History of Geology in the New Jersey Highlands and the impact of the Morris Canal with respect to Pennsylvania Coal and New Jersey Iron, Cement, and Building Stone Mining

2023 CONFERENCE PROCEEDINGS
FOR
THE 39TH ANNUAL MEETING
OF THE
GEOLOGICAL ASSOCIATION OF NEW JERSEY
October 27 & 28, 2023

Edited by
Pierre Lacombe
U.S. Geological Survey (retired)

Proceedings XXXIX

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Field Guides and Proceedings of Prior Annual Meetings

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2018	XXXV	Hydrology, Hydrodynamics, and Water Supply in New Jersey and the Delaware River Basin, Tim Macaluso
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2015	XXXII	Neotectonics of the New York Recess, Gregory Herman, and Suzanne Macaoay Ferguson
2014	XXXI	Global Environmental Issues and Local Consequences: Earth Processes and Urban Environmental Quality, Nurdan Duzgoren-Aydin
2013	XXX	Igneous Processes During the Assembly and Break-up of Pangaea: Northern New Jersey and New York City, Alan Benimoff
2012	XXIX	Geology and Public Lands, Jane Alexander
2011	XXIII	Environmental Geology of Central New Jersey, Emma Rainforth and Alan Uminski
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2009	XXVI	New Jersey Coastal Plain Stratigraphy and Coastal Processes, Deborah Freile
2008	XXV	Environmental and Engineering Geology of Northeastern New Jersey, Matthew Gorring
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2006	XXIII	Environmental Geology of the Highlands, Suzanne Macaoay and William Montgomery
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2004	XXI	Proterozoic, Paleozoic, and Mesozoic Mafic Intrusions of Northern New Jersey and Southeastern New York, John Puffer and Richard Volkert
2003	XX	Periglacial Features of Southern New Jersey and Adjacent Areas, Michael Hozik and Mark Mihalsky
2002	XIX	Geology of the Delaware Water Gap Area, Dana D'Amato
2001	XVIII	Geology in the Service of Public Health, Pierre Lacombe and Gregory Herman
2000	XVII	Glacial Geology of New Jersey, David Harper and Fred Goldstein
1999	XVI	New Jersey Beaches and Coastal Processes from Geologic and Environmental Perspectives, John Puffer
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1994	XI	Geology of Staten Island, Alan Benimoff
1993	X	Geologic Traverse Across the Precambrian Rocks of the New Jersey Highlands, John Puffer
1992	IX	Environmental Geology of the Raritan River Basin, Gail Ashley and Susan Halsey
1991	VIII	Evolution and Assembly of the Pennsylvania-Delaware Piedmont, Maria and William Crawford
1990	VII	Aspects of Groundwater in New Jersey, James Brown and Richard Kroll

1989 VI	Paleozoic Geology of the Kittatinny Valley and Southwest Highlands Area, New Jersey, Irvin Grossman
1988 V	Geology of the Central Newark Basin, Jonathan Husch and Michael Hozik
1987 IV	Paleontology and Stratigraphy of Lower Paleozoic Deposits of the Delaware Water Gap, William Gallagher
1986 III	Geology of the New Jersey Highlands and Radon in New Jersey, Jonathan Husch and Fred Goldstein
1985 II	Geological Investigation of the Coastal Plain of Southern New Jersey, Ray Talkington and Claude Epstein
1984 I	Igneous Rocks of the Newark Basin: Petrology, Mineralogy, and Ore Deposits, John Puffer

In Memorial

Otto Zapecza, 72, passed away May 27, 2023. Otto attended every Geological Association of New Jersey (GANJ) conference starting in 1984. He made presentations at a few early GANJ conferences speaking about the hydrogeologic Framework of the New Jersey Coastal Plain

Otto was born in Oxford, England and came to the United States as an infant on the Queen Mary in 1952. As a child he lived in Garfield, New Jersey with his parents. He graduated from Garfield High School and then graduated from Newark State College (Kean University) with a Bachelor of Science degree.

After graduation, Otto began his 37-year-long career with the United States Geological Survey (USGS), retiring in 2014 as a Supervisory Hydrologist. He is known for his published papers on water resources in the state of New Jersey, most recognizably the paper titled "Hydrogeologic Framework of the New Jersey Coastal Plain." Otto was a proud member of The Geological Society of America and a lifelong member of the Geological Association of New Jersey.

Otto is survived by his loving wife of 43 years, Denise; his daughter Erika and son-in-law, Kyle; Otto loved the outdoors and enjoyed gardening, travel, metal detecting, and fossil collecting. He also enjoyed golfing with his USGS buddies and planning fun and memorable adventures for his family.

Mary Chepiga, 69, passed away January 18, 2023. Mary attended many GANJ conferenced especially early in her career prior to adopting two babies.

Mary was born outside Minneapolis, Wisconsin and graduated with a Master's degree from University of Delaware. Mary started her career in Delaware with the US Geological Survey about 1980 and transferred to the New Jersey Water Resources District office about 1983.

Mary was a researcher, project chief and supervisor during her career at USGS. She also was a mentor to many younger employees and was especially supportive towards women scientists at USGS-NJ. She retired as a Supervisory Hydrologist in 2018.

Mary investigations covered topics that required knowledge of computer programming, mathematical modeling, hydrology, chemistry, estuary science, and statistics. She is best known for her report "Groundwater Flow in the New Jersey Coastal Plain"; her research for the USGS Toxic Substance Hydrology Program; and her investigation of groundwater contamination at the Picatinny Arsenal, N.J. where she used the SUTRA groundwater flow and transport model to track attenuation of contaminants downgradient of their sources. Later in her career, Mary advanced the use of the SPARROW model, which relates measured stream-flow and water-quality data to stream and land characteristics.

Mary is survived by her two sons. She too loved the outdoors and the lakes of Wisconsin.

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SCHEDULE of speakers Friday, October 27, 2023

1:00 pm Opening Remarks—**Pierre J. Lacombe** President GANJ 2022-23

1:15 pm Welcome from **Dave Sunderland** Geology Department Chairperson Lafayette College

1:30 pm Introduction Speaker: **Pierre Lacombe**

A) History of Geographic and Geologic maps of northern New Jersey
B) Anthracite Coal Mining in Pennsylvania
C) Canals In Pennsylvania
D) Mining and smelting in New Jersey Highlands

2:10 pm Guest Speaker **Michael DiMaio** Revisiting the Formation Processes New Jersey's Iron Deposits

2:30 pm Guest Speaker **Jeff Hoffman** State Geologist

2:45 pm Business Meeting Moderator **Pierre Lacombe**

State of GANJ
Treasurer's Report
Election of New Officers
Other business

3:05 pm Break for evaluating Posters

3:25 pm Introduction Speaker: Pierre Lacombe

E) Limestone and its use for Portland Cement and Lime
F) Block Stone to Build Structures

3:45 pm Guest Speaker **Joe Macasek**: Morris Canal & Banking Company & it's Mountain Climbing Canal

4:05 pm **Pierre Lacombe** Stone Sleepers of the Morris Canal Incline 9W

4:25 pm Introduction Speaker: **Pierre Lacombe**

G) Colleges that taught Geology near northern New Jersey
H) New Jersey Geological Survey and United States Geological Survey

4:45 pm Guest Speaker **Blaire Schoene:** Timing of iron oxide-apatite mineralization in core of Grenville orogen

5:05 pm Guest Speaker **Laural Goodell:** Buried Secrets: New Jersey Schoolteachers Investigate N. J Highland Iron Ore Deposits Via QUEST Summer Workshops at Princeton University

5:25 pm Introduction of next year's President Jim Peterson

Saturday, October 28, 2023, Field Trip

Start at Lafayette College

Time Distance Activity

8:00-8:30 17 miles Drive from Lafayette College to Oxford Furnace

During drive pullover for A) view of first mile of cement highway,

B) Consumers Report on Cosmetics

C) Foundry building of stone

8:30-10:30 **Stop 1** Oxford Furnace Area

A) Talk on collapsed iron ore mine
B) Talk on Iron ore in gneiss used to build dam on local stream.
C) Talk on Oxford Furnace by **Gina Rosseland**,
Assistant Administrator of Cultural & Heritage Affairs
D) Talk on Shippen Manor

10:30-10:40 2 miles Pull over for Van Nest Train Tunnel talk.

10:45-11:00 4 miles **Stop 2** Twin kilns Talk on limestone mining and kiln operation

11:00-11:15 2 miles Pullover for talk on green and red Serpentine and Sandstone Church

11:15-11:20 1 mile Pull over Pohatcong Aqueduct under the Morris Canal & Incline Plane 7W

11:45-Noon Drive to Bread Lock **Tim Roth** Speak on Canal

Noon-1:00 **Stop 4** Lunch at Bread Lock (

Introduction By Museum Curator, tour of Lock and flatwater,

Stone Basements and Limestone pile.

1:00-1:15 **Stop 5** Drive to Thomas A Edison Cement Factory Site

Talk of cement Factory operation

1:20- 1:35 Drive to stop 6 Incline Plane 9 West

1:35-3:30 **Stop 6** Incline Plane 9W Presentation by **Jim Lee Jr** and/or **Jim Lee III**

A) Talk on Incline Plane purpose
B) Tour of stone sleepers and operation of crib car moving barges
C) Tour of Turbine Chamber
D) Tour of Museum

3:30-4:00 Drive to Railroad station in Phillipsburg

A) Pull over at Incline plane 10 W
B) Pullover at Ductile Steel Plant
C) 1st RR underpass Gneiss; 2nd RR underpass Sandstone; 3rd RR underpass Limestone

4:00-4:45 **Stop 7** Railroad Tracks

A) Discuss topographic surveys of 1880s
B) Discuss railroad trestle construction.
C) Discuss Canal Boat movements across Delaware River **Tim Roth** Speak on Canal

4:45-5:00 Return to Lafayette College Campus

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Part 1

Introduction

2023 Geological Association of New Jersey (GANJ) Annual Meeting and Field Trip

This year, the 2023 GANJ lectures and field trip will focus on the early history of the discovery, mining, and transportation of coal from eastern Pennsylvania; iron ore in northern New Jersey; limestone in Morris County; and building stones along the Morris Canal.

From before the Revolutionary War to the Civil War, geology and mining was mostly a seat-of-the-pants science. Some colleges taught natural science. Few colleges taught geology. Most men and women learned geology empirically. We hope to cover the early teaching and geological surveys of the area.

GANJ 2023 will focus on three topics in the New Jersey Highlands. Topic one will cover mining of magnetite for its iron; limestone for its lime and cement; and blocks of stone for construction. These mining operations started as a means to fulfill the needs of 1600s and 1700s small-farm and building construction. By the 1800s, these small mining operations became cottage industries to satisfy a larger but still mostly local commercial market. By the late 1800s and early 1900s, the mines and quarries were full-fledged industries mining large volumes of rock and producing vast quantities of finished iron, cement, and building stone to be exported across the country.

Topic two will cover the Morris Canal and early railroads. The canal permitted, for the first time, the economical movement of massive amounts of Pennsylvania Anthracite across northern New Jersey. This stimulated the growth of the iron industry, the cement industry, and the American Industrial Revolution. The Morris Canal was a radical departure from Pennsylvanian Coal canals, which started at a navigable river near a coal mine to carry coal downstream via locks and flatwater. The Morris Canal did not start near a coal mine but rather started at the Delaware River. The coal barges were transported up local stream valleys via flatwater and locks but also via incline planes with short (1000 ft. long) railroads that carried the coal barges up steep hills. Railroads eventually replaced all the canals for moving coal, iron ore, iron ingots, lime, cement, and stone blocks.

Topic three will cover the geology of the New Jersey Highlands. During the 1600s to early 1800s, geologic investigations were simply to extract iron, limestone, building stone and coal via seat-of-the-pants knowledge of the resources. During the early 1800s, geologic investigations became a bit more sophisticated but were generally limited to fundamental economic geology. During the mid-1800s to 1900s, geologic investigation transitioned from economic to academic investigations. This transition was advanced as local colleges such as Columbia, Rutgers, and Princeton first taught geology courses as an academic endeavor and with the establishment of geological surveys including the New Jersey Geological Survey (NJGS) and U.S. Geological Survey (USGS).

The Friday lectures will cover many of these historical topics as well as recent research on the emplacement of the iron in the Highlands gneiss. Today universities are teaching geology to their young students as well as working public school teachers. Lectures will include early coal discovery and mining in the Jim Thorp area of northeastern PA and transportation of coal down the Lehigh River to the Delaware River circa 1820-1840. Additional GANJ lectures in combination with the field trip will describe geologic and hydrogeologic considerations for building the Morris Canal across northern NJ, transportation of coal on the canal and the stimulus that coal had on the existing but infant mining industries for iron ore, limestone, and building stone. Mining, smelting, and the need for geologic investigations increased exponentially upon completion of the Morris Canal in 1831. The refined and raw materials were transported via canal to the Hudson River and then used by New York City and Atlantic Coast communities. We will visit the iron mines and industry of Oxford Furnace, the Van Nest

Cut Railroad Tunnel, a small and large limestone kiln, buildings, and the Morris Canal made from various cut stone, to construct locks, incline planes, and viaducts. We will enter an underground mid-1830s hydro mechanical turbine chamber.

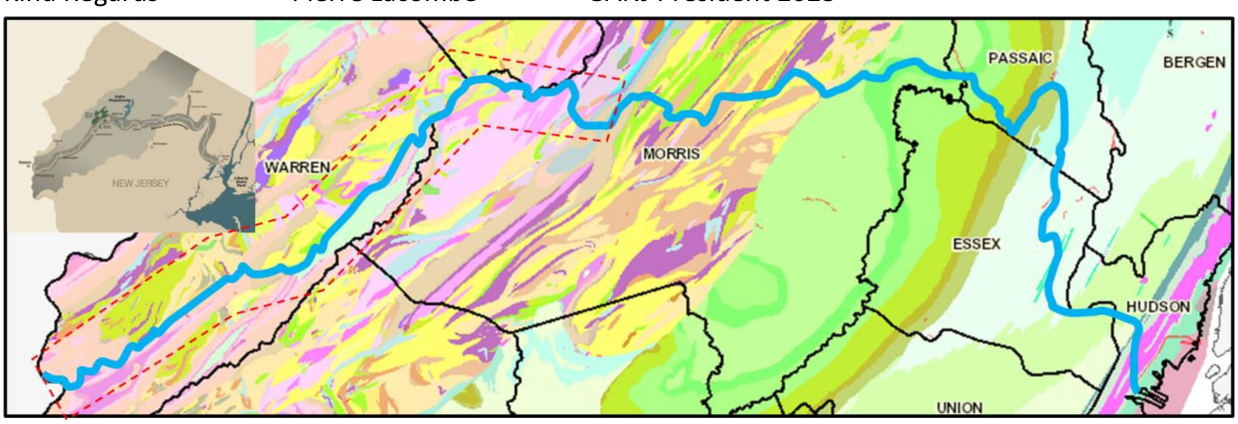
The Saturday field trip will start at the confluence of the Lehigh River and Delaware River at Easton, PA and Phillipsburg, NJ.

Saturday's field trip will drive first to the historical and modern community of Oxford Furnace to visit collapsed (and dangerous by today's standards) iron ore mines, a historical iron ore furnace, and buildings constructed of local sandstone and gneiss and the site of NJ first published geophysical survey. The second stop was to be at a Railroad train tunnel to see outcrops of gneiss. That stop had to be abandoned because Saturday is the first day of deer hunting. We did not want to put an arrow in the heart of our field trip! The third and fifth stops are at a local small operation limestone kiln and a large operation limestone kiln run by Thomas Edison. The kilns were used for cement and agricultural lime production. We will see remnants of both kilns as well as NJ first mile of highway constructed with cement pavement. Stop 4, the lunch stop is at a flatwater and lock section of the Morris Canal to learn about coal transport, construction, and stone block use as well as enter an underground water turbine. The sixth stop is at an incline plane of the Morris Canal. This 1000 ft long incline plane lifted canal boats via a cradle car on railroad tracks about 100 ft from a lower flat water section to a higher flatwater section. The railroad used stone ties/supports because creosote had not been invented. The power was derived from water wheels and later a water turbine. We will see stone block use, and the iron rails made from local iron. The last stop of the day will be at a railroad/canal intersection where we will see the first formal US Coast and Geodetic/USGS survey Benchmarks as well as the use of block stone for construction of multiple trestles. During the day we will make many pullover-stops to view small but important geologic features including a church made of serpentine and the site of a woman's successful change in the use of certain earth materials in the cosmetic industry.

This year GANJ was met by two major challenges. First, GANJ lost access for the ability to edit our webpage. We worked diligently to rectify the issue, but regaining possession of our web page took an exorbitant length of time. Thanks to the help of Jane Alexander, Jennifer Callanan, and Alex Fiore we created a temporary web page to send out and receive registration information. In January, I became ill. Thanks to 6 months of modern medicine at Penn Medicine, I recently tested free of detectable cancer.

GANJ wishes to thank Lafayette College, especially Dave Sunderlin and the faculty of the geology Department for the courtesy of using their beautiful and convenient campus to hold our meeting. Please visit their stunning mineral collection in Van Wickle Hall.

Kind Regards Pierre Lacombe GANJ President 2023



Path of Morris Canal Across the New Jersey Highlands from the Delaware River to the Hudson River.

Place Names and Origins

Lafayette College: Named for Marquis de Lafayette (6 September 1757 – 20 May 1834). Lafayette was a French aristocrat, freemason, and military officer who fought in the American Revolutionary War, commanding American troops in several battles, including the siege of Yorktown. Also, he was a key figure in the French Revolution of 1789 and the July Revolution of 1830. He has been considered a national hero in France and America.

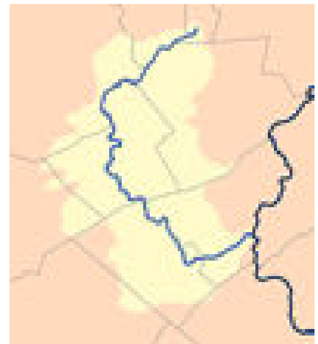
Lafayette was born into a wealthy land-owning family in Chavaniac in south central France. He followed the family's martial tradition and was commissioned an officer at age 13. He was convinced that the American Revolution was noble, and he traveled to the New World seeking glory in it. He became a Major General at age 19, but he was initially not given American troops to command. He was wounded during the Battle of Brandywine but still managed to organize an orderly retreat, and he served with distinction in the Battle of Rhode Island. In the middle of the war, he sailed for home to lobby for an increase in French support. He returned to America in 1780 and was given senior positions in the Continental Army. In 1781, troops under his command in Virginia blocked forces led by Cornwallis until other American and French forces could position themselves for the decisive siege of Yorktown.

Van Wickle Hall is home to the college's geology department. It was originally called the Van Wickle Memorial Library. It was funded by Augustus Van Wickle (son-in-law to Ariovistus Pardee (1810 – 1892) an American engineer, coal baron, philanthropist, and director of the Lehigh Valley Railroad. In the 1840s he began purchasing land in Hazleton, Pennsylvania, suspecting it contained a wealth of coal. When he began mining the area, the town went through an economic boom, and credited Pardee as its founder.

Pardee was a major benefactor of Lafayette College to which he donated over $500,000 and had a building on campus named after him. Van Wickle Hall was completed in 1900, it served as the college's first library. The building, constructed in the Romanesque Revival style, is constructed of mottled Pompeian brick with terra-cotta trimmings and a roof made of Spanish tiles, which originally featured eyebrow dormers. At the time of its completion, all 30,000 volumes previously housed elsewhere on campus were finally consolidated under one roof. It became an academic building in 1956.

Easton, Penn. Thomas Penn, the son of William Penn, married Juliana Fermor, on August 22, 1751, On September 8, 1751, Colonial Governor James Hamilton sent a letter to Wm. Penn requesting that a new town on the confluence of the Lehigh and Delaware Rivers be named Easton and that the city be in a new county called Northampton. In 1752, as requested, the city was named in honor of Lady Juliana's family estate, the **Easton**.

Lehigh River: Lehigh is an anglicization of the Lenape name for the river, **Lechewuekink,** which means **"where there are forks".** Lehigh County and Lehigh Valley are named for the river.



During 1821 - 1966, the Lehigh River was owned by the Lehigh Coal and Navigation Company, making it the only privately owned river in the United States. This private ownership continued until a local representative, Samuel Frank, promoted a bill to return control of the river to the state in 1967.

According to an environmental report from a Pennsylvania nonprofit research center, the Lehigh River watershed is ranked second nationally in the volume of toxic substances released into it in 2020. The study mirrors a previous report by the state's Department of Environmental Protection that found most of the county's waterways unsafe for swimming or aquatic life.

Brass Castle. According to local tradition, the village of Brass Castle was named after the cabin or "castle" of Jacob Brass. By 1874, this widespread community consisted of a school, sawmill, gristmill, several smithies, and about a dozen residences. Other early industries included a brickyard and a paper mill. The village is at the foot of Montana Mountain.

Governor Murphy Signs Legislation Designating Franklinite as State Mineral

07/19/2023

TRENTON – Governor Phil Murphy today signed S1727/A3393, which designates franklinite as the official mineral of the State of New Jersey. Sponsored by Senators Steven Oroho and Edward Durr and Assemblymen Parker Space, Hal Wirths, and Kevin J. Rooney, the legislation recognizes a source of New Jersey pride and a crucial contributor to the state's industrial history.

"By designating franklinite as the official State Mineral, we celebrate yet another quintessentially Jersey piece of history," **said Governor Murphy.** "Franklinite quite literally helped build our modernizing nation's foundation while fueling the growth of the railroad industry and New Jersey's local economies. This legislation will ensure that franklinite's enduring economic and cultural legacy is remembered not just in Sussex County, but across the Garden State."

"The Murphy Administration's recognition of franklinite as the New Jersey State Mineral underscores the worldwide renown and critical role that franklinite has had in the industrial history of our state," **said New Jersey State Geologist Jeff Hoffman.** "The largest deposit of franklinite in the world is in the ore bodies that supplied the Franklin Mine and Sterling Hill Mine in Sussex County. Zinc from these mines supported many uses and was crucial to early industrial development in New Jersey. Moreover, these mines were the largest supplier of zinc during World War II, providing the raw materials needed for weapons that helped protect our country and troops."

"Franklinite represents an important part of New Jersey's history for the role it played in helping to industrialize our state," **said Senator Steven Oroho.** "Found exclusively in the United States in the communities of Franklin and Ogdensburg, franklinite is a critical link to our state's mineral mining heritage and its designation as New Jersey's official state mineral is most appropriate."

"Franklinite is a mineral unique to New Jersey and was a key component to the modernization of our state during the 19th and 20th centuries," **said Senator Edward Durr.** "With the signing of this bill, New Jersey will recognize the tremendous impact this mineral has had on the construction of water, electric, and other crucial infrastructure we rely on every day."

"Franklinite is as unique to New Jersey as the Pine Barrens are and was the driving force behind the state's thriving mining industry," **said Assemblyman Parker Space.** "The discovery and mining of this rare ore built Franklin. Its importance can't be overstated."

"There are many people to thank who helped get this bill to the Governor's desk," **said Assemblyman Hal Wirths.** "Jeff Osowski of the Sterling Hill Mining Museum built the momentum for this years ago; Bill Truran took a keen interest in organizing support when he became the Sussex County Historian in 2019; and all the students in Northern New Jersey who kept writing letters to get this bill through the legislative process and now signed into law. This is a great day for everyone involved."

"Franklinite, an ore only found in New Jersey, built a town and was a driving force in our state economy while benefitting millions around the globe," **said Assemblyman Kevin J. Rooney.** "It's fitting to name it the official state mineral."

"The Sterling Hill Mining Museum has been working for years to gain recognition for franklinite as the New Jersey State Mineral. It was one of the driving forces in the economic development of Sussex County in the 1800s," **said William Kroth, President and Executive Director of the Sterling Hill Mining Museum, Inc.** "After the franklinite ore was processed to remove the zinc, it then became the source of high manganese steel, which was vital for the railroad industry. Franklinite is found nowhere else in the world in as great a quantity as in New Jersey. The Sterling Hill Mining Museum, a 501(c)(3) educational institution, is looking forward to building on this recognition in its outreach to students."

Franklinite is an oxide mineral belonging to the normal spinel subgroup's iron (Fe) series, with the formula $Zn^{2+}Fe_2^{3+}O_4$.

Official State Dinosaur of New Jersey

New Jersey designated Hadrosaurus foulkii as the official state dinosaur in 1991. Hadrosaurus foulkii was a duck-billed dinosaur that roamed the forests and swamps along the bays of New Jersey's prehistoric seacoast. Another hadrosaur fossil (Augustynolophus morrisi) was recognized as the state dinosaur of California in 2017.

From New Jersey's official website; "In the summer of 1858, Victorian gentleman and fossil hobbyist William Parker Foulke was vacationing in Haddonfield, New Jersey, when he heard that twenty years previous, workers had found gigantic bones in a local marl pit. Foulke spent the late summer and fall directing a crew of hired diggers shin-deep in gray slime. Eventually he found the bones of an animal larger than an elephant with structural features of both a lizard and a bird."

Part 2

Historical Geographic and Geologic Maps of Northern NJ and their Evolution

The first region wide maps of the western part of the New Jersey Highlands were geographic maps showing cities, rivers, mountains, and major roadways. These geographic maps were scaled in such a way that the distance and direction between cities was by seat of the pants methods. You could get from Phillipsburg to Oxford Furnace by following the map. The maps were the best available at the time. Rivers were squiggled lines on the map, and mountains were drawn by a series of vertical lines to give the impression of height. The replication of the location of mountain tops and intervening streams was simple at best.

The seven geographic maps (fig. 1) show Phillipsburg, Delaware River, Musconetcong River, mountains on the north and south side of the Musconetcong and a few inland communities. After the 1800s, color was added to divide the counties. In 1832, the Morris Canal was completed. Later geographic maps show the distance and direction to communities along the canal with much greater accuracy. With the completion of railroads by the mid-1850s, the maps showed distance and direction to communities with a new level of accuracy. However, mountains and stream locations are still quite rudimentary.

In 1840 the first Geologic Map of New Jerey was published by Rogers then Chief Geologist of the NJGS (fig 2A). The map divides the study area into two geologic units. The oldest is ‘Gneiss and etc. ‘and the youngest is ‘Limestone F(ormation) of Unit II’. The geography, like the geology remains simple.

Descriptions of the units in the Annual Report for 1840 telling. The geologic Column that accompanies the map displays geologic units from north to south and not from youngest to oldest.

In 1868 the second geologic map of New Jerey was published by Cook, Chief Geologist for NJGS (fig. 2B). The map divides the study area into four geologic units. The geologic column displays the units from oldest rocks at the base to youngest rocks at the top. The oldest rocks are gneiss and granite. Franklin Marble is labeled as White Limestone. Any rock that is conglomerate, sandstone, slaty grit, and shale in the New Jersey Highlands is defined as Potsdam Sandstone of lower Silurian age. Dolostone referred to as 'Magnesian Limestone' and Limestone labeled as 'Fossiliferous Limestone' are shown on the map as one unit. They are of lower Silurian Age. The map does not show mountains as topographic features, but it does label the mountains. The map shows other major geographic features.

In 1910 the third geologic map of New Jerey was published by Kummel, chief Geologist for NJGS (fig 2C). The map divides the gneissic units into Byram, Losee and Pochuck gneiss of Pre-Cambrian Age. The sandstone is referred to as the Hardystone of Cambrian Age and the limestone is divided into the Kittatinny and Jacksonburg of Ordovician age. Glacial sediments that overly the rocks are mapped with red stippling.

The 1910 map was edited and enhanced with areas of high magnetic attraction (fig. 2D). The map was first edited to combine the post Algonkian (Paleozoic) rocks as one unit. The Pochuck gneiss consisting of dark-colored-minerals is map separately from the Byram and Losee Gneiss which consists of light colored minerals. The light colored mineral rich gneiss is divided to highlight a 'high magnetic attraction' rock unit that likely has great iron ore potential.

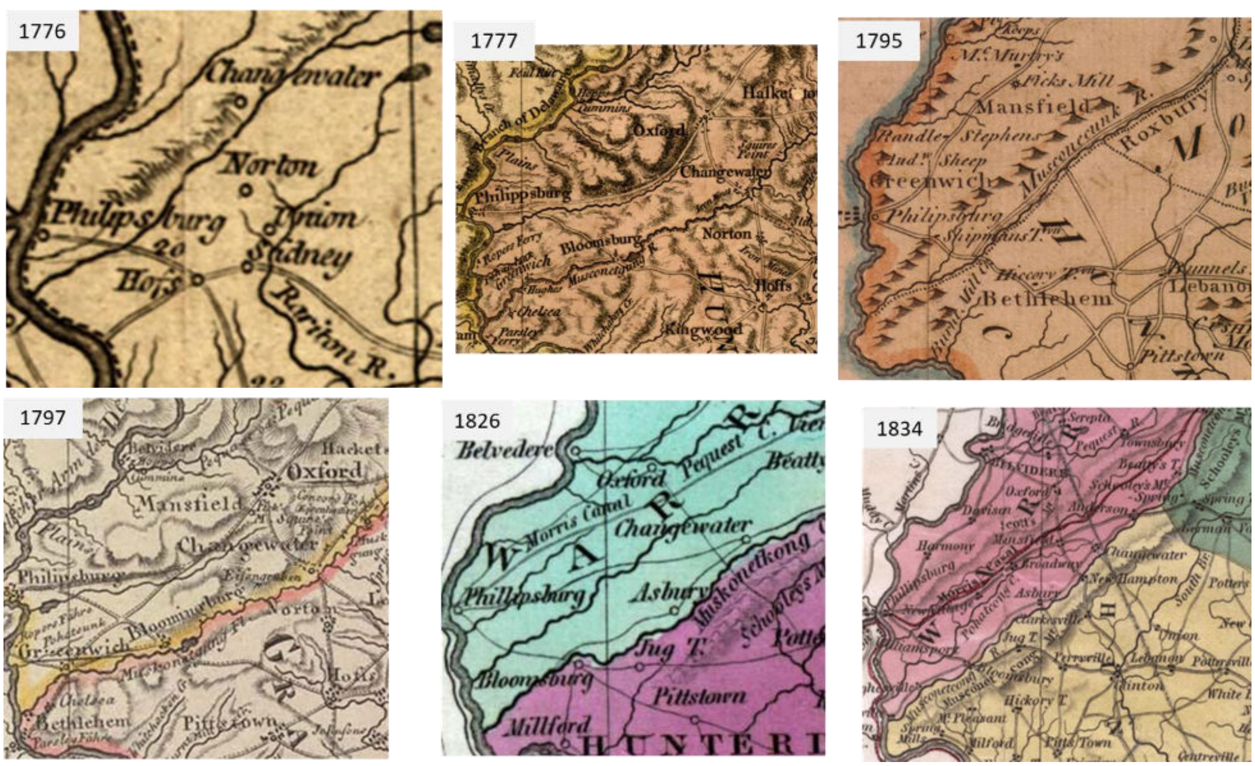


Figure 1. Early geographic maps of western parts of the New Jersey Highlands. Maps contain more information as they evolve.

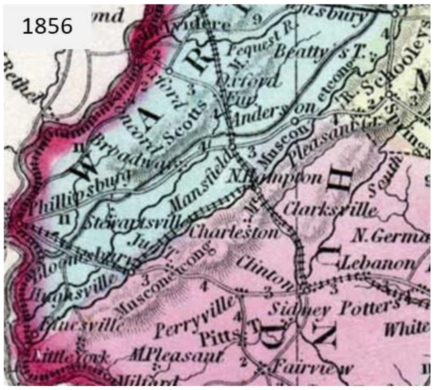
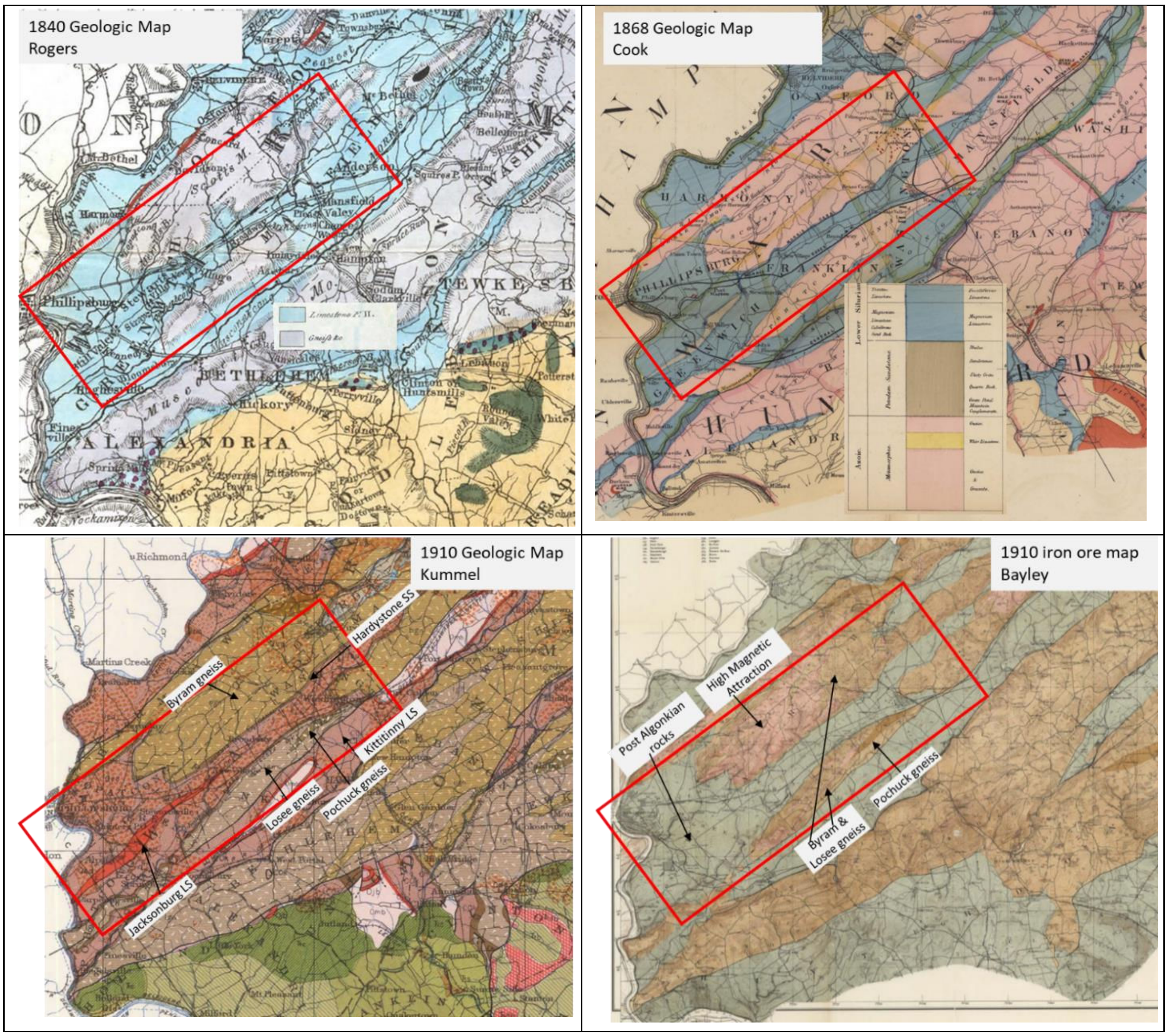


Figure 1. Early geographic maps of western parts of the New Jersey Highlands. Maps contain more information as they evolve.

