GEOLOGY

Introduction

The geology of northwest Pennsylvania and Clarion County has been studied extensively since the early 1900's. As the need for coal and oil has increased over the last century, new and faster methods of discovery and extraction of these natural resources had to be found. As a result, lengthy studies of Pennsylvanian stratigraphy and structure were conducted in order to find where and how to tap this state's abundant coal and oil reserves. The geologic data for this report is taken from several of those previous studies, as well as from actual field reconnaissance. In addition, geologic information is incorporated from available mine maps and drill hole logs and records. All reports used in compiling this text are listed under References and are referred to in the text wherever appropriate.

Structure

Regionally, the Appalachian Synclinorium plunges to the southwest which permits the Middle and Lower Kittanning coals to outcrop in many of the hilltops in the western portion of the watershed.

Northwestern Pennsylvania lies in what is known as the Pittsburgh-Huntington structural basin. This spoon-shaped depression is one of the many small folds superimposed on the flanks of the Appalachian Synclinorium and has its' center in the southwest corner of Pennsylvania.

Clarion County is in the portion of the synclinorium which is relatively flat-lying, but in parts is influenced by the Brady's Bend syncline and the Kellersburg anticline. The attitude of the strata where the Brady's Bend syncline enters the watershed is essentially horizontal until further south near the boundaries where the rocks on its' flanks have dips of 25'-75' per mile. The Kellersburg anticline is the major influence on local dip in the Piney Creek Watershed. Although it also begins to level out in the watershed, the strata in the eastern portion have dips averaging 3° or less to the southeast.

Because of the general lack of structure, there appears to be no directional pattern to the drainage.

For detailed information concerning the stratigraphy and comprehensive geology, the reader should refer to Chance (1880), Ashburner (1885), Munn (1910), Shaw and Munn (1911), Fern and Williams (1960 & 1964), and Patterson and Van Lieu (1972). A generalized discussion of the surface geology of the Piney Creek Watershed is presented in this text.

GENERAL GEOLOGY

Quaternary Series

Only a thin veneer of Quaternary alluvium exists in the beds of the main streams in the watershed.

PENNSYLVANIAN PERIOD

Conemauqh Group

The Conemaugh Group outcrops only in the extreme southeastern portion of the watershed where it is found as the cap rock on a few of the higher hills. The Conemaugh formation varies from a sandy olive-green shale to a gray shale with thick interbeds of sandstone. The sandstone becomes more massive and is the dominant member of the formation in the extreme southwestern portion of Clarion County.

Allegheny Group

The Allegheny Group extends from the top of the Upper Freeport coal to the top of the Homewood sandstone. It has an average thickness of 350'-375' and includes most of the mineable coals in the Piney Creek Watershed. The formations in this group include the Freeport, Kittanning and the Clarion, and consist mainly of interbedded shale and sandstone, clay and coal in order of decreasing abundance. A more detailed description of each formation follows.

Freeport Formation

The Freeport Formation, named for the Freeport coals, varies from 100' to 120' and extends from the top of the Upper Freeport coal to the top of the Upper Kittanning coal. These rocks occur only in isolated hilltops in the extreme southeastern portion of the watershed, and are of minor importance. The intervals between the coals are occupied by sandy shales and below the coals by the Freeport sandstone.

Kittanning Formation

The Kittanning Formation includes the interval from the top of the Upper Kittanning coal to the base of the clay under the Lower Kittanning coal. All three Kittanning coals are mined in the watershed with the Lower Kittanning showing the highest marketable value. In the southwest, especially near Shamburg, the thickness of the overburden is less than 100' and stripping of the Lower Kittanning coal is extensive. The intermediate rocks of the Kittanning Formation consist of shale and sandstone and are underlain by a fire clay giving an overall thickness of 110' to 130'.

Clarion Formation

The Clarion Formation extends from the clay at the base of the Kittanning Formation to the base of the Brookville underclay. The Clarion and Brookville (when present) coals are the most extensively mined in the Piney Creek Watershed, thus making the Clarion Formation the source of most of the acid mine drainage.

Averaging about 125' the formation consists of sandstone, shale, siltstone, coal, clay and limestone in order of decreasing abundance. The Vanport limestone, a prominant marker bed in northwestern Pennsylvania, averages between 3' to 7' thick in the south near Limestone. It is consistently overlain by a thin layer of iron oxide which was mined in the early days. The ore mined provided the raw material for the numerous iron furnaces that operated in the county in the nineteenth century.

The Clarion coals range in thickness from 0.5' to 3.5' with the Upper Clarion thicker than the Lower Clarion seam. The interval between the two is generally a 20' bed of shale, but may vary since one coal or the other is frequently missing and has made seam identification difficult. Further complication is added by the occasional appearance of the Clarion rider coal, generally less than 1.0' thick.

