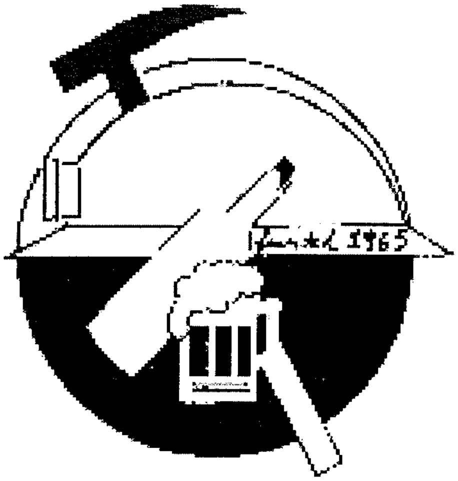
HARRISBURG AREA GEOLOGICAL SOCIETY
FIELD TRIP GUIDEBOOK
ANTHRACITE REGION



JUNE 2002

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INTRODUCTION

This field trip will travel to the Southern Anthracite region of Pennsylvania to examine the stratigraphy, structure, and environmental aspects of coal mining. During this trip, we will visit:

- The Bear Valley Strip Mine in Shamokin
- Various acid mine drainage reclamation sites in the Swatara Creek Watershed

AUTHORSHIP/ACKNOWLEDGEMENTS

This field guide was jointly prepared based on pre-existing guides used by the authors for other purposes. A history of the development of this field guide is required to give due credit to the individuals who are responsible. The Bear Valley portion of the field guide is derived from a HACC student guidebook that was developed largely on the work of Nickelsen (1979, 1987) and Edmunds and Eggleston (1984). Much information in the Swatara Creek portion of the field guide was taken from a report prepared by Daniel J. Koury, PA DEP, for EPA. Corey Cram (also PA DEP) adapted Dan's text for an Office of Surface Mining class field trip. Keith Brady then took both their efforts and modified them for the HAGS field trip, plus added a few thoughts and figures of his own. Additional credit must be given to Chuck Cravotta (USGS) for the information on Stop 2, and for many insights on the other stops. Likewise, Dan Koury provided numerous insights and suggested most of the stops. Any errors in the HAGS version of this trip are the responsibility of the authors.

FIELD TRIP AGENDA

LEAVE MEMORIAL LAKE STATE PARK -- 9:00 AM

Stop 1: Bear Valley Strip Mine, Shamokin PA – see Locations for directions

LUNCH IN SHAMOKIN – 11:30 AM

Stop 2: USGS Gauging Station at Second Mountain

Stop 3 Ravine Wetland

Stop 4 Shadle Coal Co. discharge

Stop 5a Rowe Tunnel

Stop 5b Lorberry Creek Diversion Wells

Stop 5c Lorberry Creek Chemical Treatment & Wetland

Stop 6 Zimmerman Deep Mine

Stop 7 Donaldson Reclamation Project-BAMR

ARRIVE BACK AT MEMORIAL LAKE FOR PICNIC AT 4:30 PM

LOCATIONS

Bear Valley Strip Mine is located approximately 1.9 miles southwest of Shamokin, Pennsylvania along a dead-end, single lane road. Directions from the vicinity of Memorial Lake State Park are as follows:

1. Proceed on Interstate 81 north
2. Exit at the Tower City/Tremont exit (US Route 209) – mileage log starts here.
3. 0.3/0.3 -- Turn right (west) on US Route 209
4. 1.2/1.5 -- Take a right onto Main Street in the Village of Joliett and proceed toward Good Spring.
5. 2.3/3.8 -- At the stop sign in Good Spring, proceed straight (north) on PA Route 125 over Bear Mountain.
6. 2.5/6.3 -- Cross PA Route 25 in Village of Hegins
7. 3.8/10.1 -- Continue to follow PA Route 125 to the left
8. 0.5/10.6 – Follow PA Route 125 to the right
9. 2.0/12.6 – Cross the crest of Line Mountain
10. 3.5/16.1 – Enter Gowen City
11. 0.6/16.7 – Cross Mahantango Mountain
12. 2.6/19.3 – Arrive at "T" intersection with school bus garage on left. Turn left
13. 0.3/19.6 – Continue straight along Bear Valley Avenue
14. 1.2/20.8 – Pavement ends, proceed on unpaved road (you can park here if you like—the strip mine is only a couple of hundred yards further)
15. 0.1/20.9 – Park at trail heading into woods to south. Walk along this trail to the mine.

After lunch in Shamokin, the trip will proceed south in the reverse of these directions to the Swatara Creek localities. A map showing the location of the stops is attached to the end of this guidebook. THE STOPS WILL BE VISITED IN REVERSE ORDER TO THAT SHOWN ON THE MAP—TURN EAST ON PA. ROUTE 25 IN HEGINS AND PROCEED TO STOP 7.

MINING IN THE ANTHRACITE REGION

Approximately 90% of the coal mined in the anthracite region came from beds within the lower portion of the Llewellyn Formation and the underlying Pottsville Formation. Notable coal seams include the Lykens Valley (lowest), Buck Mountain, Seven-Foot, Skidmore, Mammoth (exposed at Bear Valley), Holmes, Primrose, and Orchard seams. The Mammoth is the most extensively mined seam, followed by the Buck Mountain.

Anthracite mining was conducted by one of the following methods:

- Surface mining (such as Bear Valley Strip Mine);
- Culm bank recovery;
- River dredging; and
- Underground mining.

Surface mining is typically conducted by the long pit mining method or the block pit mining method. The long pit method is a continuous operation that advances along the outcrop of one or two associated coal seams. Block pit mining concentrates on one particular block of coal and is usually used in areas where the coal seams are discontinuous. Both methods are economically feasible to depths of 150 to 200 feet, although depths ranging up to 400 to 600 feet have been reached by using terraced mining methods.


Early 20th century underground mining

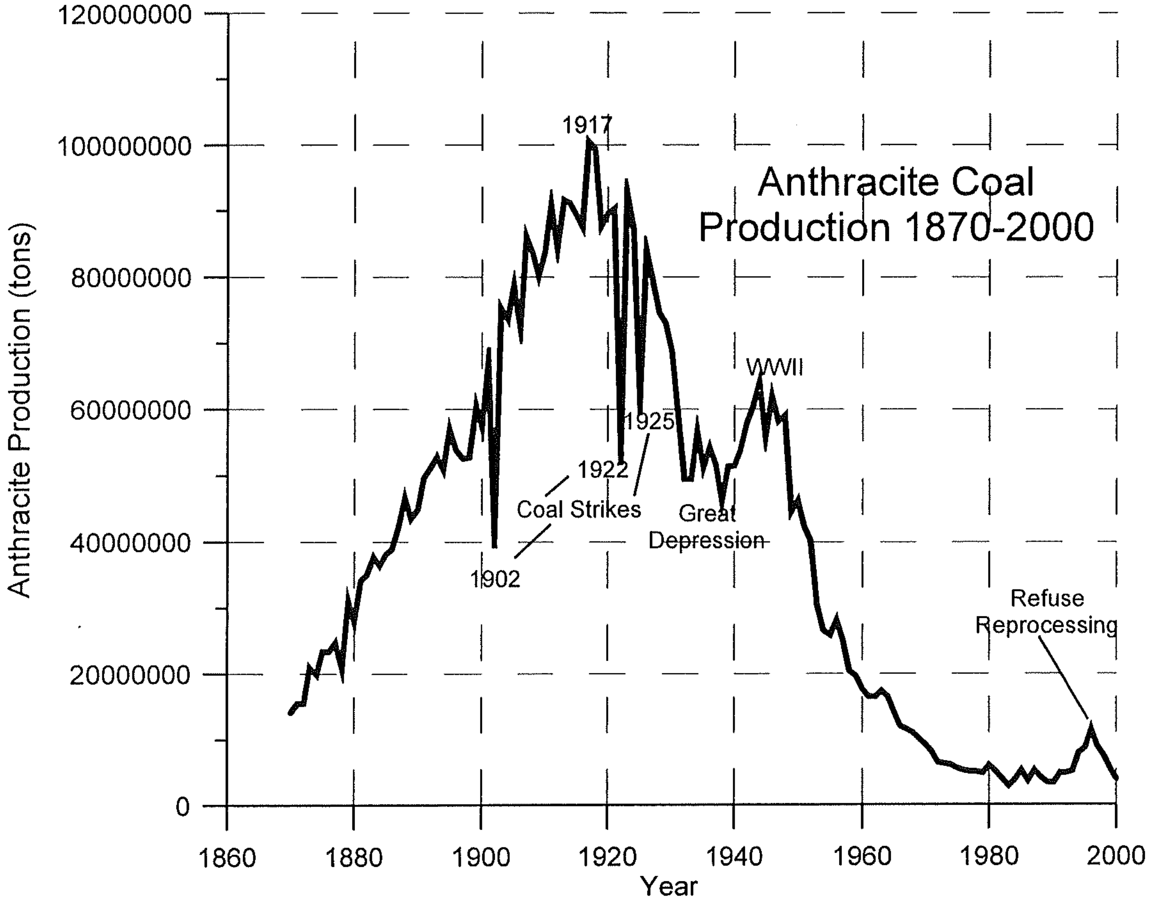
Culm bank recovery involves extracting coal from previously mined materials. The material is loaded directly onto haul trucks using small power shovels and processed either onsite or offsite to recover the coal. Coal and silt materials are also dredged from waterways within the coal mining region and in the 1970s have served as a significant source of coal; more recently, production from dredging decreased because the supply of river bed coal has been depleted

Underground mining was once the major method of anthracite production. This method has been replaced by surface mining methods because of the availability of more-powerful earth moving equipment. Underground mining is also labor intensive and production rates are low, making it economically unfeasible.

Breast and pillar mining is the predominant method of underground mining. With this method, entry to the mine is accomplished by a drift, tunnel (adit), slope, shaft, or combination of each. Two horizontal headings are driven along the strike of a coal seam from the entry (see figure below in the description for Stop 5b). The lower and larger of these two openings is called the gangway. It is used for hauling the coal from the mine, as well as for intake ventilation. The upper opening, called the monkey, is driven to provide a path for return air and an access point for breast development. Chutes and manways are driven upward from the gangway to the monkey as each is advanced. Breasts are begun above the manway and are driven updip approximately 200 to 300 feet above the monkey. Coal is drilled and blasted in the breasts and allowed to fall via the chute into a waiting coal car in the gangway. The rate of breast development is often slow because support timbers must be hauled vertically and placed manually at the working face.

MINING HISTORY

Anthracite coal mining was once the mainstay of the economy in the headwaters of the Swatara Creek watershed. Mining started in this area approximately 150 years ago and reached its peak during World War I. In 1917, Pennsylvania's anthracite production exceeded 100 million tons (90.7 million tonnes), which was mined by 156,000 men. The industry has declined significantly over the years due to competition from other energy sources and the costs of production. It hit its lowest production year in 1983 when less than 3 million tons (2.7 million tonnes) were produced. The latest figures are for Y2K, with 3.9 million tons produced. The figure below shows production through time and an explanation of some of the peaks and valleys. The most recent "peak" (if one can call it that) in 1996 is due to the mining of culm (coal refuse) piles. New markets for the coal refuse have been developed in recent years for the production of electricity and the manufacture of titanium. Elimination of these culm banks has numerous benefits: they provide an inexpensive energy source, they remove a pollution problem (sediment and acid), and eliminate an eyesore.