The 1998 and 2014 maps of the USGS and NJGS are essentially the same (fig. 2). The advantage of the 2014 map is that it is digitized to be used with GIS mapping tools so that the most recent map can be compared with historical maps and sundry other map types. The maps are shown with 15 or more geologic units. Other geographic features can be added via GIS coverages.



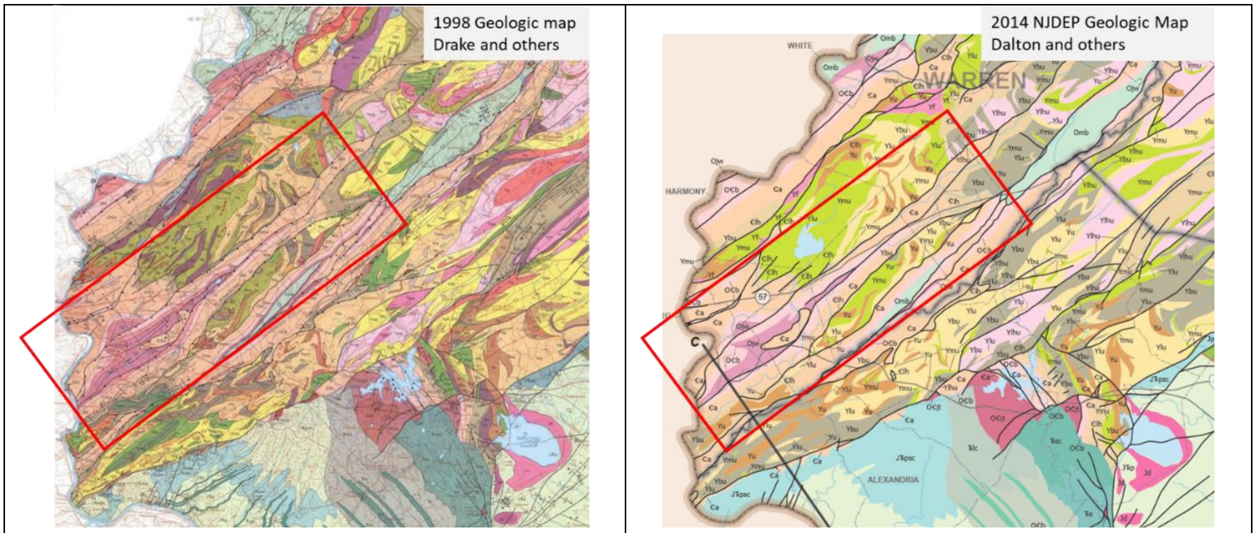


Figure 2. Geologic maps of western parts of the New Jersey Highlands. Maps contain more geologic and information as they evolve.

Geologic names for the units on the 1998 and 2014 geologic maps

Obl Obul	Beekmantown Group	**Byram Intrusive suite**		**Losee Metamorphic Suite**	
Oca	Allentown Dolomite	Ybh	Hornblende granite	Ylo	Quartz oligoclase gneiss
Cl	Leithsville Formation	Ybs	Hornblende syenite	**Rocks of uncertain origin**	
Ch	Hardyston Quartzite	Yba	Microperthite alaskite	Ya	Amphibolite
Lake Hopatcong Intrusive suite		**Meta Sedimentary Rocks**		Yam	Migmatite
Ypg	Pyroxene granite	Yk	Potassium Feldspar gneiss		
Yps	Pyroxene syenite	Yp	Pyroxene gneiss		
		Yf	Franklin Marble		
		Ymh	Hornblende quartz feldspar gneiss		

Part 3

Early History of Anthracite Coal Discovery in Pennsylvania

1762 to 1800

In 1762, Parshall Terry with other pioneers from Connecticut discovered coal near Wilkes Barre Pa. (fig. 1). In 1769, Obadiah Gore and his brother (I think his name was Al, that is a joke!) reportedly used Pennsylvania Coal for the first time in their blacksmith shop in Wilkes-Barre. Local men went into the mountains and mined a wagon load or as much as a mule could carry and then return to the shop to use the coal (fig. 2). This sort of local mining went on for a few decades, however, its use was restricted to local needs. In 1775, the first shipment of coal was barged from Wilkes Barre on the Susquehanna River. (fig. 3).

Around 1790, the US had its first fuel supply crisis. Forest wood needed to make charcoal for industry and domestic heating were quickly vanishing. Logging for this wood needed to take place farther and farther from population centers. Transport of wood or any alternative fuel became very important to people. Bituminous coal was inexpensive to import from England and more reliable than the delivery of anthracite from northern PA.

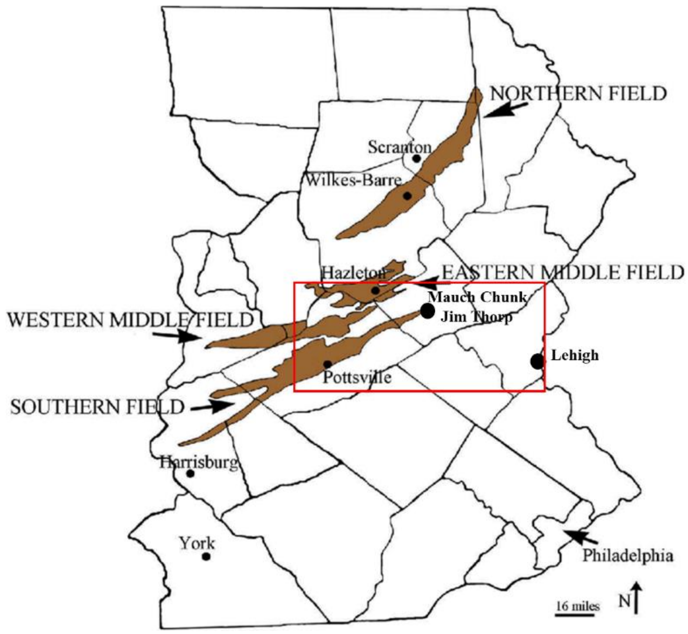


Figure 1. Map showing the four major Anthracite Coal regions of northeastern PA (red box is Map 4).

Figure 2. Mule and load of coal.

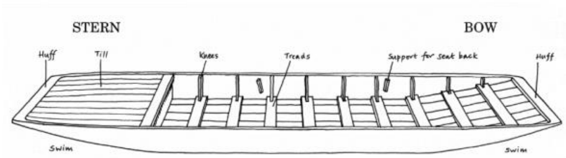


Figure 3. Early flat bottom barge for moving coal down streams.

In 1791, coal was first discovered by German immigrant Philip Ginder while hunting on Summit Hill about 6 miles west of Mauch Chunk (fig. 4). In 1792, anthracite coal mining began by the Lehigh Coal Mine Co. after Grinders discovery. The Lehigh Coal Mine Company funded by Jacob Weiss and some wealthy Philadelphia businessmen periodically sent miners to exposed coal beds near Summit Hill to mine the deposits. The company had a slow start because mining and shipping coal to Philadelphia was difficult and getting anthracite coal to burn in wood stoves was difficult.

In 1813, the first organized mining began at Beaver Meadows, about 12 miles northwest of Mauch Chunk.

In summary the first men to find coal deposits and mine the coal were not geologists. They were guys who figured out that some black rocks burned and other black rock did not burn.

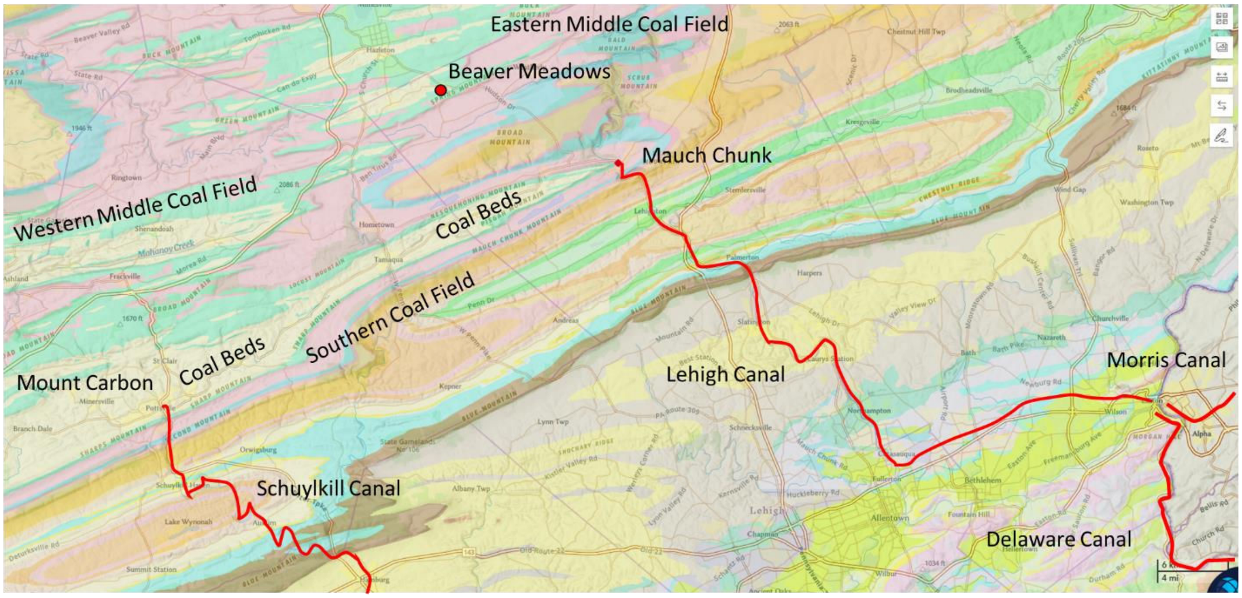


Figure 4. Geologic Map of eastern Pennsylvania showing the major coal beds in the Llewellyn Formation of the Southern Coal Field west of Mauch Chunk, the four major canals used to transport coal to Philadelphia and New Your City.

Early History of Anthracite Coal Mining, Delivery, and Use

Coal production and deliveries was a problem because the Lehigh Coal Mine Co. was run by absentee managers who relied on workers to: a) mine the coal, b) transport the coal 5 to 10 miles via mules to the Lehigh River near Mauch Chunk: c) log trees and build flat bottom, high walled boats, d) raft the coal 45 miles down the Lehigh River to the confluence with the Delaware River at Easton, and then raft the barges down the Delaware River to Philadelphia. As a result of the intermittent nature of this operation coal deliveries to Philadelphia were sporadic.

Getting anthracite to burn was a problem that was partially resolved in 1802 when Oliver Evans burned anthracite on a grate. Obviously, some information was lost at the time because in 1808 Judge Jesse Fell of Wilkes-Barre then discovered a solution to ignite anthracite with the usage of a stove with an iron grate. Then during the War of 1812 Josiah White experimented with PA anthracite. He built an anthracite coal fire on iron grates instead of a flat bottom stove. This allowed an increase in air flow through the burning anthracite thus made it burn continuously. With that adjustment, anthracite became an efficient and useful fuel.

During the War of 1812, British Navy blockades stopped the import of British bituminous coal and impeded the ocean transport of Virginia coal. British naval blockade activities stimulated the mining transport and use of anthracite coal from Pa mines.

During the war, Jacob Cist's, the son of a major financial investor in the Lehigh Coal Mine Company, began to transport Company coal to Philadelphia by the Lehigh and Delaware Rivers. Once in Philadelphia, Cist used testimonials and public demonstrations to disprove the negative remarks about anthracite and convince Philadelphians that anthracite coal could replace bituminous coal. Cist, other coal advocates, as well as State and Local government officials promoted anthracite. As a result, the War of 1812 opened the way for Pennsylvania anthracite coal to outdo Virginia's bituminous coal in the urban marketplace.

During and for the decade after the War of 1812, there was no efficient and cost effective transportation system to move coal from the mines to the cities and industrial areas. However, by the late 1820s and early 1830s the Lehigh Canal, Schuylkill Canal, Delaware Canal, and Morris Canal systems were developed. Then by the 1850s and 1860s the railroad systems to move coal were developed. The canal and railroad made coal transportation much easier and cost effective. Anthracite coal was regularly supplied to iron mining areas in the New Jersey Highlands and urban areas such as Philadelphia and New York City. Pennsylvania anthracite coal helped fuel the American Industrial Revolution.

History of Canals to Transport Pennsylvania Anthracite Coal

During the early 1800s nearly a dozen coal canals were constructed, reconstructed, and expanded in eastern Pennsylvania. Construction of most Pennsylvania coal canals started on a navigable or semi-navigable stream near the coal mine and then carried the coal downstream. Coal canals had long flatwater sections and several locks. Pennsylvania Coal canals in the GANJ 2023 study area include the Lehigh Canal (1818), Delaware Canal (1832) and away from the GANJ 2023 study area include the Schuylkill Canal (1827).

The Morris Canal in New Jersey was unlike the typical Pennsylvania coal canal. It did not start near coal mines. It started in Phillipsburg NJ opposite the confluence of Lehigh River with the Delaware River. The Morris Canal did not descend from coal mine regions but rather ascended Pohatcong Creek and then Musconetcong Creek to its crest near the south end of Lake Hopatcong. From Lake Hopatcong, the canal descended the Passaic River valley to sea level at the shoreline of the tidal Hudson River. To ascend the 760 ft. from the Delaware River and descend the 914 ft. to the Hudson River, the Canal had numerous typical flat water sections and locks combined with 23 incline planes that were atypical for most American Canals.

Lehigh River and Canal

In 1792, the Lehigh Coal Mine Co. began commercial anthracite coal mining. To move the coal from the east side of the Southern Coal Fields down the Lehigh River the Company removed boulders in the river and constructed multiple low rock dams to raise the water level behind the dam by about 18 in. A few canal boats loaded with coal collected in the pool behind the dam. About once every 3 days the water was released from the dam which allowed the coal boats to flow downstream in the small flood or "freshets". This proved to be a tenuous method of moving coal down the Lehigh River.

In 1818, the **Lehigh Coal & Navigation** Company was established by Josiah White and Erskine Hazard with plans to build a standard style canal on the river. In 1820, the improved Lehigh Canal began operations on the Lehigh River. The initial canal section was 45 miles long and flowed from Mauch Chunk to Easton. In Easton, the canal emptied out on the Delaware River for barge travel to Philadelphia. Over the next few years, the initial Canal was improved with locks and flat water and lengthened upstream to become 72 miles long.

In 1823, Josiah White made a proposal to the Pennsylvania legislature to build dams and locks on the Delaware River. In 1824, the legislature rejected his proposal; lumber and timber interests feared that damming the Delaware River would prevent them from rafting logs on the rivers to local sawmills. In 1827, a revision to the Main Line of Public Works funded the **Delaware Canal**.

Delaware Canal

The **Delaware Canal** is a small section of the massive Pennsylvania Canal network known as the Main Line of Public Works. The canal is 60 miles long and parallel to the Pennsylvania bank of the

Delaware River. The entry lock is in Easton at the mouth of the Lehigh River and the exit lock is in Bristol PA.

In 1832, the Commonwealth of Pennsylvania completed construction of the Delaware Canal to transport anthracite coal from Easton to Philadelphia. The canal failed multiple times and had to be re-engineered by Josiah White of the Lehigh Coal and Navigation Co. In 1858 Pennsylvania sold the canal to the Lehigh Coal and Navigation Co. The Delaware Canal had long, flat water sections and widely spaced locks. As a result, barge crews preferred the Delaware Canal over the Lehigh Canal because they could go faster, farther, and longer before having to go through the next lock.

The Delaware Canal carried coal, gravel, limestone, cement, and lumber—downstream from northeastern Pennsylvania to Philadelphia and manufactured goods such as iron products upstream.

In 1855, the Delaware Canal reached its shipping peak with more than 250,000 tons of coal shipped. after that year railroads carried more and more of the coal. The canals stayed in operation until the Great Depression (early 1930s). In 1931 the last canal barge plied the water. The bankrupt Lehigh Coal and Navigation Co. sold the canal back to Pennsylvania. It is thought to be the longest-lived coal canal in America.

Schuylkill Canal

A group of Germans wanted to seek the transportation rights to the Schuylkill River. They received a charter in 1815 to incorporate the Schuylkill Navigation Company. With investor funding, the Schuylkill Navigation Co. was able to construct the 108-mile long river and canal system that connected Pottsville, Pa to Philadelphia. The **Schuylkill Canal** opened in 1825 on the west side of the Southern Coal Region. The Lehigh Canal serviced the east side of the Southern Coal Region. By the early 1840s, about 500,000 tons of anthracite coal was transported annually to Philadelphia using the Schuylkill Canal.

Morris Canal

In 1831, the Morris Canal, a 107-mile coal canal, was completed from the Delaware River at Phillipsburg to tidal water of the Passaic River near the Hudson River. The canal connected Easton, Pennsylvania to New York City by crossing over the mountains of the New Jersey Highlands.

With a total elevation change of more than 900 feet, like most other canals the Morris Canal contained many flatwater sections and 23 locks that lifted and lowered canal boats up to 12 ft. However, the Morris Canal also used 23 inclined planes that raised and lowered canal boats from 60 to 120 ft in a single hill slope. Initially, water wheels but later by water-driven turbines provided the power to lift and lower the canal boats on a cradle that moved along a railroad track.

The Morris Canal eased the transportation of anthracite from Pennsylvania's Lehigh Valley to New York City and the developing industries in northern New Jersey along the Hudson River. However, more importantly the canal brought coal to northern New Jersey's growing iron industry. The Morris Canal also carried minerals and iron ore westward to blast furnaces in western New Jersey and Allentown and Bethlehem in the Lehigh Valley.

In 1839, New Jersey’s iron industry started using hot blast furnaces which caused the continuous high-volume production of plentiful anthracite pig iron.

The Morris Canal remained in heavy use through the 1860s. But railroads had begun to eclipse canals in the United States, and in 1871, it was leased to the Lehigh Valley Railroad.

Like many enterprises that depended on anthracite, the canal's revenues dried up with the rise of oil fuels and truck transport. The canal was taken over by the state of New Jersey in 1922, and formally abandoned in 1924.

Part 4

History Iron Mining and Smelting in New Jersey Highlands

1685 The earliest recorded mining of iron ore in the American colonies was probably in the Dover District, Morris County, New Jersey circa 1685. The mining and ore smelting was likely to obtain iron for cast iron pots, pans and fires shields, or wrought iron for nails, farm tools, and iron hardware for carriages and buildings. These mines and furnaces were small operations, simple cottage industries, generally run by a farmer, or group of farmers for the needs of their farms and mills. The men likely learned their skills in geology, mining and smelting while in Europe and carried those skills to America.

History of Iron Mining, Smelting, and Forging at Oxford Furnace

1741 Oxford Furnace is a historic furnace in Oxford Township, Warren County, New Jersey. The furnace was built of Potsdam Sandstone (Hardyston Quartzite) and local gneiss by Jonathan Robeson and Joseph Shippen in 1741. Robeson and his coworkers likely learned geology, mining, and smelting skills from one another or via the school of hard knocks. They likely built a rudimentary small forge/kiln or furnace earlier than this and made small batches of pig iron for local use.

Figure 1) Stone buildings in downtown Oxford Furnace A) Furnace, B) Shippen Manor, C) Grist Mill converted to Church, D Garage

At Oxford Furnace there is a small quarry in Potsdam Sandstone, where stone is occasionally quarried for nearby buildings. Before this quarry opened, stone lying loose on the slope of the mountain were picked up and used for building. The Shippen Manor Mansion is mostly made of loose field stones. Oxford furnace (old rear building, new front building, the Grist mill/church, and the garages across the street from the furnace are made predominantly of Potsdam Sandstone though there are some blocks of local gneiss (fig. 2). The Potsdam sandstone is properly a quartzite of a greyish color, fine-grained, and tolerably firm, and has proved to be a good building enduring stone. The cement used as mortar was made from local Allentown Dolostone of Jacksonburg Limestone.

1743 Oxford Furnace produced its first pig iron in 1743. This raw iron, produced in a cottage industry setting, was used locally by farms and mills. Traditions state that it was first blown by a water blast furnace. Early products of Oxford Furnace include firebacks used in fireplaces. Some firebacks were embossed with the royal coat-of-arms of Great Britain during the reign of King George II (1727-60) (fig. 2).

1755 Cannon balls were cast for the French and Indian War (1754-63) and for the American Revolutionary War (1775 – 1783)

1813 Grist mill for various food grains is built adjacent to the furnace. During 1909–1915, the mill was converted into the Oxford Colonial Methodist Church.

Figure 2. Fireback with British Royal Coat of Arms: manufacture site Oxford and year 1762

1832 Morris Canal opens. Oxford Furnace changed from using locally made charcoal and locally cut wood to Pennsylvania anthracite coal. Wm. Henry rebuilds part of the stack, bridge, cast houses, coal barn, and 6 workmen's houses. Erected new "blowing machinery" Discovered and opened Staley mine. (fig. 4) Furnace "in blast" on August 4, 1832 and produces 17-20 tons per week. John Wolle joins Wm Henry III and John Jordan. Firm's name is changed to "Henry, Jordan & Co." Their annual profit during 1832-1837 was $4000 to $7000. 1849: 900 tons. 1854: 1000 tons. 1855: 896 tons. 1856: 803 tons (fig. 3).

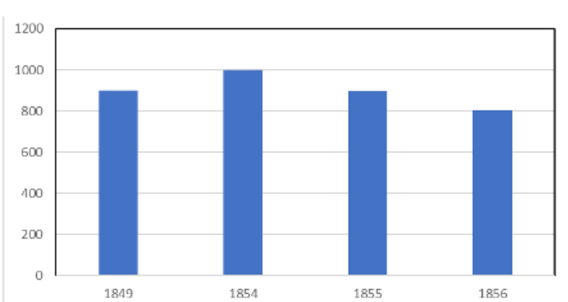


Figure 3. Tonnage of iron produced at Oxford Furnace

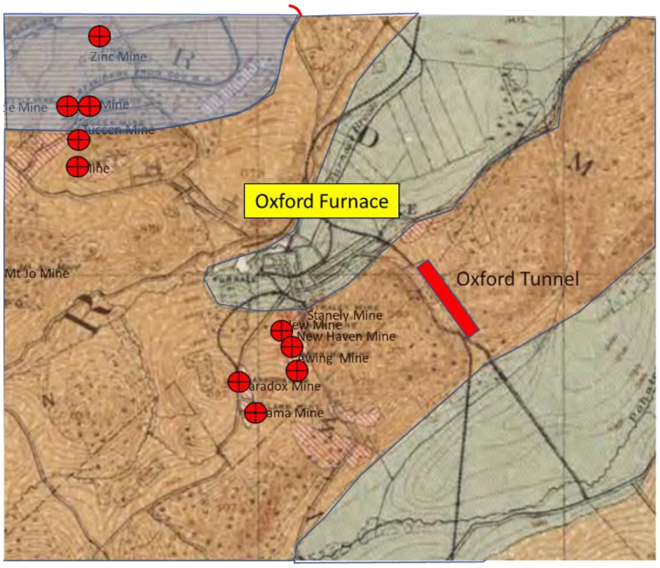


Figure 4 Location of Mines Around Oxford Furnace

1834 The first practical use in the United States of hot blast furnace technology took place at Oxford Furnace in 1834 which increased production by nearly 10%. This was organized big industry but in its infancy. Blast Furnaces were brought about by the ability to transport anthracite coal from Pennsylvania via the Morris Canal and transport out pig iron and raw iron to New York and the Hudson Valley and to Philadelphia and the Delaware Valley.

1835, Wm. Henry built a hot blast oven on top of the stack, which further increased the temperature of the blast and increased production by nearly 40%.

1856 Completion of the Warren RR enabled Pennsylvania coal to be delivered directly to Oxford Furnace thus eliminating the need to transport the anthracite from the Morris Canal.

1856

Analyses of ore from the Oxford Mines,

	1	2	3	4	5	6
Magnetic iron ore	98.1	92.5	81.7	85.9	89.5	82.3
Silica and insoluble matter	4.8	7.8	9.4	4.2	6.2	16.8
Sulphur	trace.	trace.	0.0	6.6	1.0	0.1
Phosphoric acid	trace.	0.0	0.7	0.0	0.8	0.0
Metallic iron, per cent	71.0	67.0	69.2	62.2	64.8	59.6

1 New Mine. 2 Car- Wheel Vein. 3 Harrison Mine.
4 Washington Mine. 5 Washington Mine. 6 Franklin Vein

1859, the Oxford Iron Company was incorporated by George and Selden T. Scranton. During the Civil War (1861-65), the furnace flourished and expanded. In 1863, the furnace property and Shippen Manor were sold to the Oxford Iron Company, two years following the death of George Scranton.
1865 Rolling mills and nail factory are completed.

1871, Selden and Charles Scranton and Eugene Henry built the new furnace (Oxford Number 2), but it was not as successful. This used their available capital at the start of the worst depression of the late 1800s (Panic of 1873). Sloan learned about railroads from Commodore Vanderbilt and was made president of the Delaware, Lackawanna, and Western Railroad. This rail line hauled about 60,000 tons of anthracite a year to the Oxford Furnace.

1874: Selden went bankrupt in, and by 1878, he lost his mines to foreclosure.

1884 Oxford Furnace "blown out". Oxford Furnace operated the longest of any of the colonial furnaces. It was rendered unusable due to a failure of the inner wall above the tuyere (pipe or nozzle through which air is forced into a blast furnace) in the north tuyere arch (a large crack in the masonry occurred over time).

1889 Oxford Iron Co. became bankrupt.

1893, Oxford Iron and Nail Co. purchased Oxford Iron Co. The company was reorganized by Empire Steel & Iron Co., which sold and moved the rolling mills, and rebuilt Furnace #2, which ran until 1921.

1922, the only industry operating in Oxford was iron ore mining, iron ore mining life span was from 1741 until the early 1960s.

The State of New Jersey acquired possession of the two furnaces by 1935. Furnace #2 was razed in the 1980s/1990s. The older of the furnace still stands, in part, in Oxford as a memory of a day long gone by.

The state using your tax money restored the furnace during 1997 and 2001.

Parts of Oxford Furnace and its production

General Blast Furnace Design Technology

Arches or "tuyeres" (a nozzle through which air is forced into a smelter, furnace, or forge) on three sides of the furnace can still be seen. It was through these tuyeres that air was blown into the furnace; molten iron was removed through the fourth arch. The Furnace produced 200-500-pound firebacks and pig iron in its early days; later it cranked out railroad car wheels, nails, and other useful iron objects.

In the 1700's and 1800s, blast furnaces were large stone or brick structures designed to melt the iron in iron ore to a liquid castable form. The furnaces were usually built near a natural or excavated embankment. A bridge was constructed to connect the top of the furnace to the top of the embankment, and next to loading and storage areas for the iron ore, limestone flux, and the fuel of wood, charcoal or coal.

Workers, known as bridgemen, carted wheelbarrows filled with ore, flux, and fuel across the bridge to the furnace. They would dump these materials into the internal smelting chamber.

Early furnaces were usually located near a dammed stream and the water was used to power a waterwheel. The waterwheel operated leather bellows or wooden air cylinders that blew air into the fire within the furnace.

Design of a Furnace

Generally, a furnace is comprised of two parts: A) external stack, and B) internal smelting chamber with hearth (fig 5).

The stack is comprised of an outer course of "hand-dressed, mortared, durable building stone such as gneiss, or granite, with a few feet of backup rubble. The outer course was tapered inward, so that the flat top area was less than the base. To restrain the exterior stack from expansion and contraction generated by the heat of the blast, sets of wrought iron binders were built into the stack at predetermined intervals above the springline of the arches. These full-length binders were inserted into the horizontal channels drilled and aligned into a series of stones and inserted after completion of the stack. The binders serve to tie one side of the stack to the other and to restrict movement and tensile stresses within the stack.

The external stack surrounded the internal smelting chamber to protect it from the weather and acted like a "rigid framework to counterbalance expansive forces produced by the heat of the blast and provided additional structural support. The stack did not influence the quality or quantity of the product manufactured as did the shape and configuration of the smelting chamber".

The shape and design of the smelting chamber varied from furnace to furnace and often looked a lot like a long egg standing on its flatter end. The internal smelting chamber, or bosh, consisted of three sections—the hearth (crucible), bosh and stack liner.

Hearth: shaped like a cube and consisted of sandstone blocks that were arranged for the pooling of liquefied iron

Bosh: a cylindrical, funnel-like in shape constructed on the vertical sidewalls

Stack Liner: constructed upon bosh in a reverse taper, working with the bosh to withstand intense heat made of slate, but in the 1830s, firebricks were primarily used.

Molten iron and slag (liquefied mix of non-ferrous substances or impurities removed from ore through the smelting process), drawn out through the hearth through a tap hole accessed through a large masonry arch (casting arch) that was built into the exterior furnace stack. Later furnaces incorporated multiple Tuyere arches that would evenly distribute and increase airflow and increase production of iron.

The casting arch and casting arch side of the furnace were enclosed within a large casting house with a floor consisting of sand that was used as a mold to cast marketable items such as cannons, pots, firebacks, stoves, etc. Then, "sand-filled, hand-held wooden box molds were utilized to cast smaller items. Pig iron was cast in troughs dug into the sand and sold on the open market for later processing into wrought iron in a finery forge".

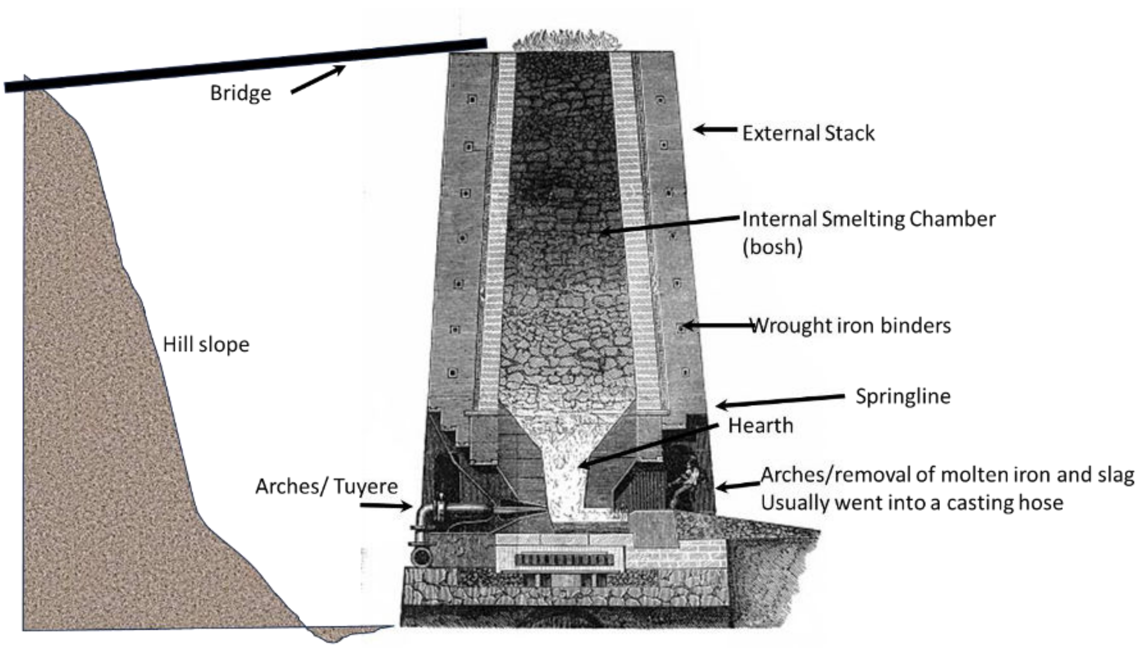


Figure 5 Diagram of a Blast Furnace

Iron ore mines and mining south of Oxford Furnace

About 10 minor and major Iron ore mines are located south of Oxford Furnace. During the field trip we will stand near the collapse feature of the McKinley mine (fig. 1). The iron ore veins strike N-S to NW - SE The dip to the East. The veins range in length from a few 100 ft to less than 2000 ft. The veins thickness is 20 to 5 ft. The depth of the veins is unknown.

