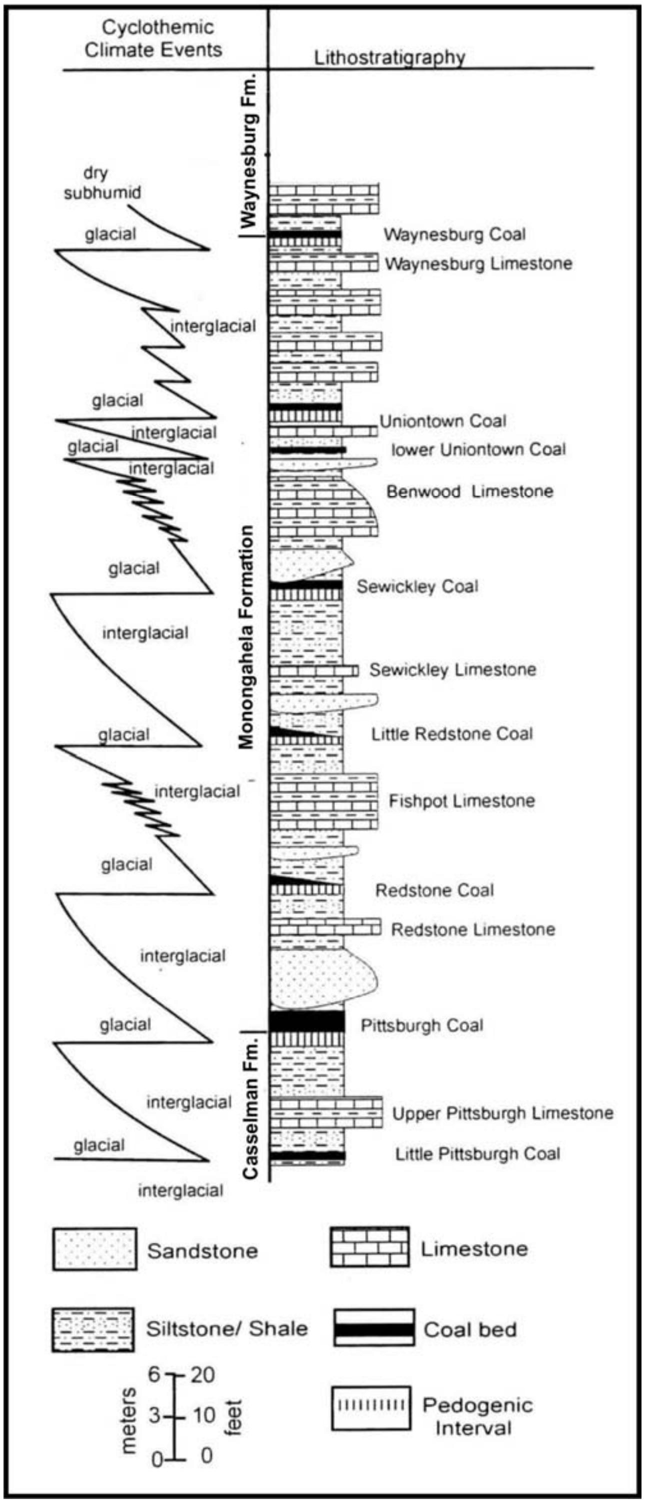


Figure 19. Comparison of Monongahela strata with interpreted climatic cycles (modified from Brezinski and Kollar, 2011).

returned to more humid conditions after deposition of more arid climate during the earlier part of the Virgillian. For example, the presence of mineable coal beds, coupled with the lack of red claystones (redbeds), reveals an increase in rainfall (Cecil and others, 1985). As a result, the Monongahela displays clear cyclothemic deposition, although the cycles are slightly different than those exhibited in the older Allegheny and Pottsville formations. Coals and underclays formed during high-latitude glacial advances, with deposition of extensive lacustrine deposits forming during interglacial episodes. This resulted in alternations of coals and carbonates (Figure 19). Brezinski and Kollar (2011) interpreted these cyclothems to have been produced by Milankovitch-driven, glacial cycles, which Heckel (2008) documented in the mid-continent.

Figure 20. Photograph of the Pittsburgh coal bed along Sygan Road in South Fayette Township, near Bridgeville. Laura Dana Brezinski for scale.

Monongahela Lithologies

Living up to its former name "Upper Coal Measures," the Monongahela Formation includes a number of mineable coals, including the Pittsburgh, Redstone, Sewickley, and Uniontown (Figure 18). The Pittsburgh coal (Figure 20) at the base of the formation is the thickest and most extensive coal seam in the Appalachian Basin, and historically has been the most economically important mineral deposit in the eastern US. Brezinski and Kollar (2011) suggested that the Pittsburgh coal appears to have been produced by abundant rainfall rather than local fluctuations in the water table fluctuations, and that the mineral underclay beneath it suggests a permanently waterlogged substrate signifying a humid to wet subhumid paleoclimate (Cecil and others, 1998; 2004). The intervening mudcracked lacustrine deposits, on the other hand, suggest that evaporation was greater than precipitation during deglaciations, with a dry subhumid climate occurring in the region.

Nonmarine limestones also are prevalent in the Monongahela Formation. The Benwood Limestone near the center of the formation (Figure 18), the most prominent nonmarine limestone in

Figure 21. Photograph of the Monongahela Formation outcrop along I-79 just south of the Carnegie interchange.

the Appalachian basin Pennsylvanian, is very thick (80 or 90 feet) (Figure 21) and widespread, extending over much of southwestern Pennsylvania, northern West Virginia, and eastern Ohio (Petzold, 1990).

Pennsylvanian Climatic Cycles

Cecil (1990) suggested that Pennsylvanian cyclothems are indicators of long-term fluctuations of wet and dry states of Appalachian climate. As a result, the lithostratigraphic subdivision of the Pennsylvanian appears related to long-term (10^7 years) climate changes. When the climate shifted to globally cool periods, the polar ice caps advanced, producing sea level falls, increased snowfall in the high latitudes, and increased rainfall in the low latitudes. What is now southwestern Pennsylvania was located about 5^{o} south of the equator at that time, so the area would have been a tropical to subtropical rainforest. When the climate warmed, ice caps retreated, snowfall in the higher latitudes decreased, and the lower latitudes, like southwestern Pennsylvania, experienced less rainfall.

Long-term climate in the U.S. during the Late Carboniferous changed several times (Figure 10). It shifted from seasonally warm and humid in the Early to Middle Pennsylvanian to warm and wet-dry cycles in the late Middle Pennsylvanian, then to warm arid cycles in the Late Pennsylvanian (Cecil, 1990; Joeckel, 1999; Cecil et al., 2004) (see Figure 10). This decrease in rainfall continued into the Early Permian. The presence and thicknesses of coals and paleosols bear witness to these climatic changes. Thick, economically mineable Lower and Middle Pennsylvanian coal beds (e.g., the Kittanning coals of the Allegheny Formation) and economically valuable, high-alumina paleosols (flint clays) indicate that tropical rainforest conditions extended throughout the Appalachian Basin, even in periods between glacial maxima. This climate regime ended by the time of deposition of the middle part of the Allegheny Formation. At the time of deposition of the upper part of the Allegheny Formation, the climate began to shift toward a drier regime as evidenced by the existence of the lower and upper Freeport limestones. This was followed by deposition of the Glenshaw Formation, characterized by localized, thin, mostly non-economical coal beds, red paleosols, and thin marine intervals. The thick Pittsburgh redbeds at the top of the Glenshaw are characteristic of carbonate-rich paleosols produced during periods of low precipitation and high rates of evaporation (Joeckel, 1995; Retallack, 2001). The Late Pennsylvanian Ames Limestone (the top of the Glenshaw) records extensive marine flooding in the upper Pennsylvanian in the Appalachian Basin (Brezinski, 1983) that indicates glacial melting was extensive. Coal beds are even less well developed in the Casselman Formation, and red paleosols are thicker and better developed. Thin, nonmarine limestones and paleosols replaced the flint clays of the lower and middle Pennsylvanian. Seasonally dry nonmarine limestones become progressively more prominent throughout the Casselman and Monongahela formations. A progressive return to higher levels of precipitation during deposition of the uppermost Casselman and Monongahela formations, and even into the lower Dunkard Group, followed the dry conditions typical of the upper Glenshaw and lower Casselman formations, as indicated by a decreasing prominence of red paleosols and a renewed deposition of thick coals (i.e., Pittsburgh, Redstone, Sewickley, and Waynesburg).

The increased precipitation and coal formation that occurred during deposition of the Monongahela Formation indicate a climatic reversal from long-term drying. The climatic conditions were short-term cycles indicating renewed dominance of glaciation in polar regions. Thick coals suggesting wet climate cycles contrast with the intervening nonmarine (lacustrine) limestones presumably deposited during drier interglacial periods. The Benwood Limestone displays well-defined nested cycles consisting of light gray to tan, laminated to massive, argillaceous, limestone and dolomitic limestone layers displaying brecciated intervals and mudcracks, especially near their tops. These alternate with siliciclastic intervals of gray or greenish-gray, silty, locally sandy, shale or shaly siltstone that range from 1 to 5 feet thick (Figure 22). Brezinski and Kollar (2011) interpreted the shale and limestone couplets within individual lacustrine units as representing short-duration, climatically driven cycles. Although they did not determine the amount of time represented by each

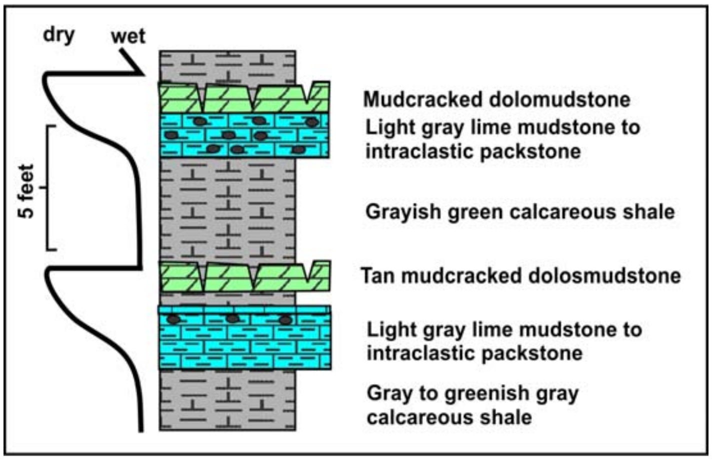


Figure 22. Idealized sedimentological expression of lacustrine climate cycles in the Monongahela Formation (from Brezinski and Kollar, 2011).

alternation, Brezinski and Kollar (2011) suggested that the vertical repetition of shale and limestone is identical to lacustrine cycles identified within the Late Triassic of the eastern United States (Van Houten, 1962; Olsen, 1986) and the Eocene of the western United States (Picard and High, 1981). Such shale and carbonate cyclicity is common in ancient lacustrine deposits. Workers such as Collinson (1978), Picard and High (1981), and Dunagan and Turner (2004) have attributed them to changes in short-term depositional factors such as climate, with each lacustrine cycle consisting of a lower shaly unit produced by high turbidity during wet periods and an upper limestone unit produced during dry periods when sediment supply and turbidity are low. Olsen (1986) suggested that the nested lacustrine cycles Triassic Lockatong Formation in the eastern U.S. resulted from alternating wet and dry periods produced by Earth's orbital precession. Brezinski and Kollar (2011) proposed a similar interpretation for the Monongahela lacustrine deposits. Above the Monongahela, the lower Dunkard Group above the Waynesburg coal beds suggests a return to increased aridity (Brezinski and Kollar, 2011). The significant coals at the base of the group become progressively less common higher in the section while redbeds become more prominent.

Biotic Response to Climate

Climatic conditions also had an effect on the Monongahela flora and fauna of southwestern Pennsylvania. For example, many of the large lycopsid trees characteristic of the early Pennsylvanian peat swamps, such as *Lepidodendron* and *Sigillaria* (Figures 23A and B), are absent from floras in late Pennsylvanian swamps (Kosanke and Cecil, 1996). The primary flora in late Pennsylvanian coal swamps are tree ferns such as *Psaronius* (Figure 23) (DiMichele and Hook, 1992; DiMichele and Phillips, 1996; Eble and others, 2006). Eble and others (2006) further suggested that the Pittsburgh coal formed in a planar peat swamp, rather than in a more areally restricted, pod-like domal swamp characteristic of early to early middle Pennsylvanian coals, e.g., the Upper Freeport coal.

Tetrapods of the Monongahela Formation occur in nonmarine limestone intervals or their closely associated paleosols representing shallow lakes that dried up during periods of decreased precipitation. High-frequency lacustrine cycles in the Fishpot, Benwood, and Uniontown limestones (Figure 18) demonstrate how ephemeral these environments were. The alternation of wet climate shales and dry climate limestones reflects the high variability of the depositional environments within the formation. This variability would have selected for vertebrates capable of moving

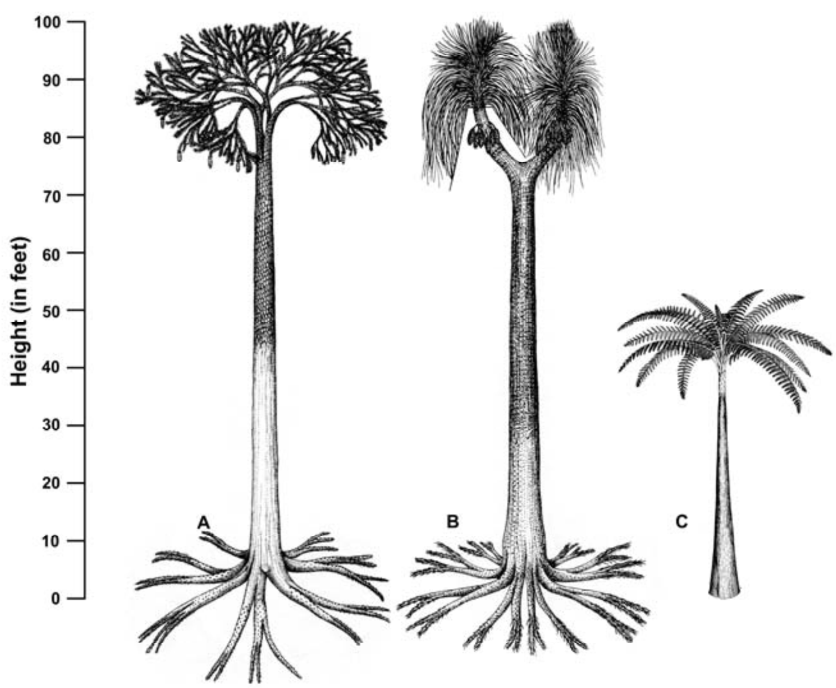


Figure 23. Some of the trees characteristic of Pennsylvanian peat swamps. A, *Lepidodendron*; B, *Sigillaria*; C, *Psaronius* (compiled from Stewart, 1983). A and B were lycopsid trees that were abundant in the Middle Pennsylvanian (Pottsville and Allegheny formations) but became extinct near the Middle-Late Pennsylvanian boundary (lower Glenshaw Formation – see Figure 18). C was a tree fern whose leaves, *Pecopteris*, have been found throughout the Pennsylvanian and Permian of the Appalachian basin.

from one wet spot to another. The long-term shift in physical environments during the Pennsylvanian is reflected in the change from small aquatic amphibians to medium-to-large, terrestrially adapted vertebrates (Lund, 1975) including the recently discovered amphibian *Fedexia* (Berman et al., 2010) (Figure 24). In fact, the fossil record preserves some of the earliest larger predatory tetrapods including the amphibian *Eryops* and the reptiles *Diadectes, Desmatodon, Edaphosaurus, and Naosaurus* (Figures 24-26).

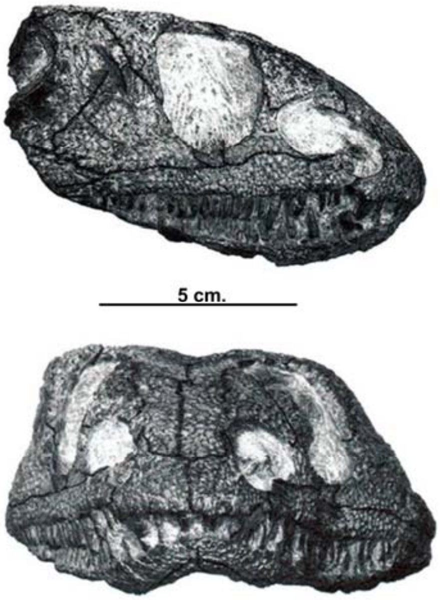


Figure 24. Photographs of the skull of *Fedexia*, a Pennsylvanian amphibian found in Robinson Township, Allegheny County, by a student from the University of Pittsburgh while on a geology field trip.

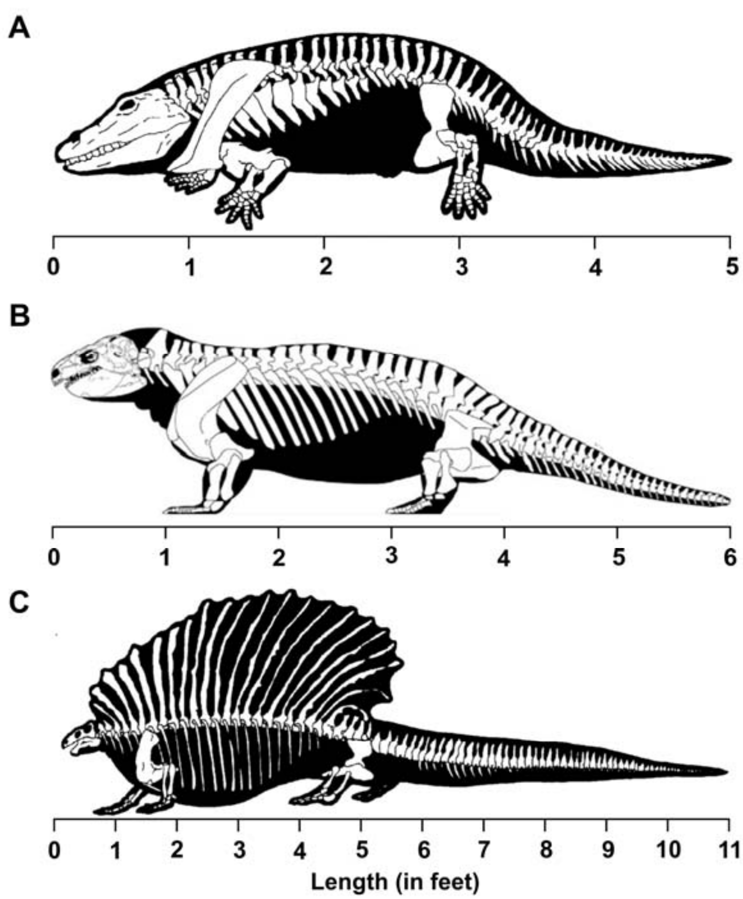


Figure 25. Some of the characteristic tetrapods of the Monongahela Formation. A, *Eryops*, was an amphibian; B, *Diadectes* and C, *Edaphosaurus*, were early reptiles (A and C from Harper, 1990; B modified from Peters, 2019).

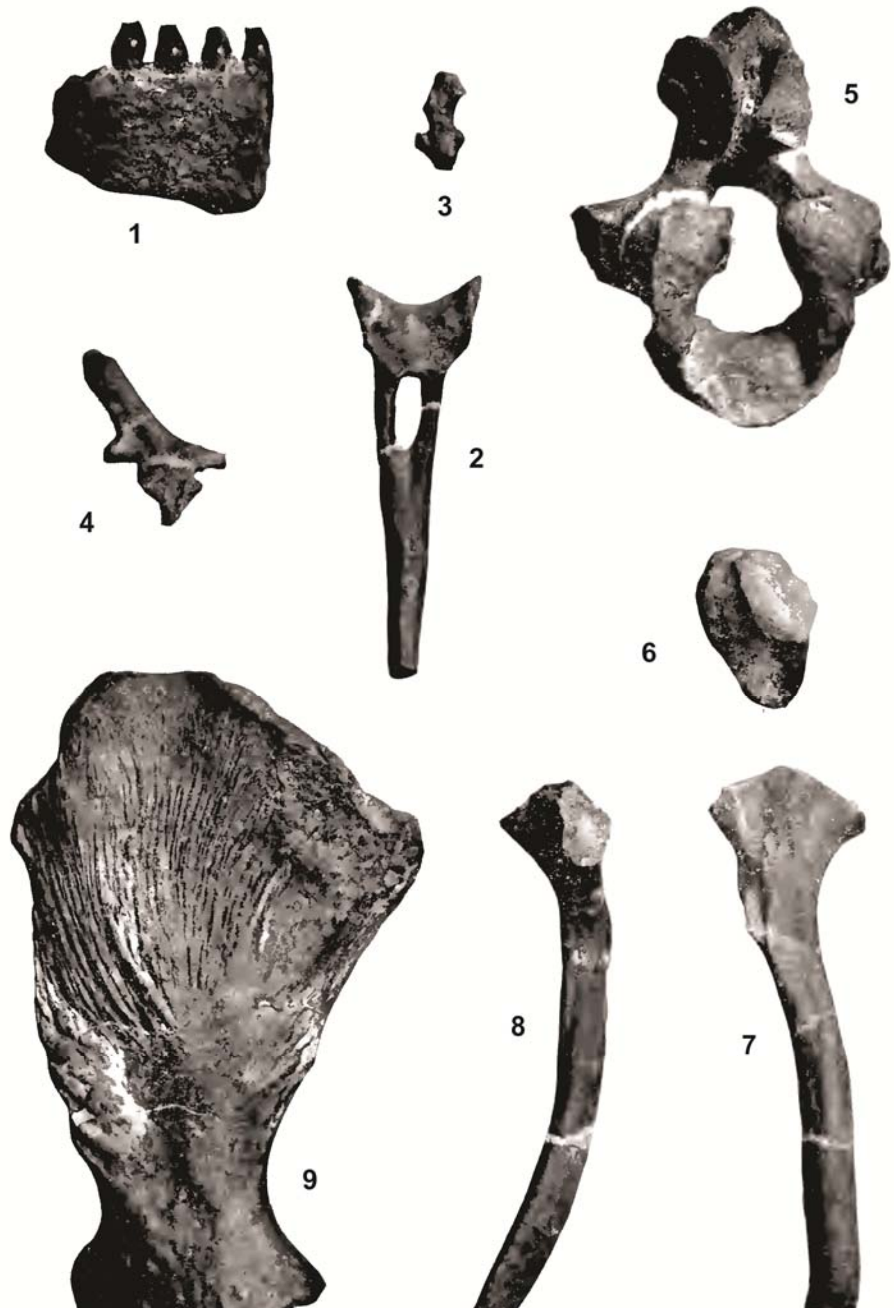


Figure 26. Illustrations of the vertebrate bones described and illustrated by Case (1908) from the Pittsburgh red beds at Pitcairn. 1, fragment of the jaw of *Desmatodon hollandi* Case with four teeth. 2, a chevron (a bone on the underside of the tail) of a diadectid reptile. 3, the neural spine of a vertabra of *Naosaurus* (?) *raymondi* Case. 4, the neural arch and spine of a caudal vertebra of an unidentified amphibian. 5, a nearly complete vertebra of an unidentified species of *Eryops*. 6, one of the pleurocentra (bones on the upper and lateral side of a vertebra) of an unidentified species of *Eryops*. 7 and 8, two somewhat distorted ribs of an unidentified species of *Eryops*. 9, the ilium (uppermost part of the hip bone) of an undetermined reptile.

