Atlas 74 cd
1971
Reprinted 1973

# Geology and Mineral Resources of the Southern Half of the Penfield 15-Minute Quadrangle, Pennsylvania

William E. Edmunds
and
Thomas M. Berg
with appendix
by
William C. Darrah

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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# Geology and Mineral Resources of the Southern Half of the Penfield 15-Minute Quadrangle, Pennsylvania

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PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

First Printing, 1971
Second Printing, 1973

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PURCHASED FROM
STATE BOOK STORE, P. O. BOX 1365
HARRISBURG, PENNSYLVANIA 17125

## PREFACE

This report describes the nature and occurrence of the various rock layers found at and below the surface of a 112-square mile area of west-central Clearfield County. Particular attention is also paid to the rock and mineral resources which have economic importance.

The surface rocks in the northeastern part of the report area consist chiefly of massive white sandstone underlain by a sequence of thinner-bedded reddish or greenish shale, siltstone and sandstone. The remainder of the area is underlain at the surface by alternating thin layers of sandstone, shale, siltstone, limestone, clay, and coal. The sequence of rock layers is described in detail and the various changes in rock type from place to place are discussed. The report also includes information on the subsurface rocks of this area based on records of the many gas wells drilled here.

Locations, quality, and quantity of the various mineral resources found in the report area are described. Coal is the most important mineral resource with unmined reserves of 190 million tons in beds over 14 inches thick, including 115 million tons in beds over 28 inches thick. The area also includes part of the Punxsutawney-Driftwood gas field. Clay and shale for use in ceramic products are an important mineral resource of the area and are described in detail.

This report provides an inventory of geologic information prerequisite to land planning and mineral resource development for the future. It is expected to be of particular use to the mineral industries in view of the extensive mineral resources cited. Highway and construction engineers will be able to evaluate ground construction conditions in advance of operations and an engineering characteristics map is included to assist in that respect. Planning organizations will be able to recognize the valuable mineral-bearing areas as well as areas where construction will be difficult. Those interested in water resources will be better able to evaluate the distribution and controls on the occurrence of ground water.

This report is intended for both professional and non-professional readers. The language used has been kept as simple as possible without sacrificing accuracy. Where more exact geological terms must be used, they are defined in the glossary at the end of the report. It is advisable that those not well versed in geology obtain the assistance of a competent professional in making important or costly decisions requiring geological interpretation.

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# GEOLOGY AND MINERAL RESOURCES OF THE SOUTHERN HALF OF THE PENFIELD 15-MINUTE QUADRANGLE, PENNSYLVANIA

by

William E. Edmunds and Thomas M. Berg

## ABSTRACT

The southern half of the Penfield 15-minute quadrangle, located in the Appalachian Plateaus Province of west-central Pennsylvania, is characterized by topography reflecting broadly folded to almost horizontal strata. Geomorphic development has apparently included expansion of Susquehanna River drainage at the expense of Allegheny River drainage.

Subsurface stratigraphic information from deep gas wells is available down to the Devonian Helderberg Formation. Surface exposures include strata from just below the middle unit of the Pocono Formation (Mississippian) up through the Pennsylvanian Pottsville and Allegheny Groups almost to the middle of the Conemaugh Group (Pennsylvanian). A regional unconformity beveling the Mississippian northward across this area has removed the Mauch Chunk Formation and part of the uppermost Pocono Formation.

Within the Pocono Formation, an upper member called the Burgoon Sandstone is recognized and outcrops along the sides of steep valleys. Thickness of the Burgoon varies from 130 to 300 feet due to erosional loss in connection with the Mississippian-Pennsylvanian unconformity. Below the Burgoon Sandstone are 200 feet of less resistant middle Pocono shales, siltstones and sandstones with some persistent red shales. Where the basal Pennsylvanian Mercer flint clay is not developed, the regional unconformity is located by paleobotanical methods and occurs within a continuous sequence of sandstones including both the Mississippian Burgoon and the upper Connoquenessing sandstone of the Pennsylvanian Pottsville.

Revised stratigraphic nomenclature for the Pottsville and Allegheny Groups is used in this report. This nomenclature, intended for use initially in Clearfield County, includes stratigraphic units that are based on key beds rather than on lithologic homogeneity.

The Pottsville Group, 60 to 160 feet thick, includes the Elliott Park and Curwensville Formations. The Elliott Park is dominantly sandstone (upper Connoquenessing sandstone) and is missing by nondeposition in the south-central half of the area. The Elliott Park Formation is distinguished from the underlying Burgoon Sandstone only with great difficulty. The overlying Curwensville Formation, a highly complex unit,

includes the economically valuable Mercer flint clay at the base. Multiple, and sometimes discontinuous coal seams, in addition to clays, shales, siltstones, sandstones, and occasional conglomerates generally characterize this formation. The massive Homewood Sandstone occurs near the top of the Curwensville and is mapped as a separate member.

The Allegheny Group (240-320 feet thick), including in ascending order, the Clearfield Creek, Millstone Run, Mineral Springs, Laurel Run, and Glen Richey Formations, is a sequence of cyclic deposits bearing several mineable coals. Intervals between coals include clays, shales, siltstones, sandstones, and some limestones. The variation in total thickness of this group is due largely to downcutting by sandstone channels of the basal part of the overlying Conemaugh Group. The transgressive-regressive cyclicity of Allegheny time produced repeated environments of deposition including in sequential order: transgressive swamps, open water, regressive swamps, distributary deltas, fluvial-erosional systems, and backswamps. Allowing for some variability, this basic cycle is characteristic of the Allegheny Group as well as the Pottsville and Conemaugh Groups.

A maximum of about 320 feet of the Conemaugh Group (Glenshaw Formation) exists in the southern Penfield area. The extensive downcutting by channels containing the lower Mahoning sandstone increases the total thickness of the Conemaugh at the expense of the underlying Allegheny Group. In addition to this widespread fluvial complex, the Conemaugh Group is characterized by claystones, shales, siltstones, flat-bedded sandstones, and occasional coals, limestones and calcareous siltstones.

The Pennsylvanian rocks in the report area were deposited on an erosion surface envisioned as a long, low ridge corresponding to the pre-Pennsylvanian outcrop belt of the Burgoon Sandstone. Subsequently, 13 or more depositional cycles of the Pennsylvanian blanketed the area.

The structure in the southern Penfield area is dominated by the broad, Chestnut Ridge anticline with a northeastern axial bearing. It is flanked on the northwest by the Punxsutawney-Caledonia syncline and to the southeast, outside of the report area, by the Clearfield syncline. The anticline displays moderately strong structural relief for folds in this region of the Allegheny Plateau. The axial plane of Chestnut Ridge dips steeply to the northwest; the fold has an asymmetric profile. A system of deep, high-angle, reverse faults has been inferred from information produced by extensive gas well drilling to the Oriskany (Devonian) sandstone. The system of faults appears to be limited to the northwestern flank of Chestnut Ridge anticline and coincident with the Rockton and Helvetia deep natural gas pools. The fault complex consists of northeast-striking reverse faults with probable splays striking north to north-

northeast. Other than some tightening of surface structure contours, no surface expression of this subsurface fault complex is seen. Two joint sets occur roughly at right angles to each other, the primary set bearing about N30°W. Master joints, possibly the extension beyond actual displacement of wrench faulting to the southeast of this area, appear to effect a subparallelism of major stream valleys in the eastern half of this report area. The folds and deep faults are apparently related to translational movements along at least two decollement slip surfaces.

As in the rest of Clearfield County, coal stands as the most important mineral commodity. The lower Kittanning no. 3, middle Kittanning, upper Kittanning, and lower Freeport coals are the principal mined seams. Reserves of these coals plus small amounts of upper Freeport coal total 190 million tons over 14 inches thick, including 115 million tons over 28 inches thick and 2.6 million tons over 42 inches thick. Other coals, although not included in this estimate, bear small additional reserves.

Eleven economically useful clay horizons occur in the map area. The Mercer high-alumina hard clay at the bottom of the Pennsylvanian section is of great value for its refractory qualities. The lower Kittanning soft clay is particularly well-developed. Other claystones and clay shales of probable economic value occur in great quantities.

Abundant natural gas has been produced primarily from deep wells penetrating the Oriskany sandstone. A small amount of gas has also been produced from shallow horizons. The Rockton (Luthersburg) Pool represents the largest producing area.

Other lesser economic resources include limestone, soils, and various construction materials—building stone, crushed stone, and sand and gravel.

In addition to surface water supplies, multiple perched water tables and sandstone aquifers (especially the Burgoon Sandstone) are potential ground water sources.

Rocks in the southern half of the Penfield quadrangle are grouped into five engineering geologic categories.

# INTRODUCTION

## SCOPE OF THE REPORT

This atlas report is another in a continuing series of general geology and mineral resource reports published by the Fourth Pennsylvania Geological Survey. The report covers the southern half of the Penfield 15-minute quadrangle and is published on the Luthersburg and Elliott Park 7½-minute quadrangles. The area covered is approximately 112 square miles.

The geologic part of the report deals almost entirely with stratigraphy and structure because a clear understanding of those two subjects is prerequisite to any other more detailed or specialized studies. The mineral resources section is designed to be of practical assistance to the mineral industries of the area. While the nature, quality, and location of various mineral resources are discussed, most production figures are deleted because they are available from more comprehensive and continuously updated publications from the U. S. Bureau of Mines and the Pennsylvania Department of Mines and Mineral Industries.

## LOCATION

The southern half of the Penfield quadrangle lies between 41°00′00″ and 41°07′30″ north latitude and between 78°30′00″ and 78°45′00″ west longitude (Figure 1 and Plate 1). The area lies entirely within Clearfield County and includes parts of Sandy, Brady, Union, Penn, Bloom, Pine, Pike, and Lawrence Townships and part of the City of DuBois.

## PHYSIOGRAPHY

The southern half of the Penfield Quadrangle lies entirely within the Appalachian Plateaus Province (Figure 1) which is a wide band of geographically similar terrain extending from New York to Alabama. It is basically

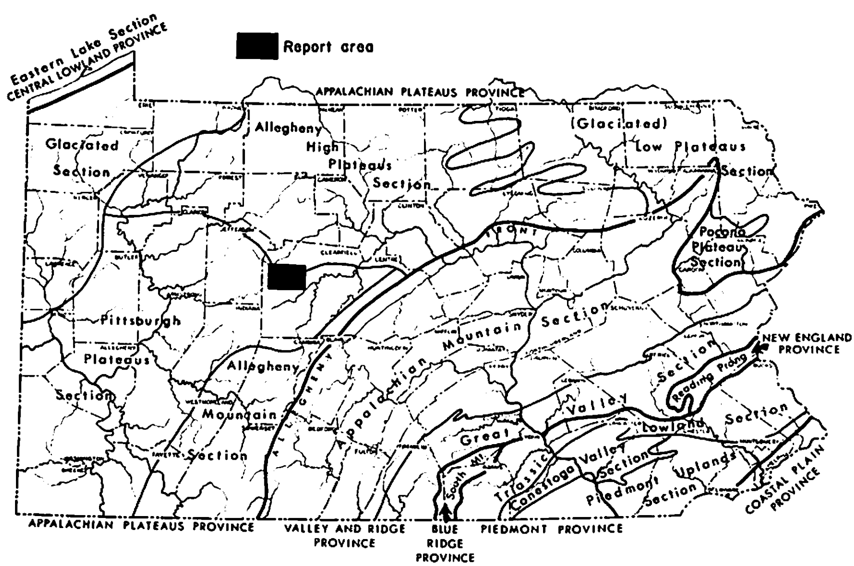


Figure 1. Physiographic provinces of Pennsylvania and location of the report area.

a high plateau, dissected by many streams. The report area can be further subdivided into two topographically distinct sections. The first is the broad, high, shield-shaped area occupying roughly the northern three-fourths of the Elliott Park Quadrangle. Topographic contours are relatively smooth with few complex digitations. The streams are few and basically straight with steep, narrow, V-shaped valleys and very broad, flat-topped interfluvial areas (Figures 2 and 3). The remainder of the report area constitutes the second topographic sub-area. The surface contours there are noticeably more irregular and the stream pattern more dense and highly dendritic.

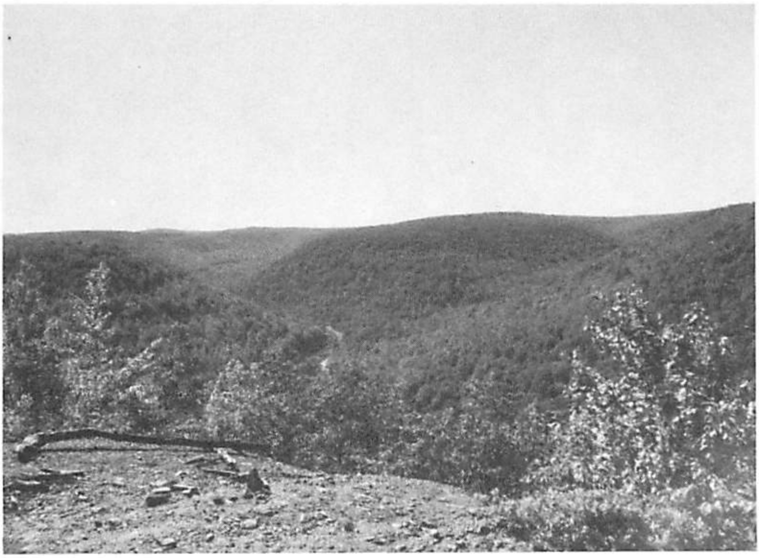

Figure 2. View up the gorge of Anderson Creek from near Ef5.

The stream valleys are relatively broad, shallow and flat-bottomed with narrow, rounded interfluvial areas. The distinctive topography of each of the two areas is directly related to differing surface rock-types, a factor, in turn, controlled by the geologic structure. The appearance of the northern Elliott Park area reflects the surface occurrence of the highly resistant Burgoon Sandstone Member along the flat-topped crest of the southwest-plunging Chestnut Ridge anticline. The topography of the remaining area results from the highly variable erosional nature of the less resistant, lithologically heterogeneous post-Burgoon rock units which are preserved in the relatively narrow bottomed Punxsutawney-Caledonia syncline and around the southwest-plunging nose of Chestnut Ridge anticline.

Figure 3. View northwest up Anderson Creek from quarry at Df20.

The local relief between the break in slope at the edge of the rolling uplands and the bottom of the adjacent stream valleys ranges from 100 to 200 feet in western Luthersburg to 400 to 500 feet along Anderson Creek, Moose Creek, and Montgomery Creek. (Montgomery Creek lies in the southeastern quarter of the Elliott Park quadrangle. Another stream called Montgomery Run lies in the northwestern quarter of the Elliott Park quadrangle.) The highest point in the report area is 2,398 feet above sea level and lies one-half mile south of the Clearfield-Rockton Pike (Pennsylvania Route 410) between the upper reaches of North Branch and Horn Shanty Branch of Montgomery Creek. The lowest point is 1,250 feet on Montgomery Creek at the point where it leaves the eastern edge of the report area. The 1,150 feet of topographic relief is primarily a reflection of the upwarping of the highly resistant Burgoon Sandstone along the crest of Chestnut Ridge anticline. The effect has been to restrain downward erosion along the anticline while permitting deeper cutting in the flanking synclines.

The report area lies astride the eastern continental divide and hence is divisible into two major watersheds. The western quarter of the area is drained by the Allegheny-Ohio-Mississippi system; the remainder by the Susquehanna system. The line of this eastern continental divide is shown on Plate 1. The western (Allegheny) drainage is divisible in the report area into two major sub-watersheds. The first is the Sandy Lick Creek system which flows into the Allegheny River via Red Bank Creek. The second is composed of Limestone Run, Stump Creek, East Branch Mahoning Creek, and Laurel Branch Run which drain into the Allegheny River via Mahoning Creek. The eastern (Susquehanna) drainage is divisible into: (1) the Anderson Creek watershed (representing about one-half the report area); (2) the individual watersheds of Bells Run, Hartshorn Run, Montgomery Creek, Moose Creek, and Lick Run (north of Hobo Hill), each of which flow directly into the Susquehanna; and (3) a 20-acre tract lying in State Game Lands 93, north of Home Camp, which drains into Bennett Branch of Sinnemahoning Creek.

The history of the physiographic relationship between the Susquehanna and Allegheny drainages in the general region of this report seems to have been expansion of the Susquehanna system at the expense of the Allegheny (Ashley, 1940). In the report area, the principal instrument of the expansion appears to have been Anderson Creek. It is likely that at an earlier stage, Anderson Creek did not breach across the main (west) axis of Chestnut Ridge anticline (Figure 4). At that stage Anderson Creek with its tributaries,

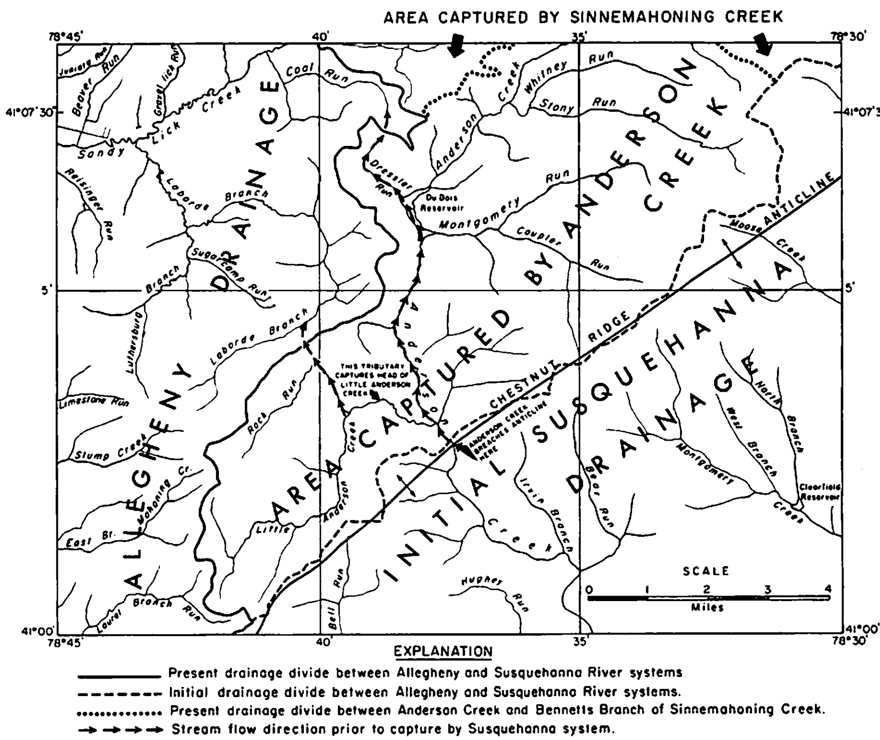


Figure 4. Watersheds of the southern Penfield area showing enchroachment of the Susquehanna drainage system into areas originally drained by the Allegheny system.

Irvin Branch and Bear Run, would have born a strong resemblance to the general pattern of Montgomery Creek and its tributaries. Anderson Creek between Home Camp and the axis of Chestnut Ridge, Montgomery Run, and Anderson Creek north of Home Camp probably drained north along Dressler Run, across the present drainage divide, and down Coal Run to Sandy Lick Creek. Little Anderson Creek, instead of swinging west at Anderson toward Anderson Creek, likely continued to flow north along the course of Rock Run, through the gap at Rockton Station, and into Laborde Branch (or even across and down Sugarcamp Run).

The lower part of Anderson Creek (southeast of the anticline axis), having a higher gradient and greater erosive capacity, breached the anticline and progressively took over the course of Anderson Creek as far as Home Camp. At this point, Montgomery Run, Anderson Creek above Home Camp, and Dressler Run were diverted to south-flowing tributaries. Simultaneously, a tributary (now the lower 1½ miles of little Anderson Creek) cut westward, capturing the remainder of Little Anderson Creek and Rock Run as well.

Anderson Creek is the southwesternmost stream draining the southeastern flank of Chestnut Ridge anticline. Because of the southwestern plunge of the anticline, it is reasonable that Anderson Creek should have been the one to effect the breach, as it had less of a gorge to cut below the resistant Burgoon Sandstone.

Anderson Creek is actually the left arm of the pincers incursion by which the Susquehanna system captured that portion of the Allegheny watershed flowing off the northwestern slopes of the elongate dome formed by Chestnut Ridge anticline in Clearfield, Elk, and Cameron Counties. The right arm of the pincers is Bennetts Branch of Sinnemahoning Creek.

## ACKNOWLEDGEMENTS

We wish to acknowledge the cooperation of Harbison-Walker Refractories Company and North American Refractories Company for granting permission to use certain valuable confidential information. We also recognize the assistance of the United States Corps of Engineers (Baltimore District) in providing drilling information connected with the Curwensville Dam project. The drilling records and soil survey reports from Interstate Route 80 were furnished by Mr. John Lambert, Soils Engineer with the Clearfield District office of the Pennsylvania Department of Transportation. We extend special thanks to Mr. Thomas Swinehart for his assistance in completing the field work for this report. A. D. Glover and G. B. Glass of the Pennsylvania Topographic and Geologic Survey and E. G. Williams of the Pennsylvania State University read the manuscript and made many valuable suggestions leading to improvement of this report. Finally, we wish to thank the coal operators and property holders in this area for their courtesy in providing access for geologic mapping.

# STRATIGRAPHY

## INTRODUCTION

The rocks exposed at the surface in the southern Penfield quadrangle are Mississippian and Pennsylvanian in age (Plate 1 and Table 1). Local thin deposits of unconsolidated Recent alluvium cover most of the major stream valleys. The surface units are as follows:

Conemaugh Group (Pennsylvanian) — lower 320 feet,
Allegheny Group (Pennsylvanian) — 240 to 320 feet,
Pottsville Group (Pennsylvanian) — 60 to 160 feet,
Pocono Formation (Mississippian) — upper 600 feet,
Approximate total — 1,250 to 1,425 feet.

Deep well drilling has penetrated approximately another 6,700 feet of section (Plate 2). The additional units encountered are:

Pocono Formation (Mississippian) — lower 400 feet,
Catskill Formation (Devonian) — approximately 400 feet,
Devonian "marine beds" — 4,900 to 5,100 feet,
Tully Formation (Devonian) — 110 to 160 feet,
Hamilton Group (Devonian) — 500 to 700 feet,
Onondaga Group (Devonian) — 50 to 100 feet,
Ridgeley ("Oriskany") Sandstone (Devonian) — up to 20 feet,
Helderberg Group (Devonian) — upper 50 feet only.

## SUBSURFACE STRATIGRAPHY

### Introduction

The western third of the report area was intensely drilled during exploitation of the gas pools there, while only scattered test wells cover the eastern two-thirds. While the detailed subsurface study possible from these extensive records is beyond the scope of this report, a number of well logs are diagrammed on Plate 2 and their probable correlation with wells in adjoining areas shown. In particular the wells of this area are correlated with wells described from southeastern Clearfield County by Edmunds (1968).

### Devonian System

#### *Helderberg Formation*

The upper 50 feet of the Helderberg Formation is a cherty dark limestone. No well in the area completely penetrates the Helderberg, but isopach data by Jones and Cate (1957) indicate that the total thickness should be about 125 to 155 feet.

It is possible that the Helderberg as used here may include the Shriver Limestone Member of the Oriskany Formation.

### *Ridgeley ("Oriskany") Sandstone*

The customary usage of the term "Oriskany" in subsurface work in western Pennsylvania is somewhat at variance with surface terminology in which the Oriskany Formation is composed of the Ridgely Sandstone and Shriver Limestone Members. In subsurface practice the Oriskany is usually treated as being identical with the Ridgeley Sandstone and the Shriver Limestone is either included in the Helderberg Formation or, if Jones and Cate (1957) are correct, it disappears.

The Ridgely ("Oriskany") Sandstone is usually calcareous and ranges from fine- to coarse-grained. It is the principal gas producing unit. The sandstone varies from a few inches to 20 feet thick, being mostly 5 to 10 feet.

### *Onondaga Formation*

The Onondaga Formation is a 50- to 100-foot thick unit consisting primarily of silty, shaly, and often cherty limestone. In some wells, the lower half to two-thirds grades to a calcareous siltstone. Thick calcareous shale interbeds are common throughout.

### *Tioga Bentonite*

Some wells, such as No. 1 Pennsylvania State Game Lands—Tract C (Fd 1), show several feet of Tioga bentonite between the Hamilton Group and the Onondaga Formation.

### *Hamilton Group*

The Hamilton Group is a 500- to 700-foot sequence of predominantly brown black to gray black shale. It is frequently calcareous, especially the lower half. The unit thins from east to west.

### *Tully Formation*

The Tully Fomation consists of 110 to 160 feet of limestone, shaly limestone, and calcareous shale.

### *"Upper Devonian Marine Beds"*

The "Upper Devonian marine beds" are 4,900 to 5,100 feet thick and are predominantly shale. The lower 400 to 500 feet is calcareous black shale. The remainder is an interbedded sequence of shale, siltstone, and sandstone, becoming progressively coarser upward. The interfingering relationship between the "Devonian marine" and the overlying Catskill redbeds is demonstrated by the occurrence of occasional thin redbeds in the upper several hundred feet of the Devonian marine of this area.

### *Catskill Formation*

The Catskill Formation is distinguished by a preponderance of red color. It interfingers with both the overlying Pocono Formation and the underlying "Devonian marine beds"; however, in most wells a clear, predominantly red zone stands out and this is taken as Catskill. For the most part the Catskill is red, reddish gray, and greenish gray shales and siltstones with occasional thick sandstone interbeds. In this area the Catskill is about 400 feet thick, and has thinned by facies change in the lower part from the 1200- to 1400-foot thick unit found in eastern Clearfield County.

## Mississippian System

### *Pocono Formation (lower 400 to 500 feet)*

The Pocono Formation in this area ranges from 700 to 950 feet thick. The loss in thickness appears to occur at both the top and bottom of the unit. The loss at the bottom, representing perhaps 100 feet, is the result of lateral facies gradation into the subjacent Catskill Formation. The loss at the top is the result of a beveling of the Pocono in connection with the Mississippian-Pennsylvanian unconformity. About 170 feet is eliminated by this beveling south to north across the report area.

The Pocono Formation in this area consists of an upper sandstone sequence (Burgoon Member, 130 to 300 feet thick), a middle red and green siltstone and shale sequence (equivalent to the Patton redbeds, about 200 feet thick), and a lower interbedded siltstone, shale, and sandstone sequence (400 to 500 feet thick). The upper sandstone (Burgoon) and middle red and green units are entirely exposed at the surface and described under the section on surface stratigraphy. The upper 60 feet of the lower sequence outcrop where the axis of Chestnut Ridge anticline crosses Anderson Creek. Well cuttings indicate that the lower sequence of the Pocono is a series of interbedded dark gray silt shales, medium light gray siltstones, and light gray to white, fine-grained sandstones. The interbeds appear to range from a few feet to 20 feet thick.

# SURFACE STRATIGRAPHY

## Mississippian System

### *Pocono Formation (upper 600 feet)*

Approximately 600 feet of the Pocono Formation outcrop at the surface in southern Penfield. Because of the thick mantle of sandstone rubble coming from the Burgoon Member at the top of the formation, much of the Pocono is poorly exposed except in artificial cuts, such as those made along Interstate Route 80, at the Clearfield Reservoir, and along the Baltimore and Ohio Railroad line along Anderson Creek.

As mentioned in the section on subsurface stratigraphy, the Pocono Formation in this area is roughly divisible into three units. The upper 60 feet of the lowest sequence is exposed where the axis of Chestnut Ridge crosses Anderson Creek.

The middle unit of the Pocono is a 200-foot thick sequence of red, green, and greenish gray clay shales, silt shales, siltstones, hackly claystones (mudstones), and sandstones. The red portion of this unit is equivalent to the Patton redbeds of subsurface terminology. The best and most complete exposure of this unit occurs along the cuts from Interstate Route 80 at Fd3, Fd6, and the west end of Clearfield Ae3. These provide overlapping sections covering the upper 160 feet. Detailed lithologies from these exposures are shown on Plate 3 and described under the section on the Mississippian-Pennsylvanian unconformity.

Miscellaneous short sections of the middle unit of the Pocono Formation are described in Appendix 1. The general nature and organization of the middle Pocono sediments, the presence of soft clays and root-worked zones, thin coal beds, minor unconformities, cross-bedding, ripple marks, and frequent plant material appear to indicate deposition in a fluvial-deltaic environment.

The Burgoon Sandstone Member forms the upper part of the Pocono Formation. The Burgoon is 300 feet thick in the No. 1 Mary E. Bailey well (Ff 12) in the southeastern corner of the report area (Plate 2). From there it thins rapidly northward and westward. The Burgoon is 160 feet thick along Interstate Route 80 at Clearfield Ae3, 130 feet in the State of Pennsylvania Tract C, No. 2 well (Ed2, Plate 2), approximately 210 to 170 feet along the various branches of Montgomery Creek, approximately 250 feet along the lower reaches of Bear Run and along Anderson Creek above Irvin Branch, and 170 feet in the Seyler well (Be 44, Plate 2).

Most or all of the thickness variation is ascribed to erosional loss at the top of the Burgoon in connection with the Mississippian-Pennsylvanian unconformity. The Burgoon is predominantly very light gray to white, very fine-grained to coarse-grained sandstone with occasional conglomerate to pebble size. In addition, the Burgoon of this area may contain up to 40 feet of dark shales and siltstones with some thin coal beds.

The best exposure of the Burgoon Member is at stations Fd3 and Clearfield Ae3 (see Plate 3 and the description under the section on the Mississippian-Pennsylvanian unconformity). Other good exposures of parts of the Burgoon Member are listed in Appendix 1.

The Burgoon Sandstone is probably a series of widespread, anastomosing fluvial deposits.

## Mississippian-Pennsylvanian Unconformity

The Mississippian and Pennsylvanian rocks of this area are considered to be separated by an extensive, though obscure, unconformity. The youngest

Mississippian rocks present are Pocono; the oldest Pennsylvanian are middle to upper Pottsville. There are no Loyalhanna or Mauch Chunk Formations (the Mississippian units normally overlying the Pocono).

In Somerset County in south-central Pennsylvania, the Pennsylvanian rocks rest unconformably upon the Mauch Chunk Formation, which with the Loyalhanna Formation, totals over 500 feet thick. Coming northward toward the area of this report, the unconformity bevels lower and lower until the last remnants of the Mauch Chunk disappear along an east-west line across southcentral Clearfield County.

So long as the Mauch Chunk red beds persist there is little problem in separating the Pennsylvanian and Mississippian sequences. However, once the Mauch Chunk is eliminated, confusion sets in. Chance (1884) introduced the initial error when he identified the red shales exposed along Anderson Creek, Montgomery Creek, Moose Creek, and elsewhere as Mauch Chunk. All of the overlying sandstones were then automatically assigned to the Pottsville Formation. Stevenson (1904, p. 203) appears to have clearly understood the problem when he wrote:

> "The great thickness assigned by earlier workers to the Pottsville in Clearfield is to be explained by the absence of the Shenango [Mauch Chunk] shales and lower beds, so that the Pottsville and Logan [Pocono] are continuous."

Stevenson's insight, however was ignored. Ashley (1940), in his report on the geology of the Curwensville quadrangle immediately to the south of this report, identified the Burgoon Member of the Pocono as Connoquenessing. He referred to the sub-Burgoon Pocono as Mauch Chunk-Pocono. This error persisted to as recently as 1960 when the Geologic Map of Pennsylvania (Gray and others, 1960) essentially repeated Chance's original mistake. Edmunds (1968) in the report on the northern half of the Houtzdale quadrangle (which lies immediately to the southeast of the Penfield quadrangle), correctly assessed the position of the unconformity and the almost complete absence of the Mauch Chunk. Edmunds' conclusions were based on the comparison of deep well records in the Houtzdale area with the long surface exposure at the Horse Shoe Curve along the Penn-Central Railroad west of Altoona where the Mauch Chunk still exists. Edmunds' proof, however, was not conclusive.

The recent construction of Interstate Route 80 through the Elliott Park and Clearfield 7½-minute quadrangles has provided an excellent and continuous series of exposures across the Mississippian-Pennsylvanian unconformity. In addition, it was possible to collect a number of plant fossils by which the position of the unconformity can be accurately and (assuming the validity of Mississippian-Pennsylvanian floral zonation) decisively located, and the relative age of the rocks thus established.

The lithologies and fossil plant collection localities are shown on Plates 3 and 4. As can be seen from the diagrams, the unconformity in this area occurs between two thick sandstones with only an occasional few feet of coal and coaly sandstone intervening. In spite of the extensive interval represented by the missing section, the unconformity is physically obscure.

The plant fossils were studied by Professor William C. Darrah and his results are included in this report as Appendix 2. Professor Darrah determined that the plant samples delivered to him were divisible into two distinct and chronologically separate groups. The lower group is characterized by *Adiantites* and *Triphyllopteris* which are representative of the Mississippian Pocono Formation (Osage-Kinderhook). The upper group is characterized by *Neuropteris tenuifolia* Brongniart, *Mariopteris nervosa* (Brongniart), and *Sphenophyllum emarginatum* Schlotheim, which distinguish the uppermost part of the Pennsylvanian Pottsville Group (upper Kanawha). Rocks containing specimens of these two distinct suites occur within as little as 15 feet of one another stratigraphically. No forms representing post-Osage Mississippian or pre-Kanawha Pennsylvanian occur in this sequence.

Referring to the paper by Read and Mamay (1964) on upper Paleozoic floral zones, the sequence along Interstate Route 80 shows their floral zone 8 resting directly and unconformably upon their floral zone 2.

The detailed lithologic description of the sections shown on Plate 4 follows:

| Station Fd 3 | *Thickness* |
|---|---|
| Curwensville Formation (Pottsville) | |
| *Coal blossom* (Mercer) | |
| *Underclay blossom* | |
| Elliott Park Formation (Pottsville) | |
| Upper Connoquenessing Sandstone Member | |
| *Sandstone*, medium-grained, light gray, few coaly fragments, 1- to 4-inch beds, cross-bedding, chaneling | 30 to 35 feet |
| *Sandstone*, coarse-grained, light gray, coal fragments, clay shale chips, carbonaceous material, beds up to 1 inch | 1 to 5 feet |
| *Sandstone*, fine-grained to very fine-grained, silty, medium-light gray, carbonaceous, coal stringers, beds to ½ inch, contains *Sphenophyllum emarginatum* Scholtheim, *Calamites suckowi* Brongniart, *Neuropteris tenuifolia* Brongniart, *Neuropteris*, *Mariopteris cf. nervosa* (Brongniart), *Cordaites* sp. (Flora sample 503) | 0 to 1½ feet |
| Coal, dirty (Quakertown ?) | 0 to ½ foot |
| Mississippian-Pennsylvanian unconformity. | ............ |
| Pocono Formation (Burgoon Member). | |
| *Sandstone*, very fine-grained to fine-grained, light gray to very light gray, beds to 8 inches | 35 feet |
| | Total appx. 68 feet |

| Station Fd 5 | *Thickness* |
|---|---|
| Pocono Formation (Burgoon Member) | |
| *Sandstone*, medium-grained with some pebbles to 5 mm, light gray to white | 5 feet |
| Cover | 60 feet |
| Pocono Formation (sub-Burgoon) | |
| *Claystone*, hackly to *clay shale*, grayish red to dark reddish brown | 1½ feet |
| *Clay*, white to grayish yellow, black streaks, root-worked | 3 feet |
| *Sandstone*, very fine-grained, clayey, medium light gray to very light gray to yellowish gray to light olive brown, limonite blebs, beds to 1 foot, cross-bedded | 11 feet |
| *Siltstone*, clayey, light olive gray, beds to 1 inch, plant fragments | 1½ feet |
| *Clay shale*, dusky yellow to grayish yellow, plant fragments | 2 feet |
| *Silt shale*, clayey, yellowish gray, clay laminae, beds to ½ inch | 8 feet |
| *Siltstone*, sandy, yellowish gray clay laminae, *Triphyllopteris latilobata* Read (flora sample 1019) | 3 feet |
| *Claystone*, hackly to *clay shale*, mottled grayish red and light gray to olive gray | 5 feet |
| *Sandstone*, very fine-grained, to *siltstone*, medium bluish gray to greenish gray, weathers light olive brown to dusky yellow, top 1 foot grades to clay with *carbonaceous streak* at top | 7 feet |
| *Claystone*, hackly, grayish red to reddish gray, soft | 3½ feet |
| Interbedded *claystone*, hackly and *clay shale*, mottled grayish red and dark greenish gray, very soft and nonresistant, weathers to very fine chips and powder, weathers red, some light to olive gray silty clay shale beds | 12 feet |
| | Total appx. 122 feet |

| Station Fd 6 | *Thickness* |
|---|---|
| Pocono Formation (sub-Burgoon) | |
| *Claystone*, hackly to *clay shale*, grayish red to dark reddish brown, weathers bright red | 17 feet |
| *Siltstone*, clayey, light olive gray, lumpy bedding | 1 foot |
| *Claystone*, hackly to *clay*, light gray to light olive gray to light yellowish gray, reddish at top, plastic, thin carbonaceous zone at top | 5½ feet |
| *Claystone*, hackly to *clay shale*, very dusky red to grayish brown, to brownish gray, some interbedded *siltstone*, dusky yellow in lower 4 feet which grades laterally to 4-foot *sandstone* | 8 to 9 feet |

| | Thickness |
|---|---|
| *Clay*, plastic, dusky yellow | ¼ foot |
| *Coal* and *coaly clay* | 0 to ¼ foot |
| Interbedded and laterally grading *siltstone* and *silt shale*, medium gray to light olive gray to dusky yellow to grayish red and dusky red, olive and yellow shades predominate, some reddish gray hackly *claystone*, top 4 feet contains *Adiantites cyclopteroides* Read, *Adiantites* sp., and *Calathiops* sp. (flora sample 504) | 14 feet |
| *Claystone*, hackly, mottled grayish red and light olive gray, rootlets, weathers to fine chips. | 18 feet |
| *Silt shale*, hackly, grayish red purple and light olive gray, micaceous, interbedded low-angle wedges 1 to 3 feet thick and 200 to 300 feet long, oscillation ripples, some very fine-grained sandstone, includes a bed of fish remains described by Professor Keith S. Thompson of the Peabody Museum of Natural History, Yale University (personal communication) as follows:<br>1. Numerous fragments of very fine fish spines from undetermined fishes.<br>2. Small numbers of scale fragments from paleoniscoid fishes.<br>3. Very numerous fragments of scales from an acanthodina fish.<br>4. Fragments of very thick bony plates which could not be attributed with certainty to any fish group.<br>5. Fragments of the dorsal spines of a pleuracanth fish.<br>6. Isolated tooth, presumably of fish origin. | 11 feet |
| *Claystone*, hackly to *clay shale*, grayish red purple to light olive gray | 1 foot |
| | Total appx. 104 feet |

| Stations Clearfield Ae3 and Ae2 | Thickness |
|---|---|
| Clearfield Creek Formation (Allegheny) | |
| *Sandstone*, medium grained, medium light gray, very micaceous, beds to 6 inches | 20 feet |
| *Clay shale*, silty, medium dark gray, siderite nodules | 12 feet |
| *Clay shale*, dark gray to medium dark gray | ½ foot |
| *Bone coal* (Clarion No. 3) | 6 to 8 inches |
| *Clay shale*, medium gray, siltier upward, two sandstone interbeds near top, plant fragments | 22 to 25 feet |
| *Coal* (Clarion No. 2) | 4 to 7 inches |
| *Clay shale*, medium gray, siltier upward, rootlets and lumpy bedding in top few feet, plant fragments | 14 to 22 feet |
| *Coal* (Clarion No. 1) | 16 to 20 inches |

| Curwensville Formation (Pottsville) | *Thickness* |
|---|---|
| *Underclay*, brownish gray, rootlets | 4½ to 5 feet |
| *Siltstone*, medium gray | 3 feet |
| *Clay shale*, medium dark gray, lower half poorly bedded with rootlets | 10 feet |
| *Coal*, shaly ( upper Mercer) | 1½ to 2 feet |
| *Sandstone*, fine-grained to very fine-grained, medium light gray to light brownish gray, plant fragments grades up to *siltstone*, clayey and sandy, medium dark gray, rootlets | 3 feet+ |
| *Cover* | 80 feet |
| *Coal and clay blossom* (lower Mercer) | |
| **Elliott Park Formation (Pottsville)** | |
| Interbedded *siltstone* and very fine-grained *sandstone* medium dark gray to grayish black, plant fragments | 9 feet |
| *Cover* | 6 feet |
| *Sandstone* (upper Connoquenessing) fine-grained to medium-grained, very light gray to light gray to light brownish gray, beds mostly from 2 inches to 2 feet, cross-bedded, thinner-bedded near top | 20 to 50 feet |
| *Coal* (Quakertown), very local | 0 to 1 inch |
| Interbedded *sandstone*, fine-grained to medium-grained, siliceous, very light gray with many small pits of dusky red clay giving the rock a moderate pink to pale red hue, lumpy bedding; and *clay shale*, mottled pink and yellowish gray lumpy bedding, *Neuropteris* sp. and *Cordaicarpus* sp. (Flora sample 971) | 0 to 6 feet |
| *Unconformity* | .......... |
| **Pocono Formation (Burgoon Member)** | |
| *Sandstone*, fine-grained to medium-grained, mostly very light gray, some to medium gray, some light gray *clay shale* beds to 2 feet, lower several feet interbedded with *silt shale* and *siltstone*, medium dark gray to dark gray, beds 0 to 6 feet, *Adiantities spectabilis* Read. (Flora samples 969 and 970) | 30 to 40 feet |
| Variable composition, but primarily dark silt shales, siltier and sandier toward top and bottom. Includes the following (no order implied): *Silt shale* medium gray, bearing *Lepidodendropis corrugatum* Dawson, *Lepidodendropsis* cf. *L. vandergrachti* (Jongmans), *Alcicornopteris* sp., and *Rhodea* cf. *R. Alleghenensis* Read (Flora samples 507 and 509); *silt shale*, grayish black to black, hackly; *silt shale*, black, papery, vitrain stringers; *siltstone*, fine-grained, micaceous, carbonaceous, plant fragments; *thin coal* | 30 to 40 feet |
| *Sandstone*, details as follows: | |
| 80–85 feet: very fine-grained to silt, medium light gray, micaceous, black and orange stain. | |

| | | Thickness |
|---|---|---|
| 40–80 feet: | very fine-grained to medium grained, very light gray | |
| 29–40 feet: | very fine-grained to coarse silt, light gray to light greenish gray, some layers almost silt shale, micaceous. | |
| 19–29 feet: | coarse-grained to very coarse-grained, granule and pebble conglomerate in top few feet, very light gray to light pinkish gray, yellow and black stain. | |
| 8–19 feet: | medium-grained to coarse-grained, very light gray to white, 1 foot pebble conglomerate bed at 10 foot level. | |
| 0– 8 feet: | medium-grained, very light gray | 85 feet |
| | | Total appx. 430 feet |

## Pennsylvanian System

### *General Stratigraphy*

The stratigraphic range encompassed by the Pennsylvanian rocks of this area extends from the upper Pottsville Group to the middle Conemaugh Group.

The stratigraphic nomenclature employed in this report for the Pottsville and Allegheny Groups is that proposed by Edmunds (1969) as shown in Figure 5. The presumed relationship between this usage and previous nomenclature is shown in Figure 6. The reasoning behind the creation of these new units, along with exact definitions and type sections, is given by Edmunds (1969). As can be seen from Figure 5 and the column of Plate 1, all units are based on key beds rather than lithologic homogeneity.

The Pottsville Group ranges from 60 to 160 feet thick. This variation stems from multiple causes, including internal thickening of lithologic units, internal addition of units, addition of units at the bottom, and differential compaction. Fundamentally, these thickness changes reflect the paleotopographic irregularity of the underlying Mississippian-Pennsylvanian unconformity surface.

The Allegheny Group varies from 240 to 320 feet thick; however 60 to 70 feet of this variation results from the incision of post-Allegheny channels into the top of the Allegheny Group and subsequent filling by the lower Mahoning sandstone of the Conemaugh Group. Ignoring this erosive loss, the Allegheny Group is between 300 and 320 feet thick.

The Conemaugh Group is the youngest geologic unit in this area (aside from alluvium) with a maximum thickness of 320 feet above the level of the upper Freeport coal at the hill just west of Reisinger Run where the Bush triangulation station is located. In addition, the lower Mahoning sandstone channel is incised another 60 to 70 feet below the upper Freeport coal over much of the report area, expanding the total Conemaugh to about 400 feet.

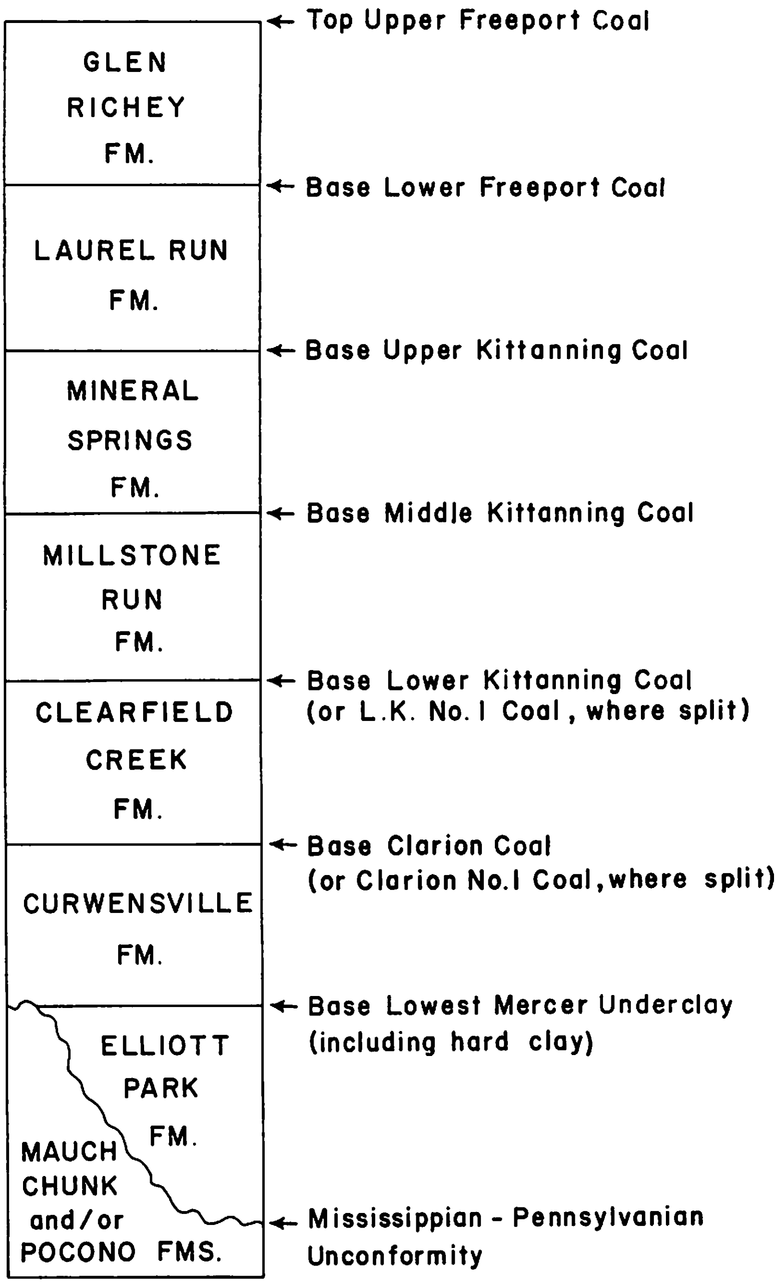


Figure 5. Formational subdivisions of the Pottsville and Allegheny Groups.

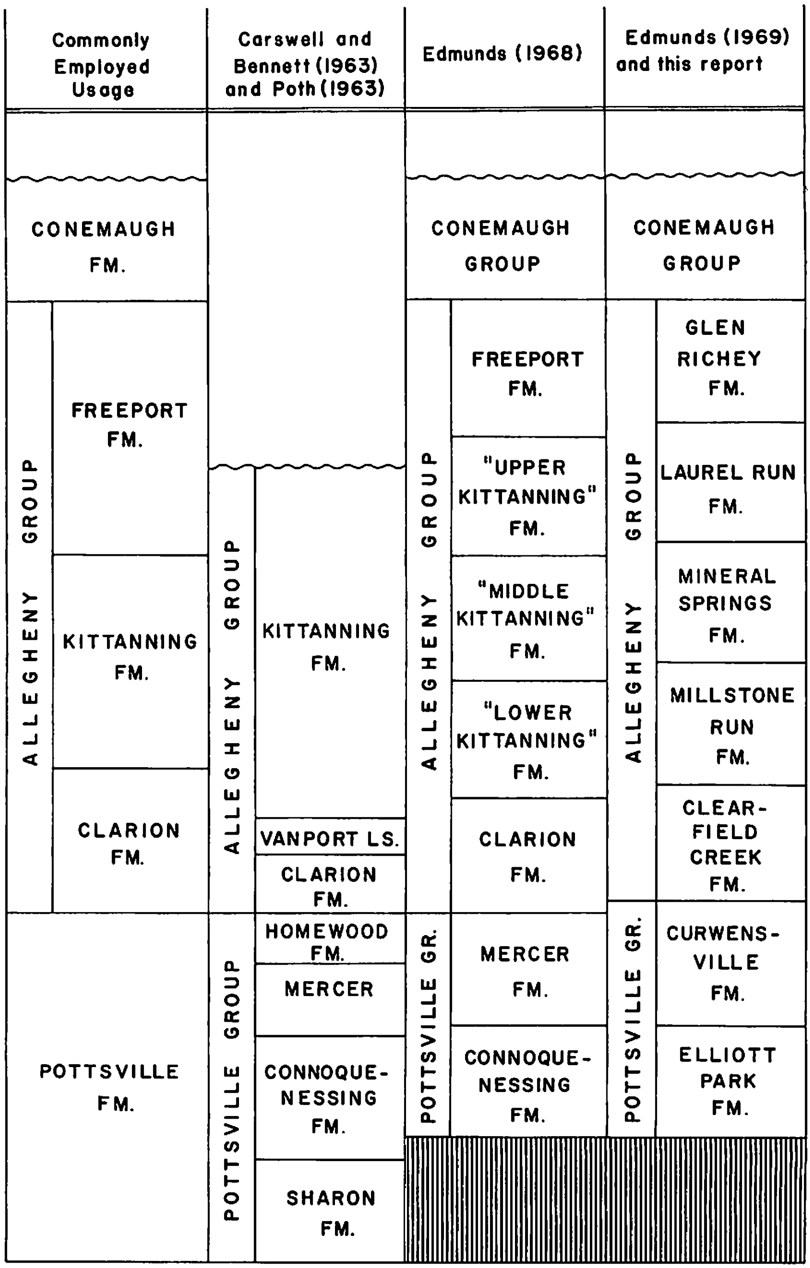


Figure 6. Comparative stratigraphic nomenclature for the lower Pennsylvanian of western Pennsylvania.

One available drill hole penetrates the greater part of the Conemaugh and Allegheny Groups (Bcl, Plate 5). It is included to show this long sequence in one vertical section. In this drill hole, Conemaugh channels have removed the upper part of the Allegheny Group.

### *Elliott Park Formation*

#### *General*

The Elliott Park Formation is the basal Pennsylvanian unit in the northeastern and northwestern quarters of the report area (Figure 7). It includes all rocks above the Mississippian-Pennsylvanian unconformity up to the base of the lowest Mercer underclay (including hard clay). It is missing by non-deposition in the south-central half of the area, and is up to 70 feet thick where present.