CURRENT MINING

There are currently 48 permitted anthracite mining operations in the Swatara watershed, 29 are active. The active operations consist of 12 underground (deep), 8 surface (strip), 8 refuse reprocessing, and 2 coal preparation plants. The remaining 19 operations are either inactive or haven't yet started. According to the 1996 Annual Production Report, 631,272 tons (572,680 tonnes) of coal were produced by 87 men in the Swatara Creek watershed.

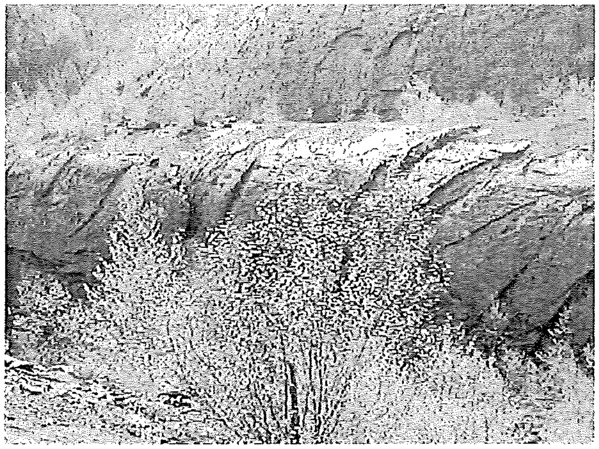
FUTURE MINING

In 1971, the U.S. Bureau of Mines indicated that the abandonment of mines in the Southern Anthracite Field resulted in the flooding of 34 percent of the field and that the largest tonnage of anthracite reserves lie where mining conditions are the most difficult. Large reserves underlie the abandoned workings and must be de-watered before they can be mined. Some of these reserves may be "lost" to future mining since the adjacent minepools, in many cases, must also be de-watered due to the unknown stability and effectiveness of the barrier pillars separating the minepools. Future mining will be governed mostly by economics and safety. Since the mid-1980s the enormous abandoned culm piles which were once considered waste, became a marketable material. It is likely that the remining and reprocessing of these piles will continue for years to come. Most of the largest culm piles in the watershed are now permitted to be at least partially remined by DEP/Pottsville District.

BEAR VALLEY STRIP MINE (Stop 1)

The Bear Valley Strip Mine is an abandoned anthracite coal mine located approximately 1.9 miles west of Shamokin, Pennsylvania. This mine is situated in the southern coalfields of Pennsylvania's anthracite coal region, which is located within the Valley and Ridge physiographic province. The strip mine provides over 30,000 square meters of continuous exposure of sedimentary rocks of Pennsylvanian age.

Unique exposures of Valley and Ridge structural geology are provided by the Bear Valley Strip Mine because of the manner in which the mine was developed. Three-dimensional fold geometry is evident, along with disharmonic folding, thrust faults, wrench faults, and extensional joints. These structures are visible because the cover was stripped to the same stratigraphic level, the Pennsylvanian Age Llewelyn Formation, exposing the upper surface of the same unit of sedimentary rock.



"Whaleback" anticline at Bear Valley

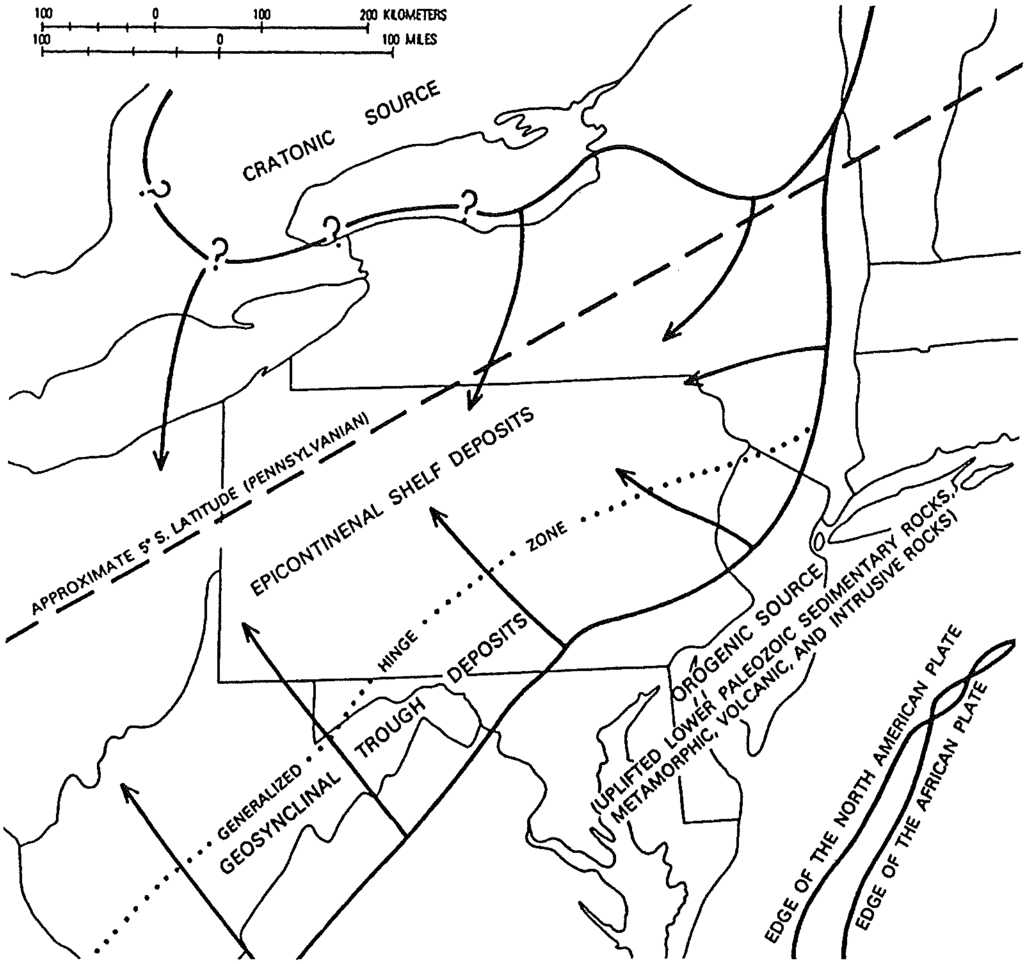
The Bear Valley Strip Mine also offers an outstanding opportunity to observe and collect fossilized plant remains from the Pennsylvanian period. In the northwest corner of the mine is a rare, upright Carboniferous tree trunk, approximately ½ meter in diameter that extends over a meter into the overlying shales and siltstones. This tree trunk has been deformed by folding into an elliptical shape. At the southeast corner of the mine are 25-foot long impressions of *lycopsid* tree trunks as well as exposures of the Mammoth Bottom Split Coal Bed #8.

The mine also offers the opportunity to observe environmental impacts associated with coal mining. Because the Bear Valley Strip Mine pre-dates the regulation requiring reclamation of strip mines, the mine remains essentially in the same condition as it was when it was abandoned. Open pits provide many opportunities for uncontrolled waste disposal and the numerous spoil piles have become a playground for off-road motorists. Acid mine drainage is visible emanating from deep mine stopes as evidenced by the orange-colored iron precipitate visible in seeps and swales.

Geology Of Bear Valley Strip Mine

The geology of the Bear Valley Strip Mine was described by R.P. Nickelsen of Bucknell University (1979, 1987) as well as an *ad hoc* field guide published by Edmunds and Eggleston (1984). The content of this guidebook, as well as the road log, is based largely on Edmunds and Eggleston's work.

Pennsylvanian Age rocks exposed at the Bear Valley Strip Mine consist of a complex, heterogenous mixture of clastic sedimentary rocks mapped as the Llewellyn Formation. Included in the Llewellyn Formation are conglomerates, subgreywacke sandstone, clay shale, and numerous coal beds. In addition, ironstone concretions (composed of the mineral *siderite* ($FeCO_3$)) are present in some of the sedimentary layers. The Llewellyn Formation was deposited during a period of rapid, cyclic sedimentation within a broad coastal plain along the western edge of a continent created during the late stages of the Appalachian Mountain building event.



Paleogeographic map of Pennsylvanian depositional environments.

At the time the Llewellyn Formation was being deposited, the predecessors to the North American and African tectonic plates were impacting each other, resulting in chain of mountains extending along a line through New York City, Philadelphia, and Baltimore. A broad wedge of clastic sediment extended northwest from this mountain range into a shallow sea that existed within much of the center of the North American continent. These sediments accumulated along a broad, flat plain via a series of high-energy interweaving river and stream channels, between which were low-lying marshes and swamps. The swamps were thickly vegetated and widespread, as evidenced by the thick and laterally continuous coal seams observed in the Llewellyn. The coal was formed from extensive accumulation of plant material in the swamps, which was subsequently buried and lithified.

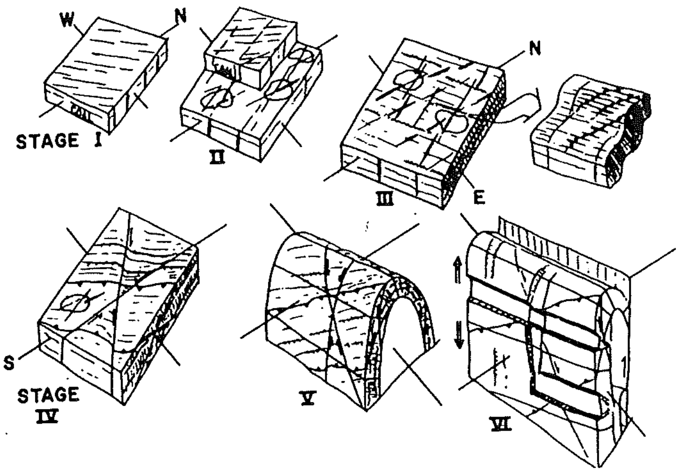
The layered sedimentary rocks of Pennsylvania's anthracite region are preserved in a series of downfolds with a deep sag (called a synclinorium) that makes up the northeastern end of the folded Appalachians. The general structural trend is between N55°E and N85°E. Within the synclinorium are innumerable smaller scale folds, anticlines and synclines, of a wide variety of types and sizes. The anticlines tend to be broader, more open structures in most cases, while the synclines are tightly closed. Most folds are parallel to each other up to the point of to which the mechanical limits of the rocks are exceeded, whereupon disharmonic folding occurs. At the Bear Valley Strip Mine, this disharmonic folding is profoundly evident in the east highwall of the mine. The disharmonic folding is generally present in the incompetent coal and shale beds. The northern limbs of anticlinal folds are commonly overturned, and high-angle thrust faulting is a common occurrence.

