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Pennsylvania Geology

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Jared Snyder (formerly of Mercyhurst University in Erie, Pa.) and an unidentified caver after leaving the muddy inside of Harlansburg Cave, Harlansburg, Pa. (see article on page 11).

—Photograph courtesy of Jared Snyder

EDITORIAL

Geology Underlies It All

Gale C. Blackmer, State Geologist
Pennsylvania Geological Survey

Well, here we are again in another dismal late winter in central Pennsylvania. Despite the bone-chilling dampness and gray skies, this was always my favorite time of year to do fieldwork in the heavily vegetated southeastern part of the state. Once the snow melts, all the leftover plants are flattened, and only bare branches impede the view of the rocks. Details of the landscape are also laid bare; the ground beneath your feet is clearly visible. While our modern climate-controlled buildings, grocery stores, and transportation systems have enabled us to live in large part detached from the landscape around us, our settler ancestors were acutely aware of its influence on their daily lives. The landscape, and the geology that underlies and controls it, were primary influences on settlement patterns and the economic development of Pennsylvania.

My house is positioned so that the view from two sides of it is of Blue Mountain, the first ridge in the Ridge and Valley Province of central Pennsylvania. As mountains go, it isn't that impressive, but it is steep, and the water gaps are narrow. That made it an effective barrier to wagon traffic. The English and German settlers who spilled out of Philadelphia in the seventeenth and most of the eighteenth centuries spread west along the Great Valley south of the mountain, satisfied with its rich limestone-based soils and water power provided by the many fast-flowing streams, and left the wild land over the mountain to the native people, trappers, and a few intrepid farmers who liked the risk and the isolation. It wasn't until after the Revolutionary War that roads were finally cut over the mountains, and the fertile limestone valleys to the north started to fill with towns and farms. It took even longer to figure out how to move goods and raw materials across the state, straddling as it does three major river basins—those of the Delaware, Susquehanna, and Ohio. Once the canals, and eventually the railroads, finally cracked that nut, Pennsylvania's economy was off to the races.

Speaking of raw materials, Pennsylvania is blessed with a great bounty of natural resources. Pennsylvania's iron industry began in 1716 in Berks County and spread across the state over the next hundred years, fed by the abundance of iron-ore deposits, forests for charcoal to fuel the furnaces, limestone for flux, and streams for water power. Pennsylvania led the colonies in iron production, and consistently produced more than half of the new nation's iron into the mid-nineteenth century. Pennsylvania coal mining began in the late 1700s and led the nation until the 1930s. Iron and coal fueled the steel industry, in which Pennsylvania was a leader until American steel collapsed in the 1980s. The oil industry started with a well in Titusville, Pa., drilled by Edwin L. Drake in 1859. Oil production in Pennsylvania has since been outstripped by natural gas with the

(continued on page 18)

New Historical Marker Commemorates a Milestone in Iron Manufacturing

John A. Harper
Pennsylvania Geological Survey, retired

A GOOD DAY TO COMMEMORATE A HISTORICAL EVENT

On a pleasant, sunny Sunday, September 10, 2017, the Pennsylvania Historical and Museum Commission (PHMC) and the Fayette County Historical Society (FCHS) unveiled a new historical marker at the side of Pa. Route 51 in Menallen Township, Fayette County (Figure 1), about six miles northwest of Uniontown. The marker commemorates a new way to manufacture iron that was introduced to America in 1817. 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 historical marker is the result of more than two years of research by Dr. Norman L. Samways[1] (Figure 2), a retired Pittsburgh metallurgist and geology enthusiast 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 PHMC and the FCHS, who coordinated the marker-dedication ceremony and an exhibition at the FCHS's headquarters in the Abel Colley Tavern and Museum nearby. The story of the furnace and the aftereffects are worth retelling.

FAYETTE COUNTY'S PIONEERING IRONMASTER

Isaac Meason (1743–1818) was a legend in Fayette County. Born in Frederick County, Va., 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[2] (Heald, 1990), and 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 gristmills 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

[1] Although Dr. Samways reviewed a penultimate draft of this article, he unfortunately passed away early in February 2018 before seeing it in print.

[2] Whether Union Furnace was the first or second iron furnace to produce iron west of the Alleghenies depends on the historian. Swank (1878, p. 51; 1892, p. 214) and Ellis (1882, p. 235) both claimed that the first to be put into production was Alliance Furnace in 1790, followed about 16 months later by Union Furnace. Heald (1990) stated that pig iron was not produced at Alliance Furnace until 1792.