ROAD LOG

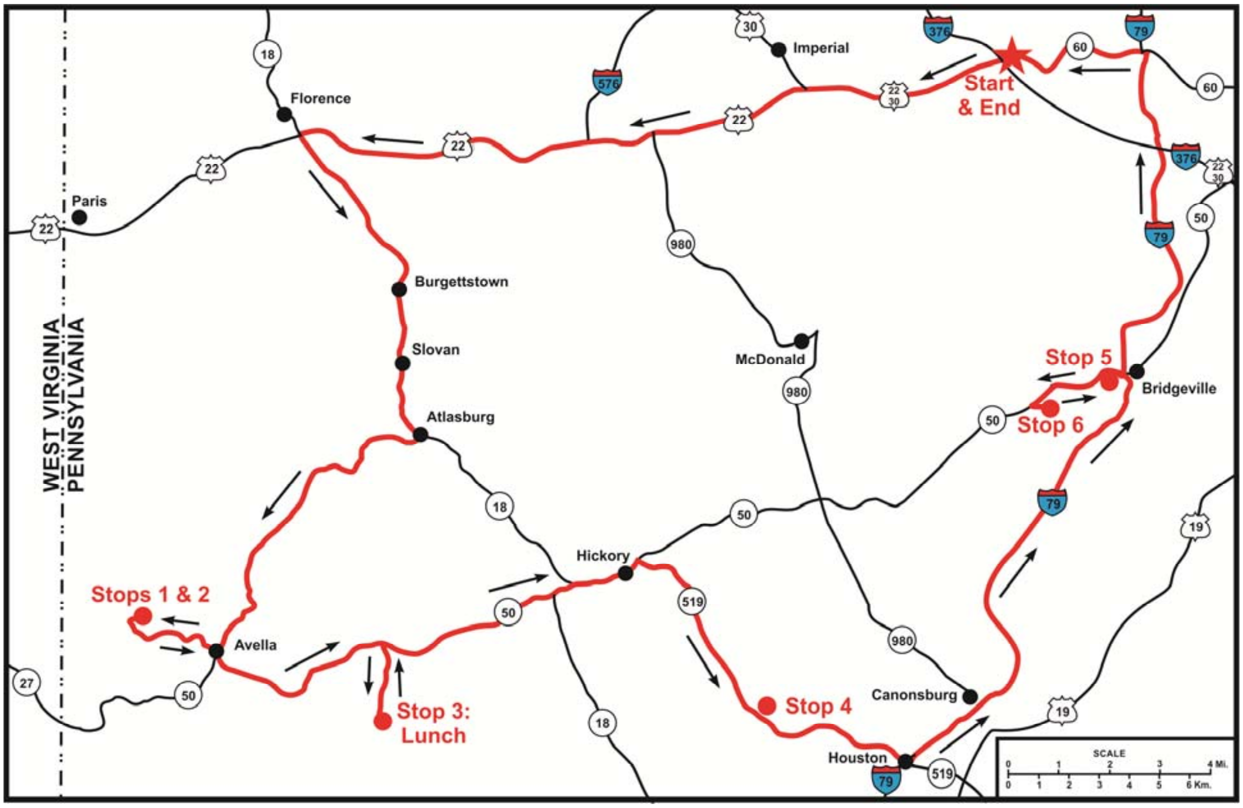


Figure 27. Map of the field trip route and stop localities.

Mileage Int.	Cum.	Description
0.0	0.0	Meet in front of the Subway shop in the shopping center at 6500 Steubenville Pike near the Robinson Towne Center. Exit the parking lot and turn right onto Steubenville Pike (PA 60).
0.3	0.3	Cross the Parkway West, I-376/PA 60 west.
0.1	0.4	Merge with traffic from US 22/30 west entering on the right.
0.2	0.6	Exit ramp to the Steubenville Pike (old US 22/30) on the right. Continue west on US 22/30.
1.0	1.6	Exit ramp to McKee Road on the right. Continue west on US 22/30.
1.0	2.6	Exit ramp to Oakdale Road on the right. Continue west on US 22/30.
1.4	4.0	Exit ramp to US 30 west and PA 978 south on the right. Continue west on US 22.
1.5	5.5	Exit ramp to the Steubenville Pike on the right. Continue west on US 22.
1.9	7.4	Exit ramp to PA 980, Potato Garden Run Road. Continue west on US 22.
0.9	8.3	Exit ramp to I-576, the Southern Beltway (incomplete) with access to Greater Pittsburgh International Airport to the north. Continue west on US 22.
1.9	10.2	Exit ramp to Bavington on the right. Notice the shale well pad on the left. Continue west on US 22.
4.7	14.9	Bear right onto the exit ramp to PA 18, Burgettstown and Florence.

0.4 15.3 At the top of the ramp, bear right at the traffic light onto PA 18 south, get into the middle lane, and cross over US 22.

0.3 15.6 Entrance to Key Bank Pavilion on the right. KeyBank Pavilion was originally named Coca-Cola Star Lake Amphitheater when it was opened in 1990. Billy Joel was the first internationally recog nized act to perform there. The venue is an outdoor amphitheater that holds approximately 23,000 people; 7,100 people can watch the shows in an open air pavilion with reserved seating, while an additional 16,000 folks can watch on a general admission lawn. An American global entertainment company called Live Nation Entertainment owns and operates the venue.

Figure 28. An enthusiastic crowd gathers for a concert at KeyBank Pavilion.

Continue south on PA 18.

0.3 15.9 Entrance to Hydro Recovery LP on the left. This company is in the business of collecting, treating, and disposing of oil and gas liquid waste in an economical and environmentally friendly manner, including recycling, as well as cleaning waste-water impoundments. Continue south on PA 18.

0.5 16.4 The dirt road to the left leads to some collection tanks for an old oil well in the Florence-Five Points field. You can see the tanks through the trees. Continue south on PA 18.

0.6 17.0 Entrance to Union Electric Steel on the left. Continue south on PA 18.

1.6 18.6 Enter the Borough of Burgettstown. Sebastian Burgett, a native of Germany by way of Berks County, Pennsylvania, was the first settler on Raccoon Creek in that part of Washington County that became Smith Township. He built Burgett's fort and grist mill about 1773. On February 28, 1795, Peter Kidd surveyed the land for Sebastian's son George Burgett to lay out a town on the south fork of Raccoon Creek, a mile north of the center of the township. The original name proposed for the town was West Boston but the neighbors decided to honor Sebastian Burgett and called it Burgettstown instead. The village grew slowly despite the Panhandle Railway running through the area as early as 1865. The Rev. J. T. Fredericks laid out an addition to the town at that time that included the rail road station. Burgettstown eventually was incorporated as a borough in 1881, but still growth was slow – up until 1910, Burgettstown was merely the center of a farming community. Old Town, as the original section was known, was some distance from the railroad station. Gradually, the space between Old Town and the newer part of Burgettstown built up until all parts formed a single town. Burgettstown as a thriving community really began sometime around 1912 when the American Zinc & Chemical Company built mills on a local farm, and coal mines opened at nearby Atlasburg. Shortly after, property values in creased and the town grew even more. Today, Burgettstown is best known as the home of the KeyBank Pavilion (see mileage 15.6).

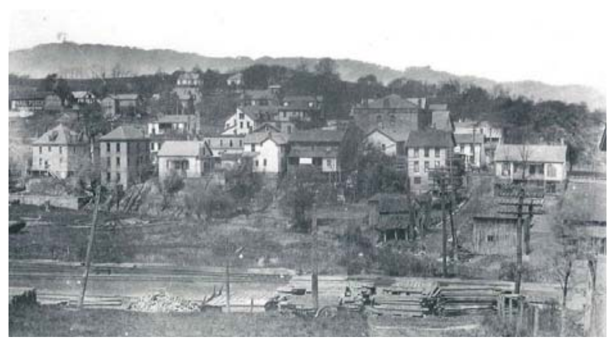


Figure 29. Photograph of Burgettstown, around 1910.

Continue south on PA 18.

0.2	18.8	Pass beneath the rail-trail of the old Panhandle Railroad. Continue south on PA 18.
0.1	18.9	Traffic light at Bridge Street. Continue south on PA 18.
1.0	19.9	Leave the Borough of Burgettstown. Continue south on PA 18.
0.9	20.8	Enter the village of Slovan. Continue south on PA 18.
1.5	22.3	Enter the village of Atlasburg. Continue south on PA 18.
0.2	22.5	Turn right onto Cross Creek Road.
0.1	22.6	Turn right at intersection with SR 4031 and continue south on Cross Creek Road.
1.6	24.2	Enter village of Cross Creek and bear right onto the third cross street, staying on Cross Creek Road.
0.3	24.5	Intersection with SR 4033 with the historic Cross Creek Church, now called Cross Creek historical marker reads:

CROSS CREEK CHURCH - Founded by Scotch-Irish Presbyterians who began to hold services in 1775 at Vance's Fort, 1 mile north. Original church built here and first pastor called in 1779. The present church building was erected 1864.

Continue south on Cross Creek Road.

2.7	27.2	Enter the village of Studa. Continue south on Cross Creek Road.
0.9	28.1	Enter the village of Patterson Mill. Notice the orange (iron-stained) abandoned mine drainage (AMD) in the creek on the right as you drive into the village. Continue south on Cross Creek Road.
1.5	29.6	Enter the village of Avella and turn right onto Browntown Road, following the signs to Meadowcroft Village and Rockshelter.
0.1	29.7	Cross railroad tracks and continue west on Browntown Road.
0.1	29.8	Turn right onto SR 4018, Meadowcroft Road. In about 350 feet, cross the bridge over Cross Creek.
1.0	30.8	The road to the left leads to the SWN Prod. Co. Joseph Powers well site approxi mately 0.5 mile back toward Avella. This is a Marcellus pad with three wells that Chesapeake Applachia drilled in 2010 to 10,446, 10,569, and 10,983 feet, and completed them in 2013 with open flows ranging from 1257 to 1858 thou sand cubic feet of gas per day (Mcfgpd) with no reported condensate or oil. The 24-hour shut-in pressures of the three wells ranged from 2020 to 2118 pounds per square inch (psi). The second well had the best numbers. South western Energy Production Co., LLC (SWN Prod. Co.) purchased the wells from Chesapeake in 2014. Table 3 shows the accumulated productions of the three wells as of March 2019.

Table 3. Comparisons of production from three wells at the SWN Prod. Co. Joseph Powers well site in Avella. Data from Pennsylvania Department of Environmental Protection.

Cumulative Production	First Well	Second Well	Third Well
Gas in Mcf	984,508.33	1,461,052.03	1,414,349.50
Condensate in Bbls	29,538.95	22,287.16	28,275.06
Oil in Bbls	41,679.91	47,572.80	54,435.82

Turn right onto Miller Road.

0.3	31.4	Although you probably won't be able to see it, Miller Road crosses the Buxton railroad tunnel. Miller Road becomes Meadowcroft Road at this point.
0.5	31.9	Cross the bridge over Cross Creek. The historical marker reads:

MEADOWCROFT ROCKSHELTER - A deeply stratified archaeological site, its deposits span nearly 16,000 years. Discovered in 1973 by Albert Miller and excavated by University of Pittsburgh archaeologists. Meadowcroft revealed North America's earliest known evidence of human presence and the the New World's longest sequence of human occupation. All of eastern North America's major cultural stages appear in its remarkably complete archaeological record.

Continue west on Meadowcroft Road.

0.2	32.1	Turn right onto Village Road and continue up the hill to the parking lot.
0.4	32.5	Enter Meadowcroft Village and park in the parking lot.

STOP 1. MEADOWCROFT HISTORIC VILLAGE AND VISITOR CENTER

Leaders: Mary Ann Gross and John A. Harper

We will stop here for the lecture by Dr. James Adovasio in the room to the far right as you enter the gift shop. Feel free to look around, use the facilities, and purchase books or memorabilia. At the end of the lecture, get back in the vehicles and return to Meadowcroft Road at the bottom of the hill.

Introduction

Meadowcroft Rockshelter and Historic Village is an outdoor history museum managed by the Senator John Heinz History Center, an affiliate of the Smithsonian Institute. It is located on Meadowcroft Road approximately three miles from Avella in Jefferson Township, Washington County, PA (Figure 30). In addition to the Rockshelter, Meadowcroft includes a visitor center with a large activity/lecture hall (Figure 31) as well as reconstructions of a sixteenth century Monongahela Indian village, an eighteenth century frontier area, and late nineteenth century rural village. The museum runs educational events for children and adults from May through October. Information can be found at the website meadowcroftinfo@heinzhistorycenter.org or by calling 724 587-3412. Figure 3 shows a layout of the premises.

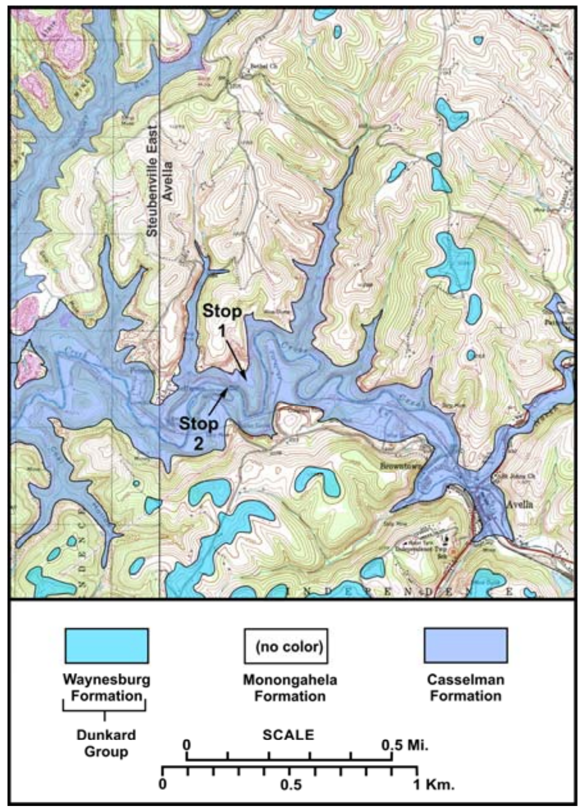


Figure 30. Map of portions of the Avella and adjacent Steubenville East 7.5-minute topographic quadrangle showing the location of Stops 1 and 2 and the local area geology (based on Skema, 1987). See the text for Stop 2 for details.

Meadowcroft Historic Village, Indian Village, and Frontier Trading Post

The Miller family has owned the grounds on the hilltop north of the winding channel of Cross Creek west of Avella where the Meadowcroft museum is located since 1795. Although the land suffered from coal mining during the 1940s and 50s, Albert and Delvin Miller wanted to restore the land and convert it to a place where young people could camp and learn about history and the natural environment. To this end, the family collected examples of nineteenth century rural architecture, including a covered bridge, an old barn, and a log cabin the Millers' great-great-grandfather had constructed in 1800 (Figure 32). Meadowcroft Historic Village opened to the public in 1969. Additional buildings were added to the village, including a log church built in the 1870s and a one-room schoolhouse (Figure 33).

Meadowcroft has also recreated a Monongahela Indian village that gives visitors a chance to visit Native Americans from the sixteenth century. The village includes wigwams (Figure 34 Top) carefully recreated artifacts, lessons in Native American agriculture, and an especially fun time for visitors – lessons in how to use an atlatl, a prehistoric spear thrower used by American Indians for hunting fish, waterfowl, and mammals (Figure 34 Bottom).

Figure 31. Photograph of the visitor center at Meadowcroft Rockshelter and Historic Village. The lecture hall is located in this building.

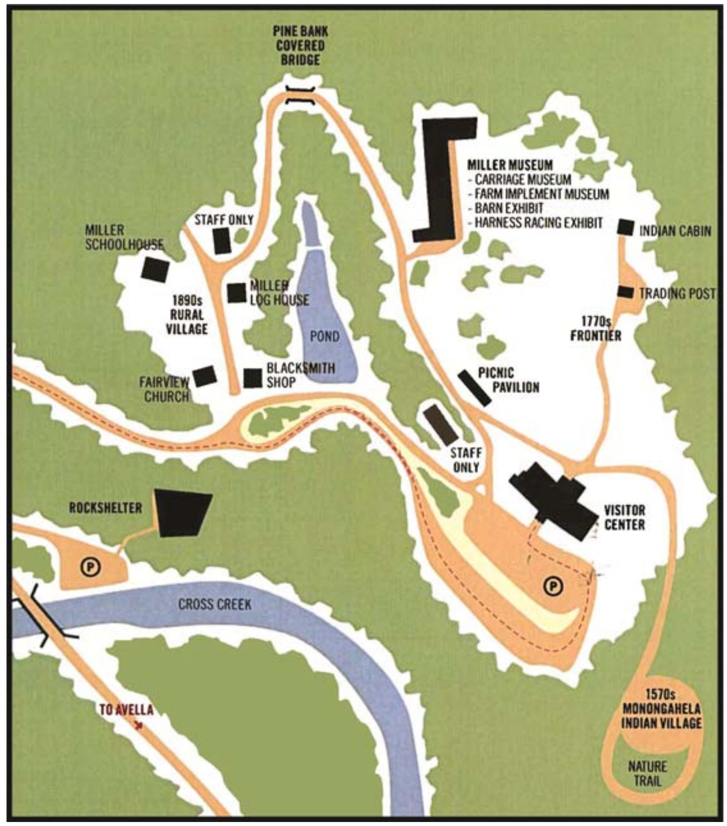


Figure 32. Map of Meadowcroft Rockshelter and Historic Village showing the locations of historic buildings and other items (modified from a handout available at the visitor center).

Figure 33. Photographs of some of the buildings in the Historic Village. Top, old church built in the 1870s (from Roberts, 2918). Bottom, the Miller one-room schoolhouse (from Kelly, 2015).

In addition, Meadowcroft also has on display a frontier trading post. When the first Europeans came to this area in the early 1700s, European (and African – yes, there was slavery in Western Pennsylvania) cultures met and had to mesh with the culture of the indigenous Native Americans (Lenapes, Shawnees, and Iroquoian-speaking Mingoes). This, of course, often resulted in violence. Yet, despite their many cultural differences, both sides shared a common need for land and resources. And so, the frontier became a cultural amalgamation as Native Americans traded furs and deerskins for European goods, while settlers adopted native crops, clothing, and survival skills. Visitors to the frontier trading post learn about the many challenges both Native American and European settlers faced when these cultures came together.

Meadowcroft Rockshelter Lecture

Dr. James M. Adovasio, Ph.D. (Figure 35), the archaeologist who, with his colleagues and students, excavated the rockshelter and put Meadowcroft on the map, will present a lecture at the visitor center. He will speak about Meadowcroft Rockshelter and where it fits into the current picture of how and when humans moved into North America. After the presentation, Dr. Adovasio will lead a tour of the Rockshelter, which in 2005 was designated a National Historic Landmark.

Following the lecture, we will drive down to the lower parking area and walk to the rockshelter site (Stop 2 – see Figure 30).

Figure 34. Photographs of Meadowcroft's Indian village. Top, two wigwams (from Anonymous, 2019a). Bottom, a modern American using a reconstructed atlatl, a prehistoric Native American hunting weapon (from Field, 2019).

Figure 35. Photograph of Dr. James M. Adovasio (left) with David Scofield, Director of the Meadowcroft Rockshelter and Historic Village. Dr. Adovasio will be lecturing and guiding the tour of Meadowcroft Rockshelter (photo courtesy of Ken Sachs).