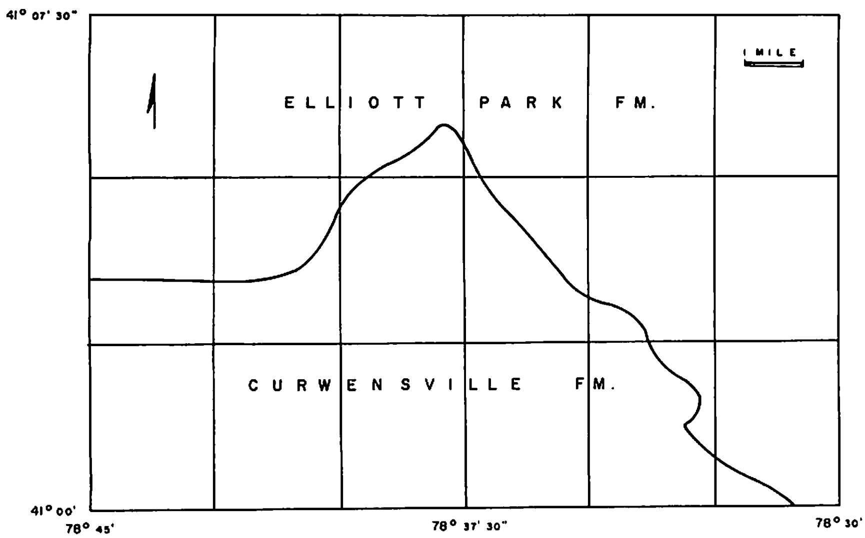


Figure 7. Basal Pennsylvanian units in the southern Penfield quadrangle.

Lithologically the Elliott Park Formation is simple, consisting almost entirely of the upper Connoquenessing sandstone with local small pods of "Quakertown" coal and interbedded sandstone and clay shale at the base.

Although widely exposed in northeastern Elliott Park quadrangle, the Elliott Park Formation is almost impossible to distinguish from the underlying Burgoon Sandstone, so similar are their general lithologies. Were it not for two excellent exposures along recently constructed Interstate Route 80, no separation could have been made. The relation between the Elliott

Park Formation and the Burgoon Member of the Pocono Formation is shown on Plates 3 and 4. Station Clearfield Ae3 is the type section of the Elliott Park Formation (see Edmunds, 1969).

In general the Elliott Park Formation is as follows (descending order):

Upper Connoquenessing Sandstone (0 to 65 feet).
"Quakertown" coal, very local (0 to 6 inches).
Interbedded sandstone and clay shale, very local (0 to 6 feet).

*Interbedded Sandstone and Clay Shale*

This is an extremely local unit with an observed maximum thickness of 6 feet at station Clearfield Ae3 (Plate 3). The sandstone is fine- to very fine-grained, micaceous, lumpy, basically very light-gray, but with numerous pits of dusky-red clay which give the rock an overall moderate pink to pale red color. The clay shale is mottled pink and yellowish gray.

Because of their thinness and local nature, these pale red sandstones and shales have been seen in place only at station Clearfield Ae3, but have been observed as float elsewhere near the presumed position of the Mississippian-Pennsylvanian unconformity. Lacking better evidence, this float may be useful in approximately locating the unconformity.

This unit probably represents the lower Connoquenessing sandstone. It is our opinion that well-developed lower Connoquenessing sandstone as well as Sharon shales, coal, and conglomerate are probably missing by non-deposition.

*"Quakertown" Coal*

A thin (0 to 6 inches) dirty coal occurs very locally in the channel bottoms below the upper Connoquenessing sandstone. It is referred to as "Quakertown" solely on the basis of its stratigraphic position and not on any evidence that it is physically or even gentically related to the more extensive Quakertown coal farther west in Pennsylvania.

*Upper Connoquenessing Sandstone*

The upper Connoquenessing sandstone is 0 to 65 feet thick and makes up the greatest part of the Elliott Park Formation. Most of the upper Conn-quenessing is a fine- to medium-grained, very light to light gray or light brownish gray sandstone with bedding from one inch to two feet thick, cross-bedding, internal channeling, and carbonized plant fragments. Locally, the lower several feet may be medium- to coarse-grained sandstone with clay shale chips to four inches across, carbonized plant material, and fragments of hard clay as at Fd4. Below this, and directly above the "Quakertown" coal is 0 to 2 feet of silty, fine- to very fine-grained sandstone with thin coal stringers and abundant carbonized plant material. In places the upper 10 to 15 feet of the upper Connoquenessing is interbedded siltstone and very fine-grained sandstone, medium dark gray to black, with plant fragments and rootlets.

### *Curwensville Formation*

#### *General*

The Curwensville Formation includes all rocks above the base of the lowest Mercer underclay (including hard clay) and below the base of the Clarion no. 1 coal. The Curwensville is a highly complex unit displaying unusually rapid lateral and vertical variability. Its thickness ranges from approximately 60 to 110 feet.

It is difficult to make a useful lithologic description of so highly variable a unit as the Curwensville Formation. Something of its general makeup can be seen from measured sections shown on Plate 6 and drill holes on Plate 21. Broadly, in its most complete form, the lithologic sequence is as follows (descending order):

Clarion no. 1 (Bigler) underclay (0 to 10 feet).
Homewood Sandstone (channel) (0 to 60 feet).
Dark shale grading up to clay shale and to sandstone (0 to 20 feet).
Upper Mercer no. 2 coal (0 to 2½ feet).
Underclay (0 to 4 feet).
Dark shale, silt shale, and sandstone (0 to 40 feet).
Upper Mercer no. 1 coal (0 to 2 feet).
Underclay (0 to 10 feet).
Conglomeratic channel sandstone (0 to 50 feet).
Silt shale and clay shale (0 to 15 feet).
Lower Mercer no. 3 coal, often as two thin coals with sandstone between (0 to 15 feet).
Dark clay shale or claystone grading up to siltstone and sandstone (0 to 35 feet).
Lower Mercer no. 2 coal (0 to 6 feet).
Mixed claystone, siltstone, underclay, hard clay, and sandstone sequence (2 to 20 feet).
Lower Mercer no. 1 coal (0 to 4 feet).
Lower Mercer hard clay and underclay (0 to 17 feet).

Generally speaking, the lower three coals and their associated sediments seem to be closely related and probably represent splits of a single coal complex. Between the third and fourth coals there appears to be a widespread unconformity, as witnessed by the deeply incised, sandstone-filled channels originating between those coals. The relationship between the upper two coals is less distinct, but there is a broad parallelism, and they may represent individual splits of a second coal complex. In the report on the northern half of the Houtzdale quadrangle to the immediate southeast Edmunds (1968) observed that there are basically two major coals in the Curwensville Formation (Mercer Formation of that report), although each may break up into several splits. It seems not unlikely that the two coal groups of the Curwensville Formation in southern Penfield quadrangle are correlatives of the upper and lower Mercer of the Houtzdale quadrangle.

This speculation seems further supported by the apparent convergence within each of the two sets of coals to the southeast in the Curwensville quadrangle (Appendix 3).

For convenience, the lower three Mercer coals will be referred to as lower Mercer no. 1, no. 2, and no. 3 coals in ascending order. The upper two Mercer coals wil be referred to as upper Mercer no. 1 and no. 2 coals upward. This is not to be taken as an exact correlation to the lower and upper Mercer coals as used farther west in Pennsylvania.

Additional information on the Curwensville Formation in north-central Luthersburg, acquired after initial completion of this report, is given in the addendum (Page 000 and Figures 37 and 38).

*Lower Mercer Hard Clay and Underclay*

The lower Mercer clay is a variable and somewhat complex unit consisting of hard clay (flint clay) and soft clay (underclay), but also locally grading into or including pockets of shale or sandstone. Thickness is 0 to 17 feet. The hard clay is limited to the area where the Curwensville Formation is or virtually is the basal Pennsylvanian unit (i. e., where the Elliott Park Formation is very thin or absent and the lower Mercer hard clay lies directly or almost directly upon the Mississippian Burgoon Sandstone). The soft clay occurs where underlain by the Elliott Park Formation (Figure 7 and Plate 19).

*Lower Mercer No. 1 Coal*

The lower Mercer no. 1 coal seems to be generally present throughout the report area, but varies from a black coaly shale streak less than an inch thick to a very shaly, bony, dull coal over four feet thick. Between stations Cf7 and Cf9, a distance of 800 feet, lower Mercer no. 1 passed from a thickness of 16 inches to 50 inches and back to 26 inches.

*Mixed Claystone, Siltstone, Underclay, Hard Clay, and Sandstone Sequence above Lower Mercer No. 1 Coal*

The interval between lower Mercer no. 1 and no. 2 coals varies from 2 to 20 feet and contains a wide diversity of lithologies including claystone, siltstone, underclay, hard clay, semi-hard clay, and sandstone. Rootlets, plant fragments and coal stringers are common.

*Lower Mercer No. 2 Coal*

The lower Mercer no. 2 coal is generally at least 1½ feet thick except where channeled out from above. In some areas it develops a 2- to 3-foot internal parting with the entire unit increasing to as much as 6 feet. The coal itself is usually dull, shaly and bony. The parting varies from black shale to heavily root-worked siltstone and sandstone.

*Dark Clay Shale or Claystone Grading up to Siltstone and Sandstone above Lower Mercer No. 2 Coal*

Except when cut out from above, this interval is usually about 10 to 35 feet thick. Although the proportions may vary, it is usually an upward gradation from black claystone or clay shale with plant fragments and occasional siderite nodules into dark gray siltstone or silt shale and into medium gray sandstone, often siliceous and strongly root-worked. Drill holes indicate that much or all of this sequence grades laterally into underclay.

Williams and Nickelsen (1958) found unspecified elements of their fossil zone no. 1 at this position at Cf15 (characteristic zonal fossil: *Lissochonetes*).

*Lower Mercer No. 3 Coal*

What is here called the lower Mercer no. 3 coal is actually a pair of thin coals or coaly zones separated by a few feet (locally up to 15 feet) of sandstone overlain by finer lithologies. This peculiar sequence is frequently useful as a marker.

*Silt Shale and Clay Shale above Lower Mercer No. 3 Coal*

This interval varies from black to medium gray clay shale or silt shale occasionally grading up to siltstone or thin-bedded sandstone. A poor specimen of a chonetid brachiopod was found in this shale at Ef3.

*Conglomeratic Channel Sandstone*

This sandstone is incised into the underlying shale and is clearly a channel filling. It varies from fine-grained sand to granule-conglomerate, and contains plant fragments up to trunk-size. The bedding is in long, flat cross-stratifications traversing the unit from top to bottom.

*Upper Mercer No. 1 Underclay*

This underclay is poorly exposed at the surface, being about 1 foot thick at Ce20 and absent except as a weathering profile at Be49 (Plate 6). In drill holes it is up to 10 feet thick and may be overlain by several feet of shale.

*Upper Mercer No. 1 Coal*

The upper Mercer no. 1 coal is exposed at the surface only at Be49 (Plate 6) although it appears in a number of drill holes. At Be49 it was 14 inches of dull, dirty, high fusain coal. Its thickness ranges from 0 to about 2 feet.

*Dark Shale, Silt Shale and Sandstone above Upper Mercer No. 1 Coal*

This interval is exposed at the surface only at Be49 (Plate 6) where it consisted of 3 to 7 feet of medium dark gray to olive gray, hackly, silty clay shale with rootlets and plant fragments. Drill holes indicate that this interval may open up to as much as 40 feet and include shales and sandstone.

*Upper Mercer No. 2 Underclay*

Up to four feet of underclay occurs at this position in some drill holes The only surface exposure of this interval, at Be49, (Plate 6) showed no underclay, although the underlying shale was root-worked.

*Upper Mercer No. 2 Coal*

The upper Mercer no. 2 coal is exposed at the surface only at Be49 (Plate 6). Here it consists of 14 inches of bright, but shaly, high sulfur, high fusain coal which grades up to a 1-foot dark gray, papery "cannel" shale. Underlying the 14-inch coal at Be49 was a 1-foot carbonaceous sandstone overlying 2 to 6 inches of black, coaly silt shale which could also be considered as part of the upper Mercer no. 2 coal. Upper Mercer no. 2 also appears in several drill holes from the area.

*Dark Shale Grading Up to Clay Shale and to Sandstone Sequence above Upper Mercer No. 2 Coal*

This interval is exposed at the surface only at Be49 where it consists of 3 feet of a platy, grayish black silt shale with purple brown iridescent stain and siderite nodules which grades up to 4 feet of soft, papery black clay shale which grades up to 9 feet plus of soft, medium dark gray clay shale which becomes siltier and interbedded with sandstone upward. This section appears in some drill holes.

*Homewood Channel Sandstone Member*

The Homewood Sandstone is 0 to 60 feet thick and unconformable at the base. In most instances the Homewood Member is a very fine-grained to coarse-grained, light gray, clayey sandstone with beds ranging from a few inches to several feet thick. In a number of places, however, it is very massive with single beds 3 to 36 feet thick and thus having an appearance strikingly different from that of any other Pennsylvanian sandstone in the area. The thicker beds are medium- to very coarse-grained, very light gray to white, displaying strong tabular cross-bedding (Figure 8) in sets ranging from a few inches to a few feet thick (except at Df20 where the entire 30-foot thick unit appears to be a single massive cross-bed set). The massive character of these thick beds appears to stem from the total lack of silt- and clay-size material which produces the bedding-plane partings in thinner-bedded sandstones. The finest grain-size is probably in the fine-grained sand range.

The massive Homewood Sandstone bed was quarried at Curwensville Ea3 (Figure 9), Curwensville Ea2, Ff11, and Df20. It forms rock cities at Curwensville Da2 (Bilgers Rocks), Df23, and Ef1. Because of the peculiar

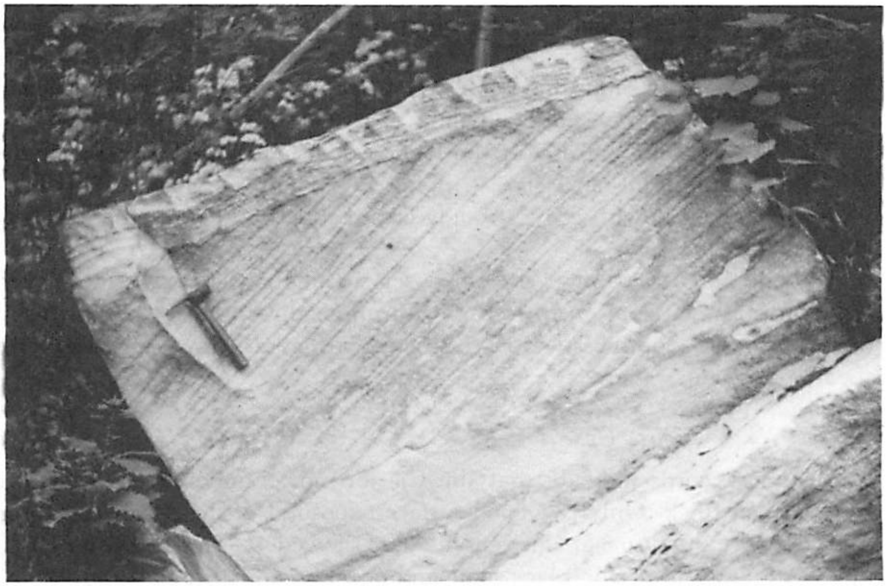

Figure 8. Float block of Homewood Sandstone below Ef7.

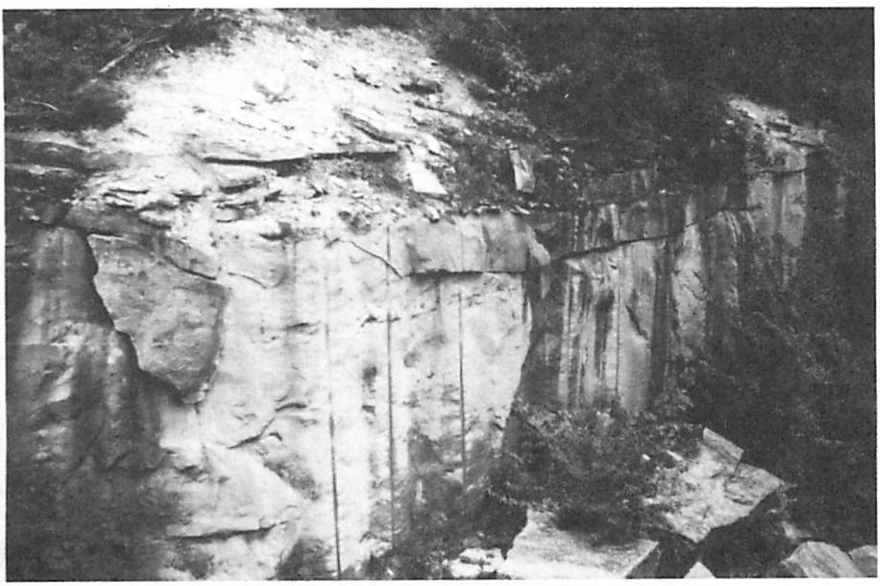

Figure 9. Quarry face in Homewood Sandstone at Curwensville Ea3.

nature of its cross-bedding it is not clear how the mas.ive bed at Df20 is related to other occurrences of the Homewood.

Above the massive bed at Curwensville Ea3 is 2 to 8 feet of very fine-grained, light-gray sandstone lying in lenses 15 to 30 feet wide. Above that is several feet of Clarion no. 1 soft clay.

The base of what is probably the Homewood Sandstone is exposed in the highwall of the semi-hard clay stripping Ef5. Here it is fine- to medium-grained, light yellowish gray, strongly cross-bedded, and composed of 3- to 10-foot thick beds.

Direction of the tabular cross-bed sets in all of the above mentioned exposures ranges from north to east with minor directions to the northwest and southeast. Southwestward cross-bed bearings are rare and westward bearings absent.

### *Clarion No. 1 (Bigler) Underclay*

Drilling records indicate that the Clarion no. 1 underclay varies from 0 to 10 feet thick. Only two good surface exposures of the clay were found in the report area. One at Curwensville Ea3 showed 4½ feet of medium light gray soft clay with a thin black shale and possibly more soft clay above lying directly on top of the Homewood Sandstone. The other exposure, a test pit at Bf28, showed a minimum of 5 feet of soft, medium light gray underclay grading up to a medium gray, root-worked silt shale directly below the Clarion no. 1 coal. It appeared to be at least 6½ feet thick in a poor exposure at Bf27.

## *Clearfield Creek Formation*

### *General*

The Clearfield Creek Formation includes all rocks above the base of the Clarion no. 1 coal and below the base of the Lower Kittanning no. 1 coal. The formation is poorly exposed at the surface although fairly well defined in drill holes (Plates 7 and 21). The Clarion no. 1 coal seems to be generally wide-spread, but somewhat thin and sometimes unconformably cut from above. The lower Kittanning no. 1 coal, a widespread seam in eastern Clearfield County (Edmunds, 1968), has deteriorated, except locally, into an obscure coaly zone near the base of the lower Kittanning underclay.

The surface exposures and all drill holes (except Bc1) that show the Clearfield Creek interval are concentrated in the southeastern quarter of the Luthersburg quadrangle. The formation in that area is normally about 50 or 70 feet thick except where local low swales, containing the lower Kittanning no. 1 coal, unconformably overlie as little as 20 feet of remaining Clearfield Creek sediments. Where the Kittanning sandstone is well developed, the Clearfield Creek Formation is expanded to as much as 80 feet.

A generalized sequence for the Clearfield Creek Formation is as follows (descending order):

Underclay (0 to 10 feet).
Kittanning sandstone with unconformity at the base (10 to 75 feet).
Shale sequence (0 to 35 feet).
Clarion no. 2 coal (0 to 2 feet).
Shale, sandstone and underclay sequence (0 to 35 feet).
Clarion no. 1 coal (0 to 2½ feet).

Drill hole Bc1 (Plate 5), a short distance north of the report area, shows an additional short interval overlying the 35-foot shale sequence above Clarion no. 2 coal. This short interval, which appears not to exist in southern Penfield, consists of several inches of underclay, overlain by one inch of coal (Clarion no. 3), overlain by a few feet of dark shale containing fossils characteristic of the Clarion no. 3 roof shale. Southward into the report area, this interval is apparently cut out by the unconformity associated with the Kittanning sandstone.

The three Clarion coals are everywhere separated in this area. In southwestern Clearfield County and in Centre County, these three seams converge into a single thick bed (Edmunds, 1968 and Glass, 1971). Hence they are actually splits of a single coal.

Measured sections of the Clearfield Creek Formation are shown in Plate 7.

Additional information of the Clearfield Creek Formation in north-central Luthersburg, acquired after inital completion of this report, is given in the Addendum (Page 00 and Figures 37 and 38).

*Clarion No. 1 Coal*

Although thin and locally cut out by the Kittanning sandstone channel, drilling records show the Clarion no. 1 coal is generally persistent. The only clear surface exposure of Clarion no. 1 is at Bf28 where it is 30 inches of moderately bright coal with no major partings.

*Shale, Sandstone, and Underclay Sequence above Clarion No. 1 Coal*

The thickness of the interval between Clarion no. 1 and no. 2 coals varies from about 15 to 35 feet. This unit consists of a lower silt shale (medium gray to black) grading up through interlaminated sand-siltstone or sand-silt shale through thin-bedded to fissile sandstone (often root-worked and siliceous with many limonite-filled, pin-head pits in the upper part), and finally into underclay.

In some instances a local unconformity develops at the contact between the thin-bedded, silicéous sandstone and the overlying underclay. At Bf16 the underclay obviously truncates the south-dipping bedding of the thin-bedded sandstone, but the contact between the two was nonetheless an imperceptible gradation. The implication seems to be that the underclay, at least in part, represents a zone of weathering and root-working on top of the sandstone.

From Bf28 and Bf29 to Bf30 the underclay is replaced by a sandstone which rests paraconformably on the lower thin-bedded siliceous sandstone. The unconformity is still distinct, however, because of an obvious root-worked zone at the top of the lower sandstone and the local presence of up to 15 inches of very soft, crumbly, gray clay shale between the two sandstones.

*Clarion No. 2 Coal*

Although thin and frequently cut out by the Kittanning sandstone channel, the Clarion no. 2 coal seems persistent. Surface exposures largely concentrated in the south-central Luthersburg quadrangle, show Clarion no. 2 as 3- to 6-inches of coal or shaly coal. Most drill holes in southeastern Luthersburg show it to be 0- to 1-foot thick.

An exposure of what is interpreted to be Clarion no. 2 coal at Rockton Station (Be27) is 21 inches thick. This identification is somewhat doubtful and is based on the presence of the thick overlying dark shale containing siderite nodules and rare *Orbiculoidea* sp.

The drill hole at Bc1 shows Clarion no. 2 split into an upper 3-inch, and lower 9-inch shaly coal separated by 44 inches of siltstone or silt shale.

*Shale Sequence above Clarion No. 2 Coal*

It seems unlikely that the original full development of this unit has been preserved anywhere in the southern Penfield area. The unconformity associated with the Kittanning sandstone appears to have cut out much of this unit everywhere. Just north of the area in the drill hole Bc1 the unconformity has lifted high enough so that the Clarion no. 3 coal is preserved. Here, the Clarion 2 to Clarion 3 interval is 43 feet. Along the southern edge of the area around Bell Run the entire unit is cut out and replaced by Kittanning sandstone. The sections available between these extremes show a 15- to 25-foot, upward-grading section of dark silt shale, silt shale, interlaminated sand-silt lithologies, and fissile to thin-bedded sandstone. The dark shale dominates this interval to the north and disappears to the south. Similarly, the siderite content decreases from north to south.

Fossils found in this sequence include a few rare *Orbiculoidea* sp. between Be26 and Be27 and a pectin, probably *Dunbarella whitei* (Meek), in the core from drill hole Bc1.

*Kittanning Sandstone*

The Kittanning sandstone and laterally related lithologies is best developed (i.e., thickest) along the southern edge of the report area and southward in the adjacent quadrangle. It rests unconformably on subjacent rocks and thickens largely by channeling at the erosional expense of these lower units.

The Kittanning sandstone and its related sediments vary in thickness from a few feet to as much as 70 feet in the deepest channel-ways. In the main channels the basal unconformity is quite distinct. Laterally, however, over what were presumably interfluves, the unconformity appears to become an obscure paraconformity, lost in the underclay or in associated flat-bedded sediments.

Lithologically, the Kittanning sandstone is predominantly very fine-grained to medium-grained, light gray, clayey sandstone with beds mostly ranging from a few inches to one or two feet thick. The bedding is arranged in large, cross-stratifications which traverse the unit from top to bottom in a horizontal distance of several hundred feet (point bars). Upward and also laterally away from the deeper parts of the channel-ways, it often grades to fissile sandstones and into rocks composed of interlaminated silt and sand.

Plant fossils are common and range from fine fragments to branch size.

*Lower Kittanning No. 1 Underclay*

The underclay referred to here is specifically that underlying the lower Kittanning no. 1 coal. This interval is exposed infrequently; however, a four-foot, weathered section was observed at Bf16. Drill hole records indicate that the lower Kittanning no. 1 underclay is not persistent. It is present in the area south of Greenville and between Little Anderson Creek and Luthersburg, but missing in the Bell Run area. Where present, it is up to 15 feet thick.

The nature of the change in thickness of this underclay is not clear. Experience with underclays indicates lateral gradation into other lithologies is most likely, but non-deposition or erosion is possible.

## *Millstone Run Formation*

*General*

The Millstone Run Formation includes those rocks lying above the base of the lower Kittanning no. 1 coal and below the base of the middle Kittanning coal. That part of the formation including and above the lower Kittanning no. 3 coal is well exposed in the many strip mines on that seam (Plate 8), but the lower part is less frequently seen. Lower Kittanning no. 1 coal is usually thin or absent, but its position can usually be distinguished in drill holes or clear surface exposures. The middle Kittanning coal, overlying the Millstone Run Formation, is a distinctly persistent bed.

The Millstone Run Formation is generally 60 to 75 feet thick. In a few very local situations where a major slump block has occurred in connection with fluvial channel-cutting late in the Millstone Run depositional cycle and the normal channel-filling has not followed, the middle Kittanning coal is laid down directly in this depression and the thickness of the Millstone Run Formation may be as little as 35 feet.

A generalized sequence for the Millstone Run Formation is as follows (descending order):

Middle Kittanning underclay (0 to 7 feet).

Lower Worthington channel sandstone, unconformable at base (0 to 55 feet).

Sandstone and associated finer lithologies with unconformity at base, includes lower Kittanning no. 4 coal in extreme southeast Elliott Park quadrange (0 to about 40 or 50 feet).

Dark shale grading up to silt shale or clay shale and to interbedded siltstone and sandstone (0 to 50 feet).

Lower Kittanning no. 3 coal (0 to about 3½ feet).

Dark shale and/or claystone grading up to underclay (5 to 30 feet).

Lower Kittanning no. 1 coal (0 to 2½ feet).

In Centre and southeastern Clearfield Counties the lower Kittanning coal exists as a single thick seam with one rider coal. Coming westward this single seam breaks up into four individual beds. The lowest split (lower Kittanning no. 1) generally persists east of the Susquehanna River, but beyond that is frequently absent. Except for very local occurrences the second split, lower Kittanning no. 2, is absent west of the Susquehanna. When the lower Kittanning splits up, the third coal, lower Kittanning no. 3, becomes the principal mined seam and is almost universally present across the width of Clearfield County including this report area. The upper split, lower Kittanning no. 4 reaches as far west as the southeastern corner of this report area (Plate 8), but is missing west of there.

*Lower Kittanning No. 1 Coal*

Little information is available on lower Kittanning no. 1 coal except in map rectangles Ae, Bf, Cf, and Df. It probably equates to the coaly stringers recorded about 25 feet below lower Kittanning no. 3 in drill hole Bc1 (Plates 5 and 8). It is also interpreted to be the coal blossom at the top of the section at Be26, although the correlation there is questionable. Examination for lower Kittanning no. 1 at points were it should appear in road banks and other outcrops failed to show its presence.

Small strip mines were opened on lower Kittanning no. 1 at Bf25, Cf23 and Df17 and 18. The only surface exposure was at Df18 where lower Kittanning no. 1 was over 19 inches thick. These few mines and drilling records, indicate that lower Kittanning no. 1 is present in the area between Little Anderson Creek and Luthersburg and west from there at least to Prescottville in the adjacent DuBois quadrangle. In the Luthersburg area, drill records indicate the coal to be locally up to 2½-feet thick.

Drilling shows the lower Kittanning no. 1 to be absent in the area around Bell Run.

In general, the lower Kittanning no. 1 coal, as well as some of the immediately overlying rocks, are best developed where the Kittanning sandstone of the underlying Clearfield Creek Formation has incompletely filled the channel in which it was deposited.

### *Dark Shale, Claystone, and Underclay Sequence above Lower Kittanning No. 1 Coal*

The interval between lower Kittanning no. 1 coal (or its horizon when absent) and lower Kittanning no. 3 coal varies from 5 to 30 feet. The presence of the thicker expression of this unit tends to coincide with the occurrence of the lower Kittanning no. 1 coal.

The only complete surface exposure of this unit was measured at Df18, as described in the following section:

| | | |
|---|---|---|
| Coal, lower Kittanning no. 3 | 2 ft. | 1 in. + |
| Underclay, many plant fragments top 1 foot | 6 ft. | |
| Claystone, very sandy, light gray | | 3 in. |
| Clay shale, highly ferruginous | | 6 in. |
| Clay shale, medium dark gray, lumpy and root-worked | 3 ft. | |
| Interlaminated sand-silt shale | | 3 in. |
| Dark clay shale, olive black | 3 ft. | |
| Dark clay shale, black, fine chips | | 4 in. |
| Coal, lower Kittanning no. 1 | 1 ft. | 7 in. + |
| | 17 ft. | 0 in. |

Based on drill holes, the maximum development of this interval shows 10 to 15 feet of dark shale overlain by several feet of clay shale and up to 20 feet of underclay. Proportions of the three lithologies vary from place to place.

Since this interval is essentially a channel filling, away from the deeper parts of the channel, it thins primarily by loss from the bottom. The dark shale disappears first, then the clay shale, and last the lower part of the underclay.

Except for rootlets and other plant fragments, no fossils were found in this section.

### *Lower Kittanning No. 3 Coal*

Except in a few very local instances where it has been relpaced by an overlying channel sandstone, the lower Kittanning no. 3 coal seems to be everywhere present. Its thickness (ignoring cut-outs), ranges from about 1½ to 3½ feet. The seam is generally bright, clean coal with a half-inch bony coal layer about one foot from the top and often a half-inch bony or shaly parting a few inches from the base.

*Sequence above Lower Kittanning No. 3 Coal of Dark-colored Shale Grading up to Lighter-colored Shale and Interbedded Siltstone and Sandstone*

Overlying the lower Kittanning no. 3 coal is a gradational upward coarsening sequence of dark-colored clay shale, dark-colored silt shale, lighter-colored silt shale, siltstone, and sandstone. The rate of gradational coarsening and the proportions of the various lithologies are not everywhere uniform, but the general trend from finer to coarser clastics upward prevails in most exposures.

The sequence is terminated by a widespread unconformity which appears to correspond to the surface upon which the lower Kittanning no. 4 coal was deposited to the east. The rocks directly below the unconformity are often weathered or root-worked. The westernmost remnant of the lower Kittanning no. 4 occurs at Clearfield Af4 and Clearfield Af55 (see also Glover, 1970).

This unconformity is distinct from a still higher (later) unconformity occurring in the Millstone Run depositional cycle. These two unconformities are hereafter referred to as the "upper unconformity" and "lower unconformity." The upper unconformity is the one which has been found associated with the late phases of the Millstone Run cycle of eastern Clearfield County (Edmunds, 1968, "lower Kittanning" Formation of that report). The lower unconformity has not been distinguished in eastern Clearfield County except as the contact between lower Kittanning no. 4 coal and subjacent rocks.

The total thickness of this sequence prior to truncation by the lower unconformity is unknown. The maximum section remaining is 40 or 50 feet. At Clearfield Af4 where the lower Kittanning no. 4 is still present, the interval between that coal and lower Kittanning no. 3 is 33 feet.

It is difficult to assess the true lateral relationship between the different lithologic elements of this interval. The basal dark shale is best developed in the central, west-central, and southwestern part of the Luthersburg quadrangle. It is unclear, however, if this increased thickness is the result of facies change from part of the lighter colored shales to the east or by addition of dark shale at the base. The latter would require thickening of the total unit, which does not appear to occur; but extra cutting by the unconformity at the top could compensate for addition at the bottom.

At the same time, the invertebrate zone overlying lower Kittanning no. 3 coal expands from a few feet in the southern Elliott Park and southeastern Luthersburg quadrangles to as much as 20 to 25 feet in north-central and western Luthersburg. The expansion of the invertebrate zone does not, however, coincide exactly with the increasing thickness of the dark shales; the former opening to the north and west and the latter to the west and southwest.

One element of the lithology remains relatively constant. The zone of siderite nodules and bands occupies an interval 15 to 25 feet thick above lower Kittanning no. 3 coal, regardless of other lithologic variations. The volume of siderite appears to increase to the northwest.

Invertebrates of the sequence include *Lingula* sp. *Chonetes* sp. *Mesolobus* sp., and pectins. Plant fragments also occur and are largely confined to the few inches immediately above lower Kittanning no. 3 coal and to the coarser-grained upper part of the section.

*Sandstone and Associated Finer Lithologies with Unconformity at Base*

This interval overlies a lower unconformity and itself is cut at the top by an upper unconformity, with the result that the section is highly variable in both lithology and thickness.

In the southeastern corner of the report area (Clearfield Af4 and Af55) a few inches of coal mark the base of the unit. This is the westernmost remnant of lower Kittanning no. 4 coal. Westward, the lower unconformity appears to represent the equivalent of the surface upon which lower Kittanning no. 4 was deposited.

The lower unconformity lies between 10 and 40 feet above the level of lower Kittanning no. 3 coal. The lower figure represents maximum incision of the channels in which this unit is deposited.

Lithologically this unit consists of very fine-grained sandstones (usually thin-bedded), interlaminated sand-siltstones or sand-silt shales, silt shale, and dark silt shale. In general, it appears to be somewhat finer-grained than the usual channel-fill sequence encountered in the Allegheny and Pottsville Groups. The filling of these channels appears to be a thickening and draping of lateral beds across the width of the channels rather than the usual point bar set and channel plug. A tidal channel origin is suggested.

Cursory examination of cross-bedding and channel axis direction suggests an easterly source direction for the sediments.

Small plant fragments occur commonly.

*Lower Worthington Channel Sandstone with Unconformity at Base*

This upper sandstone is generally fine- to medium-grained and fills channel-ways incised into lower units. The unconformity at the base of this sandstone appears to initiate about 55 feet above lower Kittanning no. 3 coal and cuts to a level as much as several feet below the coal. The lower position represents the deepest channel-cutting and the upper position, the site of the higher interfluves.

This upper sandstone usually represents deposition as large, cross-stratified, point-bar-type beds. Large multiple slump-blocks are sometimes encountered at the edge of the channel-way, as at Cd44, Cd46, between Bf41 and Bf43, and between Ff8 and Ff7.

Upward and also laterally across the interfluved areas, the sandstone grades into finer-grained, thin-bedded sandstone, siltstone, and shale. At Cf5 a local shaly coal was also associated with this unit.

Brief examination of cross-bedding, channel axis, and point-bar cross-stratification directions suggests a north to northwest source for this sandstone.

Plant material of all sizes from fragments to trunks are found in this unit.

*Middle Kittanning Underclay*

The middle Kittanning underclay is always present except in a single instance between Cf16 and Cf17 where the middle Kittanning coal was deposited in a topographic low over an incompletely filled channel-way associated with a slump block.

In general, the underclay appears to represent an upward and lateral gradation from the previously discussed upper sandstone. It is heavily root-worked and in some cases may, at least in part, represent a weathering zone.

### *Mineral Springs Formation*

*General*

The Mineral Springs Formation includes those rocks lying above the base of the middle Kittanning coal and below the base of the upper Kittanning coal. Both key beds appear to be widespread and generally persistent.

The Mineral Springs Formation is about 60 feet thick in southeastern Elliott Park, 60 to 80 feet in southeastern and south-central Luthersburg, and 80 to 90 feet elsewhere (Plate 9).

A generalized sequence for the Mineral Springs Formation is as follows (descending order):

Upper Kittanning underclay, locally with associated Johnstown Limestone (2 to 11 feet).
Mixed clastic sequence (about 20 feet).
"Luthersburg" coal (0 to 30 inches).
Variable channel-fill sequence, predominantly upper Worthington sandstone and siltstone, but also other clastics and in one instance a thick, local coal. Unconformity at base of unit (0 to 55 feet).
Grayish black to black, fine, hackly shale grading up into lighter and coarser clastics (0 to 50 feet).
"Black band" of grayish black to black shale, persistently stands out as dark band upon weathering (0 to 3 feet).
Grayish black to black, hard, brittle, thin shale (0 to 28 feet).
Middle Kittanning coal (10 to 36 inches).

*Position of the "Luthersburg" Coal and Overlying Rocks in the Stratigraphic Sequence*

The "Luthersburg" coal and the superjacent rocks up to the base of the upper Kittanning coal present a problem in stratigraphic nomenclature. Depending upon the relation of the "Luthersburg" coal to the upper Kittanning coal, this sequence can be included in either the Mineral Springs Formation or the Laurel Run Formation.

If the "Luthersburg" is a coal physically and genetically unconnected with the upper Kittanning, it and the overlying rocks up to the base of the upper Kittanning coal belong to the Mineral Springs Formation. In this case, the "Luthersburg" coal would represent a locally extensive coal swamp developed in an upland lake which existed after the filling of most of the late middle Kittanning fluvial channel-ways but prior to the arrival of the transgressing upper Kittanning coal swamp and associated backswamp. That is may not post-date all of the late middle Kittanning cycle fluvial channels is suggested at station Curwensville Ca2 (Plate 9) where a coal at the "Luthersburg" position interfingers with fluvial channel sediments. In this case the "Luthersburg" could represent a later and more widespread reflourishing of the swamp that produced the local channel coal seen at Ae7 and Ae17. An upland lake swamp such as described above, if true, is unique in the author's experience with Pennsylvanian sediments in this area.

If the "Luthersburg" coal is a split of the upper Kittanning, it and the overlying sediments should be included in the Laurel Run Formation. In no place, however, was it possible to demonstrate this relationship or even to show a tendency toward convergence of the "Luthersburg" and upper Kittanning coals, nor is the upper Kittanning known to split in this way in this general region although other coal seams do.

Because it was not possible to resolve this question by purely physical observations, the authors found it necessary to resort to inferences based on data available. Interpreting the "Luthersburg" as a split of the upper Kittanning and assigning this interval to the Laurel Run Formation would have eliminated the unusually thick Mineral Springs Formation (80 to 90 feet) and the unusually thin Laurel Run (40 feet). At the same time, however, the fresh water limestone occurring between the "Luthersburg" and upper Kittanning coals at station Ae20 (Plate 9) is probably the Johnstown limestone which, when present, always occurs below the lowest element of the upper Kittanning coal. Also, if the coal interfingering with the upper Worthington channel sandstone is "Luthersburg," it is clearly more closely related to the fluvial portion of the middle Kittanning cycle than the transgressive coal swamp phase of the upper Kittanning cycle.

Although the evidence is not conclusive, the authors are inclined to favor the "isolated upland swamp hypothesis" for the "Luthersburg" coal and have accordingly assigned it and the overlying section to the Mineral Springs Formation.

*Middle Kittanning Coal*

Within its outcrop area, the middle Kittanning coal appears to be widely and persistently present. It has been observed to range between 10 and 36 inches thick. The middle Kittanning contains a fairly persistent 1- to 2-inch shale or bone parting between 3 and 14 inches above the base.

*Grayish black to black shale above Middle Kittanning Coal*

Directly overlying the middle Kittanning coal is a 10- to 30-foot section of grayish black to black, upward-coarsening clay shale and silt shale which disaggregates to thin, hard, brittle chips, has common siderite nodules and bands, and often has an iridescent, purple brown stain and white sulfate flowers on bedding surfaces. The dark shale is thickest in a northwest-southeast band across the central part of the Luthersburg quadrangle (See Figure 10).

In the southwestern quarter of the Luthersburg quadrangle, the lower 10 to 15 feet grades to a lighter colored and sometimes sandier, but otherwise similar, shale. The remaining section above is dark shale. At Ae13 a thin and apparently isolated local coal occurred a few inches above this lower, light, sandy shale.

In northeastern Luthersburg and adjacent Elliott Park most of this dark shale interval appears to grade laterally into a narrow band of coarser and lighter colored shale and then into sandstone. At Bd12 the lower four feet over the middle Kittanning coal is covered, but above that is a six-foot, hard, dense, very fine-grained, medium light gray sandstone with fine silt laminae and finely rippled cross-bedding. Above this is five feet of lumpy, very fine-grained, light olive gray sandstone with plant fragments. Above this is a fissile to thin-bedded, very fine-grained, light olive gray sandstone with some dark shale interbeds.

A coal up to four inches thick was observed at the top of this sandstone sequence at stations Be3, Bd6 and in the drill hole at Bc1. The Section exposed at Be3 is of additional interest in that it contains both this coal and the "black band," thus eliminating the possibility that the coal and "black band" are lateral equivalents.

The dark shale as well as the lighter colored shale equivalents to the southwest contain *Dunbarella* sp., cyzicoid conchostracans, and *Lingula* sp., as well as plant fragments.

*"Black Band"*

The "black band" is a 0- to 3-foot grayish black to black clay shale or silt shale, usually papery to very fine chips. White sulfate powder and iridescent purple brown stain are common. The distinctiveness of the "black band" is less a matter of its megascopic lithology, which is generally similar to the rocks above and below, than a weathering phenomenon. While the overlying and underlying dark shales weather distinctly lighter, the shales of the "black band" remain dark, and thus stand out as a black streak.

The "black band" is absent in north-central Luthersburg at stations Bd6 and B12 and also in the Coal Hill area just southeast of the village of Luthersburg at Ae73, Be43, and between Ae78 and Ae76.

*Dunbarella* sp. occur commonly in the "black band."

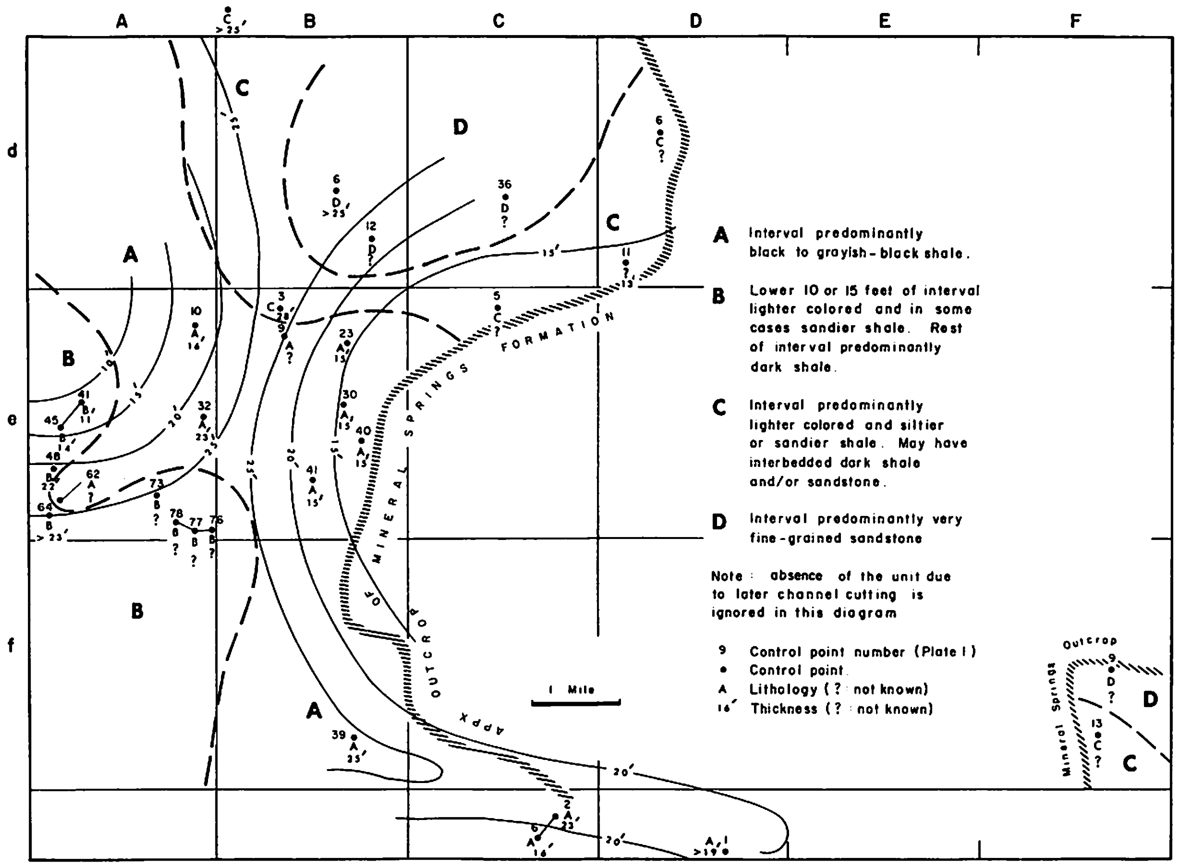


Figure 10. Generalized lithofacies and isopach map of the portion of the Mineral Springs Formation between the middle Kittanning coal and the "black band."

*Grayish Black to Black Hackly Shale above "Black Band"*

Directly overlying the "black band" across most of the Luthersburg quadrangle is an interval of grayish black to black (occasionally dark gray) silt shale which disintegrates to fine hackly chips. Siderite nodules and bands are common. The maximum development of the dark shale is about 25 feet.

In northeastern Luthersburg and adjacent Elliott Park the grayish black shale grades laterally into a medium dark gray silt shale.

To the south in the northeastern Mahaffey 7½-minute quadrangle (Curwensville Ca6 to Ca2), the unit grades to interlaminated sand-silt shale or interlaminated sand-siltstone.

In the immediate vicinity of Coal Hill (from Ae78 to Ae76 and Be43) the lower 10 to 12 feet of this black shale grades rapidly into a section of siltstone, thin-bedded sandstone and silt shale. This sand lens appears to be confined to that area.

In all cases where exposed, the dark shale interval grades upward to coarser clastics such as siltstone, sandstone, interlaminated sand-silt shale, etc. It is unclear in many cases whether this coarser, upper section is a continuous gradational facies change from the dark shale or is a thinner, flat-bedded lateral equivalent of the later channel-filling sequence which unconformably overlies the dark hackly shale. The unconformity in this case becomes a paraconformity and is often very difficult to discern.

*Dunbarella* sp. occurs commonly in this interval. In west-central Luthersburg (Ae45 to Ae41) the marine fossils *Mesolobus* sp. and *Linoproductus* sp. are found as well. Plant fragments occur frequently.

*Upper Worthington Channel-Fill Sequence*

Unconformably overlying the lower part of the Mineral Springs Formation is a lithologically variable sequence of channel filling and laterally equivalent flat-bedded sediments. The unconformity initiates at about 45 to 55 feet above the middle Kittanning coal and develops into a deeply incised channel system only in the west-central and southwest part of the Luthersburg quadrangle.

South of Limestone Run at Ae51, Ae60, Ae62, Ae63, A369, and Af6 the channel is incised in most cases to the top of the middle Kittanning coal and filled by the fine- to medium-grained upper Worthington sandstone with ½-inch to 3-foot beds and some medium dark gray to grayish black silt shale or siltstone beds.

Plant material from fragments to trunk size occurs frequently. Station Ae60 is notable for plant material.

The channel-fill sequence is exposed again at Ae7 and Ae17. Here the lithology is considerably different. Sandstone, though still present, is generally very fine-grained and represents a much smaller fraction of the total channel-fill. Dark gray to olive gray and olive black silt shale and siltstone and light olive gray clay shale and claystone are abundant. Plant material is common. In addition, the section at Ae7 and Ae17 contains a very striking local coal draped in the channel among the other sediments. The coal is up to 5½ feet thick, moderately bright to dull with high fusain content, and has a tendency to crumble to fine cubes. The seam rises and thins rapidly toward the flanks of the channel, which is estimated to be about ¼-mile wide and appears to trend between north-south and northwest-southeast. The extension of this channel is lost to the north as the interval passes below outcrop. To the south the old underground mines at Ae23 and Ae47 have tailing piles with large amounts of thick bone and coaly shale, not typical of the middle Kittanning and suggesting that at some point headings were driven into this overlying channel coal.

Except for possibly the dark shales at the top of the section at Ae51, there seems to be no correlative of the channel coal south of Limestone Run, although the upper Worthington sandstone is well developed there.

A possible explanation may be that the massive slump-block observed in the lower Worthington channel at Ae50 blocked the channel causing the stream to be diverted to a new channel elsewhere. The local coal developed in the cut-off channel-way, but was later buried when some flow was again established in the channel.

Just to the south of the report area at Curwensville Ca6, the channel sequence is again developed. Here, the channel bottoms several feet above the middle Kittanning coal and is filled with very fine-grained upper Worthington sandstone in beds from 6 inches to 7 feet thick. A coal, possibly equivalent to the "Luthersburg" coal, is interbedded as stringers with the sandstone at the top of one side of the channel.

No other cases of deep channel-cutting were observed in exposures of this interval. Elsewhere, only several feet of flat-bedded, finer-grained clastics lying 40 to 50 feet above the middle Kittanning coal are found. These rocks are interpreted to be the lateral (overbank) equivalent of the channel-fill rocks. They are separated from the underlying dark shales by an obscure paraconformity. Lithologies of this interval include very fine-grained sandstone, siltstone, interlaminated clay-silt shale, silt shale, interlaminated sand-siltstone, interlaminated sand-silt shale, claystone and directly below the "Luthersburg" coal, underclay and root-worked versions of the other rock types.

### *"Luthersburg" Coal*

The "Luthersburg" coal appears to be persistent throughout the Luthersburg quadrangle, although the authors are unacquainted with any equivalent coal at this position from other areas.

The "Luthersburg" ranges up to 24 inches thick and varies from moderately bright and fairly clean coal to dull, shaly coal.

The "Luthersburg" coal was observed at Bc1, Be8, Be10, Ae7, Ae17, Ae41, Cd36, Be41, and possibly between Curwensville Ca2 and Ca6 and at Ff13.

Between Curwensville Ca2 and Curwensville Ca6 a coal at about the position of the "Luthersburg" coal is interbedded as stringers with the upper part of the normally underlying channel-fill sandstones.

*Mixed Clastic Sequence above "Luthersburg" Coal*

Overlying the "Luthersburg" coal is a 20-foot, flat-bedded series of finer-grained clastics. There does not seem to be any distinct lithologic sequence, but included in the interval are very fine-grained sandstone, siltstone, interlaminated sand-silt shale, silt shale, black shale and claystone. All are vertically and laterally gradational. In addition to the usual grays and black, these rocks frequently have an olive cast. Plant fragments occur commonly.

*Upper Kittanning Underclay and Johnstown Limestone*

Judging from its presence as the floor of all upper Kittanning coal strip mines, the upper Kittanning underclay is a widely persistent unit throughout the report area. Only at Ae45, Ae41, Ae20, and Bd11 however, was the interval exposed.

At Ae45 and Ae41, the upper Kittanning underclay section consisted of 2 feet of dusky yellow underclay which graded into the underlying claystone.

In the railroad cut at Ae20, the interval below the upper Kittanning coal consisted of four feet of fine, medium gray underclay overlain by two 1-foot beds of clayey limestone separated by up to 1 foot of soft clay; this sequence is overlain by three feet of variegated underclay laced with limonitic limestone stringers and nodules. The limestone of this interval is interpreted to be Johnstown limestone.

At Bell the exposure showed 5 feet of silty, light olive gray underclay which graded down into lumpy, very fine-grained sandstone.

*Mineral Springs Formation in Southeastern Elliott Park Quadrangle*

The two exposures of the Mineral Springs Formation (Ff13 and Ff9 of Plate 9) from the isolated area in southeastern Elliott Park cannot be correlated easily with the Luthersburg area.

The entire section (23 feet) above the middle Kittanning coal at Ff9 and the lower 13 feet at Ff13 are interpreted to be equivalent to the lower dark shale interval of Luthersburg, but have graded to lighter colored shales and sandstone much as occurred in north-central and northeastern Luthersburg and northwestern Elliott Park.

The thin rider coal at Ff9 may be equivalent to that of Be3, Bd6, and Bc1.