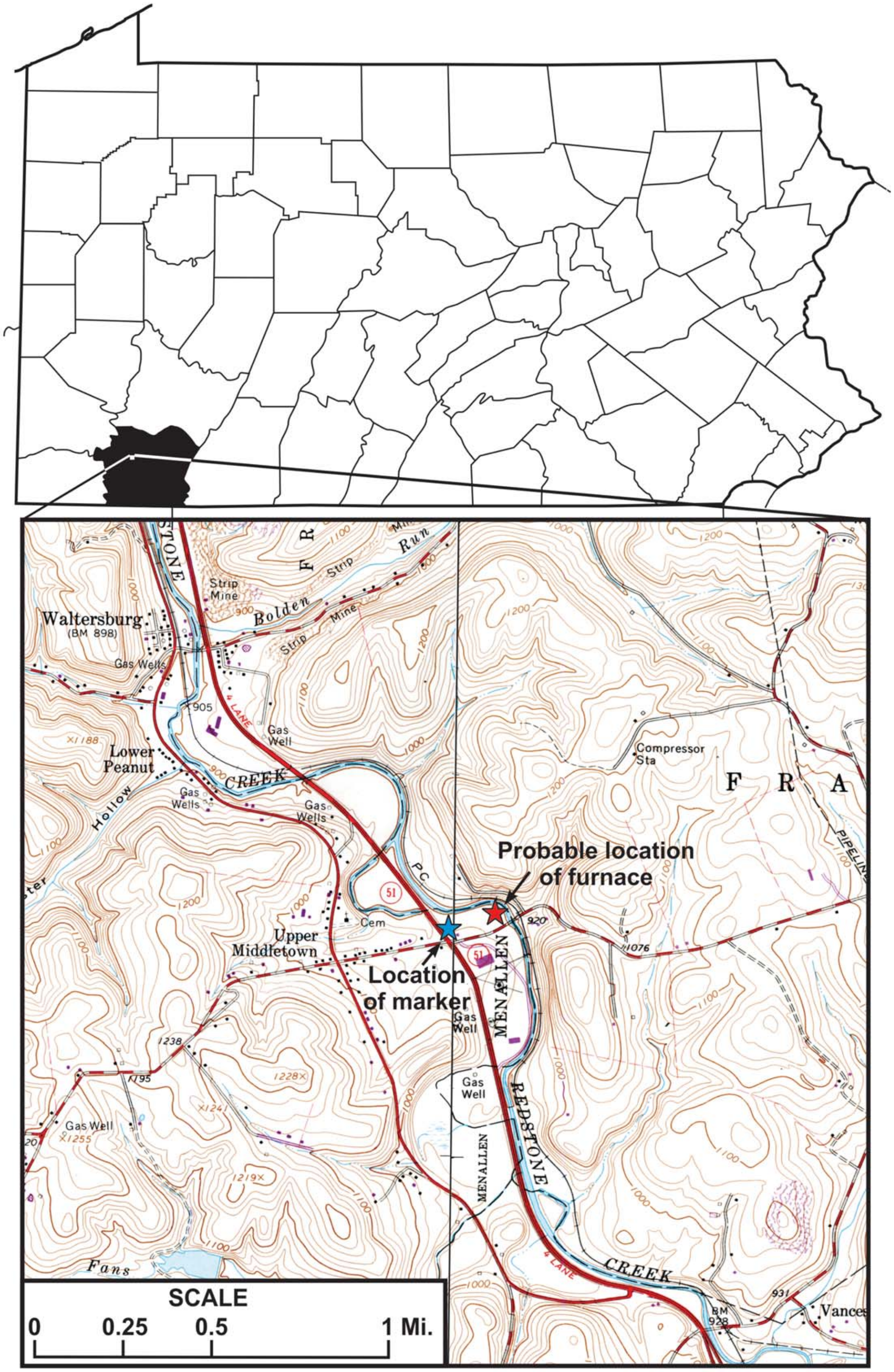

Figure 1. Location of the historical marker (blue star) commemorating the first iron puddling furnace in the United States, and the most likely location of the furnace (red star). The vertical black line in the center is the boundary between the New Salem (left) and Uniontown (right) 7.5-minute topographic quadrangles.

Figure 2. Left to right: Christine Buckelew, President of the Fayette County Historical Society, Dr. Norman L. Samways, retired metallurgist and geology enthusiast, and Kenneth Turner, Pennsylvania Historical and Museum Commission, at the unveiling ceremony for the historical marker commemorating the first puddling furnace built and operated in the United States.

suspension bridge in America, on Jacob's Creek near where he lived (Abraham, 1937; Morrison, 1983).

When Meason arrived in Fayette County, the area was well poised to become a leader in iron manufacturing because it had both abundant natural resources and major lines of transportation (e.g., the National Highway, now U.S. Route 40, and the Youghiogheny and Monongahela Rivers). Iron ore could be found in many places in the county, especially on the western side of Chestnut Ridge. Limestone for flux occurred where streams flowing down the mountains exposed thick Mississippian carbonates. Some of those same streams powered the bellows in the furnaces. Fireclays necessary for making refractory bricks occurred as underclays associated with numerous coal seams. Acres of woodlands provided the raw material for making charcoal. Even secondary resources, such as 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 Pittsburgh area with an abundance of pig iron that could be made into kettles, firebacks, and other implements. But pig iron is brittle because of the metal's high carbon content. The manufacture of many usable items, such as nails, tools, barrel hoops, shovels, and plows, required the 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.