0.4	32.9	Turn left onto Meadowcroft Road and bear left into the gravel parking lot for Meadowcroft Rockshelter.
0.2	33.1	Park the vehicles and walk to the rockshelter.

STOP 2. MEADOWCROFT ROCKSHELTER

Tour leader: Dr. James Adovasio

MEADOWCROFT ROCKSHELTER

Mary Ann Gross and John A. Harper

Introduction

Meadowcroft Rockshelter is located 30 miles southwest of Pittsburgh and 2.5 miles northwest of Avella, Washington County, Pennsylvania (see Figure 30). The site is situated on the north bank of Cross Creek, a small tributary of the Ohio River, which lies about 7.5 miles to the west. The exact location of the site is 40°17'12"N latitude, 80°29'0"W longitude.

In 1955, Albert Miller, the family historian and an amateur archaeologist, was climbing around beneath a jutting ledge of rock located above Cross Creek on his family's property In the rear of the sheltered area beneath the ledge, on the left-hand side (J. Ulery, personal comm.), he found a freshly dug groundhog burrow had exposed Native American artifacts. With some additional digging he uncovered more items, including . . . *pieces of burnt bone, flint flakes, fresh water mussel shells, and an intact flint knife, all of which validated Albert's long-held theory that native people once used the rockshelter as a campsite* (Scofield, 2015). He kept the artifacts and filled in the hole. Finally, in 1973, Miller was connected with a newly hired University of Pittsburgh archaeology professor named Dr. James Adovasio who agreed to excavate the site. By 1974, the first radiocarbon dates returned from the Smithsonian. A date of 16,000 years showed man was present long before the 11,500 years that was currently accepted dogma, and it touched off a huge controversary (Anonymous, 2018a).

Adovasio recruited University of Pittsburgh professor Dr. Jack Donahue to analysis the geology of the site. Donahue, although originally a carbonate geologist, became so involved that he helped to develop the field of geoarchaeology. He eventually went on to be the first editor of the scientific journal, *Geoarchaeology* (Adovasio and Page, 2002, p. 167).

Unless otherwise noted, the following information is excerpted from the publication *First Peoples: Archaeology at Meadowcroft Rockshelter*, produced for educational purposes by the Heinz History Center (see Anonymous, 2018a).

The Geology of Meadowcroft Rockshelter and Vicinity

***Physiography*. –** The general region where Meadowcroft is located is part of the maturely dissected Appalachian Plateau. Valley slopes account for more than half of the topography, with uplands and valley bottoms constituting less than half (Adovasio and others, 1975). The drainage pattern is modified dendritic with streams running northwestward to westward toward the West Virginia border and the Ohio River. The older streams such as Cross Creek, which undoubtedly predated the Late Pleistocene (Wisconsinan), once ran as mature, meandering streams in wide valleys. Increased precipitation and runoff, and lowered sea level during the Pleistocene glacial stages caused extensive downcutting and preservation of the present topography, including the meandering stream channels, a classic case of rejuvenation. Inasmuch as the Wisconsinan glacial boundary extended only as far south as northern Beaver County about 25 miles north of Meadowcroft, Cross Creek Valley and Meadowcroft Rock shelter probably existed in their present, or very slightly modified, configuration well before the close of the Wisconsinan Epoch around 11,000 B.P. (Adovasio and others, 1975).

***Stratigraphy and Structure*. –** The surface rocks of northwestern Washington County, including the Meadowcroft region, are layered sedimentary rocks of Late Pennsylvanian Age, including the Casselman Formation (Conemaugh Group), Monongahela Formation, and Waynesburg Formation (Dunkard Group) (Figure 30). Dominant lithologies include silty shale and argillaceous siltstone, lithic and feldspathic sandstone, non-marine limestone, and coal in decreasing order of abundance. Regional dip is 3° to 5° to the southeast, with local structures modifying the regional dip. The most prominent structure in the area of Meadowcroft is the Gillespie Dome (Figure 36), which Griswold and Munn (1907; also Shaw and Munn, 1911) considered the end of an anticlinal nose. They did not attempt to explain it further. It may be the surface expression of a pop-up in the Lower Devonian Oriskany Sandstone or possibly of a basement structure (JAH has observed some interesting folding and faulting in the Upper Ordovician Utica Shale/Trenton Limestone interval on some seismic lines in this general area of southwestern Pennsylvania). Even something related to basement structures is not out of the question.

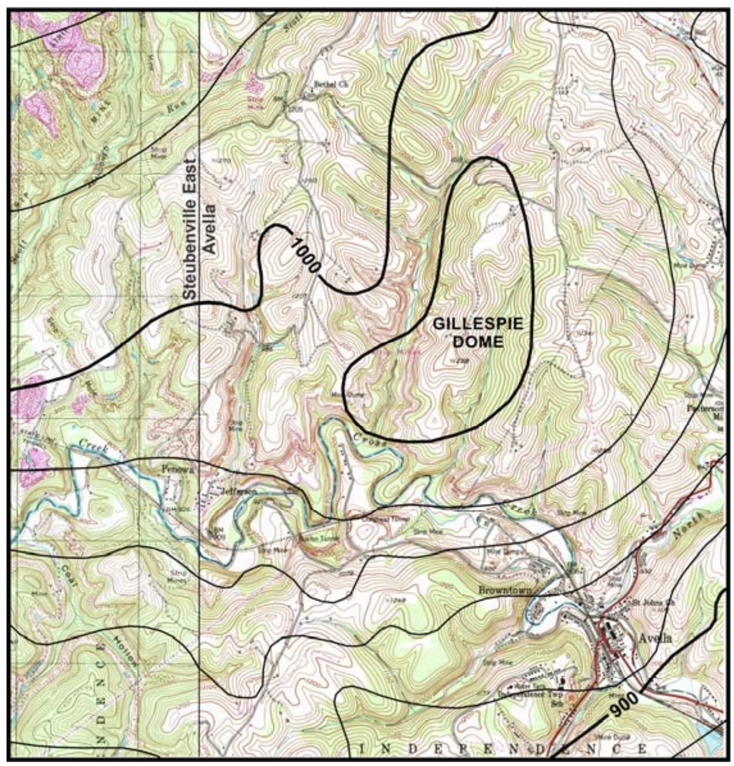


Figure 36. Regional structure map on the base of the Pittsburgh coal (from Skema, 1987).

***The Evolution of Cross Creek and Meadowcroft Rockshelter*. –** Cross Creek eroded what is now Meadowcroft Rockshelter into the Birmingham shale underlying the thick, more resistant Morgantown sandstone, which forms the roof of the shelter over, possibly, two million years or more. Figure 37 illustrates the evolution of the creek valley and the formation of the rockshelter from the Pliocene to the present. The Morgantown sandstone is a thick sequence of immature subgreywacke to protoquartzite composed of quartz grains and minor amounts of mica, feldspar, and rock fragments. It typically is considered to be of fluvial or channel origin, but see Orsborne (2014; also Orsborne and

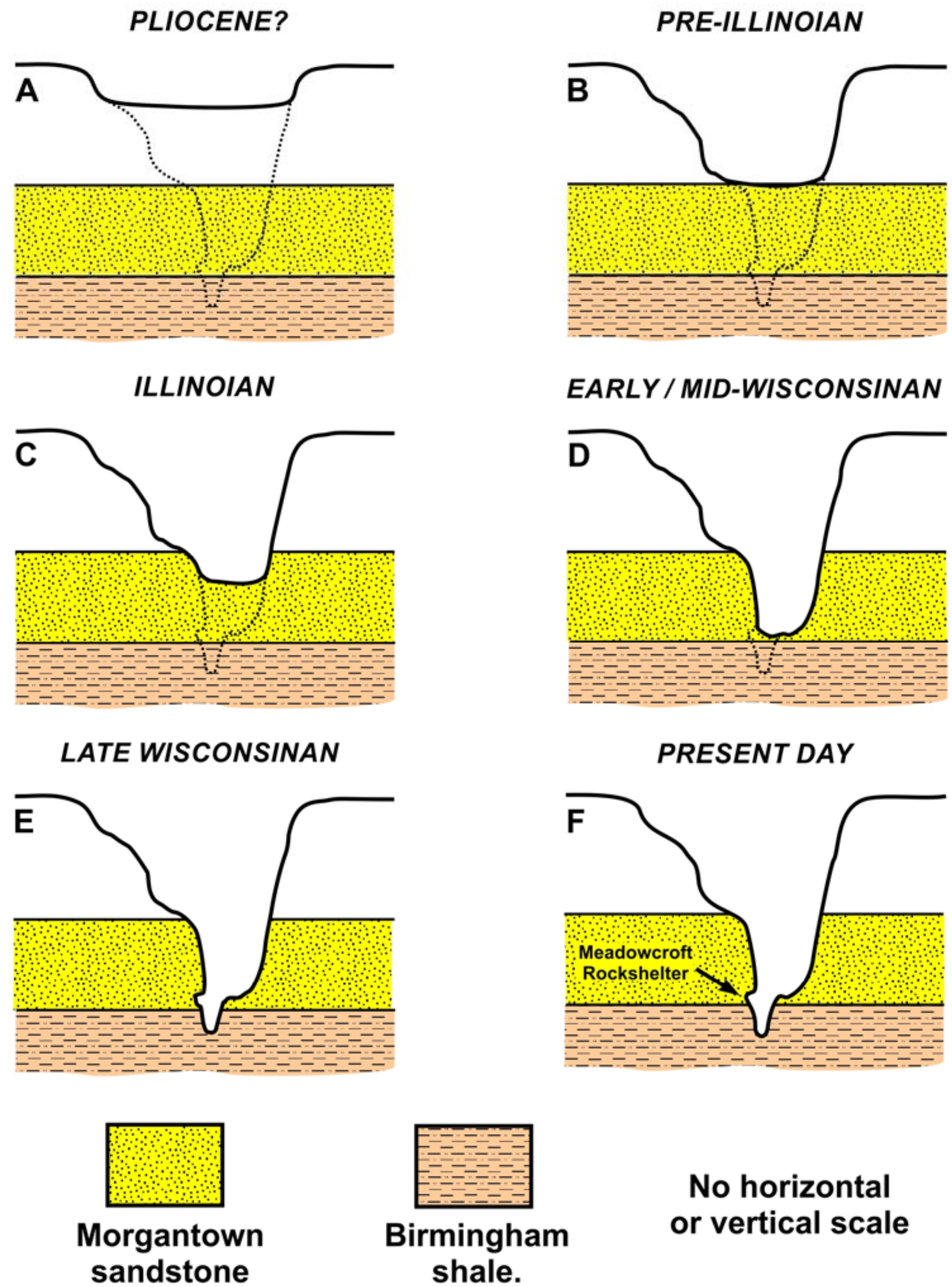


Figure 37. Evolution of Cross Creek valley and the formation of Meadowcroft Rockshelter from the Pliocene to the present. The dotted line in A to E indicates the present configuration of the valley for comparison. Notice that the rockshelter only began to be formed once the Birmingham shale became exposed in the Late Wisconsinan. Redrawn from Beynon and Donahue (1982).

Anderson, 2014) for an alternative interpretation). In Cross Creek valley, the Morgantown consists of two separate sequences of coarse-grained, cross bedded sandstone overlain by fine-grained, laminated sandstone interpreted as point-bar or sandbar deposits (Figure 38). At the rockshelter, the sandstone cliff is 72.2 feet high, its maximum thickness. It decreases in thickness both east and west along the Cross Creek valley.

Carlisle and others (1982) combined the Morgantown and Connellsville units into one they called "Morgantown-Connellsville sandstone", possibly because of the previous work of Scheinfurth (1976) who, in his stratigraphic column merely showed a continuous sequence of sandstone, briefly punctuated by shales, in the upper Casselman Formation between what is most likely the Birmingham shale and the Lower Pittsburgh limestone sequence below the Pittsburgh coal. Whether Scheinfurth (1976) was unable to split out the Morgantown and Connellsville, or simply put most of his effort into the overlying Monongahela Formation and Dunkard Group is unknown. In our opinion, however, there is little basis for including the Connellsville as part of the rockshelter. The Connellsville typically consists of sandy shales with beds of flaggy sandstone, although in some areas it can develop thick sequences of sandstone and sandy shales as much as 40 feet thick. The former description is more characteristic of the Connellsville in northwestern Washington County (Shaw and Munn, 1911). In contrast, the Morgantown most often is a massive, cross-bedded sandstone ranging from 10 to 65 feet thick throughout southwestern Pennsylvania. Another characteristic of the Morgantown sandstone that we have not observed in the Connellsville is the common presence of carbonate cement. This allows abundant weathering of the Morgantown sandstone, giving parts of it an almost smooth appearance. Honeycomb weathering, another carbonate weathering phenomenon, is also a common feature in the Morgantown, but not in the Connellsville (JAH, pers. observation). See Figure 39 for examples of honeycomb weathering.

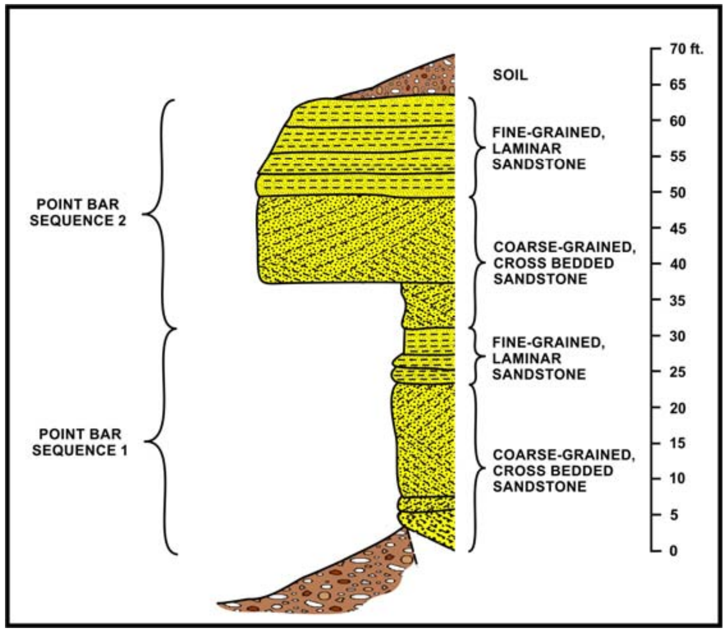


Figure 38. Illustration of Morgantown sandstone at Meadowcroft Rockshelter showing the change in sedimentary structure and grain size through the two point-bar sequences. Revised and redrawn from Carlisle and others (1982).

Meadowcroft Rockshelter

The cliff containing the Rockshelter is oriented roughly east-west with a southern exposure which allows the prevailing west to east breezes to sweep away campfire smoke and insects. The shelter is now roughly 50 feet above Cross Creek and a little over 853 feet above sea level (Figure 30). The shelter had already been formed, and was being used by animals and man, as early as 21,000 years B.P. Figure 40 shows photos of the present cliff face before development of the archaeological excavation.

The current area of the shelter is approximately 213 square feet with the roof hanging 42 feet above the modern floor. Even during the excavating, the sandstone ceiling continued to slowly erode upward and back toward the cliff. The . . . *natural strata that exist above the rockshelter's shale floor were the result of three sources: occasional rockfalls from the ceiling, providing fragments from fist-sized rocks to boulders; a steady rain of mostly quartz grains, also from the ceiling; and what is call sheetwash, meaning sediments coming down from above the rockshelter during rainstorms* (Adovasio and Page, 2002, p. 184). The . . . *sheetwash was admitted through an entrant developed by a partial roof collapse termed the Old Roof Fall* (Adovasio and others, 1984, page 363). These were the forms of erosion that caused the buildup of the stratigraphy within the shelter.

Excavations

Dr. Adovasio directed excavations at Meadowcroft from 1973 through 1979, and then lead maintenance work to preserve the site during the 1990s. He insisted on using the most advanced state of the art, interdisciplinary archaeological methods which proved to be extremely important

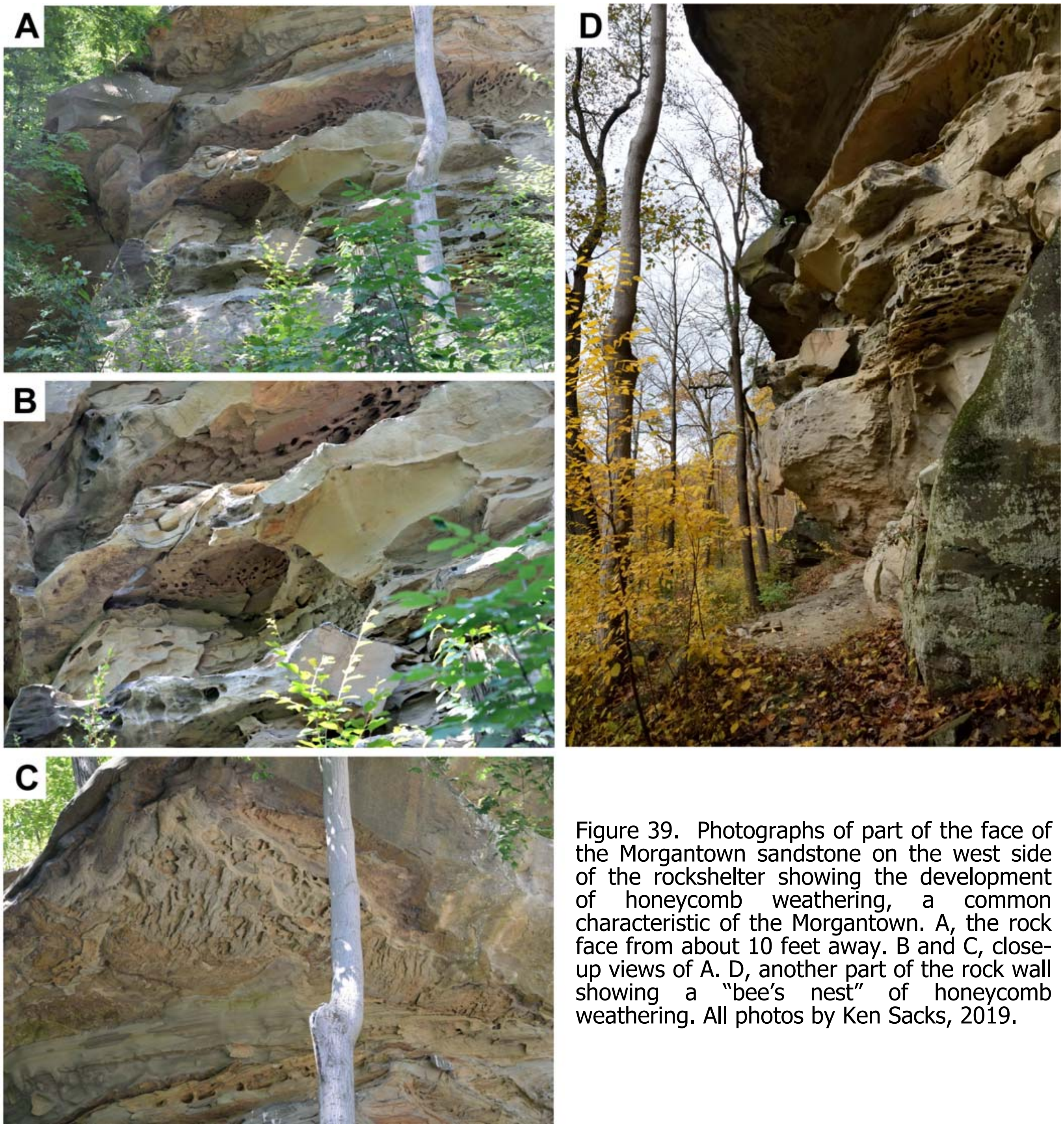


Figure 39. Photographs of part of the face of the Morgantown sandstone on the west side of the rockshelter showing the development of honeycomb weathering, a common characteristic of the Morgantown. A, the rock face from about 10 feet away. B and C, close-up views of A. D, another part of the rock wall showing a "bee's nest" of honeycomb weathering. All photos by Ken Sacks, 2019.

when radiocarbon dates before 11,500 began to appear. Approximately three-quarters of the site have been excavated. The remaining sections have been preserved for future excavation and analysis by newer methodologies and technologies that may extract significant new information.

Figure 41 shows the excavation as it appears today. The original floor level has been drawn in along the back and side walls of both photos. The crews needed to excavate down and around and, at times, through numerous falls of ceiling rock as they uncovered each unit. The large fall on the left in Figure 41A is dated to about 12,000 years B.P. and called the "Old" Roof Fall. The large number of rocks shown in front of the wooden steps fell approximately 7,000 years B.P. There is another large fall somewhat visible on the right side of the excavation in Figure 41B dated to about 2,000 years B.P. called the "New" Roof Fall. The excavation in the middle of Figure 41A, below the ladder in the front of the photo, is called the "Deep Hole". This is Stratum IIa the deepest part of the excavation

Figure 40. Early photographs of Meadowcroft Rockshelter. A, the rockshelter as seen from the south bank of Cross Creek at a time when the first wooden structure over the excavation trenches had been erected. The road to the site can be seen at the bottom of the photo. Photo by Mark McConaughy (from McConaughy, 1975). B, view of the rockshelter facing west before excavation in 1973. The large block in lower left represents a roof detachment that occurred about 12,500 years ago. Photo by James M. Adovasio (from Anonymous, 2015).