At Ff13, unconformably overlying the lower part of the section is a shallow, channel-fill sandstone overlain by a thin coal. This coal does not appear to equate with the coal at Ff9 and may be equivalent to the "Luthersburg" coal or the local channel coal of Ae7 and Ae17.

### *Laurel Run Formation*

*General*

The Laurel Run Formation includes those rocks lying above the base of the upper Kittanning coal and below the base of the lower Freeport coal. Both beds appear to be widespread and generally persistent (Plate 10).

The Laurel Run is 30 to 45 feet thick. In the small area underlain by Laurel Run in southeastern Elliott Park, the formation is not exposed but is estimated to be 50 to 60 feet thick.

A generalized sequence for the Laurel Run Formation is as follows (descending order):

Lower Freeport underclay and limestone (3 to 24 feet).
Freeport channel sandstone, unconformity at base (0 to 40 feet).
Upward coarsening mixed clastic sequence (0 to 30 feet).
Upper Kittanning coal (0 to about 30 inches).

As discussed both in the previous section on the "Mineral Springs Formation" and in the section on "Pennsylvania Depositional History," there is some question that the part of the Mineral Springs Formation including and above the "Luthersburg" coal should be assigned to Laurel Run. See those sections for details of the problem.

*Upper Kittanning Coal*

Within its outcrop area the upper Kittanning coal appears to be persistently present, except in a few instances where cut out by the Freeport sandstone channel. The thickness (ignoring cut-outs) ranges from approximately 12 to 30 inches.

The upper Kittanning is mostly moderately bright to moderately dull coal with many thin, discontinuous partings. The lower few inches is usually tough, dull, bony coal. Approximately 6 to 8 inches from the top is a very persistent 1- to 2-inch bony coal interval which, when slightly weathered, stands out as a distinctive yellow or orange streak.

*Upward-Coarsening Mixed Clastic Sequence above Upper Kittanning Coal*

The interval between the top of the upper Kittanning coal and the Freeport sandstone or, where the sandstone is absent, the base of the lower Freeport underclay and limestone, is a gradationally upward-coarsening sequence of flat-bedded clastics.

The lowest part of the section is usually grayish black to black shale which grades upward into clay shale or silt shale, into siltstone, into various rocks composed of interlaminated sand and silt or silt and clay, and into sandstone. The uppermost few feet may show a reverse grading into finer lithologies. The color of these rocks varies from the simple blacks or grays, typical of most shales and siltstones of the Allegheny Group to various shades of olive gray and greenish gray.

Except where cut out by the Freeport sandstone, the mixed clastic section is 25 to 30 feet thick.

Plant fragments occur throughout the section. No invertebrates were noted.

*Freeport Channel Sandstone*

The Freeport sandstone fills channels incised unconformably into the underlying mixed clastics and, in at least one case (Ae20), through the upper Kittanning coal. The Freeport sandstone was observed at only three places in the report area. One of these was in drill hole Dd3. The other two stations were the strip mine at Be37 and the railroad cut at Ae20.

The Freeport sandstone is very fine- to medium-grained and occurs in 1-inch to 1-foot beds. At both Ae20 and Be37 the sandstone occurred as long, sloping lateral accretion (point bar) type beds. At Be37 the upper part graded to fissile sandstone and light grayish green silt shale. At Ae20 a single layer of grayish black silt shale was interbedded with the sandstone. The lateral accretion beds at Ae20 dipped in a N60°-80°W direction, and at Be37 they dipped approximately south.

In no instance was the relationship between the Freeport sandstone and the lower Freeport underclay and limestone observed. Judging from similar situations elsewhere, they are probably, in part at least, laterally and vertically gradational. There remains also the possibility that the sandstone interpreted here as Freeport is actually a very deep incisement of the lower Mahoning sandstone.

The sandstone contains relatively few, small plant fragments.

*Lower Freeport Underclay and Limestone*

The lower Freeport underclay and limestone is a persistent, but highly variable sequence. Where seen, it ranges from as little as 1 foot of underclay to as much as 24 feet of underclay, limestone, silt shale, siltstone, claystone, and local shaly coal (Ae44 and Ae43).

Underclay permeates the entire interval, while the limestone when present, varies from scattered nodules to massive beds up to 3 feet thick (Cd22).

The limestone is argillaceous, medium gray to medium dark gray and aphanitic with some secondary calcite. It occasionally releases a strong hydrogen sulfide odor upon fracturing.

The underclay varies from root-worked claystone to soft plastic clay and varies in color from medium gray or olive gray to light gray or light olive gray.

The thin shaly coal observed at Ae43 is expected to be very local.

## *Glen Richey Formation*

### *General*

The Glen Richey Formation includes those rocks lying above the base of the lower Freeport coal and below the top of the upper Freeport coal (Plate 11).

As shown in Figure 11, most of the Glen Rickey Formation in the report area is missing due to its erosion by the fluvial channel system of the lower Mahoning Sandstone Member of the Conemaugh Group. Where this deep channeling occurs, the unconformity at the base of the lower Mahoning sandstone becomes the upper boundary of the Glen Richey Formation. In a few cases, the lower Mahoning sandstone channel is completely incised through the lower Freeport coal and into the top of the Laurel Run Formation. Here the Glen Richey Formation is entirely absent.

The one complete section (Plate 11) of the Glen Richey was obtained at Bf35. This section and drill holes from surrounding areas indicate that the original complete formation thickness was 50 to 65 feet.

A generalized sequence for the Glen Richey Formation of the Luthersburg quadrangle is as follows (descending order):

Upper Freeport coal (0 to 45 inches).
Upper Freeport underclay and limestone (0 to 23 feet).
Shale and other clastics (0 to 40 feet).
Lower Freeport coal (0 to 13 feet).

The Glen Richey Formation in the isolated area in southeastern Elliott Park quadrangle is somewhat different. The upper Freeport coal there has been cut out by the channel filled by the lower Mahoning sandstone, although it appears again farther to the southeast in the adjacent Glen Richey quadrangle (Edmunds, 1968). In addition, a rider coal (lower Freeport no. 2) is interbedded with the clastic sequence overlying the main lower Freeport bed (lower Freeport no. 1). A generalized sequence for the Glen Richey Formation in southeastern Elliott Park is as follows (descending order):

(Unconformity at base of lower Mahoning sandstone).
Upper Freeport underclay (claystone) and limestone (0 to 15 feet).
Shale sequence (0 to 7 feet).
Lower Freeport no. 2 coal (0 to 27 inches).
Mixed clastic sequence (10 to 20 feet).
Lower Freeport no. 1 coal (27 to 43 inches).

### *Lower Freeport Coal*

Even aside from cut-outs by the lower Mahoning sandstone (Figure 11), the lower Freeport coal displays extraordinary lateral variablity. From a coal that averaged 5 to 6 feet thick in the DuBois Mines in northwestern Luthersburg, the lower Freeport thins very rapidly to the south and east

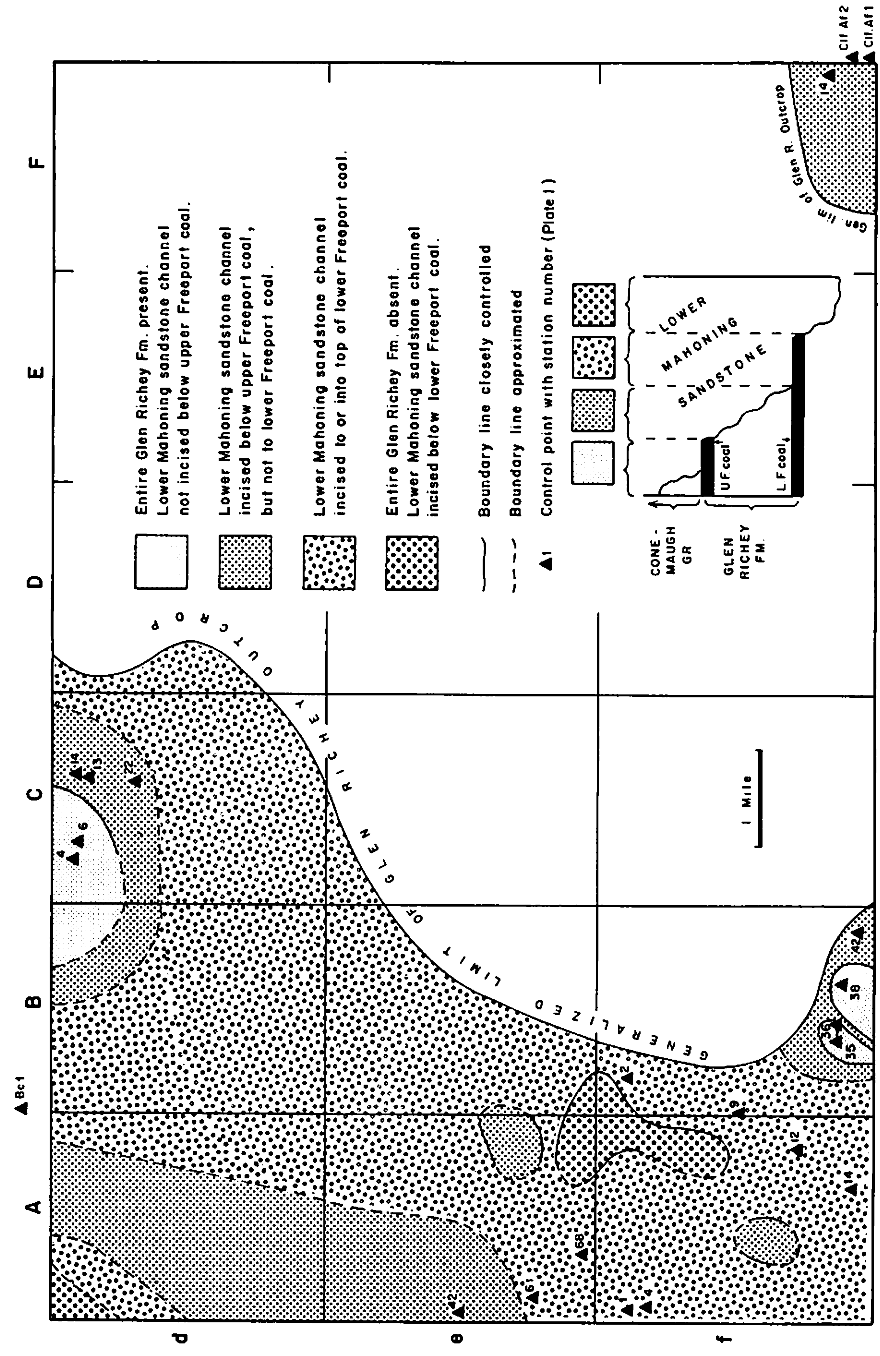


Figure 11. Erosional thinning of the Glen Richey Formation by the lower Mahoning sandstone channel.

(Plate 16) until only a few inches at most remains. Continuing on further to the southeast, the coal again thickens rapidly in the area south of Coal Hill. Within the Coal Hill mine itself, the lower Freeport varies from 5 to 13 feet thick. Most of the information available on the lower Freeport is from mining records as only a few exposures were available for direct observation. For this reason it is difficult to determine in any particular case whether thickness changes are the result of channel cut-outs or natural variability of the coal. Channel cut-outs filled by the lower Mahoning sandstone are common, but many changes in thickness are the result of total unit thinning, addition and loss of benches, splitting or lateral gradation. It was reported by a local miner that in the back-filled stripping at Af12, the lower Freeport split into two benches separated by at least several feet. This same split was encountered in recent drilling near Stanley, 2 miles west of the report area. The 11-inch lower Freeport coal at Cd22 is not cut, but has thinned naturally.

It is undertermined whether the lower Freeport coal of Luthersburg is equivalent to only the lower Freeport no. 1 of southeastern Elliott Park or equivalent to both lower Freeport nos. 1 and 2 unsplit.

*Remainder of the Glen Richey Formation above the Lower Freeport Coal*

Except for the drill holes at Cd4 and Cd6, the sections on Plate 11 represent the total information available on the remainder of the Glen Richey Formation; the reader is referred to them. Drill hole Cd4 penetrated about 1 foot of upper Freeport coal and 14 feet of underlying shale. Cd6 showed about 1 foot of upper Freeport and 25 feet of underlying shale.

Occasional conchostracans (*Leaia* sp.) occur in the shale above the lower Freeport.

## *Conemaugh Group (Glenshaw Formation)*

*General*

The Conemaugh Group is defined as including those rocks above the top of the upper Freeport coal and below the base of the Pittsburgh coal. The Glenshaw Formation is the lower of the two formations comprising the Conemaugh Group and extends from the top of the upper Freeport coal to the top of the Ames Limestone.

Being the highest stratigraphic unit (aside from alluvium) in the report area, neither the Conemaugh Group nor the Glenshaw Formation are entirely present. The maximum thickness remaining should occur below the Bush triangulation station hill, west of Reisinger Run (in reference block Ad) where the distance from the top of the hill to the position of the upper Freeport coal is about 320 feet. In addition to the usual Conemaugh thickness above the upper Freeport coal, the lower Mahoning Sandstone Member of the Conemaugh fills deeply incised channels which cut as far down as the lower Freeport coal or below over much of the report area (Figure 11). In this situation the base of the Conemaugh Group follows the sandstone downward at the expense of the Allegheny Group, adding as much as 70 feet to the Conemaugh.

There is no useful surface exposure or drill hole record of the upper 100 feet of the remaining Conemaugh Group in this area. The best factual record of the remainder is given in the log of the drill hole Bc1 as shown on Plate 5. The general interpretation of the Conemaugh is shown in the geologic column of Plate 1.

A generalized sequence for the lower 220 feet of the Conemaugh Group (290 feet including deep incision of the lower Mahoning sandstone channels) is as follows (descending order):

Albright limestone (1½ feet).
Shale, siltstone, and sandstone (about 70 feet).
Pine Creek fossiliferous siltstone (0 to 4 feet).
Shale, siltstone, and sandstone (50 feet).
Brush Creek fossiliferous shale (2 feet).
Brush Creek coal (0 to 4 inches).
Clay shale, siltstone and underclay (30 feet).
Mahoning coal (0 to few inches).
Underclay and claystone (3 to 10 feet).
Lower Mahoning channel sandstone and associated sediments (0 to 120 feet).
Shale and interlaminated sand-siltstone (0 to 55 feet).

*Shale and Interlaminated Sand-siltstone above Upper Freeport Coal*

This unit is cut out by the lower Mahoning channel sandstone system over most of the report area and poorly exposed where present. Drill holes Cd4 and Cd6 were started below the top of this interval, but showed 40 to 45 feet of gray shale or sandy shale above the upper Freeport coal. Carefully logged drill holes from the quadrangles to the west and north indicate this unit is about 50 feet thick, and is an upward-coarsening sequence of clay shale, silt shale, and interlaminated sand-siltstone.

*Lower Mahoning Channel Sandstone and Associated Sediments*

The lower Mahoning sandstone is a channel-filling sequence which, where best developed, incises unconformably through the lower 50 to 55 feet of the Conemaugh Group, through the entire Glen Richey Formation, and into the top of the Laurel Run Formation, a maximum total thickness of 120 feet.

Compared to other channel sandstones throughout the Pennsylvanian section, the lower Mahoning is extraordinary, not only from the standpoint of thickness (others are usually 75 feet thick at most), but also in its lateral extent. Most channel sandstones, although long, are usually considerably less than a mile wide. The lower Mahoning channel, however, is estimated to be at least 4 miles wide. As shown in Figure 11, the lower Mahoning is incised down to the lower Freeport coal in a broad swath across the Luthersburg quadrangle.

Because of its great thickness, the entire lower Mahoning sandstone cannot be observed in any single exposure, although some roads and trials which cut across its outcrop belt will show continuous sandstone float and small intermittent outcrops. The lower 30 or 40 feet is well exposed in strip mines on the lower Freeport coal.

The lower Mahoning sandstone is largely fine- to medium-grained with some pebble conglomerate; it is basically light gray, but usually iron-stained, clayey, and micaceous, with beds from a few inches to several feet thick. Plant material is common to profuse and ranges from small fragments to trunk-sized. Coal stringers occur frequently. The sandstone is usually bedded in large scale, sloping, lateral-accretion type lenses (point bars) with internal cross-bedding.

In some areas, much of the normally dominant sandstone grades laterally into a complex sequence of siltstone, dark claystone, calcareous sandstone, and carbonaceous sandstone with coal stringers. The drill hole Bc1 (Plate 5) appears to have passed through such a sequence between 190 and 327 feet. The 49 ½-inch coal at 212 feet in this drill hole is suspected by the authors to be a local channel coal rather than the true upper Freeport coal which is thought to be cut out. This complex of mixed lithologies appears to occur prominently along the western edge of the deeper part of the lower Mahoning channel system (Figure 11) in the area west of Luthersburg Branch and northeast toward station Bc1 (essentially the area immediately east of the DuBois no. 1 mine as shown on Plate 16).

At the flanks of the channel-ways the unconformity rises up to a position probably 5 to 20 feet below the Mahoning coal and presumably, passes into a paraconformity below or within the underclay below the Mahoning coal.

### *Mahoning Underclay and Claystone*

Below the Mahoning coal is a several-foot-thick sequence of underclay and claystone. It is poorly exposed at the surface, but shows well in the drill hole at Bc1 (Plate 5).

Approximately this same interval outcrops in a weathered road cut at Ad64. The section there consisted of a very silty, sandy, light olive brown claystone. It had no distinct bedding but disintegrated into small, irregular fragments.

### *Mahoning Coal*

The Mahoning coal is exposed only in drill hole Bc1. There and in other drill holes from surrounding areas it does not exceed a few inches thick.

*Clay Shale, Siltstone, and Underclay Sequence above Mahoning Coal*

This 30-foot interval between the Mahoning and Brush Creek coal horizons is poorly exposed in the report area; however, based on the drill hole at Bc1 and drill holes from surrounding areas, the sequence is predominantly clay shale with several feet of underclay and/or siltstone and/or interlaminated sand-silt shale at the top.

The weathered outcrop at Ae22 shows 13 feet of light olive brown clay shale overlain by 3 feet of light olive gray silt shale and fissile sandstone and may be from this interval.

In north-central Luthersburg, in the area between Memorial Church and Chestnut Run, there appears to be a second heavy sandstone above the lower Mahoning sandstone. It is not well exposed, but strong benches on aerial photographs indicate its presence. It is probably the upper Mahoning sandstone and is likely the lateral, channeling equivalent of the upper part of this interval.

*Brush Creek Coal*

The Brush Creek coal was only observed in drill hole Bc1 where it was 4 inches thick and possibly as a thin coal blossom at Ae22.

*Brush Creek Fossiliferous Shale*

Although not observed at the surface in the report area, this two-foot shale interval, which contains marine fossils, was recorded in drill hole Bc1 and from other drill holes and surface exposures in the quadrangles to the west and north. Among fossil forms noted in these adjacent areas are: Endothyroid foraminifera, planispiral non-chambered foraminifera, other foraminifera, *Lophophyllum* sp., *Mesolobus* sp., *Crurithyris* sp., *Pharkidonotus* sp., ?*Straparolus* sp., *Nuculana* sp., small worthenids, pectinid fragments, Tentaculoids, small crinoid columnals and pinnules, and ostracods plus megaspores and other plant fragments.

*Shale, Siltstone and Sandstone Sequence*

This interval between the Brush Creek fossiliferous shale and the Pine Creek fossiliferous siltstone is included in drill hole Bc1, (Plate 5) and the railroad cut at Ae2. Ae2 shows clearly all but the lower 10 feet of the interval and includes the upper fossiliferous siltstone. The section at Ae2 is as follows (descending order):

*Shale*, badly weathered (4 feet +).

Fossiliferous, calcareous *siltstone* (3 inches).

Carbonaceous *shale* (3 inches).

Interbedded *siltstone*, medium dark gray and *interlaminated sand-stiltstone*, light gray and medium dark gray laminae, both with plant fragments and mica, 3- to 6-inch beds, grading downward to *sandstone*, silty, fine-grained, medium dark gray, micaceous, plant fragments, mostly ½- to 3-inch beds (11½ feet).

*Silt shale*, medium dark gray, few siderite nodules, conchostracans (20 feet).

*Sandstone*, silty, medium light gray, 1- to 4-inch beds grading downward to fissile *sandstone*, medium gray, micaceous, trough cross-bedding (10 feet).

### *Pine Creek Fossiliferous Siltstone*

This 0 to 4-foot unit is exposed at the top of the railroad cut at Ae2 and in the drill hole at Bc1. At Bc1 it is recorded as about 4 feet of fossiliferous siltstone to silt shale. At Ae2 it is described as 3 inches of siltstone, calcareous (primarily the fossil fragments), sandy, grayish black, micaceous, 1-inch beds and highly fossiliferous.

The fossil suite includes:

Small rugose corals

Brachiopods
*Crurithyris* sp.
*Chonetes granulifer* Owen

Cephalopods
*Pseudorthoceras* sp.
? *Metacoceras*

Gastropods
*Bellerophon* sp.
*Worthenia* sp.

Pelecypod
*Astartella* sp.

Few small crinoid columnals.

### *Shale, Siltstone, and Sandstone Sequence*

Sections covering all of this 70-foot unit except the top and bottom several feet are exposed in the shale quarries at Ad1, Ad5, Ad4, and Ad18, the railroad cuts at Ad11 and Ad8, and the road cuts at Ad18, Ad2, Ad62, and Ad67 (Figure 12). This interval is composed of a generally, but by no means uniformly, upward coarsening sequence of clay shale, silt shale, siltstone, and some very fine-grained sandstone. Color ranges from light olive gray to olive gray or dark gray. Bedding thickness varies mostly between ¼-inch and 2-inches with some sandstone and siltstone up to 1-foot thick. Most of the interval is very micaceous. Plant fragments occur rarely.

### *Albright Limestone*

The Albright Limestone is recorded only in drill hole Bc1 (Plate 5). There it is described as a 19-inch medium gray, clayey limestone. It is presumed to be a fresh-water limestone.

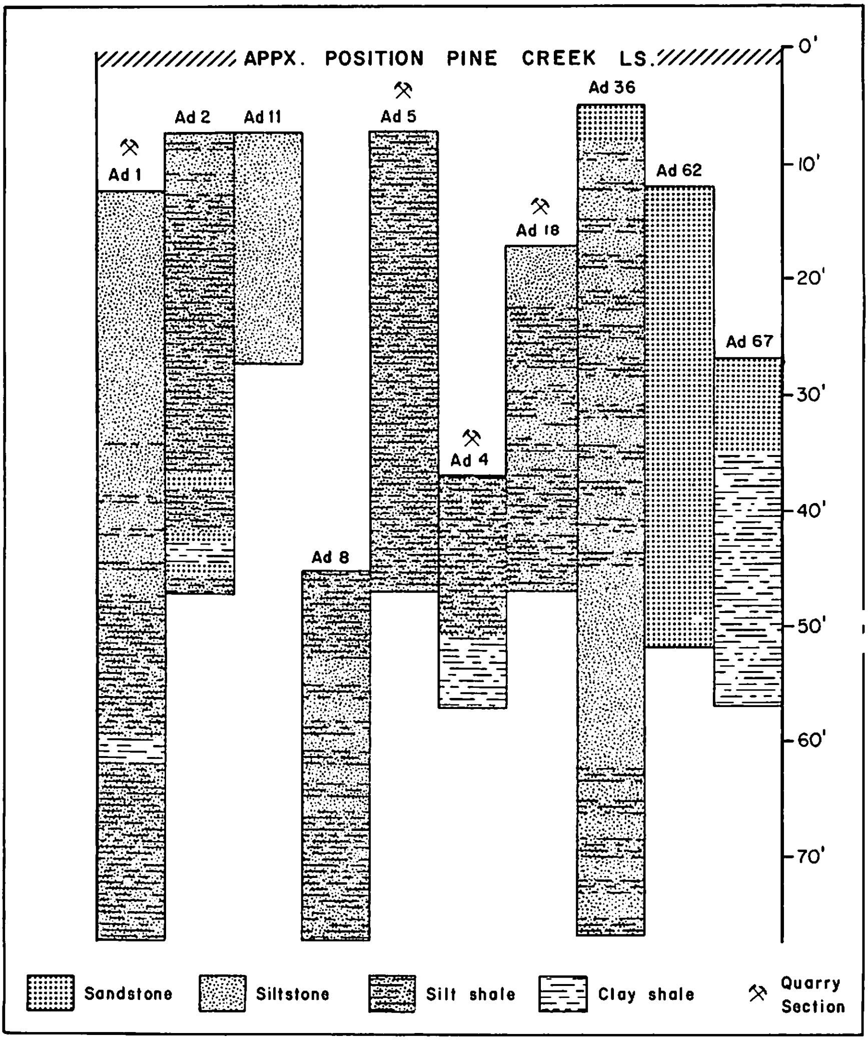


Figure 12. Correlation of measured sections below the Albright limestone.

## *Pennsylvanian Depositional History*

### *Pennsylvanian Cyclic Sedimentation*

In general aspect, the Pennsylvanian rocks of this area were deposited in a cyclical repetitive sequence of environments.

The theory and nature of these environments was discussed at considerable length by Edmunds (1968), and there is no need to redevelop the subject here. The basic aspects of Edmunds' concept are accepted as a reasonable interpretation of the depositional sequence, although continued work has suggested some minor changes and further elaborations in some respects.

The basic cycle represented in the Pennsylvanian rocks is conceived as a net open-water transgression followed by a net open-water regression. This transgression-regression is suggested to be the result of changes in the balance between the rate of basin subsidence and the rate of sediment influx. As subsidence rate increased the influx of sediments was insufficient to keep the basin filled and net open-water transgression occurred. As the subsidence rate slowed the inflowing sediments filled the basin causing prograding of the sediments and net regression.

Because of the shallow dip of the general paleoslope during Pennsylvanian time and certain other factors, this transgression-regression cycle produced, at any one place, a regular order of depositional environments.

Although the ideal place to begin consideration of the cyclic sequence is at the point of either maximum regression or transgression, both are difficult to establish exactly in practice. Since the base of the transgressive swamp sediments provides the sharpest environmental and lithologic break, it will be used as the base of the cycle. The following sequence, then, will be considered the simplest complete cycle:

6. Backswamp environment
5. Fluvial-erosional environment
4. Distributary delta environment
3. Regressive swamp environment
2. Open-water environment
1. Transgressive swamp environment

The depositional order of the six environments and the theoretical relationship of their sediments in a generalized section taken parallel to the dip of the original paleoslope is shown in Figure 13.

The subdivisions of the cycle, while based on depositional environment, are each generally represented by a fairly specific group of lithologies (Figure 14). However, no specific lithologies are absolutely required and none absolutely excluded. The depositional development of a complete cycle is shown in Figure 15. A hypothetical exposure of actual rocks representing a single simple, complete cycle is shown in Figure 16.

The cycle as discussed so far is the simplest complete case. In practice things are somewhat more complicated. One such complexity is what was termed in Edmunds' (1968) the "retrograde coal." The retrograde coal is one which develops in a direction counter to the direction of general transgression. In this respect it is quite similar to a regressive coal. In the case of a true regressive coal, however, the regressive aspect of the cycle has been irreversibly established, and the entire coal swamp is forced to retreat from the area or is overrun and buried by deltaic sediments and thus destroyed as a widespread, viable environment. In the case of a retrograde coal the main

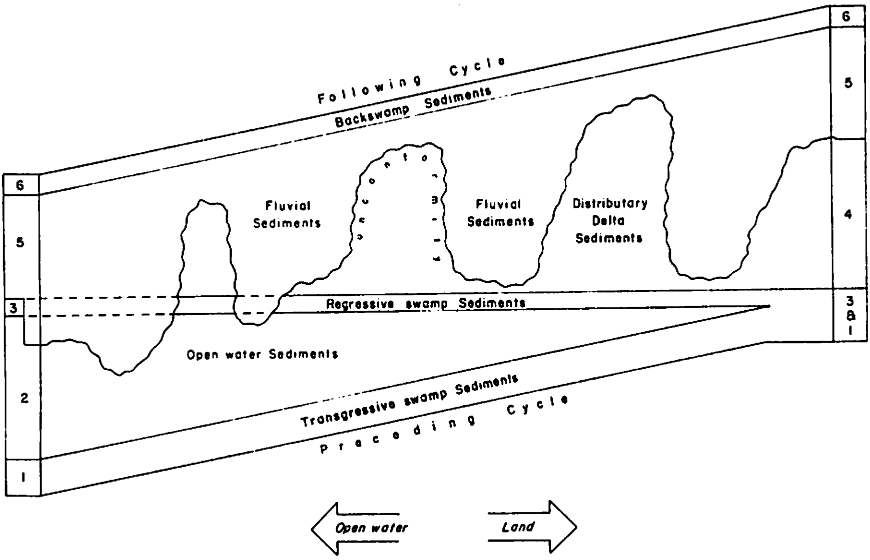


Figure 13. Generalized depositional order and physical relationship of the six environments of a Pennsylvanian depositional cycle in west-central Pennsylvania.

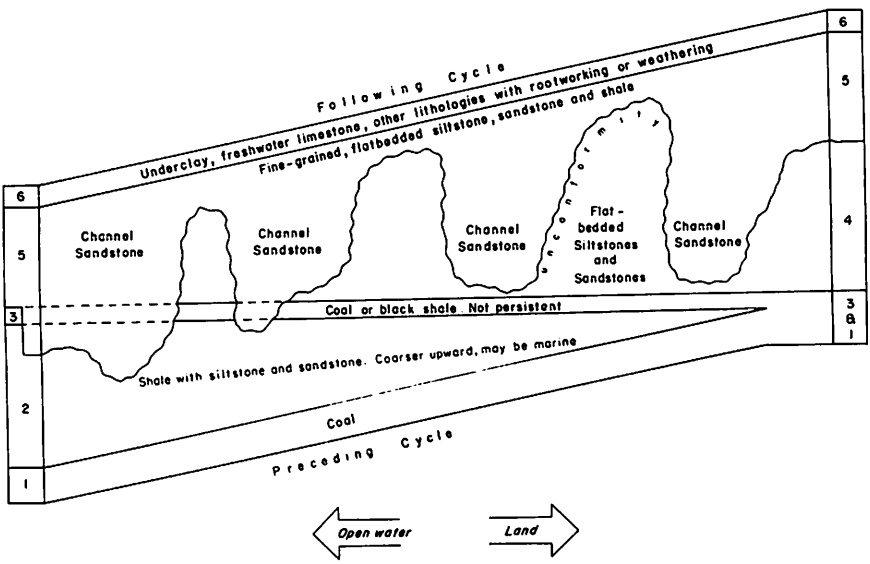


Figure 14. Usual lithologies associated with the environments of deposition shown in Figure 13.

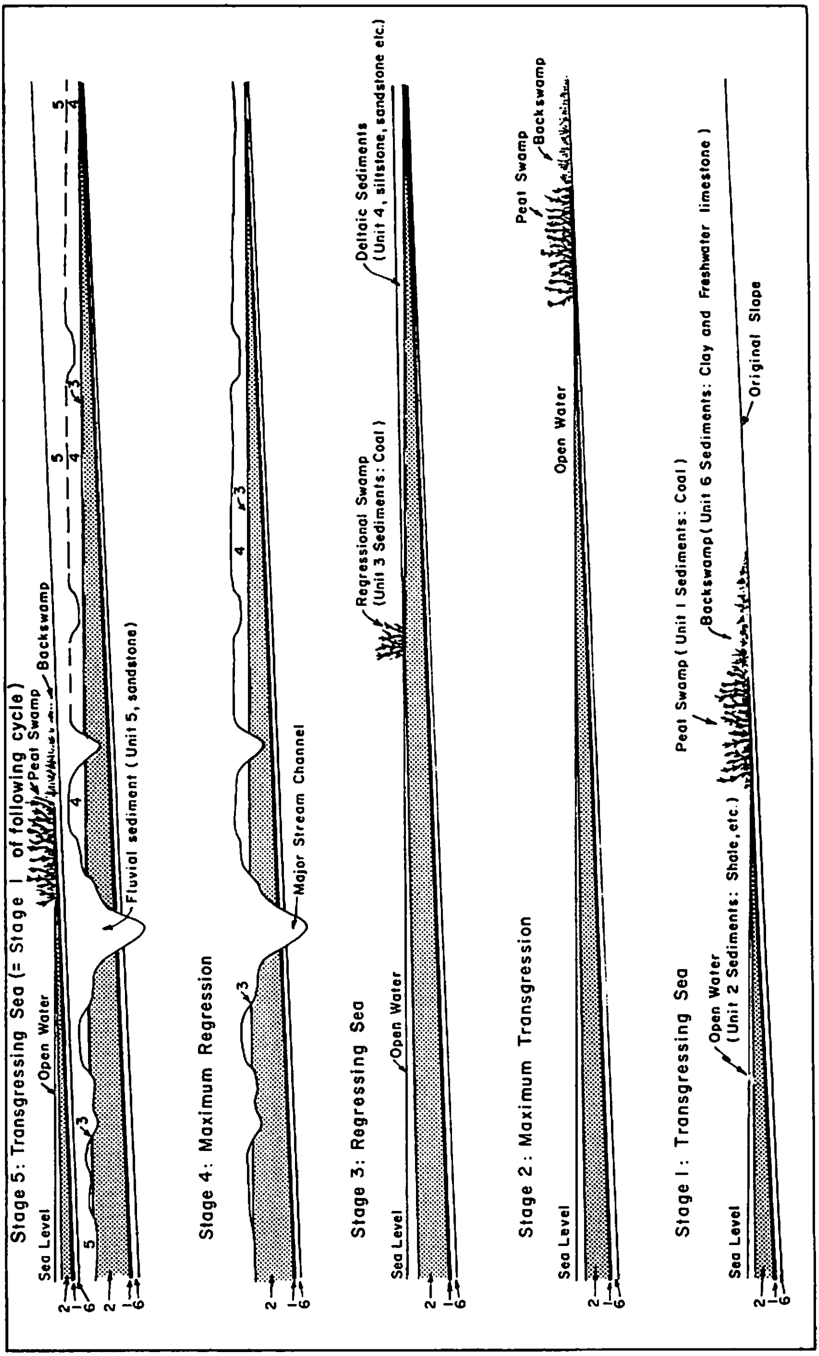


Figure 15. Generalized simple transgression and regression of the sea and resulting sediment types.

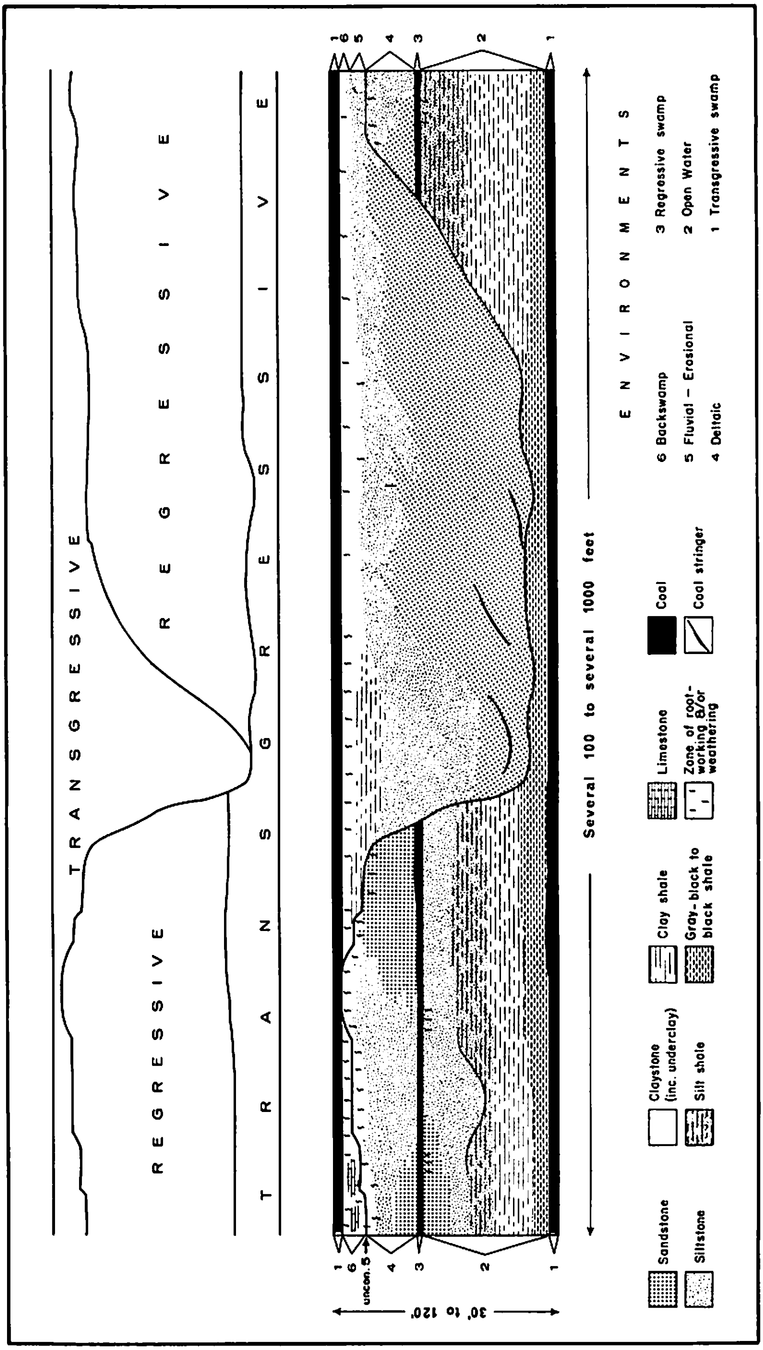


Figure 16. Hypothetical exposure of rocks representing the environments of a single, complete, simple cycle.

body of the transgressive coal swamp remains at its advanced position; but due to nearly complete infilling of the open-water basin by sediments, the main swamp begins also to develop a wide spread extension backward across the infilled open-water area. Following development of the retrograde extension of the swamp, further subsidence and transgression bury this coal with more open-water sediments. In essence, the retrograde coal is an interfingering of the transgressive swamp sediments with the open-water sediments.

Missing units are also a common problem in analyzing most cycles. Unit 1 (transgressive coal swamp), unit 2 (open-water sediments) and unit 6 (back-swamp sediments) are usually present. Unit 5 (fluvial sediments and associated unconformity) is usually present, but often hard to discern clearly except where the main channel-ways are sharply incised through lower units. Away from the channel-ways, the unit 5 environment is represented by flatbedded overbank sediments and the associated unconformity becomes an obscure paraconformity. Unit 3 (regressive coal swamp) and Unit 4 (deltaic sediments), lying directly below the unit 5 unconformity, are frequently cut out. This appears to be almost universally true toward the center of the depositional basin. In the southern Penfield quadrangle no cycle can be clearly shown to contain any representative of units 3 and 4.

*Pre-Pennsylvanian Surface*

Following the deposition of the Mississippian age rocks, this area was involved in a broad regional upwarping which left all Mississippian and older rocks with an average southerly or southwesterly dip of about 10 or 20 feet to the mile. The environment was changed from one of deposition to one of erosion. Assuming that the original thickness of Mississippian rocks was the same in Clearfield County as in Somerset County, 75 miles to the south, approximately 700 to 800 feet of the Mississippian strata were eroded away in Clearfield County.

The highest Mississippian unit remaining in the southern Penfield area is the Burgoon Sandstone which is the uppermost member of the Pocono Formation. In Somerset County the Burgoon is overlain by the 50-foot Loyalhanna Formation (sandy limestone to calcareous sandstone), followed by the 450-foot Mauch Chunk Formation (red shales and other clastics). The last remnants of the Mauch Chunk disappear near Lumber City about 5 miles south of the report area. It is not clear what happens to the Loyalhanna. It is known to become sandier northward and, upon losing its calcareous fraction, may not have been distinguished from the Burgoon.

In the southern Penfield quadrangle the Burgoon sandstone (possibly including some Loyalhanna equivalent) is everywhere immediately subjacent to the Pennsylvanian section.

The period of erosion of the Mississippian rocks extended far into Pennsylvanian time. There are no rocks representing the first 40 percent of the Pennsylvanian period.

Immediately prior to the encroachment of the sea and deposition of the first Pennsylvanian rocks in late Pottsville time, the topography of Clearfield County is believed to have consisted of a long, low ridge lying east-west across the central part of the county. The scarp slope of the ridge faced north and the dip slope south. This ridge corresponds to the Pre-Pennsylvanian outcrop belt of the Burgoon Sandstone. The south-dipping upper surface of the Burgoon forms the dip slope of the ridge. A second lower ridge corresponding to the outcrop belt of the 80-foot sandstone in the lower part of the Mauch Chunk Formation lay some distance to the south of the Burgoon ridge. The total relief from the crest of the Burgoon ridge to the adjacent lowland was small; probably less than 100 feet or, in a few cases, 150 feet. A highly generalized north-south cross-section through Clearfield County showing the topographic relief on the Mississippian-Pennsylvanian erosion surface is shown in Figure 17.

The southern Penfield area lies along the crest of the Burgoon ridge and overlaps onto the lower area to the north of the ridge.

Local drainage immediately prior to the deposition of the first Pennsylvanian sediments presumably consisted of minor rills flowing off the low slopes of the ridges into collecting streams lying in the lowlands parallel to the ridges. There is some indication from drill hole records of ravines cut transverse to the ridges, but it is not clear if they are completely cross-cutting. There is no distinct indication of the regional direction of the drainage. However, since the Pennsylvanian sequence to the south, west and north contains rocks pre-dating the earliest of Clearfield County, it would appear that the depositional onlap approached from one or more of those directions at least.

Although not clear during Pottsville time, the direction of general transgression during Allegheny deposition was from the west. From the work of Williams (1959, 1960), Williams and others (1964), and Weber and others (1965) it appears that during Allegheny time a broad, shallow embayment existed across western Pennsylvania. The position of the embayment varied somewhat from time to time, but its axis extended generally through Lawrence, Beaver, Armstrong, Jefferson and Clearfield Counties and perhaps to Tioga or Bradford Counties.

### *General features of Pennsylvanian Deposition*

From upper Pottsville time, when the first Pennsylvanian units were deposited in this area, net accumulation of sediments continued until the area was involved in the general uplift associated with the Appalachian orogeny in the latter part of the Permian Period. Subsequent erosion has

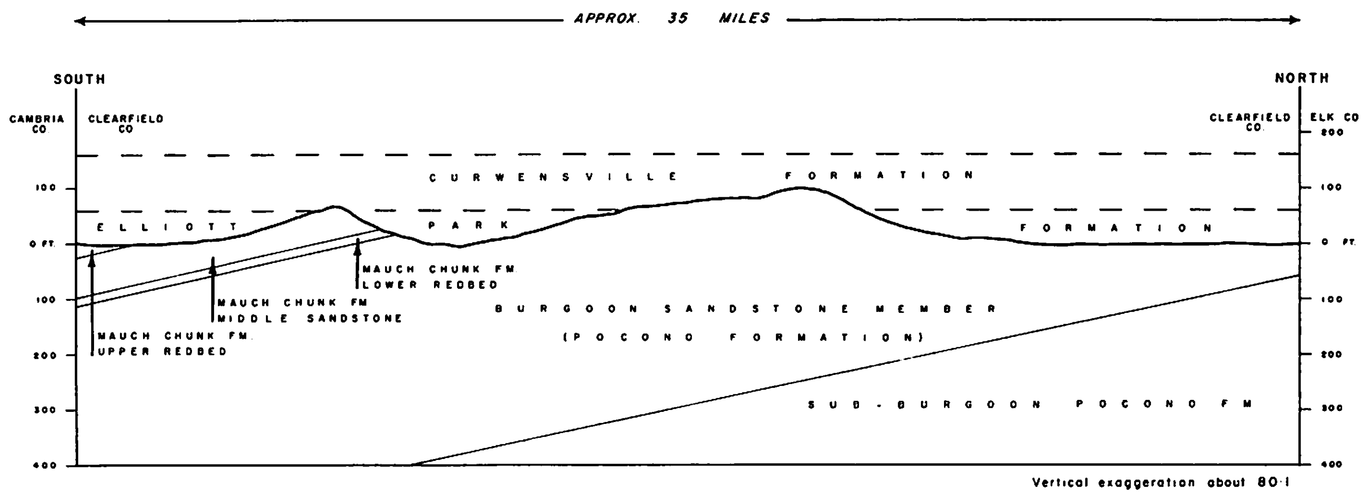


Figure 17. Generalized north-south cross-section through Clearfield County showing topographic relief of the Mississippian-Pennsylvanian erosion surface and phantom positions of subsequent lowest Pennsylvanian units.

stripped away the later Pennsylvanian and Permian rocks (Dunkard Group, Monongehela Group, and much of the Conemaugh Group).

Open water repeatedly transgressed and regressed across the face of the land, each time producing the sequence of environments and the corresponding rock units such as are described in the section on "Pennsylvanian Cyclic Sedimentation."

A generalized summary of the 13 cycles and their environmental subdivisions represented in the Pennsylvanian rocks of this area is shown in Table 1. The cycles are named for the principal coal (or coal group) occurring therein. The Sharon is named for the Sharon coal, which though not extant in this area, precedes the Quakertown elsewhere. It is doubtful that the "Quakertown" coal of this area is physically continuous with more widespread Quakertown to the west, but may represent contemporaneous patches of swamp lying upslope from the main Quakertown swamp. It may be more properly considered here as a local coal interbedded with fluvial sediments.

The lowest two cycles, Sharon and Quakertown, exist only in the lower areas of the Mississippian-Pennsylvanian erosion surface. At the conclusion of the Quakertown cycle the upper 60 feet or so of the Burgoon ridge still stood as a positive feature. The succeeding cycles blanketed the entire area.

### *High-Alumina Hard Clays*

The portion of the Burgoon ridge projecting as a positive feature at the end of the Quakertown cycle appears to be coincident with the occurrence of the lower Mercer high-alumina hard clays. The hard clay occurs only where the underlying Elliott Park Formation is absent or very thin and thus rests directly or almost directly on the Burgoon Sandstone Member of the Pocono Formation. Where the lower Mercer clay horizon is underlain by well-developed Elliott Park sandstones, it is almost always a soft clay.

In spite of the great concentration of alumina and elimination of silica required in the process, the intimate association of the hard clay with the Burgoon Sandstone suggests strongly that the hard clay is developed as a weathering product from the Burgoon. As pointed out in Edmunds (1968), it appears that soft clays (derived from fine clastic clay), hard clays (derived from colloidal clay), and diaspore (derived from aluminum hydroxide solution) are all products of the same basic environment with respect to source rock, climate, and weathering conditions. The critical difference is suggested to lie in the capacity of the drainage in the source area to remove the weathering products. Soft clays are produced from an area with sufficient drainage capacity to carry off fine clay at least—usually the broad hinterland upslope from the backswamp. Hard clay and diaspore, however, are developed in areas of such low drainage capacity that running water is unable to remove weathering products until reduced to colloidal size or even solution—usually on isolated knobs, promontories, and ridges, such as the Burgoon ridge.

Presumably weathering products similar to the high-alumina clays were developed on the Burgoon from the time it was first exposed by erosion. It is not clear, however, whether the hard clay as it exists now was a residuum accumulated throughout this long period of erosion or if it represents material largely formed and deposited in the late part of the Quakertown cycle, much the same as is the case with the usual underclay. Although hard clay does not seem to exist below any elements of the Elliott Park Formation, the upper Connoquenessing sandstone member does contain fragments of hard clay, as at Fd4. It is possible that a thin crust of hardclay (or its semi-consolidated precursor) covered the entire Burgoon outcrop belt, but that the portion lying in the lower part was scoured out by the streams which deposited the upper Connoquenessing sandstone.

Even if, however, the hard clay initially pre-dated any Pennsylvanian units of the area, that which remained probably underwent sufficient late Quakertown weathering, root-working, and local redistribution to qualify as a deposit of that cycle.

## Quaternary System

### *Periglacial Phenomena*

While no glacial deposits occur, and the area is beyond the terminus of glacial advance, some Pleistocene periglacial effects are evident. Sandstone boulder colluvium and stone stripes indicate frozen ground and frost heaving of a periglacial climate unlike today's moderate climate. Boulder colluvium is common on the broad, flat areas underlain by the thick Pottsville and Burgoon sandstones, especially in the central portion of the Elliott Park quadrangle. Stone stripes were observed on the steep slopes of Montgomery Creek and its tributaries. The stripes are long, linear piles of sandstone boulders and rubble that average 10 to 15 feet wide and many tens of feet long, aligned normal to topographic contours.

### *Unconsolidated Alluvium*

The bottoms of all major and many secondary stream valleys of the report area are floored by more or less transient deposits of unconsolidated clay, silt, sand, and gravel.

The alluvial deposits along the Allegheny River System streams (western third of the area) are proportionately wider and deeper than those of the Susquehanna streams, presumably reflecting a lower level of Allegheny transport capacity and lower down-cutting capacity.

Alluvium in Sandy Lick Creek is up to 50 feet thick, and, in addition to clay, silt, sand, and gravel, contains a considerable amount of organic

Table 1. *Generalized Lithologic Units as Used in Discussion of Individual Formations in the Text of this Report*

| Group | Formation | | | Environment of Deposition | Cycle | Transgression (T) Regression (R) |
|---|---|---|---|---|---|---|
| CONEMAUGH | GLENSHAW | Abright Limestone | | 2. Backswamp | | T |
| | | | | 5. Unconformity? | | |
| | | Shale, siltstone, and sandstone | | 2. Open water | Pine Creek | R |
| | | Pine Creek fossiliferous siltstone | | 2. Open water | | T |
| | | Shale, siltstone, and sandstone | | 2. Open water | | R |
| | | Brush Creek fossiliferous shale | | 2. Open water | | T |
| | | Brush Creek coal | | 1. Trans. swamp | Brush Creek | |
| | | Clay shale, siltstone, and underclay (including upper Mahoning sandstone as lateral equivalent?) | Underclay | 6. Backswamp | | |
| | | | Siltstone and upper Mahoning sandstone | 5. Fluvial | | |
| | | | | 5. Unconformity | Mahoning | R |
| | | | Clay shale | 2. Open water | | |
| | | Mahoning coal | | 1. Trans. Swamp | | T |
| | | Underclay and claystone | | 6. Backswamp | | |
| | | Lower Mahoning channel sandstone and associated sediments | | 5. Fluvial | | |
| | | | | 5. Unconformity | Upper Freeport | |
| | | Shale and interlaminated sand-siltstone | | 2. Open water &/or | | R |
| | | | | 4. Deltaic | | ? |

| | | | | | | |
|---|---|---|---|---|---|---|
| ALLEGHENY | GLEN RICHEY | Upper Freeport coal | | 1. Trans. Swamp or<br>1. & 3. Trans.-Reg Swamp | | ? |
| | | Upper Freeport underclay and limestone | | 6. Backswamp | | T |
| | | | | 5. Unconformity | | |
| | | Shale and other clastics (2. Open water) | Shale sequence | 2. Open water | Lower Freeport | R |
| | | | Lower Freeport no. 2 coal | 1. Trans. Swamp (retrograde) | | T |
| | | | Mixed clastic sequence | 2. Open water | | |
| | | Lower Freeport (no. 1) coal | | 1. Trans. Swamp | | |
| | LAUREL RUN | Lower Freeport underclay and limestone | | 6. Backswamp | | |
| | | Freeport channel sandstone | | 5. Fluvial | Upper Kittanning | R |
| | | | | 5. Unconformity | | |
| | | Mixed clastic sequence | | 2. Open water | | |
| | | Upper Kittanning coal | | 1. Trans. Swamp | | |
| | MINERAL SPRINGS | *Upper Kittanning underclay and Johnstown Limestone | | 6. Backswamp* | | T |
| | | *Mixed clastic sequence | | 5. Fluvial (isolated upland lake).* | | |
| | | *"Luthersburg" coal | | 5. Fluvial (isolated upland swamp).* | | |
| | | | | 5. Fluvial | | |
| | | Variable channel-filling sequence including upper Worthington sandstone | | 5. Unconformity | Middle Kittanning | R |
| | | Gray-black to black hackly shale | | 2. Open water | | |
| | | "Black band" shale | | 2. Open water (may = Retrograde Tans. Swamp) | | T |
| | | Gray black to black chip shale | | 2. Open water | | |
| | | Middle Kittanning coal | | 1. Trans. Swamp | | |

* Possible Upper Kittanning Cycle, Laurel Run Formation. See text page 36 for alternate interpretation.