THE VALUE OF A GOOD WORKING KNOWLEDGE AND PERSEVERANCE

The puddling furnace was invented by an Englishman named Henry Cort in 1783–84 and patented in 1784 (Landes, 2003), and it soon became very popular in England and Wales. In 1815, Thomas C. Lewis, who had much experience in 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 was 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,’ said 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 FURNACE

The mill was built in 1816 and 1817 on Redstone Creek at Plumsock (now Upper Middletown—see Figure 1) on the site of a forge built by Jeremiah Pears sometime around 1794 (Ellis, 1882). The property and all its facilities, which included a sawmill, gristmill, 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 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, 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 on 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.

BLAST IT ALL! WHERE’S THAT PUDDLE?

The process of puddling iron is significantly different from forging pig iron, which was the practice in the eighteenth and early nineteenth centuries. In order to produce one ton of pig iron, an early nineteenth century blast furnace (Figure 3A) required approximately three tons of iron ore, two tons of limestone for flux to remove impurities (slag), and 2.6 tons of charcoal (later, coal or coke) for fuel (Samways and others, 2014). These were dumped into the top of the furnace stack. As the materials descended toward the bottom of the furnace, hot carbon monoxide gas from the combustion of charcoal transformed the iron ore into liquid iron at temperatures on the order of 1,500 to 2,500°F. A water wheel powered the bellows that pumped air into the furnace through blowpipes called tuyeres. Approximately every six hours, the iron workers tapped the furnace (they opened a sealed hole in the hearth) and let the liquid iron flow into parallel rows of depressions in the casthouse floor. The slag separated and floated

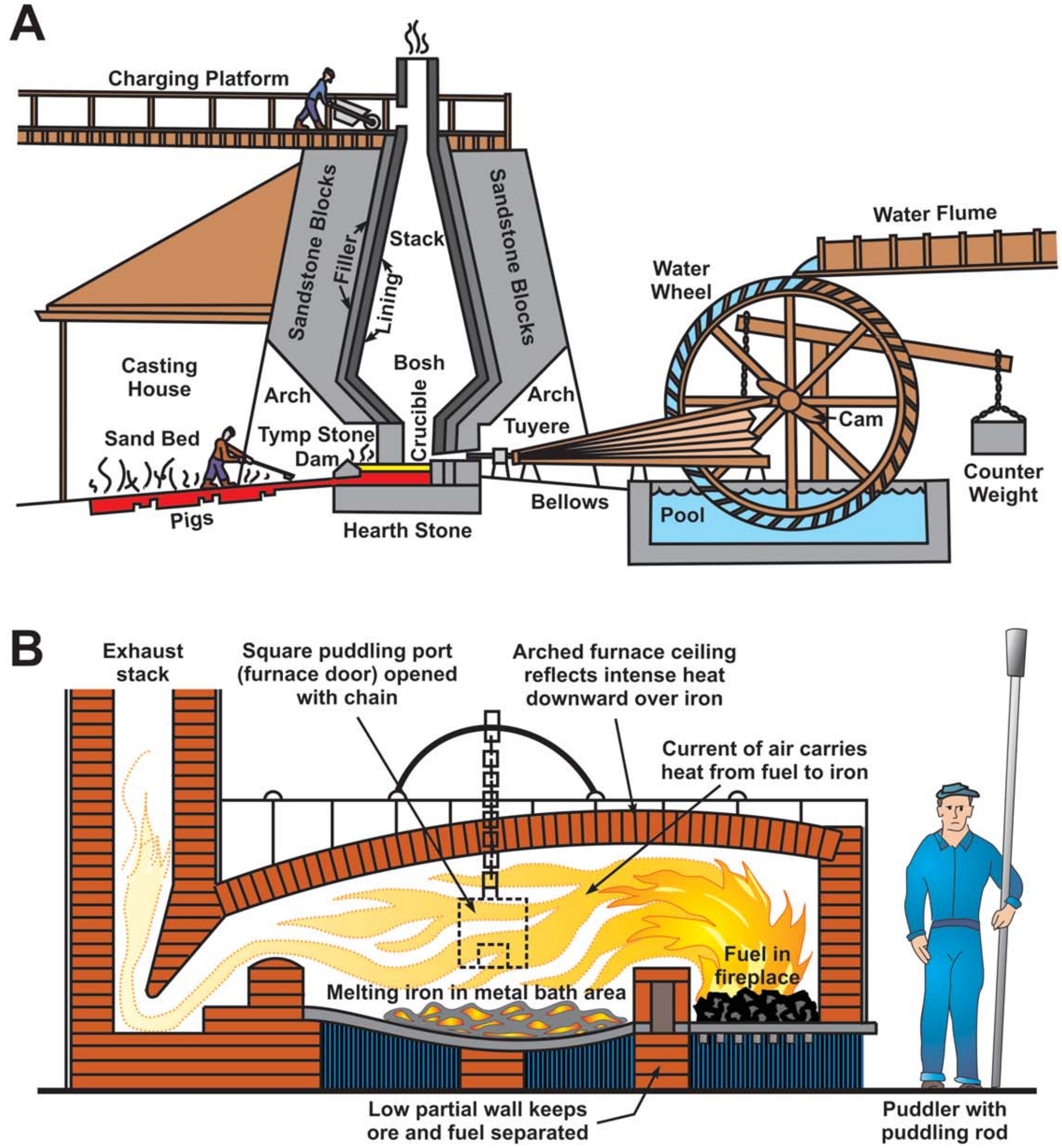

Figure 3. A. A typical charcoal blast furnace (from Samways and others, 2014). B. A puddling furnace (modified from Samways, 2016). See text for explanation of how these furnaces worked. Not to scale. Both illustrations based on drawings by David J. Vater.

