GENERAL BACKGROUND FOR TEACHERS AND STUDENTS

Introduction:

Bituminous coal is mined in 21 Pennsylvania counties: Greene, Somerset, Armstrong, Indiana, Clearfield, Washington, Cambria, Jefferson, Westmoreland, Clarion, Elk, Fayette, Lycoming, Butler, Lawrence, Centre, Beaver, Blair, Allegheny, Venango and Mercer (ranked in order of production).

Some 10 billion tons of bituminous coal have been produced in Pennsylvania during over 200 years of mining, or nearly one fourth of all coal ever mined in the United States.
Geologic history in Pennsylvania resulted in nearly flat layers of bituminous coal deposits in Western Pennsylvania. In between the veins of coal are layers of sandstone, shale and limestone. These non-coal layers are called overburden.

About 40 different beds (layers) of coal are mined in Pennsylvania, they range from a few inches to over eight feet thick. About 75 percent of Pennsylvania's coal is mined from five different beds: the Pittsburgh Coal Seam, the Upper and Lower Freeport Coal Seam and the Upper and Lower Kittanning Coal Seam. Generally, Pennsylvania's bituminous coals are somewhat higher in sulfur content than coal mined in Wyoming or other western states.

Background:

Beginning in the mid-1700's coal mining in Pennsylvania fueled the Industrial Revolution in the United States. It began to support the Colonial iron industry, then Andrew Carnegie's steel mills in the 1800's and finally electric power plants of more modern times. Pennsylvania is now the fourth largest coal producer in the United States, following Wyoming, West Virginia and Kentucky. Over 69.5 million tons of coal were mined in the state in 1995 (about 6.7 percent of U.S. production) in 878 mining operations directly employing 10,165 people. Two kinds of coal are mined in Pennsylvania- anthracite (hard coal) and bituminous (softer coal).

Over 60.8 million tons of bituminous coal were mined in 1995 - 45.1 million tons from underground coal mines and 15.6 million tons through surface coal mines. Over 86 percent of Pennsylvania's bituminous coal was used as fuel at electric power stations. The remainder was almost equally divided between its use as coking coal in steel making operations and for other industrial purposes. In 1995, 8.7 million tons of anthracite coal was mined in Pennsylvania. Since 1870, Pennsylvania's Annual Report on Mining Activities has recorded 51,483 deaths from mining accidents-- 31,113 deaths in anthracite mines and 20,370 deaths in bituminous mines. Modern mining methods, safety training and inspections in the mining industry have dramatically improved the safety record on the industry to the point where it is about equal to agriculture and the construction industry.

The environmental legacy of hundreds of years of coal mining in Pennsylvania is over 2,400 miles of Pennsylvania's 54,000 miles of streams polluted by acid mine drainage from old mining operations. Abandoned mine drainage is the single largest source of water pollution by far in the state. Modern laws and regulations require that present day mining cannot begin if it might result in harm to the environment.

Since 1967, Pennsylvania and the federal government have invested close to $500 million to correct problems from abandoned surface and deep mines. These reclamation efforts are funded by a 35 cent per ton federal fee on coal being mined today, state reclamation funds from fees and reclamation bonds that have been forfeited. Over $15 billion worth of reclamation remains yet to be done. We also have problems like the mine fire that is burning under the town of Centralia, Columbia County.

Pennsylvania has invested $20.7 million to construct 13 abandoned mine drainage treatment plants around the state to treat abandoned mine drainage discharges. This legacy has resulted in a series of environmental laws to regulate coal mining operations that began in 1913.

Economically, mining contributes about 1 percent of Pennsylvania's gross state economic product through over $1.5 billion of direct coal sales, a payroll of nearly $350 million, a support service industry with a payroll of nearly $200 million, business tax revenues of over $1.5 million.

TYPES OF MINING

The major types of underground mining conducted in Pennsylvania's bituminous coalfields are:
- ✓ room-and-pillar mining
- ✓ room-and-pillar with retreat mining
- ✓ longwall mining.