The veins were mined via the stopping method.

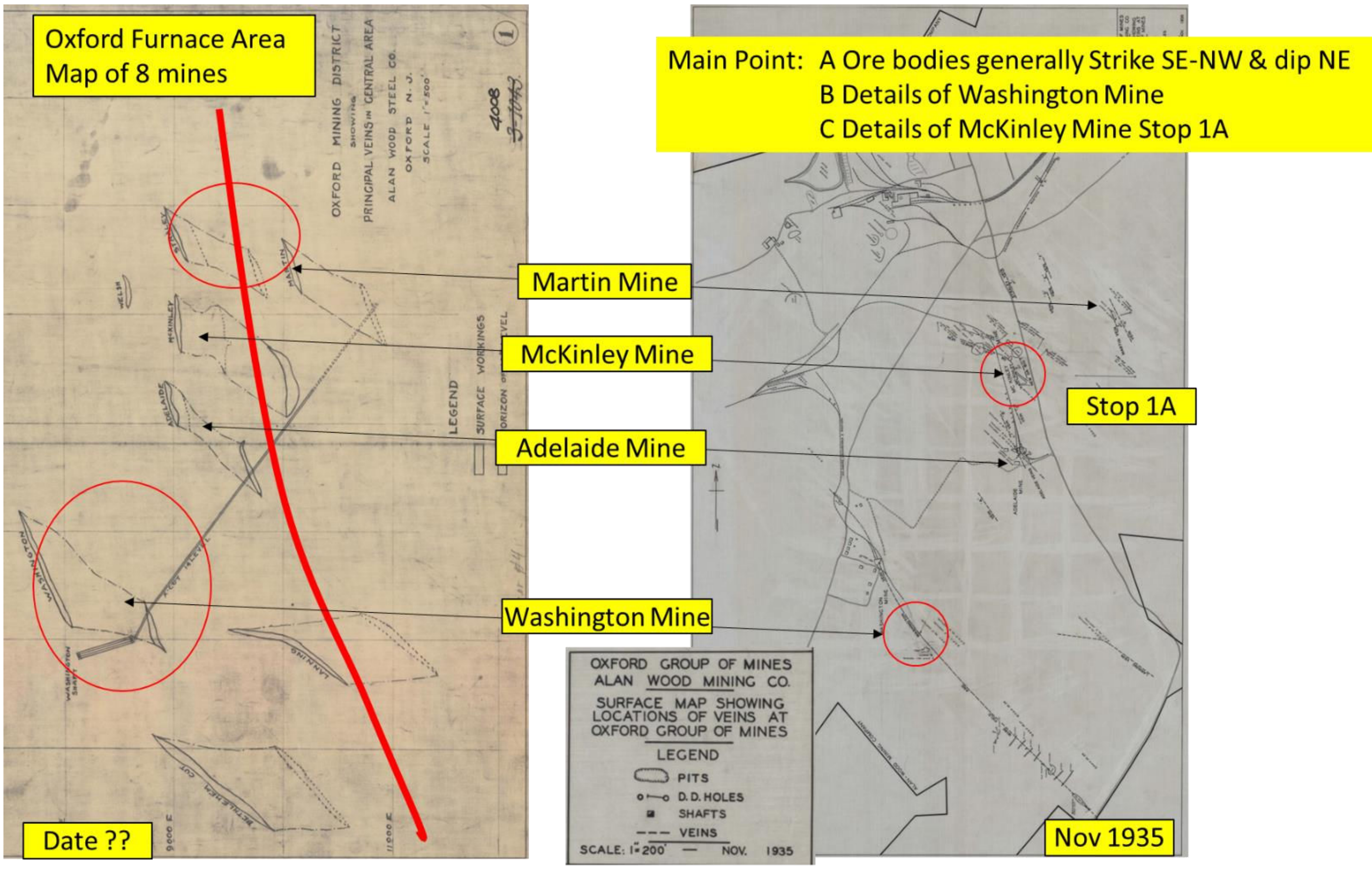


Figure 1. Map showing the location of 7 mines along mine road south of Oxford Furnace

The map and section of the Washington Vein (fig. 2) helps explain the mining operation.

Miners dig a dipping adit from point A to a depth of about 200 ft.

Via stopping they drill upwards, set explosives, and blow up the roof above them for about 100 ft thus leaving a cap of 100 ft of rock. Miners remove the fallen ore, and proceed laterally NW and SE until the end of the ore vein is reached the vein is about 50 ft wide and 1500 ft long.

Miners dig an adit an additional 100 ft deeper.

Miners then Repeat Step B

Miners repeat this process for decades until they reach a depth of more than 1,000 ft below land surface.

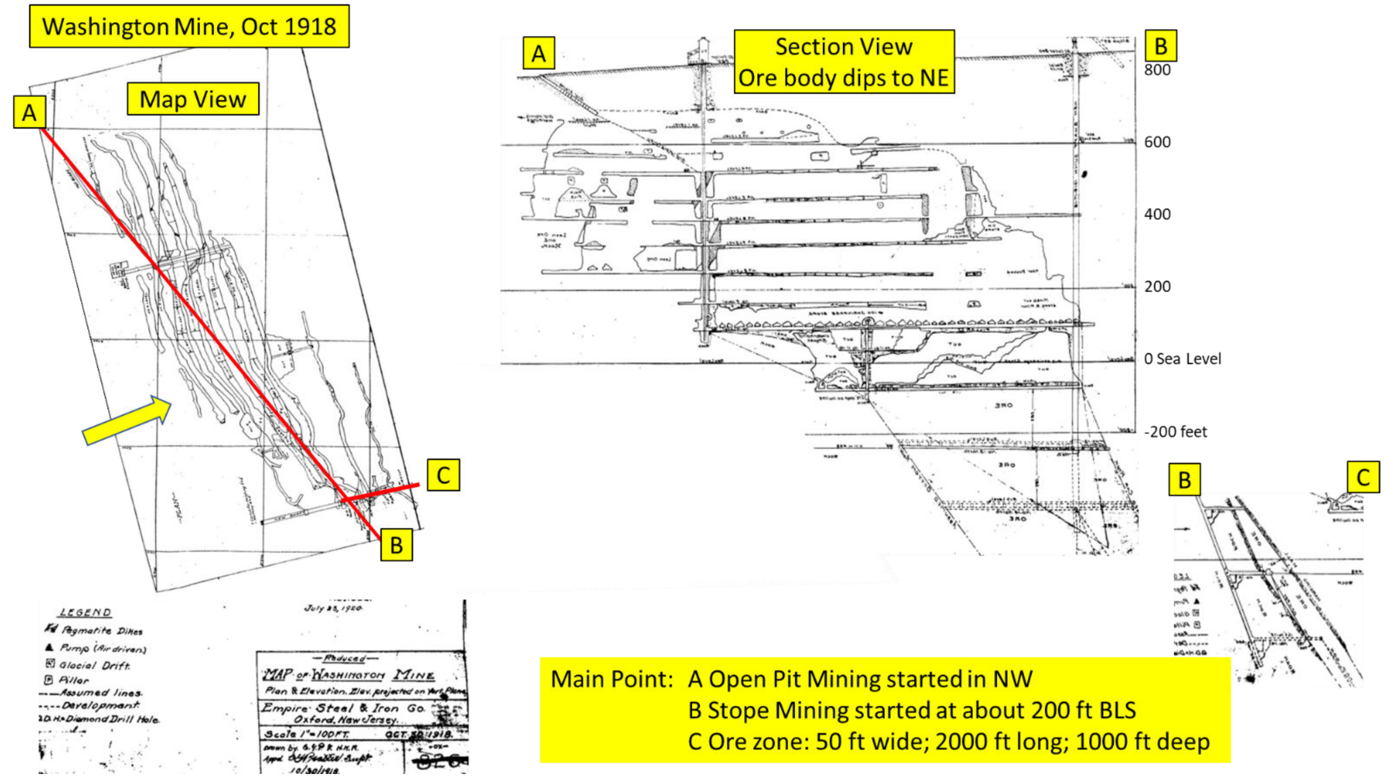


Figure 2 Map and section of Washington mine.

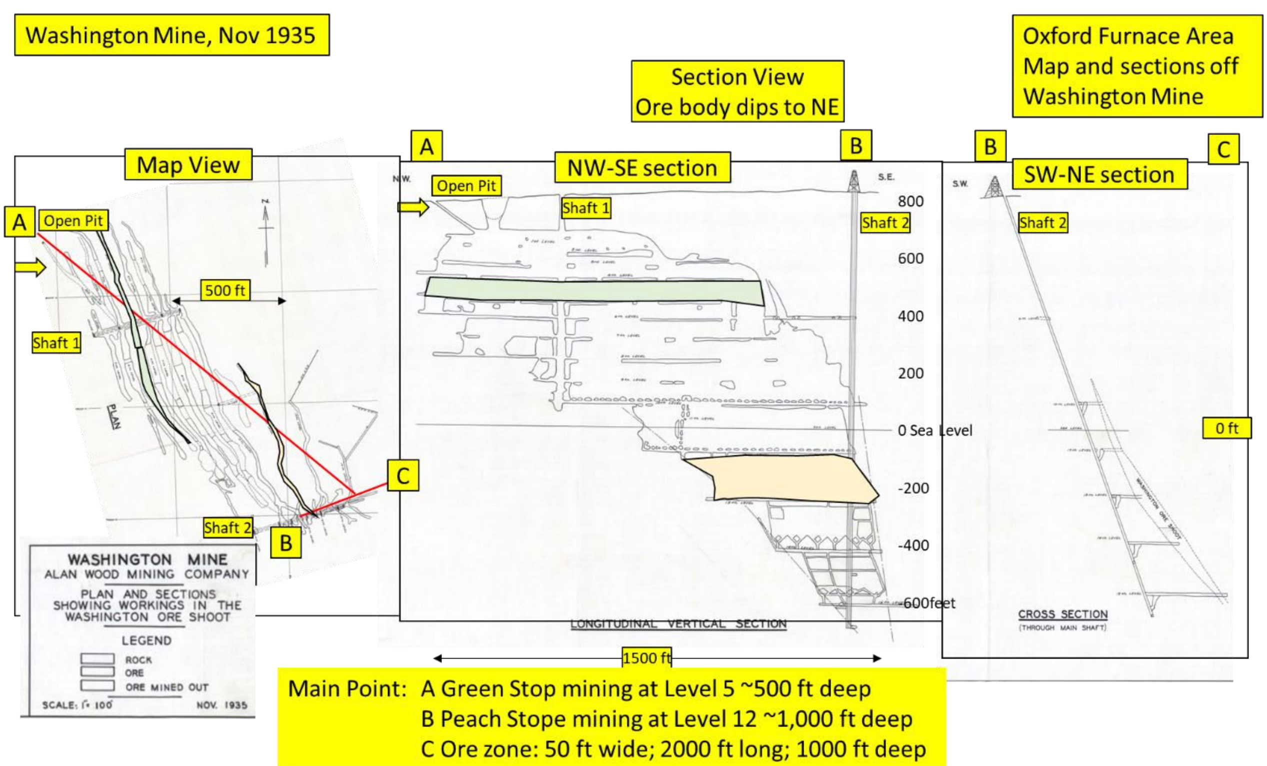
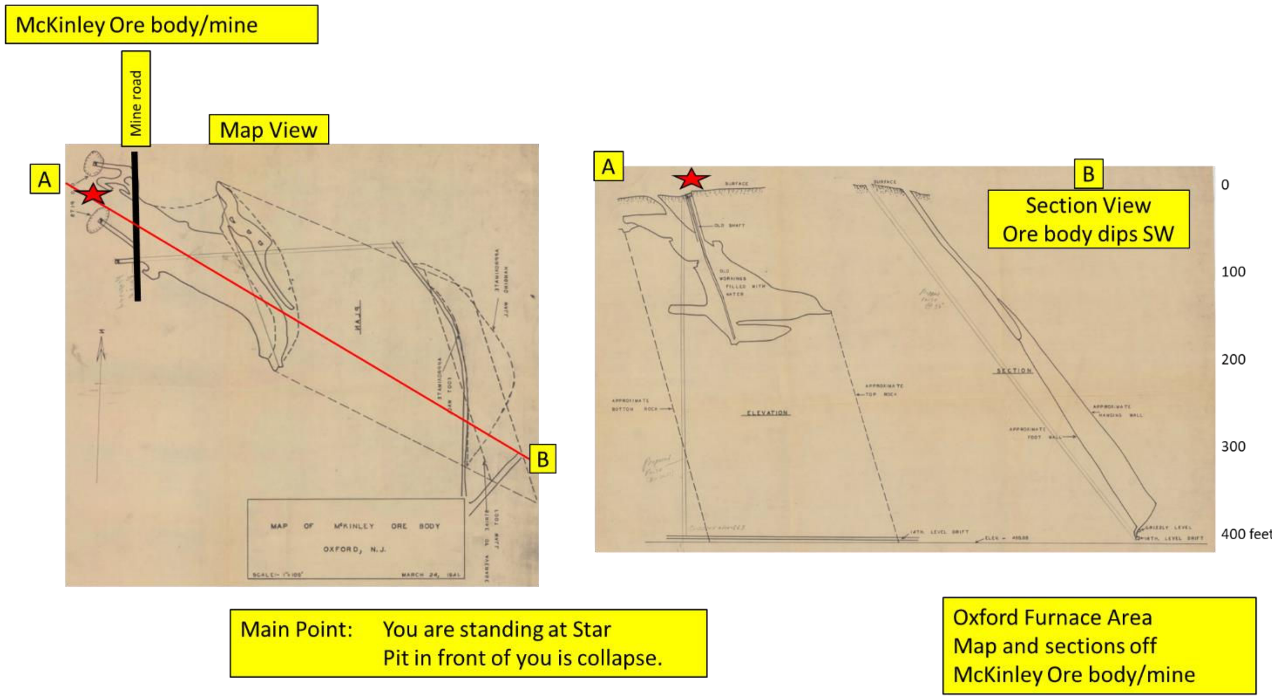


Figure 2 Map and section of Washington mine with two mine levels highlighted in green and tan. This shows the extent of the profitable ore and the progression over the years to mine deeper and deeper.

The McKinley Ore body/mine was much smaller. The map and section view show we are standing at the red star. The mine was dug to the SW and along the strike of the ore body. The ore body is about 20 ft thick, 250 ft wide and more than 400 ft deep. Ore was only recovered to a depth of about 250 ft though a 14th level drift shaft was excavated. It is unclear if additional drift shafts were dug above this level.



Geophysical Survey to locate Iron Ore Bodies

About 1879, Thomas Edison conducted a Magnetic Survey of the NJ Highlands to locate the most promising iron ore areas. Edison did this prior to locating his magnetite concentrating facility in Edison N.J. (fig. 1). Edison's survey showed large areas with a high magnetic dip, thus indicating a considerable reserve of iron ore that had not yet be mined. During Edisons survey the magnetic attraction map for Scotts Mountain shows a large magnetic anomaly for practically the whole mountain (fig.2). Edisons crew used a dip meter typical of the era (fig. 2).

The NJGS estimates that during 1807 - 1907 that about 22,522,000 tons of ore, nearly all magnetite, was mined in the Highlands. 1882 showed the greatest mass of iron ore mined with nearly 1,000,000 tons. As a result, Edison was certain there was a large amount of iron ore remaining.

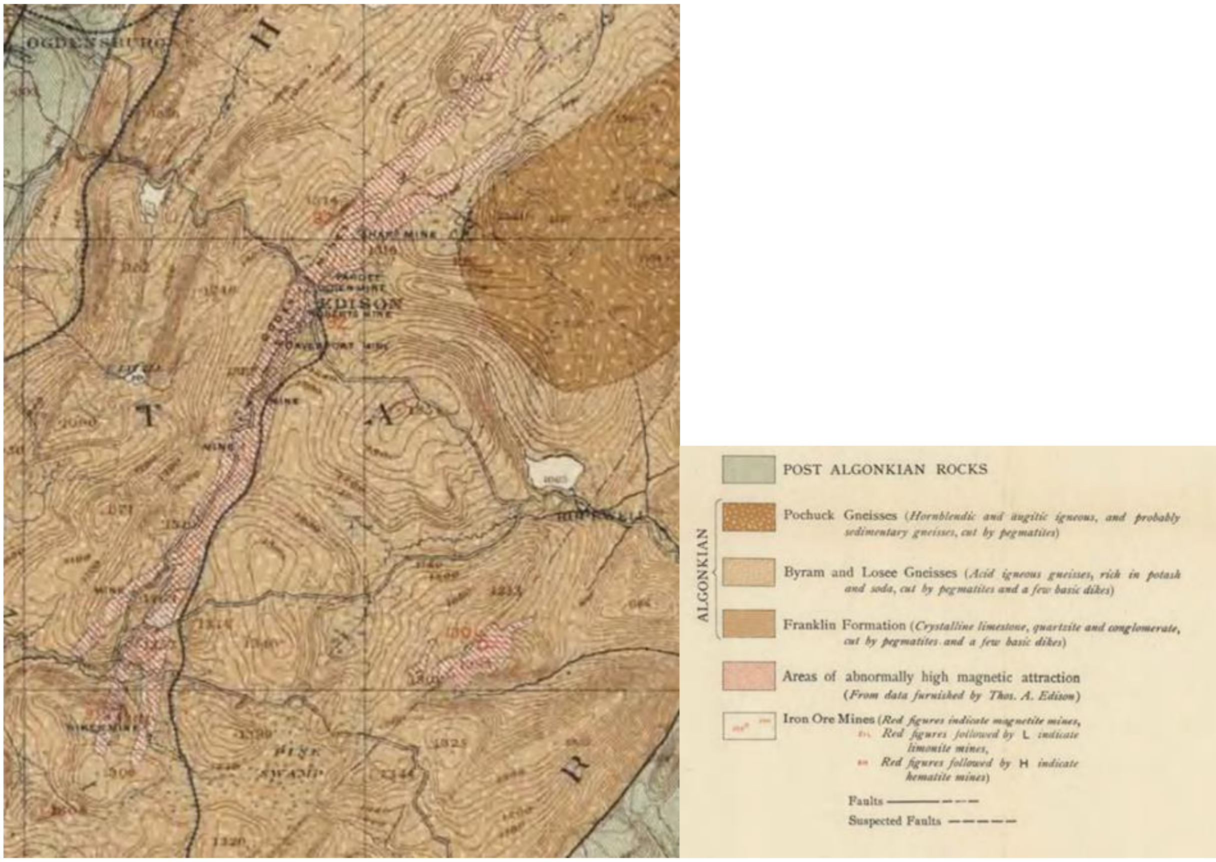


Figure 1. Geologic map of Edison mine area with red stippling over the gneiss indicative of abnormally high magnetic attraction.

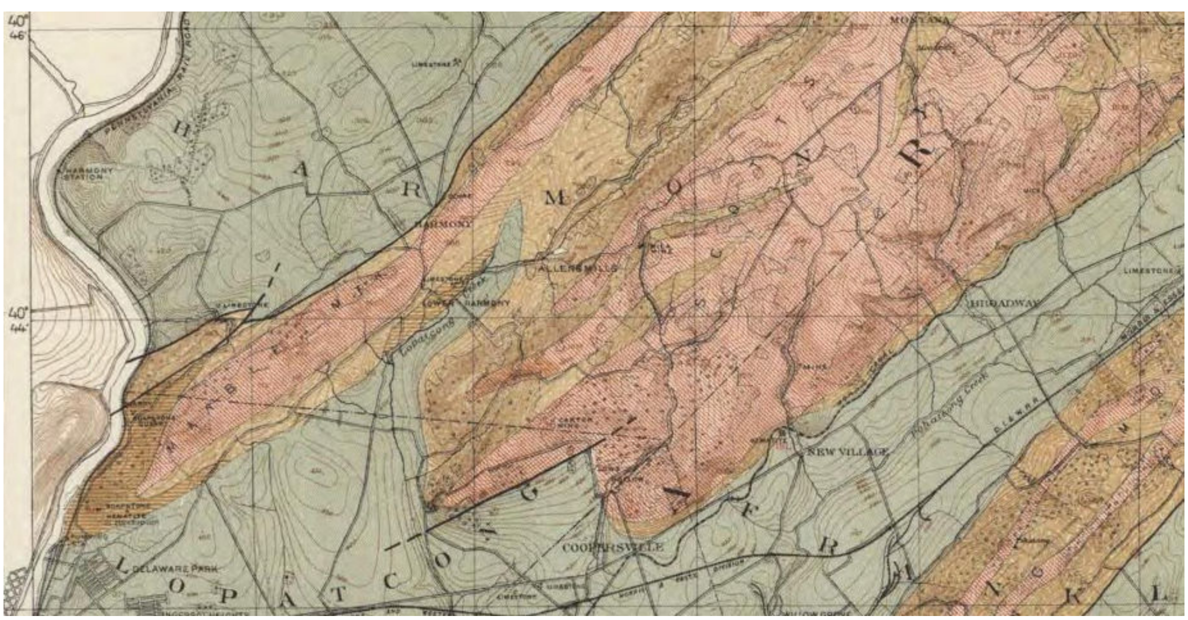


Figure. 2) Map of Scotts Mountain showing the areas with anomalously high magnetic attraction (red stippling on gneiss).

Figure 3) Typical magnetic dip meter used in late 1800s.

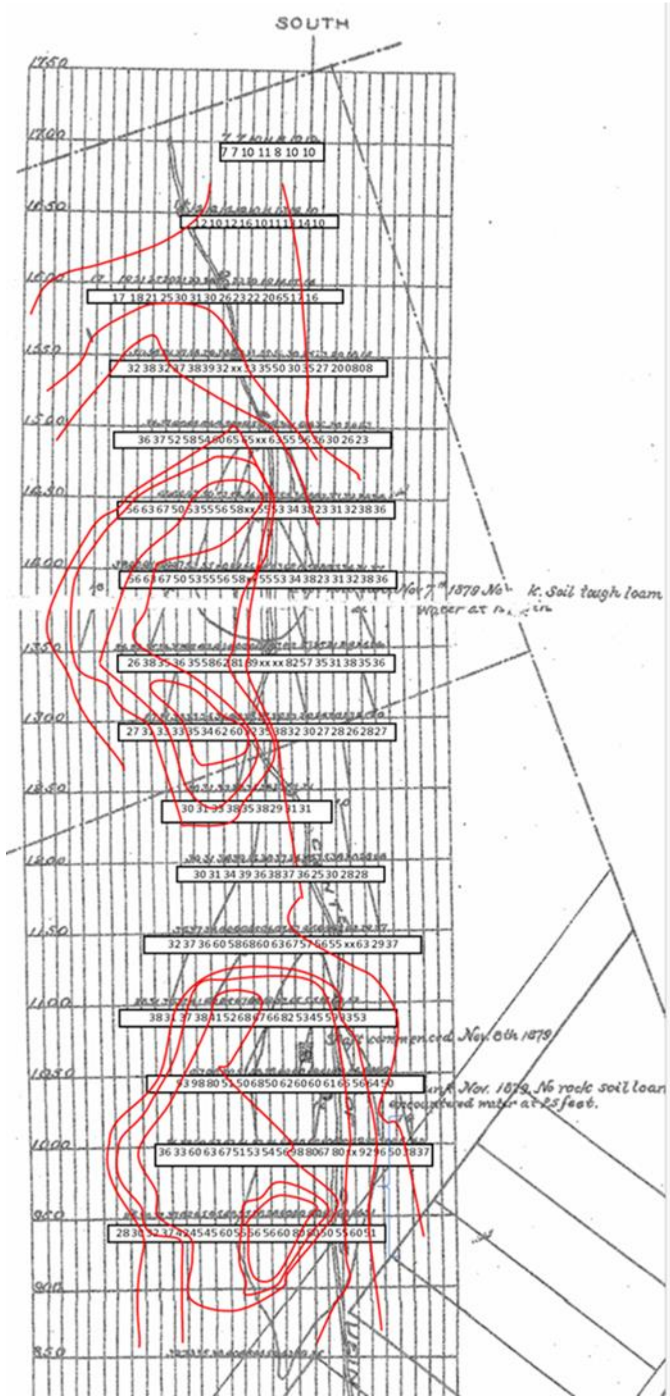


Figure 4) Magnetic dip meter survey by Scranton over the Washington iron ore mine south of Oxford Furnace. Smal figures on cross lines indicate magnetic dip. Long Arrow show direction and amount of compass variation From Annual Report of State Geologist 1879 pg. 96

Edison's and Scranton's survey crew likely used a dip meter typical of the era (fig. 3). The dip meter was generally set on a plane table or similar flat surface and the vertical ring was rotated on its bearings to obtain maximum dip of the magnetic needle. The value of the dip angle for the magnetic needle was recorded.

In 1879, Wm. Scranton conducted a compass and needle dip survey of the Washington Mine property south of Oxford Furnace (fig. 4). Scranton's map (fig. 3) shows multiple rows of small numbers which are the are magnetic dip. The numbers at the ends of each survey line are inclined toward the ore vein and indicate the magnitude of the magnetic variation. The double line through the center of the survey lines is the approximate location of the center of the Washington Mine at a short distance below land surface.

[The web page .pdf that displayed this map was not completely readable, so I took some liberties in assuming what the magnetic dip values were and I contoured the data with the red lines. This was done to make it easier for me to explain the process and not to replicate the actual data. (sorry)]

Scranton made a number of observations and concluded.

A magnetic anomaly that is confined to a very small spot and is lost in passing a few feet from it is most likely caused by a boulder of ore.

A magnetic anomaly which continues steady in the strike direction for many 100s of feet indicates a vein of ore.

A magnetic anomaly is positive and strongest toward the southwest, then it is reasonable to conclude that the vein begins with the anomaly.

A magnetic anomaly that diminishes in going northeast and finally dies out without becoming negative then that may indicate that the vein continues without a break or ending until too far off to move the compass needle.

If on passing toward the northeast along the line of a magnetic anomaly, the south pole is drawn down, then this indicates the end of the vein or an offset.

If on continuing farther still in the same direction and a positive attraction is found, then it shows that the vein is not ended; but if no attraction is shown, there is no indication as to the further continuation of the ore.

In crossing veins of ore from southeast to northwest when the dip of the rock and ore is as usual to the southeast, the positive attraction is first observed to come on gradually, as the ore is nearer and nearer to the surface, and the northwest edge of the vein is indicated by the needle suddenly showing negative attraction just at the point of passing off it. This change of attraction will be less marked as the depth of the vein is greater or as the strike is nearer to the north and south.

The steadiness and continuance of a magnetic anomaly is a much better indication of ore than the strength of the attraction.

The ore may vary in its susceptibility to the magnetic influence from impurities in its substance. It does vary according to the position in which it lies. That is according to its dip and strike; but it also varies vary much according to its distance beneath the surface.

Conclusion

Such magnetic surveys were likely the first geophysical surveys conducted in New Jersey.

Part 5

History of Limestone and its use for Portland Cement and Lime

Introduction

Cement and lime were made from limestone deposits of Warren County since the early 1700. Farmers and others needed small amounts of cement for mortar in chimneys and stone and brick homes. Farmers needed bushels of lime to “sweeten the land” due to the acidic soil where manure had been used. Lime was used to whitewash buildings, and in the tanning process to convert animal hides into leather. Farmers and others quarried small exposures of limestone, built small kilns, and made small batches of cement or lime using charcoal or wood as fuel for the kiln. Remnants of these small kilns are found scattered around the County. (fig. 1)

Figure 1A. Small limestone kiln to convert limestone to cement and lime.

Figure 1B. Musconetcong River Valley Double Lime Kiln in outcrop area of Beekmantown Group.

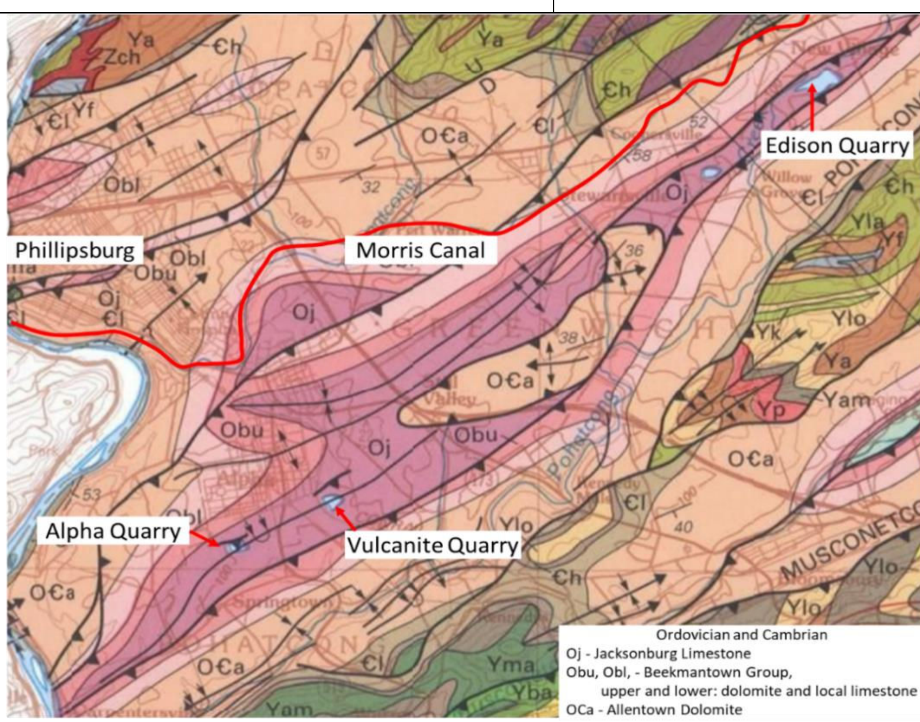


Figure 2. Geologic map showing the limit of calcareous units in study area. Map includes large abandoned quarries used by the major cement companies.

Farmers quarried the limestone rich strata within the Jacksonburg Limestone, Beekmantown Group, and Allentown Dolostone. The latter two units had thin beds of limestone within the predominately dolostone unit. By the late 1800s, Warren County N.J. was a leading producer of Portland cement mainly because of the Jacksonburg Limestone (fig. 2). Locals refer to it as “cement rock” because it provided the raw material to produce cement.

By 1898, New Jersey produced about 16 percent of the Portland cement manufactured in the United States, second only to Pennsylvania, which produced 56 % (Annual Report of the State Geologist for the Year 1900). By the year 1900, Warren County had three producers of Portland cement: Alpha Portland Cement Co., Vulcanite Portland Cement Co. and the Edison Portland Cement Co (fig. 2). The three companies tapped the Jacksonburg Limestone as their source ore for the Portland cement. The three companies were big producers, making New Jersey the second largest producer in the USA until 1908. That is when large midwestern cement operations started to expand into the market (Eckel, 1909).

The term “Portland cement” was coined in the early 1800s by Joseph Aspdin, a bricklayer from Leeds, England. He chose the name “Portland” for his cement because of its resemblance, to the white-gray calcareous Portland limestone of Jurassic age quarried on the Isle of Portland in the English Channel. Portland cement is the most common type of cement in general use throughout the world today.

The cement made from Edison Co. Jacksonburg Limestone quarries was used to build the original Yankee Stadium, as well as cement homes, and NJ first cement highway (fig. 3).

