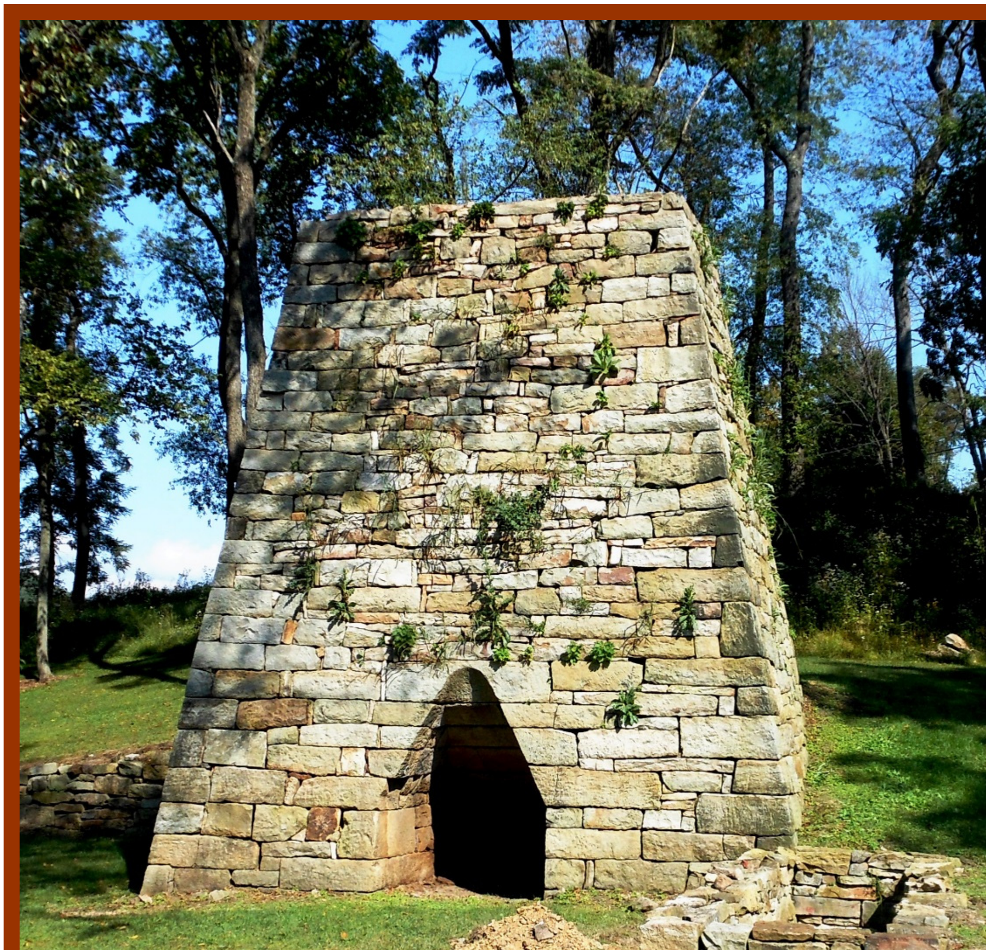
Geology of the Early Iron Industry in Fayette County, Pennsylvania



Mt. Vernon Furnace, Bullskin Township, Fayette County

Pittsburgh Geological Society Field Trip

May 26, 2018

Guidebook
PGS Spring Field Trip
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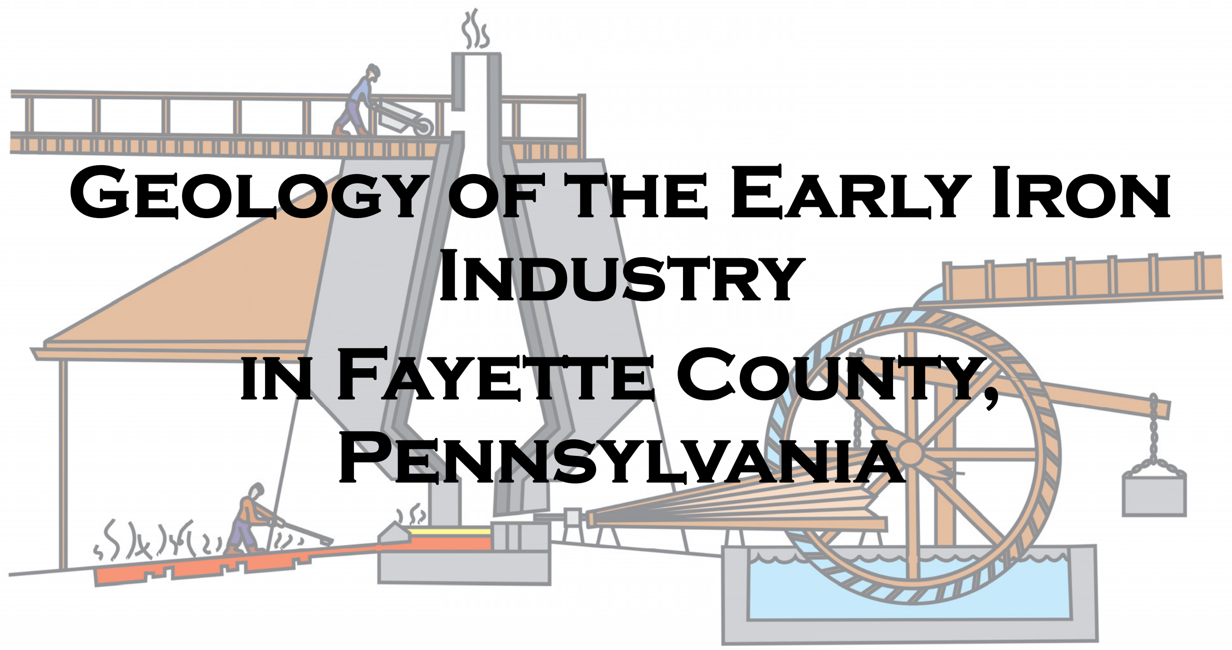

(drawing by David J. Vater)

Trip Leaders:

John A. Harper and Albert D. Kollar
Carnegie Museum of Natural History

Dedication

This field trip guidebook is dedicated to the memory of Dr. Norman L. Samways, retired metallurgist, geology enthusiast, and good friend who spent many years as a volunteer with the Invertebrate Paleontology Section of the Carnegie Museum of Natural History until a few months before his death in February 2018.

Sam, as he was affectionately called, was born in Bath, England, in 1927 and received a degree in Metallurgy from the Royal School of Mines, a constituent college of Imperial College of Science and Technology in London, England. He then received his Ph.D. from Imperial College while studying the solidification of metals, particularly steel. He and his wife Margaret ("Margy") emigrated to the U.S. in 1957 when Sam answered a newspaper ad for Jones & Laughlin Steel Corp. (later, LTV Steel) and was hired to work in metallurgical development at the J&L research laboratory. Sam and Margy moved into Chatham Village on Mount Washington and never looked back. Sam spent 20 years developing new steel-making practices, such as the continuous casting of steel, while employed by J&L, and was the author of over 100 technical papers. He also served as Technical Editor of the Association of Iron and Steel Engineers, where he was responsible for following and reporting on steel developments. He retired in 2000 after more than 40 years associated with the steel industry.

Sam was a member of Pittsburgh's first rugby team in the 1960s and was also an avid cricket fan, spending many a Saturday at South Park watching the local enthusiasts bowl and bat and field. He served on the Board of the Duquesne Incline and was instrumental in learning about and promoting the geology of Mount Washington. He was a member of the National Association of Watch and Clock Collectors, and was one of only four people entrusted with winding and synchronizing the historic Heeren Building clock that resides at the Children's Museum of Pittsburgh (Cantrell, 2014).

In retirement, Sam volunteered twice a week in the Invertebrate Paleontology Section at the Carnegie Museum from 2001 to 2017, helping curate the collections and keeping Albert and the other volunteers educated to the complexities of steel making. In 2005, Adjunct Curator David K. Brezinski named a new species of Late Mississippian trilobite, *Weberides samwaysi*, in his honor. Toward the end of his life, Sam became interested in the early iron blast furnaces in western Pennsylvania and early iron-making refinements. His more than two years of research resulted in the Pennsylvania Historical and Museum Commission's recognition of the country's first puddling iron furnace, at Upper Middletown, Fayette County Pennsylvania, and in several publications as well. It all culminated in September 2017 with the Fayette County Historical Society and the Pennsylvania Historical and Museum Commission erecting a historical marker near the site of the furnace, Stop 4 on this field trip.

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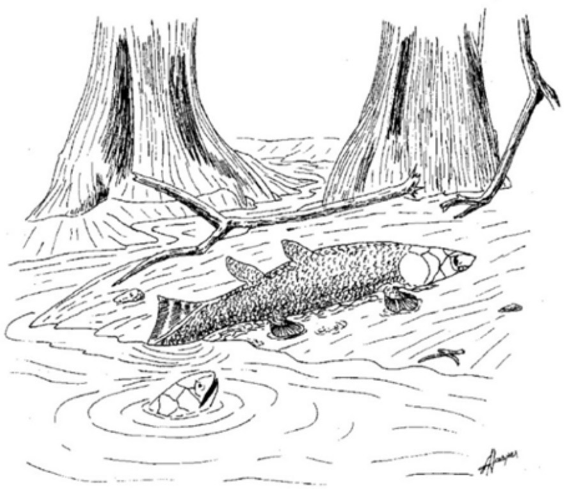

George! What the hell do you think you're doing? You get back in here right this very minute. You're going to catch your death. What'll the neighbors think?

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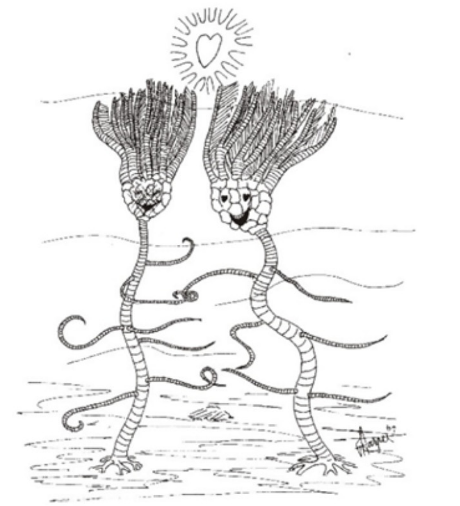

Ahh, mon Cheri, I love ze way your ambulacral grooves flutter when you laugh . . . ze rosy blush of your thecal plates . . . ze soft calcitic touch of your cirri. Come wizz me to ze PanThallassic and we'll filter-feed together!

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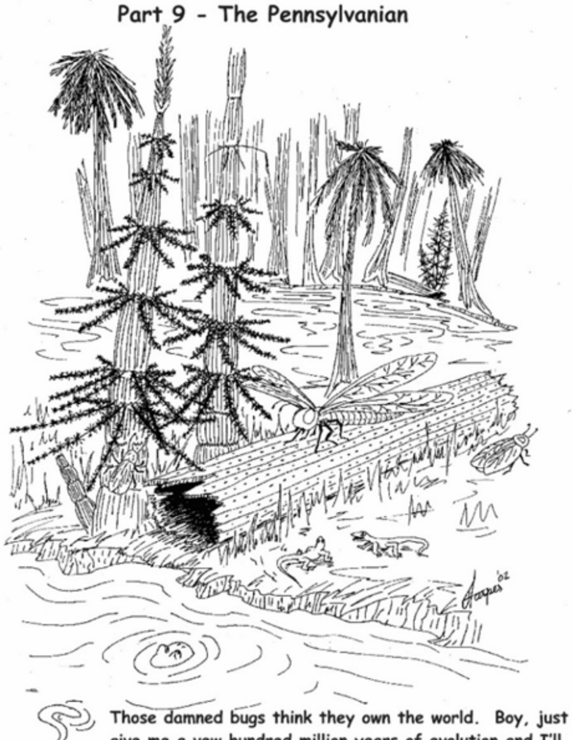

Those damned bugs think they own the world. Boy, just give me a vew hundred million years of evolution and I'll show THEM a thing or two!!!

GREAT MOMENTS IN GEOLOGIC HISTORY
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The Neanderthal are evolving! The Neanderthal are evolving!

GEOLOGY OF THE EARLY IRON INDUSTRY IN FAYETTE COUNTY, PA

Introduction

Welcome to the 2018 PGS spring field trip, an exploration of Fayette County and its pioneering iron industry. Along the way, we will have the opportunity to explore the geology of Chestnut Ridge, visit a historic iron furnace, a natural gas storage well (most people are unaware that this part of Chestnut Ridge is home to a large subsurface gas storage reservoir), a recent historical marker, and a museum highlighting the family of coal and coke baron, Henry Clay Frick.

Western Pennsylvania played a major role in the history of the iron industry in the late 1700s and into the 1800s, long before Pittsburgh became a major industrial center. Local iron ores were mined extensively and used in the numerous charcoal blast furnaces that were scattered throughout the area. Eventually, coke replaced charcoal as a fuel, ores from the upper Great Lakes area supplanted the lower quality local ores, and new processes greatly improved the production of iron and steel.

Iron was a basic necessity in the early history of the United States. Horseshoes, and the nails that kept them on the horse, pots and pans, axes and other hand tools, plow shares, wagon wheel rims, and a host of other items were made of iron, and the constant need for additional items kept the iron makers busy all year round. Small stone blast furnaces utilized abundant local raw materials: 1) sandstone masonry to build the furnace and associated infrastructure; 2) fireclay to make refractory bricks that lined the interior of the furnace; 3) iron ore, mostly siderite (iron carbonate, $FeCO_3$); 4) limestone to use as flux in the furnace to remove impurities; 5) charcoal for fuel, which required the cutting of thousands of acres of timber (coal eventually became the primary fuel source for making coke so, in a sense, the coal mining industry saved our forests from complete destruction); and 6) local streams that provided water to power the blast equipment in the furnaces and, in some cases, were a source of transportation for raw materials to the furnaces and subsequent iron products to market.

What would life in western Pennsylvania have been like without the abundance of local natural resources and the intrepid people who exploited them? An ordinary cast-iron skillet might have cost a small fortune because it would have been shipped from eastern Pennsylvania or some other state. Without plentiful coal resources, western Pennsylvania would not have attracted the diverse ethnic populations that became our ancestors. Without abundant water, Pittsburgh would never have been the Steel Capital of the World. Thus, it is fortuitous that all of these materials, and the people who had the foresight to exploit them, are part of western Pennsylvania history.

Early Iron Manufacturing

The iron industry expanded in western Pennsylvania during the early 19th century because the population was growing, as was demand for iron products. By 1811, Fayette County had 27 iron works that supplied iron products to Pittsburgh and the Ohio Valley and beyond Pittsburgh became western Pennsylvania's focus for secondary iron works such as forges, foundries, and rolling mills that fabricated an extensive range of iron products produced in blast furnaces in Fayette County and elsewhere.

The early iron industry constructed more than 180 charcoal blast furnaces in western Pennsylvania before 1850 (Figure 1). More than 30 were built before 1830 in Fayette and Westmoreland Counties, 10 in the 1700's alone. The first iron furnace constructed in western Pennsylvania was the Alliance Furnace built around 1789 near Perryopolis, Fayette County (Figure 1, location A). Other early furnaces in Fayette County included the Union Furnaces in

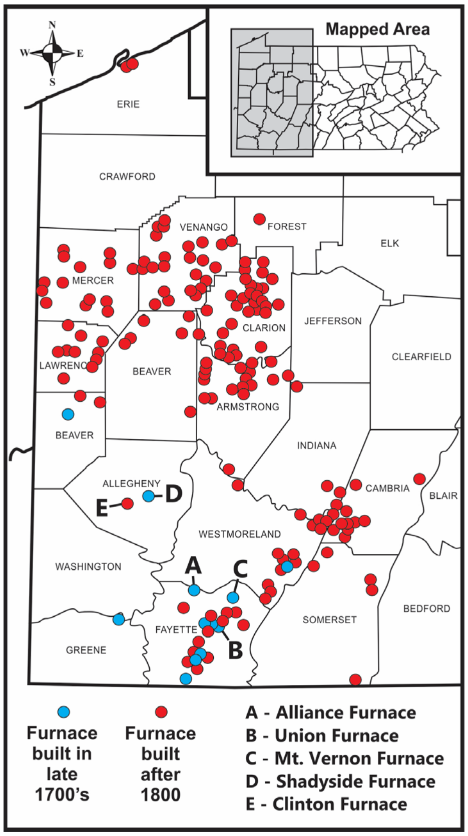

Figure 1. Map of western Pennsylvania showing locations of historic iron furnaces built before 1860 (from Samways et al., 2014).

Dunbar, 1791 (Figure 1, location B) and the Mount Vernon Furnace in Bullskin Township, 1798 (cover photo, Figure 1, location C). Most of these early furnaces were located on the west side of the Chestnut Ridge anticline close to deposits of iron ore. One exception, the Shadyside Furnace near present-day Winchester Thurston School in Pittsburgh's East End (Figure 1, location D), was built in 1793, but was only in operation for a year because of a lack of easily accessible local ore. After 1830, the majority of new furnaces were concentrated in Armstrong, Clarion, and Venango counties as other local iron ore deposits were exploited.

Figure 2 illustrates how a typical charcoal blast furnace, such as those built in the late 1700's and early 1800's, operated. It consisted of a sandstone stack that resembled a hollow, truncated pyramid approximately 30 ft (9 m) high. It was usually constructed of local sandstone blocks and lined with refractory fireclay bricks or blocks to protect the furnace walls[1]. To produce one ton of pig iron, an early 19th century blast furnace required approximately three tons of iron ore, two tons of limestone, and 2.6 tons of charcoal (later, coal or coke) for fuel (Samways et al., 2014). The furnace was continually charged at the top with charcoal, iron ore, and limestone. While the charge materials descended towards the bottom of the furnace, hot carbon monoxide gas, generated by the combustion of charcoal with air, transformed the iron ore into liquid iron at temperatures in the order of 815 to 1,370°C (1,500 to 2,500°F). The air, provided by water-powered bellows, was blown into the furnace through tuyeres (blowpipes) located at the bottom of the furnace. The water that powered the bellows typically came from nearby ponds or dammed streams, flowing through a sluice to the water wheel (Figure 2), then back to the stream. The limestone acted as a flux to remove impurities from the ore, forming a liquid slag. Every six hours or so, the furnace was tapped by opening a refractory-sealed hole in the hearth area. Liquid iron flowed into parallel rows of depressions in the casthouse floor that, when solidified, vaguely resembled piglets attached to a sow – hence the name "pig iron". Solid pig iron was processed into bars by successive reheating and forging to produce stock for making nails, wheel rims, tools, etc. Alternatively, liquid iron was removed in ladles and cast in molds into articles such as pots and stoves (cast iron products).

Raw Materials

The bedrock of western Pennsylvania provided abundant raw materials to the early iron industry in the form of iron ores, limestones, coals, fireclays, and sandstone, and the area had vast forests for producing charcoal and numerous streams for powering the furnace bellows. An early 1800s charcoal-based furnace produced around two tons of pig iron per day. Each ton

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[1] Western Pennsylvania's sandstones typically contain water in their internal pores. At high temperatures, the water can boil and build up enough pressure to make the sandstone blocks explode, so lining the stack with refractory bricks was as essential for personnel safety as for helping keep things hot in the furnace.

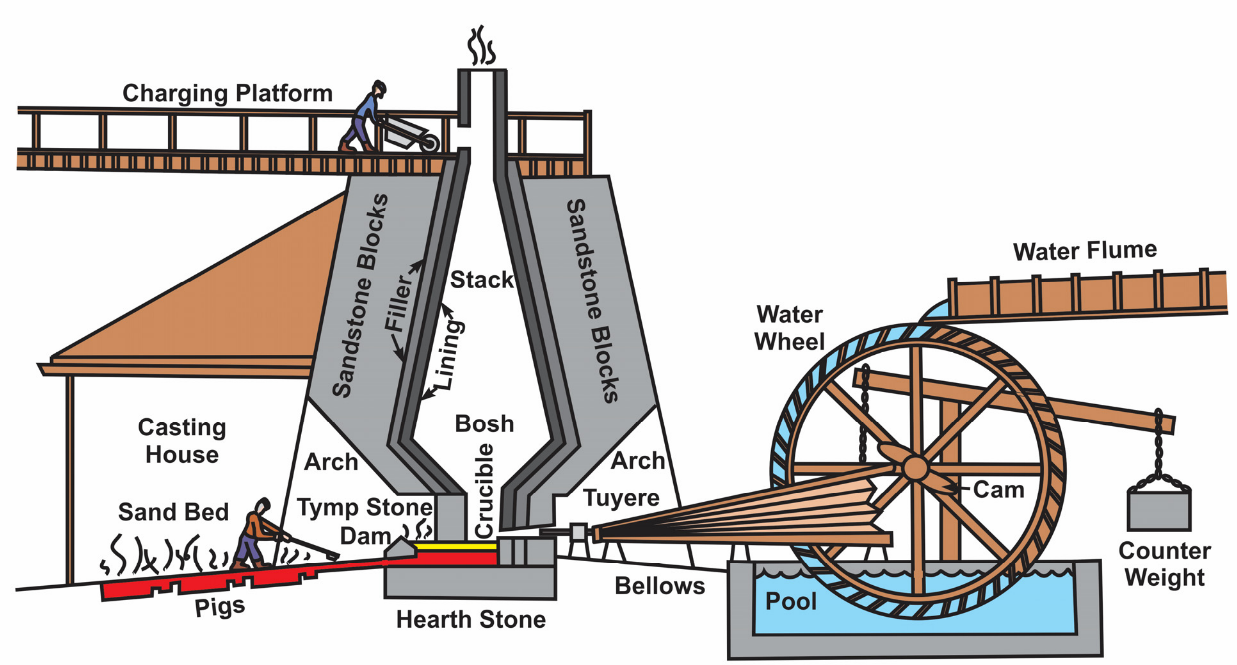


Figure 2. Schematic diagram and terminology of typical charcoal iron furnace (from Samways et al., 2014). Red—molten iron; yellow—slag. Drawing modified from original by David J. Vater.

of produced iron required a total charge of approximately three tons of iron ore, two tons of limestone, and 2.6 tons of charcoal. Iron production also spawned major support industries, such as the coke and refractory industries, which also utilized the coal and fire clay resources of the region.

Iron Ore – The readily available iron ores in western Pennsylvania were primarily siderites, although some hematite (kidney ore) and goethite or bog iron ore do occur in places in the area. See below for more information on these ores. The principal ores used in the Fayette and Westmoreland furnaces included the Mercer ores from the Pottsville Formation and Johnstown ores from the Glenshaw Formation (Figure 3). These rocks are exposed along the western slope of the eroded Chestnut Ridge anticline (Figure 4A). One furnace on the east slope of Chestnut Ridge used what was purported to be Mississippian Mauch Chunk ore (Figure 3), although the actual identity of the source formation is in doubt (J. Shaulis, pers. comm., January, 2018). In contrast, furnaces in counties such as Armstrong, Clarion, and Venango primarily used the Buhrstone and Freeport

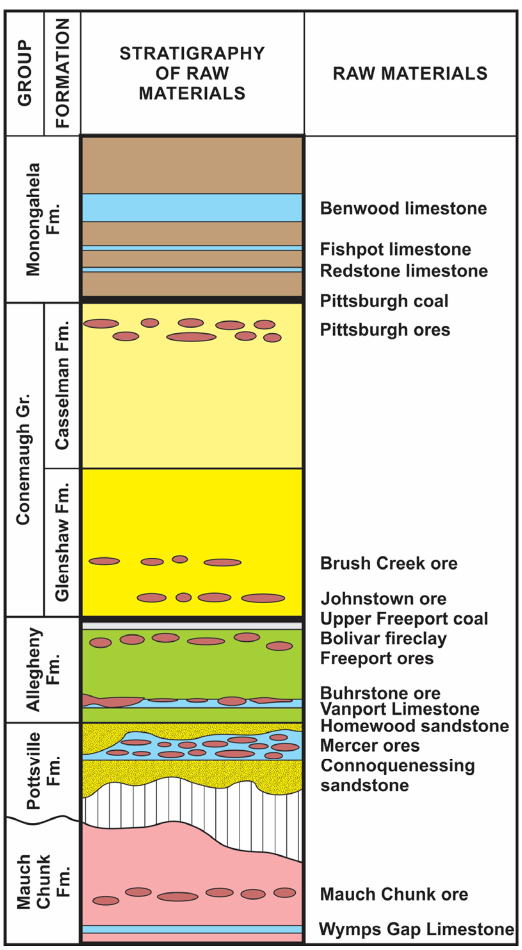
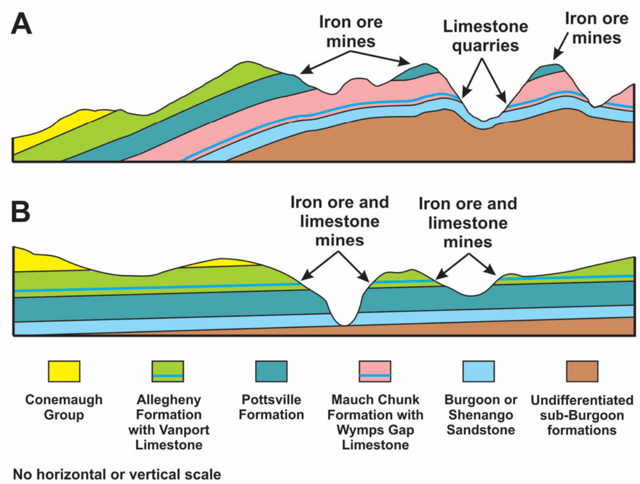


Figure 3. Generalized stratigraphic column for western Pennsylvania, showing iron ores, limestones, sandstones, coals, and fireclays (from Samways et al., 2014).

Figure 4. Cross sections of western Pennsylvania showing effect of geologic structure and topography on locations of raw material deposits. A — along Chestnut Ridge. B — northwestern Pennsylvania. From Samways et al., 2014.



sideritic ores from the Allegheny Formation (Figure 3) where they are exposed in stream valleys carved into the otherwise flat-lying rocks of western Pennsylvania (Figure 4B). The iron content of these ores varies from 30 to 40%. It was only when the Lake Superior hematite ores, containing in excess of 50% iron, became readily available through rail and water transportation that the iron-making industry shifted to the Pittsburgh area. The Clinton Furnace (Figure 1, location E) on Pittsburgh's south shore near the present-day Station Square shopping and entertainment complex was the first of these, with operations beginning in 1859.

Flux – Limestone, the flux material, occurs extensively throughout western Pennsylvania. Deposits close to the furnace operations along Chestnut Ridge include the Redstone, Fishpot, and Benwood limestones of the Monongahela Formations, and Wymps Gap Limestone of the Mauch Chunk Formation (Figure 3). The primary source of limestone for northwestern Pennsylvania furnaces was the Vanport Limestone of the Allegheny Formation (Figure 3).

Fuel – Prior to 1840, 100% of the iron produced in western Pennsylvania was made using charcoal as a fuel, which in turn required vast quantities of wood. For example, in the 1840's, an annual statewide iron production level of 100,000 tons consumed approximately 15,000 acres of forest (Samways et al., 2014). After 1840, alternative fuels such as anthracite and coke were introduced that gradually reduced the need for charcoal.

Coke, made from coal, eventually replaced charcoal as the fuel in the furnaces. In the 1800s coke was produced primarily in beehive ovens (Figure 5) by heating bituminous coal at temperatures ranging from 900 to 1,100°C (1,650 to 2,000°F) to drive off volatiles, leaving a fused-carbon structure. Because of the local availability of vast quantities of the Pittsburgh coal, a premium coal for coke-making (Figure 3), the Connellsville area in Fayette County became the center for coke production in meeting the needs of the iron industry. Although there were only 26 beehive ovens in operation in the area in 1855, the number increased very rapidly to 3,000 in 1873 and 20,000 in 1900, when more than 10 million tons of coke were produced from nearly 15 million tons of Pittsburgh coal. (A replica of a beehive coke oven is on display in Dunbar outside of Connellsville.)