on the molten iron and was removed by lowering a dam at the end of the trough. When the iron solidified in close parallel rows, it looked something like piglets suckling a sow—hence, the name "pig iron." Some early blast furnaces created cast-iron products by removing the liquid iron in ladles and pouring it into molds that resulted in items such as pots and stoves. A typical early nineteenth century blast furnace could produce two tons of pig iron per day (Samways and other, 2014), but to get the usable malleable iron, the pigs had to be reheated and forged multiple times.

The biggest advantage of a puddling furnace (Figure 3B) 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 half an 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 and to escape as gas or to form a slag. As more fuel was added, the temperature of the mixture rose from 2,100 to 2,800°F, allowing the iron to melt completely and the carbon to burn off. Eventually, when most of the carbon had burned off, the metal began forming into a spongy ball of wrought iron weighing about 75 to 90 pounds. 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 pig iron of 800 or 900 pounds, 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.

LIMESTONE AND FIRECLAYS AND IRON ORES, OH MY!

The primary iron ore available in western Pennsylvania is siderite—iron carbonate ($FeCO_3$). In Fayette County, the old blast furnaces used siderites from a variety of formations. Isaac Meason's furnaces probably used Mercer ores (Pottsville Formation, see Figure 4) from the Dunbar mines in Dunbar Township where they were well exposed along the western flank of Chestnut Ridge. Moyer (in Hickok and Moyer, 1940) considered the Mercer ores to have been the most important ores mined in the county. The iron content of these typically ranged from about 30 to about 40 percent. McCreath (1879) analyzed the Mercer ores, both the Big Honeycomb and Big Bottom ores, from the Dunbar mines and found them to have 35.8 and 35.7 percent iron, respectively. Siderite remained the primary source of iron in western Pennsylvania until Lake Superior hematite (Fe_2O_3) ores containing more than 50 percent iron became available as a result of improved rail and water transportation. When that occurred, Pittsburgh became the focus of the iron and steel industry in the United States (Samways and others, 2014).

Limestone used as flux in Fayette County furnaces came from a variety of formations, including the Redstone, Fishpot, and Benwood limestones of the Monongahela Formations, and the Wymps Gap Limestone of the Mauch Chunk Formation on the western flank of Chestnut Ridge (Figure 4). The Mauch Chunk limestones were the most likely ones used in Meason's blast furnaces in the Dunbar area.

Up until 1840, all of the pig iron produced in western Pennsylvania was made in charcoal blast furnaces. This required immense quantities of wood—it took about 15,000 acres of forest to make enough charcoal to produce 100,000 tons of pig iron per year (Samways and others, 2014). Coal and coke only came into use as fuel in blast furnaces after 1840, greatly reducing the need for charcoal.