The anthracite region is also extensively and intricately faulted. High-angle and low-angle thrust faults, bedding-plane faults, underthrust faults, and tear faults are present throughout the area. Some of the faults have been folded as well. The high-angle thrust faults generally dip to the south and are associated with mechanical failure of the synclines. Lower angle thrust faults are thought to originate from detachment of the sedimentary rocks during the initial stages of mountain building.

The structural history of the anthracite region is thought to be the result of four steps of deformation associated with the Allegheny Orogeny, the final mountain building event of the Appalachians. These steps were:

- Folding of horizontal strata in broad anticlines and synclines;
- Low-angle thrusting, followed by smaller folds on the broad folds and high-angle thrusting;
- Folding of low-angle and high-angle thrusts, and offsetting by additional high-angle thrusts;
- Development of overturned folds and offsetting of overturned folds by tear faults and high-angle thrusts.

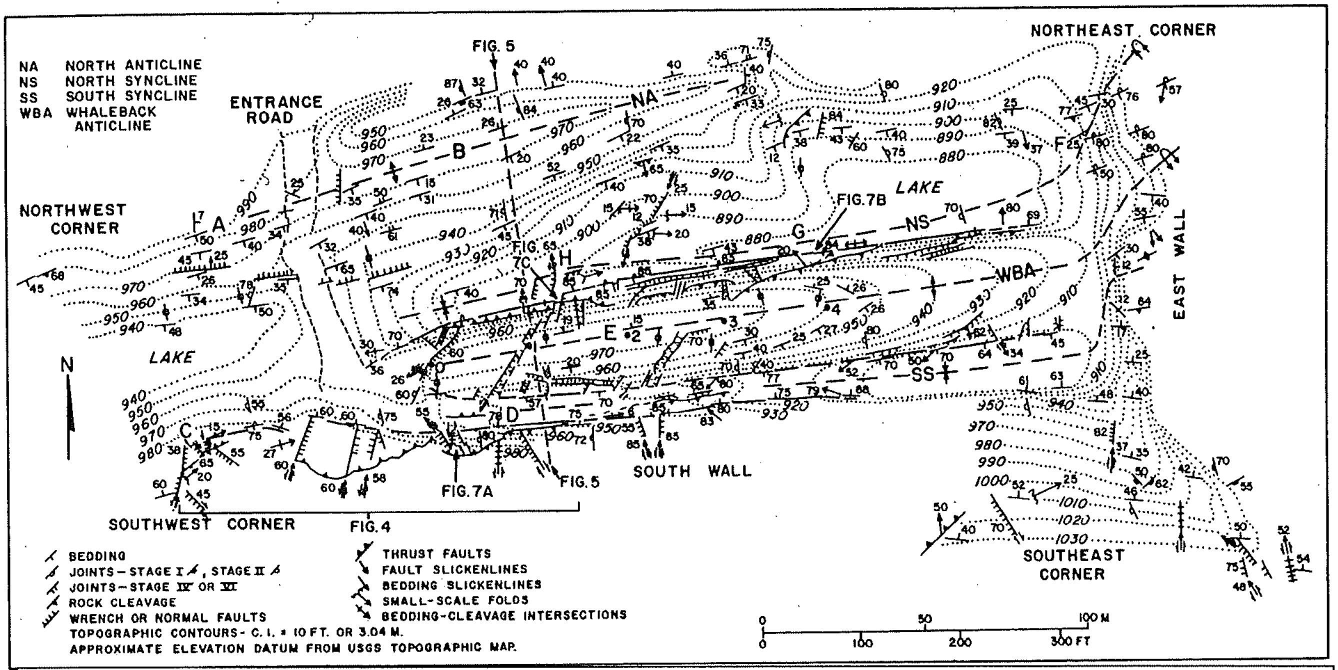
The structural expression of these events at the Bear Valley strip mine is shown in the diagram to the right.



Cartoon depicting the sequence of development of structural stages of the Allegheny orogeny. Stage I: Orthogonal joint sets form in coal; Stage II: Several sets of hydraulic extensional joints form in sandstones and shales; Stage III: Pressure solution and primary crenulation cleavage and small-scale folds form; pressure solution of Stage II joint fillings occurs; Stage IV: Conjugate wrench and wedge faults deform Stage III cleavage; Stage V: Large-scale folding of all previous structures occurs; Stage VI: Extensional joints and faults produce flattening perpendicular to bedding and layer-parallel extension, both parallel and perpendicular to fold hinges. From Nickelsen (1987).

Features To Observe In Bear Valley Strip Mine

Structural Geology: The most dramatic structural feature is the "Whaleback anticline" in the center of the mine. Walking along the crest of the anticline you will observe the best exposure of the disharmonic folding, which is visible in the east highwall of the mine. Thrust faults can be observed at the extreme southwest corner of the mine (Location C on the geologic map below) as well as elsewhere in the mine (locations B, D, and F). Extensional grabens and wrench faults are visible along the north limb of the Whaleback anticline (locations F and G).



Map showing topography, geology, and geologic localities A to H of the Bear Valley Strip Mine. Location numbers 0, 1, 2, 3, 4, are at 100 ft (30 m) intervals along the crest of the Whale back anticline. From Nickelsen (1987)

Stratigraphy and Fossils: The upright tree can be observed at Location I in the northwestern part of the mine. Note the deformation of the tree trunk.

At the southeast corner of the mine you can observe the Mammoth Bottom Split Coal Bed #8 and associated sedimentary layers. Coal was deposited in a cyclic sequence of depositional environmentals ranging from terrestrial to shallow marine.

Also in the southeast corner of the mine is an impression of a 25-foot long lycopsid tree trunk preserved in the sandstone bedding surface.

Concretions: Throughout the mine you will observe subspherical, pillow-like concretions composed of the mineral *siderite*, an iron carbonate ($FeCO_3$). These concretions formed in various freshwater and marine environments and are caused by water that was supersaturated with iron and carbonate, generally where iron-enriched fluvial water interacts with ocean water. The process is thought to be facilitated by microorganisms.

THE SWATARA CREEK WATERSHED

In 1994, with funding from EPA 104(b)(3) program, the Department of Environmental Protection (DEP) District Mining Offices were to develop a Comprehensive Mine Reclamation Strategy (CMRS) on a select watershed in their district. The concept of CMRS is to evaluate a watershed or a portion of a watershed which is affected by acid mine drainage (AMD) and develop a strategy for improving the water quality through remining, land reclamation, installing passive treatment systems, and involving local citizens and industry by encouraging them to take ownership in their watershed. The Pottsville District Office has selected the northern headwaters (43 square miles, (11,137 hectares), north of Ravine, PA) of the Swatara Creek Watershed as the Primary CMRS watershed. There have been several studies done over the past 30 years that have identified AMD as the principal type of pollution in this area. Much of this area has been heavily impacted by anthracite coal mining over the past 150 years which resulted in abandoned mine discharges. This Rehabilitation Plan is geared toward AMD and other mining related impacts on the watershed. There is currently very little industry other than mining and essentially no farming in this part of the watershed, therefore, pollutants associated with these activities were not addressed.

The AMD pollution from the headwaters of Swatara Creek has had a significant impact on the remainder of the watershed for many years. The Commonwealth proposed to construct a 750 acre, (304 ha), lake on Swatara Creek at Swatara Gap, 15 miles (24 km) downstream of the study area, over 30 years ago. The project has been delayed primarily due to poor water quality coming from the headwaters. The water quality has improved greatly over time due to remediation projects, enforcement of regulations, mine reclamation, sewage treatment in several communities, and ongoing remediation efforts with passive treatment systems. The stream has now improved, but there is now debate as to whether or not a lake should be built. There are some that believe there is nothing wrong with a nice clean stream flowing unimpeded through a valley.

The primary goal for several years was to improve the water quality to meet acceptable standards for the State Park Lake to be built. With the recent water quality and biological results and the involvement of the local community, the goal is now to restore the headwaters to a viable fishery. According to the PA Fish and Boat Commission, the water quality necessary to establish a healthy ecosystem would be pH 6.0-6.5, alkalinity > acidity by 20 mg/l, iron < 0.5 mg/l, and aluminum < 0.5 mg/l.

In the past, resources to abate the pollution sources in the watershed were limited. Projects were done in the 1970s by DER/Bureau of Abandoned Mine Reclamation at the recommendation of Operation Scarlift studies to restore and redirect stream channels. The only other resources available for pollution abatement were reclamation-in-lieu-of-civil-penalties and cooperation from active industry through remining. In recent years, EPA grants have become available for assessment and demonstration of passive treatment technologies. The increase in awareness of mine drainage treatment technologies and funding for projects has accelerated the efforts for improving the water quality in Swatara Creek. There has been a concentrated effort from state, federal, and local government, industry, and local citizens to apply for funding for abatement projects in the Swatara Creek watershed. Several passive treatment systems have been installed since 1995. There are also numerous major DEP/BAMR projects planned for the watershed through 2002 that will directly impact the water quality in many of the headwater streams.

LOCATION AND WATERSHED CHARACTERISTICS

Swatara Creek flows from the mountains of east-central Pennsylvania southwest to the Susquehanna River and eventually to the Chesapeake Bay. The Swatara Creek watershed has a great diversity of natural resources, land uses, geologic, and geographic differences within its 576 sq. mi. (149,183 ha) area. The creek plays an important role in the everyday lives of many communities serving as drinking water, recreation, and use in industry.

Swatara's headwaters begin on the Broad Mountain in Schuylkill County in the Southern Anthracite Coal Field. The creek flows to the southwest through farmlands as it meanders through the limestone valleys of Lebanon and Dauphin Counties. The creek encounters several sources of pollution in its travels. Some of the pollution is caused by man and some is naturally occurring. In some areas natural pollution is accelerated by man. Such is the case with Swatara Creek. The northern 43 sq. mi. (11,137 ha) of the watershed are located in Schuylkill County, just north of Ravine, PA and they are the focus of this study, see map at end of guidebook. The geology in this area is quite different than the remainder of the watershed. The Carboniferous strata are rich in coal, which has been an important resource in fueling the nation since the 1850's. The creek played an important role in the transport of coal and other products over the years. It also served as a disposal medium for pollution. For over 100 years, the creek transported coal silt, acid mine drainage, and sewage. Due to increasing environmental awareness and regulation over the past several years, many of these pollutants have been extremely minimized. In addition, the decline of the anthracite mining industry and more stringent regulations resulted in very minimal pollution from the active industry. However, acid mine drainage pollution emanating from abandoned underground mine openings, coal waste piles, and abandoned surface mine pits, is still impacting the water quality in Swatara Creek. It is in this area that a great effort is being made to mitigate and/or eliminate the effects of acid mine drainage pollution in the watershed.

The major subwatersheds in the study area are the Upper Swatara Creek, Goodspring Creek, Middle Creek, Lower Rausch Creek, and Lorberry Creek. Each of these subwatersheds are impacted by AMD to some degree. The water quality in all of these subwatersheds has improved over the years and continues to improve as more projects are completed. The sources of pollution identified in previous studies may no longer be a contributing pollution factor, in some cases they may no longer exist.