Refractories – Refractories made from fireclay provided protective linings for furnaces and coke ovens exposed to destructively high temperatures (often in excess of 1,100°C [2,000°F]). The refractory industry, whose roots also began in western Pennsylvania, is sometimes referred to as "the hidden industry"; it played a major, unrealized role in the growth of the coke, iron, and steel industries. The predominant raw materials for refractory brick are fireclay, sandstone, and ganister (orthoquartzite). Fireclay (aluminum silicate – $Al_2O_3.2SiO_2$), is widely distributed throughout western Pennsylvania, usually in association with coal beds where it formed from the soils that supported the coal-forming plants. The Bolivar fireclay of the Allegheny Formation (Figure 3), for example, is a premium fireclay that occurs a few feet below the Upper Freeport coal bed. Fireclay products, in addition to lining blast furnaces, are used extensively in coke ovens. Siliceous refractories from sandstone containing 90 to 96%

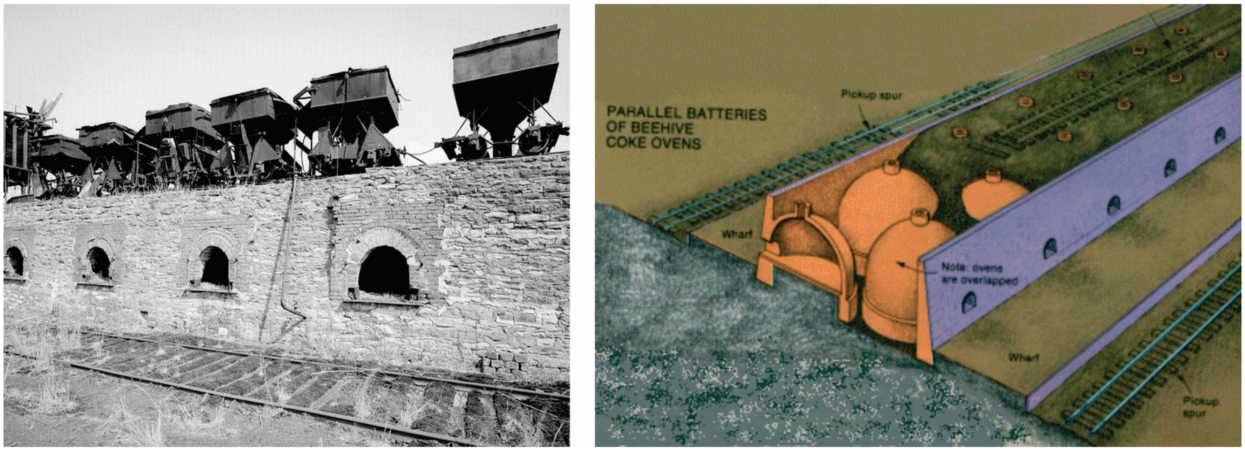


Figure 5. Beehive coke ovens. Left — coke ovens that are part of the Shoaf Historic District in Fayette County (Library of Congress, Prints and Photograph Division HAER: PA,26-SHO,1-3). Right — diagram of beehive coke oven construction (from Washlaski, 2008).

SiO_2 have been produced from the Homewood and Connoquenessing sandstones of the Pottsville Formation (Figure 3), and ganisters containing more than 98% SiO_2 occur in the mountain ridges in central Pennsylvania (primarily the Lower Silurian Tuscarora Formation). Silica bricks are used in the higher temperature regions of a coke oven. The magnitude of the demand for refractory products and, consequently, for raw materials such as fireclay and sandstone, is illustrated by the requirements of the coke industry. For example, close to 5,000 refractory bricks were used in the initial construction and rebuild of a single beehive oven. Thus, the 20,000 ovens in operation in 1900 required more than 100 million refractory bricks (Samways et al., 2014). More recently, in 1996, 80,000 tons of brick were needed for the construction of a new 268-oven facility. And, in 2012, 2.4 million bricks were laid in the construction of U.S. Steel's new 84-oven coke battery at the Clairton plant near Pittsburgh (Samways et al., 2014).

Types of Western Pennsylvania's Blast Furnace Ores

As stated previously, the primary ore used in western Pennsylvania iron blast furnaces during the early days of the industry was siderite (Figure 6A), principally in the form of nodules and other irregular masses in argillaceous and calcareous strata[2].

Siderite nodules typically are finely crystalline, break with a sharp conchoidal fracture, and are bluish-gray in color where they have not been weathered. They commonly contain about 30 to 40 percent iron and more than 0.15 percent phosphorus (Inners, 1999). Fayette County's siderite comprises two types: 1) siderite nodules imbedded in shale and clay; and 2) limestone beds that replaced by siderite. In some places, the iron limestones appear to have been enriched at the surface, but the iron content typically diminished only slightly away from the outcrop (Hickok and Moyer, 1940).

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[2] Although western Pennsylvania siderite deposits consist mostly of nodules in shales associated with marine limestones, there are exceptions. Blackband ores are siderite nodules associated with coal beds, usually found within, or, more typically, above the coal (Stout, 1944), usually in non-marine rocks. Hickock (1939) stated that there are many outcrops of siderite in the strata above the Pittsburgh coal in Pennsylvania, but the beds are not extensive, and the nodules are scattered and are commonly high in phosphorus. The Buhrstone ore of the Vanport Limestone (Allegheny Formation) is an extensive deposit that is confined mainly to the top of the limestone. This deposit resulted from the partial replacement of the limestone by meteoric waters bearing iron leached from the overlying shales. The ore, although very thick in places, is confined to the zone of weathering.

Of lesser importance were limonite (also called brown ore), goethite, hematite, and bog ore. Pyrite (FeS) and other iron sulfides and iron silicates such as chamosite, glauconite, and greenalite also occur in western Pennsylvania rocks, but were not important in the early iron industry. Limonite (FeO(OH) $\cdot nH_2O$) (Figure 6B) typically occurs from the alteration of siderite, but has also been known to occur due to the decomposition of impure iron-bearing limestones or by precipitation of soluble iron salts in wetlands and coal mine runoff. Goethite (FeO(OH)) (Figure 6C) often forms through the weathering of other iron-rich minerals, so it is commonly found in soil and other low-temperature environments. Hematite (Fe_2O_3), the most important iron ore in the world, typically occurs in western Pennsylvania as kidney ore (Figure 6D). The term "kidney ore" is named for its similarity in appearance to an internal organ. Kidney ore forms as a precipitate in cavities. Chemically precipitated hematite such as this can be relatively uncontaminated with clay or host rock inclusions, and it has a higher purity. Kidney ore supposedly was the primary ore used at Wharton Furnace (see Stop 2). Unfortunately, analyses of this ore apparently were never performed. Bog ore (FeO(OH)) also forms through precipitation. Iron in soils and rocks on uplands was separated from the parent material by acids from decaying organic matter, held in solution, and deposited by surface and groundwater in wetlands and other low-lying areas (Stout, 1944).

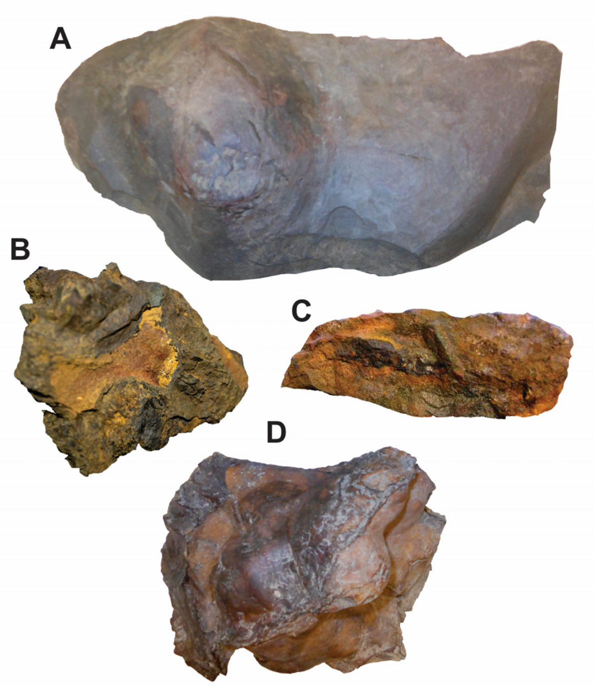


Figure 6. Examples of sedimentary iron ores that occur in Fayette County. A – siderite. B – limonite. C – goethite. D – Hematite, specifically "kidney ore".

Origin of Siderite

Siderite concretions of the type used in the early iron industry in western Pennsylvania formed in an aqueous environment after the deposition of sediment (Woodland and Stenstrom, 1979). The iron was deposited within pore spaces within the sediment (or in the rocks) by circulating iron-bearing waters. Precipitation of iron can occur prior to lithification of the sediments, during diagenesis, or after lithification. Woodland and Stenstrom (1979) determined that the most likely source of iron would have been from migrating fluids flushing through the sediments.

> "Water draining peat bogs will be relatively high in Fe^{++} ions because decaying plant material lowers pH and Eh, thus increasing the total concentration of Fe^{++} ions. Gruner (1922) and Oborn and Hem (1961) have shown that microbial activity on organic matter is important in releasing iron from soils. The effects of lateral diffusion should be reflected in a strong zonation of concretion growth with high population adjacent to the source area. There is insufficient evidence to demonstrate any such zonation." (Woodland and Stenstrom, 1979, p. 86-87)

As such, geochemical factors such as temperature, pressure, Eh, pH, iron concentration, and type and amount of organic matter are critical factors during precipitation (McGuire, 2012).

Also critical would have been the effects of biogeochemical activity, particularly by bacteria. Johnson and others (2004) felt that the evidence was overwhelming that biological processing of redox-sensitive metals (e.g., Fe) is probably the rule in surface- and near-surface environments, rather than the exception. Iron oxide produced by Fe(II) oxidation is an important sink for Fe released by terrestrial weathering. Dissimilatory[3] microbial reduction of Fe_2O_3, coupled with oxidation of organic carbon and/or H_2, is an important process by which it is reduced in both modern and ancient sedimentary environments. In fact, relatively recent microbiological evidence by Vargas and others (1998), coupled with a great deal of geochemical data, suggests that microbial reduction of Fe_2O_3 may have been one of the earliest forms of respiration on the planet (Johnson and others, 2004).

There are significant differences between siderites found in continental settings and those in marine environments. "Fresh-water" siderite is often relatively pure, having greater than 90 mol% $FeCO_3$, whereas marine siderites always are very impure, having extensive substitution of Mg and Ca for Fe in the mineral lattice. Also, marine siderite generally contains less Mn and has a higher Mg/Ca ratio than "fresh-water" siderite (Mozley, 1989). The differences between the two seem to reflect the fact that marine sediments generally undergo a more extensive period of sulfate reduction than do "fresh-water" sediments (Mozley and Wersin, 1992). The compositional variations seem to result from differences in the chemistry of early marine and meteoric pore waters; early marine pore waters generally have higher Mg^{2+}/Ca^{2+} ratios and contain less Mn^{2+} and Fe^{2+} and more Ca^{2+} and Mg^{2+} than meteoric waters.

The exposure of the iron-bearing rocks to weathering can alter the mineral form of the iron. For example, siderite within the subsurface often changes to limonite at the outcrop where weathering is most likely to occur. The famous Buhrstone ore at the top of the Vanport Limestone of northwestern Pennsylvania generally is 6 to 12 in (15 to 30.5 cm) thick (Butts, 1906), but in places, weathering of the bed resulted in fairly thick pockets of sedimentary limonite (Inners, 1999).

Occurrence of Siderite in Fayette County

The iron ores of Fayette County occur at specific positions within the stratigraphic record. In general, there are six primary ore-bearing horizons named the Pittsburgh, Mahoning, Freeport, Brookville, Mercer, and Mauch Chunk ores (Figure 3).

Pittsburgh Ore Beds. – The Pittsburgh ore occurs within the Casselman Formation of the Conemaugh Group, lying about 4 to 6 ft (1.2 to 1.8 m) below the Pittsburgh coal and above the Little Pittsburgh coal (Figure 7). They appear in various beds that the miners names Blue Lump, Condemned Flag, Big Bottom, Bed Flag, and Yellow Flag (McCreath, 1879). Hickock (1939, p. 11) stated that siderite occurs in the underclay of the Pittsburgh coal as four thin beds that are persistent throughout a large part of the county. Analyses of the ore found it averaged 35 to 40 percent iron and was low in phosphorus and sulfur. It is well developed along the Monongahela River near Point Marion and extends across the county to the area around Uniontown. The ore beds were explored as deep as 800 ft (245 m) underground where they appeared to be fairly consistent in quality. Analyses of seven Pittsburgh ore samples found the iron content to range from 29 to 42 percent (Stevenson, 1877; see Table 1). These ores were important resources for the Oliphant Furnace in Georges Township and Lemont Furnace in South Union Township (Hickok and Moyer, 1940). A few thin beds of nodules occur scattered

[3] Dissimilatory metal reduction is a process that is utilized by microbes to conserve energy through oxidizing organic or inorganic electron donors and reducing a metal or metalloid. Microbial metal reduction enables organisms to create electrochemical gradients, which provides the chemical energy required for growth (MicrobeWiki, 2012).

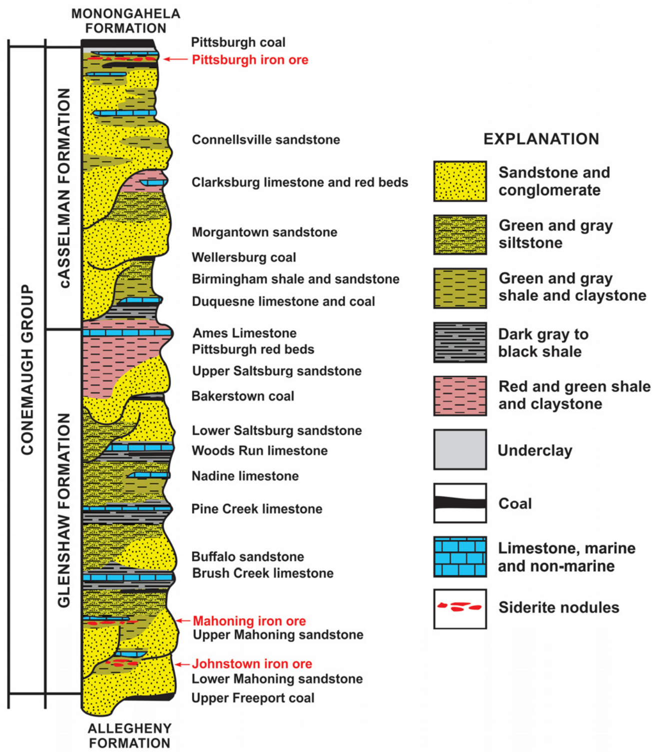


Figure 7. Generalized stratigraphic section of the Conemaugh Group in western Pennsylvania, indicating the location of major iron ore beds (in red). Redrawn from Harper and Laughrey (1987).

through the upper Casselman Formation below the Pittsburgh ore, but they are only found locally and were not considered important.

Mahoning Ore Beds. – The Mahoning ores generally occur at two horizons, one directly above the Lower Mahoning sandstone (Johnstown ore) and the other higher in the section (Mahoning ore) (Figure 7). Hickok and Moyer (1940) speculated that they probably represent sideritic phases of two Mahoning limestones. The ores occur as solid beds in some places, and are entirely missing in others, but more commonly they occur as siderite nodules in shale or clay. Creek Valley east of the anticline. They were mined at Lemont Furnace in South Union Township; Fairchance Furnace in Georges Township, and Springhill Furnace in Springhill Township (Hickok and Moyer, 1940). Stevenson (1877) reported analyses of five samples of the ore from Fayette County contained from 3.5 to 32 percent iron (Table 2).

Table 1. Chemical analysis of seven samples of the Pittsburgh ores from Fayette County (from Hickok and Moyer, 1940). Analyses were made by A. S. McCreath and D. McCreath, chemists with the Second Geological Survey of Pennsylvania in the late 1800s.

	1	2	3	4	5	6	7
Iron	33.350	39.000	42.116	35.500	35.800	35.400	20.200
Sulfur	0.155	0.011	0.041	0.145	0.047	0.319	0.415
Phosphorus	0.072	0.089	0.070	0.042	0.083	0.069	0.268
Insoluble residue	13.860	5.790	4.415	7.450	9.560	10.450	19.240

Freeport Ore Beds. – The Freeport ores also comprise two sets of beds within the upper part of the Allegheny Formation (Figure 8) – the upper bed, occurring at the level of the Upper Freeport limestone, was an important ore on the west side of Chestnut Ridge whereas the lower bed, occurring at the level of the Johnstown cement bed between the Upper and Middle Kittanning coals, was more important east of the ridge. Inners (1999) called this the Kittanning ore, which name is used here. Hickok and Moyer (1940) considered both ores to be "surface ores" for the most part, that is, they occur as limonite at the surface, but become very lean deeper in the subsurface. For example, Hickok and Moyer (1940) listed one sample from underground in Springhill Township as having only 2 percent iron. The Upper Freeport limestone ore was mined on Jacobs Creek in Tyrone Township, near Dunbar Furnace in Dunbar

Table 2. Chemical analysis of five samples of the Mahoning ores from Fayette County (from Hickok and Moyer, 1940). Analyses were made by A. S. McCreath, D. McCreath, and Professor C. F. Chandler, chemists with the Second Geological Survey of Pennsylvania in the late 1800s.

	1	2	3	4	5
Iron	32.02	18.000	11.100	3.49	5.04
Sulfur	-----	0.026	0.313	-----	-----
Phosphorus	0.20	0.261	0.018	0.12	0.10
Insoluble residue	0.85	18.190	26.090	52.35	21.25

Township, at the Springhill furnaces in Springhill Township, and on Deckers Creek in West Virginia. The Johnstown cement bed ore was mined at Furnace Run and Springhill Furnace, Springhill Township. Hickok and Moyer (1940) documented iron contents of the Upper Freeport ore ranging from 26.5 to 40.8 percent at the surface, and of the Johnstown cement bed ore ranging from 28.3 to 38.1 percent (Table 3).

Brookville Ore Beds. – The Brookville ores consist of two or three thin beds lying close to the Brookville coal near the base of the Allegheny Formation (Figure 8). The best ore lies either directly on the coal or 10 to 12 ft (3 to 3.6 m) above it. The ore found below the coal is very thin and mostly non-economical. The Brookville ore had been mined on Mount Creek near the Vernon mines in Dunbar Township, near Dunbar Creek, near Coolspring Furnace in Union Township, and near Springhill Furnace in Springhill Township. It was never mined east of Chestnut Ridge, although Hickok and Moyer (1940) found traces of it in outcrops near Ohiopyle. The ore apparently was never analyzed.

Mercer Ore Beds. – The most important iron ores found in Fayette County are part of the Mercer member of Pottsville Formation (Figure 9). Several beds of good ore occur around the Mercer coals below the base of the Homewood sandstone.

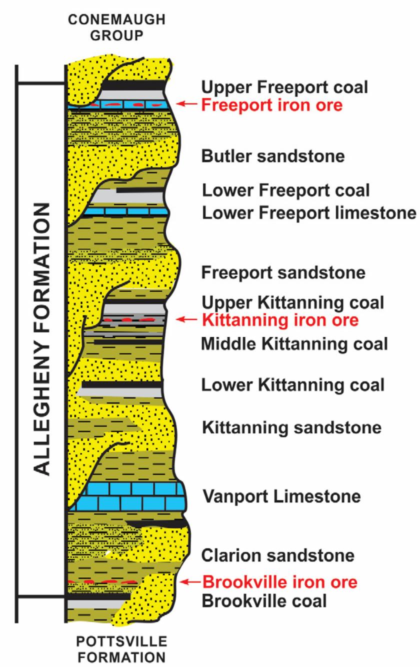


Figure 8. Generalized stratigraphic section of the Allegheny Formation, indicating the location of major iron ore beds (in red). See Figure 7 for explanation of lithologic symbols. Redrawn from Harper and Laughrey (1987).

Table 3. Chemical analysis of seven samples of the Freeport ores from Fayette County (from Hickok and Moyer, 1940). Analyses were made by A. S. McCreath and D. McCreath, chemists with the Second Geological Survey of Pennsylvania in the late 1800s.

	1	2	3	4	5	6	7
Iron	31.23	4.21	26.500	40.750	28.300	33.900	38.100
Sulfur	-----	-----	0.090	0.278	0.079	0.333	0.159
Phosphorus	1.04	0.01	0.046	0.229	0.137	0.302	0.115
Insoluble residue	16.92	3.85	13.810	5.120	13.885	18.690	9.250

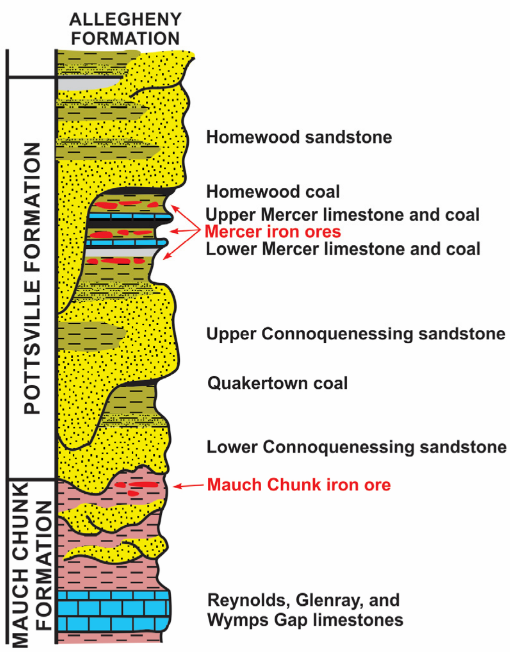


Figure 9. Generalized stratigraphic section of the Pottsville Formation and upper portion of the Mauch Chunk Formation, indicating the location of major iron ore beds (in red). See Figure 7 for explanation of lithologic symbols. Redrawn from Harper and Laughrey (1987) and Brezinski (1989).

Stevenson (1877), who documented their existence west of Chestnut Ridge, misidentified them as being within the Mauch Chunk Formation (his Umbral series). He apparently was convinced that the Homewood sandstone, which is massive on the western flank of the anticline, comprised the entire Pottsville; he did not recognize the Connoquenessing sandstone lying below it. The Mercer ore beds range from 6 to 18 in (15 to 46 cm) in thickness. Although they are typically siderite ores, at the outcrop they tend to be limonitic. Several large mines along the west flank of Chestnut Ridge provided large amounts of ore to the major blast furnaces in the county. The most important mines included the Vernon mines on Mounts Creek near Mt. Vernon Furnace, the Dunbar mines on Dunbar Creek near the Union and Dunbar furnaces, the Lemont mines near Lemont Furnace, the Coolspring mines on Shutes Run, the Fairchance mines near the Fairchance Furnace, and the Springhill mines near Springhill Furnace. Stevenson (1877; also Hickok and Moyer, 1940) provided generalized stratigraphic sections of some of these mines. Analyses of the Mercer ores by the Second Geological Survey of Pennsylvania indicated that iron contents of the ores ranged from 31.1 to 41.4 percent (Table 4).

Mauch Chunk Ore Beds. – Thin beds of hematitic iron ore 1 to 2 in (2.5 to 5 cm) in thickness occur near within 15 ft (4.5 m) from the top of the Mauch Chunk Formation (Figure 9) along the eastern flank of Chestnut Ridge south of the Youghiogheny River (Hickok, 1939). According to Inners, 1999, they also extend eastward into Bedford and Huntingdon counties). Hickok and Moyer (1940) state that these ores have never been mined, but qualify that by stating that one of the beds near Wharton Furnace (see Stop 2) was 0.5 to 2 ft (0.15 to 0.6 m) thick and was actually mined extensively on the Wharton Furnace property. These ores apparently were never analyzed.

Some Significant Early Western Pennsylvania Iron Furnaces

Alliance Furnace – Alliance Furnace, located on Jacobs Creek in Perry Township, Fayette County (Figure 1, Location A) was built and operated by Turnbull, Marmie and Company. Peter Marmie, who lived nearby in Westmoreland County, was in charge of the furnace. It was one of the first iron furnaces west of Allegheny Mountain. Two other blast furnaces, the Fairfield and Union furnaces, were built about the same time as the Alliance, so which one was actually the first is debatable. Sources vary as to the actual date of Alliance Furnace. Heald

Table 4. Chemical analysis of ten samples of the Mercer ores from Fayette County (from Hickok and Moyer, 1940). Analyses were made by A. S. McCreath and D. McCreath, chemists with the Second Geological Survey of Pennsylvania in the late 1800s.

	1	2	3	4	5	6	7	8	9	10
Iron	39.77	41.400	35.823	41.000	31.100	32.010	37.440	36.200	35.664	31.200
Sulfur	-----	0.184	-----	0.191	0.086	-----	-----	0.107	Tr.	0.253
Phosphorus	0.22	0.151	0.030	0.120	0.103	Tr.	0.250	0.154	0.008	0.120
Insoluble residue	12.98	6.430	15.568	6.810	25.960	22.150	12.000	12.980	16.700	21.930

Figure 10. Group posing in front of the Alliance Furnace ruins, Fayette County, 1897 (from PHMC, 2011a).

Figure 11. The remains of Union Furnace 1 and 2. Left – A few cut stone blocks on the hillside above Dunbar Creek indicate the location of Union Furnace 1. Right – Scattered sandstone blocks on the south shore of Dunbar Creek indicate the location of Union Furnace 2. Photos from Parks (2010a).

(1990) stated that a Fayette County Road Docket listed a furnace on Jacobs Creek in June 1789, but the furnace was only under construction at that time and was not put into blast until sometime between 1790 and 1792. After it went into blast, it produced pots, kettles, and other hollowware that settlers in the area needed to cook and process food, and cannon shot and shells for General "Mad Anthony Wayne's" troops when they fought against Native Americans in 1795. By 1793, however, the company was in financial straits because some of their clientele refused to pay, and by 1802 the furnace was out of blast, never to return (PHMC, 2011a). Figure 10 is a historic photo of the old abandoned stack.

Union Furnace – Union Furnace was located on Dunbar Creek in Dunbar Township, four miles southwest of Connellsville, Fayette County (Figure 1, Location B). According to Heald (1990), it was built in 1789 by Isaac Meason (see below). Heald also considered it to be the first furnace to produce iron west of Allegheny Mountain. It was a small stack, estimated to be 12 ft(3.6 m) high with a 3.5 ft (1 m) bosh, built into the hillside at creek level (Figure 11) . It is said to have been capable of producing only ¾ tons of pig iron daily (Parks, 2010a) but apparently was a financial success, supposedly because Dunbar iron was in great demand for its excellent quality. The ironworks consisted of the furnace, a forge, and two sawmills. Meason abandoned this furnace within three years and built a second, larger stack on a level terrace on the southeastern floodplain of Dunbar Creek. Meason, Moses Dillon, and John Gibson formed a company that also operated two local forges, a gristmill, a sawmill, two blacksmith shops, and a shoe and harness shop (Heald, 1990). Iron ore for the furnace was mined from an outcrop about 80 ft (25 m) above creek level which, considering the approximate location of the furnace, probably was Pottsville Formation (Mercer further stated that a 1794 advertisement in the Pittsburgh Gazette indicated that "their furnace had 'well assorted castings which they will sell for cash at the reduced price of £35 ($93.33) per ton.' Products included tea kettles, fire grates, Franklin stoves, andirons, wagon parts, mill parts, and clock weights. Union Furnace also produced sugar kettles for Louisiana plantations and was known as 'one of the most successful [furnaces] in the region.' Meason eventually bought out his partners and formed the Union Iron Works.