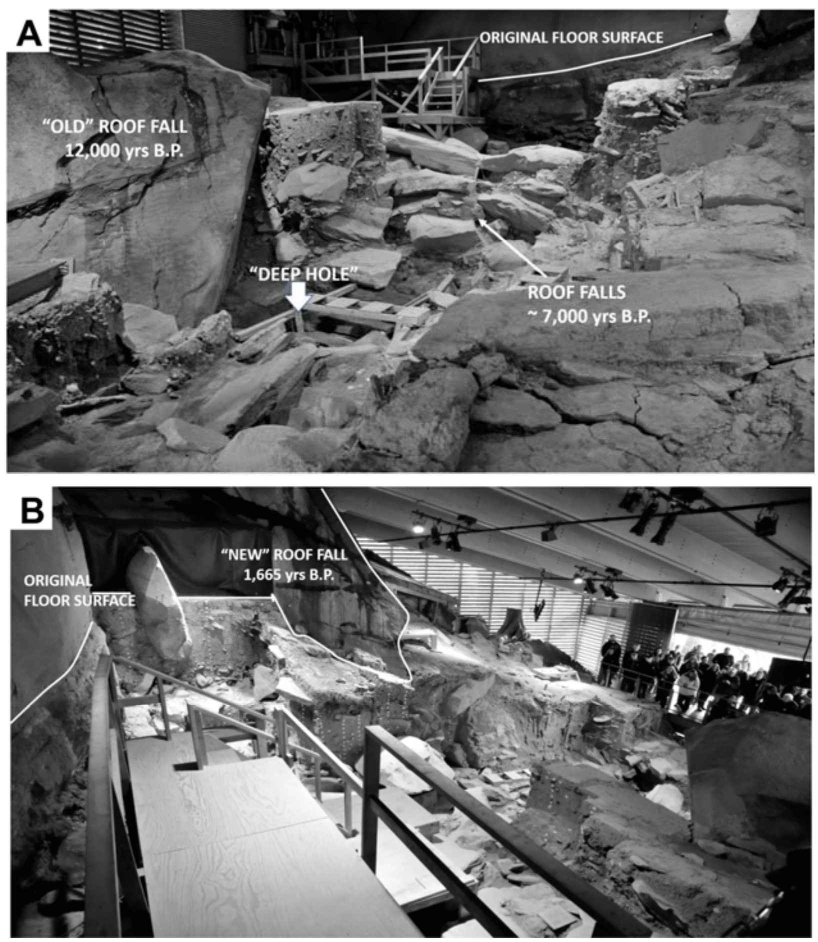


Figure 41. Photographs of inside Meadowcroft Rockshelter. A, west view of the excavation showing the trench excavated from the front of the original shelter to the back wall, the original surface floor of the shelter, the large "Old" Roof Fall, and other smaller roof falls. The Miller Lanceolate (see Figure 42) was discovered in the area of the "Deep Hole." B, east view of the excavation showing the side of the trench and the "New" Roof Fall, which destroyed a third of the shelter when it dropped. The white circular markers indicate depths of stratigraphic units and locations of artifacts. The "New" Roof Fall and original floor surface are partially obscured by a black tarp used to keep sheetwash from entering the excavation. Photo by Ken Sacks, 2019.

Figure 42. Photographs of the Miller Lanceolate. Top, the lanceolate in-situ. Bottom, The lanceolate in hand. The Miller Lanceolate was determined to be 12,000 radiocarbon years old. This is equivalent to 14,000 calendar years. Joe Yedlowski, a Temple University archeology undergraduate (Imerito, 2012), discovered the Lanceolate in 1976. Photos from Ulery (2018).

containing artifacts, where the Miller Lanceolate and organic items able to be dated were found. The white round tags define the different units and sub-units, many of which were excavated using a razor blade since a trowel was too wide. The dripline from 1973 is located roughly where the handrailing runs along the wooden platform shown on Figure 41B. The current sandstone ceiling is above the wooden roof. The dripline of the original site is located near the inside of the railing where people are standing also shown on Figure 41B. Below the handrail on the left side of the wooden platform and near the back wall in Figure 41B is where Albert Miller found the groundhog hole in 1955 (J. Ulery, personal comm, 2019).

Eleven well-defined stratigraphic units within a 16-foot thick section, spanning at least 16,000 and probably 19,000 years of intermittent occupation by human groups (Adovasio and others, 1984) were isolated inside the Rockshelter. The units were numbered from Stratum I, the oldest and deepest, to Stratum XI, the uppermost and youngest, using the results of 52 radiocarbon dates. Evidence of a continuous but intermittent record of cultural activity was found throughout the units.

> *The calibrated ages for these assays indicate a Woodland period ascription for Strata XI-IV (upper), an Archaic ascription for Strata IV (middle)- IIb, and a predominately Paleo-Indian ascription for Stratum IIa* (Anonymous, 2018b, p. 29).

"Woodland", "Archaic" and "Paleo-Indian" refer to cultural periods defined in part by the types and sophistication of the tools and other artifacts dated to those periods. It was in Stratum IIa where remnants of basketry, a modified wood spear foreshaft, and a notable lithic assemblage (the "Miller Complex") were dated by radiocarbon methods to between 16,175 and 11,300 years ago (Anonymous, 2018b, p. 29). Bone, firepits and fire floors, floral remains and shell were also found (Adovasio and others, 1976). The Miller Lanceolate was found in Stratum IIa (Figure 42 Top). In all, two million artifacts and plant and animal remains were collected from all eleven stratigraphic units. This site was one of the first to have a hookup to a mainframe computer (at the University of Pittsburgh) and . . . *to have such complete computerized records of every detail of the excavation* (Adovasio and Page, 2002, p 169).

Even though excavating this site was backbreakingly, mind-numbingly tedious, it's difficult to not be caught up in the excitement as they realized how far back in time they were exploring.

> *The following summer (1974), we returned and by early July had penetrated through layers more than ten feet deep. We had come across some twenty levels of prehistoric fireplaces, showing that at this spot for literally thousands of years people had been taking it easy, sitting around the fire, munching. We plowed on down through layer after layer, finding the remains of successively older and more or less familiar cultures, known from other digs in the Northeast. We reached a stratum that was in excess of 10,000 years old – we knew this from the kind of spear points we found in it, called early Archaic and known to date back to that period. Below the early Archaic levels, we recovered still more cultural material that was more or less familiar. Then we encountered a layer of rocks from a major spall (rock fall) from the shelter's roof that had thoroughly sealed off the sediments below.*
>
> *Breaking through the rock seal, we began to turn up decidedly unfamiliar but undeniably human-made things – artifacts. This was in levels that we knew were getting*

close to – and even deeper and therefore older than – the time period when current archaeological thought allowed humans to be. At a level that appeared to date to about 12,000 years ago, we found an intact spear point. It was about three inches long, evidently a tool that had once been bigger but had been repeatedly resharpened to its present size and perhaps simply left behind as too small. It was what archaeologists called lanceolate in shape and was unfluted (unlike Clovis points). It did not look exactly like anything else we had ever seen from the New World. (Figure 42 Bottom)

So we immediately decamped to our favorite bar in town and polished off ten kegs of beer. We named the point the Miller Lanceolate to honor Albert Miller, the generous owner of a site that now looked as if it was going to make a lot of waves (Adovasio and Page, 2002, pages 155-156).

More firepits dating back as far as 15,000 years ago were found below the Miller point, along with the remains of bones, wood, shell, basketry, cordage and several dozen stone tools, such as rhomboidal "knives", unifacial choppers and scrapers, sharp-pointed gravers, and microengravers. Hundreds of small pieces (called "debitage") flaked off of the tools were found, too. The tools were made of materials not from the site, including Kanawha chert from West Virginia, Flint Ridge material from Ohio, Pennsylvania jasper, and Onondaga chert from New York. (Adovasio and Page, 2002) (Figures 43-46).

Figure 43. Photographs of assorted Miller Complex artifacts from Stratum IIa (containing the oldest cultural remains radiocarbon dated to about 16,000 years B.P.) at Meadowcroft Rockshelter. From left to right, the Miller Lanceolate type specimen made of local Cross Creek chert; prismatic blade flake made from Onondaga chert; prismatic blade flake made from Flint Ridge chert; biface fragments made from Flint Ridge or Kanawha chert (black specimens are Kanawha). Photo from Don's Maps (2018).

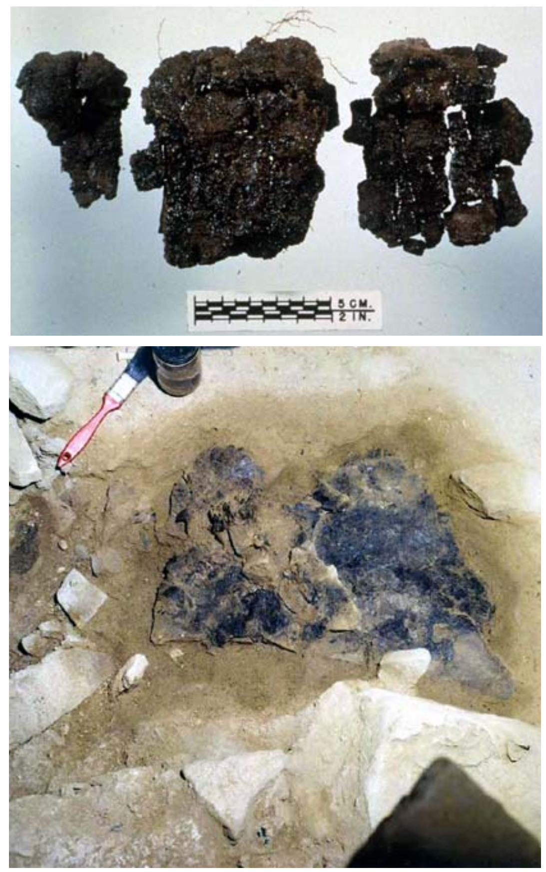


Figure 44. Photographs of Meadowcroft basketry. Top, simple basketry fragments from Meadowcroft. Bottom, large basketry fragment photographed in-situ at Meadow-croft Rockshelter. Photos from Don's Maps (2018).

Figure 45. Archaeologists found an assortment of bone objects at Meadowcroft. Many of them were from animals used for food. Humans shaped all four objects, including the awl (left) and part of a bone or ivory disc (right). From Don's Maps (2018).

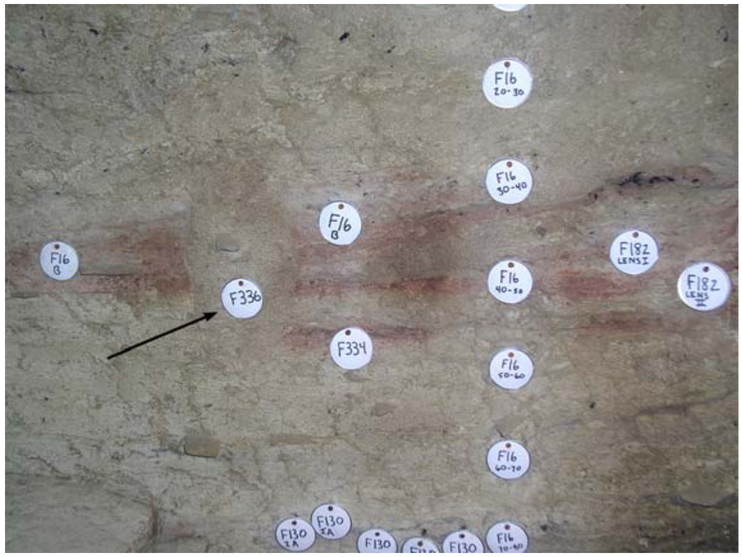


Figure 46. Close-up photograph showing evidence of ancient campfires built at the site. The heat of the fire altered the sandstone particles to the reddish color. Also evident are bits of charcoal produced in the fires. Tag F336 (at the arrow) indicates where a post hole was dug down through the existing fire pit at a later date.

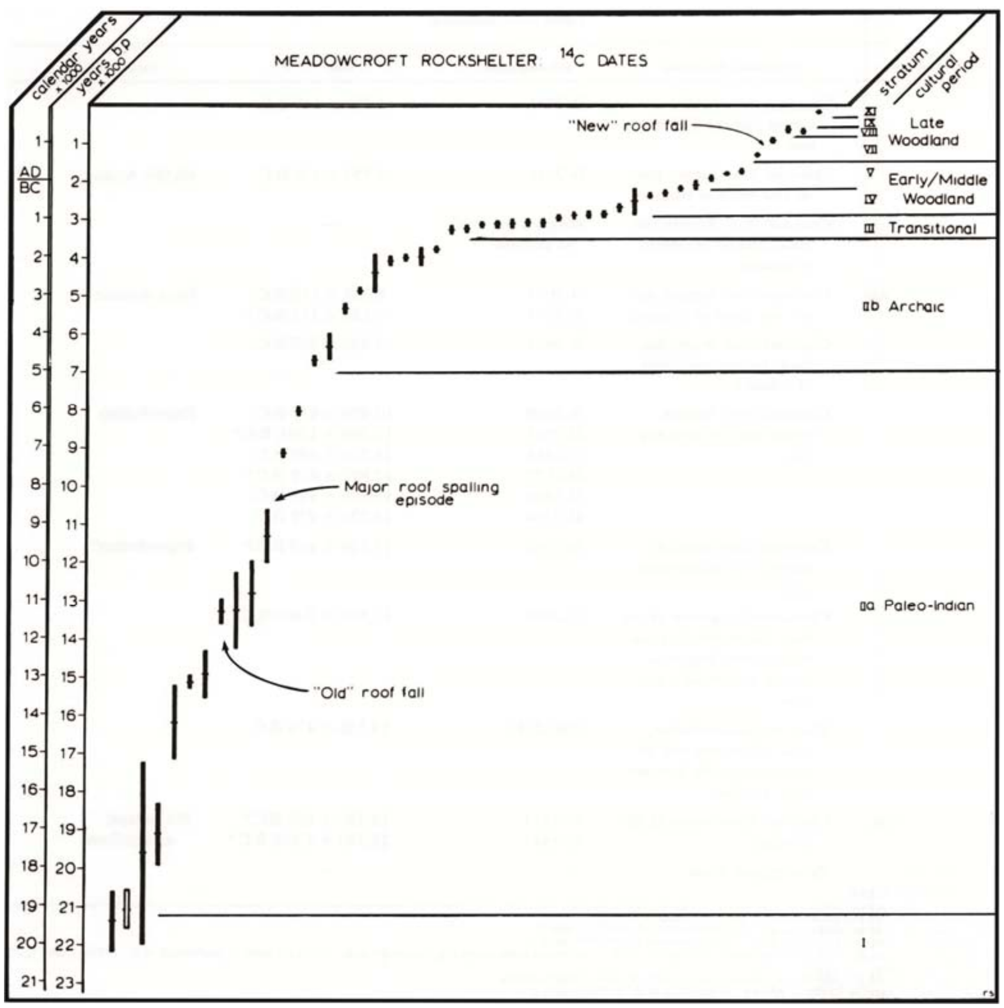


Figure 47. Plot of radiocarbon dates from Meadowcroft Rockshelter showing one standard deviation (from Stuckenrath and others, 1982).

Dating the Artifacts

A very large number of carbon-14 tests have been run on artifacts from Meadowcroft compared to tests run on other sites. Nearly 40 dates from two different laboratories were obtained by the later 1970's that told nearly the same story. A total of 52 tests were run, mostly on charcoal from fire pits. Thirteen tests were run on the pre-Clovis artifacts, again from fire pits and also on a possible basketry fragment (Adovasio and Page, 2002). In Figure 47, the dates produced from these tests are matched to the cultural period (Stuckenrath and others, 1982).

> *What they show – and this is really the most important thing about Meadowcroft – is the longest continuous use [by humans] of a single place in all of North American prehistory* (Adovasio and Page, 2002, p.181).

What About the Clovis Controversy?

For this Guidebook, "Clovis First" is too complex a subject to delve into any more than this – there are archaeologists who do not agree that humans came to North America any earlier than around the very end of the Pleistocene, when the glaciers were retreating. The Clovis culture was named after the particular stone points found at Blackwater Locality No. 1, the first site that opened near Clovis, New Mexico back in the 1930's. Once radiocarbon dating was first proposed in the late 1940's, developed and tested sufficiently by the 1960's to use for dating objects containing carbon, dates of around 11,700 years B.P. were tied to the end of the Pleistocene/early Holocene (Anonymous, 2019b). Carbon from the Blackwater Clovis site was dated to around 11,500 – 11,000 years B.P. (Anonymous, 2019b). Over the last 40+ years various reasons for skepticism over the dates produced from Meadowcroft have been brought up and rebutted. In general, though, there are now other sites in North and South America that also show ages of older than 11,000 years B.P., so the idea of Clovis artifacts being the first to show human presence is dissipating.

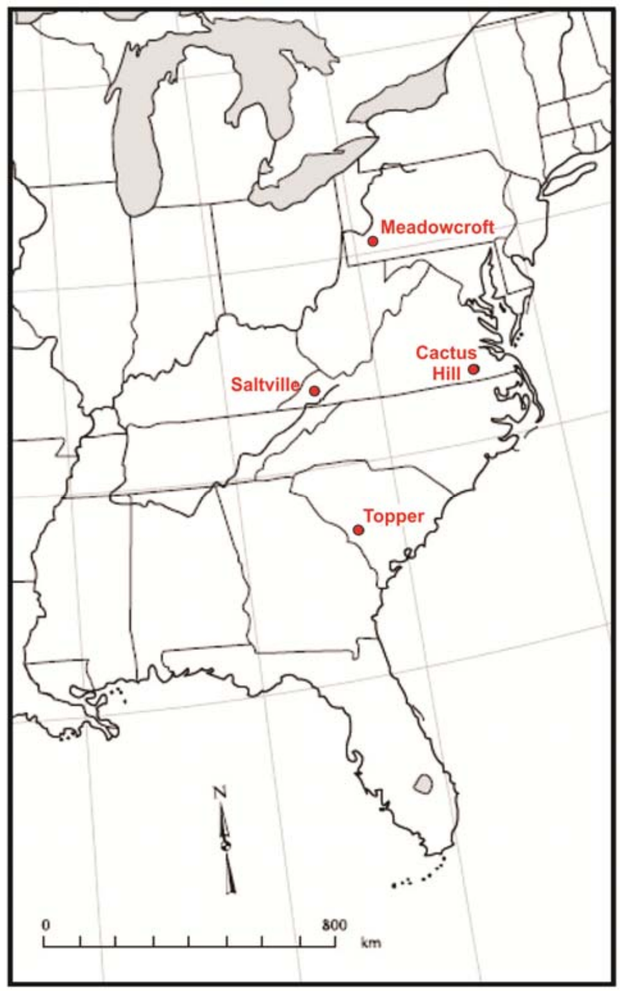


Figure 48. Map of the eastern half of the United States showing the locations of sites with evidence of pre-11,500 radiocarbon years B.P. occupation (pre-Clovis sites). Modified from Goodyear (2005).

Other Pre-Clovis Sites in Eastern North America

In addition to the findings at Meadowcroft, evidence of human presence prior to 11,000 B.P. continues to be found, particularly in Virginia and South Caroline. These sites contain younger evidence of human presence, too, including Clovis. A map of the locations of these sites is in Figure 48.

***Cactus Hill, Virginia.* –** Cactus Hill is located in Sussex County, Virginia about 45 miles south of Richmond. It was originally tested in 1988, and then excavated from 1993 through 2002. The site . . . *within is a stratified multi-component site in a sand dune approximately 1.8 m thick overlooking the Nottoway River in the interior coastal plain of Virginia* (Goodyear, 2005, p.106). Joseph McAvoy and Lynn McAvoy of the Nottoway River Survey, and Michael Johnson, a Fairfax County, Virginia archaeologist working with the Archaeological Society of Virginia have been excavating the site. Quartzite blades and flakes and charcoal concentrated in hearth-like occurrences were found below the Clovis layer.

> *McAvoy (1997) believes two separate sub-Clovis lithic horizons are present; the lower horizon consists of large prismatic blades, followed by a zone of smaller blades* (Goodyear, 2005, p.107).

Dates from late-glacial plant remains recovered from hearths range from 15,000 to 17,000 radiocarbon years B.P. (McAvoy and others, 2000).

***Saltville, Virginia.* –** Saltville SV-2 is located in Saltville Valley, Saltville, Virginia, which is in the Valley and Ridge Province of the Appalachian Mountains of southwest Virginia. Paleogeographer Jerry McDonald, a research associate with the Smithsonian Institution and the Virginia Museum of Natural History, led excavations of the site from 1992 to 1997. The site was a river that became a lake and its valley bottom was sealed with mud. This preserved the late-glacial plant and animal remains and evidence of human presence found there. In the lower part of the deposit, radiocarbon-dated horizons ranging in age from 14,510 to 13,000 radiocarbon years B.P. each bear archaeological evidence of human occupation. Proboscidean remains (skeletal and dental) and a musk ox tibia, dated to 14,510, and appearing to have been used as a tool were found. (McDonald, 2000; Goodyear, 2005, p.105)

> *The unusual condition and distribution of proboscidean bone suggests to McDonald that a single mastodon was butchered and burned*. (Goodyear, 2005, p. 106)

Chert flakes not occurring naturally in the area, and other stone and bone tools, were found in the layers above. The top layer contains faunal contents that suggest the people were eating clams and fish. (Goodyear, 2005, p.106)

In additional to the mastodon remains in SV-2, the remains of megafauna, such as giant ground sloth, woolly mammoth, mastodon, horse, elk moose, the giant short faced bear, and many musk oxen have been discovered in the Saltville Valley (Schubert, 2009). Jerry McDonald discovered the third most complete musk oxen skeleton in 1980 (McDonald and Bartlett, 1983).