LORBERRY CREEK

Lorberry Creek subwatershed drains 3.99 sq. mi. (1,033 ha) as it flows southeast to its confluence with Lower Rausch Creek. The headwaters of Lorberry Creek originate as a discharge of the abandoned Lincoln Colliery workings at the Rowe Tunnel. The tunnel is a gravity discharge of extensive interconnected underground mines. Skelly & Loy (1986) estimated that there are 460 ac. (186 ha) of unreclaimed surface mines in the headwaters area of Lorberry Creek. This area contributes to the flow from the Rowe Tunnel.

Prior to 1992 slugs of coal sediment pollution would discharge from the Rowe Tunnel. It was alleged that the active deep mine operations were washing their coal underground. These practices were halted thus greatly reducing the sediment pollution from the Rowe Tunnel. Acid and iron pollution is still discharging from the Rowe Tunnel. The tunnel discharges the majority of flow and pollutants to Lorberry Creek. A continuous flow recorder was placed on the discharge in 1992 and monthly water quality samples have been collected since that time by DEP.

Stumps Run enters Lorberry Creek 0.2 mi. (0.32 km) downstream of Rowe Tunnel. Historically, it was the major source of coal sediment pollution to Lorberry Creek and Swatara Creek, particularly during storm events. The sediment pollution resulted from 24.4 ac. (9.87 ha) of abandoned coal siltation basins, which were once part of the Lincoln Colliery complex. Stumps Run flowed through this area where it became ladened with coal sediment. Due to the size of the pollution source and the cost of reclamation, the area was broken down into three project areas. Three Reclamation-in-Lieu-of-Civil-Penalty projects were done to reclaim the area, thus mitigating the sediment problem. The projects were completed in 1994, 1995 and 1996 and totaled $131,175. Stumps Run is no longer a major source of pollution. Further enhancements may be needed in the future to insure that the erosion and sedimentation controls are maintained. The Pottsville District Mining Office employees have planted trees and wetland vegetation the past three years as an Earth Day project.

There is a discharge along Molleystown Road that is flowing from Shadle Coal Company deep mine. The mine is sealed and partially reclaimed. The discharge is currently under review by the DEP/Pottsville DMO and treatment method experiments are being performed by USGS & DOE. The mine operator will be obligated to treat this discharge.
(from Swatara Creek Watershed Rehabilitation Plan, updated 2001)

SUMMARY

- Swatara Creek is a tributary of the Susquehanna River and ultimately drains to the Chesapeake Bay.
- The Swatara Creek watershed covers 576 square miles, (149,183 ha), in Schuylkill, Lebanon, Dauphin and Berks Counties.
- Mine drainage pollution resulting from anthracite coal mining has been occurring for more than 150 years in the northern headwaters portion of the watershed.
- This study focuses on the mine drainage impacts in the 43 square mile, (11,137 ha) headwaters area which is located in the Southern Anthracite Coal Field, north of the Village of Ravine, in Schuylkill County, PA.
- The study area is in the Appalachian Region of the Valley and Ridge province. The geology of the study area consists of an alternating sequence of sedimentary rocks; conglomerate, sandstone, shale and anthracite coal with complex folding and faulting.
- The Commonwealth proposed to construct a lake in Swatara State Park more than 30 years ago by damming Swatara Creek near Lickdale, 15 miles, (24 kilometers),

downstream of Ravine. However, the project has been delayed due to poor water quality, particularly due to acid mine drainage.

- There are 5 major subwatersheds in the study area; Goodspring Creek, Middle Creek, Upper Swatara, Lower Rausch Creek and Lorberry Creek. All of the subwatersheds are impacted by mine drainage pollution to some degree.
- There have been numerous studies conducted over the past 4 decades to assess the water quality and identify pollution sources in the watershed.
- More than 100 mine drainage discharges from abandoned underground mine openings, large culm piles, and abandoned surface mines have been identified in the watershed in previous studies.
- Mine drainage is still the main pollutant in the study area, particularly mine drainage from abandoned underground mines.
- There is an ongoing concerted effort to abate the pollution sources in the watershed involving State, Local, and Federal government agencies, watershed associations, sportsmans groups and local citizens.
- DER/Bureau of Abandoned Mine Reclamation completed $3,087,668 of mine drainage abatement projects in the 1970's as part of Scarlift. The work was primarily stream channel restoration work (flumes, steam sealing and stream diversions) in the Middle Creek, Goodspring Creek, and Upper Swatara Creek subwatersheds.
- Several mine drainage abatement projects have been completed in the past 5 years which have improved the water quality significantly. The projects include reclamation of abandoned mine areas through reclamation-in-lieu of civil penalties and installation of passive treatment systems, such as, diversion wells, anoxic drains, open limestone channels and constructed wetlands.
- The main sources of coal sediment pollution "black water" were reclaimed from 1994-1996. With the numerous abandoned coal silt dams and culm piles in the watershed the potential for sediment pollution exists, however coal sediment pollution has been minimal in recent years.
- Water quality has improved greatly over the past ten years. The water quality extremes have been reduced significantly.
- Aquatic surveys have shown that benthic organisms as well as fish species diversity and quantities have increased dramatically over the past 10 years.
- There are numerous reclamation projects planned over the next several years. There are 16 projects outlined, some of which will directly impact or treat mine drainage, others are land reclamation which will indirectly impact water quality by preventing surface water from entering the minepool. Projected cost of all the projects exceeds $7.5 million. The majority of projects are under design by the DEP/Bureau of Abandoned Mine Reclamation.
- Swatara Creek has been recognized under the EPA 319 National Monitoring Program. The Ravine monitoring station is the featured monitoring point. It is the first AMD impacted stream in the United States to be a part of this program. The water quality data will continue to be collected by USGS up through 2001.

ACID MINE DRAINAGE: WHAT IS IT?

Acid mine drainage forms when pyrite oxidizes and the weathering products are dissolved in water. The overall reaction is:

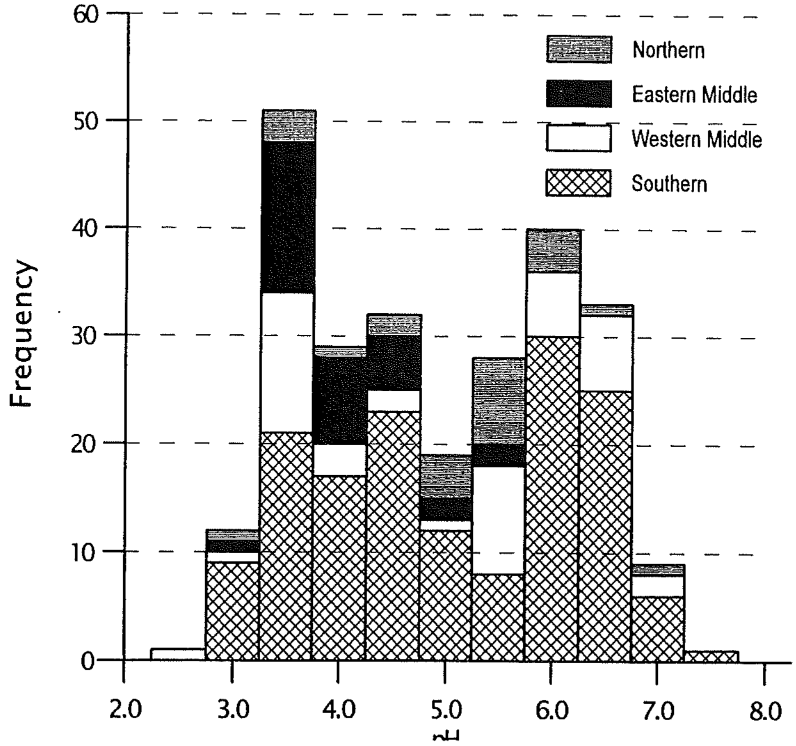
$$\mathbf{FeS_2 + 3.75\,O_2 + 3.5\,H_2O \rightarrow Fe(OH)_3 + 2\,SO_4^{2-} + 4\,H^+}$$

where pyrite reacts with oxygen and water to form iron hydroxides and sulfuric acid. The iron hydroxides are the orange coating that you see on stream bottoms affected by mine drainage.

Pyrite makes up only a very small percentage of the rock in the anthracite coal fields, typically less than a few tenths of a percent. Mining breaks up rocks and places the pyrite in an oxidizing environment where it weathers. Not all mine drainage is acid mine drainage. In fact, in the Anthracite Region about half of all mine drainage is near-neutral.

Alkaline drainage occurs where there are sufficient carbonates present to neutralize any acid that may be generated by the weathering of pyrite.

The figure below shows the distribution of pH for mine drainage in the Anthracite Region in 1977. The distribution is bimodal, with discharges being either acidic (pH ~3.5) or near-neutral (pH ~6.0). The headwaters of Swatara Creek are located in the Southern Field.

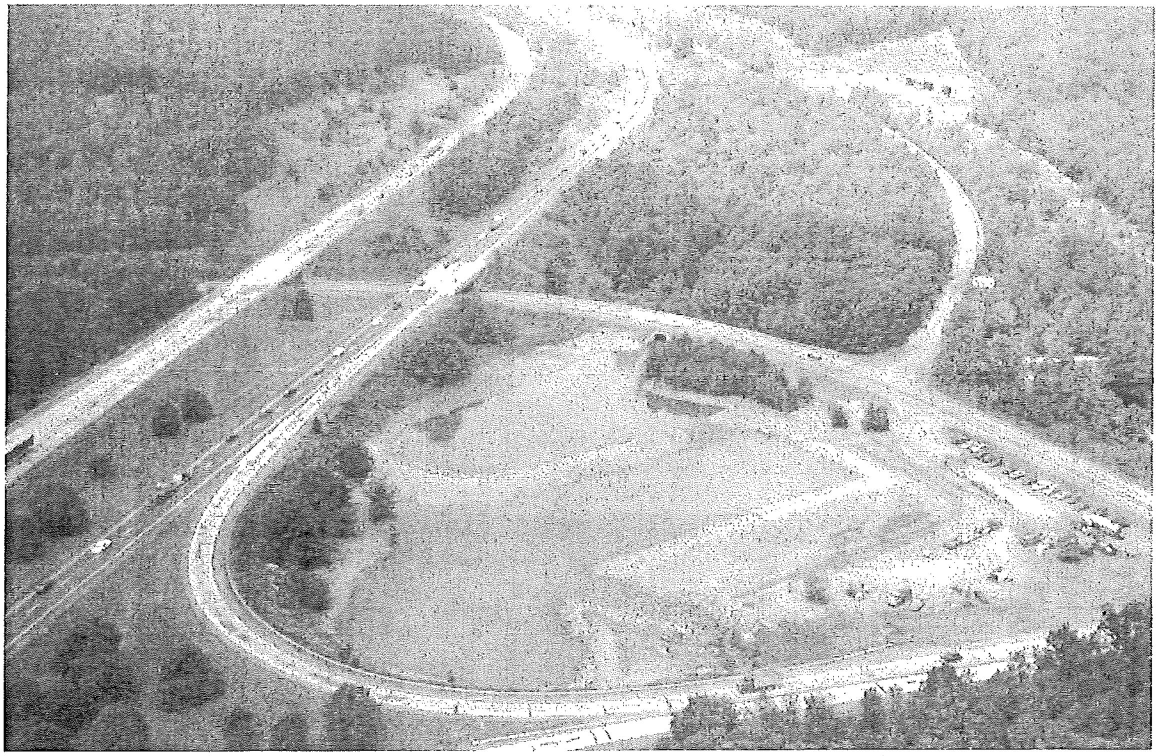


Stop 2. USGS Gauging Station at Second Mountain

At this location the USGS has a gauging station and water quality monitoring point. This point on Swatara Creek is just downstream from the coal field portion of Swatara Creek and is a good point to measure the effects of the various pollution abatement efforts that are taking place upstream. From this location you can see the road cut at Mile 103 on I-81 through Second Mountain. The sandstones of the Catskill Formation (Devonian) are exposed here. At the northern end of the cut are the sandstones and siltstones of the Pocono Fm (Mississippian). The rocks in this cut are slightly overturned.