## Table 1. *Continued*

| Group | Formation | | Environment of Deposition | Cycle | Transgression (T) Regression (R) |
|---|---|---|---|---|---|
| ALLEGHENY | MILLSTONE RUN | Middle Kittanning underclay | 6. Backswamp | Lower Kittanning | |
| | | | 5. Fluvial | | R |
| | | Lower Worthington channel sandstone | 5. Unconformity | | |
| | | Sandstone and finer lithologies. Lower Kittanning no. 4 coal (1. Trans. Swamp retrograde) present at bottom and basal unconformity absent to the east. | 2. Open water<br>Unconformity | | T |
| | | Dark shale grading up to interbedded siltstone and sandstone | 2. Open water | | |
| | | Lower Kittanning no. 3 coal | 1. Trans. Swamp (retrograde) | | |
| | | Dark shale and claystone grading up to underclay | 2. Open water | | |
| | | Lower Kittanning no. 1 coal | 1. Trans. Swamp | | |
| | CLEARFIELD CREEK | Underclay | 6. Backswamp | Clarion | |
| | | Kittanning channel sandstone | 5. Fluvial | | R |
| | | | 5. Unconformity | | |
| | | Shale sequence | 2. Open water | | T |
| | | Clarion no. 2 coal | 1. Trans. Swamp (retrograde) | | |
| | | Shale, sandstone and underclay sequence | 2. Open water | | |
| | | Clarion no. 1 coal | 1. Trans. Swamp | | |

| | | | | | |
|---|---|---|---|---|---|
| POTTSVILLE | CURWENSVILLE | Clarion no. 1 (Bigler) underclay | 6. Backswamp | | R |
| | | Homewood Channel Sandstone | 5. Fluvial | | |
| | | | 5. Unocnformity | | |
| | | Dark shale grading up to clay shale and to sandstone | 2. Open water | Upper Mercer? | T |
| | | Upper Mercer no. 2 coal | 1. Trans. Swamp (retrograde) | | |
| | | Underclay | 2. Open water | | |
| | | Dark shale, silt shale and sandstone | 2. Open water | | |
| | | Upper Mercer no. 1 coal | 1. Trans. Swamp | ? | |
| | | Underclay | 6. Backswamp | | R |
| | | Conglomeratic channel sandstone | 5. Fluvial | | |
| | | | 5. Unconformity | | |
| | | Silt shale and clay shale | 2. Open water | Lower Mercer | T |
| | | Lower Mercer no. 3 coal | 1. Trans. Swamp (retrograde) | | |
| | | Dark clay shale or claystone up to siltstone and sandstone | 2. Open Water | | |
| | | Lower Mercer no. 2 coal | 1. Trans. Swamp (retrograde) | | |
| | | Mixed sequence of claystone, siltstone, underclay, hard clay and sandstone | 2. Open water | | |
| | | Lower Mercer no. 1 coal | 1. Trans. Swamp | | |
| | ELLIOTT PARK | Lower Mercer hardclay and underclay | 6. Backswamp? | Quakertown | R |
| | | Upper Connoquenessing sandstone | 5. Fluvial | | |
| | | | 5. Unconformity? | | |
| | | "Quakertown" coal | 1. & 3. Trans-Reg.? Swamp | | |
| | | Interbedded sandstone and clayshale | 5. Fluvial? | "Sharon" | T |
| | | | Unconformity | | R |

matter. Many of the abandoned meander scars are filled with up to 10 feet of partially decomposed plant debris. The alluvium along Anderson Creek is up to 15 feet thick. Alluvium flooring smaller stream valleys is proportionately less.

# STRUCTURAL GEOLOGY

## INTRODUCTION

An understanding of the structure, or three-dimensional configuration, of bedrock is important to interpretation of all other geologic aspects of the Southern Penfield area. The extent of mineral deposits, flow of ground water, and rock stability for construction are partly determined by structure.

This portion of the Allegheny Plateau is dominated by the large, broad Chestnut Ridge anticline, with its axis crossing the map area in a northeasterly direction. Chestnut Ridge anticline is flanked by the Clearfield syncline to the southeast and the Punxsutawney-Caledonia syncline to the northwest. The axis of the latter fold crosses the northwestern corner of the map area with a trend similar to the anticline. No significant surface faulting was observed, but a complex of subsurface reverse faults is inferred from gas well information on the northwestern flank of Chestnut Ridge anticline.

Detailed surface structure is shown on Plate 1 by structure contours. In general, the eastern half of the southern Penfield area (Elliott Park 7½-minute quadrangle) is contoured on the base of the Curwensville Formation. The western half (Luthersburg 7½-minute quadrangle) is contoured mostly on the top of the lower Kittanning no. 3 coal of the Millstone Run Formation. In addition, the top of the Oriskany Formation is used as a datum over the whole area for contouring the subsurface structure associated with deep faulting. Plate 12 is a composite map showing all structure contours (100-foot contour intervals), fold axes, and subsurface fault traces. The cross-section on Plate 1 shows the structure as it appears roughly at right angles to the fold axes.

The surface structural configuration is most accurate and reliable where the lower Kittanning no. 3 coal is used as a datum. The base of the Curwensville Formation is a good datum where the Mercer hard clay is present. Where the hard clay is absent, especially in the middle part of the Elliott Park 7½-minute quadrangle, the base of the Curwensville Formation is estimated by projection down from the base of the Homewood Sandstone Member. Location of the base of this sandstone is done almost exclusively by photogeologic methods. The reliability then, of the base of the Curwensville as a datum where no hard clay exists, depends on the accuracy of our aerial photographic interpretations. Topographic benches, assumed to mark the top of many resistant units such as thick sandstones, are often discontinuous (probably reflecting areal variations in the Mississippian and Pennsylvanian fluvial depositional systems).

The deep subsurface structural configuration is based on gas well information. Although other interpretations are possible, our view of deep structure is conservative regarding degree of faulting and extreme bending of structure contours.

In some places, especially in the south-central ninth (Ef) of the Elliott Park 7½-minute quadrangle, the structure shown may reflect both paleotopography as well as the actual tectonic fabric. Other factors, such as differential compaction of various rock units, may slightly alter structure contours, but probably bear no regional significance.

## FOLDS

### Historical and Regional Background

By 1858, the broad folds of this part of western Pennsylvania were recognized and clearly documented. In that year, H. D. Rogers (v. II, p. 482-485) published detailed descriptions of the coal basins, bounded by anticlinals numbered northwestward from the Allegheny Front. The linking of the Second Anticlinal axis (separating the Second and Third Coal basins) in the northwestern section of Clearfield County to Chestnut Ridge in Fayette County seemed a fair certainty. He presented a general picture of the fold axis and described its bearing and variable plunge. In 1875, for the Second Pennsylvania Geological Survey, Franklin Platt (p. 12-15) gave a similar description of the Coal Measures with numbered axes separating the Bituminous Coal Basins. Shortly thereafter, H. M. Chance (1884, p. 22-23) added a more accurate description of the "basins" and "anticlinals" in Clearfield County and the designation of the "Second Anticlinal" as "Chestnut Ridge" became more firmly established.

In 1904, (Richardson, p. 4) the Chestnut Ridge anticline was described as the most persistent fold in the Indiana 15-minute quadrangle. The same fold is most obvious to the south in the New Florence 15-minute quadrangle (M. N. Shaffner, 1958). To the north, the anticline was clearly delineated across the northwestern portion of the Barnesboro 15-minute quadrangle by Campbell and others (1913, p. 7); they described Chestnut Ridge as one of the strongest folds of the Plateau region. In his report on the Punxsutawney 15-minute quadrangle for the Fourth Pennsylvania Geological Survey, G. H. Ashley (1926, p. 35) traced the axis of Chestnut Ridge anticline northwest across that region. In the central portion of Punxsutawney quadrangle, the fold broadens and a spur, originating on the northwestern flank, called the Kinter Hill-Richmond anticline, splits away and plunges off to the southwest, separated from the main fold by the Dixonville syncline. The spur dies out in the northeastern corner of the Indiana 15-minute quadrangle. In the northeastern corner of the Punxsutawney quadrangle, the fold amplitude of Chestnut Ridge increases again. It is indicated to cross the northwestern corner of the Curwensville 15-minute quadrangle (Ashley, 1940, p. 47). In this report Ashley alludes to the general trend of the anticline axis in the southern Penfield area, but its exact position was not clear at that time.

This general picture of the Chestnut Ridge anticline was well recognized and described by Ashley and Campbell in 1913 (p. 80-81); the reader is referred to their report for the reasoning behind their structural interpretations.

The Clearfield syncline, referred to as the "Second Bituminous Coal Basin" by workers of the Second Pennsylvania Geological Survey flanks Chestnut Ridge anticline on the southeast. H. M. Chance (1884, p. 21) referred to the "main trough of the Second Basin" as the "Ansonville-Bloomington-Clearfield-Karthaus Basin." Ashley and Campbell (1913, p. 80) were the first to clearly designate the structural basin northeast of Lumber City in the Curwensville 15-minute quadrangle as the "Clearfield syncline." Ashley (1940, p. 47) indicated that the southwestern terminus of the Clearfield syncline divided around a low anticlinal rise near Lumber City. To the northeast, Edmunds (1968, p. 76-77) described the configuration of this syncline where it crossed the northwestern corner of the Houtzdale 15-minute quadrangle. Glover (1970, p. 40) traced the axis of the fold through the southern half of the Clearfield 15-minute quadrangle. He indicates that wrench faulting makes delineation of the syncline difficult in the eastern part of his report area, but it is evident that the bearing of the axis diverges from northeast to east.

In Chance's Clearfield County report (1884, p. 23-24), the Third Bituminous Coal Basin is also termed "DuBois-Benezette" basin and is indicated to be a northeastern extension of the Punxsutawney coal field. In his discussion of Pine Township, Chance (p. 155) calls the fold the "Bennett's Branch (DuBois) Basin." Reporting on the geology of Jay Township, Elk County, C. A. Ashburner 1885, p. 266) states:

> Jay lies almost entirely within the *Third Bituminous coal basin*, which is the same basin in which the Cameron county mines are located, to the north-east. The north-eastern end has been locally designated as the *Cameron basin*, and the south-western end as the *Caledonia basin*, the former name being assigned to the basin, from the fact that the only mining operations being carried on within the confines of Cameron county are those of the Cameron Coal Company; and the latter, because one of the best explored sections of the coal measures, contained in the basin in the south-western portion, is at Caledonia.

To the southwest in this basin, the fold has been called "Punxsutawney syncline" by Ashley and Campbell in 1913 (p. 81-82) and again by Ashley in 1926 (p. 36).

In 1954, Fettke compiled a set of surface and subsurface structure maps, covering the western and north-central parts of Pennsylvania. The structural nomenclature was fairly well fixed by that publication. Although Fettke's maps do not indicate absolute coincidence of the Punxsutawney and Caledonia synclines, we believe that further work in the DuBois 15-minute quadrangle will prove this to be a correct assumption. This publication was updated by Cate's (1962) subsurface structure map of western Pennsylvania using the top of the Oriskany Formation as a datum. These publications present the most recent regional structural information that includes the southern half of the Penfield quadrangle.

## Chestnut Ridge Anticline

Chestnut Ridge anticline in this report area has an axial bearing of about N55°E. The fold axis, as drawn on Plate 1, has a slightly sinuous trend, entering the quadrangle on a northerly bearing, about 3½ miles east of the southwest corner, and then swinging eastward to Chestnut Grove. From there, the axis follows a northeasterly course, finally leaving the quadrangle just beyond Hobo Hill. The anticline is doubly plunging, forming an elongate dome with the crest in the vicinity of the left branch of Moose Creek. This fold has an asymmetric profile with its southeastern flank more steeply dipping than the northwestern flank. Around station Fe3, on the southeastern flank of Chestnut Ridge, the strata are interpreted as dipping about 500 feet per mile. On the northwestern flank, the steepest dips average about 250 feet per mile. The surface plunge of the axis is more moderate; the base of the Curwensville Formation is interpreted to drop a maximum of about 100 feet in one mile along the axis where it crosses Anderson Creek.

The fold height (structural relief) is relatively strong, compared with adjacent quadrangles. The maximum vertical distance from the bottom of the Clearfield syncline (near Irvin Park, Curwensville Borough, Curwensville quadrangle) to the crest of Chestnut Ridge anticline is nearly 1350 feet. The maximum fold height from the Punxsutawney-Caledonia syncline (bottom of double plunge near Sabula, northern half of Penfield quadrangle) to the top of the anticline is estimated at about 1550 feet.

The wave length of Chestnut Ridge anticline, measured between the two flanking synclinal axes is very nearly 16 miles (measured along the line of the structure section of Plate 1). This dimension includes an anticlinal spur developed on the southeastern flank of the anticline, which splits away from the main axis just east of the headwaters of Horn Shanty Branch of Montgomery Creek. The axis plunges towards the south and passes near Stronach in the Curwensville quadrangle; this structure is designated the Stronach spur and is shown on Plate 12.

The axial plane of Chestnut Ridge anticline is inclined, dipping steeply to the northwest. The inclination is indicated by offset of the fold axis based on the surface and subsurface datums (Plate 12). Structure contours drawn on the Oriskany Formation show the fold axis displaced to the northwest, compared to its surface position. The average dip of the axial plane is about 60°NW but this varies somewhat across the quadrangle. The steepest dip is calculated to be 78°NW where the plane crosses the eastern border of the report area.

### Punxsutawney-Caledonia Syncline

The concurrence of the Punxsutawney and Caledonia synclines, as explained above, is fairly certain. The axis (Plate 1) crosses the northwestern corner of the southern Penfield area with a bearing of N52°E. The axis plunges gently to the northeast. The operations of the DuBois no. 1 shaft mine of the Buffalo and Susquehanna Coal and Coke Company on the lower Freeport coal provide good surface structural control in this vicinity. The fold profile is complicated by deep faulting and the inclination of the axial plane is unknown. Our lack of adequate information from deep drilling in the vicinity of the syncline axis prevents further interpretation of fold geometry.

## FAULTS

### Surface Faulting

No obvious surface faulting was observed in the southern Penfield area. At station Ff4, we observed a possible fault with about a ten-foot vertical displacement, trending northwest-southeast. Since the outcrop was partially covered and slumped over, an exact interpretation is impossible.

A significant number of slump blocks, primary sedimentological structures, occur in the report area; these should not be confused with tectonically induced faults. Sedimentary slump blocks and their relation to disconformities have been treated by William and others (1965).

In addition, it should be made clear that sandstone cut-outs in coal mining operations commonly referred to as "faults" by miners are primary sedimentary structures.

### Subsurface Faulting

Deep, high-angle faults have been inferred by examination of information from wells drilled to the Oriskany Formation for natural gas (average depth about 5200 feet below sea level). The first information on deep structure was produced by extensive drilling in the Rockton Pool on the northwestern flank of Chestnut Ridge anticline during 1958. Lytle and others (1959, p. 8) recognized the existence of many high-angle, reverse faults. They state "Interpretations of the pattern of faulting in this area vary, but all agree to the extent that it is complex." The reverse nature of faulting is supported by frequent instances of repeated stratigraphic intervals in many wells. At least four separate attempts have been made to compile a reasonable picture of the complex of deep faults in this area. Cate (Lytle, and others, 1959, p. 22-23; Lytle, and others, 1960, p. 9; Cate, 1962) has done the greatest amount of interpretive work. What we believe to be an optimum view of the fault pattern is shown on Plate 12.

The fault system consists of a few persistent northeast-striking reverse faults with several probable splay faults occurring mostly between two of them. The splays have a north-northeast strike. Since we cannot infer the direction of inclination of the splay fault planes it is impossible to further classify these faults. Vertical displacement is rarely more than 100 feet. Our study of blocks of strata delineated by the fault system indicates that differential warping of the blocks has occurred. In addition, we have determined some rotational movement along at least one of the splay fault planes (Cd rectangle, Plate 12). All of our interpretations are based on apparent vertical displacements of the top of the Oriskany Formation.

The vertical extent of these subsurface faults is unknown, but no surface faulting may be seen. We assume that the fault displacements die out and are absorbed within the overlying Devonian Marine strata. One possible reflection of extensive subsurface faulting may be where regions of relatively steep surface structure appears to coincide with the area of the fault complex. Also, the spreading and southward bending of surface structure contours in the Af and Bf rectangles (Plate 12) may reflect deep fault movement. In this regard, attention should be focused on the large area of structural steepening on the southeastern flank of Chestnut Ridge anticline which may reflect a deep fault complex. To date, not enough drilling has been done to demonstrate this.

## JOINTS

### Surface Joint Pattern

In general, joints in this region have a vertical orientation. Bearings of joints at 47 stations were taken and the results are shown in Figure 18. The rose diagram shows that the jointing has two predominant bearings, roughly at right angles to each other. The primary set of this joint system bears about N30°W.; the secondary set bears about N55°E. Other less significant joint bearings were measured.

The sets were measured in various rock units, ranging from sandstone to shales and clays. No face or butt joints in coals were measured for this analysis. Although no systematic study was undertaken, it has been our observation that joint planes are generally more closely spaced in shales than in sandstones. In shales, spacing usually varies from a few inches to two feet. The spacing in sandstones is on the order of 2-6 feet. Jointing in the massive Homewood Sandstone Member has produced "rock cities," the best-known of which is Bilgers Rocks, a local tourist attraction. Huge

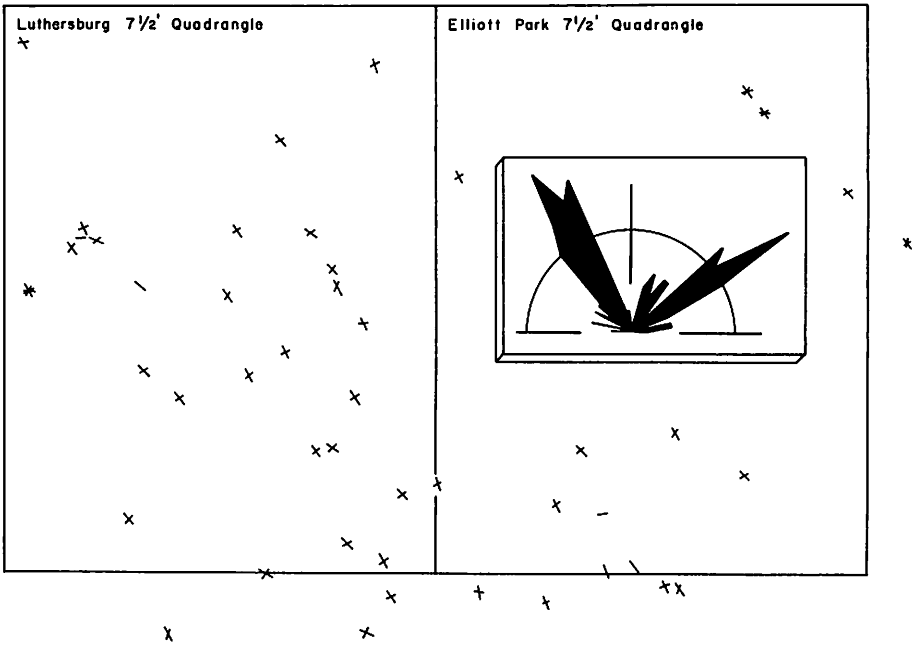


Figure 18. Major joint sets of the southern Penfield quadrangle.

blocks of the sandstone have separated along joint planes by gravity sliding, producing a maze of deep, labyrinthic passages.

In the southern Penfield area, the primary set of the joint system appears to remain normal to orientation of the fold axes. However, the irregularity added to Chestnut Ridge anticline by the Stronach spur does not seem to affect the basic orientation of the joint set. This may corroborate Nickelsen and Hough's observation (1967, p. 625) that regional orientation of joint sets shows less variation than fold axis orientation.

Our observation of joints is in general agreement with the work of Nickelsen and Hough (1967); the reader is referred to their paper for detailed interpretation of joint origin.

## Master Joints

Casual observation of the major stream valleys in the Elliott Park 7½-minute quadrangle reveals a sub-parallelism that may reflect a master joint system closely related by orientation to the surface joints discussed above. Portions of Anderson Creek with Irvin Branch and Bear Run tributaries, Montgomery Creek with West and North Branch tributaries, and Moose Creek all show a north-northwest to northwest lineation. There may be a direct relation between this topographic pattern and wrench faulting in the Clearfield and Houtzdale quadrangles (Edmunds, 1968, p. 78). The master joints that appear to extend beyond the line of zero displacement on wrench faults to the southeast may extend into this report area.

## STRUCTURAL GENESIS

Gwinn (1964, p. 863ff) has offered a most penetrating analysis of deformational origins in the central Appalachians. According to his work, the folds and deep faults in the Appalachian Plateau are related to deep translational movements of large, sheet-like blocks along at least two major levels of detachment or décollement slip surfaces. These very large, broad blocks are bounded, according to Gwinn (1964, p. 890-891), by lineaments which probably ". . . mark zones of transcurrent faulting on the margins of differentially advancing dermal thrust sheets . . ." Although no faulting is seen at the surface, fold axes tend to terminate or are deflected along these lineaments. A good example of fold axis interruption is in the central to southwestern portion of the Punxsutawney quadrangle, where Chestnut Ridge anticline broadens and a spur splits off to the southwest (see Historical and Regional Background above).

The southern Penfield area is located in a tectonic sub-province bounded by two lineaments (Gwinn, 1964, pl. 1), but is not directly affected by them. Post-Paleozoic deforming forces were directed northwesterly into this subprovince or décollement sheet, forming the broad, arcuate folds such as the anticline and syncline of this map area.

A characteristic of folding in this tectonic style is the development of thrust faults, dipping toward the syncline, that are splays off the décollement slip surface. The mechanics of this concentric folding and flexural-slip thrust process is explained in more detail by Gwinn (1964, p. 891ff). The fault complex shown on Plate 12 is most likely the high-angle extension of thrusts that have imbricated the northwestern flank of Chestnut Ridge anticline.

The anticline is noticeably oversteepened on its southeastern flank, a common feature of Plateau anticlines in this region. Gwinn (1964, p. 893-894) attributes this phenomonon to thrusting of a competent inter-décollement block (over the stationary footwall of the opposing block) beneath the northwestern flank of the original concentric fold. This process yields greater displacement along the northwest-dipping splay thrusts and consequent steepening of the southeastern flank of the anticline. The same process may well account for any lack of faulting at the Oriskany level on the southeastern flank of the fold. This possibility may, in turn, account for lack of natural gas accumulation in fault traps on this side of the anticline.

The irregularity of Chestnut Ridge anticline geometry caused by the presence of the Stronach anticlinal spur may be due to differential slip on the decollement surface as a function of lithofacies.

# MINERAL RESOURCES

## COAL

### General

Coal is the most important mineral commodity of the southern Penfield quadrangle. Almost all of the economically extractable coal is limited to the Allegheny Group (Plate 1). The principal coal seams are the lower Kittanning, middle Kittanning, upper Kittanning and lower Freeport. The great bulk of the mineable coal lies west of Anderson Creek and in the southeastern corner of the report area. Erosion has stripped away most of the coal measures elsewhere.

With the exception of the DuBois no. 1 and no. 2 shafts, all of the underground coal mining in the report area has been relatively small scale. Aside from a small pillar-pulling operation at Af11, there was no underground mining being conducted at the time of this study. Since World War II, almost all coal has been extracted by open pit methods. Most of the coal is sold for electric power generation. Underground coal mining operations are listed in Table 2.

### Chemical and Physical Characteristics

On a "moisture and ash-free" basis, most of the coal west of Anderson Creek should analyze between 65 to 70% fixed carbon and 30 to 35% volatile matter (three actual analyses available were each 67% and 33%). The coals of the southeast corner of the report area should be about 71% fixed carbon and about 29% volatile matter. Coal with less than 69% fixed carbon is classified as "high-volatile-A bituminous coal", and greater than 69% fixed carbon as "medium volatile bituminous coal."

The heat value on a "dry, ash-free" basis will fall between 15,300 and 15,600 B.t.u. per pound; and between 1,500 and 2,000 B.t.u. less on an "as delivered" basis.

Previously published proximate and ultimate analyses and other tests on coals from the southern Penfield area are shown in Table 3.

A study of the carbonizing properties of Elk, Clarion, Jefferson, Clearfield and Centre County coals is given in Birge and others (1963). Although in that report no samples were taken from the immediate southern Penfield area, the following inferences about southern Penfield coals are drawn:

1. Aside from ash and sulfur considerations, the coals of this area will coke and have carbonizing properties commensurate with other Appalachian coals of similar rank (high-volatile-A to medium volatile).
2. Upon carbonizing, the coals should average about 70 to 72% coke and

about 14 to 16 gallons of tar and light oil per ton (both on a moisture- and ash-free basis).

3. Most coals will show a slight to strong (0 to 30%) tendency to contract when subjected to oven expansion tests.
4. Gas produced by carbonization should have a specific gravity of about 0.335 to 0.365, a heat value of about 570 to 590 B.t.u./ft$^3$ and 2900 to 3200 B.t.u./lb of original coal.
5. The coals appear to have coke strength indexes comparable to other Appalachian coals of similar rank.

The preparation characteristics of Clearfield County coals are given in Crentz and others (1952). Although no samples were taken from the southern Penfield area, the conclusions from that report indicated that most coals here will require moderate to extensive cleaning to be satisfactory for metallurgical purposes. The lower Freeport and lower Kittanning are probably most amenable to upgrading.

## Coal Reserves

Reserves over 14 inches thick for the lower Kittanning no. 3, middle Kittanning, upper Kittanning, lower Freeport, and upper Freeport coals are given in Tables 4 through 8 and summarized in Figure 19. The areal distribution and variability of these seams along with specific measured sections are shown on Plates 13 through 17. Measured sections of other coals are shown on Plate 17, although no reserves have been computed for them. Of the coals for which reserves have not been calculated, only Clarion no. 1 is likely to be of sufficient importance to alter the total reserve picture appreciably. Total reserves over 14 inches for the five computed coal seams total approximately 190 million tons, including 2.6 million tons over 42 inches, 112 million tons between 28 and 42 inches, and 75 million tons between 14 and 28 inches.

The method used in the calculation of coal reserves is that used by the U. S. Geological Survey as described in Averitt and others (1969) except in the establishment of reliability categories. Three categories are used by the U. S. Geological Survey to describe the reliability of coal reserves estimates—"measured," "indicated," and "inferred." "Measured" coal is usually taken to be that within ¼ mile of a control point, "indicated" coal is that lying more than ¼ mile but less than ½ or ¾ miles from a control point, and "inferred" beyond ½ or ¾ mile. It has been the practice of the Pennsylvania Geologic Survey to consider coal as "measured" within ½ mile of a control point, "indicated" within 1 to 1½ miles, and "inferred" beyond that. For consistency, this report follows this second procedure, which does not change the total reserve picture, but does increase the proportions normally allocated to the "measured" and "inferred" categories.

Table 2. *Underground Coal Mines of the Southern Penfield Quadrangle*

| Mine Name | Ref. no. | Coal | Last Known Owner (Previous Owner) | Comments |
|---|---|---|---|---|
| Berwind or Berwind-White shaft | Ad6 | LF | Berwind-White Coal Mining Co. | See DuBois no. 1 shaft. |
| Coal Hill | Bf8 | LF | Coal Hill Mining Co. | |
| DuBois no. 1 shaft (ex-Berwind or Berwind-White shaft) | Ad6 | LF | Buffalo & Susquehanna Coke & Coal Co. (Berwind-White Coal Mining Co.) | 265 ft. shaft. Gassy mine. |
| DuBois no. 2 shaft | DuBois Fd1 | LF | Buffalo & Susquehanna Coke & Coal Co. | 170 ft. shaft. Gassy mine. |
| Fish | Dd9 | LK | W. Fish | |
| Fish | Dd10 | MK | W. Fish | |
| Jackson no. 1 (ex-Luthersburg no. 1) | ? | LK or MK | G. H. Lum Coal Co. (DuBois Mining Co.) | Reported as ¼ mi W of Luthersburg [Luthersburg Station?] on B & O R. R., may be either Ae40 or Ae37. |
| Jackson no. 2 (ex-Luthersburg no. 2) | Ae33 | MK | G. H. Lum Coal Co. (DuBois Mining Co.) | |
| Korb | Af9 Af11 | LF | Mr. Korb | Pulling pillars Oct. 1966. |
| Lucas no. 1 | ? | MK? | R. H. Lucas Coal Co. | Reported as 1¼ miles NW of Luthersburg along B & O tracks. May be one or more of Ae23, Ae24 or Ae25. |

| | | | | |
|---|---|---|---|---|
| Luthersburg no. 1 | ? | LK or MK | DuBois Mining Co. | See Jackson no. 1 |
| Luthersburg no. 2 | Ae33 | MK | DuBois Mining Co. | See Jackson no. 2. One of two mines with this name. |
| Luthersburg no. 2 (ex-Salem no. 2) | Be15 | LK | Salem Coke & Coal Co. | One of two mines with this name. |
| Luthersburg no. 3 | Be14 | LK | Salem Coke & Coal Co. | See Salem no. 2 (Ref. no Be14). |
| Pentz | Bd8 | LK | J. H. & R. H. Pentz (?) | Ownership not verified. |
| Salem no. 2 | Be15 | MK | Salem Coke & Coal Co. | See Luthersburg no. 2 of Salem Coke & Coal Co. One of the two mines with this name. |
| Salem no. 2 (ex-Luthersburg no. 3, ex-Salem no. 3) | Be14 | LK | Salem Coke & Coal Co. | One of two mines with this name. |
| Salem no. 3 | Be14 | LK | Salem Coke & Coal Co. | See Salem no. 2 (Ref. no. Be14). |
| Union No. 1 | Be32 | LK | Union Mining Co. | Location not certain. |
| Union no. 2 | Be31 | LK | Union Mining Co. | |
| Wildcat | Cd38 | LK | DuBois Moshannan Coal Co. (J. H. & R. H. Pentz) (Abel Coal Co.) | |
| Unknown | Ae23 | See comments | Unknown | May be Lucas no. 1. Although this mine enters near the level of the middle Kittanning, the large amount of discarded bone and coaly shale on the tailing suggest that it may have been driven into the overlying local channel coal. |
| Unknown | Ae24 | MK | Unknown | May be Lucas no. 1. |
| Unknown | Ae25 | MK | Unknown | May be Lucas no. 1. |

Table 2. *Continued*

| Mine Name | Ref. no. | Coal | Last Known Owner (Previous Owner) | Comments |
|---|---|---|---|---|
| Unknown | Ac6 | See comments | Unknown | Local coal above MK and below Luthersburg and UK. |
| Unknown | Be12 | MK | Unknown | |
| Unknown | Ac37 | LK | Unknown | May be Jackson no. 1. |
| Unknown | Bf38 | LF | Unknown | |
| Unknown | Bf37 | LF | Unknown | |
| Unknown | Bf36 | LF | Unknown | |
| Unknown | Ff10 | LK | Unknown | |
| Unknown | Ae64 | MK | Unknown | |
| Unknown | Ce4 | MK | Unknown | |
| Unknown | Af13 | LK | Unknown | |
| Unknown | Bf1 | UK | Unknown | |
| Unknown | Ae79 | LK | Unknown | |
| Unknown | Ae63 | MK | Unknown | May be Jackson no. 1. |
| Unknown | Ac47 | See comments | Unknown | Although this mine enters near the level of the middle Kittanning, the large amount of discarded bone and coaly shale on the tailings pile suggest that it may have been driven into the overlying local channel coal. |

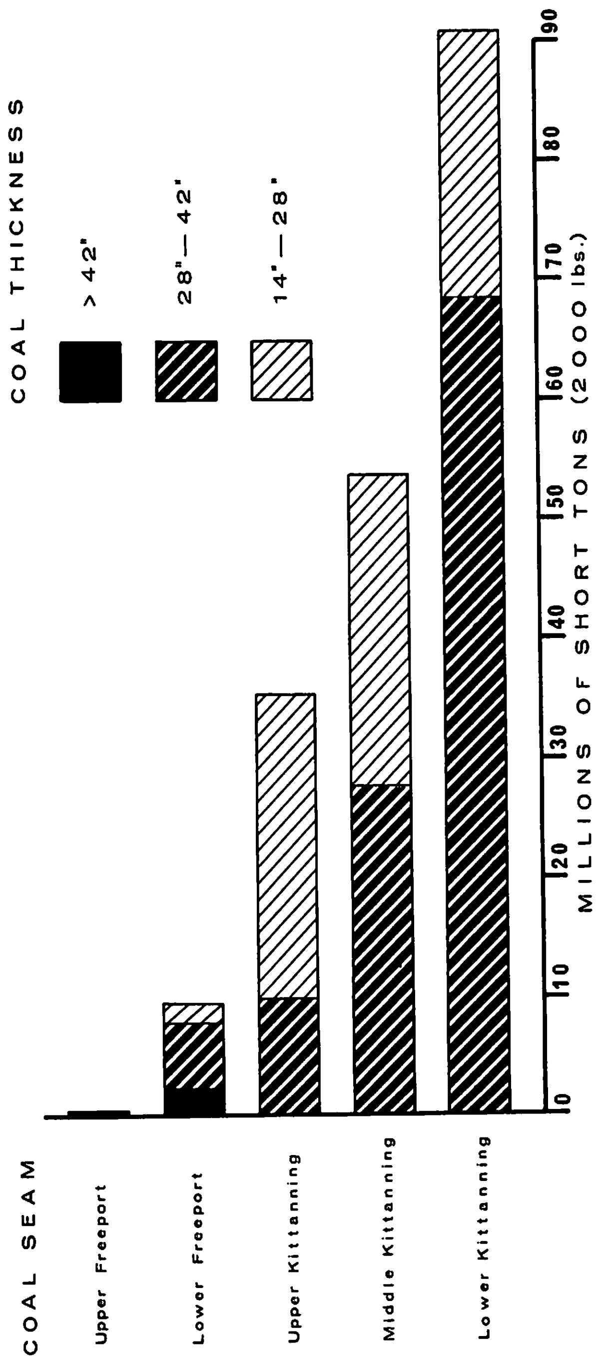


Figure 19. Coal reserves of the southern Penfield quadrangle.

Table 3. *Coal Analyses from the*

| Station Number (Adit)[1] | Coal | Location (Adit) | Mine | Location in Mine | USBM Laboratory No. | Sample Condition[4] |
|---|---|---|---|---|---|---|
| Ad6 | lower Freeport[2] | ¾ mi. NE of Oklahoma[3] | DuBois no. 1 shaft | Face of 1 room, ½ heading, 2 left heading, main south heading. | 82,495 | AR |
| Do. | Do. | Do. | Do. | Face 20 room, 2-A heading, 2 left heading, main south heading. | 82,496 | AR |
| Do. | Do. | Do. | Do. | Face 22 room, 1-D heading, 2-C heading, main west heading. | 82,497 | AR |
| Do. | Do. | Do. | Do. | Cross-cut face, 47 room, left rib, 2-D heading, 2-C heading, main west heading. | 82,498 | AR |
| Do. | Do. | Do. | Do. | Face 1 room, 4-C heading, main west heading. | 82,499 | AR |
| Do. | Do. | Do. | Do. | Composite of 82,495 through 82,499. | 82,500 | AR Dry MAF |
| Be14[5] | lower Kittanning | ½ mi. E of Luthersburg Station on B & O R. R.[3] | Luthersburg (Prob. Salem no. 2 of Table 3). | Face of 1 left heading, main heading. | 82,505 | AR |
| Do. | Do. | Do. | Do. | Face of 1 right heading, main heading. | 82,506 | AR |
| Do. | Do. | Do. | Do. | Face of 15 room, buck heading. | 82,507 | AR |
| Do. | Do. | Do. | Do. | Composite of 82,505 through 82,507. | 82,508 | AR Dry MAF |
| ? May be Ae40 or Ae37 | middle Kittanning or lower Kittanning[2] | ¼ mi. W of Luthersburg on B. & O. R. R.[3] | Jackson (Jackson no. 1 of Table 3) | Face of main heading 1400 ft. SW of mouth. | 99,138 | AR |
| Do. | Do. | Do. | Do. | Face of crop heading 1200 ft E of mine mouth. | 99,139 | AR |
| Do. | Do. | Do. | Do. | Face of 32 room, 2 left heading, 1200 ft SE of mine mouth. | 99,140 | AR |
| Do. | Do. | Do. | Do. | Composite of 99,138 through 99,140 | 99,141 | AR Dry MAF |

Footnotes

1. Mine adit location keyed to Plate 1, coal reserve plates, and table of mines.
2. Coal identification changed or modified from original source.
3. Description of mine location different from that given in original source.

## Southern Penfield Quadrangle

| Proximate Analysis: Moisture | Volatile Matter | Fixed Carbon | Ash | Ultimate Analysis: Sulphur | Hydrogen | Carbon | Nitrogen | Oxygen | Air-dry loss Percent | Heat Value: Calories | B. T. U. | Ash Softening Temp °F | Reference Source PGS = Pa. Geologic Survey USBM = U. S. Bureau of Mines |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.2 | 29.0 | 58.1 | 10.7 | 1.1 | | | | | 1.7 | 7,489 | 13,480 | 2,200 | PGS 4th, M6, pt 4, p 67 or USBM Tech. Pap. 590, p 174 |
| 2.4 | 29.2 | 60.2 | 8.2 | 1.0 | | | | | 1.9 | 7,682 | 13,720 | 2,220 | Do. |
| 2.0 | 30.8 | 60.0 | 7.2 | 1.1 | | | | | 1.6 | 7,772 | 13,990 | 2,510 | Do. |
| 2.1 | 29.1 | 59.9 | 8.9 | 1.8 | | | | | 1.7 | 7,583 | 13,650 | 2,340 | Do. |
| 1.8 | 28.4 | 59.7 | 10.1 | 1.4 | | | | | 1.4 | 7,511 | 13,520 | 2,850 | Do. |
| 2.1 | 29.4 | 59.7 | 8.8 | 1.3 | 5.0 | 76.7 | 1.4 | 6.8 | 1.6 | 7,611 | 13,700 | | Do. |
| | 30.0 | 61.0 | 9.0 | 1.3 | 4.9 | 78.3 | 1.5 | 5.0 | | 7,778 | 14,000 | | Do. |
| | 33.0 | 67.0 | | 1.4 | 5.3 | 86.1 | 1.6 | 5.6 | | 8,550 | 15,390 | | Do. |
| 3.5 | 29.6 | 56.1 | 10.8 | 2.8 | | | | | 3.0 | 7,300 | 13,140 | 2,280 | PGS 4th, M6 pt 4, p 69 or USMB Tech. Pap. 590, p 176 |
| 3.0 | 30.1 | 56.5 | 10.4 | 2.1 | | | | | 2.4 | 7,400 | 13,320 | 2,360 | Do. |
| 2.8 | 28.5 | 59.9 | 8.8 | 2.4 | | | | | 2.3 | 7,617 | 13,710 | 2,340 | Do. |
| 3.1 | 28.7 | 58.2 | 10.0 | 2.4 | 5.1 | 74.3 | 1.4 | 6.7 | 2.6 | 7,444 | 13,400 | | Do. |
| | 29.6 | 60.1 | 10.3 | 2.6 | 4.9 | 76.7 | 1.4 | 4.1 | | 7,683 | 13,840 | | Do. |
| | 33.0 | 67.0 | | 2.9 | 5.5 | 85.5 | 1.6 | 4.5 | | 8,567 | 15,420 | | Do. |
| 2.9 | 29.2 | 58.7 | 9.2 | 2.2 | | | | | 2.3 | | 13,610 | 2,340 | USBM Tech. Pap. 590 |
| 3.0 | 28.7 | 61.0 | 7.3 | 1.7 | | | | | 2.4 | | 13,920 | 2,370 | Do. |
| 2.7 | 28.8 | 59.0 | 9.5 | 2.2 | | | | | 2.0 | | 13,660 | 2,390 | Do. |
| 2.8 | 29.0 | 59.5 | 8.7 | 2.0 | 5.1 | 77.0 | 1.4 | 5.8 | 2.2 | | 13,720 | | Do. |
| | 29.8 | 61.3 | 8.9 | 2.1 | 4.9 | 79.2 | 1.5 | 3.4 | | | 14,120 | | Do. |
| | 32.8 | 67.2 | | 2.3 | 5.4 | 86.9 | 1.6 | 3.8 | | | 15,500 | | Do. |

4. Sample condition:
   AR—as received.
   Dry—dried at a temperature of 105°C.
   MAF—moisture and ash free.
5. Multiple use of the name "Luthersburg" in this area makes identification uncertain.

## Mississippian (Pocono) Coals

A few very thin coal seams occur in the Pocono Formation. They are not known to approach mineable thickness here or elsewhere in Pennsylvania. There is very little possibility that coal prospecting in the Pocono Formation will turn up anything of commercial value. Exposures of these coals are shown on Plate 17.

## Quakertown Coal

The Quakertown coal occurs near the base of the Elliott Park Formation in this area. It is absent more often than not, and where present is very dirty and not known to exceed several inches in thickness. It is commercially worthless. Measured sections of the Quakertown are shown on Plate 17.

## Mercer Coals

There are five Mercer coals in this area, called in ascending order: lower Mercer no. 1, lower Mercer no. 2, lower Mercer no. 3, upper Mercer no. 1, and upper Mercer no. 2.

All of the Mercer coals are highly variable in thickness, usually very bony or shaly, high in sulfur, rolly, and frequently absent. Their irregularity, poor quality, and difficulty in mining has virtually eliminated them from commercial consideration. Mercer coals are exposed in strip mining operations for the underlying Mercer clay, and might, in special circumstances, be disposed of commercially when thus encountered.

Measured sections of the various Mercer coals are shown on Plate 17. All Mercer coals are contained within the Curwensville Formation as mapped on Plate 1.

## Clarion Coals

(Also variously called A-coal, A′-coal and Brookville)

There are three Clarion coals; Clarion no. 1, Clarion no. 2, and Clarion no. 3 in ascending order. All are contained in the Clearfield Creek Formation (Plate 1) with Clarion no. 1 marking the base of that unit. Location of measured sections is shown on Plate 17.

Clarion no. 1 (Brookville) has been mined extensively around the headwaters of Little Anderson Creek and in a few small mines immediately west of Bell Run. It was observed to be 30 inches of moderately bright coal with no important partings at Bf28, one-half mile southwest of Chestnut Grove. Where mined just west of Little Anderson Creek, it was reported to have thinned to several inches in a matter of a few hundred feet. Most drill holes in the southern Luthersburg quadrangle show Clarion no. 1 to be less than 2 feet thick (although these drill records are not always especially reliable).

Along its extensive outcrop line in northern Luthersburg and northwestern Elliott Park quadrangles there has been no mining whatsoever; the only exposure is 18 inches at De1. Clarion no. 1 was only a few inches thick in the drill hole at Bc1 just north of the report area.

Based on limited evidence, it appears that Clarion no. 1 is thin across the northern half and in the southeastern part of the report area, and locally of mineable thickness in the southwest.

The Clarion no. 1 roof rocks are composed of shale grading upward to thin-bedded sandstone. The floor is underclay.

Surface exposures and drill holes in south-central Luthersburg quadrangle show Clarion no. 2 to be less than 1-foot thick. Little information is available elsewhere, but it seems to be generally thin throughout the area.

Indications are that Clarion no. 3 is absent throughout most of the area and probably very thin if present.

### Lower Kittanning Coals
### (also called B-coal)

In southeastern Clearfield County there are five lower Kittanning coals, named in ascending order: lower Kittanning no. 1, no. 2, no. 3, no. 4, and no. 5. Lower Kittanning no. 2 and no. 5 have disappeared westward and are absent from the report area, while lower Kittanning no. 4 exists only as a thin rider in the extreme southeastern part of the Elliott Park quadrangle.

Lower Kittanning no. 1, which marks the base of the Millstone Run Formation (Plate 1), has also deteriorated westward to a seam of only very local importance. It was not observed except in the south-central part of the report area and as thin coal stringers 25 feet below lower Kittanning no. 3 in the drill hole at Bc1. Drill records and a few small strip mines (Bf25, Cf23, Df17 and Df19) indicate lower Kittanning no. 1 is present in the area southwest of Greenville between Bigler Run and Hughey Run and in the area between Little Anderson Creek the western edge of the report area, and that it is absent in the area around Bell Run. Drill records show lower Kittanning no. 1 up to 2½ feet thick locally.

Lower Kittanning no. 3 is the most important coal seam of the report area with reserves of approximately 91 million tons over 14 inches thick including 69 million tons over 28 inches. The coal is generally 1½ to 2½ feet thick, bright and clean with a ½-inch bony layer about 1 foot from the top and another ½-inch bone or shale parting a few inches from the base.

Lower Kittanning no. 3 is overlain by up to several feet of dark shale above which is a thick sequence of lighter shale which locally grades into thin-bedded siltstone or sandstone. The floor is underclay.

The cropline of lower Kittanning no. 3 is shown on Plate 1 and the cropline, thickness variation, and measured sections on Plate 13. Table 4 shows the reserve tonnages.

# Table 4. *Lower Kittanning No. 3 Coal Reserves*

| COUNTY | Township | Area of twp. in quad. (acres) | Areas of coal lost by erosion (acres) | Coal less than 14" thick in place (acres) | Coal over 14" thick in place before mining (acres) | Mined out and lost (acres) | Coal over 14" thick remaining (acres) | CATEGORY | COAL RESERVES IN TONS OF 2000 POUNDS: 14–28" thick, acres | 14–28" thick, thousands of tons | 28–42" thick, acres | 28–42" thick, thousands of tons | > 42" thick, acres | > 42" thick, thousands of tons | TOTAL RESERVES IN TONS OF 2000 POUNDS: 14" and more thick, acres | 14" and more thick, thousands of tons | 28" and more thick, acres | 28" and more thick, thousands of tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Bloom | 9,973 | 9,022 | — | 951 | 297 | 654 | measured | 169 | 634.8 | 75 | 332.8 | — | — | 244 | 967.6 | 75 | 332.8 |
| | | | | | | | | indicated | 406 | 1,516.8 | 4 | 16.7 | — | — | 410 | 1,533.5 | 4 | 16.7 |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 575 | 2,151.6 | 79 | 349.5 | — | — | 654 | 2,501.1 | 79 | 349.5 |
| | Brady | 13,972 | 4,087 | — | 9,885 | 697 | 9,188 | measured | 86 | 334.1 | 751 | 3,920.9 | — | — | 837 | 4,255.0 | 751 | 3,920.9 |
| | | | | | | | | indicated | 1,540 | 6,074.0 | 3,975 | 19,969.9 | — | — | 5,515 | 26,043.9 | 3,975 | 19,969.9 |
| | | | | | | | | inferred | 1,452 | 5,784.2 | 1,384 | 6,744.2 | — | — | 2,836 | 12,528.4 | 1,384 | 6,744.2 |
| | | | | | | | | TOTAL | 3,078 | 12,192.3 | 6,110 | 30,635.0 | — | — | 9,188 | 42,827.3 | 6,110 | 30,635.0 |
| | City of DuBois | 382 | — | — | 382 | — | 382 | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | 26 | 127.2 | — | — | 26 | 127.2 | 26 | 127.2 |
| | | | | | | | | inferred | — | — | 356 | 1,765.9 | — | — | 356 | 1,765.9 | 356 | 1,765.9 |
| | | | | | | | | TOTAL | — | — | 382 | 1,893.1 | — | — | 382 | 1,893.1 | 382 | 1,893.1 |
| | Lawrence | 28 | 28 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Penn | 88 | 14 | — | 74 | 4 | 70 | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | 70 | 261.4 | — | — | — | — | 70 | 261.4 | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 70 | 261.4 | — | — | — | — | 70 | 261.4 | — | — |
| | Pike | 11,001 | 10,235 | — | 766 | 77 | 689 | measured | 198 | 744.0 | 18 | 80.0 | — | — | 216 | 824.0 | 18 | 80.0 |
| | | | | | | | | indicated | 356 | 1,214.2 | 22 | 99.0 | — | — | 378 | 1,313.2 | 22 | 99.0 |
| | | | | | | | | inferred | 95 | 300.5 | — | — | — | — | 95 | 300.5 | — | — |
| | | | | | | | | TOTAL | 649 | 2,258.7 | 40 | 179.0 | — | — | 689 | 2,437.7 | 40 | 179.0 |
| | Pine | 13,711 | 13,711 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Sandy | 4,810 | 38 | — | 4,772 | — | 4,772 | measured | — | — | 228 | 1,040.3 | — | — | 228 | 1,040.3 | 228 | 1,040.3 |
| | | | | | | | | indicated | 206 | 832.3 | 2,430 | 11,215.6 | — | — | 2,636 | 12,047.9 | 2,430 | 11,215.6 |
| | | | | | | | | inferred | — | — | 1,908 | 9,522.5 | — | — | 1,908 | 9,522.5 | 1,908 | 9,522.5 |
| | | | | | | | | TOTAL | 206 | 832.3 | 4,566 | 21,778.4 | — | — | 4,772 | 22,610.7 | 4,566 | 21,778.4 |
| | Union | 17,673 | 13,180 | — | 4,493 | 264 | 4,229 | measured | — | — | 558 | 2,645.4 | — | — | 558 | 2,645.4 | 558 | 2,645.4 |
| | | | | | | | | indicated | 631 | 2,556.4 | 1,252 | 5,743.5 | — | — | 1,883 | 8,299.9 | 1,252 | 5,743.5 |
| | | | | | | | | inferred | 481 | 1,947.2 | 1,307 | 5,489.5 | — | — | 1,788 | 7,436.7 | 1,307 | 5,489.5 |
| | | | | | | | | TOTAL | 1,112 | 4,503.6 | 3,117 | 13,878.4 | — | — | 4,229 | 18,382.0 | 3,117 | 13,878.4 |
| | Totals | 71,638 | 50,315 | — | 21,323 | 1,339 | 19,984 | measured | | | | | | | | | | |
| | | | | | | | | indicated | | | | | | | | | | |
| | | | | | | | | inferred | | | | | | | | | | |
| | | | | | | | | TOTAL | 5,690 | 22,199.9 | 14,294 | 68,713.4 | — | — | 19,984 | 90,913.3 | 14,294 | 68,713.4 |

Note: The measured thickness of lower Kittanning coal at Bd 23, acquired after compilation of initial data, was not used in calculation of this table. However, the thickness is compatible with the results given.

## Middle Kittanning Coal
## (also called C-coal)

The middle Kittanning coal, which marks the base of the Mineral Springs Formation, is a good quality seam, between 10 and 36 inches thick. It contains a fairly persistent 1- to 2-inch shale or bone parting between 3 and 14 inches above the base.

The middle Kittanning roof rock is dark shale, except in the area between Limestone Run and Stump Creek in western Luthersburg where it is frequently sandstone. The middle Kittanning floor is underclay.

The middle Kittanning is the second most important coal from the standpoint of reserves with over 54 million tons greater than 14 inches thick and almost 28 million above 28 inches in thickness. The cropline, thickness variation, and measured sections of the middle Kittanning are given on Plate 14. Tonnage reserves are given in Table 5.

## Local Channel Coal above Middle Kittanning coal

In the area ¾ miles east of Salem a striking local channel coal is developed a short distance above the middle Kittanning coal. This seam lies in a narrow trough-shaped channel approximately ¼-mile wide. The coal is moderately bright to dull, with a high fusain, bone, and shale content, and a tendency to crumble readily to very fine cubes. In the center of the channelway the seam reaches 5½ feet thick, but rises and thins rapidly toward the flanks of the channel.

This coal was strip mined at Ae7 and Ae17 and previously deep mined at the western end of the stripping at Ae1. The channel axis trends north-south, but it is not known how far it extends north of Ae7 or south of Ae17. The old underground mines at Ae23 and Ae47 have associated tailings-piles that contain a large amount of thick bone and coaly shale which is not typical of a mine on the middle Kittanning, and therefore suggest that at some point, headings from these mines may have been driven into this channel coal. No trace of this coal has been found south of Limestone Run.