The Brookville coal is usually found 30' below the Lower Clarion and averages 4.5' to 7' thick. However, this seam is not always present due to depositional environments in the Pennsylvanian Period. Both the Clarion and Brookville seams have high sulfur and ash content attributed to their respective coals.

Pottsville Group

The Pottsville Group extends from the base of the Clarion Formation to the base of the Lower Connequenessing sandstone, which lies unconformably on rocks of Mississippian Age. Containing three major formations, the Homewood, Mercer and Connequenessing, the Pottsville Group averages about 275' in the Piney Creek Watershed. The group consists mainly of sandstones and shales with only two recognized coal seams, neither of which are mined in the Watershed.

Homewood Formation

The Homewood Formation extends from the base of the Brookville underclay to the top of the Mercer shale. It is dominated by the coarse-grained massive Homewood sandstone which is a persistent marker bed over much of western Pennsylvania. The average thickness is 20' in the Piney Creek Watershed. The remainder of the formation is 30' of sandy shale.

Mercer Formation

This formation consists mainly of shale and limestone and two minor coal seams, the Upper and Lower Mercer. The boundaries extend from the base of the Homewood sandstone to the top of the Upper Connequenessing sandstone and averages approximately 70' in thickness. The Upper and Lower Mercer coals average 2.0' and 4.0' respectively in parts of Clarion County, but are not known to be mined in the watershed. The rocks of the Mercer Formation are seen only in the channel of the main streams in the northwest portion of the watershed.

Connequenessing Formation

The Connequenessing is a three member formation consisting of the Upper and Lower Connequenessing sandstones and the interbedded Quakerstown shale. The sandstones are massive and jointed and attain a total thickness of up to 140'. The Quakerstown shale is thick (40") with a few interbeds of sandstone and coal. The formation contacts extend from the base of the Mercer Formation to the Mississippian - Pennsylvania unconformity.

MISSISSIPPIAN PERIOD

Pocono Group

The unconformity at the base of the Pennsylvania series has caused a great amount of confusion in identifying the exact member of the Mississippian series which is present at the contact. The evidence seems to indicate that possibly thousands of feet of rock have been removed by the extensive period of erosion which marked the interval between the Mississippian and Pennsylvania depositions. According to Shaw and Munn (1911) in Clarion County and specifically in the Piney Creek Watershed, the Mississippian series begins with the middle of the Pocono Group, approximately in the Burgoon sandstone.

Generally, the sandstone has a total thickness of 300' to 320' and lies about 130' below the horizon of the Brookville coal. In the Piney Creek Watershed, it occurs only in the stream bed near the mouth of Piney Creek and actual thickness is difficult to determine.

GENERAL GEOLOGIC COLUMN PINEY CREEK WATERSHED

Period	Group	Formation	Rock Type	Thickness
Quaternary			Alluvium	Thin Layer
Pennsylvanian	Conemaugh	Conemaugh	Shale	Cap Rock
	Allegheny	Freeport	Upper Freeport Coal	3.5'-4.0'
			Sandy Shale	30'
			Sandstone	20'
			Lower Freeport Coal	4.0'
			Freeport Sandstone	40'-60'
		Kittanning	Upper Kittanning Coal	2.5'-3.0'
			Shale and Sandstone	35'-65'
			Middle Kittanning Coal	3.0'
			Shale and Sandstone	25'
			Shale	30'
			Lower Kittanning Coal	2.0'-3.0'
		Clarion	Clay	2'
			Sandstone	8'
			Shale and Siltstone	12'
			Iron Oxide	1'
			Vanport Limestone	5'-10'
			Sandstone	0'-20'
			Shale	20'
			Clarion Rider Coal	1'
			Clay and Shale	0'-25'
			Upper Clarion Coal	0'-3'
			Clay and Shale	20'
			Lower Clarion Coal	0'-3.5'
			Clay	3'
			Shale	27'
			Brookville Coal	4.5'-7'
			Clay	4'
	Pottsville	Homewood	Sandy Shale	9'
			Sandstone	20'
		Mercer	Shale	18'
			Limestone	1'
			Upper Mercer Coal	2'
			Shale	30'

GENERAL GEOLOGIC COLUMN PINEY CREEK WATERSHED (con't)

Period	Group	Formation	Rock Type	Thicknes
	Pottsville	Mercer	Limestone	2'
			Lower Mercer Coal	4'
			Shale	10'
		Connequenessing	Upper Conn. Sandstone	88'
			Quakerstown Shale	40'
			Lower Conn. Sandstone	50'
Mississippian	Pocono	Burgoon	Sandstone	varied

GEOLOGIC FACTORS AFFECTING PRODUCTION OF ACID MINE DRAINAGE

The nature and quantity of acid mine drainage produced as an aftermath of coal mining is determined by various hydrologic and geologic factors. Some of these factors are:

1. Thickness and composition of the coal seams and associated strata.
2. Depositional environments of the strata.
3. Size and chemical constituents of the pyrite and marcasite in the coal and associated strata.
4. Folding, fracturing, joints, faults and strike and dip of the strata.
5. Location and extent of mined out area.
6. Overburden thickness and character.
7. Topography.
8. Position of water tables.
9. Permeability and porosity of strata.
10. Availability of limestone for natural renovation.