The handout provided by Chuck Cravotta, USGS (portions attached at the end of this guidebook), shows the water quality improvements that have occurred at this location. Swatara Creek went from a fishless stream as recently as 1990 to 24 species of fish in 2000. Between 1975 and 1995 the stream went from net acid to net alkaline (pH less than 6 to pH greater than 6). The abatement efforts that we will be examining are some of the reasons this stream has improved and remained alkaline.

Stop 3: Lorberry Junction Wetland Project (40° 35' 29", 76° 24' 41")
This project is located in the interchange of I-81, Exit 32, Ravine (also known as Lorberry Junction) is on PennDOT property. Two shallow water impoundments were constructed to serve as aerobic wetland treatment of AMD on Lower Rausch Creek. The idea is to allow metals to settle out in the wetland and not in the stream. There are several abandoned mine discharges which enter Lower Rausch Creek at various locations upstream. The project treats all of Lower Rausch Creek near the mouth, thus treating all of the discharges collectively. The wetland cells total 2.3 ac. (0.93 ha) and the stream flow ranges from 900 gpm (0.056 m^3/s) to in excess of 11,000 gpm (0.69 m^3/s). This project was completed in December 1997 and modifications were made throughout 1998. The current water quality upstream of the wetland has a pH 6.3, Fe 3 ppm, and Mn 1.5 ppm. The goal of this project is to reduce metals pollution that Lower Rausch Creek contributes to Swatara Creek. This project was funded partially by EPA 104 (b)(3) and fines that were assessed against Pine Grove Landfill by DEP/Bureau of Waste Management. DEP's Bureau of Abandoned Mine Reclamation did all of the construction work. Additional materials and equipment were donated by local industries.



Lorberry Creek Wetland soon after Construction.

Stop 4: Shadle Mine Discharge.

There is a discharge along Molleystown Road that is flowing from Shadle Coal Company's deep mine. The mine is sealed and partially reclaimed. The discharge is currently under review by the DEP Pottsville District Mining Office. The USGS and U.S. Dept. of Energy have experimented with treatment methods. While most of the mine drainage discharging from anthracite coal mining operations is generally considered mild acid mine drainage, this mine water is severe AMD. The median water quality for three samples was pH of 3.3, conductivity of 3050, acidity 1,200 mg/l, iron 540 mg/l, aluminum 32 mg/l and manganese 34 mg/l. The pH actually drops into the 2's, downstream, as the iron precipitates out of solution.

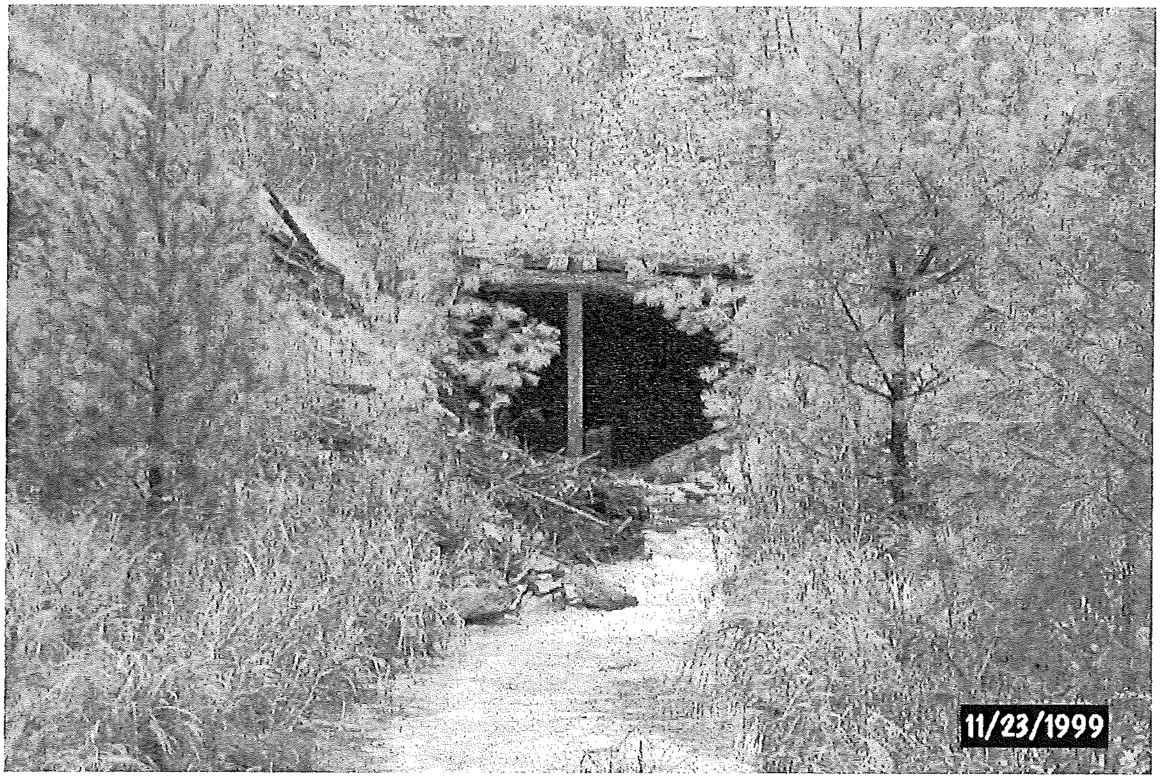
Acid-forming materials are present at the site in the form of black carbonaceous shale with pyrite. Fossil ferns can also be found at this site.

Stop 5a: Rowe Tunnel

The headwaters of Lorberry Creek originate as a discharge of the abandoned Lincoln Colliery workings at the Rowe Tunnel. The tunnel is a gravity discharge from a 6 square mile complex of interconnected underground mines. Skelly & Loy (1986) estimated that there are 460 ac. (186 ha) of unreclaimed surface mines in the headwaters area of Lorberry Creek. These areas intercept surface runoff and direct it to the underground mine complex that contributes to the flow from the Rowe Tunnel.

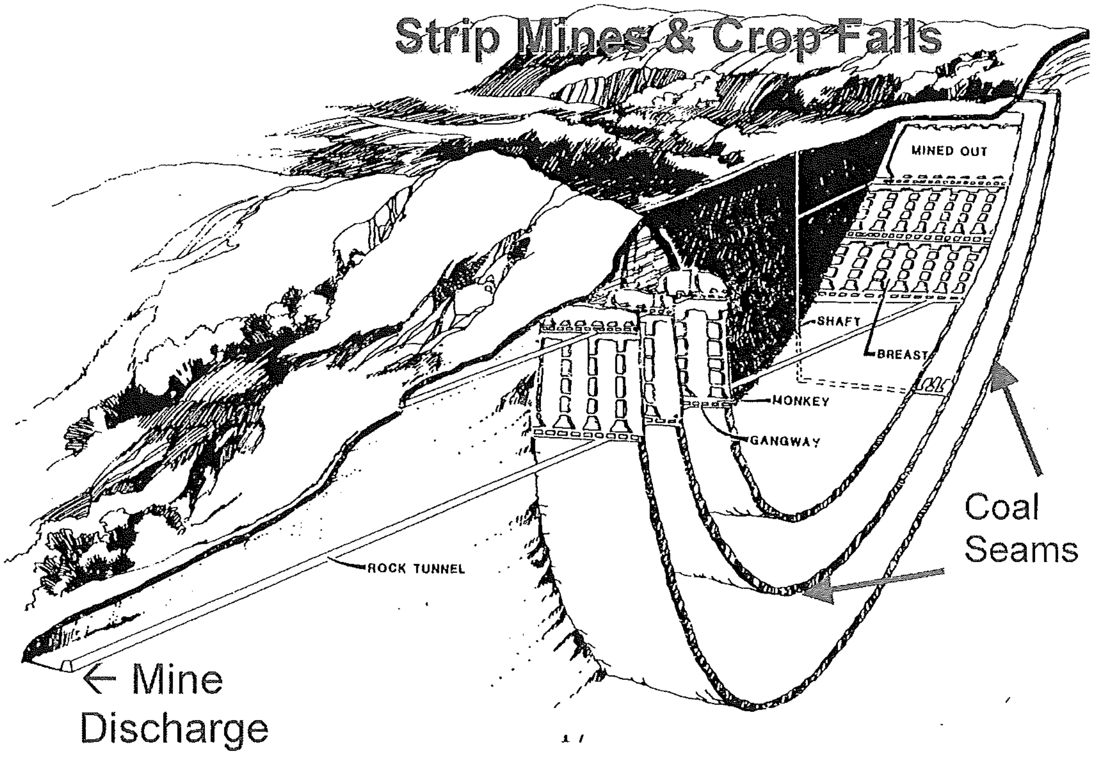
Prior to 1992 slugs of coal sediment pollution would discharge from the Rowe Tunnel. It was alleged that the active deep mine operations were washing their coal underground. These practices were halted thus greatly reducing the sediment pollution from the Rowe Tunnel. Acid and iron pollution is still discharging from the Rowe Tunnel. The tunnel discharges the majority of flow and pollutants to Lorberry Creek. A continuous flow recorder was placed on the discharge in 1992 and monthly water quality samples have been collected since that time by DEP.

Median water quality from the Rowe tunnel for 79 samples collected between January 1990 and February 1998 was pH 5.8; conductivity 238 μS/cm; acidity 18 mg/L; alkalinity 9 mg/L; Al 0.9 mg/L; Fe 8.6 mg/L; Mn 1.9 mg/L and sulfate 106 mg/L. Flow ranges from 340 to 1300 gpm, with a median of 1,770 gpm.



Rowe Tunnel Discharge.