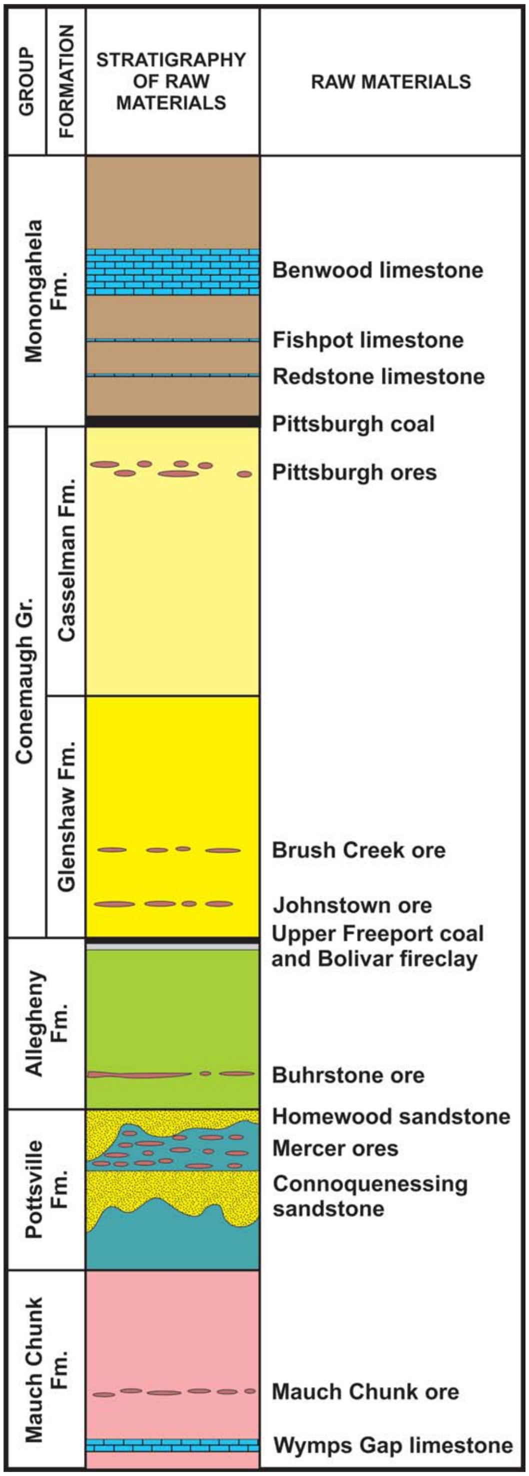

Figure 4. Generalized stratigraphic column of Pennsylvanian and Upper Mississippian formations in western Pennsylvania showing locations of iron ores, limestones, sandstones, coals, and fireclays used in manufacturing iron in the eighteenth and nineteenth centuries (from Samways and others, 2014).

The predominant raw material for refractory bricks needed to line the insides of western Pennsylvania furnaces was fireclay, composed of aluminum silicate ($Al_2O_3{\cdot}2SiO_2$). Fireclays are found throughout western Pennsylvania in association with coal beds, where they are referred to as underclays. For example, the Bolivar fireclay is a well-known clay that typically occurs a few feet below the Upper Freeport coal (Allegheny Formation, see Figure 4).

WRAP-UP

The geology of western Pennsylvania, with its abundance of raw materials for making iron (ore, limestone, fireclay, and water) and its vast forests, had resulted in the area becoming a leading center for iron and, eventually, steel production in the United States even before the introduction of new technologies. With the successful introduction of the puddling and bar rolling processes in Fayette County, there was a rapid increase in the number of new furnaces built and operated. In Pittsburgh alone, the number of puddling furnaces increased from four in 1819 to more than 800 by 1890; the number reached a peak of 5,265 throughout the country by 1884 (Samways, 2016).

Yes, the construction of the first puddling furnace and rolling mill in the United States 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 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. It lasted until 1876 when it merged with two other unions to form the Amalgamated Association of Iron and Steel Workers, what we know today as the United Steelworks (Brody, 1960), currently the largest union in North America.

And to think, it all started with a man from Wales convincing a man from Fayette County that iron could be rolled into bars! Thank you, Dr. Samways, for bringing this to our attention.

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Harlansburg Cave, Harlansburg, Pennsylvania—Disgusting Mud Pit or Cool Cave?

Katherine W. Schmid
Pennsylvania Geological Survey

INTRODUCTION

Harlansburg is the longest mapped cave in Pennsylvania (Fawley and Long, 1997; Gulden, 2013), and it attracts numerous visitors from Pennsylvania and neighboring states. The cave is easy to get to and is also close to a couple of universities, which gives students and professors a chance to try out caving. Before moving to Pennsylvania, I had visited this cave to see what Pennsylvania offers cavers like me. It is small and muddy compared to the caves that I grew up exploring in southern Kentucky. Explorers generally come out of the cave covered in mud (see photograph on page 1). Some people have even lost their boots in the deep mud. However, this cave does have a couple of features that I have never seen in any other cave. Iron ore forms complex patterns in the ceiling in some areas, and large tree-sized lycopods are exposed in other areas where the cave extends up into the overlying sandstone.

This cave is in northwestern Pennsylvania in the Northwestern Glaciated Plateau physiographic province (Figure 1), just west of the village of Harlansburg. It was discovered in 1950 when a roadcut was blasted through the Vanport Limestone. Eyewitnesses say that water flooded out of the cave when this happened (White, 1976). People also reported the presence of many beautiful formations in the cave at that time. Unfortunately, few of these are left in the cave, due primarily to vandalism and collecting.

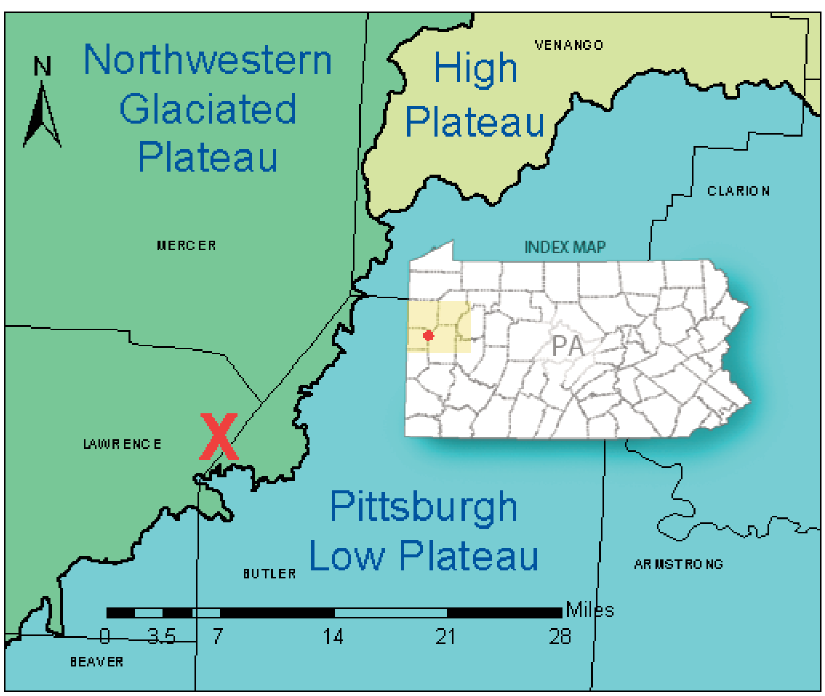

Figure 1. The location of Harlansburg Cave (the red "X") on a map showing physiographic provinces. Modified from Sevon, 2000.