The basic theory of acid mine drainage is simple and well known. Coal mining exposes the sulfur-bearing minerals, pyrite and marcasite, to air and water. These minerals are oxidized chemically and biochemically, producing sulfuric acid, ferrous and ferric sulfate, and other acid salts such as the sulfates of aluminum and manganese. The mine drainage may also contain the neutral sulfates of calcium and magnesium when calcareous rocks are present.

Recent research conducted by Williams (1960), Williams and Ferm (1960), Williams and Keith (1963), Caruccio (1968, 1970, 1972), and Caruccio and Ferm (1974), has begun to develop patterns in acid mine drainage formation in western Pennsylvania. Through the use of fossils, Williams first determined the stratigraphic paleoenvironments of deposition and their lateral variations for each of the major coal seams in the Allegheny Group. He found that in the basal. portion of the Allegheny Group, the rocks contain fossils indicative of a marine-brackish water paleoenvironment. In the upper portion of the group, fossils are present which indicate a continental freshwater paleoenvironment. In general, as one passes upward through the stratigraphic succession, the rocks grade slowly from marine to continental, indicating a slow marine regression over a long period of time. This work was further refined by Williams and Ferm (1960), who demonstrated that the basal brackish rocks in the Allegheny Group also vary laterally, becoming progressively more marine to the west.

The significance of this to the understanding of acid mine drainage was revealed in a study by Williams and Keith (1963). This study investigated the possible correlation between sulfur (primarily as pyrite) in coals and the paleoenvironment of deposition of the coals. It was found that the amount of sulfur in the Lower Kittanning coal seam increased westward, directly correlating with the westward transition from continental to marine paleoenvironment. This was inferred to hold true for the other coal seams of the Allegheny Group.

For the past eight years, Caruccio has been investigating the nature of the pyrite which causes the acid mine drainage problem. In a series of field and laboratory studies conducted in western Pennsylvania, he determined that the most significant parameters affecting acid formation are:

1. Mode of occurrence of the pyrite.
2. Distribution of certain trace elements in the pyrite.
3. Permeability of the host rock, as a contributing factor to the oxidation rate.
4. Availability of calcium carbonate for natural neutralization.
5. Groundwater pH before mining, as a control on the iron bacteria which catalyze the acid producing chemical reaction.

The studies showed that there are four types of pyrite occurrences in coal strata:

1. Euhedral crystals less than 10 microns in diameter.
2. Coarse-grained masses replacing original plant matter, greater than 25 microns in diameter.
3. Coarse-grained platy masses occupying joints in the strata, greater than 25 microns in diameter.
4. Fine-grained, framboidal pyrite, generally occurring as spherical clusters of 0.25 micron particles.

The fine-grained framboidal and euhedral pyrite appear to have been formed contemporaneously with the host strata, since the pyrite grains are aligned parallel with bedding and form an integral part of the structure. These types of pyrite are products of the paleoenvironments of deposition for the strata. The other types of pyrite are secondary forms, resulting from deposition in joints and replacement of plant material.

Caruccio has further determined that only the framboidal primary pyrite is significantly reactive. Samples containing similar amounts of total pyrite, but only a small percentage of framboidal, produce significantly less acid than samples with a high percentage of framboidal pyrite.

The reasons for the reactivity of framboidal pyrite appear to be at least partially controlled by the existence of trace elements. Size alone is not the answer, since coarse-grained pyrite was mechanically ground to a size equivalent to framboidal pyrite and tested, without a significant increase in acid production. Spectroanalysis of samples by Caruccio has shown significantly more titanium in stable pyrite than in reactive pyrite, and presence of silver in reactive samples only.
More research is being conducted to determine if silver increases oxidation tendency, or if titanium increases stability.

Recent work by Caruccio and Ferm (1974), and work in progress, has determined the framboidal pyrite to be associated with strata from back barrier and lower delta plain deposits. Criteria have been developed to recognize paleoenvironments in the field, and progress is being made toward mapping these environments in the Appalachian coal fields.

There are several implications of these studies for the Piney Creek Watershed. The surface rocks of the watershed are from the basal portion of the Allegheny Group, representing restricted near-shore marine and marine paleoenvironments. As such, the Clarion coals and associated strata contain the greatest amounts of framboidal pyrite and are, therefore, the worst acid producers.