Room-and-pillar Mining

Room-and-pillar mining involves driving tunnel-like openings to divide the coal seam into rectangular or square blocks. These blocks of coal, or pillars, are sized to provide support for the overlying strata. The openings are referred to as rooms or entries. In older mines, entries normally ranged from 8 to 30 feet (2.4 to 9.1 meters) wide, while pillar sizes varied considerably. In modern-day room-and-pillar mines, the dimensions of the mining equipment (cut width and reach of the continuous miner) and the type of haulage system employed largely determine the pillar dimensions (see Figure VI.2). Coal recovery is relatively low using the room-and-pillar method, normally ranging between 35 and 70 percent. The highest coal recovery is normally achieved when retreat mining is combined with room-and-pillar mining. This method is often referred to as room-and-pillar with retreat mining. Retreat mining is a systematic removal of coal support pillars once a mining section has been developed using standard room-and-pillar mining. The retreat phase (also known as "second mining") typically results in immediate or quick collapse of overburden into the unsupported opening. Room-and-pillar with retreat mining is a high-extraction mining method, generally recovering greater than 70% of the target coal seam.

History

Room-and-pillar mines have been active in Pennsylvania's bituminous coalfields since the late-1700s. Bituminous coal was first mined in Pennsylvania at "Coal Hill" (Mount Washington), just across the Monongahela River from the city of Pittsburgh. The coal was extracted from drift mines in the Pittsburgh coal seam, which outcrops along the hillside, and transported by canoe to the nearby military garrison. By 1830, the city of Pittsburgh consumed more than 400 tons per day of bituminous coal for domestic and light industrial use. Development of the anthracite coalfields in eastern Pennsylvania had progressed to the point where "hard coal" had captured the eastern markets. Consequently, bituminous coal production in western Pennsylvania grew principally with western population growth, expansion and development of rail and river transportation facilities to the west, and the emergence of the steel industry. Towards the last half of the nineteenth century, the demand for steel generated by the explosive growth of the railroad industry and ship building concerns, began to further impact bituminous coal production in western Pennsylvania (Puglio, 1983). Until the maturation of modern longwall mining in the 1960s, Pennsylvania's underground bituminous coal production came almost exclusively from room-and-pillar mines.

Early room-and-pillar mines did not include retreat mining; they relied on manual labor to cut the coal at the working face and the coal was hauled from the mine by horse and wagon. Today, many room-and-pillar mines use mechanized continuous mining machines to cut the coal and a network of conveyors that transports the coal from the working face to the surface (continuous haulage). The room-and-pillar mining method is used in all of Pennsylvania's underground bituminous coal mines including longwall mining operations, where it is used to develop the haulage and ventilation systems, and to delineate and support the longwall panels. Until the relatively recent advent of modern longwall mining, room-and-pillar mining had been the prime method for underground bituminous coal extraction in Pennsylvania. While room-and-pillar mining is still an important player in Pennsylvania, longwall mining continues to capture a growing portion of the Commonwealth's total underground production. Recent trends include a decline in the large high-extraction room-and-pillar mining operations, and some increase in small room-and-pillar operations that utilize continuous haulage. A complete list of all mines that produced coal during the study period is presented in Appendix C, Table C.1.

Longwall Mining

Longwall mining is a high-extraction mining method. Room-and-pillar mining methods are used to isolate a rectangular panel of coal which is then completely extracted by an automated cutting head (shearer) that moves along a track parallel to the working coal face. The shearer contains two rotating drums laced with bits that cut 2- to 3-foot swaths of coal on each successive pass. The cut coal falls onto a conveyor and is transported along the working face and eventually out of the mine. The coal within a longwall panel occupies a rectangular area which can approach 1,000 feet (305 meters) in width and be over 10,000 feet (3,048 meters) in length. Hydraulic roof supports are used to protect mine workers and equipment. As the shearing machine progresses through the panel, the roof supports are advanced. The unsupported mine roof and overlying rock then collapse into the void left behind the advancing roof supports. Once the panel is mined, the longwall machine is moved to an adjacent panel and the process is repeated resulting in near-complete extraction of the target coal seam over large areas. (See Figure VI.3)