Although the quality of the seam is poor and the extent limited, it may provide an attractive small operation because of its exceptional thickness.

Measured sections of this local coal are given on Plate 17.

## "Luthersburg" Coal

The "Luthersburg" is a coal usually lying 20 to 30 feet below the upper Kittanning, and although fairly widespread in the Luthersburg quadrangle, seems to have no correlative much beyond this area.

The "Luthersburg" ranges up to 24 inches thick and varies from moderately bright, fairly clean to dull, shaly coal.

The commercial value of the "Luthersburg" coal is slight, except in selected instances where it could be worked in conjunction with an operation on the middle or upper Kittanning.

Measured sections of the "Luthersburg" coal are given on Plate 17.

### Upper Kittanning Coal
### (also called C′-coal)

The upper Kittanning coal, which marks the base of the Laurel Run Formation (Plate 1), ranges from approximately 12 to 30 inches thick. It is usually moderately bright to moderately dull coal with numerous thin, discontinuous partings. The lower few inches are normally tough and bony. About 6 to 8 inches from the top is a very persistent 1- to 2-inch bony interval which, upon weathering, stands out as a distinctive yellow or orange streak. In a few cases, as at Ae20 the upper Kittanning is locally cut out by the channel of the overlying Freeport sandstone.

The upper Kittanning contains the third largest reserves in the report area with 25 million tons over 14 inches including almost 10 million tons over 28 inches.

The upper Kittanning roof rock is usually a thick sequence of dark shale which grades up into lighter shale and finally into thin-bedded siltstone and sandstone. The floor is underclay often with interbedded limestone.

The cropline, thickness variation, and measured sections of the upper Kittanning are shown on Plate 15. Tonnage reserves are given in Table 6.

### Lower Freeport Coal
### (also called D-coal)

Reserves on the lower Freeport coal total about 9½ million tons over 14 inches thick including slightly less than 6 million tons between 28 and 42 inches and a little over 2 million tons over 42 inches thick. Most of this remaining coal could not be easily recovered as it lies close to the margins of the old DuBois no. 1 and no. 2 shafts.

The lower Freeport marks the bottom of the Glen Richey Formation (Plate 1) and is confined largely to the northwestern corner of the Luthersburg quadrangle with scattered outliers catching the hilltops to the southeast.

The lower Freeport coal is remarkable for its variability. Aside from areas where it is cut out completely by the lower Mahoning sandstone channel, its thickness ranged from 1 to 13 feet. The lower Freeport averaged 5 to 6 feet in the DuBois mines but thinned rapidly to the northwest and southeast. The northwestly thinning is a sandstone cut-out, but the loss to the southeast may be a cut-out or internal thinning of the coal itself. South of Salem the lower Freeport again thickens, reaching a development of 13 feet

## Table 5. *Middle Kittanning Coal Reserves*

| COUNTY | Township | Area of twp. in quad. (acres) | Areas of coal lost by erosion (acres) | Coal less than 14" thick in place (acres) | Coal over 14" thick in place before mining (acres) | Mined out and lost (acres) | Coal over 14" thick remaining (acres) | CATEGORY | COAL RESERVES IN TONS OF 2000 POUNDS: 14–28" thick, acres | 14–28" thick, thousands of tons | 28–42" thick, acres | 28–42" thick, thousands of tons | > 42" thick, acres | > 42" thick, thousands of tons | TOTAL RESERVES IN TONS OF 2000 POUNDS: 14" and more thick, acres | 14" and more thick, thousands of tons | 28" and more thick, acres | 28" and more thick, thousands of tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | | | | | | | | measured | 26 | 65.5 | — | — | — | — | 26 | 65.5 | — | — |
| | Bloom | 9,973 | 9,719 | 22 | 232 | 22 | 210 | indicated | 55 | 164.2 | — | — | — | — | 55 | 164.2 | — | — |
| | | | | | | | | inferred | 114 | 426.8 | 15 | 63.9 | — | — | 129 | 490.7 | 15 | 63.9 |
| | | | | | | | | TOTAL | 195 | 656.5 | 15 | 63.9 | — | — | 210 | 720.4 | 15 | 63.9 |
| | | | | | | | | measured | 191 | 765.6 | 1,031 | 4,736.6 | — | — | 1,222 | 5,502.2 | 1,031 | 4,736.6 |
| | Brady | 13,972 | 7,090 | 246 | 6,636 | 455 | 6,181 | indicated | 1,296 | 4,669.8 | 1,472 | 6,568.2 | — | — | 2,768 | 11,238.0 | 1,472 | 6,568.2 |
| | | | | | | | | inferred | 1,490 | 4,630.1 | 701 | 3,053.8 | — | — | 2,191 | 7,683.9 | 701 | 3,053.8 |
| | | | | | | | | TOTAL | 2,977 | 10,065.5 | 3,204 | 14,358.6 | — | — | 6,181 | 24,424.1 | 3,204 | 14,358.6 |
| | City of | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| | DuBois | 382 | — | 382 | — | — | — | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| | Lawrence | 28 | 28 | — | — | — | — | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| | Penn | 88 | 26 | — | 62 | — | 62 | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | 62 | 208.7 | — | — | — | — | 62 | 208.7 | — | — |
| | | | | | | | | TOTAL | 62 | 208.7 | — | — | — | — | 62 | 208.7 | — | — |
| | | | | | | | | measured | 44 | 148.5 | — | — | — | — | 44 | 148.5 | — | — |
| | Pike | 11,001 | 10,658 | 176 | 167 | 11 | 156 | indicated | 112 | 285.3 | — | — | — | — | 112 | 285.3 | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 156 | 433.8 | — | — | — | — | 156 | 433.8 | — | — |
| | | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| Clearfield | Pine | 13,711 | 13,711 | — | — | — | — | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | measured | 44 | 92.4 | 26 | 119.5 | — | — | 70 | 211.9 | 26 | 119.5 |
| | Sandy | 4,810 | 167 | 484 | 4,159 | 2 | 4,157 | indicated | 2,085 | 6,321.7 | 642 | 2,981.2 | — | — | 2,727 | 9,302.9 | 642 | 2,981.2 |
| | | | | | | | | inferred | 1,354 | 4,073.9 | 6 | 23.9 | — | — | 1,360 | 4,097.8 | 6 | 23.9 |
| | | | | | | | | TOTAL | 3,483 | 10,488.0 | 674 | 3,124.6 | — | — | 4,157 | 13,612.6 | 674 | 3,124.6 |
| | | | | | | | | measured | 70 | 269.6 | 532 | 2,607.4 | — | — | 602 | 2,877.0 | 532 | 2,607.4 |
| | Union | 17,673 | 14,387 | — | 3,286 | 51 | 3,235 | indicated | 228 | 876.8 | 1,499 | 7,046.0 | — | — | 1,727 | 7,922.8 | 1,499 | 7,046.0 |
| | | | | | | | | inferred | 796 | 2,979.9 | 110 | 478.9 | — | — | 906 | 3,458.8 | 110 | 478.9 |
| | | | | | | | | TOTAL | 1,094 | 4,126.3 | 2,141 | 10,132.3 | — | — | 3,235 | 14,258.6 | 2,141 | 10,132.3 |
| | | | | | | | | measured | | | | | | | | | | |
| TOTALS | | 71,638 | 55,786 | 1,310 | 14,542 | 541 | 14,001 | indicated | | | | | | | | | | |
| | | | | | | | | inferred | | | | | | | | | | |
| | | | | | | | | TOTAL | 7,967 | 25,978.8 | 6,034 | 27,679.4 | — | — | 14,001 | 53,658.2 | 6,034 | 27,679.4 |

## Table 6. *Upper Kittanning Coal Reserves*

| COUNTY | Township | Area of twp. in quad. (acres) | Areas of coal lost by erosion (acres) | Coal less than 14" thick in place (acres) | Coal over 14" thick in place before mining (acres) | Mined out and lost (acres) | Coal over 14" thick remaining (acres) | CATEGORY | COAL RESERVES IN TONS OF 2000 POUNDS: 14-28" thick, acres | 14-28" thick, thousands of tons | 28-42" thick, acres | 28-42" thick, thousands of tons | > 42" thick, acres | > 42" thick, thousands of tons | TOTAL RESERVES IN TONS OF 2000 POUNDS: 14" and more thick, acres | 14" and more thick, thousands of tons | 28" and more thick, acres | 28" and more thick, thousands of tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Bloom | 9,973 | 9,922 | — | 51 | 7 | 58 | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | 11 | 47.9 | — | — | 11 | 47.9 | 11 | 47.9 |
| | | | | | | | | inferred | 7 | 27.4 | 40 | 175.7 | — | — | 47 | 203.1 | 40 | 175.7 |
| | | | | | | | | TOTAL | 7 | 27.4 | 51 | 223.6 | — | — | 58 | 251.0 | 51 | 223.6 |
| | Brady | 13,972 | 10,029 | — | 3,943 | 97 | 3,846 | measured | 455 | 1,814.0 | 114 | 495.0 | — | — | 569 | 2,309.0 | 114 | 495.0 |
| | | | | | | | | indicated | 1,211 | 4,689.0 | 774 | 3,400.7 | — | — | 1,985 | 8,089.7 | 774 | 3,400.7 |
| | | | | | | | | inferred | 29 | 101.4 | 1,263 | 5,648.8 | — | — | 1,292 | 5,750.2 | 1,263 | 5,648.8 |
| | | | | | | | | TOTAL | 1,695 | 6,604.4 | 2,151 | 9,544.5 | — | — | 3,846 | 16,148.9 | 2,151 | 9,544.5 |
| | City of DuBois | 382 | — | — | 382 | — | 382 | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | 22 | 59.4 | — | — | — | — | 22 | 59.4 | — | — |
| | | | | | | | | inferred | 360 | 1,015.7 | — | — | — | — | 360 | 1,015.7 | — | — |
| | | | | | | | | TOTAL | 382 | 1,075.1 | — | — | — | — | 382 | 1,075.1 | — | — |
| | Lawrence | 28 | 28 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Penn | 88 | 42 | — | 46 | 2 | 44 | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | 33 | 143.6 | — | — | 33 | 143.6 | 33 | 143.6 |
| | | | | | | | | inferred | — | — | 11 | 47.9 | — | — | 11 | 47.9 | 11 | 47.9 |
| | | | | | | | | TOTAL | — | — | 44 | 191.5 | — | — | 44 | 191.5 | 44 | 191.5 |
| | Pike | 11,001 | 10,906 | 95 | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| Clearfield | Pine | 13,711 | 13,711 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Sandy | 4,810 | 516 | — | 4,294 | — | 4,294 | measured | 55 | 140.3 | — | — | — | — | 55 | 140.3 | — | — |
| | | | | | | | | indicated | 2,088 | 5,746.8 | — | — | — | — | 2,088 | 5,746.8 | — | — |
| | | | | | | | | inferred | 2,151 | 6,815.1 | — | — | — | — | 2,151 | 6,815.1 | — | — |
| | | | | | | | | TOTAL | 4,294 | 12,702.2 | — | — | — | — | 4,294 | 12,702.2 | — | — |
| | Union | 17,673 | 15,277 | 38 | 2,011 | 4 | 2,007 | measured | 106 | 303.2 | — | — | — | — | 106 | 303.2 | — | — |
| | | | | | | | | indicated | 855 | 2,239.8 | — | — | — | — | 855 | 2,239.8 | — | — |
| | | | | | | | | inferred | 1,046 | 2,267.6 | — | — | — | — | 1,046 | 2,367.6 | — | — |
| | | | | | | | | TOTAL | 2,007 | 4,910.6 | — | — | — | — | 2,007 | 4,910.6 | — | — |
| | TOTALS | 71,638 | 60,431 | 480 | 10,727 | 110 | 10,631 | measured | | | | | | | | | | |
| | | | | | | | | indicated | | | | | | | | | | |
| | | | | | | | | inferred | | | | | | | | | | |
| | | | | | | | | TOTAL | 8,385 | 25,319.7 | 2,246 | 9,959.6 | — | — | 10,631 | 35,279.3 | 2,246 | 9,959.6 |

locally in the Coal Hill mine (the average for that mine was more on the order of 5 feet, however).

Throughout most of the report area, the lower Freeport coal is directly overlain by 80 to 90 feet of heavy sandstone. The only exceptions to this appear in the northwestern corner of the Luthersburg quadrangle in the vicinity of the DuBois mines, where the roof rock is shale, and in southeastern Elliott Park quadrangle where it is thin-bedded claystone and sandstone. The floor is composed of underclay with interbedded limestone.

Cropline, thickness variation, and measured sections of the lower Freeport coal are shown on Plate 16. Tonnage reserves are given in Table 7.

## Upper Freeport Coal

(also called E-coal)

Reserves on the upper Freeport coal total about 372,000 tons all over 42 inches thick. The amount of upper Freeport present is greatly circumscribed because it is cut-out by the lower Mahoning sandstone channel system across most of its potential area. In the small area in south-central Luthersburg quadrangle where the upper Freeport is not cut out, it is 45 inches thick.

Cropline, thickness variation, and measured sections of the upper Freeport are given on Plate 17. Tonnage reserves are shown in Table 8.

## Conemaugh Coals

There is sufficient Conemaugh Group remaining in northwestern Luthersburg to pick up the Mahoning, Brush Creek and Bakerstown coals. The Mahoning and Brush Creek do not exceed a few inches thick and no exposure of the Bakerstown is available. In the drill hole at Bc1, a 49-inch coal was encountered at the 212-foot level (Plate 5). It is possible that this is the upper Freeport seam; but its position with relation to other known units in the drill hole and other factors lead the authors to believe that it is more likely a local coal associated with sediments filling the lower Mahoning channel which has cut out the true upper Freeport coal (and also the lower Freeport coal as well).

## Coal-to-Coal Intervals

A general impression of the intervals between the various coal seams can be obtained from the geologic column on Plate 1. Intervals at specific locations may be obtained from the several figures showing measured sections that accompany the discussions under the heading "Pennsylvanian Stratigraphy."

The distance between Clarion no. 1 and lower Kittanning no. 3 is between 50 and 80 feet. Also included in this interval is Clarion no. 2 about 15 to 30 feet above Clarion no. 1, and lower Kittanning no. 1 (when present) 15 to 25 feet below lower Kittanning no. 3.

The distance between lower Kittanning no. 3 and middle Kittanning is 55 to 60 feet.

The section between the middle Kittanning and upper Kittanning coals is about 60 feet in southeastern Elliott Park quadrangle, 60 to 80 feet in southeastern and south-central Luthersburg and 80 to 90 feet elsewhere. This interval also includes the local channel coal from 10 to 30 feet or more above middle Kittanning in the area between Salem and Luthersburg Station, and the "Luthersburg" coal lying approximately 20 to 30 feet below the upper Kittanning.

The distance between the upper Kittanning and lower Freeport coals is about 50 to 60 feet in southeastern Elliott Park, 30 to 35 feet in central, south-central, and southeastern Luthersburg increasing to 50 feet in west-central, northwestern, and north-central Luthersburg.

The interval from lower Freeport to upper Freeport is 55 feet in southern Luthersburg.

## CLAY

### General

Clay in the southern Penfield area is limited to underclays occurring beneath the various coal seams. Almost every coal has an underlying underclay, but, from the standpoint of past and present commercial usage, those associated with the lower Mercer coals and with the lower Kittanning coal are most important.

The principal underclays listed in descending stratigraphic order are:

Mahoning soft clay
Upper Freeport soft clay
Lower Freeport soft clay
Upper Kittanning soft clay
Middle Kittanning soft clay
Lower Kittanning soft clay
Clarion no. 2 soft clay
Clarion no. 1 (Bigler) soft clay
Lower Mercer no. 3 soft clay
Lower Mercer no. 2 soft clay
Lower Mercer no. 1 hard clay

Measured sections of the various underclays are shown on Plate 18. A list of the known underground clay mines is given in Table 9.

## Table 7. *Lower Freeport Coal Reserves*

| COUNTY | Township | Area of twp. in quad. (acres) | Areas of coal lost by erosion (acres) | Coal less than 14″ thick in place (acres) | Coal over 14″ thick in place before mining (acres) | Mined out and lost (acres) | Coal over 14″ thick remaining (acres) | CATEGORY | COAL RESERVES IN TONS OF 2000 POUNDS: 14–28″ thick, acres | 14–28″ thick, thousands of tons | 28–42″ thick, acres | 28–42″ thick, thousands of tons | > 42″ thick, acres | > 42″ thick, thousands of tons | TOTAL RESERVES IN TONS OF 2000 POUNDS: 14″ and more thick, acres | 14″ and more thick, thousands of tons | 28″ and more thick, acres | 28″ and more thick, thousands of tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Bloom | 9,973 | 9,938 | — | 35 | 10 | 25 | measured | — | — | 22 | 113.3 | — | — | 22 | 113.3 | 22 | 113.3 |
| | | | | | | | | indicated | — | — | 3 | 5.4 | — | — | 3 | 5.4 | 3 | 5.4 |
| | | | | | | | | Inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | 25 | 118.7 | — | — | 25 | 118.7 | 25 | 118.7 |
| | Brady | 13,972 | 11,454 | 1,354 | 1,164 | 341 | 823 | measured | 55 | 172.5 | 96 | 485.9 | 7 | 57.5 | 158 | 715.9 | 103 | 543.4 |
| | | | | | | | | indicated | 57 | 210.9 | 374 | 2,013.3 | — | — | 431 | 2,224.2 | 384 | 2,013.3 |
| | | | | | | | | inferred | 10 | 31.4 | 224 | 1,141.9 | — | — | 234 | 1,173.3 | 224 | 1,141.9 |
| | | | | | | | | TOTAL | 122 | 414.8 | 694 | 3,641.1 | 7 | 57.5 | 823 | 4,113.4 | 701 | 3,698.6 |
| | City of DuBois | 382 | — | 200 | 182 | 23 | 159 | measured | 70 | 219.6 | 64 | 334.0 | 25 | 180.2 | 159 | 733.8 | 89 | 514.2 |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 70 | 219.6 | 64 | 334.0 | 25 | 180.2 | 159 | 733.8 | 89 | 514.2 |
| | Lawrence | 28 | 28 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | | | | | | | | measured | — | — | 28 | 145.0 | — | — | 28 | 145.0 | 28 | 145.0 |
| | Penn | 88 | 56 | — | 32 | 1 | 31 | indicated | — | — | 3 | 18.3 | — | — | 3 | 18.3 | 3 | 18.3 |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | 31 | 163.3 | — | — | 31 | 163.3 | 31 | 163.3 |
| | | | | | | | | measured | 21 | 83.4 | — | — | — | — | 21 | 83.4 | — | — |
| | Pike | 11,001 | 10,980 | — | 21 | — | 21 | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 21 | 83.4 | — | — | — | — | 21 | 83.4 | — | — |
| | | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| | Pine | 13,711 | 13,711 | — | — | — | — | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | measured | 239 | 751.6 | 273 | 1,432.4 | 270 | 2,018.0 | 782 | 4,202.0 | 543 | 3,450.4 |
| | Sandy | 4,810 | 702 | 2,537 | 1,571 | 785 | 786 | indicated | 4 | 10.0 | — | — | — | — | 4 | 10.0 | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | 243 | 761.6 | 273 | 1,432.4 | 270 | 2,018.0 | 786 | 4,212.0 | 543 | 3,450.4 |
| | | | | | | | | measured | — | — | — | — | — | — | — | — | — | — |
| | Union | 17,673 | 15,701 | 1,965 | 7 | — | 7 | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | 7 | 3.3 | — | — | — | — | 7 | 3.3 | — | — |
| | | | | | | | | TOTAL | 7 | 3.3 | — | — | — | — | 7 | 3.3 | — | — |
| | | | | | | | | measured | | | | | | | | | | |
| | TOTALS | 71,638 | 62,570 | 6,056 | 3,012 | 1,160 | 1,852 | indicated | | | | | | | | | | |
| | | | | | | | | inferred | | | | | | | | | | |
| | | | | | | | | TOTAL | 463 | 1,482.7 | 1,087 | 5,689.5 | 302 | 2,255.7 | 1,852 | 9,427.9 | 1,389 | 7,945.2 |

## Table 8. *Upper Freeport Coal Reserves*

| COUNTY | Township | Area of twp. in quad. (acres) | Areas of coal lost by erosion (acres) | Coal less than 14" thick in place (acres) | Coal over 14" thick in place before mining (acres) | Mined out and lost (acres) | Coal over 14" thick remaining (acres) | CATEGORY | COAL RESERVES IN TONS OF 2000 POUNDS: 14–28" thick, acres | 14–28" thick, thousands of tons | 28–42" thick, acres | 28–42" thick, thousands of tons | > 42" thick, acres | > 42" thick, thousands of tons | TOTAL RESERVES IN TONS OF 2000 POUNDS: 14" and more thick, acres | 14" and more thick, thousands of tons | 28" and more thick, acres | 28" and more thick, thousands of tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Bloom | 9,973 | 9,966 | — | 7 | — | 7 | measured | — | — | — | — | 2 | 10.1 | 2 | 10.1 | 2 | 10.1 |
| | | | | | | | | indicated | — | — | — | — | 5 | 34.4 | 5 | 34.4 | 5 | 34.4 |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | 7 | 44.5 | 7 | 44.5 | 7 | 44.5 |
| | Brady | 13,972 | 13,931 | — | 41 | — | 41 | measured | — | — | — | — | 37 | 247.7 | 37 | 247.7 | 37 | 247.7 |
| | | | | | | | | indicated | — | — | — | — | 4 | 25.0 | 4 | 25.0 | 4 | 25.0 |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | 41 | 272.7 | 41 | 272.7 | 41 | 272.7 |
| | City of DuBois | 382 | 382 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Lawrence | 28 | 28 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearfield | Penn | 88 | 80 | — | 8 | — | 8 | measured | — | — | — | — | 3 | 17.6 | 3 | 17.6 | 3 | 17.6 |
| | | | | | | | | indicated | — | — | — | — | 5 | 37.1 | 5 | 37.1 | 5 | 37.1 |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | 8 | 54.7 | 8 | 54.7 | 8 | 54.7 |
| | Pike | 11,001 | 11,001 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Pine | 13,711 | 13,711 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Sandy | 4,810 | 4,810 | — | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | Union | 17,673 | 17,258 | 415 | — | — | — | measured | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | indicated | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | inferred | — | — | — | — | — | — | — | — | — | — |
| | | | | | | | | TOTAL | — | — | — | — | — | — | — | — | — | — |
| | TOTALS | 71,638 | 71,167 | 415 | 56 | — | 56 | measured | | | | | | | | | | |
| | | | | | | | | indicated | | | | | | | | | | |
| | | | | | | | | inferred | | | | | | | | | | |
| | | | | | | | | TOTAL | — | — | — | — | 56 | 371.9 | 56 | 371.9 | 56 | 371.9 |

Table 9. *Underground Clay Mines of the Southern Penfield Area*

| Mine Name | Ref. No. | Clay* | Last Known Owner | Comments |
|---|---|---|---|---|
| Crescent | Ef9 | LM 1-2 | North American Ref. (Crescent Ref.) | Hard clay |
| Drucker | Bf22 | LM 1 | North American Ref. | Hard clay |
| Pearce | Bf19 | LM 1 | Harbison-Walker Ref. | Hard clay |
| Spencer | Cf10 | LM 1 | Harbison-Walker Ref. | Hard clay |
| Shively (?) | Bf23 | LM 1 | Unknown | Hard clay (?) |
| Unknown | Bf18 | LM 1 | Unknown | Hard clay |
| Unknown | Cf13 | LM 1 | Harbison-Walker | Hard clay |
| Unknown | Cf20 | LM 1 ? | Unknown | Hard clay. Apparently a slope mine. |
| Unknown | Df8 | LM 1 | North American Ref. | Hard clay |
| Unknown | Df5 | LM 1 | North American Ref. | Hardclay & possibly soft clay |
| Unknown | Ef6 | LM 3 & poss. LM 1-2 | Unknown | Semihard clay and possibly hard clay. |

* Name of each clay is the same as the coal seam below which it occurs. LM 1 = lower Mercer no. 1, LM 2 = lower Mercer no. 2, LM 3 = lower Mercer no. 3.

## Lower Mercer Clays

The lower Mercer clays underlie the three lower Mercer coals and occur in the lower part of the Curwensville Formation (Plate 1). The lowest of these lower Mercer clays marks the base of the Curwensville Formation.

Although there are three distinct Mercer clays, they are closely associated and often difficult to identify specifically from one another at any particular exposure. All three usually occur within a 25-foot interval, and in cases where normally intervening rocks are missing, may form a continuous body of clay.

Lateral variation within these clays is strong, resulting in important changes in properties in a relatively short distance. The clays may, in fact, grade into claystone or clay shale (which may also have useful ceramic properties), siltstone or even sandstone.

Plate 6 shows the correlation of the various elements of the Curwensville Formation across southeastern Luthersburg and southwestern Elliott Park quadrangles. Plate 21 (appendix 3) gives the correlations of a series of drill holes between Curwensville Dam and Salem.

Two different clay types occur in the lower Mercer interval. The first is the usual soft clay (underclay) which occurs commonly throughout the coal measures. The second is the almost unique high-alumina hard clay which occurs at this horizon as part of a band, approximately eight miles wide, which extends eastward from central Jefferson County across most of Clearfield County and then northeastward through northwestern Centre County and into central Clinton County. Soft and hard clay grade from one to the other with the intermediate stage often called semi-hard clay.

For the most part, hard clay occurs only below lower Mercer no. 1 coal, but in some cases where lower Mercer no.1 coal and other sediments which separate lower Mercer no. 1 clay and lower Mercer no. 2 clay are very thin, the lower Mercer no. 2 clay will become hard clay or semi-hard clay as well. For reasons described at greater length in the section on "High-alumina hard clays" under "Pennsylvanian Depositional History" and also in Edmunds (1968 p. 65-66), the lower Mercer hard clays occur only where they lie directly or almost directly upon the Burgoon Sandstone Member of the Pocono Formation. Where other units (Elliott Park Formation) are interposed between the Burgoon Sandstone and the lower Mercer clay horizon, soft clay occurs, rather than hard clay. The approximate area where the lower Mercer clay lies directly upon the Burgoon Sandstone (and, thus, the area of hard clay occurrence) is shown on Plate 19.

The lower Mercer no. 1 hard clay has been recorded up to 17 feet thick in this area. Lower Mercer no. 2 hard clay and soft clay is 0 to 4 feet. The lower Mercer no. 3 soft clay is 0 to 8 feet.

The lower Mercer hard clays are extensively mined in this area for use in super-duty and high-duty refractory products.

R. M. Foose (1944) produced the following table of varieties of Clearfield County refractory clays:

| | *Percent of Alumina* |
|---|---|
| "Burnt" nodule clay . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . <br>Rusty brown, porous, cindery appearance. | 70–75 |
| Fine-grained (or blue) nodule clay . . . . . . . . . . . . . . . . . . . . . . . . . . . . . <br>Homogeneous appearance; all small nodules. Finer grained and harder than green nodule clay. | 60–65 |

| | *Percent of Alumina* |
|---|---|
| Green nodule clay. Coarsely nodular, rough fracture. Usually greenish cast. | 55 (approx.) |
| Nodule-block clay. Gradation between green nodule and flint or block clay. Nodules and nodular areas less than half of mass, scattered through block clay. Greenish. Fracture more blocky though still rough. | 40–50 |
| Spotted flint. Few scattered small nodules in flint clay. Fracture smooth conchoidal. | 40–52 |
| Flint clay. Very hard, fracture smooth conchoidal with sharp edges and points. Ringing flinty noise under hammer blow. Weathers by breaking into smaller jagged fragments; never slacks down. | 38 |
| Block clay. Softer than flint clay. Fracture semi-conchoidal to irregular blocky. No ringing sound when struck. Weathers by crumbling into rounder granules than flint. | 38 |
| Semi-flint clay. Gradational from flint to soft plastic clay. Minor in amount. Hardness about same as block. Fracture rough and irregular, not very conchoidal. | 35–37 |
| Associated non-refractory clays include: | |
| Slabby soft clay. Fracture slabby and irregular. Slickensides very common. | 30 (approx.) |
| Soft (Plastic) clay. Soft. Fracture very irregular. Chips and crumbles under little pressure. Slickensides common. | 25–30 |
| Shaly clay or clay shale. Bedding evident. Fracture shaly. Siliceous. | 20–30 |

Weitz and Bolger (1951) proposed a petrographic classification which was tied to Foose's system. A slight modification of that classification by Bolger and Weitz (1952) appears below:

| *Proposed Classification* | *Classification Modified after Foose* |
|---|---|
| Diasporite . . . (over 90% aluminum hydroxide) | "Burnt-nodule" clay |
| Argillaceous diasporite . . . (over 50% aluminum hydroxide) | Fine-grained nodule clay<br>Green nodule clay |
| Diaspore claystone . . . (over 50% kaolinite) | Nodular block clay<br>Nodular flint clay |
| Flint claystone . . . (apparently all kaolinite) | Flint clay |
| Block claystone | Shaly clay |
| Soft (plastic) clay | Soft (plastic) clay |

Foose (1944) also gives the following chemical analyses of the various clay types:

*Representative Analysis of Clay Types*
Analyst—General Refractories Co.

| Type clay | Ignition loss | $Al_2O_3$ | $SiO_2$ | $Fe_2O_3$ | $K_2O$ & $Na_2O$ | $TiO_2$ | CaO | MgO | Total |
|---|---|---|---|---|---|---|---|---|---|
| "Burnt" nodule | 14.40 | 75.72 | 4.00 | 2.17 | .38 | 2.75 | .10 | .25 | 99.77 |
| Fine-grained nodule | 13.88 | 61.52 | | | | | | | |
| Green nodule | 13.05 | 54.50 | 26.27 | .80 | .95 | 2.26 | .18 | .30 | 99.25 |
| Nodule block | 13.46 | 49.94 | | | | | | | |
| Flint | 13.16 | 38.37 | 43.74 | 1.29 | .96 | 1.72 | .04 | .28 | 99.56 |
| Block | 13.40 | 37.55 | 43.40 | 1.06 | 1.51 | 1.77 | .13 | .43 | 99.29 |
| Semi-flint | 11.17 | 35.13 | 46.76 | 1.52 | 2.60 | 1.57 | .18 | .73 | 99.66 |
| Slabby soft | 8.76 | 30.99 | 52.62 | 1.63 | 3.21 | 1.28 | .30 | .75 | 99.54 |
| Plastic (soft) | 8.09 | 27.40 | 56.84 | 1.82 | 2.99 | 1.28 | .30 | .91 | 99.63 |

The following are analyses and descriptions of the lower Mercer clays taken from published reports and unpublished records of the Pennsylvania Geologic Survey:

Leighton (1941) sample no. 260, station Ef9 of this report. Crescent mine of North American Refractories Corp.

The flint clay is overlain by a coal bed usually less than one-foot thick, over which are heavy sandstones. The clay ranges from 3 to 12 feet thick, thinning being due to sandstone rolls coming down from the roof. The upper two feet of the clay is generally nodular or diasporic and is the best quality. The remainder is block or marbleized flint clay. They are usually mixed together, but for some purposes the nodular clay is kept separate. Sample no. 260 represents an average of a 10-foot face of the clay.

Water of plasticity: 20.3%
Linear drying shrinkage: 1.0%
Slaking time: 1.5 mintues
Maximum linear burning shrinkage: 4.4%
Maximum shrinkage: at cone 6
Fusion point: cone 33
Best burning range: cone 02 to cone 11
Firing color: light to dark buff
Suggested uses: fire brick

Leighton (1941) sample no. 298, station no. Bf19 of this report. From Harbison-Walker Refractories Co. Pearce mine.

Water of plasticity: 19.5%
Linear drying shrinkage: 2.2%
Slaking time: 1.5 minutes
Modulus of rupture: 25 psi

Maximum linear burning shrinkage: 4.7%
Maximum shrinkage: at cone 02
Fusion point: 31½
Best burning range: cone 07 to cone 11
Firing color: cream to buff
Suggested uses: fire brick

Unpublished sample test 74-5-2, Pa. Geologic Survey files, station Cd48. Grab sample of lower Mercer flint clay from a prospect.

Raw properties:

Water of plasticity: 12.9%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing tests:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Buff | No Bond |
| 2200 | Buff | No Bond |
| 2300 | Buff | No Bond |

Bloating test: negative
Potential use: Not suitable for use as the principal component in fired clay products.
Remarks: Might be used as a non-plastic fraction in structural clay bodies. [Not tested for high duty refractory use for which it may be suited.]
Other tests: pH 4.80.

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.84% | $K_2O$ | 0.23% |
| $SiO_2$ | 44.36 | $H_2O$ @ 105°C | 0.55 |
| $Fe_2O_3$ | 0.80 | Comb. $H_2O$ | 13.61 |
| $TiO_2$ | 1.04 | S | 0.61 |
| FeO | 0.14 | $CO_2$ | 0.16 |
| $P_2O_5$ | 0.10 | C (organic) | 0.20 |
| MnO | 0.02 | Ba | 0.01–0.10 |
| $Al_2O_3$ | 39.24 | Sr | 0.001–0.01 |
| CaO | 0.22 | Zr | 0.001–0.01 |
| MgO | 0.02 | V | 0.001–0.01 |
| $Na_2O$ | 0.04 | | |

Unpublished sample test 74-8-3A, Pa. Geologic Survey files, station De3, (See also 74-8-3B). Five feet of lower Mercer hard clay, top lies 3 feet below lower Mercer coal. Sample taken immediately above sample 74-8-3B. North American Refractories Corp. clay strip mine.

Raw properties:

Water of plasticity: 13.6%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 5.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Lt. brown | No Bond |
| 2200 | Gray-Brown | No Bond |
| 2300 | Olive | No Bond |

Bloating test: Negative. Not suitable for use as the principal component in fired clay products. [Not tested for high duty refractory products for which it is used.]
Remarks: Might be used as a non-plastic fraction in structural clay bodies
Other tests: pH 5.20.

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.56% | $K_2O$ | 0.33% |
| $SiO_2$ | 42.92 | $H_2O$ @ 105°C | 0.80 |
| $Fe_2O_3$ | 1.87 | Comb. $H_2O$ | 13.38 |
| $TiO_2$ | 2.61 | S | 0.02 |
| FeO | 0.14 | $CO_2$ | 0.04 |
| $P_2O_5$ | 0.11 | C (Organic) | 0.46 |
| MnO | 0.005 | Ba over | 0.1 |
| $Al_2O_3$ | 39.52 | Sr | 0.001–0.01 |
| CaO | 0.08 | Zr | 0.001–0.01 |
| MgO | 0.02 | V | 0.001–0.01 |
| $Na_2O$ | 0.05 | | |

Unpublished sample test 74-8-3B, Pa. Geologic Survey files, station De3 of this report (See also 74-8-3A).

Two feet of lower Mercer hard clay, top lies 7 feet below lower Mercer coal and immediately below 74-8-3A. North American Refractories Corp. strip mine.

Raw properties:

Water of plasticity: 15.6%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slowing firing test:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Tan | No Bond |
| 2200 | Gray | No Bond |
| 2300 | Gray | No Bond |

Bloating test: negative
Potential use: Not suitable for use as the principal component in fired clay products. [Not tested for high duty refractory products for which it is used.]
Remarks: Might be used as non-plastic fraction in structural clay bodies.
Other tests: pH 5.10

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.34% | $K_2O$ | 0.92% |
| $SiO_2$ | 42.18 | $H_2O$ @ 105°C | 0.34 |
| $Fe_2O_3$ | 1.98 | Comb. $H_2O$ | 13.30 |
| $TiO_2$ | 1.10 | S | 0.04 |
| FeO | 1.47 | $CO_2$ | 0.04 |
| $P_2O_5$ | 0.16 | C (organic) | 0.28 |
| MnO | 0.03 | Ba | over 0.1 |
| $Al_2O_3$ | 38.37 | Sr | 0.001–0.01 |
| CaO | 0.38 | Zr | 0.001–0.01 |
| MgO | 0.02 | V | 0.001–0.01 |
| $Na_2O$ | 0.06 | | |

Unpublished sample test 74-8-4, Pa. Geologic Survey files, station Df4 of this report.

Three-foot interval of lower Mercer hard clay with top 0 to 2 feet below lower Mercer coal. North American Refractories Corp. clay strip mine.

Raw properties:

Water of plasticity: 9.9%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow Firing test:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Tan | No Bond |
| 2200 | Buff | No Bond |
| 2300 | Buff | No Bond |

Bloating test: negative.
Potential use: Not suitable for principal component in fired play products. [Not tested for high duty refractory products, for which it is used.]
Remarks: Might be used as a non-plastic fraction in structural clay bodies.
Other tests: pH 4.80.

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.31% | $K_2O$ | 0.59% |
| $SiO_2$ | 43.60 | $H_2O$ @ 105°C | 0.68 |
| $Fe_2O_3$ | 1.52 | Comb. $H_2O$ | 12.92 |
| $TiO_2$ | 2.00 | S | 0.04 |
| FeO | 0.17 | $CO_2$ | 0.01 |
| $P_2O_5$ | 0.22 | C (Organic) | 0.21 |
| MnO | 0.02 | Ba | 0.01–0.1 |
| $Al_2O_3$ | 38.09 | Sr | 0.001–0.01 |
| CaO | 0.18 | Zr | 0.001–0.01 |
| MgO | 0.02 | V | 0.001–0.01 |
| $Na_2O$ | 0.07 | | |

Unpublished sample test 74-8-5, Pa. Geologic Survey files, station Df9 of this report.

Semi-flint clay from immediately below lower Mercer coal. This clay was skipped or discarded in mining associated higher grade hard clay. North American Refractories Corp. clay strip mine.

Raw properties:
Water of plasticity: 15.7%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Pink | 1 | 2.5 | 22.2 | 1.59 |
| 1900 | Pink | 1 | 2.5 | 19.6 | 1.69 |
| 2000 | Pink | 1 | 2.5 | 18.3 | 1.74 |
| 2100 | Cream | 2 | 2.5 | 17.0 | 1.77 |
| 2200 | Ivory | 3 | 5.0 | 15.7 | 1.82 |
| 2300 | Ivory | 4 | 5.0 | 13.9 | 1.88 |

Bloating test: negative.
Potential use: Low duty refractory products.
Remarks: Very low green strength, would probably require a binder for satisfactory forming.

Other tests:
pH 5.20
P. C. E.: cone 27
Petrographic: high quartz and mica

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 9.76% | $K_2O$ | 2.82% |
| $SiO_2$ | 52.74 | $H_2O$ @ 105°C | 0.59 |
| $Fe_2O_3$ | 1.62 | Comb. $H_2O$ | 9.65 |
| $TiO_2$ | 1.09 | S | 0.03 |
| FeO | 0.17 | $CO_2$ | 0.00 |
| $P_2O_5$ | 0.09 | C (organic) | 0.14 |
| MnO | 0.03 | Ba | Over 0.1 |
| $Al_2O_3$ | 31.03 | Sr | 0.001–0.01 |
| CaO | 0.04 | Zr | 0.001–0.01 |
| MgO | 0.30 | V | 0.001–0.01 |
| $Na_2O$ | 0.12 | | |

Unpublished sample test 74-9-8, Pa. Geologic Survey files, station Ef3 of this report.

About 3.5 feet of hard clay from between lower Mercer no. 1 and lower Mercer no. 2 coals. Clay strip mine.

Raw properties:

Water of plasticity: 9.7%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Tan | No Bond |
| 2200 | Buff | No Bond |
| 2300 | Buff | No Bond |

Bloating test: Negative
Potential use: Not suitable for use as the principal constituent in fired clay products. [Not tested for high duty refractory products for which it is used.]
Remarks: Might be used as non-plastic fraction in structural clay bodies.
Other tests: pH 4.40

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.90% | $K_2O$ | 0.76% |
| $SiO_2$ | 43.90 | $H_2O$ @ 105°C | 0.66 |
| $Fe_2O_3$ | 1.26 | Comb. $H_2O$ | 12.74 |
| $TiO_2$ | 2.11 | S | 0.39 |
| FeO | 0.78 | $CO_2$ | 0.16 |
| $P_2O_5$ | 0.13 | C (organic) | 0.64 |
| MnO | 0.02 | Ba | 0.1–0.01 |
| $Al_2O_3$ | 36.56 | Sr | 0.001–0.01 |
| CaO | 0.39 | Zr | 0.001–0.01 |
| MgO | 0.30 | V | 0.001–0.01 |
| $Na_2O$ | 0.90 | | |

Unpublished sample test 74-9-9, station Ef7 of this report.

Two-foot sample of Mercer hard clay taken from 1.7 to 3.7 feet below lower Mercer no. 2 coal. Clay strip mine.

Raw properties:

Water of plasticity: 11.7%
Working properties: Very low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Others |
|---|---|---|
| 1800 | Tan | No Bond |
| 1900 | Tan | No Bond |
| 2000 | Tan | No Bond |
| 2100 | Buff | No Bond |
| 2200 | Gray | No Bond |
| 2300 | Gray | No Bond |

Bloating test: negative
Potential use: Not suitable for use as principal constituent in fired clay products. [Not tested for high duty refractory products, for which it is used.]
Remarks: Might be used as a non-plastic fraction in structural clay bodies.
Other tests: pH 4.30

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 13.13% | $K_2O$ | 0.84% |
| $SiO_2$ | 39.64 | $H_2O$ @ 105°C | 0.56 |
| $Fe_2O_3$ | 1.62 | Comb. $H_2O$ | 13.00 |
| $TiO_2$ | 2.23 | S | 0.42 |
| FeO | 1.36 | $CO_2$ | 0.02 |
| $P_2O_5$ | 0.16 | C (organic) | 0.42 |
| MnO | 0.02 | Ba | over 0.1 |
| $Al_2O_3$ | 39.28 | Sr | 0.001–0.01 |
| CaO | 0.50 | Zr | 0.001–0.01 |
| MgO | 0.35 | V | 0.001–0.01 |
| $Na_2O$ | 0.10 | | |

## Clarion no. 1 Clay

The Clarion no. 1 clay directly underlies the Clarion no. 1 coal. Although no commercial use has been made of it in this area, it has been extensively mined for ceramic purposes farther to the east where it is referred to as the Bigler clay (Edmunds, 1968). This clay is not well exposed, although drill holes indicate that it varies from 0 to 10 feet. Where seen the Clarion no. 1 clay is soft, medium light gray underclay becoming a silt shale toward the top.

In some areas the Clarion no. 1 clay contains beds or nodules of hard clay. None was observed in southern Penfield, but it was worked for hard clay in strip mines 1½ miles south of the report area in the Curwensville 7½-minute quadrangle (1 mile west of the village of Bridgeport on the southern slope of hill 1802 at about elevation 1560).

## Lower Kittanning Clays

The main lower Kittanning clay is the clay below the lower Kittanning no. 3 coal (the main lower Kittanning seam in this area). Although theoretically there are three lower Kittanning clays (one below each of lower Kittanning no. 1, no. 2, and no. 3 coals), the general absence of lower Kittanning no. 1 and no. 2 coals allows all three clays to merge into one more or less continuous body. The interval may contain considerable amounts of shale and claystone as well. For practical purposes this group of clays will be considered as a single unit and referred to as the lower Kittanning clay.

The main soft clay portion of the interval below lower Kittanning no. 3 coal is between 5 and 20 feet thick and usually lies almost directly below the coal. This clay has been mined at two places in the southern Penfield quadrangle—at Df18 where both 6 feet of soft clay and several feet of underlying clay shale were removed and at Bf14 where 10 to 11½ feet of soft, non-silty, medium gray underclay is mined. The section at Df18 is described in detail in the section on the "Millstone Run Formation" under "Pennsylvanian Stratigraphy."

In addition, in extreme southeastern Elliott Park quadrangle, the westernmost remnant of another split of the lower Kittanning coal (lower Kittanning no. 4) still persists and is underlain by several feet of underclay. Both this coal and its underclay are absent elsewhere in the report area.

The following are the results of unpublished tests on lower Kittanning clays from the files of the Pa. Geological Survey:

Test 74-8-7A, station Df18 of this report. Nine-foot underclay and clay shale section immediately below lower Kittanning no. 3 coal. Separated from underlying test sample 74-8-7B by ½ foot of siltstone and silt shale. Sample taken from old strip mine.

Raw properties:

Water of plasticity: 13.3%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Pink | 1 | 2.5 | 15.1 | 1.83 |
| 1900 | Pink | 2 | 2.5 | 13.8 | 1.91 |
| 2000 | Tan | 3 | 2.5 | 10.3 | 2.03 |
| 2100 | Tan | 4 | 5.0 | 6.9 | 2.16 |
| 2200 | Buff | 6 | 7.5 | 3.3 | 2.26 |
| 2300 | Gray | 7 | 10.0 | 1.7 | 2.29 |

Bloating test: negative
Potential use: Face brick, structural tile
Remarks: Good firing range, low green strength
Other tests: pH 5.40

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 5.10% | $K_2O$ | 3.02% |
| $SiO_2$ | 67.72 | $H_2O$ @ 105°C | 0.43 |
| $Fe_2O_3$ | 1.28 | Comb. $H_2O$ | 5.01 |
| $TiO_2$ | 1.21 | S | 0.00 |
| FeO | 0.78 | $Co_2$ | 0.04 |
| $P_2O_5$ | 0.07 | C (organic) | 0.23 |
| MnO | 0.01 | Ba | over 0.1 |
| $Al_2O_3$ | 18.73 | Sr | 0.001–0.01 |
| CaO | 0.39 | Zr | 0.001–0.01 |
| MgO | 0.88 | V | 0.001–0.01 |
| $Na_2O$ | 0.15 | | |

Test 74-8-7B, station Df18 of this report. Five-foot clay shale interval with top ½ foot below base of sample 74-8-7A and base about 4 feet above lower Kittanning no. 1 coal. Sample taken from old strip mine.

Raw properties:

Water of plasticity: 14.5%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Pink | 2 | 2.5 | 16.9 | 1.80 |
| 1900 | Pink | 3 | 2.5 | 15.7 | 1.87 |
| 2000 | Tan | 4 | 2.5 | 13.6 | 1.94 |
| 2100 | Buff | 5 | 5.0 | 10.4 | 2.05 |
| 2200 | Gray | 6 | 7.5 | 6.4 | 2.16 |
| 2300 | Gray | 6 | 7.5 | 7.3 | 2.08 |

Bloating test: negative
Potential use: face brick, structural tile
Remarks: Fires to good buff, but low green strength
Other tests: pH 5.30

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 5.41% | $K_2O$ | 2.84% |
| $SiO_2$ | 69.12 | $H_2O$ @ 105°C | 0.55 |
| $Fe_2O_3$ | 0.80 | Comb. $H_2O$ | 5.33 |
| $TiO_2$ | 1.13 | S | 0.00 |
| FeO | 1.50 | $CO_2$ | 0.00 |
| $P_2O_5$ | 0.08 | C (organic) | 0.60 |
| MnO | 0.02 | Ba | Over 0.1 |
| $Al_2O_3$ | 17.39 | Sr | 0.001–0.01 |
| CaO | 0.39 | Zr | 0.001–0.01 |
| MgO | 0.90 | V | 0.001–0.01 |
| $Na_2O$ | 0.15 | | |

Test 84-7-18, station Clearfield Af55 of this report. Section sampled includes 6 feet of soft clay directly below position of lower Kittanning no. 4 coal (0 to 2 inches thick) and 4 feet of clay shale overlying that coal.

Raw properties:

Water of plasticity: 14.7%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 2 | 2.5 | 19.6 | 1.73 |
| 1900 | Tan | 3 | 2.5 | 16.5 | 1.85 |
| 2000 | Tan | 4 | 2.5 | 14.2 | 1.92 |
| 2100 | Brown | 5 | 5.0 | 8.5 | 2.11 |
| 2200 | Dk. brown | 6 | Expanded | .... | .... |
| 2300 | Dk. brown | 6 | Expanded | .... | .... |

Preliminary bloating tests:

Bloating test: positive
Crushing characteristics: laminar
Particle size: −¾″ to +½″
Retention time: 15 minutes

Firing test:

| Temp °F | Bulk Density gm/cc | Bulk Density lb/ft | % Abs. |
|---|---|---|---|
| 2000 | 0.91 | 57 | 13.6 |
| 2100 | 0.88 | 55 | 13.6 |
| 2200 | 0.95 | 59 | 13.2 |

Remarks: At 2200—brown, fair pore structure, sem-vitreous skin.

Recommendations: Trial run in rotary kiln.
Potential use: Light-weight aggregate.
Remarks: Color marginal for face brick.
Other tests: pH 5.30

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 6.86% | $K_2O$ | 3.24% |
| $SiO_2$ | 59.02 | $H_2O$ @ 105°C | 0.25 |
| $Fe_2O_3$ | 2.96 | Comb. $H_2O$ | 6.03 |
| $TiO_2$ | 0.83 | S | 0.43 |
| FeO | 4.10 | $CO_2$ | 0.25 |
| $P_2O_5$ | 0.19 | C (organic) | 1.33 |
| MnO | 0.11 | Ba | over 0.1 |
| $Al_2O_3$ | 19.64 | Sr | 0.001–0.01 |
| CaO | 0.25 | Zr | 0.001–0.01 |
| MgO | 1.62 | V | 0.001–0.01 |
| $Na_2O$ | 0.16 | | |

## Other Clays

Extensive underclays also occur below the Clarion no. 2, middle Kittanning, upper Kittanning, lower Freeport, and upper Freeport coals, although they have been put to no commercial use and analyses are not available for most.

Clarion no. 2 underclay varies from 0 to 4 or 5 feet thick, and is generally silty or sandy.

The middle Kittanning underclay appears to be persistently present and generally 3 to 7 feet thick. While the lower part of the middle Kittanning clay is silty or sandy, the upper half or more is usually very soft and nonsilty.

Occasionally a middle Kittanning rider coal is developed 10 to 20 feet above the main middle Kittanning. This rider will usually have a thin associated underclay which in southeastern Elliott Park was up to 3½ feet thick. An analysis of this clay at Ff9 is included with an analysis of the underlying shale under the section on "Mineral Springs Formation Shales."

The following analysis from Leighton (1941), sample 258 is on the middle Kittanning underclay (referred to as upper Kittanning in Leighton's report).

The sample is from station Ae26 of this report:

"The clay (no. 258) has good plasticity and fair green strength."
Water of plasticity: 33.6%
Linear drying shrinkage: 5.3%
Slaking time: 9 minutes
Modulus of rupture: 172 psi
Maximum linear burning shrinkage: 9.1%
Maximum shrinkage: at cone 02
Fusion point: at cone 22
Best burning range: cones 07–02
Firing color: salmon to gray
Suggested uses: Face brick, hollow tile.

The upper Kittanning underclay varied from about 2 feet to 10 feet where observed. Where thin, the clay is generally silty; and when thicker, it contains limestone beds and nodules.

The lower Freeport underclay ranges from 1 foot to 10 feet thick including a few feet of interbedded shale and/or limestone in thicker expressions. It appears to be relatively unsilty in most places.

The upper Freeport underclay is cut out by the lower Mahoning sandstone channel across most of the report area. The only two measured sections on it are shown on Plate 11.

The Mahoning clay was observed only in drill hole Bc1 where it was 6 feet thick. Its outcrop area is confined to the northwestern quarter of the Luthersburg quadrangle.

## SHALE

### General

From the standpoint of usage, shale is closely akin to clay, both being processed primarily into ceramic products. Additionally, shale is also used as surfacing on low-use, local roads and as fill.

In practice, very little shale has actually been utilized. Most that has been taken was removed in connection with mining of closely associated underclays and hard clays.

Vast amounts of shale occur at the surface in the southern Penfield quadrangle and varieties include clay shale, silt shale, claystone, black or grayish-black shale, redbeds and gradations between each of these. Almost all shale is confined to the Conemaugh and Allegheny Groups and the sub-Burgoon Pocono Formation (Plate 1). In addition, a 30 to 40 foot shaly unit occurs within the Burgoon Sandstone, about 85 feet from the base.