The situation within the watershed is aided by the presence of Vanport limestone in the southern portion. The Vanport is a major contributor to mine acid neutralization throughout much of western Pennsylvania. The lack of limestone in the north and central portions, high degree of reactive pyrite and poor reclamation practices of past mining have combined to produce the serious acid mine drainage problem in Piney Creek Watershed. Moreover, the low pH values in many areas probably encourage the growth of various iron bacteria, which act as a catalyst in the acid production process.

MINING HISTORY

Mining has occurred in Clarion County since the 1830's. A variety of mineral resources have been extracted such as natural gas, iron, oil, limestone, clay, and most importantly, coal. The iron ore industry operated in Clarion County until the late 1800's, making the extensive mining of iron ore and lime stone necessary. The main sources of these mineral deposits were the Vanport limestone and the bed of iron ore which consistantly overlies it. Another bed of iron ore lies about ten (10) feet below the Brookville coal in the northern portion of the county . At one time there were as many as 27 furnaces operating in the county, producing a total of 40,000 tons of iron per year.

Oil was discovered in Clarion County shortly after the Titusville boom in the early 1800's. By 1883, production was over 12,000 barrels per year, with an estimated 5,000 oil wells drilled. Clay and gravel were also mined extensively in this same time period. Fire clays, underlying the major coal seams, were used for brick and other construction materials.

Natural gas has been produced in the county since the late 1800's. The association of gas pools with oil and water reservoirs brought about another flurry of drilling in areas already over-populated with oil derricks. The most favorable drilling locations seemed to be in areas of strong folding where structural traps became pockets for layered pools of gas, oil and water.

Coal was first mined here in 1839. The need for a cheap, abundant source of energy for industry brought about the demand for coal, especially with the advent of the Bessemer process of steelmaking. Production from the nine mines operating in 1885 reached 373,504 tons. By 1912, the total reached 1,200,000 tons of coal. At present, over 10,000,000 tons of coal have been recovered by the shaft or deep mine method of mining alone. Although stripping of overburden got its' beginning shortly after World War I, it did not become the dominant form of coal mining until the early 1940's. At present, all current coal mining in Clarion County is done by stripping. Removal of 70' to 100' of overburden to reach a five foot or less seam of coal is common with today's equipment. Stripping has become so extensive in Clarion County, that by 1969 more than 25,000 acres or 7.0% of the ,county has been or is being stripped. Many of these operations were run near or on the limits of previously deep mined areas.

Clarion County has twelve recognized coal beds. Four of these seams are mined

Coal Bed	Thickness	Workable Area
Upper Freeport	0'-6.2'	11
Lower Freeport	0'-7.O'	20

Coal Bed	Thickness	Workable Area (sq.mi.)
Upper Kittanning	0'-4.0'	15
Middle Kittanning	0'-2.5'	29
Upper Kittanning	1'-4.5'	139
Upper Clarion	0'-4.7'	92
Lower Clarion	2'-7.0'	245
Brookville	0'-4.5'	210
Mercer	l'-2.0'	22

Source: Department of Internal Affairs, 1928 - 1961

The dominant seams in the Piney Creek Watershed are the Lower Kittanning, Upper Clarion and Lower Clarion. The Upper Kittanning, as well as the Freeport coals, have been removed by erosion. It is speculated that with 120' or less of overburden in Clarion County, 1.8 billion tons of coal remain in place from an original figure of 210 billion tons. It has also been estimated that of the remaining total, approximately 189,400,000 tons are recoverable by stripping.

Most of the mine drainage pollution comes from abandoned strip and deep mines where mining was conducted before the regulation of the industry and further aggravated by mining practices at the time. The major cause of deep mine pollution is the fact that until recently the mine openings were driven to the rise allowing for gravity draining of water from the mine. Inadequate mine design related to roof support lead to caving of the mine workings with resulting fracturing of adjacent strata. This has allowed surface and groundwater to percolate into the mine workings. Mine openings in the form of man-ways, ventilation and supply adits were not sealed following mine abandonment. In regards to strip mining, most pits were not backfilled or planted allowing surface water to infiltrate through acidic spoil, settle into impoundments and contaminate groundwater supplies. Strip mines operating on the outcrop of a hill frequently intersected old mine workings and made no provision to restore the broken outcrop barrier (by backfilling or clay packing) when stripping was completed. Mine and tipple refuse consisting of high sulphur material were not properly disposed of.

As a result of these practices, regulation of the mining industry came into existence with the Pennsylvania Clean Streams Act of 1937 (PL 1987 with amendments), the 1963 Bituminous Coal Open Pit Mining Conservation Act 133, the Land and Water Conservation Act of 1967 and the Surface Mining Conservation and Reclamation Act of 1971. Effective implementation and enforcement of these laws should eliminate or control any adverse conditions resulting from active mining operations. Meanwhile, mine drainage from abandoned deep and strip mines will continue to degrade the water quality in the area placing severe restrictions on the land and water environment.