The figure below shows a diagram of a typical rock drainage tunnel and associated underground mines in the Anthracite Coal Region. Note the interconnectedness of mines in different coal seams. Also not the uneven topography above the mine due to strip mining and "crop falls." The uneven topography traps surface runoff and often redirects it into the deep mine where it will exit as a acidic mine discharge, such as at the Rowe Tunnel



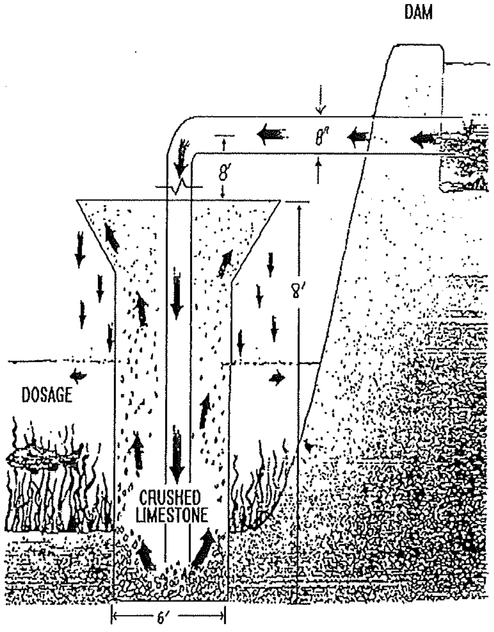
Stop 5b: Lorberry Creek Diversion Wells

A typical diversion well system consists of a dam that collects the water to be treated and diverts the water through a large (8-10 in.) diameter pipe. The water is discharged to the bottom of a metal or concrete cylinder or "well" approximately six feet in diameter and six to eight feet deep that is partially filled with limestone gravel. The water is under at least six feet of hydraulic head in order to fluidize the bed of gravel.

When the mass of particles in the diversion well is fluidized, the particles are maintained in rapid motion, and erode and abrade during frequent collisions. The grinding of stone obtained is much like what is achieved in a rotating drum or ball mill. In the case of the rotating drum, abrasion is produced by means of an electric motor or water wheel which rotates the drum and produces collisions. In the case of the diversion well, the grind and abrasion is due to a fluidized bed created with hydraulic head. A diversion well system contains no moving parts, it is simple in design, and solid in construction, making for very little maintenance.

Fluidized limestone diversion wells have been used in Scandinavia to neutralize small acidic streams since the late 1970's. Some of the first diversion wells were implemented in Norway. The first full-sized fluidized limestone wells for treatment of acid waters were constructed at Piggaboda, Sweden in 1980.

Although diversion wells are simple and relatively inexpensive to construct, not all locations and circumstances are appropriate for treatment of mine waters using diversion well systems. A minimum of eight feet of hydraulic head is required to fluidize the limestone bed. Experience has shown that fifteen to twenty feet of head is not excessive and provides better fluidization under low flow conditions. The site must be accessed year-round because the wells must be loaded on approximately a weekly basis. These systems are able to treat a finite rate of water flow and are much more efficient when treating the acid source (such as a mine discharge) rather than the receiving stream. Probably the greatest consideration is the long term commitment that must be present when maintaining a diversion well. Unlike passive systems, a diversion well system must be attended to on approximately a weekly basis for the life of the system.(from Cram, 1996, Diversion Well Treatment of Acid Water, Lick Creek, Tioga County, PA)



Schematic of diversion well.. The idea is to have the water enter at the bottom of the well thus agitating the crushed limestone.

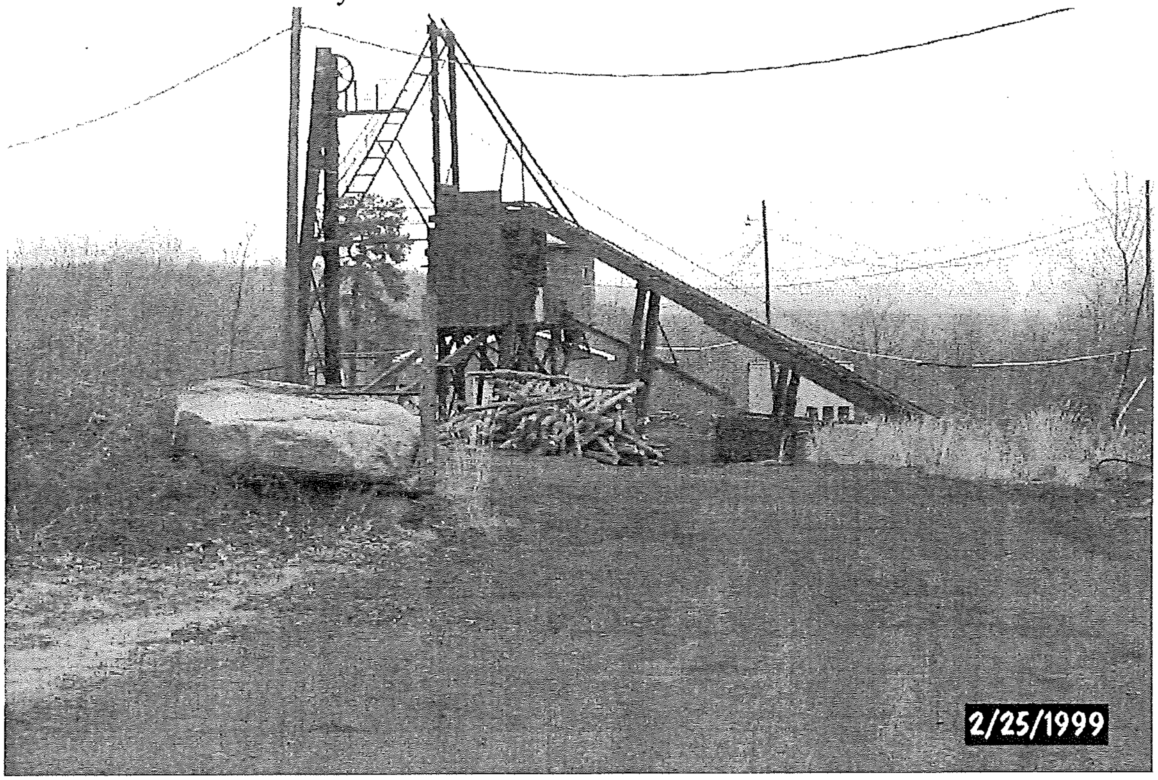
Stop 5c: Lorberry Creek Chemical Treatment and Wetland System

In October 2001 a treatment system including chemical dosing followed by a wetland was constructed. The system was designed by the Department of Energy and constructed using EPA 319 funding and other sources of funding. The treatment system collects pretreated water from the diversion wells through an intake and piping system. The water is directed to an "Aquafix" Treatment system, which delivers a metered dose of lime that is proportional to flow through the pipe. Treated water is discharged to a series of four aerobic wetlands. The treatment system is designed to improve the water quality of the Rowe Tunnel discharge and Lorberry Creek.

Stop 6: Zimmerman Underground Mine

The Zimmerman underground mine is a slope mine that follows the coal down from the surface at approximatly 30 degrees. The mine is ~2000 feet deep. Slope mines are present in the area that are 3000 feet deep. Miners are lowered in to the workings below by the coal bucket ("buggy") connected to a steel cable and powered by a 100 hp motor operated by 3 phase 480 volt current. Currently, Five miners produce around 35 buckets of coal in 6-8 hours time. Each bucket is approximately 3 tons. The material is dumped onto a vibrating screen that separates the coal from boney refuse. The Buck Mountain Seam is mined which averages seven feet in thickness. The seam varies from five to nine feet, but has been found to be a maximum of 13 feet thick in places. This same mining technology and methodology has been implemented in the area for decades. In the past the only difference is that the mine hoist was powered using an old car or similar device.

The Buck Mountain coal is the lowest coal in the Llewellyn and the base is the contact between the Pottsville and Llewellyn Formations.

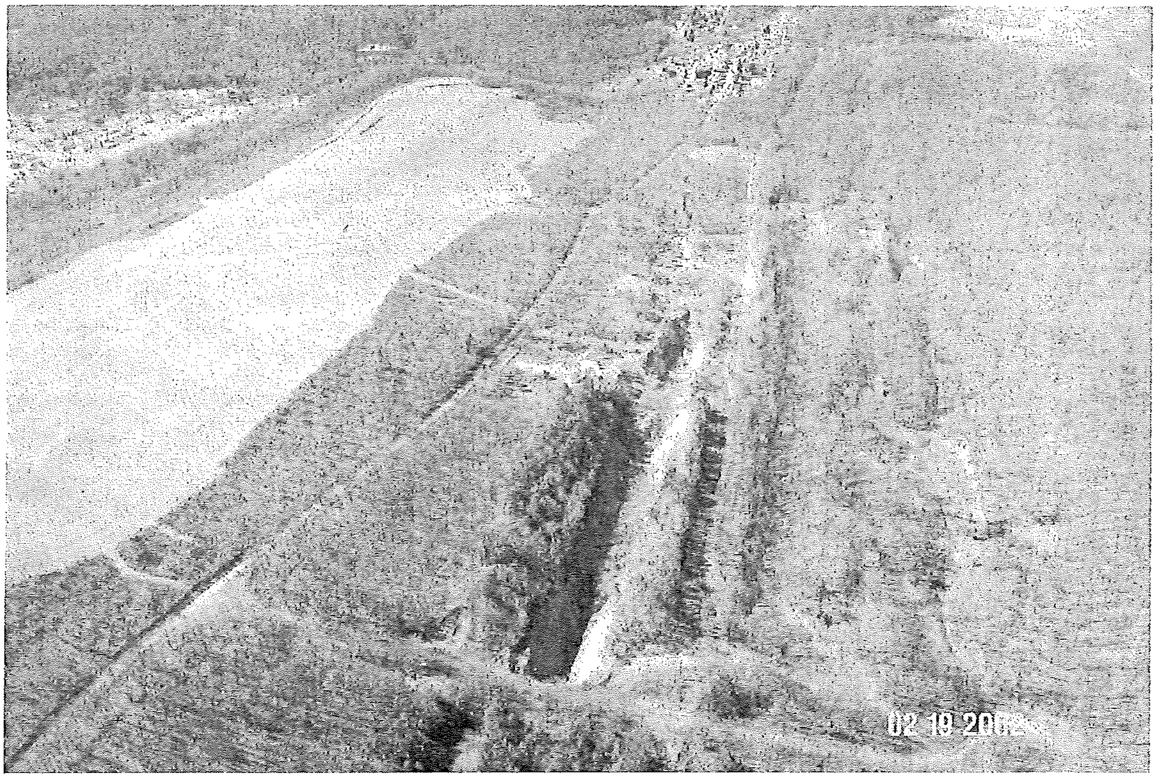


Zimmerman Underground Mine

Stop 7: Donaldson Area Abandoned Mine Land Reclamation

DEP's Bureau of Abandoned Mine Reclamation has targeted numerous AML sites in the Swatara Creek Watershed for reclamation. AML sites in the area are generally multiple parallel pits resulting from surface mining of near vertical coal seams. It is anticipated that reclamation will also result in decreased infiltration and recharge to the underground mine pool.

Numerous refuse or "culm" piles have also been removed through active mining operations. Entire piles are often of sufficient quality to be removed and used as product in cogeneration plants.