For ceramic purposes, the claystones and clay shales are the most valuable, although a certain amount of silt or sand may impart useful characteristics in some products. Silt shales are usually less desirable. Black or grayish-black shale, with high carbonaceous fraction, often require special handling, such as slow burning, and may not be worth the extra effort, but are otherwise satisfactory. Red shales are generally useable if not too silty.

### Sub-Burgoon Pocono Shales

The part of the Pocono underlying the Burgoon Sandstone contains a 200 to 225 foot-section of interbedded reddish gray or greenish gray clay shales, claystones, siltstones and sandstones. Individual beds of shale and claystone are up to 25 feet thick and laterally extensive.

The outcrop area of the Sub-Burgoon Pocono is shown on Plate 1.

The following is the unpublished result of a test on the shale and claystone of the Sub-Burgoon Pocono from the files of the Pennsylvania Geologic Survey.

Test 74-6-11, station Fd6 of this report. The section sampled is the 24 feet of red claystone and clay shale above the sandstone over the 0- to 3-inch coal shown in column Fd6 on Plate 3.

Raw properties:

Water of plasticity: 13.5%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow Firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 3 | 2.5 | 13.7 | 1.95 |
| 1900 | Tan | 4 | 2.5 | 12.0 | 2.04 |
| 2000 | Lt. brown | 4 | 5.0 | 8.8 | 2.16 |
| 2100 | Brown | 5 | 7.5 | 4.7 | 2.32 |
| 2200 | Dk. brown | 6 | 7.5 | 2.0 | 2.37 |
| 2300 | Gray | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal.
Other tests: pH 5.10

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 5.26% | $K_2O$ | 3.40% |
| $SiO_2$ | 62.30 | $H_2O$ @ 105°C | 1.10 |
| $Fe_2O_3$ | 8.47 | Comb. $H_2O$ | 5.30 |
| $TiO_2$ | 0.97 | S | 0.04 |
| FeO | 0.14 | $CO_2$ | 0.03 |
| $P_2O_5$ | 0.09 | C (organic) | 0.36 |
| Mno | 0.05 | Ba | over 0.1 |
| $Al_2O_3$ | 17.67 | Sr | 0.001–0.01 |
| CaO | 0.10 | Zr | 0.001–0.01 |
| MgO | 0.59 | V | 0.001–0.01 |
| $Na_2O$ | 0.13 | | |

## Burgoon Member (Pocono Formation) Shales

Although the Burgoon member of the Pocono Formation is predominantly sandstone, it also contains one or more sections of shale up to 40 feet thick as shown on Plate 3, Figure 28, and the geologic column on Plate 1. Most of the shales in the Burgoon are silty and dark-colored.

Unpublished analyses of some of the Burgoon shales from Ff15 are given below:

Test 74-9-12B. The section sampled corresponds to the lower 10 feet of unit 2A (dark shale) as shown on Figure 28. Sampled interval immediately underlies that used in test 74-9-12A.

Raw properties:

Water of plasticity: 15.4%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Skrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 3 | 5.0 | 17.8 | 1.79 |
| 1900 | Tan | 4 | 5.0 | 15.9 | 1.87 |
| 2000 | Tan | 5 | 5.0 | 12.9 | 1.97 |
| 2100 | Brown | 5 | 7.5 | 6.2 | 2.22 |
| 2200 | Dk. brown | 6 | 10.0 | 2.3 | 2.26 |
| 2300 | Dk. gray | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal
Other tests: pH 5.30

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 7.93% | $K_2O$ | 3.50% |
| $SiO_2$ | 59.20 | $H_2O$ @ 105°C | 0.72 |
| $Fe_2O_3$ | 0.84 | Comb. $H_2O$ | 6.10 |
| $TiO_2$ | 0.99 | S | 0.02 |
| FeO | 5.40 | $CO_2$ | 0.02 |
| $P_2O_5$ | 0.06 | C (organic) | 2.35 |
| MnO | 0.03 | Ba | over 0.1 |
| $Al_2O_3$ | 18.93 | Sr | 0.001–0.01 |
| CaO | 0.61 | Zr | 0.001–0.01 |
| MgO | 1.66 | V | 0.001–0.01 |
| $Na_2O$ | 0.14 | | |

Test 74-9-12A. The section sampled corresponds to the upper 10 feet of unit 2A (dark shale) as shown on Figure 28. The sampled interval immediately overlies that used in test 74-9-1B and grades laterally into the interval sampled for test 74-9-12C.

Raw properties:

Water of plasticity: 15.8%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 2 | 2.5 | 20.6 | 1.73 |
| 1900 | Tan | 3 | 2.5 | 17.2 | 1.86 |
| 2000 | Tan | 5 | 5.0 | 11.5 | 2.05 |
| 2100 | Brown | 6 | 7.5 | 7.4 | 2.20 |
| 2200 | Dk. brown | 7 | 7.5 | 3.4 | 2.24 |
| 2300 | Dk. gray | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal
Other tests: pH 5.50

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 8.08% | $K_2O$ | 3.60% |
| $SiO_2$ | 58.24 | $H_2O$ @ 105°C | 0.80 |
| $Fe_2O_3$ | 2.64 | Comb. $H_2O$ | 6.60 |
| $TiO_2$ | 1.03 | S | 0.04 |
| FeO | 3.67 | $CO_2$ | 0.01 |
| $P_2O$ | 0.05 | C (organic) | 2.23 |
| MnO | 0.08 | Ba | over 0.1 |
| $Al_2O_3$ | 19.47 | Sr | 0.001–0.01 |
| CaO | 0.55 | Zr | 0.001–0.01 |
| MgO | 1.59 | V | 0.001–00.01 |
| $Na_2O$ | 0.15 | | |

Test 74-9-12C. This sample is taken from unit 2C (silt shale) as shown on Figure 28. This unit is the lateral equivalent of the section from which sample 74-9-12A was taken.

Raw properties:

Water of plasticity: 16.0%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 1 | 2.5 | 25.3 | 1.66 |
| 1900 | Tan | 2 | 2.5 | 16.7 | 1.84 |
| 2000 | Tan | 4 | 2.5 | 16.0 | 1.87 |
| 2100 | Brown | 5 | 5.0 | 10.5 | 2.05 |
| 2200 | Dk. brown | 6 | 7.5 | 3.4 | 2.26 |
| 2300 | Dk. gray | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: color marginal, poor green strength.
Other tests: pH 5.80

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 5.81% | $K_2O$ | 2.74% |
| $SiO_2$ | 66.26 | $H_2O$ @ 105°C | 1.56 |
| $Fe_2O_3$ | 5.27 | Comb. $H_2O$ | 5.32 |
| $TiO_2$ | 1.01 | S | 0.00 |
| FeO | 1.22 | $CO_2$ | 0.01 |
| $P_2O_5$ | 0.09 | C (organic) | 0.86 |
| MnO | 0.04 | Ba | over 0.1 |
| $Al_2O_3$ | 15.78 | Sr | 0.001-0.01 |
| CaO | 0.66 | Zr | 0.001-0.01 |
| MgO | 0.99 | V | 0.001-0.01 |
| $Na_2O$ | 0.11 | | |

## Curwensville Formation Shales

There are a number of shale beds associated with the Mercer coals and clays of the Curwensville Formation, most notably overlying lower Mercer no. 2 coal and both upper Mercer coals (Plate 6). As is typical of the entire formation, lateral variation of the various shales is frequently strong and abrupt.

## Clearfield Creek Formation Shales

The Clearfield Creek Formation contains two fairly persistent shale units, above Clarion no. 1 coal and Clarion no. 2 coal.

The shale above Clarion no. 1 ranges up to at least 10 feet thick in places and is composed of medium gray to grayish black silty clay shale or claystone and silt shale.

The shale overlying Clarion no. 2 coal is dark colored silt or clay shale up to 20 feet or more thick. In some areas it is cut out by the Kittanning sandstone channel.

## Millstone Run Formation Shales

The main body of shale associated with the Millstone Run Formation directly overlies lower Kittanning no. 3 coal. This interval consists of an upward-grading sequence of dark clay shale, dark silt shale, and lighter-colored silt shale. The upward coarsening and the proportions of different shale types is not uniform. This shale section is usually 25 to 40 feet thick and at the top grades into siltstone and sandstone. In some areas the shales are partly or entirely cut out by the overlying sandstone channels. The proportion of dark shales increases from less than 10 percent in the east to 50 percent or more in the west. Siderite occurs commonly in this interval.

In addition, clay shale and claystone are closely associated with the underclays below lower Kittanning no.3 coal in some places. They are discussed and an analysis given under the heading "Lower Kittanning clays."

The following are the unpublished results of tests on the shale above lower Kittanning no. 3 coal:

Test 74-8-6B, station Df12 of this report. This sample is taken from the 7 feet of dark clay shale lying directly above the lower Kittanning no. 3 coal. Sample 74-8-6A was taken immediately above this sample.

Raw properties:

Water of plasticity: 12.1%
Working properties: very low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 2 | 0.0 | 17.2 | 1.75 |
| 1900 | Tan | 3 | 0.0 | 14.8 | 1.86 |
| 2000 | Lt. red | 4 | 5.0 | 10.9 | 2.01 |
| 2100 | Dk. red | 5 | 5.0 | 9.7 | .... |
| 2200 | Dk. brown | 6 | Expanded | .... | .... |
| 2300 | Dk. gray | 7 | Expanded | .... | .... |

Preliminary bloating tests:

Bloating test: positive
Crushing characteristics: laminar
Particle size: −¾″ to +½″
Retention time: 15 minutes

| Temp °F | Bulk density gm/cc | Bulk density lb/ft₃ | % Abs. |
|---|---|---|---|
| 2000 | 1.50 | 93 | 11.6 |
| 2100 | 0.72 | 45 | 13.7 |
| 2200 | 0.62 | 39 | 13.6 |

Remarks: At 2200°—Light brown, good pore structure, semivitreous skin.
Recommendations: Trial run in rotary kiln.
Potential use: light weight aggregate.
Remarks: good red for face brick, poor green strength.
Other tests: pH 6.00

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 9.27% | $K_2O$ | 4.14% |
| $SiO_2$ | 51.04 | $H_2O$ @ 105°C | 0.65 |
| $Fe_2O_3$ | 1.12 | Comb. $H_2O$ | 6.29 |
| $TiO_2$ | 0.90 | S | 0.84 |
| FeO | 7.05 | $CO_2$ | 1.92 |
| $P_2O_5$ | 0.26 | C (organic) | 1.62 |
| MnO | 0.10 | Ba | over 0.1 |
| $Al_2O_3$ | 21.99 | Sr | 0.001–0.01 |
| CaO | 0.98 | Zr | 0.001–0.01 |
| MgO | 1.91 | V | 0.001–0.01 |
| $Na_2O$ | 0.20 | | |

Test 74-8-6A, station Df12 of this report. This sample was taken from an 11-foot clay shale interval between 7 and 18 feet above lower Kittanning no. 3 coal. Sample 74-8-6B was taken directly below this sample.

Raw properties:

Water of plasticity: 14.6%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Lt. brown | 1 | 0.0 | 16.9 | 1.80 |
| 1900 | Lt. brown | 2 | 2.5 | 11.6 | 2.02 |
| 2000 | Brown | 3 | 5.0 | 10.5 | 2.04 |
| 2100 | Brown | 4 | 5.0 | 6.8 | 2.18 |
| 2200 | Dk. brown | 5 | 7.5 | 2.8 | 2.16 |
| 2300 | Dk. brown | 6 | ... | .... | .... |

Preliminary bloating tests:

Bloating test: positive
Crushing characteristics: angular
Particle size: −¾″ to +½″
Retention time: 15 minutes

| Temp °F | Bulk Density gm/cc | lb/ft³ | % Abs. |
|---|---|---|---|
| 2000 | 1.38 | 86 | 10.2 |
| 2100 | 0.98 | 61 | 11.2 |
| 2200 | 0.96 | 60 | 8.8 |

Remarks: at 2200°—dark brown, good pore structure, semivitreous skin.

Recommendations: trial run in rotary kiln
Potential use: lightweight aggregate
Remarks: color marginal for face brick
Other tests: pH 5.40

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 7.30% | $K_2O$ | 3.70% |
| $SiO_2$ | 57.16 | $H_2O$ @ 105°C | 0.45 |
| $Fe_2O_3$ | 1.11 | Comb. $H_2O$ | 5.39 |
| $TiO_2$ | 0.96 | S | 0.25 |
| FeO | 6.62 | $CO_2$ | 1.70 |
| $P_2O_5$ | 0.18 | C (organic) | 1.14 |
| MnO | 0.08 | Ba | over 0.1 |
| $Al_2O_3$ | 18.95 | Sr | 0.001–0.01 |
| CaO | 0.82 | Zr | 0.001–0.01 |
| MgO | 1.94 | V | 0.001–0.01 |
| $Na_2O$ | 0.19 | | |

## Mineral Springs Formation Shales

Except where locally cut out in west-central Luthersburg quadrangle by the upper Worthington sandstone channel, the 50-foot section overlying the middle Kittanning coal is comprised of dark gray to black shale.

In southwestern and extreme west-central Luthersburg, the lower 10 to 15 feet is lighter colored and sandier shale. In north-central and northeastern Luthersburg and northwestern and southeastern Elliott Park, the lower 15 to 25 feet grades into lighter colored, sandier shales and into sandstone. The above variations are shown on Figure 10 and Plate 9.

The following analyses on Mineral Springs shales are taken from the unpublished files of the Pa. Geological Survey:

Test 74-5-1B, station Dd11 of this report. The sample was taken from a 7-foot silt shale interval, the base of which lay about 12 feet above the middle Kittanning coal. The sample for test 74-5-1A was taken from the shale immediately overlying this sample.

Raw properties:

Water of plasticity: 14.5%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 1 | 0.0 | 19.9 | 1.72 |
| 1900 | Tan | 2 | 0.0 | 16.8 | 1.81 |
| 2000 | Tan | 3 | 2.5 | 12.0 | 1.98 |
| 2100 | Lt. red | 5 | 7.5 | 8.0 | 2.10 |
| 2200 | Brown | 6 | Expanded | .... | .... |
| 2300 | Dk. brown | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal
Other tests: pH 4.00

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 8.00% | $K_2O$ | 3.54% |
| $SiO_2$ | 57.36 | $H_2O$ @ 105°C | 0.60 |
| $Fe_2O_3$ | 2.71 | Comb. $H_2O$ | 6.64 |
| $TiO_2$ | 0.83 | S | 0.75 |
| FeO | 3.61 | $CO_2$ | 0.10 |
| $P_2O_5$ | 0.23 | C (organic) | 1.7 |
| MnO | 0.03 | Ba | over 0.1 |
| $Al_2O_3$ | 20.23 | Sr | 0.001–0.01 |
| CaO | 0.46 | Zr | 0.001–0.01 |
| MgO | 1.49 | V | 0.001–0.01 |
| $Na_2O$ | 0.20 | | |

Test 74-5-1A, station Dd11 of this report. The sample was taken from a 4-foot silt shale interval, the base of which lies about 19 feet above the top of the middle Kittanning coal. This sample was taken from the interval directly above that sampled for test 74-5-1B.

Raw properties:

Water of plasticity: 17.3%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 0.0%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 1 | 0.0 | 21.2 | 1.68 |
| 1900 | Tan | 1 | 0.0 | 19.2 | 1.76 |
| 2000 | Tan | 2 | 0.0 | 17.7 | 1.81 |
| 2100 | Lt. red | 5 | 5.0 | 13.1 | 1.95 |
| 2200 | Dk. brown | 6 | 5.0 | 5.6 | 2.15 |
| 2300 | Dk. gray | 7 | Expanded | .... | .... |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal
Other tests: pH 5.10

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 6.24% | $K_2O$ | 2.74% |
| $SiO_2$ | 63.64 | $H_2O$ @ 105°C | 0.62 |
| $Fe_2O_3$ | 6.06 | Comb. $H_2O$ | 6.14 |

| | | | |
|---|---|---|---|
| $TiO_2$ | 0.99 | S | 0.04 |
| FeO | 0.59 | $CO_2$ | 0.01 |
| $P_2O_5$ | 0.14 | C (organic) | 0.76 |
| MnO | 0.18 | Ba | over 0.1 |
| $Al_2O_3$ | 17.11 | Sr | 0.001–0.01 |
| CaO | 0.24 | Zr | 0.001–0.01 |
| MgO | 1.25 | V | 0.001–0.01 |
| $Na_2O$ | 0.15 | | |

Test 74-9-10B, station Ff9 of this report. This sample was taken from a 10-foot interval of silt shale and thin-bedded siltstone, the base of which lies 2 feet above the middle Kittanning coal and the top 4½ feet below a middle Kittanning rider coal. The sample for test 74-6-10A was taken directly above this one.

Raw properties:

Water of plasticity: 15.1%
Working properties: low plasticity
Drying defects: none
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 1 | 2.5 | 18.4 | 1.74 |
| 1900 | Tan | 1 | 2.5 | 18.5 | 1.85 |
| 2000 | Tan | 3 | 2.5 | 14.4 | 1.92 |
| 2100 | Brown | 4 | 2.5 | 12.1 | 2.00 |
| 2200 | Dk. brown | 6 | 5.0 | 7.5 | 2.15 |
| 2300 | Dk. gray | 7 | 5.0 | 6.2 | 2.15 |

Bloating test: negative
Potential use: face brick
Remarks: poor green strength, color marginal
Other tests: pH 5.30

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 4.78% | $K_2O$ | 2.20% |
| $SiO_2$ | 68.54 | $H_2O$ @ 105°C | 0.56 |
| $Fe_2O_3$ | 2.40 | Comb. $H_2O$ | 4.92 |
| $TiO_2$ | 1.01 | S | 0.00 |
| FeO | 1.94 | $CO_2$ | 0.01 |
| $P_2O_5$ | 0.12 | C (organic) | 0.29 |
| MnO | 0.06 | Ba | over 0.1 |
| $Al_2O_3$ | 16.51 | Sr | 0.001–0.01 |
| CaO | 0.55 | Zr | 0.001–0.01 |
| MgO | 1.17 | V | 0.001–0.01 |
| $Na_2O$ | 0.12 | | |

Test 74-9-10A, station Ff9 of this report. The sample was taken from a 4½-foot interval of clay shale grading up to underclay directly below a middle Kittanning rider coal. The base of the section is 12 feet above the main middle Kittanning coal. The sample for this test was taken directly above that for test 74-9-10B.

Raw properties:

Water of plasticity: 15.7%
Working properties: low plasticity
Drying defects: none.
Drying shrinkage: 2.5%
Dry strength: low

Slow firing test:

| Temp °F | Color | Moh's Hardness | % total Shrinkage | % Abs. | Bulk density gm/cc |
|---|---|---|---|---|---|
| 1800 | Tan | 2 | 2.5 | 20.4 | 1.70 |
| 1900 | Tan | 3 | 2.5 | 15.2 | 1.90 |
| 2000 | Tan | 4 | 5.0 | 10.3 | 2.08 |
| 2100 | Buff | 5 | 10.0 | 5.9 | 2.23 |
| 2200 | Gray | 6 | 10.0 | 3.0 | 2.29 |
| 2300 | Gray | 6 | 10.0 | 2.6 | 2.25 |

Bloating test: negative
Potential use: face brick, structural tile
Remarks: fires to good tan, but rather low green strength
Other tests: pH 5.40

Chemical analysis:

| | | | |
|---|---|---|---|
| L.O.I. | 8.33% | $K_2O$ | 3.36% |
| $SiO_2$ | 55.10 | $H_2O$ @ 105°C | 1.24 |
| $Fe_2O_3$ | 4.44 | Comb. $H_2O$ | 7.24 |
| $TiO_2$ | 1.04 | S | 0.11 |
| FeO | 0.85 | $CO_2$ | 0.05 |
| $P_2O_5$ | 0.08 | C (organic) | 1.29 |
| MnO | 0.05 | Ba | over 0.1 |
| $Al_2O_3$ | 23.15 | Sr | 0.001–0.01 |
| CaO | 0.33 | Zr | 0.001–0.01 |
| MgO | 1.01 | V | 0.001–0.01 |
| $Na_2O$ | 0.18 | | |

## Laurel Run Formation Shales

The upper Kittanning coal is overlain by 5 to 20 feet of upward-coarsening claystone, clay shale and silt shale. These shales appear to be persistent except in a few cases where cut out by the Freeport sandstone channel.

### Glen Richey Formation Shales

As the greatest part of the Glen Richey Formation across the report area is cut out by the lower Mahoning sandstone channels, the few areas where shale might occur near the surface are of little importance.

### Conemaugh Group Shales

The maximum remaining section of Conemaugh rock is about 320 feet thick in northwestern Luthersburg quadrangle. No information is available on the upper 100 feet, although it is likely to contain some shales.

In the lower 220 feet, the 160-foot interval between the Mahoning coal and the Pine Creek (?) limestone is composed largely of clay shale, silt shale, and thin-bedded siltstones. None of it has ever been used or tested for ceramic purposes, although the 70 feet of silt shale and siltstone immediately below the Pine Creek limestone has been extensively used as construction fill.

Where the lower Mahoning sandstone is poorly developed, a 35-foot section of underclay, clay shale, claystone, and limestone occurs below the Mahoning coal. This interval would lie about 30 to 65 feet above the position of the upper Freeport coal.

## NATURAL GAS

### General

Of the two fossil fuels produced in the southern half of the Penfield quadrangle, natural gas ranks second to coal. This area includes part of the Punxsutawney-Driftwood Field of the Appalachian oil and gas Province. More specifically, it includes slightly less than half of the Rockton (Luthersburg) Pool and about half of the Helvetia Pool. These are both deep producing pools. A small, unnamed shallow pool exists in the area south and west of Luthersburg.

Deep gas production is from the Oriskany Formation (Ridgeley Sandstone Member) and the overlying Onondaga Formation. Shallow production is reported to be from the Bradford third sand of the Canadaway Group (equivalent to upper part of the "Devonian marine"). Natural gas accumulation may well be related to the deep fault system, but variations in reservoir porosity and permeability definitely have their effects.

### Structural Setting

Boundaries of the gas pools closely coincide with the area of deep, high-angle reverse faulting on the northwestern flank of Chestnut Ridge anticline (Plate 12). In 1959, Lytle and others (p. 6-7) indicated that the trapping mechanism is primarily stratigraphic and that faulting is a complication.

Where there is enough displacement, it seems possible that gas may accumulate in the hanging wall, at the uptilted ends of fault blocks. It appears more than coincidental that dry wells frequently occur along the down-thrown sides of the northeast-trending reverse faults. In many cases then, gas accumulation may be due equally to both structural and stratigraphic trapping mechanisms.

That no pools have formed along the axis of Chestnut Ridge anticline in this area, attests to the fact that sand characteristics and thickness do strongly control gas accumulation. Lytle and others (1960, p. 10) have pointed out that the thickest accumulation of Ridgeley ("Oriskany") sandstone approximately coincides with the axis of the Punxsutawney-Caledonia syncline and thins toward the flanking anticlines.

## Producing Horizons

### *Onondaga-Ridgeley Interval ("Oriskany") (Deep Well Production)*

The Onondaga chert (Onondaga Formation, Middle Devonian) and the immediately underlying Ridgeley Sandstone Member (upper member) of the Oriskany Formation (Lower Devonian) constitute the major production interval in the report area. The Onondaga chert section averages about 40-80 feet thick and the Ridgeley Sandstone averages 10-20 feet thick.[1]

The Onondaga chert is a brownish gray, slightly silty, usually non-calcareous, bedded chert with some dark siliceous shales in the lower part. Generally, the chert does not yield the first show of gas. Only after the Ridgeley sandstone has been penetrated, and the whole interval hydraulically fractured, does the chert yield a significant gas flow (Lytle & others, 1959, p. 8). In addition, the chert section normally cannot be considered a potential reservoir unless accompanied by an effective Ridgeley reservoir.

The Ridgeley Sandstone is light gray, medium- to coarse-grained quartzose sandstone; it is usually cemented by calcite, but some silica cement occurs near the top. Sufficient pore space has been retained to make the sand body an easily exploitable reservoir.

### *Upper Devonian Sands (Shallow Well Production)*

Only sparse and inexact information is available on the shallow-sand gas pool. Cumulative production is almost negligible compared to deep-sand production. The principal producing horizon is reported to be the Bradford third sand (Canadaway Group, Upper Devonian). This unit is normally about 900 feet below the "Pink Rock" of drillers' terminology (upper part

[1] The lower member of the Oriskany Formation (Shriver) is difficult to differentiate from the underlying Helderberg Formation, so discussion of the production horizons is restrictive in that "Ridgeley" is used instead of "Oriskany" as a whole. In subsurface oil and gas terminology the term "Oriskany" refers to the "Ridgeley" only.

of the Conneaut Group—equivalent of the Catskill Formation). Comparison of shallow and deep drilling records however, indicates that sub-Bradford sandstones have been penetrated and are misnamed as Bradford sands in shallow drilling logs. In all likelihood, several horizons ranging from the Speechley down through the Kane and Haskill sands have been treated by hydrofracturing for significant gas yields.

These Upper Devonian sands are usually light brown, very fine-grained, slightly calcareous, argillaceous sandstones. The porosity is most likely fracture-type. Hydrofracturing is a standard and normally necessary completion procedure.

## Production

### *Onondaga-Ridgeley*

One hundred and fifteen deep wells have been drilled in the southern Penfield area. Of these, fourteen were dry and abandoned; ten yielded only a show of gas. Nearly all of the wells were hydraulically fractured. All the deep wells and their initial production in thousands of cubic feet per day are shown in Table 10. Their location is shown in Figures 20a and b.

The Rockton (Luthersburg) Pool was discovered in 1955 when the Eva Moore No. 1 well was completed. Drilling in the Helvetia Pool in this report area was initiated with the completion of the John R. Potter No. 2 well in 1960. The average well depth to the Ridgeley ("Oriskany") Sandstone is about 7,300 feet. Average initial production in this part of the Rockton Pool is 3,637 MCFGPD (thousand cubic feet of gas per day). For this portion of the Helvetia Pool, initial production has averaged 10,607 MCFGPD.

In 1968, the total Rockton Pool yielded 1,186,531 MCF natural gas: by the end of that year, the cumulative production was 104,482,824 MCF. As stated above, the southern Penfield acreage accounts for slightly less than half of the total pool, so these production figures are slightly more than double the actual results for this report area. In 1968, the total Helvetia Pool yielded 316,387 MCF and cumulative production at the end of 1968 added up to 15,854,991 MCF. The Helvetia figures are probably double that for the actual southern Penfield acreage. The height of activity in this area was in 1957, when forty wells were completed.

The U.S. Bureau of Mines reports the following analysis (Moore & Shrewsbury, 1966, p. 107) of natural gas in one well in southern Penfield quadrangle (well 79, table 10 and station Dd5 plate 1):

| | Index 307<br>Sample 10200 |
|---|---|
| State | Pennsylvania |
| County | Clearfield |
| Field | Rockton |
| Well Name | 4474 |

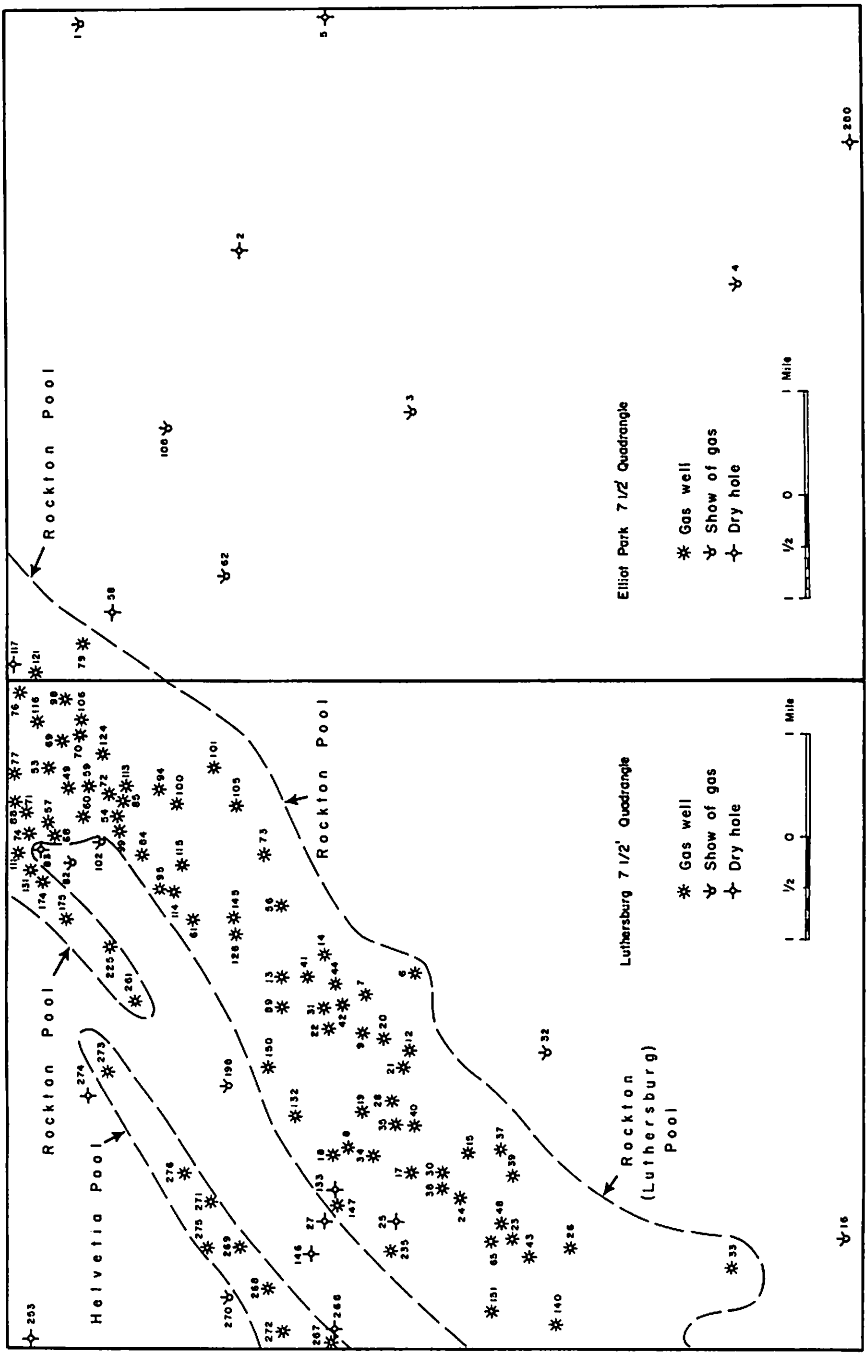


Figure 20. Gas pools and gas wells of the southern Penfield quadrangle.

| | Index 307<br>Sample 10200 (Continued) |
|---|---|
| Location | Shaw Property |
| Owner | Manufacturers Light & Heat Co. |
| Completed | 09/12/57 |
| Sampled | 10/07/65 |
| Formation | Oriskany |
| Depth, Feet | 7151 |
| Wellhead Pressure, PSIG | 480 |
| Open Flow, MCFD | 117 |
| Component, Mole Pct. | |
| Methane | 97.0 |
| Ethane | 2.0 |
| Propane | 0.1 |
| N-Butane | 0.0 |
| Isobutane | 0.0 |
| N-Pentane | 0.0 |
| Isopentane | 0.0 |
| Cyclopentane | 0.0 |
| Hexanes Plus | 0.0 |
| Nitrogen | 0.6 |
| Oxygen | 0.0 |
| Argon | 0.0 |
| Hydrogen | 0.0 |
| Hydrogen Sulfide | 0.0 |
| Carbon Dioxide | 0.1 |
| Helium | Trace |
| Heating Value* | 1025 |

* Calculated Gross BTU Per Cu Ft, Dry, At 60 Degrees Fahrenheit and 30 Inches Hg.

### *Upper Devonian Sand*

Estimated production figures for the small shallow pool are not available at present. After hydrofracturing, two wells drilled in 1964 and 1965 yielded 474 MCFGPD and 500 MCFGPD. In 1965, in the Big Run Field (about 7 miles to the southwest), the combined open flow of all shallow wells after stimulation was 48,951 MCFGPD (Lytle and others, 1966, p. 18). When the Upper Devonian stratigraphy and trends of producing sand bodies are more clearly established, and when completion techniques are improved or more properly adapted to the reservoirs, production may increase at these shallow horizons in this report area.

## LIMESTONE

The limestone resources of the southern Penfield quadrangle are limited. The only limestone beds which are known to occur are the upper Kittanning (Johnstown), lower Freeport, and Albright.

## Table 10. *Deep Natural Gas Wells*

| Pool | P. G. S. O. & G. Div. Penfield Qd. Ref. # | This Report Sta. No. | Well Name | Operator | Date Completed | Initial Production (MCFD) or status* |
|---|---|---|---|---|---|---|
| —— | 1 | Fd1 | State of Penna. Tract C, No. 1 | Manufacturers Light & Heat Co. | 12/29/53 | Show |
| —— | 2 | Ed2 | State of Penna. Tract C, No. 2 | Manufacturers Light & Heat Co. | 6/19/53 | Dry |
| —— | 3 | Ee1 | O. W. McNaul 1 | New York State Nat. Gas Corp. | 7/25/53 | Dry |
| —— | 4 | Ef2 | Abrino 1 | Greenwood Gas & Oil Co. | 8/7/53 | Show |
| —— | 5 | Fe2 | State of Penna. Tract C, No. 3 | Manufacturers Light & Heat Co. | 8/18/54 | Dry |
| Rockton | 6 | Be29 | Eva Moore 1 | Rockton Drilling Co. | 2/25/55 | 515 Discovery Well |
| Rockton | 7 | Be25 | S. M. Bailey 1 | Rockton Drilling Co. | 8/1/55 | 2,000 |
| Rockton | 8 | Ae13 | John Hayes 1 | NYSNG Corp. (N465) | 12/2/55 | 8,000 |
| Rockton | 9 | Be20 | Gertrude Kirk 1 | Hanley & Bird | 10/17/55 | 4,100 |
| Rockton | 12 | Be34 | Bolton-Gilmore 1 | Fairman Drilling Co. | 4/27/56 | 1,212 |
| Rockton | 13 | Bd16 | Brewer 1 | John Fox | 10/29/56 | 3,400 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Rockton | 14 | Be5 | Conrad Hrs. 1 | Rockton Drilling Co. | 6/24/56 | 2,147 |
| Rockton | 15 | Ae38 | Haas & Rockey | Fairman Drilling Co. | 6/26/56 | 2,700 |
| ——— | 16 | Af15 | C. P. Harris 1 | Godfrey L. Cabot Inc. | 3/13/56 | Show |
| Rockton | 17 | Ae34 | Milton Hartzfeld 1 | NYSNG Corp. (N483) | 5/28/56 | 2,075 |
| Rockton | 18 | Ae11 | Hopton 1 | John Fox | 9/7/56 | 2,600 |
| Rockton | 19 | Be11 | Nellie Jammison 1 | Fairman Drilling Co. | 5/28/56 | 750 |
| Rockton | 20 | Be33 | M. L. Kirk 1 | T. W. Phillips Gas & Oil Co. | 4/12/56 | 1,418 |
| Rockton | 21 | Be18 | M. L. Kirk 2 | T. W. Phillips Gas & Oil Co. | 8/17/56 | 850 |
| Rockton | 22 | Be7 | Kruger 1 | John Fox | 7/6/56 | 881 |
| Rockton | 23 | Ae58 | McGoughey 1 | Fairman Drilling Co. | 8/15/56 | 5,000 |
| Rockton | 24 | Ae39 | Eva Moore 2 | NYSNG Corp. (N509) | 12/28/56 | 4,191 |
| Rockton | 25 | Ae27 | Wm. F. Moore 1 | NYSNG Corp. (N485) | 10/22/56 | Dry |
| Rockton | 26 | Ae70 | Clyde Muth 1 | Fairman Drilling Co. | 10/5/56 | 450 |
| ——— | 27 | Ae5 | Ray Nelson 1 | NYSNG Corp. (N484) | 9/20/56 | Dry |

* More complete information on these wells may be found in the following Pa. G. S. references: M39, M45, PR158, PR160, PR168.

Table 10. *(Continued)*

| Pool | P. G. S. O. & G. Div. Penfield Qd. Ref. # | This Report Sta. No. | Well Name | Operator | Date Completed | Initial Production (MCFD) or status* |
|---|---|---|---|---|---|---|
| Rockton | 28 | Be16 | Ord Oaks 1 | T. W. Phillips Gas & Oil Co. | 3/8/56 | 5,500 |
| Rockton | 30 | Ae36 | Reitz 1 | I. H. Hogue | 11/23/56 | 880 |
| Rockton | 31 | Be6 | Isabel Rowland 1 | NYSNG Corp (489) | 8/3/56 | 5,500 |
| ——— | 32 | Be44 | Harvey H. Seyler 1 | Columbian Carbon Co. | 4/24/56 | Show |
| Rockton | 33 | Af8 | Stallman & Simpson 1 | Brookville Drilling Co. | 8/24/56 | 387 |
| Rockton | 34 | Ae15 | Wachob 1 | John Fox | 9/7/56 | 2,800 |
| Rockton | 35 | Be13 | T. B. Wachob 1 | NYSNG Corp. (N503) | 11/28/56 | 1,720 |
| Rockton | 37 | Ae75 | DuBois Brewing Co. 1 | Keta Gas & Oil Co. | 11/2/56 | 1,250 |
| Rockton | 38 | Ae35 | Wm. Wingert 1 | T. W. Phillips Gas & Oil Co. | 5/28/56 | 5,957 |
| Rockton | 39 | Ae74 | Charles Wingert 1 | James Drilling Co. | 12/13/56 | 1,400 |
| Rockton | 40 | Be35 | Milton Hartzfeld 2 | NYSNG Corp. (N506) | 1/17/57 | 1,750 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Rockton | 41 | Be4 | Howard Huey 1 | Hanly & Bird | 1/17/57 | 850 |
| Rockton | 42 | Be21 | John Wells 1 | Fairman Drilling Co. | 1/24/57 | 1,000 |
| Rockton | 43 | Ae59 | Burt E. Knarr 1 | NYSNG Corp (N511) | 2/7/57 | 880 |
| Rockton | 44 | Be22 | Bailey 1 | Keta Gas & Oil Co. | 2/15/57 | 950 |
| Rockton | 48 | Ae57 | Edna Nolder 1 | James Drilling Co. | 3/8/57 | 4,600 |
| Rockton | 49 | Cd24 | Barney Bailey 1 | NYSNG Corp. (N539) | 4/15/57 | 8,000 |
| Rockton | 53 | Cd12 | W. Kimmel 1 | NYSNG Corp. (N538) | 4/15/57 | 5,500 |
| Rockton | 54 | Cd30 | A. L. Orner, et ux 1 | NYSNG Corp. (N559) | 5/17/57 | 5,325 |
| Rockton | 56 | Bd15 | John B. Welty 1 | Hanley & Bird | 6/21/57 | 750 |
| Rockton | 57 | Cd8 | Raymond E. Bloom 1 | NYSNG Corp. (N564) | 6/15/57<br>2/7/58 | 60,000<br>2,400 after D. D. |
| ——— | 58 | Dd7 | Broker 1 | I. Hogue | 5/16/58 | Dry |
| Rockton | 59 | Cd23 | Rex Gray 1 Gas Dev. Co. | Swam & Finch | 6/19/57 | 6,631 |
| Rockton | 60 | Cd25 | Thomas M. Kirk 1 | Manufacturers Light & Heat Co. | 6/24/57 | 3,421 |
| Rockton | 61 | Bd9 | Scholl 1 | Devonian Gas & Oil Co. | 7/6/57 | 2,500 |

* More complete information on these wells may be found in the following Pa. G. S. references: M39, M45, PR158, PR160, PR168.

Table 10. *(Continued)*

| Pool | P. G. S. O. & G. Div. Penfield Qd. Ref. # | This Report Sta. No. | Well Name | Operator | Date Completed | Initial Production (MCFD) or status* |
|---|---|---|---|---|---|---|
| —— | 62 | Dd8 | Pa. Tract 60 1 | NYSNG Corp. (N548) | 8/20/57 | Show |
| Rockton | 65 | Ae55 | D. Swope, et ux 1 | NYSNG Corp. | 7/26/57 | 1,283 |
| Rockton | 68 | Cd26 | Leslie Bloom 1 | Conroy | 8/8/57 | 16,500 |
| Rockton | 69 | Cd20 | Glenn W. Holly 1 | Manufacturers Light & Heat Co. | 8/12/57 | 4,200 |
| Rockton | 70 | Cd19 | P. R. Bailey 1 | Harry Brunt | 8/14/57 | 3,100 |
| Rockton | 71 | Cd9 | Raymond E. Bloom, et ux 2 | NYSNG Corp. | 7/18/57 | 23,938 |
| Rockton | 72 | Cd32 | Fair 1 | Heller | 8/26/57 | 3,250 |
| Rockton | 73 | Cd43 | A. Brubaker 1 | NYSNG Corp. (N568) | 8/24/57 | 1,174 |
| Rockton | 74 | Cd7 | Emery Miller 1 | Devonian Gas & Oil Co. and Fairman Drilling Co. | 8/24/57 | 14,300 |
| Rockton | 76 | Cd16 | Sure Shot Land & Gun Club 2 | The Sylvania Corp. | 9/12/57 | 4,881 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Rockton | 77 | Cd11 | City of DuBois Tract 28 1 | NYSNG Corp. (N583) | 9/13/57 | 2,034 |
| Rockton | 79 | Dd5 | W. Shaw 1 | Manufacturer's Light & Heat Co. | 9/14/57 | 2,700 |
| ——— | 82 | Cd27 | Sarah Orner 2 | Keta Gas & Oil Co. | 9/20/57 | Show |
| ——— | 83 | Cd3 | Leslie Bloom 2 | Lomega Exploration, Ltd. | 10/1/57 | Dry |
| Rockton | 84 | Cd37 | Lafayette College 1 | Rockton Drilling Co. | 9/27/57 | 3,900 |
| Rockton | 85 | Cd31 | H. LaRock 1 | Manufacturer's Light & Heat Co. | 9/20/57 | 2,700 |
| Rockton | 88 | Cd10 | Chas. Blanchard 1 | NYSNG Corp. (N594) | 11/3/57 | 8,000 |
| Rockton | 89 | Bd17 | Green Glen 1 | Hanley & Bird | 10/15/57 | 1,800 |
| Rockton | 94 | Cd34 | D. W. Conrad 1 | Manufacturer's Light & Heat Co. | 10/25/57 | 1,900 |
| Rockton | 95 | Cd39 | Scholl 2 | Devonian Gas & Oil Co. | 11/5/57 | 4,000 |
| Rockton | 98 | Cd17 | Sure Shot Land & Gun Club 3 | The Sylvania Corp. | 11/15/57 | 2,013 |
| Rockton | 99 | Cd29 | S. E. Orner 1 | T. W. Phillips Gas & Oil Co. | 11/27/57 | 1,853 |
| Rockton | 100 | Cd35 | M. N. Laborde 1 | C. Heller | 11/29/57 | 600 |
| Rockton | 101 | Cd47 | R. C. Brubaker 1 | NYSNG Corp. (N595) | 11/27/57 | 400 |

* More complete information on these wells may be found in the following Pa. G. S. references: M39, M45, PR158, PR160, PR168.

Table 10. *Continued*

| Pool | P. G. S. O. & G. Div. Penfield Qd. Ref. # | This Report Sta. No. | Well Name | Operator | Date Completed | Initial Production (MCFD) or status* |
|---|---|---|---|---|---|---|
| ——— | 102 | Cd28 | A. L. Orner 2 | T. W. Phillips Gas & Oil Co. | 12/13/57 | Show |
| Rockton | 105 | Cd45 | Ansel Beer 1 | NYSNG Corp. (N596) | 12/23/57 | 2,157 |
| Rockton | 106 | Cd18 | City of Dubois | NYSNG Corp. (N591) | 1/2/58 | 1,099 |
| ——— | 108 | Ed1 | Pa. Tract 62 1 | NYSNG Corp. (N547) | 1/4/58 | Show |
| Rockton | 111 | Cd5 | Emery Miller 2 | Devonian Gas & Oil Co. | 1/15/58 | 20,000 |
| Rockton | 113 | Cd33 | City of DuBois 2 | NYSNG Corp. (N509) | 1/13/58 | 622 |
| Rockton | 114 | Cd40 | H. T. & L. M. Shaffer 1 | T. W. Phillips Gas & Oil Co. | 1/31/58 | 2,600 |
| Rockton | 115 | Cd42 | Telford Bogle 1 | Fairman Drilling Co. | 2/2/58 | 1,600 |
| Rockton | 116 | Cd15 | City of DuBois 4 | NYSNG Corp. | 2/4/58 | 1,712 |
| Rockton | 117 | Dd1 | Sure Shot Land & Gun Club 4 | The Sylvania Corp. | 2/19/58 | Dry |

| | | | | | | |
|---|---|---|---|---|---|---|
| Rockton | 121 | Dd4 | Green Glen 1 | Fairman Drilling NYSNG Corp. (N640) | 3/17/58 | 1,600 |
| Rockton | 124 | Cd21 | Gordon Bender 1 | Guy McCracken | 4/8/58 | 106 |
| Rockton | 126 | Bd13 | George Bloom 1 | John Fox | 4/17/58 | 3,150 |
| Rockton | 131 | Cd1 | Emery Miller 3 | Devonian Gas & Oil Co. | 5/14/58 | 18,500 |
| Rockton | 132 | Be1 | John E. Hayes 2 | NYSNG Corp. (N623) | 5/21/58 | 1,992 |
| Rockton | 133 | Ae9 | Art DuFour 1 | NYSNG Corp. (N643) | 5/29/58 | Dry |
| Rockton | 140 | Ae65 | Wm. Kardysuaska 1 | NYSNG Corp. (N647) | 6/9/58 | 1,300 |
| Rockton | 145 | Bd14 | H. T. Shaffer 1 | Sam Jack, et al | 7/17/58 | 1,700 |
| ——— | 146 | Ae1 | F. J. Cocran 1 | NYSNG Corp. (N656) | 10/18/58 | Dry |
| Rockton | 147 | Ae8 | Joel Horne, et al 1 | NYSNG Corp. (N659) | 8/14/58 | 4,055 |
| Rockton | 150 | Bd19 | Green Glen 1–a | Fairman Drilling Co. | 9/25/58 | 2,214 |
| Rockton | 151 | Ae49 | C. W. Rafferty 1 | NYSNG Corp. (N669) | 9/24/58 | 504 |
| Rockton | 174 | Cd2 | Pentz Estate 2 | Rockton Drilling Co. | 4/3/59 | 6,100 |

* More complete information on these wells may be found in the following Pa. G. S. references: M39, M45, PR158, PR160, PR168.

## Table 10. (*Continued*)

| Pool | P. G. S. O. & G. Div. Penfield Qd. Ref. # | This Report Sta. No. | Well Name | Operator | Date Completed | Initial Production (MCFD) or status* |
|---|---|---|---|---|---|---|
| Rockton | 175 | Bd3 | Pentz Estate 3 | Rockton Drilling Co. | 4/24/59 | 7,600 |
| ——— | 198 | Bd21 | Harvey Murray 1 | NYSNG Corp. (N685) | 5/5/59 | Show |
| Rockton | 225 | Bd4 | Green Glen 1–b | Fairman Drilling Co. | 11/17/59 | 2,320 |
| Rockton | 235 | Ae21 | N. C. Utzinger 1 | NYSNG Corp. (N688) | 2/12/60 | 1,712 |
| ——— | 253 | Ad7 | City of DuBois 2 | Kewanee Oil Co. | 6/3/60 | Dry |
| Rockton | 261 | Bd5 | Green Glen 1–c | Fairman Drilling Co. | 7/6/60 | 2,504 |
| ——— | 266 | Ae4 | John R. Potter 1 | NYSNG Corp. (N782) | 10/13/60 | Dry |
| Helvetia | 267 | Ae3 | John R. Potter 2 | NYSNG Corp. (N790) | 9/29/60 | 30,370 |
| Helvetia | 268 | Ad65 | Herman L. Delp 1 | NYSNG Corp. (N791) | 10/7/60 | 11,614 |
| Helvetia | 269 | Ad63 | William Barr 1 | NYSNG Corp. (N749) | 11/4/60 | 5,082 |
| ——— | 270 | Ad58 | George Witmore 1 | S. W. Jack Drilling Co. | 11/16/60 | Show |

| | | | | | | |
|---|---|---|---|---|---|---|
| Helvetia | 271 | Ad61 | Walter Dunlop 1 | NYSNG Corp. (N798) | 12/18/60 | 19,512 |
| Helvetia | 272 | Ad66 | DuBois Nat. Bank (H. E. Ginler Est.) 1 | NYSNG Corp. (N796) | 12/23/60 | 10,504 |
| Helvetia | 273 | Bd2 | Green Glen 1–d Wt. 3580–2 | Fairman Drilling Co. | 1/12/61 | 2,115 |
| —— | 274 | Bd1 | Green Glen 1–e Wt. 3580–3 | Fairman Drilling Co. | 2/6/61 | Dry |
| Helvetia | 275 | Ad59 | J. L. Chick 1 | Lee E. Minter NYSNG Corp. | 2/21/61 | 4,470 |
| Helvetia | 276 | Ad60 | E. B. Shettler 1 | NYSNG Corp. (N801) | 3/21/61 | 1,185 |
| —— | 280 | Ff12 | Mary Bailey 1 | Fairman Drilling Co. | 6/21/64 | Dry |
| —— | — | Ae14 | Unknown | Unknown | Unknown | Unknown |
| —— | — | De2 | Unknown | NYSNG Corp. (N552) | Incomplete (58) | Abandoned |
| —— | — | Bd20 | Unknown | Unknown | Unknown | Unknown |

* More complete information on these wells may be found in the following Pa. G. S. references: M39, M45, PR158, PR160, PR168.

The Albright Limestone lies 185 feet above the position of the upper Freeport coal, and was observed only in the drill hole at Bc1 where it was described as a 19-inch, medium gray, clayey limestone.

The upper Kittanning (or Johnstown) limestone occurs in association with the underclay below the upper Kittanning coal. This interval was exposed at only three places in the area. At two of these (Ae41 and Bc1) the limestone is absent. At the third site (Ae20) the limestone exists as two one-foot beds separated by up to one foot of underclay.

The lower Freeport limestone is found in close association with the underclay below the lower Freeport coal. This interval was exposed in eight places in or near the southern Penfield quadrangle. The limestone was absent in three (Bf4, Curwensville Ba1, and Curwensville Ca4), existed only as scattered nodules and concretions in two (Be24 and Ae30), and as one or more beds in three (Cd22, Ae43, and Ae68). The above exposures of the lower Freeport limestone are shown diagrammatically as part of Plate 10. The bedded exposures are described as follows:

*Exposure at Ae43*

| | |
|---|---|
| Coal and shaly coal (lower Freeport) | 0'11" |
| Clayey siltstone, olive gray | 7' |
| Claystone, olive black to dark gray | 7' |
| Interbedded hard dense, finely crystalline, medium gray limestone and underclay or silt shale (interbeds 2 inches to 1 foot thick) | 15' |
| Bony coal and coaly shale | 0'6" |
| Underclay, olive black | 1' |
| Limestone, very clayey, medium gray | 1' |
| Total bedded limestone: appx. | 8 feet |

*Exposure at Ae68:*

| | |
|---|---|
| Coal blossom (lower Freeport) | |
| Underclay, light gray | 1' |
| Silty sandstone, light gray, lumpy | 3'6" |
| Clay shale, black | 6" |
| Limestone, ferruginous, one bed | 1' |
| Limestone, brecciated, medium gray to dark gray, clayey, silty, ¼" to 2" beds | 2' |
| Underclay, silty, small limestone nodules, light olive gray | 6" |
| Limestone, dense to clayey, dark gray, ¼" to 2" beds | 1' 6" |
| Interbedded limestone, dense to clayey, dark gray and underclay | 2' |
| Underclay, light olive gray, with nodules and stringers of limestone | 3' |
| Total bedded limestone | 5½' |

*Exposure at Cd22:*

| | |
|---|---|
| Coal, lower Freeport | 11" |
| Clay shale, black, plant fragments | 1' |
| Underclay, medium light gray | 3' |

| | |
|---|---|
| Clay shale, black | 2′ |
| Underclay, light olive gray to medium gray | 4′ |
| Limestone, medium gray to medium dark gray, finely crystalline | 1′ |
| Silt shale, olive gray | 2′ |
| Limestone, medium gray to medium dark gray, finely crystalline, lower 3 ft. is one bed | 4′+ |
| Total bedded limsestone | 5′+ |

The lower Freeport limestone was quarried at Ae43 and Cd22, but the use to which it was put is not known. Chance (1884) reports the lower Freeport limestone was quarried for local agricultural use from the hill immediately east of Luthersburg (hill 2007).