***Topper, South Carolina.* –** Topper is located on the eastern side of the Savannah River in Allendale County on a Pleistocene terrace. The pre-Clovis-age levels had been excavated yearly since its 1998 discovery. (Goodyear, 2005, p.107) Topper was discovered in 1981 by Dr. Albert Goodyear, a semi-retired University of South Carolina archaeologist, and first excavated is 1986 (Hanks, 2018).

> *The site complex includes a terrestrial chert outcrop and quarry exposed on the hillside and in an adjacent creek bed, which is mantled by sands* (Goodyear, 1999; Goodyear and Charles 1984).

Thousands of artifacts of Clovis-age have been recovered from here.

> *Beneath the Clovis horizon at Topper are two meters of Pleistocene-era alluvial sand; between these alluvial deposits and a layer of clay several feet thick below it, an array of artifacts were discovered that were dubbed "The Topper Assemblage." Comprised of a variety of scrapers and other simple lithic tools, optically stimulated luminescence dating determined that this region of strata dates back to as much as 15,200 years BP, according to studies by archaeologist Michael Waters of Texas A & M University in the late 1990s.*
>
> *However, some of the lithic artifacts recovered from even deeper strata at Topper could date as far back as 50,000 years, according to some estimates. Such artifacts have been met with criticism. Among the notable opponents to the idea of 50,000-year-old artifacts anywhere in North America, let alone in South Carolina at a site like Topper, had been Michael B. Collins of Texas State University. However, mounting evidence in recent years has continued to push back the timescales on the earliest human occupations in North America; among the latest was the aforementioned paper in Science Advances* earlier this year which discussed evidence for early human projectile manufacture at the Gault site in Texas going back as much as 20,000 years (ironically, this paper lists Collins as a co-author).
>
> *In light of such discoveries, perhaps Topper's earlier legacy cannot be ruled out after all. Newer studies have continued in relation to the "Topper assemblage" as well; among the most recent had been the 2015 doctoral dissertation written by Tennessee graduate student Douglas Sain, whose work was discussed by J.M. Adovasio and David Pedler in their 2016 book, Strangers in a New Land: What Archaeology Reveals About the First Americans.*
>
> *Adovasio writes: "Sain has concluded that the pre-Clovis Topper Assemblage artifacts are indeed genuine, and that a small sample of the tools show microscopic evidence of human use in the form of edge polish (the smoothing of sharp edges via repetitive action), striadons (fracture lines resulting from contact with another object), residue (plant or animal material adhering to the artifact), and edge damage (chipping of the artifact's edge*

through use). His research has also concluded that the Topper Assemblage artifacts are indeed in situ, and hence did not migrate downward into the deposit from overlying archaeological levels. It remains to be seen what the professional archaeological community will make of Sain's findings, but if the Topper Assemblage finds widespread acceptance a radical reworking of our understanding of pre-Clovis stone technology will be in order."

Topper's assemblage of pre-Clovis artifacts may not always be disputed by the broader community of North American archaeologists. Perhaps with the help of similar discoveries occurring elsewhere in the Americas right now, archaeologists will be encouraged to return to the Topper assemblage with a fresh eye. With any luck, they too will be convinced that a human presence in North America goes back farther in time than the anthropological community would previously have ever guessed (Hanks, 2018).

Leave Stop 2 and return to the intersection of Browntown Road and Cross Creek Road in Avella.

2.4	35.5	Bear right onto Cross Creek Road then right again onto Avella Street. Follow Avella Street (PA 50 east) through town and into Independence Township.
2.6	38.1	The road to the left leads to yet another Marcellus pad. Continue east on PA 50.
0.5	38.6	Avella Area Elementary School on the left. Continue east on PA 50.
1.1	39.7	Enter the village of Rea and turn right onto County Park Road.
1.6	41.3	Numerous dirt roads to the right and left lead to even more numerous Marcellus well sites. Turn left just before the lower parking lot and drive up the hill to the upper lot. Drive through the parking lot to the access road to Pavilion #3 and park at the pavilion.

STOP 3. CROSS CREEK COUNTY PARK – LUNCH

Our lunch stop is at Cross Creek County Park (Figure 49). At 3,500 acres, it is Washington County's largest park. The park features Cross Creek Lake for boating and fishing, as well as picnic shelters, playgrounds and a hiking trail. We will have lunch at Pavilion #3 on the top of the hill overlooking the lake (Figure 50).

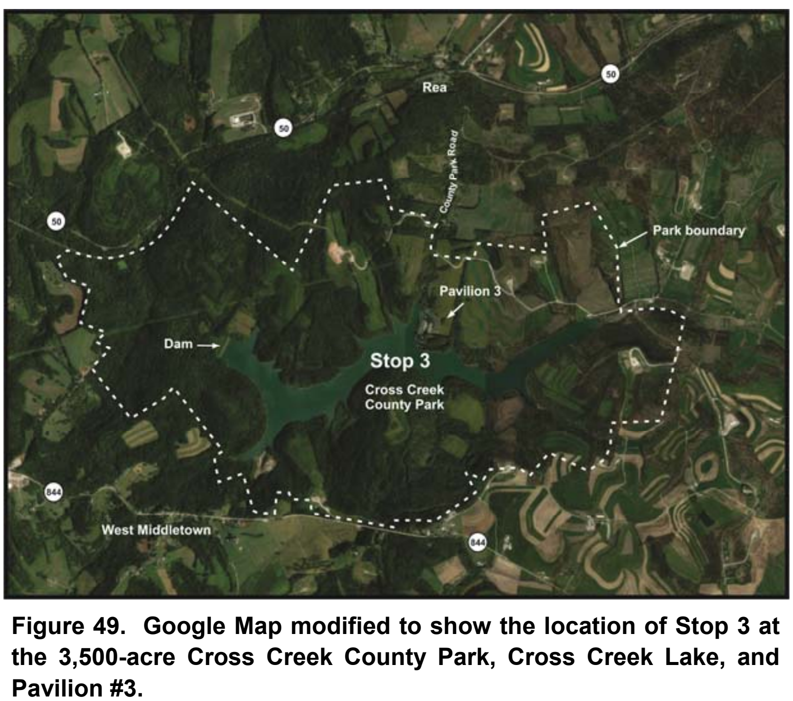


Figure 49. Google Map modified to show the location of Stop 3 at the 3,500-acre Cross Creek County Park, Cross Creek Lake, and Pavilion #3.

Cross Creek Lake (Figures 49 and 51) is a beautiful 244-acre fishing and boating lake (but not swimming), and there are a few lakeside benches to sit and relax and enjoy the view. Leashed pets are welcome and hunting is allowed. Composting toilets are available near the park office as well as at Pavilion #3.

Pennsylvania Fish and Boat Commission biologists have developed aquatic resource management plans for "open to the public" county and municipally owned lakes and reservoirs such as this. Fisheries Management Area 8 biologists conducted a fish population survey of Cross Creek Lake to update the fisheries management plan and evaluate special fish harvest regulations that apply to this reservoir.

Figure 50. Photograph of Pavilion #3 at the top of the hill overlooking the lake.

Figure 51 . Photograph of Cross Creek Lake and some of its amenities (picnic pavilions, picnic benches, park benches, etc.) (from Discover the Burgh, 2019).

Figure 52 . Photographs of some of the fish available in Cross Creek County Park. A, saugeye (from Ventorini, 2007); B, largemouth bass (from Indiana Gazette, 2019); C, bluegill (from Fishidy, 2019).

The Washington Co. Department of Parks and Recreation, which owns and operates the park, enforces a 10-horsepower boating limit on the lake, and maintains a paved boat launch ramp, courtesy docks, and a handicapped-accessible fishing pier, all located in the same vicinity on the north shore of the Lake. Anyone interested in fishing should be aware that a fishing permit, obtainable from the Department of Parks and Recreation office, is required for all boaters using the lake, launch ramp, and courtesy docks. There are also several shallow "No Wake Zones" located around the lake.

The lake is fairly turbid, relatively deep (up to 60 feet near the dam), and very fertile, which contributes to maintaining one of the densest largemouth bass populations in Pennsylvania (Ventorini, 2007). The lake, with numerous submerged stumps, large woody debris, and submerged and floating aquatic vegetation, provides excellent habitat for warmwater species. Gamefish include saugeye (Figure 52A), channel catfish, and largemouth bass (Figure 52B); panfish include black crappie, bluegill (Figure 52C), redear sunfish, and brown bullhead. Cross Creek Lake is a big bass hot spot. Few other waters in the state have largemouth bass weighing more than 5 pounds. In Pennsylvania's List of Biggest Fish of 2010, the #4 entry came from this Cross Creek Lake. It was 23.5 inches long and 15 inches in girth and weighed 8 pounds 2 ounces (Bleech, 2012). The lake also is considered to be an exceptional fishery for quality-sized black crappie and bluegill.

Return to PA 50 in Rea and turn right.

2.9	44.2	The dirt road to the left leads to still yet another Marcellus well site. In about 400 feet, just before crossing the railroad tracks, look to the left and see what effect shale-gas money has had on some of Washington County's landowners (Figure 53).
1.8	46.0	Enter the village of Woodrow. Continue east on PA 50.
0.5	46.5	Pass under railroad tressle. Continue east on PA 50.
0.2	46.7	Another Marcellus well site to the right. Continue east on PA 50.

Figure 53. Photograph of a local farm modified by the effects of a Marcellus shale gas lease.

1.2	47.9	Intersection with PA 18 south on the right. Continue east on PA 50.
0.1	48.0	Hickory United Presbyterian Church on the left and cemetary on the right. Continue east on PA 50.
0.4	48.4	Intersection with Burgettstown Road (PA 18 north) on the left. Continue east on PA 50.
0.6	49.0	Enter the village of Hickory. Although you won't be able to see it, the road passes over the Hickory Tunnel on the Norfolk & Southern Railroad just before the Old Hickory Inn on the right.
0.8	49.8	Turn right onto PA 519 south.
2.4	52.2	Enter the village of Westland. Continue south on PA 519.
0.5	52.7	MarkWest Houston rail yard on the left.
0.8	53.5	MarkWest Pipeline Office on the left.
0.2	53.7	Enter the village of Export at the intersection with Ullom Road on the right (not to be confused with the Borough of Export in Westmoreland County). MarkWest Processing on the left.
0.1	53.8	MarkWest gate on the left.
0.3	54.1	Turn left into MarkWest Plant Entrance Gate 1 – drive up to the blue building and park.

STOP 4. TOUR OF MARKWEST HOUSTON, PA PLANT

Tour leader: Kristy Budavich, Local Government Affairs Representative, MarkWest (MPLX)

Figure 54. Location of the MarkWest Houston plant along PA 50 just northwest of Houston, PA.

Introduction

The MarkWest (MPLX) Houston plant on PA 519 between the towns of Houston and Hickory (Figure 54) is a major facility in the Marcellus/Utica natural gas production field (Figure 55). Its purposes include the gathering, processing and transportation of natural gas, and the gathering, transportation, fractionation, storage and marketing of natural gas liquids (NGLs) extracted from the hydrocarbon-rich Marcellus found in southwest Pennsylvania. Today we will be given a tour of this facility. Please listen carefully to the safety guidelines we are given and wear any protective

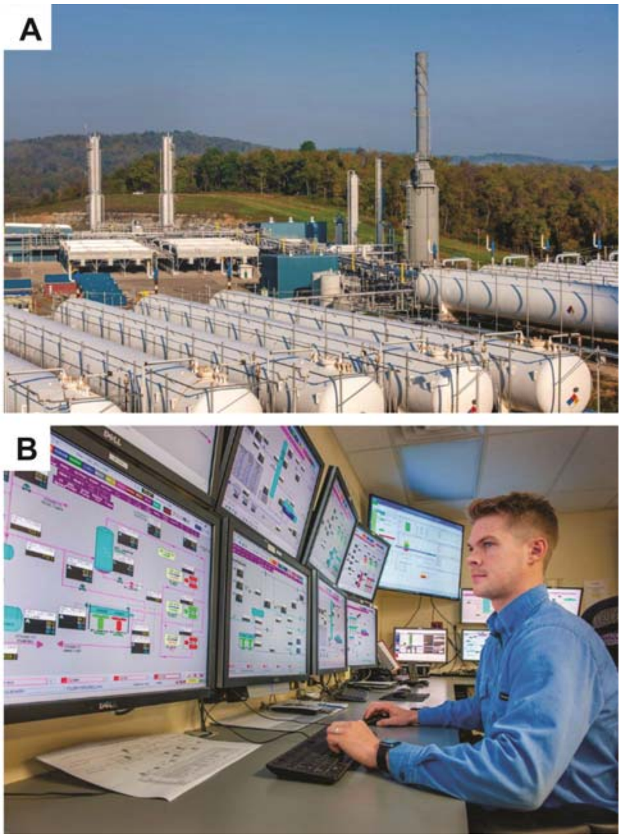


Figure 55. Photographs of the MarkWest Houston Complex in Houston, PA. A, the MarkWest Houston Plant extracts and separates higher hydrocarbons from the "wet" Marcellus shale gas produced in this area. Source: MPLX Image Gallery (http://www.mplx.com/ content/inline-images/mpc/about/image_gallery/markwest/7028za_2172m.jpg). **B, the MarkWest Houston Plant has a large control room manned 24 hours a day.** Source: MPLX Image Gallery (http://www.mplx.com/content/inline-images/mpc/about/image_gallery/markwest/7028za_5009m.jpg).

eyewear or ear protection that may be handed out before the tour.

Table 4 shows the types of products that may be produced from the NGLs coming from the Houston Plant. The following discussion, including the embedded figures, is taken from MPLX (2018)

About MPLX

MPLX is a diversified, growth-oriented master limited partnership formed in 2012 by MPC to own, operate, develop and acquire midstream energy infrastructure assets. We are engaged in the gathering, processing and transportation of natural gas; the gathering, transportation, fractionation, storage and marketing of NGLs; the transportation, storage and distribution of crude oil and refined petroleum products; as well as refining logistics and fuels distribution services. MPLX provides services in the midstream sector across the hydrocarbon value chain through our Logistics and Storage and Gathering and Processing segments.

Logistics and Storage

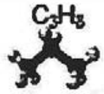
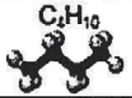
MPLX transports, stores and distributes crude oil, refined products and other hydrocarbon-based products, primarily in the Midwest and Gulf Coast regions of the U.S. Assets consist of a network of wholly- and jointly-owned common carrier crude oil and refined product pipeline systems and associated storage assets, refined product terminals, storage caverns, refining logistic assets, and an inland marine business.
We own, lease, operate or have interest in approximately 10,000 miles of crude and refined product pipelines. We also own, lease or have interest in 62 light product terminals in the Midwest, Gulf Coast and Southeast regions of the United States. Our terminal facilities are used for the receipt, storage, blending, additization, handling and delivery of refined petroleum products. We have butane and propane storage caverns in Illinois, Michigan and West Virginia.

In addition, MPLX provides fuels distribution services to MPC and owns refining logistic assets consisting of tanks with approximately 56 million barrels as well as refinery docks, loading racks and associated piping.

MPLX's marine operations include 20 owned towboats as and more than 255 owned and leased barges that transport refined products and crude oil on the Ohio, Mississippi and Illinois rivers and their tributaries and inter-coastal waterways. Our marine repair facility is a full-service marine shipyard located on the Ohio River adjacent to MPC's Catlettsburg refinery.

We also have interest in various joint-interests, including LOOP LLC (Louisiana Offshore Oil Port), the only U.S. deep water oil port located offshore in Louisiana, which offloads crude oil from marine vessels destined for onshore storage and pipeline transport.

Table 4. What are natural gas liquids and how are they used? (from the U.S. Energy Information Administration (EIA).

NGL Attribute Summary				eia
Natural Gas Liquid	Chemical Formula	Applications	End Use Products	Primary Sectors
Ethane	C_2H_6 	Ethylene for plastics production; petrochemical feedstock	Plastic bags; plastics; anti-freeze; detergent	Industrial
Propane	C_3H_8 	Residential and commercial heating; cooking fuel; petrochemical feedstock	Home heating; small stoves and barbeques; LPG	Industrial, Residential, Commercial
Butane	C_4H_{10} 	Petrochemical feedstock; blending with propane or gasoline	Synthetic rubber for tires; LPG; lighter fuel	Industrial, Transportation
Isobutane	C_4H_{10} 	Refinery feedstock; petrochemical feedstock	Alkylate for gasoline; aerosols; refrigerant	Industrial
Pentane	C_5H_{12} 	Natural gasoline; blowing agent for polystyrene foam	Gasoline; polystyrene; solvent	Transportation
Pentanes Plus*	Mix of C_5H_{12} and heavier	Blending with vehicle fuel; exported for bitumen production in oil sands	Gasoline; ethanol blends; oil sands production	Transportation

C indicates carbon, H indicates hydrogen; Ethane contains two carbon atoms and six hydrogen atoms

Pentanes plus is also known as "natural gasoline." Contains pentane and heavier hydrocarbons.

Natural gas liquids (NGLs) are hydrocarbons – in the same family of molecules as natural gas and crude oil, composed exclusively of carbon and hydrogen. Ethane, propane, butane, isobutane, and pentane are all NGLs (see table above). There are many uses for NGLs, spanning nearly all sectors of the economy. NGLs are used as inputs for petrochemical plants. burned for space heat and cooking, and blended into vehicle fuel. Higher crude oil prices have contributed to increased NGL prices and, in turn, provided incentives to drill in liquids-rich resources with significant NGL content.

The chemical composition of these hydrocarbons is similar, yet their applications vary widely. Ethane occupies the largest share of NGL field production. It is used almost exclusively to produce ethylene, which is then turned into plastics. Much of the propane, by contrast, is burned for heating, although a substantial amount is used as petrochemical feedstock. A blend of propane and butane. sometimes referred to as “autogas," is a popular fuel in some parts of Europe, Turkey, and Australia. Natural gasoline (pentanes plus) can be blended into various kinds of fuel for combustion engines, and Is useful in energy recovery from wells and oil sands.

By the Numbers

> Pipeline network includes more than 8,000 miles of pipeline across 17 states.

> Butane, propane and liquefied petroleum gas storage caverns with a combined capacity of 4.175 million barrels.

> Terminal facilities in the Midwest, Gulf coast and Southeast regions of the United States with a total shell capacity of approximately 23.7 million barrels.

> Tank farm assets at certain MPC refineries with a storage capacity of approximately 56 million barrels.

> Marine business that owns and operates 23 boats and 256 bargers.

Gathering and Processing

MPLX operates several natural **gas gathering systems**, which have a combined throughput capacity of approximately 5.9 bcf/d (billion cubic feet per day). The scope of gathering services we provide depends on the composition of the raw or untreated gas at producer customers' wellheads. For dry gas, we gather, and if necessary, treat the gas and deliver it to downstream transmission systems. For wet gas that contains heavier and more valuable hydrocarbons, we gather the gas for processing at a processing complex.

MPLX's natural gas processing complexes remove the heavier and more valuable hydrocarbon components from natural gas. We operate natural gas processing complexes in the Marcellus shale, Utica shale, Appalachia region, and Southwest region with approximately 8.9 bcf/d of natural gas processing capacity.

Once natural gas has been processed at a natural gas processing complex, the heavier and more valuable hydrocarbon components, which have been extracted as a mixed NGL stream, can be further separated into their component parts through the process of **fractionation**. Our NGL fractionation facilities have a capacity of approximately 610,000 bpcd (barrels per calendar day) and separate the mixture of extracted NGLs into individual purity product components for end-use sale. We sell basic NGL products, including ethane, propane, normal butane, isobutene, natural gasoline and other primary products such as ethylene and propylene.

By the Numbers

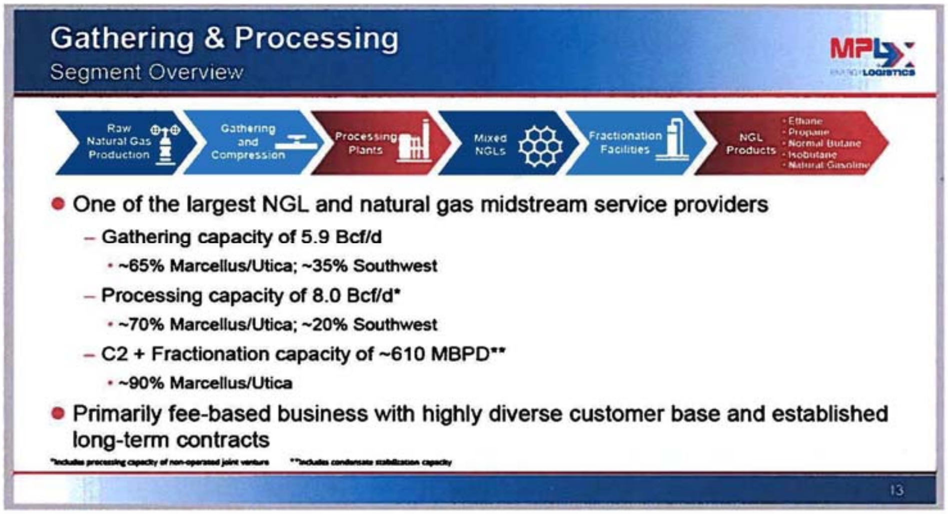
> Natural gas gathering systems in *five* states, which have a combined throughput capacity of approximately 6.8 bcf/d.