Mt. Vernon Furnace – This was another furnace constructed and operated by Isaac Meason, who also owned Union Furnace 1 and 2 and Dunbar Furnace at Dunbar, and Ross Furnace in Westmoreland County (Bullskin Township Historical Society, 2018) . According to

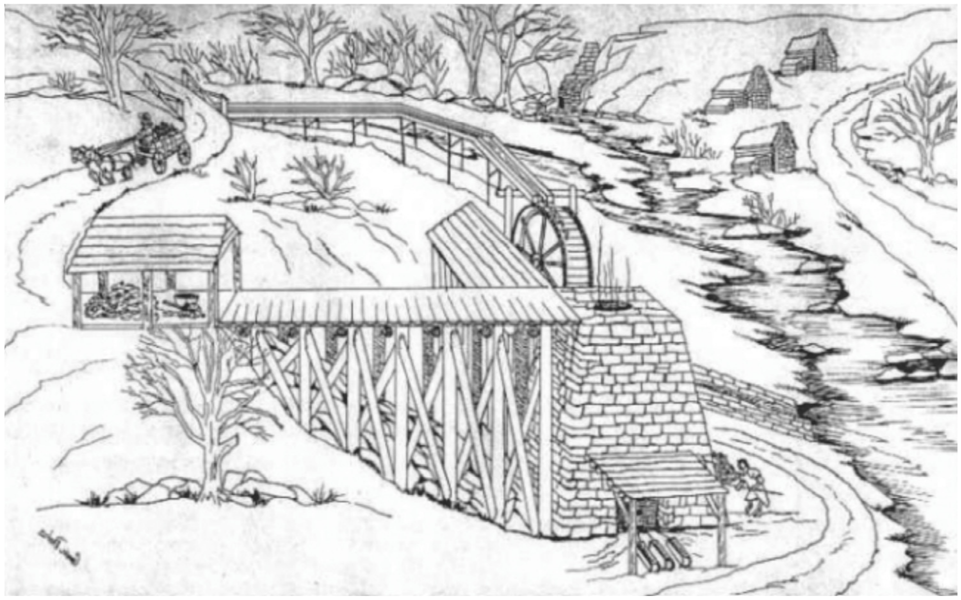


Figure 12. An artist's rendition of Mt. Vernon Iron Furnace when it was in operation (from Bullskin Township Historical Society, 2018).

Swank (1878), Meason built Mt. Vernon Furnace (front cover and Figure 12) in Bullskin Township, Fayette County (Figure 1, Location C), prior to July 1800, and then rebuilt it in 1801; it was probably in construction between 1795 and 1800 (Parks, 2010b). An iron lintel above the main opening has the letters "MT VN 1801".

The abundance and excellence of raw material found in the rock formations along the west side of Chestnut Ridge, plus the vastness of the forests in the late 1700s and early 1800 and the presence of Mounts Creek made this site an excellent choice for constructing a furnace. In addition to the furnace, the Mt. Vernon works also had mills to cut lumber and grind feed for the animals. Woodsmen cut the trees and work horses dragged the trees from the woods to the mill where they were cut into smaller pieces. Those pieces were then stacked and covered with earth, and ignited to make charcoal to fuel the furnace. The timber lands were cut over every 25 years (Bullskin Township Historical Society, 2018). The forest was in its second growth of timber by the time the furnace went out of blast in 1830 (Swank, 1878, gives the date as 1824; Parks, 2010b, said 1825). Iron from the furnace was used to cast moulded products that were transported to Connellsville for shipment down the Youghiogheny River. Products from the furnace made their way by water as far away as Louisiana (Bullskin Township Historical Society, 2018).

The Mt. Vernon ore mines, located in the hills to the east of the furnace, operated from 1795 until 1830. The Mercer ores (Figures 3 and 9) supplied the siderite from beds generally ranging from 0.5 to 1.5 ft (0.2 to 0.5 m) thick (Stevenson, 1877; Hickok and Moyer 1940). These ores were relatively high in iron, although not nearly as high as other kinds of ores (magnetite – 72% iron; hematite – 70% iron; goethite – 63% iron). Following the demise of the furnace, the mined ore was shipped to the Charlotte Furnace in Scottdale until the 1880s via a narrow gage railroad (Bullskin Township Historical Society, 2018). The mine openings were completely collapsed by the time Hickok and Moyer (1940) examined the area in the 1930s, and not much is left of these mines today. According to the Bullskin Township Historical Society (2018):

> If you were taking a walk through the woods, you would probably miss the Mine Entrance unless you knew what you were looking for. The Ore Mines were

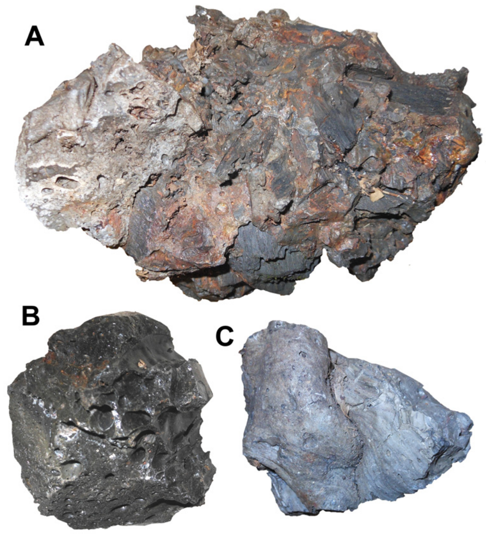


Figure 13. Some samples of slag from the Mt. Vernon Iron Furnace in the collections of the Carnegie Museum of Natural History (CM). A — large chunk of slag containing fragments of charcoal (CM 58024). B — slag glass (CM 58025), similar to obsidian. Note the vesicles (open holes) where hot gases from the iron furnace were trapped. C — specimen of ropey slag (CM 58026) similar to pāhoehoe lava like that found around Hawaiian volcanoes.

> located on the hill above the Furnace. There were numerous mines carved into the hill. There must have been many different entrances, but this is the only one that is still known of. It has been sealed shut with rocks for safety reasons and over the years has been over grown by vegetation. A small stream of water running from the mine entrance shows signs of sulphur. On our trip, we were fortunate enough to find some ore in the creek bed. We also saw the slag piles around the mine area.
>
> It took a lot of hard work and muscle to do what these Pioneers did. And given the type of equipment that was available in that time period (Horses; Mules; Axe; Picks, Shovels, etc.) It gives us great pride to honor these people that helped build our township. We hope that our future generations will enjoy our Heritage from the past and gladly pass it on.

Near the mine is a large pile of slag. Slag is also found on the park grounds scattered through the woods. Figure 13 shows some of the varieties of slag found at the park.

Mt. Vernon Furnace was placed on the National Register of Historical Places in 1991 (Parks, 2010b; Anonymous, 2018b). In 2004, the heirs to the furnace site deeded the 1.6-acre plot to the Bullskin Township Historical Society, which has a project in process to restore the furnace (Parks, 2010b). The historical society plans ultimately to restore the site to its original operating condition, including a waterfall and working water wheel.

Shadyside Furnace – George Anshutz, Anthony Beelen, and William Amberson built this furnace (Figure 1, Location D) sometime around 1792 or 1793 (depending on who you believe). Not a whole lot is known about it. A historical marker on the southeast corner of Bayard Street and Amberson Avenue, next to the Winchester-Thurston school in Oakland, reads:

SHADYSIDE IRON FURNACE

> *Built on lowlands here in 1792. Birth of the iron industry in the Pittsburgh region. It made stove and grate castings. Closed about a year later due to lack of ore and wood."*

The furnace only operated for about a year because the local ore supply was insufficient, and ore transported in from the Apollo area was too expensive. As a result, Pittsburgh became a center for secondary iron manufacturing – forges and rolling mills and such, that turned pig iron from furnaces in Fayette County and other western Pennsylvania areas into useable products. When the Pennsylvania Railroad was built through the area around 1860, the furnace was demolished. It had stood where about where Amberson Avenue ends above the railroad and East Busway in the Shadyside neighborhood, although no one is certain of its exact location.

Clinton Furnace – This was only the second iron furnace constructed in Pittsburgh (Figure 1, Location E). Graff, Bennett and Company, which owned a rolling-mill concern in Pittsburgh, constructed Clinton Furnace in 1859 to integrate its operations backward into iron production (PHMC, 2011b). There is a Historical Marker at Station Square that reads:

CLINTON FURNACE:

> *Pittsburgh's first successful blast furnace for making pig iron. Operations began near here, 1859, using Connellsville coke as fuel. The furnace's technology initiated a new era, leading to more advanced furnaces capable of producing huge amounts of iron and resulting in the modern blast furnace. Clinton Furnace played an important role in establishing Pittsburgh's dominance in iron and steel making. Operation ended in 1927.*

The furnace was still operating when Pittsburgh's "native artist", John J. Kane painted a picture of it sometime in the 1920s (Figure 14).

Clinton Furnace was especially important because it was the first furnace to use coke exclusively for fuel. It was so successful that coke-fueled furnaces spread across Pennsylvania and became the dominant form of blasting and other iron and steel manufacturing. The company initially used coke made strictly from the Pittsburgh coal mined at Connellsville. After its early success, however, the company switched to coke made from local coal mines to reduce costs. Unfortunately, that didn't work and the company returned to using Connellsville coke because it had fewer impurities and produced better quality iron.

Figure 14. Painting by Pittsburgh native John J. Kane entitled Old Clinton Furnace. The furnace was located at the base of Mt. Washington on the south side of the Monongahela River where the current Highmark Stadium is located. Photo of Kane's painting from Lenin Imports (2018).

Clinton Iron Furnace produced 11,000 tons of iron per year, an exceptionally high output. In fact, it was more than twice the tonnage that a typical anthracite furnace could produce and six times the tonnage that the average charcoal furnace produced. By raising the blast pressure in the furnace, as well as increasing the blast temperature and the size of the furnace, the company was able to raise their output above the rated capacity of the furnace (this is called "hard-driving"). Soon, other furnaces followed suit. One furnace produced an amazing 26,000 tons of iron in 1874 using the hard-driving bituminous-coke technology. Steel firms and ironmasters in eastern Pennsylvania did not hard-drive their anthracite furnaces because the structure of anthracite resists the rapid combustion that hard-driving entailed, so by 1875, western Pennsylvania's bituminous furnaces surpassed the output of anthracite furnaces. Between 1880 and 1900, the number of furnaces using anthracite or an anthracite/coke mixture fell from 158 to 70 with only 28% of the state's total iron-making capacity. Instead, the anthracite furnace owners built larger and larger bituminous-coke furnaces with greater blast pressures and hotter blasts, increasing output in the best furnaces to more than 50,000 tons per year by the 1890s.

When Clinton Furnace first went into blast it was considered an enormous producer of iron, yet in terms of output and production costs the later blast furnaces were as far ahead of Clinton as it was of the charcoal and anthracite furnaces. By 1900, 70 coke-fueled furnaces produced 71% of Pennsylvania's iron, with charcoal accounting for a mere one percent of capacity.

When Graff, Bennett and Company erected Clinton Furnace, few would have envisioned how this step would help transform the iron and steel industries. Opening this furnace was one in a chain of events that contributed to far bigger iron furnaces, the dominance of bituminous-coke furnaces, and the growth of an integrated steel industry that eventually made Pittsburgh famous.

The J. V. Thompson Limestone Quarry

This quarry, one of the most famous and prolific fossil collecting sites in Pennsylvania, originally was to have been a stop on this field trip. Unfortunately, the Pennsylvania Department of Transportation (PennDOT) has ruled the quarry off-limits owing to safety issues. Since we have gone to all the trouble to put the write-up of the quarry together, however, we decided to include it here in the introduction for your edification.

The site is an old abandoned quarry in the Mississippian Wymps Gap Limestone. The quarry originally was owned and operated by Josiah Van Kirk "J. V." Thompson (1854-1933) (Figure 15), a Uniontown banker who made his fortune buying and selling coal lands. An associate of Henry Clay Frick, at one time he was considered one of America's wealthiest men.

Figure 15. Photograph of J. V. Thompson (modified from Find A Grave, 2010).

The old quarry (Figure 16A) once was the largest Wymps Gap quarry in Fayette County; it supplied much of the stone used in surfacing local sections of US 40 (Hickok and Moyer, 1940). It is currently being used in part as a storage yard for the Pennsylvania Department of Transportation (PennDOT) (Figure 16B). The former fossil collecting site is several hundred feet north of US 40, but you can still see much of the quarry behind the storage sheds (Figure 16C).

The Thompson Quarry used to be an excellent locality for collecting well-preserved fossils until PennDOT took it over. Many of the fossils have weathered loose from the limestone and

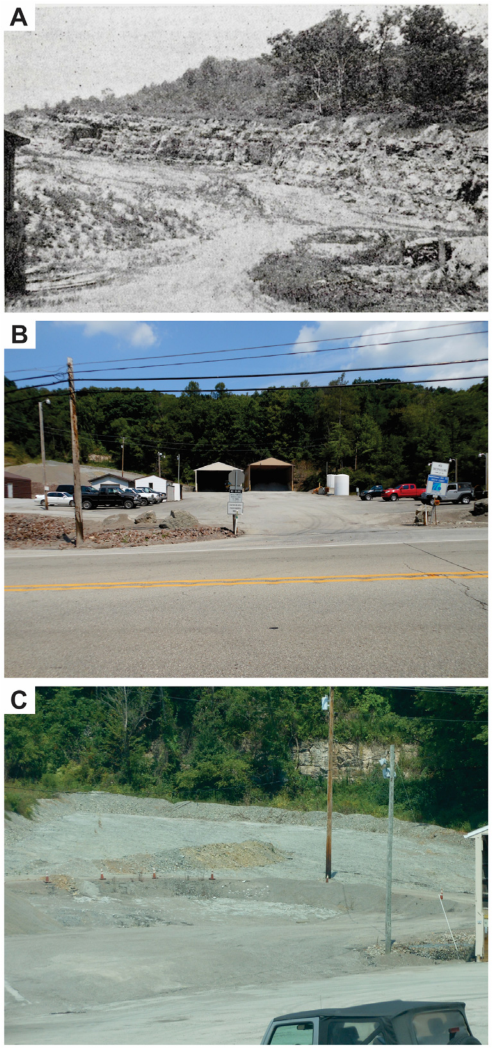


Figure 16. Photographs of the J. V. Thompson Quarry. A – As it appeared in the 1930s (from Hickok and Moyer, 1940). B – the PennDOT maintenance facility; C – the quarry showing the sloping quarry floor and a small exposed area of the quarry wall.

could be collected whole. Large shells and other pieces lie directly on the ground. It is one of the few places in western Pennsylvania where complete crinoid calices and complete trilobite carapaces can be found, and the slopes below the quarry highwalls provided many good specimens, particularly of brachiopods, but because much of the quarry is now overgrown the underbrush hides most of the good material, and briars run rampant They can be very thick in this area, so even the avid collectors would have wanted to add a good pair of gloves and long pants to their collecting gear.

Geology

The limestone exposed in the Thompson Quarry is the Wymps Gap Limestone, a northern tongue of the thick and extensive Greenbrier Group of West Virginia (Figures 17 and 18). The Wymps Gap thins from northeast to southwest in southwestern Pennsylvania, attaining a maximum thickness of about 20 m (65 ft). About 11 m (36 ft) of Wymps Gap are exposed at the Thompson Quarry, striking approximately northeast and dipping about 10 degrees southeast. Horowitz & Rexroad (1972) used conodont biostratigraphy to propose that the limestone in the Thompson Quarry was middle Chesterian (= upper Visean on the global time scale) in age (Figure 19). Brezinski (1984) interpreted the limestone on the sloping quarry floor to be the result of deposition in moderately shallow water during a marine transgression. Fossil diversity increases up-section through the successive carbonate layers and in the main limestone bench. Faunal composition changes from a predominantly bivalve-productid brachiopod association at the base of the rhythmically-bedded sequence to a productid-bryozoan-bivalve association at the top (Brezinski, 1984). The overlying dark gray argillaceous limestone was deposited at or near maximum deepening as indicated by a higher faunal diversity, an increase in number of presumed stenotopic species (i.e., organisms able to live only in a restricted range of environments), and a lack of current features.

The lithology of the Thompson Quarry floor consists of rhythmically interbedded silty medium-gray micaceous shale and claystone, and gray lime mudstone (Rollins and Brezinski, 1988). Shaly intervals vary in thickness from 0.5 cm to 10 cm, whereas the carbonate beds, which contain abundant skeletal material, generally range from 5 to 7 cm in thickness. Upper surfaces of many of the carbonate beds exhibit evidence of current activity in the form of graded beds, convex-up positions of concave-convex shell material, and shell lags. Portions of bedding surfaces provide evidence of minimal post-mortem transport in the form of *in situ* occurrences of nuculid and pinnid bivalves, productoid brachiopods, as well as crinoid calyces with attached arms, delicate fenestrate bryozoa, and articulated trilobite exoskeletons. The interbedded shale and carbonate strata are overlain by the main carbonate bench of the Wymps

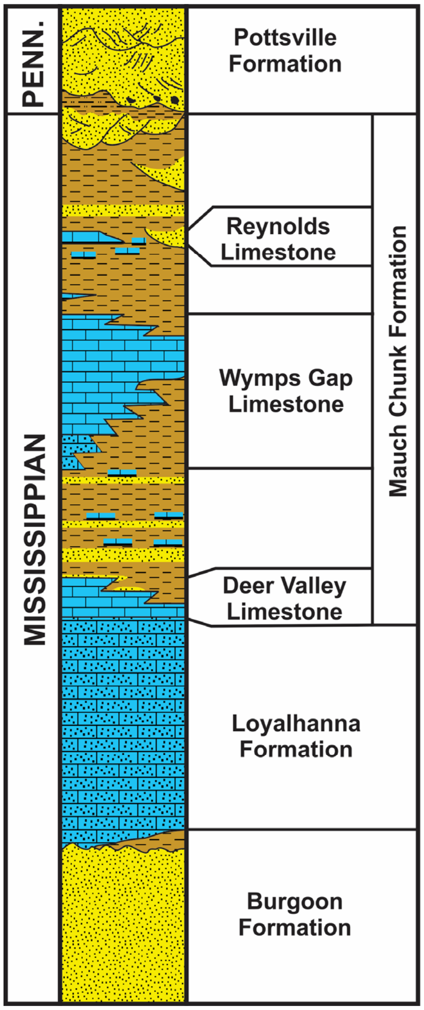


Figure 17. Stratigraphic section of Upper Mississippian strata in south-western Pennsylvania (modified from Rollins and Brezinski, 1988).

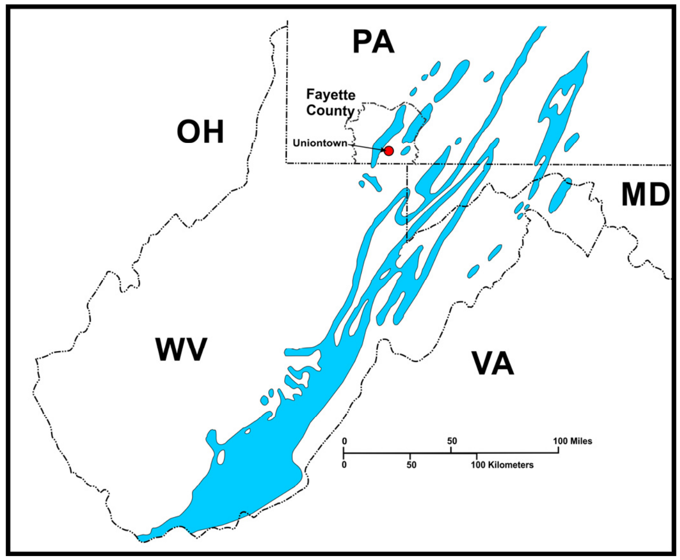


Figure 18. Geographic extent of outcrops of the Upper Mississippian Greenbrier Group and related strata in West Virginia and Pennsylvania (modified from Carney and Smosna, 1989).

Gap Limestone, which at Thompson Quarry is 7 m (23 ft) thick and consists of a dark gray, argillaceous, medium-bedded, lime wacke-stone. This lithology generally lacks current features, but does contain an abundant brachiopod-bryozoan-pelmatozoan assemblage.

Fossils

Frances Benson (1934) seems to have been the first to have published a faunal study of these limestones when she studied the brachiopods. Weller (1936) recorded a trilobite, *Kaskia chesterensis,* from what he called the Maxville Limestone, apparently the Wymps Gap. Miller and Collins (1947) described the new nautiloid species *Endolobus greenbrierensis,* and Strimple and Horowitz (1971) described a new species of crinoid from these beds. Horowitz and Rexroad (1972) studied the conodont fauna from the Thompson Quarry and concluded that the age of the Wymps Gap was late middle Chesterian. Simonsen (1983) described the bryozoans, Rollins and Brezinski (1988) discussed the interactions of crinoids and platyceratid gastropods, Carter and others (2008) described a new

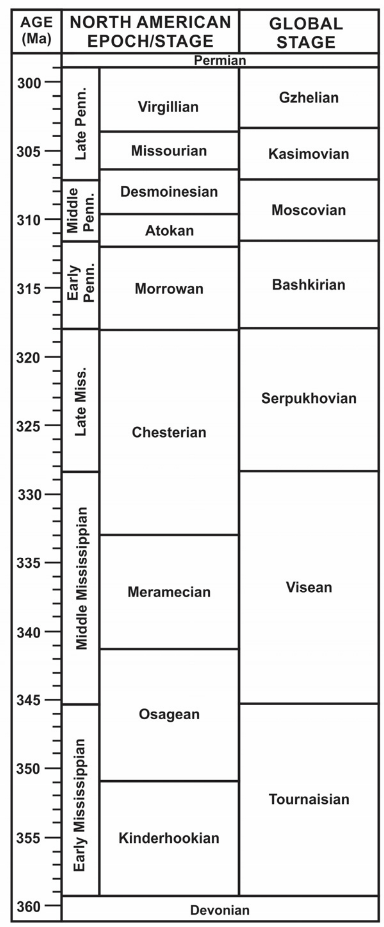


Figure 19. Global and North American stages of the Carboniferous (Mississippian and Pennsylvanian).

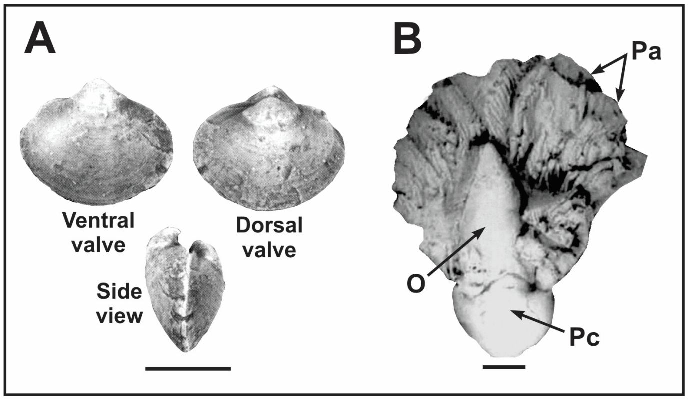


Figure 20. Photographs of some of the interesting fossils found at Thompson Quarry. See text for explanations. A. Three views of *Phyricodothyris lauriegrahamae* (modified from Carter et al., 2008). B. *Platycrinites* with a cap -shaped *Orthonychia* attached (modified from Rollins and Brezinski, 1988). O – *Orthonychia*. Pa – *Platycrinites* arms. Pc – *Platycrinites* calyx. Scale bars = 10 mm.

brachiopod species, *Phrycodothyris lauriegrahamae (*Figure 20A), and Brezinski (2008, 2009) documented the trilobites.

Such fossil groups can be found in the Wymps Gap Limestone at Thompson Quarry as well as at many other localities in southwestern Pennsylvania. Included in these groups are one or, more often, several species of corals, bryozoans, brachiopods, ostracodes, trilobites, gastropods, bivalves, cephalopods, echinoids, blastoids, crinoids, and various fish teeth (see Table 5 and Plate 1). At the Thompson Quarry, fossils are often weathered free of the limestone so they can be collected whole with little effort. Fragments of echinoids occur mainly as plates and spines, sometimes attached to the plates. Also, quite common are crinoid stems, spines, arms, and calices, although not typically articulated into whole specimens. Rare examples of tiny articulated specimens of *Platycrinites* were documented by Rollins and Brezinski (1988) from the quarry floor, many of which had equally tiny specimens of the platyceratid gastropod *Orthonychia* attached (Figure 20B). Most paleontologists consider platyceratids to have been coprophagous (feeding on excrement) commensal organisms on crinoids. The crinoids/platyceratid associations Rollins and Brezinski (1988) found appeared to be more parasitic than commensal, with the gastropods apparently taking advantage of the crinoids' aerosol filtration feeding habit, apparently to the detriment of the crinoids. Although there is no guarantee that the tiny crinoids and gastropods will be found on our field trip, it might be interesting to look for them on the quarry floor.

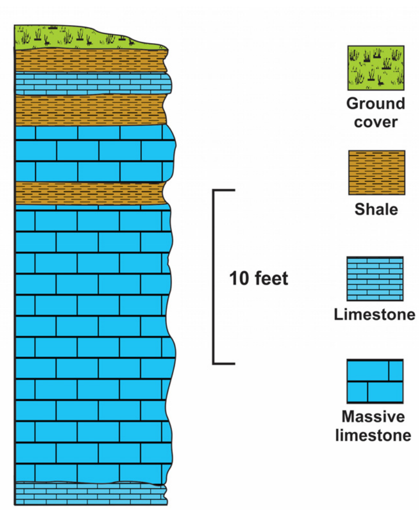


Figure 21. Generalized stratigraphic section of the Wymps Gap Limestone at the J. V. Thompson Quarry (modified from Simonsen, 1981).

Simonsen (1981) identified three genera of fenestrate bryozoans, *Fenestella*, *Polypora*, and *Septopora* (Plate 1). This is important because the delicate fronds of fenestrate bryozoans are excellent paleoecologic indicators, biostratigraphic guides, and sedimentologic contributors. Most of the fenestrate bryozoans collected in the Wymps Gap Limestone were found in the shale and lower massive limestone lithofacies (Figure 21). Many brachiopod species are found in assemblages containing these fenestrate bryozoans. The large percentage of calcareous matter and the apparent lack of sand-sized particles suggests that the fenestrates inhabited an offshore, normal marine, shallow environment. The water was deep enough to be below wave base and, therefore, was relatively quiet. It is entirely possible that water depth was 50 feet or more. The fenestrate bryozoans were bottom dwellers (i.e. sessile benthic) and filtered the water that passed by them in order to capture their microscopic prey. The preferred bottoms were limy mud bottoms as revealed by the various lithofacies.

Table 5. List of fossil genera that have been documented from the Greenbrier and equivalent limestones in Pennsylvania and West Virginia.