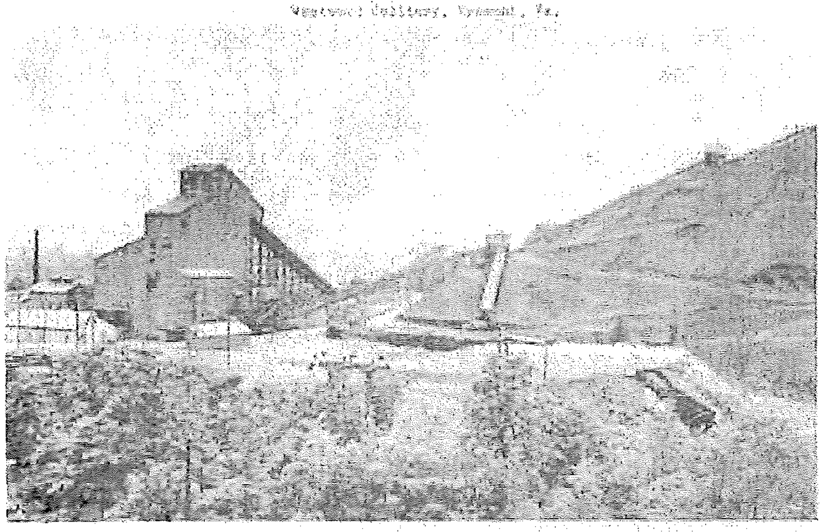
Donaldson Reclamation Sites. Note the abandoned strip mines and crop falls. These cause surface water to directly enter deep mines, increasing the flows and pollution loads of the mine discharges.

Additional Stop -- Westwood Generating Station

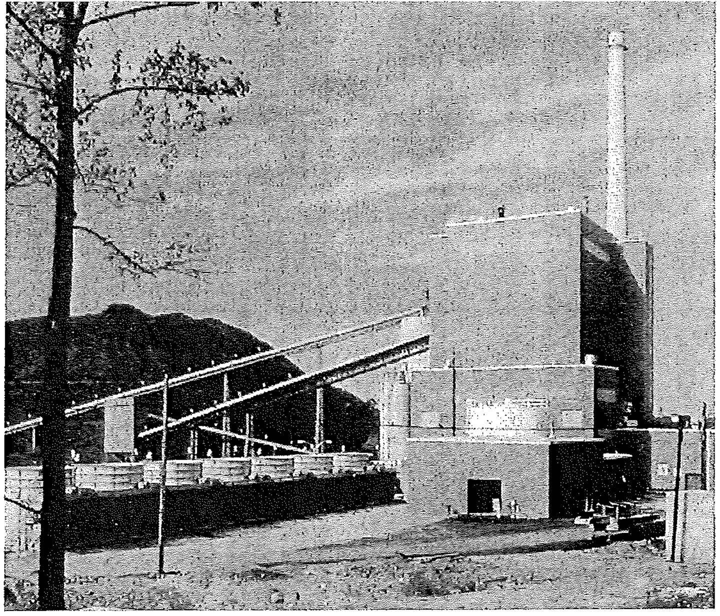
Location: East side of intersection of I-81 and Route 209, Tremont, PA (closest town is actually Juliett).

The Westwood Generating Station, built in 1988, is a 30-megawatt power plant that uses a Circulating Fluidized Bed (CFB) boiler to convert coal waste into electricity. The plant is burning culm (waste coal) with 2800-4200 Btu/lb. Limestone is used to reduce sulfur emissions during the combustion process.. The plant uses about 1,200 tons of culm and 80 tons of limestone per day. The culm was produced from the Westwood Colliery, which apparently served several mines on several coal seams.

Burning of this waste product produces several benefits: 1. The plant employs about 30 people and contributes about $5,000,000 per year into the local economy. 2. The plant produces enough energy to serve 21,000 homes. 3. Burning of the culm bank eliminates an eyesore. 4. Elimination of the culm bank will reduce sediment and acid mine drainage pollution. 5. What was a wasteland will be reclaimed and revegetated.



Top: Post Card from ~1910 showing colliery and associated culm bank. Bottom: Modern Plant about 1990.



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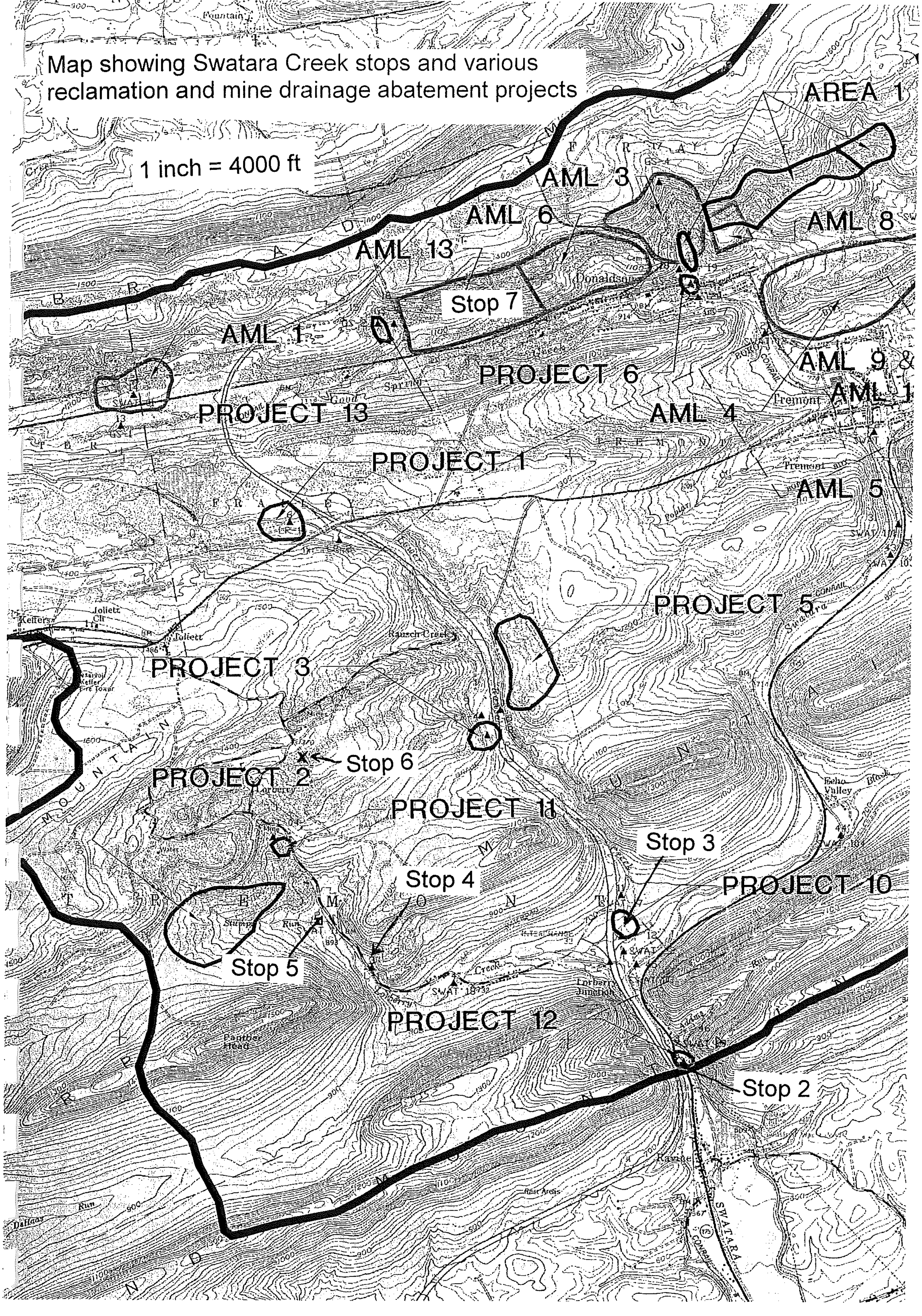


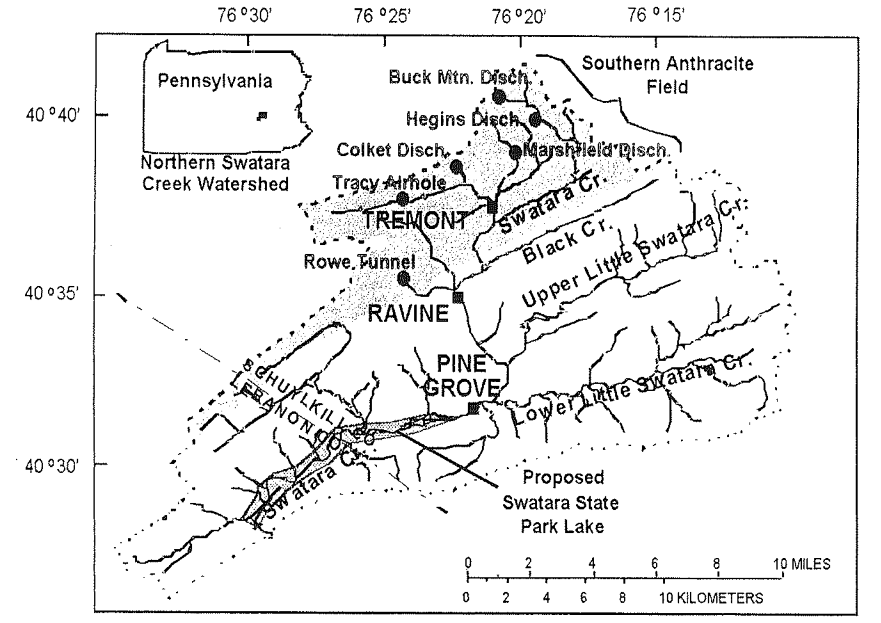
Map showing Swatara Creek stops and various reclamation and mine drainage abatement projects

science for a changing world

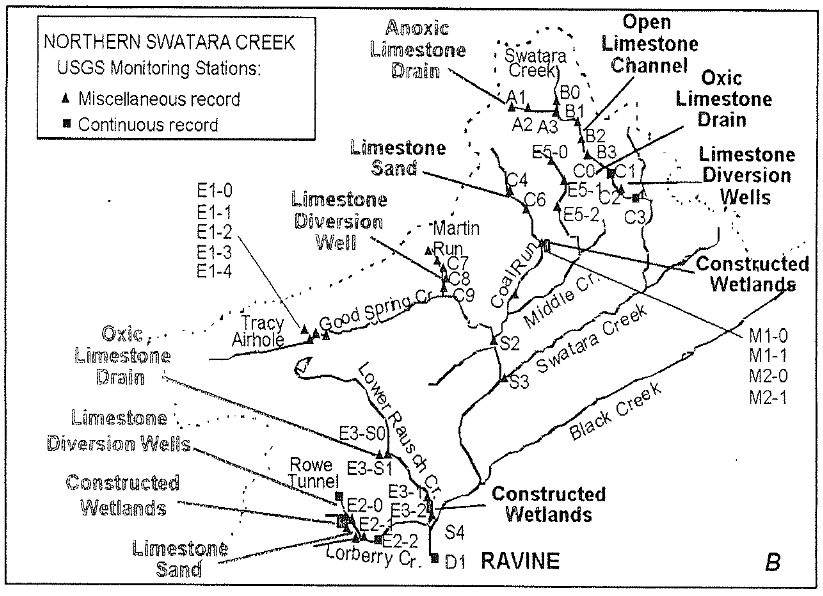
In cooperation with **Pennsylvania Department of Environmental Protection**
Schuylkill County Conservation District
U.S. Department of Energy