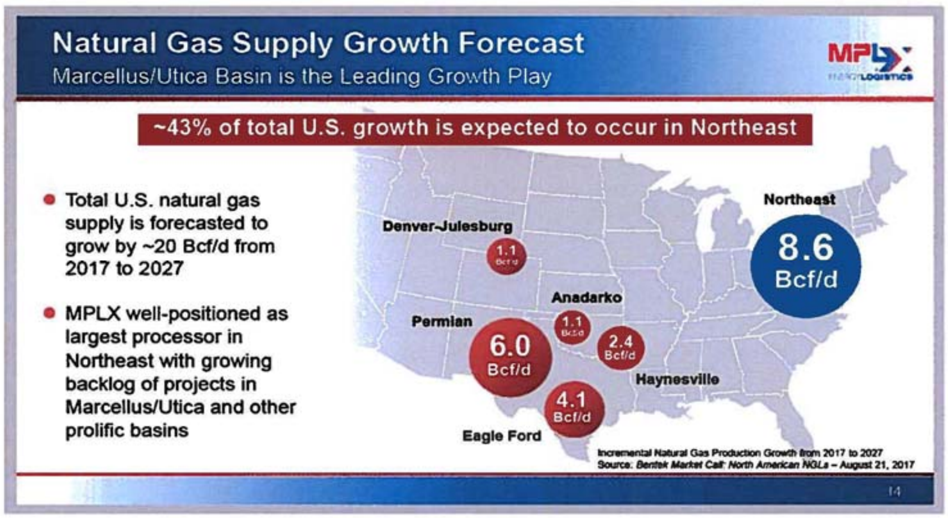
> Operate natural gas processing complexes in the Marcellus shale, Utica shale, Appalachia region, and Southwest region with approximately 9.3 bcf/d of natural gas processing capacity.

> NGL fractionation facilities that have a capacity of approximately 710,000 barrels per calendar day.

Marcellus/Utica Operations

MPLX operates five complexes in the Marcellus shale, including processing, gathering, and C2+ fractionation at the Houston Complex in Pennsylvania; processing and de-ethanization at the Majorsville Complex in West Virginia; processing and de-ethanization at the Mobley Complex in West Virginia; processing and de-ethanization at the Sherwood Complex in West Virginia; and processing, gathering and C2+ fractionation at the Bluestone Complex in Pennsylvania. We also





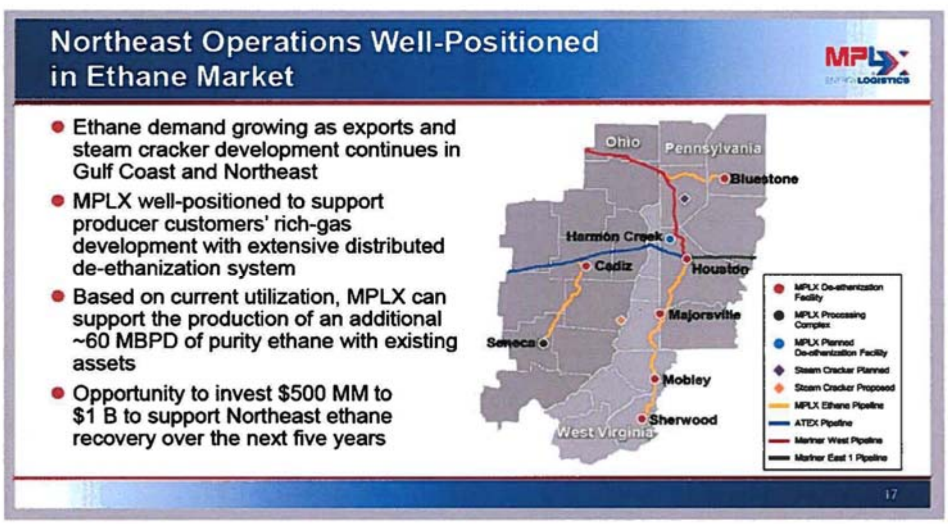


Figure 56. Overviews of MPLX gathering, processing, natural gas supply, and northeast operations (from MPLX, 2017).

Table 5. Gathering, processing, C2+ fractionation, and condensate capacities at MPXL's Marcellus and Utica operations (from MPXL, 2018).

Marcellus Operations

Gathering Capacity	*1.4 bcf/d*
Houston System	1.2 bcf/d
Bluestone System	0.2 bcf/d
Processing Capacity	*5.3 bcf/d*
Bluestone Complex	0.4 bcf/d
Houston Complex	0.7 bcf/d
Majorsville Complex	1.3 bcf/d
Mobley Complex	0.9 bcf/d
Sherwood Complex	2.0 bcf/d
C2+ Fractionation Capacity	*311 mbpd*
Bluestone Complex	81 mbpd
Houston Complex	100 mbpd
Majorsville Complex	80 mbpd
Mobley Complex	10 mbpd
Sherwood Complex	40 mbpd

Utica Operations

Gathering Capacity	*2.4 bcf/d*
Ohio Gathering System	1.1 bcf/d
Jefferson Gas System	1.3 bcf/d
Processing Capacity	*1.3 bcf/d*
Cadiz Complex	0.5 bcf/d
Seneca Complex	0.8 bcf/d
C2+ Fractionation Capacity	*220 mbpd*
Cadiz Complex	40 mbpd
Hopedale Complex	180 mbpd
Condensate Stabilization	*23 mbpd*
Ohio Condensate	23 mbpd

operate one condensate stabilization facility with 2 mbpd (million barrels per day) of capacity near the Houston Complex.

MPLX's Utica operations consists of three complexes in Ohio, including processing and de-ethanization at the Cadiz Complex; processing at the Seneca Complex; and C3+ fractionation at the Hopedale Complex. Ohio Condensate operates one condensate stabilization facility with 23 mbpd of capacity. In addition, there are two gathering facilities in Ohio, Jefferson Gas System and Ohio Gathering System.

Figure 56 presents overviews of various MPXL operations, and Table 5 shows the capacities of MPXL's various Marcellus and Utica operations.

Leave Stop 4 and turn left onto PA 519.

0.3	54.4	Enter the village of McConnells Mills (not to be confused with the state park in Butler County). Continue south on PA 519.
0.4	54.8	Western Area Tech School on the left.
0.7	55.5	Washabaugh Farm on the right.
0.3	55.8	ATI Houston Operations on the right.
0.4	56.2	Enter the Borough of Houston.
0.1	56.3	Paxton Farm Road on the right. 1907-era Isaac Paxton Homestead on the right.
0.5	56.8	Turn left onto East Pike Street, then in 325 feet, turn right onto South Main Street.
0.1	56.9	Cross Chartiers Creek and the Pittsburgh and Ohio Central Railroad tracks.
0.4	57.3	Pass under I-79.
0.1	57.4	Turn left onto the entrance ramp to I-70 north.
0.2	57.6	Merge with traffic on I-79 north.
0.2	57.8	Pass under the Canon-McMillan Alumni Bridge (Boone Avenue). Canon-McMillan High School is on the left and behind it is the disposal site for a former mill that processed uranium and other ores between 1911 and 1957. *For the next nine years, the site was used only for storage under a U.S. Atomic Energy Commission contract. In 1967, the property was purchased by the Canon Development Company and was leased to tenant companies for light industrial use. Historical milling operations at the site generated radioactive mill tailings, a*

		predominantly sandy material. Some of the tailings were shipped to Burrell Township 50 miles away to be used as additional fill in a railroad landfill. Surface remediation consisted of consolidating and encapsulating all contaminated material from the Canonsburg site and local contaminated vicinity properties I nto an on-site engineered disposal cell. The disposal cell occupies approximately 6 acres of the 37-acre tract of land. (USDOE, 2018)
0.6	58.4	Cross over PA 980.
0.5	58.9	Exit ramp to Weavertown Road and Canonsburg on the right. Continue north on I-79.
0.2	59.1	Pass over Weavertown Road.
0.6	59.7	Pass under McClelland Road.
0.3	60.0	Entrance ramp from McClelland Road on the right. Continue north on I-79.
0.6	60.6	Pass over Morganza Road and the Pittsburgh and Ohio Central Railroad tracks. Southpointe Town Center on the left, includes 589 acres of suburban business park. Among the many corporations, including Fortune 500 companies that are fixtures here, are ANSYS, Inc., CONSOL Energy, Mylan, EQT, Nobel Energy, and Range Resources. The latter three are among the biggest exploration and development companies in the Marcellus, Geneseo, and Utica shale plays in the Appalachian basin. Bill Zagorski of Range Resources, a PGS Corporate Member, is credited with discovering and developing the modern Marcellus play in the basin. Continue north on I-79.
0.4	61.0	Cross Chartiers Creek.
1.2	62.2	Exit ramp to SR 1032 and Hendersonville on the right. Continue north on I-79.
0.3	62.5	Pass over SR 1032.
0.6	63.1	Pass over SR 1010, Cecil-Hendersonville Road.
0.7	63.8	Pass over Baker Road. National Cemetary of the Alleghenies on the left.
0.8	64.6	Pass under County Line Road.
0.4	65.0	Country Meadows Retirement Community on the right.
0.2	65.2	Exit ramp to northbound rest stop on the right. Continue north on I-79.
0.6	65.8	Pass under Alpine Road.
0.6	66.4	Pass under County Line Road.
1.4	67.8	Bear right onto the exit ramp to PA 50 and Bridgeville. Notice the fine outcrops of Benwood Limestone (Monongahela Formation) on both sides of I-79.
0.3	68.1	Get into the left hand lane and turn left at the bottom of the ramp onto Miller's Run Road (PA 50).
0.1	68.2	Pass under I-79.
0.2	68.4	Turn left at the second traffic light onto Todd A. Miller Drive.
0.1	68.5	Pass Children's South hospital, then turn right into the parking lot across the road and park. This is the site of the former Star City South Fayette 14 movie theater.

STOP 5. FORMER PLEISTOCENE BOG SITE

Leaders: Albert D. Kollar and John A. Harper

There is not a lot to see at Stop 5, unfortunately, because the Pleistocene bog that occurred at this stop was destroyed decades ago during coal mining operations. However, our stop here will allow us to discuss what is known about the bog and give us a chance to observe some Pleistocene terraces formed during two iterations of Lake Monongahela (Figure 57).

Introduction

A fossil peat bog at one time was located where the large building at the end of Todd A. Miller Drive sits. The building was constructed in 2000 and called the Star City South Fayette 14 movie theater. It was located on the site of the former Mulach Steel plant, which before that was an abandoned strip mine. South Fayette Township officials had thought the theater would be a good way to add a long inactive piece of property to the tax rolls and at the same time begin developing the South Fayette suburbs of Bridgeville. Declining business due to competition from the nearby Destinta

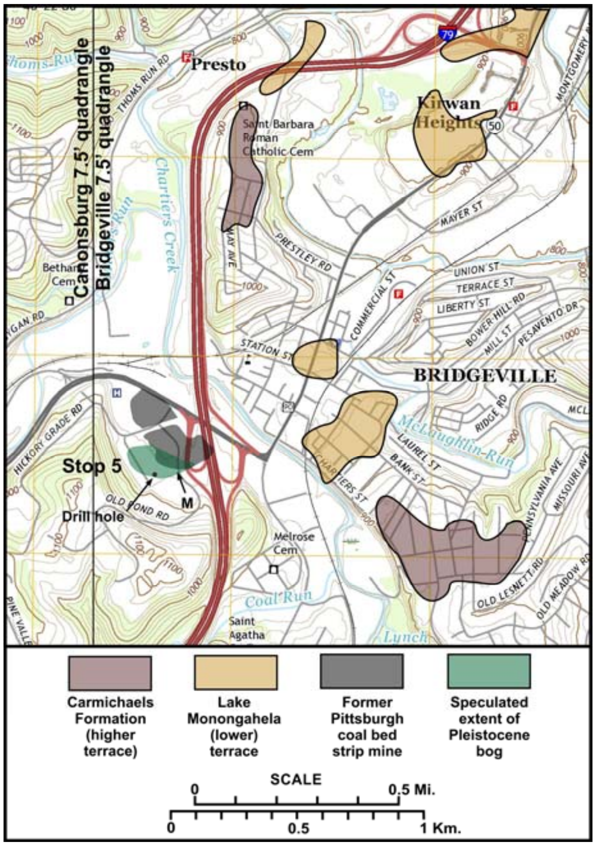


Figure 57. Map of portions of the Bridgeville and adjacent Canonsburg 7.5-minute topographic quadrangles showing the location of Stop 5, the speculated extent of the Pleistocene bog (based on Schopf and Cross, 1947, fig. 1), and the locations of Pleistocene lake terraces along the Chartiers Creek valley (based on Shaw and Munn, 1911). See the text for details.

20 Theatres at the Great Southern Shopping Center, however, forced the Star City Cinemas to close in 2005. The building was slated to be redeveloped as an office building and shopping center but instead it was reopened in 2006 as a second-run movie house with discounted tickets called the Screenworks 14. Screenworks closed the theater for good in 2008, and it was demolished in 2017. Since then, a new office building has sprung up in its place.

Besides the occurrence of the peat bog, the Bridgeville area is also of interest because of other Pleistocene aspects. At least three distinct Pleistocene terrace levels occur in the area also, each formed through different iterations of Lake Monongahela. The highest terrace is capped by Carmichaels Formation (see p. 3), whereas Pleistocene lacustrine sediments cap the lower one (Figure 57) and alluvium fills the creek valleys (see Plate 1 for a composite view of all the known terrace deposits that occur in the Chartiers Creek drainage system). Two terraces can be seen on the hill southeast of the peat area (Figure 58) and several more can be seen to the north and northeast. Given the amount of residential and commercial development of the Bridgeville area over the last 100+ years it is uncertain if any of the Carmichaels sediments still exist. If they do, they should be able to be seen in fresh excavations.

Pleistocene Bog

As documented by Schopf and Cross (1947), the bog occurred as an exposure of Pleistocene peat in a strip mine in South Fayette Township adjacent to Bridgeville. They considered discovery of the peat deposit was unusual because it existed in the same small area where the Pittsburgh coal occurred at shallow depth. The peat was found in the face of the strip pit about 10 or 12 feet above the level of the coal, which was situated under shallow cover at the base of a hillside where Chartiers Creek formed a tight meander on the west side of Bridgeville (Figure 57). Coal was first mined at the site during the World War I, which is probably when the peat deposit was first exposed. The peat did not attract attention at that time. Chunks of it could still be found in old spoil banks from the early

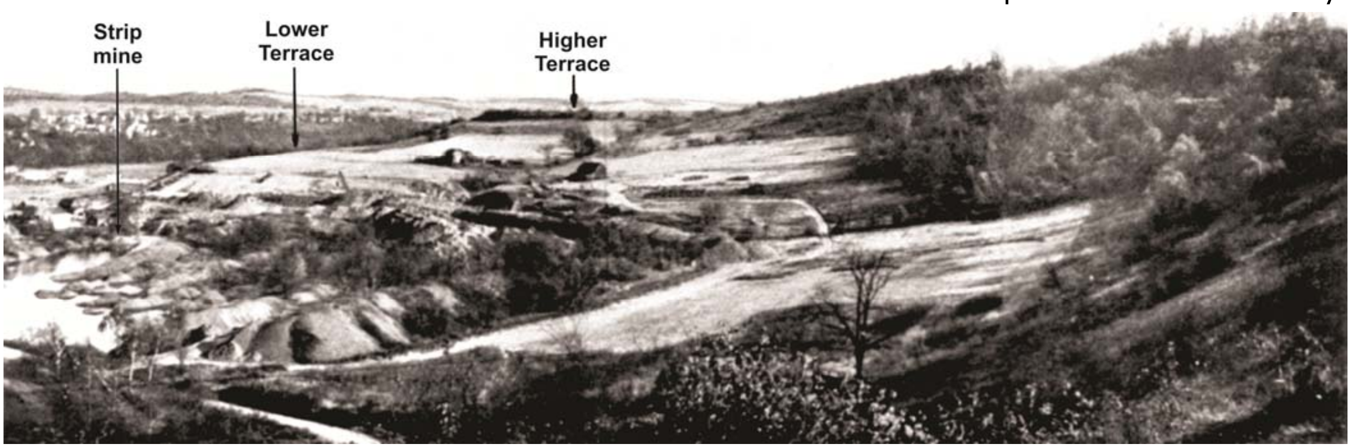


Figure 58. Photograph of the strip mining operation and Pleistocene terraces taken from the crest of the hill west of the Chartiers Creek meander at about 980 feet elevation. The view is east to south-southeast with Bridgeville in the background. The higher terrace is covered with Carmichaels Formation, the lower terrace with later Lake Monongahela lacustrine sediments (modified from Schopf and Cross, 1947, fig. 3).

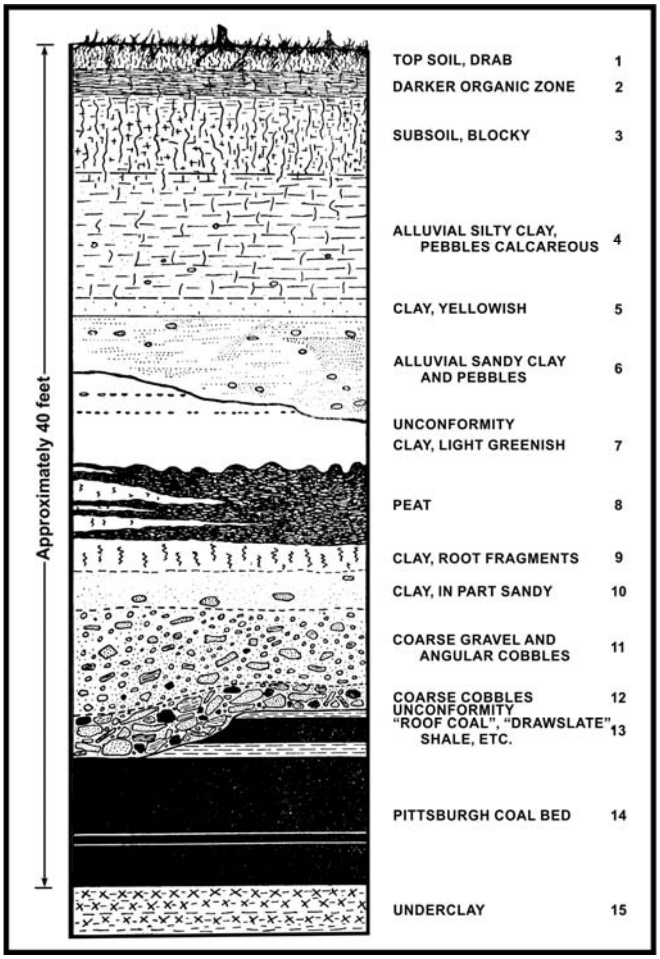


Figure 59. Diagram of the geologic section exposed at the Hussey Strip Operation near Bridgeville (from Schopf and Cross, 1947, fig. 2).

mining operation when the Pittsburgh Coal Company[2] renewed mining early in the summer of 1945. Schopf and Cross (1947) visited the site in June 1945 and began documenting the peat and associated sediments.

The elevation of the top of the bog was approximately 820 feet. The lowest terrace level above the current Chartiers Creek flood plain is about 60 feet above the level of where the peat was found. The peat formed on a substrate of clay and coarse gray gravel and cobbles, which overlaid the coal bed locally, while finely textured plastic clay, oxidized alluvium, and soil occurred above the peat (Figure 59). Figure 60 illustrates the irregular contact of peat with the overlying clay. Thicknesses of the strata above the bedrock unconformity between units 12 and 13 in Figure 59 varied quite a bit. Schopf and Cross (1947) described the peat as thinning and becoming very clayey, with increasing thickness of clay partings toward the eastern part of the mine. At the eastern end of the mine, the strata consisted almost entirely of bedrock. Although most of the glacial-age strata ended abruptly against the bedrock slope, the peat deposit itself was not truncated abruptly. Rather, close to the hill east of the mine the strata beneath the peat was thicker and less distinctive. Eventually, the peat graded laterally into clay. A coal core taken near the speculated southern extent of the bog (drill hole in Figure 57) showed that the peat probably was present beneath several more acres of potential coal reserves. The core reached the coal at a depth of 64 feet 8 inches. The strata above bedrock were not preserved, but the core record indicated "sand, clay and vegetable matter" at a depth of 48 feet to 54 feet 8 inches. Apparently the contours of the bedrock surface controlled the actual area of peat.

Schopf and Cross (1947) speculated that the Bridgeville peat probably formed during a short-term warming period ("intersubstadium") within the Wisconsinan glacial stage (Figure 61) following ponding of Chartiers Creek to the level of the peat. Later additional ponding to a higher level (Wisconsinan age Lake Monongahela) drowned the peat and preserved it under later sediments. They considered the bog unusual because it was located at a significant distance south of the known limit of glaciation in Butler County. Most deposits of Pleistocene peat recorded outside the glacial border in the eastern United States were considered to have been of interglacial origin, so they weren't classified as being related to active glaciation as in the case of the Bridgeville deposit.