Corals
- *Cystilasma*
- *Triplophyllum*

Bryozoans
- *Batostomella*
- *Fenestella*
- *Fenestrellina*
- *Pinneretepora*
- *Polypora*
- *Rhombopora*
- *Septopora*
- *Tabulipora*

Brachiopods
- *Chonetes*
- *Cleiothyridina*
- *Composita*
- *Cranaena*
- *Dielasma*
- *Diaphragmus*
- *Dictyoclostus*
- *Echinoconchus*
- *Eumetria*
- *Girtyella*
- *"Lingula"*
- *Linoproductus*
- *Martinia*
- *Orthotetes*
- *Productus*
- *Reticulariina*
- *Rhipidomella*
- *Phricodothyris*
- *Schellwienella*
- *Spirifer*
- *Tornifer*

Ostracodes
- *Amphissites*
- *Feffenina*
- *Geffenites*
- *Geisina*
- *Glyptopleura*
- *Healdia*
- *Microcoelonella*
- *Persansabella*
- *Sansabella*

Trilobites
- *Kaskia*
- *Paladin*

Gastropods
- *Bellerophon*
- *Murchisonia*
- *Naticopsis*
- *Orthonychia*
- *Platyceras*
- *Straparollus (Euomphalus)*
- *Strobeus*

Bivalves
- *Allorisma*
- *Nucula*
- *Phestia*
- *Sanguinolites*
- *Septimyalina*
- *Sulcapinna*

Nautiloids
- *Endolobus*

Edrioasteroids
- *Hemicystites*

Echinoids
- Miscellaneous plates and spines

Blastoids
- *Pentremites*

Crinoids
- *Agassizocrinus*
- *Ampelocrinus*
- *Cryphiocrinus*
- *Eupachycrinus*
- *Phacelocrinus*
- *Phanocrinus*
- *Platycrinus*
- *Talarocrinus*
- Miscellaneous plates, spines, and columnals

Miscellaneous Fish Teeth

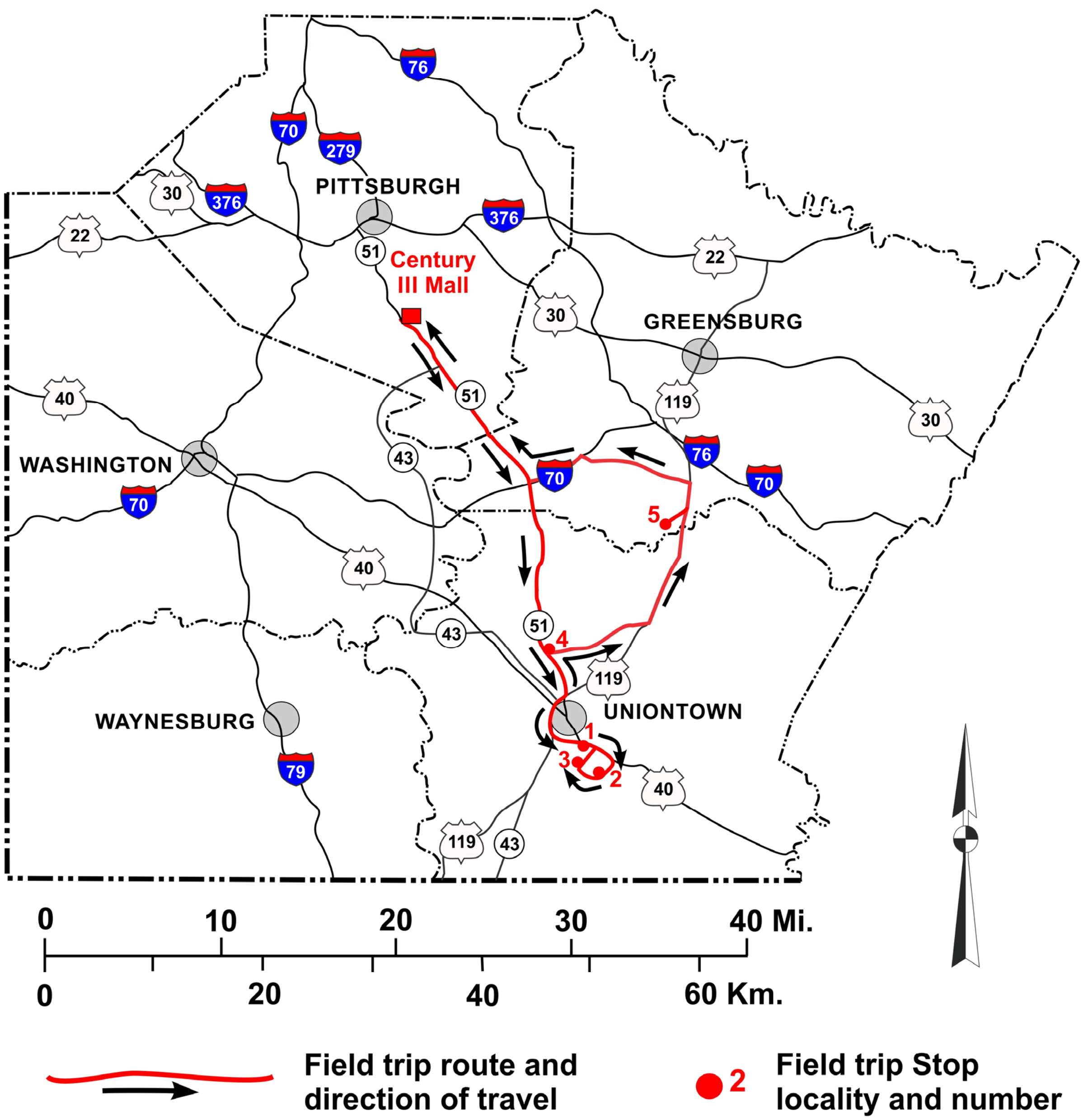


Figure 22. Simplified road map of southwestern Pennsylvanian showing the route of the field trip and the locations and numbers of Stops.

Road Log and Stop Descriptions

Mileage		
Int.	**Cum.**	**Description**
0.0	0.0	Leave Century III Mall and turn left onto PA 51 southbound at the traffic light. See Figure 22 for route map.
0.4	0.4	Southland shopping center on the left. The hills behind the shops on both sides of the highway have been affected by mine subsidence. Collapse features can be seen behind the northernmost shops at Southland, and mine collapse weakened the rocks behind the shops on the left enough that a large rockfall in the 1980s destroyed a couple of cars parked in the parking lot of a Ponderosa restaurant that was also damaged. The restaurant is no longer there.
0.9	1.3	Cross Lewis Run. Lewis Run winds back and forth beneath PA 51 over the next 2.6 mi (4.2 km) before entering Peters Creek.
2.2	3.5	Exit to PA 43, the Mon-Fayette Expressway to the right. Continue south on PA 51.
0.5	4.0	Cross Peters Creek in Large, PA, a community within the Borough of Jefferson Hills. Peters Creek starts in Nottingham Township, Washington County, and flows 16.8 mi (27 km) to the Monongahela River at Clairton, Allegheny County.
0.1	4.1	Cross Norfolk Southern Railroad tracks.
2.2	6.3	Cross the Regis R. Malady Bridge (also called the Elizabeth Bridge) over the Monongahela River and enter the Borough of Elizabeth.
0.1	6.4	Elizabeth was founded in 1787 by Samuel Mackay, Stephen Bayard, and Bayard's wife Elizabeth Mackay Bayard, and they named the place Elizabeth Town in honor of Bayard's wife. Elizabeth supposedly is the site where the keelboat used for the historic Lewis and Clark Expedition was built in 1803, although the City of Pittsburgh disputes that. The town was incorporated as a borough in 1834. Elizabeth also lends its name to one of the deepest oil and gas producing sandstones of the Upper Devonian Venango Group.
1.7	8.1	The road to the right leads to the Kelly Run landfill, which is currently operated by Waste Management. The original operator, William M. Fiore, was convicted and imprisoned for plotting to murder Chuck Duritsa, former Regional Director of the Pennsylvania Department of Environmental Protection. Fiore spent a total of 14 years in prison before dying in 2003 while still incarcerated, As the story goes, Chuck always got a bus home to Greensburg, and Fiore had one or two of his henchmen waiting to ambush Duritsa at his bus stop. But that particular day, Chuck had gotten a ride home with a coworker. Talk about being lucky!
1.8	9.9	Intersection with PA 48, Scenery Drive, to the left. Continue south on PA 51. Round Hill Park, one of Allegheny County's numerous parks, is about half a mile to the left. The park has a working from that helps supplement the park's expenses.
1.2	11.1	Exit to PA 136 to the right. Continue south on PA 51.
0.8	11.9	Enter Westmoreland County. Westmoreland County was formed in 1773 from part of Bedford County that lay to the west of Laurel Hill. Following

		the tradition of the time, the county was named for a county in England. One historian waggishly said the name was very appropriate because it lay to the **west** and had **more land** than had been occupied up to that time.
0.3	12.2	Rostraver Airport lies off to the left.
2.4	14.6	Exit to PA 201 on the right. Continue south on PA 51.
0.1	14.7	Cross over PA 201.
1.2	15.9	Cedar Creek Park, called the premiere access point to the Youghiogheny River Trail for Westmoreland County residents, is off the left.
1.1	17.0	Exit to I-70 W. Continue south on PA 51.
0.1	17.1	Cross I-70.
0.3	17.4	Intersection with PA 981 on left. Continue south on PA 51.
1.7	19.1	Enter Fayette County. Fayette County was created from the southern portion of Westmoreland County in September 1783 and named for the Marquis de la Fayette (Lafayette), the famous Frenchman who assisted George Washington during the American Revolution.
2.5	21.6	Enter the Borough of Perryopolis. This town has a lot of social and geologic history. George Washington bought some land here when it first became available. In 1770, he declared it "as fine a land as I have ever seen, a great deal of rich meadow; it is well watered and has a valuable mill seat." The mill was completed in 1776 and encouraged other businesses to follow. Eventually, the town of New Boston sprouted. Washington drew up plans for the streets to be laid out in the shape of a wagon-wheel, but he never saw his dream come to fruitition. After he died, his estate sold the land and, in 1814, the town was laid out using Washington's plans, and named for Admiral Oliver Hazard Perry, who won the famous victory of Lake Erie during the War of 1812. The main part of the borough is to the west of PA 51, but you can see the wagon-wheel shape of the town center in aerial photography (Figure 23).

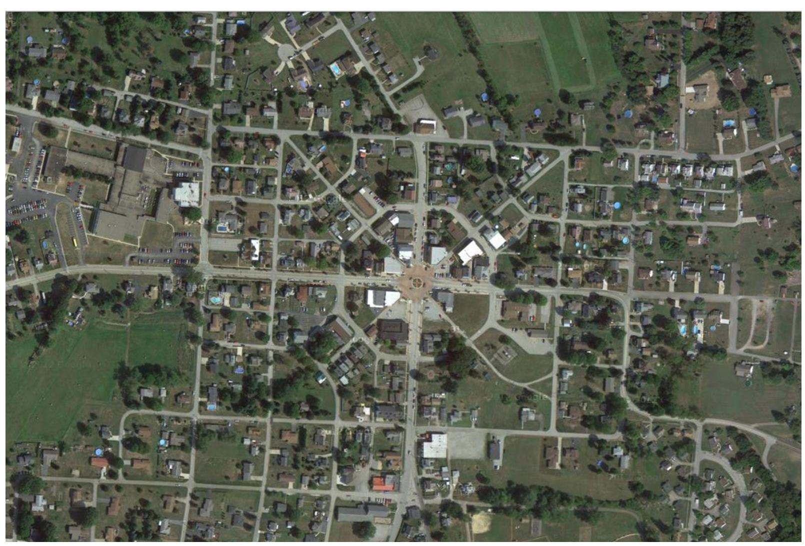


Figure 23. Aerial photograph of Perryopolis, showing the wagon-wheel-shaped town center, as laid out by George Washington, who originally owned the land. From Google Maps.

Geologically, Perryopolis and its environs lie within a cut-off meander of the Youghiogheny River. This meander was abandoned sometime before or during the early Pleistocene. The Pleistocene Carmichaels Formation

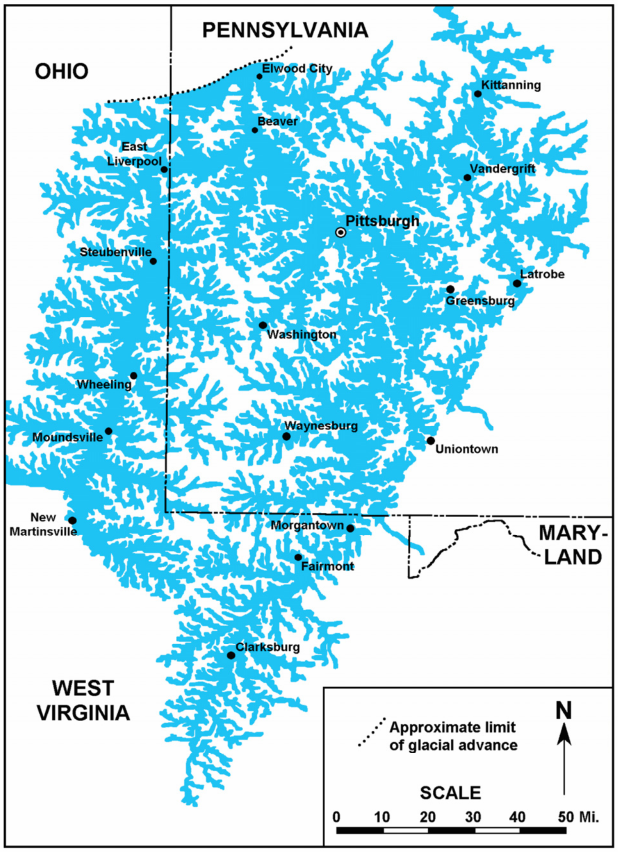


Figure 24. Reconstruction of the possible configuration of Lake Monongahela based on a water-surface elevation of 1,100 ft (335 m) above current mean sea level, as proposed by Marine (1997). The total extent of the lake in Ohio and Allegheny River valleys is not shown. Modern towns and state boundaries are included for reference. Image from Harper (2002).

consists mostly of alluvial and lacustrine deposits. The lowest material is coarse, because it was deposited by an active stream. Above and often interbedded with this are large clasts of rock that can be identified as bedrock the Youghiogheny River encountered in its trip through the Allegheny Mountain Section. Fine, laminar clays indicate deposition in quiet water, probably Lake Monongahela (Figure 24). The Carmichaels Formation is about 35 feet thick in Perryopolis, or at least it was before development of the area disturbed much of the land. In the late 1800s and early 1900s, the sand was being used to make glass, and the clays for brick. Campbell (1903) reported that Pleistocene plant fossils had been found in the clays here, but none of the fossils had been preserved for examination.

1.7 23.3 The historical marker on right reads: *COKE OVENS - The bee-hive ovens nearby are typical of the region. Coke was first made from coal near Connellsville in this type oven about 1840. Since 1870 use of coke has been vital to steel making.*

0.9 24.2 Enter Village of Star Junction. This village was founded when the Washington No.2 Mine was opened by the Washington Coal and Coke Company in 1893. The name derives from its origin as the railroad depot at the end of the line for the Washington Run Railroad. As in Perryopolis, Star Junction had its own coke oven business (Figure 25).

0.6 24.8 Exit to PA 201 on the right. Continue south on PA 51.

0.1 24.9 Cross under PA 201.

4.3 29.2 The fossiliferous Ames marine zone crops out just above the level of the

Figure 25. Beehive coke ovens operated in Star Junction. The coke ovens were in Stickel Hollow on the Washington Run Railroad, which later was owned by the P&LE Railroad. It appears that the rail bed became the four-lane PA 51 (from Boyles, 2018).

bench along the hillside to the left. This is actually a pretty good place to go fossil collecting.

0.3 29.5 Enter the Village of Waltersburg. Waltersburg is home to the Coal Miners Memorial at the Park Hill Mine & Coke Works. The Park Hill Mine & Coke Works opened in 1905 on the Pennsylvania Railroad and the P. V. & C. Railroad at Waltersburg. Besides the mines, Park Hill also operated 58 coke ovens). The Waltersburg gas field, one of the larger Upper Devonian gas fields in Fayette County, was discovered in 1910 along the axis of the Fayette anticline (Figure 26).

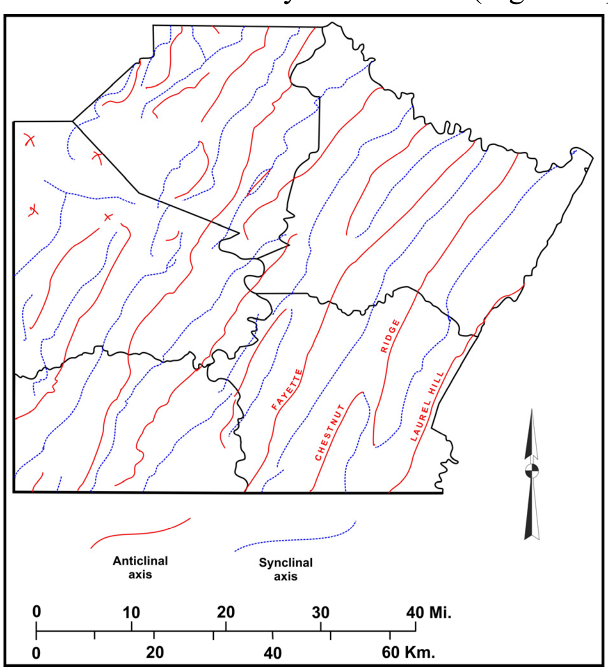
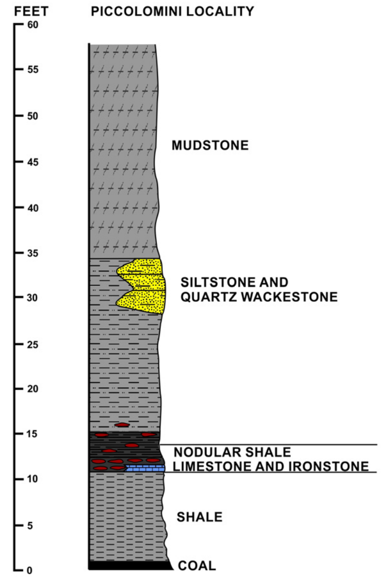


Figure 26. Structural axes of southwestern Pennsylvania (modified from Faill, 2011).

0.2 29.7 The Waltersburg Mine to the left is a coal strip mine in the Lower Bakerstown coal that was operated by Piccolomini Contractors Inc. Donahue et al. (1972) descibed and discussed the asymmetrical transgressive-

Figure 27. Stratigraphic section of the Woods Run marine zone and adjacent rock units at the Piccolomini coal mine in Waltersburg, Fayette County (modified from Shaak, 1975).



regressive nature of the Woods Run marine zone found at this mine (Figure 27). Unfortunately, they misidentified the marine zone as the Brush Creek based solely on the assumption that the black coloration of the marine shales associated with the limestone was unique to that marine zone.

0.9 30.6 Cross Redstone Creek. This is the creek that lent its name to the Redstone coal of the Monongahela Formation. Redstone Creek runs from the western slope of Chestnut Ridge near Uniontown to the Monongahela River at Brownsville. The creek was so named because the exposures of coal on the hillsides near Brownsville sometimes became ignited and burned, much as modern bone shale piles burn or smolder, turning the overlying shale a bright red color (called "clinker" or "red dog").

0.5 31.1 Enter the Village of Upper Middletown. This used to be called Plumsock, and is the site of the country's first puddling iron furnace (see Stop 4).

2.8 33.9 There's a good view of Chestnut Ridge and Uniontown ahead.

1.0 34.9 Cross under PA 43, the Mon-Fayette Expressway, westbound entrance ramp from US 119. Figure 28 shows the route map for this portion of the field trip, which includes the first three stops. Continue south on PA 51.

0.2 35.1 Cross under PA 43 eastbound entrance ramp to US 119 North, turn right onto entrance ramp to US 119 South, and merge with traffic.

0.9 36.0 Exit ramp to US 40 West. 0.2 mi (0.3 km) west on US 40 is a McDonald's Restaurant that is famous for introducing the Big Mac to the world. The Big Mac was created by Jim Delligatti, an early Ray Kroc franchisee, who was operating several restaurants in the Pittsburgh area. The sandwich was invented at Delligatti's McDonald's on McKnight Road in Ross Township. It was originally called the Aristocrat, but customers apparently found the name difficult to pronounce and understand. In a second attempt to introduce the sandwich, Delligatti named it the Blue Ribbon Burger. That failed also. Then Esther Glickstein Rose, a 21-year-old advertising secretary working at McDonald's corporate headquarters in Oak Brook, IL, suggested the name Big Mac and that stuck. The Big Mac debuted at Delligatti's Uniontown restaurant in 1967, selling for 45 cents. Delligatti designed it to

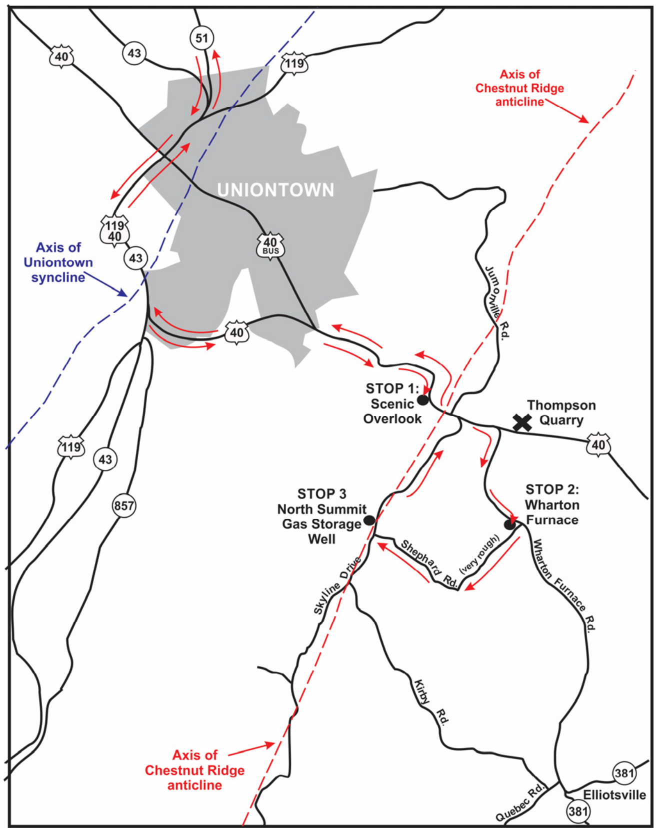


Figure 28. Map of the field trip route and localities for Stops 1 to 3 in the Uniontown/ Chestnut Ridge area.

		compete with the Big Boy sandwich, a popular burger sold at Eat 'n Park restaurants. The Big Mac proved popular, and it was added to the menu of all US McDonald's in 1968 (Anonymous, 2015).
		Continue south on US 119/40.
0.8	36.8	Exit ramp for McClellandtown Road. Continue straight on US 119South/US 40 East.
1.4	38.2	Exit ramp to Walnut Hill Road. Continue straight on US 119 South/US 40 East.
0.9	39.1	Get in either of the left two lanes and continue on US 40 East where US 119 South splits off to the right.
0.3	39.4	Cross under Morgantown Road (old US 119).
1.5	40.9	Cross bridge over Stadium Drive.
0.2	41.1	Cross bridge over Southwest Pennsylvania Railroad tracks.
0.2	41.3	Cross bridge over Redstone Furnace Road.
0.4	41.7	Exit ramp to Hopwood. Continue straight on US 40 East.
1.2	42.9	Runaway truck ramp and outcrop of Upper Mississippian Burgoon Formation on the left. Before the truck ramp was installed and US 40 straightened out, there was an S curve and this area was known locally as the "Turkey's Nest". According to Searight (1894) the area supposedly got its name from the workmen constructing the National Road who found a turkey's nest here. There was a stone bridge over Lick Run along this section of road that was one of the largest stone structures on the National Road. The

bridge had an immense stone wall on the south side (Figure 29). In the early 1900s the Automobile Club of Fayette County had hill-climbing races up and down the National Road that led to perilous moments for drivers at the "Turkey's Nest" and the S curve. Motor Age reported on a race that was "fatally exciting", i.e., two drivers died and several others were hospitalized (Anonymous, 2014).

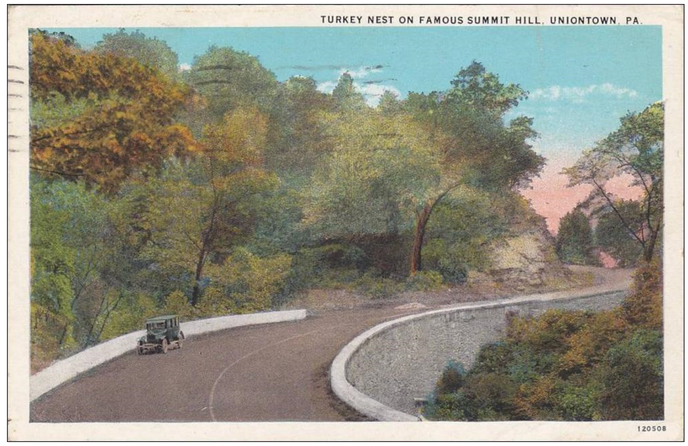


Figure 29. Vintage early 20th century postcard showing the S curve and stone bridge at the Turkey's Nest on the National Highway (now US 40) (from Playle's Auction, 2013). Notice the ledge of Burgoon Sandstone that, although pared back during road reconstruction, is still in evidence along the highway.

0.2 43.1 Exit to Lick Hollow Picnic Area on the right. Continue straight on US 40 East.

0.9 44.0 The open area to the left is the site of the former Big Watering Trough Restaurant and, later, the Empire Dance Hall. Originally, the area was occupied by William Downard who lived in a stone house built against the hillside. Because of limited space, he never set up a tavern, but he did maintain a spring and a big watering trough for the horses pulling wagons and stage coaches over the mountain on the National Road. Searight (1894) said it would have been almost impossible for big teams to make it up the mountain in hot weather without the water. Apparently, Mr. Downard was eccentric, however, and refused to let people he didn't like use the water. Later, when the restaurant opened, there was enough room to park automobiles, and their owners used the water to refill the radiators (Figure 30). Today, the buildings are long gone, but the trough is still there and it is called Lick Hollow Spring (FindASpring.com, 2016). A long rubber hose propped up by a cinderblock spews out gallons of cold, fresh mountain water into the trough, which then empties and continues flowing down the

Figure 30. Vintage early 20th century post-card showing the Big Watering Trough Restaurant on the Nation Highway (now US 40) about 5 mi (8 km) east of Uniontown (from Miner, 2015).

mountain beside US 40.

0.4 44.4 Bear right into the Scenic Overlook parking area.

STOP 1. SCENIC OVERLOOK AND INTRODUCTION TO THE GEOLOGY OF CHESTNUT RIDGE

Introduction

At this first stop, we have a scenic overview of Uniontown and the northwest flank of Chestnut Ridge anticline. Looking across the Uniontown syncline, you can see Hopwood in the near distance and Uniontown behind it (Figure 31), although I dare anyone to show me where the one ends and the other begins. Hopwood is a historic village founded by John Hopwood in November 1791. The village was a major resting stop to and from the western territory along the National Road and as such it was a site of considerable commerce. Hopwood has evolved with the times, yet many significant National Road period structures remain today. The village boasts several native cut-stone houses and many former inns and taverns, including several on the National Register of Historic Sites. The city of Uniontown was founded by Henry Beeson on July 4, 1776, the date of the signing of the Declaration of Independence. The National Road was routed through Uniontown in the early 1800s and the town grew along with the Road.

Figure 31. View of Uniontown and the northwest slope of Chestnut Ridge from Stop 1, the scenic overview on US 40 near the summit of the mountain. "On a clear day, you can see forever", but it wasn't an especially clear day when the photo was taken.

Uniontown is the birthplace of General George Marshall, author of the Marshall Plan that helped reconstruct Europe after World War II. It has hosted nine US Presidents, and been the home of several historic figures.

The Chestnut Ridge Anticline

From this vantage point we can see only a tiny portion of Chestnut Ridge, the surface expression of one of western Pennsylvania's anticlines. This and other folds in southwestern Pennsylvania (Figure 32) were produced during the formation of the Appalachian Mountains. They are subdued structures by comparison to the intensely folded and faulted strata in central Pennsylvania, but they are still significantly complex as a result of steeply dipping strata, faulting, lineations, and a complex array of joints. All the "major" anticlinal folds in western Pennsylvania generally are arcuate, being convex to the northwest and parallel to the arc of the central Appalachians. Structural

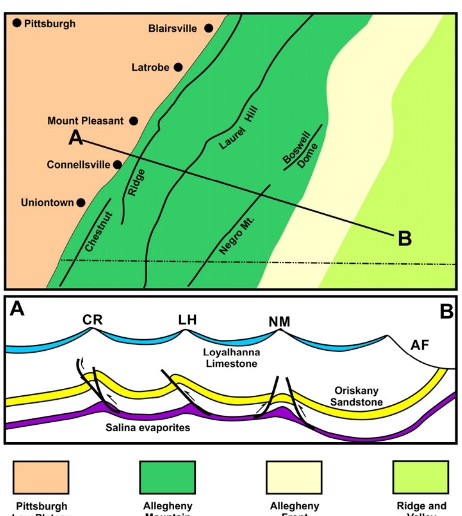
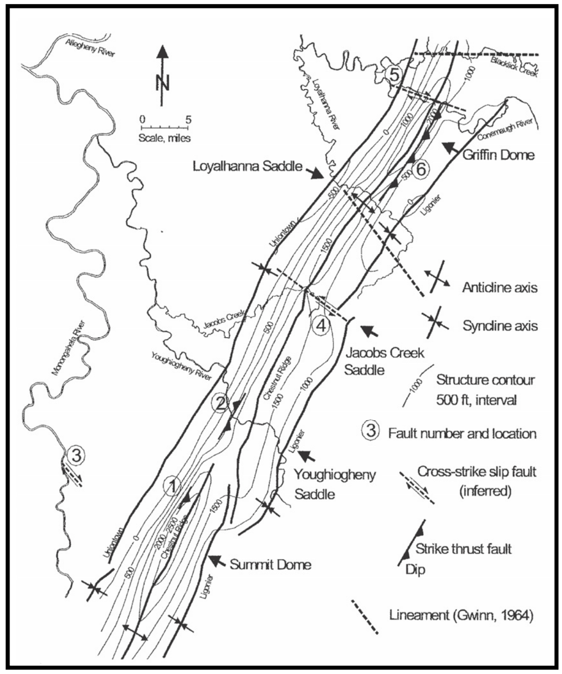


Figure 32. Location of the "major" anticlinal structures and a generalized cross-section through southwestern Pennsylvania (modified from Iannacchione and Coyle, 2002).