Restoration and Monitoring of Aquatic Quality in a Coal-Mined Watershed, Swatara Creek at Ravine, Pennsylvania

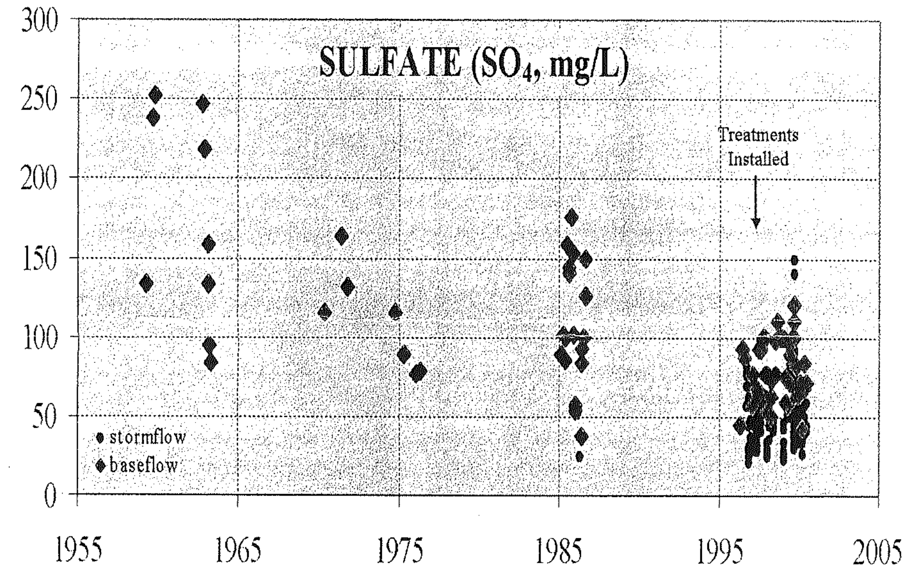
Charles A. Cravotta III, Michael D. Bilger, Robin A. Brightbill (U.S. Geological Survey, New Cumberland, PA 17070) and Daniel Bogar (Pennsylvania Department of Environmental Protection, Harrisburg, PA 17105)

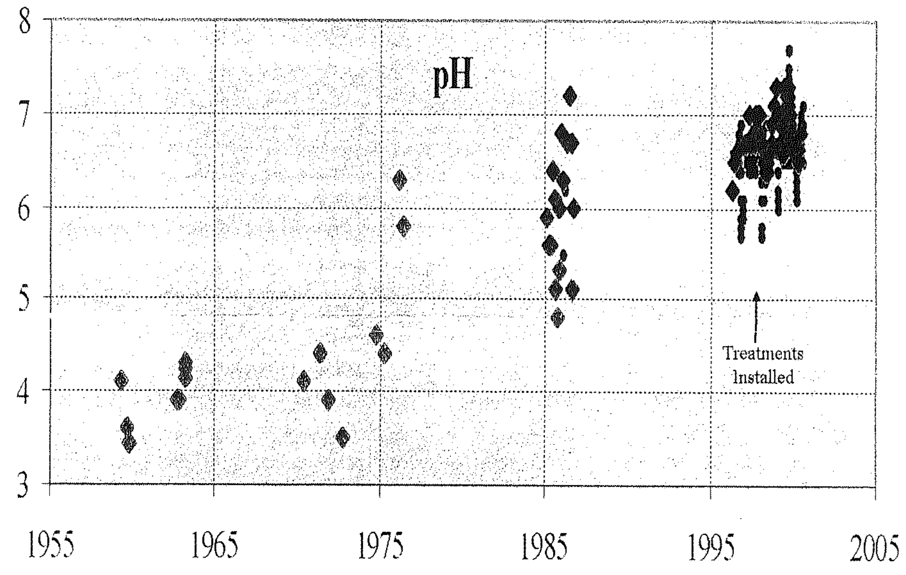


Swatara Creek drains an area of 577 mi² within the Ridge and Valley Province in east-central Pennsylvania. The upper 43-mi² area above Ravine is underlain by the Southern Anthracite Field. Although several surface and underground anthracite mines presently are active, most mines in the Swatara Creek Basin were abandoned before 1960. Once abandoned, the underground mines flooded producing numerous large discharges that are contaminated with acidity, sulfate, and metals. The polluted drainage from these abandoned mines affects water quality miles downstream. Construction of the proposed Swatara State Park Reservoir has been delayed until the AMD is remediated.

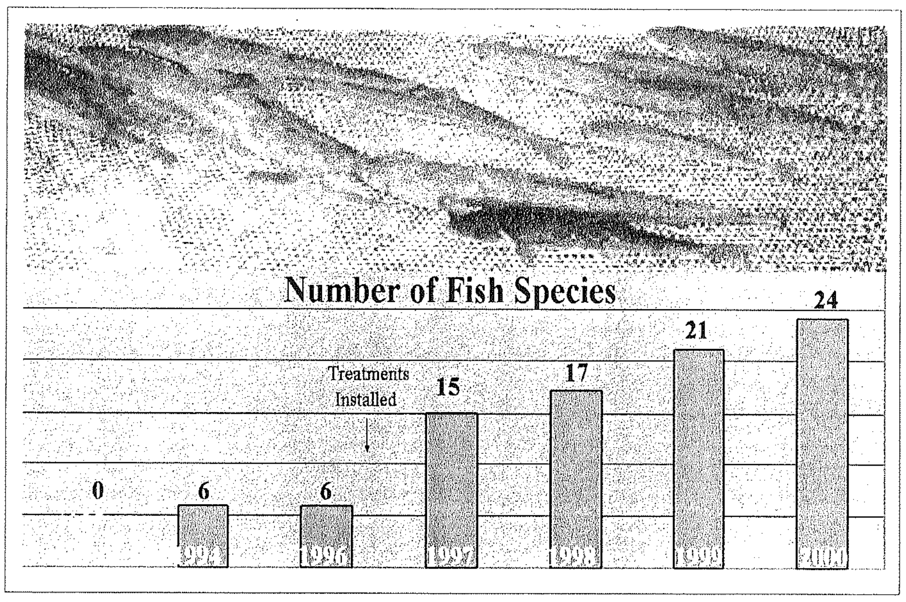


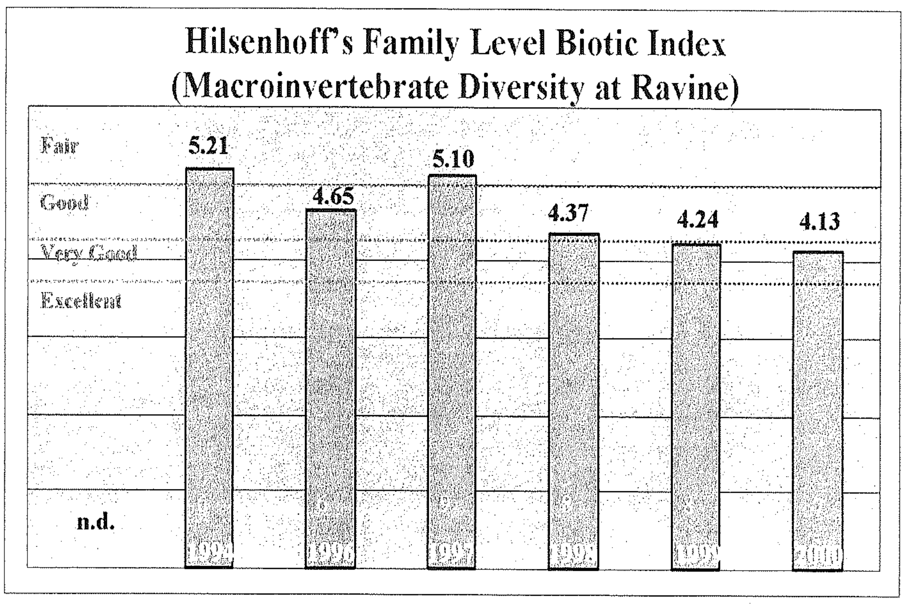
To neutralize AMD in the Swatara Creek Basin above Ravine, a variety of treatment systems were installed in 1995 through 1997 including limestone-sand dosing, open limestone channels, anoxic and oxic limestone drains, limestone diversion wells, and wetlands. Additional treatments and reclamation work have been completed since then. To characterize untreated mine drainage and treatment-system performance, data on flow rate and water quality throughout the basin were collected during baseflow and stormflow conditions in 1995-2001. Data for the station on Swatara Creek, near Ravine, indicate cumulative effects of AMD remediation and transport of pollutants from the mined part of the basin.





Baseflow data collected periodically since 1959 at Ravine indicate significant improvement in water quality. For example, sulfate declined while pH increased sharply after 1975 from 3.5-4.4 (median ~4) to 4.6-7.0 (median ~6). The decline in SO_4 concentration probably was caused by a decline in pyrite oxidation after flooding of the abandoned mines had minimized inflows of oxygenated air and water. The associated increase in pH was caused by the onset of carbonate buffering that occurred when the rate of alkalinity production equaled or exceeded acid production. Although a variety of environmental factors could affect pH and SO_4 concentrations, consistently near-neutral pH with variable SO_4 concentration at Ravine during 1998-2000, particularly during stormflow, imply that the recently implemented limestone treatments have neutralized acid, further improving water quality. At near-neutral pH, the transport of dissolved metals typically is attenuated owing to precipitation and adsorption. Nevertheless, recent monitoring indicates elevated concentrations and transport of Fe, Al, Mn, and trace metals during stormflow and elevated concentrations of Fe, Mn, Co, Cu, Pb, Ni, and Zn in streambed sediments relative to unmined areas and to toxicity guidelines for aquatic invertebrates and fish. The metals are ubiquitous in the fine fraction (<0.063 mm) of bed sediment in mining-affected tributaries and the main stem of Swatara Creek and represent a long-term source of contamination.





As a consequence of the improved water quality in Swatara Creek at Ravine, the fish community has rebounded. No fish were present during ecological surveys in 1985 and 1990; however, in 1994 and 1996 six species of fish were found. Increasing numbers of fish species have been found annually since 1996. In 2000, twenty-four species of fish were documented, including cold-water species such as brook trout and sculpin and warm-water species such as sunfish, pickerel, and bullhead catfish. Although the majority of the fish species are considered to have moderate tolerance to pollution, several intolerant species including river chub, cutlips minnow, and longnose dace, have been reported since 1997.

An increased abundance of benthic macroinvertebrate taxa that are considered intolerant of pollution indicates water quality improved from fair in 1994 to very good in 2000. Nevertheless, Hydropsychidae (caddisflies) and Chironomidae (midges), which are known to tolerate acidic conditions, were dominant. Although subordinate, the appearance of Ephemeroptera (mayflies) in 1997 and later years is significant in that these animals are sensitive to acidic conditions and considered intolerant to pollution. The benthic macroinvertebrate community recorded for 1999 and 2000 can be characterized as moderately impacted based on total taxa and slightly impacted based on total mayfly, stonefly, and caddisfly taxa.

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