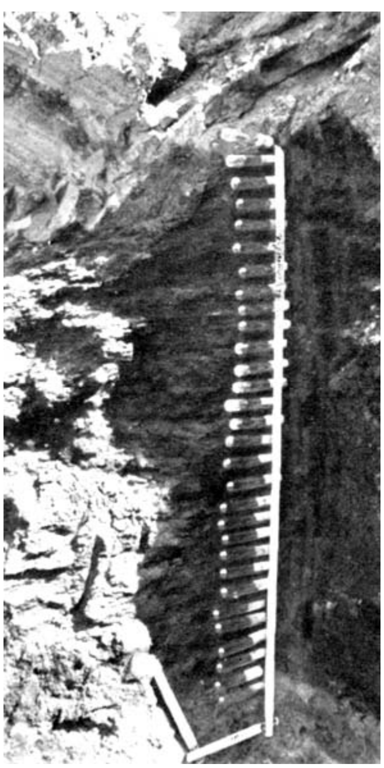


Figure 60. Photograph of the cleaned face of the peat deposit showing test tubes in place for sampling the peat for pollen analysis. Notice the irregular upper surface of the dark-colored peat (from Schopf and Cross, 1947, fig. 7).

[2] The Pittsburgh Coal Company was a Pittsburgh-based bituminous mining company controlled by the Mellon family. In 1945 it merged with the Consolidation Coal Company (now Consol Energy).

Schopf and Cross (1947) also documented a few species of plants from the peat. They used test tubes at regular intervals within the peat to collect samples for pollen analysis (Figure 60), but the analyses were not complete by the time of publication of their report. The assemblage of mosses, ferns, club mosses, and seed plants that had been identified at that point was sufficient to indicate boreal conditions with the neighboring hill slopes occupied by predominantly by a coniferous forest at the time the peat was being deposited. In addition, numerous insect remains were found in the peat, many showing their original coloration, that were sent to the Carnegie Museum in Pittsburgh for study. Bones of a fossil elephant (mastodon) were recovered from the peat that, according to Rudy Eller, former Curator of Invertebrate Paleontology at museum, were well-preserved but disarticulated (Figure 62). The approximate location of the bones is indicated by the M in Figure 57.

Age of the Peat Bog

As mentioned previously, the top of the bog was located at an elevation of approximately 820 feet, which is a lower than the earlier Pleistocene alluvial terrace deposits mapped by Shaw and Munn (1911). It is actually closer in elevation to the late Wisconsinan gravels near the mouth of Chartiers Creek in McKees Rock, suggesting a Late Wisconsinan age for the deposit (Schopf and Cross, 1947; Richardson, 1985). Radiometric dates derived from various samples of the peat confirmed the peat bed was formed during the Late Wisconsinan (Arnold and Libby, 1951; Suess, 1954; Flint and Rubin, 1955; Volman 1981). Table 6 indicates the various published dates for various samples of the peat. A cluster of three dates from various peat samples indicate that the most probable date is approximately 23,170 year B.P.

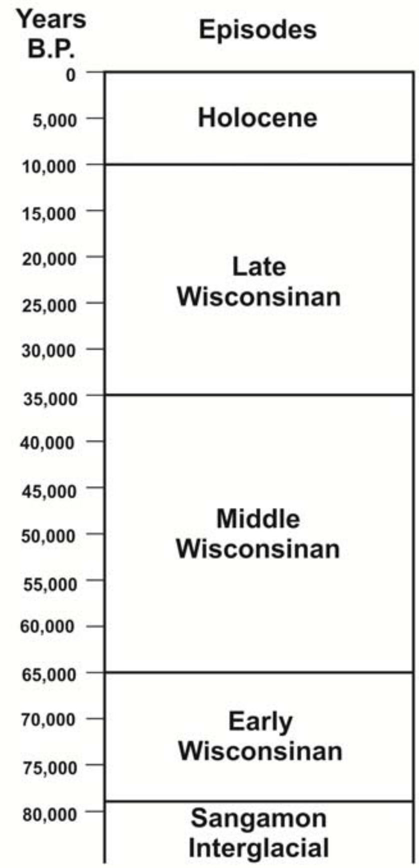


Figure 61. Generalized diagram of the Wisconsinan Stage (based on data reported by Dawson, 2013).

Figure 63 shows a generalized sequence of events illustrating how the Bridgeville peat bog might have been created and covered during the Late Wisconsinan. This illustration agrees well with numbers 2 through 6 of Schopf and Cross's (1947) suggested sequence of deposition for the Quaternary sediments at the Bridgeville mining site and their explanation of the development of the ponding that allowed the bog to form:

1. active local erosion, possibly accompanied by torrential flooding, resulted in accumulation of unsorted cobble and gravel deposits
2. pond-water flooding of the area, to a depth corresponding approximately to the present peat elevation, greatly retarded erosion and permitted deposition of fine-textured sediments
3. aquatic plants grew rooted in the fine-textured clay and somewhat later a lush growth of aquatic or semi-aquatic mosses formed a bog and accumulated to become peat

Table 6. Chronological dates established for the Bridgeville peat bog based on radiocarbon analyses. Ages based on data from Dawson (2013) and shown in Figure 61.

Sample Number	Date B.P.	Age	Reference
C-438	>16,000	Late Late Wisconsinan	Arnold and Libby, 1951
SI-4237A	31,390 +86	Early Late Wisconsinan	Volman, 1981
SI-4237B	23,340 +600	Middle Late Wisconsinan	Volman, 1981
SI-4237C	23,170 +270	Middle Late Wisconsinan	Volman, 1981
W-66	23,000 +800	Middle Late Wisconsinan	Suess, 1954; Flint and Rubin, 1955

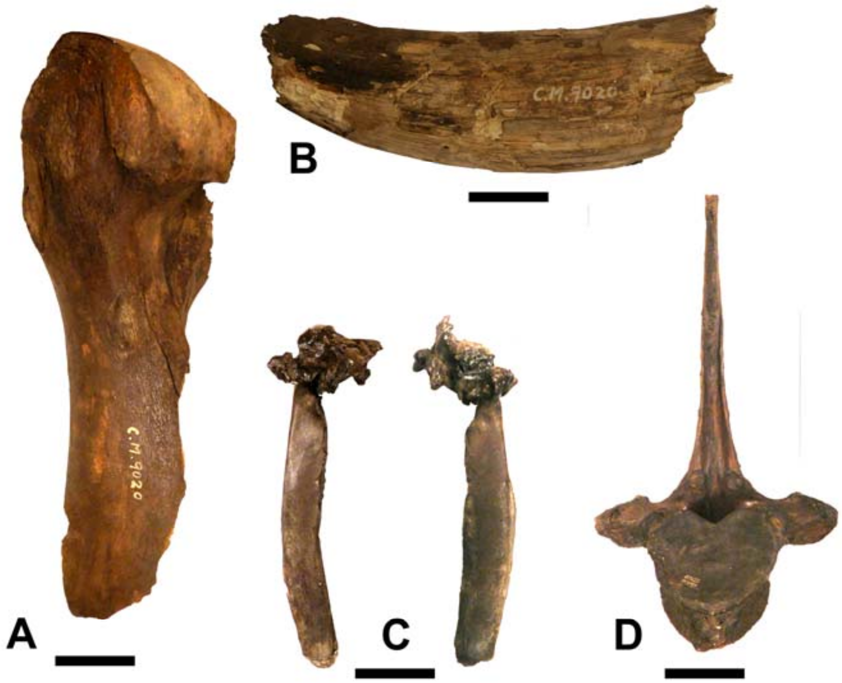


Figure 62. Photographs of some of the mastodon bones found in the Bridgeville peat bog and now in the collections of the Carnegie Museum. Scale bars = 10 cm. A, lower left foreleg, CM 9020. B, part of one tusk, CM 9020. C, two ribs, CM 9156. D, a vertebra, CM 9161.

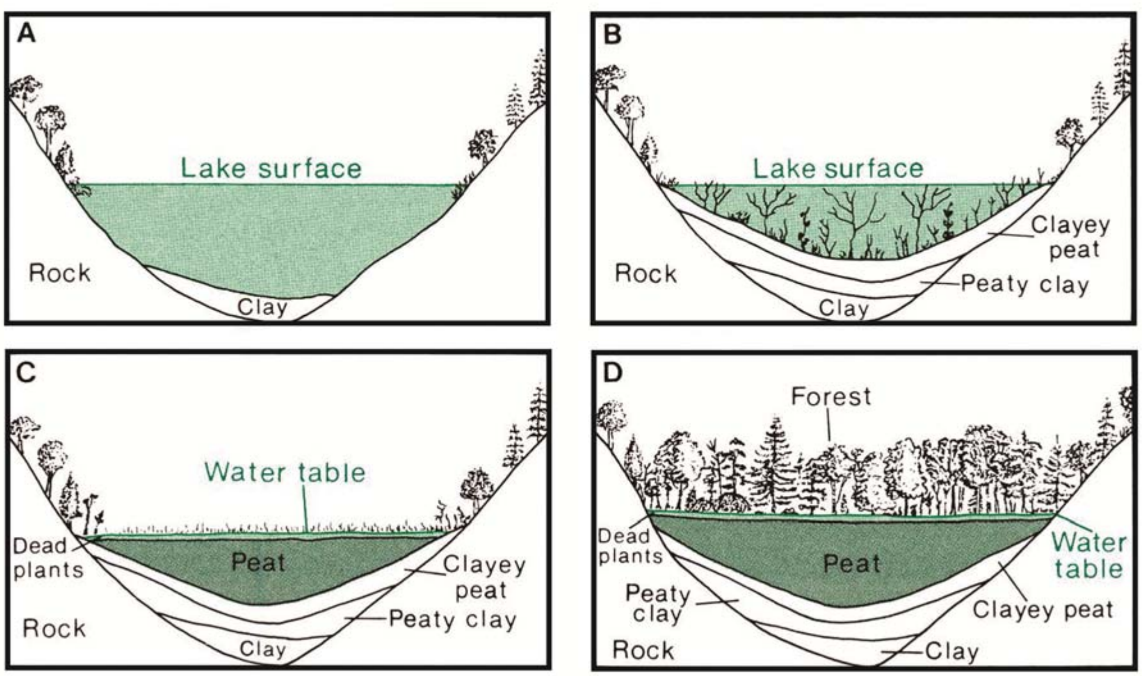


Figure 63. Generalized diagram showing the transition from a pond or lake to a peat bog and ultimately to a forest (from Sevon and others, 1999, fig. on p. 10).

4. pond flooding of the area to a higher level terminated bog conditions and was followed by deposition of dense plastic clay on top of the peat

5. the ponded area was drained and subjected to moderate erosion as the present drainage was established; silty and sandy deposits of the existing flood plain were laid down

6. a soil profile has developed on the flood-plain alluvial deposits with at least local leaching of carbonates to a depth of over five feet

Although a very local damming of Chartiers Creek might account for deposition of gravel and accumulation of peat, the presence of clay above *the peat can hardly be explained in this way, and it seems reasonable to believe that the whole succession is related to Pleistocene events affecting the Pittsburgh region. Two successively higher levels of ponding in the Chartiers Valley are indicated. Valley train deposits in the Ohio River Valley could have blocked the mouth of Chartiers Creek where it empties into the Ohio eight miles below Bridgeville, and there is abundant proof of the great depth attained by the Ohio Valley filling. No other agency has been recognized that could account for successive levels of ponding at Bridgeville*. (Schopf and Cross, 1947, p. 439-430)

0.1	68.6	Return to PA 50 and turn left.
0.1	68.7	Miller's Run Road exits on the right. Continue west on PA 50.
0.1	68.8	Traffic light. Continue west on PA 50.
0.9	69.7	Intersection with Mitchell Street on the right. From here to Alpine Road, the Benwood Limestone and associated strata are exposed on the south side of the road (to the right). See Stop 6 text.
1.0	70.7	Turn left onto Alpine Road. In about 400 feet, cross the road and park on the gravel berm.

STOP 6. PENNSYLVANIAN ICE AGE STRATIGRAPHY

Leader: John A. Harper

Introduction

Stop 6 is the only stop where field trip attendees will have the opportunity to get out and bang on some rocks. It is a combination of a series of roadcuts along PA 50 beginning at mileage 69.7 (intersection of PA 50 and Mitchell Street) and Alpine Road at mileage 70.7 west of Bridgeville (Figure 64). These roadcuts expose strata within the middle and upper Monongahela Formation and the lowermost Waynesburg Formation (Figure 65).

PA Route 50 Outcrops

Possibly the best exposure of the Monongahela Formation in the Appalachian basin is the deep roadcut along I-79 at the Carnegie interchange (see Figure 21 on p. 16) where almost the entire formation, from the Pittsburgh coal to a "blossom" of the Uniontown coal above the Benwood Limestone, is exposed. We will see this roadcut on the return trip to our starting point in Robinson but will not be visiting it. The outcrops along PA 50 west of Bridgeville, on the other hand, show limited parts of the Monongahela Formation, most of it being Benwood Limestone (Figure 65). As we drive past, see if you can pick out the various stratigraphic units.

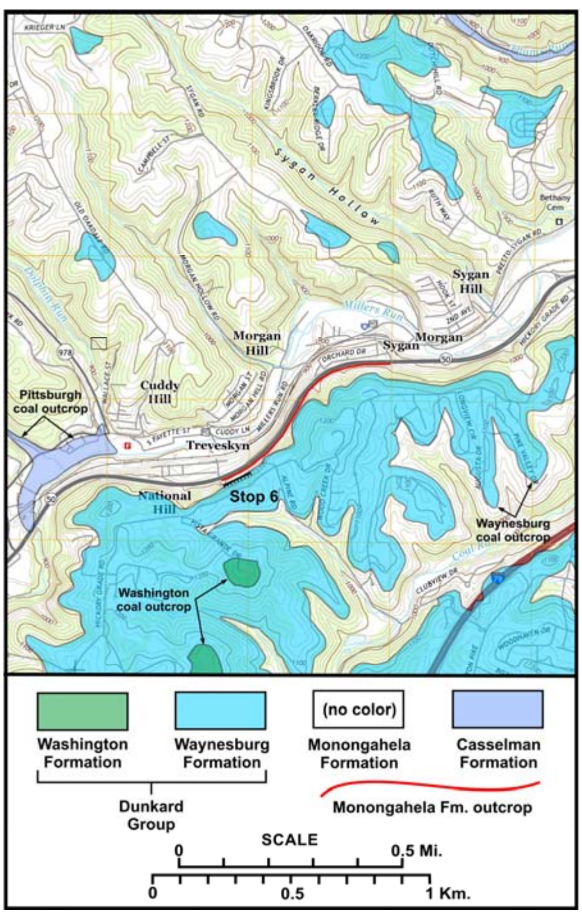


Figure 64. Map of a portion of the Canonsburg 7.5-minute topographic quadrangle showing the location of Stop 6, the local area geology (based on Dodge, 1985), and the outcrop of Monongahela Formation strata along PA 50. See the text for details.

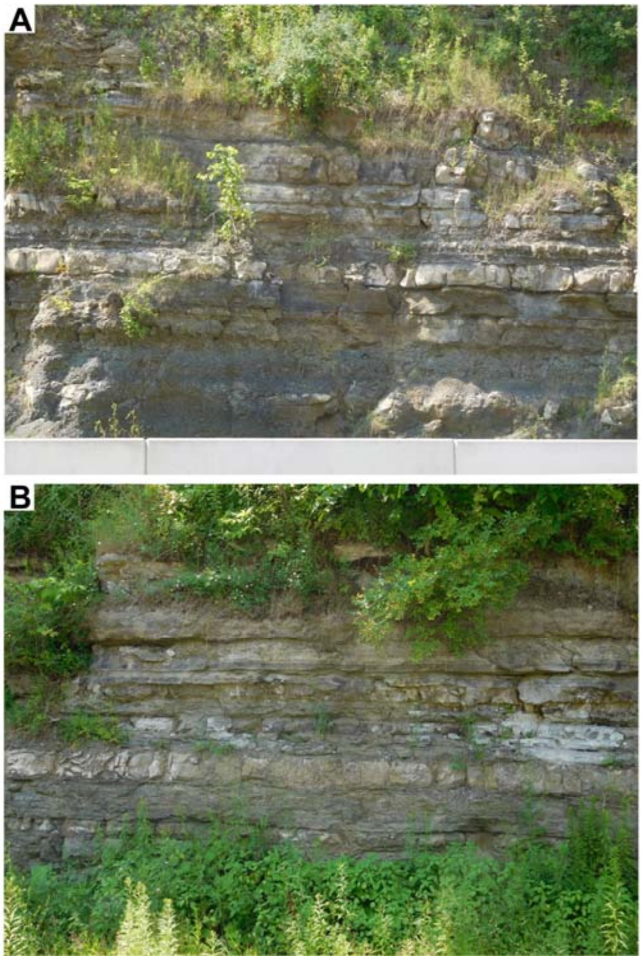


Figure 65. Photographs of the Benwood Limestone along PA 50 west of Bridgeville.

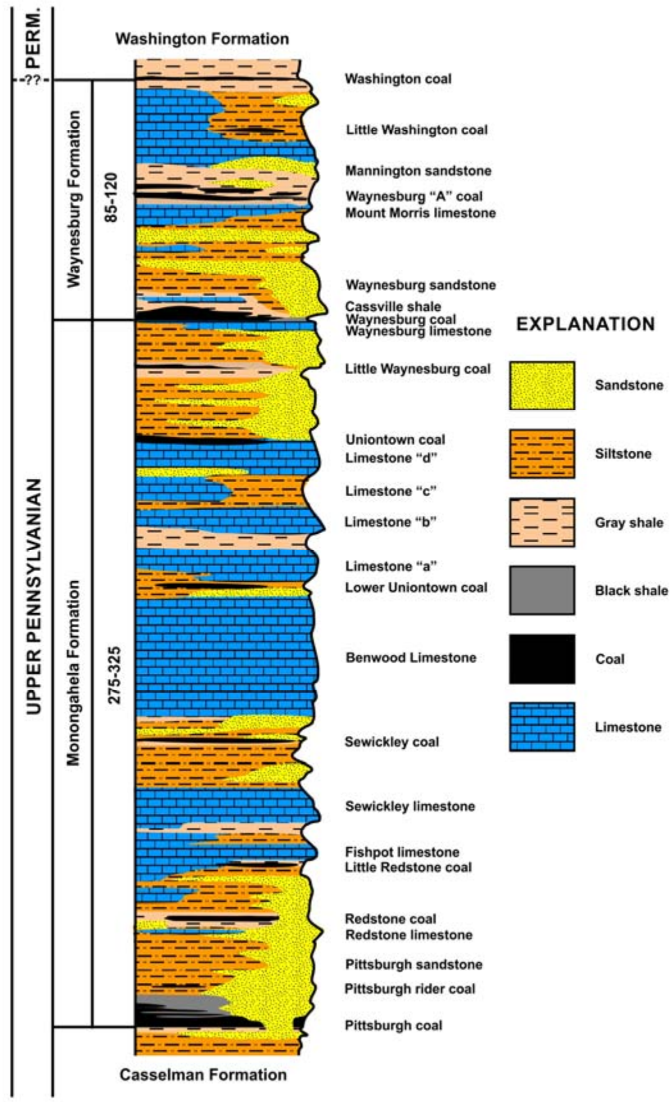


Figure 66. Generalized stratigraphic diagram of the Monongahela and Waynesburg formations in western Pennsylvania. Based on Schweinfurth (1976).

The Actual Stop 6: Alpine Road Outcrop

We will drive part way up Alpine Road, turn onto the gravel shoulder on the left (north) side of the road and park. Be careful crossing Alpine Road. Cross the concrete block barrier and gather on the talus, but be careful of possible falling rocks.

Stratigraphy

This roadcut exposes the uppermost beds of the Monongahela Formation (see p. 12-19 for more information) and the lowermost beds of the Waynesburg Formation (Figure 66). Both formations were deposited cyclically, but the cycles vary with facies provinces (Cross and Arkel, 1951; Beerbower, 1961; Martin, 1998; Fedorko and Skema, 2013) (see below). As mentioned previously (p. 13), Berryhill and Swanson (1962) moved the lower boundary of the Dunkard Group to the base of the Waynesburg coal, formerly considered the top of the Monongahela Formation. It is currently accepted by both USGS and Pennsylvania Geological Survey stratigraphy, but has not been accepted universally outside of Pennsylvania (Fedorko and Skema, 2011; 2013). The Waynesburg Formation, whose type locality is Waynesburg, Greene County, PA, formerly was part of the Washington Formation within the Dunkard Group.

Berryhill and Swanson (1962) divided the approximately 100-feet-thick Waynesburg Formation into three unnamed members that included all the rocks from base of Waynesburg coal bed to the base of Washington coal bed (Figure 66), but that tripartite division is not used here. The thick, massive Waynesburg sandstone is the dominant lithology in the lower member. The middle member includes sporadic nonmarine limestones and some lenticular beds of impure coal. The Little

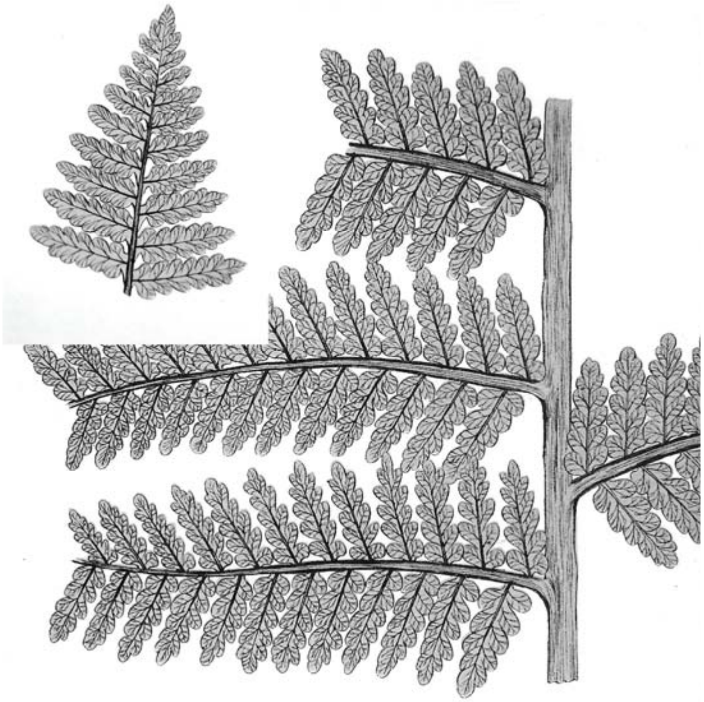


Figure 67. Illustration of *Callipteris conferta*, once thought to be a Permian index fossils, but now known to occur in Upper Pennsylvanian strata as well. From Fontaine and White (1880).