Figure 33. Generalized structure contour map of Chestnut Ridge from Fayette County to Indiana County on the top of the Loyalhanna Formation with major fold structures, surface faults, lineaments, and rivers and streams (from Iannacchione and Coyle, 2002).



relief on these anticlines decreases to the northwest. The Chestnut Ridge anticline forms the western boundary of the Allegheny Mountains, being the westernmost anticline having significant structural relief. The amplitude of folding in the Allegheny Mountains approaches 3,000 feet. Bedding commonly dips 5 degrees, but on the western flank of Chestnut Ridge bedding steepens to an average of 8 degrees, and is nearly 25 degrees approximately 2 miles west of the summit (McElroy, 1988). West of Chestnut Ridge, folding is much more gentle, with the maximum amplitude between the Fayette anticline and the Uniontown syncline (the anticline and syncline to the west of Chestnut Ridge) at 900 feet.

Hickok and Moyer (1940), Shaffner (1958, 1963), McElroy (1988), and Iannacchione and Coyle (2002) all reported on the shape and character of the Chestnut Ridge anticline. The crest of the anticline varies in elevation significantly; the highest areas form enclosed contour elevations (domes) with Summit dome lying midway between the Cheat River gorge to the southeast in West Virginia and the Youghiogheny River gorge to the northeast (Figure 33). Giffin Dome lies farther northeast between Loyalhanna Creek in Westmoreland County and Blacklick Creek in Indiana County. Three prominent structural depressions (saddles) have rivers or streams that cross them: 1) the Youghiogheny River crosses the anticline at the Youghiogheny saddle northeast of the Summit dome; 2) Jacobs Creek crosses the Jacobs Creek saddle northeast of the Youghiogheny saddle; and 3) Loyalhanna Creek crosses at the Loyalhanna saddle southwest of the Giffin dome. The structure and stratigraphy of the field trip area, with the locations of the first three stops, are shown in Figure 34.

No major faults extend to the surface in Fayette County, although Hickock and Moyer (1940) reported three minor faults. Seismic sections and gas well logs indicate that numerous faults exist in the deep subsurface beneath Chestnut Ridge (Shumaker, 2002; see Stop 3 for more information). A moderate amount of jointing may be found in some limestone and sandstone beds. Sandstone jointing is commonly confined to thick, homogeneous beds (McElroy, 1988)

Caves and Caverns

There are 33 known caves along the length of Chestnut Ridge (Iannacchione and Coyle, 2002); most if not all are in the Mississippian Loyalhanna Formation. The caves generally consist of a single passage extending several hundred yards, but a few, such as Laurel Caverns, are made up of extensive interconnecting passages. Most of the caves are found within Summit and Griffin domes, two structural highs along Chestnut Ridge (Figure 33). In these areas, the Loyalhanna has the greatest elevations and outcrop exposures, producing deeply weathered joints and, in many places, caves.

Oil and Gas Exploration

Drilling for oil and natural gas along Chestnut Ridge began possibly early in the 20th

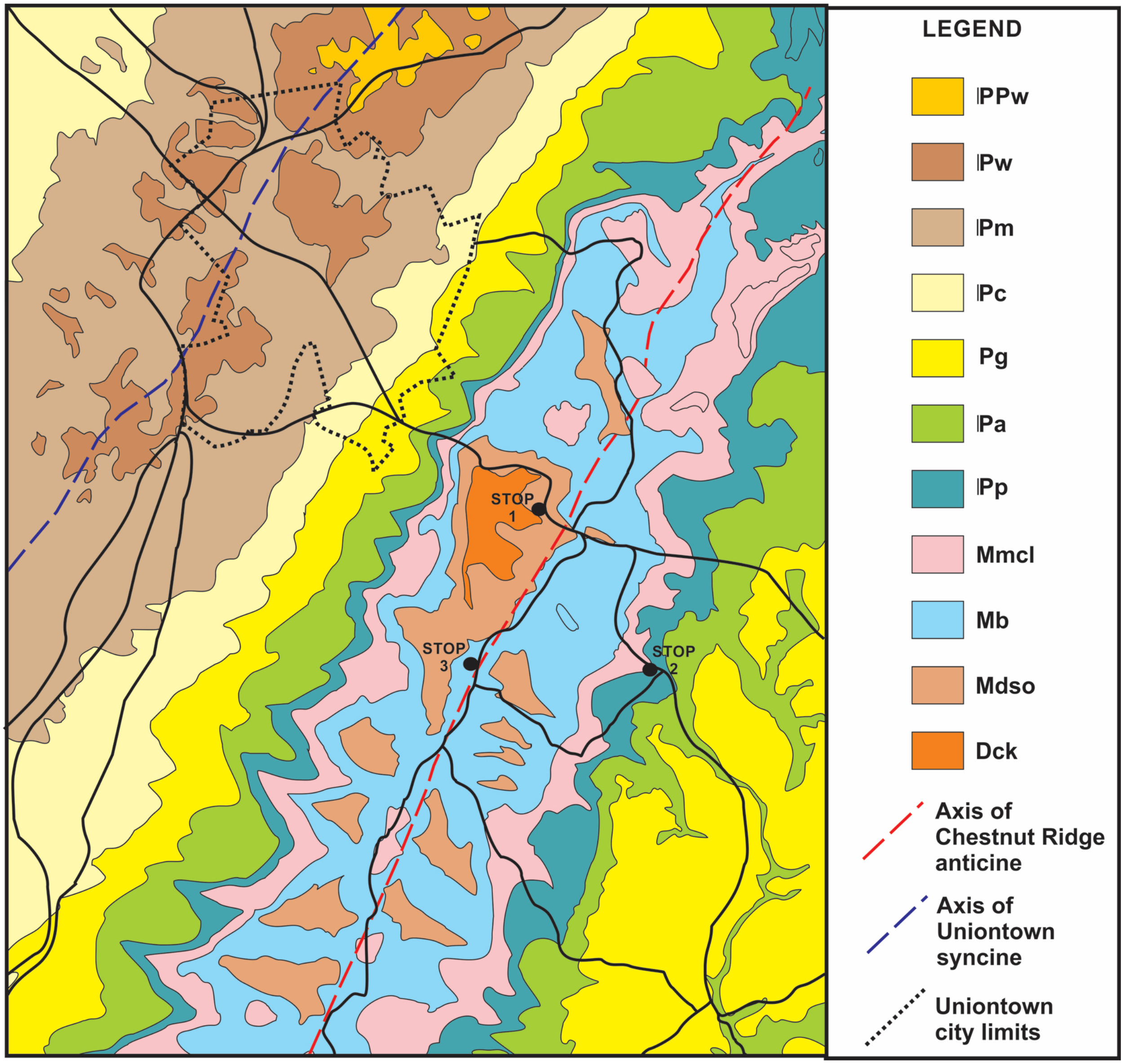


Figure 34. Geologic map of the field trip area (based on McElroy, 1988, pl. 1) showing the roads and the first three stop locations on Chestnut Ridge . Abbreviations in the legend include: Dck – Catskill Formation; MDso – Shenango Formation through Oswayo Formation; Mb – Burgoon Formation; Mmcl – Mauch Chunk and Loyalhanna formations; IPp – Pottsville Formation; IPa – Allegheny Formation; IPg – Glenshaw Formation; IPc – Casselman Formation; IPm – Monongahela Formation; IP – Waynesburg Formation; IPP – Washington Formation.

Century with exploration of shallow (Pennsylvanian through Upper Devonian) rocks in Indiana County. Deep drilling (to targets below the Upper-Middle Devonian boundary) began in March 1935 when William E. Snee, an explorer from West Elizabeth, PA, formed a partnership with the Potter Development Company of Potter County, PA, and began drilling a well to test the Lower Devonian Oriskany Sandstone on Summit dome (Fettke, 1940). The first well, drilled by cable tool rig on the lease of Leo F. Heyn (which includes the location of the Summit Inn), encountered 1,800 thousand cubic feet of natural gas (Mcfg) with an initial rock pressure over 3,025 pounds per square inch (psi) at a depth of 6,611 ft (2,015 m) in the upper part of the Middle Devonian Huntersville Chert in August 1936. The well was finally completed for production in April 1937. Over the next two years, five more producing wells and a dry hole were completed on the dome, which became known as Summit field, and more were drilled in the 1940s. During all of this activity, the anticline and dome were viewed as being relatively simple structures. With additional exploration in the second half of the 20th Century, previously unsuspected structures were discovered at depth, particularly in wells drilled to or through the Silurian Salina Group salt beds. Geologists found repeated geologic sections that suggested significant faulting occurred from below the base of the Devonian up into the more shaly section of the Upper Devonian. The Middle Devonian section is intensely faulted. The faults originate within the Salina and quickly rise into a series of branching splay thrust faults under the limbs of the anticline. Yet the section below the Salina salt appeared to be regular with little or no evidence of complex structure because the salt acts as one of the principal décollements beneath much of western Pennsylvania.

For additional information on gas exploration and storage, and the deep structure of Chestnut Ridge, see Stop 3.

Leave Stop 1 and carefully merge with traffic on US 40 East.

Figure 35. Vintage early 20th century postcard showing the historic Summit Inn at the summit of Chestnut Ridge on the National Highway (now US 40). From Summit Inn Resort (2012).

0.5 44.9 Historic Summit Inn Resort (Figure 35) on the right. Searight (1894, p. 232) wrote, "[The Summit Inn] ... is on the apex of Laurel Hill, and has the advantage of pure air, and an extensive and charming; view of the surrounding and underlying country. At this point large finger boards were erected, indicating distances and routes to the Washington Springs, Dulaney's Cave [Laurel Caverns] and Jumonville's Grave, which are landmarks indelibly impressed upon the memories of surviving wagoners and stage drivers. The property here belongs to Col. Samuel Evans, a wealthy and well known citizen of Fayette county. Ephraim McClean kept the house here for many years, and made it famous by the excellence and style of his entertainment. His flannel cakes and spring chickens have passed into history, as unrivalled productions of culinary art and tempters of the appetite. There is a large spring and bath house here. This has ever been a favorite resort of parties in pursuit of pleasure. Here the youth, beauty and fashion of Uniontown were wont to come to while away an evening in eating, dancing and other diversions. The rooms were small, but the pleasure was unbounded. Here also the yeomanry of the county came to make a harvest home, or celebrate an anniversary. The drive, up and down the mountain, is delightful, and formed no small share of the pleasure incident to the old time parties at this popu1ar place of resort."

The road to the left goes to Jumonville Glen, part of the Fort Necessity

		Historic Site. It is part of Braddock's Road. Just past the Summit Inn on the right is Skyline Drive. It is the most direct route to Laurel Caverns. Continue straight on US 40 East.
0.7	45.6	Turn right onto SR 2003, Wharton Furnace Road and drive south toward Elliotsville.
0.3	45.9	Jackson Drive on the left. Continue south on Wharton Furnace Road.
0.8	46.7	Enter Forbes State Forest. Beware of deer crossing the road.
0.7	47.4	Bear right into the parking area of Wharton Furnace just before the intersection with Shephard Road.
1.6	51.8	Intersection with Skyline Drive. Turn right.
0.1	51.9	Pull to the side of the road and cross Skyline Drive to the fenced-in-area.

STOP 2: HISTORIC WHARTON CHARCOAL BLAST FURNACE

Introduction

Wharton Furnace is located in Forbes State Forest along Wharton Furnace Road about two miles south of US 40 on the eastern flank of Chestnut Ridge. The furnace was built along Chaney Run in 1837 by Andrew Stewart (1791-1872) (Figure 36), a member of the U.S. House of Representatives. It went into operation in 1839. Stewart began construction in 1837 and began operating it as a cold-blast furnace in 1839 with a capacity of three tons. He converted it to hot-blast in 1855 and increased its yield to seven tons in the process. Lesley (1859) claimed the furnace had not been operated for years when he wrote his seminal book on the iron industry in the US, but Stevenson (1878) and McCumber (2007) indicated that it produced as late as 1873, including manufacturing cannonballs for the Union during the Civil War. Figure 37 is a portion of a local property tax map of the area showing the furnace, related outbuildings, and access roads. Stewart managed the furnace until 1856. It was blown in again in 1858 and kept in blast until being idled. The iron was hauled to Brownsville, loaded onto flatboats on the Monongahela River, and shipped to Pittsburgh.

Figure 36. Drawing of the Honorable Andrew Stewart (from Find A Grave, 2003).

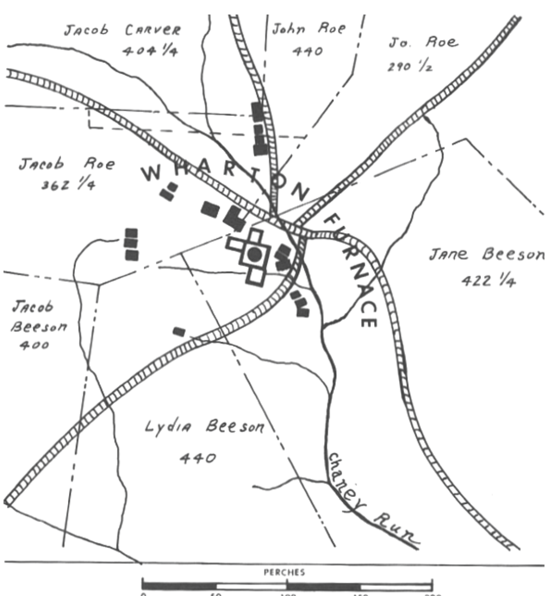


Figure 37. Property tax map of the Wharton Furnace area showing the locations of the furnace, outbuildings, and roads (from Coke Oven Mike, 2017).

The Pennsylvania Department of the Interior (now Conservation and Natural Resources) restored the Wharton Furnace in 1962, clearing the land, repairing the stack, and building a small parking lot and small bridge over the creek for visitor access (McCumber, 2007). The cut stone stack (Figure 38A) measures 33 ft (10 m) wide, by 31 ft (9.5 m) deep, by 31 ft (9.5 m) high. Commemorative plaques interpret the site, and a large slab of pig iron, supposedly one of the last ingots produced at

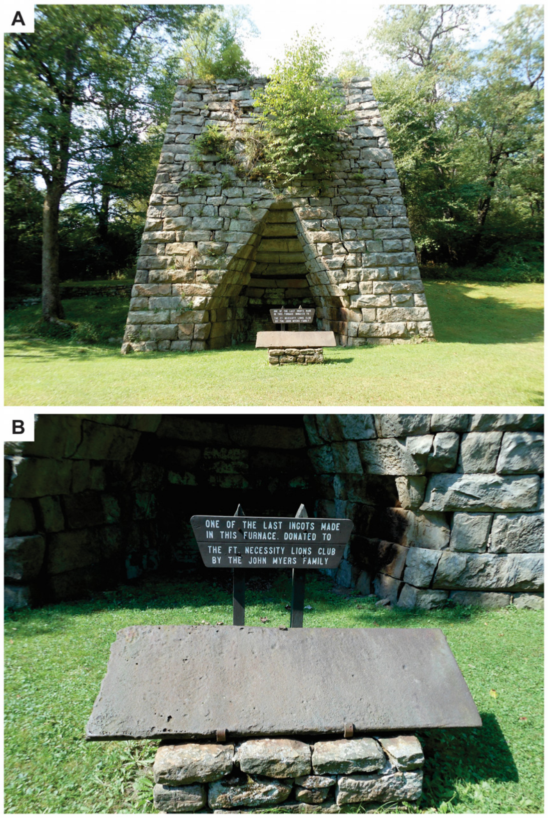


Figure 38. Photos of the remains of Wharton Furnace at Stop 2: A – The stack from the front. B – One of the last ingots produced at the furnace.

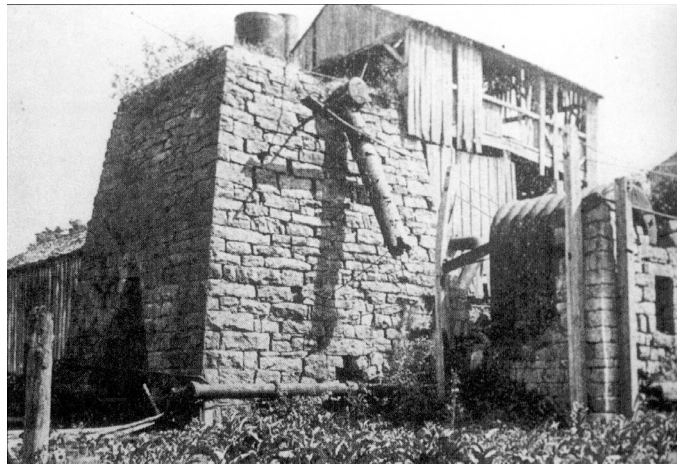


Figure 39. 1899 photograph of Wharton Furnace (from Coke Oven Mike, 2017).

the furnace, is on display in front of the stack (Figure 38B). Figure 39 shows the furnace as it appeared in the 1899.

The Furnace

The stack was built and lined with Morgantown sandstone (Casselman Formation), which occurs on the hill across the creek from the furnace (Stevenson, 1878). It is also possible that the Bolivar fireclay (Allegheny Formation), which is 10 ft (3 m) thick where it is exposed near the furnace, was used for the refractory bricks. Stevenson (1878) said the "Mount Savage coal bed" (= Upper Mercer coal of modern usage) was mined extensively at the furnace. He found three mine openings while doing field work in the 1870s, but all had been deserted for many years. A pile of cinders near the furnace indicated that the coal was of inferior quality. The operators tried to use it for coking, but it contained too much sulfur and ash and it was rejected after a short test. The "Mountain limestone" (the combined Reynolds, Wymps Gap, and Deer Valley limestones – see Figure 17) was quarried on Chaneys Creek about a mile from Wharton Furnace and used for flux at the furnace. The Reynolds Limestone was no longer exposed in the 1870s, but the Wymps Gap was 20 ft (6 m) thick and loaded with fossils. It was separated from the 8-ft (2.5-m) thick Deer Valley by about 40 ft (12 m) of shale.

Iron Ore

Until 1880, Pennsylvania produced more iron ore than any other state in the nation (Brown and Ehrenfeld, 1913). Despite this statistic, there generally was not enough ore produced in the state to supply all the iron furnaces and foundries, and most ore was imported to meet local demand. Iron ore was discovered in Fayette County before 1792.

For the most part, the ores mined and smelted in western Pennsylvania consisted of siderite. In Fayette County, these typically came from beds associated either with coal seams or in the Pottsville Formation (Mercer ores – see Figures 3 and 9), although the Mauch Chunk apparently provided some mineable beds on the east side of Chestnut Ridge. Siderite is a low-quality iron ore, with an average of 48.27 percent iron, as opposed to magnetite (Fe_3O_4) with 72.4 percent iron and hematite (Fe_2O_3) with 70 percent iron (Ashley, 1931).

Stevenson (1878) found that there was often a shell of iron oxide (hematite) on the siderite close to the outcrop. He described the ore mined at Wharton Furnace as being from what he called the "Little Flag ore bed" (Figure 40), which he considered to be hematite, rather than siderite. Hickok and Moyer (1940) agreed. They described thin beds of hematitic ore in the upper beds of the Upper Mississippian Mauch Chunk Formation on the eastern flank of Chestnut Ridge south of the Youghiogheny River. Most of these ore beds are only a few inches thick, but near Wharton Furnace one of the beds was as much as 2 ft (0.6 m) thick. Stevenson (1878) stated that the ores were mined energetically both by benching and drifting, with benching extending for long distances both north and south from Chaneys Creek. An additional ore bed, called the Big Bottom, was opened on the hillside as well, but was completely concealed when Stevenson was there. Stevenson (1878, p. 220) found the quantity of good ore sufficient to supply the furnace:

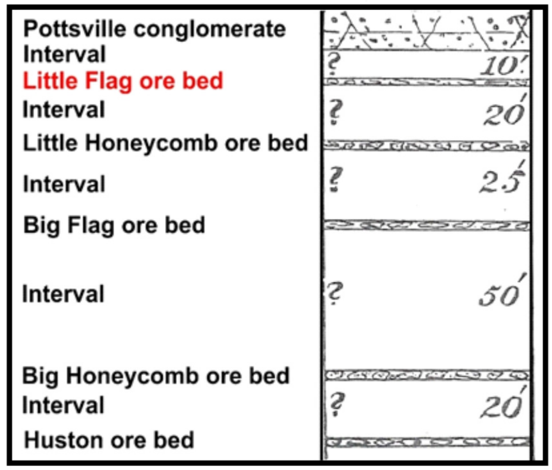


Figure 40. Stevenson's (1878) section of Pottsville and Mauch Chunk on the hillside about 0.24 mi (0.4 km) west of Wharton Furnace showing the placement and names of Mauch Chunk iron ore beds. The Little Flag ore bed (in red) was the primary ore used in Wharton Furnace.

> The ores near Wharton Furnace seem to be present in great quantity and to be of excellent quality, but owing to the dilapidated condition of all the drifts and benchings it was found impossible to inspect the beds or to procure specimens for analysis. It is sufficient, however that from these ores iron of excellent quality was made during many years and that the cost of manufacture was moderate. All the profits were absorbed by the cost of shipping the metal to market, as the nearest outlet was at Brownsville on the Monongahela, 20 miles away, to which point the iron had to be hauled in wagons.

Stevenson described the ore beds as ranging from 3 to 10 in (7.5 to 25.5 cm) thick, with the percentage of iron ranging from 22 to 35 percent. In all occurrences, he found the ores had been oxidized on the outcrop but, except for the Little Honeycomb and Little Flag, all were siderite at the time of mining.

Exit the parking area, turn right onto Shephard Road, and cross Chaney Run

1.0	48.4	Cross McIntire Run.
0.5	48.9	At the intersection, turn right and continue on Shephard Road.
1.6	50.5	Intersection with Skyline Drive. Turn right.
0.1	50.6	Pull to the side of the road and cross Skyline Drive to the fenced-in area.

STOP 3: NATURAL GAS STORAGE IN NORTH SUMMIT STORAGE FIELD

Introduction

Anyone driving along Skyline Drive between Laurel Caverns and US 40 would have to be blind or completely unobservant to not notice the gas storage field equipment sitting in clearings both beside the road and back in the forest. On the other hand, the lay person should not be expected to know the difference between a gas production well and a gas storage well.

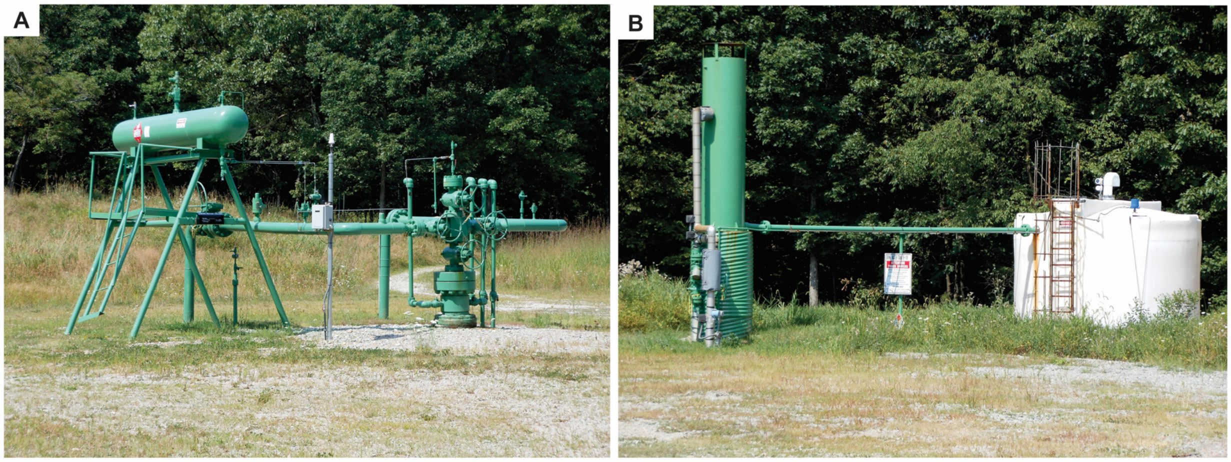


Figure 41. Photos of the Indian Creek Coal & Coke Co. well at Stop 5: Left– the gas well's "Christmas tree" is on the right; Right – a fluids storage tank.

The well site where we're stopping (Figure 41) is now a gas storage well, but it was originally drilled as a producing gas well. This is the New Penn Development Co. and William E. Snee #1 Indian Creek Coal & Coke Company well drilled on the William Johnson lease in 1938. It was the third well drilled by the partnership. By March 11, 1939, the well was making about 900 thousand cubic feet of gas (Mcfg) from 115 ft (35 m) into the Middle Devonian Huntersville Chert. When the well finally reached the Oriskany Sandstone at 7,103 ft (2,165 m), they found the Oriskany was dry.

North Summit Storage Field

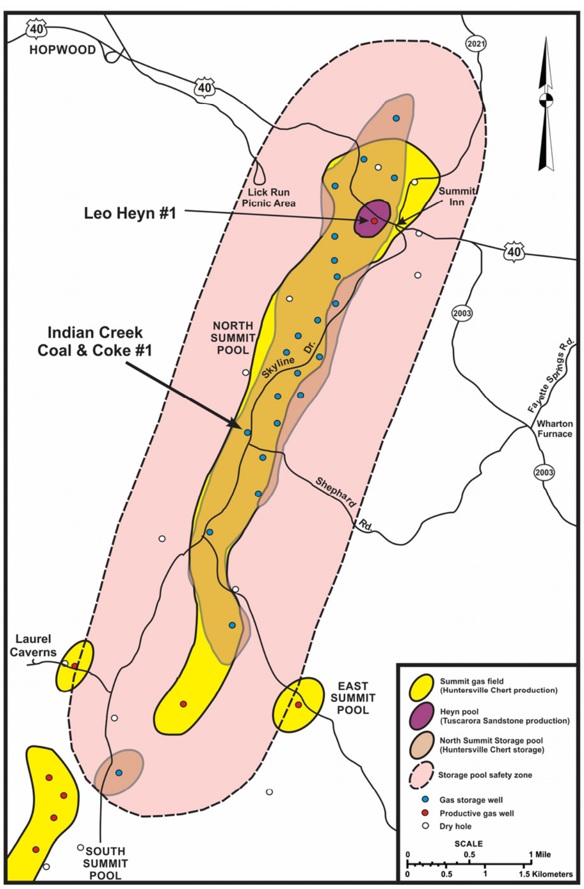


Figure 42. Map of North Summit Storage field (based on Shumaker, 2002 and files of the Pennsylvania Geological Survey).

The North Summit Storage field (Figure 42) is located about 4 mi (6.5 km) southeast of Uniontown on the Chestnut Ridge anticline. The Summit field, as it was originally called, was discovered in 1937 with the completion of the Snee and New Penn #1 Heyn well near the Summit Inn. Discovery of the field was based on the anticlinal theory. The Heyn well was spudded using a cable-tool rig on the topographic crest of the mountain and was completed on April 23, 1937 with an initial open flow of 2,000 Mcfg and a pressure of 4,478 psi at a depth of 6,611 ft (2,015 m) in the Middle Devonian Huntersville Chert (Figure 43; see below). With that discovery, development of the field proceeded rapidly, with 14 producing wells and several dry holes defining the limits of the reservoir. In 1943, the Heyn well was drilled deeper to 7019 ft (2,139 m), then to 8,450 ft (2,576 m) in 1944. Tests reported 100 Mcfg containing hydrogen sulfide in the Helderberg limestones at 7,183 to 7,200 ft (2,189 to 2,195 m) and 650 Mcfg at 7,300 to 7,345 ft (2,225 to 2,239 m) in the Upper Silurian Tonoloway (below the Helderberg). These shows were not enough for a commercial well, however. In 1964, the well was once again deepened, to 11,571 ft (3,527 m) to test the Lower Silurian Tuscarora Sandstone. The well supposedly flowed 2,000 Mcfg in the Tuscarora after hydraulic fracturing, but the gas tested at only 865 BTU. Normally, natural gas has a BTU value of about 1,000 with a composition that includes greater than 90 percent methane and a few percent ethane. The Tuscarora gas had only 82 percent methane and two percent ethane. Fully 15 percent of the gas composition was nitrogen, whereas in a normal natural gas the nitrogen content typically is less than one percent. Between the high nitrogen content and other troubles with the well, it was plugged and abandoned on August 16, 1964. In 1967, another Tuscarora test was drilled in the Snee #1 Ricks well to a depth of 12,041 ft (3,670 m) on the east flank of the surface fold about 1 mi (1.6 km) southeast of the Heyn well.