Modern longwall mining has been part of Pennsylvania's mining industry for over 30 years. In the late-1960s longwall mining was conducted on the Upper Freeport and the Upper and Lower Kittanning coal seams by Barnes & Tucker Coal Co. (No. 20 and No. 24 mines), Eastern Associated Coal Corp. (Delmont mine), Rochester & Pittsburgh Coal Co. (Lucerne No. 6 mine), and Bethlehem Steel Corp. (No. 32 & 33 mine). Technological improvements along with the gradual shift of longwall operations to the thick, expansive, flat-lying Pittsburgh coal seam (ideal for longwalling) have combined to make longwall mining the major method for underground bituminous coal extraction in Pennsylvania. Longwall mining was first conducted on the Pittsburgh seam in Pennsylvania in 1970 at Gateway Coal Company's Gateway Mine. Over the next two decades the Pittsburgh seam would become the prime longwalling seam in Pennsylvania.

Longwall mining presently accounts for approximately 75% of all underground bituminous coal production in the Commonwealth. The history of modern longwall mining in Pennsylvania is illustrated by the list of all longwall mines, past and present that is presented in Table VI.1.

Early History (1875 – 1950)

Longwall mining is believed to have originated in Shropshire, England toward the end of the seventeenth century (Laird, 1973). Longwalling was not conducted in the United States until 1875 when newly arrived Welsh coal miners introduced the method. Mine layout in this early period was radial, typically incorporating two shafts sunk from the surface to the coal seam with perpendicular entries driven for a distance of 125 to 250 feet from the shafts. The ends of the entries were then connected by a series of perimeter entries and yield pillars forming a hexagon- or octagon-shaped panel. The delineated panel was then mined using a series of small advancing faces, with the roof being supported by timbers or jacks. The coal at the face was undercut, usually by hand, to a distance of 2 to 3 feet and supported by timbers on 4- to 6-foot centers. When undercutting was completed, the timbers were knocked out, allowing the immediate face coal to break free. In cases where the face coal did not break free under its own weight the coal had to be frequently wedged and sometimes blasted free. The loose coal was then hand loaded and removed from the mine, usually by horse and wagon.

Very few advances in longwall design or related technological improvements occurred between 1875 and 1950. The most significant improvement was the development of the steel jack, which was first introduced in 1912 for roof control at the working face. In 1924, a belt conveyor and partial chain conveyor were introduced. Maximum production ranged from 750 tons per day in 1915 for a wood-prop longwall to 850 tons per day by 1935 when steel jacks and conveyor haulage technology reached maturity. Longwall mining remained labor-intensive. The advancement of roof support and haulage equipment as mining progressed still required extensive manual effort and remained a significant production constraint. (Barczak, 1993)

Modern Longwall Mining

The years between 1950 and 1960 saw considerable changes in longwall technology. The most significant technological development during this period was the introduction of the mechanized cutting head known as the plow or coal plane. The plow replaced the labor-intensive method of undercutting practiced in the 1875-1950 period. As mechanized longwall equipment evolved, the profile of the panel changed from the small faces and radial geometry of the early mines to a single face developed across a large rectangular panel. Modern longwall mining began in the United States in 1952 at Eastern Associated Coal Corporation's Stotesbury Mine near Beckley, W. Va. It involved the mechanized extraction of a relatively large coal panel using a German-made coal plane. Three panels were successfully mined between 1952 and 1958, producing an average of 530 tons per shift. The primary constraint to increased production from longwall operations during this era was roof-support advance. Roof supports still needed to be advanced manually.

In 1954 the British developed a powered, self-advancing roof support. In the early 1960s the new self-advancing roof supports, along with a newly developed cutting head known as a shearing machine (shearer), were introduced into U.S. mines. The new shearers used a electrically powered rotating cutting head (drum) that was capable of cutting 24- to 28-inch deep "shavings" of coal on each pass. The number of U.S. longwall faces reached 18 by 1966. However only eight remained in continuous production throughout the 1960s and U.S. mining companies viewed longwall mining as having a mixed record of success. Longwall mining still accounted for only 0.4 percent of the total underground coal production (Barczak, 1993).