The cave is a network maze of interconnected passages in which it is very easy to get lost (Figure 2). In fact, over the years, many people have become lost and have had to be rescued. For safety and security reasons, the cave is currently gated and managed by the Mid-Atlantic Karst Conservancy.

Multiple attempts have been made to map the cave. The concentrations of iron ore in this cave make it challenging to create an accurate map using a compass. This is not a common problem; iron and manganese oxide deposits are rare in caves (Spilde and others, 2005). Fawley and Long (1997) mapped Harlansburg Cave with the Westminster Student Grotto (a local caving club member of the National Speleological Society) and reported a length of close to 4 miles (6.5 km). Kim Metzgar, a member of the Mid-Atlantic Karst Conservancy, has been working on getting a more accurate map of the cave for years (Opatka-Metzgar, 2004). In helping her, I also became interested in this cave's unique mineralogy.

BEDROCK GEOLOGY

Pennsylvanian-aged sediments in this area are marked by repeating cyclothem sequences, where beds of shale, coal, shale, limestone, shale, and sandstone layers of varying thicknesses make up each sequence (Bragonier, 2011). These rhythmic sequences are caused by rising and falling sea levels. Harlansburg Cave formed in the limestone component of one of these sequences. The limestone is about 23 feet (7 m) thick in this area and is overlain by the Buhrstone ore and the Kittanning units of the Allegheny Formation (Bragonier, 2011). The middle and lower Kittanning members (as defined by Poth, 1963) are composed of coal, shale, coal, shale, and finally, coarse-grained channel sandstones. The roadcut exposes an almost complete cyclothem sequence. Figure 3 shows this sequence; Figure 3A shows the rocks exposed in the roadcut, and Figure 3B shows the layers exposed in the cave. The underlying Scrubgrass Coal is not exposed here.

Vanport Limestone. The Vanport Limestone is a shallow marine limestone (Miller, 1934) and contains fossils, including echinoderms, that are sometimes exposed within the cave. This limestone was originally known as the Ferriferous limestone because of its close association with the Buhrstone iron ore bed. It was first called the Vanport Limestone by I. C. White in 1878 (Lamborn, 1951). White described the Vanport as the most characteristic stratum in the lower productive coal series. "It is the largest, purest, and most massive limestone, and always possesses a peculiarity of composition and organic remains, by which one thoroughly familiar with it can unerringly distinguish it at a single glance from any other limestone in the group" (White, 1876, p. 60). White also noted that the Vanport was highly valued as a flux for iron and was extensively quarried in Vanport, Pa., about 25 miles south-southwest of the cave. The Vanport has been rated as the most valuable limestone in the Carboniferous strata (Miller, 1934).

The Vanport Limestone is present sporadically throughout northwestern Pennsylvania, and its thickness is highly variable where it is present. This variability appears to be controlled by two things: first, by existing topography at the time of deposition, and later, by erosion as sea levels receded after deposition (Miller, 1934; Bergenback, 1964). The limestone thins to the northwest where clastic deltaic deposits were deposited at the same time that the upper Vanport Limestone was forming (Weber and others, 1965). In Lawrence County, the thickness of the limestone ranges from 14 to 23 feet (about 4 to 7 m), which is more constant than thicknesses found in other counties (Miller, 1934). This consistency was a factor in the development of this cave in the Vanport as the longest cave in Pennsylvania.

Buhrstone Iron Ore. The Buhrstone iron ore overlies the Vanport Limestone. This ore only exists where the Vanport Limestone is present, but it is not always present at the top of the Vanport (White, 1879; Coyle, 2003). Containing 40 percent iron (White, 1879; Coyle, 2003), it was mined for use in iron

Figure 2. Map of Harlansburg Cave showing sample locations for this study (modified from Opatka-Metzgar, 2004). A photograph of the joint patterns and boxwork seen in the ceiling of the cave near sample location 2 is shown for comparison with the pattern of the cave passages.