## CONSTRUCTION MATERIALS

### General

Abundant quantities of source rock for such construction materials as dimension sandstone, crushed sandstone, crushed silt shale and siltstone, and sand and gravel are found in the report area.

### Dimension Stone

The Homewood Sandstone Member of the Curwensville Formation (Plate 1) is the most acceptable source of dimension stone. This unit has been quarried at stations Ff11 and Df20, and at stations Curwensville Ea3 (Figure 9) and Curwensville Ea2. Large blocks of heavy construction stone were produced at these quarries. The quarries have been idle since the 1920's. During active production, sandstone blocks were used in construction of the railroad bridge across the Susquehanna River at Rockville, the Market Street bridge at Harrisburg, Princeton University chapel, the Pittsburgh museum, Philadelphia subways, and other heavy construction projects. The combination of widely spaced vertical joint planes and horizontal bedding planes yields good, large, rectilinear blocks; cross-bedding planes are not usually planes of weakness in this unit. At the old Bloom Run quarry (Df20), a massive, single bed up to 25 feet thick was quarried, yielding blocks 30 inches thick and 12 feet long (Stone, 1932, p. 114-115).

Thin-section analyses of stone from the Bloom Run quarry show the following results:

| | |
|---|---|
| *Thin-section no.* | 74d–32 (Figure 21) |
| Location | Sta. Df20 |
| Stratigraphic horizon | Homewood Sandstone-massive bed |
| Grain size range (mm.) | 0.15–0.70 |
| Average grain size (mm.) | 0.30 |

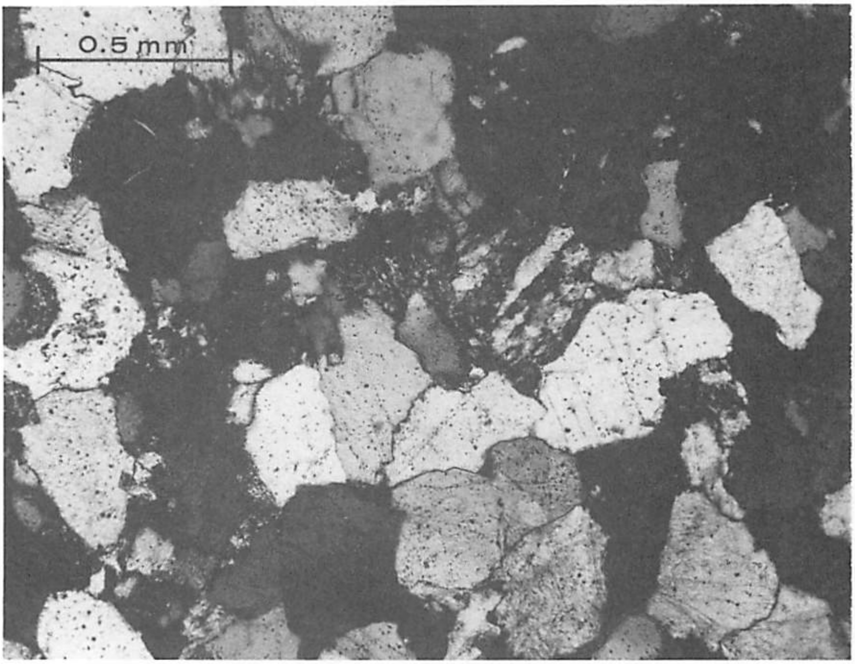


Figure 21. Photomicrograph of Homewood Sandstone.

| | |
|---|---|
| Composition, 500 point-count % | |
| Quartz* | 82.0% |
| Chert fragments | 0.2 |
| Metamorphic rock fragments | 3.2 |
| Coarse mica > 0.03 mm. | 0.2 |
| Ilmenite, Magnetite, Hematite | Trace |
| Zircon | 0.2 |
| Leucoxene | 0.6 |
| Kaolinite matrix | 2.0 |
| Sericite or illite matrix | 5.4 |
| Microcrystalline quartz cement | 0.6 |
| Authigenic silica cement | 5.6 |
| Siderite cement | 0.0 |
| *Thin-section no.* | 74d–33 |
| Location | Sta. Df20 |
| Stratigraphic horizon | Homewood Sandstone-above massive bed |
| Grain size range (mm.) | 0.10–0.40 |
| Average grain size (mm.) | 0.25 |
| Composition, 500 point-count % | |
| Quartz* | 74.3% |
| Chert fragments | 1.5 |

* Includes quartz, polycrystalline quartz, and metaquartzite

| | |
|---|---|
| Metamorphic rock fragments | 3.0 |
| Coarse mica > 0.03 mm. | 2.3 |
| Ilmenite, Magnetite, Hematite | Trace |
| Zircon | Trace |
| Leucoxene | 1.1 |
| Kaolinite matrix | 5.2 |
| Sericite or illite matrix | 7.3 |
| Microcrystalline quartz cement | 0.4 |
| Authigenic silica cement | 4.7 |
| Siderite cement | 0.2 |

The description of the Homewood member is included in the section on surface stratigraphy. This thick sandstone of structural quality is well-developed in the southern half of the Elliott Park quadrangle. It usually forms a distinctive bench that can be identified on aerial photographs. Where the member can be separated by this method, it is shown on Plate 1.

Stone (1932, p. 114) points out that the sandstone is soft when freshly quarried, but becomes harder on exposure. This may be a desirable characteristic for future exploitation of the numerous surface exposures remaining.

Other sandstones are thickly developed in the area, especially the Burgoon Sandstone, upper Connoquenessing sandstone, Kittanning sandstone, and Lower Mahoning sandstone. For dimension stone, these are less desirable than the Homewood sandstone because of greater textural variations, more closely-spaced bedding planes, well-developed trough-shaped cross-bedding, and contamination by clay galls and organic detritus.

## Crushed Stone

### *Sandstone*

The surface stratigraphic section includes about ten sandstone units that would be suitable for use as crushed and broken stone. Uses would include road metal, railroad ballast, riprap, concrete aggregate, and miscellaneous aggregates. Crushed sandstone may be produced from the Burgoon Sandstone, upper Connoquenessing sandstone, the unnamed sandstone below the upper Mercer no. 1 coal, Homewood Sandstone, Kittanning sandstone, lower Worthington sandstone, upper Worthington sandstone, Freeport sandstone, lower Mahoning sandstone, and upper Mahoning sandstone. Smaller sandstone bodies occur throughout the section, but are far more discontinuous and generally not too thick.

The sandstones may be subdivided by appearance into two very broad groups: (1) the Burgoon and Pottsville sandstones and (2) the Allegheny and Conemaugh sandstones. Although it is often possible to see considerable internal variation within a single stratigraphic unit, this grouping is a good generalization for the entire report area.

The first group (Burgoon-Pottsville) is generally coarser than the second. The Burgoon, upper Connoquenessing, and Homewood are dominantly medium-grained. Sandstones of the second group (Lower and Upper Mahoning, for example) are dominantly fine-grained. Burgoon and Pottsville sandstones also appear to bear a lower percentage of dark, iron-bearing minerals than the Allegheny-Conemaugh sandstones. The Mahoning sandstones contain, by field examination, around 2% to 5% dark minerals. The first group of sandstones contain on the average of 1% dark minerals.

There is also an observable color difference between the two groups. The first group tends to be very light gray to pinkish gray or light brown; the second group tends to be light gray to yellowish gray.

The sandstones of the first group (Burgoon-Pottsville) were analyzed by thin-section in connection with our work on the stratigraphy involving the Mississippian-Pennsylvanian unconformity. Selected analyses are shown below:

| | |
|---|---|
| *Thin-section no.* | 74d–2 (Figure 22) |
| Location | Sta. Clearfield Ae3 |
| Stratigraphic horizon | U. Connoquenessing ss.—Just above the Mississippian-Pennsylvanian unconformity |
| Grain size range (mm.) | 0.15–0.50 |

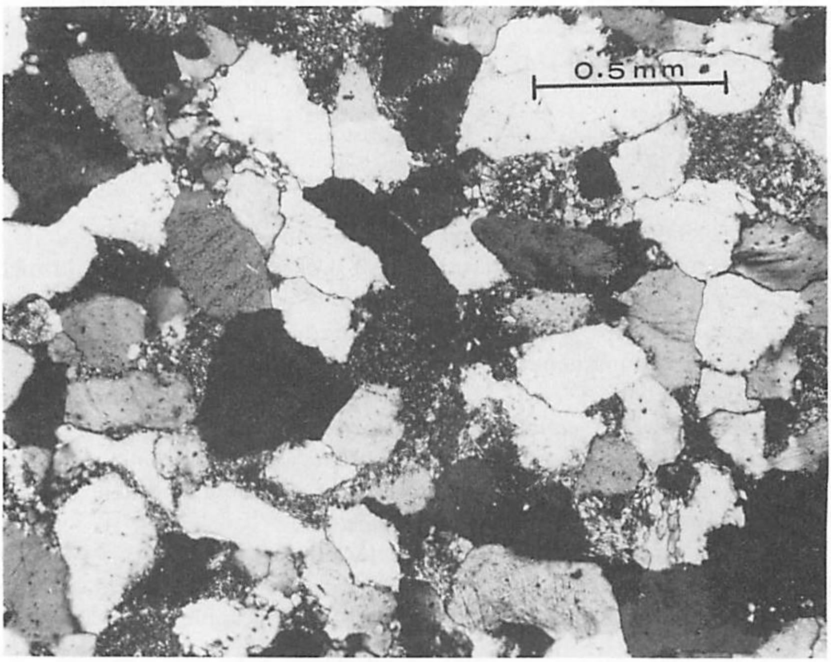


Figure 22. Photomicrograph of upper Connoquenessing Sandstone.

| | |
|---|---|
| Average grain size (mm.) | 0.20 |
| Composition, 500 point-count % | |
| Quartz* | 77.3% |
| Chert fragments | 1.2 |
| Metamorphic rock fragments | 0.2 |
| Coarse mica > 0.03 mm. | 2.1 |
| Ilmenite, magnetite, hematite | 0.3 |
| Zircon | Trace |
| Leucoxene | 1.0 |
| Kaolinte matrix | 2.7 |
| Sericite or illite matrix | 8.1 |
| Microcrystalline quartz cement | 4.6 |
| Authigenic silica cement | 2.5 |
| Siderite cement | 0.0 |

| | |
|---|---|
| *Thin-section no.* | 74d–29 |
| Location | Sta. Fd3 |
| Stratigraphic horizon | Upper Connoquenessing sandstone |
| Grain size range (mm.) | 0.15–0.55 |
| Average grain size (mm.) | 0.25 |
| Composition, 500 point-count % | |
| Quartz* | 65.2% |
| Chert fragments | 3.8 |
| Metamorphic rock fragments | 1.4 |
| Coarse mica > 0.03 mm. | 4.4 |
| Ilmenite, magnetite, hematite | 1.0 |
| Zircon | 0.0 |
| Leucoxene | 1.0 |
| Kaolinite matrix | 6.4 |
| Sericite or illite matrix | 10.2 |
| Microcrystalline quartz cement | 3.8 |
| Authigenic silica cement | 2.6 |
| Siderite cement | 0.2 |

| | |
|---|---|
| *Thin-section no.* | 74d–1 (Figure 23) |
| Location | Sta. Clearfield Ae3 |
| Stratigraphic horizon | Burgoon Sandstone—Just below the Mississippian-Pennsylvanian unconformity |
| Grain size range (mm.) | 0.10–0.40 |
| Average grain size (mm.) | 0.25 |
| Composition, 500 point-count % | |
| Quartz* | 69.3% |
| Chert fragments | 0.8 |
| Metamorphic rock fragments | 0.4 |
| Coarse mica > 0.03 mm. | 0.6 |
| Ilmenite, magnetite, hematite | 1.4 |
| Zircon | Trace |
| Leucoxene | 1.2 |
| Kaolinite matrix | 3.7 |
| Sericite or illite matrix | 13.8 |

* Includes quartz, polycrystalline quartz, and metaquartzite

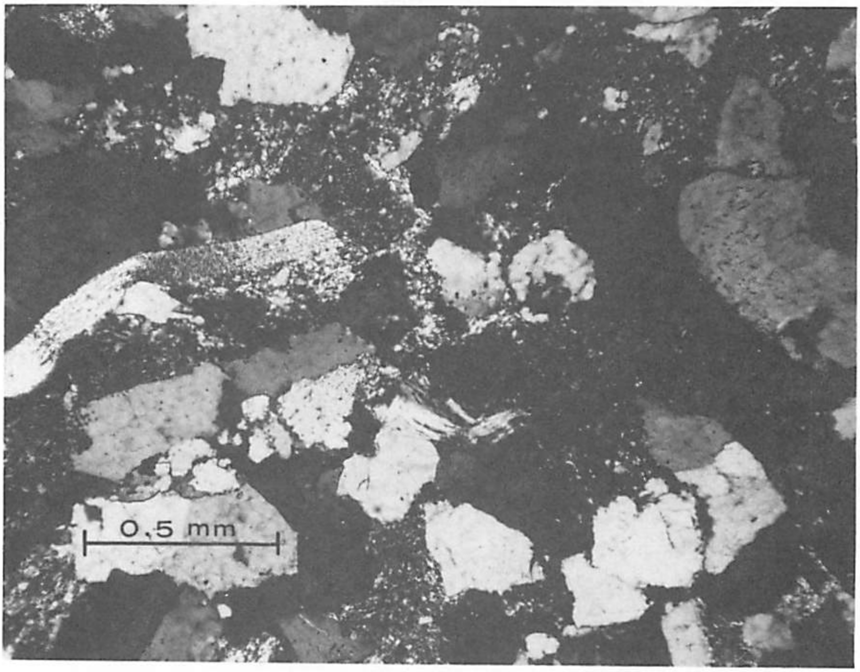


Figure 23. Photomicrograph of Burgoon Sandstone.

| | |
|---|---|
| Microcrystalline quartz cement | 7.3 |
| Authigenic silica cement | 1.5 |
| Siderite cement | 0.0 |

| | |
|---|---|
| *Thin-section no.* | 74d–3 |
| Location | Sta. Clearfield Ae3 |
| Stratigraphic horizon | Burgoon Sandstone—just above middle dark siltstone unit |
| Grain size range (mm.) | 0.09–0.40 |
| Average grain size (mm.) | 0.25 |
| Composition, 500 point-count % | |
| Quartz* | 69.6% |
| Chert fragments | 5.1 |
| Metamorphic rock fragments | 1.0 |
| Coast mica > 0.03 mm. | 0.5 |
| Ilmenite, magnetite, hematite | 0.9 |
| Zircon | 0.1 |
| Leucoxene | 0.9 |
| Kaolinite matrix | 2.1 |
| Sericite or illite matrix | 13.8 |
| Microcrystalline quartz cement | 5.5 |
| Authigenic silica cement | 0.5 |
| Siderite cement | 0.0 |

* Includes quartz, polycrystalline quartz, and metaquartzite

Analyses for the Homewood Sandstone are given in the section on structural sandstone.

Great piles of sandstone rubble (Figure 24) have been left at the quarries where structural sandstone was produced (Homewood Sandstone).

Large quantities of fragmented sandstone, unmixed with other rock types, occur on the spoil piles from strip mines on the lower Freeport coal or limestone and the upper Kittanning coal at stations Ae61, Ae68, Ae18, Ae19, Af12, Af10, Af4, Af1, Af3, Bf9, Bf2, Bf45, Bf42, and Cd22. In many of these same mines, the unbroken sandstone remains exposed in the highwall.

*Siltstone and Silt Shale*

There is a plentiful supply of siltstone and silt shale included in the surface rocks of this area. A considerable quantity is used as road metal in maintaining low-use secondary roads. For the most part, this road metal is taken from strip mine spoil piles, although a borrow pit is maintained at Cd36 as well. The material from this borrow pit is derived from the upper part of the Mineral Springs Formation.

In the area around the villages of Shaffer and Oklahoma in northwestern Luthersburg quadrangle, several quarries have been opened on the silt shale-siltstone interval below the Albright Limestone horizon in the Conemaugh Group. This silt shale and siltstone provides excellent road metal

Figure 24. Rubble pile, Homewood Sandstone quarry at Curwensville Ea3.

and road fill and is used extensively as riprap in the swampy alluvial plain of Sandy Lick Creek (locally called the "Meadow"). The material from this interval compacts well, has a high bearing strength, low shrinkage, and low water absorption. The City of DuBois presently maintains a public quarry at Ad1 (Figure 25). Older quarries were operated at Ad18, Ad5, and Ad4. The material from these presumably went into fill and road metal for local roads and as riprap for the railroad. This unit is discussed under "Pennsylvanian Stratigraphy" and is shown in measured sections on Figure 12.

## Sand and Gravel

The flood plains of Sandy Lick Creek, Laborde Branch, Luthersburg Branch, and some reaches of Anderson Creek (especially upstream from DuBois Reservoir) are floored with alluvial gravel, sand, silt, and clay (Quaternary alluvium of Plate 1). Probably the thickest deposit is along Sandy Lick Creek. Just north of the Luthersburg quadrangle, where Interstate Route 80 crosses Sandy Lick Creek, up to 50 feet of silty and clayey material was penetrated by augur borings.

These unconsolidated alluvial sands and gravels reflect, and are evidently derived from the exposed surface rock types in the watershed. Cobbles

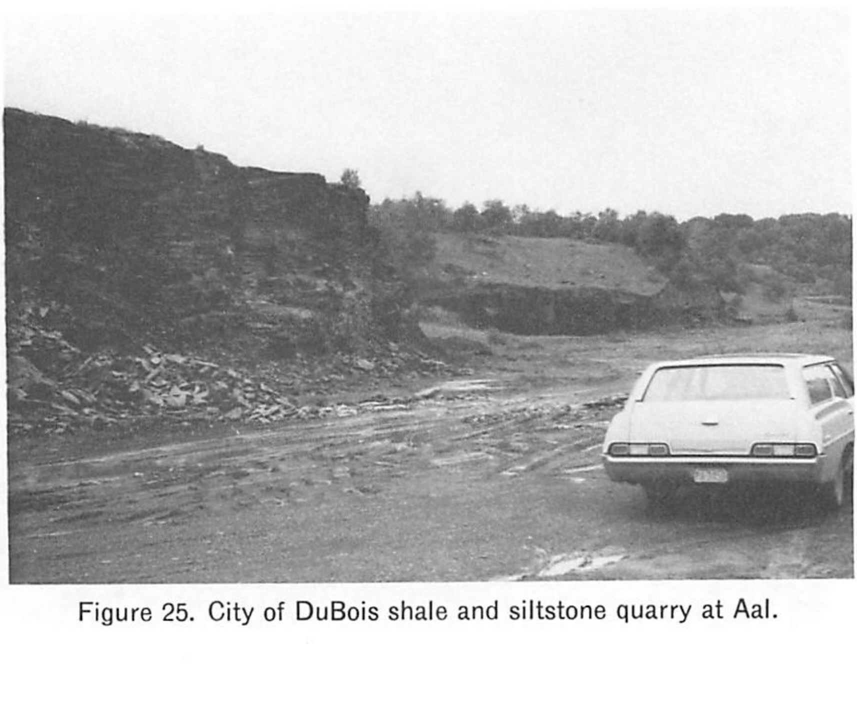

Figure 25. City of DuBois shale and siltstone quarry at Aal.

and pebbles of sandstone are common, as are smaller fragments of siltstone and shale. Abandoned meanders in these deposits often contain significant amounts of poorly compacted organic matter.

At present, no sand and gravel operations are active in the alluvial deposits of this report area.

Partially disaggregated sand may also be obtained on a smaller scale from the deeply weathered tops of sandstone bodies, especially in the central part of the Elliott Park quadrangle. Where there is low structural relief along Chestnut Ridge anticline and surface drainage is poor, the sandstones have often become quite friable, yielding an easily removed layer of sand 6 to 10 feet thick.

## SOILS

The last published information covering soils of this area is that of Winston and others (1919) for the U. S. Department of Agriculture soil survey of Clearfield County. According to that survey, the great majority of soils in the southern Penfield area fall into the Dekalb series[1] soils. This series includes zonal podzols (Soil Survey Division, 1938, p. 1022) and gray brown podzolic soils and azonal lithosols (Baldwin and others, 1938, p. 995). Small, local areas that tend to be wet and poorly drained are included in the Lickdale series; like the Dekalb, these soils are probably podzolic. Second in order of areal abundance is a miscellaneous type called "rough, stony land"—azonal lithosols distributed on the steep valley slopes. The Dekalb and Lickdale series and "rough, stony land" are all residual upland soils. The stream bottom soils are included in the Pope series which are azonal, alluvial soils (Soil Survey Division, 1938, p. 1134).

With regard to texture, the Dekalb series in southern Penfield includes stony loam, stony silt loam, gravelly loam, gravelly sandy loam, gravelly silt loam, silt loam, and shale loam. The Lickdale series includes only silt clay loam. The Pope series includes loam and silt loam. The range of textures for these three soil series are shown in Figure 26. Since Winston and others (1919, p. 30) do not classify the soil texture of "rough, stony land," it is not represented in Figure 26.

In general, the soils of the southern Penfield area are probably not more than one to three feet thick and usually have poorly developed profiles or none at all (azonal). In most cases, the soil (especially in the Elliott Park quadrangle) will strongly reflect bedrock characteristics.

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[1] A soil "series" is based on taxonomic and genetic criteria and bears geographic implications. For a more detailed discussion of soil series and soil classification, see Soil Survey Staff, U.S.D.A. (1960).

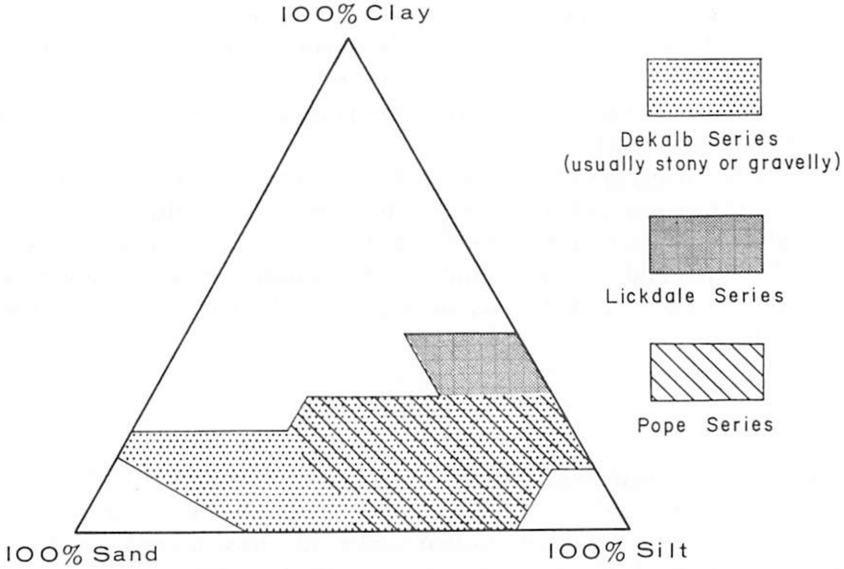


Figure 26. Diagram of soil types of the southern Penfield quadrangle.

## WATER

### SURFACE WATER

The report area lies astride the eastern continental divide (Plate 1), and is, therefore, separable into two major watersheds. The western quarter of the area drains into the Allegheny-Ohio-Mississippi system, and the remainder into the Susquehanna system. Laurel Branch Run, East Branch Mahoning Creek, Limestone Run and Sandy Lick Creek and its tributaries are part of the Allegheny system. All other streams are included in the Susquehanna system.

Surface streams of the southern Penfield quadrangle provide the principal public water supply for the City of DuBois and Clearfield and Curwensville Boroughs. Water for DuBois is pumped from DuBois Reservior on Anderson Creek (capacity 615,000,000 gallons). Much of Clearfield's water comes from Clearfield Reservoir on Montgomery Creek (capacity 210,000,000 gallons). The remainder is normally taken from a smaller reservoir on Moose Creek a short distance east of the report area. The Moose Creek Reservoir (capacity 20,000,000 gallons) has been temporarily closed (1965 to present) because of the heavy influx of clay and silt induced by construction of nearby Interstate Route 80. Curwensville draws its water from Bear Run and Irvin Branch where the water is picked up in catchment basins and piped to two concrete reservoirs in Curwensville (combined capacity

1,026,000 gallons) and from a small reservoir on the west branch of Hartshorn Run (capacity about 6,000,000 gallons).

Water quality from Anderson Creek (including tributaries) above DuBois Reservoir dam, from Panther Run, Irvin Branch, Bear Run, Hartshorn Run (except east branch), and all branches of Montgomery Creek is apparently satisfactory. Little or no mining has been carried out in their watersheds, population is sparse, and the road-net relatively thin. As mentioned earlier, the quality of Moose Creek has been seriously impaired by the influx of silt and clay from the construction of Interstate Route 80, although this situation should improve as conditions stabilize.

The quality of the remaining streams, including all Allegheny drainage, Anderson Creek and its western tributaries below DuBois Reservoir, and Bells Run has been seriously reduced by acid and other waste products from mining. Table 11 shows analyses of the water in Anderson Creek taken a short distance above its junction with the Susquehanna River (McCarren, 1964).

The low-flow frequency (i.e. the frequency at which a particular minimum average discharge rate will occur over seven consecutive days or more) is given in Busch and Shaw (1966) for Anderson Creek near its mouth as:

A 7.7 cfs average discharge for 7 days or more will occur on average once every 2 years.

A 3.8 cfs average discharge for 7 days or more will occur on average once every 10 years.

## Ground Water

Most ground water in this area is encountered in sandstones and in shales directly overlying coal seams and their associated underclays. The sandstones provide large, permeable aquifers. The coal and underclay beds act as a relatively impermeable barrier to the downward percolation of ground water, which then tends to collect in a zone overlying the coal and underclay. Because of their higher permeability, sandstones will usually produce greater amounts of water than shales.

In addition to the natural capacity of a rock to hold water (porosity) and its ability to allow water to flow through (permeability), two other natural factors affect the amount of water available. The first of these is geologic structure. Water tends to flow through the rocks in a down-dip direction, so that, in effect, water will drain away from the anticlines and into the synclines. In this way, a particular rock-unit will produce more water and will be less affected by periods of drought in the synclines than on the anticlines. The second factor is the size of the recharge area. The source of ground water is rain which, after falling on the surface, sinks into the ground. Thus a rock unit which underlies only a small hilltop will

## Table 11. *Analyses of Water in Anderson Creek*

| Date of collection | Mean discharge (cfs) | Temperature (°F) | Silica ($SiO_2$) | Aluminum (Al) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Total acidity as $H_2SO_4$ | Specific conductance (micromhos at 25°C) | pH | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 11, 1945* | ... | 70 | 4.6 | 2.1 | 0.24 | .80 | 88 | 3.1 | .. | .. | 0 | 53 | 1.0 | . | 0.6 | 84 | 56 | 56 | 25 | 170 | 3.85 | 4 |
| Oct. 7, 1957 | 8.0 | 56 | .. | ... | .38 | .88 | .. | .. | .. | .. | 0 | 81 | 3.0 | .. | .2 | .. | 38 | 38 | 39 | 245 | 3.60 | 2 |
| Apr. 26, 1960 | ... | .. | ... | ... | ... | ... | .. | .. | .. | .. | .. | 57 | ... | .. | ... | .. | .. | .. | 20 | 177 | 3.90 | 1 |

[On dates marked by an asterisk (*) calcium and magnesium were not determined separately] receive only a small amount of water, whereas a rock unit underlying a wide area will receive a much greater amount. Other matters such as degree of fracturing of the rock, lateral composition variability, and the nature of the overlying and underlying units also produce an effect on water potential.

Each of the major sandstones and the zones overlying each of the major coal and underclay beds (see geologic column on Plate 1) are potential sources of ground water.

The largest, most widespread, most persistent potential aquifer is the Burgoon Sandstone (including the upper Connoquenessing sandstone, where present). For any given area, the amount of water from the Burgoon should be the largest available from any unit, and, in addition, the quality of water from the Burgoon is likely to be superior to that obtained from aquifers higher in the section, except possibly in the deeper part of the Punxsutawney-Caledonia syncline where its water may be saline. The Burgoon has not been effected by mining operations and has no coals or high sulfur shales to cause high acidity, high iron content, or undue hardness. The Burgoon also has the added advantage that it underlies the entire report area.

Other potentially good sandstone aquifers include the lower Mahoning, Kittanning, and Homewood sandstones and an unnamed sandstone lying between the Homewood and the Mercer hard clays (see column on Plate 1). Of more restricted importance are the upper Mahoning, upper Worthington, and lower Worthington sandstones. Most of the above sandstones are of the "shoestring" type, that is they are long, narrow bodies of sand. Although extending for many miles in their long direction, they are usually less than one-half mile wide and up to 50 feet thick. Away from their area of development, they may be missing entirely.

The lower Mahoning sandstone, although basically similar to the rest, is extraordinarily well developed. Its channel width may exceed four miles and it is close to 100 feet thick. The approximate extent of the lower Mahoning is shown in figure 11.

A water-bearing zone frequently occurs in the shales directly overlying coal and clay beds which provide an impermeable floor. The flow and recovery rates may be low because of the small permeability of the shale, and the acid and high-iron content may be objectionable. Each of the major coals of the area may provide an aquifer such as described above, but the lower Kittanning and, to a lesser degree, Clarion no. 1 and middle Kittanning coals have been observed to produce considerable ground water.

Table 12 gives a summary of data from 21 wells located in and near the report area. The location of these wells is shown on Figure 27.

In addition to information from regular water wells, a large amount of water was encountered during excavation of the shafts for the DuBois no. 1 mine (Ad6). This shaft was started a short distance above the Pine Creek limestone (Conemaugh Group) and was sunk to the lower Freeport coal

Table 12. *Water Wells in and near the Southern Penfield Area (table modified and expanded from Lohman, 1938).*

| Location No. Figure 27 | Location No. in Lohman (1938) | Location | Owner or name | Topographic situation | Altitude (feet)[a] | Type of supply[b] | Depth (feet) | Diameter (inches) | Principal Water-Berring Beds: Depth to top of bed (feet)[c] | Thickness (feet) | Character of material[d] | Geologic horizon | Length of casing (feet) | Depth to water level (feet) | Method of lift[e] | Yields (gallons a minute) | Use of water[f] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CITY OF DUBOIS | | | | | | | | | | | | | | | | |
| 1 | 7 | DuBois | Associated Gas & Electric Co. | Valley | 1,400 | Dr | 165 | 8 | (?) | (?) | Sandstone | Low. Mahoning Ss and/or Laurel Run and Mineral Springs Fms. | 60 | 10± | N | 200± | N | Wells 1 and 2 were used from 1915 to about 1918 but are now filled up. Water reported hard, saline, and acid. Wells were pumped by air lift. Cased through 60 feet of gravel and mud. |
| 2 | 8 | do. | do. | do. | 1,400 | Dr | 204 | 10 | (?) | (?) | do. | do. | 60 | 6± | N | 400± | N | |
| | | SANDY TWP. | | | | | | | | | | | | | | | | |
| 3 | 12 | Sandy | DuBois Coca-Cola Bottling Works | do. | 1,410 | Dr | 112 | 10 | (?) | (?) | Sandstone | do. | 80 | 1± | P | 50± | C, I | Reported to flow occasionally. Leaves white centers in ice cakes. See analysis. |
| 4 | 16 | 1.9 miles east of West Liberty | Clyde Askey | Slope | 1,520± | Dr | 120 | 6 | 100 | 20 | Gray shale | Shales above Mahoning coal | 35 | 70± | H | 18± | D | |
| 5 | 18 | Shaffer | George Coughlin | do. | 1,410 | Dr | 100 | 6 | (?) | (?) | Sandstone? | Lower Mahoning Ss (?) | 15 | 40± | H | 18± | D | Reported small draw-down. |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UNION TWP. | | | | | | | | | | | | | | | | |
| 6 | 23 | 0.9 mile southeast of Narrows Creek | John Du Bois Estate | Slope | 1,470± | Dr | 580 | 6 | 180 | (?) | (?) | Laurel Run or Mineral Springs Fm | (?) | +11± | F | (?) | N | Test for coal. Reported large flow. |
| 7 | 24 | 1.3 miles southeast of Narrows Creek | Cal Hoover (former owner) | Canyon | 1,480± | Dr | 80 | 6 | 30 | 50 | Gray shale | Glen Richey and/or Laurel Run Fm. | (?) | +0.1± | F | (?) | N | Driller's location not checked. |
| 8 | 25 | 1.2 miles north of Home Camp | Fred Weber | Hillside | 1,790 | Dr | 78 | 10 | NB | (?) | Shale | Glen Richey Fm. | 22 | 37 | N | 1-3 | D | Pump to be installed. |
| 9 | 26 | Rockton | Wilber Kirk | do. | 1,740 | Dr | 85 | 8 | 20 | 65 | Sandstone | Up. Connoquiness-ing and/or Bur-goon Ss. | 20 | 20± | P | 5 | D | |
| | | PINE TOWNSHIP | | | | | | | | | | | | | | | | |
| 10 | 27 | 0.3 mile southwest of Smith Fire Tower | Clark Camp | Upland | 2,150 | Dr | 90 | 6 | NB | (?) | do. | Burgoon Ss | 15 | 15± | H | 5± | D | Driller's location not checked. |
| 11 | — | 1.2 miles NNW of Elliott Park Fire tower | Pa. Dept. of Forests and Waters | Slope | 2,065 | Dr | 165 | 6 | 100 and 150 | (?) (?) | Sandstone | Burgoon Ss | 20 | 85 | P | 27 | (?) | No drawdown after 3 hr. pumping. |
| 12 | 47 | Northwest corner of township | U.S. Dept. of Commerce (air-plane landing) | Ridge | 2,200 | Dr | 91 | 6 | (?) | (?) | do. | Burgoon Ss | 20 | 10± | H | 5± | D | Water reported good. |
| 13 | 48 | do. | Greenwood Camp | do. | 2,200 | Dr | 50 | 6 | (?) | (?) | do. | Burgoon Ss | (?) | 10± | P | 5± | D | |
| 14 | 49 | 2 miles northeast of Grampian | Mr. Heer | Hillside | 1,700 | Dr | 86 | 6 | (?) | (?) | Gray ss | Kittanning | 20 | 18± | H | 5± | D | Clay reported beneath the sandstone. |
| 15 | 50 | do. | George Solly | do. | 1,730 | Dr | 44 | 6 | 12 | 32 | Sandstone | Kittanning Ss | (?) | (?) | H | (?) | D | Well drilled into aban-doned Clarion clay drift. Water accumu-lates in reservoir con-structed beneath well. Several similar wells in same drift are 29 and 38 feet deep. |

## Table 12. *Continued*

| Location No. Figure 27 | Location No. in Lohman (1938) | Location | Owner or name | Topographic situation | Altitude (feet)[a] | Type of supply[b] | Depth (feet) | Diameter (inches) | Principal Water-Bearing Beds: Depth to top of bed (feet)[c] | Thickness (feet) | Character of material[d] | Geologic horizon | Length of casing (feet) | Depth to water level (feet) | Method of lift[e] | Yields (gallons a minute) | Use of water[f] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BRADY TOWNSHIP | | | | | | | | | | | | | | | | |
| 16 | — | 0.8 miles east to Luthersburg | Luthersburg Water Co. | Slope | 1,860 | Dr | 260 | (?) | 53 and others | (?) | Gray Shale | Millstone Run Fm. | (?) | 80 | — | 10.7 | P | Drawdown: 0.88 ft., pumping for 75 min. at 10.7 gpm. 100% recovery in 19 minutes. 5 gr. hardness, pH 6.3. Conductance 260. |
| 17 | 57 | 0.3 mile north of Salem | Walter Baker | Hillside | 1,630 | Dr | 75 | 6 | NB | (?) | Shale | Glen Richey Fm. | 7.5 | 30± | H | 10± | D | Nearby dug wells reach a perched water table. |
| 18 | 58 | 0.7 mile northwest of Luthersburg | A. L. Frantz | Ridge | 1,740 | Dr | 120 | 7 | NB | (?) | do. | Millstone Run Fm. | 10 | 95± | H | 10± | D | Prob. producing above L. K. clay. |
| 19 | 59 | 0.3 mile northwest of Luthersburg | Mr. Marshall | do. | 1,760 | Dr | 70 | 6 | NB | (?) | do. | Millstone Run or Mineral Springs Fm. | 20 | 32± | H | 10± | D | Prob. producing above M. K. clay. |
| 20 | 60 | 0.7 miles west of Luthersburg | (?) | do. | 1,790 | Dr | 189 | 8 | 170 | (?) | Black shale | Clearfield Ck. or Curwensville Fm. | 48 | 149± | P | 16± | D, S | Prob. producing above Clarion no. 1 clay. |
| 21 | 63 | 2.6 miles southeast of Luthersburg | Ralph Wingart | Slope | 1,920 | Dr | 110 | 8 | NB | (?) | Shale | do. | 32 | 26± | A | 10± | D | do. |

[a] Altitudes taken from nearest contour on topographic map unless otherwise indicated.
[b] Dr, drilled well.
[c] NB, near bottom.
[d] Sh, shale; ss, sandstone.
[e] A, air lift; F, natural flow; H, lift pump, hand-operated; N, none; P, force pump, power-operated.
[f] C, condensing or cooling; D, domestic; I, industrial; N, none; P, public supply.

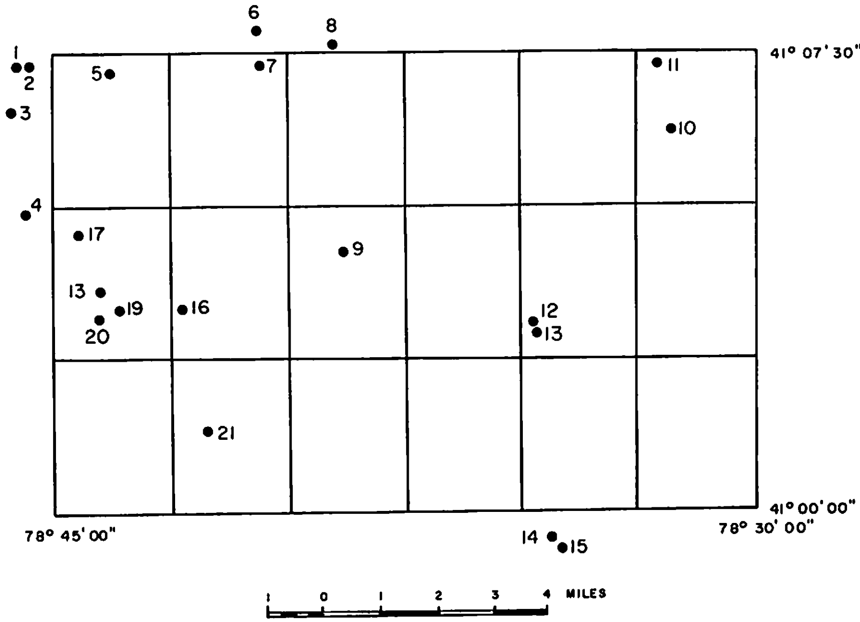


Figure 27. Location of water wells listed in Table 12.

265 feet below. The first water was met at 40 feet, and by a depth of 80 feet, 800 gallons per minute was being pumped from the shaft. More water was encountered at 100 feet. This interval lies in the silt shales and siltstone between the Brush Creek and Pine Creek horizons. At 154 feet an additional 1,000 to 1,500 gallons per minute gushed from a "crevice in the rock," probably in the upper part of the lower Mahoning sandstone or from rocks closely associated with the Mahoning coal and underclay.

## ENGINEERING GEOLOGY

Plate 20 is a generalized summary of the estimated foundation and excavation characteristics of the various geological units outcropping at the surface in the southern Penfield quadrangle. Each unit is grouped into one of five categories, the characteristics of which are described on the plate.

Related matters such as ground water and construction materials are discussed under their own headings.

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# GLOSSARY

This glossary is intended primarily for nontechnical readers, thus the definitions are often somewhat simplified.

*Alluvium*. Soil, sand, gravel or other similar detrital material deposited by running water.

*Anticline*. An upfold or arch of stratified rock in which the beds dip in opposite directions from the crest.

*Aquifer*. A formation or rock unit that is water bearing.

*Azonal Soil*. Soil without well-developed profile or zone characteristics.

*Basement*. A widespread complex of igneous and metamorphic rocks underlying the sedimentary rock sequence.

*Bedding*. The physical separations within sedimentary rocks along planes of stratification dividing rocks of similar or different lithologies.

*Blossom (Coal)*. Decomposed outcrop of a coal bed.

*Bone (Bony Coal)*. A coal high in inorganic material, usually clay and fine silt. Bone covers the range between clean coal and carbonaceous claystone.

*Cannel Shale*. A black shale consisting of silt and clay that was deposited with swamp organic ooze.

*Clastic*. Composed of material mechanically eroded from pre-existing rocks. Refers primarily to clay, silt, sand, gravel, etc.

*Compaction*. The decrease in the volume of sediments resulting from compression. It is usually caused by the weight of overlying sediments.

*Contour, Structural*. An imaginary line connecting points of equal elevation on a selected stratigraphic unit.

*Contour, Topographic*. An imaginary line connecting points of equal elevation on the surface of the earth.

*Cross-bedding*. The arrangement within a rock unit of strata or bedding at an angle to the main planes of stratification or the main bedding surface of that rock unit.

*Décollement*. The independent folding and faulting of sedimentary beds resulting from the sliding of those rocks along a detached zone above underlying rocks. Also the detachment surface upon which sliding takes place.

*Dendritic Drainage*. A drainage system which is characterized by an irregular branching pattern.

*Detrital*. Composed of material mechanically eroded from pre-existing rocks. Refers primarily to clay, silt, sand, gravel, etc.

*Devonian*. A geologic time unit—the interval between about 405 and 345 million years ago.

*Diaspore*. A clay mineral with the general formula $AlO(OH)$. Its composition is approximately 85% $Al_2O_3$ and 15% $H_2O$.

*Diastem.* A minor depositional break or hiatus within sedimentary rocks.

*Dip.* The angle at which a stratum of rock is inclined to horizontal.

*Disconformity.* A major depositional and erosional break within a sequence of sedimentary rocks, the rocks on either side of which are bedded essentially parallel.

*Facies.* The sum of all the characteristics of a rock unit; including composition, color, bedding, fossil suite, and any other characteristic which can be measured or described. When one or more aspects of a rock unit change vertically or laterally (such as grading from shale to sandstone), this variation is spoken of as *facies change.*

*Fault.* A fracture or fracture zone within the rocks along which there has been some movement of the two sides relative to one another. This should be distinguished from a coal miner's fault, which is a term used to describe any disruption of a coal seam.

*Flint Clay.* See Hard Clay.

*Flora (Fossil).* An assemblage of fossilized plants.

*Fold.* A bend or flexure produced in rock strata by forces operating after deposition of the rock.

*Fold Height.* Maximum difference in elevation of a specific datum between axes of an anticline and flanking syncline. (See *Structural Relief*).

*Footwall.* The rock mass beneath a fault plane.

*Formation.* A body of relatively homogeneous rock or interval bounded by key beds (q.v.), usually tabular, and mappable at the surface of the earth.

*Friable.* Poorly cemented and easily crumbled.

*Fusain.* An ingredient of coal that has a fibrous structure like charcoal.

*Group.* A rock-stratigraphic unit next higher in rank than a formation (q.v.).

*Hanging Wall.* The rock mass above a fault plane.

*Hard Clay.* A hard, brittle variety of clay found beneath some coal seams with a sharp concoidal fracture. It has a strong superficial resemblance to limestone. Pure hard clay is composed mostly or entirely of very finely crystalline kaolinite (q.v.), but may contain various impurities such as iron oxide, silica, diaspore, boehmite, etc. Hard clay also grades into the more usual soft clay (q.v.).

*Igneous Rocks.* Rocks formed by solidification from a molten or partially molten state.

*Illite.* A general term covering all mica-like clay minerals which are hydrous potassium-aluminum silicates with various amounts of other cations such as iron, manganese, etc.

*Interfluve.* The area between adjacent streams flowing in the same general direction.

*Joint.* A fracture in a rock, usually more or less vertical, along which no movement has taken place.

*Kaolinite.* A clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$.

*Key Bed.* A bed that is distinctive enough to make it easily identifiable over a wide area. Key beds such as coals are often used as boundaries for a formation (q.v.).

*Lithology.* The physical characteristics of a rock usually as determined by examination with the naked eye or with the aid of a low power magnifier.

*Lithosol.* A soil having no clear soil morphology or profile and consisting of freshly or only partly weathered rock fragments. This soil usually occurs on steep hillsides.

*Master Joint.* A large and persistent joint passing through all rock masses in an area and of a magnitude considerably greater than normal surface joints. A master joint may be the extension of fracture beyond displacement of a major fault (q.v.).

*Member.* A part of a formation (q.v.), but not defined by specific shape or extent. A member may extend beyond the main body of a formation.

*Mississippian.* A geologic time unit—the interval between about 345 and 310 million years ago.

*Muscovite.* A mica mineral occurring as thin transparent sheets or flakes with the composition $KAl_3Si_3O_{10}(OH)_2$.

*Paleobotany.* The study of fossil plants.

*Paraconformity.* An unconformity (q.v.) above and below which the strata are parallel and the contact a simple bedding plane.

*Paleotopography.* The relief and contour of the land at a specific time in the geologic past, usually defined by a fossil erosion surface or unconformity (q.v.).

*Peat.* An accumulation of partially decomposed and disintegrated plant material.

*Pennsylvanian.* A geologic time unit—the interval between about 310 and 280 million years ago.

*Periglacial.* Referring to the region adjacent to the margin of a glacier or ice sheet.

*Permeability.* Ability of a rock to transmit fluids.

*Physiography.* The study of the surface features of the earth; their form, nature, origin, and development, and the changes they are undergoing.

*Podzol.* A zonal soil (q.v.) group characterized by an ash-gray color in the upper part of the soil profile. It is bleached soil, usually low in iron and lime, formed in moist, cool climate.

*Point Bar.* An arcuate sand and gravel deposit that accumulates on the inside of a river meander bend.

*Porosity.* The volume percentage of pore space or interstices in a rock with reference to its total volume.

*Progradation.* A seaward advance of the shoreline resulting from nearshore deposition of sediments brought to the sea by rivers. *Prograded Sequence* and *Prograded Rocks*—The rocks resulting from the sediments deposited in a prograding situation, usually becoming coarser-grained upward.

*Regression*. The gradual contraction of a shallow sea resulting in the emergence of land when sea-level falls or the land rises or when progradation (q.v.) occurs.

*Relief* (*Structural*). The difference in elevation between high and low points of a selected stratigraphic datum horizon, reflecting the amount of folding and/or faulting.

*Relief* (*Topographic*). Amount of variation in elevation of the surface of the earth.

*Reverse Fault*. A fault which has the hanging wall (q.v.) moved upwards relative to the footwall (q.v.).

*Rider Coal*. A thin seam of coal separated from, and overlying a thicker one.

*Rootlets*. Thin, flat, fossil roots (usually 1/8 to 1/4 inch wide), commonly found laced throughout clays beneath coal seams. Occasionally some rootlets are found attached to larger, identifiable roots of coal swamp plants.

*Sediment*. Solid material, both mineral and organic, which is being or has at one time been transported from the site of its origin by air, water, or ice.

*Sedimentary Rocks*. Rock formed from an accumulation of sediments, which may be composed of mineral and rock fragments, plant or animal remains, chemical action products, or evaporation products.

*Sedimentation*. The study of all matters affecting sediments from the initial formation of sediments from a parent rock, through the transportation of sediment from the site of its formation to the site of its deposition, and the process of deposition and consolidation into rock.

*Siderite*. A mineral composed of iron carbonate ($FeCO_3$). The siderite nodules and bands discussed in this report are a mixture of siderite and clay.

*Soft Clay*. A non-bedded clay occurring below a coal seam. Also called underclay or plastic clay.

*Splay Fault*. A minor fault diverging from a larger one at an acute angle and genetically related to it.

*Spur* (*Structural*). A subordinate fold, branching away in map view, from a major fold.

*Stratigraphy*. The study of stratified sedimentary rocks.

*Stratum* (Plural: *strata*). A single sedimentary bed or layer.

*Stream Capture*. The diversion of the upper part of one stream by the headward growth of another stream. Also called stream piracy.

*Strike*. The compass direction of a horizontal line included in the surface of an inclined stratum or other planar feature. The direction of strike is perpendicular to the direction of dip (q. v.).

*Structural Geology.* The study of the structural or external form of the rocks of the earth as produced by movements within the earth and also the nature and cause of these movements.

*Structural Relief.* See Relief, structural.

*Structural Contour.* See Contour, structural.

*Subsidence.* The sinking of a large part of the earth's crust.

*Syncline.* A downfold or depression of stratified rock which dip inward toward the axis of the fold.

*Tectonic.* Refers to rock structure resulting from deformation of the earth's crust.

*Topographic Contour.* See Contour, topographic.

*Topographic Relief.* See Relief, topographic.

*Transgression.* The gradual expansion of a shallow sea resulting in the submergence of land when sea level rises or the land falls.

*Type Section.* An accurately located section of measured and fully described strata representing the original concept of a certain formation (q.v.).

*Unconformity.* A surface of erosion and/or non-deposition separating younger and older rocks.

*Underclay.* A non-bedded clay occurring below a coal seam. Also called plastic clay or soft clay.

*Watershed.* The area within a drainage divide above a certain point on a stream.

*Wrench Fault.* A fault whose plane is approximately vertical and the movement along which is basically horizontal.

*Zonal Soil.* A soil produced on well-drained, high areas, occupying most of any region. Zonal soils, by the influence of good drainage and long duration of soil-forming processes, are characterized by distinctive horizons or zones.

# APPENDIX 1

## MEASURED SECTIONS OF THE POCONO FORMATION

### BURGOON SANDSTONE MEMBER (UPPER 130- TO 300-FOOT SANDSTONE SECTION)

Station Ff15 (top of section is about 80 feet below top of Burgoon Member) (Figure 28):

| | Thickness |
|---|---|
| 9. *Sandstone*, medium-grained, very light gray, very siliceous, 6-inch to 1-foot beds. | 15 feet |
| 8. *Dark shale*, black, weathered, thin clay zone at top and bottom. | 5 feet |
| 7. *Sandstone*, mostly medium-grained, but ranges from silt to medium-grained, mostly light gray to very light gray, limonitic stain, mostly 6-inch to 1-foot beds, mostly very siliceous, some ripple marking in siltier beds, some cross-bedding | 45 feet |
| 6. *Coaly shale*, black, blocky coal-like fracture | ½ foot |
| 5. *Underclay*, silty, dark yellowish brown, rootlets. | 2 feet |
| 4. Interbedded *siltstone* and very fine-grained *sandstone*, medium dark gray to dark gray, micaceous, common plant fragments, upper 4 feet is root-worked, lower 1 foot is silt shale, moderate olive brown. | 20 feet |
| 3. *Sandstone* lenses, medium- to fine-grained, highly siliceous, light olive gray to various shades of red gray. | 0 to ½ feet |
| 2. *Silt shale* (2C), medium gray to dark gray, up to 15 feet thick, grades laterally into *dark silt shale* (2A), grayish black to black, probable *Adiantites* sp. and other plant fragments, up to 26 feet thick. Included within the dark silt shade is a lensoidal *sandstone* (2B), fine-grained to medium-grained, banded light gray and medium dark gray, abundant plant material up to branch size, lenses are 0 to 1 foot thick. | 26 feet |
| 1. *Sandstone*, coarse to very coarse-grained, very light gray. | 3 feet |
| | 117 feet |

Station Ff2 (top about 100 feet below top of Burgoon Member):

| | |
|---|---|
| *Sandstone*, medium- to coarse-grained, very light gray, cross-bedded, beds 2 inches to 6 feet, one 6-foot bed, 30 feet above base is a *conglomerate* with pebbles to ¼ inch and a dark red matrix. | 40 feet |

Station Ce8 (top about 160 feet below top of Burgoon Member): Following is a series of descriptions taken at 4-foot intervals from top to bottom:

*Sandstone*, medium-grained, very light gray.
*Siltstone*, clayey, light gray, lumpy bedding.
*Sandstone*, fine-grained to very fine-grained, very light gray, micaceous.
*Sandstone*, fine-grained to medium-grained, light gray, clayey, micaceous, ¼-inch to ½-inch beds.
*Sandstone*, fine-grained, light gray, spheroidal weathering.
*Sandstone*, medium-grained to coarse-grained, very light gray, spheroidal weathering.