Washington coal forms the base of the upper member, which consists mostly of sandy siltstones and sandstones containing plant fossils. Although the USGS considers the Waynesburg Formation to be Late Pennsylvanian and Early Permian in age, this is still being debated. The Waynesburg coal had been dated previously as Early Permian based on Fontaine and White's (1880) classic study of the plant fossils. The roof shales above the coal contain many plant fossils having Permian affinities, but they also contain all the Pennsylvanian species contained in the rocks below the coal. *Callipteris conferta* (Figure 67), a plant fossil whose first appearance in the rock record . . .

> *was adopted by early International Carboniferous Cong-esses as the terrestrial index fossil to the base of the Permian, a conclusion since complicated by the report of* C. conferta *from the Stephanian C of Europe (Havlena 1970) and the Virgilian of Kansas (Leisman et al., 1988) where it is associated with undoubted Pennsylvania marine fossils.* (Blake and Gillespie, 2011b, p. 112)

In fact, *C. conferta* first appears in the northern hemisphere along with a sporadic Permian-like assemblage in the Upper Pennsylvanian (Blake and Gillespie, 2011a). As such, calling anything lower than the Washington coal Permian is quite controversial. It is currently considered to be no older than Virgilian (Late Pennsylvanian) and no younger than Wolfcampian (Early Permian).

Facies Provinces

Martin (1998) identified three facies provinces within the Dunkard Group, which Fedorko and Skema (2013) also identified in the Monongahela Formation – upper fluvial plain, lower fluvial plain, and fluvial-lacustrine deltaic plain. Limestone sequences in the Monongahela are best developed in the fluvial-lacustrine deltaic plain facies but also extend well into the lower fluvial plain. Figure 65 and illustrates some of these fluvial-lacustrine deltaic plain limestones along PA 50.

The upper fluvial plain facies of both the Monongahela and Waynesburg exhibits thin, dark gray to black, organically enriched, nonfissile claystone/fissile shale beds that can be correlated with coal beds in downslope cycles (Fedorko and Skema, 2013). Fedorko and Skema interpreted these dark-colored beds as paleosol-surface horizons that they called "A horizons." These were underlain by thin, gray, sticky, waterlogged soils lacking in oxygen that lithified to claystones, stratigraphically equivalent to the underclays of coals. Although drainage in the upper fluvial plain was, in general, sufficient to prevent the accumulation of organic matter (and, therefore, peat formation), the surface still remained wet enough to form the dark organic matter of the A horizon while reducing presence of the material immediately beneath it.

Chemical conditions favorable for organic matter accumulation, peat formation, and the eventual formation of coal developed in the lower fluvial plain and fluvial–lacustrine deltaic plain because poorer drainage occurred there. Fluvial shales, siltstones and/or sandstones typically overlie the A horizon in the upper fluvial plain facies and the coal beds in southwestern Pennsylvania (Fedorko and Skema, 2013).

A good example of this can be seen here at Stop 6 where a thin limestone bed underlies a dark, organic-rich shale, which in turn is overlain by a relatively thick sandstone (Figure 68). The thin, gray to buff-colored Waynesburg limestone underlies a slightly thicker sequence of dark gray to black claystone and shale, which in turn is overlain by the Waynesburg sandstone (Figure 66). The dark gray to black claystone and shale, an A horizon paleosol, occupies the position of the Waynesburg

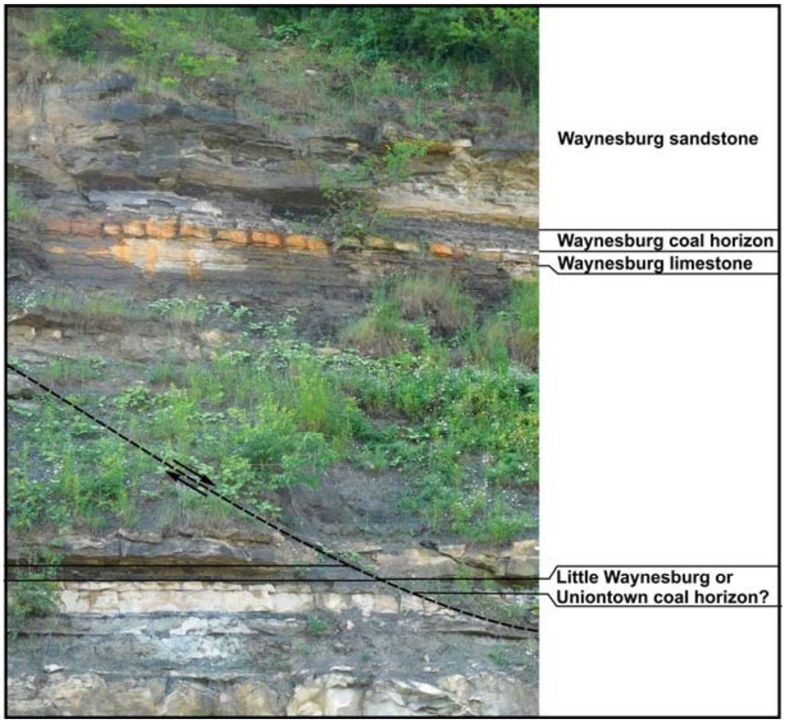


Figure 68. Interpreted photograph of the upper Monongahela Formation and lower Waynesburg Formation at Stop 6. Notice the orange stain (acid-mine-drainage) on the Waynesburg limestone (upper Monongahela Formation), indicating the position of the Waynesburg coal horizon above it. This locality also exposes a good example of a listric normal fault (dashed line) that most likely resulted from ~300 million year old slumping (landslide).

coal. A similar situation appears lower in the section where the horizon of the Little Waynesburg coal (or possibly the Uniontown coal) occurs. Fragments of dark gray to black, organic-rich shale representing these A horizons can be found and examined in the talus on the slope between the outcrop and Alpine Road (Figure 69A).

Strata in the fluvial–lacustrine deltaic plain province, in particular, include thick, well-developed, coal beds and gray- to buff-colored limestones. This province is best illustrated by the Monongahela and Waynesburg formation in the northern part of the Dunkard Basin (Arkle, 1959; Martin, 1998; Fedorko and Skema, 2013). The limestones often exhibit features such as desiccation cracks, breccias, and nodular fabrics such as that illustrated in Figure 69B. They can be laminated, but frequently become nodular upwards, and often are interbedded with argillaceous limestone, calcareous mudstone or claystone paleosols, and calcareous shale, comprising cyclic limestone sequences more than five feet thick. Fedorko and Skema (2013) interpreted the calcareous and non-calcareous claystone and mudstone paleosols within these sequences as having formed through subaerial exposure and dissolution of the nonmarine limestone.

> *The nearly ubiquitous subaerial exposure features and the claystone paleosols indicate repeated rise and fall of water levels in carbonate rich lakes* . . . *Some of the named and mappable limestone sequences such as the Lower Washington limestone and the Monongahela Group Benwood limestone, best developed in the fluvial–lacustrine deltaic plain and lower fluvial plain, can be correlated to coeval vertic paleosol profiles in the upper fluvial plain . . . leading to the conclusion that the cause of subaerial features in the limestones was climate drying* (Fedorko and Skema, 2013, p. 13).

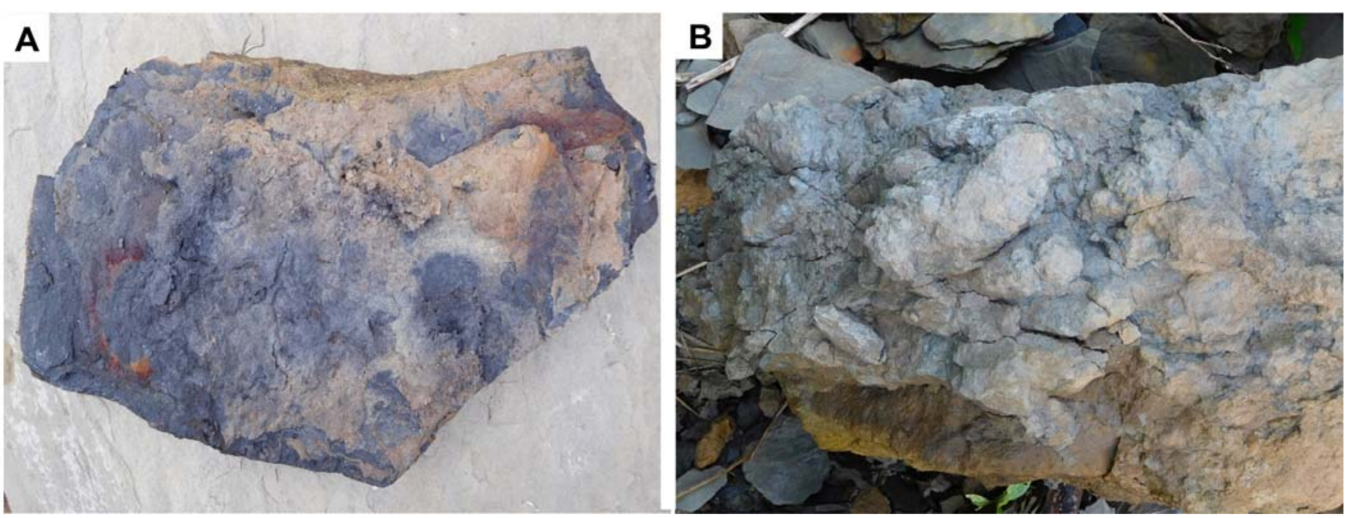


Figure 69. Photographs of some of the sedimentary features that can be seen at Stop 6. A, fragment of dark gray to black claystone and shale (A horizon paleosol) occupying the position of the Waynesburg coal. B, nodular fabric in dessicated limestone from the upper Monongahela Formation.

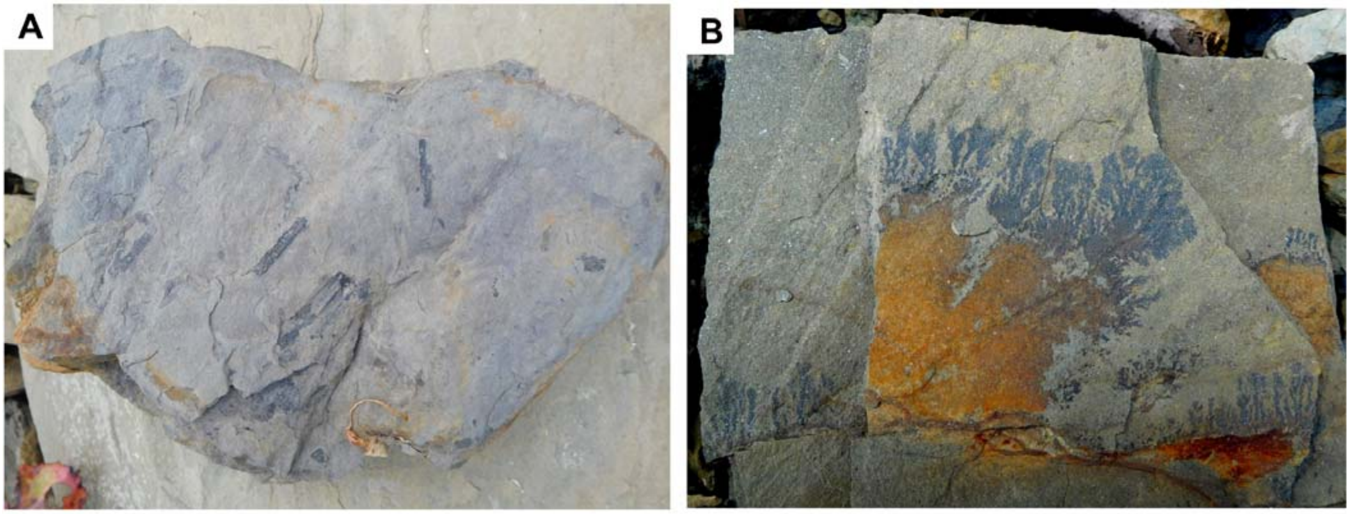


Figure 70. Photographs of additional sedimentary features from Stop 6. A, carbonized plant macerals. B, manganese dendrites. C, "Liesegang banding" in sandstone.

Things to See and Collect

Besides the two sedimentary items mentioned above, there are other things at this site to collect and take home if you wish. I did not find any identifiable plant fossils on my previous excursions, but you should be able to find carbonized plant debris in the talus (Figure 70A). The large limestone boulders, and possibly even some of the smaller clasts, contain fragments of nonmarine lifeforms, probably mostly bivalves. Avid searching might also net you some very tiny nonmarine gastropods; they are well known from the Benwood limestone at other localities.

In addition, some "artistic" sedimentary features exist at this site that are easily collected and could be displayed at home. I found manganese dendrites on the bedding planes of thin-bedded sandstones (Figure 70B), and some sandstone clasts featuring "Liesegang banding" (Figure 70C). These irregular reddish, brownish, or orangish-brown bands formed as precipitation lines of iron-rich minerals like hematite, limonite, or goethite along groundwater chemical interfaces in porous rocks such as sandstones. Although commonly referred to as "Liesegang banding," this feature actually does not fit into the original concept described by Liesegang (1896). True Liesegang banding refers to parallel bands of precipitate formed by diffusion along a single chemical gradient during a single event. Features such as that shown in Figure 7C typically consist of sets of irregularly concentric iron bands, with different sets of bands often oriented in different directions. The sets also cut across and dissolve older sets, indicating that more than one precipitation event occurred by moving groundwater over long time periods (Wells and others, 2003).

2.5	73.2	Return to Bridgeville, pass under I-79, and turn right onto the entrance ramp to I-79 north.
0.3	73.5	Merge with traffic on I-79 north and pass over PA 50.
0.2	73.7	Cross Chartiers Creek and what's left of the Bridgeville and McDonald Branch of the Pittsburgh, Cincinnati, Chicago and St. Louis Railroad.
0.2	73.9	In the old floodplain to the left is Carvana, an eight-story car vending machine, and Topgolf, an indoor entertainment complex that includes a driving range.
0.8	74.7	Pass under Prestley Road.
0.4	75.1	Exit ramp to Kirwan Heights on the right. Continue north on I-79.

0.2	75.3	Pass under entrance/exit overpass for the Kirwan Heights interchange.
0.2	75.5	Entrance ramp from Kirwan Heights on the right. Continue north on I-79 and pass under Steen Road.
0.4	75.9	Cross the bypass channel of Chartiers Creek and pass under Thoms Run Road. The bypass channel of Chartiers Creek was constructed to prevent flooding of the highly meandering creek (see Plate 1). The original channel is to the right (east) of here. See Barner and others (2001) for more information.
0.7	76.6	Pass under Hilltop Road.
0.1	76.7	Beginning of one of the most spectacular roadcuts in western Pennsylvania. Over the next 0.5+ miles the roadcut exposes most of the Monongahela Formation (Figure 21 on p. 16) See Brezinski and Kollar (2011) for more information.
0.3	77.0	Exit ramp to Carnegie and Oakdale on the right. Continue north on I-79.
0.2	77.2	Pass over West Main Street and the abandoned tracks of the Panhandle Division of the Pennsylvania Railroad. Approximately 1.5 west of here, at Walkers Mills, the railroad right-of-way has been converted into the 29.2-mile Panhandle Trail, which ends in Colliers, West Virginia.
0.4	77.6	Pass under Ewing Road.
1.1	78.7	Exit ramp to Pittsburgh via I-376/US 22/US 30, the Parkway West. Continue north on I-79.
0.3 -	79.0	Pass over I-376/US 22/US 30, the Park way West.
0.3	79.3	Entrance ramps from both the west-bound and eastbound Parkway West. Continue north on I-79.
1.5	80.8	Bear right onto the exit ramp to PA 60, the Steubenville Pike.
0.2	81.0	Turn left (west) onto PA 60.
1.3	82.3	Intersection with Beaver Grade Road on the right. Continue west on PA 60.
0.6	82.9	Old pipe rig oil derrick on the right. See Figure 71 caption for information.
1.0	83.9	Turn right into the parking lot in front of Subway and other shops.

Figure 71. Photograph of an old pipe rig originally drilled on the Jane Riddle lease, date unknown. The current operator is Raymond D. (Ray) Langer, an independent oilman from Coraopolis who established his company in 1964. This well, currently called the Langer #2 Riddle well, produces from the Upper Devonian Venango Group, probably the Fifth sand, at 2,386 feet. This well is in the Moon Run-Crafton oil field, part of the McDonald oilfield complex.

End of field trip. We hope you learned something and had fun.

Have a safe trip home.

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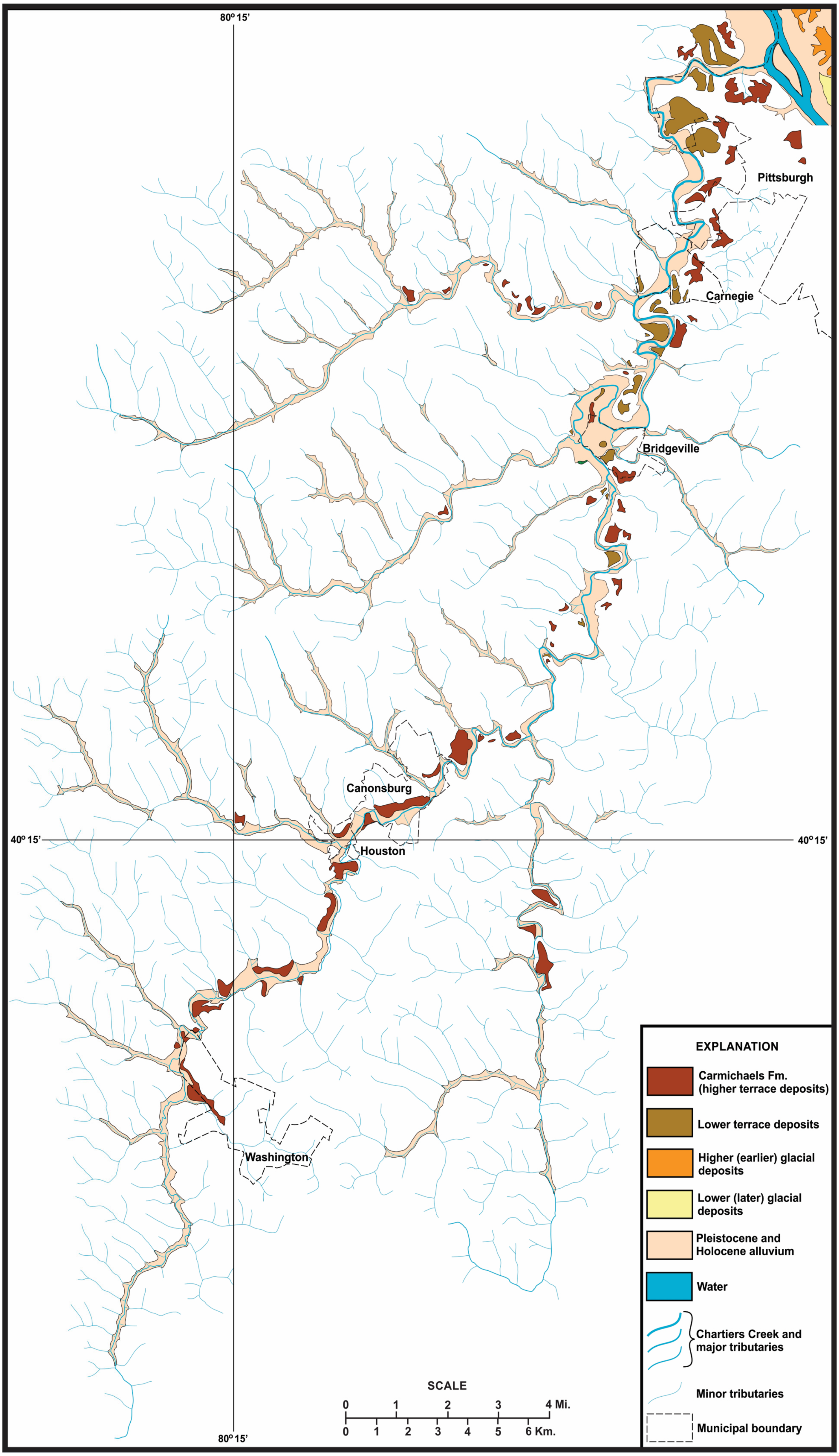

Plate 1. Map of the Chartiers Creek watershed showing locations of Quaternary (and possibly earlier) alluvial deposits. Notice that Chartiers Creek and some of its major tributaries travel through entrenched meanders. This map is based on early 20th century topographic and geologic mapping by Shaw and Munn (1911),