Between 1966 and 1975 high-capacity roof-support systems were developed which drastically improved safety and production in longwall mines. The introduction of the double-drum shearer helped set a production record of 6000 tons per day in a northern Appalachian longwall mine in 1969. In the mid-1970s the new double-drum shearer was widely employed in U.S. longwall mines. By 1975, 28 different coal companies operated 58 longwall faces and accounted for 3.1 percent of total U.S. underground coal production.

Continued technological improvements during the 1980s led to an increase in longwall production in recent years. Advancements included; (1) high-capacity hydraulic shields combined with electrohydraulic control systems allowing for fast roof-support advance with less labor; (2) increased shearer power; and (3) faster haulage speeds.

The Mining Legacy

During mining operations, the coal seam was usually located below the groundwater level, so the mine would fill up with water if the mining company did not pump the water out of the mine during the mining operation.

In the roof of the mine, was pyrite or fool's gold, FeS_2, to see information, makeup, uses, sources and other information about pyrite, check out the following web site. http://www.minerals.net/mineral/sulfides/pyrite/pyrite.htm. The two elements that make up pyrite are Iron and Sulfide. Pyrite is commonly found in the rock layers overlying coal seams.

When the mine was "played out", the company abandoned the mine and stopped pumping the water out of the mine. Eventually, the roof would probably collapse and the mine would be filled with the rocks and minerals that were in the roof, things such as pyrite, sandstone, shale and limestone. Just like when you put sugar in water, the water will begin to dissolve the minerals, and the pyrite will dissolve into iron (Fe^{+2}) particles and sulfate (SO_4^{-2}) particles.

The products of AMD formation, acidity and iron, can devastate water resources by lowering the pH and coating stream bottoms with iron hydroxide, forming the familiar orange colored "yellow boy" common in areas with abandoned mine drainage.

Many areas also contain naturally occurring limestone ($CaCO_3$) deposits which neutralizes acidity. To determine whether or not a mine will create acidic drainage, coal companies must analyze how much pyrite and neutralizers are in the rocks which will be disturbed by mining. Then DEP can determine whether or not a site can be mined without harming the environment. By law, DEP cannot issue a permit for new coal mining where it is determined mining will cause acid mine drainage.

When the mine is filled up with ground water, there needs to be an outlet, often times that outlet is a seep, or sometimes it is a borehole that was drilled for any of a number of reasons. When the water exits the mine, the reaction begins.

The Chemical Reaction of AMD

The first reaction, which occurs in the mine, is the physical and chemical weathering of pyrite, which includes the oxidation of pyrite by oxygen to produce sulfate and ferrous iron. This reaction generates two moles of acidity for each mole of pyrite oxidized.

(1) $2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$

(1) Pyrite + Oxygen + Water → Ferrous Iron + Sulfate + Acidity

The second reaction, which occurs when the mine water comes in contact with oxygen, involves the oxidation of ferrous iron to ferric iron. Certain bacteria increase the rate of oxidation from ferrous to ferric iron. This reaction rate is pH dependant with the reaction proceeding slowly under acidic conditions (pH 2-3) with no bacteria present and several orders of magnitude faster at pH values near 5. This reaction is referred to as the "rate determining step" in the overall acid-generating sequence.

(2) $4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O$

(2) Ferrous Iron + Oxygen + Acidity → Ferric Iron + Water

The third reaction, which may occur, is the hydrolysis of iron. Hydrolysis is a reaction that splits the water molecule. The formation of ferric hydroxide precipitate (solid) is also pH dependant. Solids form if the pH is above about 3.5 but below pH 3.5 little or no solids will precipitate.

(3) $4\ Fe^{3+} + 12\ H_2O \rightarrow 4\ Fe(OH)_3 \downarrow + 12\ H^+$

(3) Ferric Iron + Water → Ferric Hydroxide (yellowboy) + Acidity

Reference: http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_AMD.htm
Reference: http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Bituminous_Coal_Mining.htm
Reference: http://www.dep.state.pa.us/dep/deputate/minres/bmr/act54/sec6.htm
Reference: http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Coal_Mining_in_Pennsylvania.htm