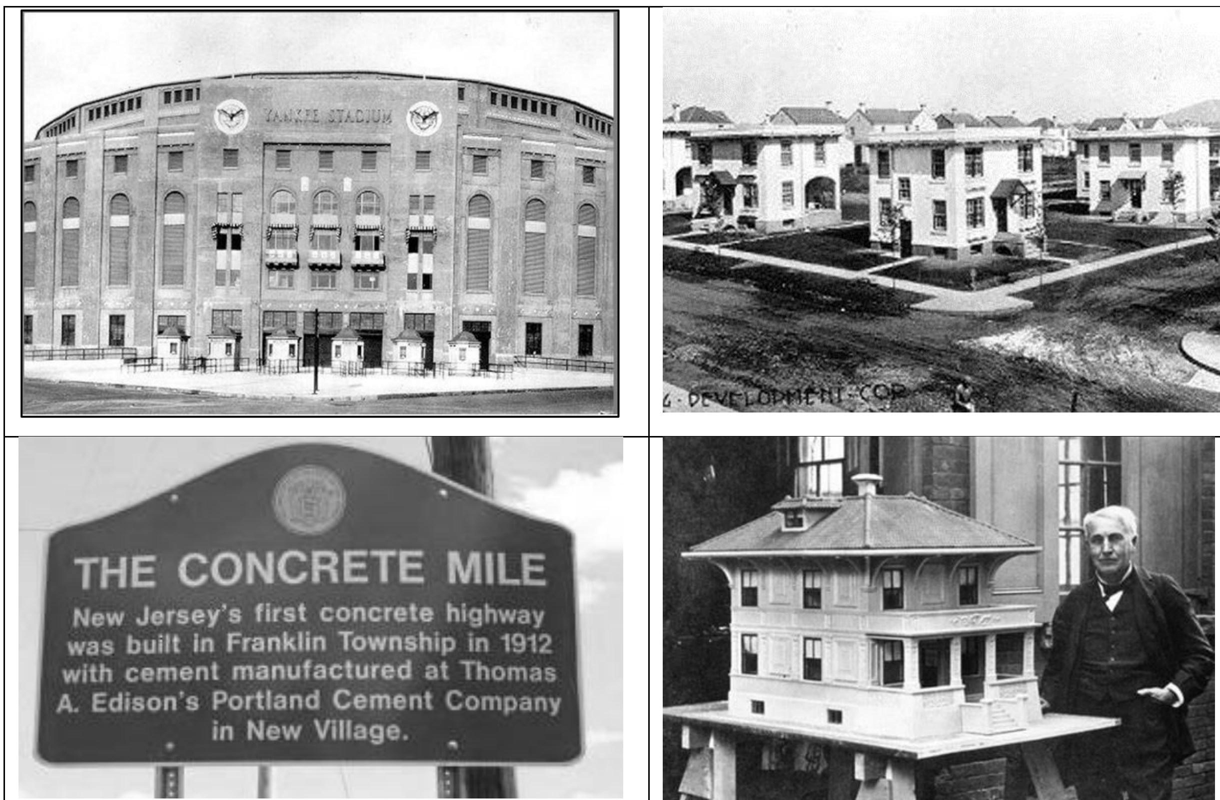


Figure 3. Structure made from cement made from Jacksonburg Limestone: A) Original Yankee stadium, B) homes in Philspburgh NJ, C) Highway in New Village, NJ. and D) Thomas Edison and model of cement homes.

Over 100 years ago, the great inventor Thomas Edison decided to build a large cement plant in New Village, New Jersey for his business, the Portland Cement Company. After constantly experimenting with new uses for his concrete, Edison received permission from New Jersey's highway department to construct a one mile section of concrete highway. The original highway lasted many years until the road was redone in 1954, leaving squares of the original concrete intact. A segment of the original highway can also be found on display at the Edison National Historic Site in West Orange, New Jersey.

Geology and the Limestone Units

Sediments of the Jacksonburg Limestone were deposited during the Ordovician when this area was covered by a warm sea. Jacksonburg sediment sequence shows the sea deepened during the Ordovician. The lower part of the Jacksonburg Limestone is referred to as the "cement lime", and it was deposited in shallow water that contained a high percentage of calcium carbonate and abundant fossils. The upper part of the Jacksonburg Limestone, called the "cement rock", was deposited in deeper water based on its increased clay content and lesser number of fossils. The limestone is dark gray to black and breaks with an even fracture (fig. 4).

Figure 4. Road cut along Interstate 78 in Alpha Boro, Warren County, showing the Jacksonburg Limestone. Photo by T. Pallis.

Clay deposited in the deeper water contained silica, alumina, magnesium, and iron. These elements are important cement constituents. Limestone formations north of Warren County have little clay in them because the water was shallower. The sea continued to deepen over time and the Jacksonburg Limestone was replaced by turbidite deposits of shale and siltstone forming the Martinsburg Formation.

Jacksonburg Limestone chemistry based on (Dalton and Markiewicz, 1972) is

calcium carbonate,	67 - 98 %,	magnesium carbonate,	1 - 6 %
alumina and iron	0 - 6 %	silica	2 – 35 %

Jacksonburg Limestone had nearly perfect proportions of accessory minerals (silica, alumina, and iron) however, additional calcium was desired, therefore, Franklin Marble was added to augment the cement (Lewis and Kummel, 1914).

Portland cement was made by preparing a finely ground mixture of limestone and clay which was placed in a cement kiln and heated to more than 2000° F. The kilns heat transformed the mixture into clinkers which were masses or lumps of material. To finish the cement process, the clinkers were ground to a fine powder and gypsum was added.

Portland Cement Industry in New Jersey

In 1891 the Whitaker Cement Company constructed the first large commercial Portland cement plant in New Jersey. The plant consisted of a small rotary kiln next to his Jacksonburg Limestone quarry in Alpha (Lesley, 1924). In 1895, he sold the plant to the Alpha Portland Cement Company which operated until the end of WWI. (fig. 2 and 4a).

In 1894, the Vulcanite Portland Cement Company built a plant in Alpha to supply material for their road paving business (Lesley, 1924). Vulcanite's Jacksonburg Limestone quarry was less than a mile east of the Alpha limestone quarry (fig. 2). Vulcanite's plant and quarry covered 300 acres. It ceased cement making in 1932 (Rock Products, 1943). Two adjacent quarries at Vulcanite operated independently.

Figure 4 a) Alpha Cement Company Plant Alpha, NJ, b) Flat Iron Building, New York City made from Vulcanite Portland Cement.

Thomas Alva Edison and associates bought farmland in Franklin Township after they found suitable Jacksonburg Limestone in the subsurface for the manufactures of Portland cement. The Edison Portland Cement Co. incorporated on June 9, 1899, and began operations in 1901 and ceased operations about 40 years later at the end of WWII.

Jacksonburg Limestone was quarried using dynamite inserted into holes created by steam drills. The loose rock was then loaded onto rail cars and hauled up and out of the quarry. The limestone was sent to the mill for processing and then put into the kiln (fig. 5).

Portland cement from the Edison plant was used in many applications including roads and buildings. Edison envisioned pre-cast houses built of concrete poured into large wooden molds. Some of the houses were built in a few places including Union and West Orange, New Jersey, (fig. 3) however they never caught on and were not commercially successful.

After 1910 the Portland cement industry in New Jersey began to decline because of overproduction and competition from foreign and domestic cement producers. The final blow came when a dispute erupted after Charles Edison, the son of Thomas Alva Edison, was elected Governor of New Jersey in 1939. The dispute concerned inappropriate contracts for the purchase of Edison's Portland cement by the state of New Jersey. Governor Edison (also known as Lord Edison) denied any wrongdoing but thought it would be best to shut down the cement operations to refute any charges against him. On April 17, 1942, the Edison Portland Cement Company notified its workers that it was shutting down permanently. It was the last operating Portland cement company in New Jersey at the time of its closure. (New York Times, 1942).

The first geologist to distinguish dolomite from limestone was Déodat Gratet de Dolomieu; a French mineralogist and geologist. He recognized and described the distinct characteristics of dolomite in the late 18th century, differentiating it from limestone. That's why the mineral was named after him.

Figure 5a. Steam drill in Edison Quarry

Figure 5b. Train steam shovel, Edison Quarry

Figure 5c. Electric Cable Railway, Edison Quarry

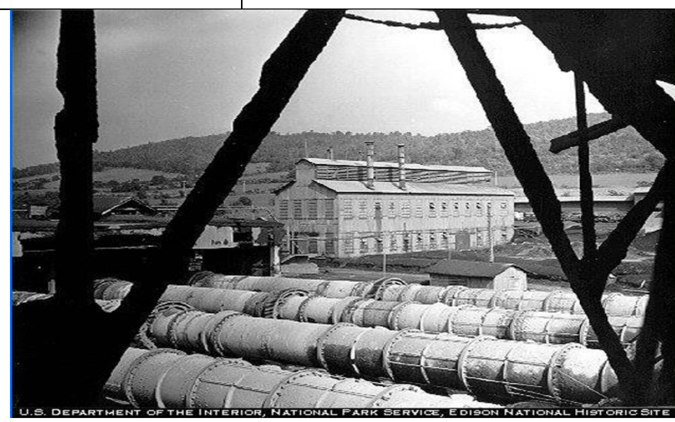


Figure 5d. Horizontal Kilns, Edison Cement Plant

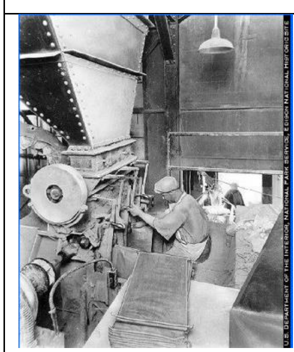


Figure 5e. Bagging Cement, Edison Cement Plant

Figure 5f. Edison Steam engine, at Ford Museum

Much of the text in this essay is from New Jersey Geological and Water Survey Information Circular "The Jacksonburg Limestone and the Portland Cement Industry of New Jersey" prepared by Ted Pallis and Don Monteverde (2015). The original text can be found at: jacksonburg-limestone.pdf (state.nj.us)

Part 6

History of Block Stone to Build Structures

The first houses built in the New Jersey Highlands were likely log cabins with a chimney likely made of field stones. With time, some houses were built of stone blocks or at least the foundation was of stone blocks. Churches, barns, gristmills, iron forges, bridges, incline planes, locks and other buildings were bult of stone blocks. For some structures, the stones were simply picked from the farm fields or were float on the edge of the mountains. Hence such stones were called field stones. For other structures the blocks stone were quarried from outcrops.

Some indurated stones are naturally blocky because of joints and bedding planes. Conglomerate, sandstone, and limestone are indurated (hard), easy to quarry, and easy to shape. Such stones were most frequently used for building structures. Other stones such granitic and gneiss are not quite as naturally blocky, but they are indurated and fairly easy to shape into blocks. Lastly some stones are fissile and break apart too easily upon exposure to the elements. Generally, these stones ae not used for structures.

As a result, most structures are constructed using the more blocky sandstone and conglomerate and fewer houses are from the worked gneiss and granite. Throughout this report there are photographs of stone structures. Stone structures built prior to the completion of the canal (1832) are likely constructed of local field stone or from a rock quarry located within a short distance of the structure. Stone structures built after the Canal was completed and also located on the canal or a short distance from the canal then it is possible that the stone was imported from some distant quarry that was relatively close to the canal. Stone structures built after the railroads were completed may be local but may have come from any location within hundreds of miles from the structure.

The two structures of Oxford Furnace, the Gristmill converted to a church, and the garage on the east side of the furnace and church are made of stone blocks of Hardystone quartzite (page 14, fig. 1)). The rock was quarried with a ¼ mile of the furnace. Oxford Furnace Dam along the hiking trail is made of stone rubble of gneiss from the local mines. Shippen Manor is made of local field stones and Hardystone quartzite and gneiss from a nearby small quarry (page 14, fig.1). The marble plaque for the Warren Railroad in the retaining wall at the Museum is Cockeysville Marble from Pennsylvania.

The twin kilns south of Washington are made of local Beekmantown group limestone (page 25, fig. 1B). The green church in Washington is made of serpentine, sandstone, and slate imported via train from Chester County Pa.

The former Bowers Iron Foundry Building (fig.1) is made of Hardystone quartzite local quarried and from field stones. The Consumer Research building south of the Bowers Building are also Hardystone Quartzite (fig. 2). The privately owned Plane Tenders house (fig. 3) is too far from the road to determine the rock type but it is likely Hardystone Quartzite like the dozen or so homes along Route 57 between Washington and Bread Lock. (I only inspected 5 or 6 of the homes)

The aqueduct at the base of Incline Plane 7W is constructed of local gneiss (fig. 4). The stone wall made of stone sleepers (fig. 5) that were used to build the railroad for incline plane 7W are a granitic gneiss that was likely moved via canal from a stone quarry 5 to 50 miles east of the incline.

The foundation of the barn at Bread Lock is constructed of field stones and contains sandstone, gneiss, limestone, and other local rock types. The lock at Bread Lock and the lock tenders house basement are made of gneiss that was likely quarried or picked from the field within a few miles of the lock.

The stone sleepers used for the railroad bed of Incline Plane 9W are made of granitic gneiss dolostone, fossiliferous limestone, sandstone, and quartzite (page 48-49). The well-shaped sleepers at the top of the incline are imported from quarries along the canal and as far east as 50 to 75 miles. The poorly shaped sleepers on the incline surface are local dolostone and limestone and were quarried within only a few 100 ft of the incline.

Figure 1. Former Bowers Iron Foundry Building made of Hardystone quartzite locally quarried and from field stones.

Bowerstown is an unincorporated community in Washington Township, Warren County, founded in 1829 by Jesse Vanetta and Michael B. Bowers with the building of an iron foundry.

The community then developed around the Morris Canal, in particular, Inclined Plane 7 West and the boat basin by the Pohatcong Creek. in 1843 the foundry concentrated on producing iron plows.

In 1934–1935, Consumers' Research built an office building, and later a research laboratory, 1939–1940, on the Bowers Foundry property. The contributions of consumer advocate Mary Catherine Phillips, author of Skin Deep: The Truth About Beauty Aids – Safe and Harmful and member of the Board of Directors of Consumers' Research, is recognized here on the New Jersey Women's Heritage Trail. In 1986, the office building was bought by the Warren Hills Regional School District for use as district offices by the Board of Education.

The Bowers Foundry, rubble stone, and the Consumers' Research office and laboratory buildings, both of Colonial Revival style, are at the center of the district.

After the Morris Canal was decommissioned in 1924, Washington Township purchased Inclined Plane 7 West and the aqueduct over the Pohatcong Creek to build Plane Hill Road. The plane tender's house also remains, but with modern additions on both sides. The retaining wall by the house on Old Bowerstown Road uses sleeper stones from the inclined plane as the base layer.

Figure 2. Consumers Research office

Figure 3. Plane tenders house Stone section

Figure 4. Aqueduct to permit Pequest stream to flow under Morris Canal.

Figure 5. Granitic gneiss stone sleepers repurposed to make a stone wall. Formerly these were used to support the rails of Incline 7 west.

Figure 5. Entrance of Canal Incline plane 11 West on the Delaware River

The stone at the entrance to the Morris canal at Incline plane 11 West consist of a Stockton or Passaic sandstone arch and gneiss and limestone walls. (fig. 5).

First Methodist Episcopal Church (Washington, New Jersey)

Figure 1. First Methodist Episcopal Church, Washington, NJ. built 1895-98. Stone used includes serpentine (green), sandstone (pink), and slate (roof).

First Methodist Episcopal Church, also known as United Methodist Church, was built during 1895-98. Exterior walls are constructed of green serpentine from Brinton's Quarry in West Chester, Pennsylvania. Serpentine is an ultramafic rock that Includes the minerals serpentine, steatite, and other alteration products of peridotites and pyroxenites. The serpentine is likely lower Paleozoic. The stairs and widow frames are red pebbly sandstone from the Triassic Piedmont. The slate roof was salvaged from earlier churches on or near the site. The sandstone and slate were likely quarried in Pennsylvania.

The church was designed by Samuel A. Brouse in a Richardsonian Romanesque architectural style. The church's form is asymmetrical, with a round tower on the west side and a taller, square bell tower of the east side.

The green of the serpentine stone is accented with a double set of pink sandstone pilasters on either side of the rounded arch entrance in the east tower (fig. 2). These are complimented by a single pink sandstone pilaster on either side of the post and lintel system over the west tower entrance (fig.1). The pilasters are integral components of the corbels that support the rectangular applied stonework in the flat arch over the entrance in the west tower.

The church's west elevation is dominated by a gable that projects from the steeply pitched roof covered with Slate (fig. 3). The church contains many stained glass windows. One stained glass window contains the letters "WCTU" intertwined in its design. The letters signify the Women's Christian Temperance Union.

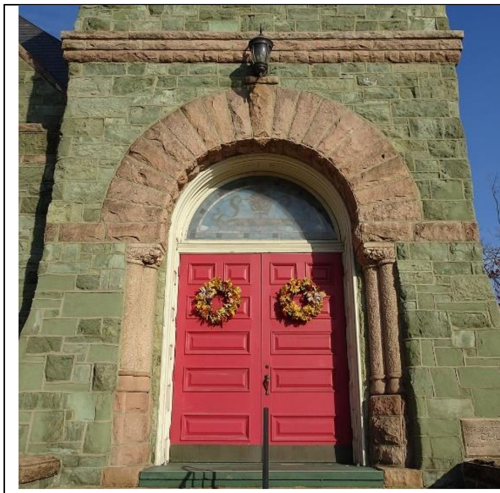


Figure 2. East entrance showing Serpentine walls and sandstone doorframe.

Figure 3. Roof of slate

Figure 4. Stain glass window with initial WCTU for Women's Christian Temperance Union

Starting as early as 1730, the use of serpentine gained popularity in West Chester, Penn. Because of its natural beauty, green serpentine was used throughout the area for barns, homes, and churches, as well as shipped to other areas of the country for construction purposes. During the latter half of the 1800s, builders constructed homes and public buildings of green serpentine stone quite often from Brinton's Quarry in West Chester, Pennsylvania. Examples include:

A) University of Pennsylvania: College Hall (1871 72); Logan Hall (1873-74); University Hospital (1873-74); and the Hare Medical Laboratory (1878). Today, only College Hall and Logan Hall remain.

B) West Chester University: Recitation Hall (1891-93); Demonstration School, aka the Model School (1899); and Old Library (1902-04).

C) More than 100 houses of worship including Richmond, VA and South Bend, IN, a number of large buildings in Chicago, and many homes in the vicinity of Brintons quarry south of West Chester.

Serpentine was easily quarried and carved, however, it is relatively soft and does not hold up well in industrialized areas with high levels of pollution. One reason that this church has survived for nearly 130 years is due to the rural nature of Washington with minimal air pollution and the care and attention that has been given to it over the last century. You will notice many serpentine blocks have been patched with a green mortar.

The stone was used for this church because it was unusual and highly promoted by the quarry owner. The fact that the quarry owner and the building contractor were connected would have played a large part in selecting this stone as well.

Part 7

History of the Morris Canal

The Morris canal passed through the heart of New Jersey's iron district and provide the transportation system that would create new commercial activity and enable rustic settlements like Dover and Rockaway to grow into thriving industrial towns. The canal opened in 1831.

When completed, the canal extended 102 miles across the rugged highlands of New Jersey, from Phillipsburg on the Delaware River, uphill to its summit level near Lake Hopatcong, and then down to Jersey City. To accomplish this, a system of 23 lift locks and 23 inclined planes were built to overcome the impressive elevation change of 1,674 feet (fig. 1). The canal's famous water-powered inclined planes were an engineering marvel that enabled canal boats to be raised or lowered up to 100 feet at a time.

Mule-drawn canal boats transported up to 70 tons of cargo and took five days to cross the state. In the heyday of the canal, hundreds of boats carried everything from coal and iron ore to agricultural products. As New Jersey's first industrial transportation system, the canal promoted commerce and shaped the economic development of the northern part of the state.

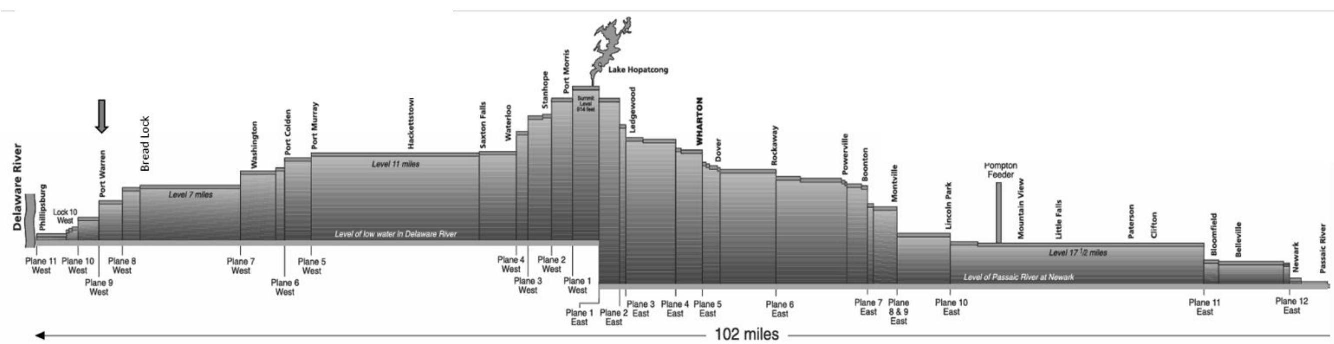


Figure 1 Section showing location of Morris Canal incline planes across the NJ Highlands.

Inclined Planes and Canal Boats

Inclined planes used waterpower to raise and lower canal boats up to 100 feet at a time (fig. 2a). Water from the upper canal level was used to create the motive power to raise and lower the boats. The water then flowed back into the next lower level and was used over and over farther down the canal. The original inclined planes, built in the 1820s, used a counterbalance system powered by an overshot water wheel. The early planes worked but were not powerful enough to be economically successful. Engineer William Talcott redesigned the planes in the 1850s, he used more powerful cast-iron reaction turbines (fig. 2b). The new planes could raise and lower boats carrying 70 tons of cargo (fig. 2 c, d, e)

Initially iron chains were used then wire cables likely from Roebling Wire Mills were used.

Iron for the chains and wire were likely from the NJ Highland's iron mine.
Grade of inclined planes varied from 1:11 to 1:20. Plane 9 West, has grade of 1:15
Largest plane on the canal; with Vertical lift: 100 feet Length: 1,510 feet to the summit.
Approximate time for transit: 12 minutes

Boats

Cargo Capacity--1831 boats- 18 tons; 1845 boats- 44 tons; 1860 boats- \70 tons
1860 boat dimensions: 91 ft long; 10.5 ft wide; 6.5 feet draft when loaded.
Weight-- boat, cargo and cradle: 110 to 125 tons

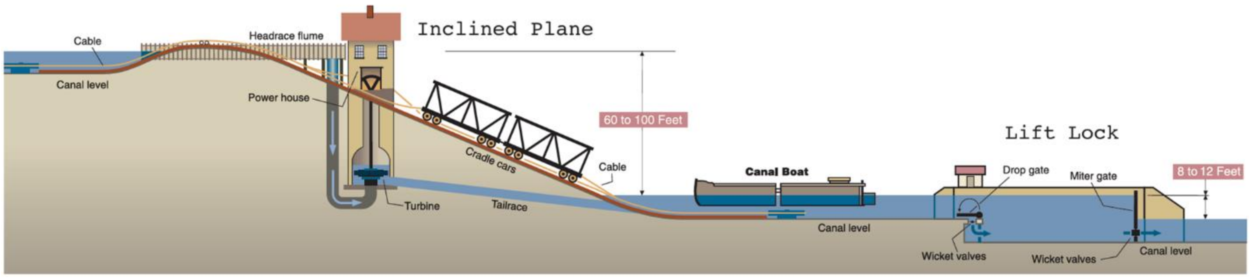
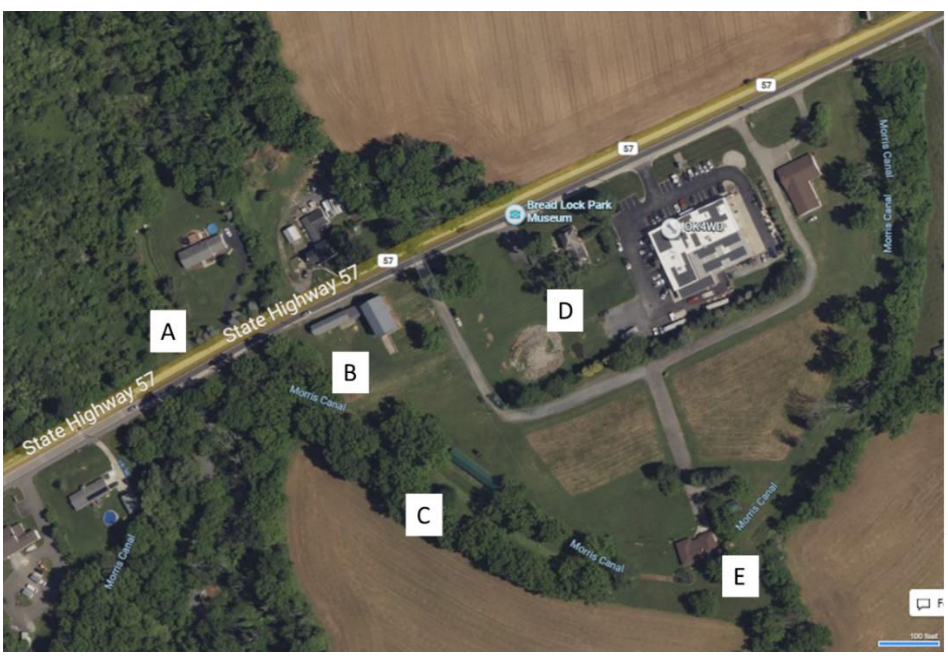


Figure 2. A) Diagram of typical incline plane.

Lake Hopatcong: In 1820s, Canal built dam to raise the water level 12 feet and create the primary water source that filled water need for east and west divisions of the Morris Canal.
Lake Musconetcong: In 1845, the canal dammed Musconetcong River at Stanhope to create Lake Musconetcong a secondary water source that filled needs for west divisions of the Morris Canal.

History of Bread Lock Park

Lock 7 West became known as "Bread Lock Park" because the store at the end of the lock sold goods to boatmen, including homemade bread and pies. Today most of the lock is buried. Most stones of the lock are gneiss and the stones used to build the foundation of the house are also mostly gneiss. however, a short section of the canal has been cleared and offers a lovely walk. Visitors can also enjoy the nature and exercise trails around the perimeter of the park, as well as the Warren Heritage Museum.



A. Cement mile
B. Barn Foundation of Field stone
C. Lock 7 W and building foundation of gneiss
D. Pile of limestone with chert nodules, algal stromatolite, and other fossils.
E. Bread Lock Museum

Exposed stone sleepers of the Morris Canal Incline Plane 9 West

By Pierre Lacombe

Introduction

The Morris Canal is one of about 86 canals built in the United States prior to 1840 (von Gerstner 1842). Most early American canals were water only canals with flat water sections interspersed with locks that could raise and lower canal boats from 8 to 15 ft. The Erie Canal, Delaware Canal, Lehigh Canal, and Delaware & Raritan Canal are such flatwater and lock canals. The Morris Canal was significantly different in that it used dry sections termed Incline Planes to raise and lower a canal boat in a crib car that road on railroad tracks. Fewer than five canals in America used incline planes. In 1795-1805, the Connecticut River Canal at South Hadley, Mass. was the only canal in New England that used an incline plane with a crib car to raise and lower canal boats. Power to raise and lower the crib car and canal boat was supplied by a water wheel. The incline was constructed to bypass the waterfall/rapids at South Hadley. The Pennsylvania Main Line used crib cars that could be loaded and unloaded with canal boats to move passengers and freight between Philadelphia and Pittsburgh. Workers of the Allegheny Mountain section of the Main Line floated canal boats onto crib cars then moved the loaded crib cars along multiple sections of railroad over the mountain. Gently sloped sections of the railroad were traversed by trains pulled by steam locomotives. The 22 steep sections or Incline Planes of the railroad were traversed by crib cars carrying canal boats. The power to move the trains up and down the incline planes was provided by a stationary steam engine at the top of each incline.

A few early railroads used incline planes in the same fashion that canals used incline planes. The Mohawk & Hudson Railroad between Schenectady and Albany, New York; the Philadelphia & Columbia Railroad between the two named cities; and the Delaware & Hudson Canal Company gravity Railroad between Carbondale and Honesdale, Pa., each employed incline planes with stationary steam engines to climb and descend steep hills.

The Morris Canal constructed 23 incline planes along the 107 mile trip across the mountains of the New Jersey Highlands (fig. 1). The incline planes ranged from 800 to 1,600 ft. long. The change in elevation between the top and bottom of each incline plane ranged from 50 to 100 ft.

Purpose and Scope

The purpose of this document is to describe the results of an investigation of the rail bed made of in situ blocks of stone (also known as stone sleepers) for Inline Plane 9 West located about 4.5 miles east of the Delaware River at Phillipsburg, N.J. During the field investigation the author visited and described stone sleepers for incline planes 10 West, 7 West, 6 West, and 2 East to compare with the stone sleepers of Incline 9 West.

Data collected from each in situ and ex situ stone sleeper includes location, rock type, length, width, and thickness (if measurable). Data collected from the top surface of each sleeper includes number of spike holes; spike hole arrangement, spacing, depth, and diameter; and width of chiseled grooves and rail wear marks.

The scope of the investigation was focused on 246 stone blocks that initially supported wood rails and later rolled iron Stevens-style flat bottom rails. A large database, developed by and available from the author, was used to prepare this article.

Data collected regarding quarry features consists of: pin and feather tool spacing, depth, and diameter. Additional data collected from in situ sleepers consists of: sleeper spacing along and between rails and the arrangement of sleeper stones. Minor data compiled during the investigation includes ironware (i.e., spikes, plates, rails, and connectors).

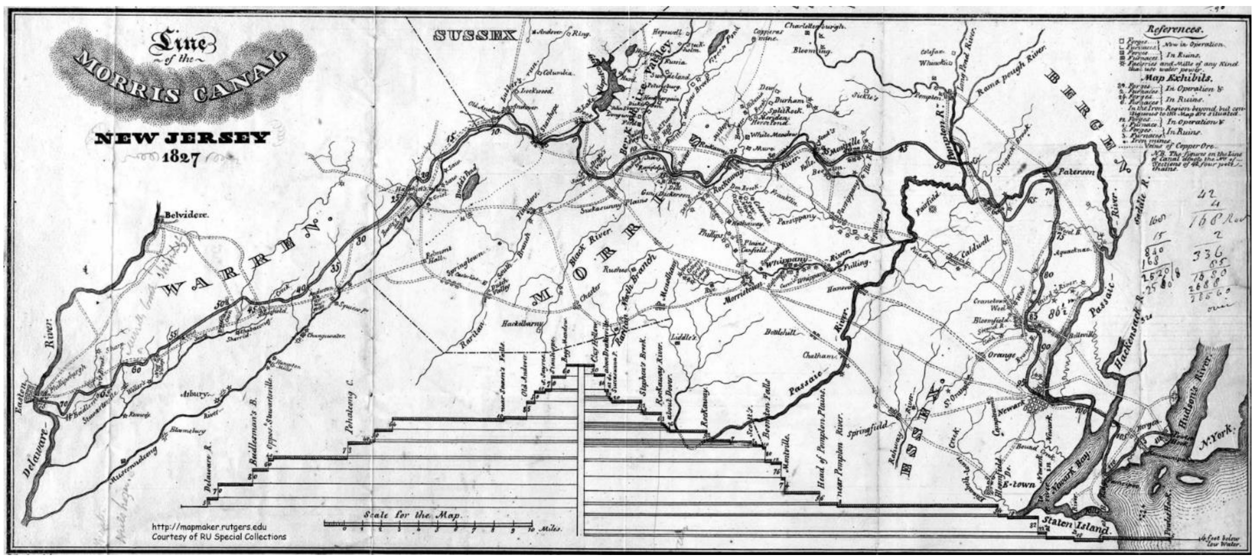


Figure 1. 1827 map and profile of the Morris Canal showing the location of the incline planes.

Previous investigations of stone sleepers

Franz von Gerstner (1997) investigated more than 80 early canals and 150 early railroads in the United States during 1838-39. He described canal construction, economics, and operation.

Lacombe (2021) described stone sleeper types used and reportedly used by 34 early American railroads and canals including the Morris Canal.

Method of Investigation

The investigation of Incline Plane 9 West began by clearing all partially exposed stone sleepers. The top and sides of exposed in situ sleepers were cleaned of lawn litter, weeds, sand and gravel using a shovel, clipper, and broom. The cleaned stones were left for a week or so to allow rainwater to wash away remaining surface dirt.

Once sleepers were exposed and cleaned, the rows and sleepers were labeled. Row A and B supported the rails for the south railroad track and rows C and D supported the rails for the north railroad track. The sleepers were numbered sequentially from east to west.

A base line was established at the top of the incline perpendicular to the four rows of sleepers and about 100 ft. east of the most uphill and most easterly sleeper. A 100 ft. long measuring tape was laid out and pulled tight across the top of each row starting with Row A. A weighted cloth sack about 1 inch wide and 3 in. long was placed at every 2 foot mark on the tape measure. The whole array was photographed in 2 ft. intervals. The author recorded the distance between the base line (0 ft.) and the east and west end of each stone sleeper in the row. The author identified the rock type of each sleeper. The rock types are granitic gneiss, quartzite, limestone/dolostone, and sandstone.

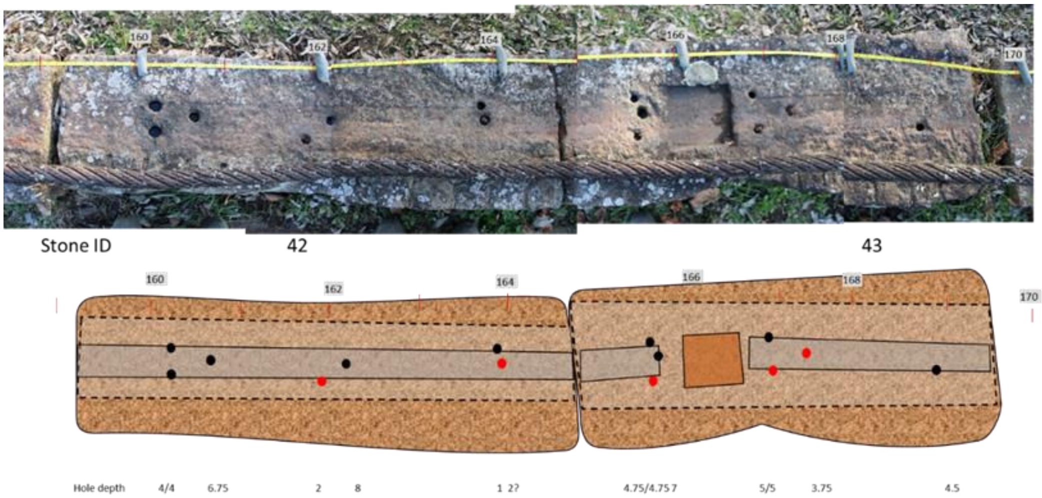


Figure 2. A) Composite photograph of stone sleepers with yellow tape measure and weight sacks at two ft. intervals; B) drawing of the stone sleepers showing rock type, chiseled grove, iron rail wear marks, square box cut and spike holes with and without iron spikes.