Subsequent drilling on Chestnut Ridge discovered additional pools on separate fault blocks, prompting the original area to be called North Summit pool. The North Summit pool was converted to natural gas storage during the 1990s by Consolidated Natural Gas Company (CNG). It is now operated by Dominion Transmission, Inc. Natural gas is pumped into the reservoir in the off-peak season for later use in the winter months. An extensive series of pipelines connects the field with suppliers in the southwest and consumers in the northeast.

Stratigraphy

The primary producing and storage formation in North Summit field is the Middle Devonian Huntersville Chert (Figure 43). This formation occurs primarily in western Pennsylvania and West Virginia, with the best development south of Clarion and Jefferson counties in Pennsylvania. In general, the formation grades eastward into the Needmore Shale, northward into the Clarence Member of the Onondaga Limestone, and westward into the Bois Blanc Formation. Lithologically, it is typically microcrystalline, massive, and hard, varying from translucent to opaque, and in color from white to dark brown and dark gray. It commonly includes some dolomite, quartz, glauconite, pyrite, calcite, and trace fossils (Flaherty, 1996). Sherrard and Heald (1984) considered the Huntersville to be of biogenic origin because of the large quantities of sponge spicules present throughout the formation. Because it lacks feldspathic and pyroclastic material, a volcanic origin is unlikely. Basan and others (1980) suggested the formation resulted from diagenetic replacement of carbonate sediment, indicated by replacement of skeletal calcite, relict carbonate fabrics, and gradation from solid chert to siliceous limestone (and to nodular chert in the Bois Blanc to the west.) The

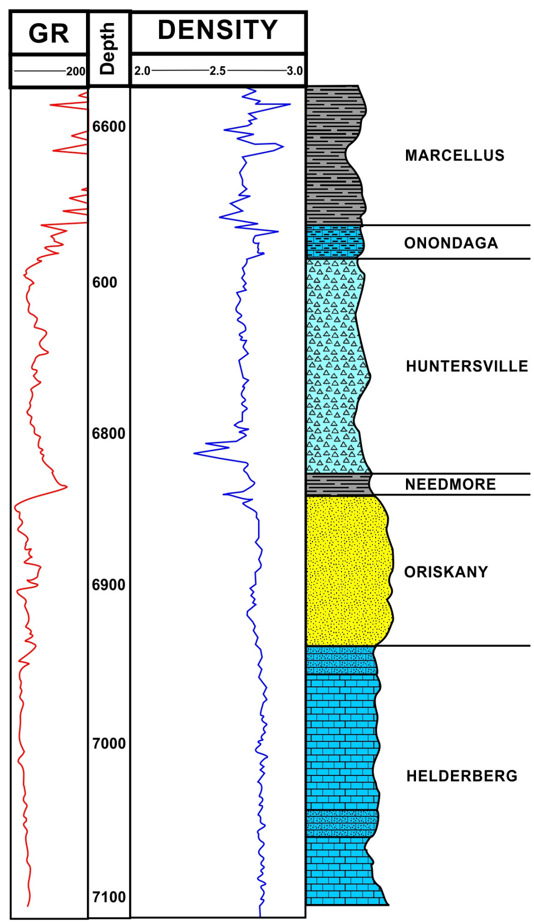


Figure 43. Stratigraphic section from the Middle Devonian Marcellus Formation to the Lower Devonian Helderberg Group in the North Summit Storage field (modified from Shumaker, 2002). The original target of drilling was the Oriskany Sandstone, but gas was found instead in the fractured Huntersville Chert.

Huntersville varies in thickness from less than 100 ft (30 m) near the northern limit in Forest and Elk counties to more than 250 ft (76 m) in Greene County, Pennsylvania, and Monongalia County, West Virginia.

The Lower Devonian Oriskany Sandstone acts as a secondary reservoir throughout most of the area where the Huntersville Chert occurs. It is typically a light gray, medium- to coarse-grained quartz sandstone. The grains commonly are cemented with calcite or silica (Edmunds and Berg, 1971; Flaherty, 1996). The formation ranges from about 17 ft (5 m) thick in the northern and western parts of western Pennsylvania to 241 ft (73.5 m) thick in southeastern West Virginia, averaging 68 ft (20.7 m) (Flaherty, 1996).

Geologic Structure

Campbell (1902) described and named the Chestnut Ridge anticline based on surface stratigraphic units found on the topographic ridge. Structural relief at the surface is about 3,000 ft (914 m) into the Uniontown syncline on the northwest, but only about 2,000 ft (610 m) into the Ligonier syncline on the southeast (Cathcart and others, 1939; McElroy, 1988). Surface rocks basically are unfaulted, but Hickok and Moyer (1940) found a small southeast-dipping reverse fault along old US 40 on the west flank of the fold and Shumaker (2002) found a small, west-dipping reverse fault in the Mauch Chunk and Loyalhanna section at a quarry about three miles northwest of Summit. Joints in the exposed sandstones and limestones on the anticline form an orthogonal system (Hickok and Moyer, 1940). Coal cleats are close to parallel with joint trends in other rocks.

At depth, the gas reservoir is complexly faulted. Gwinn (1964) provided a generalized cross section across the anticline to the south of North Summit Storage field (Figure 44A) and a structural map of the area (Figure 44B) and indicated that the thrust faults in his diagram extend northward through the storage field. Gwinn (1964) emphasized the concept that Oriskany and Huntersville reservoirs were broad folds formed from fault sheets thrust over a depressed core. This model of a broad surface fold cored by outward-dipping flank thrusts adjacent to a relatively undeformed and depressed axial zone has been widely accepted for Appalachian

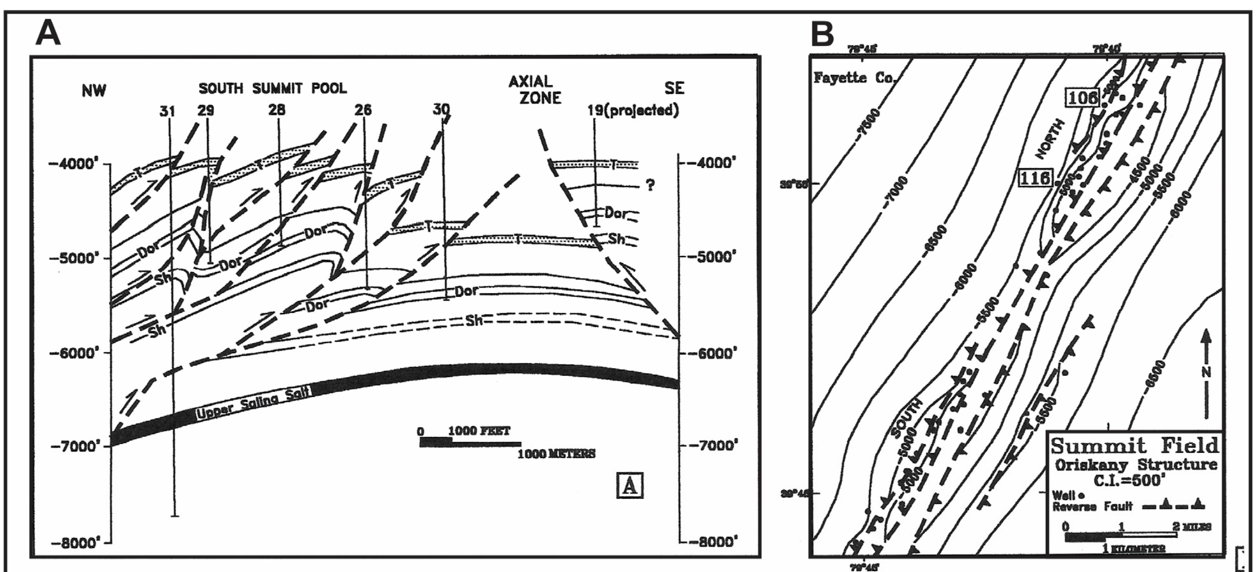


Figure 44. A – Cross section of Chestnut Ridge south of North Summit Storage field showing Gwinn's (1964) concept of Appalachian Plateau folds. At depth, the anticline supposedly is a graben overstepped by thrust sheets splaying off the detachment fault in the Upper Silurian Salina salt beds. B – Structural map of the area (from Gwinn, 1964).

Plateau anticlines for many years (see for example, Harper, 1989; Harper and Patchen, 2003). Gwinn's cross sections suggest that rocks above the Salina detachment deformed as a single lithostructural unit. Gwinn also indicates that Oriskany and Huntersville gas in Appalachian Plateau structures was trapped by sealing faults in an imbricated reservoir. Interpretations vary regarding the stratigraphic level of the primary detachment horizon under the Allegheny Mountains. Gwinn (1964) suggested that the Chestnut Ridge anticline is detached at the level of both the Upper Ordovician Utica and Reedsville shales and the Salina salt beds. He also postulated that those folds detached in the Utica and Reedsville determine the location of folds above the Salina salt beds in the Allegheny Mountains of Pennsylvania and West Virginia. In addition, Shumaker (2002) pointed out that shales of the Middle Cambrian Rome Formation form an important basal detachment horizon in high-relief folds of the Allegheny Mountains adjacent to the Allegheny Front in West Virginia, so this detachment should not be ignored.

Shumaker (2002) used new data, particularly new seismic sections and modern geophysical logs run by CNG in both old wells and newly drilled ones, to reinterpret the structure of Chestnut Ridge anticline at the level of the Huntersville Chert and Oriskany Sandstone. His analysis showed that Gwinn's (1964) faulted and depressed axial zone is actually an anticlinal fold (compare Figure 44 with Figures 45 and 46) – the crest of the subsurface anticline follows the crest of the surface anticline! New data from several wells

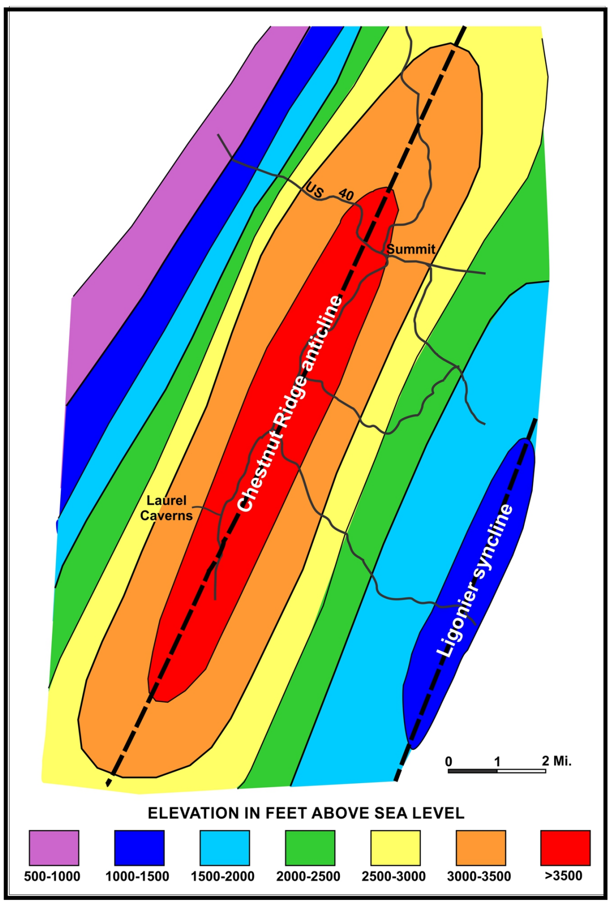


Figure 45. Surface structure of Chestnut Ridge southeast of Uniontown. Structure contours on the Middle Pennsylvanian Upper Freeport coal, Allegheny Formation, are estimated in most places. Modified from McElroy (1988) and Shumaker (2002).

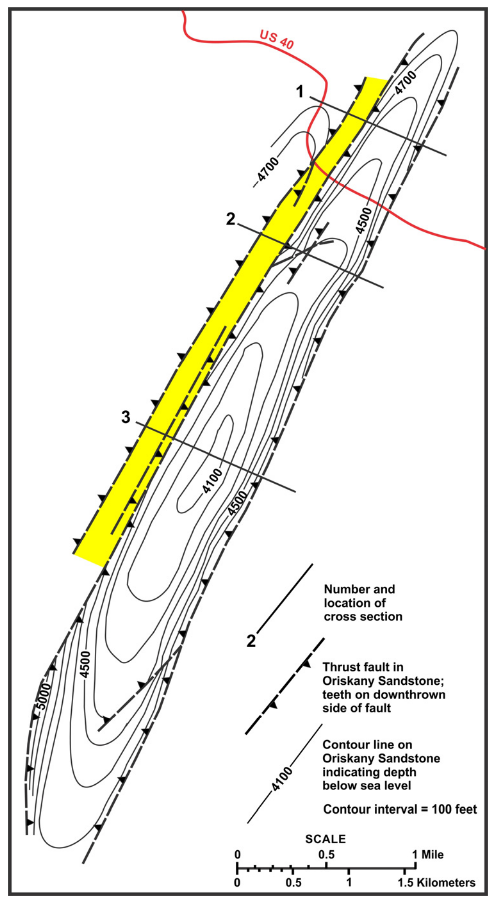


Figure 46. Structure map of Chestnut Ridge on the Lower Devonian Oriskany Sandstone (modified from Shumaker, 2002). Compare with Figure 45. Lines 1 to 3 indicate lines of cross section shown in Figures 47 to 49.

confirm the presence of a structural high west of the central anticline, but that they are separated by a deep structural low (Figure 46). Shumaker (2002) provided three cross sections of the anticline interpreted from all of the new data (Figures 47to 49) that show Chestnut Ridge is far more structurally complex at depth than anyone suspected. Mull these illustrations over for a while and see if you develop a headache!

The strata above the Middle Devonian Tully Limestone is far less deformed than the rocks below it. Wiltschko and Chappel (1977) suggested that most of the deep faults splaying off the Salina detachment were absorbed by the Upper Devonian shales and did not extend above the Tully. Although the frequency of faulting is far less at the surface than at depth, there are faults in the shallow (Pennsylvanian and Mississippian) strata along Chestnut Ridge. Whether these are extensions of the Lower and Middle Devonian faults, or are merely mimicking them, is unknown.

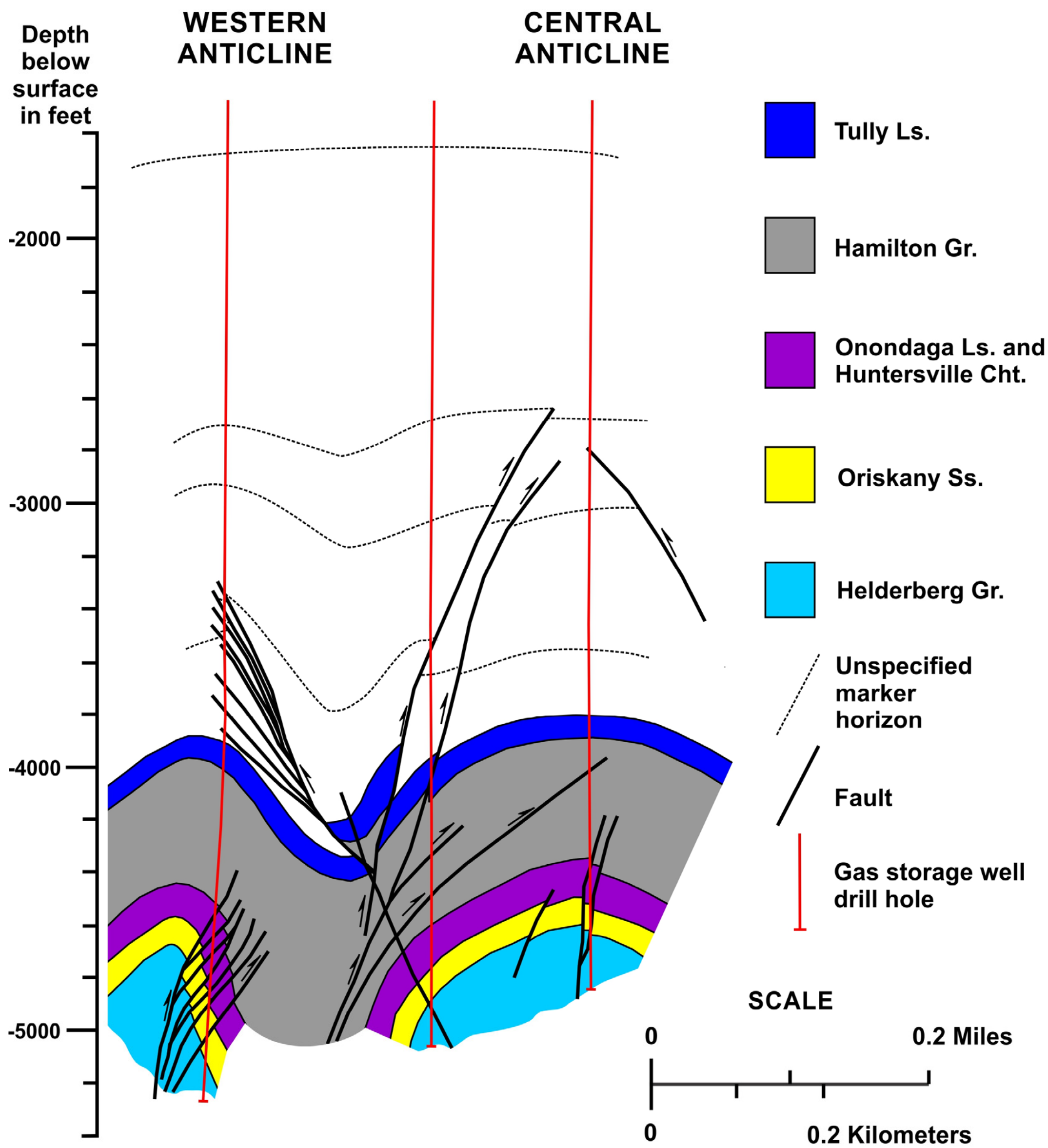


Figure 47. Cross section 1 (modified from Shumaker, 2002; see Figure 46 for the location).

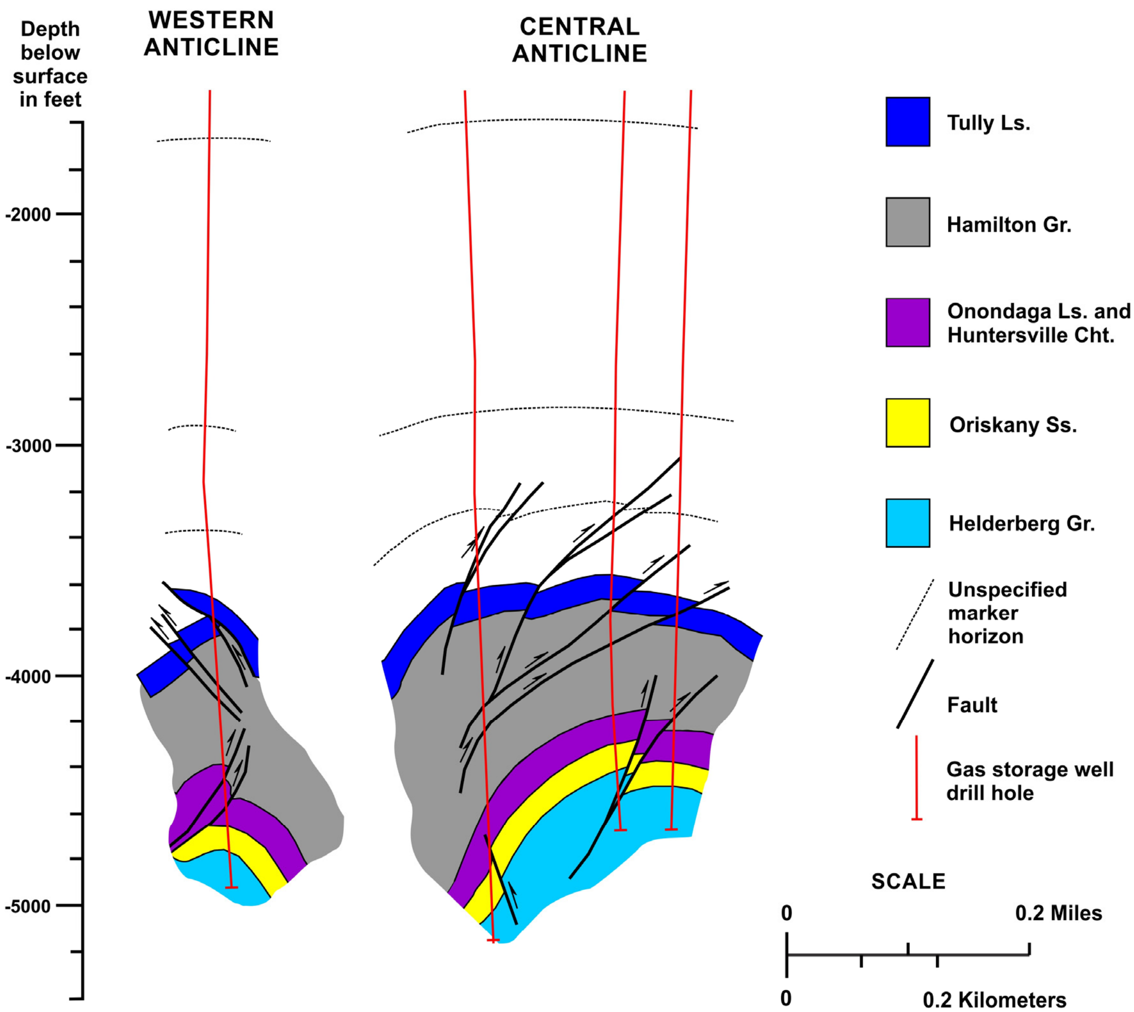


Figure 48. Cross section 2 (modified from Shumaker, 2002; see Figure 46 for the location).

Leave Stop 4 and continue north on Skyline Drive. You will notice storage equipment and access roads on both sides of Skyline Drive almost as far as US 40.

1.3	53.2	Leaving Forbes State Forest.
0.5	53.7	Summit Golf Course on the right.
0.4	54.1	Historic Summit Inn on the right at intersection with US 40. Carefully turn left onto US 40 West.
0.9	55.0	The watering trough (see mile 44.0) can be seen to the right.
1.1	56.1	Runaway truck ramp at the "Turkey's Nest" on the right.
0.6	56.7	Business Route US 40 exits to the right. Continue straight on US 40 West.
2.9	59.6	Cross Morgantown Road and continue straight on US 40 West.
0.5	60.1	Merge with traffic from US 119 and continue straight on US 119 North/US 40 West.

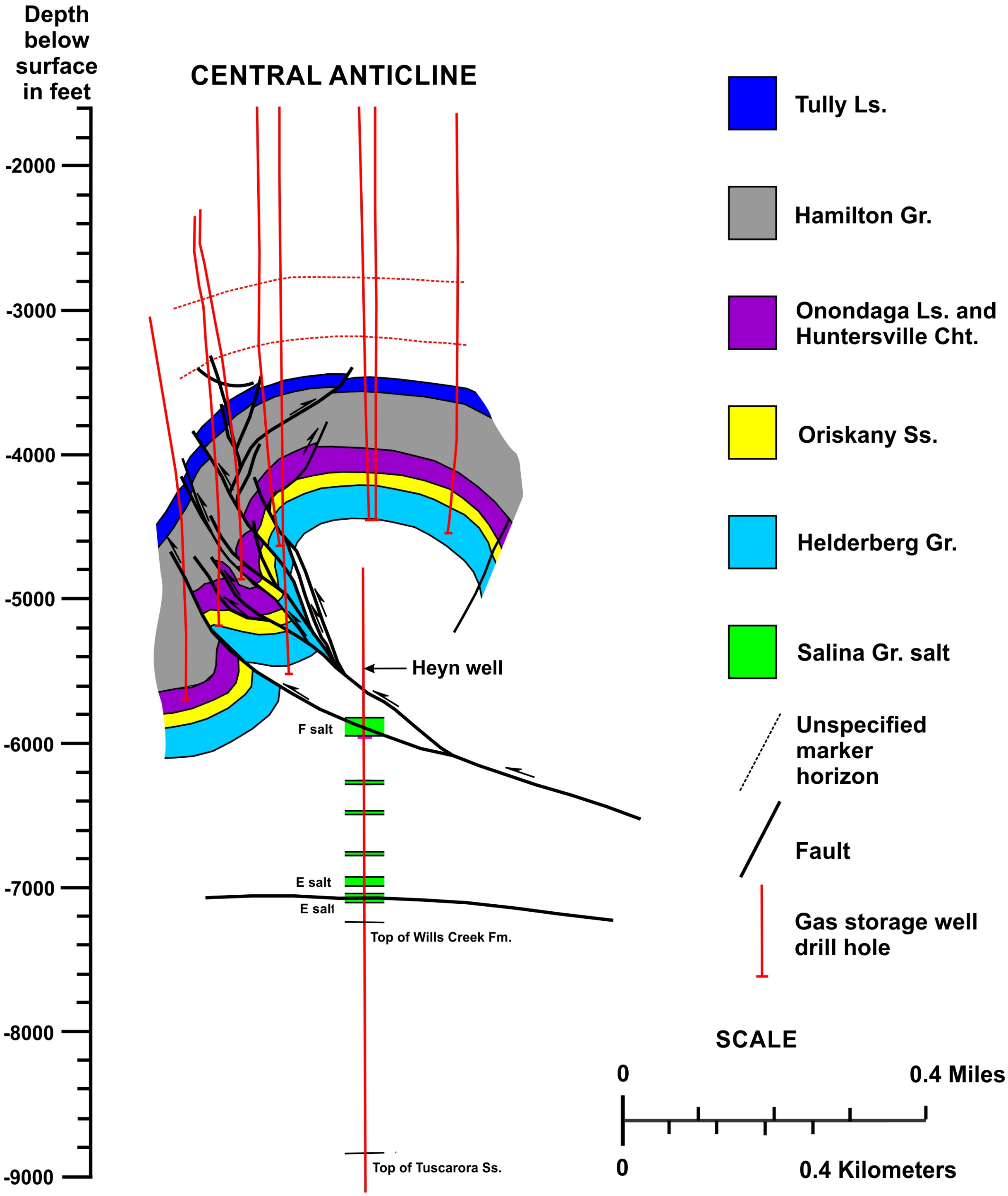


Figure 49. Cross section 3 (modified from Shumaker, 2002; see Figure 46 for the location).

0.3	60.4	Exit to Walnut Hill Road on the right. Continue straight on US 119 North/US 40 West.
1.4	61.8	Exit to McClellandtown Road, PA 21, on the right. Continue straight on US 119 North/US 40 West.
0.8	62.6	Exit to West Main Street, US 40 West, on the right. Continue straight on US 119 North.
1.0	63.6	Bear right onto exit ramp for Pittsburgh Street (PA 51).
0.2	63.8	Turn left onto PA 51 North.
2.5	66.3	Intersection with Cutler Road to the left, Bitner Road to the right.
1.5	67.8	Intersection with Keisterville West Middletown Road to the left, Laurel Hill Road to the right. Turn right onto Laurel Hill Road, then left into the parking lot of Uniontown Kawasaki. Pull over to the far left and park by the historical marker.