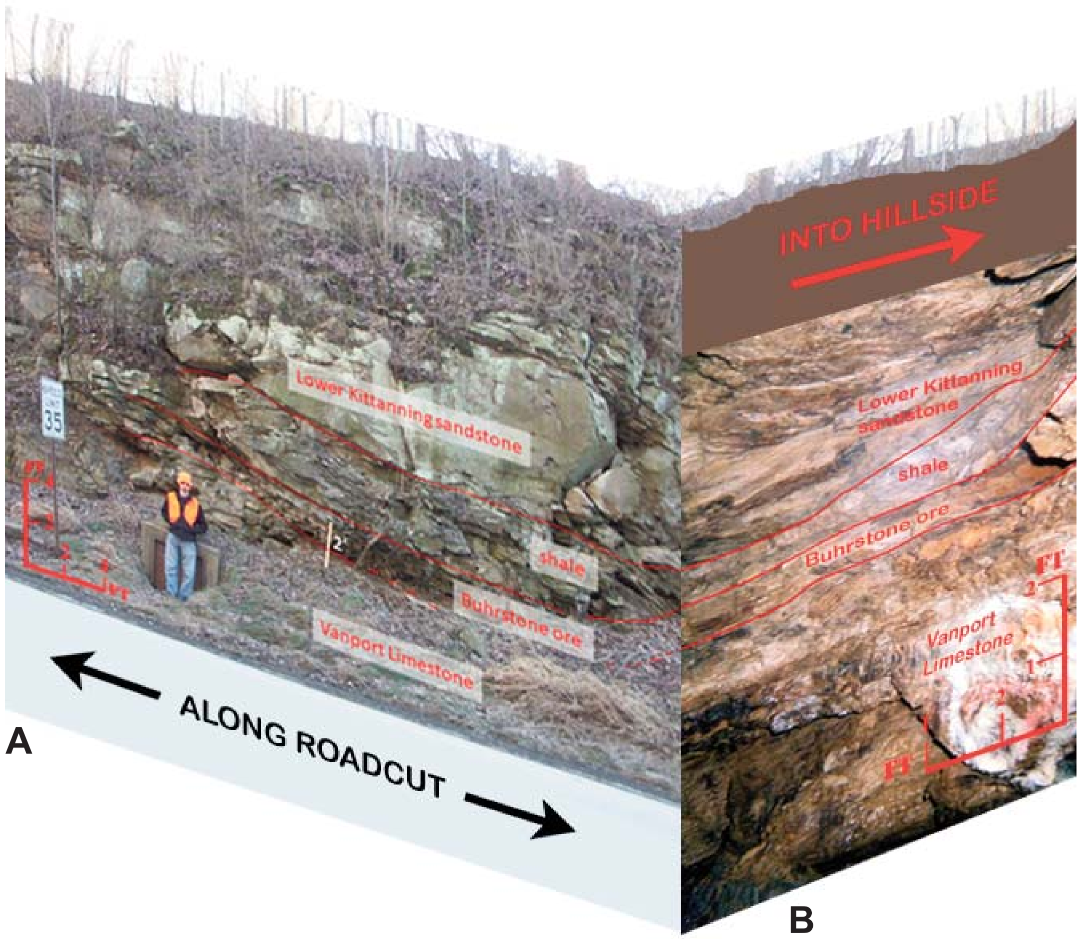

Figure 3. A. The rock formations exposed in the Harlansburg roadcut. Aron Schmid is standing in front of a closed entrance to the cave. B. The rock formations exposed within Harlansburg Cave.

furnaces during the first half of the 1800s. Measured thicknesses range from 0.5 to 20 inches (1.3 to 51 cm) (Coyle, 2003). The ore is at its thickest in the Harlansburg roadcut and is 20 inches (51 cm) thick near the cave entrance. It tends to be thickest at the base of the lower Kittanning sandstone where channel sands cut into the limestone (Coyle, 2003).

Kittanning Sandstone. Above the Buhrstone ore is the Kittanning sandstone. Tree-sized lycopods and other plant fossil fragments are found in this sandstone where it is exposed in the cave. The lower Kittanning sandstone member (as defined by Poth, 1963) forms a channel sand where it cuts into the limestone cave (Coyle, 2003). This member ranges from 7 to 56 feet (2.1 to 17 m) thick, averages about 30 feet (9 m), and is thickest where channels have been cut down into the limestone (Poth, 1963).

MINERALOGY

Before the 2013 National Speleological Society convention in Shippensburg, Pa., I studied samples from this cave (from sample locations shown in Figure 2) and found that the Vanport Limestone is mostly composed of calcite with minor amounts of quartz, goethite, aragonite, and hydrotalcite; the Buhrstone ore is mostly composed of quartz and goethite and minor hematite and kaolinite; the shale layer between the ore and the overlying sandstone is composed primarily of muscovite with minor amounts of quartz and kaolinite; and the Kittanning sandstone is composed primarily of quartz with minor mica and kaolinite.

The mineralogy of the Burhstone ore has led to some unique formations in the cave. During deposition of the ore, iron-rich acidic waters may have enlarged existing joints in the limestone and filled them with ore minerals. Later dissolution removed the limestone and left the more resistant goethite and quartz, which created a structure known as boxwork (Figures 2 and 4). Boxwork is defined as a mineral deposit found in caves and composed of intersecting mineral blades projecting from a wall, ceiling, or floor (Hill and Forti, 1997). Boxwork in this cave exists in complex patterns in the ceiling of the cave. These complex patterns are similar to the pattern made by the passages in the map of the cave (Figure 2).