The digital photographs were downloaded into PowerPoint and edge-mapped based on the distance markings on the tape measure (fig. 2A). The outline of each stone was drawn (fig. 2B). The stone shape was filled with a color code and pattern to indicate the rock type of the sleeper (fig. 3). The chiseled zone on the top of the sleeper is shown by two dashed lines that represent the edge of the chiseling. The mass of the chiseled area is filled with a transparent color to highlight the zone. The rail wear zone is shown as a 4 in. wide gray rectangle (fig. 4). The spike holes were drawn as small black dots and triangles and color coded black for open holes and red for spike holes with iron spikes still in place (fig. 5). Rectangular chiseled recesses that were about 8 in. by 7 in. were outlined and filled with a transparent orange (fig. 6).

The result of the photographs and drawings is a pictorial representation of the rail bed for interpretation (fig. 2B). The composite of the photographs and drawings were then used in the field. The photographs provided the length of each sleeper. The width and thickness (if measurable) were recorded. The depth of each spike hole (if measurable) was recorded. The depth of each spike hole was added to the drawing. Other characteristics were noted and recorded.

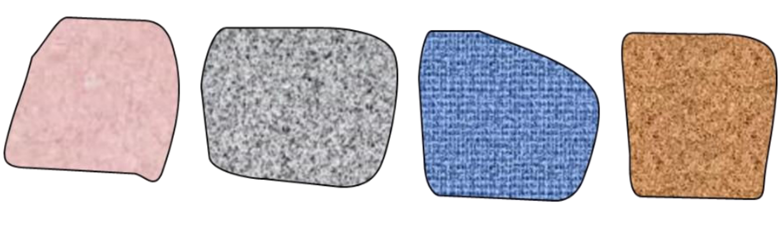


Figure 3. Drawing of outline of stone sleeper shape and color code for the four rock types.

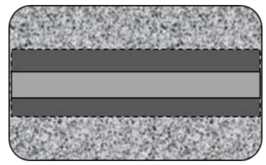


Figure 4. Drawing of chiseled band and rail wear band along the center line of most stone sleepers. Chiseled band has dashed lines to show boundary of the approximately 8 in. wide band. The rail wear band is about 4 in. wide and is colored light gray.

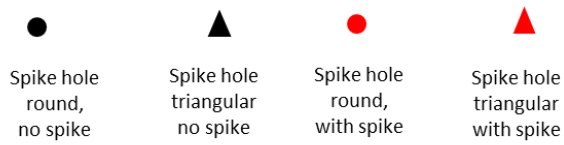
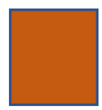


Figure 5. Symbols for spike holes found in top surface of stone sleepers.



The cut box is 8 in. long and 7 in. ft. wide.

Figure 6. Symbols for recessed boxes are found at intervals along the top surface of stone sleepers.

This author created a field sheet to record measurements and other features for each sleeper. Field sheet data was transferred to an electronic database and augmented with the sleeper's latitude and longitude and other regional data.

Incline Plane 9 West General Characteristics

Incline Plane 9 West is about 1,600 ft. long, about 30 ft. wide, and raised and lowered canal boats 100 ft. from the lower flat water section to an upper flat water section. The incline is only one of three incline planes for the Morris Canal that had a double set of tracks. The tracks had a gauge of 12 ft. Stone sleepers in Rows A and B formed the south set of railroad tracks. Stone sleepers in Rows C and D form the north set of railroad tracks. Both sets of rails were used to move canal boats loaded onto cradle cars up and down the incline.

Stone Sleeper Size, Arrangement, and Number

The stone sleepers of Incline 9 West range in length from less than 1 ft. (fig. 7) to more than 6 ft. (fig. 8). The average width is 18 in and the average thickness is 14 in. During construction stone sleepers were generally laid end to end along their long axis with no appreciable gap between adjacent stone blocks (Appendix 1). However, in some locations a single long sleeper was laid sideways to support the rail of both Rows B and C (fig. 9). In general, about 38 stones were needed to build 100 ft. of rail foundation. In total each 1,600 ft. rail needed 600 sleepers. Approximately 2,400 sleepers were used to build Incline 9 West.

There are about 231 stone sleepers exposed in Incline 9 West. Some stone sleepers are so severely broken that it is difficult to determine if they were set as a single stone or as multiple stones.

Figure 7. Four stone sleepers with one that is less than 1 ft. long.

Figure 8. Single stone sleeper that is more than 5 ft. long.

Figrure 9. A series of stone sleepers with one sleeper that supported rails for both Rows B and C.

Rock Types

The major rock types are granitic gneiss, quartzite, limestone/dolostone, and sandstone. Granitic gneiss is a common rock in the New Jersey Highlands. There were many quarries where it could have been quarried. Reports suggest that the granitic gneiss was quarried west of Incline Plane 7 West Generally, the stone blocks are large and well-formed box shape that are up to 6 ft. long.

Quartzite is commonly found in the Hardyston Quartzite. In the Musconetcong River valley, quartzite is mapped on the north side of the valley separating the limestone floor of the valley and the metamorphic rocks of Scotts Mountain. Blocks of quartzite are generally well formed.

Limestone/dolostone are found in the Jacksonburg Limestone and Allentown Dolostone. These formations form the valley floor of the Musconetcong Valley. At the top of the incline these blocks are well formed but in the main part of the incline the shapes of the blocks are quite random. Many of the blocks are broken in multiple locations indicating that each block is not very thick.

The few sandstone blocks used in Incline 9 West are likely from the Passaic Formation and were quarried 50 miles east of the Incline.

Surface Grooves, Rail Wear, Spike Holes, and Apron Cuts.

The top surface of the stone sleepers shows a long wide chiseled groove likely made to flatten the top surface of the stones once they were set in place (fig. 10). The groove is 8 in. wide and the full length of each stone sleeper. During initial construction, a long wood rail that was up to 8 in. wide and 8 in. thick was likely set in the groove. The wood rail was held to the stone sleepers by multiple trenails and iron spikes. The wood rail was drilled with a hand auger and the stone sleeper was drilled with a drill bit. In all likelihood the wood rail was initially capped by a strap iron rail that was screwed to the inside edge of the wood rail. Alternatively, a strap iron rail could have been placed on top of a wood lath. The lath was about 3 in. thick and 4 in. wide and held to the wood rail by iron spikes.

Along the center of the long wide groove is a very flat and in places polished surface, (fig. 11) that generally runs the full length of each stone sleeper. These flat polished surfaces are interpreted to be wear marks by a later generation of flat bottom iron rails as designed by Robert Stevens. The flat polished surface is 3 in. wide and was created by the vibration of the iron rail against the stone.

Figure 10. Wide Chiseled Groove on top surface of stone sleepers.

Figure 11. Narrow smoothed ware mark in chiseled grove that is created by abrasion of steel on stone.

Box-Shaped Cuts

Rows A and B have 26 box shaped cuts that were chiseled into the stone sleepers (fig. 12). Each box cut is about 7 in. long and 8 in. wide and about 1 in. deep. The stone sleepers in rows A and B between 100 and 160 ft. from the west measuring point contain boxes that are uniformly 12 ft. apart. The chiseled boxes from 160 to 300 ft. from the west measuring point are spaced ranging from 1.5 ft. to 26 ft. Either these more westerly stone sleepers have been moved many feet over the years, or the iron and steel rails that were used in the section of track were of various lengths. Stone sleepers without box shaped cuts include the full length of rows C and D and the section of rows A and B, between 300 and 400 ft. west of the baseline.

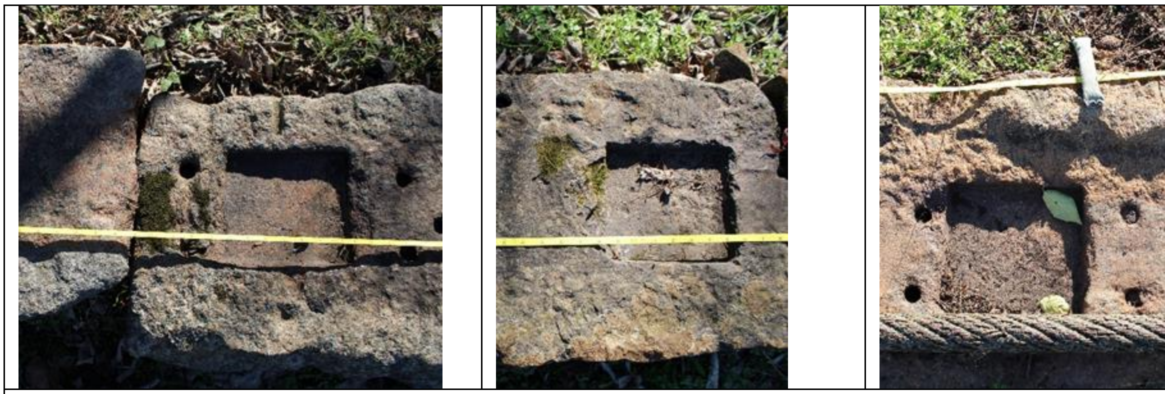


Figure 12. Box cuts in top of stone sleepers. Cast iron chairs were set in cut and abraded the cut to a smooth box.

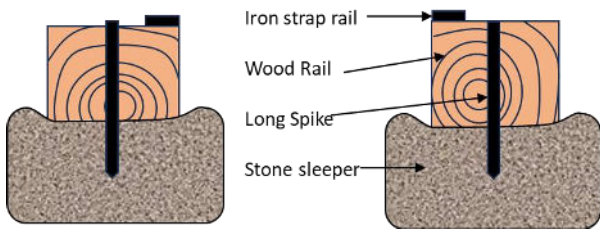
Spike Holes near the Box-Shaped Cuts.

There are hundreds of spike holes exposed in 231 stone sleepers that were investigated. The spike holes were used to fasten wood and iron rails to the stone sleepers. To understand the spike hole arrangements, it is necessary to understand the five types of rails likely used on Morris Canal Incline Plane 9 West.

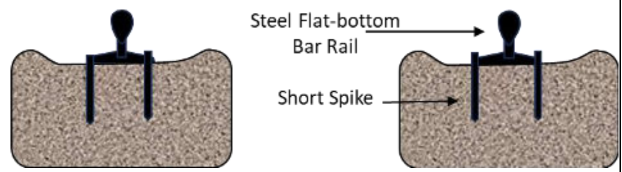
Type 1 and Type 2 rails are quite similar. Both types consist of a stone block topped by a wood rail that is about 8 in. wide and 6 to 8 in. thick. (fig. 13 A and B). The wood rail is spiked to the stone sleeper. For Type 1, the wood rails are topped by an iron strap rail that is screwed or spiked to its inside edge. For Type 2, the iron strap rail is mounted on a wood lath that is near the center of the wood rail. The lath is about 4 in. wide and 3 in. high. Type 2 rails were much easier to maintain in that the gauge could be adjusted with little effort and the wood lath could be repaired as it aged. Type 1 rails required more effort to repair as the wood aged. Spike holes drilled in the stone to hold the wood rail in place were near the centerline of the chiseled groove (fig. 1). The holes were likely drilled at about 5 ft. intervals. Each spike hole is wide and deep. It is unclear which near center of sleeper holes correspond to the type one and type two rail construction.

Rail types 3, 4, and 5 as quite similar. They consist of a stone sleeper topped by a flat-bottom bar rail (fig. 13C, D, and E). Flat-bottom bar rails were designed by Robert Stevens in 1830 and first used on the Camden & Amboy Railroad in 1831. The pear shaped rail presently on display at incline Plane 9 West was most likely manufactured in Trenton, N.J. from iron mined in the New Jersey Highlands.

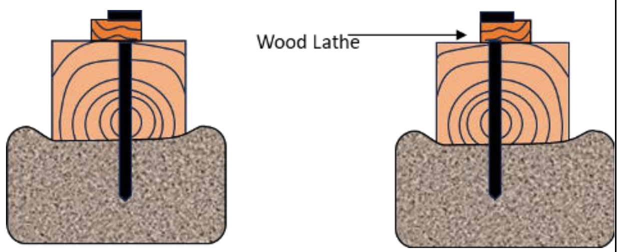
For Rail Type 3, the flat-bottom bar rail was spiked directly to the stone sleeper (fig. 13C). This provides for a very rough ride, not that the coal minded a rough ride, but the jolting of the crib car and the canal boat likely caused time consuming and costly maintenance problems for both. In addition, there was a great deal of abrasion between the stone sleeper and iron rail. This can be observed in many of the stone sleepers. Spike holes drilled to hold the flat bottom iron rail to the sleeper are at the outer edge of the rail ware marks. The spike holes are about 1 in. in diameter and 4 to 5 in. deep. The spike holes do not line up with the chiseled box cuts of Type 4 rails.



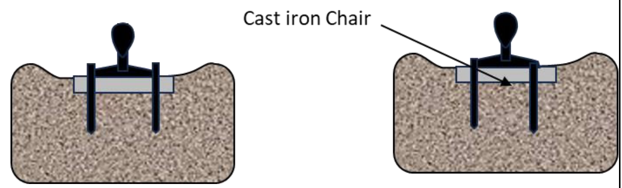
Rail Type 1: Wood rail topped by strap iron edge rail



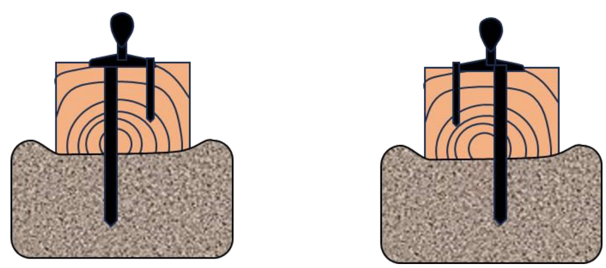
Type 3: Flat bottom bar rail.



Rail Type 2: Wood rail topped by lath and strap iron center rail.



Type 4: Cast iron chair that cradled flat-bottom bar rails.



Type 5: Wood rail topped by flat bottom bar rail.

Figure 13. Five types of rails likely used at Incline Plane 9 West during the hundred years that the Morris Canal 9 West was in operation.

For Rail Type 4, the flat-bottom rail is spiked to the cradled in a cast iron chair (fig. 13D). The chair held the ends of two rails firmly which prevented the rise and fall of one rail with respect to the other rail as the loaded cradle car passed over the joint between two rails. The cast iron chair was recessed into the stone sleeper; therefore, the remaining section of iron flat bottom rail generally sat upon the stone sleeper. The ride was rough and the abrasion of the rail against the stone sleeper was significant. Dual spike holes for the type 4 rails are located inside the chiseled box cut or within 6 in. from the outside edge of the chiseled box cut. By following the rail wear mark, it is common to find single drillholes at the edge of the rail wear marks that alternate from the right to the left side of the rail and are spaced about every 3 ft.

For Rail Type 5, the flat-bottom bar rail is spiked to a wood rail that is in turn spiked to the stone sleeper (fig. 13E). This arrangement provided a somewhat cushioned ride for the crib car and the canal boat thus reducing the maintenance needed for the earlier style rail construction. The spike holes like those for Rail Types 1 and 2 are along the center line of the stone sleepers and are likely spaced about every 3 to 5 ft. At this point in the investigation, it is not possible to separate the spike holes for rail types 1, 2, and 5.

Figure 14. Spike holes for Rail Type 4: A) Two spike holes with square spikes on each side of a rail wear mark, B) Single spike hole on side of a rail wear mark; and C) multiple spike holes with no apparent pattern.

Figure 15. A) Two spike holes (for Rail Type 4) on each side of a rail wear mark adjacent to a chiseled box cut. A) Large diameter single spike hole for Rail Types 1, 2, and 5 between spike hole set. B) Two spike holes set within a chiseled box cut.

Table 1. Rock types and length of Stone sleepers

Rock Type	Row A	Row B	Row C	Row D	total	
Granitic Gneiss	39	45	37	11	132	42%
Dolostone/Limestone	64	13	0	19	96	31%
Quartzite	0	13	15	27	55	18%
Sandstone	18	4		7	29	9%
Number of sleepers	121	75	52	64	312	
Max Sleeper length	5.4	5.5	6.3	3.9		
Average length of Sleeper	3.1	2.8	2	2.1		
Min sleeper length	1	1	0.2	0.8		
Exposed Sleepers Length	205	175	149	179		
Stones per 100 ft	59	43	35	36	43	

Discussion

Stone sleepers for Incline Plane 9 West were used to support wood and iron rails for the crib cars that carried canal boats up and down the incline plane. Of the approximately 2,400 stone sleepers used to construct the incline plane 312 stone sleepers are exposed and were described. Of the four rock types, 42 % are granitic gneiss common in the hills on the north side of the canal, 31 % are dolostone or limestone, which is the rock that underlies the valley, 18 % or quartzite which outcrops between the mountain and the valley and 9 % are sandstone imported from the eastern part of the canal (fig. 16).

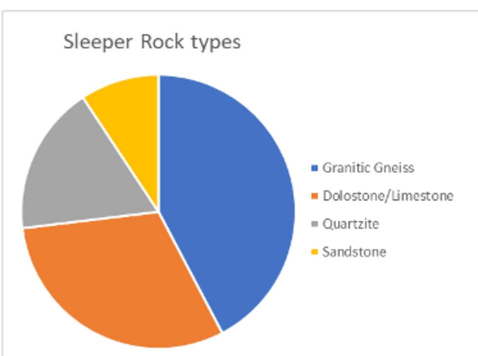


Figure 16. Pie diagram showing the percentage of the four major rock types on Incline Plan 9 West

Nearly all granitic gneiss sleepers are well shaped blocks. They are only used in the upper part of the Incline Plane for the four rows of sleepers (fig. 17). In Rows A and B granitic gneiss blocks can be quite long, with a maximum length of 5.5 ft. Nearly 50 % of the granitic gneiss blocks in Rows A and B are greater than 4 ft. long. Only two of the granitic gneiss blocks in Rows C and D are more than 4 ft. long. It is thought that Rows A&B were built at a different time than Rows C&D.

The remaining exposed section of rows A and B were constructed using limestone/dolostone and sandstone. The limestone/dolostone is most used in the upper part of incline for Rows A and B.

Limestone is only rock type used in the lower part of the incline plane for all four rows. Blocks of limestone in the upper part are well formed and can be quite long. However, the limestone blocks used in the lower part are not well shaped blocks and are generally quite short. A few limestone/dolostone blocks are in the upper part of Rows C and D. This change in construction material again suggests that Rows A and B were built at a different time than Rows C and D.

Quartzite blocks are only found in Rows C and D and only in the upper part of the incline plane. This again reinforces the interpretation that Rows C and D were constructed at a different time than A and B.

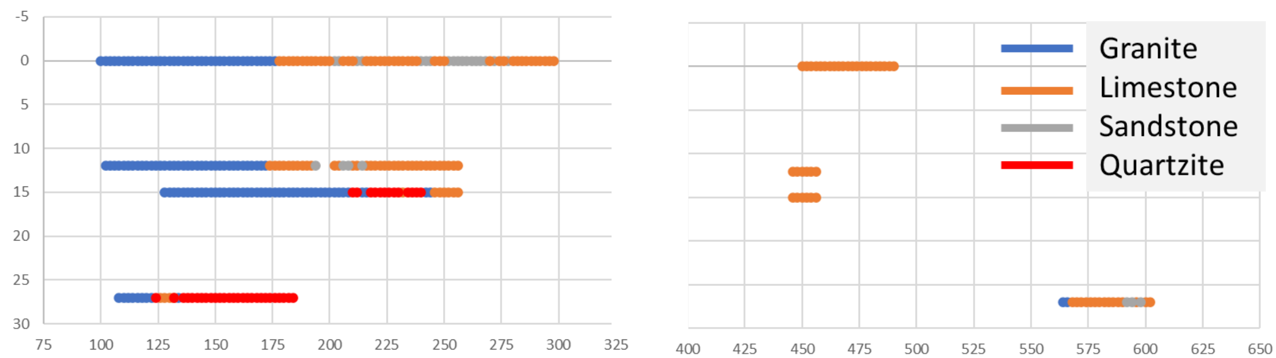
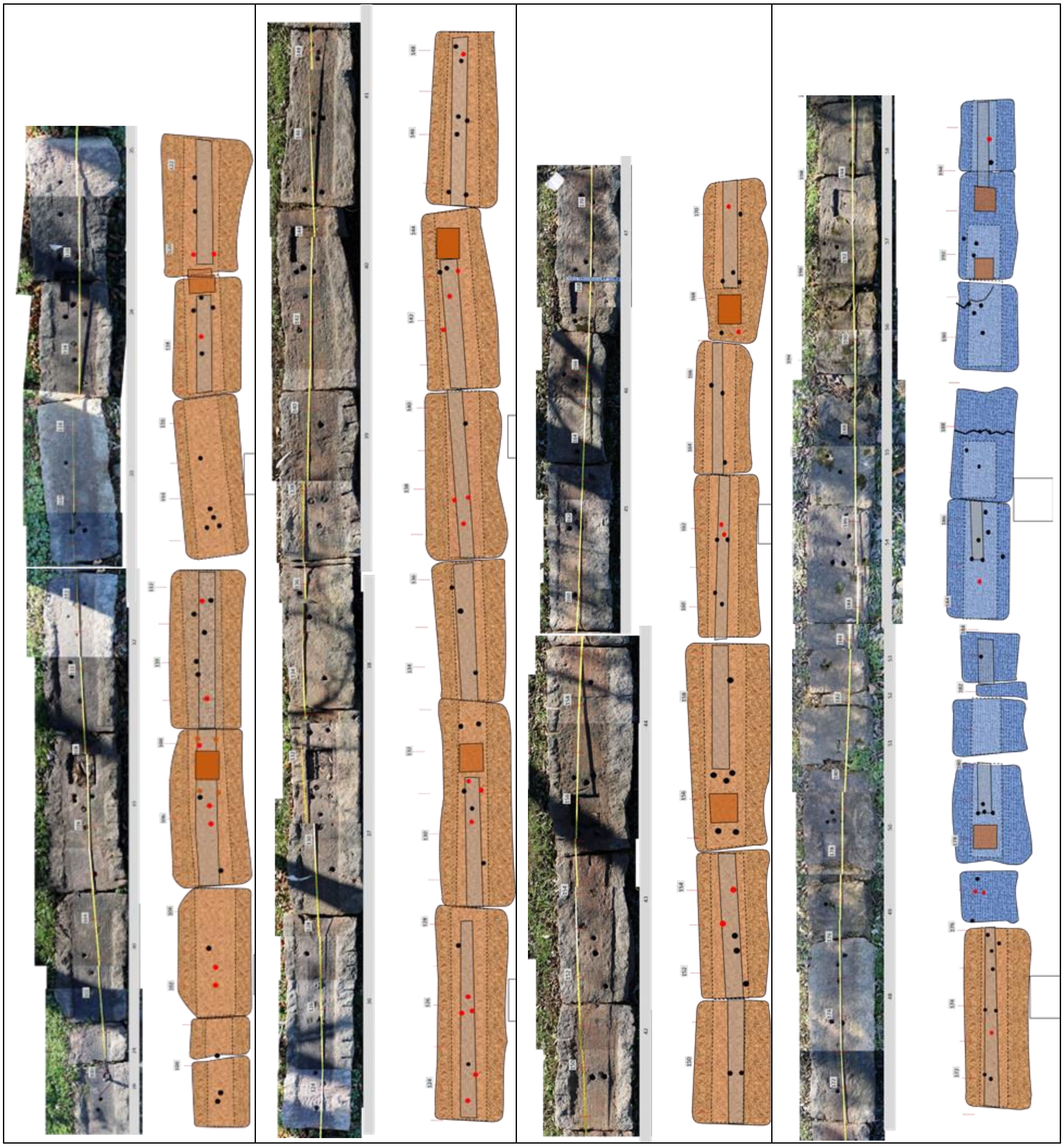


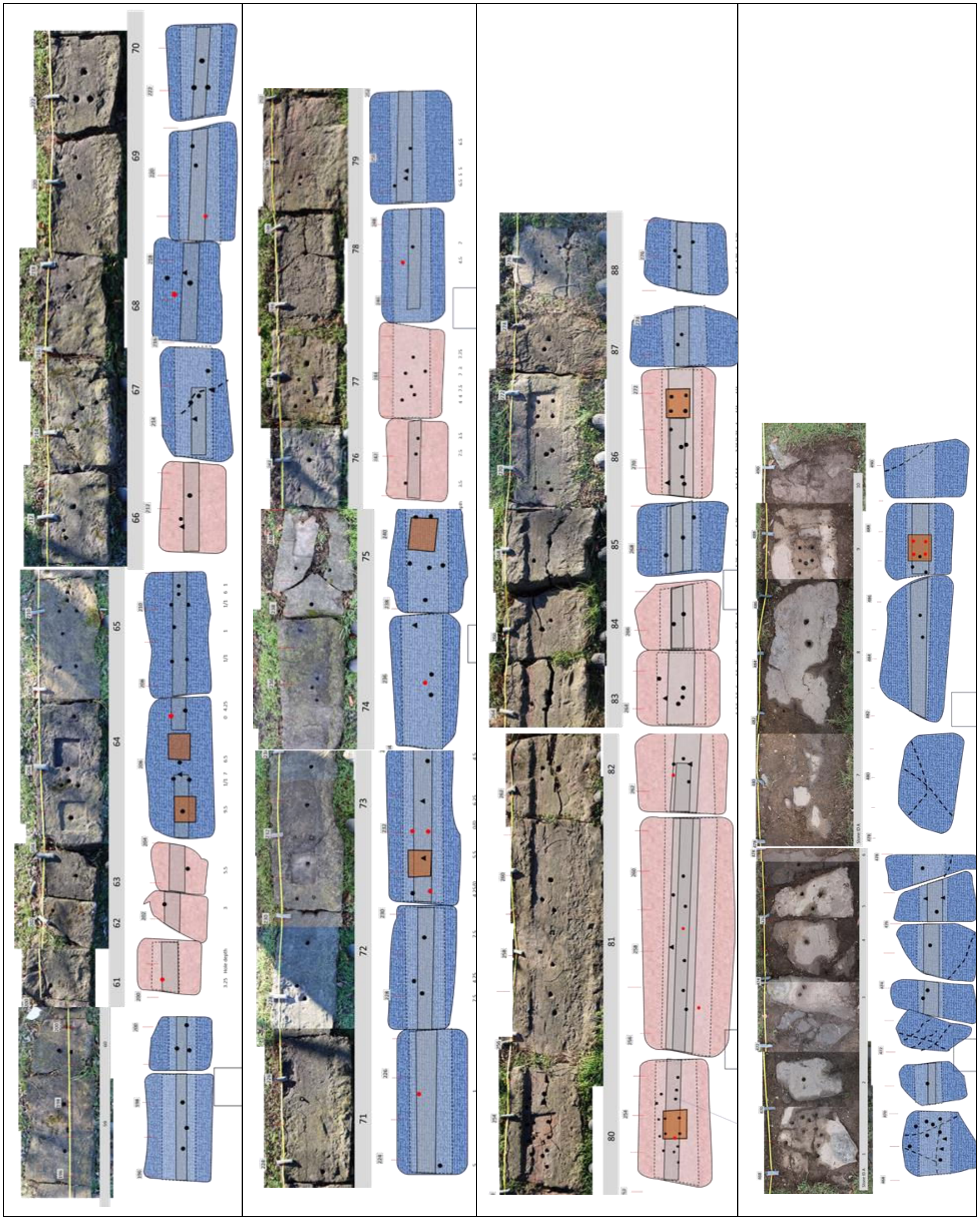
Figure 17. Diagram showing the array or rock types used in Rows A through D, Incline Plane 9 West

Conclusion

Incline Plane 9 West is one of more than eight Incline Planes that have exposed in situ stone sleepers. An investigation of the remaining Incline planes with stone sleepers will provide a more thorough foundation of the construction methods used for the incline planes of the Morris Canal and changes in rail design over the near century of operation.



Appendix 1.1. Composite photo and drawing of stone sleepers for Row A from 100 to 200 ft.



Appendix 1.2. Composite photograph and drawing of stone sleepers for Row A from 200 to 300 ft. and 468 to 491 ft.

Part 8

Early History of Colleges that Taught Geology near Northern New Jersey

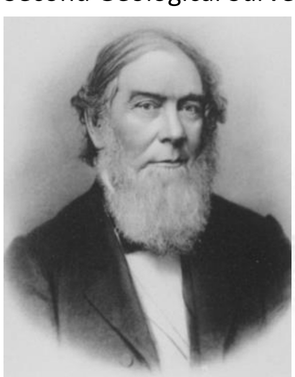
Prior to the Revolutionary War there were about a dozen colleges in the United States. Most colleges focused on teaching men how to be gentleman and ministers. No colleges focused on teaching Geology though some taught Natural Science which included some rudimentary geology. This essay covers the teaching of Geology at the University of Pennsylvania, Princeton University, Columbia University, Rutgers University, West Point Military Academy, and Lafayette College.

University of Pennsylvania


The **University of Pennsylvania** was founded circa 1740 by Benjamin Franklin. U. Penn was also one of the first academic institutions in the country to have multidisciplinary teaching in different faculty areas.

Geology education at the University of Pennsylvania began in 1749. It was taught with the sciences of botany and chemistry. In 1835, Geology was formally established at the University of Pennsylvania and Henry Darwin Rogers was appointed Professor of Geology and Mineralogy.

The succession of natural scientists and geologists taught at U. Penn through much of the 1800s. **Alexander D. Bache** taught chemistry, surveying, and engineering during 1828-41. He left U. Penn to head the U.S. Coast Survey in 1843. **Henry Darwin Rogers** taught geology during 1835-46. While an U. Penn educator he also conducted a geologic and mineralogic survey of New Jersey (1835-40). In 1836, Rogers became 'Geologist in Charge' of the Pennsylvania Geological Survey. **Ferdinand V. Hayden,** taught at U. Penn starting 1865. In 1867 he became director of the U.S. Geological and Geographical Survey of the Territories. **J. Peter Lesley,** taught at U. Penn during 1872-78. In 1874, he became director of the Second Geological Survey of Pennsylvania and worked there for a few years.




Alexander D. Bache Henry Darwin Rogers Ferdinand Hayden J. Peter Lesley

Alexander Dallas Bache was originally an army engineer, then professor at University of Pennsylvania from 1828 to 1841. In 1843, Bache became Superintendent of the United States Coast Survey. He mapped the American coast by a skillful division of labor and the erection of numerous observing stations. In addition, Bache ensured that geomagnetic and meteorological data were collected.

Henry Darwin Rogers, major interest was the Appalachian Mountains of Pennsylvania which Rogers saw as great folds of sedimentary rock. He believed that an interpretation of these folds would lead to an understanding of the dynamic processes that had shaped the earth. From Rogers' efforts to explain these Pennsylvania folds came the first uniquely American theory of mountain elevation, a theory that Rogers personally considered his most significant achievement. In 1840 he wrote “Description of the Geology of the State of New Jersey”. Figure 1 shows a Roger geologic map and section of the geology of the Scotts Mountain are thus of Oxford Furnace area.

Rogers describes the rocks of the Highlands in terms of Primary rocks, Lower Secondary rocks, Middle Secondary rocks, and Trap rocks in his geologic timetable. He did not use the modern terms Precambrian, Lower Paleozoic, Middle Paleozoic, and Jurassic.

Rogers describes the Highlands rocks as part of the “Gneiss System” with the same minerals as granite but differ from the true granites by possessing a stratified structure. He described schists and concluded with the academic hypothesis, termed the “metamorphic theory”. It appears that the concept of metamorphism was just a theory in 1840.

Rogers’ descriptions of the gneiss and iron rich zones are in a section on “Igneous rocks and metalliferous veins”. He never used the mineral name “Magnetite”, the ore mineral is only referred to as “oxidulated iron” or “magnetic iron ore”. Rogers noted that the ore veins exhibit a tendency to cleave by numerous natural joints and form a structure which suggests a strong analogy to the horizontal columnar arrangement seen in many vertical dykes of lava and basalt. Thus, his interpretation is that the veins of iron ore have been injected, while in a fused or molten state, into the gneiss, and are not in the strict sense beds formed contemporaneously with the surrounding rock.

Rogers describes scores of iron ore veins from northeast to southwest in the Highlands in remarkable detail. The last ore veins Rogers describes are near Oxford Furnace in Scott’s Mountain. Rogers notes the direction of the veins is parallel with the bearing of the strata of granitoid gneiss. He states:

There appear to be at least two principal veins, but the precise thickness of either is difficult to ascertain, owing to their varying constantly in their dimensions. The quantity of ore, however, is enormously great. ‘The veins are divided here and there, by thin beds of the rock, into several parallel branches, so that the aggregate width of the ore has not been wrought in many places. The adjoining strata are, moreover, considerably disordered, and the veins are, in consequence, thrown out of direction by two or three large faults. These are connected with detached or broken off portions of the lodes, two of which are known to sweep round a curve of almost semicircular form.