STOP 4: THE COUNTRY'S FIRST PUDDLING IRON FURNACE

Introduction

On September 10, 2017, the Pennsylvania Historical & Museum Commission (PHMC) and the Fayette County Historical Society (FCHS) unveiled a new historical marker along PA 51 in that commemorates a new way to manufacture iron introduced to America in 1817 (Figure 50). The text of the marker reads:

AMERICA'S FIRST IRON PUDDLING FURNACE

In 1817 ironmaster Isaac Meason and Welshman Thomas Lewis built a puddling furnace and bar rolling mill here using a process from Wales that revolutionized the iron industry. It removed carbon from brittle pig iron creating malleable wrought iron in one step, making iron production much more efficient and less costly. Later, "puddlers" in Pittsburgh formed the first metals union, the Sons of Vulcan, forerunner of United Steelworkers.

The marker resulted from more than two years of research by retired Pittsburgh metallurgist and geology enthusiast Dr. Norman L. Samways (Figure 50 center; see also Dedication on p. ii), whose interest in early iron manufacturing in Pennsylvania led him to rediscover the location of America's first puddling furnace. Although "iron puddling" sounds like it must have something to do with molten iron spilling on the factory floor, it was an important step toward modern steelmaking. Dr. Samways brought the potential for a historical marker to the attention of the HMC and the FCHS.

Figure 50. Historical marker dedicated September 10, 2017 in Fayette County. Participating in the ceremony were, from left to right, Fayette County Historical Society president Christine Buckelew, Norman L. Samways, retired metallurgist whose research led to the marker's creation, and the Pennsylvania Historical & Museum Commission's Kenneth Turner (from Harper, 2018).

Isaac Meason, Fayette County's Premier Iron Master

Isaac Meason (1743-1818) was a legend in Fayette County. Born in Frederick County, Virginia, he moved to Fayette County sometime around 1770. In 1789, he became involved in iron manufacturing when he built and began operating Union Furnace, one of the first furnaces to produce iron west of the Allegheny Mountains. He eventually became one of the wealthiest men in western Pennsylvania (Abraham, 1937). Over the years, Meason's wealth and prosperity allowed him to become involved in all manner of local commercial, judicial, and political power brokering in the area. He was an associate judge of Fayette County for many years and a member of the Supreme Executive Council of Pennsylvania. Besides iron works, he built grist mills and salt works; he was intimately involved in the construction of the first bridge across the Youghiogheny River at Connellsville; and he had enough foresight and business sense to provide the iron necessary for the construction of the first iron suspension bridge in America, on Jacob's Creek near where he lived (Abraham, 1937; Morrison, 1983).

Fayette County was well situated to become a leader in iron manufacturing when Meason arrived because it had abundant natural resources as well as major lines of transportation that ran through or near it (the National Highway, now US 40, and the Youghiogheny and Monongahela rivers). Iron ore was found in many places in the county, especially on the western side of Chestnut Ridge. Limestone for flux was plentiful. There were numerous streams that could be dammed to provide water to power the bellows in the furnaces. Fireclays associated with numerous coal seams were available to make refractory bricks[5] . Western Pennsylvania was a vast forest that provided the raw material for making charcoal. Even secondary resources, like good quality sandstones for building furnace stacks, were plentiful (Kollar and others, 2014). Meason took advantage of all of it and provided both Fayette County and the burgeoning foundry industry in the Pittsburgh area with an abundance of pig iron that could be made into a variety of implements.

Pig iron, which has a relatively high carbon content, is brittle. The manufacture of many usable items, such as nails, tools, barrel hoops, shovels, and plows, required iron to be ductile, which in turn required multiple reheatings and forgings under large, crude trip hammers to remove the carbon. Isaac Meason made a fortune manufacturing pig iron, but the process of manufacturing good-quality iron was unsatisfactory and time-consuming, and it was next to impossible to roll the iron into bars or sheets.

Thomas C. Lewis and Isaac Meason

The puddling process (see below) was invented by an Englishman named Henry Cort in 1783–84 and patented in 1784 (Landes, 2003), and soon became very popular in England and Wales. In 1815, Thomas C. Lewis, who had much experience with puddling furnaces and rolling mills in his native Wales, came to America to promote interest in these new technologies. He tried to convince ironmasters in New Jersey and eastern Pennsylvania that iron could be rolled into bars, but they thought his concept wildly impractical, if not impossible. So, Lewis moved west to Fayette County where he encountered Isaac Meason. Meason immediately saw the viability of the technology Lewis described and entered into an agreement with him to build and operate the new furnace and rolling mill. Ellis (1882, p. 240) described an amusing incident that occurred while the new puddling furnace was being built.

> Two iron-masters from Lancaster County, by the names of Hughes and Boyer, rode all the way on horseback, nearly two hundred miles, went to Mr. Meason, and tried to convince him that it was impossible to roll iron into bars. Mr. Meason told them to go and talk to Mr. Lewis about it, which they did, and told him it was a shame for him to impose on Mr. Meason, as it might ruin the old gentleman. Mr. Lewis replied to Mr. Hughes, "You know you can eat?" "Why, yes," he knew that. "Well, how do

you know it?" He could not give a reason why, but he knew he could eat. "Well," says Mr. Lewis, "I will tell you how you know it, - you have done it before; and that is why I know I can roll bar iron. I have done it before!" "Very well," said Mr. Hughes," go ahead, and when you are ready to start let us know, and we will come and see the failure.

According to promise they did come on, but left perfectly satisfied of its success . . .

America's First Puddling Iron Furnace

The mill was built in 1816 and 1817 on Redstone Creek at Plumsock (now Upper Middletown – see Figure 51) on the site of a forge built by Jeremiah Pears sometime around 1794 (Ellis, 1882). The property and all its facilities, which included a saw-mill, grist-mill, slitting mill, and rolling mill (built before 1800, probably the first rolling mill west of the Alleghenies), as well as the forge (Swank, 1892), had come into Meason's possession in 1815 (Ellis, 1882), and this was chosen as the location of the new furnace. Lewis was appointed the chief engineer in the construction of the new mill. His brother George, a first-rate mechanic, came over from Wales after the mill opened to be in charge of the rolling mill; two other brothers also worked at the furnace (Samways, 2016). The new mill, built for making bars of all sizes and hoops for cutting into nails, incorporated two puddling furnaces, a refinery, a heating

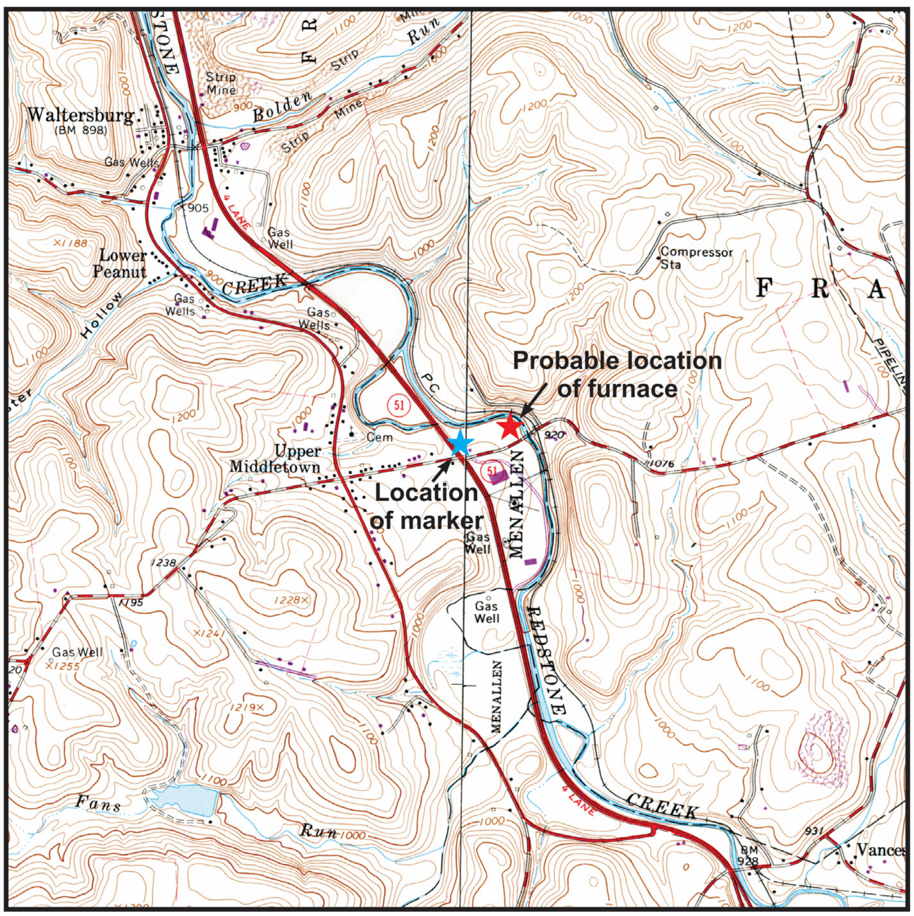


Figure 51. Location of the historical marker (blue star) commemorating the first iron puddling furnace in North America, and the most likely location of the furnace (red star). The vertical black line in the center is the boundary between the New Salem (left) and Uniontown (right) 7.5-minute topographic quadrangles (modified from Harper, 2018).

furnace, a tilt-hammer, and a lathe for turning the rolled bars of iron; coal, rather than charcoal, was used in the puddling and heating furnaces and coke was used in the refinery. The pig iron, initially forged in a blast furnace (Figure 2), was puddled (see below). The grooved rolls made for the bar rolling process were cast at Dunbar Furnace, another Meason property in nearby Dunbar. The mill went into operation on September 15, 1817 and, although Meason died in 1818, it continued to operate until 1831 when a flood in Redstone Creek caused the partial destruction of the mill. Following that, the machinery was disassembled and taken to Brownsville on the Monongahela River (Swank, 1892).

It took a while before the proven success of puddling and rolling found a wider audience. In 1844 and 1845, the manufacture of rails for railroad tracks began in earnest, giving puddling a leading position in the manufacture of iron in America (Fritz, 1910). Before too long, other puddling and bar rolling mills were springing up around western Pennsylvania. By 1819, four of them were operating in Pittsburgh.

The process of puddling iron is significantly different from forging pig iron, which was the practice in the 18th and early 19th century (see Stop 2). The biggest advantage of a puddling furnace (Figure 52) was in keeping carbon in the fuel from coming into contact with the iron by separating them in the hearth and blowing hot air from the burning fuel over the iron. In the process, a two-man crew consisting of a puddler and his helper were armed with long, hooked rods called “puddling bars”. The furnace was charged by placing pig iron or cast iron in the metal bath area and then heating it until the top began to melt, forming a “puddle” (Samways, 2016), then an oxide such as mill scale was added. This process typically took about one half hour. A shallow wall separated the metal from the fuel, thus preventing the introduction of additional carbon into the iron. A strong current of air was blown through and the puddler or his helper stirred the mixture with a puddling bar through doors in the furnace. This helped oxygen in the atmosphere to react with any impurities in the pig iron to escape as gas or to form a slag. As more fuel was added, the temperature of the mixture rose from 1,150 to 1,538°C (2,100 to 2,800°F), allowing the iron to melt completely and the carbon to burn off. Eventually,

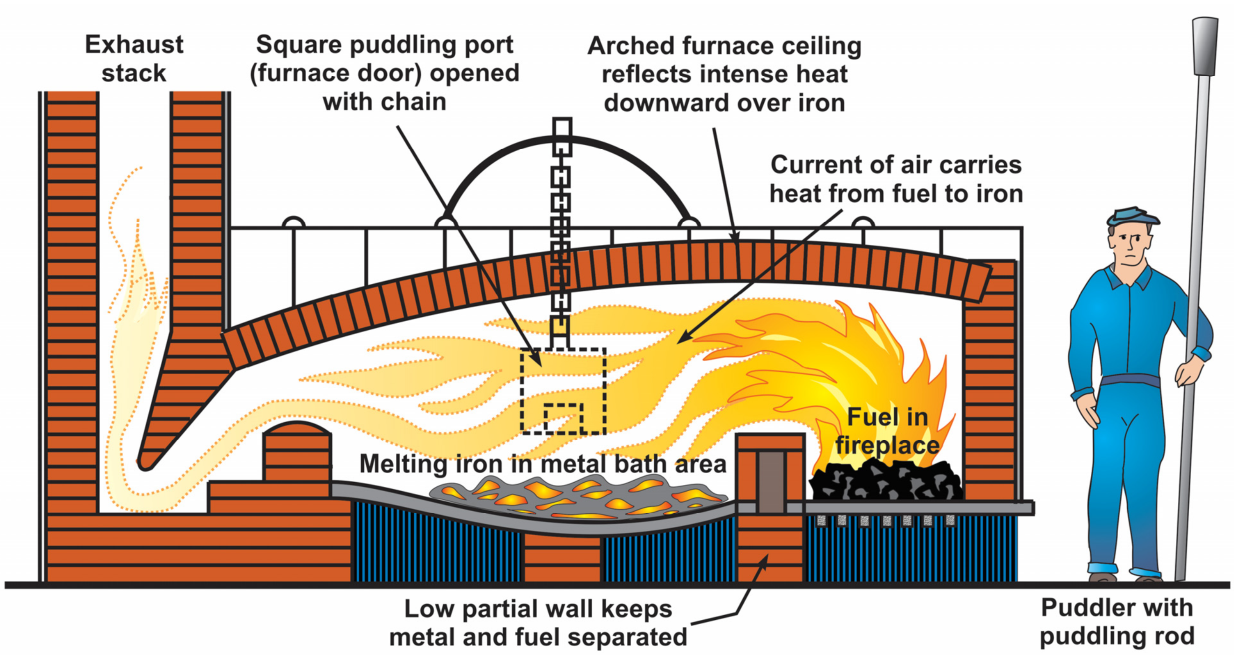


Figure 52. Schematic diagram and terminology of a typical puddling iron furnace (modified from Samways, 2016). See text for explanations of how these furnaces worked. Not to scale. Based on a drawing by David J. Vater.

when most of the carbon had burned off, the metal began forming into a spongy ball of wrought iron weighing about 35 to 40 kg (75 to 90 lb). Then the puddler used the hook on the puddling bar, or a pair of tongs, to pull the large balls out of the furnace where they were taken directly to be rolled into flat or round bars. Working together, the puddler and his helper could produce about 1.6 tons of malleable iron in a half-day shift. Unfortunately, the life of a puddler typically was short, about 30 or 40 years, because of the exposure to intense heat and fumes, as well as the strenuous labor involved. But because the puddler had to be highly skilled and able to sense when the iron balls were ready to be removed from the furnace, the process was never able to be automated (Landes, 2003).

The puddling process dominated iron making for nearly 80 years. The Bessemer process, which produced steel, began to replace the puddling furnace in the 1850s. It converted pig iron into steel for a fraction of the cost and time that a puddling furnace required to make wrought iron. An average puddling furnace used a charge of about 365 or 410 kg (800 or 900 lb), whereas a Bessemer converter used a charge of 15 tons (Overman, 1854). Because the puddling process was limited by the amount that a puddling crew could handle, it was impossible to increase the effectiveness of a puddling furnace. It couldn't be scaled up; it could only be expanded by increasing the number of furnaces and puddlers.

Unionization

The construction of the first puddling furnace and rolling mill in the U.S. led to a major change in the way American iron and steel were manufactured, but it also led to many social changes. After a strike by puddlers in Pittsburgh in 1849 and 1850 practically shut down the industry, the companies countered by lowering wages and hiring new puddlers. In 1858, a group of puddlers met in a bar in downtown Pittsburgh and formed a labor union called The Iron City Forge of the Sons of Vulcan (Brody, 1960). This was the first American labor union to represent iron and steel workers, and it was also the strongest union in the country. Although the American Civil War boosted demand for steel, giving the puddlers a raise in wages, when the war ended in 1864, the steel plant owners cut wages, forcing the Sons of Vulcan to go on strike. The strike lasted eight months, after which the owners of American Iron works (forerunner of J&L Steel) negotiated a contract with the Sons of Vulcan that set wages based on the price of iron. This was the first union contract in America. The Sons of Vulcan lasted until 1876 when, after numerous mergers and reorganizations, it became the Amalgamated Association of Iron and Steel Workers, what we know today as the United Steelworks (USW) (Brody, 1960), currently the largest union in North America.

Leave the parking lot, and turn left onto Laurel Hill Road.

0.2	68.0	Cross Redstone Creek.
1.3	69.3	Intersection with Strong Road and the name changes to Upper Middletown Road. Continue straight on Upper Middletown Road.
0.5	69.8	Intersection with Bitner Road. Continue straight on Upper Middletown Road.
0.9	70.7	Intersection with Elm Grove Road on the left and Barron Road on the right and the name changes back to Laurel Hill Road. Laurel Hill Presbyterian Church and Cemetaries ahead on the left. Continue straight on Laurel Hill Road.
1.3	72.0	Butte Road enters from the right and the road name changes to West Crawford A venue. Continue straight on West Crawford Avenue toward Connellsville.
0.3	72.3	Intersection with Little Summit Road to the left and Eighty Acres Road to

		the right. Continue straight on West Crawford Avenue.
0.9	73.2	Intersection with Little Summit Road to the left and Hill Farm Road to the right. Continue straight on West Crawford Avenue.
1.0	74.2	Enter Village of Leisenring. Continue straight on West Crawford Avenue.
0.5	74.7	Arch Bridge Road enters from the right. This road leads into Dunbar, PA, where Isaac Meason erected the Union Iron Furnaces (both of them – see p. 10). Continue straight on West Crawford Avenue.
1.6	76.3	Cross Opossum Run.
0.5	76.8	Enter the City of Connellsville. During the French and Indian War, General Edward Braddock (Figure 53) crossed the Youghiogheny River at Stewart's Crossing, basically the middle of what is now Connellsville. Connellsville was officially founded as a township in 1793 by Zacharia Connell, a Revolutionary War captain of the militia. It became a borough in 1806, then in 1909, after merging with New Haven, it became the first official city in Fayette County. Mining of the great Pittsburgh coal seam in the area during the late 19th and early 20th centuries earned Connellsville the title of "Coke Capital of the World". Henry Clay Frick owned numerous mines and coke ovens throughout the region (see Stop 5). Connellsville at one time had more millionaires per capita than any other city in the United States.

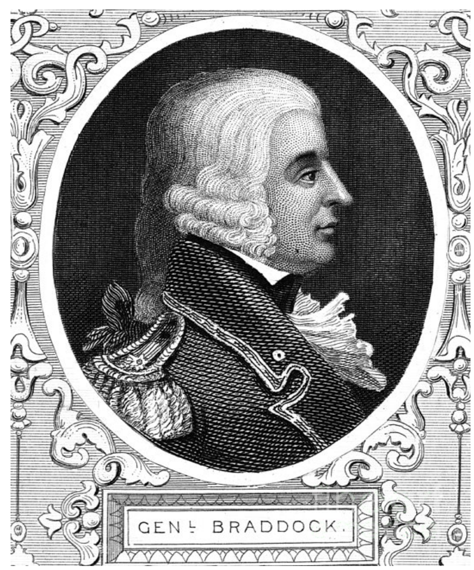


Figure 53. Portrait of General Edward Braddock (from Van Sickle, 2018).

0.4	77.2	Cross North 8th Street, US 119 South, and proceed to South 8th Street, US 119 North. Turn left onto South 8th Street and drive north on US 119.
0.2	77.4	End one-way on US 119. Continue north on US 119.
0.2	77.6	Cross the Youghiogheny River and continue north on US 119.
0.6	78.2	Leave the City of Connellsville and continue north on US 119.
2.6	80.8	Intersection with PA 982, Pleasant Valley Road on the right. Pleasant Valley Road leads to Mt. Vernon Iron Furnace (see p. 11). Continue north on US 119.
1.0	81.8	Exit ramp to Everson on the right. Everson, which was named for local mill owner, Benjamin Mozart Everson, was incorporated as a borough in 1903. The borough has a long history of coal and coke production, as well as

		railroads (Everson Borough, 2017). Continue north on US 119.
1.4	83.2	Intersection with Kingsview Road on the left and Crossroads Road on the right at the traffic light. Continue north on US 119.
1.0	84.2	Intersection with McClure road at the traffic light. Continue north on US 119.
0.5	84.7	Cross railroad tracks, then cross Jacobs Creek and enter Westmoreland County. Continue north on US 119.
0.2	84.9	Cross the Coal & Coke Trail, a rail-trail that links Mt. Pleasant and Scottdale. Like most rail-trails, it provides outdoor recreation for walkers, joggers, bikers, hikers, and cross-country skiers who can enjoy beautiful natural areas and wildlife while following Jacobs Creek past old coke ovens (Westmoreland County, 2018). Continue north on US 119.
0.5	85.4	Bear right onto the exit ramp to PA 819.
0.1	85.5	Turn left onto PA 819 toward Scottdale and cross US 119.
0.2	85.7	Entrance and exit ramps to and from US 119 South on the left. Continue straight on PA 819.
0.5	86.2	Bear right onto Frick Avenue and enter West Overton Village.
0.1	86.3	Turn left into the parking lot behind the West Overton Museum and park.

STOP 5: WEST OVERTON VILLAGE, WESTMORELAND COUNTY – BIRTH PLACE OF COKE MAGNATE HENRY CLAY FRICK

Introduction

Henry Overholt led a group of German Mennonites from Bucks County, Pennsylvania to this area in 1803. He took over a small farm with two stills in operation (Library of Congress, 2018), and in 1800 established West Overton Village (Anonymous, 2018d). His son, Abraham Overholt (1784-1870) (Figure 54), took over the farm in 1818, built a house, and added a steam powered grist mill to the property. Today the village (Figure 55) operates as a museum complex, an example of a nineteenth-century rural industrial village. It is the only pre-Civil War village still intact in Pennsylvania (Anonymous, 2018d), and is currently a stop on the American Whiskey Trail (West Overton Village, 2018). It encompasses 19 buildings, a collection of mid-19th century buildings in a Greek Revival architectural style. The village represents the transformation of American culture from an isolated agrarian society, represented by farming, animal husbandry, barrel making, weaving, and whiskey distillation, to an industrial society, represented by coal mining and coke production. It was added to the National Register of Historic Places in 1985.

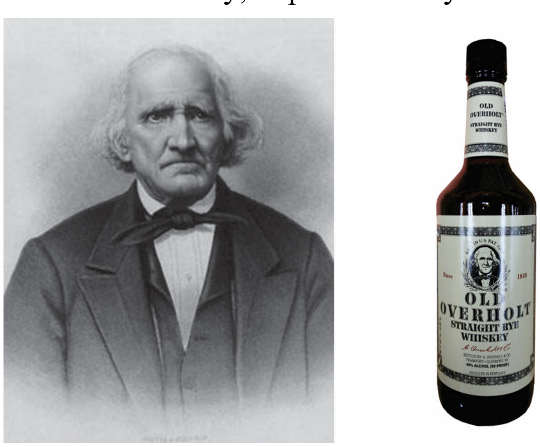


Figure 54. Photograph of Abraham Overholt (left — from Anonymous, 2018c).) Overholt was the namesake of Old Overholt rye whiskey (right), which began distillation in 1810 in Broadford, Pennsylvania. Today, Old Overholt is produced in Clermont, Kentucky, at the Jim Beam distillery, which is a subsidiary of Suntory Holdings of Osaka, Japan!

Abraham Overholt expanded the family distilling business and with his son, Henry, established the A. & H. S. Company, and over the decades they added more buildings and businesses. Besides the Abraham

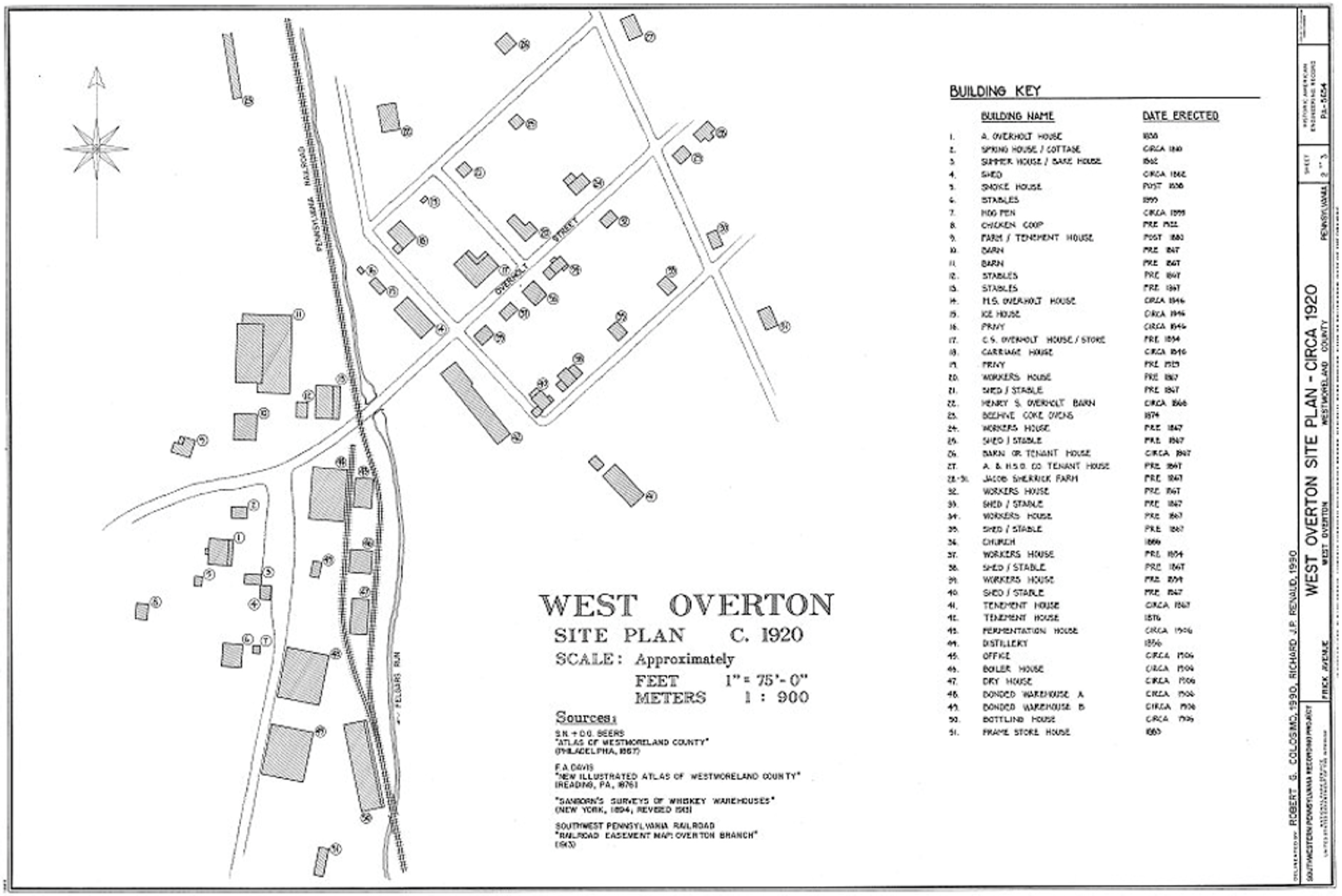


Figure 55. Layout of West Overton Village (from Library of Congress, 2018).