FOSSILS

The Vanport Limestone is a fossiliferous marine limestone. Jared Snyder of the Mid-Atlantic Karst Conservancy found and photographed a crinoid calyx in the cave (Figure 5A). In another section of the cave, he found some crinoid stems in which the calcite had been replaced by the iron ore. These are exposed as small circles having star shapes in the center (Figure 5B).

In contrast, large tree-sized lycopods are exposed in the ceiling where the cave extends up into the Kittanning sandstone (Figure 6). These fossils are molds of trunks that preserve some of the internal structure of the plant. Goethite in the sandstone gives these fossils their reddish color. In literature searches, there has been no mention of such fossils in the lower Kittanning sandstone member. According to Poth, 1963, plant fossils are most abundant in the middle member of the Kittanning sandstone. Large casts are described in the middle Kittanning sandstone in Clearfield County (Glass 1972) to the east. The fossils in the Harlansburg cave may have been preserved in the lower member as delta deposits prograded from the northwest.

Figure 4. Iron-ore boxwork in the ceiling of Harlansburg Cave.

Figure 5. Crinoid fossils exposed in the Harlansburg Cave. A. Stem (3 to 4 inches long) and partial calyx and arms. B. Crinoid stems. The peculiar-looking object beneath the scale bar is a mud-covered fingertip of a glove. Photographs courtesy of Jared Snyder, Mid-Atlantic Karst Conservancy.

CONCLUSION

I have returned to Harlansburg Cave many times since my first visit, to help map the cave and to help lead novice cavers through the cave. I get covered in mud when I visit the cave, but I always enjoy seeing the complex patterns the iron ore forms on the ceiling and the large lycopod fossils. This cave is one of the few caves in the Vanport Limestone that I have had the privilege to visit.

ACKNOWLEDGMENTS

I am grateful to the Mid-Atlantic Karst Conservancy for allowing me access to this cave and granting me permission to initiate study for the 2013 National Speleological Society convention; to Kim Metzgar for leading trips through Harlansburg Cave and for sharing her map with me; to Jared Snyder for helping with my study and for sharing his photographs with me; and to Aron Schmid for caving in Harlansburg Cave with me and for assisting me with my study and my photographs. I also want to thank Robin Anthony (Pennsylvania Geological Survey) for helping me with some of the figures for this article.

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Figure 6. Plant fossils in the cave ceiling in Kittanning sandstone. Those on the left and in the center are Sigillaria, *and the one on the right next to the pencil is* Lepidodendron *(Mitch Blake, 2013, personal communication).*

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BUREAU NEWS

From the Stacks . . .

Jody Smale, Librarian

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- *Foundations of engineering geology,* 3rd ed., by Tony Waltham, Spon Press, 2009.
- *Geology for civil engineers,* by A. C. McLean and C. D. Gribble, Taylor and Francis, 2008.
- *Minerals—A very short introduction,* by David J. Vaughan, Oxford University Press, 2014.
- *Pursuing sustainability—A guide to the science and practice,* by Pamela Matson, William C. Clark, and Krister Andersson, Princeton University Press, 2016.

Editorial *(continued from page 2)*

recent advent of new technologies to extract gas from shale. All of these resources, along with less sexy but still necessary commodities such as aggregate, sand and gravel, lime, cement, and clay, are here to fuel Pennsylvania's economy because of the state's underlying geology. Likewise with the rich soils that feed the agricultural industry, the ecosystems that support the forests, and the scenic features that form the core of many parks.

Perhaps on the next dismal late winter day, when it's just too nasty to be outside, you can curl up with your favorite hot beverage, gaze out the window in wonder at the geologically controlled landscape, and ponder all you owe to the geology beneath your feet.

Gale C. Blackmer

Gale C. Blackmer,
State Geologist

A Look Back in Time

An unidentified man is surrounded by ice piled along the bank of the Susquehanna River in Harrisburg on March 10, 1926. Although the name of the man is not given, it may be former State Geologist (from 1919 to 1946) George Ashley, who lived in Harrisburg near the river.

To see more photographs from the bureau's archives, please visit the library's Historical Photographs Collection page.

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Open-File Miscellaneous Investigations **(February 2018)**

- Water depth of George B. Stevenson Reservoir—Sinnemahoning State Park, Cameron County, Pennsylvania (supersedes OFMI 15–01.0)

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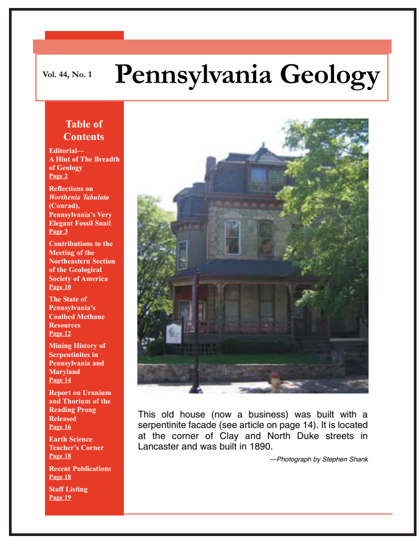

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This old house (now a business) was built with a serpentinite facade (see article on page 14). It is located at the corner of Clay and North Duke streets in Lancaster and was built in 1890.

—*Photograph by Stephen Shank*

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