Some portions of the adjacent strata contain the oxidulated magnetic iron in a crystalline state, disseminated in sensible proportions through the rock, or rather through certain layers, either associated with the hornblende or replacing it.

The greater part of the ore resembles in quality that of the ranges before described, being the magnetic oxide of iron, either compact and massive, or in granular crystallization. It has the defect common to nearly all the veins in the primary region; that is to say, it is apt to be too compact fer easy reduction in the furnace. It yields an excellent iron and seems especially well suited for making castings.

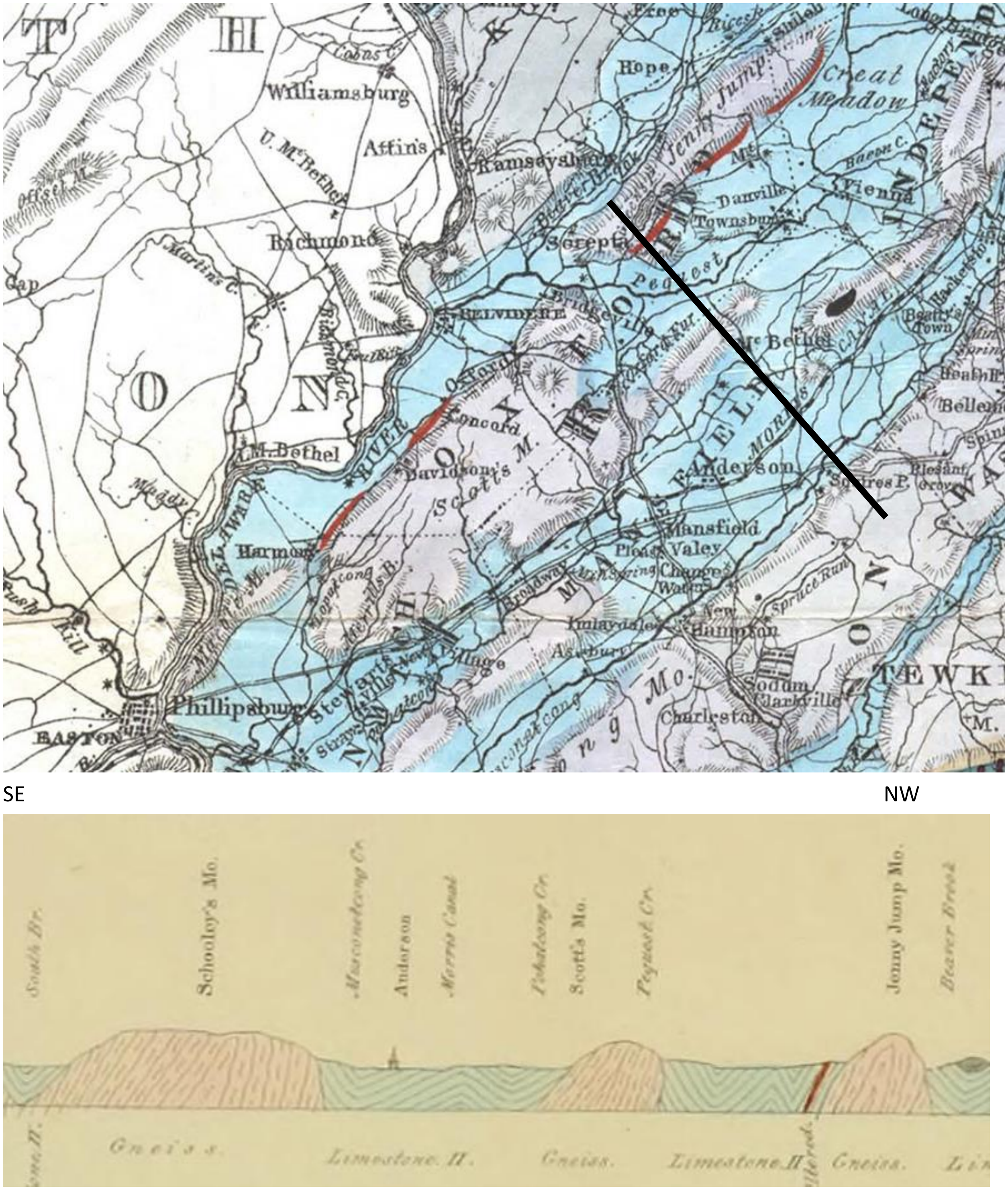


Figure 1. Part of Rogers' 1840 geologic map and section of the geology across the Morris Canal and Scotts Mountain.

Rogers' conclusion about the ore is that the Primary strata (Precambrian gneiss) existed in all probability at a rather steep inclination before the intrusion of the veins. The ore veins were extruded from their deep source during the epochs which preceded the deposition of the secondary strata (Lower Paleozoic sediments).

In Rogers' conclusion he writes: Respecting the geological date of these veins of magnetic iron ore, it seems difficult, from the imperfect nature of the data afforded by the region, to arrive at positive conclusions. The views which we here venture to suggest in the light of the hypothesis on the subject, are offered as merely conjectural. They are deemed at the same time worthy of a place in our account of the geology of the Highlands, as assisting to throw light upon other questions hereafter to arise, and as opening a train of inquiry interesting to future investigators—some of whom, let us hope, may hereafter find an inviting field for research in the structure and former physical history of this mountain belt. This leads directly to the papers in this proceeding offered by Princton and Rutgers researchers.

Ferdinand Hayden led geographic and geologic surveys of the Nebraska and Western Territories for the United States Government. Hayden and Fielding B. Meek studied geology and collected fossils in Nebraska. To measure distances during their journeys into the western frontier Hayden employed the use of an odometer, a device used by mappers to estimate distances traveled. The device was mounted on a mule-drawn cart that measured distances as the cartwheels rolled along. Because of rough terrain the device was accurate to within about 3%.

Hayden was a member of the Megatherium Club. Many members had no formal education but came by their expertise through extensive direct observation. They spent their weekdays in the rigorous and exacting work of describing and classifying species. But their nights were spent in revelry. They particularly enjoyed partaking in ale, oysters, eggnog, and whatever other fineries their meager budgets could afford. On Sundays, however, they recuperated from the week's stresses and excesses with long nature hikes.

Peter Lesley spent three years (1838-41) assisting Henry Rogers in the first geological survey of Pennsylvania. He made extensive and important research in the coal, oil, and iron fields of the United States and Canada. In 1856 he published "Manual of coal and its topography" (fig. 3). Lesley then taught at U Penn during 1872-78.

In the introduction of "The Manuel of Coal and its Topography" Lesley wrote:

> There are, no doubt, few native businessmen of Philadelphia, who cannot remember the panic occasioned by the news that the miners had reached the bottom of the Mauch Chunk Summit Mine; after having benched down through seventy feet of nearly solid coal. 'The summit mine' had been confidently regarded as but the vertex of a solid mountain of the mineral. The depth of the mine and therefore the contents of which were considered quite incalculable. Lehigh Coal and Navigation Stock fell twenty per cent for the same misconception of the mineral coal. 'Knowledgeable People' had bestowed upon the Summit mine such a marvelous depth, blinded the public to the fact of its much more marvelous lateral extent. Men were terrified to learn that the Mauch Chunk Mountain was not a solid mass of coal but had yet to learn, that one-sixth or eighth of the United States was underlaid by beds of it.

In 1863 Lesley examined the Bessemer ironworks in Sheffield England for the Pennsylvania Railroad Company. In 1903 he published "The iron manufacturer's guide to the furnaces, forges and rolling mills of the United States". He cites the following about Oxford Furnace.

> 44. Oxford Steam Hot-blast Charcoal and Anthracite Furnace,….is said to be the oldest remaining furnace in the Union, ancient castings being found in chimney backs a century old, and pigs are found stamped 1755 (45?) It is in complete repair and runs two-thirds of the year on charcoal and one-third on anthracite, sometimes using one-sixth anthracite. It is 8 feet wide across the bosh by 35 feet high and made in 1857. 906 tons of car wheel iron nearly all of it manufactured into wheels upon the spot. Formerly the iron was rafted in Durham boats from Foul Rift down the Delaware to Philadelphia. Its ores are black magnetic from banks half a mile distant, worked since 1743.

Lesley cites a great deal about many more iron furnaces in the area and produces a map (fig. 2) Box 44 is the Oxford Furnace.

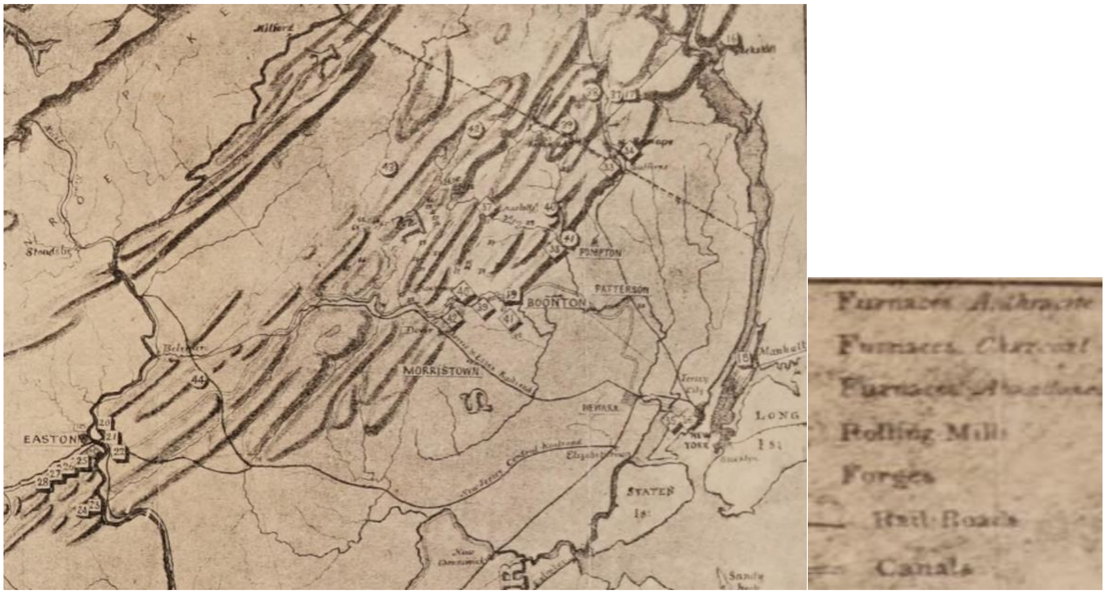


Figure 2. Map by Lesley (1903) show the location of Major iron Furnaces in Northern NJ 44 is oxford furnace.

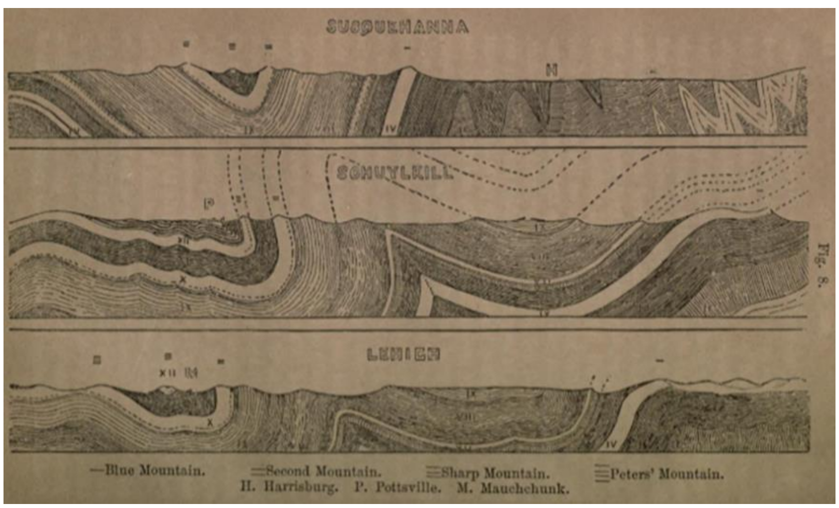


Figure 3. Lesley (1856) produces the first geologic cross section of the geology or the coal district in northeastern Pa Mauch Chunk is Letter M on Lehigh Section

Lesley notes that: the seams of slate and rock around the walls of the Mauch Chunk Summit Mine should have prepared us for the appearance of the bottom slate of all.

Lesley writes of miners who lack a geologic understanding of coal who think every there is black slate then exploring that region will lead to coal beds … In the upper valley of the Delaware and Schuylkill near Stroudsburg and Orwigsburg and in many other places, men have spent years, long lives in fact, and fortunes in digging vainly into this black slate for coal.

Lesley divides USA coal into 3 time realms: The series of which the coal formation is the last has received the now generally accepted name of Palaeozoic (sp), or the rocks containing the relics of the Ancient Life. Those which follow the coal are called rocks of the Middle Life, Mesozoic. Those which belong to the most recent times and to our own New Life, are called Kaiuozoic.

Lesley writes of PA coal fields….In the great coal regions of the United States, we are concerned only with the Palaeozoic (sp) strata which underlie the coal. They form a floor for it, in some parts seven miles thick. Along the banks of the Schuylkill, Susquehanna, Juniata, Potomac, and New Rivers, they are so thrown up and stand upon their edges that they can be measured directly through from top to bottom, from the coal down to the Potsdam Sandstone**,**

Lesley writes that erosion has removed vast quantities of rock in the past. And over many time periods rock was removed and sediments were deposited. He states. this not once or twice, but many times, as they alternately rise and fall in a succession of vaults and basins; the basins being solidly preserved beneath the surface, but the vaults swept away into the Atlantic. (See Fig. 8, representing three sections north and south through Mauch chunk, Pottsville, and Harrisburg; through the Kittatinny, Second, Sharp, and Peters' Mountains.) The coal measures, where they spanned the vaults, are of course gone. Where they remain, they exist in narrow troughs along the centre lines of the great basins.

Princeton University

Originally founded as the College of New Jersey by New Light Presbyterians to train ministers, **Princeton University** retains a number of landmarks from its rich history, such as its oldest building, Nassau Hall, which dates to 1756. Nassau Hall was technically the temporary capital of the US for four months in 1783, when the Continental Congress met there.

Arnold Henri Guyot - 1807-1884, Guyot Hall Guyot Hall gargoyle

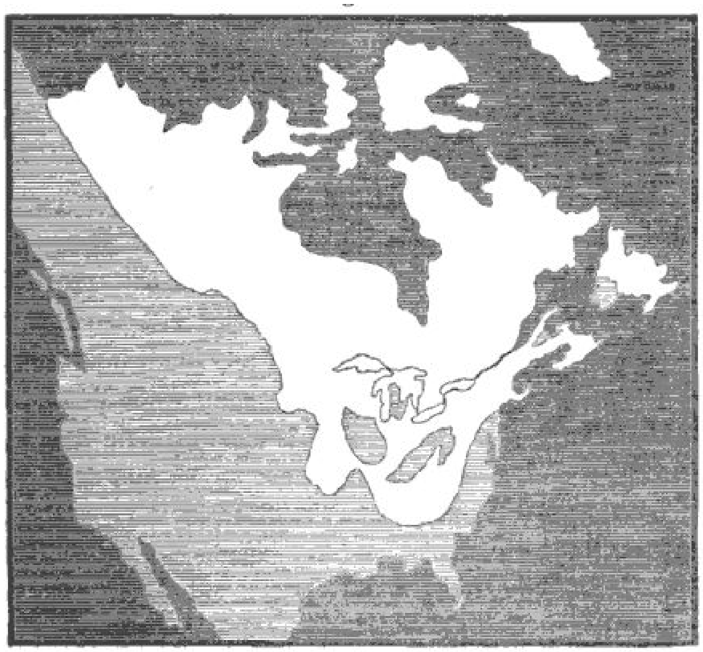
The department of geoscientific studies at Princeton University dates from 1854, when **Arnold Guyot was** appointed by the College of New Jersey as Professor of Geography and Physical Geology. Guyot, formerly a professor at the University of Neuchatel, left Switzerland in the wake of the revolution of 1848, and lectured at Cambridge, Mass., before joining the Princeton. Guyot would remain the sole instructor in geological sciences during 1854-1873. In that time, he was largely responsible for the genesis of the Geological Museum, which grew out of the fossils and geological specimens he collected for instructional purposes.

Guyots scientific work in the United States included the perfection of plans for a national system of meteorological observations. Which lead to the establishment of the United States Weather Bureau.

Guyot rejected Darwin's theory of human evolution, and at the same time, he accepted Hugh Miller's views on the book of Genesis, thinking that the days described there might have taken a longer period of time. Scientist James Dwight Dana described Guyot as "a fervently religious man, living as if ever in communion with his Heavenly Parent; a Christian, following closely in the footsteps of his Master.

In 1873, **Dr. Franklin C. Hill**, joined Princeton as Curator of the Geological Museum, and **Dr. Henry R. Cornwall** joined as Professor of Analytical Chemistry and Mineralogy

In 1849 Guyot presented a series of 12 lectures with slides on the "Lectures of Comparative Physical Geography in it Relation to the History of Mankind". Below is one slide of land of North America exposed during the Carboniferous (fig. 1). Guyot notes that only northeast North America is a large island (white area). The rest of the continent, particularly the lower Mississippi; much of the Great Planes, and the Rockey Mountains exist but are below sea level.



America at the Coal Epoch.

Figure 1. Guyot's slide of North America during the Carboniferous. White area exposed; gray area is below sea level. And contains Rockey Mountains.

Columbia University

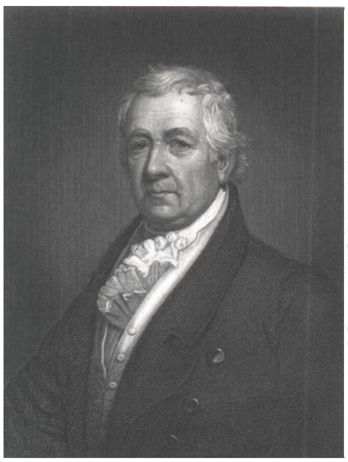
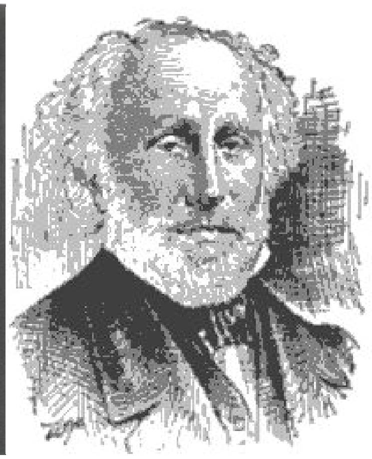
Located in New York City, **Columbia University** was chartered in 1754 as King's College by royal charter of George II of Britain and renamed Columbia College in 1784 after the US gained independence. The Geology Department extends back into the late 1700's when geology was first being studied in colleges. However, our department wasn't officially founded until 1866.

During 1795 and 1801 **Samuel L. Mitchel** oversaw curricula for Geology, Meteorology, Mineralogy, Botany, and Zoology. Geology then was focused on collecting fossils and minerals and naming them. When Mitchell retired in 1802 Geology teaching ceased until 1820. The first geologic course taught at Columbia was Blowpipe Analysis by Charles A Joy.

In 1820 **James Renwick** became professor of Natural and Experimental Philosophy and Chemistry. He taught geology and mineralogy. Renwick collected and purchased mineral collection from around the world. One mineral collection was a gift of the Russian government.

During the 1800s, geology was focused on state geologic maps and economic geologic maps to determine the natural resources of a state. This led to the Columbia School of mines created in 1864.

In 1892 the school of Pure Science took over graduate work in Geology Minerology and other non-engineering sciences.


Samuel L. Mitchel James Renwick David Bate Douglass

Samuel L. Mitchel taught at Columbia from 1795 and 1801. Mitchill knew Merriweather Lewis before the Expedition of 1803 departed and likely spoke to Lewis about its scientific objectives.

Mitchell met with M. Lewis in 1806, only two days after Lewis returned to Washington. Mitchell wrote that Lewis gave a description of the 'burning plains' up the Missouri. (Lewis likely was referring to lignite beds in North Dakota and to pseudo-volcanoes he encountered in northeastern Nebraska.) Mitchell interpreted that "minerals called volcanics are not necessarily the production of volcanoes, but of plains burning underground". Mitchill summarized his conversations with Lewis: *In Europe, lava, slag and pumice are the products of burning mountains or volcanos; but in some of the countries through which the Missouri passes there are vast burning plains, where all the volcanic productions are formed by the intensity of fire, without the smallest appearance of a mountain.*

Mitchill suggested renaming the United States of America Fredonia.

In 1828, Mitchill was asked to authenticate the "Reformed Egyptian" characters that J. Smith said were from golden plate. Mitchill was unsympathetic to the view that Indians were related to the Jews or the Egyptians. Mitchell was one of the few scholars who believed that Native Americans were descended from Asians.

James Renwick taught geology at Columbia College during 1820-1854. Circa 1825, while Renwick was a professor, he reexamined the idea of using inclined planes instead of locks to raise and lower canal boats. Renwick's plan was similar to the incline plane built on the Connecticut River Canal at South Hadley (fig. 1).

Renwick's original inclined plane designs seemed to use double tracks on all planes. The descending track would have a cradle car that held more weight in water or a canal boat than the loaded canal boat on the ascending track. Thus, the system theoretically would not have needed external power. The final plan was to build mostly single incline planes and only a few double incline planes. The descending cradle car weighted with water of a heavy canal boat was replaced by an overshot waterwheel to supply power.

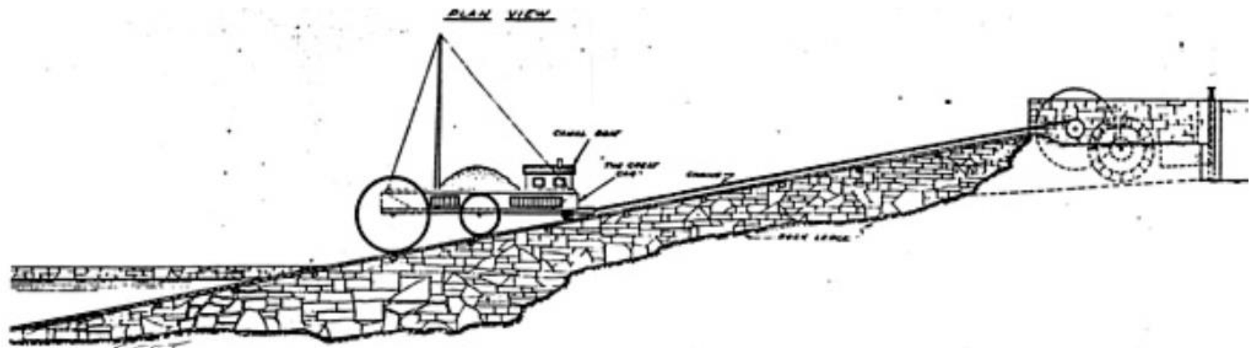


Figure 1. Drawing of Incline plane built on the Connecticut River Canal at South Hadley used during 1795-1805.

The early planes were constructed by different contractors and differed greatly. In 1829, the canal company hired David Bates Douglass from West Point, who became the chief engineer of the planes. He supervised the construction of the remaining planes to be built as well as rebuilt the already completed planes so that they were of uniform construction.

In addition to Renwicks collegiate duties he wrote the textbooks, *Outlines of Natural Philosophy (*1832), *Outlines of Geology prepared for the use of the Junior Class of Columbia College 183*8, Elements of Mechanics (1832), and First Principles of Chemistry (1840) were among the first works of their kind published in the United States.

Rumford's 100 page Geology textbook is divided into 3 sections: 1) Physical Geology, 2) Geognosy, and 3) Geogeny. Physical Geology covers the shape and density of the earth, geothermal features, distribution of continents and oceans, terrain of valleys, hills and mountain chains. He describes the two continents with the old continent being Eurasia and its peninsula Africa and the new continent being North and South America. In Rumford's section on 'Rocks and Fossils' he tersely covers joints, faults, fissures etc. and the animal and plant kingdoms.

In Section II "Geognosy" Rumford begins by stating that the earth is not as it was first created but rather the present state of the crust has been obtained by slow and gradual steps that can be divided into geologic epochs. Rumford divides rocks of the earth into: a) 4 types of *Modern Sediments; b)* 5 Types of *stratified ancient formations* and c) 6 types of *unstratified Ancient formations.* He provides detailed site descriptions of the various units. Of local interest when Rumford described one type of modern sediment he states. That in the *Schooley's Mountain (New Jersey Highlands) massive blocks of rock are imbedded in diluvial gravel. The passage of such blocks has left deep groves in the formations over which they must have traveled. Such grooves have been observed in England and the United States.* (Rumford is describing glacial erratics and striations).

Of local interest when Rumford described one type of Ancient stratified sediment (**Supermedial Order**) he states *the new red sandstone of Connecticut exhibits tracks of the feet of gigantic birds.* Rumford is describing the three toe tracks of Triassic dinosaurs. A few other local examples describe the iron ores and limestone of our study area but in limited detail.

In Section III *Geogeny* Rumford describes the way the crust of the earth has attained it present state. (I believe Geogeny is derived from geology genesis). Rumford describes in elementary terms erosion, volcanoes, earthquakes, cementation, and subterranean heat. He speculates about coal, volcanoes, evolution, glaciers, geothermal gradients, and geobasins. His ideas on geobasins may be the foundation for my early education regarding geosynclines, the precursor of earth formation prior to plate tectonics.

Renwicks son designed the Smithsonian Building

Near or soon after the end of the Civil War Columbia University developed a School of Mines, Department of Paleontology, and Department of Minerology and Metallurgy. In 1892 Columbia U. developed the School of Pure science which took over studies in Geology Minerology and non-engineering sciences.

Rutgers University

Rutgers was chartered as Queen's College in 1766; and became Rutgers University in 1924. It was originally affiliated with the Dutch Reformed Church.

Lewis C. Beck first taught Geology during 1830-53. He was the professor of chemistry and natural science. He also was mineralogist for New York Geological Survey and wrote the book Minerology of New York. Though most minerals have a formal name 'magnetite' is referred to as magnetic oxide of iron or magnetic iron ore.


George H Cook George H Cook

George H. Cook initially taught chemistry, mineralogy, geology as well as math and theology at Rutgers during 1853-89. Later in his academic career he became the vice president of Rutgers. During 1842-53 and prior to teaching at Rutgers he taught at RPI and the Albany Academy.

While teaching at Rutgers he became the NJ State Geologist (1864-89). During this time, he over saw the publication of more than 35 Annual Reports of the NJ Geological Survey as well as the. the Second edition of the Geology of New Jersey. More is available on his reports in the Section on the NJGS and USGS

Lewis C. Beck 1864, where he describes the geophysical magnetometer manufactured by W&L E Gurley Company used to map magnetic ore bodies in the New Jersey Highlands.

Lafayette College

Lafayette College in Easton, Pennsylvania. Was founded in 1826. **Peter Arrell Browne** taught Mineralogy and Geology from 1837 to 1847. At the end of the Civil War (1865) Lafayette appointed **Charles Henry Hitchcock,** as Chair of Geology and Mineralogy (though Hitchcock bibliography does not state that). Hitchcock was assistant state geologist of Vermont 1857-61, state geologist of Maine 1861–62 and 1866-67, and of New Hampshire, 1868-78. He taught at Dartmouth College during 1868 and 1908. Hitchcock was a founder of the Geological Society of America.

Geology continued its presence at Lafayette with Professor Rossiter Raymond and Frederick Burritt Peck who served from 1896 to 1925, With the appointment of Freeman Ward in 1926 at Lafayette geology blossomed into a full-fledged "department."

In 2023 Lafayette has a full geology Department with **David Sunderlin** as Department Head. He and his fellow professors and students are host to this year's GANJ Meeting

West Point Military Academy

The United States Military Academy was established in 1802. West Point had a major role in our nation's history during the American Revolution both as a fortification but also as a training and education site for military needs.

Major Sylvanus Thayer considered the "Father of the Military Academy," served as Superintendent from 1817-1833. Aware of our young nation's need for engineers, Thayer made civil and military engineering the foundation of the curriculum and the top few in each class became engineers. The Academy was the first engineering school in the United States

During the 1800s, USMA graduates were largely responsible for the construction of the bulk of the nation's earliest waterways including the Morris Canal and the Delaware and Raritan Canal, and Panama Canal West point graduates also are responsible for the engineering of Americas earliest Railroads including New Jersey's Camden and Amboy Railroad and Pennsylvania's Philadelphia and Columbia Railroad both built in the early 1830s.

Part 9

Early History of New Jersey Geological Survey and United States Geological Survey

In 1835 the New Jersey Geological Survey began. **Henry Darwin Rogers** was appointed as the first State Geologist and his term culminated with the publication of "Description of the Geology of the State of New Jersey" in 1840. From 1840 to 1853 there was no funding for the NJGS.

In 1854 **William Kitchell** was the second NJ State Geologist with the intent to map the topography and geology of the counties of New Jersey starting with Cape May. The legislature suspended funding in 1856 and Kitchell worked as a self-funded worker as part of the State Agriculture Society. He published the 1st, 2nd, and 3rd annual reports on the Geological Survey of New Jersey. Kitchell died in 1861.

In 1861 **George H. Cook** continued Kitchell's work but did it on a statewide not on a county basis. In 1864 legislative funding was restored. Cook oversaw the publication of the Annual reports from 1864 until his death in 1889.

In 1878, the US Geological Survey began. Its initial focus, in cooperation with the US Coast and Geodetic Survey, was to establish mean sea level and create a topographic map of the US. Mean sea level was established at Sandy Hook, New Jersey.

New Jersey Geological Survey

The first NJGS geologic report on geology and mining concerning Oxford Furnace and surrounding area was written by Rodgers in 1840.

Oxford Mine from Rogers 1840

The following text is taken from Henry Rodgers (1840) ***"Description of the Geology of the State of New Jersey".*** Rogers did not use many modern terms in his descriptions, and in some cases, he used geologic terms that are not used today, or their definition has been significantly altered. The following terms fall into those categories. Precambrian, Cambrian, Ordovician, etc. are not used. ***Primary Rocks*** are defined as 1) crystalline rocks that are (a) extensively stratified (foliated) e.g. gneiss and (b) not stratified (not foliated) e.g. granitoid, felspathic granite, sienite. The word m***etamorphic*** is used, however it is defined as a hypothesis referred to as the ***metamorphic theory***. The word magnetite is not used. The term used is ***magnetic iron ore*** and it consists of two parts **peroxide of iron** and **protoxide of iron**. ***Strike and Dip*** are used to denote the direction of the foliation with the assumption that foliation is ancestral bedding in the gneiss.

Roger speculated that an iron rich ore body was extruded into the gneiss. Rogers hoped for research on this topic in the future.

Rogers described the rocks of the Oxford Furnace area: Scott's Mountain consists of primary rocks made up of gneiss. The mountain is surrounded by limestone.

Rogers described the Igneous Rocks and Metalliferous Veins of the Highlands. —The metalliferous veins of the primary region of the State, though extremely numerous and widely distributed, embrace but few varieties. As regards their general structure, they are very nearly alike; while the only ores they contain in large amounts are iron and zinc; with iron being by far the most abundant.

Rogers described the Structure of the Veins/ore bodies. —In their form the ore bodies are unequivocally genuine lodes or veins, and often of considerable longitudinal extent coinciding with occasional slight deviations, with the direction of the strata which include them. The ore bodies are usually between walls of the granitoid gneiss, to which they are parallel, not only in strike, but in dip. The orebodies have many minor irregularities, such as changes in thickness, from bulges with great width to thin to almost imperceptible dimensions. This observation suggests the fullest force to the whole mass of injected matter, regarding it as one vein. The distribution of the ore within the vein is liable to even greater irregularities. Viewing these veins comprehensively, they consist of metalliferous ore and other minerals, particularly hornblende and felspar. In some locations, the ore constitutes the body of the vein, resting in contact with the gneiss rock of the wall. In other locations the ore occupies only a part of the thickness of the mass, being bounded on either one or both of its sides by the non-metalliferous minerals, usually termed the gangue. In other sites again, the vein of ore is split by a wedge of the same gangue, which either entirely cuts it off on one side, or partially divides the vein.

In some places gangue comprises the chief width of the vein, and the ore lies in detached long lenses with their longer axes in the direction of the course of the vein. These insulated masses of ore, denominated ***pots* or *pools*** by the miners, are sometimes more than a hundred feet long, with a thickness that varies from five to forty feet. Where detached orebodies are found lodged in the country rock of gneiss. 'They are commonly called ***horses*** by the miners. In some places the entire vein is cut through by faults commonly almost at right angles, and totally interrupting its continuity.

The structure of these metalliferous veins, seem strongly to imply that they are real veins of injection, and not true beds, contemporaneous with the adjoining gneiss, as some have supposed. The common thickness of the metalliferous veins is from six to twelve feet. The inclination or pitch varies some dip with the strata that enclose them, at as low an angle as 50°. Othe veins can be vertical. In shallow excavations the workings are open to the sky. The deepest shaft yet sunk (1840), that of the Mount Pleasant Mine, near Dover, in Morris County, is only about two hundred and twelve feet below the surface.