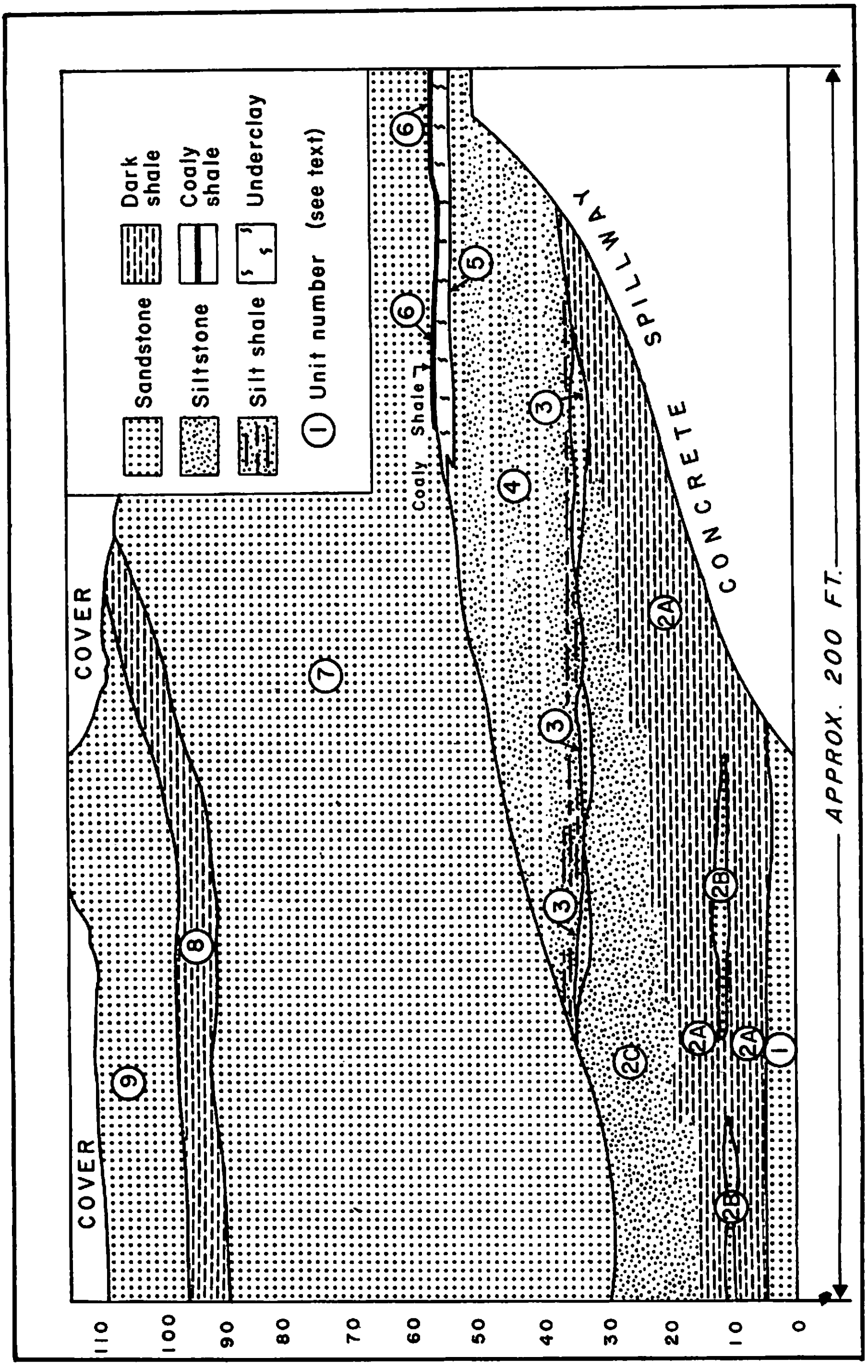


Figure 28. Exposure of the Burgoon Member of the Pocono Formation at Clearfield Reservoir (Appendix 1).

| | |
|---|---|
| *Conglomeratic sandstone*, medium-grained to ½-inch pebbles, very light gray, graded bedding, clay-chip conglomerate. | |
| *Sandstone*, fine-grained to medium-grained, very light gray, hematite concretions, beds to 2 feet. | 35 feet |

Station Ce7 presents a generally similar section to Ce8.

Station Ce14 (top about 75 feet below top of Burgoon Member):

| | |
|---|---|
| *Sandstone*, fine-grained, very light gray, 1-inch to 5-foot beds, multidirectional cross-bedding, large-scale cross-stratification (point bar deposits). | 25 feet |

Station Ce15 (top about 110 feet below top of Burgoon Member):

| | |
|---|---|
| *Sandstone*, fine-grained, very light gray, 6-inch to 2-foot beds | 20 feet |

Station Ce16 (top about 175 feet below top of Burgoon Member; almost at base of Burgoon):

| | |
|---|---|
| *Sandstone*, fine-grained, white, beds 2-inches to 4 feet, most beds 1 to 2 feet, spheroidal weathering, cross-bedding (most dip about northwest) | 35 feet |

MIDDLE 200-FOOT RED AND GREEN SILTSTONE AND SHALE SEQUENCE

Station De6 (top about 220 feet below base of Burgoon Sandstone Member).

| | |
|---|---|
| Interbedded *siltstone* and *sandstone*, 1-inch to 3-inch beds, light olive gray | 20 feet |

Station Cf4 (top about 190 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Siltstone*, cross-bedded, 1½-foot beds, ripple marks | 8½ feet |
| Cover (probably mostly red shale) | 11 feet |
| *Sandstone*, very fine-grained, dusky yellow to light olive gray, micaceous, strongly cross-bedded (dip west to northwest), 1-inch to 4-inch beds | 20 feet |
| | 39½ feet |

Station Df1 (top about 200 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Sandstone*, very fine-grained, dusky yellow to light olive gray, micaceous, cross-bedded, upper 10 feet is 1-inch to 4-inch beds, lower 10 feet is 6-inch to 2-foot beds | 20 feet |
| | 20 feet |

Station Ff1 (top about 220 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| Interbedded *siltstone* and very fine-grained *sandstone*, sandier upward, light olive gray, beds from 1/16-inch to 1-foot (most less than 2 inches), small-scale cross-bedding, small plant fragments | 35 feet |

Station Ce11 (top about 10 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Bedded clay*, very tough, medium gray | 1 foot |
| *Sandstone*, fine-grained, weathered and stained | ¼ foot |
| *Claystone*, hackly (mudstone), red to blackish red | ¼ foot |
| *Sandstone*, fine-grained, hard, weathered | ½ foot |
| Irregularly mixed mass of limonitic clay nodules and sandstone fragments | 2 feet |
| *Siltstone*, light olive gray | 2 feet |
| *Shale*, gray red with some light olive gray bands | 5½ feet |
| | 11½ feet |

Station Ce10 (top about 15 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Siltstone* to *silt shale*, light gray | 1½ feet |
| *Claystone*, hackly (mudstone), dusky red, mica (probably equals lowest unit of Sta. Ce11) | 6 feet |
| *Siltstone*, clayey, light olive gray | 11 feet |
| *Claystone*, hackly (mudstone), grayish brown, soft | 1 foot |
| *Siltstone*, light olive gray, micaceous | ½ foot |
| *Silt shale*, medium gray to pale olive gray, limonitic | ½ foot |
| *Siltstone*, clayey, light olive gray, micaceous | 5 feet |
| | 24 feet |

Station Ce9 (top about 20 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Claystone*, hackly (mudstone), mottled dusky red and dusky yellow-green | 1½ feet |
| *Siltstone*, clayey, light olive gray, 1-inch to 4-inch beds, micaceous | 8 feet |
| *Claystone*, hackly (mudstone), grayish red, top 1 foot bleached by ground water to very light green gray | 5 feet |
| *Claystone*, hackly (mudstone), silty, light olive gray | 4 feet |
| *Claystone*, hackly (mudstone), light olive gray, mottled with red, very soft | 1½ feet |
| *Claystone*, hackly (mudstone), gray red mottled with light olive gray | 1 foot |
| | 21 feet |

Station Ce17 (top about 30 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Claystone*, hackly (mudstone), grayish red, some light olive gray sandstone stringers | 5 feet |
| *Siltstone*, light olive gray, 1-inch to 4-inch beds | 1½ feet |
| Cover (probably mostly claystone, hackly, grayish red) | 8 feet |
| *Silt shale*, light olive gray, lumpy, poor bedding, possibly root-worked | 1 foot |
| *Siltstone*, light olive gray | 2 feet |
| Interbedded *siltstone*, *silt shale*, and very fine-grained *sandstone*, olive gray to light olive gray (siltstone and silt shale), moderate yellow brown (sandstone), current ripple marks | 6½ feet |
| *Sandstone*, fine- to very fine-grained, dusky yellow to light olive gray, plant impressions, cross-bedded (about N 30° W), 3-inch to 1½-foot beds | 4 feet |
| | 28 feet |

Station Ce19 (top about 160 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Sandstone*, very fine-grained, light olive gray, very micaceous, plant fragments, cross-bedding | 7 feet |
| *Claystone*, hackly (mudstone), light olive brown, siliceous, very hard | 4½ feet |
| *Claystone*, hackly (mudstone), grayish red | 2¼ feet |
| *Siltstone*, olive gray to light olive gray, micaceous, slightly siliceous | 2 feet |
| | 15¾ feet |

Station Df2 (top about 180 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Sandstone*, very fine-grained, dusky yellow, micaceous, clay pebbles and plant fragments at base, dark (lower 2 feet, red) clay matrix | 6 feet |
| *Silt shale*, dusky brown to very dusky red, few beds greenish gray | 5 feet |
| | 11 feet |

Station Curwensville Ea1 (top about 80 feet below base of Burgoon Sandstone Member). Section from Anderson Creek to 15 feet above railroad track:

| | |
|---|---|
| *Claystone*, hackly (mudstone), grayish red | 5 feet |
| *Silt shale*, dusky brown to blackish red with thin light olive brown beds | 16 feet |
| *Claystone*, hackly (mudstone), grayish red with some greenish gray stringers | 33 feet |
| | 54 feet |

Station Df1 (top about 100 feet below base of Burgoon Sandstone Member):

| | |
|---|---|
| *Siltstone*, light gray, weathered | 2 feet |
| *Siltstone*, olive gray | 1 foot |
| *Siltstone*, hackly (mudstone), gray red | 5 feet |
| | 8 feet |

In addition, minor outcrops of the middle unit of the Pocono Formation occur at Ce18, Df3, Df22, Ef4, Fe1, Fe2, and Fd2.

# APPENDIX 2

## PALEOBOTANY OF THE POCONO AND POTTSVILLE ON INTERSTATE 80, PINE TOWNSHIP, CLEARFIELD COUNTY

by

William C. Darrah

The following report summarizes observations on a series of small collections of fossil plants from beds exposed during the construction of Interstate Route 80 in Clearfield County. A preliminary examination indicated that both Mississippian-Pocono and younger Pennsylvanian plants were present.

Although the Carboniferous floras of the United States have not been monographically studied or revised during the past fifty years, their zonation has been carefully determined (Darrah, 1937 and Read and Mamay, 1964). Any fairly well preserved representative collection that is accurately identified can be assigned to an acceptable stratigraphic position. The Mississippian floras are less known both as to plant content and occurrence but their chronologic sequence is well established. Two factors seem to be responsible. (1) For some unknown reason plant-bearing Mississippian sediments at any one horizon contain usually a very small number of species, commonly two or three occasionally only one. The bed may be followed horizontally for some distance with little variation in plant content. This is in marked contrast with most Pennsylvanian florules that generally include a modest variety. (2) The absence of commercial coals in the Mississippian rocks in Pennsylvania has discouraged search for fossil plants. The only work of significance on Mississippian plants in the United States was done many years ago by David White. More recently Jongmans (1937), Jongmans, Gothan and Darrah (1937), Darrah (1949) and Read (1955) have published short contributions that suggest a close similarity between the Lower Carboniferous floras of eastern North America and western Europe.

One problem does complicate the study of Paleozoic fossil plants in the United States. Most species have been poorly described, especially those of Dawson and Lesquereux during the nineteeenth century. The illustrations accompanying their publications leave much to be desired. As a result, some paleobotanists have deliberately ignored earlier work and redescribed as new many species already known but poorly defined. Meanwhile, European paleobotanists, making field collections in the United States have recognized the presence of forms widely-known in Europe but having different designations in the United States.

During the period 1865 to 1875, Lesquereux (1879), Dawson (1873) and Meek (1875) described most of the abundant forms known from the Mississippian rocks of North America. Because they worked independently, the same plant may be known by two or more names. International standard taxonomic procedures were not yet established and specific references seem almost capricious.

The confusion of names was heightened by the publication of two papers by Jongmans (1937), based upon very meager and superficial field collections in Pennsylvania, West Virginia and Virginia. Jongmans dismissed as worthless the descriptions published by Dawson and Lesquereux, using the simple argument that, being inadequately figured, the species were invalid. Darrah (in Jongmans, 1937) pointed out that all of the supposedly new species were already known to American geologists.

Read (1955) chose to avoid the use of conflicting names and the necessity for taxonomic revision, by describing additional supposedly new species without recourse to the classic literature, but by this action he actually aggravated the situation.

To minimize further confusion of species designations, I shall use, whenever possible, the original names of Lesquereux and Dawson, because they represent the starting points for American paleobotany and future revision must begin with their work. When these are not applicable, the designations proposed by Read will be followed because they are accompanied by excellent illustrations.

The following list of collections has the sample numbers given by William E. Edmunds of the Pennsylvania Geological Survey. The station locations on Plate 1 are given in parentheses following the sample number. The recognizable fossil plants found at each site are indicated. Identifications have been confirmed by comparison with the type specimens of Meek, Lesquereux, David White and Read in the United States Museum. The summary follows a chronologic stratigraphic sequence, lowest or oldest first. In several instances the plant assemblages of two stations are the same and which precedes is not determinable by the plants alone.

Lowermost members of the section with plant fossils are represented by 1019, 504, and 505. 504 is probably lowest.

504 (Fd6) Gray green mudstone. Plant remains sparse but include the following forms:

*Adiantites cyclopteroides* Read
*Adiantites*, stems, rather large fragments but not exhibiting the typical branching.
*Calathiops* sp. A type of pteridosperm fructification.

1019 (Fd5) This light yellowish sandstone contains many ferruginized impressions of small, but well preserved, fragments of *Triphyllopteris latilobata* Read. *Triphyllopteris* show considerable morphological variation especially in the lobation of the pinnules. Probably this is a growth form of *Triphyllopteris virginiana* Meek. As will be discussed in detail later, *Triphyllopteris* is a reliable index of Pocono formations. Present also at this station are several specimens of *Lepidodendropsis scobiniforme* (Meek) Darrah which may be as Lesquereux long ago suggested, a *L. corrugatum* (Dawson).

505 (Clf. Ae3) This gray green mudstone is highly fossiliferous but unfortunately almost entirely limited to stem fragments, some quite large, of *Triphyllopteris*. A few well-preserved pinnules of *T. latilobata* have also been observed.
A single specimen of an undetermined plant is noteworthy. It consists of 8 or 9 small linear leaves, the largest 9 mm in length and 1.5 mm wide, clustered around an axis which, however, is preserved only at the base. Because the attachment of the leaves is not shown in the specimen it is not possible to determine whether the axis was noded or not. If the former condition pertained, the specimen would be a sphenopsid, possible related to *Asterocalamites*. If, on the other hand, the stem was not jointed, it would be a lycopsid related to *Lepidodendropsis*. The evidence suggests that it is more likely an *Asterocalamites* but positive identification cannot be accomplished without additional specimens. Neither *Asterocalamites* nor *Lepidodendropsis* would be unexpected in this horizon.

506 (Clf. Ae3) Plant remains characterized by abundant large spores and small seeds, comprise all of the recognizable fossils. The seed form is referable to *Lagenospermum* sp. as described by Read. It measures 3.4–4 mm by 1.8 — 2.2 mm, quadrate, slightly wider at the base tapering somewhat to apex. Probably not round in transverse section. Several broken specimens show thickness of integument which is approximately 0.3 mm. The megaspores are of a lepidodendrid, in all likelihood, *Lepidodendropsis*. Lesquereux observed similar spores in association with *Lepidodendropsis* in Pottsville Gap a century ago.

507 (Clf. Ae3) Little paleobotanical material of significance occurs in the small collection from this horizon. The dark friable mudstone contains fragments of stems mostly, perhaps exlusively, of *Adiantites*. One specimen, 70 mm. long, shows two fine branch departures, indicating clearly the identity of the plant.

508 (Clf. Ae3) The collection from this horizon consists of a few small sand casts or oolitic bodies about 0.7 mm in diameter. Under the binocular microscope these globular structures seem to be lithological rather than biological in origin. A 5 gram sample was macerated for spores or plant tissue. No recognizable organic material, however, was recovered from the sludge. Presumably, therefore, the structures are of inorganic orgin.

969 (Clf. Ae3) The fissile dark shale collected at this horizon contains large numbers of a single species, *Adiantites spectabilis*. Read, beautifully preserved but rather fragmentary.

Three moderately large stems are present, one measuring 90 mm x 14 mm. The stems are minutely striate, with striations parallel.

The leaflets are repeatedly unequally birfurcated, each lobe terminating in a bluntly rounded tip, resulting in an overall thalloid appearance. The leaflets are finely striated.

*Adiantites spectabilis* Read is an index fossil of the upper Pocono and its occurrence here, in profusion, is significant.

970 (Clf. Ae3) Many fragments of *Adiantites*, mostly of stems, identical with forms found at 969.

509 (Clf. Ae3) A significant plant assemblage occurs in this collection.

*Lepidodendropsis corrugatum* (Dawson) Darrah a fine specimen 156 mm x 18 mm.
*Lepidodendropsis* cf. *vandergrachti* (Jongmans) Darrah possibly a form of *L. corrugatum* Dawson
*Alcicornopteris* sp.
*Adiantites*, stems but no pinnules
*Rhodea* cf, *allegheniensis* Read
*Rhodea* cf. *tionestana* Read
This collection is unquestionably upper Pocono, containing all the diagnostic genera found in this facies.

971 (Clf. Ae3) A small collection from this horizon includes one fine identifiable specimen showing two seeds and a neuropterid pinnule.

*Cordaicarpus* sp.
Pteridosperm seed gen. undetermined.
*Neuropteris*, small terminal pinnule
The age is Pennsylvanian, no neuropterids are known from the Mississippian.

502 (Clf. Ae3) Plant fragments common but very poorly preserved; indeterminate.

503 (Fd3) The small assemblage of fossil plants includes the following identifiable forms:

*Sphenophyllum emarginatum* Schloth.
*Calamites suckowii* Brgt.
*Neuropteris tenuifolia* Brgt.
*Neuropteris* sp.
*Mariopteris* cf. *nervosa* (Brgt).
*Cordaites* sp. leaf fragments

The age is certainly Pennsylvanian and the absence of *Neuropteris ovata*, *Neuropteri scheuchzeri* and *Pecopteris* of the *lamuriania* type strongly indicates that this is uppermost Pottsville (Mercer?), certainly not higher than a Clarion coal. The *Sphenophyllum emarginatum* is more characteristic of the Allegheny while *S. cuneifolium* is characteristic of the upper Pottsville, but overlaps in both formations.

501 (Clf. Ae3) The only form in the small collection from this locality that can be identified accurately is *Stigmaria fucoides*, the rhizophore of several types of arborescent lepidodendrids. The size and scar arrangement are those of the Pennsylvanian lepidodendrids and not of the Pennsylvanian *Lepidodendeopsis*.

*Stigmaria* has little stratigraphic value except to suggest Pennsylvanian.

Several specimens of a small sturdy stem, with maximum width of 15 mm are present. All are fragmentary and decorticated, lacking distinguishing features. Probably they represent fern stems.

Small fragments of carbonaceous fusainoid material are abundantly scattered in the coarse micaceous matrix.

A 10 gram sample was crushed and macerated for spores. Only one type of megaspore was found in small numbers—a large trilete (180-200 microns), flanged and with apical prominence. It is of lepidodendrid affinity.

## DISCUSSION

The determinations given in the preceding enumeration indicate two significant features:

(1) The presence of two diverse plant assemblages, one Mississippian (Pocono) the other Middle Pennsylvanian.

(2) A hiatus representing a considerable interval including uppermost Mississippian and lower Pennsylvanian. The extent of this interval can be determined from the plant records.

Table 13. *Zones Recognized in Mississippian Floras*

| Geologic Unit | Characteristic Plant Genera | | | Sample No. |
|---|---|---|---|---|
| Mauch Chunk | Fryopsis | Sphenopteridium | Rhodea | None |
| Pocono | Lepidodendropsis | Triphyllopteris and Adiantites | Rhodea | 509, 969, 970<br>506<br>505<br>1019, 504 |

It will be noted that the floral subdivisions indicated in the table rely upon genera rather than upon species. This is a fortunate circumstance because of the unsettled status of many of the specific names involved.

The larger part of the lower half or more of the Mississippian has been called the zone of *Lepidodendropsis*.

*Lepidodendropsis* is a genus of small sized lepidodendrids, characterized by (1) small leaf scars open at the lower end and (2) scars very unequally disposed, closely or distantly, depending upon age and portion of the stem system preserved. Although the generic name was not proposed until 1933, species referable to this group were well known to Dawson (as *Lepidodendron corrugatum*), to Lesquereaux (*Stigmaria minuta*), and to Meek (as *Lepidodendron scobiniforme*). All three of these growth forms are today considered as variants of *Lepidodendropis corrugatum* (Dawson) Darrah. The genus is most remarkably restricted to the Mississippian (also as Lower Carboniferous of Western Europe) and is an important diagnostic fossil form.

Next in abundance and breadth of distribution are the fern-like impressions of *Adiantites* and *Triphyllopteris*. Although their botanical relationships are not fully understood, their stratigraphic ranges are well delimited. Both genera have numerous highly variable species which are poorly distinguished from one another. Dawson was inclined to recognize a few polymorphic species, while many other investigators preferred to separate many species. American usage is chaotic and the various described species are in need of monographic revision. As in the case of *Lepidodendropsis*, however, it is again possible to rely on the presence of genera in determining stratigraphic position.

*Rhodea* is a form genus based upon highly dissected, generally delicate fern-like foliage and probably belongs to the same general botanical group as *Adiantites*. The genus embraces nearly a hundred species widely distributed in the Lower Carboniferous sediments of the Northern Hemisphere. It ranges through much of the Upper Mississippian and approaches in form the genus *Sphenopteridium* Darrah (1967).

All of the fossil plants collected below the unconformity are of Mississippian Pocono age. More specially they are referable to the Burgoon or upper Pocono. The presence of *Lepidodendropsis*, *Adiantites*, *Triphyllopteris* and *Rhodea* permits no other interpretation.

Above the unconformity the situation is not so readily determined. In the lowest members of this sequence, the rock matrices are coarse and the contained plant fragments poorly preserved, decorticated and obviously mechanically macerated during transport. The presence (in 503) of *Lepidodendron*, *Stigmaria*, *Calamites*, *Sphenophyllum* and *Neuropteris* clearly affirms Pennsylvanian. The small collection from 971 contains *Cordaicarpus* and *Neuropteris*, both indicative of Pennsylvanian. *Neuropteris* is not known from the Mississippian.

In attempting to determine the relative age within the Pennsylvanian, one is influenced by absence of certain index species as well as by the presence of others. There is no indication of lowest Pottsville equivalents. Such well-known forms as *Neuropteris pocahontas* and *Mariopteris acuta* and species of *Sphenopteris* would normally occur. Instead we find *Neuropteris tenuifolia*, *Mariopteris nervosa*, and *Sphenophyllum emarginatum*. These species span upper Pottsville and lower Allegheny, or, to state this in other terms from lower Mercer through Clarion, or somewhat higher.

Read and Mamay (1964) in their compilation of the zonation of the Pennsylvanian floras consider the major portion of the Kanawha formation as the zone of *Neuropteris tenuifolia* (their Zone 8). *Mariopteris nervosa* is also characteristic of this stage. *Sphenophyllum emarginatum*, while occasionally present, is more common in the succeeding Zone 9, i.e. the zone of *Neuropteris rarinerous* of Allegheny age.

## *CONCLUSIONS*

The section in Clearfield County represented by fossil plants is largely Mississippian of upper Pocono age, equivalent to the Burgoon, and a small span of Middle Pennsylvanian, uppermost Pottsville or Kanawha age. Missing are the Mauch Chunk and nearly the whole extent of the Pottsville.

# APPENDIX 2

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# APPENDIX 3

## CORRELATION OF THE UPPER POCONO FORMATION (BURGOON MEMBER) AND THE POTTSVILLE AND LOWER ALLEHGENY GROUPS BETWEEN THE CLEARFIELD AND DUBOIS COAL BASINS

The Pennsylvanian section in the western half of this report area lies in the DuBois Coal Basin (Punxsutawney-Caledonia Syncline). Much of the recent Mississippian-Pennsylvanian stratigraphic work including Pennsylvanian formational nomenclature was developed in the Clearfield and Houtzdale-Philipsburg coal basins to the east. The DuBois basin is separated from the Clearfield Basin by the southwest plunging arch of Chestnut Ridge anticline. To establish the stratigraphic and nomenclatural equivalency between the DuBois and Clearfield Basins it was necessary to carry a line of correlation around the southwestern nose of Chestnut Ridge through the northwestern part of the Curwensville and Mahaffey 7½-minute quadrangles and into the Luthersburg quadrangle. This was done by use of a series of 72 drill holes provided by North American Refractories Company Harbison-Walker Refractories Company, and the U. S. Corps of Engineers.

The authors' correlations and inferred intervening section, as well as locations are shown on Plate 21.

As almost all the lithologies recorded on the logs were in driller's terminology (which itself was not entirely consistent), the authors were required to take the liberty of translating them into more conventional geologic terms. The driller's terms are, however, included in the legend of Plate 21.

Plate 21 demonstrates that in general, the geologic formations and their defining key beds persist well. The lower Kittanning no. 1 coal (key bed at the base of the Millstone Run Formation) thins to nothing in the central part of the section line, but clearly exists at both extremities. The Clarion no. 1 coal (key bed at the base of the Clearfield Creek Formation and also the Allegheny Group) is cut out periodically by channeling, but is otherwise quite persistent. The middle Kittanning coal (key bed at the base of the Mineral Springs Formation) and the lower Mercer clay (key bed at the base of the Curwensville Formation) hold up well with minor local exceptions.

Beyond the consistency of the basic correlations, the line of sections demonstrates clearly the extreme variation encountered in the Pennsylvanian sequence. Lateral facies changes are pronounced, although some may be the result of inconsistent logging. The striking effects of erosional channeling are obvious. Most, but not all, of the channels are sandstone-filled. The multiple splitting of the Mercer coals is readily apparent. The terms "upper Mercer" and "lower Mercer" are as used in Clearfield County and cannot be equated to similar terms used farther west.

The Mississippian Burgoon Sandstone Member of the Pocono Formation unconformably underlies the Pennsylvanian rocks throughout the area. The intimate relationship of the Mercer hard clay to the Mississippian-Pennsylvanian unconformity and the underlying Burgoon is clearly shown.

In addition to the line of section developed from the drill holes, an excellent, permanent reference section of the entire upper Burgoon-Pottsville-lower Allegheny interval is provided in a series of cuts made in conjunction with the construction of the Curwensville Dam. The section exposed is shown on Plate 22 and in Figures 29 through 36. The following is the lithologic description of the units shown on Plate 22 with corresponding unit numbers:

Allegheny Group

Millstone Run Formation

27B. *Siltstone* to *silt shale*, medium gray, many siderite nodules, bedding, is contorted and upturned, interfingers sharply with 27A; 0 to 8 feet thick.

27A. *Sandstone*, very fine-grained to medium-grained, mostly fine-grained, gray to light pink gray, clay matrix, common mica and dark minerals, common plant material (fragments to trunk-size), clay-pebble conglomerate, beds 4 feet at base to 6 inches upward, beds dip south: 0 to 18 feet thick.

26. *Siltstone*, light gray, lumpy bedding, up to 7 feet thick.

25. *Coal*, bright, one bed, exists as discontinuous bed; 0- to 1-foot thick.

24. *Silt shale*, dark gray, numerous plant fragments; 0 to 6 feet thick.

NOTE: Units 24 through 27B appear to be abnormally bedded and may be involved in a slump block (paleo-landslide). Unit 25 may be a torn up fragment of unit 22.

23. *Clay shale*, gray black, hard, hackly, *Lingula* sp. and plant fragments; 1 to 2 feet thick.

22. *Coal*, bright, one bed with several minor partings; 1 foot 4 inches thick. (lower Kittanning no. 3 coal).

21. *Underclay*, light gray, rootlets; 5 to 12 feet thick.

20. *Silt shale*, gray black, thin chips, brittle. Anthraconauta sp. and plant fragments, grades up into *silt shale*, medium dark gray, $\frac{1}{4}$-inch chips, sideritic, grades up into silty *clay shale*, medium gray, mica, $\frac{1}{4}''$-chips, grades up into *silt shale* to *siltstone*, light olive gray, hackly, stigmaria and large siderite nodules in upper 2 feet, grades up into unit 21; 7 to 14 feet thick.

19. *Coal*, up to four benches, lower benches are best developed in lows and thin and disappear over highs, top bench most persistent; maximum development


Figure 29. Photograph of portions of the reference section shown on Plate 22.

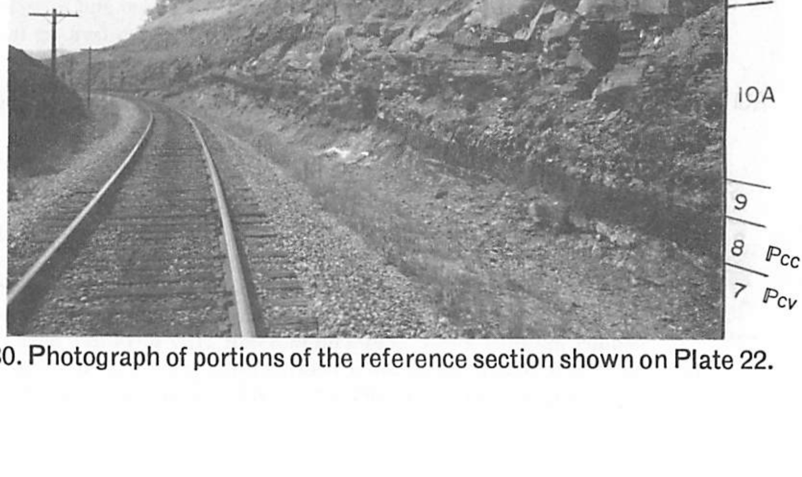


Figure 30. Photograph of portions of the reference section shown on Plate 22.

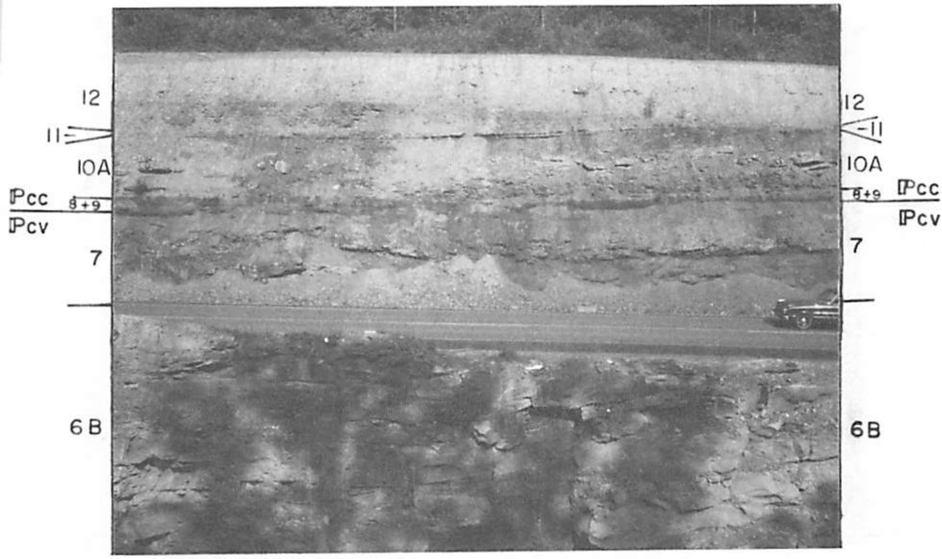


Figure 31. Photograph of portions of the reference section shown on Plate 22.


Figure 32. Photograph of portions of the reference section shown on Plate 22.

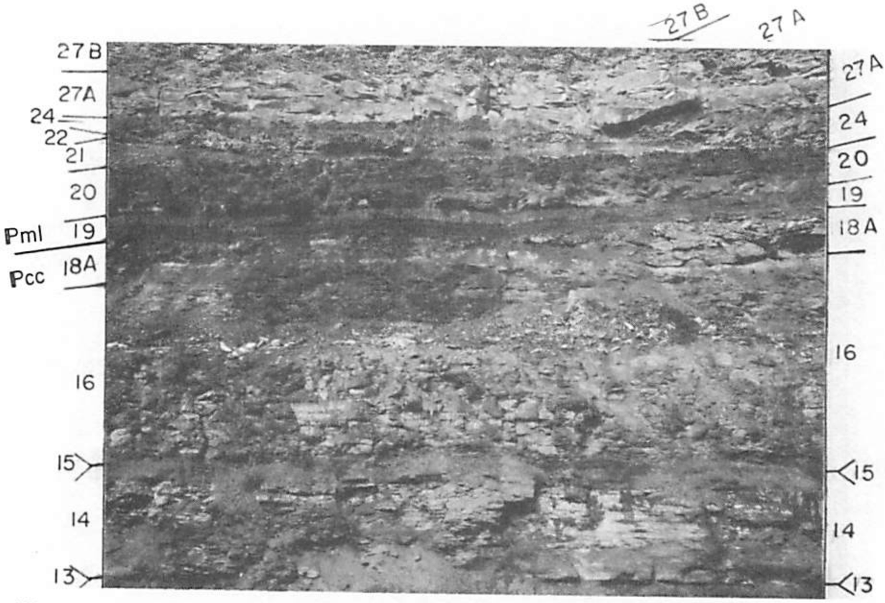


Figure 33. Photograph of portions of the reference section shown on Plate 22.


Figure 34. Photograph of portions of the reference section shown on Plate 22.

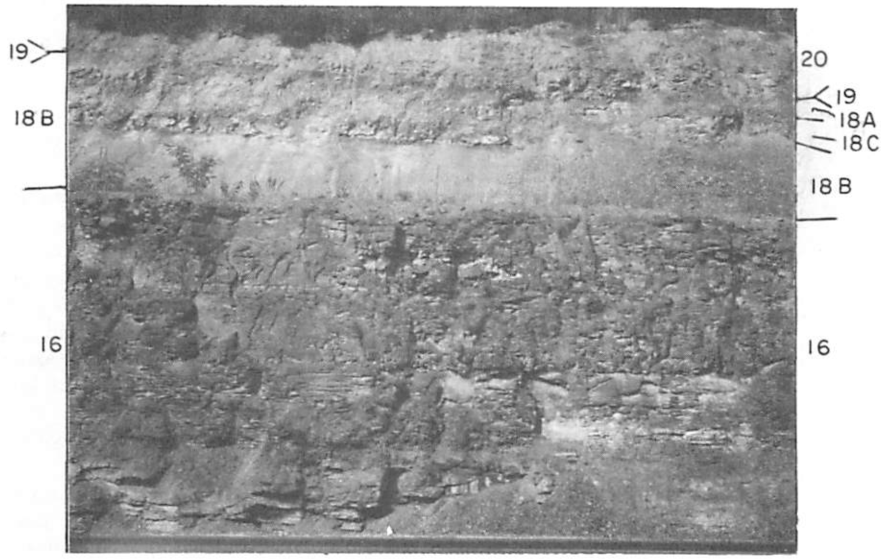


Figure 35. Photograph of portions of the reference section shown on Plate 22.


Figure 36. Photograph of portions of the reference section shown on Plate 22.

shows (from base) coal-11 inches; sandstone-4 inches, coal-4inches, shale-3 inches, coal-1 foot 1 inch, shale-6 inches, coal-1 foot 8 inches, entire unit appears to pinch out southward; 0 to 5 feet thick (lower Kittanning no. 1 coal).

Clearfield Creek Formation

18C. *Siltstone*, light olive gray, hard, grades laterally into 18A and 18B; up to 5 feet thick.

18B. *Siltstone*, light gray, weathers to small irregular chips, grades up to *silt shale*, black, thin chips, grades laterally into 18A and 18C; 0 to 24 feet thick.

18A. *Sandstone*, silt to granule size, mostly fine-grained to medium-grained, mostly light gray, but also light pink gray, medium light gray, medium gray and medium dark gray, common mica, clay matrix, some thin *silt shale* beds clay-chip conglomerate, common dark minerals, plant material from fine fragments to trunk-size, beds 1 inch to 4 feet, thinner-bedded upward, major beds dip toward southeast, may be a point bar, grades laterally to 18B and 18C; 0 to 13 feet thick. Possible Kittanning sandstone.

17. *Siltstone*, light gray, weathers to very fine chips, clayey upward, rootlets, mica, resembles a silty "underclay"; 0 to 4 feet.

16. *Clay shale*, medium light gray, fine chips, very wet zone, weathers to gray clay (1 foot), sharply overlain by clayey *silt shale*, medium dark gray, numerous small and some large siderite nodules and one or two bands of siderite nodules, hackly chips, pelecypods, grades up to *silt shale*, medium light gray to light green-gray, hackly, scattered siderite nodules, grades by interbedding upward to *siltstone*, medium light gray with bluish cast, small irregular blocks to a few inches thick, some large siderite nodules, grades up to *sandstone*, very fine-grained, very silty, very micaceous, beds mostly ½ inch to 2 inches, medium light gray, three 3- to 6-inch siderite bands, upper part lumpy and root-worked, grades to unit 17 where present; 20 to 26 feet thick.

15. *Shaly coal*, high fusain, fine cubic fracture; 4 to 6 inches thick (Clarion no. 3 coal).

14. *Silt shale*, medium gray, hackly, small plant fragments, grades up to *interlaminated sand-silt shale*, silt to very fine-grained sand, medium dark gray, micaceous, ¼- to 3-inch beds, small plant fragments, grades up to *silt shale*, black, many small plant fragments, thin chips (3-inches thick), grades up to *clay shale*, olive gray, soft (6 to 9 inches thick); 7 to 10 feet thick.

13. *Shaly coal*, granular; 0 to 3 inches (Clarion no. 3 coal).

12. *Silt shale*, dark gray to black, locally coaly, micaceous (1 inch), grades up to *silt shale*, black, some very fine-grained sand alminae, thin platy chips, abundant plant fragments (2 feet), grades up to *silt shale*, medium dark gray, fine mica, few plant fragments, grades up to *silt shale*, medium dark gray, fine mica, few plant fragments, sand laminae increasing upward, grades up to *interlaminated sand-silt shale*, medium dark gray (silt) and light gray (sand) laminae, micaceous, few plant fragments, some banded sideritic zones, grades up to *sandstone*, very fine-grained with some silt laminae, ¼- to 3-inch beds, few plant fragments, grades up to *sandstone*, silt to very fine-grained sand, lumpy bedding, numerous plants (fragments, leaves, and twigs), micaceous, mudcracks, grades up to *clay*, unlithified, yellow gray (few inches); 26 to 29 feet thick.

11. *Coal*, dull, high fusain content, numerous partings; 6 inches to 2 feet 6 inches (Clarion no. 2 coal).

10B. *Sandstone*, very fine-grained, medium light gray to medium gray, small plant fragments, some internal slumping, root-worked where directly overlain by

11, exists as laterally gradational lenses within 10A; 10A and 10B are 3 to 20 feet thick.

10A. *Silt shale*, black, hard, brittle, thin chips becoming hackly chips upwards, grades up to *silt shale* medium gray to gray black, hackly to splintery chips, many plant fragments, irregular bedding, siderite nodules, upper part root-worked and locally grades up to dark gray underclay where directly overlain by 11; grades laterally into 10B; 10A and 10B are 3 to 20 feet thick.

9. *Silt shale*, black, hard, brittle, thin chips, common plant fragments; 0 to 2 feet thick.

8. *Coal*, bright, several non-persistent partings; 1 foot 1 inch to 1 foot 8 inches thick (Clarion no. 1 coal).

Pottsville Group

Curwensville Formation (type section)

7. *Siltstone*, sandy, medium gray, blocky fragments, *stigmaria*, grades up to *clay shale*, medium dark gray, very fine chips (approaches underclay), grades up to *semihard clay* with some hard clay nodules to 2 feet, medium gray, some sandstone lenses, grades up to *underclay*, silty; *stigmaria*, medium light gray; 10 to 15 feet thick.

6B. *Sandstone*, silty, silt to fine-grained sand, medium light gray, silica cement, micaceous, dark minerals, some coaly stringers, plant impressions up to trunk-size, some dark gray *silt shale* beds, major beds dip approximately southwest (point bar development), beds mostly 1 to 4 feet, some cut-and-fill structures; 8 to 20 feet thick, including 6A.

6A. Interbedded *sandstone*, very fine-grained and medium gray, and *silt shale*, dark gray, 1- to 2-inch beds, micaceous, plant fragments, unit cuts 5 and 4; up to 10 feet thick.

5. *Coal*, 2 to 5 inches (lower Mercer).

4. *Hard clay*, medium gray to medium dark gray, appears to be mostly high-alumina diaspore block clay, 6-inch to 1-foot beds, hard, splintery to conchoidal fracture, numerous small bodies presumed to be diaspore; 6 to 9 feet thick.

Elliott Park Formation

3. Irregularly interbedded *silt shale*, dark gray, splintery chips; clayey, sandy *siltstone*, blocky, gray brown to dusky brown; and some *sandstone*, very fine-grained, medium light gray, all grading up to *claystone*, medium dark gray, hard, numerous pinpoint pits of a white clay mineral which weathers out leaving the rock surface pitted with many small holes, 2-inch beds; 3 to 5 feet thick.

2. *Clay*, unlithified, soft, wet, appears to be disintegrating from a soft, silty clay shale; few inches.

Mississippian-Pennsylvanian unconformity

Pocono Formation, Burgoon Member (possibly Mauch Chunk Formation, middle sandstone—see Figure 17)

1. *Sandstone*, fine-grained to medium-grained, very light gray to light gray, beds 6 inches to 5 feet, most beds 2 to 5 feet, top 6 feet thinner bedded, cross-bedding (dip S50° to 70° E), most has a small amount of white clay matrix with some silica cement (very light gray sandstone), the remainder has considerable silica cement and little clay matrix (light gray sandstone), variable mica content, variable dark mineral content (some thin but persistent dark mineral laminae), some carbonized plant material; 36 feet plus.

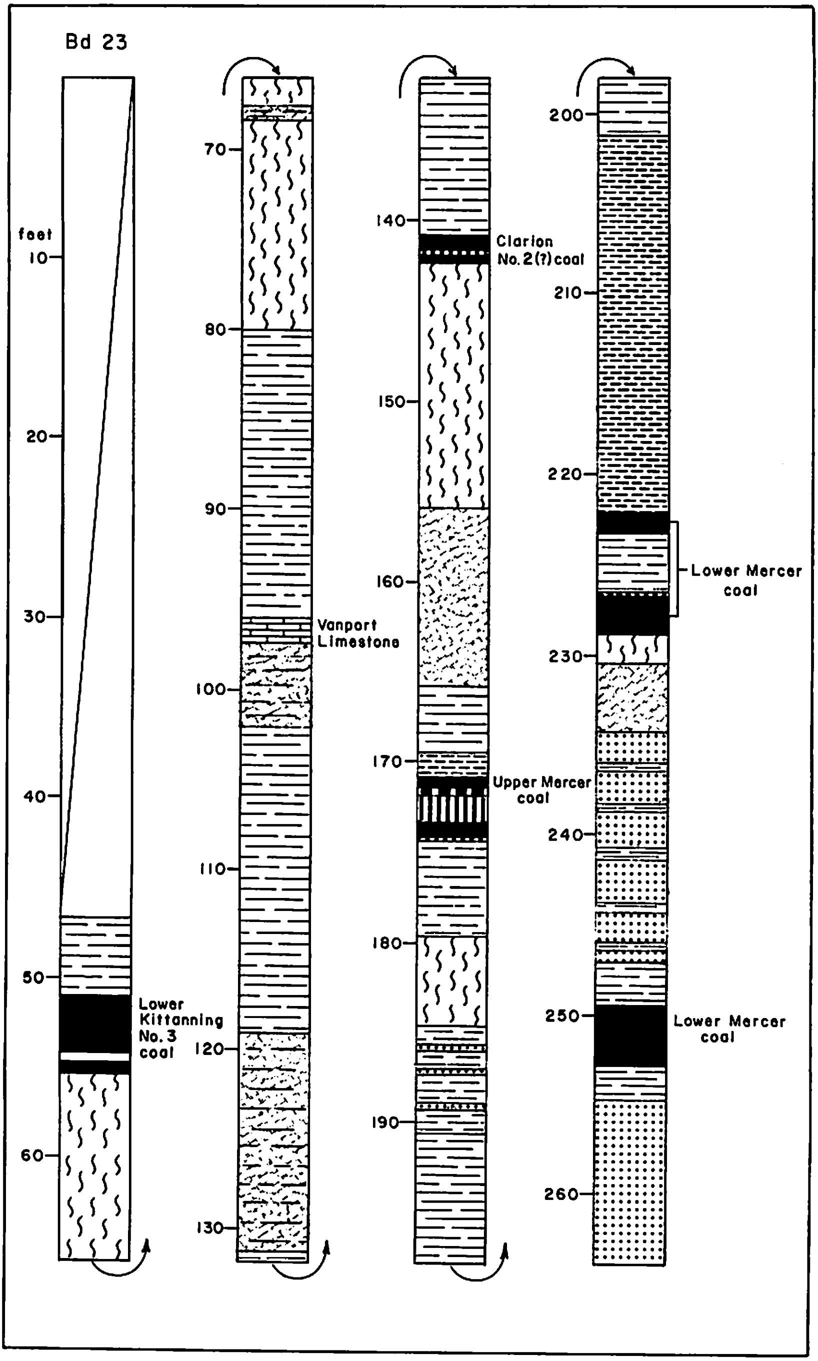


Figure 37. Drill hole at Bd22 (Addendum).

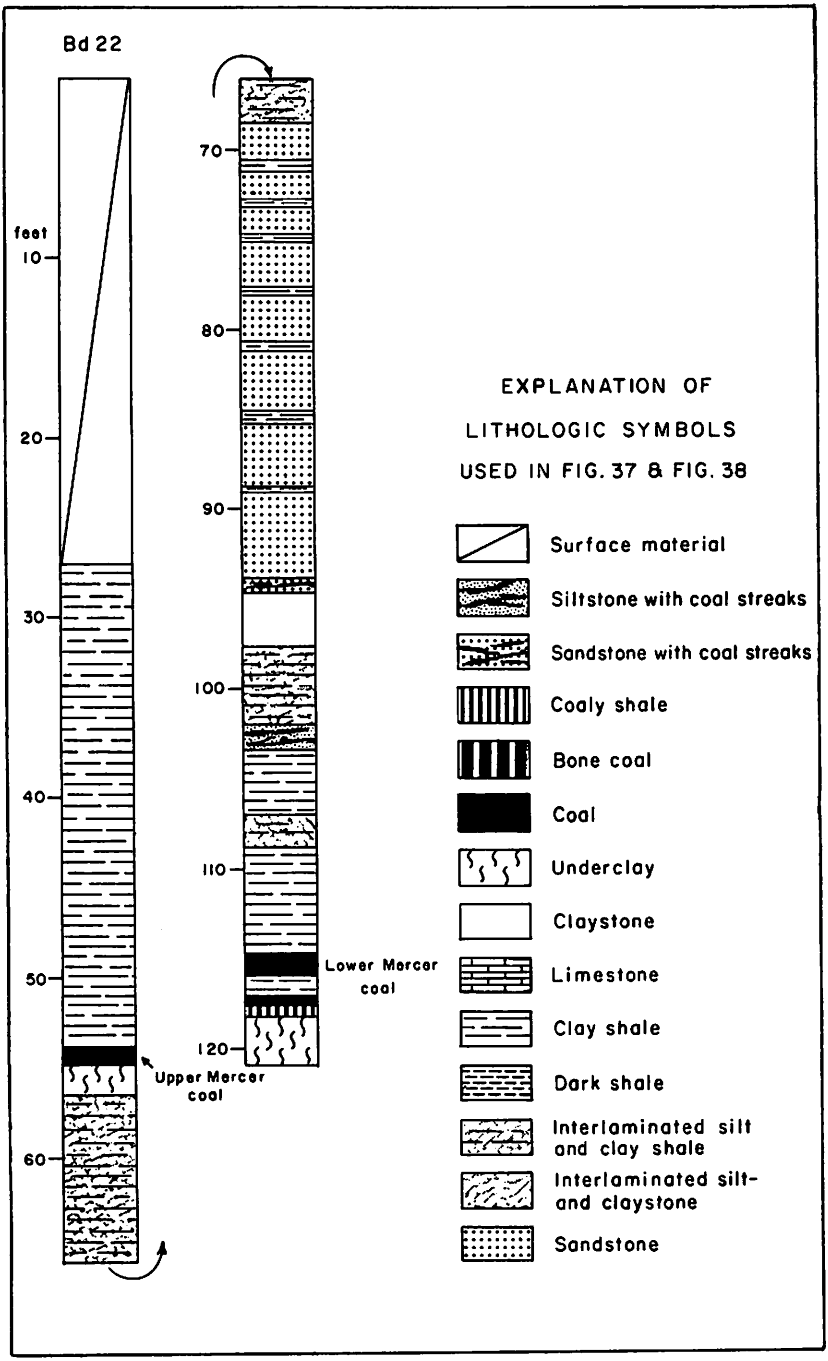


Figure 38. Drill hole at Bd23 (Addendum).

# ADDENDUM

After completion of the main body of this report, two drill holes (Bd22 and Bd23) were obtained which provide additional information on the Curwensville and Clearfield Creek Formations in north-central Luthersburg quadrangle.

These drill holes are shown in Figures 37 and 38. The Mercer and Clarion coal seams encountered have been added to Plate 17; and the lower Kittanning coal of drill hole Bd23 is shown on Plate 13, and although it was not used in calculating lower Kittanning coal reserves, it is compatible with the results. Clays recognized in the drill holes are shown on Plate 18.

The Clearfield Creek Formation of drill hole Bd23 is 62 feet thick and includes a 17-inch limestone which may be equivalent to the Vanport Limestone.

It is not clear whether or not Bd23 penetrated the entire Curwensville Formation, but, assuming that the sandstone at the bottom of that drill hole is upper Connoquenessing or Burgoon, the Curwensville Formation would be 112 feet thick at that point.