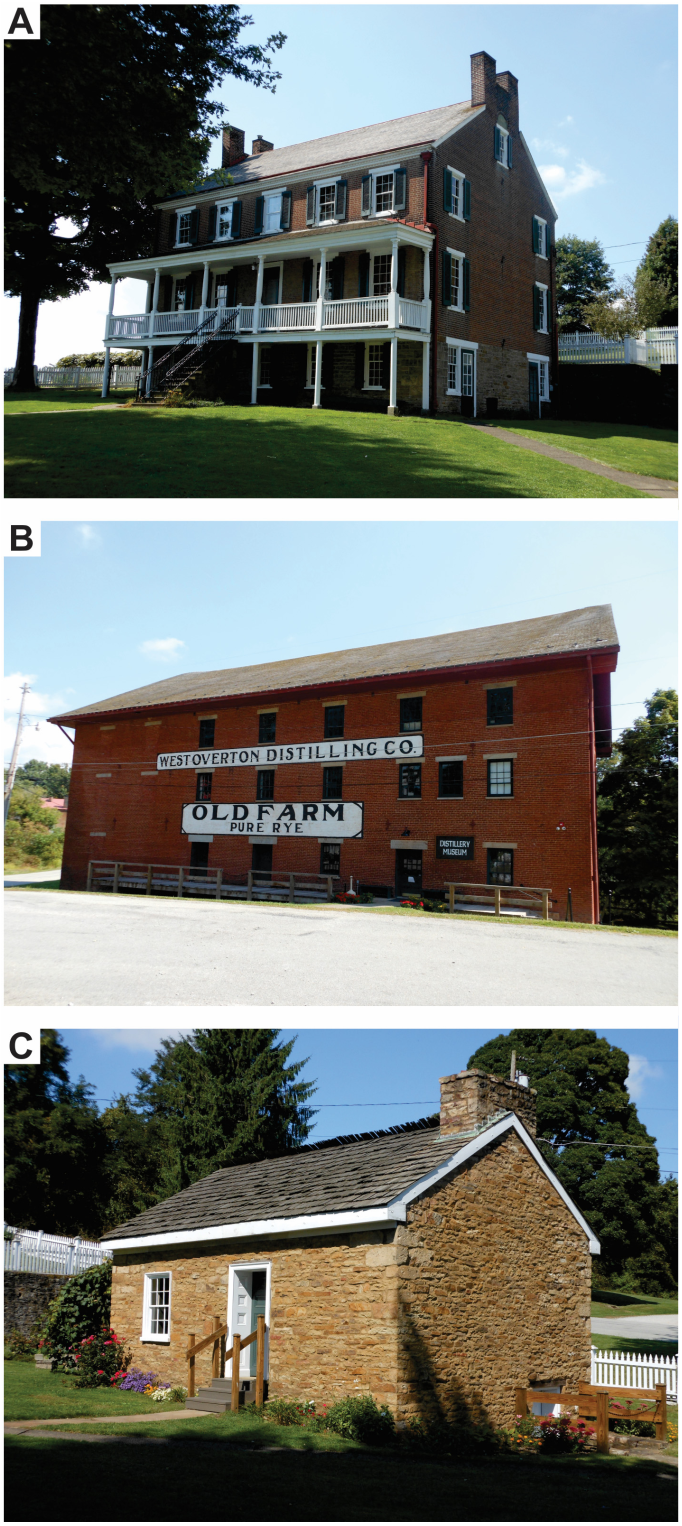


Figure 56. A – The Abraham Overholt Homestead, built in 1838, is now the headquarters of the West Overton Village & Museum. B – The Overholt Distillery, built in 1859, also housed a steam-powered grist mill. The building is now the museum for West Overton Village & Museum. C – This springhouse associated with the Abraham Overholt Homestead is where Henry Clay Frick was born.

Overholt Homestead (Figure 56A), built in 1838, there is also the Distillery (Figure 56B), built in 1859, which is now the Museum. The Distillery produced Old Farm Pure Rye Whiskey (West Overton Village, 2018). As a museum, it now focuses on the Overholt industries – whiskey distillation, grist milling, coal mining, and coke production. It also houses a fine display of Civil War-era artifacts. Other buildings in the village (Figure 55) include the Christian S. Overholt Store and House, the Overholt Mill, also built in 1859, and brick homes for Overholt employees (McCumber, 2005). Adjacent to the Homestead, and across the road from the Distillery, is the Springhouse (Figure 56C) where Abraham's daughter, Elizabeth, and her husband John Frick, had a son, Henry Clay Frick, born in 1849. Frick, as most Pittsburghers are aware, was a prominent industrialist, financier, art collector, and colleague of Andrew Carnegie.

The West Overton Distillery Museum features life-size dioramas that highlight the industries of West Overton Village between 1800 and 1919. Displays include coverlet weaving, coal and coke production, and whiskey distillation.

Henry Clay Frick

Henry Clay Frick (Figure 57) was born in Pennsylvania's coal-rich Connellsville region. He never lived far from his Overholt grandparents as a youngster and spent a lot of time in their company. As a young man, he went to work in a second distillery owned by his grandfather in Broadford, about 8 mi (13 km) from West Overton. While working there as a bookkeeper, Frick got interested in the coke business and eventually began building ovens to produce coke for the Pittsburgh market (McCumber, 2005).

Frick vowed to be a millionaire by the time he was 30. In 1871 at the age of 21, Frick, two of his cousins, and a friend

Figure 57. Photograph of Henry Clay Frick (from Walsh, 2017).

joined in a small partnership to build 50 beehive coke ovens to turn coal into coke for use in steel manufacturing (see Figures 5 and 25 for images of coke ovens). Frick visited Judge Thomas Mellon for a $10,000 loan (Apelt, 2000). He soon recognized that it would be more economical to build another 50, requiring a second $10,000 loan. Frick bought out the partnership and renamed the business H. C. Frick & Company. This company ultimately employed 1,000 workers and controlled 80% of the coal output in Pennsylvania. The company operated both mines and banks of beehive coke ovens in Washington and Fayette counties (Figures 58 and 59). Some of the brick structures are still visible in Fayette County (Anonymous, 2018a).

As with pig iron, three basic materials are needed to produce steel – iron ore, limestone, and coke (instead of charcoal). The Carnegie Steel Company had an invaluable and seemingly unlimited source of coke through its connections with Frick and his company (Wall, 1989). According to Warren (2001, inside front cover blurb):

> In 1913 the Connellsville coke district made about 47% of America's metallurgical coke and some 18% of the global output. It covered a stretch of land running roughly thirty miles north and south of the small Pennsylvania town of Connellsville, underlain by the superb metallurgic[al] coal of the Pittsburgh seam. Thousands of beehive coke ovens operating on a strip of land three miles wide made the coke that fed the iron furnaces and steel mills that helped catapult the United States to world leadership.

Limestone, especially the high-quality Vanport Limestone (Figure 3), was readily available in western Pennsylvania. High-quality iron ore, on the other hand, was essentially nonexistent in the area. Therefore, it had to be imported from Minnesota. But the supply of ore was not easily secured because Carnegie was reluctance to get involved in ore mining and then having to pay high railroad shipping rates to his Pittsburgh steel mills. Frick and Henry Oliver, a boyhood friend of Carnegie, had the foresight to invest in the vast Mesabi iron ores of northern Minnesota (Figure 60). In 1893, they offered the Merritt brothers[4] "one-half of the stock of the Oliver Mining Company, conditioned on a loan of half a million dollars, secured by a mortgage on the ore properties, to be spent in development work." (Van Brunt, 1921, p. 409). Shortly thereafter, the depression hit and the Merritt's loan of $500,000 was called. After the

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[4] Leonidas and Alfred Merritt prospected for iron ore in the 1880s in an area of Minnesota that Native Americans called the "Mesaba." The Merritts became the first succeed when they found rich, marketable ore on the west end of what became known as the Mesabi Range. The rest of the Merritt family, including five brothers and some nephews, got involved shortly after, and the brothers opened their first successful mine in 1890 and a railroad for transporting the ore was built in 1891. Unfortunately, the Merritts' creditors wanted their loans repaid, but the Merritts didn't have the money, so they asked John D. Rockefeller to help. Rockefeller agreed on the condition that he acquire a significant interest in the Merritts' company, and the Merritts caved. But the stock did not hold its value, and by 1894, the Merritts had to sell their remaining shares to Rockefeller for a pittance. They received $1,000,000 in the deal, just enough to pay their creditors (Minnesota Historical Society, 2008)

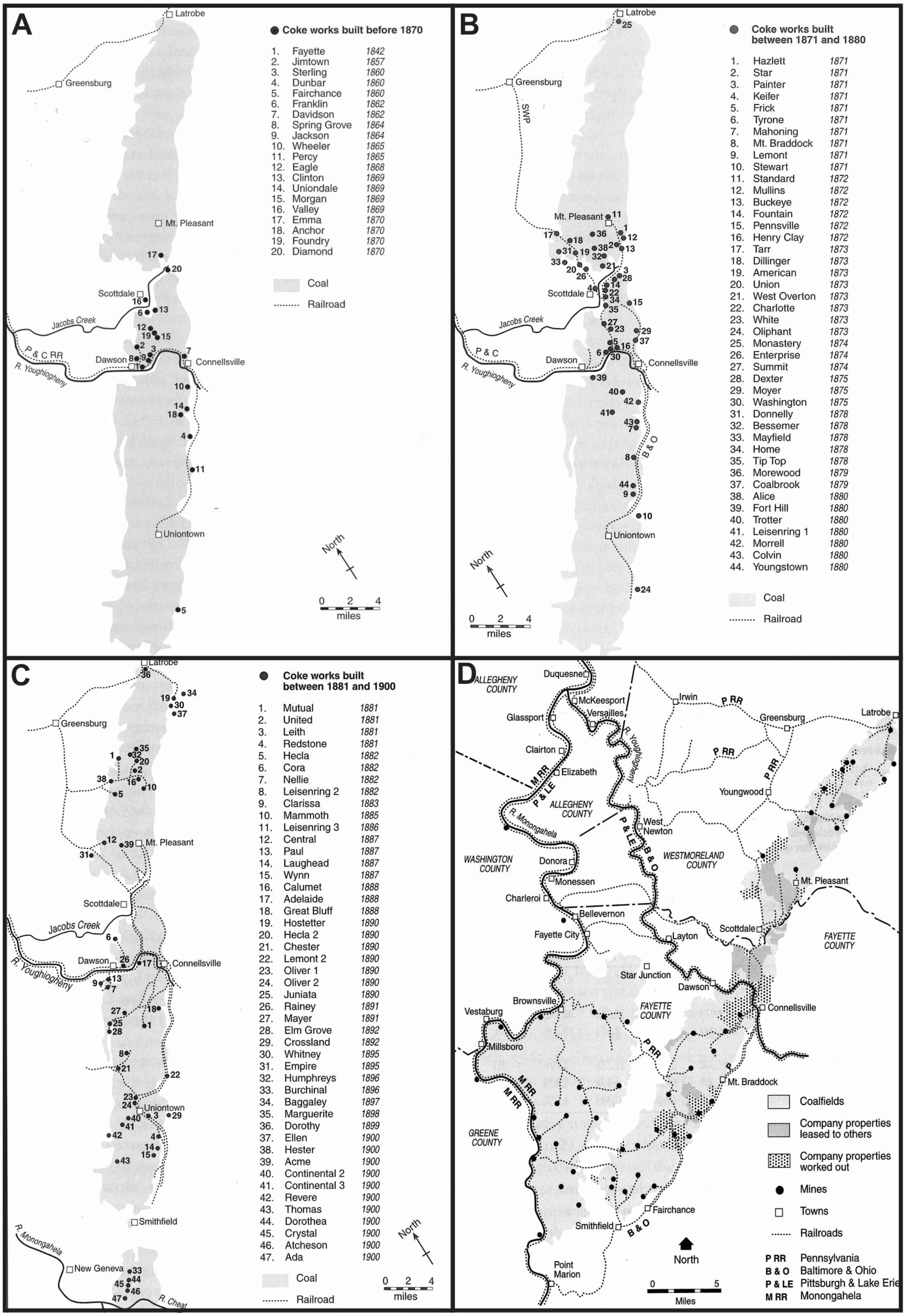

Figure 58. Maps of the H. C. Frick & Company coke works. A – Established before 1870. B – Established between 1871 and 1880. C – Established between 1881 and 1890. D – Established by 1937. From Warren (2001).

Figure 59. H.C. Frick Coke Company coal mines in the Westmoreland and Fayette counties, Pennsylvania, ca.1936 (from Washlaski, 2008).

Figure 60. U.S. Steel's Minntac iron ore mine in Minnesota (is high-quality ore that helped make Pittsburgh the Steel City (from Associated Press, 2017).

Figure 61. The Homestead strike of 1892 culminated in a fierce battle between the Pinkertons and the striking steelworkers and sympathetic residents of Homestead. This image depicts a gun battle at close quarters that did not actually take place. The Pinkertons disembarked from their barge only after the shooting had ended. "Fort Frick" (the Carnegie Steel Works)

depression of 1893, the Oliver-Frick-Carnegie consortium formed an alliance with John D. Rockefeller, who had been financially supporting the Merritts, for half of the Mesabi ores fields. It was not until 1901 that all Mesabi ore holdings, including Rockefeller's were under the control of the newly formed US Steel Corporation (Wall, 1989).

Over the years, labor policy strained the Frick/Carnegie partnership, especially Frick's actions in the infamous Homestead Steel Strike of 1892 (Walsh, 2017). The Amalgamated Association of Iron and Steel Workers, a newly formed labor union, went on strike at the Homestead Works of the Carnegie Steel Company. Striking workers locked the company staff out of the factory and surrounded it with pickets. Frick, well-known for his anti-union policies, had a fence topped with barbed wire constructed around mill (called "Fort Frick" by strikers) and hired the Pinkerton Agency to guard it even as negotiations were taking place. Three hundred Pinkerton detectives with Winchester rifles arrived on two specially-equipped barges, setting off a battle between workers and Pinkerton detectives (Figure 61). Nine workers and one detective died and 70 were injured. It took the intervention of 8,000 state militia, under the command of Major General George R. Snowden, to stop the confrontation. While the battle raged, Frick issued an ultimatum to Homestead workers, threatening to evict striking workers from their homes and refusing to speak with union representatives. When an assassin nearly killed Frick, negative publicity of the event caused the strike to collapse (Walsh, 2017). About 2,500 men lost their jobs and those who stayed saw their wages cut in half. As a result, he became "the most hated man in America" (Anonymous, 2018a).

The Frick-West Overton Legacy

Frick died of a heart attack on December 2, 1919, the same year that Prohibition closed the Overholt Distillery in West Overton (McCumber, 2005). He was buried in Homewood Cemetary. His will included 150 acres (60.7 hectares) of undeveloped land bequeathed to the City of Pittsburgh for use as a public park and a trust fund of $2,000,000 to assist with its maintenance. Frick Park opened in 1927, and by 1942 its size had increased to almost 600 acres.

In 1922, the Frick's only surviving child, Helen Clay Frick (Figure 62), began to purchase the buildings in West Overton where her father

Figure 62. Portrait of Helen Clay Frick as a young woman (from Gutowski, 2014).

Figure 63. The Frick Art Collection Museum on the Upper East Side in Manhattan (from Anonymous, 2018e).

Figure 64. Clayton, Henry Clay Frick's mansion in the Point Breeze section of Pittsburgh.

was born. In 1928, Helen Frick founded the Westmoreland-Fayette Historical Society to operate and maintain the site, now known as West Overton Village & Museums (McCumber, 2005).

Frick had started to collect art as soon as he started making his fortune, and he left a substantial art collection that can be seen in three separate venues:

- The Frick Art Collection occupies the Frick family mansion on the Upper East Side of Manhattan (Figure 63). The mansion, built between 1912 and 1914 by architect Thomas Hastings of Carrère and Hastings, became the Frick family's permanent home upon completion, although they had already moved to New York by 1905. Frick willed the house and all of its contents, including art, furniture, and decorative objects, to New York City as a public museum. His widow continued living in the mansion with their daughter Helen Clay Frick. It was only after Mrs. Frick died in 1931 that the house began to be converted into a public museum that finally opened in 1935.
- The Frick's Pittsburgh home, an eleven-room, Italianate-style house Henry and his wife purchased shortly after their marriage in 1881. This house was built in the 1860s, but the architect is unknown. Pittsburgh architect Andrew Peebles made some modifications and the house was renamed "Clayton" (Figure 64). Pittsburgh architect Frederick J. Osterling made further modifications in 1892. Helen Clay Frick moved back to Clayton in 1981 and lived there until her death in 1984. Clayton opened to the public in 1990 as the Frick Art & Historical Center.
- The Henry Clay Frick Fine Arts Building on the campus of the University of Pittsburgh (Figure 65) is home to Pitt's History of Art and Architecture Department, Studio Arts Department, and the Frick Fine Arts Library. The City of Pittsburgh donated the land for

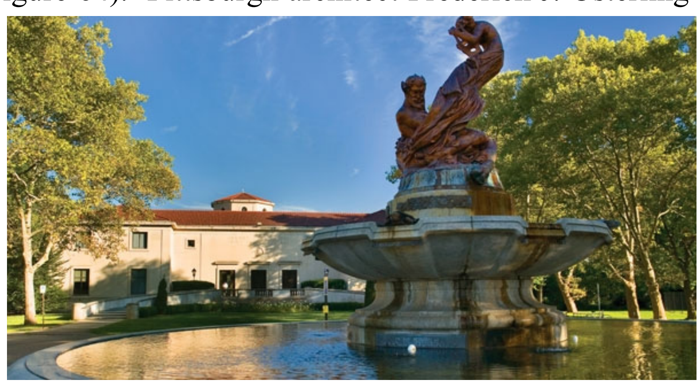

Figure 65. The Frick Fine Arts Building on the campus of the University of Pittsburgh. Victor Brenner, who designed the fountain, also sculpted the portrait of Abraham Lincoln seen on the U.S. penny (from University of Pittsburgh, 2018).

the building to the university, and the architects, Burton Kenneth Johnstone Associates, designed it after Pope Julius III's (1487–1555) Villa Giulia in Rome. The building was a gift from Helen Clay Frick, who had established the Fine Arts Department at Pitt in 1926 and continued to fund it through the 1950s. Construction of the building began in 1962, and it opened to the public in 1965. By the late 1960s, however, she had become very unhappy with the way Pitt was managing the building and the department (among her objections was the inclusion of modern art, which she hated), and severed her ties with the university. It was at this point that she began creating The Frick Art Museum at Clayton, which is now the Frick Arts & Historical Center.

Leave West Overton Village and return to US 119.

0.8	87.1	Cross the highway and turn left onto the entrance ramp to US 119 North.
0.1	87.2	Turn right onto entrance ramp to US 119 and merge with traffic.
1.1	88.3	Intersection with S. Quarry Street on the right and Quarry Street Extension on the left. Continue north on US 119.
0.5	88.8	Cross under PA 981.
0.3	89.1	Bear right onto the exit ramp to PA 31.
0.2	89.3	Turn left onto PA 31 North and cross over US 119.
3.0	92.3	Enter Ruffs Dale, an unincorporated community in East Huntingdon Township, Westmoreland County. Continue north on PA 31.
1.6	93.9	Intersection with Oden Road on the left and the access road to the Pittsburgh Pike on the right. Bear left and continue north on PA 31.
4.0	97.9	Cross under 1-70, bear right onto the entrance ramp to I-70 West, follow the loop, and merge with traffic on I-70 West.
2.3	100.2	Exit ramp to Flying J Travel Center on the right. Continue straight on I-70 West.
1.4	101.6	Cross the Youghiogheny River and continue on I 70 West.
0.9	102.5	Bear right onto the exit ramp to PA 51 North.
0.2	102.7	Merge with traffic on PA 51 North and return to Century III Mall.
16.8	119.5	Century III Mall. End of the field trip. Drive safely on your return home.

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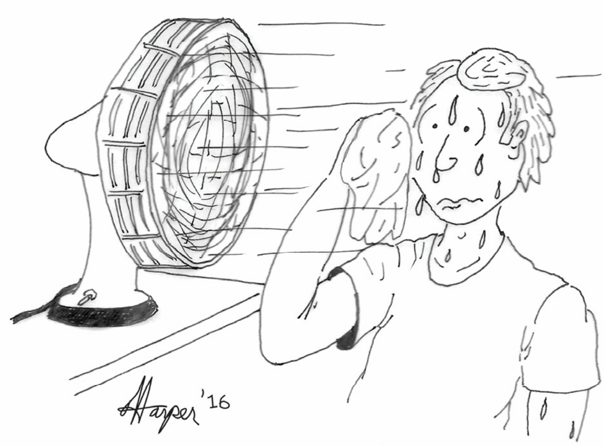
HARPER'S GEOLOGICAL DICTIONARY



THERMAL METAMORPHISM - the pronounced change in atmospheric temperatures resulting from heated political disagreements over the scientific validity of climate change.

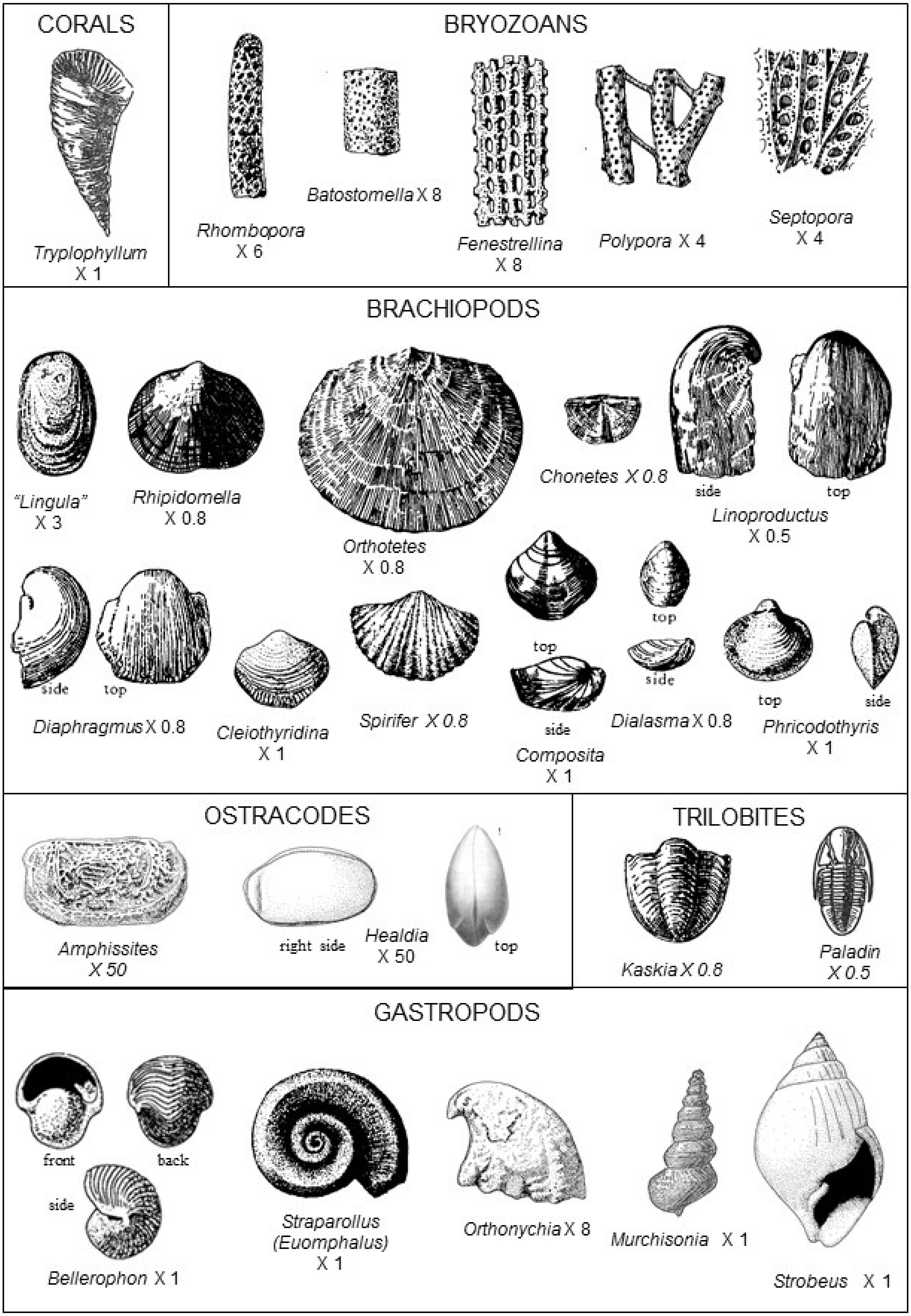
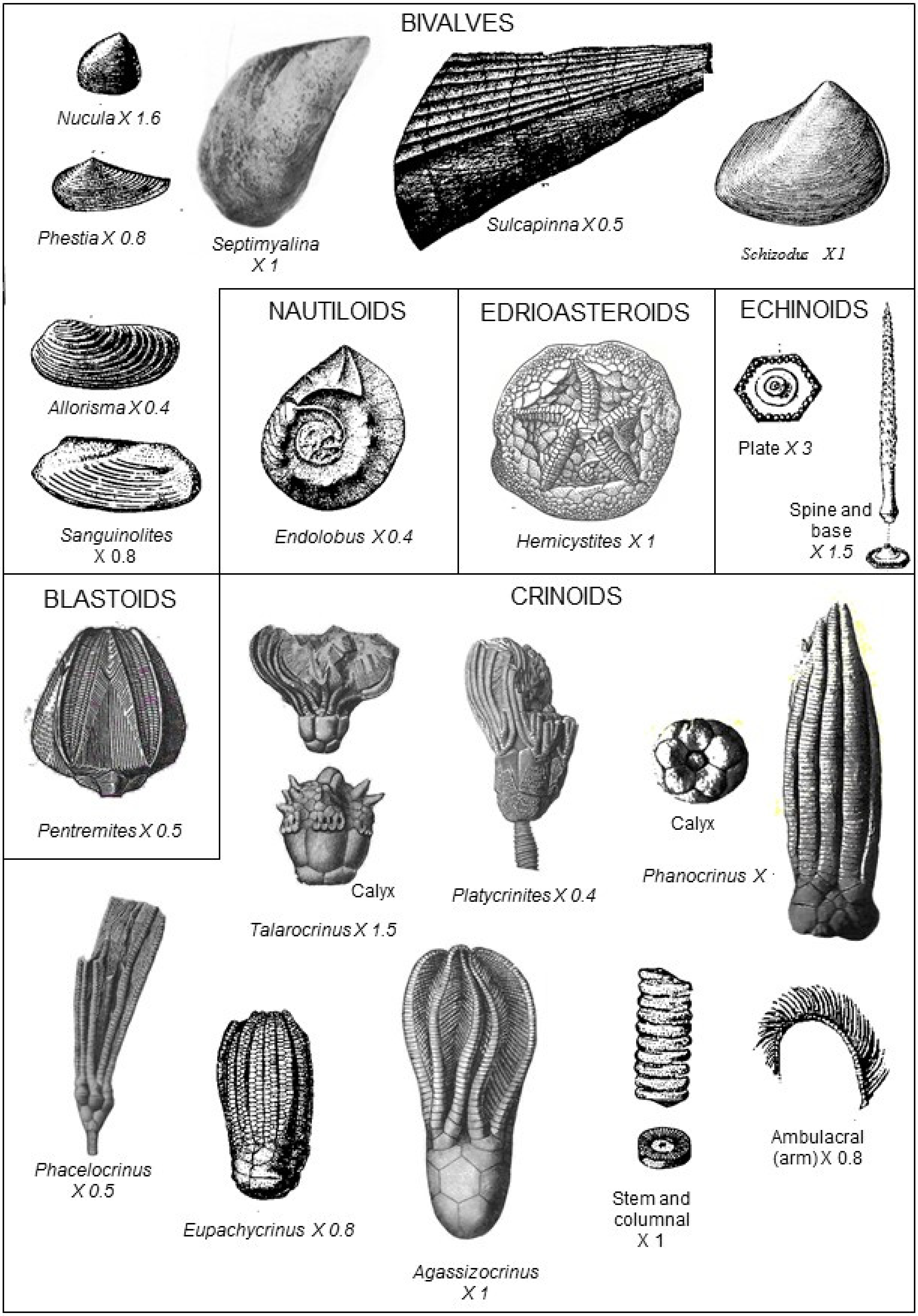


Plate 1. Illustrations of fossils that might be found at the Thompson Quarry


BIVALVES
Nucula X 1.6
Phestia X 0.8
Septimyalina X 1
Sulcapinna X 0.5
Schizodus X 1
Allorisma X 0.4
Sanguinolites X 0.8
NAUTILOIDS
Endolobus X 0.4
EDRIOASTEROIDS
Hemicystites X 1
ECHINOIDS
Plate X 3
Spine and base X 1.5
BLASTOIDS
Pentremites X 0.5
CRINOIDS
Calyx
Talarocrinus X 1.5
Platycrinites X 0.4
Calyx
Phanocrinus X
Phacelocrinus X 0.5
Eupachycrinus X 0.8
Agassizocrinus X 1
Stem and columnal X 1
Ambulacral (arm) X 0.8