Rogers described the Nature of the Ore: The ore belongs to the species denominated by mineralogists ***oxidulated* iron** or ***magnetic iron ore* and** is of two varieties—compact and granular. In its purest form, this mineral consists of two atomic proportions of the ***peroxide* of iron,** and one of the ***protoxides***, which is equivalent to nearly 72% of the former, and a little more than 28% of the latter—yielding about 72% of metallic iron. In less pure and more common ore the amount of metallic iron ranges from 60 and 72%, The ore is magnetic, endowed with the property of attracting soft iron, and affecting the magnet. Masses of it are frequently met with possessing a distinct magnetic polarity, the opposite ends manifesting a repulsive action upon the corresponding ends of the needle. Such specimens are termed loadstones.

Though the pure variety is often massive, and mingled with but little foreign mineral matter, yet this is really less productive in the manufacture of iron than the granular or imperfectly crystalline kind, in which we find a moderate proportion of small crystals of hornblende, felspar, quartz, and other minerals, interspersed with the ore. Some of the ore contains a small proportion of titanium. ‘The veins often exhibit a tendency to cleave by numerous natural joints, extending across from one wall towards the other; a structure which suggests a strong analogy to the horizontal columnar arrangement seen in many vertical dikes of lava and basalt. Rogers final interpretation based on his observations is that the veins of ore have been injected, while in a fused or molten state, into the gneiss, and are not in the strict sense beds formed contemporaneously with the surrounding rock.

This point, though at first sight unimportant, and seemingly one of mere theory, is more practical to the miner since it acquaints him with the nature of the veins in which he is operating.

The following are Rogers descriptions of the mines near Oxford Furnace, Scott’s Mountain, in Warren County.

Rogers described the iron ore veins for many Highland mines in detail. Below is his brief description of veins in the vicinity of Oxford Furnace, which is a region of chief importance in N.J.

The direction of the veins at Oxford Furnace is parallel with the bearing of the strata of granitoid gneiss. There appear to be at least two principal veins, but the precise thickness of either is difficult to ascertain, owing to their varying constantly in their dimensions. The quantity of ore is enormous. ‘The veins are randomly divided by thin beds of the rock, into several parallel branches. The aggregate width of the ore has not been mined in many places. The adjoining strata are considerably disordered, and veins are thrown out of direction by two or three pretty large faults. These are connected with detached or broken off portions of the lodes, two of which are known to sweep round a curve of almost semicircular form.

Some of the adjacent strata contain oxidulated magnetic iron in a crystalline state, disseminated through the rock, or through certain layers, that are associated with the hornblende or replacing it.

Most ore is magnetic oxide of iron that is compact and massive, or in granular crystallization. Such ore is too compact for easy reduction in the furnace. This is common to nearly all the veins in the Highland. The ore yields an excellent iron and seems especially well suited for making castings.

Roger flowerily states he hopes that this favored region of New Jersey, so eminently enriched by nature with that most valuable of mineral treasures, iron, is destined to behold, at no very distant day, a brighter era as a manufacturing district. Two important new methods are now used in Oxford Furnace, a) hot blast furnace and b) substitution of anthracite coal for charcoal these methods ar peculiarly well adapted to remove some difficulties which occur with compact magnetic ores. Such ore requires a more elevated temperature for their profitable reduction than can be developed by charcoal and ordinary air blast.

Rogers Conclusions—The first theory: the primary strata existed at a rather steep inclination before the intrusion of the veins. It is inconceivable how a forced injection of fluid ore could enter a series of beds, lying in a nearly horizontal position, without causing and occupying fissures perpendicular to the strike of the strata. The fact that similar veins—those of the altered white limestone of Sussex (marble)— occupy a corresponding position in reference to the neighboring strata and appear to have been produced after the formation of the limestone, suggest that the veins formed after the heaving of the gneiss.

If the gneissic strata were previously nearly vertical, then the molten ore would easily inject into the plane of the stratification of the rock, this being the direction in which the strata would most readily give way. If the rule is true, then it provides information for seeking and opening mines in this region. One is, that the veins of ore may be expected to follow the same layer or bed of rock for a considerable distance: and that the nature, therefore, of the adjoining rock, will often prove a clue for finding a previously known vein in the direction towards which it is prolonged. Another suggestion is, that when levels are cut, or shafts sunk to reach a vein, the indications of which are witnessed upon the surface, the excavations should be made on that side of the presumed outcrop of the vein which is towards the **underlie, or dip** of the gneiss, because the vein, keeping parallel with the rock, will descend in that direction.

Respecting the geological date of these veins of magnetic iron ore, it seems difficult, from the imperfect nature of the data afforded by the region, to arrive at positive conclusions. The views which suggest in the light of the hypothesis on the subject, are offered as merely conjectural. They are deemed at the same time worthy of a place in our account of the geology of the Highlands, as assisting to throw light upon other questions hereafter to arise, and as opening a train of inquiry interesting to future investigators—some of whom, let us hope, may hereafter find an inviting field for research in the structure and former physical history of this mountain belt.

In examining the question of the date of the veins of magnetic iron ore, our attention is at once called to the interesting general fact, that these veins lie exclusively in the primary rocks. I think we must conclude that most, if not all of these veins of ore, were extruded from their deep source beneath the surface, during the epochs which preceded the deposition of the first widely dispersed secondary strata.

Rogers table of the average percent of each oxide of metal in Oxford mines

Peroxide of iron,	67.25	Protoxide of iron,	26.50
Oxide of manganese,	0.50	Oxide of titanium,	a trace.
Silica,	2.10	Alumina, &c.	3.00

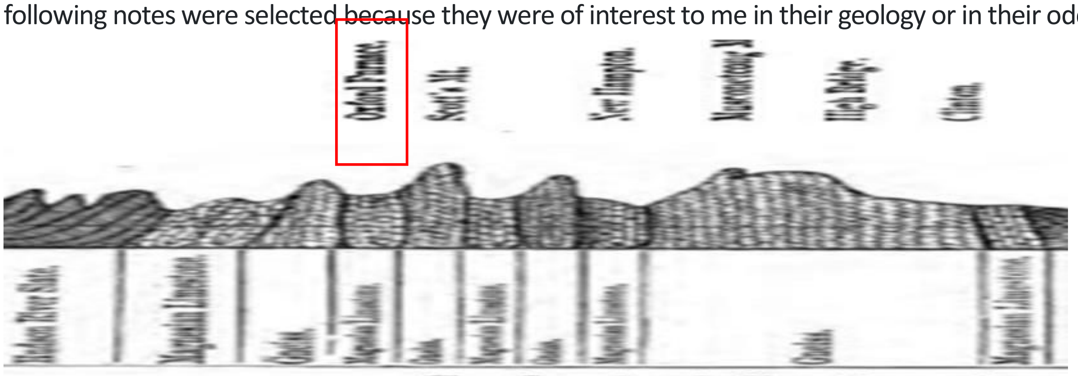
Rogers discusses Forging of ore: Rogers notes that the shallow weathered ore is better suited for the furnace than the deep unweathered ore. He notes that trials were conducted of mixing loamy clay with the ore prior to forging and the results were encouraging.

Roger notes that some forges use magnetic separating machine prior to forging but that is limited to mine sites with a lower grade of ore (Ringwood, and Hibernia).

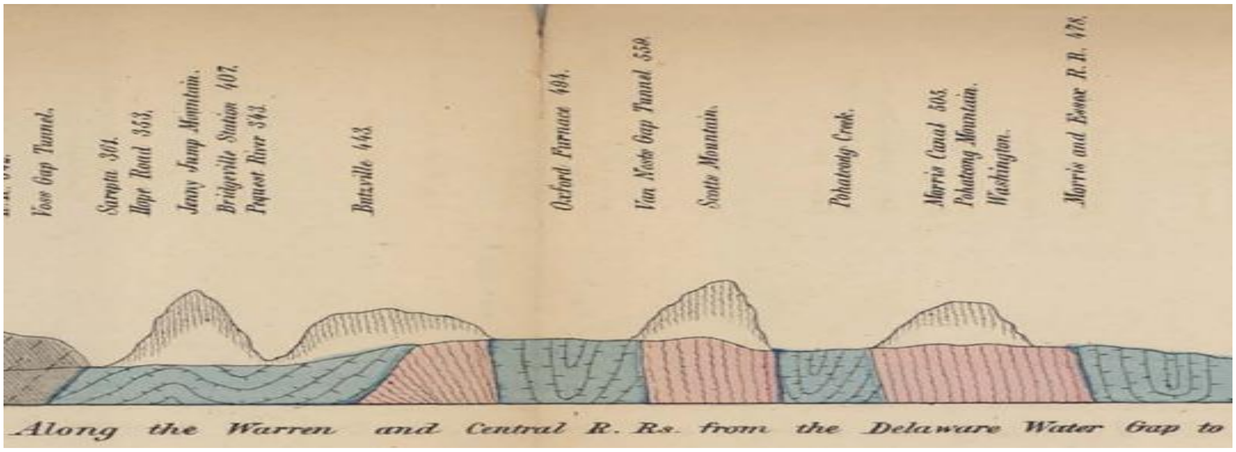
Roger notes that: Some of veins of magnetic iron ore, that penetrate the gneiss, are older than the ore and no ore veins that penetrate the blue limestone.

Roger notes that the limestone valleys are synclines and Scotts Mountain is high in part because it is an anticline.

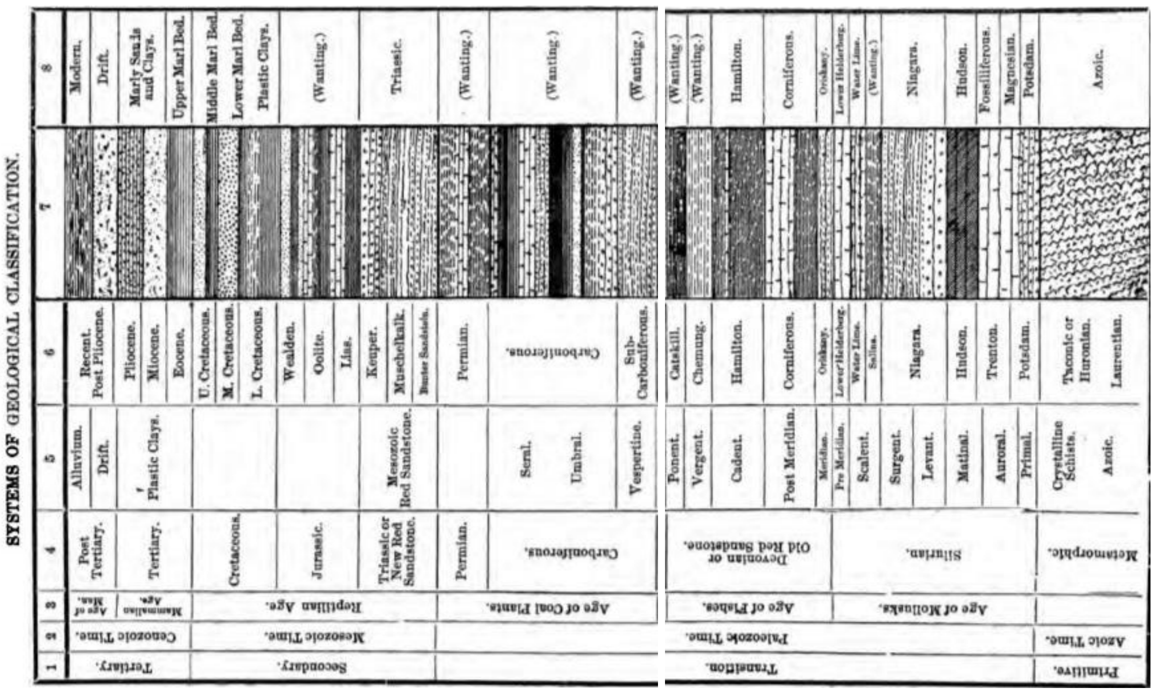
George Cook produced nearly 26 annual NJGS reports while Chief Geologist of the NJ Geological Survey. Most annual, where describing the New Jersey Highlands or the Oxford furnace area, are focused on economic geology and therefore simply state how much ore was mined or how much iron was made. The following notes were selected because they were of interest to me in their geology or in their oddity..



Rogers geologic section is little different than his 1840s section.

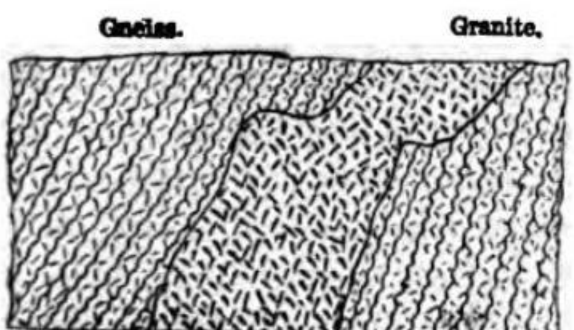


Cook 1968



Cooks first Geologic Column (1868) has interesting column subheadings.

Fig. 18.



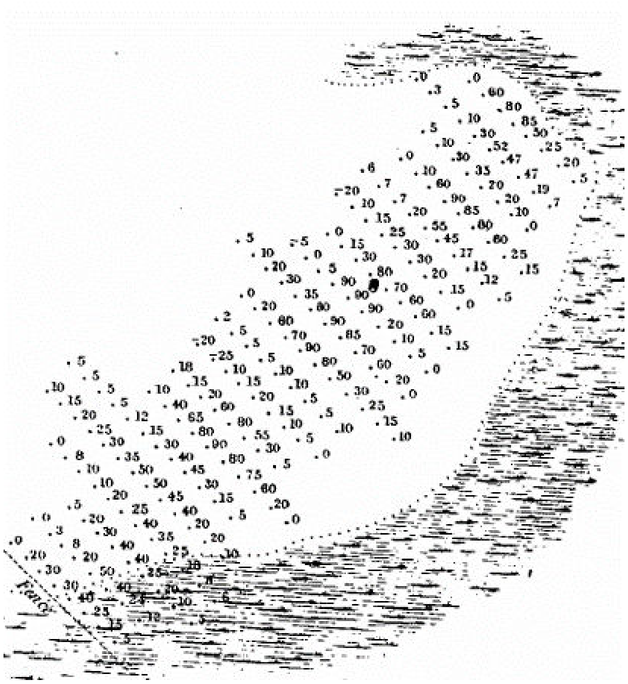
Granite dike in Pequest rock-cut, Warren R.R.

Cook notes that rocks of the Van Nest Gap Tunnel: greenish-grey, hard rock, feldspar, quartz, and hornblende. Some of the rock pinkish tinge.

Cook notes that some beds of the rock (gneiss) are so peculiar as to be identified in hand specimens; but generally, there is so much uniformity that hand specimens from the different belts and from different localities cannot be locally identified.

Cook defines the origin of the rocks as metasedimentary rocks and that the iron is also a metasedimentary rock and was likely deposited as a bog iron.

Cook 1874 presents a Magnetics Survey of a mine in Passaic County. Data for a similar type of magnetic survey is available for mines in Oxford Furnace. Unfortunately, the numbers in the webpage pdf are not legible.



Magnetic survey of Land of Scranton and Rutherford West Milford Township Passaic County

Cook 1874 notes that stone from the iron mines should not be used as building stone because the ore has pyrite that will weather to a rusty brown oxide that spoils the appearance of the stone. Cook also notes that brownstone is well adapted for architecture and is quarried in large quantities. Most quarries are on the Delaware River, Passaic River, and Morris Canal.

Cook often refers to magnesium Limestone which was his term for Dolostone.

In 1875 Cook notes that the limestones used at Oxford Furnace were from Warren County, specifically from Face's 2 quarry, near the Pequest River, from the quarry at Changewater, and No. 3, from the Warren Railroad cut, about a half mile east of Washington.

The Washington vein was surveyed by Wm. H. Scranton, and a map of the magnetic survey was printed in the **Annual Report, for 1879, page 96** unfortunately the numbers are not legible in the .pdf version of the report. Cook notes that the opening on this very regular line of magnetic attraction has discovered a very long and regular ore bed. The ore is found to be less sulfurous as the workings get deeper. The average breadth of the ore is nine feet.

Cooks report on exploration for iron ore by Magnetic Needle

The magnetic properties of the ore are very marked and are well known. Specimens taken from near the surface, are in many cases good and permanent magnets. And in some places the whole mass of ore is so highly magnetic as to cause the steel tools used in working it to become permanent magnets and capable of attracting other pieces of iron or steel.

The principal portion of the ore, after it is mined, is not permanently magnetic itself, but it is always capable of being attracted by the magnet, and hence its name of Magnetite.

In 1884 Oxford furnace is one of 3 mines in SW part of Highlands that is still in operation. Cook notes that Spain and Africa iron ore can be shipped to furnace in NJ at less cost that mining an shipping ore from NJ to the same furnaces.

In 1885 the United States Coast and Geodetic Survey ran a line of levels across the State from Sandy Hook to Phillipsburg

1889 George Cook Died September 22, 1889, so he did not finish the 1889 Annual Report

The text of the 1889 report digests the previous Annual Reports and summarizes them. It divides the NJ Highland gneiss into 4 rock types: 1) Mount Hope Type, 2) Oxford type, 3) Franklin Type, and 4) Montville type.

Summary Emplacement of Iron ore

Supposing these beds to be original deposits, their nearly uniform dip to the southeast can only be explained by imagining the whole of this disturbed belt of Huronian rocks to lie in a series of anticlinal and synclinal waves, collapsed and leaning over on their northwest sides. Professor James T. Hodge, whose original manuscripts has been kindly furnished for these descriptions believes them to be veins ejected through parallel fissures conforming to the interstitial or bedding planes of the metamorphosed rocks in which they occur.

On the other hand, Dr. Kitchell of New Jersey in his third annual report of the geological survey for 1856 expresses the contrary and at present the more probable opinion that they are of sedimentary origin. He writes:

That the rocky formation of this district, including the gneiss, the hornblende and mica schists, the magnetic iron ore, and the quartzo-feldspathic rocks, are of metamorphic origin, there can be but little doubt; consequently, it is conceived that they were originally deposited by water in a horizontal position, that they are composed of materials derived from preexisting rocks, and that they were subsequently disturbed in their position, and altered by metamorphic agencies, which have caused them to assume their present form and position. The origin, therefore, of these deposits of magnetic iron ore, is identical and cotemporaneous with the rocky strata in which they are enclosed.

The Oxford furnace ores are black magnetic from 45 to 60 per cent, and in the immediate vicinity of the furnace, which was built and blown in March 1743. The ores lie in granitoid gneiss, conformably, in two principal and very variable beds, separated here and there by parallel beds of rock, as in double and triple coal beds, so that the whole thickness of ore is not always taken out. Several faults also heave the beds sideways and cause fractures and squeezes, one of which makes almost a semicircle. The adjacent strata or rather certain beds are full of crystals of magnetic ore replacing or associated with their hornblende crystals. The ore itself is here as elsewhere both massive and fragmentary and the massive ore is always refractory but makes an excellent iron. The forge pig bears a high character. Another bed of ore was opened in 1847 quarter of a mile from the furnace, one lens-shaped mass of which was 16 feet thick this “blue magnetic vein” is now reported by Mr. Scranton 22 ft. thick and making good bar iron; the Harrison vein being red-short and the black magnetic vein makes the best car-wheel iron. In 1858 another large bed was opened, and the sales of ore to other works are over 1,000 tons a month.

US Geological Survey

The United States Geological Survey was established on March 3, 1879, and placed in the Department of the Interior, and charged it with the responsibilities to classify public lands, and examine the geological structure, mineral resources, and products of the national domain. The legislation stemmed from a report of the National Academy of Sciences, which in June 1878 had been asked by Congress to provide a plan for surveying the Territories of the United States that would secure the best possible results at the least possible cost.

In 1879, the first duty of the Geological Survey was to map and classify of the public lands, (lands west of the Allegheny Mountains and claimed by some of the colonies. Prior to mapping the resources discussion showed that a good spatial, topographic, and costal map was needed. The first facet was to establish Mean Sea Level. The US Coast and Geodetic Survey, the USGS, the Navy, the shipping industry the States and academia agreed in 1878 to measure Sea level at Sandy Hook NJ at 15 minute intervals for 5 years and then the Mean Sea Level would be established based on the data collected.

Part 10

Early history of Warren Railroad and Oxford Tunnel

The Warren Railroad in Warren County, N.J. served as part of the Delaware, Lackawanna, and Western Railroad's (DL&W) mainline from 1856 to 1911. It predominately moved coal from PA coal mines to New York City and places in between.

The Warren Railroad was chartered on February 12, 1851, by the New Jersey legislature, to connect the DL&W in Manunka Chunk to the Central Railroad of New Jersey (CNJ), in Hampton. **(fig. 1).** The 19 mile railroad connection was constructed in anticipation of a merger between the DL&W and CNJ railroads. That merger never happened! The railroad's date of organization was March 4, 1853, and construction began in June 1853.

Mountainous terrain made the Warren Railroad expensive to build, requiring a large amount of excavation, three large bridges, and two tunnels. The northern tunnel is the Manunka Chunk Tunnel. The southern tunnel is the Van Nest Tunnel.

In October 1857, DL&W formally leased the Warren Railroad. The tracks were originally 6-ft gauge, the same gauge as the DL&W's Pennsylvania tracks. A third rail was added to CNJ's 4 ft-8 ½ in. standard gauge track so that trains could use both rail gauges.

Manunka Chunk Tunnel

The Manunka Chunk Tunnel was the first constructed section of the Warren Railroad. Construction began in 1854 and it was opened for rail travel in 1856. Taking a little less than 2 years to construct. The tunnel passes through soft shale of the Martinsburg Formation (Omb), a turbidite sequence (fig. 1). Initially the tunnel was constructed for a single track. In 1869 a second tunnel was excavated. The tracks were originally 6 ft. gauge, continuous with the DL&W's Pennsylvania tracks. A third rail was added to CNJ's 4 ft 8 ½ in standard gauge track.

The tunnel remained active for many years, although service dwindled once the New Jersey Cut-Off Line was completed to the north in nearby Columbia, NJ in 1911. By 1948, there was only one freight train passing through the tunnel and no passenger service. In 1948, the eastbound tracks were ripped up from the old main line, leaving Manunka Chunk as a single track line. In April 1970, the Erie Lackawanna Railroad stopped train service past Washington, thus closed the Manunka Chunk Tunnel for good.

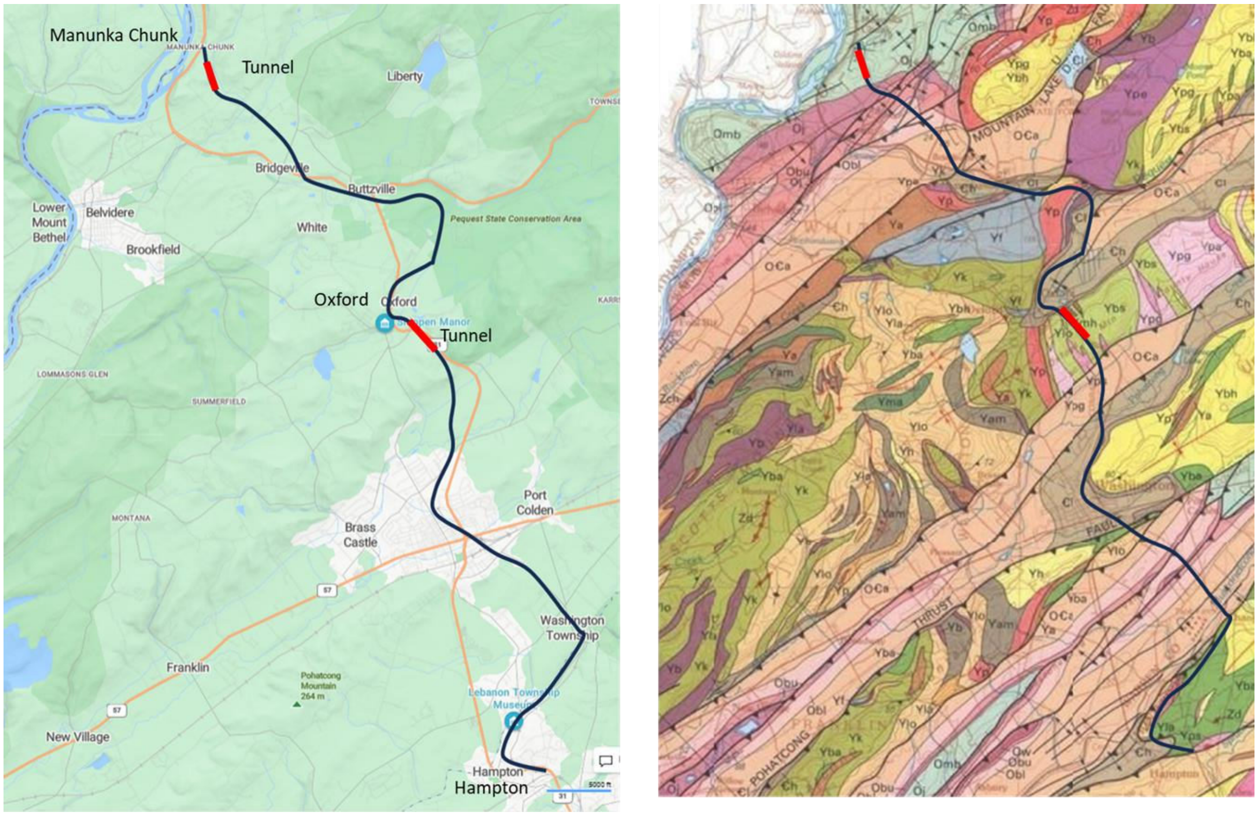


Figure 1. Warren Railroad on modern A) road map and B) geologic map showing location of the Manunka Chunk and Oxford Tunnels.

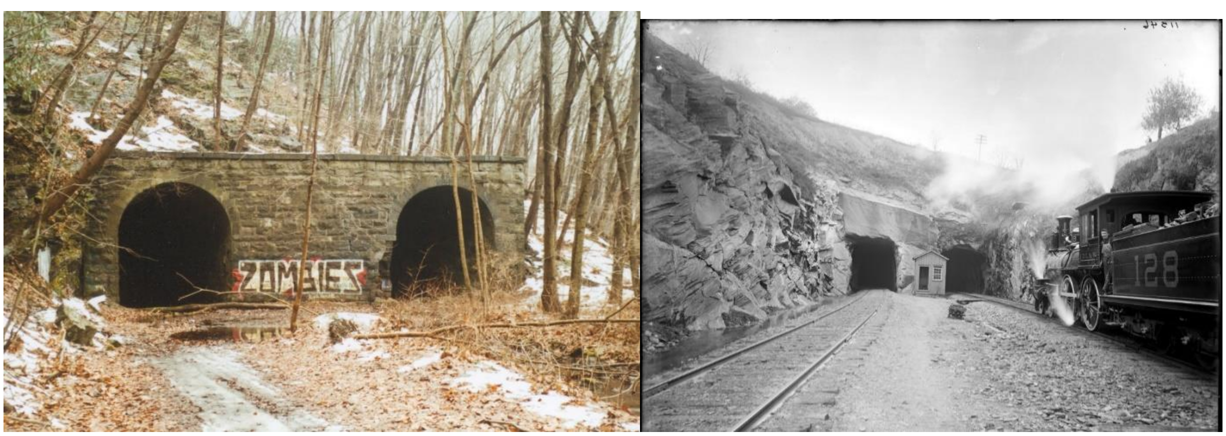


Figure 2. Manunka Chuck Tunnel west and east entrance. Out crop of Martinsburg Formation.

Oxford Tunnel (also known as Van Nest Gap Tunnel)

In late 1854, construction of the Oxford Tunnel began. Completion of the tunnel was delayed due to inconsistent funding, American Civil War, era technology, and issues with digging through the 3,002 ft long, hard to mine gneiss. The 18 ft. high tunnel was completed in September 1862. Thus, it took more than 7 years to complete the tunnel (fig. 3).

The New York Times account of the tunnel construction noted many obstacles. The rock is a syenite (quartz poor granite) (Ybs), thus the hard, seamless rock, offering the most stubborn resistance to construction. During excavation almost every form of underground mining operations proved necessary. Multiple rock types were encountered including quicksand and an unusual quantity of water. Almost one-half of the Tunnel is substantially timbered and arched with store masonry; the balance being carefully and skillfully excavated through the solid rock requires no artificial support. The tunnel proper is owned by the state of New Jersey, but the eastern and western entrance cuts are privately owned and posted with no trespassing signs (fig. 3).

In the parapet, at the west end of the tunnel, was a handsome marble slab, on which is chiseled the dates of commencement and completion, and the names of the President of the Warren Railroad, Mr. John J Blair, the Chief Engineer, Mr. James Archibald, and the contractors Messrs. McAllister and Wiestling – this marble slab is relocated to the Shippen Manor Museum in Oxford Furnace (fig. 2). The Marble is likely Cockeysville Marble from Pennsylvania.

When the Warren Railroad opened in 1856, the Van Nest Gap Tunnel was not yet completed, and a temporary track was constructed over the top of the gap. When the tunnel was completed in September 1862, and the temporary track removed. The opening of the tunnel relieved trains of the slow and arduous climb over the top of the Van Nest Gap.

The M&E track was originally built with a gauge of 4 ft 10 in. but by July 1866 the track was converted to standard gauge of 4 ft 8 ½ in. During the first few decades of operation, the tunnel suffered intermittent water damage due to flooding and leakage from the overlying gneiss.

In 1869, Oxford Tunnel was double tracked. By the 1890s, larger locomotives and rolling stock had trouble passing through the tunnel. In 1901, the railroad replaced the double tracks with gauntlet tracks within the tunnel, effectively turning the tunnel into a single-track bottleneck. A gauntlet track is two tracks that overlap. The gauntlet track maximized the overhead and side clearances in the tunnel but restricted the tunnel to a single-track section.

In 1968, Storm damage near Oxford, led to the railroad's demise. By April 1970, all remaining trackage was removed between Washington and Manunka Chunk. (Fig. 3

WARNING: The tunnel is owned by the state of New Jersey. The inside of the tunnel poses a falling rock and debris hazard. Chain link fence prevents entry to the tunnel.

Figure 3. The eastern portal of Oxford Tunnel on the Old Road in August 2011.

Figure 4. A marble plaque placed in 1862 on the parapet of the west entrance to the Van Nest Train Tunnel, now at Shippen Manor Museum.

Part 11

Buried Secrets: New Jersey Schoolteachers Investigate New Jersey Highland Iron Ore Deposits Via *QUEST* Summer Workshops at Princeton University

Laurel P. Goodell
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Princeton University's QUEST summer workshops (Questioning Underlies Effective Science Teaching) bring schoolteachers to campus to enhance their understanding and confidence in STEM by engaging in activities as adult learners. Each year several workshops are offered and while Princeton scientists provide content (often the "broader impacts" for research grants), Princeton's Program in Teacher Preparation plays a critical role in facilitating curriculum development, recruiting participants, obtaining financial support for teachers in low-income districts, and providing logistical support. "Lead Teachers" for each workshop – previous QUEST participants -- serve as facilitators and lead sessions that focus on classroom applications and pedagogical techniques such as Next Generation Science Standards.

Buried Secrets: The Geological Significance, Formation and History of Iron Ore Deposits in the New Jersey Highlands was a 2023 QUEST unit led by Professor Blair Schoene, Geosciences Lab Manager Laurel Goodell, Geoscience Research Specialist Isabel Koran and Martha Friend (Princeton Regional School District), with funding provided by one of Schoene's NSF research grants.

In the 18th and 19th centuries, over a hundred mines in Precambrian rocks of the Highlands made New Jersey a major U.S. iron producer. This activity drove local economies, spurred settlement of the region, and helped fuel the industrial revolution. *Buried Secrets* engaged participants in exploring fundamental questions related to the formation and age of this iron ore.

First, teachers spent two days on campus learning about New Jersey geology, rocks and minerals, and plate tectonics. This included a presentation by Pierre Lacombe of the USGS (retired) on historical aspects of the mining. The centerpiece of the week, however, was an all-day field trip to the Highlands. Teachers hiked past flooded mine entrances and the remnants of Thomas Edison's mining complex near Sparta, NJ, that once employed hundreds of workers in a completely deforested landscape. The group then completed transects across the now reforested bedrock, searching for outcrops, mapping rock types and measuring metamorphic foliation.

The last two days were back on campus, where participants merged their field measurements to discover they had mapped a bedrock structure that could be interpreted as a several kilometer-scale fold. Next, teachers examined textures in ore samples and experimented with igneous intrusion models, which indicated an igneous origin for the ore bodies that must post-date metamorphism. Finally, teachers learned about absolute dating, toured Schoene's high-precision Thermal Ionization Mass Spectrometry laboratory and evaluated data that confirmed the post-metamorphic timing of ore emplacement.

As a result of their *Buried Secrets* experiences, participants made significant gains in understanding the geology of New Jersey and the processes that occur at plate boundaries. They also benefitted from exposure to the interdisciplinary toolkit of fieldwork, experiments, modeling, and lab analyses that geoscientists use to address scientific questions.

QUEST does not end with the last day of a summer workshop. To facilitate implementation of activities beyond QUEST, teachers leave with resources and materials to use in their own classrooms. Many teachers are repeat participants, and some become Lead Teachers themselves. Over the years, QUEST has impacted thousands of elementary, middle, and high school students as they perform their own QUEST-type investigations guided by QUEST-trained teachers.

2023 QUEST workshop teachers examine a flooded iron mine entrance near Ogdensburg, NJ where Thomas Edison's "New Jersey and Pennsylvania Concentrating Company" operated from 1891-1900. The orientation of the ore, and the mine, generally follows the trend of the metamorphic foliation. At its peak, the workings employed almost 500 workers, but was a financial failure. Thomas Edison did have a few other successful ventures, of course!

QUEST teachers visualizing and measuring the orientation of foliation in gneisses of the New Jersey Highlands.

Revisiting The Formation Processes New Jersey's Iron Deposits

Michael DiMaio[1], Linda Godfrey[1], Ryan Mathur[2]

[1]Rutgers University, [2]Juniata College

The New Jersey Highlands record an extensive tectonic history of multiple mountain building events. The Grenville orogenic cycle, between 1.3 to 1.1 billion years ago, is associated with multiple iron, copper, and zinc deposits that have been exploited as early as the 1690's by early Dutch settlers. The Franklin Marble hosted Sterling Hill Zinc deposit is likely a result of crustal thinning in an early Grenville back arc basin which created a Sedimentary Exhalative (SEDEX) style deposit. Though the zinc deposits of the Franklin Marble are the most renowned and studied, there are hundreds of economic grade metal deposits throughout the Highlands. While some of these deposits are hosted in metamorphosed sedimentary deposits like the Franklin Marble, others are hosted in or adjacent to igneous units. Volkert et al (2010) place different episodes of magmatism at the end of the Grenville Orogenic cycle, after closure of the back arc basin hosting New Jersey's SEDEX deposits. These episodes of later magmatic activity may be responsible for some of the numerous iron mines that were worked until the 20th century including Thomas Edison's Sparta Mountain mine, or Edison Mine.

Metal isotopes can be used to uncover the original processes that concentrated these metamorphosed economic deposits, and here, we address the fractionation of stable iron isotopes ($^{56}Fe/^{54}Fe$, reported as $\delta^{56}Fe$, relative to IRMM 014) found in the magnetite ore. The Edison Mine is seated in microcline gneiss (Ym) approximately 2 miles southeast of Sterling Hill Mine. Ym is inferred to be a metamorphosed arkosic sandstone that was deposited in a Grenvillian back arc basin, though a rhyolite protolith has also been proposed. Magnetite within this Ym was the primary ore mineral of the Edison Mine. Mine workings in the unit are closely associated with magmatic arc rocks (Volkert and Monteverde, 2013; Volkert and Drake, 1999) and the gneiss displays local partial melting often with magnetite on the contact with the melt and residual gneiss. Much of the ore body has been removed but the ore that remains contains accessory apatite, actinolite, and wollastonite and does not show the same metamorphic fabric of the gneiss. The remnants of the ore body leave open the question whether this and other deposits are strictly SEDEX, like Sterling Hill, or are magmatic Iron Oxide Apatite (IOA) deposits seen in other subduction zones like that of the Grenville orogeny. There are many formation models of IOA deposits, but generally all include immiscible iron rich fluids separating from magmatic bodies on accreted margins of a subduction zone. In addition to field relations, $\delta^{56}Fe$ values from the Edison Mine have a lower average and a less variation than those of the Franklin Marble and other NJ SEDEX deposits (Wanaque, Warwick, Ringwood and Roseville). The Edison Mine iron isotope average is +0.36 per mil, and range between -0.07 and +0.79 per mil (N=7), whereas values for SEDEX deposits throughout NJ average +1.02 per mil with a wider range of +0.22 to +1.55 per mil (N=8). The δ56Fe average from the Edison deposit is similar to bulk silicate Earth (BSE). The greater variation of magnetite from SEDEX deposits is likely due to fractionation during partial iron oxidation within an anoxic water column or quantitative deposition of Fe from fluids that leached oxidized Fe from the basin margin. Further sampling is underway to further constrain δ56Fe values between deposit types, as well as obtaining δ18O values of the magnetite to determine if there is a magmatic origin of these iron rich fluids.

Sources:

Volkert, Richard A., Aleinikoff, John N., Fanning, Mark C., 2010, "Tectonic, magmatic, and metamorphic history of the New Jersey Highlands: New insights from SHRIMP U-Pb geochronology", From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region, Richard P. Tollo, Mervin J. Bartholomew, James P. Hibbard, Paul M. Karabinos.

Volkert, Richard A. and Monteverde, Donald H., 2013, Bedrock Geologic Map of the Franklin Quadrangle, Sussex and Morris Counties, New Jersey: US Geological Survey National Geological Mapping Program Map GMS 13-4, Scale 1:24,000.

Volkert, Richard & Drake Jr, A.A., 1999, Geochemistry and stratigraphic relations of Middle Proterozoic rocks of the New Jersey Highlands. US Geological Survey Professional Paper. C1-C77.

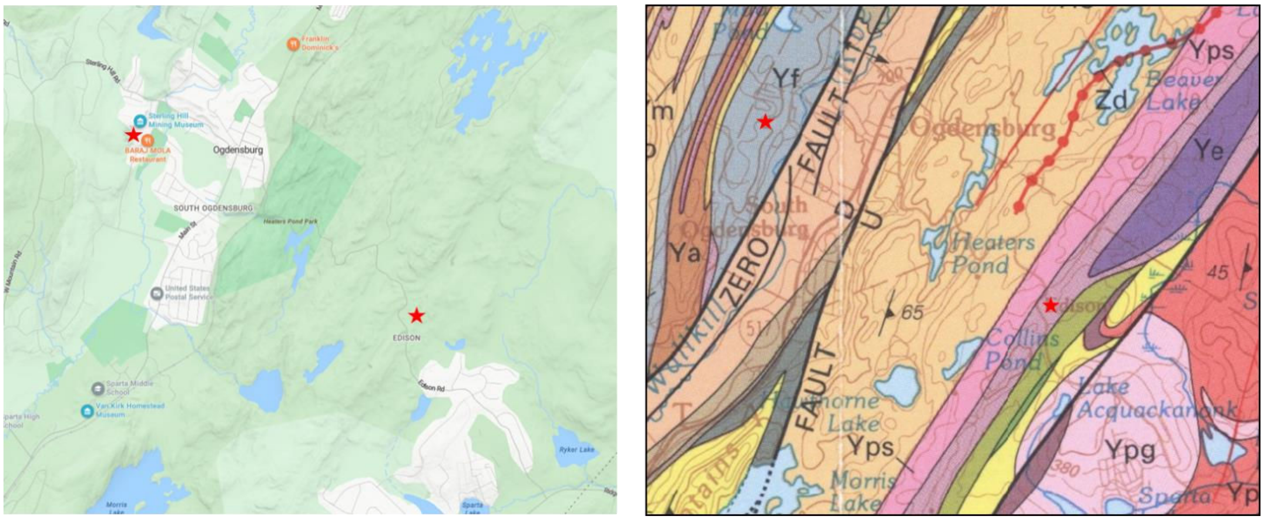

Figure 1 Maps showing the location of the Sterling Hill Mine (NW star) in Franklin Marble (Yf) and the Edison mine (SE star) in the microcline gneiss (Ym).

Morris Canal & Banking Company and It's Mountain Climbing Canal

Joe Macasek

From the very moment of its inception the Morris Canal needed to deal with geology and geography. Its promoter, George McCulluch, wanted to promote iron mining and iron making in Morris County and its investors wanted to transport coal from mines in Pennsylvania to markets in east coast cities. To accomplish any of this they had to engineer a route over the New Jersey Highland, around the Watchung ridges in Passaic County, and cross coastal marsh land to reach New York Harbor. In this presentation we will look at what they did and what they accomplished.

Timing of iron oxide-apatite mineralization in the core of the Grenville orogen, New Jersey Highlands, USA

Blair Schoene[1], Isabel Koran[1], Victor Guevara[2], James Maeder[2], Alyssa McKanna[3]

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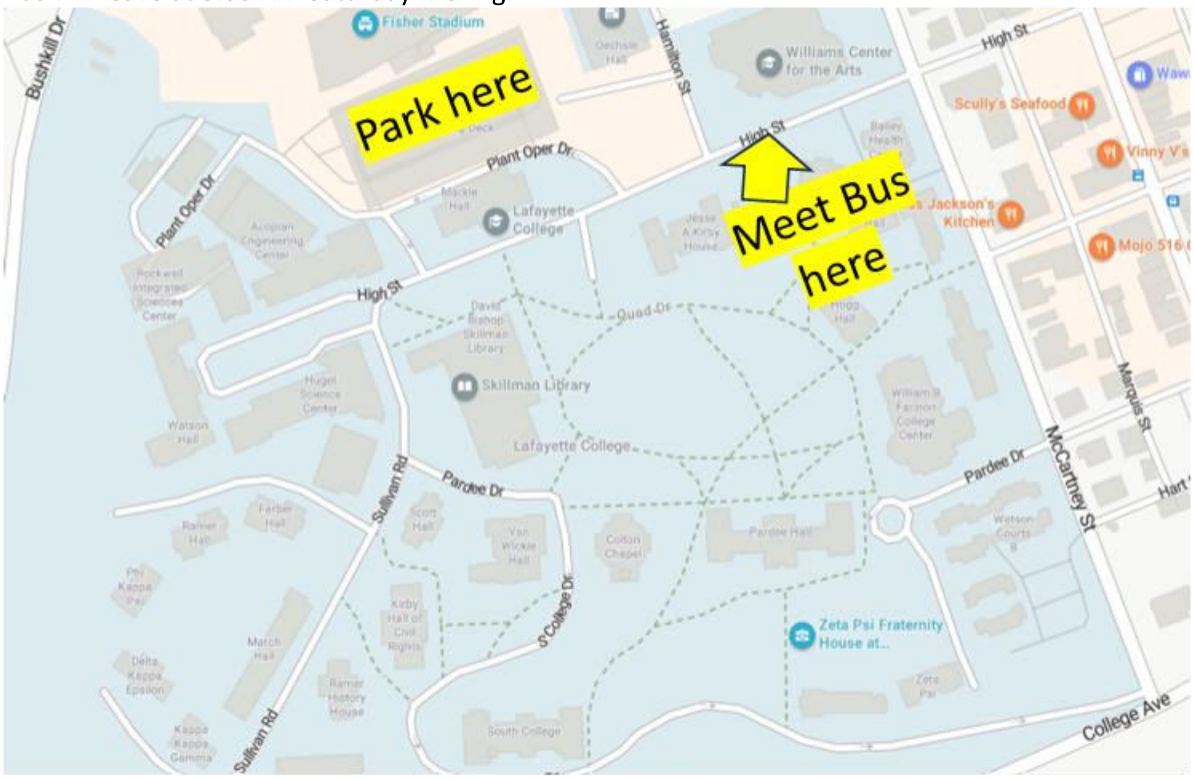
3. Los Alamos National Laboratory, Los Alamos, NM

The New Jersey Highlands record ~350 Myr of Mesoproterozoic activity on the margin of Laurentia, culminating in the Grenville orogen and assembly of the supercontinent Rodinia. This inlier in the Appalachians of the eastern United States also hosts hundreds of iron oxide-apatite (IOA) deposits. The tectonomagmatic processes underlying IOA mineralization are hotly debated, and their genesis in the context of a large collisional orogen remains poorly understood. We employ a suite of high-precision and high-spatial resolution geochronological techniques, in concert with detailed textural and geochemical analysis, to constrain the timing of mineralization of these REE-rich, phosphate-bearing metallic ores. Ore zircons from five IOA deposits across the Eastern and Western New Jersey Highlands, dated by U-Pb LA-ICPMS, notably lack the older 1.4-1.1 Ga cores found in ore-proximal and ore-distal gneisses. Some veins crosscut the pervasive gneissic foliation of the region, which is associated with peak granulite-facies conditions that previous workers have dated at ca. 1060-1030 Ma. We therefore rule out syn-magmatic or syn-depositional emplacement with the protoliths of the host lithologies in a magmatic arc or back-arc basin setting prior to continental collision. Precise U-Pb ID-TIMS dates of chemically abraded zircons from the same suite of ore samples show mixing between age domains that span the 1030-920 Ma post-Grenville timeframe, rather than a single mineralization event. Apatite U-Pb ID-TIMS dates range from 1030-820 Ma and represent a minimum age for the onset of IOA mineralization and a maximum age for the last episode of IOA re-mineralization, respectively. Texturally-controlled monazite U-Th-Pb dates span roughly the same period of time, and we suggest that the range of dates in these three geochronometers represent post-emplacement long-lived fluid circulation and recrystallization. A variety of geochemical and textural evidence support repeated in-situ recrystallization, including extremely radiogenic zircon Hf signatures in the most phosphate-rich ores; patchy zonation of apatite grains revealed in BSE imaging and exsolution of monazite from apatite; reprecipitation rims on interstitial monazite grains; and multiple generations of Ti- and Al-rich exsolution lamellae in magnetite. Temporal correlation with similar REE-bearing IOA deposits in the Adirondack Highlands region of the Grenville Province provides evidence for a shared tectonic history and suggests that the processes driving mineralization operated on an orogen-wide scale.

Field Trip October 28, 2023 Part 12

Park Cars at Markle Parking Deck Parking Garage right behind Markle Hall Lafayette University
Walk to Bus 1 ½ blocks to High St., in front of Williams Center for the Arts
Bus will leave at 8:00 AM Saturday Moring

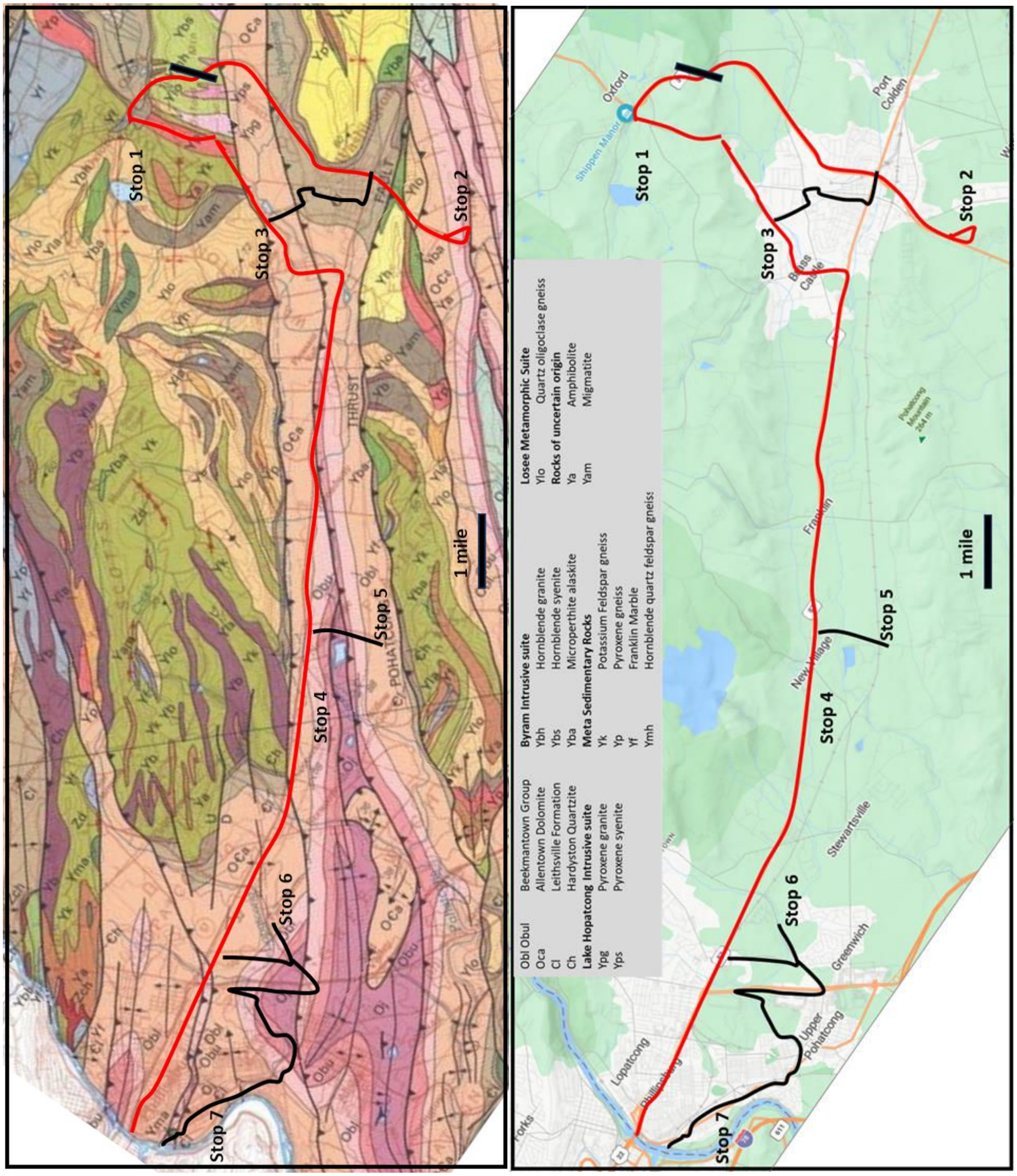


Leave Campus Turn East on Route 22
<u>Mile 0</u> middle of Delaware River Drive over Delaware River:
Mile 0.3- 0.5 south side of Rt 22 are outcrops upper and lower Beekmantown Group --dolostone and limestone (Obu and Obl)
Mile 2.6 Railroad Tracks on south side of Rt 22
Mile 3.5 Scott Mountain on north side of Bus
Mile 3.6 Cross over Lopatcong Creek
Mile 5.2 Richline Road and Highway sign for the Concrete mile note stone shed on north side of Road

Concrete Mile - First mile of concrete highway built in New Jersey. Cement made from Jacksonburg Limestone (Oj) quarried just south of the Road-- see Pond NW of Stop 5

Mile 5.6 Pohatcong Mountains on south side of road
Note: Hills on the north side of road are the Scotts Mountain and are Precambrian Gneiss. Hills on the south side of road are Pohatcong Mountains and also are predominately gneiss. Rocks forming the valley

is predominately limestone. Pohatcong River drains this valley. The Morris Canal (dashed blue line) is on south side of bus for most of this drive section until Bread Lock at Stop 4



Mile 6.2 Bread Lock our lunch stop (later in day) Stop 4 om above map
Mile 6.3 Cross over Morris Canal
Mile 6.7 to 9.4 Stone houses on either side of road conglomerate, fieldstone, sandstone, gneiss
Mile 11.9 Turn north (left) onto Brass Castle Road.
Mile 12.1 Pass over Pequest Brook

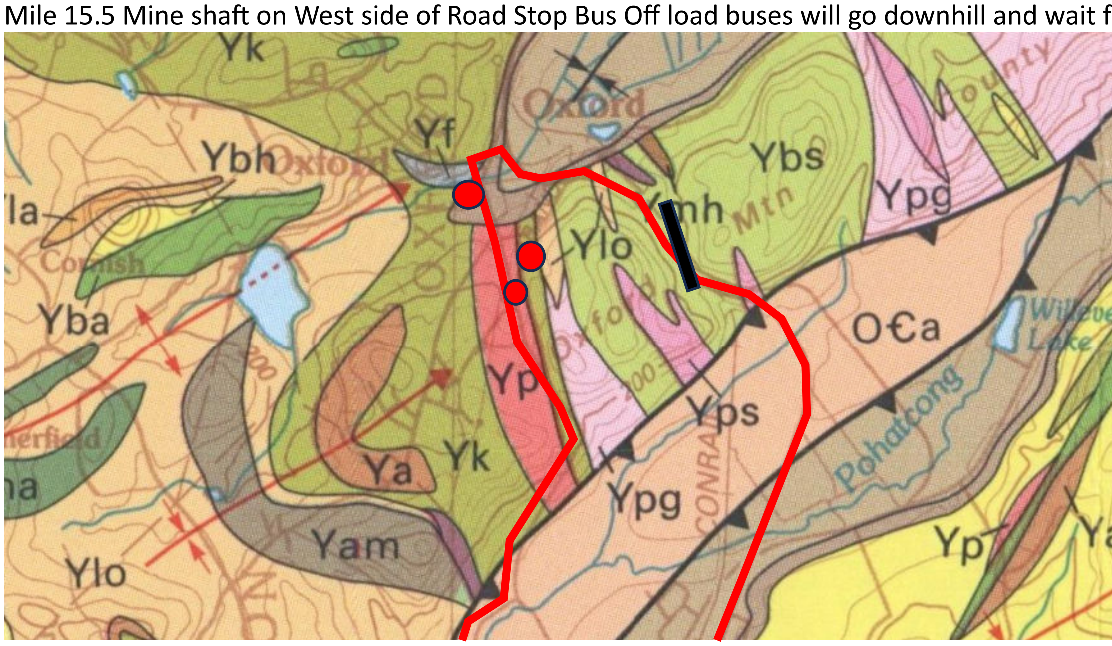
Mile 12.6 Turn Northeast (fight) onto Bowerstown Road
Mile 13.4 Slight left Turn onto old Bowerstown Road
Mile 13.5 Stop to look at Stone sleepers used to build railroad for incline plane 7 West Stop on map

Blocks of Precambrian gneiss used as stone sleepers for the short railroads of the Morris Canal Incline Planes. From Incline 7West

Mile 13.6 stop to see from bus window…..**Women's Heritage Trail**

Inscription. In the 1930s, Margarette Phillips working for the precursor of Consumers Reports wrote an expose' on harmful ingredients of women's cosmetics, harmful clays and oils.

Mile 14.0 Turn north (left) onto Mine Hill Road
Mile 15.2 Crest of Hill in small cluster of homes
Mile 15.5 Mine shaft on West side of Road Stop Bus Off load buses will go downhill and wait for us.



Description of Stop 1 Oxford Furnace Mines and Oxford Furnace
Walk on West side of Road to view into collapsed mine (For details of mine, see page 12)
Walk on East side of Road to view 2nd mine collapse site.
Walk into woods to view former earthen dam with magnetite riprap potential collection site.
Walk north on trails to trail head Park. Walk north on Road to Oxford Furnace to view furnace. (for details of furnace, see page 13)
Walk to Shippen Manor Mansion to view fieldstone construction using Hardyston Quartzite (Ch) (Potsdam Sandstone) (for details of Hardyston Quartzite, see Page 14)
Mile 16.1 Board Bus near Oxford Furnace Drive Belvidere Ave East
Mile 16.2 Turn South onto State Highway 31
Mile 16.2 Oxford Railroad Tunnel aka Van Nest Tunnel (for Details of Warren Railroad and Tunnel, see page 15). We were going to hike to tunnel but today is the first day of NJ Deer Hunting season and we opted to not lose anyone to an arrow piercing.
Tunnel entrance cut is through Hornblende Syenite (Granite, quartz poor)
Mile 20.2 (4) cross Route 57 near downtown Washington
Mile 21.9 (5.7) Turn left on to Hawk Point Blvd
Mile 22 Turn Left onto Shop Rite parking entrance road

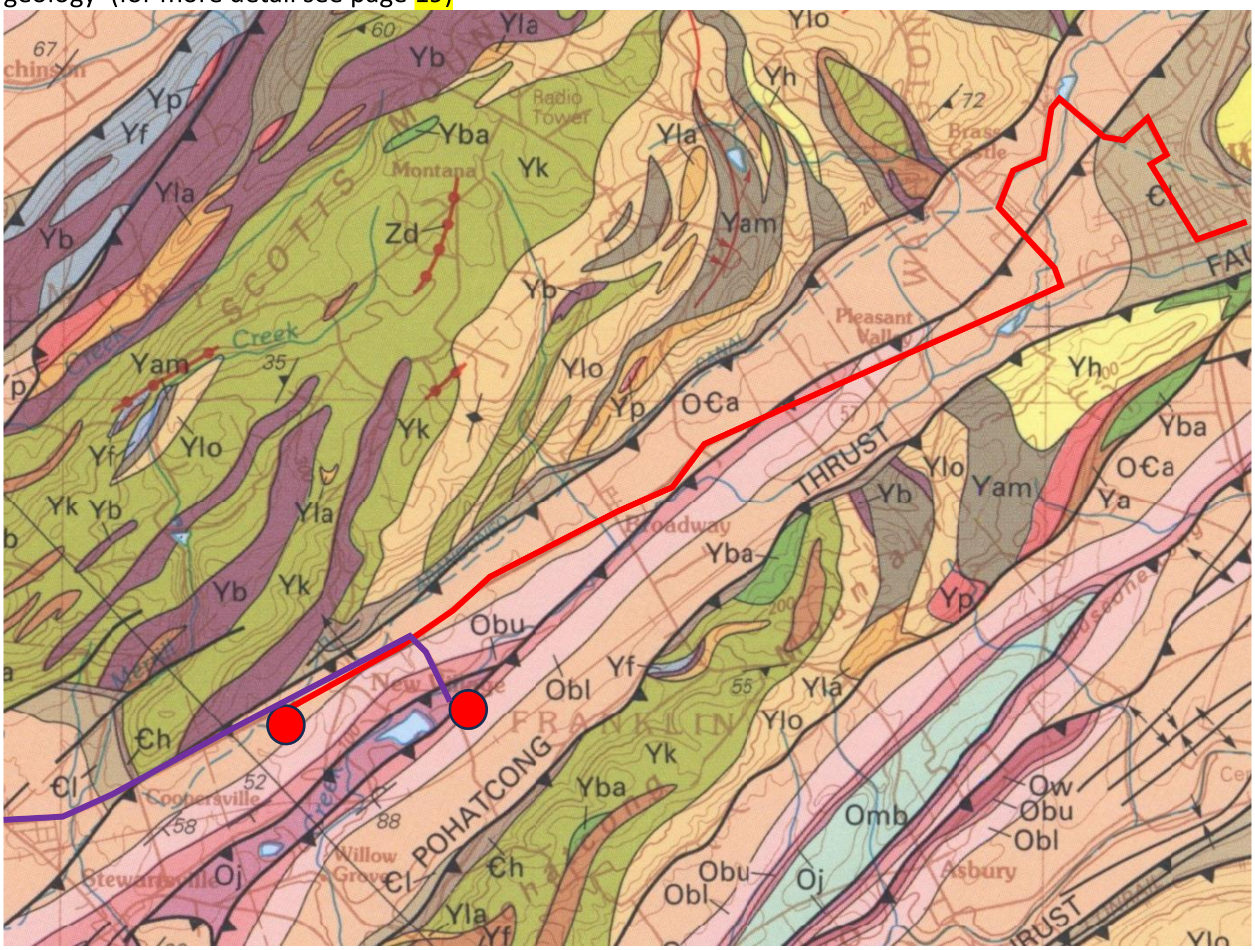
Stop 2 Mile 22 Limestone Kiln on side of road view stone of Beekmantown Group and discuss lime and cement manufacturing. See page 16
Mile 22.2 Turn right in front of Shop Rite
Mile 22.3 turn Left onto Club House Drive
Mile 22.5 Turn Right onto State Highway 31
Mile 23.9 Turn Left onto West Washington Ave aka Rt 57
Mile 24 Green Church on North side of Rt 57. Serpentinite from the quarry near West Chester University, Chester County, PA. Sandstone and Slate also likely from (for more detail see page 17)
Mile 24.3 Turn North on North Lincoln Ave
Mile 24.5 Jog right at W Johnson Ave
Mile 24.8 Pull over for view of canal boat captains house For (more Detail on Canal boat Captain see page 18)

Short description

Mile 24.9 Turn Right onto Whycoff St
Mile 24.9 Turn left onto Belvedere Ave
Mile 25 Turn West onto Kinnaman Ave
Mile 25.2 Turn right (northwest) onto Plane Hill Road
Mile 25.4 Top if Incline Plane 7 West
Mile 25.6 Base of Incline plane 7W and Aqueduct over Pequest Stream
Pull into small lot Get off Bus

Stop 3 Description of Incline stone sleepers and canal viaduct see page 19

Mile 25.6 Turn Southwest (left) onto Bowerstown Road
Mile 26.4 Turn Southeast (left) onto Brass Castle Road
Mile 26.5 Cross over Morris Canal
Mile 27.1 Turn West onto Route 57
Mile 32.7 Turn into Bread Lock Park Museum Parking Lot for Lunch and tour of Museum and locks and geology (for more detail see page 19)

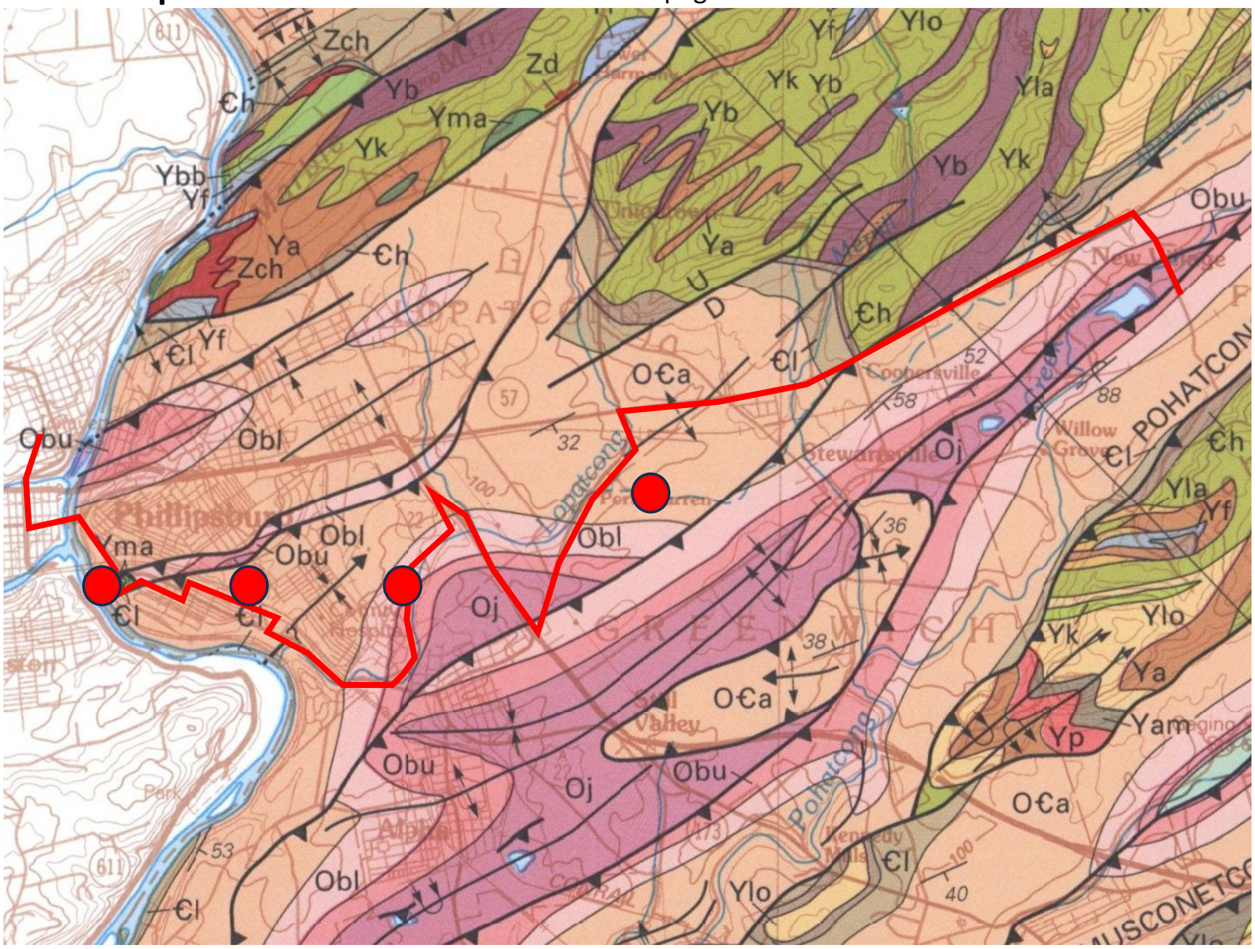


AFTERNOON

Mile 0 Return to Highway 57 turn East (right)
Mile 0.8 Turn Southeast (right) onto Edison Road
Mile 2.0 Turn into parking lot of Former Edison Cement plant

Stop 4

Discuss History and geology of Edisons cement plant see page 21
Return to Edison Road head north
Mile 3 miles Turn West (left) on Route 57
Mile 7.5 Turn South onto Stryker Road.
Mile 8.6 Turn Left onto Uniontown Road
Mile 9.2 **Stop 5** Morris Canal Incline Plane 9 West see page 22



Return to Busses drive Southwest on Uniontown Road
Mile 10.2 Turn North on Rt 22
Mile 11.4 Turn West on Rand Blvd
Mile 11.5 Turn East onto Lock St
Mile 12.3 Stop 6 Incline 10 West
Mile 13 Turn South on Arrowhead Drive
Mile 13 Turn West on South Main Street
Mile 14 Turn right (north) on Abbot St
Mile 14.1 Turn left (west) on Sitgreaves St
Pull over for Talk on Iron Foundry
Mile 15 Turn West on South Main St
Mile 15.4 Turn left South on Elizabeth St
Mile 15.4 Parking lot for walk to River

Stop 7 Delaware Rive and train Tracks see page 23

Return to Bus and Return to Campus a 2 mile drive
Mile 15.5 turn left onto South Main St.
Mile 15.3 Turn West Across Delaware River
Mile 15.6 Turn Right North onto 3rd St return to Lafayette Campus.